VRIJE UNIVERSITEIT BRUSSEL
Faculteit Toegepaste Wetenschappen
Vakgroep Elektrotechniek en Energietechniek

The electric vehicle: raising the standards

Ir. Peter VAN DEN BOSSCHE

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Promotor: Prof. Dr. Ir. G. Maggetto

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Colophon

Set in Poliphilus and *Blado Italic*.

Acknowledgments

This work is the result of research performed, and experience built up during the past decennium during which I have been involved with electric vehicle standardization. The finalization of this thesis would not have been possible however without the support of many who have directly and indirectly contributed to this project.

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Among the references that were used, two merit a particular note: the work by Gijs Mom, who highlighted the relevance of the historical research and showed me the way to the historical sources, and the work by Stanley Hills, which I discovered in my early days as a student and which contributed to arouse my interest in electric vehicles.

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Jury

- ☞ Prof. Alain Barel, Chairman, Vrije Universiteit Brussel, Belgium
- ☞ Prof. Jean Vereecken, Vice-Chairman, Vrije Universiteit Brussel, Belgium
- ☞ Prof. Gaston Maggetto, Promotor, Vrije Universiteit Brussel, Belgium
- ☞ Prof. Philippe Lataire, Vrije Universiteit Brussel, Belgium
- ☞ Dr. Joeri Van Mierlo, Vrije Universiteit Brussel, Belgium
- ☞ Dr. Giampiero Brusaglino, Centro Ricerche Fiat, Orbassano, Italy
- ☞ Dr. Michael F. Mangan, Standardization Expert, Edgworth, England

Summary

This thesis presents the evolution of standardization in relation to electrically driven vehicles in the past, present and future. It is the result of historical and bibliographical research on one hand and of the author's personal experience in several standardization committees on the other hand. Starting with the genesis of the first specific electric vehicle standards in the early 20th century, the evolutions of this subject are followed up throughout the years, passing through the renewed interest in electric vehicles the last quarter of the century, up to the new developments like hybrids and fuel cells which are bringing the electric road vehicle into the 21st century. Special attention has been devoted to the drafting process of the standards and the roles played by the various standardization bodies and their mutual interaction.

The work is concluded with the formulation of a number of statements and recommendations concerning the future of the standardization of electrically driven vehicles.

Samenvatting

Dit proefschrift behandelt de evolutie van de normalisatie in verband met elektrisch aangedreven voertuigen in verleden, heden en toekomst. Het is enerzijds voortgekomen uit geschiedkundig en bibliografisch onderzoek, en anderzijds uit de persoonlijke ervaring van de auteur in verscheidene normalisatiecomités. Beginnend met het ontstaan van de eerste normen specifiek voor elektrische voertuigen aan het begin van de 20ste eeuw, werd de evolutie terzake opgevolgd door de jaren heen, via de hernieuwde belangstelling voor elektrische voertuigen gedurende het laatste kwart van de eeuw, tot en met de nieuwe ontwikkelingen zoals hybride voertuigen en brandstofcellen die het elektrisch voertuig in de 21ste eeuw begeleiden. Bijzondere aandacht werd besteed aan het wordingsproces van de normen en aan de rol van de verscheidene normalisatie-organismen en hun onderlinge wisselwerking.

Het werk wordt besloten met het formuleren van een aantal stellingen en aanbevelingen aangaande de toekomstige normalisatie van elektrisch aangedreven voertuigen.

Résumé

Cette thèse traite de l'évolution de la normalisation relative au véhicule à propulsion électrique : au passé, au présent et au futur. Elle est basée d'une part sur des recherches historiques et bibliographiques et d'autre part sur l'expérience personnelle de l'auteur au sein de différents comités de normalisation. Les évolutions dans le domaine ont été suivies, partant de la genèse des premières normes spécifiques pour le véhicule électrique au début du 20ième siècle, en passant par le renouveau d'intérêt pour le véhicule électrique au cours du dernier quart de siècle, jusqu'aux développements nouveaux tels les véhicules hybrides et les piles à combustible, qui accompagnent le véhicule électrique vers le 21ième siècle. Une attention particulière fut attribuée aux processus d'élaboration des normes et au rôle des différents organismes de normalisation ainsi que de leur interaction mutuelle.

L'ouvrage est conclu par l'énoncé d'un nombre de propos et de recommandations concernant la future normalisation des véhicules à propulsion électrique.

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Glossary of organizations, acronyms etc.

ACEA	Adivsory Committee on Environmental Aspects (IEC)
ACEC	Advisory Committee on Electromagnetic Compatibility (IEC)
ACOS	Advisory Committee on Safety (IEC)
AECV	All Electric Combat Vehicle
AIEE	American Institute of Electrical Engineers
ANSI	American National Standards Institute
APC	Armoured Personnel Carier
APU	Auxiliary Power Unit
AREI	Algemeen Reglement op de Elektrische Installaties
ASTM	American Society for Testing and Materials
AVERE	Association du Véhicule Electrique Routier Européen
BEC/CEB	Belgisch Elektrotechnisch Comité/Comité Electrotechnique Belge
BESC	British Engineering Standards Committee
BEV	Battery Electric Vehicle
BIN/IBN	Belgisch Instituut voor Normalisatie / Institut Belge de Normalisation
BMS	Battery Management System
BS	British Standard
BSI	British Standards Institution
BT	Bureau Technique (Technical Board)
BTTF	Task Force of the Technical Board
CD	Committee Draft
CDV	Committee Draft for Voting
CEC	Commission of the European Communities
CEN	Comité Européen de Normalisation
CENEL	Comité Européen de Normalisation Electrotechnique
CENELEC	European Committee for Electrotechnical Standardization
CFEC	Consumable Fuel Energy Converter
CISPR	International Special Committee on Radio Interference
CITELEC	Association of European cities interested in electric vehicles
CNG	Compressed Natural Gas
CNS	Chinese (Taiwan) National Standard
CS	Central Secretariat
DDPT	Dynamic Discharge Performance Test
DEF STAN	Defence Standard (UK)
DET	Dynamic Endurance Test
DIN	Deutsches Institut für Normung
DIS	Draft International Standard
DOD	Department of Defense (US)
ECE	Economic Commission for Europe (United Nations)
EDTA	Electric Drive Transportation Association (2003/)
EFTA	European Free Trade Association
EMC	Electromagnetic compatibility
EN	European Standard
ENV	European Prestandard

EPA	Environmental Protection Agency (US)
EPAC	Electric Power Assisted Cycle
ESA	Electrical/electronic Sub-Assembly
ETSI	European Telecommunications Standards Institute
EU	European Union
EV	Electric Vehicle
EVA	Electric Vehicle Association (UK)
EVAA	Electric Vehicle Association of America (1910-1916); Electric Vehicle Association of the Americas (-2002)
EVAAP	Electric Vehicle Association of Asia-Pacific
EVSE	Electric Vehicle Supply Equipment
FCEV	Fuel Cell Electric Vehicle
FDIS	Final Draft International Standard
FEM	Fédération Européenne de la Manutention
HEV	Hybrid Electric Vehicle
HFEDS	Highway Fuel Economy Driving Schedule
HMMWV	High Mobility Multipurpose Wheeled Vehicle
ICE	Internal Combustion Engine
ICNIRP	International Commission on Non-Ionizing Radiation Protection
IEC	International Electrotechnical Commission
IEE	Institution of Electrical Engineers (UK)
IEEE	Institute of Electrical and Electronics Engineers (USA)
IEV	International Electrotechnical Vocabulary
ISO	International Organization for Standardization
ITU	International Telecommunications Union
JEVA	Japan Electric Vehicle Association
JEVS	Japan Electric Vehicle Association Standard
JIS	Japanese Industrial Standard
JISC	Japanese Industrial Standards Committee
JWG	Joint Working Group
KS	Korean Standard
LPG	Liquified Petroleum Gas
MOD	Ministry of Defence (UK)
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organization
NBN	Norme Belge/Belgische Norm
NC	National Committee
NEC	National Electrical Code
NELA	National Electric Light Association
NEV	Neighbourhood Electric Vehicle
NFPA	National Fire Protection Association
NWIP	New Work Item Proposal
PACT	President's Advisory Committee on future Technology (IEC)
PEM	Proton Exchange Membrane (Fuel Cell)
prEN	Draft European Standard
prENV	Draft European Prestandard
PRCD	Portable Residual Current Device

PWI	Preliminary Work Item
RCD	Residual Current Device
RESS	Rechargeable Energy Storage System
SAE	Society of Automobile Engineers (from 1916: Society of Automotive Engineers)
SC	Sub-Committee
SFUDC	Simplified Federal Urban Driving Cycle
SME	Small- and Medium-sized Enterprises
SOC	State of Charge
SRBE/KBVE	Société Royale Belge des Electriciens / Koninklijke Belgische Vereniging van Elektrotechnici
STANAG	Standardization Agreement (NATO)
TC	Technical Committee
UDDS	Urban Dynamometer Driving Schedule
UL	Underwriters' Laboratories, Inc.
UNIPEDE	Union Internationale des Producteurs et Distributeurs d'Energie Electrique
USABC	United States Advanced Battery Consortium
VDE	Verband der Elektrotechnik Elektronik Informationstechnik e.V.
VUB	Vrije Universiteit Brussel
WG	Working Group
ZEV	Zero Emission Vehicle

1 PURPOSE, SCOPE AND JUSTIFICATION

Let us raise a standard to which the wise and honest can repair.
George Washington, Remarks at the Constitutional Convention, 1787

1.1 *Introduction*

In urban traffic, due to their beneficial effect on environment, electric vehicles[1] are an important factor for improvement of traffic and more particularly for a healthier living environment.
Electric vehicles have been among us for more than one hundred years now, and while during the largest part of the twentieth century their presence has been rather marginal, the energetical and environmental constraints the world is facing today make it clear that electrically driven vehicles are presenting a sensible approach for solving mobility problems, particularly in cities.

The emergence of the electrically driven vehicle, either as a completely new technology or as a new field of application of existing technologies, represents particular challenges in the field of standardization. It encompasses in fact various domains of technology such as electric traction motors, power converters, storage batteries, battery chargers and general automotive technologies, each of which have their own traditions and constraints in the field of standardization. The analysis presented in this work aims to allow an inclusive insight of the scene, in order to identify significant trends or problem areas where specific actions might be needed.
"Standardization" on itself may in fact seem to be a rather dreary subject, particularly to the general reader who is not actively involved in it, but its study allows to get a distinct vision on the underlying technologies and on the actors behind them.

This thesis presents a work of considerable originality, since the specific area of electric vehicle standardization has not yet been covered as such. A number of historical works on the development of electric vehicles have been written during the past decade, but these did not focus specifically on standardization issues.
The presence of a comprehensive document giving an overview of all aspects of electric vehicle standardization, from the past to the future, will provide a key reference to all interested actors in the field, informing the reader on the current developments in the field. It aims to contribute to an enhancement of knowledge

[1] In the course of this work, unless stated otherwise, the term "electric vehicle" is used generally as meaning "electrically propelled vehicle", encompassing both battery-electric, hybrid-electric and fuel cell vehicles.

about standards and standardization, since we feel that there is a considerable lack of knowledge and understanding of standards and their significance. The subject is very rarely present in teaching curricula, and for many people the whole concept of international standardization remains somewhat elusive. The differentiation between "standards" and "regulations" is not always clearly perceived. Some standards like the ISO 9000 series may be widely publicized these days, but these are often mistaken for "product quality" standards rather than the procedural standards that they actually are.

1.2 *Scope*

The thesis aims at those fields of standardization that are of primary relevance towards electrically driven vehicles. It thus includes standardization of electric traction-related components, charging infrastructures, as well as safety issues and performance measurements for electrically driven vehicles.
The potential scope for the work being extremely broad, it was necessary however to define some limitations as to the areas being covered in this thesis. As it principally focuses on the standardization of the electrically driven vehicle, matters related to non-electric subjects such as internal combustion engines or general automotive standardization and regulations have been generally considered as being outside of the scope of the work, except in some specific cases where deemed useful.

1.3 *Approach*

The approach followed in the redaction of this work is primarily chronological, considering electric vehicle standardization from its first beginning up to prospects for future developments.
After a brief introductory chapter on the concept of "standardization", extensive interest has been given to the developments in the first part of the twentieth century, an era which could be rightly described as the first "golden age" for the electric vehicle on one hand, and an era which saw the emergence of national and international standardization activities on the other hand. Several standardization realms have been considered: the electric vehicle community, the automotive community and the electrotechnical community, each of which having their own characteristics. The genesis of standardization activity in these spheres is described, and standard development related to the electric vehicle is analysed, from the inception to the application.

This part of the work has been largely based on American source materials, on one hand due to the fact that particularly in the field of standardization, the electric vehicle development in the United States has been very significant in the concerned

period. The influence of American standards on European standardization work in the field has also been taken into account.
On the other hand, a considerable quantity of reference materials on the subject was available; in this framework, we are particularly indebted to the extensive collections of the John Crerar Library at the University of Chicago.
This allowed to construct a comprehensive study of the matter, and this choice should certainly not be considered as a too restrictive one.

The relevance of taking into account materials that are nearly one hundred years old in a thesis of the "applied sciences" faculty might be questioned. However, as in many things, current and future evolutions cannot be understood without knowing and understanding the past, and much can still be learnt from the opinions of the statements of the electric vehicle men of that period. One should also note that history is part of our culture, in the field of technology as much as in other domains. Whereas the scientists and the engineers are indeed shaping our future, unfortunately it has to be deplored that some of them are tainted with "recentism" and with a certain contempt towards historical technology and industrial archaeology, sad attitudes which deny them the status of genuine intellectuals.
The considerable amount of attention devoted to this part of the work is thus fully justified.

The period 1920-1970 saw the electric vehicle relegated to the background, except for industrial vehicle applications. The evolution of standardization relevant to this application will be analysed. As this period saw the emergence of the industrial battery-electric vehicle as a considerable field of application of the technology, standards applicable in this field (particularly concerning connectors, batteries and motors) have been considered up to this day.

The renaissance for the electric road vehicle came in the last quarter of the twentieth century. With it came a broad effort on the field of standardization, performed by various organizations such as IEC, ISO and their various regional counterparts. The prepared standards and technical reports related to electric vehicles will be described and analysed, as well as the relationship between these organizations: the IEC/ISO positioning on electric vehicles, and the specific case of European standardization. The contribution on this part will reflect the author's personal experience in electric vehicle standardization built up by activities in the electrotechnical standardization committees during the last ten years.

Specific attention will be given to areas such as EMC, where a close relationship between standardization and regulation occurs, and to the impact of general vehicle regulations, such as the documents published by ECE.
Standardization specifically aimed at "small" electric vehicles, such as wheelchairs and electric bicycles will also be taken into account.

Finally, the impact of standardization on the implementation of electric and hybrid drive systems for defense applications will be treated, due to the potential for dual-use application of to both military and civilian technologies.

The "electric vehicle" however encompasses more than just the battery-electric vehicle. Hybrid electric vehicles, which come in different configurations, and fuel-cell electric vehicles are examples of new technologies the use of which is expected to take a considerable expansion in the 21st century. Standardization activities in this field are of course also taking off, and the main trends of this activity will be reported on.

The thesis will be concluded with a general overview on electric vehicle standardization issues and an outlook to the future.

2 STANDARDIZATION

"Standardization" - it is, I am afraid, a rather barbarous word.
Sir John Wolfe Barry, chairman of the British Engineering Standards Committee

The main issue of this work being "standardization", it seems desirable, at the outset, to define this concept.
What is a "standard", and how does it come to being?
From a general point of view, a "standard" can be described as[2]:

- ☛ *"that which is of undoubted authority; that which is the test of other things of the same kind" (Johnson)*
- ☛ *"that which is established as a rule or model by the authority or public opinion, or by respectable opinions, or by custom or general consent" (Webster)*
- ☛ *"that by which quantity or quality is fixed or regulated, rated, estimated" (Richardson)*

If applied to technical or industrial standardization, the definition is more specified, while keeping the same signification, as is shown from the official definition of a standard by the international standardization bodies:

> *"a standard is a document, established by consensus and approved by a recognized body, that provides, for common and repeated use, guidelines or characteristics for activities or their results, aimed at the achievement of the optimum degree of order in a given context"*[3]

The origin of standards goes back, historically, to the earliest beginnings of human culture, the first formal standards being established being weights and measurements.
With the advent of the industrial revolution, the introduction of rational production methods involving division of labour, and the increased mobility through the availability of railroad transportation, the need for industrial standardization emerged, and by the end of the nineteenth century specialist organizations devoted to standardization came into existence. It was soon appreciated in fact that effective standards could only be developed by competent technical bodies, as attempts for standardization drafted by legislature often yielded unusable, inadequate or foolish specifications. The road was shaped by the electrical industry, which was new and did not have a body of precedents or earlier practices to follow, and was the first to take hold of international standardization properly, as will be seen in the next chapter.[4]

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[2] Sir John Wolfe Barry, The "James Forrest" lecture 1917; Minutes of Proceedings of the Institution of Civil Engineers, Vol CCIV (1918) p332

[3] IEC/ISO Guide 2, Ed 7.0, IEC/ISO, Geneva, 1996

[4] Cf. John W. Lieb, Jr., comment on the EVAA Meeting of 1911-02-27; The Central Station, Vol 10 n9 (1911-03) p245

What makes standardization, as taken into account here, unique is the way the documents are implemented: standardization in fact is the fruit of voluntary collaboration between actors in the field, backed by a recognized body such as a national or international standards organization.
The fundamental base principles of successful standardization, which were already present in early standardization work[5], and which are reflected up to this day in the activities of the various standardization bodies, can be summarized in a few main points as follows.

- ☞ The standardization work should represent the interests of all stakeholders concerned, as well producers as consumers; it should not be purely academical, but in close touch with practical requirements.
- ☞ Standards should not be promulgated "ex cathedra" like articles of faith but should be the fruit of a democratic process based on consensus by all concerned.
- ☞ Standardization bodies should undertake their work only when there is a specific demand for it.
- ☞ Standardization work should be at all times subject to revision, in order to incorporate improvements and to reflect the evolution of technology.

The two last points put the attention to the imminent danger of "overstandardization". Standards should serve recognized needs; there is no need for "standardization for the sake of standardization". Furthermore, standards should not be allowed to "crystallize", ultimately retarding further developments, so that the various trades would become hide-bound, or their methods stereotyped. This point can be well summarized in the following statement:

> *"Standardization is a useful servant, but a bad master."*[6]

Standards can be divided according to their characteristics; a single standard document however can embody one or more of these features[7].

- ☞ There are *terminology* standards (glossaries), defining the meaning of terms and proposing graphical symbols to be used in a certain field, thus allowing easy and unambiguous communication between various actors;
- ☞ There are *dimensional* standards, which give precise descriptions of a product. These promote interchangeability and provide simplicity, reducing the number of sizes and varieties in use, and thus allowing significant cost savings in design and production. Typical examples are screw thread standards, or dimensions for plugs and sockets.
- ☞ There are *performance* or *quality* standards, which define performance requirements, to ensure a product is suitable for its duty. A particular type of these standards are specifications defining safety requirements
- ☞ There are *test* standards, which define the accordance to specifications under controlled and uniform conditions. These are indispensable companions to

[5] Cf. Sir John Wolfe Barry, op.cit.,p337
[6] Norman F. Harriman, Standards and Standardization, p. 19
[7] Cf. C. Douglas Woodward, BSI: the story of standards, p3

performance standards, as they describe the way conformity to these can be assessed.

☞ There are *recommended practices* for the design, installation and maintenance of equipment

The useful societal impacts of standards are manifold[8].
They have a value for education, presenting guidance and information to both user and manufacturer who want to make or use a new product. They have a value of simplification and rationalization, reducing time and material expenditures and thus allowing a conservation of energy and material resources. They finally have a value of certification, serving as hallmarks of quality.

To many people however, the notion of "standardization" is most forbidding. They see it as the antithesis of individuality, as a process that will reduce everything to a drab monotony[9]. With standardization in the true sense of the word however, this should not be the case, as said above standardization should be a faithful servant, who makes life easier, and not an evil master imposing his will. The democratic process in which standards are drafted and revised, and the voluntary aspect that is at the base of industrial standardization are factors guaranteeing this. In the case when standards are absorbed by legislation and are enforced by the government, care must be taken that the implementation and the follow-up of these legal documents are performed with the same principles and exerting the same care than for proper standard documents.
Generally speaking, the benefits of standardization and its influence on our world are so considerable that one can in fact say that:

> *"Standardization, in a sense, is the bed-rock of civilization"*[10].

Let's now, in the following chapter, go back to the exciting times of early twentieth century, and witness how an emerging new product, the electric vehicle, hailed as a "scientific method of transportation"[11], will make use of standardization, which we will hail here as a "scientific method of organization".

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[8] Cf. F.A. Sweet (CSA) quoted in Charles D. Sullivan, Standards and standardization, p. ix
[9] Cf. Norman F. Harriman, op.cit., p126
[10] Samuel M. Vauclain, introduction to Norman F. Harriman, op.cit., p. xv
[11] Day Baker; The Central Station, Vol. 9 n6 (1909-12) p146

3 THE GOLDEN AGE (1890-1920)

Le fluide électrique, silencieux, obscur et froid, parcourt son conducteur métallique sans l'influencer autrement ni manifester son passage. Mais, vient-il à rencontrer une résistance, l'énergie se révèle aussitôt avec les qualités et sous l'aspect du feu. Un filament de lampe devient incandescent, le charbon de cornue s'embrase, le fil métallique le plus réfractaire fond sur-le-champ. Or, l'électricité n'est-elle pas un feu véritable, un feu en puissance? D'où tire-t-elle son origine, sinon de la décomposition (piles) ou de la désagrégation des métaux (dynamos), corps éminemment chargés du principe igné?
Fulcanelli, Les demeures philosophales.

3.1 Introduction: The electric vehicle in the late nineteenth and early twentieth century

3.1.1 Early history

The history of electric vehicles has been thoroughly documented in a number of recent works. In this paragraph, we will limit ourselves to draw the main highlights of early electric vehicle development, and to show some typical application fields.

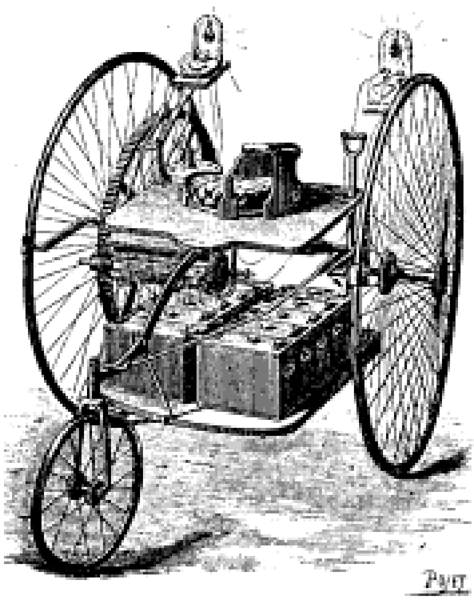

Figure 3.1: W. Ayrton and J. Perry's electric tricycle of 1882[12]

The first road vehicle to be propelled with electricity was a tricycle demonstrated in Paris in 1881 by Gustave Trouvé - five years before the alleged "invention of the

[12] Ernest H. Wakefield, History of the Electric Automobile, fig1.6

automobile" by Benz and Daimler[13] -, followed by another tricycle in 1882 by W. Ayrton and J. Perry in England (Figure 3.1).[14] These were lightweight vehicles, based on bicycle construction.
The subsequent development of the electric vehicle was that of a "horseless carriage", which retained the body style of the horse vehicle[15].
Figure 3.2 shows a French example from 1902. Development took place in several countries, particularly in France (Jeantaud, Krieger) and the United States.

Figure 3.2: An electric horseless carriage[16]

These "first generation" electric vehicles had their heyday in the last decade of the 19th century. The first years after 1900 would already see a competition from gasoline vehicles, with the battery being considered the main weak point of the electric vehicle:

> *"No modern invention has enlisted so large an expenditure of time and money with so little result as the electric storage battery."*[17]

In 1904, the Belgian Society of Electricians stated that the electric vehicle was a luxury item, largely being displaced by the gasoline motor:

> *"L'automobile électrique alimentée par accumulateurs constitue l'appareil de luxe par excellence. Son prix d'achat et son entretien limitent ses applications aux trajets sur routes planes, aux petites vitesses et aux très grosses bourses. Actuellement, ces*

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[13] Gijs Mom, Geschiedenis van de auto van morgen, , p56
[14] Ernest H. Wakefield, op.cit.; p2
[15] Ibid., p15 (NOTE: the mention "Ibid." in the footnotes refers to the document in the preceding footnote.)
[16] AEM, Elettrica, il futuro della prima auto, p43
[17] "Electric Vehicles and their Limitations", The Horseless Age, 4 (1899) quoted in D. Kirsch, The Electric Vehicle and the Burden of History, p59

> *voitures ont presque disparu; l'on peut dire que l'automobilisme ne fait plus guère usage que du moteur à benzine."*[18]

The first decade of the century was thus described by contemporary sources as a "dark age" for the electric vehicle.[19]
A new interest in electric propulsion would arise however by the end of the decade, which was due to the availability of better batteries, both lead-acid (such as the "Exide Ironclad" with tubular positive plates) and alkaline (such as Thomas Alva Edison's nickel-iron battery)[20].

3.1.2 Electric utility vehicles

The commercial vehicle presented a considerable application field for the electric vehicle. It was mainly proposed as a replacement for the horse-drawn vehicle, economic analyses of horse versus electric vehicles showed a cost advantage of around 25% in favor of the electric[21]. The electric vehicle proved particularly suitable for short-distance, frequent-stop service like urban delivery work. An example is shown in Figure 3.3.

Figure 3.3: An early Ransomes "Orwell" vehicle. The drive was on the front wheels.[22]

[18] Bulletin de la Société Belge d'Electriciens, Vol 21 (1904), p22
[19] D. Kirsch., op.cit., p88
[20] Cf. G. Mom, op.cit.,p426-428, and Richard H. Schallenberg, Prospects for the Electric Vehicle - A Historical Perspective, ¶11
[21] Cf. Schallenberg, op.cit., ¶111
[22] Stanley M. Hills, Battery-electric vehicles, , fig2

Electric vehicles also saw application for utility duties and municipal services, such as the electric hearse from Figure 3.4, which was introduced in Milan from 1913. In 1930, all 37 hearses operating in Milan were electric[23].
Further applications in this field included the use of electric vehicles by fire brigades in Germany[24], and by post offices in France, Germany and Italy.

Figure 3.4: An electric hearse in Milan[25]

3.1.3 Electric passenger cars

From the early "horseless carriages", the electric passenger car continued to develop, with two specific types which could be discerned: the "open" type (Figure 3.5), which reflected the more "sportive form of the gasoline car, and the "closed" type (Figure 3.6), which was specifically aimed at city use. The electric passenger car of the time tended to be an expensive product aimed at the upper classes (to replace the horse and buggy), and was much more expensive than gasoline cars[26]. A 1914 catalog[27] listed most electric vehicles in the $2000 - $3000 range, where gasoline cars were available from $950.

[23] G. Mom, op.cit., p561
[24] Cf. G. Mom, op.cit., p343-386
[25] AEM, op.cit., p101
[26] Cf. Schallenberg, op.cit, ¶111
[27] Handbook of Automobiles, , 1914

Figure 3.5: "Open type" Krieger electric vehicle, driven by King Victor Emmanuel III of Italy[28]

The electric passenger vehicles would be eventually displaced by the gasoline car, not primarily because of technical aspects, or because of their higher cost, but also because of the psychological advantage of the gasoline vehicle as an "adventure machine", and the spirit of "freedom" which emanated from it.[29]

> *"The gasoline car so changed the public's desire for transportation that the electric was no longer adapted to that new desire. This was a serious disadvantage."*[30]

Figure 3.6: "Closed type" electric vehicle as city car[31]

[28] AEM, op.cit.,p83
[29] Cf. G. Mom, op.cit., p577-592 and Schallenberg, op.cit., ¶IV
[30] Schallenberg, op.cit., ¶III

It has to be remarked however that electric vehicles played a considerable role in early racing. The Belgian Jenatzy, with his famous "Jamais Contente" (Figure 3.7) was the first to exceed the record speed of 100 km/h: on May 1, 1899, on the racetrack of Achères, France, he reached a speed of 105,85 km/h[32]; the "torpedo" shape of his vehicle, with low windage, would be at the basis of modern automobile design, since "essentially all cars built since 1902 have been of the modified torpedo form"[33].

Figure 3.7: "Torpedo type" vehicle: Jenatzy's "Jamais Contente"

In some cases, solutions were presented which could still be considered "advanced" up to this day. Wheel hub motors for example were already experimented early 20th century in Germany and in the United Kingdom.

The motor in Figure 3.8, manufactured by Gottfried Hagen in Kalk bei Köln, Germany is a typical example. The 2,5 horsepower motor weighed only 36 kg, its suspension brackets included, and had an efficiency of 82% at half load and 85% at full load. A vehicle fitted with such motors was able to cover a 100 km range at a 30 km/h speed on one charge, using a lead-acid battery weighing only 350 kg, with a 5-hour capacity of 34 Wh/kg. Whether these figures were real or publicitary, they would still be outstanding today.[34]

These wheel hub motors would become unfashionable quite soon however, as their high unsprung mass had a bad influence on driveability: due to gyroscopic effects, vehicles became more likely to sway and harder to steer.[35]

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[31] AEM, op.cit.,p51
[32] J.A. Grégoire, 50 ans d'automobile. Part 2: la voiture électrique, p94
[33] E. H. Wakefield, op.cit., p241
[34] W. Häntzschel-Clairmont, **Die Praxis des modernen Maschinenbaues**, p553-555
[35] E.E. Seefehlner, **Elektrische Zugförderung**, Berlin, Julius Springer, 1922, p 534

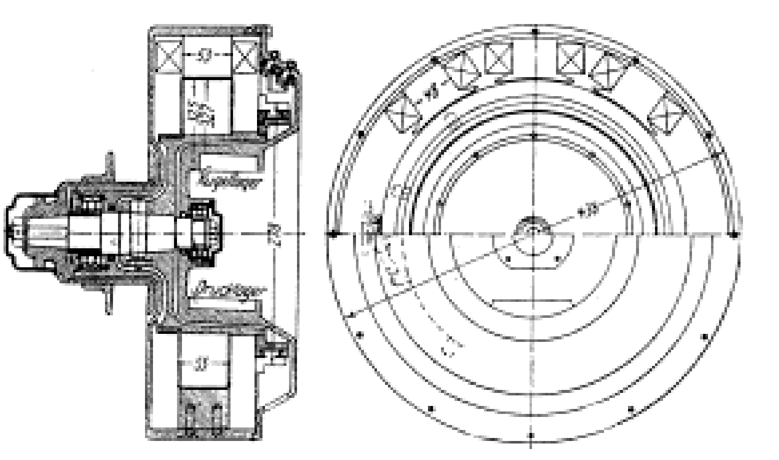

Figure 3.8: Wheel hub motor[36]

3.1.4 Electric taxis

Figure 3.9: A British electric taxi-cab, photographed in 1927 when it was 24 years old and had travelled over 180000 miles. It attained a speed of 28 miles per hour and did 45 miles on one charge.[37]

The electric vehicle also saw application as a taxicab. Fleets were deployed in London[38], Paris[39] and the United States[40] in the last years of the 19th century. Battery

[36] W. Häntzschel-Clairmont, op.cit.
[37] S.M. Hills, op.cit., fig1
[38] G. Mom, op.cit.,p140-149
[39] Ibid., p149-164
[40] Ibid., p164-189

problems have been cited[41] as the main reason for these experiments not to be successful. These ill-fated experiments hampered further investment in electric taxis. Some vehicles, like the one in Figure 3.9, did soldier on for a long time however.

3.1.5 Battery-electric vehicles in public transport

The advantages of the electric vehicle for frequent stop service in city centers made it of course also attractive for public transport applications.

Battery-powered streetcars (trams) were experimented in a number of cities, they were rapidly displaced however by externally (overhead, or in some cases, conduit track) supplied vehicles, the batteries being the main problem area:

> *"L'insuccès des accumulateurs doit être en grande partie attribué à deux causes: déchargement jusqu'à épuisement et ensuite rechargement à outrance en vue d'obtenir une plus grande somme d'énergie emmagasinée, ou à intensité très forte, désireux que l'on était de diminuer la durée du rechargement; cette manière de procéder devrait forcément amener la destruction rapide des électrodes et accréditer l'idée que les batteries secondaires ne peuvent assurer le service régulier d'un tramway."*[42]

Battery-operated vehicles were however deployed as buses, which were not captive to a rail track.
An early example of a "bi-mode" vehicle was presented in 1899 by Siemens and Halske in Berlin. It was an overhead-powered electric tram which was however able to leave the rails, operating as a battery-powered bus, the batteries being charged from the overhead line.[43]
From 1907 to 1910, a fleet of 80 battery-electric buses operated in London[44].
A further well-documented example was the deployment of battery-electric buses in Lancaster, England, in 1916[45], where five buses were used on two routes of each about 1,5 miles. These 22-seat buses were fitted with 300 Ah Edison A8 nickel-iron batteries. The batteries were charged at night, with boosting charges given at the terminal (Figure 3.10) if necessary. The charging at the depot took place by placing four batteries in series across the 460 V d.c. supply, with an adjusting rheostat to give a 60 A charging current. Very little resistance was thus needed, and after one hour the resistance could be shorted. When only three batteries had to be charged, the resistance was suitably adjusted; it was claimed that the energy loss resulting

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[41] Ibid., p195
[42] Bulletin de la Société Belge d'Electriciens, Vol 9 (1892) p233
[43] Ibid, Vol 17 (1900) p398
[44] G. Mom, op.cit., p400
[45] S.M. Hills, op.cit., p129

from this practice was comparable with the loss of running a motor-generator set at part load however[46].

The buses were considered reliable, as "it was a very rare thing for a trip to be missed owing to a mechanical or electrical fault".[47] The vehicles were still running in 1924, for which year extensive exploitation data are available. Income from bus operation was 11,83 (old) pence per mile, with working expenses of 15,14 pence per mile, of which 2,57 pence electric power cost[48]. The system thus operated at a loss; it is interesting however to compare these figures with the cost of petrol buses of the same period, where the working costs averaged 16,50 pence per mile, of which 4,07 petrol cost[49].

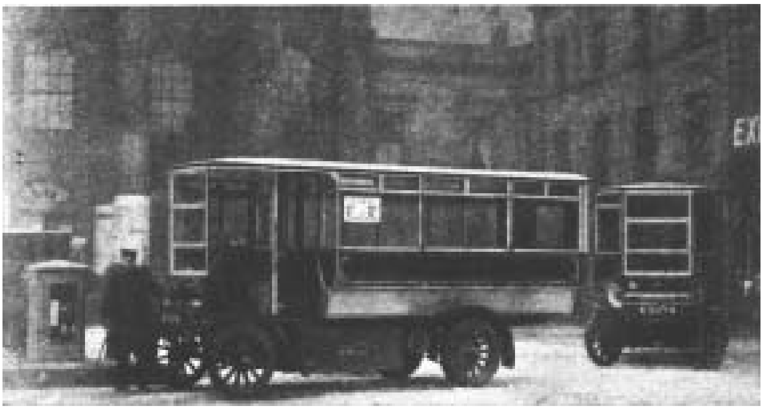

Figure 3.10: Electric bus in Lancaster being charged in Market Square[50]

3.1.6 Hybrid vehicles

The idea of hybrid vehicles and electric transmissions also surfaced. The first hybrid, the "Auto-Mixte" was developed as early as 1896 by the Belgian company Pieper. In 1901, two petrol-electric vehicles (Figure 3.11) were built by the "Fabrique Nationale d'Armes de Guerre" in Herstal, Belgium, with the help of Camille Jenatzy. These vehicles were fitted with a 60 HP engine and a 40 HP electric motor, giving the vehicle a total power of 100 HP. In France, series hybrid concepts were developed by Krieger from 1902, whereas in Germany, hybrid vehicles were manufactured by Lohner-Porsche[51].

[46] Ibid.
[47] Ibid.
[48] Ibid., p132
[49] Ibid., p133
[50] Ibid., fig94
[51] G. Mom, op.cit., p239-241

Figure 3.11: FN-Jenatzy 100 HP petrol-electric vehicle[52]

In 1904, a vehicle was presented by Thury of Geneva, which had all the features of what is now called a parallel hybrid. It was perceived as presenting a lower cost than series hybrid solutions, and was fitted with by a gasoline engine of either two or four cylinders in V, delivering 8 or 16 horsepower, a shunt-wound electric motor, and two clutches on a common driving shaft as shown in Figure 3.12. The battery was either a 60 V type weighing 150 kg or a 88 V type weighing 500 kg, giving an electric range of respectively 5 or up to 40 km. The vehicle could be used either in pure electric (silent), pure gasoline or hybrid mode, and could even be used as a mobile power plant.[53]

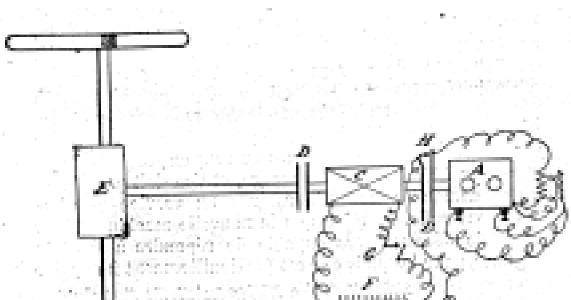

Figure 3.12: Thury parallel hybrid[54]
(Note the ignition wiring taken from one cell of the battery)

[52] RACB, Historicar, N° VII/VIII, 2000-02, P21
[53] Bulletin de la Société Belge d'Electriciens, Vol 21 (1904) p22-27
[54] Ibid., p22

The hybrid vehicle idea lived on, and was extensively discussed by the SAE in 1914, where Harry E. Dey made the following statement:

> *"Is the electric starter of the flywheel armature type a step in the evolution of the combination gasoline-electric machine? It would appear that if this outfit were made larger it would recharge the battery whenever the engine had surplus power, and give the power back to assist the engine whenever overloaded. The electrical equipment could be comparatively small in rating compared with that of the engine. A number of inventors worked along these lines in the early days of the automobile, but for some reason unknown to the writer did not succeed in commercialising the system. Perhaps they were too far ahead of the times, and we may yet get this system as an evolution of the motor starter."*[55]

The "flywheel armature" starting motor cited here is quite close to the "alternator-starter" propagated on today's "mild hybrids"; the idea was thus clearly "ahead of the times"...

Dey saw his hybrid vehicle with a gasoline engine of twenty to thirty horsepower, with a motor dynamo flywheel of about five horsepower, compound wound to provide a series characteristic in traction and to avoid excessive charging rates. A battery of 100 Ah at 60 V was deemed sufficient to obtain a range of 20 to 25 miles in electric drive. The presumed advantages of the system were comparable to the arguments that are cited in favor of hybrids today.[56]

Buses with electric transmission (without traction battery) were in use on Fifth Avenue in New York City. They had a 35 horsepower engine, a 7 kW generator and two 3 kW motors. It was stated however that they were expensive in construction and that the beauty of the electric transmission, "that the motors respond to the demands upon them", was offset by the gasoline consumption which was 25% more than a mechanical transmission. R. McAllister Lloyd thus stated:

> *"There is no particular advantage in an electric transmission, it seems to me."*[57]

These arguments against electric transmission were countered by William P. Kennedy, a well-known electric vehicle advocate[58], who stated that the high cost was due to their manufacture in experimental quantities (an argument which is valid up to this day!), and that the lower maintenance cost and the particular advantages of the electric transmission could well prove its value in certain applications:

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[55] Gasoline-Electric Vehicles, SAE Transactions 1914 part2, p304, statement by Harry E. Dey
[56] Ibid.
[57] Ibid., p308, statement by R. McA. Lloyd
[58] Cf. G. Mom, op.cit., p445

> *"Do we not condemn the gasoline-electric type of machine for engineering or theoretical considerations rather than practical, for instance, by laying stress, as pointed out, on the gasoline consumption or some minor consideration without reference to its economy or practicability as a whole?"*[59]

Other implementations of the gasoline-electric drive also existed however, with 260 buses by Tilling-Stevens operating in London[60], or with the electric transmission system developed by Entz, the performances of which were stated to be equal to mechanical transmissions[61].

This system consisted of two direct current machines, one of which with its stator directly connected to the engine crankshaft, taking the place of the flywheel. This machine acted as both a clutch and a generator; its armature was mounted on a large hollow shaft. The second machine had its armature mounted on the same hollow shaft, its stator being stationary. A sectional view of this transmission is shown in Figure 3.13.[62]

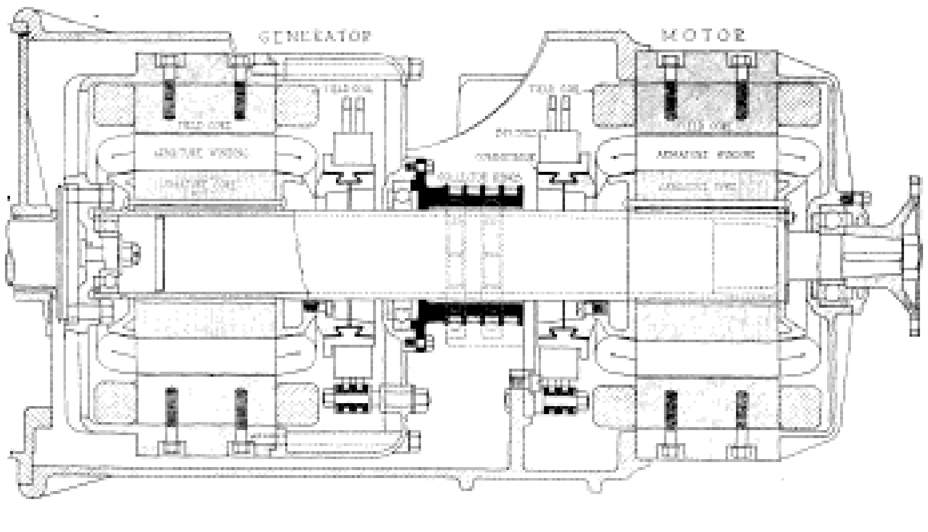

Figure 3.13: Entz electric transmission

[59] Gasoline-Electric Vehicles, SAE Transactions 1914 part2, p310
[60] Ibid., p315, statement by P.K. Hexter
[61] Ibid., p312, statement by M.R. Machol
[62] J.B. Entz, The Electric Transmission on Owen Magnetic Cars, SAE Bulletin, Vol x n5 (1916-08) p656

3.2 The genesis of electric vehicle standardization from within the electric vehicle community: the activities at the Electric Vehicle Association of America

One of the first actors to get involved in specific standardization work concerning electric vehicles was the "Electric Vehicle Association of America" (EVAA) which was active from 1910 to 1916, and which should not be confounded with its near namesake EVAA (Electric Vehicle Association of the Americas) that has been promoting the electrically driven vehicle in recent years, until late 2002 it changed its name in "Electric Drive Transportation Association" (EDTA).
The EVAA's standardization activities will be described after a short historical overview of the association[63].

3.2.1 The Electric Vehicle Association of America

Figure 3.14: The EVAA

The EVAA inception meeting took place on June 8, 1910 in the office of Arthur Williams, general inspector of the New York Edison Company and past-president of the National Electric Light Association (NELA), an association uniting electric utilities. This meeting assembled "one of the most representative bodies of men comprising the allied interests of the central stations[64] and the electric vehicle and storage battery manufacturers of the country".[65] It was considered of such importance that Thomas Alva Edison attended in person; he was much interested in the incorporation of a nationwide association for the advancement of the electric vehicle.
The incorporation on August 29 and the charter meeting on September 1 marked the formal launching of the Association, which was to be known as "The Electric Vehicle Association of America". Among its 29 charter members, there were ten

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[63] A. Jackson Marshall, Brief Historical Review of the EVAA, The Central Station, Vol 15 n9 (1915-03) p234
[64] The term "Central Station" was used in that period to designate electricity generating stations and electric utilities.
[65] The Electric Vehicle Association of America; The Central Station, Vol 9 n12 (1910-06) p292

representatives of central stations, eleven vehicle manufacturers, six battery men and two others. The first President was William H. Blood, Jr., an insurance expert from Boston, who had chaired the Boston-based "Electric Vehicle and Central Station Association", which was founded in 1909, and would join the EVAA in November 1910 as the "New England Section". The first Vice-President was Arthur Williams.

Figure 3.15: Wm. H. Blood, Jr.

Figure 3.16: Arthur Williams

The association was quite successful, its membership growing steadily, and local sections being founded in a number of cities. In 1916 there would be 1138 members and 17 local sections[66].

The EVAA set up a number of technical Committees to deal with several aspects of electric vehicles, treating subjects such as "Publicity and Advertising", "Insurance", "Legislation", "Operating Records", "Garages and Rates", and also "Standardization" which will be discussed in more detail below.

The official organ of the association was "The Central Station", a monthly "devoted exclusively to the interests of electric lighting and power stations".

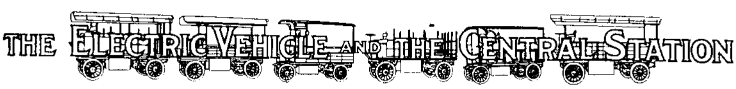

Figure 3.17: "The Central Station" frontispiece with an allegory of electricity, and its electric vehicle section.

[66] G. Mom, op.cit., p424-5

It was published by H.C. Cushing, Jr. of New York City, who was also a founding member of the association. Each issue featured a section "The Electric Vehicle and the Central Station". The frontispiece is shown on Figure 3.17.
The association held annual Conventions in New York (1910 and 1911), Boston (1912), Chicago (1913), Philadelphia (1914) and Cleveland (1915), each in the month of October. These featured executive sessions, as well as the presentation of technical papers on various subjects concerning electric vehicles.

For an analysis of the history of the EVAA and of the policies it pursued, reference can be made to thorough studies which have been made on the subject by Dutch automobile historian Gijs Mom[67] and by UCLA professor David Kirsch[68].
In the framework of this work however, which is focused on standardization, it is nevertheless interesting to mention some main issues.
One first characteristic is the fact that the EVAA's policies were mainly determined by the interests of the central stations, particularly those in big cities. Their interest in electric vehicles concerned on one hand their own vehicle fleets, on the other hand the selling of electric energy and the use of electric vehicles to level the station's load. For this reason, large commercial fleets in big cities received the most interest, rather than individual vehicles.
The EVAA's interest for technical developments remained rather limited. It evolved to a closed movement, dominated by the central station interests, almost a sect devoted to the electric vehicle ideology[69]. This culminated in the famous "Electric Vehicle Creed", signed in 1915 by a number of central station managers, which we reproduce in Figure 3.18, to witness the strength of this document and the particular interest it has raised in us.

"A CREED"

WE BELIEVE
In the electric vehicle.
That the electric vehicle is destined to supersede other forms of transportation, at least for city and suburban work.
That the electric vehicle merits the full and hearty recognition and co-operation of the central station and other electrical interests NOW, in order that the electric vehicle might come into its own with all possible speed.
That the future development of the electric vehicle presents highly profitable new business for the central station.
In the policy of central stations using wherever possible electric vehicles; likewise advocating and otherwise promoting their use.

Figure 3.18: The Electric Vehicle Creed[70]

[67] G. Mom, op.cit. ¶8.3, p411-494
[68] David A. Kirsch, The Electric Vehicle and the Burden of History
[69] G. Mom, op. cit, p464, p490
[70] The Central Station, Vol14 n12 (1915-06) p395

At the sixth convention in Cleveland, October 1915, the President of the NELA, E.W. Lloyd, expressed the wish to come to a closer collaboration between the two associations[71]. The NELA, which united central station interests, being a much bigger association than the EVAA, invited the EVAA to affiliate with it as a section to be known as the Electric Vehicle Section. This invitation was accepted on March 10, 1916[72], marking the end of the EVAA as an autonomous organization. It went on as the Electric Vehicle Section of NELA before finally being phased out in the mid-1920s.

3.2.2 The call for the need of standardization

The utility of standardization for the development of the electric vehicle had been recognized as early as 1900. Battery tray sizes and charging infrastructure had been cited as suitable subjects for standardization[73].

It took however ten years, and the creation of the EVAA, for concrete actions to be performed in this domain.
The first convention of the EVAA was called to order on October 18, 1910 in the concert hall of Madison Square Garden, New York City[74]. This meeting united nearly 300 delegates and representatives, from the central station, vehicle, battery and allied interests.
The address of President William H. Blood, Jr., highlighting the aims and policies of the new association, was considered a document of great importance. The need for standardization is directly addressed, deploring the fact that up to that moment, manufacturers were working independently in perfecting their machines.

> *"There has been little or no attempt to standardize. There has been so little community of interest manifest in the past that practically every manufacturer has even gone so far as to have his own type of charging plug, which adds greatly to the inconvenient of the electric vehicle user. A standard charging plug is now being talked of, and it is confidently expected that through the efforts of this association one may soon be adopted."*[75]

Besides the charging plug issue, President Blood identifies the motor voltage:

> *"Let us get together and agree upon some standard voltage",*

and the size of batteries:

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[71] The Central Station, Vol15 n5 (1915-11) p129
[72] "EVAA absorbed by the NELA", The Central Station, Vol 15 n9 (1915-03) p233
[73] Cf. D. Kirsch, op.cit., p104
[74] "The First Convention of the EVAA", The Central Station, Vol 10 n5 (1910-11) p 137
[75] Ibid., p 138

> *"It would add to the satisfaction of the electric vehicle owners if the size of batteries could be made uniform",*

as desirable areas for standardization work. Also, he forwarded the idea of standardising the type of chassis for the vehicle:

> *"a standard type of chassis would further reduce the cost of manufacture and would simplify the problem of those responsible for the daily operation of the cars".*

Finally, the standardization of tire sizes is mentioned as:

> *"making it easier for the customer to use electric vehicles and simpler for the garage to carry a proper stock of tires".*

The statements expressed in this key address already deal with several key standardization issues, such as:

- ☞ Adding convenience to the user and manufacturer,
- ☞ Simplifying manufacturing,
- ☞ Reduce the cost of manufacturing.

As for the last point, it is stated that

> *"the present prices of electric vehicles are not as low as they should be, but now that we are successfully passing out of the development period and as we are beginning to manufacture standard machines in large quantities, a material reduction should necessarily be the result..."*[76]

This argument concerning the high purchase price of electric vehicles is one that still holds today, nearly a century later...[77]

The base for standardization remains co-operation between the different actors involved:

> *"I think co-operation is one of the lines along which the activity of every central station should be exercised. Co-operation with the salesman and with the manufacturer, especially along the lines of standardization. It seems to me that this is one of the most important subjects which should be looked into - standardization of the plugs, and battery and the voltage of the motors particularly."*[78]

Standardization was considered

> *"one of the most important things that our association has to do with"*[79].

[76] Ibid., p 138
[77] Cf. Electric Vehicle Working Group - Evaluation of Targeted Transport Projects; p27
[78] R.L. Lloyd, discussion on the December 1911 meeting of the EVAA; The Central Station, Vol 11 n7 (1912-01), p203
[79] Ibid., remark by F.W. Smith

3.2.3 Standardization of charging plugs

The first item to be addressed was the standardization of the charging plug.

3.2.3.1 Battery charging

In order to address this issue, let's have a look on how electric vehicles were charged in that period. Charging of electric vehicles in those times could be done in different manners (all involving conductive charging), depending on whether a d.c. or an a.c. network was used.

3.2.3.1.1 Charging from d.c. network

Direct current distribution networks were still in widespread use during the concerned period. These allowed easy charging of batteries, with the use of a rheostat for current regulation.
Figure 3.19 shows a typical layout of a rheostat panel which was presented commercially.

Figure 3.19[80]: Battery charging rheostat panel

It came fitted with voltage and current measurement devices, and presented several protective measures:

☞ A low current cut-out, to prevent the battery from discharging into the line should the line voltage drop too low,

[80] "Battery Charging Rheostat", The Central Station, Vol 8 n8 (1909-02) p187

- ☞ A maximum voltage cut-out which opens the circuit when the battery voltage reaches the desired level,
- ☞ An overload circuit breaker to insure the battery against being charged at an excessive rate,
- ☞ A solenoid switch breaking or making the main line charging circuit,
- ☞ An electrical interlock to prevent the operator from closing the circuit except when the control lever is in the "off" position (i.e. with all resistance in circuit).

This device protects the battery under all conditions and requires no attention during use because of the voltage cut-out.
It is clear however that such system will present a low energy efficiency when the battery charging voltage is much lower than the supply voltage, since the difference in voltage will come over the rheostat resistance.

3.2.3.1.2 Charging from a.c. network

The gradual adoption of alternating current for electricity distribution raised the need for rectifying devices allowing battery charging.
Direct current could be obtained through using a rotary converter (motor-generator), as shown in Figure 3.20[81].

Figure 3.20: Motor-generator set in use for home charging

The first manifestation of "power electronics" came with the introduction of the mercury-arc rectifier, which was introduced as early as 1905 by the General Electric Company. It was hailed as having a higher efficiency and lower investment and

[81] AEM, op.cit., p.59

operating costs compared to motor-generator sets. Furthermore, it was of easy use, able to be operated by "any man of ordinary intelligence"[82].

Figure 3.21[83] shows an example of a rectifier assembly for vehicle battery charging.

Figure 3.21: Mercury-arc rectifier for battery charging.

The efficiency of the rectifier compared with the other solutions is shown by the Table 3.1, which already highlights the superior characteristics of the "power electronics" solution.

Battery		*Efficiencies*		
Number of batteries	Cells per battery	With d.c. supply 110 V	With MG set	With Rectifier Garage Outfit
5	24	44%	44%	75%
4	30	58%	59%	84%
4	40	64%	50%	84%
6	24	50%	54%	84%

Table 3.1: Efficiency of battery charging[84]

[82] "The New Mercury Arc Rectifier", The Central Station, Vol 5 n1 (1905-07) p30
[83] The Central Station, Vol 8 n7 (1909-01)
[84] R.E. Russel, "Mercury Arc Rectifier Automobile Garage Outfit", The Central Station, Vol 7 n6 (1907-12) p759

3.2.3.2 Plugs

All these charging devices needed of course to be connected to the vehicle. Special plugs had to be designed for this purpose, as the use of proper "plugs" for connecting electric appliances had not widely been developed.

Figure 3.22: Appliance "plug" for lamp socket[85]

The first use of electricity had been for lighting, and when next its usefulness for other applications became apparent and all kinds of small electric appliances were being put on the market, the connection of these appliances to the network was initially not done with a "plug" as we know it now, but with a "plug" designed to fit a lamp socket rather than a conventional socket-outlet. The standard household socket-outlet would in fact only emerge five years later than the EVAA standard electric vehicle plug described later in this paragraph[86].

Such a "plug" however was not suited for electric vehicle connection, due to its limitation in current. Specific charging plugs were thus designed, and the lack of standardization in the field became a problem with the rapid increase of electric vehicle use by the end of the first decennium of last century.

It did frequently happen in fact that electric pleasure cars (as passenger automobiles were then called) or, also, commercial trucks were operating some distance from their home garage and needed access to some other garage or charging station. The absence of a fitting charging plug became a troublesome problem, only to be resolved easily, with some pieces of wire and some moments work, by the "practical electrician or the skilled driver that we sometimes find" [87]. It was clear however that this knowledge was not often present with the average driver or garage man, and

[85] The Central Station, Vol 5 n6 (1906-11) p 447

[86] Cf. D. Kirsch, op.cit., note73, p257

[87] Day Baker, "Desirability of a charging plug for all electric vehicles", The Central Station, Vol 10 n3 (1910-09) p77

> *"it at once becomes apparent that if electric vehicles are to be the great success we all confidently expect, not only must we have plenty of charging stations, but these stations must be equipped with suitable charging plugs"*[88].

At that time, about eight different patterns of charging plugs were in use, the concentric design being the most popular, adopted by practically all builders of commercial vehicles and at least one of the pleasure type. Concentric plugs designed for electric vehicle charging had already been introduced to the market in 1902[89]. However, the plugs being offered on the market often were of poor quality, defective in strength and thus condemned by fire underwriters. An example of such an early plug is shown in Figure 3.23.

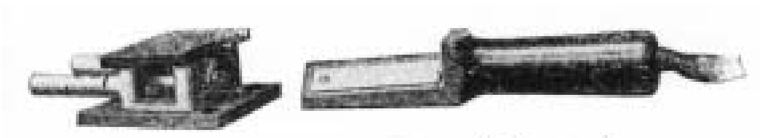

Figure 3.23: An early type of charging plug[90]

> *"There are 10 or 12 different makes - cheap things. If you throw them on the floor, they will short circuit. What we want is a standard plug so that wherever we are we can go into the nearest garage and get our charge."*[91]

The standardization of two sizes of charging plugs and receptacles, a heavy form for commercial wagons and trucks and a lighter form for "pleasure" cars, was considered as

> *"one of the greatest conveniences for the users of electric vehicles"*

The introduction of such equipment was supported by all large manufacturers of electric vehicles at the time[92]:

- *"Rauch & Lang Company says: 'The engineering department report that they would be glad to work with any other company in standardizing the electric plugs on various pleasure and commercial vehicles.'"*
- *"Baker Electric Vehicle Company says: 'Your idea is good. We would be pleased to co-operate.'"*
- *"General Vehicle Company says: 'We would like very much to see the adoption of some standard plug for all vehicles.'"*
- *"Anderson Carriage Company writes: 'We think that this is a very good idea if something good could be obtained that would work satisfactorily without going into excessive weights as in the case of some now on the market.'"*

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[88] Ibid.

[89] G. Mom, op.cit., p434, note 155

[90] H.C. Cushing Jr., The Electric Vehicle Hand-Book, New York, 1921, p315

[91] Alexander Churchward, The Standardization of the Electric Vehicle, discussion; The Central Station, Vol 12 n5 (1912-11) p 166-

[92] Day Baker, op.cit.

- ☚ *"S. W. Bailey Company says: 'The idea is good. We would be pleased to co-operate.'"*
- ☚ *"Babcock Electric Carriage Company says: 'You may have our co-operation in every way.'"*
- ☚ *"The Waverley Company says: 'If a committee could be appointed to make recommendations, they could no doubt agree on a number of things which ought to be standardized.'"*
- ☚ *"Columbus Buggy Company says: 'We think the idea is a very good one.'"*

It was thus believed that one of the first standardization tasks to be performed by the newly formed Electric Vehicle Association of America would be the appointment of a "Committee on Design and Adoption of a Universal Charging Plug", that would work in harmony with the National Board of Fire Underwriters as to secure the adoption of a standard and safe plug.

On its monthly meeting of the Board of Directors, held on December 20, 1910, at the offices of Stone & Webster, New York City[93], the Association announced its intention to appoint a number of committees, the "Committee on Standardization" being mentioned in the first place.

This committee, consisting of representatives of both vehicle and battery manufacturers, started its activities from early 1911. It reported to the Board of Directors of the Association in March 1911, when two meetings had been held and sketches and specifications for the proposed concentric plug were being prepared, similar to the ones used by the pleasure car manufacturers and also acceptable to the commercial car people, while observing the rules of the Board of Fire Underwriters[94].

The plug was presented on the Second Annual Convention of the EVAA[95] by its chairman Alexander Churchward, the electric vehicle expert of General Electric Company, and the Chairman of the EVAA Standardization Committee.

> *"As you no doubt know, every company - especially the pleasure vehicle manufacturers - have their own type of charging plug which is not interchangeable. We have been able to get a charging plug which, I believe, will be acceptable to at least ninety-five per cent. of the manufacturers, although the price is higher than they have been making their own, yet they are willing to pay something for standardization. (...)*
>
> *The plug which I now present to you has been laid out to carry one hundred amperes continuously and one hundred and fifty amperes overload.*
>
> *I have interviewed most of the leading pleasure vehicle manufacturers and they have agreed to use this type of plug, and in this connection you must remember that there are*

---

[93] December meeting of the EVAA, The Central Station, Vol 10 n7 (1911-01), p191

[94] Meeting of the Board of Directors of the EVAA, 1911-03-28; The Central Station, Vol 10 n10 (1911-04) p274

[95] Alexander Churchward, Charging plug; The Central Station, Vol 11 n5 (1911-11) p125-

at least four or five pleasure vehicles for every commercial vehicle made. Therefore, in presenting this plug to you, I believe we have made a step in the right direction."

The design of the plug was voted upon in the standardization committee[96], and adopted with 7 votes against one, and thus as standard by the Electric Vehicle Association.
There was some concern however about the thickness of the outside shell, which was deemed a bit too weak for the work it had to perform. It was advised however that shell should be made of high carbon steel or case hardened, and the proposed thickness retained[97].
(Some problems with breakage of the receptacle persisted however, and the design would be slightly changed in 1916; see §[98]3.3.3.1.)
The original standard sheet is presented in Figure 3.24, and the design was promptly adopted as a standard by several vehicle manufacturers.

A view of plug and receptacle is shown in Figure 3.25 and Figure 3.26.

The plug came in two dimensions, one rated 50 A and the other 150 A. These ratings were subject to discussion however[99], particularly the rating of the smaller plug, which was 50 A for the underwriters, although it was stated by the committee that it could carry up to 100 A. The "absolute necessity" for larger equipment was cited. The small plug would get its 100 A rating many years later however by the SAE (cf. §3.3.3.1)
The EVAA's directors passed a resolution[100] that a standard set of connectors had to be sent to all manufacturers, still facing the difficulty of non-matching connections, and stating:

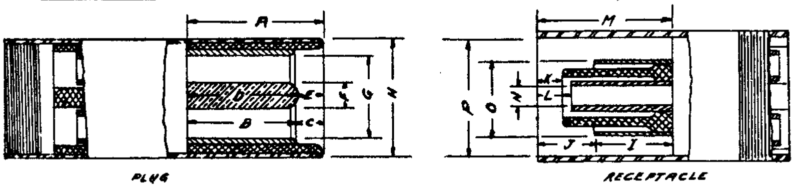
"It seems such a small matter to have a standard plug for charging vehicles".

[96] Report of Committee on Standardization, The Third Annual Convention of the EVAA, The Central Station, Vol 12 n4 (1912-10) p117
[97] Ibid.
[98] Throughout this work, the symbol § is used for references to other paragraphs of the text, whileas ¶ is used to reference to paragraphs or clauses of other documents or standards.
[99] Statement by Mr. Curtis (Boston) at the November 1912 meeting of EVAA; The Central Station, Vol 12 n6 (1912-12) p190
[100] Ibid., Statement by Mr. Williams (New York Edison Company)

Electric Vehicle Association of America

124 W. 42ND ST.
NEW YORK

Standard Charging Plugs and Receptacles.



Contacts must be accurately concentric to insure interchangeability.

* Capacity	A	B	C	D	E	F	G	H	I	J	K	L	M	Machine N	Spring N	Machine O	Spring O	P
50 AMP	$1\frac{15}{16}$	$1\frac{9}{16}$	$\frac{9}{8}$	$1\frac{5}{8}$	$\frac{5}{16}$	.373 .375	1.125 1.127	1.725	$1\frac{1}{8}$	$\frac{7}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	2	.375 .377	.360 .365	1.123 1.125	1.136 1.140	$1\frac{3}{4}$
150 AMP	$2\frac{3}{8}$	$1\frac{9}{16}$	$\frac{13}{16}$	$2\frac{1}{16}$	$\frac{5}{16}$	.435 .437	1.406 1.408	2.100	$1\frac{13}{32}$	$1\frac{5}{16}$	$\frac{5}{16}$	$\frac{7}{16}$	$2\frac{3}{32}$	.437 .439	.422 .427	1.404 1.406	1.416 1.421	$2\frac{1}{8}$

* The National Board of Fire Underwriters have approved plugs of the above dimensions for these ratings with an allowable overload of 50%.

Polarity— Outside contact positive, inside contact negative.

Terminals—Should be large enough to receive cable having a rating, according to the Underwriter's Code "Table B," at least equal to the normal rating of plug.

Terminals are to be marked + and – to correspond to polarity of contacts as above.

COMMITTEE ON STANDARDS
E.R. Whitney. Chairman.
Alexander Churchward.
J.R.C. Armstrong.
H.H. Rice.
W.E. Holland.
E.J. Ross Jr
E. Gruenfelt.
Charles Blizzard.
J.H. Hertner.
Louis Burr

Dec 10th 1913

Recommended by Standardization Committee and accepted by E.V.A.A. Oct. 1912 and Oct 1913.

Figure 3.24: EVAA standard charging plug

Figure 3.25: 150 A charging plug with handle[101]

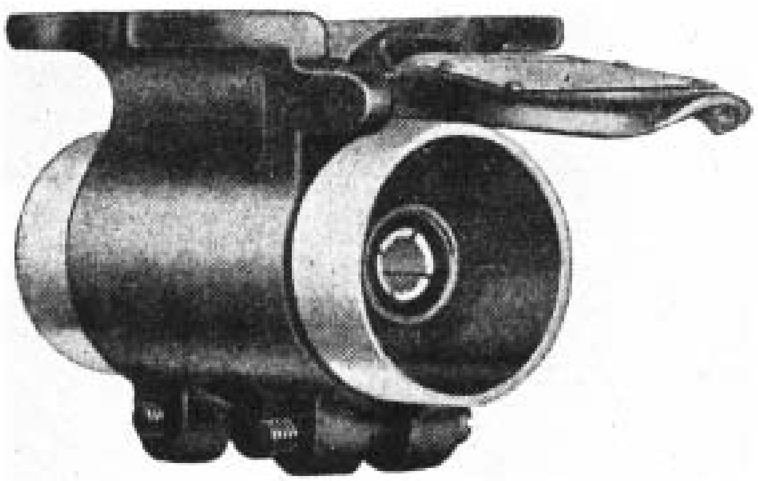


Figure 3.26: 150 ampere-hour (sic) charging receptacle[102]

3.2.3.3 The standard plug enters the scene

In 1913, the number of electric vehicles in use throughout the United States reached a number of 30000[103].

At the fourth Annual Convention of the Electric Vehicle Association of America, held at the Hotel La Salle, Chicago, on October 27, 1913, President Arthur Williams (of the New York Edison Company) summarized the issues of the standard charging plug[104], highlighting again what standardization is all about:

> *"It is important that manufacturers should standardize all the connecting parts of vehicles so as to permit charging at any point. This relates to the car, whether devoted to*

[101] E.E. LaSchum, The Electric Motor Truck, p124
[102] Ibid., p126
[103] The Central Station, Vol 12 n8 (1913-02) p231
[104] President's address, EVAA Fourth Annual Convention; The Central Station, Vol 13 n5 (1913-11) p156

> *business or pleasure. Nothing is more annoying or destructive of charging efficiency than to find at a charging point a set of connections which do not fit. This has been referred to before. Much has been - much is to be - accomplished in this matter of standardization."*

The report of the Standardization Committee at this convention[105] recommended the adoption of the larger size plug, to take care of heavier trucks, with a rating approved by the underwriters of 150 A, and an overload rating of 225 A.
Another issue tackled in this report is the polarity of the terminals in the concentric plug. Of thirteen manufacturers using the concentric plug, nine made the center terminal negative, and five made the center terminal positive[106]. Also, the large majority of vehicles then in service had the center terminal negative; the Committee thus recommended adopting as a standard practice "outside terminal positive, inside terminal negative".

There were some remarks on the experience with the concentric plugs[107] in use, which often did not offer the desired alignment, and were difficult to adjust once they had been damaged through misalignment and the resulting burning of contacts. The Committee investigated a number of plugs manufactured and did find that interchangeability was not always optimal due to inaccurate manufacture; to this effect, tolerances to insure straight interchangeability were settled upon.
The Committee also decided on a method on publishing information on standards: the "standard sheet"[108].
The report of the Standardization Committee was put up to discussion within the EVAA meeting.

It was also suggested that the development of plugs for general heavy current-consuming devices should be followed, and the electric vehicle standardization activities taking advantage of this development.

One significant remark about standardization was made by Mr. Lloyd[109], who warned against too fast proceeding with standardization work facing a changing technology:

> *"... that we ought to be a little cautious before going on record at this convention on something which might again next year have a definite change."*

This argument was refuted however, through the recognition of a need for a two sizes of plugs (a small one for pleasure vehicles, and a larger plug for heavier trucks) and the need for some immediate standardization action facing the "tremendous confusion" that was present at that time.

---

[105] Report of Standardization Committee; The Central Station, Vol 13 n6 (1913-12) p251
[106] Ibid., as stated. However, nine plus five make fourteen!
[107] Ibid., remark by Mr. Chapin
[108] Ibid.
[109] Ibid., remark by Mr. Lloyd

> *"We want to have something, if it is only a temporary standard, that would be arranged for all trucks."*[110]

This discussion already put forward a most typical problem faced by standardization committees: the trade-off between having a standard ready to be used, and the fact that such standard might become obsolete due to the evolution of the technology.

The collaboration with the Society of Automobile Engineers was also deemed interesting[111]; such collaboration would be developed soon (see §3.3.2).

3.2.3.4 Standard products for all markets

That standards are not necessarily forcing one single product on the market, or are not necessarily promoting one single manufacturer, becomes clear in the statements made at the fifth EVAA convention, held in Philadelphia in October 1914.
The EVAA Standardization Committee stated explicitly that it was not to standardize any particular make of plug, but confined itself to standardizing dimensions as to ensure interchangeability[112].
This interchangeability of accessories was considered of foremost value:

> *"The wiring connection and the make-up of the plug may be patented features and may be different in England than they are here or in New York, but the fact that the plugs are interchangeable is the important feature."*

3.2.3.5 The standard plug goes international.

The standard concentric plug found its way abroad, and more particularly to the fast growing electric vehicle industry in the United Kingdom[113]. The great importance of standardizing the plug and socket was brought to the notice of the British Engineering Standards Committee (the forerunner of the British Standards Institution known up to this day) by the Electric Vehicle Committee of the Incorporated Municipal Electrical Association in March 1914. In October of the same year, a proposed standard design based on the recommendations of the Electric

---

[110] Ibid., remark by Mr. Whitney (Commercial Truck Co. of America - Chairman of Standardization Committee)
[111] Ibid., remark by Mr. Conant (Gould Storage Battery Co.)
[112] Fifth Annual Convention of the EVAA, Sixth session; The Central Station, Vol 14 n5 (1914-11) p155
[113] Charging plug; March meeting of the EVAA; The Central Station, Vol 13 n10 (1914-04)

Vehicle Association of America was considered. In order, however, not to depart from their guiding principle of interfering as little as possible with invention and progress, the Sub-Committee on Electrical Accessories decided not to suggest any detailed design as standard, but to confine their attention to standardizing only the essential points necessary to secure interchangeability between any charging plug and socket.

The report was approved on July 22, 1915. In 1917, the Electric Vehicle Committee of the Incorporated Municipal Electrical Association invited the BESC to consider the modifications implemented by the SAE (§3.3.3.1), as this would add considerably to the mechanical strength of the plug, without affecting interchangeability. This first revision to BS 74 was implemented in September 1917, and described the same dimensions of plug and socket as the American SAE standard specification for the 150 A plug. The smaller, 50 A size was not considered.

The scope of the British standard considered "All Charging Plugs and Sockets for use on Circuits up to 120 V and for Currents not exceeding 150 A carried for one hour".

Furthermore, the standard mentioned requirements for the material of the shell of plug and socket (which had to be either solid drawn mild steel or bronze tubing), and for the materials of the contacts (which had to be gunmetal). Dimensions of "Go" and "Not Go" gauges to determine the size of the components were also presented.
The accessories had to be fitted with an earthing connection, and specifications were given for insulation and electrical connection (cable lugs).

The plug and socket are illustrated in Figure 3.27.

A cutaway view of the accessory is shown in Figure 3.28. (Note that the British term "socket" is used here rather than the American "receptacle".)

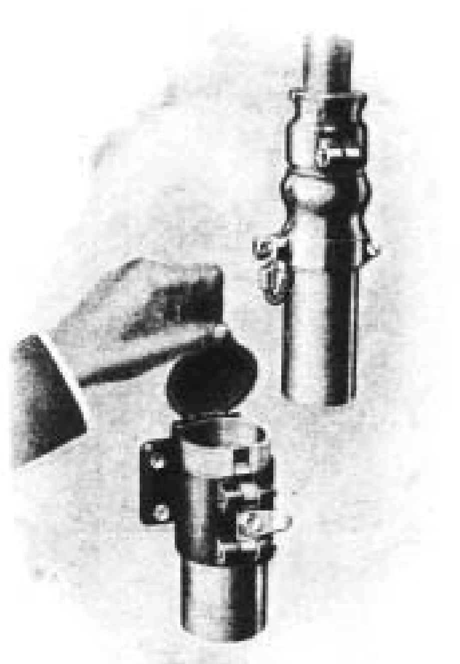


Figure 3.27: British Standard Vehicle Charging Plug and Receptacle[114]

It is interesting to remark the statement, in one of the monographs about electric vehicles, that

> *"Messrs. Watlington & Co. Ltd., now the English Electric Supplies Ltd., introduced the form of plug and socket made by the Albert and J.M. Anderson Manufacturing Company of Boston, Mass. This form is the subject of a patent taken out in 1911 and was closely followed by the Electric Vehicle Committee when considering this subject and arriving at a standard"*[115]

The Anderson company was indeed involved with the manufacturing of plugs (see also §3.3.3.1). The mention of a "patent" is surprising however, since patented equipment is usually not adopted as a general standard, such practice giving an unfair advantage to the patent holder[116]. Furthermore, the American sources (where the equipment originated) did not mention any reference to a specific patent, except for one reference to "patented features" mentioned in §3.2.3.4.

[114] Charles Guthrie Conradi, Mechanical Road Transport, p132
[115] W. Worby Beaumont, Industrial Electric Vehicles and Trucks, , p150 LHL
[116] As the number of this patent was not given, we have not been able to retrieve it yet.

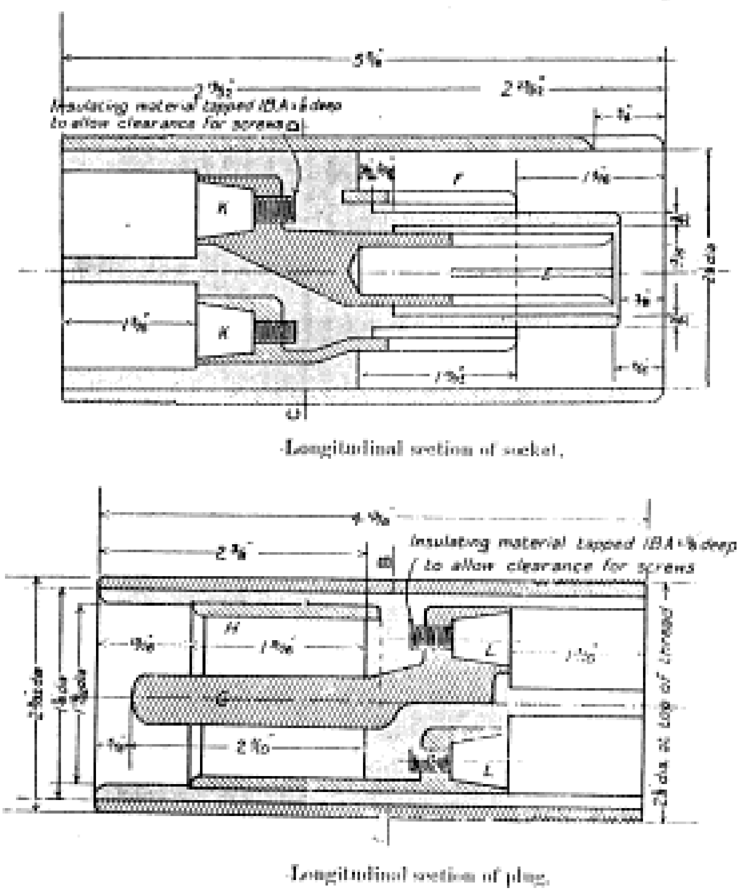


Figure 3.28: Longitudinal section of plug and socket[117]

[117] W. Worby Beaumont, op.cit.

3.2.4 Standardization of voltage

A second standardization issue that was tackled by the Electric Vehicle Association of America concerned the battery voltage, or, otherwise said, the number of cells in a battery.
The rationale behind this issue was presented in a paper by Alexander Churchward at the February 1911 meeting of the EVAA[118].
The necessity of standardizing the voltage was identified for three reasons:

- ☞ The nationwide interest shown for electric vehicles, where it could not be expected that all "central stations" provide charging facilities at a great variety of voltages, considering the cost of doing so;
- ☞ Proper charging facilities at public garages are much easier with standardized charging equipment;
- ☞ A vehicle usually charged at a private garage may be charged while "en tour" at any other garage or charging station.

The electric vehicle market presented a wide array of voltages; historically the voltage levels had been increasing from 20 or 24 V (10 or 12 lead-acid cells) in early vehicles to 80 or 88 V (40 or 44 cells). The tendency was all the time to increase the number of cells.

An overview of the voltages in use is given in Table 3.2. The proposed standard levels (marked with asterix in the table) correspond to respectively 30, 40 or 42 lead-acid cells or 40, 60 or 62 alkaline cells. It appears from Table 3.2 that the adoption of two charging voltages, with a small amount of regulating resistance, would simplify matters considerably. One should also note that the maximum voltage required for the higher proposed level is close to 110 V, allowing the charge to be performed from an 110 V d.c. network with minimal losses in the regulating resistance.

The tendency to go to higher voltages allows higher power without drawing excessive currents, and to improve efficiency. A comparison of motor efficiency showed that particularly commutator losses at the brushes increase with lower voltages (the efficiency loss at normal load being 2,7% due to brush loss alone)[119]

The use of "metalline" brushes was proposed to increase the efficiency, but it was stated that the characteristics of a standard motor designed to use graphite brushes were not correct for metalline brush, and that it would not be worth to change the motors.

---

[118] Alexander Churchward, The Standardization of the Electric Vehicle, Meeting of the EVAA held on 1911-02-27 in the Engineering Societies' Building, 29 West 39th street, New York City; The Central Station, Vol 10 n9 (1911-03) p245-

[119] Ibid.

	Number of cells	Rated voltage	Maximum charging voltage required
Lead	10	20	26
	12	24	31
	14	28	36
	20	40	52
	24	48	62
	27	54	70
	28	56	72
	30	60	77,5 *
	32	64	82,5
	36	72	92,5
	40	80	102 *
	42	84	107 *
	44	88	112
Alkaline	40	48	72 *
	50	60	90
	60	72	108 *
	62	74,4	112 *

Table 3.2: Number of cells in batteries[120].
*The proposed standard values are marked with * in the last column.*

The main conclusions forwarded by Alexander Churchward in his paper, which summarize the need for standardization of voltage, are the following:

> *"My own impression is that we must increase the voltage and decrease the current within practical limits. If we can do this, the number of cells in all the various makes of vehicles of a given capacity will be the same. The number of plates, or the charging current, will be approximately the same for same size vehicle of different makes.*
> *When you adopt one or more standard voltages, then the charging plugs, cables and resistances, etc., can be made to take care of all makes of vehicles, and you will give the central station man a chance to get after customers and boost the electric vehicle for all he is worth."*[121]

The presentation of this paper was followed by an extended and interesting discussion of the subject, held by several actors in the field.

A general view of standardization issues and the impact of standardization was given by J.W. Lieb, Jr., the vice-president of the New York Edison Company, who had a long experience in electrotechnical standardization through the AIEE (cf. §3.4.4). Concerning standard voltages, he highlighted the "entirely useless and

[120] Ibid.
[121] Ibid.

wasteful dissipation of energy" that resulted from charging odd voltage batteries with rheostatic control.[122]

Bruce Ford, of the Electric Storage Battery Company, presented a view from a battery standpoint[123]. He underlined the main advantages of standardization, and noticed the interest in standardizing battery plates to a limited number as well. Battery plates are the parts on a battery that wear out, and that were, in these times, routinely replaced.
Mr. Ford supported the proposal of Mr. Churchward for three or four voltage standards, but suggested to match the respective voltages for lead and alkaline batteries, proposing 28 lead cells as a standard rather than 30, the corresponding charging voltage of 72 V, being the same as 40 alkaline ("Edison") cells.

An electrotechnical point of view was presented by Mr. J.D. Forrer of the Westinghouse Company[124].
He opens with a concise statement on the value of standardization for the electric vehicle:

> *"If the electric vehicle is to reach the full measure of success which we all know it will in time, simplicity and cheapness both in construction and operation would be undoubtedly be very important factors, and if we are to attain the highest state of development along these lines, it can be done only along the broad path of standardization."*

Mr. Forrer also suggested an adaptation of the voltage levels to be selected. A motor generator set or a rotary converter, being fed from a 55/110 V three wire system, could operate without problem (and with reduced losses) within a range of 70 tot 140 V, and would thus be quite flexible as to the battery voltage to be connected. He stated however that the adoption of 30 battery cells (60 V) as a minimum would be a handicap for the builder of lighter vehicles, which "might" come into regular use.
He further highlighted some of the essential aspects of the standardization process: the necessity of co-operation amidst differing opinions, and once more the need to carefully standardize facing future developments is raised: standard documents, once approved, are liable to stand for a number of years, and if found to be wrong, they can have done a lot of damage.

> *"The evil that men do lives after them".*

The proposed standardization of battery voltage levels also affected the standardization of motor voltages of course. The two proposed standard levels

[122] Ibid., discussion, remark by J.W. Lieb, Jr.
[123] Ibid., discussion, remark by Mr. Ford
[124] Ibid., discussion

correspond to two standard motors - 60 and 85 V motors[125], these voltages corresponding to the average throughout the range of the battery.

The standardization of the voltage was adopted by electric vehicle manufacturers; on the second annual convention of the EVAA in 1911, it was stated that nearly all companies now made vehicles within reasonable limits of the two proposed standards, the difference not varying greater than 28 to 32, and 40 to 44 lead cells respectively. This evolution was considered satisfactory by the Standardization Committee, as the charging apparatus could easily take care of these variations around the two standards[126], with rated charging voltages of 78 V on the smaller vehicles and 110 V on the larger vehicles being used[127].

Apart from the standardization work carried out by the Standardization Committee of the EVAA, some work in the field was performed by the local sections of the association which had come to being in major US cities. The standardization of voltage was discussed for example in a meeting of the Chicago section, where "simplification" was cited as one main advantage of adopting a standard number of cells. Furthermore, the waste in energy when charging batteries with a small number of cells from a direct current system was cited: these would actually require as much power as a full-size battery of 40-42 cells, due to the dissipation in the rheostat.[128]
A motion was seconded to appoint a (local) standardization committee "for the purpose of doing what was necessary to standardize the number of cells in vehicle batteries, to have unlimited scope, and if necessary, to take up the subject of sizes of trays, jars, etc., even to working along the lines of standardizing vehicle lamp voltages, lamp sockets, etc." [129]
The report of the Chicago committee, after being approved by the Chicago section, was submitted to the national standardization committee[130].

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[125] Ibid., discussion, remark by Mr. Williams
[126] Alexander Churchward (Chairman of Standardization Committee), Standardization of voltage; The Central Station, Vol 11 n5 (1911-11) p125-
[127] Alexander Churchward, The Standardization of the Electric Vehicle, February 1912 meeting of the EVAA; The Central Station, Vol 11 n9 (1912-12) p254
[128] Statement by Harry Salvat - Fashion Automobile Station; 1915-03-09 meeting of the Chicago Section of the EVAA; The Central Station, Vol 14 n12 (1915-06) p381
[129] Chicago Section, 1915-02-02 meeting, The Central Station, Vol 14 n9 (1915-03)
[130] Chicago Section, 1915-08-31 meeting, The Central Station, Vol 15 n4 (1915-10) p97

3.2.5 Standardization of speed

A third attempt at standardization taken on by the Electric Vehicle Association of America concerned the standardization of speed.
The speed of the electric vehicles proposed on the market did in fact increase every year; this was not being caused by technological evolution, but by marketing: "the salesman finds it easier to dispose of a car which will go faster than that of its nearest competitor"[131].
This phenomenon raised safety concerns among the Standardization Committee. Electric "pleasure" vehicles were in fact advertised to be simple and easy to operate, and were thus popular with women and even children. This gave rise to the following concern, which could still be expressed openly in an era not yet affected by "political correctness":

> *"But when you stop to consider that one of these glass-enclosed vehicles weighs nearly one ton and a half, with passengers, and is capable in some cases of making 25 miles on good level roads, do you not think that the speed is too high for a vehicle to be properly controlled by a woman or a child. Twenty miles an hours I consider very fast, yet the braking strain is 56 per cent. greater at 25 miles than at 20 miles."*[132]

Alexander Churchward did talk this matter over with several manufacturers, who would welcome some standard maximum speed, "providing that the different companies would stand by it". This would not concretize however, the speed remaining, under influence of the (gasoline) sports car, a major marketing tool for the vehicles.

A deeper reasoning concerning standardization of speed developed however taking into account the effect of speed on the energy consumption of a vehicle. It was clearly recognized in fact that excessive speeds would dramatically increase energy consumption, this effect being caused both by tire losses and wind resistance ("windage").
A measurement campaign had been set up with an electric vehicle fitted with graphical recording instruments[133], and by combining road tests (performed on a course in New York City presenting "average conditions") with dynamometer tests performed in the factory it was possible to separate the various losses due to tires and windage.
It became clear that the power required did rise very rapidly as the speed was increased over 17 to 18 miles per hour.

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[131] Alexander Churchward, The Standardization of the Electric Vehicle, February 1912 meeting of the EVAA; The Central Station, Vol 11 n9 (1912-03) p254-261
[132] Ibid.
[133] Alexander Churchward, The Standardization of the Electric Vehicle; The Central Station, Vol 11 n9 (1912-03) p254-261 - see also The Central Station, Vol 12 n5 (1912-11) p166

Alexander Churchward thus suggested the following speeds for electric pleasure vehicles:

☞ Closed type (Coupé) - (Figure 3.6)
 - ☚ 19 mph with pneumatic tires
 - ☚ 18 mph with solid cushion tires

☞ Open Victoria type - (Figure 3.5)
 - ☚ 20 mph with pneumatic tires
 - ☚ 19 mph with solid cushion tires

For really fast speed, the design of the vehicle had to be adapted, and an aerodynamic so-called "Torpedo" design adapted. A typical example of the "torpedo" design is Jenatzy's well-known "Jamais Contente", shown in Figure 3.7. This type of vehicle was not considered a good suggestion for practical use; as stated above, it would however have a deep influence on future automobile design (cf. §3.1.3).

The speed/consumption problem was also analyzed from the commercial vehicle side.
The ideal speed to be selected depended on minimizing tire and windage losses; a "critical speed" was defined, where a minimum tractive effort is necessary, this being mainly dependent on the deformation of the tires. For heavy commercial vehicles, the proposed speeds were rather low (e.g. 7,5 mph for a 3-ton truck); such speeds compared very favorably however with the electric truck's main competitor: the horse-drawn vehicle, for which an average speed of 2,5 mph for a 3-ton vehicle was cited.

The commercial demand for high speed was also commented: should manufacturers meet the desires of the purchasers for a high-speed car, or should the speed be standardized (i.e. limited) for the benefit on energy consumption and efficiency of operation? The argument cited here is typical for the position of the electric vehicle circles of the time:

> *"I think in this, as in a great many other things, it is best to educate the public as to what is best for them, and not always to give them what they want."*[134]

The adoption of high speeds was in fact strongly frowned upon, for the energy consumption reasons mentioned above, which were one factor in disfavor of the electric vehicle due to limitations in range, but also for the higher strain on the tires. This argument was of course also valid for gasoline vehicles, the adoption of moderate-speed electrics being advocated as a much more economical solution for

[134] Ibid., remark by Mr. Lloyd (Electric Storage Battery Company, Philadelphia)

commercial vehicles. This way, the low speed of the electric was publicized as its advantage[135].

> *"As an economic feature in the transport of goods, the electric truck would long ago have secured the dominating position, but for the foolish notion some have derived from the gas car craze that high speed and power are essential to the moving of goods (...) With the lower speeds soon going into effect it is apparent that the alleged advantages of the gas car over the electric have ceased to exist."*[136]

The attractiveness of a high-speed vehicle would however prove to be greater, and the definition of a standard maximum speed was not materialized.

3.2.6 Tires and tire efficiency

The tires turned out to be very critical components for the electric vehicle.[137] The influence on energy consumption was considerable, as it was stated that the same vehicle with two different makes of tires could have a difference in range as high as 25 to 30 per cent.
The issues concerning the use of tires were discussed at the EVAA meeting in March 1911, where the desirability of standardization was cited, particularly concerning the "solid cushion" tire (the most popular type used for electric vehicles in that period), where it was stated that

> *"some types which are classified alike vary nearly 40 per cent. in the volume of rubber as between different makes. (...) This naturally complicates the question of comparing tires and makes a great variation in the mileage and service which can be expected."*[138]

To allow comparison of tires, the Standardization Committee suggested that a maximum tractive effort or bar pull be standardized for a given size of tire, so that all vehicles would be on an equal basis with the given tire.[139]
The expression of a definite method of testing tires for efficiency was not easy however. There was a considerable confusion, especially among tire manufacturers, about the various methods in use.
In 1913, the Committee sent out a circular asking for data on the matter, it was not yet able to formulate a recommendation however.[140]
The matter was later to be treated by the SAE (see §3.3.3.7).

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[135] Cf. G. Mom, op.cit, p. 436-8
[136] Speed Maniac New Menace to Trucks, The Central Station, Vol 11 n12 (1912-06), p367
[137] Cf. G. Mom, op.cit., p523-529
[138] Dan C. Swander, Tires - their use and abuse; The Central Station, Vol 10 n10 (1911-04) p276-283
[139] Alexander Churchward, Report of Committee on Standardization, Third Annual Convention of the EVAA, Boston, 1912-10-8/9; The Central Station, Vol 12 n4 (1912-10) p117
[140] Report of Standardization Committee; The Central Station, Vol 13 n6 (1913-12) p251

3.2.7 Standardization of battery jars and trays

The problem of battery standardization had already been tackled in defining standard voltages (§3.2.4). However, the physical size of the battery also lent itself to standardization work.

Some backgrounds behind this issue are discussed in a paper presented at the New York section of the EVAA[141], where the standardization work on batteries was advocated in order to facilitate battery exchange between vehicles in fleets, limiting the number of reserve batteries to be kept available. An experiment is cited where battery compartments in a fleet of 65 trucks were made to agree in shape and size with a predefined standard; the number of extra batteries needed for these vehicles was reduced from 24 to 11, representing a reduction in investment of $ 5.000[142].

The idea was further developed by Day Baker, from the General Vehicle Co. in Boston, who had also pioneered the standardization of the charging plug, cf. §3.2.3.2. Facing the growing popularity of the gasoline truck, which was seeing an expansion of its market (also due to the demand from the war in Europe, in which the United States would soon be involved), and which was considered as a threat to the electric vehicle,[143] he highlighted the advantages of battery exchange and service systems to make the electric truck a more attractive product. He called upon the NELA (which by then had absorbed the EVAA) as

> *"the real arbiter of the destiny of the Electric truck, to establish battery compartment standards. These must admit of the interchangeable use of any make of battery which is constructed on lines and with characteristics approved by the nela"* [144]

The interest of this work however was not confined to the vehicle user and manufacturer. It also presented a special interest for the electricity producer, marking the central stations as stakeholders in this standardization work:

> *"With standardized battery cradles it would be practical, should any Central Station desire, to sell Electric Current by the mile, a method already demonstrated with some success in Hartford and Boston. This method of vending current would be sure to become popular, as it converts kW-hours into terms which all vehicle users readily understand."*[145]

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[141] S.C. Harris, Methods of design and operation which assure the efficiency of the electric vehicle, presented at the New York Section, 1915-12-28; The Central Station, Vol 15 n7 (1916-01) p187
[142] Ibid.
[143] Cf. G. Mom, op.cit., p468
[144] Day Baker, A Standardized Universal Battery and Compartment Essential for Making the Electric Truck Popular"; The Central Station, Vol 16 n8 (1917-02) p179
[145] Ibid.

Day Baker's suggestion was positively acclaimed as "a step in advance of any present system", which "struck what sounds like the keynotes of success".[146]
"Battery service" schemes were in fact deployed in some cities like Hartford, Conn., where it also become clear that a thorough standardization of battery sizes would not be acceptable to all manufacturers.[147]

Standardization work in the electric vehicle field had at that moment already been shifted to the SAE however, (cf. §3.3.2), and it was under the aegis of this institution that activities in this direction would proceed, as will be discussed in §3.3.3.4.

[146] Popularizing Electric Trucks; The Central Station, Vol 16 n8 (1917-02) p191
[147] Cf. D. Kirsch, op.cit., p153-162

3.3 *Automotive standardization development*

3.3.1 The creation of the SAE

In its early days, the automobile industry was characterized by the activity of a large number of manufacturers each working on himself, and it was perceived that technical progress was retarded through the lack of exchange of knowledge and ideas.
With no concerted action being performed between different manufacturers, and with consequently no standardization of components or materials in place, each component could only be used on that particular car for which it was especially designed. This led to a great expense of production and difficulties in service, and was a heavy burden for economical efficiency of the whole automobile sector.[148]

The concept of "interchangeable manufacture" was one of the key issues in the development of the mechanical industry and of series production methods that necessitated the manufacture of identical components. Such scheme can only be based however on the use of standards, these standards concerning measure, form, material quality, workmanship, component sizes, etc.

The need for standardization in the automobile industry had a technical background, as many old established standard practices showed to be inadequate. For example, there grew a need for finer screw threads. A number of common essential components were also standardized, to allow components and assemblies to be made in one plant and assembled with the final product in another plant. Besides this standardization of form, there came also a standardization of material quality, particularly concerning the properties of steels, in order to insure greater uniformity and dependability. [149]

Economies deriving from adopting standards were identified as follows:
- ☞ In the drawing room, the availability of standard designs can save much detail work.
- ☞ For purchasing departments, the existence of standardized products enlarges the possible sources of supply, and increases the ease to substitute materials or subassemblies.
- ☞ Standard products are more likely found in stock and are of lower prices. These conditions make for free competition and consequent reduction in costs.
- ☞ In the manufacturing process, concentration on relatively few standard types allows manufacturers to benefit from economics of scale. Standard holes and

[148] George W. Dunham, The Standardization Work of the SAE; SAE Bulletin, Vol xi n6 (1917-03) p632
[149] Karl W. Zimmerschied, The Value of Standards in the Manufacture of Automobiles, SAE bulletin Vol IX n1 (1915-10) p15-18; also reproduced in SAE Transactions 1915 part2, p464

threads allow the use of standard tool; standardization reduces the cost of tools and the number of tools required.

☞ The conformity to a published standard is a major selling argument, which establishes a feeling of confidence.[150]

The need arising to have a technical society dealing specifically with the nascent automobile industry, allowing exchange of ideas and expanding of the knowledge base, including the development of engineering standards, was expressed in the early years of past century, leading to the inception of the "Society of Automobile Engineers":

> *"Now there is a noticeable tendency for automobile manufacturers to follow certain accepted lines of construction, technical questions constantly arise which seek solution from the cooperation of the technical men connected with the industry. These questions could best be dealt with by a technical society. The field of activity for this society would be the purely technical side of automobiles."*[151]

The SAE was founded in 1905 in New York City, seeing its membership expanding rapidly.
One of the first standardization issues covered concerned that humble but essential component which is the screw. The SAE screw-thread standard was established in 1906, meeting an urgent need and being a success from the start, bringing order in the chaos of screw-threads that existed. The next great stride was to decrease the number of unnecessary sizes of products such as steel tubing, where the standard number of sizes had been reduced from nearly two thousand to one hundred and fifty, meeting all necessary needs and allowing simplification of manufacture, less stock problems, lower prices and better products[152].

SAE was supported financially by the National Automobile Chamber of Commerce; this support enabled it to "carry on its standardization work more aggressively"[153].

SAE activities, particularly in the field of standardization were however to expand to other sectors. Representatives from other sectors, like the electric vehicle (see §3.3.2 below), but also the (agricultural) tractors, through the Society of Tractor Engineers, and the emerging aeronautic industry, through the American Society of Aeronautic Engineers, made a pitch to SAE for oversight of the development for technical standards in the respective fields of business. The aircraft section in particular saw the benefits of standardization, in order to reduce the number of components in use:

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[150] Ibid.
[151] Peter Heldt, The Horseless Age, 1902, quoted in http://www.sae.org/about/history.htm
[152] George W. Dunham, op. cit., p633
[153] William H. Vandervoort, Presidential Address, SAE Bulletin Vol IX n4 (1916-01) p197

> *"Just now history is repeating itself and, as in the automobile industry, each engineer and draftsman is allowing his ingenuity and artistic fancies to prevail in the design of bolt and screw heads, bolt and screw bodies, thread forms and pitches, rod ends, cotter-pin holes, castle nuts, turnbuckles, steel wire rope ends, strut ends, and in fact the design of every item, important and trivial, that makes up the whole machine. This procedure is not indicative of good design or good business."*[154]

The helping hand of the SAE was thus wanted to save the situation.

In 1916 the "Society of Automobile Engineers" thus became the "Society for Automotive Engineers", representing engineers in a wide array of vehicle- and mobility-related activities. Standards development became a vital part of SAE's service to the industry and to society.

The procedure for adoption of standards by the early SAE reflects the same sound and safe principles that are still used in today's standardization work, and that are key elements in its success[155]:

- ☞ There is no forcing of any kind in the formulation of standards.
- ☞ No subject is considered for standardization except in answer to a normal, spontaneous demand.
- ☞ There is a specific procedure for approving new subjects and for preparing reports through the work of the divisions in charge of standardization in a specific field.
- ☞ Acceptation of standards is done by voting.
- ☞ Standards are published and made available to all interested parties.

The danger of overstandardization, which could hamper technical progress, was clearly recognized however:

> *"We are going slowly because there is danger of trying to standardize too much. There is quite as great a danger as trying to standardize too little. There are certain suggestions which have come, which ask the standardizing of certain matters that I and many of us who have considered the subject are sure should never be standardized. It would tend to throttle original work, and that must not be throttled by any standards."*[156]

The SAE also understood the key value of international collaboration in standardization matters, as stated by the society's president William H. Vandervoort in 1916:

> *"Along the lines of standardization, it is the desire of the Society to bring about a closer relationship between the manufacturers of the United States and European countries. While we fully appreciate the many serious obstacles standing in the way of international standards, we nevertheless believe that an effort should be made towards*

[154] Henry Souther, Proceedings at standardization meeting, SAE Bulletin, Vol XI n5 (1917-02) p490
[155] George W. Dunham, op. cit., p634
[156] Henry Souther (Chairman of Standards Committee), SAE Transactions, 1911, p328

> *co-operation in that direction at this time, feeling that the situation can never become more favourable than it is to-day."*[157]

The "favorable situation" must of course be understood in the light of the war which was going on and which necessitated the intensification of co-operation between the allied countries...

The war created in fact its own needs for standardization: the military tendency the world over is towards uniformity, and towards standard designs. The military authorities had every reason to encourage the movement towards standardization in automobile engineering. Although the tendency to introduce one standard design of vehicle was opposed by manufacturers (because "no single vehicle can monopolize the good features of automobile design") nevertheless the standardization of components, particularly concerning repair and maintenance work was recognized as necessary. Such features could in fact be adopted "without interfering in any way with the scope of the designer and without arresting progress".[158]

The SAE standards were made available in the comprehensive "SAE Handbook", the aim of which was to be "the textbook of automobile engineering"[159]. It is published yearly up to this day, and grew from a pocket-size booklet to today's three volumes with thousands of pages.

3.3.2 Collaboration EVAA- SAE and transfer of standardization activities to SAE.

3.3.2.1 Position of EVAA

Through the efforts of the Standardization Committee of the Electric Vehicle Association of America, a cordial relationship had been established with the Society of Automobile Engineers, which had appointed an Electric Vehicle Committee, to give careful consideration to electric vehicle conditions in the automobile world[160].
On the June 1914 meeting of the EVAA, Mr. E.R. Whitney, Chairman of the Standardization Committee, offered a resolution requesting the establishment of a collaboration in standardization matters between the EVAA and the SAE[161]. The

[157] William H. Vandervoort, op.cit.
[158] War Standardization Lessons, SAE Bulletin Vol X n1 (1916-04) p450
[159] Standards committee reports, introduction, SAE Transactions 1911, p61
[160] April meeting of the EVAA, The Central Station, Vol 13 n11 (1914-05) p420
[161] June Meeting of the EVAA, held in the Auditorium of the Consolidated Gas Company, 130 East 15Th street, New York City, on 1914-06-19; The Central Station, Vol 14 n1 (1914-07) p13

Standardization Committee of the EVAA was to remain active, "insofar it could be of assistance in supplementing the efforts of the SAE Standardization Committee, and also for the purpose of acting upon matters of peculiar significance to the electric vehicle industry".
This action was reported as being favorably received by the SAE[162].

3.3.2.2 Position of SAE

At the meeting of the SAE Standards Committee in 1914, the remark was made that the SAE up to that moment had neglected the electric vehicle completely.
There was already an "Electrical Equipment Division", however, which had evolved from the "Electric Lighting Division", and which was focused on starting batteries and electrical equipment for gasoline vehicles.
It did issue for example recommendations on insulation requirements of electrical apparatus on gasoline automobiles, dimensions of starting batteries, starting/lighting battery ratings, fuse dimensions and wiring systems[163].
The latter subject concerned the choice between the single-wire and the two- wire system, and became the subject of deep discussions. Both systems had their advantages, the most obvious being respectively simplicity and reliability. In 1913, the SAE recommended to leave the matter and take no action for the moment.[164]
A statement by the Electrical Equipment Division to recommend the single-wire grounded return system was rejected at the 1914 Summer meeting of the SAE[165], as there was still too much discussion going on about the merits of the two systems to make a definite recommendation. The tendency was however clearly towards the single-wire system that would become general in its use.

W.H. Conant, of the Gould Storage Battery Co., who also was a member of the EVAA Standardization Committee, moved to form an Electric Vehicle Division within the SAE, for the purpose of aiding the electric vehicle industry just as other divisions of SAE were aiding the gasoline car industry. This motion was put to a vote and carried; the standardization work already performed by the EVAA was acknowledged and further collaboration welcomed.[166]

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[162] E.R. Whitney, Standardization, July Meeting of the EVAA, The Central Station, Vol 14 n2 (1914-08) p43
[163] Fourth report of Electrical Equipment Division, SAE Transactions 1914 part 1, p7
[164] Report on Electric Lighting Division, SAE Transactions 1913 part 1, p28
[165] Fifth Report of Electrical Equipment Division, SAE Transactions 1914 part 2, p17
[166] On electric vehicle standards and practices, Meeting of the Standards Committee, New York, 1914-01-05; SAE Transactions 1914 part 1, p163-4

3.3.2.3 Transfer of activities

The further standardization actions concerning electric vehicles were gradually transferred to SAE. In 1916, Whitney suggested that the Standardization Committee was to be disbanded, the work being handled under an agreement with the SAE[167]. The personnel of the Electric Vehicle Division of the SAE Standardization Committee was in fact identical with that of the EVAA Standardization Committee[168] [169], with the exception of two or three members, and the EVAA Standardization Committee, later to become the NELA Electric Vehicle Section Standardization Committee, was relegated to the role of an advisory or consulting committee, reporting to the NELA about the standardization work in progress[170].

The NELA committee, which counted up to 15 members at its heyday[171], had shrunk to just five members in 1920[172]; the next year, it had disappeared altogether[173].
The SAE Electric Vehicle Division in 1915 consisted of 19 members, and had sub-divisions devoted to "Motors and Controllers", "Batteries, Wiring and Charging", "Speed and Mileage Ratings" and "Tires".[174] The total membership of the SAE Standards Committee was 120.

3.3.3 Activities of the Electric Vehicle Division in the SAE Standards Committee

The Electric Vehicle Division continued the work of the EVAA Standardization Committee and also took on new subjects.

3.3.3.1 Standardization of charging plugs

The concentric plug standardized by the EVAA (§3.2.3.3) was also adopted as a SAE standard, and featured in the SAE Handbook.

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[167] Standardization Committee, Meeting held in New York City, 1916-10-13; The Central Station, Vol 16 n5 (1916-11) p121
[168] Report of the Standardization Committee, NELA Thirty-Ninth Convention, Chicago, Ill., 1916-05-22/26 - Electric Vehicle Sections Papers and Reports, p50
[169] Third report of Electric Vehicle Division, Annual meeting of the SAE, SAE Transactions 1916 part2, p3
[170] Electric Vehicle Section, Report of Committee on Standardization, read before the National Electric Light Association at its Fortieth Convention held in Atlantic City, N.J., 1917-05-28/06-01, p16
[171] Standardization committee, The Central Station, Vol 14 n10 (1915-04) p313
[172] Electric Vehicle Section, NELA Proceedings, 1920, p816
[173] Electric Vehicle Bureau, NELA Proceedings, 1921, p1354-5
[174] SAE Bulletin, Vol IX n2 (1915-11), p104

In 1916 however a few dimensions of the receptacle were slightly changed following a suggestion by the Anderson Manufacturing Company[175], a major manufacturer of charging plugs up to this day. Some dimensions were enlarged, lengthening the sleeve and insulating members of the receptacle. The reason for this change was to obviate the present tendency towards breakage of the shell when the plug is inserted or withdrawn.[176] The proposed changes are shown in Table 3.3.
The change was adopted by letter ballot, 67 votes to one.[177]

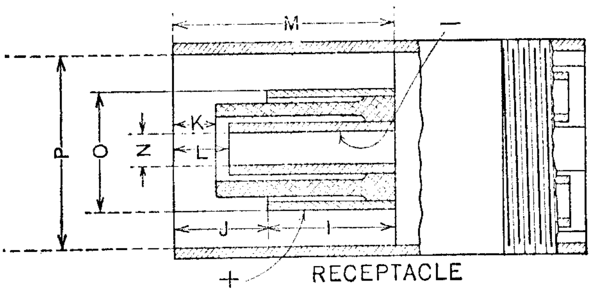

Figure 3.29: Charging receptacle

With these dimensions, the plug continued to feature as a SAE standard throughout the years to come.
From 1929 however, the 50 A version, was presented with a rating of 100 A, its dimensions remained unchanged.
The last time the concentric plug appeared in the SAE Handbook as a SAE Standard was in 1939[178].

	50 A		150 A	
Dimension	Proposed	Present	Proposed	Present
J	1 1/8	7/8	2	1 5/16
K	5/8	3/8	1	5/16
L	5/8	3/8	1 1/8	7/16
M	2 1/4	2	3 13/32	2 3/32

Table 3.3: Changes in charging receptacle dimensions (inches)[179]

3.3.3.2 Standardization of voltage

The recommended voltage levels (§3.2.4) were further adapted by the SAE, which recommended the adoption of two classes of motors for electric vehicles, one for 80 to

[175] Electric Vehicle Division Report, SAE Bulletin Vol IX n4 (1916-01) p289
[176] Electric Vehicle Division Report, SAE Bulletin Vol X n4 (1916-07) p519
[177] Standards adopted by letter ballot, SAE Bulletin Vol X n5 (1916-08) p595
[178] SAE Handbook 1939, p124
[179] Charging receptacles, Fourth Report of Electric Vehicle Division, SAE Transactions 1916 part 2, p13

85 V operation, the other for 60 to 66 V operation. The characteristic curves for each of the limit voltages had to be furnished by the manufacturer.[180]

The recommended battery voltage was defined as 42 cells (84 V) for lead-acid batteries and 60 cells (72 V) for nickel-iron alkaline batteries. The use of 44 cell batteries was reported to give problems at charging (due to low supply voltages encountered).[181]
The aim of choosing these levels was clear:

> *"that all electric vehicles should be equipped so that they can be charged from a 110-volt service"*[182]

The scope of the motor voltage recommendation was limited to electric vehicles "other than industrial trucks". For industrial trucks (defined as "small electric trucks to replace manual labor, generally operating within buildings and shop enclosures") lower voltages (24 or 36 V) were (and are still up to this day) more popular. The industrial truck however was not considered as being in the scope of the Division's activities[183].

3.3.3.3 Speed and mileage ratings

For this, we come to another type of standard: the performance standard, which allows the user to objectively assess a product's operational characteristics.
In those days just like today, the performances of electric vehicles were a sensitive issue, and the subject was one of the first to be tackled by the Electric Vehicle Division of the SAE. The approach followed differed from that taken initially on speed standardization by the EVAA (§3.2.5), focusing on performance measurement rather than imposing limits.
The first form of recommendation to be proposed on the SAE meeting in January 1915 was as follows:

> *"Electric vehicle speed ratings shall be based on continuous operation with one-half load over hard, smooth and level roads or pavements at the actual average battery voltage.*

[180] Motor voltage, Second Report of Electric Vehicle Division, SAE Transactions 1915 part 2 p12. Also in SAE Handbook, 1921-03, B41 and 1923-07, B102.
[181] Number of cells in standard battery equipment, Second Report of Electric Vehicle Division, SAE Transactions 1915 part 2 p13
[182] Remark by R. McA. Lloyd (General Vehicle Co.), Discussion on Second Report of Electric Vehicle Division, SAE Transactions 1915 part 2, p84
[183] Discussion, Second Report of Electric Vehicle Division, SAE Transactions 1915 part 2 p12

Electric vehicle mileage ratings shall be based on the rated five-hour discharge capacity of the battery and a continuous run with one-half load over hard, smooth and level roads and pavements."[184]

It was soon realized that defining a standard for electric vehicle performance ratings was not a straightforward thing, and a thoroughly critical discussion was held on the subject, under the motto:

"I think we ought to be interested in the work that is being done by the Standards Committee and not let anything go through that we really do not approve."[185]

The mileage rating definition based on the five-hour rating of the battery had been selected based on the battery manufacturers' practice of defining this rate as the "normal" discharge rate. This was not always matched to the real discharge rate when fitted in the vehicle, which was in many cases lower than the five-hour rate, it was stated that "electric vehicles are almost all run six or seven hours with the batteries that are in them".[186] The difference with the five-hour rate then provided a "safety factor"; however, the practical object of this defined rating was questioned. It had been proposed by the committee "to give a basis for comparison" but not to describe "a particular test" [187].
As the mileage rating according to the proposed specification was likely to give a lower value than the actual mileage to be covered by the vehicle, which would be a disadvantage for the manufacturer required by the Government or by some other purchaser to furnish a certain mileage, as the standard rating would be "all the rating he would get credit for"[188].
This report on speed and mileage ratings was eventually not accepted at the January 1915 SAE meeting, and referred back to the committee.

The Second Report of the Electric Vehicle Division stated that the matter was still under discussion, a revised definition being submitted to manufacturers.[189]
The result of this correspondence was given in the Third Report:

"Electric vehicle speed ratings shall be based on continuous operation with one-half load over hard, smooth and level roads or pavements at the actual average battery voltage.
Electric vehicle mileage ratings shall be based on a continuous run at the SAE rated speed with one-half load over hard, smooth and level roads or pavements."[190]

[184] Speed and mileage ratings of electric vehicles; SAE Transactions 1915 part 1, p6
[185] Discussion, Speed and Mileage ratings of electric vehicles; SAE Transactions 1915 part 1, p56-60
[186] Remark by R. McAllister Lloyd, discussion on Speed and mileage ratings, SAE Transactions 1915 part 1, p6
[187] Ibid., remark by A. J. Slade, Chairman of Electric Vehicle Division
[188] Ibid., p8, remark by R. McA. Lloyd
[189] Speed and mileage rating, Second Report of Electric Vehicle Division, SAE Transactions 1915 part 2 p13
[190] Third report of Electric Vehicle Division, Annual meeting of the SAE, 1916-01-04; SAE Transactions 1916 part 1, p1

The mileage definition had been modified, making both definitions in their "simplest possible form", although it was stated that "it was found impossible to secure any unanimity of opinion among the vehicle manufacturers".
These standards were adopted by letter ballot, each with 36 votes against one.[191]
It is clear that mileage ratings of electric vehicles are not an easy thing to standardize, as they are strongly dependent on the type of use of the vehicles. This problem exists up to this day[192].

3.3.3.4 Standardization of battery jars

The standardization of battery jars was a subject that arose the interest of the EVAA, as described in §3.2.7.
The subject was taken on in the Third Report of the Electric Vehicle Division (1916), where it was stated that:

> *"Any such general standardization and interchange of batteries will have to be brought about gradually and rather deliberately. We first propose to consider the standardization of battery-jar dimensions, reducing the number of jars recommended as good practice to the minimum number practicable, in the same manner that other standards have gradually been reduced from a large to a comparatively limited number."*[193]

During the year 1916, considerable work was been done. A meeting was held on February 25, where aside from the Division members, representatives of five leading battery manufacturers were present. The chief work of this meeting was in regard to dimension of battery jars, as a preliminary to standardizing dimensions of trays to facilitate the interchange of batteries[194].
A proposal was agreed upon for all dimensions except the length (which is a variable based on the number and thickness of plates and thus the battery capacity). A table of proposed lengths was prepared by the Division and submitted to battery makers for discussion, with the aim of reducing the number from about fifty to about twenty-five or thirty.

A standard was eventually proposed in 1917. It recommended two types of battery jars, with respectively "high" and "low" ribs on the jar bottom. These ribs support the plates; the high rib jars have a larger electrolyte reserve and some more place for sediment deposit, thus allowing a longer life. The dimensions proposed are shown in Table 3.4.

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[191] Work of the Standards Committee, SAE Bulletin Vol IX n6 (1916-03) p382
[192] Cf. Electric Vehicle Working Group, op.cit., p18
[193] Third report of Electric Vehicle Division, Annual meeting of the SAE, 1916-01-04; SAE Transactions 1916 part 1, p3
[194] Work of the Standards Committee, SAE Bulletin vol XI n6 (1916-03) p339

	High-Rib Jars		Low-Rib Jars	
	in.	mm	in.	mm
Height over all	13 5/8	346,1	12 7/16	315,9
Width	6 1/8	155,6	6 1/8	155,6
Thickness of wall	1/8	3,2	1/8	3,2
Height of rib	2 3/4	69,9	1 3/4	44,5
Height above rib	10 5/8	269,9	10 7/16	265,1
Lenghts of jars	2	50,8	2	50,8
	2 5/16	58,7		
	2 1/2	63,5		
	2 9/16	65,1	2 3/4	69,9
	2 13/16	71,4		
	3	76,2		
	3 1/8	79,4		
	3 5/16	84,1		
	3 1/2	88,9	3 1/2	88,9
	3 11/16	93,7		
	3 13/16	96,8		
	4	101,6		
	4 1/4	108,0	4 1/4	108,0
	4 5/16	109,5		
	4 1/2	114,3		
	4 25/32	121,4		
	5	127,0	5	127,0
	5 5/16	134,9		
	5 1/2	139,7		
	5 3/4	146,1	5 3/4	146,1
	6	152,4		
	6 1/4	158,8		
	6 1/2	165,1	6 1/2	165,1
	6 3/4	171,5		
	6 7/8	174,6		
	7	177,8		
	7 1/4	184,2	7 1/4	184,2
	7 3/8	187,3		
	7 1/2	190,5		
	7 3/4	196,9		
	8	203,2	8	203,2
	8 1/4	209,6		

Table 3.4: Dimensions for storage battery jars[195]

It was clear that the proposed number of lengths, amounting to thirty-two for the high-rib jars, often with minute differences between them, still seemed excessive, it reflected the differences however existing between various makes of batteries.

[195] Fifth report of Electric Vehicle Division, SAE Transactions 1917 part 1, p8; metric conversion added

Furthermore, the establishment of standards for the arrangement of battery cells in trays was announced.
This report was adopted by letter ballot, 95 votes to one, in 1917[196] and was published as a standard in the SAE Handbook. (Figure 3.30).

The standard was revised in March 1921[197], abandoning the "low-rib" jars, rationalizing jar sizes and adding a number of long jars for heavy-duty vehicles. The new standard also added specifications for the "hard-rubber" (ebonite) material of which the jars were made.

A "recommended practice" for the arrangement of battery trays for industrial trucks and tractors was adopted in August 1920[198]. It stated simply that:

> *"one type of tray of 12 cells shall be used for lead batteries for both industrial trucks and tractors. Batteries for industrial trucks shall consist of one tray unit, and batteries for tractors shall consist of two tray units."*

This recommended practice was further worked out, and in July 1923 a more detailed specification for the battery trays was adopted, for both lead-acid and nickel-iron batteries[199]. These are shown in Figure 3.31 and Figure 3.32.

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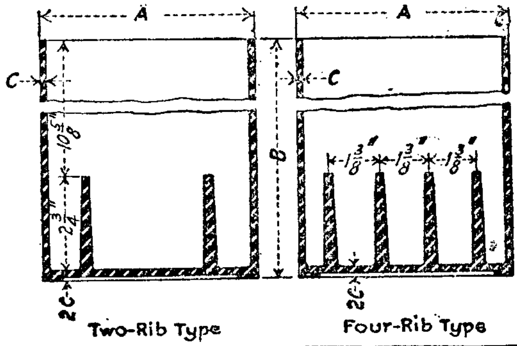
196 Standards adopted by letter ballot, SAE Bulletin Vol XI n6 (1917-03) p711
197 SAE Handbook, 1925, p B39
198 Ibid., p B41
199 SAE Handbook 1926, p B105-B106

STORAGE BATTERY JARS
(Concluded)



Class	Overall Width (A)	Overall Height (B) $\pm\frac{1}{32}$	Wall Thickness (C)	Overall Length: Nominal	Overall Length: Tolerances	Nominal Inside Length
1	$6\frac{3}{16}$ $+\frac{1}{32}$ $-\frac{3}{64}$	$13\frac{11}{16}$	$\frac{5}{32}$ $+0$ $-\frac{1}{64}$	$2\frac{1}{16}$ $2\frac{9}{16}$ $2\frac{7}{8}$ $3\frac{1}{16}$ $3\frac{9}{16}$ $4\frac{1}{16}$ $4\frac{5}{16}$ $4\frac{7}{8}$ $5\frac{1}{16}$ $5\frac{9}{16}$	$+\frac{1}{32}$ $-\frac{3}{64}$	$1\frac{3}{4}$ $2\frac{1}{4}$ $2\frac{9}{16}$ $2\frac{3}{4}$ $3\frac{1}{4}$ $3\frac{3}{4}$ 4 $4\frac{9}{16}$ $4\frac{3}{4}$ $5\frac{1}{4}$
2	$6\frac{1}{4}$ $\pm\frac{3}{64}$	$13\frac{3}{4}$	$\frac{3}{16}$ $+\frac{1}{128}$ $-\frac{1}{64}$	$5\frac{7}{8}$ $6\frac{1}{8}$ $6\frac{1}{4}$ $6\frac{5}{8}$ $6\frac{7}{8}$ $7\frac{1}{8}$ $7\frac{3}{8}$ $7\frac{1}{2}$ $7\frac{5}{8}$	$\pm\frac{3}{64}$	$5\frac{1}{2}$ $5\frac{3}{4}$ $5\frac{7}{8}$ $6\frac{1}{4}$ $6\frac{1}{2}$ $6\frac{3}{4}$ 7 $7\frac{1}{8}$ $7\frac{1}{4}$
3	$6\frac{1}{4}$ $+\frac{3}{64}$ $-\frac{1}{16}$	$13\frac{3}{4}$	$\frac{3}{16}$ $+\frac{1}{128}$ $-\frac{1}{64}$	$8\frac{1}{8}$ $8\frac{5}{8}$ $8\frac{3}{4}$ $8\frac{7}{8}$ $9\frac{3}{8}$ $9\frac{5}{8}$ 10 $10\frac{3}{8}$	$+\frac{3}{64}$ $-\frac{1}{16}$	$7\frac{3}{4}$ $8\frac{1}{4}$ $8\frac{3}{8}$ $8\frac{1}{2}$ 9 $9\frac{1}{4}$ $9\frac{5}{8}$ 10
4	$6\frac{1}{4}$ $\pm\frac{1}{16}$	$13\frac{3}{4}$	$\frac{3}{16}$ $+\frac{1}{128}$ $-\frac{1}{64}$	$10\frac{5}{8}$ $11\frac{1}{8}$ $11\frac{1}{4}$ $11\frac{7}{8}$ $12\frac{5}{8}$	$\pm\frac{1}{16}$	$10\frac{1}{4}$ $10\frac{3}{4}$ $10\frac{7}{8}$ $11\frac{1}{2}$ $12\frac{1}{4}$

All dimensions in inches.

From the report of the Electric Vehicle Division, adopted by the Society March 1917. Revised by the Electric Transportation Division March 1921.

Mar.
1921

Figure 3.30: Standard for storage battery jars

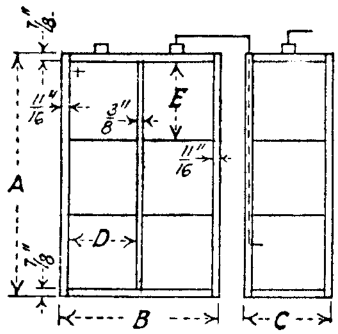


FIG. 1

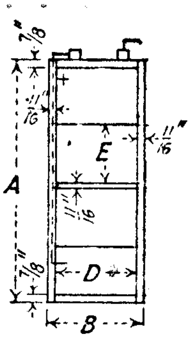


FIG. 2

TABLE 1—LEAD-ACID STORAGE-BATTERY TRAY DIMENSIONS

Fig. Nos.	Nominal Truck Capacity, Tons	Range of Jar Widths or Lengths, In., Incl.	A Max.	B Max.	C Max.	D	E
1	½	Up to $4\frac{5}{16}$	20½	10½	5¾	$4\frac{5}{16}$	$6\frac{3}{16}$
1	1	$4\frac{5}{16}$ to $5\frac{1}{16}$	20½	12	6½	$5\frac{1}{16}$	$6\frac{3}{16}$
1	2	$5\frac{9}{16}$ to $6\frac{7}{8}$	$22\frac{9}{16}$	$14\frac{3}{8}$	$7\frac{11}{16}$	6¼	$6\frac{7}{8}$
2	3½	$7\frac{1}{8}$ to $8\frac{1}{8}$	$27\frac{11}{16}$	$9\frac{5}{8}$	...	$8\frac{1}{8}$	6¼
2	5	$8\frac{5}{8}$ to $10\frac{5}{8}$	$27\frac{11}{16}$	$12\frac{1}{8}$	...	$10\frac{5}{8}$	6¼

The maximum height of all lead-acid storage-battery tray assemblies shall be 16 in.

LEAD-ACID STORAGE-BATTERY TRAY ARRANGEMENTS

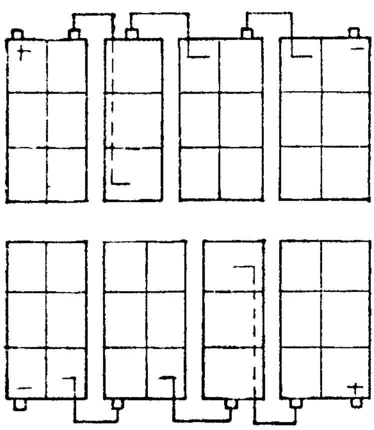


FIG. 1—TRAYS FOR ½, 1 AND 2-TON TRUCKS

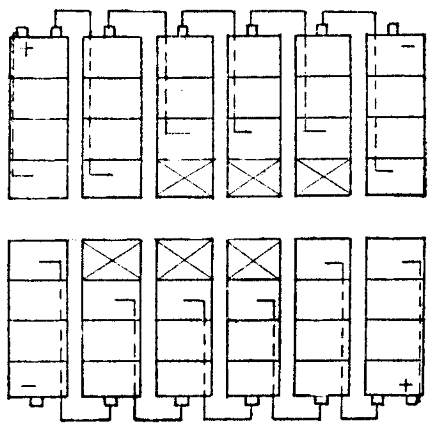


FIG. 2—TRAYS FOR 3½ AND 5-TON TRUCKS

Figure 3.31: Lead-acid storage battery tray dimensions (inches)

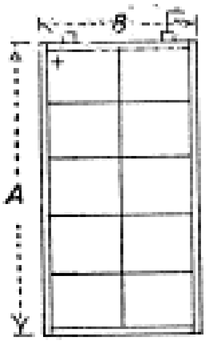


Fig. 3

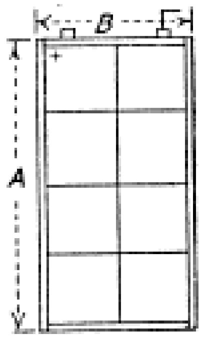


Fig. 4

Table 2—Nickel-Iron Storage Battery Trays With Bottoms

Fig. Nos.	Nominal Truck Capacity, Tons	Type of Battery	A[1]	B	Battery[2] Height
3	½	A5	20½	12¼	15⅛
3	1	A6	23 7/32	12¼	15⅛
3	1	A7	26⅛	12¼	15⅛
4	2	A8	24⅝	12¼	15½
4	3½	A10	26⅜	15½	15½
4	5	A12	26⅜	18	16¼

[1] Includes ¼-in. bumpers at both ends. In adding terminal plates, subtract ¼ in. from the terminal plate height.
[2] Maximum height of batteries in trays with the caps closed.

Nickel-Iron Storage-Battery Tray Arrangement

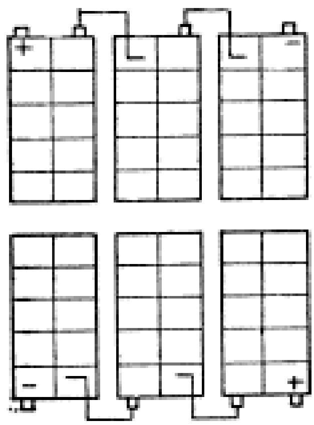


Fig. 3—Trays for ½ and 1-Ton Trucks

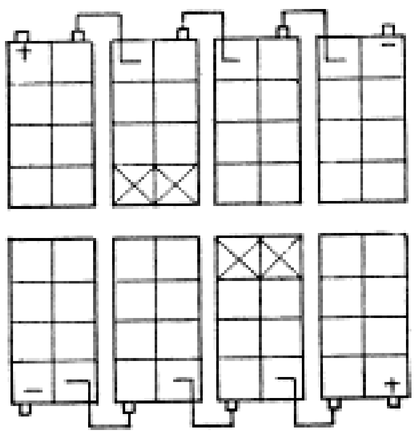


Fig. 4—Trays for 2, 3½ and 5-Ton Trucks

Figure 3.32: Nickel-iron storage battery tray dimensions (inches)

3.3.3.5 Motor name-plates

The following statement concerning the standardization of motor name-plates was adopted in 1915:

> *"It is recommended that each motor shall carry a name-plate setting forth the following particulars:*
> - ☛ *Manufacturer's name and address*
> - ☛ *Whether series, shunt or compound automobile motor*
> - ☛ *Frame size*
> - ☛ *Volts*
> - ☛ *Amperes*
> - ☛ *r.p.m.*
>
> *Under volts, amperes and r.p.m. should be given the figures for both high and low limits of voltage as recommended above."*[200]

This statement reflected standard electrotechnical, rather than automotive, practice, as it followed the recommendation of the AIEE Standardization Rules[201].

3.3.3.6 Motor ratings

The recommended practice on motors (featuring the motor voltage and motor name-plate recommendations described above) was completed in 1923 with a paragraph about motor rating:

> *"The rating of electric automobile propulsion motors shall be based on a temperature rise not to exceed 65 deg. cent. (117 deg. fahr.) by thermometer, or 75 deg. cent. (135 deg. fahr.) by resistance after 4 hr. of continuous operation at normal rated load.*
> *The tests shall be made on a stand with the motor covers arranged as in service."*[202]

This clause should of course be compared with the motor ratings as defined by the AIEE Standardization Rules and discussed in §3.4.5 below. The temperature rise of 65 resp. 75 °C corresponds to the standard admissible temperature rise of 50 °C, augmented with the values stated in the AIEE rules (cf. §3.4.5 below). The proposed duration of the test, four hours, is an addition of the SAE.
This clause was only included in the SAE Handbook in 1923; the SAE was however following up the AIEE activities in the field as early as 1916.[203]

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[200] Motor name-plates, Second Report of Electric Vehicle Division, SAE Transactions 1915 part 2 p12. Also in SAE Handbook, 1921-03, B41 and 1923-07, B102.
[201] Cf. AIEE Standardization Rules, version 1909, ¶313
[202] SAE Handbook, July 1923, B102
[203] AIEE Standards for Electric Vehicle Motors; SAE Bulletin, Vol X n1 (1916-04) p526

3.3.3.7 *Efficiency test of solid tires*

This matter was given careful consideration by the SAE Electric Vehicle Division, based on a number of tests which have been made from practical experience by members, and recommendations were given covering the rebound method of testing solid tires for efficiency. These recommendations were not adopted however, principally because of lack of familiarity with the method recommended[204].
It may seem strange why this subject, which seems of equal significance for gasoline vehicles, was referred to the Electric Vehicle Division, were it not that the extra consumption involved would seriously affect the range of the electric vehicle, and thus be "a matter of life and death with the electric truck to have efficient tires"[205], whereas it is only a question of the amount of fuel with the gasoline truck.

3.3.3.8 *Standardization of lamps*

One of the first areas where the collaboration between EVAA and SAE showed effective results in the field of standardization was the standardization of lamps for vehicles.
This presented several aspects: the standardization of the lamp socket and the standardization of the voltage.
The SAE already had the Ediswan bayonet socket standardized for automobile use, and this was adopted also by the standardization committee of the EVAA[206]. The need for standardization in this matter was felt from the user's side: "it was very foolish to have to keep a stock of 30 to 40 different types and sizes of lamps"[207].
Another point related to this matter was the lamp voltage to be adopted. This was of course closely related to the battery voltage, the use of an auxiliary (12 V) battery and its d.c.-d.c. converter not being the custom at that time.
At a meeting of the Philadelphia Section of the EVAA[208] in December 1914, the subject of automobile illumination was discussed, and the standardization of components was hailed as to give the users "prompt service and lower prices".
Vehicle lamps could be manufactured for various voltages as desired, but the ordering of small quantities of odd voltages caused of course extra costs to be avoided. It was recommended that lamps would be offered on the market in 6 V

[204] Report of the Standardization Committee, NELA Thirty-Ninth Convention, Chicago, Ill., 1916-05-22/26 - Electric Vehicle Sections Papers and Reports, p50
[205] Report of Electric Vehicle Division, SAE Bulletin, Vol XI n 1 (1916-10) p89
[206] Alexander Churchward, Report of Committee on Standardization, Third Annual Convention of the EVAA, Boston, 1912-10-8/9; The Central Station, Vol 12 n4 (1912-10) p117
[207] Statement by Harry Salvat - Fashion Automobile Station; 1915-03-09 meeting of the Chicago Section of the EVAA; The Central Station, Vol 14 n12 (1915-06) p381
[208] EVAA Review of Activities - Philadelphia Section Meeting, 1914-12-09; The Central Station, Vol 14 n8 (1915-02) p242

intervals ranging from 24 V to 90 V. Any other voltages should be listed at a considerably higher price to discourage their use.
It was clear however that the main criterion for choosing the lamp voltage was the battery voltage, and one could easily choose from that range voltages corresponding to the selected battery voltages.

The Electric Vehicle Division of the SAE also considered the standardization of electric vehicle lamps, since there was considerable diversity in them, with three types of base being used, and fifteen different voltages. The Division hoped to agree on one type of base, three sizes of bulbs and three voltages. Nine or ten different lamps would than take the place of 150 or 200 different varieties in use.[209]
In its Fifth Report (1917), it stated however that

> *"apparently the desired standards have nearly been determined, but the Division is not yet ready to report them for adoption."*[210]

3.3.3.9 Standardization of cable

The fourth report of the Electric Vehicle Division also reported on the proposed standardization of charging cable.[211] The Division had under consideration the standardizing of a line of circular duplex cable. This is being taken up to arrive at a uniform outside diameter and to provide for clamping the cable mechanically where it enters the charging plug, and also with a view to eliminating a number of types and sizes of cable in use.
Cable insulated in a circular form was preferred, both to prevent kinking and to have a uniform style of clamp for securing the cable to the plug and relieve the strain from the soldered joint, as required by the underwriters.
The Division had tentatively agreed, after correspondence with the various cable manufacturers, upon a line of cables to consist of the five equivalent sizes: 6, 4, 2, 1 and 0.[212,213] These correspond to square millimeter sections of respectively 17, 21, 34, 42 and 53.
The Division however did not determine the construction of the cable, or its permissible cover temperature, because these matters were being deliberated by two other societies, including the AIEE, which requested not to adopt any standard until its committee could complete its work.[214]

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[209] Electric Vehicle Division, SAE Bulletin Vol XI n 1 (1916-10) p74
[210] Fifth report of Electric Vehicle Division, SAE Transactions 1917 part 1, p9
[211] Fourth Report of Electric Vehicle Division, SAE Transactions 1916 part 2, p13
[212] Report of the Standardization Committee, NELA Thirty-Ninth Convention, Chicago, Ill., 1916-05-22/26 - Electric Vehicle Sections Papers and Reports, p50
[213] Electric vehicle division report, SAE Bulletin Vol IX n 4 (1916-01) p289
[214] Electric vehicle division report, SAE Bulletin Vol XI n 1 (1916-10) p89

This request highlights one other main condition of effective standardization and collaboration between standardization bodies: the fact that the adoption of contradictory documents must be avoided at all cost.

The standardization of sizes for wiring inside the vehicle was also considered, but it was decided that there was no particular advantage to be gained in standardizing sizes for the car wiring proper. However, a request was received from the AIEE for information as to good practice in the sizes of stranded cables used for vehicle wiring. The Chairman of the Electric Vehicle Division was authorized to notify the AIEE of a number of sizes in general use which could be considered good practice: sizes 000, 00, 0, 1, 2, 4, 6 and 8[215]. These correspond respectively to square millimeter sections of approximately 85, 67, 53, 42, 34, 21, 17 and 8.

3.3.3.10 Evolution of electric vehicle standardization in SAE

The work of the SAE Electric Vehicle Division had been intensive, but its activities were limited in time. Since its inception in 1915, it had produced five six-monthly activity reports, the outcome of which has been discussed in the paragraphs above. After 1917 however, with the United States entering the First World War, the electric vehicle became relegated to the background, and fewer activities of the Division could be discerned, apart from adaptations to existing standards as published in the SAE Handbook.

[215] Electric vehicle division report, SAE Bulletin Vol IX n 4 (1916-01) p289

3.4 Electrotechnical standardization development

3.4.1 The history of international electrotechnical standardization: the electrical units

The first impulse towards international electrotechnical standardization was based on the need for unification of electrical measures.
The inception of the international electrical units dated from a paper read at the British Association for the Advancement of Science meeting of 1861, by telegraph engineers Sir Charles Bright and Latimer Clark. [216] This paper led to the formation of the British Association Committee of Standards of Electrical Resistance, which was appointed at the suggestion of Prof. William Thomson, later Lord Kelvin. The principal object of the Committee was, first, to determine what would be the most convenient unit of resistance, and second, what would be the best form and material for the standard representing that unit.[217]
At that time, no coherent system for the measurement of electric quantities had met general approval.

For expressing electrical resistances for example, not less than a dozen different units were in use[218], most of them derived from the resistance of a physical standard (an arbitrary length of a certain wire), several of which were used in telegraph practice. There was also the "absolute" system, devised by W. Weber, which existed mainly "on paper", and was not understood or used by practical men however, where electrical units are being derived from the base units of length, mass and time using the basic equation of electromagnetical force between two parallel conductors[219]:

$$F = \frac{2\mu \times I_1 \times I_2 \times l}{r} \qquad (3\text{-}1)$$

where F is the force, I_1 and I_2 the current in the conductors, l the length of the conductors, r the distance between them and μ equals 10^{-7} (in SI units).

[216] Silvanus P. Thompson, The Aims and the Work of the International Electrotechnical Commission, Paper read before the Institution of Electrical Engineers on 1912-12-19; IEE Journal, vol 50 (1913) p306-326
(Also published in French translation: Le but et l'œuvre de la Commission Electrotechnique Internationale; Bulletin de l'association des ingénieurs électriciens sortis de l'institut Montefiore, Liége, Tome XIII (1913) 3e série, p367)
[217] Reports of the Committee on Electrical Standards appointed by the British Association for the Advancement of Science, Cambridge, at the University Press, 1913, p xvii
[218] Fleeming Jenkin, Report on the new unit of electrical resistance proposed and issued by the Committee on Electrical Standards appointed in 1861 by the British Association; Reports of the Committee on Electrical Standards, London, E.&F.N. Spon, 1873
[219] Cf. Wilfried Taveirne, Eenhedenstelsels en Groothedenvergelijkingen: overgang naar het SI

In this system, electrical resistance is being expressed with the dimension of an absolute velocity.

The Committee was active from 1862 to 1870 and was reappointed in 1881, featuring in its ranks famous physicists and electricians such as William Thomson (Lord Kelvin), James Clerk Maxwell, James Joule and William Siemens. It considered to combine the advantages of the material standard and those of the absolute system, and decided that a material standard should be prepared, equal to a value in the absolute system of ten million meters per second, the magnitude of one meter per second being too small for practical use. For this unit, the name "Ohmad" was suggested, which was adopted abbreviated as "ohm"[220]. For the construction of the material standards, many experiments were performed with resistance coils, as well as with mercury columns, as proposed by Werner von Siemens.
The committee also formulated definitions of other electrical units like the "volt", "coulomb", "farad" and "weber" (the unit for electrical current, later called "ampere").

This British initiative got an international dimension at the International Congress of Electricity held in Paris in 1881[221], which was the first of its kind, being a meeting of delegates sent officially either by governments or by recognized scientific institutions. The Congress agreed to the names of the electrical units ohm, volt, coulomb and farad, and changed the name of the unit of current from "weber" to "ampere".
The second Congress, held in Paris in 1889, adopted the "watt", the "joule" and the unit for self-inductance.
In 1892, the British Board of Trade proposed the name of "Kelvin" for the practical unit of electrical energy, the kilowatt-hour, but Lord Kelvin declined this honor[222]; he would be awarded after his death with the unit for temperature.
The International Electrical Congress of Chicago, in 1893, reaffirmed the units, calling them "international" electrical units, and assigned the name "henry" to the unit for self-inductance.

In the following years, work was performed in the direction of a more precise specification of the values of these units. The International Conference on Electrical Units and Standards, held in London in 1908, registered the definitions of the international units and defined a material standard for the ohm and the ampere, which were chosen as "fundamental electrical units"[223].

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[220] Reports of the Committee, p. xix
[221] S.P. Thompson, op.cit.,p309
[222] Ibid., p323
[223] R.T. Glazebrook, Inaugural Address, London, 1906-11-08; IEE Journal Vol 38 (1906-1907), p9

☞ the international ohm was defined as the resistance of a column of mercury with a mass of 14,4251 g and a length of 106,300 cm at constant diameter, measured at 0 degrees Celsius
☞ the international ampere was defined as the current which deposits 1,118 mg of silver in 1 second out of a silver nitrate solution[224]

The units were to be legally introduced in several countries: in Belgium for example, a proposition of law was enacted in 1901, which stated:

> *"Il est institué pour le Royaume un seul et même système d'unités électriques, ayant pour bases l'ohm, l'ampère et le volt"*[225]

The choice of material standards for the units of electrical current and resistance would prove to be a wrong one however.
The material definitions were chosen as to be equal to the absolute electromagnetic units defined in 1881; the increasing precision with which measurements could be performed showed some small differences however. This led to differences between the international electrical units and the mechanical units. The international ohm for example was not fully equal to the ohm from the "meter-kilogram-second" (MKS) system[226]:

$$1\ \Omega_{int} \equiv 1{,}00049\ \Omega \qquad (3\text{-}2)$$

In 1901, the Italian engineer Giovanni Giorgi (1871-1950) showed that it is possible to combine the mechanical units of the metre-kilogram-second system with the practical electric units to form a single coherent four-dimensional system by adding to the three base units, a fourth base unit of electrical nature. The (absolute) ampere was adopted as a fundamental unit, defined as follows:

> *The ampere is that constant current which, if maintained in two straight parallel conductors of infinite length, of negligible circular cross-section, and placed 1 metre apart in vacuum, would produce between these conductors a force equal to 2 * 10^{-7} newton per metre of length.*[227]

All other electrical units could be derived from the ampere and from the mechanical units.
The main advantage of the Giorgi system was to overcome the historical opposition between scientists and technicians, bonding together electromagnetical and mechanical units and obtaining a simple, rigorous system, built on a sound concept and easy to use.

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[224] W. Taveirne, op.cit., p153
[225] Bulletin de la Société Royale Belge d'Electriciens, Vol 18 (1901) p87
[226] W. Taveirne, op.cit., p158
[227] Ibid., p.155

Giorgi's idea did not have a large audience at the time however; the "MKSA system" or "Giorgi system" was accepted only in 1935 by the International Electrotechnical Commission, and the "absolute" units replaced the "international" units from 1948. In 1960, this became known as the "International System of Units" (SI) that is used throughout this day.

3.4.2 The standardization of electrical machines; inception of the International Electrotechnical Commission

With a system of units being defined, other questions came forward when considering the international electrical collaboration which was establishing itself. One problem area was that of terminology. The word "dynamo" for example was used in English, French and German, but did not mean the same thing in them all. A unification in nomenclature was becoming essential, "because the mischief that arises in disputes about specifications and contras is almost invariably due to looseness of language and want of precision in definitions".[228]
Furthermore, there was no common approach to the rating of electrical machinery. A 100-kW machine in one country was not necessarily a 100-kW machine in another country, particularly when referring to alternating current, as the usages and regulations as to rating were differing from one country to another.
Thirdly, there was a great divergence in the use of symbols representing the various electrical quantities.

The first to consider such problems were the Americans through the American Institute of Electrical Engineers (which would merge in 1963 with the Institute of Radio Engineers, to form the Institute of Electrical and Electronics Engineers, the IEEE known up to this day). These activities are discussed more extensively in §3.4.4.
Other countries, like Germany, France and the United Kingdom followed suit.
The time had become ripe however to make a more determined and permanent effort in the matter. At the International Electrical Congress held in September 1904 at St. Louis, Missouri, many delegates felt that the time had arrived to secure international co-operation on a proper and permanent basis. The following resolution was unanimously passed proposing the formation of an International Commission:

[228] S.P. Thompson, op.cit., p312

Figure 3.33: The government delegates at the International Electrical Congress, St. Louis, 1904

> *"The committee of the Chamber of Delegates on the standardization of machinery, begs to report as follows:*
> *That steps should be taken to secure the co-operation of the technical Societies of the world by the appointment of a representative Commission to consider the question of the Standardization of the Nomenclature and Ratings of Electrical Apparatus and Machinery*
> *If the above recommendation meets the approval of the Chamber of Delegates, it is suggested by your committee that much of the work could be accomplished by correspondence in the first instance, and by the appointment of a general secretary to preserve the records and crystallize the points of disagreement, if any, which may arise between the methods in vogue in the different countries interested.*
> *It is hoped that if the recommendation of the Chamber of Delegates be adopted, the commission may eventually become a permanent one."*[229]

The work of constituting such Commission was taken up by the (British) IEE; statutes were drawn up at a preliminary meeting in London on June 26-27, 1906, where thirteen countries were represented. Lord Kelvin was appointed as the first President of the Commission, and Colonel Crompton as the first Honorary Secretary[230]. A young British engineer, Charles LeMaistre, became General Secretary, and would serve in this post until his death in 1953[231]; after the Second

[229] Transactions of the International Electrical Congress at St. Louis, 1904, published under the care of the General Secretary and the Treasurer; p44, Minutes of the third meeting of the Chamber of Delegates, at 2.30 PM on 1904-09-15 in the Hotel Jefferson.
[230] R.T. Glazebrook, op.cit., p12-13
[231] C. Douglas Woodward, BSI: the story of standards, p49

World War, he would be involved in the founding of the International Organisation for Standardization ISO (cf. §5.3.1)[232].
The influence of this man was so huge that he was labeled "the deus ex machina of international standardization"[233].
The Central Office of the IEC was established in London; it would move to Geneva in 1948.

The principles underlying the practical organization of the IEC were established as follows:
☞ in each country a local Electrotechnical Committee is formed, either by a recognized technical society or by the government;
☞ the local committees act as members of the IEC; each has equal rights and obligations, and equal voting power.

This democratic structure remains up to this day, and has shown to be a key condition for the establishment of effective international co-operation in the field of standardization.
The base of effective standardization is in fact consensus of opinion, as a result of co-operative action, by common consent of the concerned parties, and not by one section of the community imposing its opinions on the other.[234]

The IEC would be the first real step in the promotion of international standardization as we now know it, and it was the electrical industry that provided this. It preceded the creation of general national standards bodies, except in the UK, where the British Engineering Standards Committee, forerunner of the British Standards Institution, was created in 1901. This has led to the situation that up to to-day in most countries electrical standardization is performed by a separate national electrotechnical committee than general standardization.

The IEC held meetings in London (1908), Turin (1911) and Berlin (1913). In 1912, twenty-two countries were affiliated, with others showing their interest, underlining the world-wide character of the movement.
By 1914 the IEC had formed four technical committees to deal with Nomenclature, Symbols, Rating of Electrical Machinery, and Prime Movers. The Commission had also issued a first list of terms and definitions covering electrical machinery and apparatus, a list of international letter symbols for quantities and signs for names of units, an international standard for resistance of copper, a list of definitions in

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[232] Willy Kuert, The founding of ISO; Friendship among Equals, 1997
[233] Clayton H. Sharp, Discussion on Standardization (Le Maistre), AIEE Transactions, Vol XXXV part I (1916), p497
[234] C. LeMaistre, Standardization, Cleveland, Ohio, June 27, 1916; AIEE Transactions Vol XXXV part (1916), p491

connection with hydraulic turbines, and a number of definitions and recommendations relating to rotating machines and transformers[235].

Its success can be summarized by the following words, spoken before the Institution of Electrical Engineers in 1912:

> *"This promotion of a better understanding between electricians, of various nations by general agreement as to terminology, symbols, and the classification of electrical machinery, is sure to foster the free development of international trade and to be a general benefit both to the purchaser and the maker. Last, but by no means least, these regular international gatherings, during which national prejudices are laid aside and at which many lasting friendships are made between electricians of different nationalities, must undoubtedly be a not unimportant factor in furthering the peace of the world."*[236]

But alas, this world is not ruled by the electricians, and barely two years after these words were spoken, the peace of the world would be torn apart in a bloody war, which forced the IEC to suspend its activities until 1919.

3.4.3 IEC rating of electrical machines

One of the most significant achievements of the IEC was the definition of a document on the rating of electric machinery and apparatus; a first report on rating was presented on the meeting in Berlin in September 1913[237], with a revised version adopted at the plenary meeting held in London in October 1919[238].

This document still showed a discrepancy existing between different countries on the definition of the concept "rating"[239]:

> *Definitions dealing with the subject of "Rating":-*
> *Great Britain: The rating of an electrical machine is the output assigned to it by the maker, together with the associated conditions, all of which are marked on the Rating Plate.*
> *(Note: a machine may have a test rating or a service rating, or both, assigned to it, and marked on the rating plate.)*
> *United States of America: The rating of a machine is the output marked on the Rating Plate and shall be based on, but shall not exceed, the maximum load which can be taken from the machine under prescribed conditions of test. This is also called the Rated Output.*

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[235] Historical overview on IEC website, http://www.iec.ch/about/history/hentry-e.htm
[236] S.P. Thompson, op.cit., p320
[237] Reproduced in AIEE Standardization Rules, ed. 1918, p110-120
[238] Reproduced in AIEE Standards, ed. 1922, p141-156
[239] Ibid., appendix IV, p155

(The term "maximum load" does not refer to loads applied solely for mechanical, commutation or similar tests.)
France: The rating of a machine is determined by the conditions of working such as speed, pressure, current, power factor, etc., as indicated on the Rating Plate.
Italy: The output of a machine is the normal or average output, that is to say, the load at which the machine can work under normal conditions.

These definitions are reproduced here in order to show the, albeit slightly, different opinions existing on the subject of "rating", which, it must be said, remains somewhat of an elusive concept.

The IEC rating as defined in this document was established as a "test" rating, aimed at enabling an exact comparison to be made between machines of different makes.[240]
It had two classes: the continuous rating and the short time rating; in both cases, the limiting condition for the machine being the temperature rise, the value of which, and the way to measure it, were also defined in the document.
Furthermore, it recommended lists of informations which were to be given with inquiries and orders for electrical machines, and defined the markings to be put on rating plates.
Other issues, such as dielectric tests, mechanical tests and commutation, were at that moment still "under consideration".

3.4.4 Standardization of machines - the AIEE standardization rules

The first step taken by the American Institute of Electrical Engineers towards the standardization of electrical apparatus was a topical discussion on "The Standardization of Generators, Motors and Transformers" which took place simultaneously in New York and Chicago on the evening of January 26, 1898[241].
The AIEE saw itself as the competent body for electric standards work, as similar work in other domains was already been catered for by technical societies, like the American Society of Mechanical Engineers, which defined standard methods for steam boiler trials.
The first problem was of course what exactly to standardize. The standardization of electric apparatus proper was deemed less desirable:

"However, I think that for many reasons it would be found impracticable and probably not for the best interests of the business to establish any such standard sizes or lines of apparatus which would be equally satisfactory to the designing engineer, the consulting engineer, the manufacturer and the user. Moreover, not suppose this Institute would

[240] Ibid., ¶8, p142
[241] The Standardizing of Generators, Motors and Transformers, AIEE Transactions, Vol XV, p3-32

care to attempt to introduce any standards which did not admit of definite determination or which the rapid evolution of the business would soon render useless."[242]

What should be rather worked upon were the terms used to define certain characteristics of electrical machines, such as efficiency, regulation or rating, and the method of determining such terms. These features were relevant to every commercial transaction, and the AIEE had already been approached by the New York Electrical Society to consider some plans for standardization.[243]

"I think the work of the Institute in regard to standardization should lie in the line of definitions, and not in the line of saying what should be, or should not be, good apparatus, or what should or should not be good standards of apparatus. (...) The question of what regulation should mean, what temperature elevation should mean and how it should be measured, what efficiency should mean, etc., are eminently practical and proper technical questions which I think might save a great deal of trouble and dispute if they were settled and defined with the recommendation of the Institute. They would facilitate progress and enable people to understand each other with greater precision than they do at present. But I should be inclined to regard with disfavour any attempt made to standardize apparatus in any other way then by the process of evolution among business interests."[244]

It was believed that the apparatus would eventually "standardize itself"[245], as non-standard products (for example machines made for odd voltages would be discouraged due to their higher prices), and that "standardization of apparatus is a natural growth"[246].

The standards should of course be prepared by a working committee; there was however considerable discussion on who should form this committee, and more particularly on whether or not manufacturers should be part of it.

Arguments against the representation of manufacturers within the standardization committees were the following:

☞ To have all manufacturers represented, would make the committee cumbersome, to have only a few, and the others excluded, would prejudice the work.[247]

☞ No manufacturer would allow free access to its shops to a committee composed of its competitors.[248]

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[242] Ibid., p5, comment by E.W. Rice, Jr.
[243] Ibid., p6
[244] Ibid., p10, comment by Dr. A.E. Kennelly
[245] Ibid., p11, comment by Townsend Wolcott
[246] Ibid., p17, comment by Frank A. Pattison
[247] Ibid., p12, comment by Dr. Cary T. Hutchinson
[248] Ibid.

- ☞ The manufacturers would probably prefer not to be directly represented in the committee.[249]

On the other hand, the benefits of having manufacturers were also stated:
- ☞ "Having a committee to recommend how manufacturers should make apparatus, without having any manufacturers on that committee, is something like playing Hamlet with Hamlet left out."[250]
- ☞ "The presence of manufacturers would be a safeguard against injudicious recommendations being formulated."[251]
- ☞ "The experience derived from actual contacts with factory methods is absolutely necessary to the successful determination of the questions affecting standardization of apparatus."[252]
- ☞ Existing standardization experience largely emanates from the manufacturers.[253]

Eventually, a sensible view was given by Charles P. Steinmetz, who stated that the committee must be composed of the "best men available", whether manufacturers or not.[254]
This focusing on having the standardization work performed by knowledgeable and impartial experts, is one of the main conditions to come to effective work in the field.

He also focused on the aspect of standardizing test methods, taking into account the "exactness" of electrical engineering:

> *"in the whole field of engineering, no branch is so much developed theoretically as electrical engineering"*[255]

The measurement of efficiencies is taken as an example; particularly for larger machines these are difficult to perform, the usual technique of summing up individual losses being a "dangerous" thing since there might be other losses coming in and since there was still some difference of opinion on certain phenomena such as hysteresis.

The need for efficiency standards was further developed in the parallel discussion that took place in Chicago the same evening. Requirements for efficiency were written in specifications by consulting engineers, but there was no sure way to determine this, and efficiency test curves supplied by manufacturers were often incomplete and uncommented.

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[249] Ibid., p14, comment by John W. Lieb, Jr.
[250] Ibid., p15, comment by Dr. A.E. Kennelly
[251] Ibid.
[252] Ibid., p16, comment by Gano S. Dunn
[253] Ibid., p19, comment by F.V. Henshaw
[254] Ibid., p20, comment by Charles P. Steinmetz
[255] Ibid.

> *"Though specifications often designate efficiencies to a second decimal, they are rarely measured within one or two per cent., at best, and more rarely are engineers able to verify their own specifications regarding efficiency. It is very desirable that a committee on standards should formulate precise directions for a determination of efficiencies."*[256]

This meeting went a bit further into technical details, and also cited other subjects as interesting to be standardized, such as the quality of insulating materials (where the dielectric strength was deemed to be a more significant parameter than the high ohmic resistance), the sparking limits for commutating machines, and the ratings of alternating current machines with respect to the power factor of the load.

The opinions expressed in these discussions were thus generally favorable to the idea of standardization.

As a result of this discussion, a Committee on Standardization was appointed, consisting of seven members under the chairmanship of Francis B. Crocker, among them famous electricians such as Charles P. Steinmetz, the pioneer of alternating current, Elihu Thomson, founder of the Thomson-Houston Co., and John W. Lieb, Jr., who built the electric network in Milan, Italy.
One will note that manufacturers were duly represented!

The report of this Committee was presented and accepted on June 26, 1899[257].
This first comprehensive standards document treated electrical apparatus under the following heads:
☞ Commutating machines,
☞ Synchronous machines,
☞ Synchronous commutating machines (i.e. synchronous converters and double-current generators),
☞ Rectifying machines or pulsating-current generators
☞ Stationary induction apparatus,
☞ Rotary induction apparatus.

The subjects covered were the following:
☞ Efficiency: definition, description of the different losses and methods of measurement;
☞ Rise of temperature: methods of measurement (by resistance) and maximum recommended values;
☞ Insulation and dielectric strength: methods of measurement;
☞ Regulation: definitions for different equipment;
☞ Rating: definitions;
☞ Recommended voltages and frequencies;
☞ Recommended overload capacities.

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256 Ibid., p28, comment by Prof. Stine
257 Report of the Committee on Standardization, AIEE Transactions, Vol XVI, p255-268

As a result of changes and developments in the electric art, it was subsequently found necessary to revise the original report, with revisions published in 1902[258].

A second revision was decided upon in 1905, and the work of the Standards Committee went on, rearranging the standardization rules as to facilitate easy reference. From 1907, the committee became a standing Committee within the AIEE, its size gradually growing; it consisted of sixteen members when the revised Standardization Rules were presented in 1911.
During the following years, the committee undertook a radical revision of the rules, particularly in connection with the subject of "rating", reflecting IEC activities in this domain. It was further enlarged in 1913, and sub-committees were formed on the following subjects:
☞ Sub-committee No.1. on Rating,
☞ Sub-committee No.2. on Telegraph and Telephone Standards,
☞ Sub-committee No.3. on Railway Standards,
☞ Sub-committee No.4. on Nomenclature and Symbols,
☞ Sub-committee No.5. on Wires and Cables,
☞ Sub-committee No.6. on Rating and Testing of Control Apparatus.

Collaboration with other societies was established for relevant matters, such as the American Society for Testing Materials, the Association of Edison Illuminating Companies, the Electric Power Club, the National Electric Light Association, the American Electric Railway Engineering Association, the Institute of Radio Engineers and also the Society of Automobile Engineers.

A step to international standardization collaboration was made through the co-operation with the British Engineering Standards Committee, which was established in 1915-16.[259]
The collaboration with the IEC was also established, and successive editions of the AIEE standardization rules showed an increasing degree of conformity with the international IEC standard. The importance of agreement on international standards was to be strongly emphasized, and IEC rating agreements were published in the AIEE standards handbook in order to give them the widest publicity[260].

[258] Report of the Committee on Standardization, AIEE Transactions Vol xix (1902) p1075-1092
[259] History of the Standardization Rules, AIEE Transactions, Vol xxxv part2 (1916) p1551-1555
[260] AIEE Standardization Rules, 1918 edition, p108

3.4.5 AIEE Standardization relating to electric vehicles

The Standardization Rules as approved in 1916[261] contained specific reference to the rating of electric vehicle motors:

> *RATING OF AUTOMOBILE PROPULSION MOTORS AND GENERATORS (Road vehicles)*
> *835 - Continuous Rating. Automobile propulsion motors and generators shall be given a continuous rating, expressed in kilowatts output available at the shaft at specified speed. The machines shall be able to operate continuously at their rated outputs without exceeding any of the limitations referred to in ¶260.*
> *836 - Short-Time Rating. Owing to the variety of services which road vehicles are called upon to perform, no single standard period for short-time ratings is recommended.*
> *837 - Nominal Rating. No special nominal rating is required for automobile propulsion motors or generators.*
> *838 - Temperature Rises. Owing to space limitations and the cost of carrying dead weight on automobiles, it is considered good practice to operate the propulsion machinery at higher temperatures than would be advisable in stationary machines. The rating of automobiles motors and generators shall be based upon temperature rise, on a stand test and with motor covers arranged as in service, fifteen degrees by thermometer or twenty-five degrees by resistance, above those of ¶379.*
> *839 - Efficiency and Losses. Unless otherwise specified, the efficiency of automobile propulsion machines shall be based upon the output at the shaft, using conventional losses as tabulated in ¶440. When such machines are of low voltage, the great influence of brush-contact losses on the efficiency requires that these losses be determined experimentally for the type of brush used.*

In the version published in 1922[262], the paragraphs concerning electric vehicles were simplified to just one, retaining the principle of temperature rise:

> *Ratings of Automobile Propulsion Machines*
> *5205 - Automobile Propulsion Machines: The rating of automobile motors and generators shall be based upon temperature rise, on a stand test and with motor covers arranged as in service, fifteen degrees by thermometer or twenty-five degrees by resistance, above those of Table 200.*

The idea that automobile motors may be operated at higher temperatures than stationary motors had been justified with space and weight considerations; one other argument which can be added here is that the working life (in hours) of a vehicle motor is usually much less than of a stationary industrial motor. This working life is strongly dependent on operating temperature.

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[261] Standardization rules of the AIEE, approved by the Board of Directors, 1916-06-28, supplement to Pender's Handbook for Electrical Engineers, New York, John Wiley & sons Inc., 1916

[262] Standards of the AIEE, 1922 revision

The need to specify a nominal rating for automobile motors is not recognized; this also marks the difference with other electric traction motors like those for railway use.

The 1922 version however saw the addition of a new Chapter X presenting standards for storage batteries. These were believed to be of considerable value in establishing standard methods of rating for batteries.
This chapter consisted mainly of a number of definitions concerning storage batteries, and further defined standard reference temperature for discharge test (25 °C) and gave the following general statements on rating:

> *10201 - The capacities of storage batteries for different classes of service are not directly comparable. The capacity depends upon the discharge rate, reference temperature of electrolyte (which has been standardized as 25 °C), specific gravity of electrolyte, and final voltage allowed.*
>
> *10202 - Storage batteries shall be rated in accordance with the following tabulated capacity specifications:*
>
> ☚ *Ampere-hour capacity,*
> ☚ *Discharge rate,*
> ☚ *Reference temperature of discharge: 25 °C,*
> ☚ *Specific gravity of electrolyte at 25 °C,*
> ☚ *Final voltage limit per cell on discharge.*
>
> *10301 - Batteries shall be tested as required to determine if the rated capacity is obtained under the conditions as given in capacity specifications.*

The standard contained no dimensional references however, unlike the SAE document in this domain, its scope not only covering traction batteries but also all kinds of stationary batteries.

3.5 Overview of early standardization

The research performed for this chapter has drawn a general view of electric vehicle standardization in the early twentieth century.
Some interesting conclusions can be drawn from this study, if considering the standardizing parties on one hand and the actual impact of standardization on the other hand.

3.5.1 Parties involved

The standardization work concerning electric vehicles was initially taken on by organizations like EVAA whose main aim was to promote the electric vehicle.
It was shifted quite soon to specialist standardization bodies like SAE; this situation has remained up to this day, where electric vehicle promotion organizations, like the new EVAA, or AVERE, are not drafting standards themselves; although many of their members actively perform standardization work, they do so in the framework of an organization like IEC or ISO which has the international authority for the redaction of standards.
The JEVA in Japan is a notable exception to this case however.

Most of the actual standards of the period concerned were taken up by the SAE, which profiled itself as the main standardization body in the field. Contacts with other bodies such as the AIEE were established in a spirit of co-operation; there was no sign yet of the "competition" between different organizations which would come into play later.

3.5.2 Impact of standardization

3.5.2.1 Successful standards

Some of the standards developed can be designated as successful, in the sense that they saw a large acceptance in the market and did continue to be supported further in time.
A first example are the dimensional standards of charging plugs (§3.2.3 and §3.3.3.1), which saw continued application in the electric vehicle field. The subject of this standardization continues to generate interest, as work on plugs and connectors is in progress up to this day.

The standardization of traction battery jars and trays (§3.2.7 and §3.3.3.4) found also a wide application. These standards allowed several manufacturers to propose interchangeable products, thus enhancing competitiveness and ultimately lowering the cost for the end user.

Voltage standards (§3.2.4 and §3.3.3.2) found their application out of practical and cost reasons; it should be said however that standard voltages also became imposed indirectly due to the introduction of standardized battery trays, thus fixing the number of cells in use.

3.5.2.2 The question of ratings

The definition of ratings for electric vehicle motors (§3.3.3.6 and §3.4.5) took into account the specific operating conditions of electric vehicles, which are differing from industrial electric motors. The application of electrotechnical ratings on electric road vehicle will continue to be a difficult issue however.

Speed and mileage ratings (§3.3.3.3) were the subject of considerable discussions, as it is difficult to define a rating of speed or mileage which is coherent to real use of the vehicle, the energy consumption of an electric vehicle being strongly dependent on the type of mission. The definition of such rating and of the test cycles for it will remain a constant discussion point up to the now, as will be seen below.

3.5.2.3 Botched standards

The attempt to standardize speed (§3.2.5) was botched. This standardization, which in practice would mean the definition of a standard maximum speed, was not feasible facing the rush for high speeds, fueled by the "race" aspects of the gasoline vehicles. This speed argument continues to counter the electric vehicle up to this day, even if it is, particularly in urban conditions, void of much rationality.
Standardization of tires (§3.2.6 and §3.3.3.7) also proved difficult, and the committees did not come out of it or manage to come to an agreement.

3.5.3 Further evolutions

After 1920, the electric road vehicle receded into niche applications, such as industrial vehicles. The effect of this phenomenon on the standardization of electric vehicles and their components will be the subject of the following chapter.

4 THE INTERMEDIATE PERIOD: THE EMERGENCE OF THE INDUSTRIAL ELECTRIC VEHICLE

Electricity is undoubtedly the instrumentality and measure of all life, action and enjoyment, and originates that galvanic action which establishes it.
Orson Squire Fowler, Sexual science as taught by Phrenology.

4.1 *The evolution of vehicle application*

4.1.1 Generalities

After their development in the first two decades of the twentieth century, the electric vehicle went in limbo, pressed to the background by the soaring success of the internal-combustion engine.

For specific applications however the battery-electrics continued to deliver good services and were developed further. These include the industrial vehicle, and, in a number of countries, the commercial road vehicle.

4.1.2 The industrial vehicle

The introduction of modern industrial practices, particularly the "American" style of production known from the automotive industry, involved a greater need for material handling inside shops and factories. Battery-electric vehicles proved to be very effective tools for material handling. Their ease of operation, simple mechanism, low electricity consumption and the absence of noxious emission fumes made them particularly suitable for industrial work.
Types of trucks that were available in this period include[263]:

- ☞ The simple platform truck
- ☞ The end- or side-tipping truck
- ☞ The crane truck
- ☞ The elevating-platform truck
- ☞ The lifting or tiering truck
- ☞ The high-lifting or stacking truck
- ☞ The non-elevating tilting frame or fork truck
- ☞ The electric tractor.

A typical electric tilting and tiering truck from the period is shown in Figure 4.1.

[263] S.M. Hills, op.cit., p84

Up to this day, the electric vehicle keeps a very strong share of the industrial vehicle market. Other than the automobile market, which is strongly influenced by societal and emotional factors, the industrial vehicle market considers its products as "machines" or "appliances", which are selected and deployed following rational considerations.

Figure 4.1: A typical industrial electric vehicle from the 1930's[264]

The industrial vehicle development benefited from standardization work, particularly concerning battery size standardization (cf. §4.2.4).

4.1.3 The commercial road vehicle

As for the commercial vehicle, the events of the First World War caused a large development of the combustion-engined truck which displaced the electric in most application fields.

The advantages of the electric vehicle for urban distribution duties continued to be well understood however, and it was further to be deployed for this application in several countries. The best known of these vehicles is of course the British "milk float" for dairy delivery, of which several tens of thousands were deployed.

[264] S.M. Hills, op.cit., fig81

Figure 4.2: An electric dairy delivery vehicle[265]

Municipal services also saw the benefits of electric vehicles, a typical application being refuse collection. In the mid-1930s, not less than 93 British cities had electric sanitation vehicles, the largest fleets being used in Birmingham, Sheffield, Glasgow and Nottingham.[266]

Figure 4.3: An Electricar tractor with refuse collector from Sheffield (1931)[267]

Electric vehicles continued to be used by the electricity supply industry, both for work vehicles (e.g. tower wagons for overhead line maintenance) as for delivery

[265] S.M. Hills, op.cit., fig31
[266] G. Mom., op. cit., p565
[267] S.M. Hills, op.cit., fig50

duties. Figure 4.4 shows an example, showing the "streamlined" design which was popular in the 1930s.

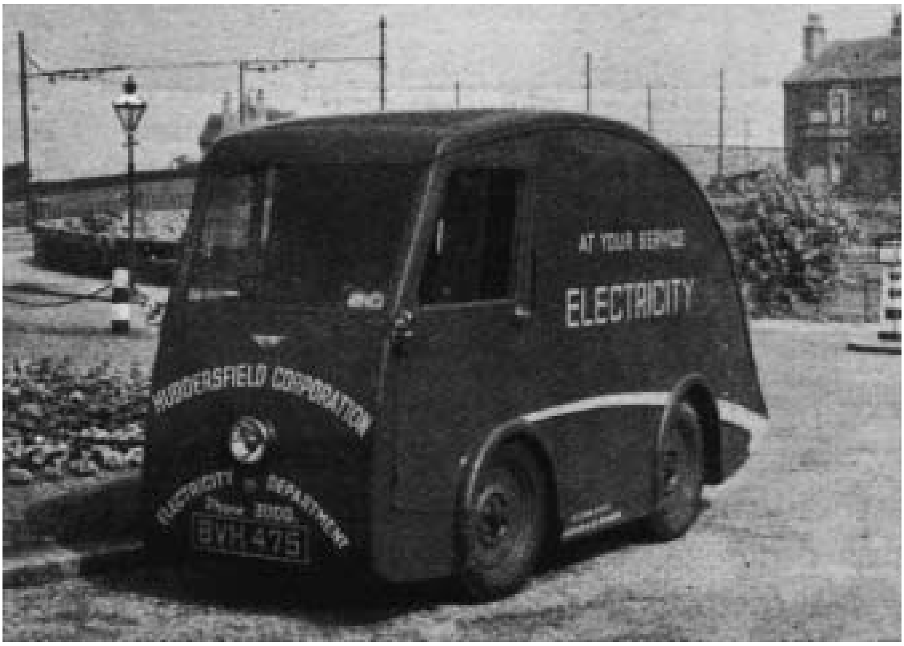

Figure 4.4: A streamlined "Metrovick" electric[268]

4.1.4 The electric passenger car

During the 1920s, the electric passenger car almost vanished. The 1924 New York National Auto Show was the first not to feature one single electric vehicle[269], and in the United Kingdom the number of electric passenger cars had dwindled to just three specimens by 1938[270].

A revival of the electric passenger car was however to be caused by the Second World War and its fuel shortages. In France, several vehicles were developed, such as the Mildé-Krieger, the streamlined lightweight vehicle of Pierre Faure (which saw series production) shown in Figure 4.5 or the CGE-Tudor developed by J.A. Grégoire of Figure 4.6.

[268] S.M. Hills, op.cit., fig57
[269] G. Mom, op.cit., p551
[270] Ibid., p565

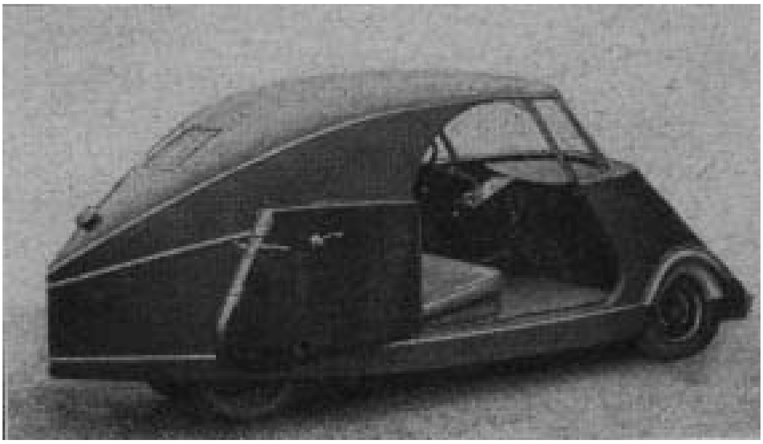

Figure 4.5: Faure electric vehicle[271]

The CGE-Tudor vehicle was characterized by its aluminium bodywork resistant to corrosion. One of these vehicles covered a record distance of 250 km on one charge, at an average speed of 43 km/h[272].

Figure 4.6: CGE-Tudor electric vehicle (1942)[273]

The opportunities of the electric passenger car were also considered in the United Kingdom.[274] The arguments cited sound familiar: vehicles used in cities do not need a range of hundreds of miles, and the electric's good acceleration from rest is a

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[271] G. Mestayer, Les véhicules électriques, p71
[272] J.A. Grégoire, 50 ans d'automobile. Part 2: la voiture électrique. p162-165
[273] Ibid, facing p159
[274] S.M. Hills, op.cit., p139-152

particular advantage. Using one stop for opportunity charging, longer distances up to 100 miles would be feasible:

> *"It is quite in the scope of such a vehicle to make a journey from London to Bournemouth, or from London to Clacton, in a day, and give the user a very comfortable journey with time available en route for sightseeing and meals."*[275]

The Wilson-Electric utility car, pictured in Figure 4.7, is a typical example of the period. Fitted with a 60 V, 210 Ah battery, it had a range of 40 to 50 miles (64 to 80 km) and a maximum speed of 28 mph (45 km/h).

Figure 4.7: Wilson Electric utility car.[276]
(Note the dimmed war-time headlight.)

A typical evolution caused by war conditions was the conversion of gasoline vehicles to electric traction. Such solutions were developed among others by the French firm Ragonot[277].

[275] Ibid., p144
[276] Ibid., fig105
[277] G. Mestayer, op.cit., p75-82

4.2 The evolution of standardization

As the concerned period saw the large development of the electric vehicle as industrial vehicle, standardization issues concerning industrial vehicles have been taken into account in this chapter up to the present day. The evolution of standardization in the fields considered in Chapter 3 (i.e. charging plugs, voltages, battery cells and motors) will be analyzed, and new evolutions in the field considered where appropriate.
At first however, a war-time proposal for standardizing whole vehicles will be presented.

4.2.1 A proposal for a standard electric vehicle

In the competitive automobile market, the introduction of a "standardized" vehicle never has proven successful, as such standardization would not be accepted by competing manufacturers. One such attempt however was done in the United Kingdom at the outbreak of the Second World War, where the use of battery-electric vehicles was seen as a desirable development, as electrical energy could be produced with domestic sources of power (i.e. coal). However, the restriction in supply of raw materials such as steel hampered the expected progress.
On the suggestion of the Ministry of Supply, the UK Electric Vehicle Association formed a Standardization Sub-Committee for the purpose of preparing a specification for a "standard electric vehicle of 1-ton payload capacity"[278].
This standard specification would unfortunately not lead to a series production of electric vehicles, due to the war situation and the scarcity of rubber, with retail deliveries being restricted by government action.

The design and specification of this vehicle reflect the state-of-the-art of electric vehicles in that period.

- ☚ *The chassis frame is of simple but strong design with cross-members upon which the body is directly mounted, the front being dropped to afford easy access to the driver's seat.*
- ☚ *Transmission is direct from the motor to the back axle through a short, one piece tubular shaft equipped with Layrub patented -joints giving a cushioned drive and requiring no lubrication.*
- ☚ *The back axle is of the double-reduction type with three-quarter floating shafts of high-tensile steel carried on roller bearings, and a casing formed in one piece of the banjo type. The first reduction is obtained by helical gearing, and the final drive is affected by spiral bevels.*

[278] S.M. Hills, op.cit., p203

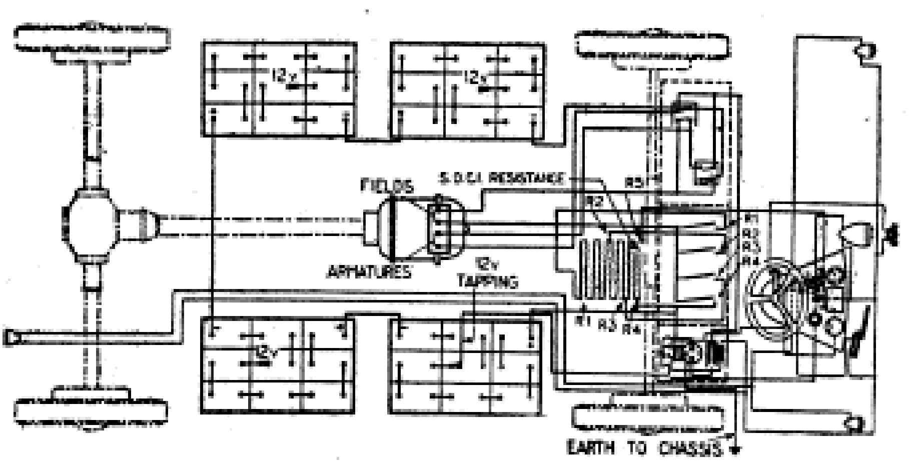

Figure 4.8: Outline diagram of chassis of standard one-ton battery electric vehicle, showing the wiring connections[279]

- *An H-sectioned front axle of high-tensile steel is employed. In this, the pivots are inclined; they afford a large bearing area and are provided with radial-roller thrust bearings. Taper-roller bearings are used for the wheels, and self -aligning interchangeable ball joints are provided on the track rod and drag link.*
- *Steering is effected by an 18-in. steering wheel with Marles double-roller gear, the design allowing a small turning circle and self-centring steering.*
- *Lockheed-operated Girling brakes are mounted at front and rear, the foot brake working on low pedal- and pipe-line pressure. The hand-brake lever is of the Bendix telescopic pistol-grip type, with a rack and pawl device, and so positioned as not to impede ingress or exit at either side of the cab. This parking brake works through a mechanical rod-operated compensator and acts only on the rear wheels.*
- *Detachable steel-disc wheels are employed which carry single 23-in. by 5-in. high-pressure tyres, and a spare wheel is included in the equipment.*
- *On the electrical side, the motor, of GEC manufacture, is rated at 8 h.p. and the specification for it is that laid down by the Ministry of Supply Machine Tool Control (DIEE). It embodies British Standards Specification 173/1941, as regards both rating and construction.*
- *A Wilson delay-action four-speed controller with foot-operated hydraulic mechanism provides progressive acceleration, and prevents excessive wear or stressing which. might otherwise occur through too rapid operation. A BSS, 50-amp. charging plug is mounted in the controller assembly, and is arranged with an interlocking, double-polo isolating switch for the 12-volt lighting system, and accessories.*
- *The battery consists of thirty-six lead-acid cells grouped in sets of nine and fitted into steel trays, two being mounted in pannier fashion at each side of the main frame*

[279] Ibid., p204

members. The trays are of standard dimensions so that they are interchangeable so far as a particular vehicle or other vehicle of similar type is concerned, and will accommodate batteries made by any of the well-known makers.

- ☛ *A suppressed zero moving-coil volt-meter, calibrated on similar lines to those of the conventional motor-vehicle fuel gauge, is mounted on the dash panel. Measurement of the state of voltage of the battery can be obtained, as required, by operating a press switch.*
- ☛ *A standard body has also been designed which may be quickly changed to suit the particular class of transport work which has to be undertaken. Interchangeable canvas side screens are provided instead of doors.*[280]

4.2.2 Standardization of charging plug

4.2.2.1 The concentric plug in America.

The concentric charging plug remained a SAE standard until 1939 (§3.3.3.1), without any changes.

4.2.2.2 The evolution in the United Kingdom: BS 74 and the small charging plug

The standard BS 74 (cf. §3.2.3.5) was revised in 1929[281], with only minor changes that could be summarized as follows:

- ☞ The rating of the plugs and sockets was specified as 150 A continuous, or 200 A for one hour, at voltages not exceeding 250 V.
- ☞ Terminals shall be marked for polarity (the centre contact being negative).
- ☞ Some tolerances on dimensions were added, and dimensional requirements for cable lugs and cable grips added (65 mm² for main cables, 15 mm² for earthing cable).

A new and major revision of BS 74 would appear in 1937[282]. Since the revision of 1929, large numbers of vehicles requiring smaller charging currents had in fact come into use; this was particularly the case for small industrial vehicles. A plug and socket rated at 50 A continuous (65 A one-hour) was thus proposed to meet the requirements for these vehicles. For vehicles requiring larger charging currents up to 150 A, the existing design was retained.

[280] Ibid., p.203-204
[281] BS 74:1929
[282] BS 74:1937

The 50 A plug however was of a completely different design, not being concentric anymore, but of a pin-and-sleeve type, the socket being permanently attached to the vehicle, and the plug to the charging cable.
It was a four-contact plug, having one earthing and one pilot contact. The introduction of a pilot contact (the functionality of which was not described in the standard however) was almost a prophetic step forward, featuring a device which would become commonplace sixty years later on electric vehicle charging connectors, as discussed in §5.2.5.3.3.

The device, for which aluminium was preferred as material, for lightness, also featured a pivoting cover of the socket, interlocking with the plug, which may control a switch.

BS 74 saw a further revision in June 1949[283], due to the experience which showed a need for modification in the details of the 50 A plug-and-socket. The 150 A plug-and-socket remained the same.
The principal changes to the 50 A plug-and-socket were as follows:
- ☞ The withdrawal-pull required to disengage a plug from a socket had been reduced without impairing goodness of contact.
- ☞ The position of the fixing flange had been altered to meet the change in practice in mounting sockets on dashboards of vehicles.
- ☞ The provision of an alternative means of interlocking an auxiliary switch with the operation of a plug in a socket.

A further amendment to BS 74 published in 1956[284], stated that, concerning the rating, a.c. mains connections were not covered by the specification.

The standard BS 74 was finally withdrawn in June 1975.

4.2.2.3 Plugs and sockets for larger currents: BS 3214

When BS 74 was issued, it met the needs of the industry for fittings up to 150 A rating. By 1960, the requirement had arisen for fittings of an increased rating, not only for charging but also for main traction current duties. This was particularly due to the practice on heavy industrial vehicles, where the practice was developed to have batteries, fitted with one connector for both charging and discharging. These batteries were often charged off the vehicle, and the same connector of the battery was used to connect them to the charger or the vehicle traction circuit.
In 1960, the standard BS 3214 was published, with as its scope "Plugs and locking sockets intended for use in electrically propelled vehicles". These devices, rated for a

[283] BS 74:1949
[284] Amd. PD2477 (1956) to BS 74

continuous current of 300 A at a maximum direct voltage of 125 V, were fitted with four contacts, namely two main current-carrying contacts and two pilot contacts. A locking device (handle) was provided in order to maintain full contact pressure and to prevent accidental removal of the plug.[285] A view of the connector specified by BS 3214 is shown in Figure 4.9.

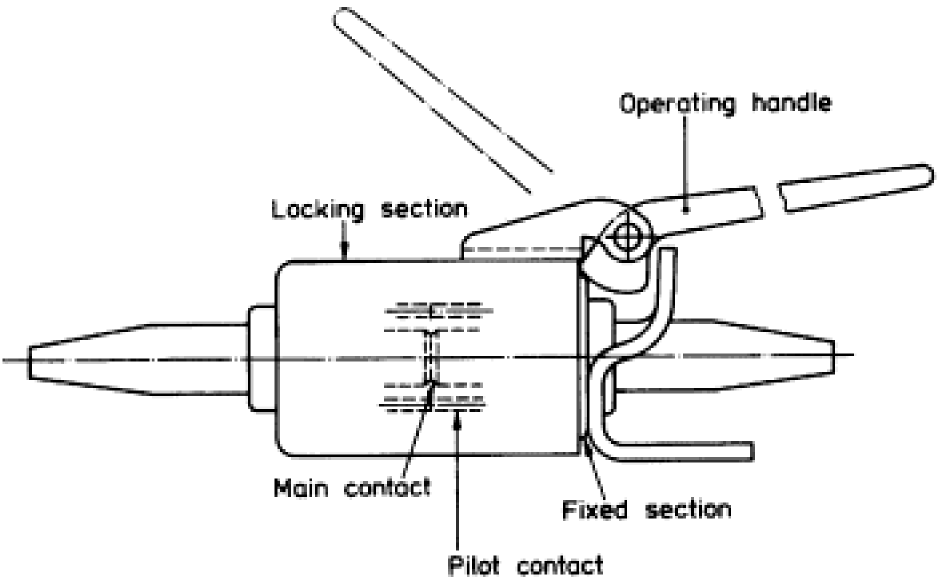

Figure 4.9: Locking connector (BS 3214) in closed position[286]

This standard was revised in 1974[287], introducing metric measures and raising the rating to 320 A.

Some detail amendments were further made in 1981[288] and 1985[289]. A final amendment from 1989[290] restricted the scope of the standard: its title became "Specification for locking connectors for battery operated vehicles, excluding industrial trucks, (320 A rating)".

This exclusion of industrial trucks from the scope of the standard for these connectors effectively wiped out their largest application field and left only a small replacement market (mostly for road vehicles such as milk floats) to this type of

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[285] BS 3214:1960
[286] BS 3214, amd3640 (1981), fig 11
[287] BS 3214:1974
[288] AMD3640, amendment slip No.1 to BS 3214:1974, 1981-10-30
[289] AMD4873, amendment No.2 to BS 3214:1974, 1985-07-31
[290] AMD6125, amendment No.3 to BS 3214:1974, 1989-07-31

connector[291]. It can be explained through the fact that their open butt-contacts, offering a protection degree of IP0X, cannot be made to pass the requirements of the European standard on industrial trucks, which will be discussed in the §4.2.2.5.

4.2.2.4 Standardization work by the "Fédération Européenne de la Manutention"

The "Fédération Européenne de la Manutention" (FEM) is the European manufacturers association of materials handling, lifting and storage equipment. It was founded in 1953 and has 14 national sections as members. It represents the technical, economic and political interests of the industry. FEM serves technical progress and improves safety at work through the establishment of guidelines and business codes.
FEM is a bridgehead between industry and authorities, formulating and communicating industry's position to European legislation.
Its technical section "Industrial Trucks" has prepared several standard documents concerning industrial electric vehicles; due to a decision dated 6th October 2000 in the plenary meeting of the FEM Section Industrial Trucks, many of these documents have been withdrawn however, since they were identical to and replaced by international EN and/or ISO standards. In fact, the official standards were in many cases derived from the FEM documents, being prepared by the same delegates under the aegis of their national standardization committees.

In the domain of connectors, FEM has issued two specifications. FEM 4.007A defines the operational requirements and test procedures; it has now been replaced by the European standard EN 1175-1 and will be further discussed in §4.2.2.5.

FEM 4.007B defines dimensional requirements for connectors to ensure interchangeability. These connectors represent a pin-and-sleeve design with provision for two pilot contacts (no earth contact) and an adjustable voltage key with standardized settings for battery voltages of 24, 36, 48, 72, 80 and 96 V, standard voltage values which come from the ISO 1044 document (cf. §4.2.3.3 below). In case of utilization of this connector for other voltages, a special voltage key shall be used.
A schematic view of the plug and socket to FEM 4.007B is shown in Figure 4.10.
These connectors are now widely used for industrial electric vehicle applications and are often referred to as "Euroconnectors". A typical example is shown in Figure 4.11.

[291] Don Gribble, EVA Manual, Sec 1.5, p4

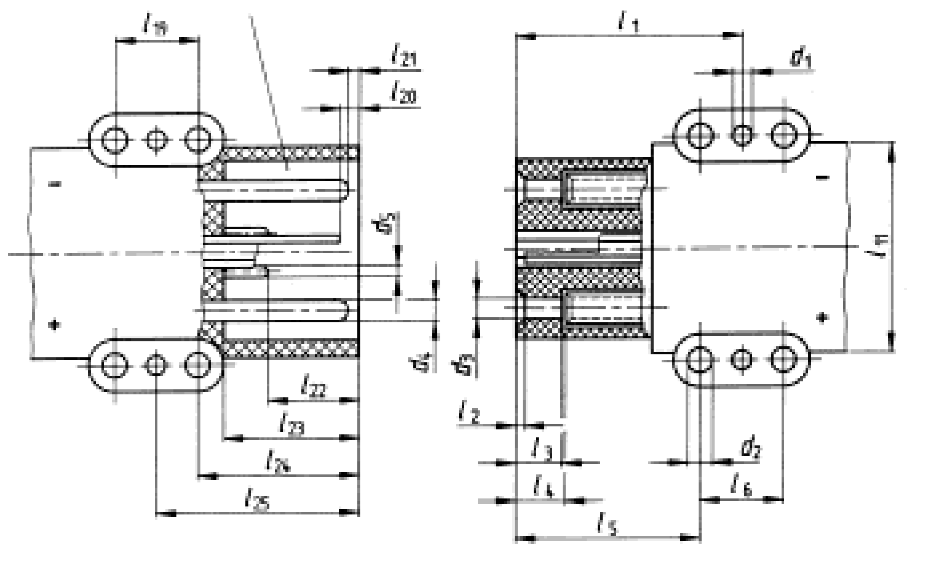

Figure 4.10: Plug and socket to FEM 4.007b[292]

The German standard DIN 43589-1 is virtually identical to the FEM 4.007B specification.

Figure 4.11: Euroconnector[293]

[292] FEM 4.007b:1993

[293] UMA Connector AB, Värnamo, Sweden

4.2.2.5 Connector specifications in European standardization

The European standard EN 1175-1 "Safety of industrial trucks - Electrical requirements - Part 1: General requirements for battery powered trucks", which will be further discussed in §4.2.6.2, specifies in its Annex A (normative) the design, testing and coding for traction battery connectors.
This standard is a further development of a European Council Directive[294], which, on its turn, was derived from the FEM 4.007A specification for as far as the connectors are concerned[295].

Annex A defines two voltage ranges covering nominal voltages up to 96 V and above 96 V up to 240 V respectively. Each range comprises three modes, with nominal currents of 80, 160 and 320 A. The connectors for the 96 V range are also intended to break the motor current in case of emergency.[296]

The standard describes requirements and type-test methods for these connectors. It preconizes a IP2X protection degree for the half-connector to be fitted to the battery[297]. The butt type design BS 3214 can thus not pass this requirement.

The FEM 4.007B Euroconnector discussed in §4.2.2.4 and shown in Figure 4.10 and Figure 4.11 has been cited as an example of a connector complying to this standard.

It is sometimes thought that complying to EN 1175-1 (which is derived from FEM 4.007A) means that the connector design should follow FEM 4.007B. This is not so however[298], since EN 1175-1 only defines safety features and performance parameters and does not define dimensions.

Several other well-used designs of battery connectors do in fact comply with the standard; a popular example of this kind is the "Anderson" SBE family of connectors, which makes use of wiping, overlapping-type contacts rather than pin-and-sleeve ones. (Figure 4.12).

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294 Directive 86/663/EEC; connector specifications are given in Addendum C to this document.
295 D. Gribble, op.cit.
296 EN 1175-1:1998, Annex A
297 Ibid., ¶A3.9
298 D. Gribble, op.cit., sec1.5, p4-5

Figure 4.12: Anderson SBE connector[299]

4.2.3 Standardization of voltages

4.2.3.1 The call for standardization

The limitation of the number of voltage levels was considered a key element to rationalize the industry. The monograph by S.M. Hills stated that

> *"... there is considerable variation in voltage, and while it is not practical, possibly, to determine a standard voltage for all vehicles, the range might certainly be shortened, and similarly the ampere-hour capacity might be standard to a few capacities at the five-hour rate. Thus voltages might be 60 volts (30 cells), 72 volts (36 cells) or 144 volts (72 cells) and the capacities at the five-hour rate 180, 240, 300."*[300]

Standardized voltages were indeed proposed in a number of standards.

4.2.3.2 Standard voltage levels in BS 1727

The motor standard BS 1727:1971 (see also §4.2.5.3 for a more detailed discussion of this standard) defined a number of standard nominal voltages, being
12; 24; 36; 48; 72; 80 and 96 V[301].

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[299] Anderson Power Products
[300] S.M. Hills, op.cit., p190
[301] BS 1727:1971, ¶2

In the 1987 revision however, these levels were dropped, it was just stated that "vehicle motors shall have a rated voltage of 96 V or below"[302].

4.2.3.3 Standard voltage levels in ISO 1044

The international standard ISO 1044 specifies a series of voltages for lead-acid traction batteries for electric industrial trucks. This standard was prepared by the technical committee ISO/TC110 "Industrial trucks", Sub-Committee SC2 "Safety of powered industrial trucks". It was first published as an international standard in 1975, reproducing the technical recommendation ISO R1044/1969.

It is a bit surprising to see this subject, which is clearly electrotechnical and thus typically the province of the IEC, being covered in an ISO standard. The interaction between ISO and IEC will be discussed further in §5.4.

The first edition from 1975 defined two series of standard voltages:
Serie I: 12; 24; 36; 48 and 72 V
Serie II (only for lead-acid batteries): 40 and 80 V
If an intermediate value would be needed in this series, the value of 60 V was recommended.[303]
In the second edition, published in 1985, the two series were integrated, the value of 40 V dropped and higher voltages added. The standard voltages became:
12; 24; 36; 48; 72; 80; 96 and 120 V.
If an intermediate value would be needed in this series, the value of 60 V was recommended.[304]
In its third and current edition, published in 1993, even higher voltages are mentioned:
12; 24; 36; 48; 72; 80; 96; 120; 144; 160; 192 and 240 V
The intermediate value of 60 V was dropped.[305]

4.2.3.4 Standard voltage levels in NBN E 52-021

The Belgian standard NBN E52-021 "Industrial trucks - Voltages of traction batteries for industrial trucks" was published in 1976. It reproduces the values stated in ISO 1044:1975[306].

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[302] BS 1727:1987, ¶3.1
[303] ISO 1044:1975, ¶2
[304] ISO 1044:1985, ¶2
[305] ISO 1044:1993, ¶2
[306] NBN E 52-021:1976, ¶2

4.2.3.5 Standard voltage levels in IEC 60038[307]

The international standard IEC 60038 "IEC standard voltages" defines a number of preferred voltages, including d.c. voltages. As for d.c. voltages, this standard applies to:

- ☞ Traction systems
- ☞ d.c. equipment having nominal voltages below 750 V d.c.; such equipment covering batteries (from primary or secondary cells), other power supply devices, electrical equipment and appliances.[308]

The "traction voltages" (nominal voltages 600; 750; 1500 and 3000 V[309]) are clearly intended for heavy traction (rail, metro, tram,...) rather than for battery-electric vehicles. The 600 V nominal voltage class however can be found back in some of the largest battery-electric vehicles such as buses.
For the equipment having a nominal voltage below 750 V d.c., a number of preferential and supplementary voltages have been defined, from 2,4 V to 600 V[310]. These are reproduced in Table 4.1, with the omission however of the voltages below 12 V which are not relevant for battery-electric vehicles.

4.2.3.6 Standard voltage levels in NBN C10-001

The Belgian standard NBN 10-001 defines a series of standardized d.c. voltages: 6; 12; 24; 48 and 60 V[311]. This standard is however not aimed at battery traction, but at general low-voltage d.c. components.

4.2.3.7 Overview

A general overview of voltage levels in the standards referenced above is given in Table 4.1.

[307] From 1997, all IEC standards are numbered in the 60000 series. Hence, IEC 38 became IEC 60038. In this work, IEC standards are referenced to with the number that was in use at the time of the reference, i.e. IEC 38 before 1997, IEC 60038 after.
[308] IEC 60038:1983+A1:1994+A2:1997, Scope
[309] Ibid., Table 2
[310] Ibid., Table 6
[311] NBN C 10-001:1990, ¶3.2

ISO1044 ED. 1975	ISO1044 ED. 1985	ISO1044 ED. 1993	BS2550 ED. 1954	BS1727 ED. 1971	IEC60038 ED. 1983 pref.	IEC60038 ED. 1983 supp.	NBNC10-001 ED. 1990
12	12	12		12	12		12
						15	
24	24	24	24	24	24		24
						30	
36	36	36	36	36	36		
40						40	
48	48	48	48	48	48		48
(60)	(60)		60		60		60
72	72	72	72	72	72		
80	80	80		80		80	
	96	96	96	96	96		
					110		
	120	120					
						125	
		144					
		160					
		192					
					220		
		240					
						250	
					440		
						600	

Table 4.1: Standard voltage levels

One can see that the number of voltages proposed as standard has expanded quite significantly from the two levels (60 V and 84 V) which had been proposed early twentieth century (cf. §3.2.4).

On one hand, low voltage levels (e.g. 12 V or 24 V) appeared as standard, for the smaller classes of industrial battery electric vehicles such as hand-pallet trucks, floor sweepers and the like.

On the other hand, higher voltages also appeared, and the voltage levels continue to rise. This phenomenon reflects the technological evolution in the field: these higher voltages are used for heavy-duty vehicles, particularly those fitted with a.c. traction motors.

The standardization of voltages also of course has an influence on the standardization of the battery: voltage affects the number of cells, while ampere-hour capacity will affect the area of plate. Both thus affect the dimensions of the battery container. These issues will be discussed in the following paragraph.

4.2.4 Standardization of batteries

4.2.4.1 The need for battery standardization

The issue of battery sizes offers a good example of the benefits that can be achieved through standardization.
When batteries in standardized sizes are available from different manufacturers, the vehicle user can in fact choose from a large array of products to cater for his needs. Manufacturers can market their batteries focusing on arguments like high capacity, long life, low cost, reduced maintenance, good customer service and the like. Competition becomes open, which will reduce the price for the customer compared to an odd type of battery for which he would be dependent on one single manufacturer.
Standardization of batteries for industrial vehicles has focused on lead-acid types, since these are nearly universally used; the alkaline (nickel-cadmium and nickel-iron) types which were introduced in the early 20th century (cf. Figure 3.32) having almost vanished from the market, except for specialist applications, due to their higher cost compared with lead-acid batteries.

4.2.4.2 The international standard IEC 60254

Within the IEC, standardization of batteries is dealt with by TC 21.
The first version of the international standard IEC 254 "Lead-acid traction batteries" was published in 1967, featuring only definitions and general test conditions.
A standard containing dimensional specifications for battery cells, IEC 254-2, followed in 1973, being supplemented in 1974 with the addition of the "extra-low" 290 mm high cell.
The second edition of IEC 254-1 was published in 1983, incorporating general requirements and methods of test; this standard was also adopted as Belgian standard NBN C 58-254-1 in 1985.
The second edition of IEC 254-2, published in 1985, rationalized cell sizes and also featured the marking of cell polarity and the sizes of terminals. These dimensions were retained in the current version of the standard, IEC 60254-2:1997 "Lead-acid traction batteries - Part 2: Dimensions of cells and terminals and marking of polarity on cells", to which an amendment of 2000 added the ranges of cells the use of which was prevalent in Asia resp. North America[312]. The corresponding values are given in Table 4.2.

The first part of the standard, IEC 60254-1 "Lead-acid traction batteries - Part 1: General requirements and methods of test" saw its third revision in 1997. It applies

[312] IEC 60254-2, tables 1, 2, 3.

to all traction battery applications which include road vehicles, locomotives, industrial trucks and mechanical handling equipments.[313] The standard defines conditions for the following tests[314]:

- Capacity test
- Charge retention test
- High-rate discharge performance test
- Cyclic endurance test

For "light road vehicle" traction batteries, used in vehicles such as light passenger vehicles, motor cycles, light commercial vehicles, etc., a specific test procedure is offered, which uses a capacity test based on one-hour (rather than five-hour) capacity taking into account the specific discharge characteristics of such vehicles. This clause also defines a "dynamic" discharge performance and endurance test, taking into account that in electric road vehicle applications, traction batteries shall be capable of supplying widely varying current rates. [315] This paragraph emanates from the activities of the electric vehicle standardization committees, as will be seen in §5.2.4.

IEC 60254-1 and -2 were also implemented as European standards (EN) with the same number, which means that they are automatically implemented as national standards in all EU countries.

4.2.4.3 The British Standard BS 2550

Following the call from industry[316], a British Standard for lead-acid traction batteries, BS 2550, "Specification for lead-acid traction batteries", was first published in 1954. This standard covered those types of traction batteries which are used for the propulsion of battery-electric road vehicles in the four-wheeler, three-wheeler and pedestrian-controlled categories[317]. The standard however did not claim to apply to industrial truck-type batteries, for which a further British Standard would be prepared[318].

This standard contained specifications for design, rating and testing of batteries, and also dimensional specifications for battery trays, rather than for the battery cells themselves.

[313] IEC 60254-1:1997, ¶1, Scope.
[314] Ibid., ¶4, Testing procedures.
[315] Ibid., ¶6, Testing procedures for light road vehicle traction batteries.
[316] Cf. S.M. Hills, op.cit., p189
[317] BS 2550:1954, Scope
[318] Ibid., Foreword

The total number of cells in a battery was defined as 12; 18; 24; 30; 36 or 48[319], giving respective voltages of 24; 36; 48; 60; 72 and 96 V. These values have also been incorporated in Table 4.1 above.

Standard sizes of the battery trays were defined for standard battery capacities of respectively 95; 110; 125 and 140 Ah (6 cells per crate) and 195; 220; 255; 305 and 350 Ah (9; 12; 15 or 18 cells per crate)[320].
The standard BS 2550 was modified in 1971, this time explicitly including batteries and cells for industrial trucks, because "the cells are the same as those supplied for electric road vehicles"[321].
Furthermore, it had not be proved possible to include the sizes of assembled batteries, because the wide variety of assemblies of individual cells in general use precluded this. Dimensions for individual cells were included instead, with an attempt been made to rationalize these dimensions, in order to achieve a further reduction of variety in the future.

The recommended cell sizes all had a width of 160 mm; these are in fact known in the battery trade as "BS-cells".

Performance tests had been modified in accordance with the IEC agreement (i.e. the standard IEC 254 published in 1967)[322].

The 1983 revision of BS 2550 accords even closer to IEC 254, following the international standard where possible, and describing dimensions virtually identical to those in IEC 254-2. It also features however construction guidelines for battery trays, including specification for the thickness of timber and steel, for which there was no equivalent in IEC 254[323].

BS 2550:1983 was eventually superseded by BS EN 60254-2:1997, the implementation as European standard of IEC 60254-2.

4.2.4.4 German battery standards

4.2.4.4.1 Cell sizes: DIN standards and the adoption of the international standard

German battery standards relating to traction battery sizes have been developed early. Two standards specifically addressed batteries for vehicles:

[319] Ibid., ¶6
[320] Ibid., ¶7
[321] BS 2550:1971, foreword
[322] Ibid.
[323] BS 2550:1983, appendix F

- ☞ DIN 43567-1, relating to pasted-plate batteries; the first edition of this standard went back to 1938; the last edition dates from 1967.
- ☞ DIN 43567-2, relating to tubular-plate batteries; first edition 1943, last edition June 1977.

The 43567 series also contained standards for auxiliary batteries for railroad applications.

German battery cells had a width of 198 or 200 mm; these are in fact known in the battery trade as "DIN-cells", to distinguish them from the narrower BS-cells. The international standard IEC 60254-2 features both series.

The sizes specified in these documents have now been superseded by the international standard sizes from IEC 60254-2, first in the framework of the standard DIN 43595 (first published in 1975 and revised in 1981), later as the European standard DIN EN 60254-2:1998 (first edition 1989), this is identical to IEC 60254-2, with however an (informative) national annex explaining the typical German nomenclature for battery cells, e.g. 5 PzS 300 L, where:

- ☞ 5: number of positive plates (i.e. 11 total plates)
- ☞ PzS: Positive tubular plates "Panzerplatten"
- ☞ 300: 5h capacity of the cell (5 plates of 60 Ah)
- ☞ L: wide series (200 mm).

4.2.4.4.2 Battery assembly standards

Industrial electric vehicles often make use of interchangeable batteries. A number of standard battery assemblies (in the 24, 48 or 80 V range) have been described in German standard. They use standard cells (wide series) as to IEC 60254-2.
These standards describe sizes, weights and electrical data of battery assemblies for industrial truck applications:

- ☞ DIN 43531 for 48 V batteries
- ☞ DIN 43535 for 24 V batteries
- ☞ DIN 43536 for 80 V batteries.

These are purely German standards (widely used in other countries though), stating in fact that

> "Für den Anwendungsbereich dieser Norm bestehen keine entsprechenden regionalen oder internationalen Normen"[324]
>
> *[For the application field of this standard there are no corresponding regional or international standards].*

These standards were introduced in 1977 (1984 for 43531), revised in the early eighties, and withdrawn in June 1995, to be reinstated in December 1998 taking

[324] DIN 43531:1998, also DIN 43535:1998 and DIN 43536:1998

into account the provisions of EN 1175-1 and of the European Low Voltage Directive[325].

Another German standard, DIN 43593, describes the standard marking plate for traction batteries.

4.2.4.5 FEM battery standards

Document FEM 4.007C, published in 1980, gives values for the sizes of traction battery cells. These are virtually identical to the values to be presented in IEC 254-2 (1985) and BS 2550 (1983), as can be seen in Table 4.2.
It can be easily understood here that the international standardization has followed standardization practices established within the industry.

4.2.4.6 A specific standard for light electric vehicle batteries: BS 7483

Based on a proposal from the Electric Vehicle Association of Great Britain, with the support of the Department of Health, the British Association of Wheelchair distributors and the British Surgical Trades Association, a standard has been prepared in 1991 to cover requirements for power sources for small mobile equipments where experience has proved that starter batteries are inadequate and that traction batteries complying with BS 2550 are not appropriate.[326]
This standard, BS 7483 "Specification for lead-acid batteries for the propulsion of light electric vehicles" aims at batteries for light vehicles such as wheelchairs and golf trolleys, defining tests for actual (five-hour) capacity, high-rate discharge performance and endurance in cycles.

The tests proposed in this standard are comparable to those in IEC 60254-1.
The standard BS 7483 does not state any dimensional specifications.

4.2.4.7 Opportunity charging in IEC standardization

The implementation of opportunity charging can greatly enhance the deployability of electric vehicles by substantially increasing the total output of energy a battery can deliver in one working day. However, adequate precautions must be taken to prevent early deterioration of the battery.

[325] Council Directive 73/23/EEC
[326] BS 7483:1991, foreword

To this effect, Technical Committee 21 "Secondary Cells and Batteries" of the IEC prepared a Technical Report, IEC 1044:1990, presenting recommendations for the use of opportunity charging for traction batteries.
This document states points to be considered when planning to introduce opportunity charging[327], as well as some points to be considered for the operational procedures[328].
Although mainly aimed at industrial vehicles, this document presents interesting insights which can also prove useful for electric road vehicles.
This document was also implemented as an European standard (EN 61044:1992).

4.2.4.8 Overview of battery standardization

An overview of standardized lead-acid cell dimensions is shown in Table 4.2.
When comparing these values with each other on one hand and with the values defined in early standardization (Table 3.4) on the other hand, one can come to the following conclusions for each of the three dimensions of the battery cells:

☞ For the cell width, two series, a narrow one of 160 mm and a wide one of 200 mm have now been firmly established around the world, with slightly different measures in North America however. The width of the narrow series is nearly identical to the width defined in the 1917 SAE standard.

☞ For the cell height, a series of six to seven values has been defined, reflecting the variety in application needs. The 1917 SAE standard only defined one single height which was at the low side of today's series; the demand for higher capacity batteries for heavy industrial trucks created the need for higher cells.

☞ For the cell length, there is still a variation in the series presented between the narrow and wide cells on one hand and between different countries on the other hand. The series of values corresponds to the number of plates in the cell; differences can be explained through the variation in manufacturing practice and traditions existing in different countries. Cell length of course depends on the number of plates in the cell, the differences could be explained through differing practices in manufacturing present. The difference between narrow and wide cells in the IEC 254-2 standard as to cell length however is to be explained as a remainder of older manufacturing traditions.

☞ Comparing with the 1917 SAE standard, we see that the excessive list of values proposed has been reduced to a rational level; the values used for North American batteries to-day were in fact already present in this list. The reduction from thirty-two values(in the 5 to 21 plate range) to just eight is a good example of the beneficial and rationalizing effect of standardization.

☞ The cells of 23 plates and more are obviously not provided for in general list due to the limited use of such cells.

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[327] IEC 1044:1990, ¶4

[328] Ibid., ¶5

IEC 254-2 ed. 1973 sup. 1974		BS 2550 ed.1971 recomm. sizes	BS 2550 ed. 1971 other sizes			DIN 43567-1 ed.1967 flat plate	DIN 43567-2 ed.1977 tubular plate	IEC 254-2 ed. 1985	BS 2550 ed. 1983 FEM 4.007c ed. 1980		IEC60254-2 ed.1997		IEC60254-2 2000 Asia cells	IEC60254-2 2000 America cells		
series								series			series			series		
E	L							E (f)	L		E	L		narrow	wide	
cell width		cell width				cell width	cell width	cell width			cell width		cell width	cell width		
160	200	160 (a)	162 (b)	226 (c)		198 (h)	198 (h)	160	200 (d)		160	200	160	158,8	219,2	
cell height		cell height		cell height		cell height	cell height	cell height		type	cell height		cell height	cell height	(e)	
290	290	292	292			320	320	295 (g)		A	300		360			
350	350	359	359			335	340	370	370	B	370	370	390			
415	415	432	432			395	400	440	440	C	440	440	435			
485	485	489	489				475	500	500	D	510	510	450			
565	565	546	546			535	565	555	555	E	555	555	530			
									605	F		605	560			
740	740			759			720	750	750	G	750	750	740			
cell length		cell length			plates	cell length (i,j)	cell length (k)	cell length			cell length		cell length	cell length		plates
	48					50	47		47			47		50,8		5
	66		64		7	65	65	64	65		64	65	62	69,9		7
79		79			9	80		79			79		80			
	86						83		83			83				
													92	88,9	88,9	9
95		95		97	11	95		95			95		96			
	104						101		101			101	111			
111		111		116	13	111		111			111			108,0	108,0	11
	122						119		119			119				
127		127		132	15	126		127			127		130	127,0	127,0	13
	140						137		137			137				
145		145			17	141		145			145		146	146,1	146,1	15
	158					156	155		155			155				
160		160			19			160			160		163			
														165,1	165,1	17
176	176	176			21		174	176	174		176	174	179			
														184,2	184,2	19
192	194	192			23		192	192	192		192	192	192			
208		208			25			208			208		208	203,2	203,2	21
225			226		27								227	222,3		23
241			241		29								246	241,3		25
			257		31									260,4		27
			273		33									279,4		29
			289		35									298,5		31
														317,5		33

Notes:
(a) width 159 mm for 9-plate to 15-plate cells
(b) width 159 mm for 7-plate cell
(c) width 222 mm for 11-plate cell
(d) width 198 mm for BS 2550
(e) no height specified for North American cells
(f) called N in FEM 4.007.c
(g) not specified in FEM 4.007c
(h)147 mm for h=320mm;196-200 for others
(i) 50, 80 mm for h=320mm
(j) 59,74,90,105,122,137,153,168 mm for h=535mm
(k)45-63-81mm for h=340mm

Table 4.2: Standard cell sizes for lead-acid traction batteries

4.2.5 Standardization of motors

4.2.5.1 The need for motor standardization

The call for standardization of motors was raised again when considering the practice of (small) electric vehicle manufacturers purchasing their motors on the open market. As it was recognized that motor efficiency was a key factor in the design of the electric vehicle, the need for a standard in the field was perceived:

> *"There are signs that the significance of this question of motor efficiency is not realized as fully as should be. It might therefore help in promoting the use of electrics if a British Standard specification was produced for an electric-vehicle motor."*[329]

4.2.5.2 General traction motor standards

A number of specific standards for electric traction motors have been developed, such as the international standard IEC 349 (first edition 1971), now numbered in the 60000 series as IEC 60349.

IEC 60349 has now developed in a comprehensive family of standards, covering all aspects of traction motors:

- ☞ IEC 60349-1:1999: Electric traction - Rotating electrical machines for rail and road vehicles - Part 1: Machines other than electronic convertor-fed alternating current motors
- ☞ IEC 60349-2:2002: Electric traction - Rotating electrical machines for rail and road vehicles - Part 2: Electronic convertor-fed alternating current motors
- ☞ IEC/TR2 60349-3:1995: Electric traction - Rotating electrical machines for rail and road vehicles - Part 3: Determination of the total losses of convertor-fed alternating current motors by summation of the component losses

These standards are distinct from the general family of rotating electrical machine standards, IEC 60034. They are specifically aimed at

> *"rotating electrical machines forming part of the equipment of electrically propelled rail and road vehicles. The vehicles may obtain power either from an external supply or from an internal source."*[330]

This scope thus includes also battery-electric, diesel-electric or hybrid vehicles.

[329] S.M. Hills, op.cit., p189
[330] IEC 60349-1, ¶1.1, Scope

These standards are however more aimed at heavy applications such as rail traction, than at electric road vehicles. Their scope in fact states:

> *"It is not intended that this standard should apply to machines on small road vehicles such as battery-fed delivery vehicles, works trucks, etc."*[331]

The standard is thus not applicable to motors for most light battery-electric vehicles, though it might be applicable for motors for heavy-duty electric road vehicles such as buses or heavy goods vehicles.

IEC 60349 describes several aspects of the motors: definitions, characteristics, marking, type tests, routine tests. The general definition of "rating" is given as: a "combination of simultaneous values of electrical and mechanical quantities, with their duration and sequence, assigned to a machine by the manufacturer"[332].

Tests to be performed on the motors are described in detail, divided in type and routine tests:

- ☞ A type test is a "*conformity test made on one or more items representative of the production*"[333] and is intended to establish the ratings, characteristics and performance of new types of machines.
- ☞ A routine test is a "*conformity test made on each individual item during or after manufacture*"[334] and is intended to demonstrate that each machine is sound both electrically and mechanically, and that it is essentially identical with the machine that has been type tested. Routine tests are normally carried out on all machines produced.

The multitude of tests, particularly routine tests, presented in this standard makes it in fact less practical for application on electric road vehicles: these tests would turn out too expensive for a product which is produced in large numbers such as an automobile. This standard is more suited for vehicles like locomotives, which are produced in smaller series, and where the purchaser is also more likely to demand from the manufacturer explicit compliance to standards.

A standard such as this is thus not likely to be accepted by vehicle manufacturers, it would be another case of "overstandardization". The development of specific standards for electric road vehicle motors is still an issue, as will be seen in the following chapter.

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[331] Ibid.

[332] IEC 60349-1, ¶2.2

[333] International Electrotechnical Vocabulary IEV-151-16-16 - IEC 60050(151)

[334] International Electrotechnical Vocabulary IEV-151-16-17 - IEC 60050(151)

4.2.5.3 A specific standard for battery vehicle motors: BS 1727

A specific standard for battery vehicle motors came to being in 1951, as British Standard 1727 "Specification for motors for battery operated vehicles", following a demand from industry "in view of the increasing importance of battery-operated vehicles".[335]

In its first version of 1951, the standard defined ratings (continuous, one-hour, 15-min) for traction motors, and the corresponding temperature rises acceptable, for class A and class B insulation.

The document also described in detail the "Hopkinson" method for determining motor efficiency.
It contained no indication however for the rated voltage of the motors.

The standard was revised in 1971 based on proposals by the Electric Vehicle Association of Great Britain. A clause was added stating standard nominal voltages (see §4.2.3). Furthermore, temperature rise levels were adapted to the evolution of insulation technology, introducing insulation classes E, B, F and H[336].

A third revision of BS 1727 was published in 1987, based on a proposal by the British Industrial Truck Association to bring the standard into line with modern usage and technology.
The following bodies were represented in the technical preparation of this standard:
- ☞ British Battery Makers' Society
- ☞ British Industrial Truck Association
- ☞ Electric Vehicle Association of Great Britain
- ☞ Electricity Supply Industry in England and Wales
- ☞ National Dairymen's Association
- ☞ Railway Industry Association of Great Britain
- ☞ Rotating Electrical Machines Association (BEAMA)

The standard specifies the classification and performances of d.c. electric motors having rated voltages up to 96 V, forming part of the electrical equipment of battery operated industrial trucks, tractors and road vehicles.[337] The use of a.c. motors is not taken into consideration; such motors have indeed only come into use for battery-electric vehicles during the 1990s.
It defines requirements and tests for protective enclosure levels (IP24 for road vehicles, IP20 for industrial trucks)[338], rated output, overspeed withstand capability,

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[335] BS 1727:1951, foreword.
[336] BS 1727:1971, ¶3.2
[337] BS 1727:1987, ¶1, Scope
[338] Ibid., ¶3.2

insulation, commutation, efficiency, soundness, braking characteristics and marking. Type tests and routine tests are also presented.
For the permissible temperature rise, the values defined are higher than those generally associated with the temperature classes as defined in the general insulation classification standard BS 2757. This is justified because "experience has shown that machines to this British Standard have an adequate insulation life at temperatures greater than those associated with the temperature classes in BS 2757."[339] The corresponding values are given in Table 4.3.
These higher temperature ratings for electric vehicle motors were already encountered in earlier practice, cf. the AIEE standards discussed in §3.4.5 above.

Component	Method	Maximum temperature rise (°C)			
		Class E	Class B	Class F	Class H
Armature	Resistance	105	120	140	160
Field	Resistance	115	130	155	180
Commutator	Electric thermometer	105	120	140	140

Table 4.3: Permissible temperature rise and method of determination (BS 1727)[340]

The routine tests described in BS 1727 are the following[341]:

- ☞ Soundness test
- ☞ Speed vs. current characteristic
- ☞ Commutation test
- ☞ Overspeed withstand capacity (125%)
- ☞ Dielectric test (insulation voltage withstand capability)
- ☞ Dielectric test (insulation resistance to earth)

Furthermore the following type tests are defined:

- ☞ Temperature rise test
- ☞ Determination of characteristic curves for output, motor torque, thermal rating and efficiency.

Overall, this standard is much simpler in structure than IEC 60349; the simplicity of the routine tests makes it more acceptable for electric vehicle standardization.

339 BS 1727:1987, note to Table 1.
340 Ibid., Table 1.
341 Ibid., ¶12.2

4.2.5.4 Motor specifications for industrial vehicles in European standardization

Annex B of the standard EN 1175-1, (see also §4.2.2.5 and §4.2.6.2) specifies manufacturing and test rules and the specification of output of motors in battery operated industrial trucks.[342]
The requirements and test procedures defined by this standard are virtually identical to those of BS 1727:1987, except that taking into account the nominal voltages covered up to 240 V, a higher test voltage of 1500 V has been prescribed for the dielectric test for nominal voltages over 96 V.[343]

4.2.6 Safety standards

4.2.6.1 Battery safety standards

The specific hazards associated with the operation of traction batteries have led to the drafting of standard codes of practice to define and promote their safe use.

4.2.6.1.1 BS 6287

BS 6287:1982 is the British Standard Code for Safe Operation of Traction Batteries. This document presents a standard of good practice and takes the form of recommendations concerning the safety and health aspects associated with the handling, usage and charging of lead-acid and alkaline traction batteries. It is interesting to note that this document explicitly mentions alkaline batteries, which by the time it was written were acquiring renewed interest for traction applications.
Topics covered by this standard include:
- ☞ Electrolyte;
- ☞ Electrical energy;
- ☞ Evolution of gases;
- ☞ Handling and installation;
- ☞ Routine checks;
- ☞ Charging;
- ☞ Repair.

4.2.6.1.2 VDE 0510

VDE 0510 is a German family of standards about batteries. This standard has a long history, the first edition going back to 1942. The current base document of this series

[342] EN 1175-1:1998, Annex B
[343] Ibid., ¶B4.7

is the fifth edition, VDE 0510:1977, the "VDE-specification for electric storage batteries and battery plants".
This general document refers to the construction, housing, operation and testing of storage batteries and battery plants. It treats both stationary and traction batteries, defining ventilation requirements, water and electrolyte composition, battery trays and battery rooms, testing and charging.

The series has been extended with several subdocuments which will eventually replace the base document.
Part 3 is the one relevant for electric vehicles.
VDE 0510-3 "Batteries and battery installations; Traction batteries for electric vehicles" was first published in 1989, replacing relevant sections of VDE 0510:1977 relating to traction batteries. A new edition from 2001 has been published as a draft standard, concentrating more on the safety aspects. It is however likely to be replaced with EN 50272-3.
VDE 0510-3:1989 describes installation and safety measures for traction batteries; it applies to both industrial trucks, small electric vehicles like wheelchairs, electric road vehicles and even battery-electric rail vehicles[344].

4.2.6.1.3 EN 50272

CENELEC TC21X is working on the European standards of the EN 50272 series. The EN 50272-3, about traction batteries, has been published in 2002.
As this document was a result of the co-ordination between TC21X and TC69X, it has been treated under the TC69X chapter (§5.5.3.4 page 242)

4.2.6.2 European safety standard for industrial electric vehicles

One of a package of European standards for the safety of industrial trucks, EN 1175-1 "Safety of industrial trucks - Electrical requirements - Part 1: General requirements for battery powered trucks" was approved by CEN on 23 November 1997 and published in January 1998, to be adopted by EU member countries, and conflicting national standards withdrawn, by July 1998.
Under a mandate given to CEN by the CEC and the EFTA, and supports essential requirements of the EU Machinery Directive[345], EN 1175-1 had been prepared by Technical Committee CEN/TC150 "Industrial Trucks - Safety", the secretariat of

[344] VDE 0510-3:1989, ¶1.2
[345] Directive 98/37/EC of the European Parliament and of the Council

which is held by BSI. The preparation of this document started in the late 1980s; a draft version was published in 1991[346].
EN 1175-1 was prepared to be a harmonized standard to provide one means of conforming with the electrical aspects of the Essential Safety Requirements of the EU Machinery Directive.

The standard specifies electrical and related mechanical safety requirements for design and construction of the electrical installation in battery powered industrial trucks with nominal voltages up to 240 V.[347]
(One will notice that this 240 V is the same upper voltage limit than defined in ISO 1044 discussed above in §4.2.3.3.)

EN 1175-1 does not address the subjects of charging traction batteries or electromagnetic compatibility.

It contains a risk assessment stating significant hazards with industrial electric trucks, with corresponding requirements to limit the risk or remove the hazard in each situation.[348]

The standard states general requirements for electric industrial truck safety under the following topics:

- ☞ Traction battery safety (¶5.1): installation and protection, constraining, disconnection
- ☞ Battery connectors (¶5.2 - annex A)
- ☞ Heat dissipating electrical components (¶5.3)
- ☞ Electric motors (¶5.4 - annex B)
- ☞ Contactors (¶5.5 - annex C)
- ☞ Electromechanical brakes (¶5.6)
- ☞ Protection against electric shock (¶5.7): protection against direct and indirect contact - no connection of traction circuit to the vehicle frame allowed
- ☞ Protection of electrical equipment (¶5.8): short circuit and overcurrent protection
- ☞ Safety related control systems (¶5.9): functional safety, prevention of unwanted movements
- ☞ Conductors (¶5.10)
- ☞ Wiring practices (¶5.11)
- ☞ Battery charging (¶5.12)
- ☞ Emergency switching off (¶5.13)
- ☞ Dielectric type test (¶5.14)
- ☞ Insulation routine test (¶5.15)

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346 CEN/TC150/WG4 N75 (May 1991)
347 EN 1175-1:1998, ¶1: Scope
348 Ibid., ¶4, based on EN 1050:1996 - Safety of machinery - Principles for risk assessment

¶6 of this standard states additional safety requirements for battery voltages exceeding 120 V. The main features include insulation of the battery (¶6.1), no emergency disconnection with the battery connector (¶6.2.2), equipotential bonding (¶6.3.3), frame fault detection (¶6.3.4).

EN 1175-1's normative annexes A (referring to connectors) and B (referring to electric motors) have been treated in §4.2.2.5 and §4.2.5.4 respectively. A further annex, C, gives requirements for the performance, testing and specification of d.c. electromagnetic contactors for nominal voltages up to 240 V and a rated thermal current not exceeding 400 A[349].

[349] EN 1175-1:1998, annex C

4.3 Overview and conclusions

The development of the electric vehicle into the industrial vehicle field has given rise to extensive standardization work being performed in the field. The main conclusions from this research can be summarized as follows:

Standards were obviously developed in the fields where these are most useful for rationalization, simplification and cost reduction, such as standard connectors and standard batteries; for the latter, the number of sizes used has been reduced to a series simple enough to be rational but extended enough to cater for all industrial vehicle needs.
Other standards, like the standard on voltage, have led to an extension of the number of standardized values, reflecting the evolution of the technology in the field.

There is also the emergence of a new type of standard: the safety standard, which states a number of requirements for the considered equipment in order to be used safely.
These standards go beyond the domain of mere industrial standardization, as they become embedded in legislation and regulation.
This can be seen for example when considering the influence of EU directives (legislation) on EN standards (standardization). The particular case of standardization in the European Union will be discussed further in next chapter, which will treat of standardization work on electric road vehicles during the last part of the twentieth century.

5 A NEW AWAKENING (1970-2000)

Les esprits trop subtils, je l'affirme, songent à des chimères,
mais le chercheur assidu trouvera la vérité en suivant la voie simple de la nature.
Philalèthe - L'entrée ouverte au palais fermé du Roi.

5.1 The evolution of vehicle application

The last quarter of the twentieth century saw a considerable growth in interest for the electrically driven vehicle, which can be ascribed to both technological and societal reasons:

☞ On the technological field, the development of power electronics gave rise to efficient and lightweight traction power converters and battery chargers which were a real breakthrough in electric vehicle technology.

☞ On the societal field, the oil crisis of 1973 on one hand and the emerging concern for the environment brought the electric vehicle forward as an alternative technology.

Figure 5.1: A PGE vehicle from the Brussels EV Experiment[350]

The emergence of electric vehicle technology took place worldwide, with new vehicles and new types of applications being developed. One such new application was the automatic rent-a-car system, an innovative urban transportation system for which electric vehicles are ideally suited.

[350] This picture was taken in November 1985 in the author's hometown of Mechelen, Belgium, on one of the first outings of these vehicles after they were fitted with on-board chargers.

A well-known experiment in the field was run in Brussels from 1980 to 1992, animated by Prof. Maggetto of the Vrije Universiteit Brussel, where a fleet of 9 electric vehicles built by PGE was deployed. These vehicles were a good example of the technology of the 1980 period, using lead-acid batteries, and a separately excited d.c. motor fed through a thyristor chopper, thus enabling field weakening and regenerative braking.
In the framework of the "Brussels EV Experiment", research was also performed on fast charging techniques; the vehicle shown in Figure 5.1 covered the distance from Brussels to Paris and Versailles using intermediate fast charges in June 1984, en route to the EVS-7 symposium[351].
The automatic rent-a-car concept continued to be developed; a successful example operating this day is the "LISELEC" project in La Rochelle, where Peugeot 106 and Citroën Saxo vehicles are deployed.

Many of the pioneer work on electric vehicles was performed by small companies, such as PGE, or Boxel, who manufactured the van of Figure 5.2 with its innovative utility body design.

Figure 5.2: Boxel electric van

A larger-scale development of electric vehicles however seems very difficult without the involvement of major car manufacturers. Particularly in countries like France, where there were strong incentives from the government and electric utility sector, car manufacturers developed products based on their existing ICE bodies.

[351] G. Maggetto, Fr. Heymans, J.-L. Van Eck, Brussels Electric Vehicle Experiment. Influence of biberonnage on an urban fleet of rented vehicles. Use of a High-frequency charger. EVS-7, Versailles, 1984

Among the most successful electric vehicles on the European market today are the products of PSA, which are marketed under the Peugeot and Citroën brands, and of which several thousand units are now on the road. Figure 5.3 shows a Peugeot Partner electric van, one of the fleet deployed by the Belgian Post in the framework of the European "EVD-POST" project[352]. Similar vehicles were also used in the "ELCIDIS"[353] project for goods distribution in cities. This vehicle is representative for the electric vehicle technology of the 1990s. It is fitted with a nickel-cadmium battery, and driven by a d.c. motor; for the power conversion with the chopper, transistors have displaced the thyristors however. A high-frequency on-board charger allows the vehicle to be charged at any standard power outlet.
Electric vehicles were also manufactured by other major European car builders like Renault (Clio, Express, Master, and the recent Kangoo) or Volkswagen (Citystromer).

Figure 5.3: A Peugeot Partner electric van

Electric vehicle development was not confined to Europe however. American initiatives in the field went forward, mainly under the impulse of the California ZEV mandate. One of the vehicles proposed was the GM EV1, a sleek sports coupe powered by an a.c. motor shown and fitted with either lead-acid or nickel-metal-hydride batteries. It is shown in Figure 5.4.
Unfortunately, due to political and economical reasons, the ZEV mandate has been toned down by legal action, and the great breakthrough of electric vehicles in California has not yet taken place.
Advanced electric vehicles were also developed by all Japanese manufacturers.

[352] EVD-POST, Final report
[353] ELCIDIS, Final report

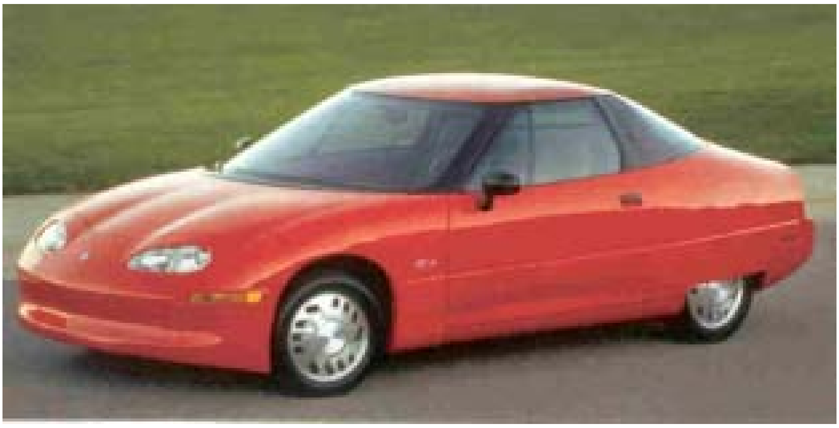

Figure 5.4: The General Motors EV1 [354]

Electric vehicles were also deployed for other applications. Figure 5.5 shows the Gulliver battery-electric minibus built by Tecnobus of Italy; this vehicle is now at home in the historical centres of Rome and Florence and introduced in France (Bordeaux) through the joint efforts of the Ponticelli bus company and EDF.

Figure 5.5: Gulliver electric bus

Research and development work on electric vehicles took place on a world-wide scale, and standardization work soon followed, being performed both on national, regional and international scale. As to highlight the role of the respective players in the field, this chapter will be divided according to the organizations behind the standardization work, with some special attention however for specific problems in the field.

[354] General Motors

5.2 IEC Standardization work

5.2.1 The activities of TC69

Technical committee 69 "Electric road vehicles and electric industrial trucks" of the IEC was founded in 1969, as a Study Committee. It held its first meeting in Stockholm in September 1970.

The scope of this Technical Committee concerned both electric road vehicles and electric industrial trucks; to this effect, it had been proposed to constitute a specific sub-committee SC69A for the industrial trucks, since the technological differences between these two applications merited a different approach, and since work in one field may delay work in the other[355]. This did never materialize however, also because no national committee was found ready to take up the work for this sub-committee[356], and it has not been created up to this day, even if the matter has been discussed at intermediate times[357]. Furthermore, the activities of IEC TC69 have been concentrating nearly exclusively on electric road vehicles, and not much IEC work has been devoted specifically to industrial electric trucks.
The extension of TC69's scope must also be considered facing the developments on the electric vehicle market, where, particularly in the United States, new applications are emerging such as the "neighbourhood electric vehicle" (NEV); these low-speed vehicles use a technology which is more reminiscent of small industrial battery-electric vehicles than of road vehicles.

5.2.2 Early work of IEC TC69

The first working group to be active within TC69 was WG1, which dealt with terminology and vehicle performance issues. In 1970, a draft document was circulated[358], which defined primarily kinematical and dynamical notions. A second draft was circulated in February 1973, introducing notions such as "ENCO" (energy consumption), which was to be plotted in function of the speed, its value being "bounded but indeterminate" at very low speeds. [359]

During the first meeting of TC69, the delegates found it desirable to prepare safety rules for electric road vehicles. The safety code for industrial trucks of the "Fédération Européenne de la Manutention" (cf. §4.2.2.4) could serve as basis for a

[355] BEC/CEB Commission 69 - Procès-verbal de la reunion 1980-11-21, Doc. PV N°7
[356] IEC TC69, Minutes of the meeting in Amsterdam 1982-10-26/28, Doc. PV2549/CE69 ,¶ X
[357] IEC TC69, Minutes of the meeting in Florence, 1992-09-30, Doc. RM3556/TC69, ¶IX
[358] IEC TC69, Doc. 69(Sec)3, 1970-03, "Fundamental terms concerning electric road vehicles"
[359] IEC TC69, Doc. 69(Sec)10 and 69(Sec)11, 1973-02

first draft. This was circulated in June 1971, a second draft prepared and discussed during the March 1972 meeting in Brussels.[360]
On this meeting, it was agreed to divide the document on safety in three parts:

- ☞ Part A: Vehicles
- ☞ Part B: Power source
- ☞ Part C: electric supply - recharging devices

The battery document proposed a division of vehicles in two classes[361]:
- ☞ Class A: Public service and goods vehicles, where the vehicles are operated from a garage or depot, where skilled and trained personnel is employed to service and maintain the vehicles
- ☞ Class B: Privately owned vehicles usually operated by technically untrained personnel.

For Class B vehicles, stricter safety regulations were foreseen, as well as a lower voltage limit (120 V, while on Class A up to 400 V was allowed).

The vehicle document still strongly reflected industrial vehicle practices, with requirements for battery charging installations (including eye-wash bottles).
It also contained a rather strange statement on starting the vehicle:

> *"It shall not be possible to switch on the motor when mechanically connected to the driving system"*[362]

The meaning of this statement seems unclear, since most electric vehicles (particularly industrial-type electric vehicles) have a fixed transmission, with the motor permanently connected to the driving system.

TC69 formed a global view on electric vehicle safety, adopting the attitude that all road vehicles should be capable of being operated in a similar manner and should meet the same fundamental operating requirements (safety etc.). This means that electrically propelled vehicles had to correspond in these respect with ICE vehicles.
TC69 considered that the potential widespread use of electric vehicles and their use by domestic operators, called for wider and more serious consideration of operating and safety requirements than hitherto used. It had to be acknowledged that the extensive use up to now of self propelled vehicles (particularly in the UK) and of overhead-line fed electric vehicles for public services (trams, trolleybuses etc.) had been by commercial undertakings, who can exercise their own rules and regulations on specially trained personnel. [363]

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[360] IEC TC69, Doc. 69(Sec)8, 1973-01, Third draft, Safety of electric road vehicles, Part A: Vehicles
[361] IEC TC69, Doc. 69(Sec)9, 1973-01, "Safety of electric road vehicles", Part B: Power source
[362] IEC TC69, Doc. 69(Sec)8, 1973-01, ¶3.2
[363] Doc. ISO/TC22/SC21 (Sweden 1) 2E, "Proposals for work on electric vehicles outside the scope of IEC TC69", 1973

To this effect, it considered a number of issues of influence, which were outside the classical electrical scope however:

- ☞ General stability of the vehicle (taking into account the weight of the battery)
- ☞ General mechanical safety
- ☞ Braking
- ☞ Steering
- ☞ Transmission
- ☞ Tires.[364]

The field of activity of IEC TC69 would change however with the inception of ISO TC22 SC21 in 1973 and the IEC/ISO agreement (cf. §5.4.2 page 221). At the TC69 meeting held in Ljubljana in October 1973, a few days after the ISO TC22 SC21 meeting, it was decided to transfer the work on vehicle safety and terminology to ISO, and to disband WG1[365].
On this meeting, three ad-hoc working groups were formed, which became permanent working groups as follows:

- ☞ WG2: Definitions and measuring methods concerning the performance of motors and motor control systems, including protection of personnel against electric shocks and protection of electrical components.
- ☞ WG3: Electric energy storage system, including protection of personnel against electric shocks and protection of electrical components.
- ☞ WG4: Power supplies and chargers, including external power supplies to vehicles, on-and off-board chargers, protection of personnel against electric shocks, protection of electrical components, d.c. and a.c. connections.

(A fifth working group, WG5, dealing with Electric hybrid road vehicles, will be treated in §6.2.1.)

5.2.3 Vehicle component standards: the work of IEC TC69 WG2

5.2.3.1 Historical background

IEC TC69 WG2 took on work on a number of aspects of the electrical components of the electric vehicle, this according to the division of work between IEC and ISO.

Its task was focused on

> *"definitions and measurement methods of functional aptitude of motors and motor control systems, including safety of personnel against electric shocks and protection of electrical components"*[366]

[364] Ibid.
[365] IEC TC69, Minutes of the meeting in Ljubljana, 1973-10-29/31, Doc. RM1665
[366] BEC/CEB, letter of 1974-05-14, Doc. 5642/43223

The following subjects were taken into account:
☞ Wiring and connectors
☞ Instrumentation
☞ Rotating machines
☞ Controllers.
For each of these subjects, a first draft was discussed at the IEC TC69 meetings held in 1980. As a result of this meeting, draft documents were submitted to the National Committees for approval under the Six Months' Rule in October 1981.

As the committee responsible for these documents wanted to reduce the time needed to prepare them as much as possible, due to the need felt at the time to have some reference documents available, it was deemed possible that "reference was made to areas of activity which should properly be covered by other committees such as ISO TC22 SC21"[367]. It was expected to have the documents harmonized in a later phase; this never took place however, and the documents remain unchanged in the IEC catalogue up to this day.

5.2.3.2 IEC 783

The publication IEC 783 "Wiring and connectors for electric road vehicles"[368] was published in 1984, based on the draft 69(CO)9[369]; its publication was explicitly supported by 16 National Committees.

Its object is to provide general rules for all external wiring and connectors, both for heavy and light currents. It defines environmental conditions and safety rules, making reference to the then draft standard ISO/DIS 6469. It also states some very general requirements for connectors.

5.2.3.3 IEC 784

The publication IEC 784 "Instrumentation for electric road vehicles" was published in 1984, based on the draft 69(CO)10[370]; its publication was explicitly supported by 16 National Committees.

IEC 784 aims to define the type of instruments and signaling devices which could be fitted to electric vehicles, and how they should be fitted.

[367] IEC 783:1984 - Preface; also in IEC 784, 785, 786
[368] IEC 783:1984
[369] 69(Central Office)9, based on 69(Sec)21
[370] 69(Central Office)10, based on 69(Sec)22

The document defines instrumentation in the following classes:

☞ Indicating meter devices for the state-of-charge[371], for which any of all of the following instruments are proposed:
    - a state-of-charge indicator
    - a voltmeter
    - an amperemeter, which should be provided for vehicles with regenerative braking

    If one considers the electric vehicles which are on the market today, one can see that the state-of-charge indicator is present in all vehicles. Several solutions are provided, of varying accuracy, the measurement of the exact state of charge of a battery, particularly a battery with aqueous electrolyte, not being a problem which is fully resolved yet. Simple state-of-charge indicators often consist of compensated voltmeters, while more elaborate solutions are based on ampere-hour meters.

    Although a simple voltmeter, particularly if used in conjunction with an amperemeter, allows to an experienced operator to make a good estimation of the battery state-of-charge, this instrument is rarely found on production vehicles, its information being deemed of limited value to the average "consumer" driver.

    Amperemeters are often present, although not scaled in amps, but rather fitted with a simple green/amber/red scale as "econometers", notifying operators of their momentary energy consumption and assisting them in acquiring an energy-efficient driving style.

☞ Control lights and indicating devices[372]: a number of indicators is proposed to inform the operator about the operating conditions of the drive system and the battery.

Proposed warning devices include overtemperature, overspeeding, concentration of undesirable gases, auxiliary battery monitoring, leakage current. Supplementary indicating devices are a "controller-on" indication, reversing indication, regenerative braking indication, charging indication and interlock monitoring device.

Most electric vehicles now on the market feature a number of these warning lights, although their standardization, if any, is more clearly to be considered the province of ISO TC22 SC21.

IEC 784 further gives some concise safety recommendations for instrumentation References to EMC matters in this document are discussed in §5.9.7.

[371] IEC 784:1984, ¶3.1

[372] IEC 784:1984, ¶3.2

5.2.3.4 IEC 785

The publication IEC 785 "Rotating machines for electric road vehicles"[373] was published in 1984, based on the draft 69(CO)11[374]; its publication was explicitly supported by 16 National Committees.

It aims to lay down general rules for the design, installation and testing of traction and auxiliary motors on electric road vehicles, and to indicate the technical requirements and testing conditions for them.

The specifications in this document are largely based on IEC 349.
The motors are required to operate at maximum current when supplied at a voltage range from 75% to 110% of their nominal voltage. It is stated however that these limits refer primarily to lead-acid traction batteries and might be changed for other types of traction battery.
As for regenerative braking, the motor should be able to generate its maximum current in a voltage source of 125% nominal battery voltage.

The overspeed withstand limit is defined at 110%, less than the 125% specified in BS 1727 (§4.2.5.3).

Installation requirements however refer to ISO/DIS 6469.2; these mostly refer to protection of personnel against direct and indirect contact.

IEC 785 defines the following type tests, which should follow the general guidelines given in IEC 349[375]:

- ☞ Performance tests, to ensure that the motor meets the agreed specification with regard to torque, speed, power, commutation, voltage limits and/or other characteristics.
- ☞ Temperature rise, where the temperature limits of IEC 349 are taken as reference. An exception is made for the commutator and slip-rings, for which a temperature rise of 120 K is permitted. An interesting note states that the motor should withstand continuous operation during at least one complete battery discharging cycle while performing an urban driving cycle (defined in a relevant ISO standard or other).
- ☞ Commutation, to be checked at all powers and speeds in the normal operating range.

Furthermore, the following routine tests are described:

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[373] IEC 785:1984
[374] 69(Central Office)11, based on 69(Sec)22
[375] IEC 785:1984, ¶6

- ☞ Power output test, to ensure that the agreed torque-speed characteristics are achieved.
- ☞ Mechanical tests, for dimensions, noise, vibration and overspeed limits.
- ☞ Dielectric tests, to ensure that the insulation is sound.
- ☞ Insulation tests, between the windings and frame.

References to EMC matters in this document are discussed in §5.9.7.

5.2.3.5 IEC 786

The publication IEC 786 "Controllers for electric road vehicles"[376] was published in 1984, based on the draft 69(CO)12[377]; its publication was explicitly supported by 16 National Committees.

The object of IEC 786 is to outline the minimum recommended requirements for construction and performance of electric vehicle traction controllers.

Also referring to the draft international standard ISO/DIS 6469, it defines environmental conditions and construction requirements.
Furthermore, it makes a number of recommendations as to safe operation of the controller in the vehicle, covering issues like:

- ☞ Controller switch-on procedure
- ☞ Controller reset
- ☞ Change in selected direction
- ☞ Simultaneous operation of accelerator and brake
- ☞ Emergency disconnect
- ☞ Operation under fault conditions
- ☞ Electrical interlocks
- ☞ Adjustments in service.

Most of these issues however were also covered by ISO/DIS 6469.

IEC 786 further defines a number of type and routine tests for the controllers.
References to EMC matters in this document are discussed in §5.9.7.

[376] IEC 786:1984
[377] IEC TC69, Doc. 69(Central Office)12, based on 69(Sec)23

5.2.3.6 WG2 in the 1990s

After publishing the documents IEC 783 to 786, WG2 became dormant for a number of years.
At the meeting of IEC TC69 which was held in Stockholm, Sweden in 1988, it was stated that

> *"the work of WG2 for the time being was fulfilled and no work was going on. Should the Committee, however, find new tasks for WG2, its work would be taken up again."*[378]

WG2 was reconvened in 1990[379] with the following list of tasks being circulated to seek experts among national committees:

- ☞ Electric traction motors and traction control systems
- ☞ Vehicle system instrumentation
- ☞ Interfacing and communication protocols
- ☞ Electromagnetic compatibility (EMC)
- ☞ Mains supply to the vehicle (heating, transformerless charging)
- ☞ Wiring and connectors, including extreme environmental effects
- ☞ Interconnection between the high and low voltage systems on the vehicle
- ☞ Interface between the electrical and the mechanical braking system
- ☞ System safety, including the effects of contact with "high voltage"
- ☞ Liaison with ACOS (the IEC Advisory Committee on Safety) in relation to system safety
- ☞ Liaison with ISO TC22 SC21 re: mechanical design aspects.

In 1994, a review of the four documents IEC 783 to 786 was proposed by the IEC Central Office[380]. The voting results[381] gave a slight majority to maintain the documents as they were, rather than revise them. Only one member country proposed to withdraw IEC 783 and 784.

The rapid evolution of the technology for electric and hybrid vehicles (e.g. the emergence of alternating current drive technology) however let the need arise to develop adequate standards and technical documents relating to electric vehicle traction.

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[378] IEC TC 69, Minutes of meeting held in Stockholm on 1988-06-1/2, Doc. RM3108/TC69

[379] BEC/CEB, Circular of 1990-11-06, Doc. 5642/43450

[380] IEC TC69, Doc.s 69(CO)23, 24, 25, 26,quoted in Doc. 69(CO)31B, Agenda for the IEC TC69 meeting in Anaheim, 1994-12

[381] IEC TC69, Doc.s 69(CO) 27, 28, 29, 30, quoted in Doc. 69/50/RM, Minutes of the IEC TC69 meeting in Anaheim, 1994-12

To this effect, it seemed highly desirable to re-activate WG2, focusing its activities on the different aspects of electric and hybrid vehicle traction systems, in close collaboration with other competent bodies within IEC and ISO.

TC69's Strategic Policy Statement for 1992 stated the need to examine the reports IEC 783 to 786, and expand them or convert them to real standards as appropriate, taking into account that traditional methods of specifying system performance were no longer appropriate for high-performance electric road vehicles. WG2 should act as "the focus for vehicle system activities such as electric system management and in-vehicle communications"[382].

At the IEC TC69 meeting held in Florence, Italy at the occasion of the EVS-11 symposium in October 1992, the following working items for WG2 were proposed[383]:

- ☞ Integration of motors and controllers
- ☞ Definitions of terms
- ☞ Ratings definition and measurements
- ☞ Wiring and connectors: rating of wiring and connectors
- ☞ Instrument for SOC, interface between battery management system and meters, Diagnostic systems (ISO might have communication protocol worked out)
- ☞ Study and application of existing EMC requirements (IEC, CISPR)
- ☞ Influence of electrical fields on people (this topic was considered of utmost importance)
- ☞ Personal safety and safe operation of the vehicle, fail safe operation.

The safety issue was considered a priority; the proposal for activities in this area also came forth from activities by CITELEC, which had, in 1992, made a study about electric vehicle safety aspects on behalf of the European Commission[384]. This study was written by the author and marked his entry in the world of international standardization, analysing existing standards and regulations and highlighting areas where further work was needed.
The mutual competence of IEC vs. ISO in such issues was already raised at this occasion[385].

No further activities by WG2 took place for the next two years, since the workgroup had no convenor. On the TC69 meeting held in Anaheim, California, Peter Van den Bossche was appointed convener of WG2.[386]

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[382] IEC TC 69, Strategic policy statement, 1992-01, Doc. 69(Sec)33
[383] IEC TC69, Minutes of meeting held in Florence on 1992-09-30/10-01, Doc. RM3556/TC69
[384] P. Van den Bossche, Safety characteristics of electric vehicles in city traffic, CITELEC, 1992
[385] IEC TC69 meeting in Florence, 1992-10-01, personal notes
[386] IEC TC69, Minutes of the meeting held in Anaheim, on 1994-12-07/98, Doc. 69/50/RM, 1995-02

This allowed the author to proceed to the reactivation of WG2 and to engage in the co-ordination of actual standardization work. A first meeting was held in Brussels, Belgium, on November 15th, 1995, and the first activity field of WG2 would be the revision of IEC 785 and 786, with assessment of power rating methods and efficiency measurements.
Further developments were also planned on other components such as cables, dc/dc converters, and the like. It was felt that a close collaboration with other interested parties (ISO, vehicle manufacturers,...) was essential for the activities of WG2 and was to be systematically sought after if required.[387]

The documents IEC 785 and IEC 786, both dating from 1984 and not amended since, were thus proposed for revision. The rapid evolution of electric vehicle technology makes it desirable to consider a revision taking into account the latest developments.
Due to the fact that machines and their controllers may be closely matched, and must in many cases be considered as one unit, it was proposed that 785 and 786 be revised into a single comprehensive document, particularly regarding testing procedures.
However, the description and testing of motors and controllers as single components still had to be observed (a market for such components existing particularly in the field of industrial electric vehicles, which are also covered by IEC TC69, although the Committee has been mostly devoted to road vehicles).

After the initial meeting of WG2 in Brussels , a meeting was held on February 12-13, 1996, in Frankfurt, Germany[388], where a draft version[389] was discussed.
This document was circulated among IEC National Committees, and accepted as New Work Item Proposal 69/77/NP, which was to emanate in the new standard IEC 61981.
TC69 resolved to adopt the following title for this standard:

> *"On-board power equipment for electric road vehicles"*[390]

Ten countries (Belgium, Canada, Czech Republic, Germany, Italy, Japan, Russian Fed., South Africa, Sweden, Switzerland - the USA agreed to participate but its voting documents were lost) voted in favor of accepting this draft as a NWIP; there was one vote against, from France[391], who saw no reason to pursue this standardization work. The French car manufacturers were of the opinion that on

[387] IEC TC69, Minutes of the meeting held in Brussels, on 1995-11-16/17, Doc. 69/68/RM, 1996-02
[388] IEC TC69 WG2(Sec)3: minutes of the meeting in Frankfurt
[389] 69/75/CD, circulated 1996-05, replaced by 69/77/NP
[390] Resolution No.2, Plenary Meeting of TC69 in Osaka, Japan, 1996-10-17/18; Appendix 3 to Doc. 69/88/RM
[391] IEC, Result of voting on NWIP 69/77/NP, Doc. 69/86/RVN

one hand the clauses on safety would be the province of ISO rather than IEC, and that on the other hand the characteristics of the motors and controllers were not to be defined through IEC standards, but through proprietary specifications by the manufacturers themselves[392].

However, further work on this proposal was interrupted pending discussions between IEC TC69 and ISO TC22 SC21 in the framework of the Steering Committee developed between these bodies.
From the automotive industries (represented in ISO) the mere necessity of developing component standards was put to question. Furthermore, the current roster for IEC TC69WG2 reflected a heavy representation of the electrotechnical sector, with a low representation of vehicle manufacturers.

At the latest meeting of the IEC/ISO Steering Committee, which was convened in December 1999, it was thus decided to discontinue the work on IEC 61981.

5.2.3.7 New activities for WG2?

The development of advanced drive systems for electric and hybrid vehicles created the opportunity for new action horizons for WG2 to emerge however. In his position of WG2 convener, the author has performed further research on these issues which have led to the findings described in the following paragraphs.

The evolution in power electronics in fact showed steady progress, with new components (GTO, MOSFET, IGBT) and new control techniques (microprocessors) which introduced the possible use of a.c. motors (particularly asynchronous induction motors, synchronous permanent-magnet motors and variable reluctance motors) in variable-speed applications including traction. Asynchronous motors are cheaper to manufacture, require less maintenance and are more sturdy then d.c. ones. The typical a.c. driven electric vehicle contains an inverter which transforms the d.c. from the battery in a.c. for the traction motor. During regenerative braking, the motor functions as generator, feeding a.c. to the inverter, which rectifies it to recharge the battery. The current levels during this braking can be high, up to the maximum acceleration current, corresponding to the full power of the vehicle.

This recharging capability of the inverter could also be used however during battery charging from an external a.c. supply, at high power levels. This leads to the possibility of fast charging, with a high-power a.c. connection, which represents a much lighter infrastructure than the off-board fast charging stations which supply the vehicle with d.c.

[392] French commentaries (PSA and Renault) on 69/75/CD

Furthermore, such structure offers the opportunity of supply network management, using the batteries of electric vehicles (or the fuel cell power plant in a fuel cell vehicle) connected to the network as "peak shaving" units, feeding a.c. in the network through the inverter.

The use of the traction inverter for charging presents the following features which differ it from the "ordinary" charging procedure of batteries:

- ☞ The charging of the battery is done through a vehicle component (the inverter) which also performs other functions in traction, and not through a dedicated (on or off board) charger.
- ☞ Since the inverter is not necessarily (and in most cases is actually not) providing galvanic isolation between the d.c. "motor" side, the d.c. "battery" side and the a.c. intermediate circuit and external a.c. connection, the vehicle traction circuits, including the battery, are directly connected to the a.c. supply network during charging. This is a fundamental difference with conventional chargers, which in virtually all cases are isolated between input and output through the use of a (low or high frequency) transformer. This may have an impact on equipment safety.
- ☞ A bi-directional power flow may exist between the vehicle and the supply network.

The inverter and battery (or fuel cell), being connected to the network, become an "electric device". There is a clear overlap here between the activities traditionally attributed to IEC (the electric devices connected to the network) and those catered for by ISO (the vehicle itself, including its traction components).

The concept of "electric device" makes it desirable to proceed to standardization, in order to address the following issues:

- ☞ Safety: protection of personnel
- ☞ Interference with the network, including EMC issues (particularly in the case where a bi-directional energy flow between the vehicle and the network is foreseen)
- ☞ Difference between stand-alone component performance and "on-vehicle" performance.

At this moment, few, if any, international standards exist for electric vehicle components. Vehicle manufacturers of course draft specification sheets for components, for the use of their component suppliers. Although these sheets may present the format and the structure of standards documents, they are not to be considered as such, being proprietary documents geared at one specific product, vehicle, or application. Also, contrary to real international standards, such documents are generally not freely available to the public.
The vehicle manufacturers do not perceive the need for such standardization work, which is considered an impediment for technical progress and for the development

of proprietary know-how. It is not customary either to define construction standards for thermal vehicles.

Based on these findings, it was proposed in 2000 by the author to start work on a new document:

> *Electric traction equipment of electric road vehicles - connection to the electric supply network.*

with the following scope and object:

> *This standard is applicable to electric power equipment on electric and hybrid road vehicles which can be energised by both the main on-board energy source and the external electric supply network. Examples include on-board inverters which are used for traction as well as for charging.*
>
> *The object of this standard is to lay down general rules for the design, installation and testing of electric power equipment on electric and hybrid road vehicles which can be energised by both the main on-board energy source (traction battery) and the external electric supply network, and to indicate the technical requirements and testing conditions for them.*

The contents of such standard would include:

- ☞ Normative references
- ☞ Definitions
- ☞ Construction issues
- ☞ Safety issues
- ☞ Interference issues
- ☞ EMC issues
- ☞ Testing and verification procedures.

The new document, although clearly falling in the province of IEC, should be an answer to the needs of ISO since it refers to electric vehicle components and thus to the vehicle itself. Due to the close interweaving of vehicle-related aspects and equipment-related aspect, and reflecting the ideas of the agreed division of labor IEC/ISO, close collaboration with ISO would have to be sought on relevant matters. This also implies that the roster of IEC TC69 WG2 would have to be extended with delegates from the automotive sector.

To be acceptable to automotive manufacturers, the new document should not be too restrictive in imposing constructional limitations, but rather give a support for recommended practices.

As there has been however no meeting of the IEC/ISO Steering Committee, nor of IEC TC69, since, this proposal has not yet been materialized.

The problems surrounding the division of work between IEC and ISO on electric vehicle standardization issues will be treated in particular in §5.4.

5.2.3.8 Overview of WG2 documents

A synoptic overview of the works by IEC TC69 WG2 is shown in Figure 5.6.
In this figure, as well as in the others of its kind, the following conventions are used:

- ☞ Dark background: standards published.
- ☞ Light background: standardization work in progress.
- ☞ White background: no activities (work not yet started, stopped, or standards withdrawn).
- ☞ The major milestones in the standardization process are shown with their stage codes (cf. §8.9).
- ☞ Merged documents have been indicated with an arrow.
- ☞ The column for 2002 shows the current status of the document.

		1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
IEC 60783	*Wiring and connectors for electric road vehicles*	PPUB																		PPUB
IEC 60784	*Instrumentation for electric road vehicles*	PPUB																		PPUB
IEC 60785	*Rotating machines for electric road vehicles*	PPUB																		PPUB
IEC 60786	*Controllers for electric road vehicles*	PPUB																		PPUB
IEC 61387	*Electric power equipment for electric road vehicles*						PNW							1CD						DEL
IEC 61981	*On-board electric power equipment for electric road vehicles*													PNW						PWI

Figure 5.6: IEC TC69 WG2 activities

5.2.4 Battery standards: the work of IEC TC69 WG3

5.2.4.1 IEC TC69 WG3 and the revision of IEC 254-1

The initial task of TC69 WG3 was focused on:

> *"Energy storage systems, including safety of personnel against electric shocks and protection of electrical components"*[393]

As for standardization of batteries, the IEC standardization activities were performed by IEC TC21. The main standard about (lead-acid) traction batteries was the IEC 254 discussed in §4.2.4.2.
The special case of the electric road vehicle however, where the discharge cycles are often shorter than for industrial vehicles, made IEC TC69 to give special consideration to this matter in its WG3.
WG3 performed its activities in close relationship with TC21, and saw its task as to make recommendations towards TC21 to be incorporated in standards like IEC 254. In the year 1982, TC21 was revising that standard, and WG3 was awaiting the revised version to take action on the matter[394].
In April 1985, WG3 produced a draft document 69(SEC)29 which was circulated in TC69: "Lead-acid traction batteries for use with electric road vehicles"[395]. Although the structure and the wording of this document closely reflected IEC 254-1, it introduced some new approaches such as the one-hour discharge capacity[396], which also was the base for defining energy density[397], and high rate discharge performance[398].
Tests described in this document include capacity test, charge retention test, high-rate discharge performance test and cyclic endurance test[399].
In the same period, WG3 asked TC69 members to comment on whether the endurance test in IEC 254-1 was relevant to electric road vehicle batteries, and whether a dynamic capacity test and peak power test were necessary[400].

The response of the Belgian national committee on this issue supported the publication of 69(SEC)29 but also highlighted the work performed by the European

[393] BEC/CEB, letter of 1974-05-14, Doc. 5642/43223
[394] IEC, Minutes of the TC69 meeting held in Amsterdam on 1982-10-26/28, Annex B, Report by WG3 Secretary P.D. Gibbons.
[395] IEC TC69, Doc. 69(Sec)29, 1985-04
[396] Ibid., ¶3.2.2
[397] Ibid., ¶3.4
[398] Ibid., ¶3.5
[399] Ibid, ¶11-13
[400] IEC TC69, Doc. 69(Sec)30, 1985-05

Electric Road Vehicle Association, AVERE, which had made up a document describing test specifications for "road electric vehicle batteries"[401] (see also §5.5.12). This AVERE document presented a specific approach which the Belgian National Committee recommended to be considered by TC69. It addressed in fact all issues raised by WG3 in document 69(SEC)30[402]:

☞ The endurance tests described by AVERE reflected more truly the real exploitation parameters of electric road vehicles.
☞ The AVERE specification took into account dynamic discharge parameters.
☞ It also measured peak power.
☞ It took into account different temperatures of operation.

5.2.4.2 *Further activities at WG3 - Dynamic test cycles*

A draft proposal covering test methods and definitions for lead-acid electric road vehicle traction batteries prepared by WG3 was published as Amendment 1 to IEC 254-1:1990[403].
Further efforts by WG3 concentrated on the preparation of a Dynamic Capacity Test Cycle representative for the usage pattern of an electric vehicle in city driving.

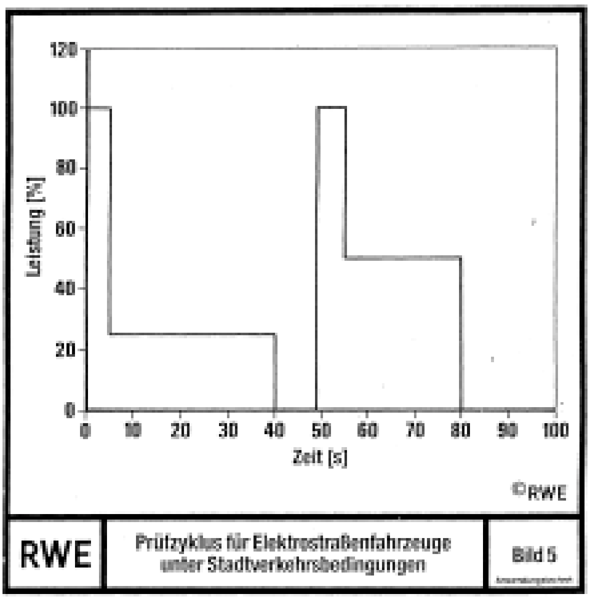

Figure 5.7: Proposed RWE dynamic test cycle[404]

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[401] AVERE Technology and Standard Committees, Road Electric Vehicle Batteries, Test Specifications, 1982
[402] BEC/CEB, Response to 69(Sec)30 of IEC, 1985-07
[403] IEC TC69, Minutes of meeting held in Florence on 1992-09-30/10-01, Doc. RM3556/TC69, Appendix 1

On the 1988 meeting of IEC TC69, a report on battery test procedures for WG3, was presented[405]. The main objective of this paper was to present a dynamic capacity cycle for road vehicles, using experience gained from existing test cycles (like the SAE J227 - cf. §5.6.2, and the ECE cycle) to come to a simple and representative test regime.

The proposed test cycle, illustrated in Figure 5.7, did not take into account regenerative braking or very high value peak currents, since without these parameters

"the net result of the test is not sufficiently altered as to make the test invalid".[406]

The proposed cycle was anticipated as a preliminary means of assessment; reservation on the elimination of regenerative braking and high peak currents were expressed however.

During 1990-91, WG3 continued to work on this issue and prepared a draft which was presented to TC21 in April 1992.

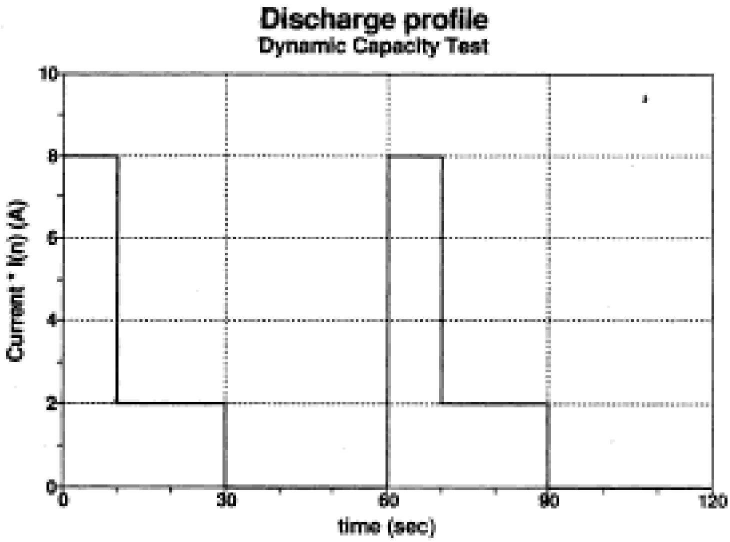

Figure 5.8: WG3 dynamic test cycle[407]

The cycle, shown in Figure 5.8, is easy to perform and was expected to result in an accurate capacity value to be stated as "nominal". The cycles had to be executed up to a cut-off voltage of 1,5 V/cell.

The dynamic discharge test was eventually published as such in the new version of IEC 60254-1[408].

[404] IEC TC 69, Minutes of meeting in Stockholm on 1988-06-01/02, Doc. RM3108/TC69., Annex 1

[405] Ibid., Annex 1 (proposal by Mr Frank Klein, RWE), and Annex 3 (Doc. 69(Stockholm/WG3/Ad-hoc)6)

[406] Ibid., Annex 3

[407] IEC TC69, Minutes of meeting held in Florence on 1992-09-30/10-01, Docrm, Appendix 1

5.2.4.3 Work on nickel-cadmium batteries

On the TC69 meeting held in Florence in 1992, the preparation of a draft regarding the dynamic capacity for NiCd batteries was announced. The major part of it (particularly, the test cycle) would be identical to the lead-acid battery test, except the temperature and the cut-off voltage parameters (the latter becoming 0,8 V per cell)[409]. Work on this issue continued during the next two years, with a document presented as CDV in 1994, which was accepted by 10 votes to one[410]. The negative vote came from Canada, which in its comment stated that the proposed test conditions were not realistic, one of its main flaws being the absence of regenerative braking.

The document was published as IEC Technical Report 1382-1 "Nickel-cadmium rechargeable cells and batteries for electric road vehicle propulsion applications - Part 1: Dynamic discharge performance test (DDPT) and dynamic endurance test (DET)" in July 1996[411].
This document was published as a Technical Report of "type 2" (which means a "prospective standard for provisional application"), and not as a full-blown standard.
IEC 1382-1 makes reference to the general NiCd battery standard IEC 60623 "Secondary cells and batteries containing alkaline or other non-acid electrolytes - Vented nickel-cadmium prismatic rechargeable single cells", prepared by prepared by SC21A "Secondary cells and batteries containing alkaline or other non-acid electrolytes", of IEC TC 21 "Secondary cells and batteries".
IEC 60623 specifies marking, designation, dimensions, tests and requirements for vented nickel-cadmium prismatic secondary single cells.

IEC 1382-1 defines a dynamic discharge performance test and a dynamic endurance test.
In November 1995, a NWIP was launched to amend IEC 1382-1 considering the influence of short high power pulses (resulting from regenerative braking) during the dynamic discharge test[412]. This NWIP was accepted seven votes to two[413].

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408 IEC 60254-1:1997, ¶6.2.3
409 IEC TC69, Doc. RM3556/TC69, Appendix 1
410 IEC TC69, Doc. 69/65/RVC, 1996-01
411 IEC 1382-1:1996
412 IEC TC69, NWIP 69/64/NP, 1995-11
413 IEC TC69, Doc. 69/70/RVN, 1996-04

5.2.4.4 Further new work by WG3

WG3, which had become very active by the mid 1990's, did start work on a number of subjects:

- Watering and venting systems: work on the subject "Consideration of the impact and testing requirements for battery watering and venting systems, where appropriate" did start as early as 1989[414]. A proposal had been prepared in 1995[415]. It was perceived however that this topic involved also vehicle design issues which were the province of ISO, the work within IEC TC69 WG3 could not be further progressed, and work on this subject, which was to emanate in IEC 1385, was suspended in 1996.[416]

- "More complex battery systems and battery management" (IEC 1382-2 TRO): work on this topic had been considered; it had been postponed however until the work on dynamic test cycles would be completed[417]. In 1996, the project as such was cancelled because then ongoing proposals to develop a generic battery test standard would render it obsolete[418].

- Work on defining tests to determine the effects of "chopped" current waveforms and of regenerative braking was also considered. This project, which was to emanate in IEC 1383, was deleted in 1995.[419]

- Charge acceptance: the main objective on this proposed work was to present a value for the charge acceptance of a nearly fully charged battery (taking into account a regenerative braking situation). The aspects of boost charge and rapid charge were also be included in this proposal, which could than be named "Charge characteristics of EV batteries"[420]. Limited work however had been possible on this subject, as it was closely related to parameters contained in other standardization work. A decision was thus made to delay this NWIP until it could be part of a comprehensive standard of road vehicle batteries[421].

Furthermore, in the summer of 1995, WP3 circulated a number of NWIPs:

- "Sealed nickel-metal hydride cells for electric road vehicle propulsion applications" [422], proposing to develop a standard for DDPT and DET for "sealed" NiMH batteries, based on the provisions of IEC 1382-1 for vented

[414] IEC TC69, Work programme 69/82/PW, 1996-08
[415] IEC TC69 WG3, Minutes of meeting in Brussels 1995-11-15, contribution by Mr. Kalker, RWE
[416] IEC TC69 WG3, Minutes of meeting in Geneva, 1996-07-02
[417] IEC TC69, Minutes of meeting in Florence, 1992
[418] IEC TC69 WG3 report to the meeting in Osaka, 1996-10, Doc. 69/83/NF
[419] IEC TC69, Minutes of meeting in Florence, 1992
[420] IEC TC69 WG3, Minutes of meeting in Paris, 1995-09-19/20
[421] IEC TC69 WG3, Minutes of meeting in London, 1996-03-27
[422] IEC TC69, NWIP 69/55/NP, 1995-07

NiCd batteries. This NWIP was accepted with 9 P-members supporting it, and 3 P-members against[423]. This project, IEC 1893, would eventually be merged with IEC 61982-2.

☞ "Sealed nickel-cadmium rechargeable cells for electric road vehicle propulsion applications" [424], proposing to develop a standard for DDPT and DET for "sealed" NiCd batteries, based on the provisions of IEC 1382-1. The proposal was accepted with 9 P-members voting in favour, one abstention and one against[425]. This project, IEC 1382-2, would eventually be merged with IEC 61982-2.

☞ "Preferred sizes and voltages of battery monoblocs for electric vehicle applications"[426]. The need for this kind of work was perceived, since no international standard existed for electric vehicle battery modules (unlike for example for traction cells, such as IEC 60254-2) and that national standards were being developed in several countries such as the USA, Japan and Germany. It was clearly recognized that the acknowledgment of new standards would be more difficult if national standards are strongly implanted, hence the proposal of a NWIP on this subject, which constitutes a key element for cost reduction through preventing an uncontrolled proliferation of monobloc types in use.
Following the favorable vote on this NWIP (11 P-members were supporting, 1 not supporting)[427], a draft questionnaire was circulated[428], which summed a number of monobloc size already implemented in existing or future national standards (Table 5.1). This received only limited response, by Japan and the United States[429], with a number of additional sizes suggested. A preliminary paper was prepared; at a 1996 WG3 meeting however, it was stated that

> *"it is considered in some quarters that a document of this nature is not viable at this stage of electric vehicle development and would be rejected by many vehicle developers"*[430]

The draft document prepared in 1996 for circulation to WG3 members[431] showed only a limited number of battery sizes, due to the limited response on the first questionnaire. It also defined a number of terminal arrangements.
The subject (IEC 61894) would be deleted in 1998.

[423] IEC TC69, Doc. 69/62/RVN, 1995-11
[424] IEC TC69, NWIP 69/60/NP, 1995-08
[425] IEC TC69, Doc. 69/67/RVN, 1996-02
[426] IEC TC69, NWIP 69/56/NP, 1995-07
[427] IEC TC69, Doc. 69/63/RVN, 1995-11
[428] IEC TC69 WG3, Minutes of meeting in Brussels, 1995-11-15; questionnaire by A.de Guibert
[429] IEC TC69 WG3, Minutes of meeting in London, 1996-03-27, Appendix 2
[430] IEC TC69 WG3, Minutes of meeting in Geneva on 1996-07-02
[431] IEC TC69 WG3, Circular letter TC69-622 by A. Austin, 1996-08-15

Voltage	Length	Width	Height
12	388	116	175
12	210	175	175
12	306	175	190
12	295	130	200
6	244	190	275

Table 5.1: Preferred monobloc cell sizes (mm)

5.2.4.5 A new approach: the generic battery standard

The experts of WG3 duly recognized the value of having a generic, battery system independent, standard for testing electric vehicle batteries, raising the issue on the 1995 meeting in Brussels[432]. The idea was further discussed on 1996 meetings in London[433] and Geneva[434], where a draft paper was presented[435]. This document, circulated as NWIP "Testing of batteries for electric road vehicles" was then circulated in July 1996[436], explained the rationale behind this work as follows:
Traction batteries developed up to then had in fact all been focused on a specific type of battery, and were not useable, neither intended, to compare different batteries between them and to select the optimal type of battery for a given electric vehicle application. Furthermore, new evolutions in electric vehicle technology also created new requirements for battery testing:

- Batteries with higher capacity became available, allowing the customer to select either a high or low capacity battery for an application with the same discharge profile.
- The difference between peak power and average power became greater with vehicle performances increasing.
- High-power regenerative braking could reach levels similar in magnitude to drive power.
- Some driving systems are tuned to maintain constant power by increasing the current to compensate for voltage drop at end of discharge.
- Many batteries come fitted with a battery management system (BMS), and realistic tests can only be made of the battery with its BMS as a whole unit.
- Users and vehicle manufacturers are interested in the operation of battery systems under extreme conditions (including temperature) and not in just average value.

[432] IEC TC69 WG3, Minutes of meeting in Brussels, 1995-11-15
[433] IEC TC69 WG3, Minutes of meeting in London, 1996-03-27
[434] IEC TC69 WG3, Minutes of meeting in Geneva, 1996-07-02
[435] Ibid., paper prepared for WG3 "Testing of batteries for electric road vehicles" by Dr. Mangan
[436] IEC TC69, NWIP 69/78/NP, 1996-07

Furthermore, one should also take into account the usage pattern of the battery in a hybrid vehicle, which is fundamentally different compared with a battery-electric vehicle.

The NWIP thus aimed to identify strengths and weaknesses in the performance of complete battery systems, this information being of great use to both vehicle and battery manufacturers. It proposed the following set of tests:

- ☞ Benchmark tests for capacity, power, charge acceptance, internal resistance, memory effect, operating voltage window and self discharge.
- ☞ Test cycle modifiers: battery age, battery temperature, ambient temperature.
- ☞ Abusive testing: in order to identify the limits of operation imposed by a BMS, some tests in abusive condition were proposed: continuous discharge at maximum power, recharge at maximum regenerative power as function of state of charge, thermal cycling.

It was stated that these test provisions were also valid for hybrid vehicles.
The NWIP was accepted ten votes to one[437].

5.2.4.6 TC69 joins effort with TC21

At a meeting held in Geneva in April 1996, the IEC "Group A" Committee of Action requested to set up a joint working group between TC69, TC21 and SC21A to develop a coherent set of battery standards for electric vehicle under the leadership of TC21[438].
TC21 deals with "Secondary cells and batteries", whileas SC21A deals more specifically with "Secondary cells and batteries containing alkaline or other non-acid electrolytes". The constitution of the JWG was communicated to all NCs in July 1996.

The JWG had its first meetings in Frankfurt (October 1996) and Paris (March 1997). At these meetings, the title and scope of the JWG were discussed and defined as follows:

> *Title: Secondary batteries for the propulsion of electric and hybrid-electric road vehicles*
> *Scope: To develop a coherent set of battery standards embracing secondary electro-chemical systems, for propulsion duties in electric and hybrid-electric vehicles, taking into account existing standard, those currently under development and proposed future work of TC21/SC21A/TC69.*[439]

[437] IEC TC69, NWIP 69/87/NP, 1996-11
[438] IEC TC69, Minutes of the meeting held in Geneva on 1996-04-11, Results of the Group A Committee of Action meeting held on 1996-04-10
[439] IEC JWG TC21/SC21/TC69, Minutes of the meeting held in Paris on 1997-03-17, Doc. 69/94/INF

It is interesting to see that in the title the term "propulsion" was chosen, whereas the first version discussed on the Frankfurt meeting spoke of "traction". This vocabulary reflects automotive practice - the international standard terminology standard ISO 8713 however considered the terms "traction battery" and "propulsion battery" as equivalent[440]. The European standard EN 13447 states on this issue:

> *"Traction is the term used with the same meaning as propulsion, but for historical reasons, this is the most widely used term."*[441]

The JWG agreed on considering the battery system as a "black box", i.e. the battery together with its peripherals and BMS (if any) as shown in Figure 5.9. It was also realized that co-operation with ISO was necessary in order to avoid conflicting work.

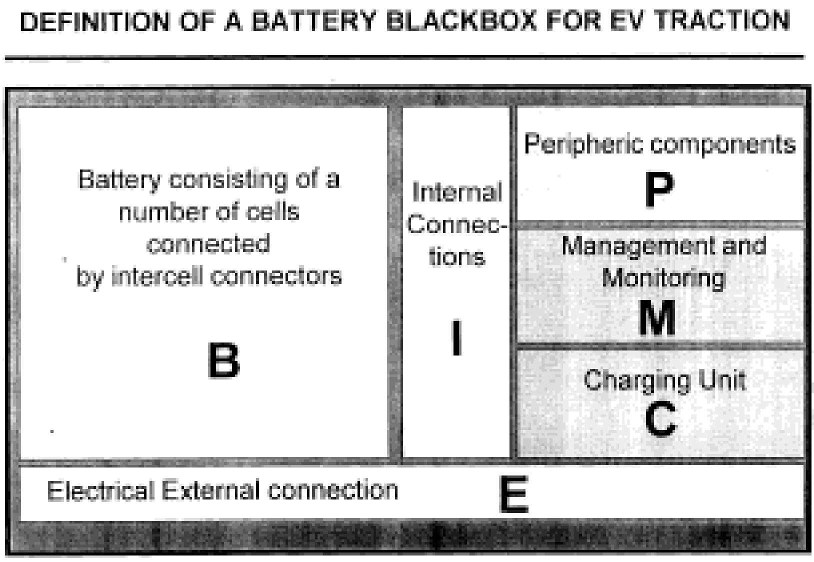

Figure 5.9: The battery as a "Black Box"[442]

Ongoing work by TC21 on one hand and TC69 on the other hand was divided as follows[443]:

☞ There was one project by TC21 outstanding, "Specifications dedicated to the requirements of secondary lead-acid batteries for electric road vehicles" (21/407/NP). It was anticipated that this would be absorbed in the new "black box" project.

☞ The outstanding TC69 WG3 projects discussed above were all appropriate for adoption by the JWG:

  - ☛ Sealed NiCd - Dynamic capacity testing (69/60/NP) - project 1382-2.

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[440] ISO 8713:2002, ¶3.55

[441] EN 13447:2002, ¶3.1

[442] IEC JWG TC21/SC21A/TC69, Minutes of the meeting held in Frankfurt on 1996-10-23

[443] IEC JWG TC21/SC21A/TC69, Minutes of the meeting held in Paris on 1997-03-17, Doc. 69/94/INF

- ☛ Sealed NiMH - Dynamic capacity testing (69/55/NP) - project 1893.
- ☛ Preferred sizes and voltages (69/56/NP) - project 1894.

☞ The project 1382-1 was also assigned to the JWG, but it had by that time already been published as a Technical Report.

☞ The project 69/78/NP - Testing of batteries for electric road vehicles - was assigned to the JWG as basis of the "Black box" project.

With all outstanding projects having been adapted by the JWG, there were no NWIPs left for consideration by TC69 WG3.[444] The WG3 was then disbanded, all future work to be handled by the JWG.[445]

Two working groups were formed in the JWG, working respectively on the dynamic testing and the "Black Box" project; each of them meeting twice in 1997.

5.2.4.7 A standard for dynamic performance testing: IEC 61982-2

The projects 1382-1 A1 (69/64/NP), 1382-2 (69/60/NP) and 1893 (69/55/NP) were all to be incorporated in a single generic standard, covering all or most types of batteries.[446]
It was also decided that this project would embrace clause 6 of IEC 60254-1 (the testing procedure for light road vehicle lead-acid traction batteries - see §5.2.4.2) and the Technical Report IEC 61382-1 (see §5.2.4.3)[447].
A first Committee Draft, was circulated in November 1997 as document 21/435/CD. Comments were received, and in January 1999 the second Committee Draft, 21/467/CD[448] was circulated to national committees.
The final draft, 21/567/FDIS, was adopted as International Standard IEC 61982-2 in August 2002.

IEC 61982-2:2002 "Secondary batteries for the propulsion of electric road vehicles - Part 2: Dynamic discharge performance test and dynamic endurance test" specifies tests and requirements for capacity and endurance tests. Its objective is to specify certain essential characteristics of cells and batteries together with the relevant test methods for their specification. These tests were aimed specifically at batteries for light passenger vehicles, motor cycles, light commercial vehicles, etc.[449]

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[444] IEC TC69 WG3 report to the TC69 meeting in Orlando, 1997-12, Doc. 69/97/INF
[445] IEC TC69, Minutes of the meeting held in Orlando on 1997-12-18/19, Doc. 69/106/RM
[446] Ibid.
[447] IEC TC21, Committee Draft 21/435/CD, 1997-11, Introductory note
[448] IEC TC21, Committee Draft 21/467/CD, 1999-01
[449] IEC 61982-2:2002 - Scope

The standard defines the rated capacity of the battery as the three-hour capacity[450], and defines test cycles for dynamic discharge both with and without regenerative braking. The test cycle without regenerative braking is similar in shape to the dynamic test cycle defined by IEC TC69 WG3 (the actual values of the current however are given in the (informative) Annex A to the standard) and shown in Figure 5.8; the test cycle with regenerative braking is shown in Figure 5.10.
The DDPT in both of these cases is performed by discharging the battery according to those cycles down to the final discharge voltage of the battery.[451]
This voltage is also specified in Annex A, which states a value of 1,5 V for lead-acid, 0,8 V for nickel-cadmium or nickel-metal hydride, and 1,7 V for sodium-nickel-chloride batteries.
For the (destructive) DET the battery is subjected to repeated charge and discharge cycles following the same test cycles; a DDPT is performed to record the capacity development. The end-of-life criterion is reached when the capacity falls to 80% of its value prior to the endurance test.[452]

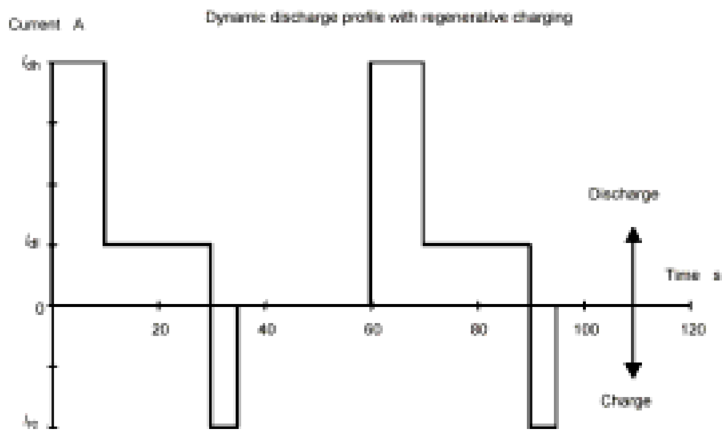

Figure 5.10: Dynamic discharge test with regenerative braking[453]

IEC 61982-2 states clearly that its ddpt and det are intended for the comparison of batteries of the same electrochemical system[454]. To compare different types of batteries however, one must make use of a vehicle-based, “Black Box” approach, which is the subject of a separate standard as discussed in the following paragraph.

[450] Ibid., ¶4.1
[451] Ibid., ¶4.2.4
[452] Ibid., ¶4.3.4
[453] Ibid., Figure 2
[454] Ibid., ¶4.4.1

5.2.4.8 Performance and life testing: IEC 61982-3

The JWG TC21/SC21/TC69 started work on the project 1982 (69/78/NP) about battery testing, which was initially known as the "Black Box" project.
A first Committee draft, under the title "Testing of secondary batteries for electric road vehicles" was circulated in October 1998 as 21/458/CD[455]. The document was eventually published in June 2001 as International Standard IEC 61982-3 "Secondary batteries for the propulsion of road vehicles - Part 3: Performance and life testing (traffic compatible, urban use vehicles).
The rationale behind this standard, as stated in its introduction[456] cites the same arguments that were raised when proposing the initial NWIP (cf. §5.2.4.5).
The standard is applicable to electrical energy storage systems for "general purpose, traffic compatible, light urban use electric road vehicles" such as cars and vans, and not for public transport vehicles, scooters, or large commercial vehicles, for which special standards were to be developed later.
The test procedures reflect the "Black Box" approach: they are defined as function of the vehicle requirements, without reference to the actual composition of the electrical energy storage system. This will allow comparison:

- ☞ between the performance of different types of electrical energy storage systems
- ☞ between the performance of the same type of electrical energy storage system with different capacities

The standard defines three fundamental tests: capacity (range), power (performance) and life, as well as a number of optional tests.[457]

The vehicle-based approach creates the need to make some assumptions about electric vehicle operation in urban traffic. The following figures are chosen as generally representative of town operation[458]:

- ☞ average road speed: 30 km/h
- ☞ energy consumption from the battery:

$$E = 100\frac{\text{Wh}}{\text{Tkm}} \qquad (5\text{-}1)$$

This average speed and energy consumption are equivalent to an average power drain from the battery of 3 kW per tonne of vehicle weight.

It is interesting to compare these figures with real-life consumption of electric vehicles. In its "12 Electric Hours" demonstrations, citelec has used empirical curves

[455] IEC TC21, Committee Draft 21/458/CD, 1998-10
[456] IEC 61982-3:2001, Introduction
[457] Ibid., Scope
[458] Ibid., ¶3

giving a relationship between the weight of the vehicle (W, in tonnes) and the consumption in watt-hours per tonne-km in city traffic[459]:

Low consumption: $$E = 80 + \frac{80}{W} \tag{5-2}$$

Average consumption: $$E = 150 + \frac{100}{W} \tag{5-3}$$

High consumption: $$E = 220 + \frac{120}{W} \tag{5-4}$$

The lower limit is to be considered as the cumulation of a very economical driving style ("light foot") with an advanced energy efficient drive technology (motor, converter, charger). The high limit can be considered as a combination of a "heavy foot" with a less efficient technology. These values were established in the late 1980s; today's electric vehicle technology tends to converge towards the lower consumption level.
For a one-tonne vehicle, this would give respectively a consumption of 160, 250 and 340 Wh/km. These are consumptions measured at grid level; to take into account the consumption at battery level one must look at the respective efficiencies of the battery and the charger. Considering a typical efficiency of 75% for the battery and 90% for the charger, one obtains the "low consumption" value of 108 Wh/Tkm, which is comparable to the 100 Wh/Tkm stated in IEC 61982-3.

The reference cycle defined in this standard is based on the Dynamic Stress Test (DST) defined by the United States Advanced Battery Consortium (USABC), which in turn was based on the "Simplified Federal Urban Driving Cycle" (SFUDC). It is measured in relative power output; for the average power drain of 3 kW as stated above, the peak power becomes 24 kW. It is shown in Figure 5.11, discharge powers being recorded as negative values[460].

For high-performance vehicles, the steps with maximum discharge power and maximum regenerative power (shown with arrows in Figure 5.11) may be adjusted to reflect the actual power capability of the drive system[461].

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[459] P. Van den Bossche, G. Maggetto, The "Twelve Electric Hours" Competition: A Good Way to Evaluate Electric Vehicles in City Traffic, EVS-11, Florence, 1992
[460] IEC 61982-3:2001, ¶4.1
[461] Ibid., ¶4.2

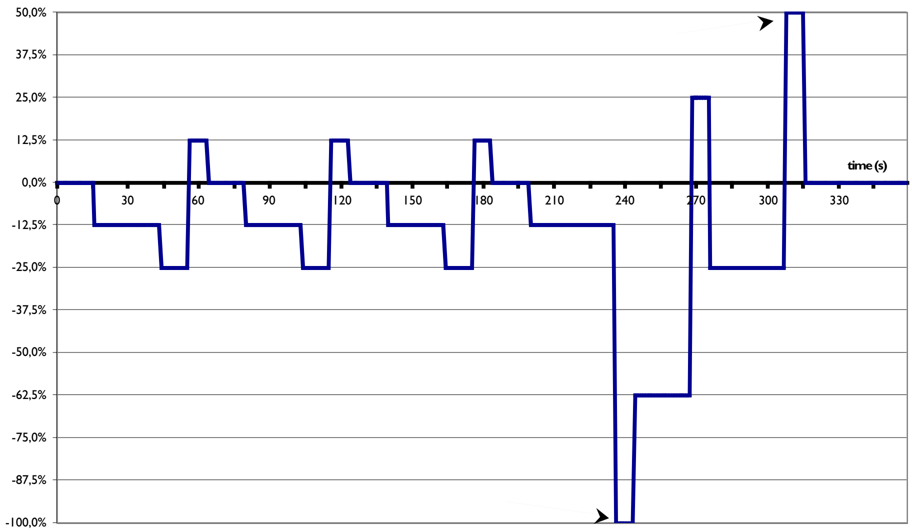

Figure 5.11: Dynamic stress test discharge cycle[462]

The standard also features a "battery screening test"[463], which is an overview of the procedures to be taken when selecting a battery for a certain vehicle, in collaboration between the battery manufacturer and the vehicle manufacturer, incorporating a graph of the calculated range of the vehicle as a function of the battery weight.

The actual tests described in this standard represent a quite original approach and do in a number of points differ from ordinary battery tests, hence the need for further consideration here.

First, it is interesting to note that the "capacity" test of "traditional" battery standards, which involved either a discharge at constant current like IEC 60254-1[464], or a dynamic discharge cycle like IEC 61982-2[465], is replaced by a "energy" test[466]. From the vehicle standpoint, the energy content of the whole battery pack (expressed in kWh) is in fact more interesting than the capacity (in Ah) of individual battery cells. Also, the criteria for the end of the test are different: whileas a traditional battery discharge test is performed down to a pre-defined cut-off voltage (e.g. 1,5 V per cell), the "Black Box" approach dictates that the test is stopped either when the battery can not deliver the required power or when the discharge is terminated by the battery management system.

[462] Ibid., graph derived from data in Table 1
[463] Ibid., ¶4.3
[464] IEC 60254-1:1997, ¶4.2
[465] IEC 61982-2:2002, ¶4.2.4
[466] IEC 61982-3:2001, ¶5.2.3

As for the life testing[467], the end-of-life criterion is comparable: the life test is terminated when the energy delivered by the battery per cycle falls below 80% of the reference energy content. During this test, for each cycle, the battery is discharged down to 20% state of charge; this criterion also reflects practical electric vehicle operation, rather than references to cell voltages.

Another test which is unique to this standard is the determination of maximum power and battery internal resistance. These parameters are in fact key elements for determining vehicle performance. The maximum deliverable power is defined in the standard as

> *"the power at which the current that is drawn depresses the battery terminal voltage to ⅔ of the open circuit value"*[468]

This value is not equal to the real theoretical maximal deliverable power however. If one considers the battery system to be represented by a voltage source V_{oc} and an internal resistance R_{batt}, as shown in Figure 5.12, the power P_{load} delivered to the load becomes:

$$P_{load} = V_{load} \times I = (V_{oc} - R_{batt} \times I) \times I = V_{oc} \times I - R_{batt} \times I^2 \qquad (5\text{-}5)$$

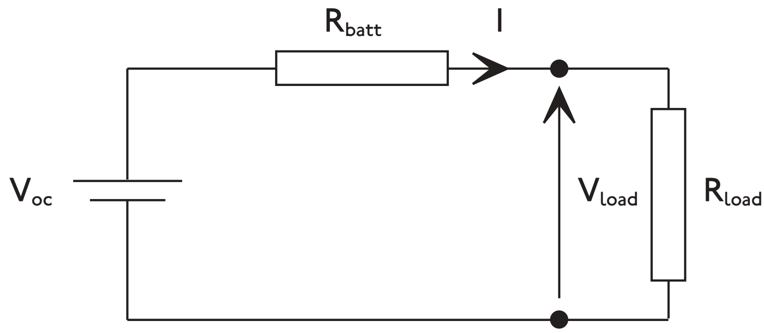

Figure 5.12: Battery scheme

The maximal value of this power is obtained when its derivative becomes zero:

$$\frac{\mathrm{d}P_{load}}{\mathrm{d}I} = V_{oc} - 2 \times R_{batt} \times I = 0 \qquad (5\text{-}6)$$

in which case

$$I = \frac{1}{2} \times \frac{V_{oc}}{R_{batt}} \qquad (5\text{-}7)$$

[467] Ibid., ¶5.2.5
[468] Ibid., ¶5.2.6

and

$$V_{load} = V_{oc} - R_{batt} \times \frac{1}{2} \times \frac{V_{oc}}{R_{batt}} = \frac{1}{2} \times V_{oc} \qquad (5\text{-}8)$$

The maximum value of the power is thus obtained when the terminal voltage of the battery is equal to ½ of the open-circuit voltage. This is not a very efficient operating point however, since only 50% of the power is actually delivered to the load. Furthermore, it is to be considered a mere theoretical value, as most batteries wouldn't be able to take the strain: for a lead-acid cell for example, with a rated voltage of 2 V, this would mean a terminal voltage as low as 1 V!
For this reason, the standard defines its maximum power level at a terminal voltage of ⅔, and not ½, of the open circuit voltage. This value still puts a heavy strain on the battery (1,33 V terminal voltage for a lead-acid cell for example), and the standard states that the determination procedure for the maximal power is actually a theoretical calculation, the determination of true maximum power by experimentation not being normally necessary to perform.

Let's now see how the standard performs this calculation. Starting from voltage and current measurements at the measurement points corresponding to 12,5% and 100% power level in the cycle of Figure 5.11, the internal resistance R_{batt} is calculated:

$$R_{batt} = \frac{V_{12,5\%} - V_{100\%}}{I_{100\%} - I_{12,5\%}} \qquad (5\text{-}9)$$ [469]

From this value, one becomes the open-circuit voltage V_{oc}:

$$V_{oc} = V_{12,5\%} + I_{12,5\%} \times R_{batt} \qquad (5\text{-}10)$$

The current needed to depress the voltage to ⅔ V_{oc} is calculated as follows by the standard:

$$I_{pk} = \frac{2}{3} \times \frac{V_{oc}}{R_{batt}} \qquad (5\text{-}11)$$

which yields the calculated maximum power:

$$P_{max} = \frac{2}{3} \times V_{oc} \times I_{pk} \qquad (5\text{-}12)$$

[469] Ibid. In the standard, the voltage and current values are referred to the order point on the cycle (V_{14} and V_{15}) - here percentage values have been chosen for clarity.

It should be noted however that the expression (5-11) is not correct.
To depress the voltage at the terminals to ⅔ V_{oc}, the voltage drop over the internal resistance has to be equal to ⅓ V_{oc} (cf. Figure 5.12), which corresponds to a current of:

$$I_{pk} = \frac{1}{3} \times \frac{V_{oc}}{R_{batt}} \qquad (5\text{-}13)$$

The peak current value, and hence the maximum power, calculated by this standard, are thus twice the value according to its definition!

A number of tests about the charging behaviour of the battery are also provided in the standard:
- ☞ Charge efficiency (¶5.2.7.1): this is also a test typical for the vehicle application, it is the energetic efficiency (Wh) of the battery, including the losses associated with the battery management system. (but not of the charger)
- ☞ Fast charging (¶5.2.7.2) from 40% to 80% SOC, a mode of operation which also reflects electric vehicle opportunity charging practices.
- ☞ Partial discharge (¶5.2.8), the test consisting in 10 partial discharge cycles from 100% to 80% SOC, followed by a battery capacity (energy content) test as described above, in order to assess a potential "memory effect" on the battery.
- ☞ The range between minimum and maximum voltage during the energy test is recorded as the operating voltage range (¶5.2.9).

Test cycle modifiers are foreseen to determine the effects of battery ageing (¶5.3.2) and ambient temperature (¶5.3.3). Furthermore, tests in extreme operating conditions (¶6) aim to identify the limits of battery operation imposed by the BMS, highlighting the requirement for accurate and reliable interfacing between the BMS and the vehicle system in order to protect the integrity of the battery.

Finally, with a view towards high temperature batteries such as the "Zebra", thermal cycling tests are foreseen, but their details remain under consideration in the current version of the standard.

5.2.4.9 Test parameters for batteries: IEC 61982-1

A NWIP "Test parameters for batteries used for the propulsion of electric road vehicles" was circulated in May 2000, proposed by the Japanese National Committee[470]. It was accepted in January 2002[471], the first Committee Draft was

[470] IEC TC21, Doc. 21/511/NP
[471] IEC TC21, Doc. 21/549/RVN

circulated in Janaury 2003.[472] Although this document is still very succinct, it defines the main lines along which IEC 61982-1 will be structured.
The purpose of this standard is to consolidate the various test regimes for batteries which had been developed around the world by a number of organizations, and whose differences made correlation of data difficult, through the introduction of a basic set of test parameters to render test results more meaningful.[473]
Tests are divided in two categories:

- ☞ Type tests, which test the product on its own. Tests proposed in this document include a rated capacity test, with a 3 h rating (with 5 h and ½ h as options). The final voltage for the discharge test (3 h) is defined as 1,68 V for lead-acid cells, 1 V for alkaline cells and 2,2 V for sodium-nickel-chloride batteries. It also mentions dynamic discharge tests, without specifying a particular test cycle however.[474]
- ☞ Application tests, which test the product subjected to specific application criteria and in interaction with its environment. These are performed in conjuction with the vehicle's battery management system, if applicable. The document states that in this case, the discharge testing will often make use of a constant-power discharge to simulate real-life operation, rather than a constant-current discharge as used conventionally.[475]
- ☞ The document also gives a calculation for peak power using the same principles as in IEC 61982-3 (§5.2.4.8), without making the calculation error of (*5-11*) however.

5.2.4.10 Overview of WG3 activities

A synoptic overview of the activities of IEC TC69 WG3, and of the electric-vehicle related activities of IEC TC21 is shown in Figure 5.13.

[472] IEC TC21, Doc. 21/581/CD, 2003-01
[473] Ibid., Introduction
[474] Ibid., ¶4
[475] Ibid., ¶5

		1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
IEC 61382-1 TR2	Nickel/cadmium rechargeable cells and batteries for electric road vehicle propulsion applications - Part 1: Dynamic discharge performance test and dynamic endurance test	PNW					1CD		PPUB						PPUB
IEC 61382-1 Amd1 TR2	Amendment to IEC 1382-1 (69/46/CDV)							PNW		Merge 61982-2					Merged
IEC 61382-2	Sealed nickel/cadmium rechargeable cells for electric road vehicle propulsion applications							PNW		Merge 61982-2					Merged
IEC 61382-2 TR0	More complex battery systems which include battery management	PNW						PWI	DEL						DEL
IEC 61383	Definition of tests to determine the effects of chopped current waveforms and the effects of regenerative braking	PNW						DEL							DEL
IEC 61385	Consideration of the impact and testing requirements for battery watering and venting systems, where appropriate	PNW							DEL						DEL
IEC 61893	Sealed nickel/metal hydride rechargeable cells for electric road vehicle propulsion applications							PNW		Merge 61982-2					Merged
IEC 61894	Preferred sizes and voltages of battery monoblocs for electric vehicle applications							PNW			DEL				DEL
IEC 61974	Specification dedicated to the requirements of secondary lead-acid batteries for electric vehicles								PNW		DEL				DEL
IEC 61982-1	Test parameters for batteries used for the propulsion of electric road vehicles												PNW		ANW
IEC 61982-2	Secondary batteries for the propulsion of electric road vehicles - Part 2: Dynamic discharge performance test and dynamic endurance test							PNW		ICD		2CD		CDV	PPUB
IEC 61982-3	Secondary batteries for the propulsion of electric road vehicles - Part 3: Performance and life testing (traffic compatible, urban use vehicles)								PNW		1CD	CDV		PPUB	PPUB

Figure 5.13: Overview of IEC TC69 WG3 activities

5.2.5 Infrastructure standards: the work of IEC TC69 WG4

5.2.5.1 IEC 718

The initial task of WG4 was focused on:

> *"Power supply sources and chargers (including power supply sources external to the vehicle, chargers mounted or not on the vehicle, safety of personnel against electric shocks, protection of electrical components and a.c. or d.c. connectors)"*[476]

The first major publication by IEC TC69 WG4 was the standard IEC 718 "Chargers for electric road vehicles". It applied to the charging of batteries for electric road vehicles, excluding industrial vehicles, wheelchairs, trolleybuses or rail vehicles[477]. This document defined safety requirements for protection against electric shock, requirements for connectors and test procedures for chargers (off-board only, on-board chargers being "under consideration").

A first draft for IEC 718 was circulated in 1976[478]. It stated definitions and general requirements; defining three categories of charging:
- ☞ "Slow charge", in 8 to 10 h
- ☞ "Normal charge" in 3 to 6 h
- ☞ "Rapid charge" in less than 3 h

The document also attracted the attention of ISO TC22 SC21 WG1, who proposed to restrict its scope to battery chargers which were not a permanent vehicle component. Furthermore, the ISO committee stated that the IEC classes of vehicle (Class A and B, as mentioned in §5.2.2) were not necessary to define the requirements on battery chargers, and that

> *"the mentioned classes are unacceptable in view of existing regulations on road traffic and should be deleted".*[479]

The document was further discussed on the 1978 meeting of IEC TC69 in Florence[480].

IEC 718 was published in 1978, but got proposed for revision already in the same year; a draft revision[481] was presented to the TC69 meeting in Amsterdam[482]. The revisions involved a change of the name of the document to "Electrical equipment for the supply of energy to battery-powered road vehicles", scope and object remaining the same.

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[476] BEC/CEB letter of 1974-05-14, Doc. 5642/43223
[477] IEC 718:1982, "Chargers for electric road vehicles", Scope
[478] IEC TC69, Doc. 69(Sec)17, 1976-07
[479] Doc. ISO/TC22/SC21/WG1 N10, 1976-07-26
[480] BEC/CEB, Procès verbal de la reunion 1978-06-02, Doc. PV2
[481] IEC TC69, Doc. 69(Sec)28, 1982-09
[482] IEC TC69, Minutes of the meeting in Amsterdam, 1982-10-26/28, Doc. PV2549/CE69

A number of issues which were still under consideration in the first edition, such as on-board chargers, were covered.

In 1988, the revision of IEC 718 was accepted fourteen votes to two[483], and the document received final editing notes for publication as the second edition of IEC 718. This put a temporary end to the activities of WG4; work to be addressed in the future included communication between the battery and the charger systems, and special requirements for rapid and/or opportunity charge, the latter in collaboration with WG3.

The second edition of IEC 718 was eventually published in April 1992.

In its series of figures showing different combinations of protection measures, one can easily discern a drawing error however. When looking at the traction battery in the scheme of Figure 5.14, it is clear that the "cells" are put in opposition instead of in series. This error went unnoticed for several years.

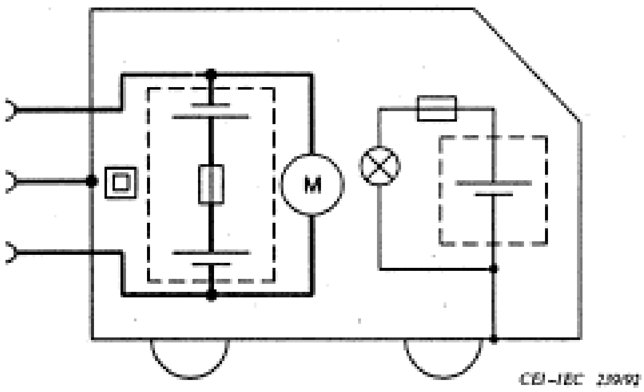

Figure 5.14: Scheme from IEC 718:1992 [484]

During the 1990s, the work of WG4 expanded considerably. It was rapidly agreed upon that IEC 718 content was not longer completely well adapted to the evolution of the electric vehicle technology, because it tried to cover all and every aspects of electric vehicle charging.
New work was to be taken up by WG4, and it was formally decided to keep IEC 718 with minimum corrections for the time going, and to prepare new and separate documents for on-board charger, off-board charger and inductive charger, as discussed in the following paragraph.[485]

[483] IEC TC69, Minutes of the meeting in Stockholm, 1988-06-01/02, Doc. RM3108/TC69, Voting report on Doc. 69(CO)19
[484] IEC 718:1992, Figure 3 (partim)
[485] IEC TC69, Minutes of the meeting in Anaheim, 1994-12-07/08, Doc. 69/50/RM, Annex C: Report from IEC TC69 WG4

WG4 had prepared a revision, circulating as a NWIP[486] in 1994 and covering the following aspects:
- ☞ Corrections of existing mistakes.
- ☞ Suppression of section 6 "Data indicating and recording instruments" which was considered too general, already covered by existing IEC standards for classical electrical equipment and out of scope for electric vehicle on-board equipment.
- ☞ Addition of new general safety aspects related mainly to the protective measures to be taken with on-board chargers.
- ☞ Transposition of requirements (like EMC) to the new documents that were being drafted, each time as it appears relevant to do so.

This resulted in a CDV being circulated (69/54/CDV), which was approved (with comments) in March 1996[487].
The final version of the standard would be published in May 1997.
IEC 60718 was eventually withdrawn in 2002, to be replaced with IEC 61851-21 and 61851-22.

5.2.5.2 *Conductive charging: the road to IEC 61851*

5.2.5.2.1 The new WG4: globalizing the work of CENELEC BTTF 71-1

In 1992, the subject of standardizing charging infrastructure was considered in Europe with the inception of CENELEC task force BTTF 71-1 (§5.5.2 below). The work of this task force was subsequently transferred to IEC and accepted in the work programme of WG4, which was then defined as follows:[488]

- ☞ Use IEC 718 as base of the work, to be completed or rectified.
- ☞ Reorganize the document in a structure of type part one, part two, with part 1 for general considerations and part 2 divided as follows:
    - ☛ Part 2.1: direct connection of electric road vehicle to a.c. supply system (on-board charger)
    - ☛ Part 2.2: indirect connection of electric road vehicle to a.c. supply system (off-board charger)
    - ☛ Part 2.3: indirect connection of electric road vehicle to a.c. supply system through inductive coupling system.

The new consist of WG4, which included the BTTF71-1 members with addition of American and Japanese experts, had its first meeting in Paris in November 1992[489],

[486] IEC TC69, Doc. 69(Sec)42, 1994-07
[487] IEC TC69, Doc. 69/69/RVC
[488] IEC TC69, Ad-hoc WG4 program of work, Doc. IEC/TC69/WG4/Sec(Florence)1, 1992-10
[489] IEC TC69 WG4, Minutes of the meeting in Paris, 1992-11-16, Doc. IEC/TC69/WG4(Sec)3, 1992-11

under the convenorship of Mr. Maire from EDF (later to be succeeded by Mrs. Flageat and Mr. Fantin), where it was agreed to make limited corrections to IEC 718, and to prepare two self-contained standards for on-board charger and off-board charger, having the following structure:

☞ Scope and object
☞ Normative references and definitions
☞ Electric vehicle requirements
☞ Supply terminal requirements
☞ Electric vehicle connection to supply terminal.

The BTTF 71-1 document[490] would consist the start of this work.

WG4 became a very active working group and can be considered a consummate example of international standardization at work. The experts from the different national committees were very active in analysing and commenting the draft standards, letting the documents grow through subsequent versions, and considering relevant information about the evolution of electric vehicle technology in all parts of the world, such as fast charging communication protocol, inductive charging (see §5.2.5.4), EMC issues (see §5.9.8) and the like. The author has actively participated in the work of WG4 as delegate of the BEC (Belgian Electrotechnical Committee).

Figure 5.15: International standardization at work: the IEC TC69 WG4 meeting in St. Helena, California, 1997

[490] Doc. IEC/TC69/WG4(Sec)2

The members of WG4 congregated frequently throughout the decade:
☞ November 1992 in Paris, France
☞ April 1993 in Paris, France
☞ September 1993 in Paris, France
☞ January 1994 in San Pietro di Strà, Italy[491]
☞ May 1994 in Paris, France
☞ December 1994 in Anaheim, California
☞ February 1995 in Brussels, Belgium
☞ May 1995 in Paris, France
☞ October 1995 in Warren, Michigan
☞ February 1996 in Frankfurt, Germany
☞ June 1996 in Paris, France
☞ September 1996 in Coventry, England
☞ January 1997 in St. Helena, California
☞ June 1997 in Mendrisio, Switzerland
☞ November 1997 in Paris, France
☞ March 1998 in Brussels, Belgium
☞ September 1998 in New York City, New York
☞ December 1999 in Paris, France
☞ June 2000 in Milan, Italy
☞ October 2000 in Montréal, Québec
☞ May 2001 in Brussels, Belgium

The new documents prepared by the group went through several draft versions, their structure being updated and modified, their contents gradually improving and expanding.
The main change in document structure, which was decided in 1996[492], based on a proposal by the chairman of TC69, Dr. Mangan[493], was to put the documents "direct connection" and "indirect connection" under one standard "Electric vehicle conductive charging system", with a part 1 for general requirements, and subsequent parts covering respectively the requirements for the electric vehicle, the a.c. charging station and the d.c. charging station.
This would become the standard IEC 61851, thus sealing the fate of IEC 60718.
A fourth part, covering the communication protocol between the d.c. charging station and the electric vehicle, had been envisaged but was eventually deleted taking into account the division of work with ISO.
As of today this has led to a coherent set of standards about conductive charging. After a brief overview of their content, some of the particular features that were the

[491] Note that the venue of this meeting, the Villa Barbariga in San Pietro di Strà, Italy, was also the home of the "PGE" electric vehicles of Brussels Electric Vehicle Experiment fame (Figure *5.1*).
[492] Report from the WG4 convenor to the TC69 meeting in Osaka, Doc. 69/79/INF, 1996-07
[493] Doc. IEC/TC69/WG4(Mangan)6, 1996-04

result of the work of WG4, among others the “charging modes” and the “control pilot” will be discussed.

5.2.5.2.2 IEC 61851-1

IEC 61851-1: “Electric vehicle conductive charging system - Part 1: General requirements” was published as an International Standard in 2001.
It applies to equipment for charging electric road vehicles at standard a.c. supply voltages up to 690 V and at d.c. voltages up to 1000 V, defining the functionality of the electric vehicle supply equipment (EVSE) and the physical interface between EV and EVSE. Protection of personnel against electric shock is equally covered

5.2.5.2.3 IEC 61851-21

IEC 61851-21: “Electric vehicle conductive charging system - Part 21: Electric vehicle requirements for conductive connection to an a.c./d.c. supply”, published in 2001, defines safety and functional requirements as well as electrical characteristics, for the electric vehicle when it is connected to the EVSE.

5.2.5.2.4 IEC 61851-22

IEC 61851-22: “Electric vehicle conductive charging system - Part 22: AC electric vehicle charging station”, also published in 2001, states functional and safety requirements, and defines dielectric and environmental tests for conductive a.c. electric vehicle charging stations.

5.2.5.2.5 IEC 61851-23

IEC 61851-23: “Electric vehicle conductive charging system - Part 23: DC electric vehicle charging station” is now at CD stage, the last version being circulated dating from 1999. It is comparable in structure to IEC 61851-22, focusing on the particularities of the d.c. charging station however.

5.2.5.3 Key features of IEC 61851

These standards of the IEC 61851 family feature a number of key issues which have characterized them.

5.2.5.3.1 Charging “cases”

The conductive charging of an electric vehicle involves the physical connection of the EV to the EVSE through the use of a cable. This cable can be organized in several ways, these are the so-called charging "cases". This concept was been introduced already at the first BTTF meeting in 1992.[494]

The following three cases can be distinguished:

☞ Case "A", where the charging cable is permanently attached to the vehicle at fitted with a *plug*, to match the terminal s*ocket-outlet*.

☞

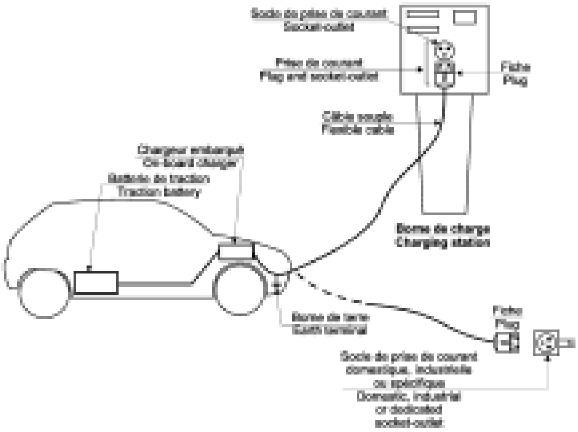

Figure 5.16: Case "A" connection[495]

☞ Case "B", where a detachable cable is used, fitted on one end with a *plug* to match the terminal *socket-outlet*, on the other hand with a *connector* to match the *vehicle inlet*.

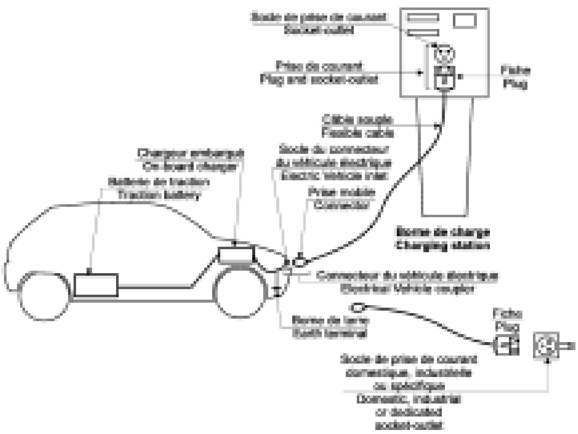

Figure 5.17: Case "B" connection

[494] BTTF 71-1 meeting at Paris, 1992-06-30, personal notes

[495] Figure 5.16, Figure 5.17, Figure 5.18: IEC 61851-1

☞ Case "C", where the charging cable is permanently attached to the terminal, and fitted with a *connector* to match the *vehicle inlet*.

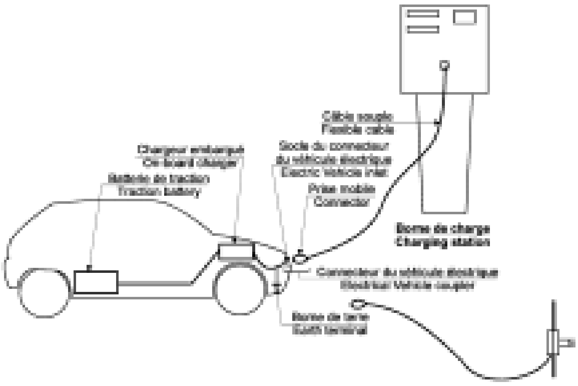

Figure 5.18: Case "C" connection

The relevance of defining these cases goes beyond the mere convenience of illustration. The installation and the location of the charging cable in fact is able to raise a number of safety and operational concerns, particularly in relation to the EVSE which is located on a public highway. Cables permanently attached to such an unit (as in Case "C") could be a target for vandalism or misuse; furthermore, live connectors trailing on the ground could form a safety hazard.

The issue also attracted the attention of UNIPEDE, the international association of electricity producers and distributors, which made a following statement on the point, which was submitted to IEC TC69 WG4 and CENELEC TC69X in 1993.[496]

UNIPEDE was of the opinion that the cable should be fixed to the vehicle and not to the supply terminal (therefore excluding Case "C"), for the following economic, safety, security and operational reasons:

☞ The main charge takes place at night, typically in a garage where supply points already exist. A Case "C" configuration would necessitate new infrastructure to be provided.

☞ It is more sensible to use the same cable for public charging point (which is used less often than the garage charging), than to require the owner of the public charging point to install an unnecessary cable at extra cost.

☞ The installation of the cable on the vehicle using an integrated automatic tension reel will provide flexibility, speed and convenience of use.

☞ There is a much greater danger of vandalism and theft if the cable is installed at a public charging point.

☞ If the cable is permanently attached to the supply point, the safety systems will be more complex and expensive.

[496] UNIPEDE statement, Doc. CLC/BT(SG)2110, 1993-08

This document was discussed in WG4 on its September 1993 meeting[497], with comments received from Japan and the UK, opposing a number of UNIPEDE arguments. As it was not yet deemed feasible to take a definite standpoint at the moment, it was decided by WG4 that all three cases "A", "B", "C" should be covered in the standard, so that more experience could be collected.

When considering today's technological development in the field, one can see that indeed the cases are selected following application needs:

- Case "A" is rarely used today, and mostly in small-size electric vehicles. It often comes with an interlocked socket-outlet onboard the vehicle for to safely stow the plug and cable while on the road. The use of tensioned reels for stowing the cable has not become very popular, due to the space and cost constraints of mounting such equipment on board the vehicle. Reliability and safety issues, particularly considering thermal load when the cable is partly rolled up, are also an issue.
- Case "B" offers a flexible solution which is the most widespread on electric vehicles today, at least on the European market. A cable, stowed in the vehicle, allows charging at any socket-outlet, whileas the connector on the vehicle allows access to (fast) charging stations. These accessories must mate of course, but that's just the point of standardization. In case of damage, the cable can be replaced easily.
- Case "C" is the preferred solution for fast charging stations, where the cables used are heavy and cumbersome. However, it is also favoured for normal charging with a.c. connection, particularly in the United States.[498]

5.2.5.3.2 Charging "modes"

Whileas the "cases" describe the physical organization of connecting the EV to the EVSE, the "charging modes" give a more general indication about how the charging is organized.

The simplest distinction one can made here is the one between

- On-board charger: "a.c. charging station"
- Off-board charger: "d.c. charging station"

However, the connection of the on-board charger to the a.c. charging station merits some deeper consideration. The vehicle may in fact be charged at just any socket-outlet which happens to be around and which can be an ordinary accessory of any standard (domestic or industrial) type. This is what is called a "non-dedicated" infrastructure.

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[497] Doc. IEC/TC69/WG4(Sec)15

[498] Cf. Doc. IEC/TC69/WG4(Toepfer)6, Letter by Mr. Toepfer to Dr. Wouk, 1994-01

On the other hand, special socket-outlets for electric vehicles can be foreseen, this then constitutes a "dedicated" infrastructure. This allows the implementation of supplementary functionalities and safety-related measures.

This has to be seen facing the development of an electric vehicle market, where it is most likely that the deployment of vehicles will go ahead of the deployment of dedicated infrastructures, especially taking into account the availability of compact, lightweight, high-frequency on-board chargers which can make use of the standard 230 V, 16 A socket-outlet which is nearly universally available (at least in European countries). Vehicles will charge at home garages or municipal depots, using existing socket-outlets, and will go for any available socket-outlet when they venture out. Publicly accessible dedicated infrastructures, on the other hand, may call the need for more elaborate safety measures and functionalities to be put in place; these have been extensively covered by the IEC 61851 standards, but it is a fact of reality that, at least in the first period of electric vehicle deployment, most charging will take place at non-dedicated infrastructures.

Hence the need to define a number of "charging modes" which describe the way of charging, and allow to define their specificities in the standards.

The concept of "charging modes" made its first appearance at the Warren meeting in October 1995[499], where it was suggested to make the distinction between on-board charging using either:

☞ Standardized socket-outlets, where only national regulations would apply
☞ Dedicated socket-outlets, with communication and other supplementary functions

The three modes were defined as follows in the subsequent draft document of December 1995[500]; this was also the first draft that was made according to the new structure, consisting of separate documents "general requirements", "EV requirements" and "a.c. charging station".

☞ Mode 1: "the connection of the EV to the existing a.c. supply network utilizing standardized socket outlets/connectors and associated plugs normally used to supply other equipment than electric vehicles"
☞ Mode 2: "the direct connection of the EV to the a.c. supply network utilizing dedicated ev supply equipment"
☞ Mode 3: "the indirect connection of the EV to the a.c. supply network utilizing an off-board charger"

No reference to voltage or current levels were deemed necessary in the definition of the modes, so that they would be applicable to all levels of charging, at either low or high power. This was particularly considered when taking into account the

[499] Doc. IEC/TC69/WG4(Sec)47, 1995-12

[500] Doc. IEC/TC69/WG4(Sec)48, 1995-12: Electric vehicle conductive charging system - Part 1: General requirements, ¶6.2

opportunity of high-power charging from an a.c. socket-outlet using the vehicle's (a.c.) drive system as charger. At the WG4 meeting held in Frankfurt in February 1996, it was decided that for Mode 1 and 2 no minimal or maximal current limits would be indicated[501].

Mode 1 charging however gave rise to extensive discussions. It was viewed upon differently in various countries. In those areas where electric vehicles were already been deployed, Mode 1 was the most common way of charging, making use of existing infrastructure. For new developments however, Mode 1 presented a number of flaws, which can be summarized as follows:

☞ The safe charging of an electric vehicle necessitates a sound earthing of the conductive parts of the vehicle, in combination with a residual current device (RCD). Without proper earthing, a hazardous situation for indirect contact could occur with a single earth fault within the vehicle, as shown in Figure 5.19. The RCD is used to terminate this hazardous situation. In most countries, RCDs are now prescribed for all new electric installations; there are still a lot of locations however where they are not present, and it is often difficult for an EV user to know, when plugging in the vehicle, whether or not a RCD is present. Whileas some countries leave this responsibility to the user, Mode 1 has therefore been prohibited in a number of countries.

☞ For the application in public places, there was a considerable concern to implement live standard socket-outlets in places where these could be exposed to the elements, vandalism or unauthorized access. Countries like Italy banned Mode 1 charging from publicly accessible locations, leaving it only an option for private garages.

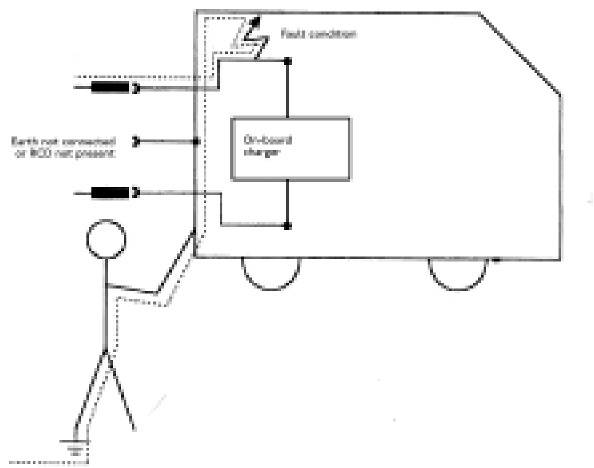

Figure 5.19: Hazardous situation in Mode 1 without proper earthing

[501] Doc. IEC/TC69/WG4(Sec)53, ¶7.1

☞ In some countries, the existing a.c. supply network is ill-suited for electric vehicle charging. The standard North American socket-outlet for example, delivers 15 A at 120 V, giving a maximum power of just 1,8 kW, which is a bit puny for charging an automobile-sized electric vehicle as it would imply unacceptably long charging times. Mode 1 was thus impractical there for reasons connected with the a.c. supply network, and vehicles would be more likely to use only dedicated charging infrastructure to access the network. It should be remarked however that 240 V electricity is readily available in the American domestic environment[502]; it was not considered a viable option however to propose this 240 V for Mode 1 charging of electric vehicles since handling 240 V is considered a too hazardous occupation for the "ordinary person"[503]. This position is also caused of course by the "litigation culture" which is prevalent in the United States.

☞ The need existed however to give a vehicle an emergency charge if it got stuck far from its charging station. This could be done, albeit slowly, at a standard outlet; for safety reasons however a special solution was provided, featuring an in-cable control box (which could also be part of the plug) with protective circuitry. This configuration had in fact most of the functions of Mode 2 whilst using a non-dedicated socket-outlet. This adapter box was mentioned in the December 1995 draft[504].

At the WG4 meeting in Paris in June 1996[505], the US delegation insisted to add an optional control pilot to Mode 1; an agreement was found in defining this mode as a new one, "Mode 2", the former Mode 2 and Mode 3 then becoming Mode 3 and Mode 4.
These changes where then included in the draft dated June 1996[506] and communicated to the plenary meeting of TC69 in Osaka in October 1996[507].

The final version of the international standard IEC 61851-1 comes to the following definition for the charging modes[508], the application of which will be briefly commented here:

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[502] American practice for domestic electricity supply is based on a 240 V center tap ("two-phase") distribution, giving access to 120 V for lighting and general appliances; the full 240 V is used for fixed high-power appliances such as cookers, heaters, and the like; it is normally not made available through socket-outlets.

[503] An "ordinary person" being a person who is neither a skilled person nor an instructed person, according to the International Electrotechnical Vocabulary IEV-826-09-03 - IEC 60050(826)

[504] Doc. IEC/TC69/WG4(Sec)48,¶6.5

[505] Doc. IEC/TC69/WG4(Sec)58,¶6

[506] Doc. IEC/TC69/WG4(Sec)55, Electric vehicle conductive charging system - Part 1: General requirements

[507] Doc. 69/79/INF

[508] IEC-61851-1:2001, ¶6.2

Mode 1 charging: connection of the EV to the a.c. supply network (mains) utilizing standardized socket-outlets, rated up to 16 A, at the supply side, single-phase or three-phase, and utilizing phase(s), neutral and protective earth conductors. The use of Mode 1 charging depends on the presence of a residual current device (RCD) on the supply side. Where the presence of an RCD on the supply side cannot be ensured by national codes, mode 1 charging is not permissible.
Note 1: In some countries, Mode 1 charging may be prohibited by national codes
Note 2: A "standardized socket-outlet" is one which meets the requirements of any IEC or national standard.
Note 3: In France, Germany and Italy, the limitation to 16 A for Mode 1 charging is not applicable.

At the TC69 meeting in Frankfurt in 1999[509], it was decided to limit Mode 1 to a rated current of 16 A (single phase or three phase). This decision was not supported by France, Germany and Italy; hence this limitation does not apply to those countries.
Although there is a general vision that Mode 1 is not the preferable solution due to potential safety hazards and limited extra functionality, it has been included in the final standard from a realist point of view: Mode 1 exists, it is even the most frequently used way to charge electric vehicles, and the availability of Mode 1 charging allows the deployment of electric vehicles on a large scale without the need for special infrastructures to be deployed at an extra cost to the user. A standard (European) socket-outlet provides 3,5 kW of power which is reasonable for charging (one hour of charge typically corresponding with 15 km driving for a medium-sized electric vehicle), and such socket-outlets are readily available everywhere or can be installed at very low cost. The protection of personnel against electric shock through the use of a RCD is deemed sufficient in most countries.
The use of Mode 1 charging, with RCD protection of course, will remain the preferred choice for private EV owners or small businesses, at least for the years to come.

Mode 2 charging: connection of the EV to the a.c. supply network (mains) utilizing standardized socket-outlets, single-phase or three-phase, and utilizing phase(s) neutral and protective earth conductors together with a control pilot conductor between the EV and the plug or in-cable control box.

The introduction of Mode 2 charging in the USA reflects the American infrastructure process which developed electrical standards and code language that was adopted by the National Electrical Code (NEC 625 - see also §5.6.9), this ensured that personnel protection and other safety considerations were implemented in all charging systems utilized (inductive or conductive).
Mode 2 is to be considered a transitional solution that has not seen extensive application outside the United States. Its global relevance is thus rather limited.

[509] IEC TC69, Minutes of the meeting in Frankfurt, 1999-12-08/09, Doc. 69/123/RM

> *Mode 3 charging: direct connection of the EV to the a.c. supply network (mains) utilizing dedicated EVSE where the control pilot conductor extends to equipment permanently connected to the a.c. supply network (mains).*

Mode 3 is the dedicated EV supply equipment for a.c. charging stations, featuring full control pilot (see below §5.2.5.3.3) protection and functionality.

> *Mode 4 charging: indirect connection of the ev to the a.c. supply network (mains) utilizing an off-board charger where the control pilot conductor extends to equipment permanently connected to the a.c. supply.*

Mode 4 refers to the off-board charger; the use of off-board chargers for electric road vehicles today mostly means the use of fast chargers, since most electric vehicles of small to medium size are fitted with on-board chargers. Only heavy duty vehicles like buses make regular use of off-board chargers for standard charging duty.
The concept of charging "modes" defined by WG4 must be distinguished from the concept of charging "levels" developed in the United States, which is based on the range of power levels anticipated to be available for EV charging[510]:

- ☞ Level 1: allows charging by plugging into the most commonly available grounded electrical outlet in each country.
- ☞ Level 2: the primary method of charging, using special equipment for connection, at a higher power level (240 V, 40 A in the USA).
- ☞ Level 3: fast charging, in about the same time it takes to refuel an ICE vehicle.

The introduction of the concept of charging modes has been a strategic step for the development of the WG4 infrastructure standards, since it has allowed to define several fields of application with each their own need for specific standardization. This list of charging modes may seem arbitrary and mundane; it represents however the outcome of a considerable effort by the members of the working group in order to represent the different and often diametrically opposed approaches followed in several countries.

5.2.5.3.3 "Control pilot" and additional protection measures

The paragraph about charging modes mentioned the notion of "control pilot", a device which is able to ascertain a number of safety measures and additional functionalities of the dedicated (i.e. not Mode 1) EVSE.

[510] C. Toepfer, EV Charging Systems Vol. 2, Report of the Connector and Connecting Station Committee, Doc. TR-104623-V2, Project 2882, Electric Power Research Institute, 1994

The "control pilot" is defined as follows in IEC 61851-1:

> *"the control conductor in the cable assembly connecting the in-cable control box or the fixed part of the EVSE and the EV earth through the control circuitry on the vehicle. It may be used to perform several functions."*[511]

The control pilot is thus basically an extra conductor, in addition to the phase(s), neutral and earth conductor in the cable assembly.

The concept of "control pilot" made its way into the final standard through elaborate discussions within the working group, which will be studied here a bit more in detail than other features, on one hand because of the relevance of the issue for EV charging stations and on the other hand because it forms an excellent illustration of the actual operation of a standardization committee.

An example of a system with control pilot was first presented to the first WG4 meeting in November 1992[512], concerning a charging point for electric boats which was then being deployed in the Norfolk Broads in England.
This infrastructure involved a dedicated socket-outlet, fitted with a 30 mA RCD and with an earth loop monitor which continuously controlled the integrity of the earthing circuit through injecting a small current in the "pilot" conductor, which returned through the protective earth conductor. If this loop was interrupted, the main contactor would open, cutting off the supply.
A particular feature of such circuit is that, when no vehicle is connected to the socket-outlet, the socket is completely dead. Power is only delivered when the plug is correctly inserted and the earth circuit is proved to be sound by the operation of the earth loop monitor.
For safe operation of the system, the connection process shall be such that the earth connection is made first and the pilot connection is made last. During disconnection, the pilot connection shall be broken first and the earth connection shall be broken last. This sequence also ensures that power is never interrupted at the power contact pins of the plug, thus eliminating arcing and prolonging the service life of the connection devices.
In this application, the impedance of the control loop was defined at 1 Ω.
Similar systems for automotive applications, developed in France, defined a control loop impedance of 1000 Ω, which would be the value adopted for electric vehicle use.

The first draft of the new document contained a blank paragraph about "inspection of electrical continuity of earthing connection"[513]; the April 1993 version has this paragraph worked out, giving a first indication of the control pilot:

[511] IEC 61851-1:2001, ¶3.7
[512] Safe power for electric boats, Doc. IEC/TC69/WG4(Benning)1
[513] Doc. IEC/TC69/WG4(Sec)2, ¶1.4.4.5

Vehicle requirements: *"During the load operation on the public highway, the electric continuity of this possible protection conductor can be permanently controlled by the terminal. In this case, an adapted device will have to be envisaged on the vehicle."*[514]

Supply terminal requirements for public area: *"If the electric continuity of the protective conductor is no longer detected by the terminal, it shall be released immediately from tension."*[515]

The requirements for other than public places were still blank.

The issue was further discussed on the September 1993 meeting[516], and the vehicle requirements were amended in the next draft:

Vehicle requirements: *"During the load operation on public area, the electric continuity of this protection conductor, if required, shall be permanently monitored by the a.c. supply terminal. In case of loss of electrical continuity of the protection conductor, a.c. supply must be switched off."*[517]

Which also added requirements for the a.c. supply terminal:

"Identification of the presence of an Electric Vehicle: the function of these terminals is to ensure that a connection is only made if there is an Electric Vehicle physically present."[518]

"As soon as the connection of all components has been made, the effectiveness of the earth connection (if any) of the vehicle framework must be continuously monitored from the supply terminal."[519]

These functionalities are of course those of the control pilot, although it is not yet mentioned as such.

The next version, dated March 1994 made the difference between public and non-public areas clear:

Supply terminal requirements for public area: *"If the electric continuity of the protective conductor is no longer detected by the terminal, it shall be released immediately from voltage. This apply only on public area."*[520]

Supply terminal requirements for non-public area: *"The system used to control the continuity of the protective conductor when charging the Electric vehicle on public areas must not prevent the electric vehicle to be charged when connected to a conventional domestic socket-outlet."*[521]

This configuration (the concept of "modes" was not yet introduced then) reflected the practice which had been developed in France, using a plug compatible with the

[514] Doc. IEC/TC69/WG4(Sec)10, ¶10.4
[515] Ibid., ¶13.3.4
[516] Doc. IEC/TC69/WG4(Sec)15, ¶7, changed by Doc. IEC/TC69/WG4(Sec)24, ¶2
[517] Doc. IEC/TC69/WG4(Sec)16, ¶10.4
[518] Ibid., ¶18.1
[519] Ibid., ¶20.1
[520] Doc. IEC/TC69/WG4(Sec)23, March 1994, ¶13.3.4
[521] Ibid., ¶14.2

domestic one, albeit with an extra contact for the pilot conductor when used at a public charging station.

The discussion on the control pilot, and more in general on safety issues for public versus non-public charging continued to play a major role in the activities of WG4. It seemed difficult to come to an agreement on the earth loop monitoring everywhere, even for charging in public areas. In Germany for example, it was not planned to have an earth loop monitor even for public charging[522].
Generally spoken, some experts, particularly from the United States, thought that electric vehicles needed a high level of safety and that the requirements for public charging shall be extended everywhere. On the other hand, some countries will not impose the same safety requirements for non-public charging.[523]

The draft of December 1995, which also was the one introducing the "modes", introduced the notion of "safety pilot circuit", which was to be capable to perform the following functions (even if other means are allowed to perform these functions)[524]:
☞ Verification of proper vehicle connection
☞ Verification of equipment ground
☞ Providing basic information (such as determining if ventilation is required)
☞ Transmitting EVSE ampacity.
The two last points are extra functionalities that go beyond the classical definition of the control pilot.
The concept of transmitting the EVSE ampacity was introduced following some concerns raised by US experts, that an EV being plugged in on a branch circuit might trip its circuit breaker when this would be rated lower than the ev or when at the same time other high-power appliances (such as a washing machine) would be connected. Other experts considered this a user's problem however: if plugging in a washing machine and a flat iron on the same circuit, the breakers might trip too.
A January 1996 draft prepared by US experts proposed to use a modulated signal through the control pilot for communicating the current rating to the vehicle:

> *"the EVSE can provide the maximum continuous current rating, and by inference the current rating of the protective circuit breaker to the vehicle by pulse width modulating the oxillator duty cycle."*[525]

This was based on a proposal by Ford Motor Company[526].
This approach would also be reflected in the SAE J1772 document, which would become the de-facto standard for conductive charging in the US (§5.6.6.1 below).

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[522] Doc. IEC/TC69/WG4(Sec)43, Minutes of the meeting 1995-05-30, ¶6
[523] Ibid., ¶7
[524] Doc. IEC/TC69/WG4(Sec)48, ¶6.6
[525] Doc. IEC/TC69/WG4(USA)7, ¶3.11.5
[526] Stephen J. Newton, Safety pilot pulse width modulation for ampacity marking, Ford Motor Company, 1995-05

On the February 1996 meeting in Frankfurt[527], WG4 decided to replace the term "safety pilot" with "control pilot", and defined a 8 A, 1 mm^2, 30 V rating for the conductor. It was voted and agreed to make the pilot circuit mandatory for modes 2 and 3. Experts were invited to submit sample diagrams of pilot circuits; contributions were received from several countries such as the United States[528], Switzerland[529], France [530]and Japan[531].
The June 1996 meeting of WG4 allowed to discuss the functionalities of the control pilot circuit, where the opinions of different countries were involved shown in Table 5.2.
It was agreed that the mandatory functions were 1, 2, 4 and 5. Function 3 and 7 are optional, function 6 may be an indirect function.

These specifications were included in subsequent versions of the document, notably the Committee Draft circulated in 1997, where the attention of the national committees was drawn to comment on the required functionalities. This document also stated:

> *"To perform these functions, a control pilot circuit is mandatory. This circuit consisted of the control pilot conductor, the protective earth conductor, EV supply equipment control electronics and further electronics aboard the electric vehicle."*[532]

The comments on this Committee Draft[533] reflected the position of the various National Committees about charging modes and control pilot.

		France	USA	Japan
1	Ground check	Y	Y	Y
2	Vehicle connection	Y	Y	Y
3	Ventilation		Y	Y
4	De-energization	Y	Y	Y
5	Allow energization	Y	Y	Y(?)
6	Locking retaining device	Y		
7	Ampacity (current rating)		Y	

Table 5.2: Control pilot functionality (IEC TC69 WG4, 1996)

The specifications were retained in the CDV version[534], coming eventually to the International Standard IEC 61851-1[535], where the following functions are defined for Modes 2, 3, and 4 (for Mode 1, no additional function is necessary):

[527] Doc. IEC/TC69/WG4(Sec)53, ¶7.2
[528] Doc. IEC/TC69/WG4(USA)8, 1996-05
[529] Doc. IEC/TC69/WG4(Mathoy)1, 1996-04
[530] Doc. IEC/TC69/WG4(France)6, 1996-05
[531] Doc. IEC/TC69/WG4(Japan)14, 1996-06
[532] IEC 61851-1, Committee Draft 69/91/CD, 1997-05, ¶6.5
[533] Doc. 69/103/CC, 1997-11

- Mandatory functions:
  - *Verification that the vehicle is properly connected*: the EVSE shall be able to determine that the connector is properly inserted in the vehicle inlet.
  - *Continuous protective earth conductor integrity checking*: earth continuity shall be continuously verified.
  - *Energization of the system*: if the control pilot circuit is established correctly, it shall allow energization of the system.
  - *De-energization of the system:* if the control pilot circuit is interrupted, the power supply shall be interrupted (but the control circuit may remain energized).
  - *Selection of charging rate*: a manual or automatic means shall be provided to ensure that the charging rate shall not exceed the rated capacity of the a.c. supply network. (This very general statement "manual or automatic means" leaves open all options, from a simple indication over a manual switch to an automatic ampacity selection)
- Optional functions:
  - *Determination of ventilation requirements of the charging area*
  - *Detection/adjustment of the real time available load current of the supply equipment*: means shall be provided to ensure that the charging rate shall not exceed the real time available load current of the supply equipment. (This is the full ampacity selection as intended in the original US proposal.)
  - *Retaining/releasing of the coupling*: a mechanical means should be provided to retain/release the coupler.

These functionalities are performed by the control pilot circuit, which is mandatory in Modes 2, 3 and 4.

The standard does not specify normative requirements for the operation of the control pilot circuitry. Its *informative* annexes however give some examples:

- Annex B describes the PWM control circuit as used in the United States, with its full functionality and circuit parameters. A typical circuit is shown in Figure 5.20.

[534] IEC 61851-1, Committee Draft for Vote 69/114/CDV, 1999-05

[535] IEC 61851-1:2001, ¶6.4

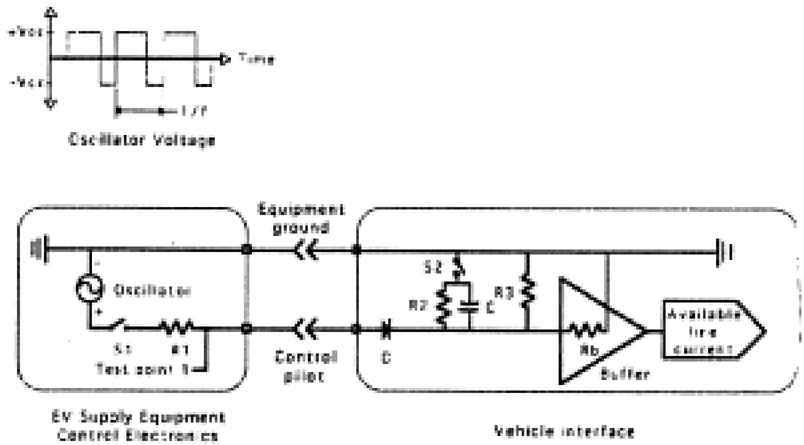

Figure 5.20: Typical PWM control pilot circuit[536]

☞ Annex C describes the functionality of the charging system with control pilot in all charging modes. It is based on a proposal from France. The configuration for Mode 3 - Case B charging is illustrated in Figure 5.21.

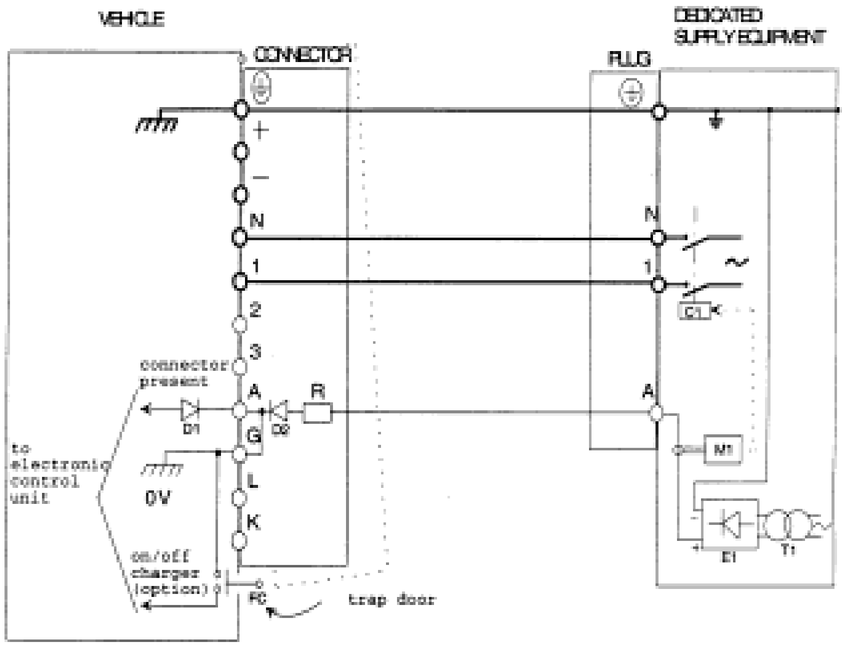

Figure 5.21: Control pilot in operation Mode 3 - Case B[537]

[536] IEC 61851-1:2001, Annex B

5.2.5.3.4 Power indicator

A different approach to adapting the power absorbed by the charger to the ampacity of the supply circuit is the so-called "power indicator", defined as:

> *"resistor value identifying supply rating recognition by the vehicle"*[538]

The principle of operation of the power indicator is presented in the (informative) annex D to IEC 61851-1.
It is intended for Mode 1 operation, particularly in countries where the rating of standard domestic plugs and sockets is lower than 16 A, and where vehicles are both charged at domestic socket-outlets, and at IEC 60309-2 socket-outlets rated 16 A. To allow full-power 16 A charging while still being able to access lower-rated domestic sockets, the indication of the actual ampacity is realized by a resistor built into the a.c. charging cordset. (Figure 5.22). An open circuit stands for the default rating of 16 A.
This device was included quite late into the document, it only appears in the 1999 CDV version. It is based on a proposal from Switzerland, where the domestic socket-outlet is only rated 10 A.

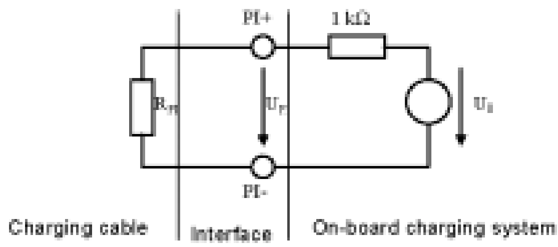

Figure 5.22: Power indicator[539]

5.2.5.3.5 Connector interface

The availability of different power levels and modes of charging, and the necessity for extra contacts for control pilot, power indicator and serial data communication (the latter being optional in Mode 2 and 3, and mandatory in Mode 4 to allow the vehicle to control the off-board charger, except in the case of dedicated off-board chargers) has created the need to define the requirements for the physical conductive interface between the power supply and the electric vehicle.

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[537] Ibid., Annex C
[538] Ibid., ¶3.15
[539] Ibid., Annex D

Position	Universal			Basic	Functions
	High power a.c./a.c.	High power d.c./a.c.	Domestic a.c.	a.c.	
	U_A	U_D	U_{32}	B	
1	500 V 250 A	600 V 400 A	-	-	High power d.c./a.c.
2	500 V 250 A	600 V 400 A	-	-	High power d.c./a.c
3	500 V 250 A	-	-	-	High power a.c.
4	400 V 32 A	400 V 32 A	400 V 32 A	400 V 32 A	L1
5	400 V 32 A	400 V 32 A	400 V 32 A	400 V 32 A	L2
6	400 V 32 A	400 V 32 A	400 V 32 A	400 V 32 A	L3
7	400 V 32 A	400 V 32 A	400 V 32 A	400 V 32 A	Neutral
8	Rated for fault	Rated for fault	Rated for fault	Rated for fault	PE
9	30 V 2 A	30 V 2 A	30 V 2 A	30 V 2 A	Control pilot
10	30 V 2 A	30 V 2 A	30 V 2 A	-	Communication 1 (+)
11	30 V 2 A	30 V 2 A	30 V 2 A	-	Communication 2 (-)
12	30 V 2 A	30 V 2 A	30 V 2 A	-	Clean data earth
13	-	-	-	30 V 2 A	Power indicator
14	-	-	-	30 V 2 A	Power indicator

Table 5.3: Overview of the vehicle interface requirements[540]

The design of the interface did grow with the other specifications in the developing standard document to eventually evolve to two designs at the vehicle interface[541]:

☞ A "universal" interface which provides for all modes of charging. It features "domestic" a.c. connection (up to 32 A), and *either* high power a.c., *or* high power d.c., since it is deemed unlikely that these two would be used at the same time. The universal interface contains up to 12 contacts, which may be used or not: one may have a high-power connector, featuring *either* a.c. *or* d.c. high power, as well as domestic a.c. contacts, or a "domestic" connector, featuring only domestic a.c. contacts. The universal vehicle inlet shall be intermateable[542] with *either* the high power a.c. connector *or* the high power d.c. connector. Both types of vehicle inlet shall be intermateable with the domestic a.c. connector. The ratings of the contacts are shown in Table 5.3. Lower current values are available.

☞ A "basic" interface, for modes 1, 2 and 3 charging only, providing for "domestic" a.c. connection only, single-phase or three-phase. This consists a lower cost solution for vehicles which do not require fast charging. The "basic" vehicle inlet shall be intermateable with either the single-phase or the three-phase "basic" connector. It shall not be intermateable with accessories of the universal interface type. Ratings are shown in Table 5.3. Lower current values (e.g. 16 A) are available.

540 IEC 61851-1:2001, Table 1

541 Ibid., ¶8.1

542 "Intermateability: the ability of like accessories to join together with the mating accessories they are intended to be used with" (IEC 62196/CDV, ¶2.16)

In both cases, the "domestic a.c." connection can be rated up to 32 A, allowing semi-fast charging at 7 kW single-phase, or up to 22 kW three-phase, a power which for small-and medium size electric vehicle is already to be considered fast charging.

5.2.5.3.6 EMC issues

EMC issues in the 61851 standards are discussed in the EMC chapter (§5.9.8).

5.2.5.3.7 Communication between vehicle and charging station

The issue of communication between the vehicle and the charging station was initially intended to constitute a part of the standard. Proposals had been drafted by France in 1994[543]; this document was also circulated in CEN TC301 (§5.5.8.1) and would eventually be treated by CENELEC TC69X, emanating in the European prestandard ENV 50275-2-4.
Within the IEC committee, it proved difficult to come to an agreement on this draft, since communication protocols in the USA and in Japan were different.[544]
The subject thus did not make into the IEC 61851 standards. It was resurfaced however at the IEC/ISO Steering Group meeting in 1999, where it was passed to ISO TC22 SC3 (§5.4.3).

5.2.5.3.8 Future developments of IEC 61851

The IEC ACEA[545] has asked IEC TC69 to consider the environmental aspects associated with its work. To this effect, it could be proposed to include requirements and tests for charger efficiency in the next version of IEC 61851.[546]

5.2.5.3.9 Conductive charging according to IEC 61851: overview

Figure 5.23 gives examples of mains a.c. and d.c. charging situations, illustrating the different Modes and Cases, as well as the interfaces and the implementation of the control pilot.

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[543] Doc. IEC/TC69/WG4 (France) 4
[544] Doc. IEC/TC69/WG4 (Sec) 42, Minutes of the WG4 meeting held in Brussels, 1995-02-14/15
[545] IEC Advisory Committee for Environmental Aspects, not to be confounded with the "Association des Constructeurs Européens d'Automobiles"
[546] IEC TC69, Letter by secretary Craig Toepfer, 2002-10-01

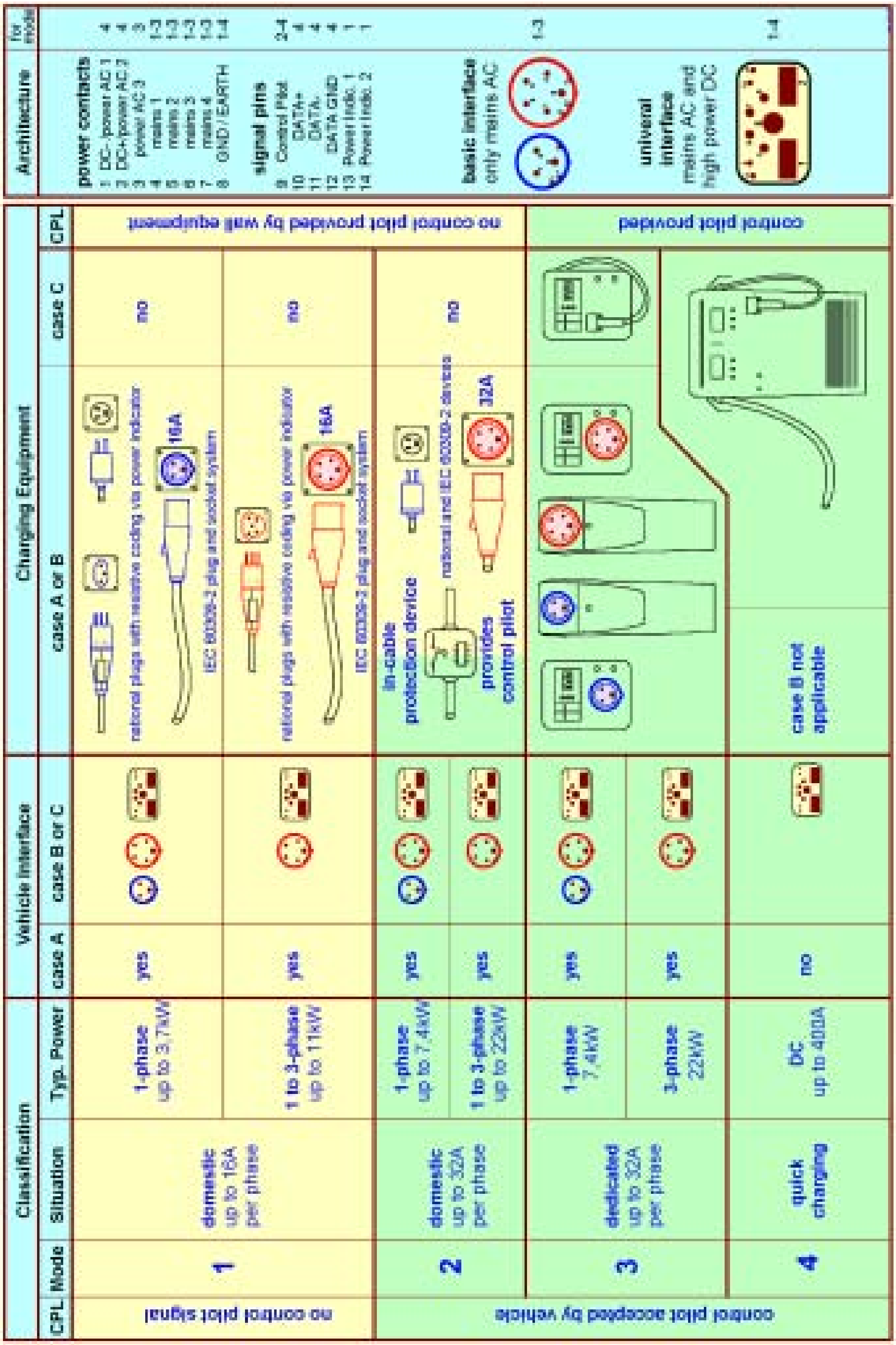

Figure 5.23: Examples of conductive charging system situations[547]

[547] IEC 61851-1:2001, Annex E (informative)

5.2.5.4 *Inductive charging: the road to IEC 61980*

5.2.5.4.1 Towards an inductive charging standard

The concept of inductive charging was first raised on the TC69 meeting in Florence in 1992, where the ad-hoc work programme of WG4[548] proposed to draft a part of the new charging standard:

> *"Part 2.3: The indirect connection of electric road vehicle to low voltage a.c. supply system through inductive coupling system"*

Work on the issue started within WG4, with a first discussion on the Paris meeting in September 1993[549], where an overview of safety issues for (paddle-type) inductive chargers was presented[550]. Concern did rise on the effects of high-frequency current on the human body.

A first draft for part 2.3[551] was prepared late 1993, and commented by WG4[552], consequently, on the WG4 meeting in May 1994[553] it was decided that the document was to be rewritten into the form of a proper IEC standard[554].

On the May 1995 WG4 meeting[555], a discussion was held about the draft on inductive charging to be prepared. The SAE recommended practice J1773 about inductive charging (see also §5.6.6.2) had been distributed among WG4[556] and it was suggested to incorporate this in the new IEC document. This document however described one particular inductive charging system, which was then being implemented in the United States. With different inductive charging systems being developed in other countries[557], it seemed to early to specify physical and dimensional characteristics in an IEC standard which had to be a general document. A number of experts disapproved of keeping dimensional characteristics, as the subject was considered an evolving technology, which should not be hampered by premature overstandardization.

After long discussion, it was decided to prepare a draft for the general document.

A draft on general requirements was presented in May 1996[558], which raised comments by experts from Belgium[559] and France[560], highlighting the fact that this

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[548] IEC TC69, Doc. IEC/TC69/WG4/Sec(Florence)1, 1992-10

[549] Doc. IEC/TC69/WG4(Sec)15, ¶8

[550] Doc. IEC/TC69/WG4(Rutledge)1, 1993-09

[551] Doc. IEC/TC69/WG4(Rutledge)3, 1993-09

[552] Doc. IEC/TC69/WG4(Sec)29, 1994-05

[553] Doc. IEC/TC69/WG4(Sec)30, ¶8, 1994-05

[554] Cf. Report from WG4 to TC69 meeting in Anaheim, Doc. 69/50/RM, Annex C, December 1994-12

[555] Doc. IEC/TC69/WG4(Sec)43, 1995-06

[556] Doc. IEC/TC69/WG4(USA)1, 1995-02

[557] Cf. APAS-TAUT 0006 Project Report. This project, performed by Davis Derby, VUB and CITELEC, used a mains-frequency system with automatic coupling through vehicle positioning, without cable or paddle.

[558] Doc. IEC/TC69/WG4(USA)10, 1996-05, "Electrical equipment for the supply of energy to electric road vehicles - General requirements - Inductive charging equipment"

document was written with only manual-connected inductive charging in mind and was not oriented towards automatic connection.
The subject was circulated among national committees as a NWIP in 1996, which was accepted by ten votes to six, with five countries abstaining.[561] The abstentions included the USA, which lost the voting document but who supported the work[562].
A new revised version of the general requirements was circulated in May 1997[563], incorporating various comments on the previous version[564]. This was further discussed and modified on the Mendrisio meeting in June 1997[565], where a good agreement was achieved on the general requirements for inductive charging. An improved version was circulated in 1998[566], and subsequently discussed by WG4. The document would consist of a general part and a specific part covering one particular solution. [567] These were discussed on WG4 meetings in Paris[568], Milano[569] and Montréal[570]; both Parts 1 and 2 were circulated as CD in November 2000. No further discussion of the comments has taken place however, since there have been no WG4 or TC69 meetings since May 2001.

The structure of the standard allows that additional parts be developed to document requirements for other specific types of inductive charging systems, e.g. certain automatic systems requiring no manual intervention. This technology is still in development however and various solutions have been proposed. The EVIAC project for example (in which the author has been actively involved, performing the project preparation phase and providing, on behalf of CITELEC, a report on the standardization aspects) encompassed four technological solutions for inductive charge systems:[571]

☞ Chained-ring type coupler (Figure 5.24)
☞ Coupler with passive mechanical alignment
☞ Asymmetrical coupler
☞ Intermediate frequency coupler

It was thus deemed too early to start standardization work on this issue.

[559] Doc. IEC/TC69/WG4(CITELEC)3, 1996-09
[560] Doc. IEC/TC69/WG4(EDF)1, 1996-09
[561] IEC TC69, Doc. 69/85/RVN, Result of voting on 69/76/NP "Connection of electric vehicles to an a.c. supply via inductive coupling", 1996-11
[562] IEC TC69, Minutes of the meeting in Osaka, 1996, Doc. 68/88/RM, ¶IX
[563] Doc. IEC/TC69/WG4(Sec)68, 1997-05
[564] Doc. IEC/TC69/WG4(Sec)69, Comments on Doc. IEC/TC69/WG4(USA)10, 1997-05
[565] Doc. IEC/TC69/WG4(Sec)70, 1997-08
[566] Doc. IEC/TC69/WG4(Sec)68, version 1998-07
[567] Doc. IEC/TC69/123/RM, 2000-03, ¶9.3
[568] Doc. IEC/TC69/WG4(Sec), 1999-12
[569] Doc. IEC/TC69/WG4(Sec)91, 2000-06
[570] Doc. IEC/TC69/WG4(Sec)94, 2000-10
[571] EVIAC, Final technical report, 2000.

Figure 5.24: Chained-ring type coupler developed at VUB

5.2.5.4.2 The draft standard IEC 61980-1[572]

This document covers general requirements for electric vehicle inductive charging systems. Aspects covered include the characteristics and operational conditions of the supply equipment and interface to the vehicle. It applies to both manual and automatic charger-vehicle interface.
The general structure of an inductive charger is shown in Figure 5.25. Every inductive charging system that can be imagined corresponds to this scheme, independently of operating frequency or physical shape. This scheme, and the definitions of its components, are the fruit of long reflections among WG4 experts[573].

The document states general requirements on EMC, protection against electric shock, dielectric requirements and environmental tests.
EMC issues in the 61980 standards are discussed in the EMC chapter of this work (§5.9.9).

[572] IEC 61980-1, Committee Draft 69/125/CD, 2000-11
[573] Cf. Doc. IEC/TC69/WG4(Wouk)1, 1995-10

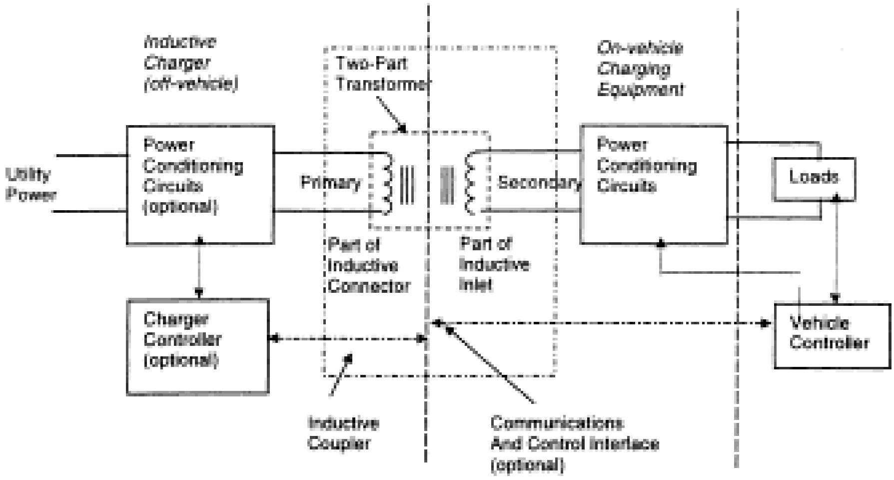

Figure 5.25: General scheme of inductive charger[574]

5.2.5.4.3 The draft standard IEC 61980-2[575]

This document, which is in fact based on the American document SAE J1773 (see also §5.6.6.2) covers the physical, electrical and performance requirements for a specific manual connection inductive charging system, the "Paddle Type 1" inductive coupler.

The "Paddle Type 1", shown in Figure 5.26, is distinguished from other paddle types by the following characteristics[576]:

- ☞ It contains no provision for the circulation of cooling fluids.
- ☞ It is constrained to an input power of 7,68 kW.
- ☞ Its diameter (width of the paddle) measures 106 mm.

The document describes electrical and physical requirements for the paddle system, including the electrical power transfer functions, critical dimensions, environmental and mechanical tests.

[574] IEC 61980-1, Committee Draft 69/125/CD, Figure 1
[575] IEC 61980-2, Committee Draft 69/126/CD, 2000-11
[576] Ibid., Scope

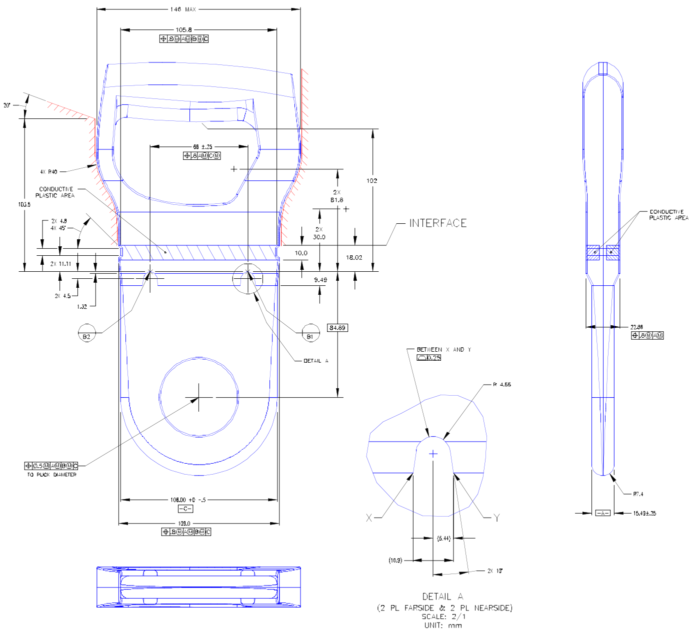

Figure 5.26: "Paddle type 1" inductive charger[577]

5.2.5.4.4 The fate of IEC 61980 ?

At this day, both IEC 61980-1 and IEC 61980-2 are still in CD stage. However, the development of inductive chargers has faded, with most manufacturers now going conductive. As continued support for the finalization of these standards has become unlikely, these projects may well be discontinued in the future.[578]

5.2.5.5 Overview of WG4 activities

An overview of the work of IEC TC69WG4 and IEC SC23H WG6 is shown in Figure 5.27.

[577] IEC 61980-2, Committee Draft 69/126/CD, Figure 7
[578] IEC TC69, Letter by secretary Craig Toepfer, 2002-10-01

		1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
IEC 60718	Chargers for electric road vehicles	PPUB																				DEL PUB
IEC 60718 2ed.	Electrical equipment for the supply of energy to battery-powered road vehicles	PNW					CDIS					PPUB					DEL					DEL PUB
IEC 60718 3ed	Electrical equipment for the supply of energy to battery-powered road vehicles													PNW		CDIS	PPUB					WPUB
IEC 61851-1	Electric vehicle conductive charging system - Part 1: General requirements										PNW		1CD				2CD			CDIS	PPUB	PPUB
IEC 61851-1 ff	Electric vehicle conductive charging system - Part 1: General requirements																				BPUB Merge	Merge
IEC 61851-2	Indirect connection of electric vehicles to a.c. supply through an off-board charger													PWI	PNW		DEL					DEL
IEC 61851-3	Electric vehicle conductive charging system - Part 3: Communication protocol between charging station and electric vehicle														PNW				DEL			DEL
IEC 61851-21	Electric vehicle conductive charging system - Part 21: Electric vehicle requirements for conductive connection to a.c./d.c. supply														PNW		1CD		CCDV	CDIS	PPUB	PPUB
IEC 61851-22	Electric vehicle conductive charging system - Part 22: a.c. electric vehicle charging station														PNW		1CD		CCDV	CDIS	PPUB	PPUB
IEC 61851-23	Electric vehicle conductive charging system - Part 23: d.c. electric vehicle charging station														PNW		1CD					PWI
IEC 61980-1	Electric equipment for the supply of energy to electric road vehicle using and inductive coupling - Part 1: General requirements											PWI				PNW				1CD		1CD
IEC 61980-2	Electric equipment for the supply of energy to electric road vehicle using and inductive coupling - Part 2: Manual connection system using a paddle															PNW				1CD		1CD
IEC 62196-1	Plugs, socket-outlets, vehicle couplers and vehicle inlets - Conductive charging of electric vehicles - Part 1: Charging of electric vehicles up to 250 A a.c. and 400 A d.c.													PNW		1CD			PNW		1CD	ADIS

Figure 5.27: Activities of IEC TC69 WG4

5.2.6 Connector standards: the work of IEC SC23H WG6

Within the IEC, TC23 is a large Technical Committee for "Electrical Accessories". Its Subcommittee 23H deals with "Industrial Plugs and Socket-Outlets"; this SC has drafted the well-known standard IEC 60309 "Plugs, socket-outlets and couplers for industrial purposes".
Part 1 of this standard states general requirements; Part 2 is a dimensional standard which defines the popular family of IEC 60309-2 industrial plugs (blue-coloured for 230 V, red for 400 V) also known in commerce as "CEE-Plugs".

In 1994, SC23H set up a new working group, WG6, on plugs and socket-outlets for electric vehicles; its convenor, Mr. Nathan, reported on the TC69 WG4 meeting in Anaheim in 1994[579].
The WG considered the several charging modes, and intended to prepare requirements for plugs, socket-outlets, vehicle inlets and connectors, considering the current draft of WG4[580]. It expressed the preference to realize one single type of vehicle inlet for the different modes[581]. The author participated in WG6 as delegate of the BEC.
SC23H WG6 had discussed this draft and reported[582] back to TC69 WG4, commenting on the references to IEC 309-1, which is a very general document, and IEC 309-2, which is a detailed dimensional standard. To take into account the specificities of the electric vehicle, a new standard would be needed for this application, with IEC 309-1 applying for general requirements. WG6 was also supportive of the compulsory earthing and earth monitoring of the EV. This was further discussed in the WG4 meeting in May 1995, which was attended by a WG6 delegation[583].
Further delegates from National Committees were subsequently appointed in this working group. WG6 started on a draft, which would provisionally be known as "IEC 309-EV" and which was presented to WG4 on its February 1996 meeting[584].
This document intended to be either an additional part of IEC 309 or a stand-alone document, in which case the applicable parts of IEC 309-1 would be incorporated. It was far from complete, depending still on input from WG4 concerning the definition of charging modes and the required functionalities.[585]
SC23H WG6 congregated regularly to further work on this document, closely following the activities of TC69 WG4, with which it shared a number of experts, and bringing in the contribution of the plug and socket manufacturers among its members. The direct participation of such experts consisted a worthy input from

[579] Doc. IEC/TC69/WG4(Sec)37, 1994-12, ¶2
[580] Doc. IEC/TC69/WG4(Sec)31 (referenced in some sources as (Sec)43), 1994-07
[581] IEC SC23H WG6, Scope of work, Statement by Norman Nathan, 1995-06-07
[582] Doc. IEC/TC69/WG4(23h)1, 1995-02
[583] Doc. IEC/TC69/WG4(Sec)43, 1995-06
[584] Doc. IEC/TC69/WG4(Sec)53, 1996-04
[585] Doc. IEC/SC23H/WG6(Dresden)6 Revised (IEC 309-EV), 1996-09

practice. The discussions which accompanied the subsequent versions of 60309-EV were characterized by a lively exchange of viewpoints about plug and socket issues, which allowed the drafting of the new standard.

One issue which arose early in the discussion was based on a German proposal[586] for the use of modified IEC 60309-2 products for Mode 3 charging at up to 32 A. Mode 3 charging however necessitated the use of a control pilot contact; this could be incorporated in the plug, while still keeping it interplugable with a standard IEC 60309-2 socket-outlet, adding extra contacts. This was an invention made by Mennekes of Germany, who had patented[587] it, but who, in 1998 decided to stop preparing the production of these accessories. They kept hold of the patent rights however[588]. Charging stations featuring this design continued however to be developed by Brusa of Switzerland, using hand-modified IEC 60309-2 devices (cf. §5.2.8.2, Swiss infrastructures). In 2001, Mennekes resumed the development of these accessories, and production prototypes are now available.

Another discussion was whether accessories should be rewirable or not. A number of experts preferred non-rewirable accessories for reasons of cheaper (mass) production and higher safety (less risk of tampering or unauthorized repair), while others preferred rewirable ones since these offered lower long-life costs, being available for maintenance or repair rather than having to throw away the whole cable assembly.

In this framework, the definition of "rewirable accessory" was widened[589]. On the Paris meeting in February 1999[590], the following definitions were introduced[591], in order to allow a more diverse approach:

> *"rewirable accessory": an accessory so constructed that the cable or wiring can be replaced. It can be either of the following:*
>
> ☚ *"user-serviceable accessory": an accessory so constructed that it can be rewired, or parts can be replaced, using commonly available tools and without having to replace individual parts of the accessory.*
> *Example: an ordinary plug which can be disassembled and wired using a common screwdriver*
>
> ☚ *"field-serviceable accessory": an accessory so constructed that it shall only be rewired by the manufacturer's authorized personnel.*
> *This can be accomplished through one or more of the following means:*
>
> - *necessity of the use of special tools (i.e. crimping tool, soldering equipment,…)*

[586] Doc. Germany/23H/73/CD, 1997-01

[587] German patent DE 196 13 793 A1, 1997-10-09 "Mehrpolige Steckvorrichtung nach DIN EN 60309/IEC 309"

[588] Correspondence between SC23H WG6 (Mr. Norman Nathan) and Mennekes GmbH, 1998-10

[589] This definition is one of the author's personal contributions to international standardization.

[590] IEC SC23H WG6, Meeting in Paris, 1999-02-03, personal notes.

[591] IEC 60309-EV, Draft version 1999-05-03, ¶2.21

- *necessity of replacing individual parts of the accessory (i.e. replacement of terminals, pins,…)*
- *necessity to break seals to disassemble the accessory*

The notion of "field-serviceable" accessories allows for accessories which provide adequate protection against unauthorized manipulations while still being repairable or replaceable if needed. It also allows the use of crimped contacts which may be advisable for high-current applications.

In November 1999, the draft of "IEC 60309-EV" was circulated to National Committees as a NWIP[592]:

> *"Plugs, socket-outlets, vehicle couplers and vehicle inlets - conductive charging of electric vehicles - Part 1: Charging of electric vehicles up to 250 A a.c. and 400 A d.c."*

This NWIP was accepted with 19 votes to nil, with one abstention; the project got the number IEC 62196-1 allocated[593].
As the work proceeded, a CD[594] was circulated in 2001, and comments[595] received from the NCs, which led to the CDV[596] circulated (in parallel vote IEC/CENELEC) in March 2002. This was accepted[597] with 14 votes to 1, further discussion on the comments took place on the WG6 meeting in Beijing in October 2002[598], in order to prepare a FDIS document. On the plenary SC23H meeting, which took place at the same occasion, it was stated that the market needs have changed, but that the standard prepared by WG6 might be used as a background and guidance document.[599]

The standard IEC 62196-1 applies to accessories for electric vehicles intended for use in conductive charging systems which incorporate control means, with ratings up to 690 V, 250 A a.c. or 600 V, 400 A, d.c. It does not apply to Mode 1 or Mode 2 plugs and sockets, i.e.

> *"those standardized accessories used in charging systems where the use of such accessories constructed to the requirements of other standards is permitted"*[600]

The accessories where this standard is applicable present the same structure already proposed in IEC 61851-1. The following accessories can be specified (see Figure 5.28, the denomination of the interfaces is as shown in Table 5.3 above):

---

592 IEC SC23H, Doc. 23H/95/NP, 1999-11
593 IEC SC23H, Doc. 23H/96/RVN, 2000-03
594 IEC 62196-1, Committee Draft, Doc. 23H/105/CD, 2001-03
595 IEC SC23H, Doc. 23H/107/CC, 2001-11
596 IEC 62196-1, Committee Draft for Vote, Doc. 23H/114/CDV, 2002-03
597 IEC SC23H, Doc. 23H/127/RVC, 2002-10
598 IEC SC23H WG6, Minutes of the meeting in Beijing, 2002-10-23
599 IEC SC23H, Minutes of the meeting in Beijing, 2002-10-25, Doc. 23H/130/RM
600 IEC 62196-1, Doc. 23H/114/CDV, Scope

- Plug and socket-outlet: Mode 3 operation up to 32 A:
    - Basic interface
    - Universal interface rated 32 A (U_{32})
- Vehicle inlet:
    - Basic interface
    - Universal interface rated 250 A a.c. (U_A)
    - Universal interface rated 400 d.c. (U_D)
- Vehicle connector:
    - Basic interface
    - Universal interface rated 32 A (U_{32})
    - Universal interface rated 250 A a.c. (U_A)
    - Universal interface rated 400 d.c. (U_D)

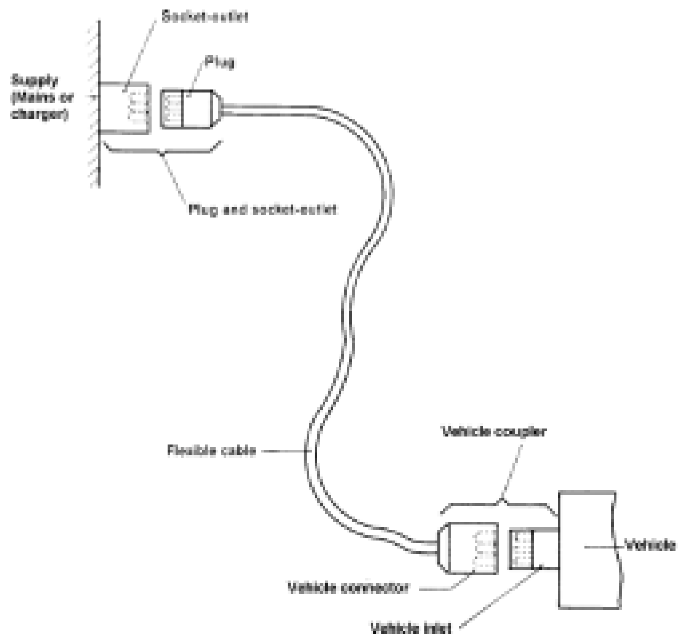

Figure 5.28: Diagram showing the use of the accessories[601]

The intermateability of connectors to vehicle inlets is as shown in Table 5.4.
The standard defines general requirements for marking, protection against electric shock, provision for earthing, construction requirements, dielectric strength. These are based on IEC 60309-1 but adapted for the specificities of the electric vehicle application where appropriate.

[601] Ibid., Figure 1

	Vehicle connector			
Inlet	U_A	U_D	U_{32}	B
U_A	Yes	No	Yes	No
U_D	No	Yes	Yes	No
B	No	No	No	Yes

Table 5.4: Intermateability of connector and vehicle inlet[602]

The requirements set by this standard are extensive; it is not a dimensional standard however, and subsequent parts may consist of standard sheets particular solutions (cf. the case with IEC 60309-1 and 60309-2). A report presenting some possible solutions has been prepared by CENELEC in Europe (§5.5.3.4).

The future of SC23H WG6 and its activities will be decided after the voting on the FDIS for IEC 62196-1.

5.2.7 Protection devices: the work of IEC SC23E WG7

IEC SC23E handles "Circuit breakers and similar equipment for household use"; its WG7 deals with "Protective devices for battery powered vehicle supplies". This WG was set up in 1994 and established to provide appropriate standard requirements for RCDs used in electric vehicle applications.
Its convenor, Mr. Legatti, reported to the IEC TC69 WG4 meeting in Anaheim in December of that year[603], where he expressed the need for his working group to get information from WG4 on some particularities of EV charging. There might in fact exist specific areas that need special consideration that could conceivably fall outside of existing RCD standards. SC23E thus needed input from vehicle and/or charging system manufacturers.[604]

The initial work on this project was characterized by a quite slow progress, as stated on the 1996 TC 69 meeting in Osaka[605].

The convenor of SC23E WG7 presented a document[606] to the 1997 TC69 meeting in Orlando, identifying the following problem areas that might need special requirements:

[602] Ibid., Table 2
[603] Doc. IEC/TC69/WG4(Sec)37, ¶3
[604] Communication by R. Legatti, Convenor SC23E WG7, to TC69 WG4, 1995-02
[605] IEC TC69 WG4, Doc. 68/88/RM, ¶IX
[606] Doc. 69/107/INF

☞ EMC immunity: appropriate immunity safety factors had to be associated with the protective devices, the requirements of the TC69 standards[607] serving to develop immunity requirements for the protective devices.

☞ Residual leakage currents at higher than power frequencies: the use of high-frequency chargers may cause high-frequency residual currents above the threshold for RCDs intended for personnel protection applications. RCDs may be insensitive, or too sensitive, for such currents, creating the risk for reduced protection or unwanted tripping.

In 1999, SC23E circulated a Committee Draft[608], followed by another version later that year[609], for an annex to the portable RCD (PRCD) standard IEC 61540, which applies to portable devices consisting of a plug, a residual current device (RCD) and one or more socket-outlets or a provision for connection, rated currents not exceeding 16 A for rated voltages not exceeding 250 V a.c. Such devices could for example be used as part of the control box for Mode 2 charging.

The main characteristic of the proposed PRCD device is that, in addition to the usual Phase/Neutral contacts, it is provided with a protective earth (PE) disconnect contact. The concept was originated in Australia, caused by a number of fatalities that have occurred.
A possible hazardous situation was in fact identified which could arise in the event of supply miswiring: when a live phase was wired to the PE conductor, the vehicle frame would become live and the touch voltage would be at a hazardous potential since the vehicle is insulated from the earth by its tires. This hazardous situation can *not* be terminated by an ordinary PRCD device that does not cut the PE contact.
The proposed device would open its three poles if the voltage of the PE conductor rises above earth to an unsafe level caused by miswiring or damage. It would contain circuitry to monitor the three supply wires and only permit the contacts to close if the relationship between the three conductors provides for a safe application.

In 2001 a NWIP was circulated to develop a full standard on PRCDs for electric vehicle applications[610]. This NWIP was accepted 12 votes to 3[611]; the first Committee Draft on what will become IEC 62235 "Requirements for PRCDs for battery-powered vehicle applications" was circulated in May 2002[612].

[607] IEC 61851-2-1, at that time Committee Draft 69/92/CD, 1997-05
[608] IEC SC23E, Doc. 23E/367/CD, Draft-Annex E to IEC 61540, 1999-02
[609] IEC SC23E, Doc. 23E/391/CD, Draft-Annex E to IEC 61540, 1999-09
[610] IEC SC23E, Doc. 23E/475/NP, 2001-11
[611] IEC SC23E, Doc. 23E/485/RVN, 2002-03
[612] IEC SC23E, Doc. 23E/499/CD, 2002-05

5.2.8 Practical implementation of conductive charging infrastructures

Conductive charging infrastructures have been deployed in a number of countries. This paragraph will give some typical examples of infrastructures that are used in practice, with relevant references to standardization issues.

5.2.8.1 France

In France, over 500 publicly accessible charging stations have been installed, most of them in and around Paris. Figure 5.29 shows a typical installation with two 16 A socket-outlets. These were designed to be "Mode 3" (with control pilot). Due to the poor performance of the chosen accessories however (special plugs which were compatible with French domestic plugs, but which were mechanically weak and very expensive), standard domestic plugs are now used, which means that these infrastructures now work in Mode 1. The presence of a RCD is deemed sufficient protection.

Figure 5.29: EDF charging station

5.2.8.2 Switzerland

Switzerland has a large network of public charging stations under the "Park & Charge" concept: a membership systems where EV users receive a key giving access to all charging stations and pay for their energy through a yearly vignette to be stuck on the vehicle's windscreen. Most of these charging stations are Mode 1, using either Swiss domestic socket-outlets (which are rated 10 A), or IEC 60309-2 socket-outlets

rated at 16 A. Newer types however include Mode 3 functionality, allowing booster charges at 32 A, with control pilot (cf. Figure 5.23). These make use of the “type 1” connection devices as described in the CENELEC report (see also §5.5.3.4); these are interplugable with IEC 60309-2 socket-outlets, allowing Mode 1 charging at other locations.
An example of such charging post in use at Mendrisio is shown in Figure 5.30.

The Park&Charge concept has been adopted in other countries, most notably Germany and Austria, and can be considered a step towards a Pan-European electric vehicle charging network. Standardization of the infrastructures will of course be a major element in the implementation of such a network.

Figure 5.30: Charging station in Mendrisio, Switzerland

5.2.8.3 Italy

Italian regulations impose the use of Mode 3 charging equipment in all places accessible to the public; Mode 1 is confined to privately-owned garages.
The accessories used are the “type 2” connection devices as specified in the CENELEC report, these are also covered by a national Italian standard. The small size of these accessories make them also suitable for use in two-wheel electric vehicles like electric scooters for which there is a huge potential in Italy.

5.2.8.4 Belgium

5.2.8.4.1 Proposal for Brussels Capital Region

In Belgium, the government of the Brussels Capital Region is pursuing the deployment of a network of publicly accessible charging stations on its territory, the deployment of publicly accessible infrastructures being a key element in the public promotion of electric vehicles. To this effect, it has commissioned the Vrije Universiteit Brussel with a preliminary study[613]; this work has been performed by the author.
The main outcomes of this study were focused on the choice of locations for the location of charging stations and the choice of the infrastructure itself. This last aspect has been largely facilitated by the author's personal involvement in the standardization committees (particularly IEC TC69 WG4 and CENELEC TC69X WG3), allowing a direct feedback from new standardization work which proved very useful in the definition of a totally new public charging infrastructure.
A first proposal for the Brussels Capital Region involves about thirty locations for implanting charging stations, a schematic overview of which is given in Figure 5.31:

- ☞ Eleven locations (marked A to K) in key activity zones and transit points where high electric vehicle activity can be expected.
- ☞ Twenty locations in residential areas, (marked R) typically located near the centres of the local communities constituting the BCR (including one in the former commune of Laken which is now merged with the city of Brussels). These are also aimed at those private users who do not have access to a private garage.

Artists's impressions of proposed charging locations are shown in Figure 5.32 and Figure 5.33.
The possibility of installing charging points in existing multi-storey car parks has also been taken into account; the interest of the main car park operator in Brussels to participate in such a project was very limited however.

Concerning fast (Mode 4) charging stations, two potential locations have been identified in peripheral locations, one in the north-western area of the Region and in the south-east. Even if it can be forecast, in accordance with the experience gained in France, that their actual use will be fairly low, the Mode 4 fast charging stations answer to a need: their mere presence can serve as a psychological "insurance" for EV drivers, giving them the confidence to exploit the whole range of their vehicle.

[613] P. Van den Bossche, J. Van Mierlo, G. Maggetto, Practical Infrastructure Development For Electric Vehicles In Brussels Capital Region, EVS-19, Busan, 2002

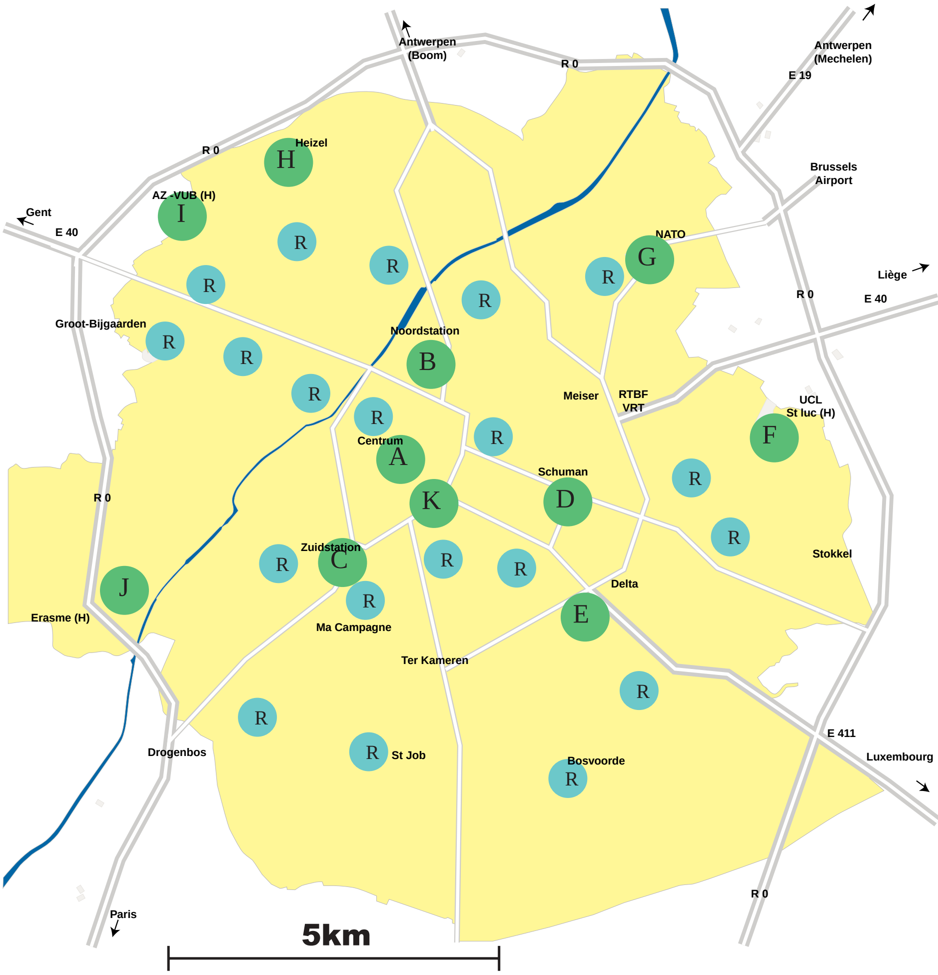

Figure 5.31: Proposed locations for charging infrastructures in Brussels Capital Region

5.2.8.4.2 Charging Posts

The infrastructures to be deployed on the urban thoroughfare must be integrated of course in its urban environment, being a kind of "urban furniture". Furthermore, they must be strong enough to withstand collisions with vehicles and acts of vandalism, both of which are unfortunately regular occurrences in a metropolitan city area.

Steel posts for electricity distribution are offered on the market; these devices are strongly built, have an acceptable aspect blending nicely in the cityscape and are specifically provided to allow the passage of a cable even in closed and locked position.

It has been clearly recommended to fit these charging posts with Mode 3 socket-outlets only, in order to ensure a high safety level for infrastructures implanted in the public domain. Mode 1 charging will be reserved for private garages.

It is foreseen to equip each charging post with two single-phase 230 V Mode 3 socket-outlets rated up to 32 A, thus allowing semi-fast charging. The switchgear to be implemented for each socket-outlet consists of:

☞ An automatic circuit breaker to protect against short-circuits and overcurrents;
☞ A residual current device for the protection of personnel;
☞ A control pilot monitor which allows the socket-outlet to become live if an electric vehicle is correctly connected, and which monitors the continuity of the protective earth conductor.

Figure 5.32: EV charging station proposed for downtown Brussels, Belgium

The choice for Mode 3 charging imposes the use of special accessories with an additional contact for the pilot conductor.

The selectrion of the accessories to be implemented is still under consideration, with both "type 1" and "type 2" devices according to the CENELEC report (§5.5.3.5.2) now being investigated by VUB-ETEC as to their operating characteristics such as user friendliness and durability.

Figure 5.33: EV charging station proposed at the Atomium in Brussels

5.2.8.4.3 Payment system

The implementation of an electronic payment and access control system using "Proton" electronic purse cards has been investigated. The cost of such a system however is unlikely to be covered by the revenue from a single charging post; a more efficient solution is to go to a membership system compatible with the Swiss "Park&Charge" network.

5.2.8.5 United States

In the United States, Mode 1 charging is not permissible; Mode 2 is used for emergency "Level 1" charging at low power (120 V, 15 A).
The standard mode of conductive charging is Mode 3, using a wall control box with the protective circuitry (RCD and control pilot) as shown in Figure 5.34. Note that this is a Case "C" configuration, with the cable permanently attached to the fixed infrastructure.

Figure 5.34: Case C infrastructure in the United States[614]

[614] AVCON Corporation, Cudahy, Wisconsin

5.3 ISO Standardization work

5.3.1 Generalities

The International Organisation for Standardization, better known under its short name (not its acronym!) ISO, was born from the union of two organizations. One was the ISA (International Federation of the National Standardizing Associations), established in New York in 1926, and administered from Switzerland. Despite its transatlantic birthplace, its activities were mainly limited to continental Europe and it was therefore predominantly a "metric" organization; the standardizing bodies of the main "inch" countries, the UK and the US, never participated in its work, though Britain joined just before the Second World War.

The other was the UNSCC (United Nations Standards Coordinating Committee), established by the US, UK and Canada in 1944 to bring the benefits of standardization to bear both on the war effort and the work of reconstruction. Britain's ex-colonies were individual members of the organization; continental countries such as France and Belgium joined as they were liberated; membership was not open to Axis countries or neutral countries.

The UNSCC was administered from the London offices of another international standardization organization: the IEC (cf. §3.4.2), which was founded in 1906 and whose secretary was Charles LeMaistre, who had also been involved in the founding of the ISA, and who had taken up the job of secretary-general of the UNSCC.[615]

In 1946, delegates from 25 countries convened in London, under impulse of LeMaistre, and decided to create a new international organization, which was "to facilitate the international co-ordination and unification of industrial standards". The ISO began to function officially on 23 February 1947. The first ISO standard was published in 1951 with the title "Standard reference temperature for industrial length measurement".

ISO has currently over 140 member organizations on the basis of one member per country. It is a non-governmental organization: its members are not governments, but standards institutes. Its activities are carried out in a democratic framework: each member has one vote, no matter what the size or the economical or political strength of its country. ISO standards are voluntary documents, developed by consensus among experts from the sectors which have expressed the need for standardization in a particular field. Up to now, ISO has published more than 13500 International Standards.[616]

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[615] Willy Kuert, The founding of ISO; Friendship among Equals, Geneva, ISO, 1997

[616] ISO in brief, ISO, Geneva, 2002

5.3.2 ISO TC22 SC21

Within the ISO, TC22 is responsible for "Road vehicles". Due to the extensive nature of this subject, TC22 has a large number of sub-committees responsible for specific aspects. Sub-committee 21 deals with "Electric road vehicles".
ISO TC22 SC21 was founded in 1972 and held its first meeting in Frankfurt/Main, Germany, in October of that year.[617] Mr. Wolfram Galle from Germany was appointed secretary of the SC, a position he holds up to this day. This meeting happened one day after an ad-hoc IEC/ISO meeting (cf. §5.4.2), where a proposal for the division of work on electric vehicles was discussed, which was further worked out on the SC21 meeting. The division of labour was agreed upon, with no changes to be made to it without the joint agreement of ISO TC22 SC21 and IEC TC69.[618]
SC21 further discussed its title and scope, and set up two working groups:

- ☞ WG1, dealing with vehicle safety, vehicle operating conditions and energy storage installation;
- ☞ WG2, dealing with terminology, definitions and methods of measurement of energy consumption and vehicle performance.[619]

The works of SC21 would be highly cyclic in nature, with periods of high activity alternating with periods of relative dormancy. This explains why it has not published a definitive international standard before the end of the 20th century. The main period of dormancy were the 1980s, when the interest for zero-emission vehicles had waned particularly in Germany, also due to the Tchernobyl disaster and the association made by the German public between electric vehicles and nuclear power plants.
Most of the initial work of SC21 took place on working group level: the second official plenary sub-committee meeting would only be held in 1993, twenty years after the first meeting!

5.3.3 Vehicle safety standards: the work of ISO TC22 SC21 WG1

5.3.3.1 Early activities: towards a single electric vehicle standard

The first idea of SC21 was to develop a single comprehensive standard (which would get the number ISO 6469) on electric vehicles, encompassing both safety and performance aspects. A scheme for this document was presented in 1975, and featured the following structure:[620]

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[617] Doc. ISO/TC22/SC21 (Sec6) 33E, Minutes of the 1st meeting, 1973-10-18/19
[618] Doc. ISO/TC22/SC21 (Frankfurt 3) 31, Resolution 4 taken at the 1st meeting
[619] Ibid., Resolution 8
[620] Doc. ISO/TC22/SC21/WG1 N1E, 1975-06

☞ Scope
☞ Terminology (to be prepared by WG2)
☞ Specifications (to be prepared by WG1):

> *"The technical specifications to be respected in production and operation of electrical road vehicles refer to the characteristics and the dimensions of vehicles and to protective measures excluding any danger to persons as far as possible, to the definition of a safety level which must be maintained and to the preservation of the operative safety of the vehicle and of its electrical operating means. Statements can further be made on ways for obtaining good and reliable operating behaviour of electrical systems in the vehicle."*

☞ Testing (WG1) and definition of measurement methods (WG2):

> *"Testing methods, which are to be developed, refer to the proof of the respect of specification details or of the characteristics of the vehicle, as indicated by the manufacturer. They are grouped in type inspections and individual tests. Normally, direct tests will be provided, but procedures by replacement or by indirect methods, especially for the proof of the respect of a safety level, have to be fixed. All measuring methods used for the tests need a definition."*

The standardization of component specifications however raised some concern, as expressed in the following reaction by the Italian committee:[621]

> *"As far as we are concerned, we are against the standardization of electrical, mechanical and dimensional characteristics of these devices and the relative circuits, in order to avoid any delay of technical and technological progress".*

WG1 congregated five times during the 1970s, and presented a draft proposal in 1978.[622] This document defined "specifications on properties of road vehicles propelled by electric motors". Many sections of this document were still skeletal, the sections on protection against direct and indirect contact, as well as general functional protection requirements were worked out in more detail. Testing and measuring methods were not defined yet; these would be treated by WG2 (§5.3.4.1).

Although no official plenary SC21 meetings took place during that time, there were regular joint meetings of WG1 and WG2 to discuss the progress on ISO 6469. Other issues discussed on this level included the problem of regenerative braking and its influence on the homologation of vehicles (regenerative braking only working on the driven wheels, whileas service braking has to work on all wheels with a senseful distribution of efforts, thus relegating regenerative braking to a "retarding" role)[623].

Other subjects discussed included the power rating of the propulsion system, where the need for a definition arised for fiscal and homologation purposes, and for which

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[621] Doc. ISO/TC22/SC21/WG1 (Italy 1) 2, remark on N1 by Dr. Brusaglino
[622] Doc. ISO/TC22/SC21 N37E, "Specifications for electric road vehicles", 1978-06
[623] Doc. ISO/TC22/SC21/WG1 N42E, Minutes of the 3rd joint meeting in Stuttgart of WG1 and WG2, 1979-05-02/03, ¶6

the 30-minute power (at maximum speed) was specified[624], as well as the interaction with the preparation of ECE regulations, where ISO/DIS 6469 would be considered for the draft ECE regulations on electric vehicles.[625]

The draft of ISO 6469, without these performance tests established yet, was circulated for voting as a DIS in 1979, after being submitted to ISO TC22 SC21 and IEC TC69. Comments received on this document included the statement by the UK committee that the electric vehicle would not need specific requirements for EMC, and that the common rules for ICE vehicles could apply. Electric traction had in fact been used for many years in road vehicles like trolley buses, with no malfunctions or other problems.[626]

ISO/DIS 6469 would be considered by IEC TC69 WG2 for their work on component standards IEC 783 and IEC 786 (§5.2.3).

During the next years, the activities of SC21 and its working groups would become quiet. A second version of the document, ISO/DIS 6469.2[627], would be circulated in 1989, its publication being "necessary for the follow-up of electric vehicle problems". This document still contained a lot of paragraphs "under consideration" and did not show much progress since the 1979 version.

5.3.3.2 New activities and adoption of the CEN standardization work

The early 1990s saw a worldwide increase in the interest for electric vehicles, and for their standardization. By 1992, IEC TC69 had resumed a high level of activity, and CEN TC301 had started up. This would also thrust new activities for ISO TC22 SC21; on the plenary meeting of ISO TC22 which took place in Tokyo in 1992, it was resolved to reactivate SC21[628]. Furthermore, a formal liaison with CEN TC301 would be established[629], and the relationship with IEC TC69 considered[630].

The second meeting of SC21 took place, following this reactivation, in March 1993[631], where the ongoing activities of the other committees (IEC, CEN) were discussed. Particular concerns were uttered about the activities of CEN TC301, which

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[624] Ibid.
[625] Letter by UNECE to ISO TC22 SC21 secretariat, 1984-07-31
[626] Doc. ISO/TC22/SC21/WG1 N43, Minutes of 4th joint meeting in Turin of WG1 and WG2, 1979-10-18/19
[627] ISO/DIS 6469-2:1989 "Electric road vehicles - Specifications"
[628] Doc. ISO/TC22/SC21 N109E, 1993-03, Resolution 535 taken at the meeting of ISO TC22
[629] Ibid., Resolution 531
[630] Ibid., Resolution 527
[631] Doc. ISO/TC22/SC21 N113, Minutes of the 2nd meeting held in Frankfurt/M, 1993-03-18/19

had launched its work on safety standards, and where the need for a liaison was strongly felt, informing SC21 of all TC301 activities and programmes. Double work had to be avoided, with the opportunity of ISO considering and implementing (through parallel approval procedures as defined in the Vienna agreement between ISO and CEN) the work that had been started by CEN.[632]

The sub-committee also considered its running work programme. The document ISO/DIS 6469.2 was deemed unacceptable for publication as a standard, and had to be revised by a reactivated WG1.[633]
This led to a new draft, ISO/DIS 6469.3[634], which would be circulated to national committees early 1994[635], comments on this document being discussed at the next SC21 meetings.
A major change in policy would take place however in 1995 when SC21 considered the work performed in CEN TC301[636]: the draft European standards prEN 1987-1, -2 and -3 (§5.5.9) were circulated as ISO/WD 6469-1, -2 and -3.[637] The CEN documents were in fact in a more advanced state, whileas the ISO/DIS 6469.3 still was a very general document. This step is to be considered as a common-sense avoidance of supplementary and duplicate work.

WG1, which had been disbanded in 1995[638], was reactivated in 1996 to refine the three parts of ISO/CD 6469[639]. The drafts were discussed and adapted in WG1, and circulated for vote as CD in 1999[640]. Comments resulting from this CD vote were processed into the final versions, which were unanimously approved in the DIS ballot in 2000[641].

The comments accompanying this final ballot were mostly editorial; in 6469-1, a technical remark from France and the UK to require a minimum insulation resistance of 500 Ω/V for a new battery (instead of 100 Ω/V), just like the specification in EN 1987-1, was rejected by the secretariat.
As the approval of the standard was unanimous, and only editorial comments were agreed to, WG1 recommended to forward the DIS to the ISO central secretariat for publication, skipping the FDIS stage.[642]

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632 Doc. ISO/TC22/SC21 N113, ¶7.2
633 Doc. ISO/TC22/SC21 N112E, Resolution 54 taken at the 2nd meeting, 1993-03-18/19
634 ISO-DIS 6469.3:1994
635 Doc. ISO/TC22/SC21 N129E, Resolution 60 taken at the 3rd meeting, 1993-12-03/04
636 Doc. ISO/TC22/SC21 N170E, Resolution 67 taken at the 6th meeting, 1995-04-05/06
637 Doc. ISO/TC22/SC21 N223E, Secretariat's report to TC22, 1997-08, ¶7.3, Resolution 69
638 Doc. ISO/TC22/SC21 N170E, Resolution 65 taken at the 6th meeting, 1995-04-05/06
639 ISO TC22 SC21, Resolution 77 taken at the 7th meeting, 1996-10-10/11
640 Doc. ISO/TC22/SC21 N264E to N266E, Report of voting on ISO/CD 6469-1 to -3, 1999-05
641 Doc. ISO/TC22/SC21 N289E to N291E, Report of voting on ISO/DIS 6469-1 to -3, 2000-08
642 Doc. ISO/TC22/SC21 N301E, Minutes of the 12th meeting held in Troy, 2000-10-11, ¶7.1, SC21/WG1 Resolution 1

The three standards were eventually published in November 2001, after final redaction by ISO/CS.[643]

5.3.3.3 ISO 6469-1: Battery safety

ISO 6469-1 specifies requirements for the on-board electrochemical storage of energy for the propulsion of exclusively battery powered electric road vehicles (passenger cars and light commercial vehicles) for the purpose of protecting persons and the vehicle environment. Like the other standards of the series, it is applicable for working voltages up to 1000 V a.c. or 1500 V d.c. (or lower according to national regulations), and does not necessarily apply to assembly, maintenance or repair of the vehicles.[644]

It states requirements for marking (¶5 - with the symbol shown in Figure 5.35, if the voltage exceeds 25 V a.c. or 60 V d.c.), insulation resistance (¶7.1 - which should be at least 100 Ω/V throughout the life of the battery), ventilation (¶7.3 - with maximal allowable hydrogen concentrations of 1% in normal operation, and 2% in case of first failure), traction battery over-current interruption (¶8) and specifications for battery safety in case of crash or roll-over (¶9, 10).

Figure 5.35: The well-known voltage warning symbol[645]

The (informative) annexes to this standard present a more precise way to measure the insulation resistance (Annex A), and a calculation for the ventilation air flow for a vented battery (Annex B).

5.3.3.4 ISO 6469-2: Functional safety

ISO 6469-2 specifies requirements for functional safety means and protection against failures related to the specific hazard of the electric propulsion system of battery-electric passenger cars and light commercial vehicles[646].

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[643] Doc. ISO/TC22/SC21 N309E, Minutes of the 13th meeting held in Berlin, 2001-11-16

[644] ISO 6469-1:2001, Scope

[645] IEC 60417, Symbol 5036

[646] ISO 6469-2:2001, Scope

It defines how the electric drive system shall be organized for safe functional operation. The main requirements are summarized here, as they are typical for electric vehicle operation:

- ☞ Power-on procedure (¶5.1): at least two deliberate, distinct actions shall be performed in order to go from the "power-off" to the "driving enabled" mode. Also, the driving system shall be disabled when the vehicle is physically connected to the charging network. An obvious device (visual or acoustic signal) shall indicate permanently or temporarily that the propulsion system is ready for driving.
  These requirements are needed due to the fact that, contrary to an idling ICE, an electric propulsion system enabled for driving is completely silent.
- ☞ Indication of reduced power (¶5.2.1): if the power is automatically reduced due to e.g. overheating, this shall be indicated to the driver.
- ☞ Indication of state of charge (¶5.2. 2): a low state of charge shall be indicated to the driver by an obvious device. When the battery is fully discharged, the vehicle shall meet the following requirements:
  - ☛ It shall be possible to move the vehicle out of the traffic area by its own propulsion system - this implies that a sudden stop on a flat battery is not allowed.
    This requirement creates special considerations for those batteries which keep the same performance until the end of discharge.
  - ☛ A minimum energy reserve shall still be available for the lighting system, as required by national and/or international standards or regulations, when there is no independent energy storage for the auxiliary electrical circuit.
    One should note that this does not imply that the presence of an auxiliary battery is compulsory, as it is often thought. Rather, the signal to the driver to stop the vehicle at the end of discharge shall allow some reserve energy to pull over and to keep the vehicle's lights on.
- ☞ Releasing the accelerator pedal during driving (¶5.2.3) should not result in a deceleration greater than that of a comparable ICE vehicle.
  This requirement is unique to ISO 6469-2 and is not found in the corresponding EN 1987-2. It was introduced based on the comments received after the 1999 CD voting.[647] This addition was supported by SC21, taking into account legal authorities requirements, such as the actuating of vehicle stop lights when a considerable braking torque would be applied when driving the electric vehicle at "high idle speed" (i.e. with the accelerator pedal released).[648]
- ☞ Driving backwards (¶5.3): if this is achieved by reversing the electric motor, it shall require either two actions to be performed by the driver, or, if only one action is required, the transition shall only be allowed when the vehicle is stationary or moving slowly.

[647] Doc. ISO/TC22/SC21 N272E, Report of WG1 TO SC21, 1999-12

[648] Doc. ISO/TC22/SC21 N286E, Minutes of the 11th meeting in Naples, 1999-11-15, ¶14

The maximum reverse speed shall be limited, although this is left to the manufacturer's discretion.
If driving backwards is not achieved by reversing the electric motor, existing regulations for ICE vehicles apply.

- ☞ Parking (¶5.4): when leaving the vehicle, the driver shall be informed if the vehicle is still in driving mode.
This does not go as far however as the standards for industrial electric vehicles (cf. §4.2.6.2), where it is mandatory that the driving system is disabled when the operator leaves the vehicle (e.g. by using a seat switch)[649], such operation being much more common in the use pattern of an industrial vehicle than for a road vehicle.
- ☞ Main switch (¶5.5): a main switch shall make it possible to disconnect at least one pole of the on-board electrical energy source. It shall be activated by a manual device positioned within the driver's hand reach; this device may be the same as that used for the power on procedure - i.e. the "ignition" key switch. A different or additional disconnect device may also be provided.
Note that there is not a requirement for a separate red "emergency" stop device, as in industrial electric vehicles[650]; such device might in fact constitute a liability on a road vehicle when it would be operated during driving by unauthorized personnel (e.g. a child passenger).
- ☞ EMC (¶5.6): this is treated in the EMC chapter (§5.9.10).
- ☞ Vehicle auxiliary functions (¶5.7) shall meet the relevant national or international standards or regulations.

Furthermore, the following requirements are defined for protection against specific failures of the electric traction system:

- ☞ Unintentional vehicle behaviour (¶6.2): in the event of a single failure in a stationary vehicle, the propulsion shall be cut off to prevent unintended vehicle movement.
Note that this requirement is stricter than the one stated in EN 1987-2 (up to 0,1m movement allowed)[651] or in the early drafts of ISO 6469 (up to 0,3 m movement allowed)[652]; the European standard for industrial electric vehicles states on this subject that any uncontrolled full power travel condition shall be terminated within 0,2 s[653].
- ☞ Electrical connections (¶6.3): any unexpected disconnection of electrical connectors shall not result in hazardous behaviour of the vehicle.

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[649] EN 1175-1:1998, ¶5.9.5
[650] EN 1175-1:1998, ¶5.13
[651] EN 1987-2:1997, ¶6.1
[652] ISO/DIS 6469.2:1989, ¶3.9.4.2
[653] EN 1175-1:1998, ¶5.9.4 - Note that this paragraph is entitled "pulse control travel systems"; "pulse control" being, for historical reasons, the common name for power electronic drive systems (most of which are indeed "pulse controlled") in industrial electric vehicles.

A situation where this could occur is for example created when the connection to the battery is severed during a phase of regenerative braking, and the motor armature becomes shorted through the controller, leading to a very strong and uncontrolled braking torque.[654]

☞ Auxiliary electrical circuits (¶6.4): these shall be protected against overvoltages when not galvanically isolated from the power system.
Since the auxiliary circuit is, in most vehicles, connected to the vehicle chassis, the galvanic isolation between auxiliary and power circuits is implicitly required by the minimum insulation resistance requirement between the electrical circuit and the electrical chassis stated by ISO 6469-3[655], even if the standard does not explicitly proscribe a non-galvanically isolated auxiliary circuit. The isolation of the auxiliary circuit (through the use of a galvanically separated d.c./d.c. converter) remains a recommendable practice for personnel safety and to avoid unwanted operations through stray currents[656].

☞ Overcurrent cut-off device (¶6.5): a circuit-breaker, cut-off device or fuse shall switch off at least one pole of the on-board energy source in case of over-current. This device may be the main switch specified in ¶5.5 or de battery over-current device according to ISO 6469-1. It shall be possible to reactivate the propulsion system only by the normal power-on procedure after the fault has been cleared.
This reactivation by normal power-on procedure seems difficult however if a fuse has blown…

☞ Owner's manual (¶7): special attention shall be given to aspects specific to electric road vehicles.

5.3.3.5 *ISO 6469-3: Protection of personnel*

ISO 6469-3 specifies requirements for the protection of persons against electrical hazards on battery-electric road vehicles when the vehicles are not connected to an external power supply (in which case IEC 61851-21 applies).
Electrical circuits on-board electric vehicles belong to one of the voltage classes defined in Table 5.5; for Class A circuits, no specific protection measures against electrical hazards are required. The value of 60 V d.c. or 25 V a.c. is selected taking into account humid weather conditions; the upper values can be lower in accordance with national standards or regulations; in EN 1987-3 for example they are 750 V d.c. and 500 V a.c.

[654] The author can relate about this phenomenon from his own experience…
[655] ISO 6469-3:2001, ¶6.2.2
[656] Cf. P. Van den Bossche, Safety characteristics of electric vehicles in city traffic, ¶6.2.9

Class	V d.c.	V a.c.
A	0 - 60	0 - 25
B	60 - 1500	60 - 1000

Table 5.5: Voltage classes (ISO 6469-3)[657]

Protection against direct contact shall be provided either by basic insulation of live parts, by barriers/enclosures, or both (¶5.2).
In case of a fault of the basic insulation (¶5.3), protection shall be provided by using either:

- ☞ Class I equipment, where protection against electric shock[658] is ensured by equipotential connection of exposed live parts using a protective conductor.
- ☞ Class II equipment, where protection against electric shock is ensured by using double insulation or reinforced insulation.

The requirements for the insulation are also stated (¶6.2), the minimum insulation resistance being 1000 Ω/V for class I equipment and 5000 Ω/V for class II equipment. These values apply at the end of the conditioning period for the test (8 h preconditioning at a temperature of 5 ± 2 °C, followed by 8 h at a temperature of 23 ± 5 °C and a humidity between 85 and 100%); during the condition period, a transient insulation resistance ten times lower is allowed.
Dielectric strength tests are to be performed using an a.c. voltage dependent on the maximum working voltage U of the equipment:

- ☞ Class I equipment with basic insulation: $2\,U$ +1000 V (min. 1500 V)
- ☞ Class II equipment with supplementary insulation: $2\,U$ + 2250 V (min. 2750 V)
- ☞ Class II equipment with double or reinforced insulation: $2\,U$ + 3250 V (min. 3750 V)

The continuity test for potential equalization (¶6.4) makes use of a d.c. current equal to 1,5 times the maximum current, or 25 A, whichever is greater; the maximum resistance of the connection being 0,1 Ω.
These are heavy currents indeed (cf. the discussion in §5.8.9.4), which may demand heavy test equipment.

ISO 6469-3 defines requirements for several types of enclosures which can be used to shield live parts from direct contact(¶6.3). Directly accessible enclosures shall comply with protection degree IP XXD; underneath the vehicle, if the ground clearance does not exceed 30 cm, IP XXB is sufficient.
For enclosures accessible behind a cover, several cases are described:

- ☞ whether or not the enclosures are accessible with or without tools or maintenance keys;

[657] ISO 6469-3:2001, Table 1
[658] The standard states "direct contact"; cf. the discussion on this terminology in §5.3.4.2

☞ whether or not they are located in the passenger and load compartments;
☞ whether or not removal of the cover affects the live parts within the enclosure, by opening the circuit or by switching off the power to these live parts.

Finally, the standard states requirements for protection against water effects (¶7), where three tests are proposed:
☞ "washing" test, using a hose nozzle
☞ "heavy rainstorm" test, using a spray nozzle
☞ "flooding" test, driving the vehicle through 10 cm of water
In all these cases, insulation resistance shall be at least 100 Ω/V; if an insulation monitoring system is provided, it shall disconnect the power if the insulation drops below this value.

ISO 6469-3 is currently under revision, the notion "protection against direct contact" being replaced by "protection against electric shock", according to the changes implemented in the proofreading of ISO 8713 (§5.3.4.2).[659]

5.3.4 Vehicle performance standards: the work of ISO TC22 SC21 WG2

5.3.4.1 Early activities

The first document to be circulated by SC21 was actually the American document SAE J227 (§5.6.2.1) which had come out the year before.[660]

Two first drafts had been prepared in 1973 on vehicle performance tests:
☞ Road performance[661], specifying tests for
  - Maximum speed (over 1 km)
  - Acceleration
  - Gradeability (at 0, 20 and 40 km/h)
☞ Specific energy consumption[662], using the following speed cycles:
  - Constant speed 30 km/h
  - Constant speed 50 km/h
  - Constant speed 90% of maximum speed
  - Stop-and-go cycle (shown in Figure 5.36), with a cruising speed of 18, 30 or 50 km/h depending on the vehicle's maximum speed.

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[659] Doc. ISO/TC22/SC21 N321E, Minutes of the 14th meeting in Rome, 2002-05-03
[660] Doc. ISO/TC22/SC21 (Sec 1) 1E, 1972-12
[661] Doc. ISO/TC22/SC21 (Germany-4) 18D, "Bestimmung der Fahrleistung von Elektro-Straßenfahrzeugen", 1973-09
[662] Doc. ISO/TC22/SC21 (Germany-3) 16D, "Bestimmung des spezifischen Energieverbrauches von Elektro-Straßenfahrzeugen", 1973-09

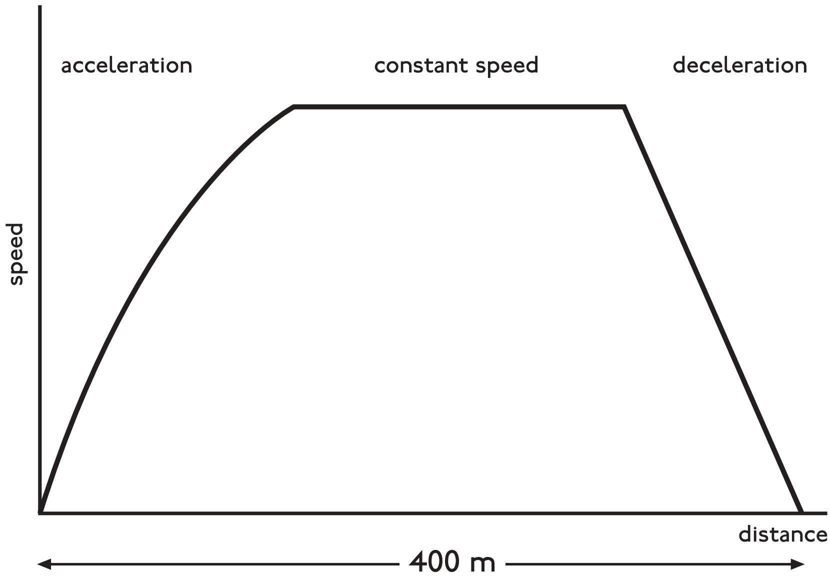

Figure 5.36: ISO speed curve (1973)

This cycle is worth further consideration: its abscissa is characterized by *distance* to be driven, and not by *time*, such as most other cycles in common use. This represents an approach which is much closer to the real mission of a road vehicle, the basic purpose of which remains to drive from point X to point Y.
A bus for example, has to cover the fixed distance between its stops.
Time-driven characteristics, on the other hand, have been designed to be more easily reproduced in an artificial laboratory situation, such as on a chassis dynamometer bench.

The work on these subjects would be the task of ISO TC22 SC21 WG2, which would not become really active until 1977 however, with a first meeting held in Munich in June 1978[663].

At a common meeting of WG1 and WG2 in 1979[664], the French experts of WG2 were invited to prepare a proposal for the determination of road performances, which would be integrated as an addendum into the ISO 6469 document[665].

During the 1980s, also WG2 would become very quiet. Draft documents on road performance and energy consumption would not be circulated before 1990, not as an addendum to ISO 6469 however, but as standards in their own right, ISO 8715 and ISO 8714 respectively.

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[663] Doc. ISO/TC22/SC21/WG2 N6, Minutes of the 1st meeting in Munich, 1978-06-14/15
[664] Doc. ISO/TC22/SC21/WG1 N42E, Minutes of the 3rd joint meeting in Stuttgart of WG1 and WG2, 1979-05-02/03
[665] Doc. ISO/TC22/SC21/WG2 (France 1) N18, "Road performances and reference power"

5.3.4.2 ISO 8713: Terminology

Although ISO had taken over the terminology work from IEC TC69, and initially showed some activity on the subject[666], no progress was made at that time. On the second meeting of SC21, which took place in 1993, it was resolved to elaborate the terminology standard after the ongoing work would be completed.[667]
The work resumed in 1997. One year later, a draft was completed; WG2 did steer clear however from the complicated subject of defining hybrid vehicle structures:

> *"the experts voluntarily limited the definitions in this document to those for pure electric vehicles, thus limiting the definitions related to electrochemical storage to the terms used in the standards, and excluding all definitions for electric vehicles."*[668]

The draft of ISO/DIS 8713 was circulated in March 2000 for voting and approved unanimously.[669]

In the course of checking the proof for publication however, a major mistake in was discovered affecting the consistency of this standard and of ISO 6469-3.[670]
In 1999, the definitions of "class I" and "class II" equipment had been changed from "protection against electric shock" to "protection against direct contact", the term "shock" being considered too threatening, although it was recognized it is still in common use in the IEC world.
The term "direct contact" means "electric contact of persons or animals with live parts"[671]. In the context of "protection against failures" however, which is achieved by the use of class I or class II equipment, the main objective is to avoid that contact to "exposed conductive parts" becomes a hazard, by preventing that these parts become live (class II approach), or to connect all these parts so that no potential difference can occur between them (class I approach).
The notion of "direct contact" in the definitions of the classes of equipment is thus misleading, and it should be replaced by "electric hazard" or "electric shock".
It was the intention of SC21[672] to correct this before publication, preferring the term "electric shock" as being more specific, and inserting its definition from the IEV ("physiological effect resulting from an electric current through a human or animal body"[673]), and to adapt these terms in ISO 6469-3 as well.
The standard had already been printed however, and was published in May 2002, still featuring the old definition with "direct contact".

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[666] Doc. ISO/TC22/SC21/WG2 N1, Terminology, 1978-03
[667] Doc. ISO/TC22/SC21 N112, Resolution 55 taken at the 2nd meeting, 1993-03-18/19
[668] Doc. ISO/TC22/SC21 N240E, Activity report of WG2 to SC21, 1998-11
[669] Doc. ISO/TC22/SC21 N293, Voting on ISO/DIS 8713, 2000-08
[670] Doc. ISO/TC22/SC21 N320E, Proof of ISO 8713, 2002-04
[671] International Electrotechnical Vocabulary IEV-195-06-03 - IEC 60050(195)
[672] Doc. ISO/TC22/SC21 N321E, Minutes of the 14th meeting in Rome, 2002-05-03,¶7
[673] International Electrotechnical Vocabulary IEV-195-01-04 - IEC 60050(195)

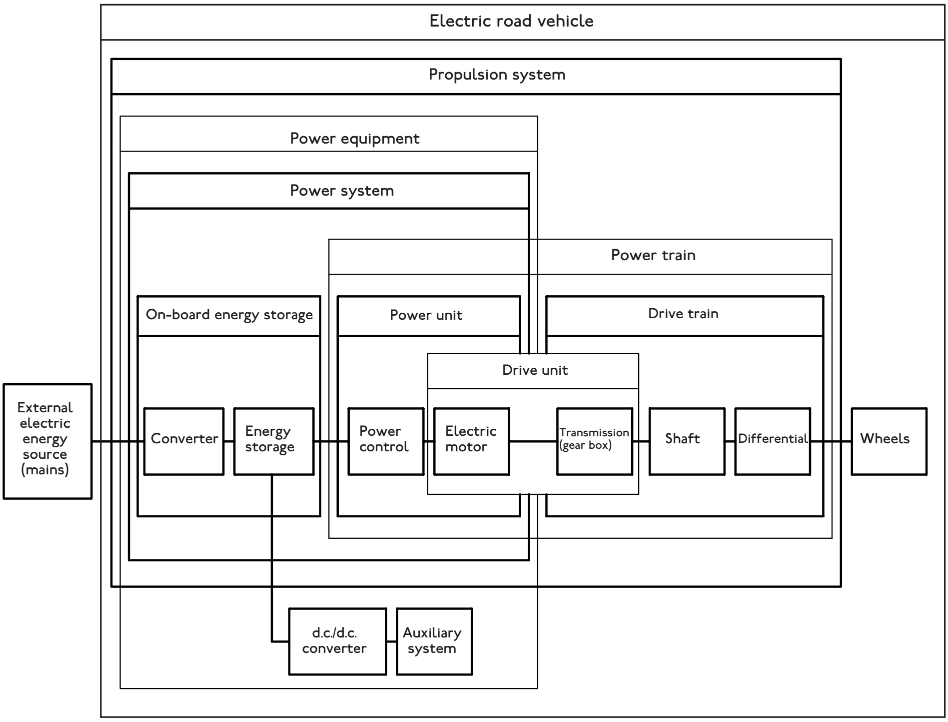

Figure 5.37: Grouping of components in electric road vehicles[674]

ISO 8713 establishes a terminology for the components of electric road vehicles and related terms, concentrating primarily on defining components and terms specific to electric road vehicles. It does not define terms for hybrid or fuel cell vehicles, although it recognizes that these require further consideration[675]. This will be further treated in §6.3.3.3.

A number of definitions of the components of the electric traction system (like "drive train") differ from those given in the corresponding European standard EN 13447 (§5.5.6.5), as can be seen by comparing Figure 5.37 with Figure 5.45.

5.3.4.3 ISO 8714: Reference energy consumption and range

The draft of ISO/DIS 8714[676], circulated for voting in September 1990, specified the general procedure to measure the reference range of electric vehicles. It made use of the ECE-15 cycle, which is the forerunner of the European urban cycle shown in Figure 5.43.

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674 ISO 8713:2002, Figure 1
675 ISO 8713:2002, Scope
676 ISO/DIS 8714:1990 "Electric road vehicles - Reference energy consumption"

This was further discussed on the second meeting of SC21 in 1993, where it was resolved to review the document, reactivating WG2, and taking into account the experiences of CEN TC301 (who were working on EN 1986-1, §5.5.6.3)and of non-European experts.[677]

The experts took into account the forthcoming new European test cycle, which also featured an extra-urban cycle (Figure 5.44), which meant the test procedures would have to be adapted for low-speed electric vehicles. ISO/CD 8714 would be redrafted by the ISO experts in collaboration with the CEN experts, taking into account two different objectives:[678]

☞ to establish the energy consumption in typical day-to-day usage

☞ to establish the maximum continuous range between charges

The discrepancy between these two items takes into account that, in daily use, the displacements covered by an electric vehicle are often less than the full range; however, one must take into account that in most cases a charge after such a partial discharge will lead to higher energy consumption values, due to the contribution of the final charge.

The draft was further discussed in 1994[679], and circulated for vote in August 1995. The draft was not approved, since only four out of seven voting P-members supported it (a ⅔ majority being needed). Negative votes came from France and Italy, the draft not being in line with draft ECE regulations[680], and the USA, who quite rightly stated:

> *"This portion of the test is suitable for vehicles which operate within Europe. However, to be a truly international document, it should include the driving cycles of other markets such as the United States and Japan"*[681]

The Swiss supported the document, but made an interesting comment:

> *"Looking at the minor differences existing between ISO/DIS 8714-1 and CEN/prEN 1986-1 and considering the rules established in the Vienna agreement, we are surprised to see that no common document has been developed."*[682]

The document thus had to go back to the committee, which resolved to reactivate WG2, and to assign it the revision the document including three regional alternatives for the driving cycle: United States, Japan, and Europe.[683]

The new draft, with common definitions and test procedures, as well as test cycles and end of test criteria in regional annexes, was circulated for voting as a CD in

[677] Doc. ISO/TC22/SC21 N112E, Resolution 52 taken at the 2nd meeting, 1993-03-18/19

[678] Doc. ISO/TC22/SC21 N129E, Minutes of the 3rd meeting, 1993-12-03/04

[679] Doc. ISO/TC22/SC21 N148E, Minutes of the 4th meeting, 1994-05-09

[680] ECE 101, cf. §5.8.10

[681] Doc. ISO/TC22/SC21 N196E, Voting on ISO/DIS 8714-1, 1996-06

[682] Ibid.

[683] Doc. ISO/TC22/SC21 N226E, Activity report of WG2 to SC21, Resolution 78 of SC21

1999, and unanimously approved.[684] The scope of this document was limited to vehicles with a maximum speed no less than 70 km/h.
The possibility of combining both consumption and range measurements in a single procedure was examined and agreed upon[685]. This means that with the ISO 8714 test, unlike the EN 1986-1 test (§5.5.6.3) for example, the calculation of the energy consumption will be done based on a charge after a full range test. This procedure makes use of the full potential of the vehicle, and will yield lower Wh/km values compared with a partial discharge test such as in EN 1986-1, which corresponds to a subobtimal use of the vehicle from an energy point of view. Although the proposal of a single test procedure was also motivated by the resulting simplification and reduction of test expenses, a more commendable technical standard has been the result.

Voting of the DIS followed in 2000; the international standard was submitted for publication in September 2001[686] and was eventually published in November 2002.

ISO 8714 specifies test procedures for measuring the reference energy consumption and range of purely electrically propelled passenger cars and commercial vehicles of a maximum authorized total mass of 3500 kg and a maximum speed of 70 km/h or above.[687]
It defines a common test procedure, consisting of:
☞ Initial charge of the traction battery (¶7.4.2); the battery is first fully discharged and then charged according to its normal procedure.
☞ Application of the test sequence until the end-of-test criterion is reached, and measurement of the reference range thus obtained. (¶7.4.3)
☞ Charging of the battery and measurement of the energy consumption at the mains. (¶7.4.4)
☞ Calculation of the reference energy consumption in Wh/km (¶7.4.5)

Three test cycles are proposed, for different regions:
☞ European driving cycle (Annex A), consisting of four basic urban cycles (Figure 5.43) and one extra-urban cycle (Figure 5.44); this corresponds to test sequence n° 2 of European standard EN 1986-1 (§5.5.6.3). The test sequence n° 1, consisting of only urban cycles, has not been considered here since the scope of ISO 8714 only encompasses vehicles able to exceed 70 km/h.
☞ American driving cycle (Annex B), defining either an "urban" test cycle (Figure 5.52) or a "highway" test cycle (Figure 5.53). These are the cycles used in the American document SAE J1634 (§5.6.2.2).

[684] Doc. ISO/TC22/SC21 N268E, Voting on ISO/CD 8714, 1999-05
[685] Doc. ISO/TC22/SC21 N240E, Activity report of WG2 to SC21, 1998-11
[686] Doc. ISO/TC22/SC21 N309E, Minutes of the 13th meeting in Berlin, 2001-11-16
[687] ISO 8714:2002, Scope

☞ Japanese driving cycle (Annex C), consisting of a 10-mode pattern (Figure 5.57) repeated three times, followed by a 15-mode pattern (Figure 5.58) once; this corresponds to the test cycles specified in the Japanese standard JEVS Z108 (§5.7.2.1).

Each of these cycles has its own end-of-test criterion; these are quite comparable however.

It is thus clear that ISO 8714 constitutes a truly international standard, which takes into account the difference in local conditions and local practices which may exist in different areas of the world while implementing a common test procedure; as such the international standard can supersede existing regional and national standards, achieving the ideal of global standardization. The American standard SAE J1634 has in fact already been cancelled following the publication of ISO 8714.

In the framework of elaborating this standard, it was also proposed in 1993 to draft a separate standard for determining the reference energy consumption of heavy-duty electric road vehicles exceeding 3500 kg. A special driving cycle was proposed by the German committee, as illustrated in Figure 5.38.

This standard would have become ISO 8714-2; the project would be abandoned however in 1996.[688]

It is however interesting to cast a look at the cycle of Figure 5.38; just like the cycle proposed in the initial 1973 draft (Figure 5.36), it is defined by covered distance, and not by driving time.

[688] Doc. ISO/TC22/SC21 N223E, Secretariat's report to TC22, 1997-08, Resolution 71

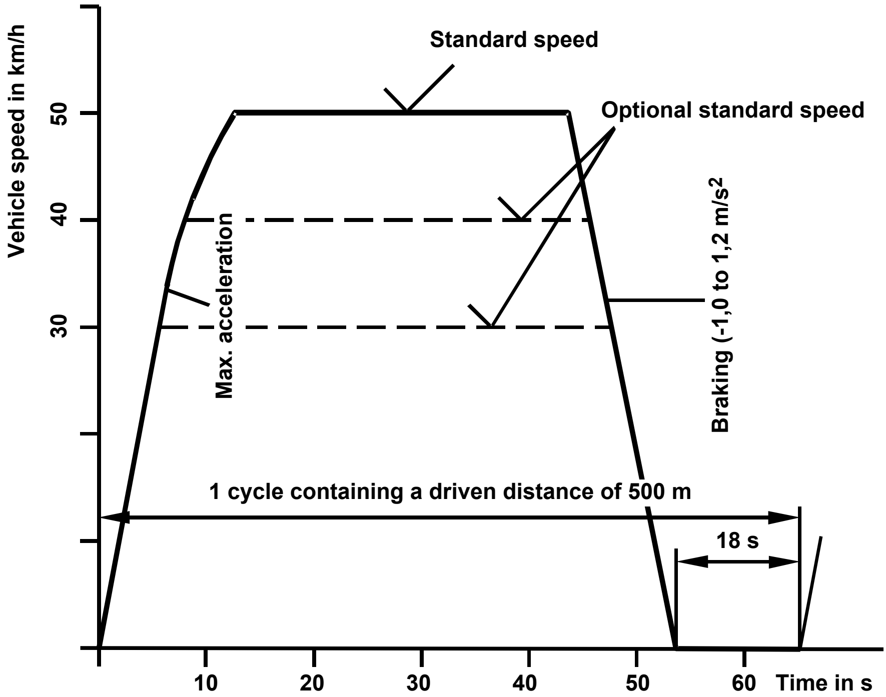

Figure 5.38: German proposal for heavy-duty driving cycle[689]

5.3.4.4 ISO 8715: Road operating characteristics

The draft of ISO/DIS 8715[690], circulated for voting in September 1990, defined test methods for reference power and driving performance. The reference power was defined as the power measured at the electric power source (battery terminals) at maximum constant speed; driving performances considered were:

- ☞ Maximum speed,
- ☞ Hill climbing ability,
- ☞ Hill starting ability,
- ☞ Acceleration capacity.

Also this document was slated for revision at the second SC21 meeting, taking into account existing international practices. It was also foreseen to provide a procedure for measuring the driving range; this subject would later be transferred to ISO 8714.[691]

Also this document was reviewed taking into account the state of discussion in CEN TC301.[692] It was circulated for vote in August 1995, together with

[689] Doc. ISO/TC22/SC21 N111E, 1993-03

[690] ISO/DIS 8715:1990 "Electric road vehicles - Road operating characteristics"

[691] Doc. ISO/TC22/SC21 N112E, Resolution 53 taken at the 2nd meeting, 1993-03-18/19

[692] Doc. ISO/TC22/SC21 N159E, Minutes of the 5th meeting, 1994-12-08/09

ISO/DIS 8714, but 8715 was approved[693], and accepted as an international standard by SC21 in 1997.[694]
The voting on the document as FDIS lingered on due to technical problems with the French version at the CS level; since the DIS voting was positive without any disapproval, the document could be published as an international standard however.[695]

ISO 8715 was eventually published in June 2001. It specifies procedures for measuring the road performance of purely electrically passenger cars and commercial vehicles of a maximum authorized total mass of 3500 kg.[696]

The test procedures include:
☞ Maximum thirty minute speed (¶9.1)
☞ Maximum speed over (twice) 1 km (¶9.3)
☞ Acceleration ability 0 to 50 km/h and 50 to 80 km/h, at 60% SOC (¶9.5, 9.6)
☞ Speed uphill, on 4% and 12% slope (¶9.7)
☞ Hill starting ability (¶9.8)

The (normative) Annex A describes the determination of the total road load power of the vehicle and the calibration of the chassis dynamometers.
The test procedures in this standard are identical to those in the European standard EN 1821-1 (§5.5.6.2). The corresponding American standard, SAE J1666 (§5.6.2.3) has now been cancelled, and the Japanese standards on the subject, JEVS Z110 (§5.7.2.3) and JEVS Z112 (§5.7.2.5) are also covered by the procedures of ISO 8715. Once more, an international standard with a global mission has thus been drafted.

5.3.5 Other work by ISO TC22 SC21

The sub-committee also followed the activities on the field of ECE regulations, and more particularly the GRPE working group of WP29, which was active on fields relevant for electric vehicles. These regulations are discussed in §5.8.

The work by ISO TC22 SC21 on the field of hybrid and fuel cell vehicles will be treated in §6.2.2 and §6.3.3, respectively.

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693 Doc. ISO/TC22/SC21 N223E, Secretariat's report to TC22, 1997-08, ¶7.1D
694 Doc. ISO/TC22/SC21 N234E, Resolution 82 taken at 9th meeting, 1997-12-12/13
695 Doc. ISO/TC22/SC21 N286E, Minutes of the 11th meeting, 1999-11-15, ¶8
696 ISO 8715:2001, Scope

5.3.6 Environmental standardization

Although going beyond the scope of electrically driven vehicles, it seems interesting to cast a brief light on the issue of environmental procedure standards.

The issue of "environmental standardization"[697] has come to a new light in the framework of "environmental management standards", which are organizational standards allowing a pro-active approach to the management of environmental isues. Within ISO, such standards are treated by TC207, which was set up in 1993.

TC207 has developed a family of standards in the ISO 14000 series, addressing aspects of environmental management such as environmental management systems, environmental auditing, environmental labeling, environmental performance evaluation and life cycle assessment. As procedural standards, they can be compared with the ISO 9000 family of quality management standards (which are developed by ISO TC176, with whom TC207 works closely together).
The ISO 14000 standards provide a common framework for managing environmental issues, through the implementation of the concept of "environmental management", which approaches all environmental aspects of an organization in a structured and systematic way. The basics of environmental management systems are laid down in the international standard ISO 14001.
Implementing an environmental management system allows an organization on one hand to obtain an overall view of all environmental aspects of the processes and to identify those areas where improvements can be realized, and on the other hand to create a "green" image which benefits its relations with customers, the general public and the government.
Key elements in an environmental management system are the analysis of the environmental aspects of the organization, the implementation and organization of critical processes with monitoring and correction when needed, in order to reach a continual improvement of the environmental impact. The standards also provide a number of tools to assist the environmental management process, such as environmental auditing (covered by ISO 19011) and life cycle assessment (covered by standards in the ISO 14040 series).
Although the initial ideas behind the ISO 14000 family were process-oriented rather than product-oriented (cf. the ISO 9000 process quality standards), the same principle has been specifically applied to product development; this has emanated into the publication of the technical report ISO/TR 14062 "Environmental management - Integrating environmental aspects into product design and development"[698].

[697] Environmental management - the ISO 14000 family of international standards, ISO, 2002
[698] cf. Lee, K.M., Environmental management: integrating environmental aspects into product design and development, ISO Bulletin, 2002-09

This document describes concepts and current practices concerning the integration of environmental aspects in product design and development. It is characterized by a holistic approach: not only the product itself, but also strategic and management issues should be addressed in the framework of this integration process.
Strategic considerations[699] include general organizational issues, product-related issues and communication strategies.

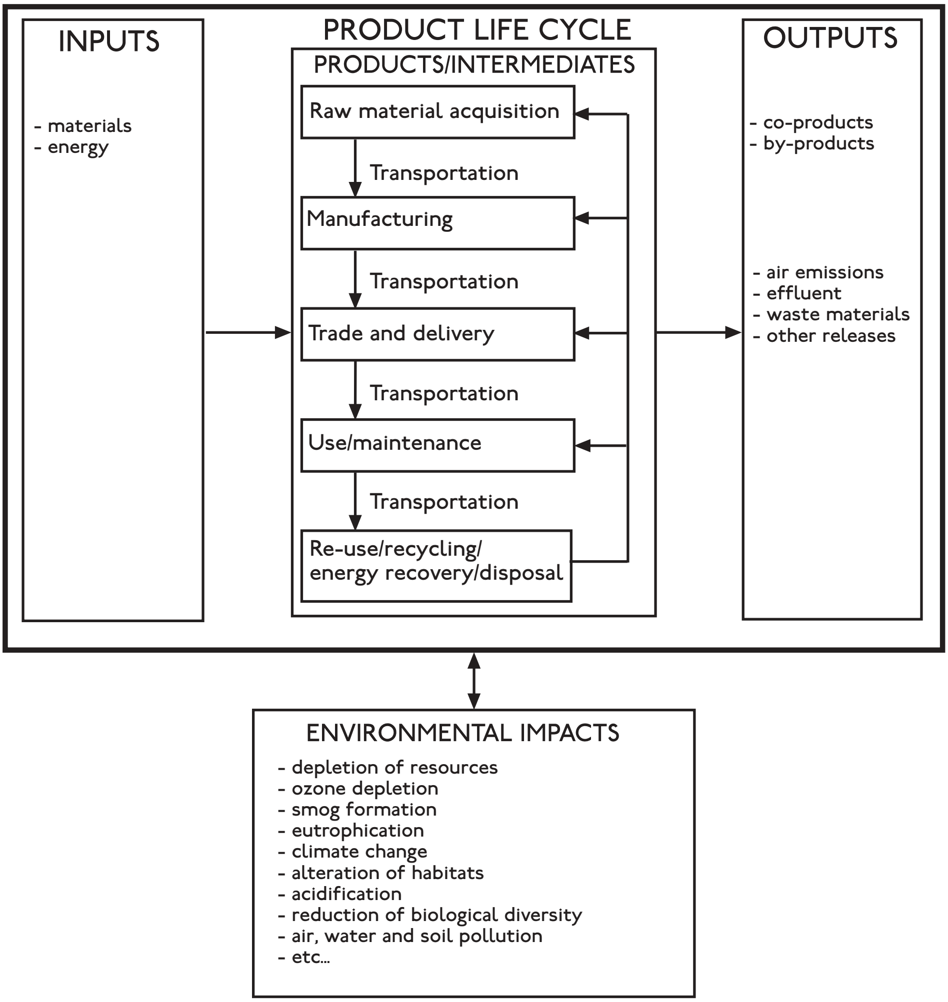

Figure 5.39: Inputs and outputs and examples of environmental impacts associated with a product life cycle[700]

Management considerations[701] describe the role of management and its commitment to the environmental integration programme. The need for a proactive and multidisciplinary approach is highlighted.

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[699] ISO/TR 14062:2002, ¶5
[700] Ibid., Figure 1

Product considerations[702] take into account the global environmental impacts of the product. These impacts occur in all stages of the product life cycle, as shown in Figure 5.39. The integration at an early stage of environmental impacts in the product development process and a thorough analysis of the product life cycle allows to identify and resolve the trade-offs which will occur during the product design process. The overall approach aims at setting product-related environmental objectives, like conservation of resources and prevention of pollution and attempting to meet them through the optimal design and development approaches.

The environmental management standards provide a setting to assess the overall environmental impact of a product. Furthermore, the adoption of environmental management systems will have its influence on product standardization in general, taking into account the potential impact of requirements stated in product standards (e.g. material choices) facing the overall environmental assessment of the product.

Considering the electrically driven vehicle, it is clear that there are a number of issues where this holistic approach can yield a beneficial outcome for the environmental image of such vehicles.

One notable example is the proposed 2005 ban[703] on the use of cadmium in traction batteries through the European "end-of-life" directive[704], where a complete life cycle analysis of the electric vehicle could prove the fact that traction batteries are indeed an environmentally responsible application of cadmium, due to their full recyclability and taking into account that there is a unavoidable production of cadmium (which is a by-product of zinc production), that has to be used in a sensible and environmentally friendly manner.[705]

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[701] Ibid., ¶6

[702] Ibid., ¶7

[703] European commission press release IP/02/366, 2002-03-06

[704] Directive 2000/53/EC

[705] Cf. CITELEC viewpoint on NiCd traction batteries, 2001-05-23

5.4 *The relationship between* IEC *and* ISO *in the field of electric vehicle standardization*

5.4.1 Introduction

With standardization of the electric road vehicle becoming a key issue, the question arises which standardization body would have the main responsibility for electric vehicle standards. This problem is less straightforward then it looks: the electric vehicle, which introduces electric traction technology in a road vehicle environment, represents in fact a mixed technology:

☞ on one hand, the electric vehicle is a road vehicle, the standardization competence for which is the province of ISO;
☞ on the other hand, the electric vehicle is a piece of electrical equipment, the standardization competence for which falls under the wings of the IEC.

Furthermore, there is a fundamentally different approach taken towards the concept of standardization in the automotive and the electrotechnical world. There is a different "standard culture", the origin of which can be traced back to historical reasons. This dichotomy had been encountered by AVERE[706] in its studies on standardization and regulation (see also §5.5.12).

☞ As seen in §3.4 above, there is a long tradition for standardization in the electrotechnical industry, as well a stronger tendency to standardize all and everything. Electric motors are covered by extensive IEC standards covering their construction and testing. Even subjects such as the colour code of wires are standardized (e.g. green and yellow for the protective or earth conductor). In the electrotechnical industry in fact, the role of specialist component manufacturers acting as suppliers to equipment manufacturers has always been more common.
Electricians do not only want to define the vehicle as a whole, but also to standardize its components, on a point of view of safety, environment, quality and interchangeability.
Furthermore, the customers of the electrotechnical industry are more likely to be powerful corporations (e.g. railway companies) who tend to enforce very strict specifications on the equipment they order or purchase, hence the need for more elaborate standards to ensure the compliance of the equipment. Industrial electrical equipment is also designed for an extended service life: continuous operation during several years, which corresponds to up to 100000 hours.

☞ In the car manufacturing world on the other hand, standardization is limited to issues which are subject to government regulations (safety, environmental

[706] AVERE, Situation actuelle des comités d'études, 1979-09-20, Doc. FB/EV 7.3

impact, performance measurement) and to the areas where interchangeability of components is a key issue. Since car manufacturers desire to develop their own technical solutions which embrace their proprietary technological know-how and which give their products an unique market advantage, there are few standards covering combustion engines for example.
Car manufacturers accept that a vehicle, *as a whole,* is subjected to safety and environmental regulations, but do not feel the need for definition of individual components.
Furthermore, the automobile has become a mass-market product: extensive routine tests on every produced vehicle would be prohibitively expensive, and the customer is more likely to be a "consumer", less interested in demanding compliance to specific international standards. The expected service life of an automobile (5000 to 10000 hours) is also much lower than of an industrial electrical machine.

This difference is further reflected in the constitution of the technical committees and their working groups which deal with electric vehicle standardization in respectively IEC and ISO. In the IEC committees many of the delegated experts are electricians or component manufacturers, whileas in ISO there is a much stronger input from vehicle manufacturers.

5.4.2 Early collaboration IEC-ISO on electric vehicles

Following the setting up of ISO TC22 SC21, an informal liaison meeting between representatives of ISO and IEC was held in Frankfurt in October 1973.[707] The representatives of both organizations there unanimously agreed that it was necessary for both to be involved in the wide range of work, and emphasized in particular that a close liaison should exist between the two organizations, to this effect it would be recommended to be involved in each other's work through inviting representative on each other's working groups. A joint IEC/ISO committee however was not feasible for administrative reasons.[708]
A provisional division of work was agreed, which was modified very slightly at the subsequent meeting of ISO TC22 SC21 (cf. §5.3.2), and which is reproduced in Table 5.6. It was agreed upon in general by IEC TC69.

As a result of this, a number of results of the work carried out since the start of TC69 in 1969 were transferred to ISO TC22 SC21, covering the following subjects:
☞ Definition of fundamental terms
☞ Methods for measuring performance of electric road vehicles.

[707] Letter by IEC General Secretary C.J Stanford to ISO Secretary-General C. Sturen, 1978-10-27, Appendix: IEC TC69, Minutes of Ljubljana meeting, 1973
[708] Doc. ISO/TC22/SC21 (Sec 6)33E, Minutes of the 1st meeting, 1973-10-18/19

Tasks of ISO TC22 SC21	Tasks of ISO TC22 SC21 with assistance of IEC TC69	Tasks of IEC TC69 with assistance of ISO TC22 SC21	Tasks of IEC TC69
Vehicle operating conditions	Energy storage installation	Safety of persons against electric shocks	External electric power supply to vehicle
Definitions and methods of measurement of vehicle performance	Definitions and methods of measurement of energy consumption	Definition and methods of measurement of the performance of motors and motor control systems	External chargers Electrical energy storage system
Vehicle safety	Terminology	Voltages Specific connections Chargers carried on vehicles	Protection electric components

Table 5.6: Division of work IEC/ISO (1973)

At the IEC TC69 meeting held in Florence in June 1978, it was noticed that the draft of ISO 6469 was overlapping with subjects felt to be the province of IEC, for example electrical safety of vehicles, which was then being covered in the draft for the ISO 6469 standard (§5.3.3 above). A proposal presented by ISO TC22 delegates present at that meeting as observers was discussed and accepted as a guideline for future co-operation between the different working groups of IEC TC69 and ISO TC22 SC21.[709]

This document addressed the following working items[710]:
☞ Energy storage installations: SC21 WG1 with collaboration of TC69 WG3.
☞ Definition and methods of measurement of energy consumption: SC21 WG2 with collaboration of TC69 WG2.
☞ Terminology: SC21 WG2 with collaboration of TC69 WG2, 3 and 4.
☞ Safety of personnel against electric shocks: TC69 WG 2, 3 and 4 in collaboration with SC21 WG1.
☞ Definitions and methods of measurement of the performance of motors and motor control systems: TC69 WG2 in collaboration with SC21 WG2.
☞ Voltages: TC69 WG2 in collaboration with SC21 WG2.
☞ Specific connections: TC69 WG4 with collaboration of SC21 WG1.
☞ Charger carried on vehicles: TC69 WG4 with collaboration of SC21 WG1.

Collaboration means that the chairman or another expert of the co-operating WG collaborates in the responsible WG; the established paper being submitted to the co-operating WG for comments, before sending it to the national committees.

[709] IEC TC69, Daily report on the meeting in Florence, 1978-06-27, Doc. 69(Florence/Sec)15
[710] IEC TC69, Doc. 69(Florence/ISO Observers)7, 1978-06

The matter was also discussed by the Belgian Electrotechnical Committee, which had its own study commission 69 dealing with electric vehicles, and which stated in a 1979 meeting:

> *"Il est regrettable que deux organismes internationaux travaillent sur le même sujet sans coordination effective."*[711]

At the same meeting, the BEC (the Belgian Electrotechnical Committee) proposed the BIN (the Belgian institute dealing with general standardization) to vote against the draft of ISO 6469, not only because of the technical content of the document (which was deemed to vague, general and incomplete), but also out of principle, since the subject matter belonged to IEC competence.

Although TC69 still abode by the agreement reached in 1973, it was felt that better co-operation was desirable, particularly at WG level, and that the borderline between the two committees should be determined more strictly.[712]

On the 1988 meeting of IEC TC69, ISO had expressed the wish to send an observer, no applications in this sense were received by IEC however.[713]
The discussion went on during the next few years, and by 1990 a modification was proposed by ISO, where all work on vehicle standardization, including equipment specifications when assembled in the vehicle, would be ISO's responsibility.[714] This modification (Draft resolution 63) is given in Table 5.7; differences with Table 5.6 are italicised.

Tasks of ISO TC22 SC21	Tasks of ISO TC22 SC21 with assistance of IEC TC69	Tasks of IEC TC69 with assistance of ISO TC22 SC21	Tasks of IEC TC69
Vehicle operating conditions Definitions and methods of measurement of vehicle performance Vehicle safety *Electro-mechanical energy storage system*	Energy storage installation Definitions and methods of measurement of energy consumption *Safety of persons against electric shocks* *Specific connections* *Chargers carried on vehicles*	*External electric power supply to vehicle* Definition and methods of measurement of the performance of motors and motor control systems *External chargers*	*Electro-chemical* energy storage system Protection of electric components

Table 5.7: Division of work IEC/ISO (1990 proposal)

[711] BEC/CEB, Commission 69, Procès-verbal de la reunion 1979-01-15, Doc. PV N°3
[712] Letter by IEC General Secretary, op.cit.
[713] IEC TC69, Minutes of meeting in Stockholm 1988-06-01/02, Doc. RM3108/TC69, IX
[714] ISO TC22 SC21, Draft resolution 63 - Extract from ISO TC22 SC21 N148E, quoted in IEC TC69, Minutes of the meeting in Anaheim 1994-12-07/08, Doc. 69/50/RM

This proposal was discussed at the IEC TC69 meeting in Anaheim in 1994[715], where it was proposed to use only two responsibility levels instead of four (ISO for on-board equipment and IEC for off-board equipment).

During the next year, several proposals for division of work were drafted and circulated. Table 5.8 shows a document prepared by Dr. Sporckmann of ISO TC22 SC21 and circulated at the TC69 meeting in Brussels in October 1995.

ISO	IEC
Work items related to the electric vehicle as a whole, e.g. road performance, energy consumption or noise emissions	*Work items related to infrastructure including connector design*
☞ The security of the EV including security of the components except work items related to special features of the connection of the EV to the mains. ☞ All specifications belonging to homologation, e.g. motor power. ☞ Mechanical and electric requirements of components, which are important for working together of the EV as a whole, e.g. dimensions of the battery, voltage and current limits of the battery. ☞ Terminology and symbols ☞ EMC	☞ Security only when the EV is connected to the mains, e.g. overvoltage, venting of garages. ☞ Characteristics of the electric components of the EV, e.g. disturbances of the charger, battery capacity, test procedure of drive and electrical connection, wiring above 80 V.

Table 5.8: Division of work IEC/ISO (1995 proposal - Sporckmann)

Another proposal, by Dr. Mangan, chairman of IEC TC69, was discussed at the ISO TC22 SC21 meeting in Berlin in April 1995 and shown in Table 5.9.[716] The topics in the table marked with "*" would warrant the assistance of IEC resp. ISO. At the same meeting, a proposal[717] was presented by Dr. Orchowski, taking into account the former one, but differentiating according to the following reasons:

☞ Electrotechnical components such as cables are already standardized by ISO for general automotive applications, and shall remain ISO domain for EV, as to ensure compatibility between all automotive cables and efficiency in standardization. Amendments to specific EV requirements shall consider expertise of IEC standards, if any.

☞ For electrotechnical components not used in ICE vehicles and only standardized in IEC, the IEC standards shall be checked and adapted, where necessary, to general automotive conditions.

☞ Standards for components and items belonging to the interface vehicle/charging station should be covered by either ISO or IEC standards, according to compatibility reasons.

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715 IEC TC69, Minutes of the meeting in Anaheim 1994, Doc. 69/50/RM

716 ISO TC22 SC21, Doc. N162

717 ISO TC22 SC21, Doc. N167E

☞ In any case, all standards on EV shall be consistent with the overall vehicle conditions and requirements set by the vehicle manufacturer (and legal requirements, if any).

ISO	IEC
☞ Acoustic noise, chargers, fans, drive systems, etc. Definition and test procedures ☞ Communication throughout the vehicle system* ☞ Surface touch temperatures, drive system, battery, etc. ☞ Electrified roadways* ☞ Electromagnetic fields in and around vehicles* ☞ On-board energy storage mounting, mechanical characteristics, safety requirements, etc.* ☞ On-board chargers, mechanical requirements, safety interlocks, etc., test procedures* ☞ Battery disconnection devices and fusing.* ☞ Safety risks of gas, leakage of material, earth leakage limits, etc.* ☞ Safety test procedures for complete battery systems: electrical, mechanical, thermal* ☞ Vehicle performance: range, test cycle, etc.	☞ Connection of the vehicle to the mains supply. Earth leakage detection, current interruption, safety of persons.* ☞ Connector design: forces, protection, current capacity, a.c./d.c., number of contacts, environment* ☞ Chargers: performance, requirements, mains supply distortion ☞ Touch voltages and protection, a.c./d.c.* ☞ Inductive charging. High frequency, low frequency.* ☞ d.c. charging; normal rate, high rate.* ☞ Test procedures and definitions for drive system power, rating, etc. ☞ Test procedures and methods of measurements of battery characteristics, including those for hybrid systems and the effect of battery management*

Table 5.9: Division of work IEC/ISO (1995 proposal - Mangan)

The ISO TC22 SC21 meeting in Berlin passed the following resolution:

> *"Mr. Andersson (IEC/TC69) and Mr. Sporckmann (ISO/TC22/SC21) were asked to draft a more detailed proposal on the basis of the proposals of work partition from IEC TC69 chairman, see document N162, and ISO TC22 SC21, see document N167."*[718]

The plenary meeting of TC69, held in Brussels in October 1995[719], was attended by the chairman of ISO SC21 and the secretary of ISO TC22, who stated that it was essential for standards not to be developed in parallel, and that electric vehicles were to be standardized in the same way as all other road vehicles: ISO deals with the vehicle as a whole, while IEC must concern itself with (electrical) components.
Both IEC and ISO delegates at that meeting agreed the necessity for co-operation, and in some cases, JWGS would be appropriate and useful.

During the year 1996, intensive discussions on the Work Programme went on within both IEC and ISO committees. At a joint meeting held in Geneva on April 12, 1996, a new document to be used as basis of an agreement between IEC and ISO, was discussed; an updated proposal was subsequently worked out and circulated as an administrative circular within the respective IEC and ISO Committees[720]. It is

[718] ISO TC22 SC21, Meeting in Berlin, 1995-04-05/06, Resolution 68, Doc. N170E
[719] IEC TC69, Minutes of the meeting in Brussels, 1995-11-16/17, Doc. 69/68/RM
[720] IEC TC69, Doc. 69/80/INF and ISO TC22 SC21, Doc. N206E, 1996.

reproduced in Table 5.10. One can see that some aspects like wiring have been moved to the ISO side.

ISO	IEC
Work items related to the electric vehicle as a whole	*Work items related to electric components and electrical supply infrastructure*
☞ Operation and energy performance of the vehicle. ☞ Environmental conditions: shock, vibration, thermal, dust, water, oils, etc. ☞ *Safety of vehicle, not connected to supply.* ☞ Interactions between operator and vehicle - vehicle symbols. ☞ EMC when not connected to the supply. ☞ Installation of on-board components; drive system, battery system, charging system, etc. ☞ Operational requirements of components related to their operation inside the vehicle. ☞ On-board information interchange, dialogue between vehicle systems. ☞ *Abuse testing of electrochemical storage systems; electrical, mechanical, thermal, etc.* ☞ *Gas hazards generated by the vehicle, on- and off-board the vehicle.* ☞ Cables and connectors within the vehicle.	☞ *Safety and operational aspects when the vehicle is connected to the supply, via an a.c., d.c. or inductive link.* ☞ *Drive train performance measurement and test procedures; characteristics, ratings, efficiency, power.* ☞ *Battery performance measurement and test procedures; characteristics, ratings, efficiency, power.* ☞ *Charger performance measurement and test procedures; characteristics, ratings, efficiency, power.* ☞ *Other (electrical) components, measurement and test procedures except cables and connectors.* ☞ Infrastructure for charging; charging system ratings. ☞ EMC when the vehicle is connected to the supply. ☞ *Communications between the vehicle and the supply using vehicle communications standards.*

Table 5.10: Division of work IEC/ISO (1996 proposal - Sporckmann)

5.4.3 The IEC-ISO Joint Steering Committee

At the IEC TC69 meeting in October 1996, it was agreed to propose to ISO the formation of a Steering Committee, according to ISO/IEC Directives[721], and to recommend this steering committee to consider a number of activities as suitable for JWGs. These activities include "terminology", as well as a number of items from both the ISO and IEC listings; these have been italicised in Table 5.10.

The following resolution was accepted:

> *"TC69 resolves to propose to ISO that a joint steering committee be formed according to the ISO/IEC Directives, Annex A, clause A3.1, with the responsibility to steer the work and to propose, where necessary, joint working groups placed under the relevant IEC or ISO body to ensure the exchange and circulation for comments of committee documents"*[722]

[721] ISO/IEC Directives - Part 1: Procedures, 1995, Annex A, ¶A3.1

[722] IEC TC69, Minutes of the meeting in Osaka, 1996-10-16/17, Doc. 69/88/RM, Appendix 3, Resolution No. 1

ISO TC22 formally approved the proposal to establish the IEC/ISO Steering Group at its plenary meeting in Berlin in May 1997, where the following resolution was approved:

> *"TC22 mandates the chairman of SC21 to form a steering committee with the chairman of IEC TC69. With the confidence in the chairman to make decisions, the steering committee is to define the future work program and to allocate the work items to the responsible committee. The work shall be allocated as follows:*
>
> ☛ *ISO TC22: Vehicle and its components*
>
> ☛ *IEC TC69: Infrastructure for electric vehicles*
>
> *TC22 requests the ISO Central Secretariat to inform the Central Secretariat of IEC."*[723]

One should note the difference in scope proposed by ISO in this resolution, which brought all components within the domain of ISO.

A number of work items under consideration were circulated within ISO and IEC for comments in order to develop a project-based work program between ISO and IEC[724]:

- ☞ Methods of measurement of vehicle response, performance and range
- ☞ Methods of measuring system efficiencies/energy consumption
- ☞ Electrical safety; connected to mains and stand-alone
- ☞ EMC, connected to mains and stand-alone
- ☞ On-board high voltage cables, connectors and fuses
- ☞ Methods of measuring drive system power
- ☞ Dimensions of common components, e.g. batteries
- ☞ Connection and communications between vehicle and infrastructure
- ☞ Operating environment for the vehicle, connector and charger
- ☞ Methods of measuring battery system performance
- ☞ Measurement of charging times, efficiencies and conditions
- ☞ On-board communications protocol.

The first meeting of the IEC/ISO Steering Group took place in Paris on October 9th, 1997[725]. The Group was composed of eight members, among them the chairmen of IEC TC69 and ISO TC22 SC21. The author took part in the Steering Group as convener of IEC TC69 WG2.

This meeting defined the terms of reference for the Steering Group as follows:

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[723] Resolution No.568 - Formation of ISO TC22 SC21 - IEC TC69 Steering Committee, quoted in letter from Mr. M.A. Smith, Director, Standards Department, ISO to Mr. J.-P. Broton-Dias, Technical director, IEC, 1997-11-17.

[724] IEC TC69, Doc. 69/100/INF, Report on the activities of the steering group formed to allocate the projects and control the partition of work between IEC TC69 and ISO TC22 SC21.

[725] Minutes of meeting of the Joint IEC/ISO Steering Group, 1997-10-09.

- ☛ *The Steering Group will deal with issues related to the standardization of battery-electric road vehicles.*
- ☛ *The Steering Group shall work on behalf of the vehicle manufacturers, the utilities, the component suppliers and other partners with a legitimate interest in standardization, in the formulation of the work programme related to the standardization of battery-electric road vehicles.*
- ☛ *The Steering Group shall first collect information from the relevant parties noted above on the requirements for standards as an aid to safety, commercialisation, functionality and testing.*
- ☛ *The Steering Group shall formulate the work programme, advising on the objectives of each work item, setting the timescale, agreeing the host organization and confirming the document circulation procedures.*
- ☛ *The Steering Group shall be prepared to recommend that certain items of work within IEC and ISO shall be terminated or postponed.*

As for the definition of a work programme, it was agreed to seek guidance from interested parties in the field by letter and direct contact.
The interest of car manufacturers for guidance documents and standards about system safety was recognized, as well as the interest for standardization of charging connections. Product specifications intended for suppliers fell outside the scope of international standardization.
Links with regional standards organizations should be maintained where appropriate; regional differences in practices will occur (e.g. for electric supply networks), but the objective is to ensure that the basic documents are the international standards produced by IEC and ISO.

The Steering Group agreed to have the ongoing work of IEC TC69 WG2 (see §5.2.3.6) suspended until the work programme had been finalized.

To assess the interest in the field for electric vehicle standardization, a questionnaire was circulated in November 1997, and again in the spring of 1998, to vehicle manufacturers, suppliers and utilities worldwide.

Further meetings of the Steering Group took place in Brussels (March 23rd, 1998) and Esslingen (October 12th, 1998), where the current activities of the different standardization committees were presented[726]. Problem areas identified concerned mostly the co-ordination of European standardization activities by CEN-CENELEC with those of IEC-ISO, particularly the work of CENELEC TC69X, who had issued ENV documents based on a draft version of the corresponding IEC standards, and who was working on a document concerning the communication protocol between vehicle and charger (cf. §5.5.3.2).

[726] IEC/ISO Steering group on electric vehicles, Minutes of the meeting in Esslingen, 1998-10-12

The results of the questionnaire, also discussed at this meeting, confirmed the current standardization subjects on electric vehicle and did not indicate strong demand on other subjects. The following topics were given a high priority for standardization work:

- ☞ Vehicle-related performance procedures
- ☞ Safety issues
- ☞ Charging infrastructure communication issues and connectors

The Steering Group reported officially about its activities to both IEC and ISO Central Office, expressing its concern about the apparent lack of co-ordination between international and European standardization, which created the risk of duplication of work and the creation of a dual standard for the same purpose. [727]

A further meeting of the Joint Steering Group was held in Frankfurt on December 7th, 1999, where the main outcomes were the following[728]:

- ☞ The work by IEC TC69 WG2 on IEC 61981 "On-board power equipment for electric road vehicles" was to be discontinued (cf. §5.2.3.6). The WG2 was to be reactivated however to address grid-connected considerations (methods of measurement, bi-directional power flow, etc), difference between stand-alone component performance and on-vehicle performance, and design rules for EMC (cf. §5.2.3.7).
- ☞ The EMC work by IEC TC69 was to be co-ordinated with IEC TC77 and CISPR. The difference in tests and measurements for EMC was to be harmonized between IEC and ISO. EMC up to 5 GHz would be identified by ISO.
- ☞ The development of a communication protocol for d.c. charging (cf. §5.2.5.3.7) would be the task of ISO TC22 SC3 WG1 "Electrical and electronic equipment - Serial data communication", this WG already being involved with similar communication protocol issues for automotive applications. IEC 61851-3 was to be deleted from the IEC TC69 WG4 work programme. To this effect, the secretaries of IEC TC69 and ISO TC22 SC21 addressed a request to ISO TC22 SC3 WG1.[729]
- ☞ The progress in IEC/ISO participation, ISO/CEN and IEC/CENELEC harmonization was noted, the idea being for IEC and ISO to provide international standards for regional and national acceptance.
- ☞ The new work of the IEC TC105 on fuel cells (cf. §6.3.2) was reviewed; it was supported by ISO TC22 SC21 and IEC TC69.

[727] Report of the joint steering group IEC TC69 and ISO TC22 SC21, letter of Dr. Sahm and Dr. Mangan to Mr. M.A. Smith and Mr. J.-P. Brotons-Dias, 1998-12-08

[728] Summary of IEC TC69/ISO TC22 SC21 joint committee meeting, Frankfurt, 1999-12-07 (also Doc. ISO/TC22/SC21 N316E)

[729] Doc. ISO/TC22/SC3/WG1 N801, 2000-10-12

5.4.4 Conclusions

The study performed relating to the discussion between IEC and ISO on the subject of electric vehicle standardization are illustrating two main issues which are characteristic of international standardization activities:

- ☞ On one, hand, with several standardization organizations active on the same subject, there is a real danger that much effort will be lost through parallel work, leading to different and potentially conflicting standards on the same topic. Such "standards" are a source of confusion and are of no useful purpose.
- ☞ On the other hand, the collaboration between different organizations, if implemented efficiently, will allow standardization work to advance and to obtain positive results.

It should be stressed that IEC and ISO should not consider themselves as competitors, but as complementary bodies, each apporting their expertise to the field. IEC and ISO have been created as separate bodies for historical reasons, but now they exist together (even sharing the same building complex in Geneva), and they should co-exist and collaborate.

The division of standardization work on a specific subject like the electric vehicle has involved a lot of discussions, which can run out of hand when each party keeps defending its "turf" (in this case: is it a car or an appliance?), reasoning out of tradition and emotion. It is essential that such differences be overcome and that the future standardization work is performed in a spirit of collaboration and joint effort toward a common goal which is the drafting of clear and useful standards which benefit both the manufacturer and the user.

For the electric vehicle, the idea to have vehicle aspects treated by ISO and electrical aspects treated by IEC is a reasonable solution; it should be taken into account however that electrical power components clearly belong to the sphere of IEC and can benefit from IEC's long experience in the field.

The same arguments about collaboration between organizations can of course also be cited concerning international vs. regional standardization bodies.

5.5 *Regional standardization work in Europe*

5.5.1 CENELEC: Introduction

CENELEC, the European Committee for Electrotechnical Standardization, was set up as a factual association on January 1, 1973 as the follow-up of the earlier CENEL which had started in 1959 as a collaboration between European national electrotechnical committees. CENELEC acquired legal personality in 1977 as an international association under Belgian law, its constituting members being the national electrotechnical committees of 14 countries: Germany, Austria, Belgium, Denmark, Finland, France, Ireland, Italy, Norway, Netherlands, Portugal, United Kingdom, Sweden and Switzerland. Its purpose lies in:

> *"the scientific, technical an economic fields and consists in the one hand in the harmonisation of the national electrotechnical standards published by the national organisations entrusted with such publication, and on the other hand in removing trade barriers which may result directly or indirectly from the measures applied in the member countries to indicate or certify conformity to standards of a given product, in particular by means of a mark or a certificate."*[730]

CENELEC has always pursued a close interrelatedness between its European standards and international IEC standards. In 1996, two-thirds of European electrotechnical standards are very close (in most cases identical) to IEC standards, only one-third being "home-grown" European standards. IEC work serves in over 90% of the cases as direct inspiration for CENELEC work. These figures are much higher than for general non-electrotechnical standardization: only 40% of CEN standards are identical to international ISO standards.[731]

In 1980, facing the increasing interest for electric vehicles and the standardization work being performed by IEC TC69 in the field, there were proposals to create a committee on electric road vehicles within CENELEC. The idea was supported among others by AVERE, who stated, through its Belgian section the following motives[732]:

- ☞ Elimination of technical differences between CENELEC countries concerning vehicle homologation (this concern was also raised by the EEC).
- ☞ Establishment of harmonized safety rules for use of the electric vehicle by the general public.
- ☞ Standardization of voltage levels and connectors in order to allow charging in different countries.

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730 CENELEC, Memorandum and Articles of Association, 1977-04

731 Schepel, H. and Falke, J., Legal aspects of standardisation in the member states of the EC and EFTA, p35

732 Letter by J.Voos to the BEC, 1980-03-13

☞ The experiences and the progress of ISO and IEC work, allowing the drafting of European standards.
☞ The preparation, in a number of countries, of national standards on electric vehicles, which would ideally be harmonized within CENELEC.

After consultation with members of the AVERE study committee on standardization (cf. §5.5.12), it was deemed however that the constitution of a CENELEC working group was premature and would risk to make double use with the works of ISO TC22 SC21 and IEC TC69.[733]

5.5.2 CENELEC BTTF 71-1

In view of the developments in the field of electric vehicles and more particularly their infrastructure, a number of national committees, particularly the French one, felt a need for standardization in the field which was not satisfactorily covered by international standards such as IEC 718. CENELEC (71BT) thus decided to set up a Task Force, BTTF 71-1, "Charging and connectors for electric vehicles", under French convenorship, the task of which was to prepare drafts, trying to come into accordance with all National Committees involved in order to facilitate the acceptance of drafts prepared through NC voting procedures.

BTTF 71-1 had its first meeting in Paris on June 30, 1992, where it changed its title to "Electric road vehicles: connection of external electrical power"[734] and considered a draft for a new standard prepared by the French NC.

This standard would apply to "electric road vehicle batteries charging devices used in public areas", only covering conductive charging.[735] Two parts were provided:
☞ Direct connection of electric road vehicles to low voltage a.c. supply systems (on-board charger)
☞ Indirect connection of electric road vehicles to low voltage a.c. supply systems (off-board charger)[736]

In both parts, aspects covered included characteristics and operating condition of the supply device and the connection of the vehicle, electromagnetic compatibility, operators and third party electrical safety and the characteristics to be complied with by the vehicle with respect to the supply infrastructure.

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733 Letter by J.Voos to the BEC, 1980-06-06
734 CLC/BTTF 71-1(Sec)5, Minutes of the meeting of 1992-06-30. As a sidenote, this was the first real standardization meeting which the author attended, and thus his "baptism of fire" in the world of standardization.
735 CLC/BTTF 71-1(Sec)4, Scope, 1992-07
736 CLC/BTTF 71-1(Sec)3, 1992-07

It was foreseen to produce a DIS for the first part by the end of 1993 and for the second part by the end of 1995, the delay for the latter allowing some time for stabilization of the rapid charging technology.

IEC 718:1992 was to be used as a base for the work, relevant clauses being referred to whenever possible. However, the approach of this standard was sometimes considered either incomplete (it contained no provisions on EMC for example) or too precise (defining on-board charger mechanical characteristics, which are considered more the car manufacturer's responsibility).
Furthermore, this meeting saw the introduction of an interesting concept: the three charging "cases" as definition of options for the physical connection of an electric vehicle to a supply terminal. This has been discussed in §5.2.5.3.1.

In accordance with the IEC/CENELEC co-operation agreement on new work, the new document was proposed to IEC TC69 for voting as a NWIP[737]. This was supported positively[738], and consequently the Technical Bureau (73BT) of CENELEC decided to transfer the work to IEC TC69, the Task Force BTTF 71-1 being converted to WG4 of IEC TC69, providing that IEC would be able to prepare a DIS within the same target date proposed by CENELEC (i.e. end 1993).
The BTTF meeting of November 1992, which had already been scheduled, became an IEC TC69 WG4 meeting. The further activities of WG4 on these items have been discussed in §5.2.5.2 above.

5.5.3 CENELEC TC69X

5.5.3.1 Inception

In June 1993, the Italian NC proposed to set up a Technical Committee within CENELEC dealing with electric road vehicles[739].
The rationale behind this proposal was to reflect, at an European level, the situation on a global level where there is on one hand TC69 in IEC and on the other hand TC22 SC21 in ISO. Furthermore, the interest to draft specific European standardization was growing, due to the increasing tendency of European directives to make reference to standards, or to mandate standardization bodies for the preparation of new standards.[740] (cf. §5.5.11).
Whileas in Europe there was CEN TC301 as equivalent of the ISO TC22 SC21, there was no equivalent on the CENELEC side, hence the proposal to have a TC69X for implementing at European level IEC publications and for promoting new activities

[737] IEC TC69, Doc. 69(CENELEC)1, 1992-05
[738] IEC TC69, Minutes of meeting in Florence 1992, Doc. RM3556/TC69
[739] Doc. CLC/BT(IT)148, 1993-06
[740] CLC TC69X, Minutes of the first meeting, 1993-12-15, Doc. CLC/TC69X(Sec)8

for the electric aspects of the vehicle. It was recognized that a close co-ordination with CEN TC301 would be necessary to ensure consistency and to avoid duplication of work.
The committee was set up by 76BT of CENELEC, which allocated the secretariat to the French NC, and which expressed satisfaction about the repartition of work as resolved by CEN BT.[741]
CEN had proposed the following repartition:
☞ All aspects relating to construction and performance: CEN
☞ Electrical equipment outside the vehicle (sockets, cables) and some electrical equipment inside the vehicle (batteries): CENELEC
☞ Safety aspects: CEN working group with CENELEC collaboration[742]
For the last item however, CENELEC stated that a joint CEN/CENELEC working group, reporting to both CEN TC301 and CENELEC TC69X should be responsible.[743]
77BT of CENELEC asked the central secretariat to organize a meeting between TC301 and TC69X in order to work out a harmonized work programme.[744] This meeting took place on November 5, 1993 in Brussels.[745]
78BT of CENELEC agreed formally the draft agreement concerning the work repartition[746]; it would not be until April 1995 however that a formal agreement on the repartition was achieved.[747]

TC69X held its first meeting in Brussels in December 1993, under the chairmanship of Mr. Thione.[748]
The provisional title of CENELEC TC69X "Electric Road Vehicles"[749] was accepted as "Electrical systems for electric road vehicles", and its scope as:

> *"to prepare European standards related to electrical systems specifically designed for road vehicles, totally or partly electrically propelled from self-contained power sources, with special reference to:*
> ☛ *Charging systems and devices (off board)*
> ☛ *Connection between vehicle and external charging devices (power and control signals)*
> ☛ *Electrical safety (on- board and off-board)*
> ☛ *Selected electrical problems"*[750]

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[741] Doc. CLC/TC69X(Sec)2, Annex A, 1993-10
[742] 32 CEN/BT, Resolution BT114/1993
[743] Doc. CLC/BT(SG)2149, 1993-09
[744] Doc. CLC/TC69X(Sec)2, Annex A, 1993-10
[745] Doc. CLC/BT(SG)2183, 1993-11
also Doc. CEN/TC301 N21
[746] Decision D78/115, Doc. CLC/TC69X(Bxl/Sec)1, 1993-12
[747] Doc. CEN/TC301 N69, Resolution BT30/1995 by CEN BT, and Resolution D83/151 by CENELEC BT
[748] CLC TC69X, Minutes of the first meeting, 1993-12-15, Doc. CLC/TC69X(Sec)8
[749] Doc. CLC/TC69X(Sec)4, 1993-10
[750] Doc. CLC/TC69X(Sec)10, Decision 1-2/93

This scope encompasses all kinds of electric vehicles, including hybrid vehicles an excluding only externally-supplied electric vehicles such as trolleybuses. Also, it was understood that auxiliary systems supplied at low voltage were out of the scope of TC69X, except these directly energized from the mains or from the traction battery (d.c./d.c. converter, heating, air conditioning)[751].

The meeting approved the draft agreement on the work repartition between TC301 and TC69X as a basis for the work programme of TC69X:

> *"The principles of mutual participation and information are considered (...) as applicable, and favourable for the efficiency of standardization of both mechanical and electrical aspects of electric vehicles, as well as other principles of cooperation produced by this agreement."*[752]

TC69X continued to follow up the work on chargers and connectors being performed at IEC TC69 WG4.

As for its own working programme, proposals were received, from France and Italy. After discussion, it was decided to create three working groups with the following preliminary work programme[753]:

☞ WG1: "Charging of electric vehicles - design and operational aspects"

☞ WG2: "Charging of electric vehicles - environmental aspects"

☞ WG3: "Electrical safety of electric vehicles", the latter under CEN TC301 convenorship. It was difficult to find a convenor for this group, and in 1994 it was thus decided[754] to suppress WG3, and have the safety aspects dealt with by CEN TC301, TC69X only considering the case when the vehicle was connected to the power supply (WG1), or the issue of the effect of magnetic fields (WG2).

5.5.3.2 Charging infrastructure: the work of TC69X WG1

TC69X WG1 held its first meeting in Brussels, on February 16, 1995[755]. This happened one day after a meeting of IEC TC 69 WG4, thus underlining the close links that existed between these working groups, which shared the same subject of work, the same convener - Mrs. Flageat from EDF - and most of the European experts.

Its scope being "Definition of constructional and operating principles of electric vehicles charging systems", it initially started work on a set of six documents:

☞ prEN 50AAA-1: General considerations

☞ prEN 50AAA-2: Connection to a.c. power supply

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[751] CLC TC69X, Minutes of the second meeting, 1994-04-06, Doc. CLC/TC69X(Sec)20

[752] Doc. CLC/TC69X(Sec)9, Decision 1-1/93

[753] Doc. CLC/TC69X(Sec)11, Decision 1-3/93

[754] CLC TC69X, Minutes of the third meeting, 1994-11-22, Doc. CLC/TC69X(Sec)22

[755] CLC TC69X WG1, Minutes of the meeting, 1995-02-16, Doc. CLC/TC69X/WG1(Sec)2

- ☞ prEN 50AAA-3: Connection to d.c. power supply
- ☞ prEN 50AAA-4: Inductive coupling
- ☞ prEN 50AAA-5: Dialogue between vehicle and charging station
- ☞ prEN 50AAA-6: Electrical safety of the charging process; this item was later deleted[756] since it was implicitly included in all the preceding documents.

The WG took into account the work being performed by IEC: both the revision of IEC 718[757] and the new document[758] (cf. §5.2.5.2).
It was recognized that the IEC documents were still under development and were to undergo changes; starting CENELEC work from the current IEC draft might lead to different documents to be developed.
However, it was recognized that Europe might be in the need of a document concerning electrical safety, if IEC documents were not to be available for some years.
Another key issue of WG1 work would be the communication protocol between the vehicle and the off-board charger: since different protocols had been proposed in the USA, Japan and France, it was unlikely to have IEC agreement on a single protocol.

Concerning the revision of IEC 718, it was resolved to recommend CENELEC BT to refuse a parallel vote when this document was to be circulated as FDIS. Although IEC 718 was the only finished document available at the moment, its approach was considered as not fully reflecting the state of the art, particularly concerning safety matters, and as inconsistent with the new work in progress within TC69X.[759]

On its next meeting, held in S. Pietro di Strà in November 1995[760], WG1 expressed its concern about the ongoing evolution in IEC TC69 WG4, where different opinions on safety matters between American and European delegates (cf. discussions on charging modes, §5.2.5.3.2 and control pilot, §5.2.5.3.3 above) were delaying the work on the new standard. It was felt that a standard with basic requirements for charging was needed in Europe, the sooner the better.

A new structure of documents for conductive charging was proposed, partly reflecting the IEC document structure:

- ☞ Part 1: General requirements; a draft of this document[761] was discussed on the meeting.
- ☞ Part 2-1: Electric vehicle requirements
- ☞ Part 2-2: AC electric vehicle charging station
- ☞ Part 2-3: DC electric vehicle charging station

[756] CLC TC69X, Minutes of the fourth meeting, 1995-11-23, Doc. CLC/TC69X(Sec)25
[757] Doc. IEC/TC69/WG4(Sec)32
[758] Doc. IEC/TC69/WG4(Sec)31
[759] CLC TC69X, Minutes of the fourth meeting, 1995-11-23, Doc. CLC/TC69X(Sec)25
[760] CLC TC69X WG1, Minutes of the meeting, 1995-11-30, Doc. CLC/TC69X/WG1(Sec)4
[761] Doc. CLC/TC69X/WG1(Padova)1

☞ Part 2-4: Communication data link

Documents covering the first three parts[762] were discussed at the WG1 meeting in March 1996[763], and, after some modifications[764], submitted to TC69X, who agreed to transfer them from WG level to TC level, and who appointed an Editing Committee for these documents. They were circulated in 1997 as prEN50275-1, 2-1 and 2-2.
In the meanwhile, WG1 continued its work, and prepared the document on the d.c. charging station[765], which was submitted to the TC69X secretariat in the May 1997.
A document on the communication protocol, based on a French contribution, from IEC TC69 WG4[766], which also had been discussed in CEN TC301 (§5.5.8.1) was also to be circulated as a secretariat document in the summer of 1997.[767] This standard is based on the ISO 14230 "Keyword Protocol 2000".
On its 1997 meeting, TC69X decided to have these documents, after a final review by WG1 and by an editing committee, published as ENV, rather than to wait for the final publication of the IEC standards.
ENV stands for "European prestandard"; this concept is less stringent than a regular EN (European standard), not implying any obligation from the countries which do not want to acknowledge it, and allowing review in a short period of time. It is initially valid for three years. The decision to go ENV was fuelled by the urgent need to have documents published on an European level, taking into account the perceived slow progress at IEC level, while leaving all options open for the future.[768]

All documents were eventually published as ENV in September 1998:
☞ ENV 50275-1: Conductive charging for electric vehicles - Part 1: General considerations
☞ ENV 50275-2-1: Conductive charging for electric vehicles - Part 2.1: Connection of an electric vehicle to an a.c./d.c. supply
☞ ENV 50275-2-2: Conductive charging of electric vehicles - Part 2.2: a.c. charging station
☞ ENV 50275-2-3: Conductive charging for electric vehicles - Part 2.3: d.c. charging station
☞ ENV 50275-2-4: Conductive charging for electric vehicles - Part 2.4: Communication protocol between off-board charger and electric vehicle

TC69X waited and watched for the developments in IEC TC69 WG4. On its 2000 meeting, it decided to keep the ENV 50275 series in their present stage and

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762 Docs. CLC/TC69X/WG1(Sec) 5, 6, 7
763 CLC TC69X WG1, Minutes of the meeting, 1996-03-27/28, Doc. CLC/TC69X/WG1(Sec)10
764 Docs. CLC/TC69/Brussels 1, 2 and 3
765 Doc. CLC/TC69X(Sec)11
766 Doc. IEC/TC69/WG4(France)5
767 Doc. CLC/TC69X(Sec)29
768 CLC TC69X, Minutes of the sixth meeting, 1997-09-17, Doc. CLC/TC69X(Sec)31

recommended their application until the complete IEC 61851 series would be ratified as European EN standards.[769] This was endorsed by CENELEC BT: the ENV 50275 is not to be withdrawn before ratification of the complete EN 61851 series[770].
IEC 61851-1 was accepted through parallel vote and published as EN 61851-1 on December 1, 2001. IEC 61851-21 and IEC 61851-22 followed suit on October 1, 2002. IEC 61851-23 still being in CD stage, the full ratification of the series will have to wait for now.

This creates the awkward situation that different versions of the same standard are in circulation at the same time, a situation which may lead to confusion and which is certainly not favouring efficient implementation of the standards neither enhancing the credibility of these standards.
The creation of these separate documents was actually considered[771] a violation of the "IEC-CENELEC agreement on planning of new work and parallel voting"[772].

Since the IEC series did not include a standard communication protocol for d.c. charging station, it was decided however to convert ENV 50275-2-4 into a EN, with the same name and number.[773] The ISO/IEC steering group on electric vehicles (§5.4.3) would however oppose CENELEC work in this domain, since it was considered the responsibility of ISO as such communication protocol had to be consistent to on-board protocols already developed by ISO. [774]

The applicability of these IEC documents of the 61851 series to the specific European needs was taken into consideration at the 2000 meeting of TC69X[775]. It was agreed[776] that these standards (in particular 61851-2-2 and 61851-2-3) might be applied to the implementation of the European Low Voltage Directive.
Also, TC69X was of the opinion that IEC 61851-21, IEC 61851-22 and IEC 61851-23 could be used as harmonized standards for the implementation of the EMC directive.[777] This was however subject to the competent body within CENELEC; the advice of the CENELEC EMC consultant stated that the standard would not be appropriate for publication as an EMC harmonized standard, mainly because it contained EMC clauses "under consideration" which is not acceptable[778].

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[769] CLC TC69X, Minutes of the ninth meeting, Decision 2-1
[770] CENELEC BT, Decision D107/089
[771] IEC/ISO Steering Group on Electric vehicles, Minutes of meeting, 1998-10-12
[772] This is the so-called "Lugano agreement" (1991-10), modified in 1996-09 as the "Dresden agreement" (IEC, Doc. 115/AC, 1997-08-15)
[773] CLC TC69X, Minutes of the ninth meeting, Decision 2-2
[774] IEC/ISO Steering Group on Electric vehicles, Minutes of meeting 1998-10-12
[775] CLC TC69X, Minutes of the ninth meeting, 2000-11-21, doc. CLC/TC69X(Sec)43
[776] Ibid., decision D1-1
[777] Ibid., decision D1-2
[778] Doc. CLC/TC69X(Sec)46, 2001-06 - Comment on prEN 61851-21

The work on inductive charging would be postponed, since the experience already available at different national committees was deemed insufficient to provide normative guidance[779]. At subsequent TC69X meetings, the evolutions of the IEC documents on the matter ware waited for[780].
Taking into account the research work still in progress in this field, it was decided[781] not to prepare a standard on this issue, but a technical report, which would make use of the outcomes of the European EVIAC[782] project which was being performed at the time.
At its 2000 meeting, TC69X, taking into account the technical developments in the field, decided not to go on with specific activity on this field but to wait for the ratification of the IEC 61980 standards. Accordingly, the work item was deleted from the TC69X program of work.[783]

5.5.3.3 *Environmental aspects: the work of TC69X WG2*

WG2, convened by Mrs. Bötner of PGE, had its first meeting in S. Pietro di Strà, Italy, in May 1994[784]. It took on an ambitious working programme, its initial work being focused on several topics:

5.5.3.3.1 Gaseous and chemical emissions produced by batteries of different kinds, and ventilation required

The work started from a draft proposal that had been prepared by Italian experts mainly based on the German VDE 0510-3 standard (see also §4.2.6.1.2). It also took into account input from CEN TC301 work in progress[785]. Discussions on this subject among the WG involved areas like ventilation criteria and building regulations[786] for garages; the need was felt to produce two standards, one for private and company garages (project prEN 50BBB-1) and one for public garages (project prEN 50BBB-2).

A draft for prEN 50BBB-1 was circulated to TC69X in 1996, and integrated into a secretariat document by a specially appointed editorial committee. No decision was taken about the real need to distinguish between private and public garages. [787]

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779 CLC TC69X, Minutes of the fifth meeting, 1996-05-23, Doc. CLC/TC69X(Sec)27
780 CLC TC69X, Minutes of the sixth meeting, 1997-09-17, Doc. CLC/TC69X(Sec)31
781 CLC TC69X, Minutes of the eighth meeting, 1999-09-14, Doc. CLC/TC69X(Sec)40
782 EVIAC, op.cit.
783 CLC TC69X, Minutes of the ninth meeting, Decision 7-1
784 CLC TC69X WG2, Minutes of the meeting in S. Pietro di Strà, 1994-05-26/27, Doc. 16, p1
785 Doc. CEN TC301/WG4/N120, Electric road vehicle - ventilation of closed areas used for charging
786 Example from Italy considered by WG2: "Norme di sicurezza per la costruzione e l'esercizio di autorimesse e simili", Gazzetta ufficiale, 1986-02-15
787 CLC TC69X, Minutes of the fifth meeting, 1996-05-23, Doc. CLC/TC69X(Sec)27

This draft was circulated in 1997 as document prEN50276; this document seemed technically correct but encountered strong objections, particularly from France where a regulation was in preparation and some conflicts might occur.[788]
With WG2 no longer in activity by that time, the work was transferred to the JWG TC21X/TC69X (§5.5.3.4).

5.5.3.3.2 Airborne acoustical noise emitted during charging (project prEN 50CCC)

Noise emissions during charge were considered a "fundamental problem" by WG2[789]; it was considered that the noise during battery charging, whether it came from the charger itself or from cooling fans, could be a major disturbance that had to be contained.

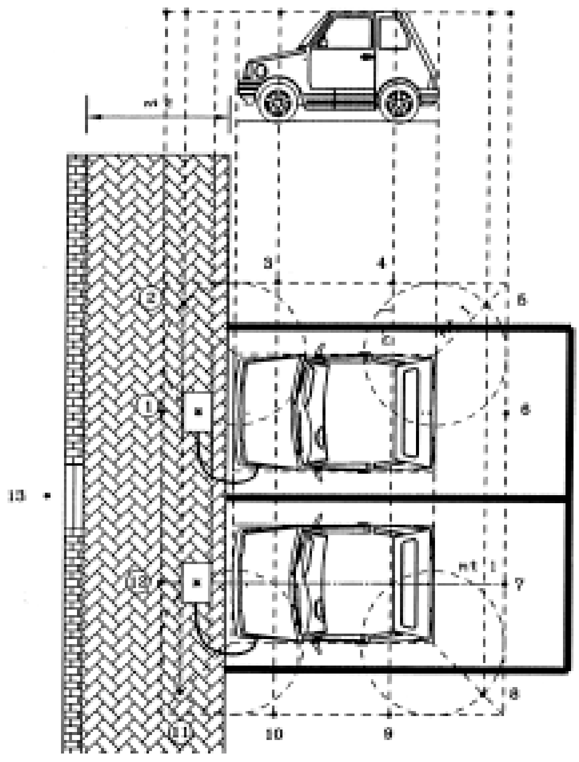

Figure 5.40: Noise measurements during charging[790]

[788] CLC TC69X, Minutes of the sixth meeting, 1997-09-17, Doc. CLC/TC69X(Sec)31
[789] Presentation of WG2 activity at TC69X meeting, 1994-03, Doc. CLC/TC69X/WG2/DOC1
[790] CLC/TC69X/WG2, working document. The discerned reader will recognize the particular silhouette of the PGE electric vehicle.

The need was thus felt to have a common European way to measure acoustical noises during charge, in order to make possible providing both new apparatus or installations with a certified noise level. Furthermore, it was deemed interesting to verify if there is a minimum distance to respect between two charging points, in order to maintain audible sound within tolerated levels.

Based on existing (Italian) law on noise limitation, and on some initial work performed by CEN TC301[791] (see also §5.5.8.2), an extensive proposal[792] was drafted for noise measurement techniques on electric vehicles under charge; an example of measurement set-up is shown in Figure 5.40.
On the fifth TC69X meeting in 1996[793], it was decided to suspend the work on this item to avoid duplication of work with CEN, the matter being concerned as a vehicle-related issue which would be the province of CEN TC301, who would perform further work on the subject (see §5.5.8.2).

5.5.3.3.3 Disturbances and interferences associated with the charging process (project prEN 50DDD-1)

This topic embraced the complex problematic of electromagnetic compatibility. Attention was focused on the following topics:
☞ Immunity of charging systems to disturbances and interferences
☞ Admitted level of emissions of charging systems
The WG studied the documents which had been prepared by IEC TC69 WG4 on charging infrastructure, which were punctually analysed. It was however of the opinion that further work was needed, concerning the development of all other EMC aspects.[794]
A draft for the first part, concerning harmonics, was circulated in the fall of 1995, which was a result of work by Italian experts based on IEC 61000-3-2.
The potential input from IEC TC69 WG4 was again raised at the 1996 TC69X meeting[795].

By 1997, WG2 had ceased its activity, without having produced any full standards by itself despite having been very active in its first phase.
The work on this subject however was deemed essential to be continued, normative guidance being needed in Europe more than elsewhere because of the EMC directive[796]. The TC69X Secretary had foreseen to prepare a first draft by the end of

[791] Doc. CEN TC301/WG4/N112, Technical report on limits of airborne noise from the charging of electric vehicles, 1994
[792] Doc. CLC/TC69X/WG2/SG2/DOC 15
[793] CLC TC69X, Minutes of the fifth meeting, 1996-05-23, Doc. CLC/TC69X(Sec)27
[794] CLC TC69X WG2, Report from the convenor to TC69X, 1994-11-16, Doc. 32
[795] CLC TC69X, Minutes of the fifth meeting
[796] CLC TC69X, Minutes of the sixth meeting, 1997-09-17, Doc. CLC/TC69X(Sec)31

1998; it was eventually decided however to delete this item from the agenda of TC69X, the aspect being covered sufficiently by the new international standard IEC 61851[797].

5.5.3.3.4 Assessment of electromagnetic fields associated with vehicle operation and charging (project pREN50DDD-2)

This topic was added from the defunct WG3. Not much work was done on it at first, since the project was announced to be delayed on the 1995 TC69X meeting[798]. On the next meeting in the Spring of 1996, it was stated that this part might be issues as ENV.
After the demise of WG2, activities on the subject were continued by TC69X in order to draft a Technical Report (and not a Standard)[799]. It was suggested to work in co-operation with CEN, and to create a JWG to prepare this technical report.[800] This was endorsed by CEN TC301, who mandated two experts, Dr. Brusaglino and Mr. Pineau, to collaborate with TC69X. It was decided however not to start the activity before the work of TC69X WG3 would be completed, and to establish at that date a new JWG CLC TC69X/CEN TC301[801].

5.5.3.4 TC69X and the battery standardization work of TC21X

The CENELEC BT had asked TC69X and TC21X (the Technical Committee working on batteries) to work together in a joint working group. A meeting of this JWG took place in Milan on October 21, 1998. As a result of this meeting, the decision was taken to delete the subject "Gaseous emissions" from the work programme of TC69X and to incorporate the specifications from preN 50276 as paragraph 6 of prEN 50272-3 "Safety requirements for secondary batteries and battery installations - Part 3: Traction batteries", which was being prepared by TC21X.

A draft version was circulated for comments in 1999[802]; the final draft of this document was circulated in July 2000. TC69X took note of this document and made several comments:

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[797] CLC TC69X, Minutes of the eighth meeting, 1999-09-14, Doc. CLC/TC69X(Sec)40
[798] CLC TC69X, Minutes of the fourth meeting, 1995-11-23, Doc. CLC/TC69X(Sec)25
[799] CLC TC69X, Minutes of the seventh meeting, 1998-09-14, Doc. CLC/TC69X(Sec)35
[800] CLC TC69X, Minutes of the eighth meeting,
[801] CLC TC69X, Minutes of the ninth meeting, Decision 6
[802] Doc. CLC/TC21X(Sec)90, 1999-05

- TC21X did not reproduce TC69X's proposal exactly.
- The requirements defined by TC21X are based on regular lead-acid batteries, and are not suitable for advanced batteries fitted with a BMS. Particularly, the demand for air ventilation on controlled charging systems seemed excessive.

In this framework, TC69X decided[803]:

- To confirm its availability to co-operate with TC21X in order to modify the document in a way not to hinder the future development of EV meanwhile fulfilling safety requirements.
- To invite TC69 experts to analyse and comment the document through their national committees.
- To establish an ad-hoc WG, in charge of elaborating an alternative proposal.

The European standard EN 50272-3 was published in 2002. It will be maintained by TC21X with parallel information to TC69X.
The document is based on a number of national European battery standards (including BS 6287 and VDE 0510, cf. §4.2.6.1), as well on the European standards for electric vehicle safety (EN 1987-1, cf. §5.5.9) and electric truck safety (EN 1175, cf. §4.2.6.2).
EN 50272-3 applies to secondary batteries and battery installations for traction applications, including electric industrial trucks, electric road vehicles and battery-electric locomotives. It covers lead-acid, nickel-cadmium and other alkaline batteries.[804]
This standard provides safety requirements covering the following issues:

- Protection against electric shock; when discharging the battery on the vehicle, the following requirements apply:
    - Nominal voltage ≤ 60 V: no protection against direct contact required.
    - Nominal voltage > 60 V and ≤ 120 V: protection against direct contact required.
    - Nominal voltage > 120 V: protection against direct and indirect contact required.
- Protection of short circuits and protection from other effects of electric current
- Provision against explosion hazards by ventilation: specifications are given for ventilation requirements.
- Provision against electrolyte hazard.
- Battery containers and enclosures
- Accommodation for charging/maintenance
- Battery peripheral equipment/accessories:
    - Battery monitoring system.
    - Central watering system.
    - Central degassing system.

803 CLC TC69X, Minutes of the ninth meeting, Decisions 5-1, 5-2, 5-3
804 EN 50272-3:2002, Scope

- ☚ Thermal management system.
- ☚ Electrolyte agitation system.
- ☚ Catalyst vent plugs.
- ☚ Connectors (plugs/sockets)

5.5.3.5 *Connection devices: the work of TC69X WG3*

5.5.3.5.1 Inception of WG3

In 1998, the European commission expressed a wish to the General Assembly of CENELEC to get a standardized European plug for the electric vehicle. As a result, the 96BT made the following decision:

> *"96/38 BT decided to prepare a European standard covering the connections for conductive charging of electrical vehicles and to allocate this work to CLC TC69X, inviting them to take due account of the French contribution and of the work in progress in that field, in particular of the future ENV50275 series."*[805]

The chairman of TC69X, Mr. Thione, who branded this a "political decision", then decided to form a new working group, WG3 "Connective device for EV conductive charging", with as scope:

> *"To standardize the physical and operational characteristics and requirements of plugs, socket-outlets, inlets and connectors specifically designed and used for charging of EV, installed on the EV charging station or fitted to the EV charging cable or mounted on the vehicle in order to ensure the interoperability of the EV in different locations and conditions."*[806]

The next two years, TC69X WG3 would congregate seven times, to discuss its working plan and objectives, [807] and refining its scope:

> *"Considering the lack of widespread devices meeting the requirements of EV charging (modes 1 to 3) in Europe, the objective of CLC TC69X WG3 is to prepare a technical specification for EV charging connective devices, based on the functional requirements of IEC publication 61851 and to compare technical solutions proposed by the industry, to choose and to propose an unified solution for the interface design e.g. in form of standard sheets, in cooperation with IEC SC23H WG6."*[808]

In 1999, the German National Committee however requested to CENELEC BT that WG3 be disbanded, because of the overlap of its activities with IEC SC23H WG6. 108BT replied that WG3 could remain in existence as long as it monitored the IEC work and did not create its own work. This decision of BT was endorsed by TC69X

[805] CLC TC69X, Minutes of the seventh meeting, 1998-09-14/15, Doc. CLC/TC69X(Sec)35
[806] Ibid.
[807] Doc. CLC/TC69X/WG3/Paris(1), Minutes of the meeting in Paris, 1999-06-16
[808] Doc. CLC/TC69X/WG3/Paris(2), Minutes of the meeting in Mendrisio, 1999-09-15

not to stop WG3 work but to recommend it to value and possibly support/accelerate the IEC work.[809]

WG3 considered a number of solutions that were present on the market, deciding to base its requirements on IEC 61851, thus requiring the control pilot, and to restrict the current rating to 32 A, in accordance with the requirements for the "basic" interface of IEC 61851-1. Specifications for the accessories would be based on "IEC 60309-EV", the IEC SC23H document.

One main issue of discussion was the intermateability with existing IEC 60309-2 accessories. This concept was based on the Mennekes design (cf. §5.2.6), about which the issue of intellectual property was raised; this was clarified however through a statement by Mennekes that in case of demand the solution would be available for other manufacturers.[810]
The Italian experts presented a dedicated plug and socket-outlet developed by Scame of Italy, fitted with an extra contact for the control pilot, which was not interplugable with any existing accessory. Interplugability was not desired in Italy, for safety reasons. Considerable discussions concerned this "private" solution, which was deemed contraproductive from a standardization point of view. Due to the needs expressed by the Italian committee, where a non-interplugable infrastructure was being required by the government, the interplugable solution was not acceptable for Italy[811]. The scope of WG3 had thus to be extended to include in its report a so-called "Type 2" non-interplugable device[812]. This decision was endorsed by TC69X.[813]
The general agreement in WG3 supported the interplugable solution however.

5.5.3.5.2 The CENELEC connector report

TC69X recommended to publish the WG3 document in the form of a CENELEC report, subject to formal approval of CENELEC BT, to be transmitted to IEC SC23H WG6 for consideration and inclusion in the future standard IEC 62196.[814]
The draft document was finalized on the last meeting of WG3 which took place in Fehraltorf, Switzerland, on March 27, 2001, and subsequently sent to TC69X for circulation to the National Committees[815]. It was approved by TC69X in September, and endorsed by CENELEC BT in December 2001.

[809] CLC TC69X, Minutes of the eighth meeting
[810] Doc. CLC/TC69X/WG3/Paris (Sec4), Minutes of the meeting in Essen, 2000-01-25
[811] Doc. CLC/TC69X/WG3/Sec 8, Minutes of the meeting in Milan, 2000-06-16
[812] Doc. CLC/TC69X/WG3/Sec 8bis, Minutes of the meeting in Paris, 2000-11-22
[813] CLC TC69X, Minutes of the ninth meeting, Decision D4
[814] CLC TC69X, Minutes of the ninth meeting, Decision 3
[815] Doc. CLC/TC69X/WG3(CONV)16, Minutes of the meeting in Fehraltorf, 2001-03-27

In March 2002, the final version of the report R069-001 "AC connection devices for electric vehicle conductive charging" was eventually published.
This report proposes two different sets of requirements for EV connection devices, corresponding to two different approaches[816]:

- ☞ "Type 1" connection devices: Electric vehicles should benefit from existing infrastructure. Compatibility requirements allow them to be charged on standardized socket-outlets.
- ☞ "Type 2" connection devices: Electric vehicles may only be charged on dedicated socket-outlets. The infrastructure permits only Mode 3 charging and prevents compatibility with existing socket-outlets.

The report proposes draft standard sheets for the two types, based on existing commercial products: the Mennekes adapted IEC 60309-2 plug (see also §5.2.6) for Type 1 and the Scame EV plug for type 2.
The next step for WG3 is to issue standard sheets in co-operation with IEC SC23H WG6 and its IEC 62196 standard (§5.2.6).

5.5.3.5.3 Type 1 connection devices

These are based on EN60309-2, with the following additional requirements:

- ☞ Plug and inlet are interplugable with the corresponding socket-outlet and connector EN 60309-2 rated 16/20 A - 6h[817] (a three-phase configuration is also provided)
- ☞ Power contacts are rated 32 A.
- ☞ Up to three additional signal contacts are provided (one mandatory for the control pilot and two optional for the power indicator).
- ☞ Accessories may be fitted with a device to detect a fully inserted mating accessory.

A drawing of the concept is given in Figure 5.41.

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[816] Ibid., Foreword
[817] This "6h" does not refer to a time rating, but to the relative position of the earth contact on the 60309-2 accessory.

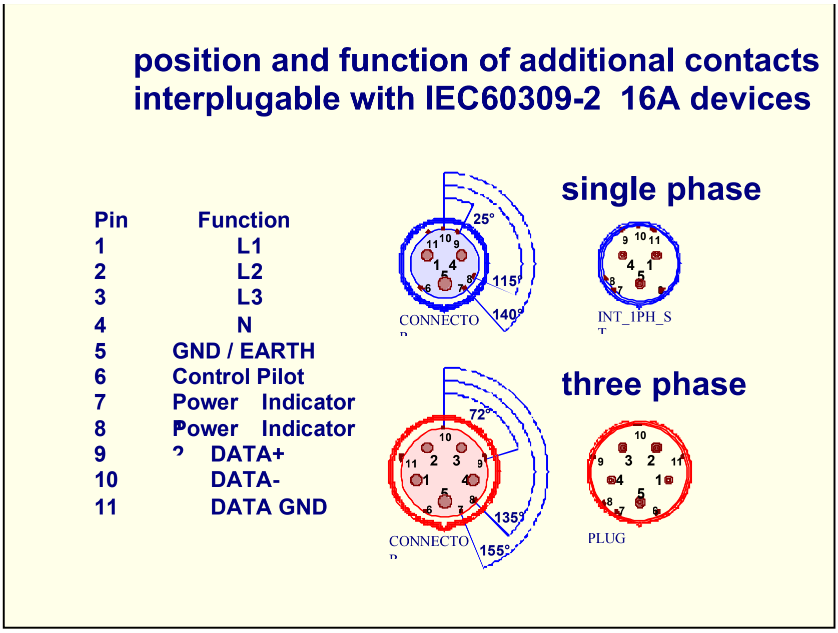

Figure 5.41: Concept sheet for connection devices type 1[818]

5.5.3.5.4 Type 2 connection devices

These are dedicated to EV charging, permitting charging under Mode 3 and preventing compatibility with existing socket-outlets.
Specific additional requirements apply to meet the need of EV:

- Power contacts are rated 16 A.
- One additional contact is provided for the control pilot.
- Two additional contacts may be provided.
- Accessories may be fitted with a device to detect a fully inserted mating accessory.

These devices shall not be compatible with any device which is complying with the common industrial and domestic plugs described in the standards EN 60309-2, EN 60320 or IEC 60083.
A drawing for a typical Type 2 construction is given in Figure 5.42. This particular type of plug is also described in a draft Italian national standard[819].

[818] CLC R069-001:2002, Annex A
[819] Comitato Elettrotecnico Italiano, Progetto C.773, Foglio di unificazione di prese a spina per la connessione alla rete elettrica di veicoli elettrici stradali

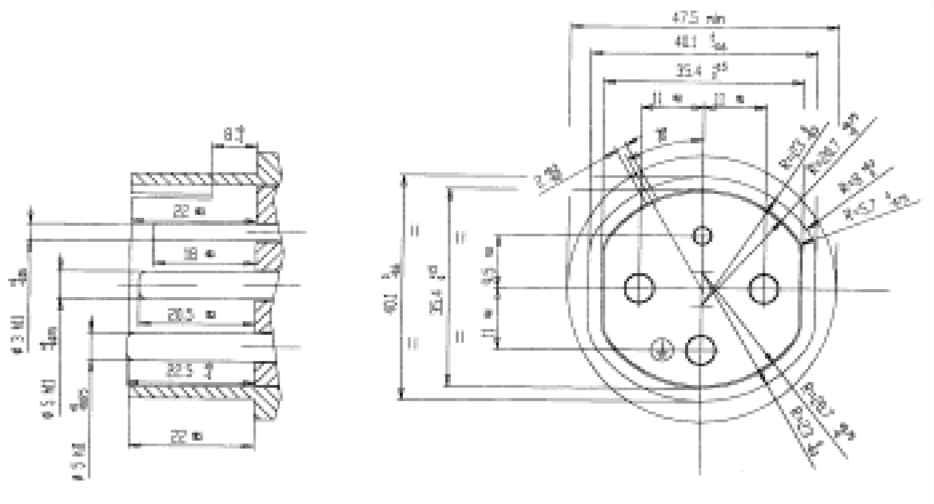

Figure 5.42: Typical construction of a type 2 plug[820]

[820] CLC R069-001:2002, Annex B

5.5.4 CEN: Introduction

CEN, the European committee for standardization, was founded in 1961 in Paris. In 1975 it moved to Brussels and became an international association under Belgian law, a statute it shares with CENELEC, and also with organizations like CITELEC and AVERE. Its aim is described in its statutes:

> *The aim of the association is the implementation of standardization throughout Europe to facilitate the development of the exchange of goods and services, by the elimination of the barriers set by provisions of a technical nature. It therefore implements technical, scientific and economic procedures specific to the standardization studies, in conjunction with the International Organization for Standardization (*ISO*) and any other private or public organization representing European and worldwide interests. It facilitates the development of procedures for the mutual recognition of conformity test results to standards, as well as for European systems of conformity assessment to standards, to be implemented either by* CEN *itself or by other parties.*[821]

CEN is the only European organization recognized by Directive 98/34/EC[822] for the drafting and adoption of European standards in all areas, with exception of electrotechnology (dealt with by CENELEC) and telecommunication (dealt with by ETSI). Members of CEN are the national standardization organizations.

CEN considers itself as an integrated system, the "CEN-system" for European standardization, aiming to support the achievement of the European single market and to enhance the competitiveness of European players in the global market, by ensuring the most efficient input of Europe to international standardization activities and co-operation.

Co-operation between CEN and ISO is regulated through the so-called "Vienna Agreement", - the pendant of the "Lugano" or "Dresden" agreement between IEC and CENELEC - which essentially recognizes the primacy of international standards, but which takes into account the particular need for regional standardization in Europe. The agreement defines two modes for collaboration, either under ISO or under CEN lead, with documents developed within one body notified for the simultaneous approval by the other. The main issue is to avoid the duplication of work.

The role of CEN and CENELEC in European standardization and regulation will be enhanced through the EU's so-called "New Approach", which will be further discussed in §5.5.11.

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[821] CEN statutes, (edition 1995)

[822] Directive 98/34/EC

5.5.5 CEN TC301

Like most other standardization bodies, CEN is organized through Technical Committees. TC301 is responsible for "Electrically propelled road vehicles".
CEN TC301 was created in 1992, at the demand of the French National Committee[823], due to the demand from car manufacturers to have harmonized European standards on electric vehicle performance evaluation and safety, the corresponding committee for international standards, ISO TC22 SC21, not having met for several years. The first meeting of TC301 took place on October 15-16, 1992[824]. On this occasion, the scope and mission of the TC were discussed, as well as the relationships with ISO, IEC and CENELEC, which had just passed its work of task force BTTF 71-1 to IEC TC 69 (§5.5.2). There was some resent about this passing of activity to IEC, as the stake was seen as mostly "European". Furthermore, German car manufacturers reported about

> *"the difficulty in making their views heard within authorities in which 'electricians' were in the majority"*

and therefore proposed that the linking of the vehicle to the power supply terminals should not be delegated to the IEC but to the ISO.

At the beginning five working groups were created:
☞ WG1: Performance measuring methods
☞ WG2: Safety of regenerative braking
☞ WG3: Noise during recharging
☞ WG4: Liaison and dialogue between vehicle and charging station
☞ WG5: Safety - other aspects

The work of WG3 would be integrated into WG4. [825]

On its third meeting in November 1993[826], the problem of regulations and type approval was considered. It was approved that electric vehicles had to be considered just like thermal vehicles for type approval purposes, and that therefore existing directives and regulations should be adapted to cover electric vehicles when possible. This could be performed either using the "old" or the "new" approach (cf. §5.5.11). The German delegation was in favour of the old approach, meaning that the future CEN standards would have to be integrated in the directives. The choice between old and new approach however felt beyond the scope of the TC.

[823] G. Brusaglino et al., Development of standards for electrically propelled road vehicles in the European committee for standardization, Technical Committee 301, EVS-16, Beijing, 1999
[824] Doc. CEN TC301 N4E, Minutes of the 1st meeting in Paris, 1992-10-15/16
[825] Doc. CEN TC301 N22E, Minutes of the 2nd meeting in Paris, 1992-12-17
[826] Doc. CEN TC301 N22, Minutes of the 3rd meeting, 1993-11-08

Another issue discussed concerned the collaboration with CENELEC TC69X, and the draft agreement reached (cf. §5.5.3.1) which had been created in July 1993, was discussed. It was recognised that the split between car manufacturers and electricians had historical backgrounds.

The subject was further discussed at the next TC301 meeting[827], where it was stated that duplication of work had to be avoided; the opinions on the draft agreement diverged however: whileas a number of delegates approved the agreement, others were against, in particular the German delegation, who stated:

- *that the vehicle had to be regarded as a whole because of the interconnection of the systems;*
- *that the work was already in progress at ISO;*
- *that, if there was an urgent European need, the work should be conducted by CEN.*

The chairman of CENELEC TC69X, Mr. Thione, who attended the CEN TC301 meeting, highlighted the fact that

> *"the electric vehicle presented the particularity of being connected 90% of its lifetime to the network"*

and that thus CENELEC would concentrate on the charging system aspects.

TC301 did not achieve a common position on the matter[828], as stated before (§5.5.3.1), a formal agreement would only be reached in 1995.

5.5.6 Performance standards: the work of CEN TC301 WG1

5.5.6.1 Introduction

WG1, under the convenorship of Dr. Brusaglino, started its work on performance standards for "electrically propelled road vehicles", encompassing both electric and hybrid vehicles.

As it proved difficult to consider a comprehensive standard for all types of hybrid vehicles, it proved necessary to make the distinction between hybrids fitted with a thermal engine (ICE-powered generator) and other types (including fuel cell generators)[829],

The work programme of WG1, as approved in 1994[830], considered three classes of vehicles:

- "Pure electric vehicles", i.e. battery-electrics.
- "Thermal hybrid vehicles", i.e. hybrids fitted with a ICE engine.
- "Other hybrid vehicles than those fitted with a thermal machine", this includes fuel cell vehicles.

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[827] Doc. CEN/TC301 N42E, Minutes of the 4th meeting in Paris, 1994-03-24

[828] Doc. CEN/TC301 N68E, Resolution 31 taken at the 7th meeting, 1995-03-30

[829] Doc. CEN/TC301 N51E, Minutes of the 6th meeting in Paris, 1994-10-14

[830] Doc. CEN/TC301 N52E, Resolution 27 taken on the 6th meeting, 1994-10-14

For each class of vehicle, the following standards would be drafted:
☞ "Measurement of road operating ability"
☞ "Measurement of energy performance"
☞ "Measurement of emissions" (this one not for the pure electrics of course!)

5.5.6.2 EN 1821-1: Road operating ability

A first working item, "Measurement of road operating ability of pure electric vehicles" was issued in November 1993[831], and presented to TC301 in March 1994[832]. This document was prepared in harmonization with ISO TC22 SC21[833].
It was circulated in 1995 to national committees as prEN 1821-1[834] for comments. It was accepted by all voting members except Austria and Germany[835]. The negative position of Germany was not based on the content of the draft itself, but on the fact that the German committee preferred to have the corresponding international standard (ISO 8715, §5.3.4.4) being approved as an European standard[836]. TC301 had however initiated this work, with ISO TC22 SC21 following, and thus the CEN document was much more advanced than the ISO draft.
TC301 resolved to submit the document for a formal vote, and to request ISO TC22 SC21 to align the draft ISO/DIS 8715 as close as possible to prEN1821-1.[837]

The final standard EN 1821-1[838] "Electrically propelled road vehicles - Measurement of road operating ability - Part 1: Pure electric vehicles" was published in August 1996, that is five years before the corresponding ISO document.

It specifies test methods to measure road performances of electric road vehicles, and defines the following tests:
☞ Maximum thirty minute speed
☞ Maximum speed
☞ Acceleration 0 to 50 km/h
☞ Acceleration 50 to 80 km/h
☞ Speed uphill
☞ Hill starting ability
The normative appendix to the standard states the procedure to determine the total road load power and the calibration of the dynamometer.

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[831] Doc. CEN/TC301/WG1 23
[832] Doc. CEN/TC301 N37
[833] Doc. CEN/TC301/WG1 N30, Minutes of the meeting in Helsinki, 1994-08-30
[834] Doc. CEN TC301 N79
[835] Doc. CEN/TC301/N77 Voting report on prEN 1821-1
[836] Doc. CEN/TC301 N83E, Minutes of the 8th meeting in Paris, 1995-11-28, ¶6.1
[837] Doc. CEN/TC301 N84E, Resolutions 34 and 35 taken on the 8th meeting, 1995-11-28
[838] EN 1821-1:1996 "Electrically propelled road vehicles - Measurement of road operating ability - Part 1: Pure electric vehicles"

These tests, and the procedure to perform them, are identical to those specified in ISO 8715:2001. The differences between the two documents are only of an editorial nature, and the relationship between them is clear.

The history of this standard underlines one of the problems related with international standardization: the fact that global work bears the risk to proceed on a much slower scale than regional work, and that regional standardization bodies may publish their own documents, in order to cover a demand for standards, before the international standards are ready. In this case, the documents are well aligned, so there is no risk for confusion, unlike the case with IEC 61851 vs. ENV 50275 discussed in §5.5.3.2.

When this standard was slated for review after 5 years, TC301 decided to keep it as it was.[839]

5.5.6.3 EN 1986-1: Energy consumption and range

WG1 also started the work on a standard for energy performance. A WG draft was circulated in 1994[840]. TC301 decided to limit the scope to vehicles of categories M1, M2, N1, N2 (cf. definitions in §5.8.5), i.e. cars, vans, minibuses and light trucks; heavy-duty vehicles of categories M3 and N3 were considered as within the scope of TC301, but they might require a separated standard for the measurement of the energy performances.[841]

The document, circulated as prEN1986-1, was submitted to national committees late 1995, and supported by all except France and Germany[842]. The Germans once again preferred the adoption of ISO 8714 as EN ISO 8714, whileas France asked to align the standard to ECE regulations. This concerned the choice of the cycles: the regulation ECE 101 (§5.8.10) only provided the mixed cycle (urban + sub-urban). WG1 proposed an alternative, to have only urban cycles[843]; this was subsequently endorsed by TC301[844], and the document was then submitted to formal vote.

EN 1986-1 "Electrically propelled road vehicles - Measurement of energy performances - Part 1: Pure electric vehicles" was published in July 1997.

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[839] Doc. CEN/TC301 N175, Minutes of the 17th meeting in Paris, 2001-02-07, Resolution 70
[840] Doc. CEN/TC301/WG1 N25, became CEN/TC301 N36
[841] Doc. CEN/TC301 N52E, Resolution 26 taken at the 6th meeting, 1994-10-14
[842] Doc. CEN/TC301 N88, Vote on prEN1986-1, 1996-02
[843] Doc. CEN/TC301/WG1 N44, Minutes of the 11th meeting in Paris, 1996-04-18
[844] Doc. CEN/TC301 N101, Resolution 45 taken on the 9th meeting, 1996-04-19

It describes procedures to apply in order to measure energy consumption and range, making use of two test cycles[845]:

☞ test sequence n° 1, consisting of four basic urban cycles (basic urban cycle shown in Figure 5.43). This basic cycle, taken from European directive[846], has a length of 1017 m and an average speed of 18,77 km/h. Maximum acceleration is 1,04 m/s^2.

☞ test sequence n° 2, consisting of four basic urban cycles and one extra-urban cycle (extra-urban cycle shown in Figure 5.44). The extra-urban cycle has a length of 6956 m and an average speed of 62,6 km/h; the average speed of the test sequence n° 2 is 33,6 km/h for a total distance of 11 km. Maximum acceleration is 0,69 m/s^2.

The energy consumption test can consist of:

☞ either seven times test sequence n° 1; this gives a distance of 28 km.

☞ or two times test sequence n° 2; this gives a distance of 22 km.

The first option is more appropriate when comparing electric vehicles among each other, particularly if low-speed vehicles are involved; the second one is appropriate for comparing EV with ICE vehicles.[847]

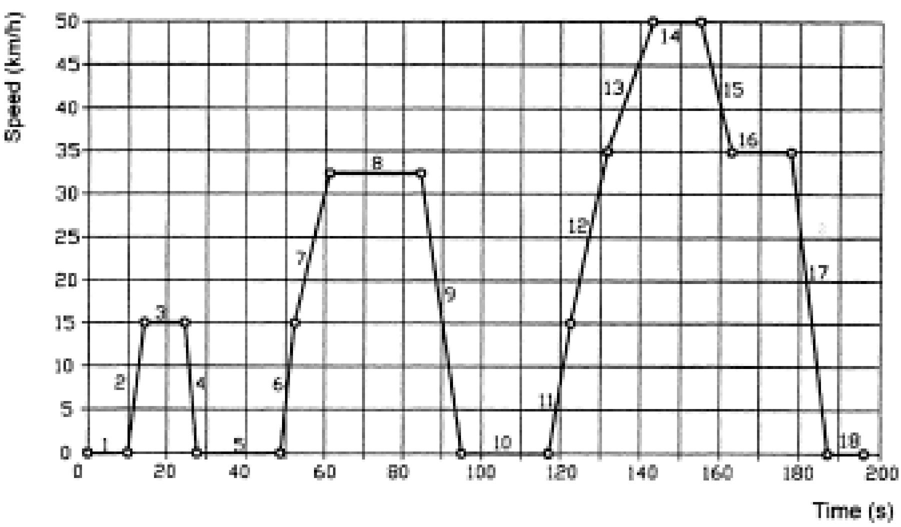

Figure 5.43: European urban cycle[848]

[845] EN 1986-1:1997, ¶4.1

[846] Council Directive 91/441/EEC

[847] EN 1986-1:1997, ¶5.1

[848] EN 1986-1:1997, ¶4.1.1

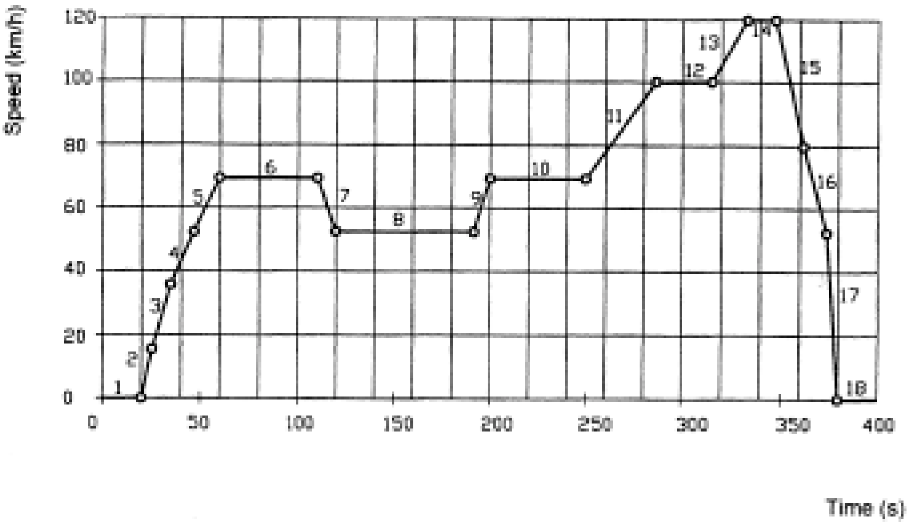

Figure 5.44: European extra-urban cycle[849]

The vehicle is recharged after the test procedure, this means after having covered a distance of 28 or 22 km only; this is way below the actual range of a typical electric vehicle. The recharge will thus be a partial one, and the measured energy consumption will be higher than the consumption measured after a full discharge due to the influence of the consumption of the final charge. This argument was the subject of a comment made by the Belgian committee (i.e. by the author) on the draft of 1986-1. [850] (cf. the remarks on ISO 8714, §5.3.4.3)

The maximum range of the vehicle is measured[851] through driving test sequence n° 2 until the end-of-test criterion is met, which can be either:[852]

- ☞ when the vehicle is unable to meet the reference curve up to 50 km/h
- ☞ when an indication is given by the vehicle to the driver to stop.

The document EN 1986-1 is mainly identical to ISO 8714:2002; the international standard however does not contain a specific test for range, just specifying "reference range" through its definition taken from the terminology standard ISO 8713.[853]

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[849] EN 1986-1:1997, ¶4.1.2
[850] Belgian comments (P. Van den Bossche, G. Maggetto) on prEN 1986-1, 1997-03-14
[851] EN 1986-1:1997 ¶6
[852] EN 1986-1:1997, ¶4.3
[853] ISO 8713:2002, ¶3.49

5.5.6.4 EN 1821-2, EN 1986-2, EN 13444-1

These standards, covering hybrid vehicles, will be discussed in the chapter on hybrids (§6.2.3 below).

5.5.6.5 Terminology: EN 13447

Although the subject "terminology" was initially dealt with by TC301 WG5, it would be taken over by WG1 after WG5 had finished its work on EN 1987, particularly concerning the definitions of various types of electric and hybrid vehicles[854].

A terminology standard may seem at first sight to be a mundane glossary of terms; the choice of these terms may however reflect particular visions on the subject, and may thus well be worth further consideration.
The drafting of the CEN terminology standard gave rise to considerable discussion, addressing in particular the issue of defining the types of vehicles and drive trains, and the parallel work which was going on in ISO on the document ISO 8713 (§5.3.4.2), on which a German delegate stated:

> *"Although you and myself are working here on a CEN-level, we should regard our work always as input into ISO."*[855]

One particular point of interest is the definition of a "hybrid vehicle"; the "type of vehicle" could in fact be defined using two different approaches[856]:

- ☞ The "energy approach", which makes reference to the external energy source supplied to the vehicle for traction purposes.
- ☞ The "traction approach", which makes reference to the type of engine powering the wheels of the vehicle.

An "electric vehicle" can thus be either an electrically supplied vehicle (energy approach), or an electrically propelled vehicle (traction approach) or both.

Initial drafts of the terminology document defined a "hybrid vehicle" as follows:

> *"An electric hybrid (road) vehicle is an electrically propelled road vehicle integrating an electric traction system which permits a pure electric driving mode, and having at least one additional other form of on-board energy source (for traction purpose).*
> *Note: Vehicles integrating an electric machine for functional assistance to the engine such as load-levelling device, starter, electrically driven auxiliary units, etc. shall not be considered as electric hybrid vehicles, in so far they do not allow a pure electric mode."*[857]

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[854] Doc. CEN/TC301 N84E, Resolution 38 taken on the 8th meeting, 1995-11-28

[855] Doc. CEN/TC301/WG1 N60, German comments on CEN/TC301/WG1 N57, by Dr. K. Orchowski, 1997-07

[856] Doc. CEN/TC301/WG1 N35, Minutes of the 7th meeting of WG1 in Stuttgart, 1995-07-06/07

This definition requires a pure electric driving mode, and thus excludes vehicles like the Toyota Prius (Figure 6.1), which has no pure electric driving mode (except at very low speeds) and where the electric machine can be considered indeed as a "load-levelling device", optimising the utilization of the ICE.
Such vehicles where not regarded as "true hybrids" by a number of European national committees. The presence in these committees of European car manufacturers (who did not have a similar product on offer) might well have been a factor in this standpoint. It was the opinion of TC301 delegates that

> *"if the electric energy source was only used for assistance to the ICE, the vehicle should not be considered as an electric hybrid vehicle to be covered by TC301 with specific test procedures (although it is recognized that there is a rate of hybridation)"*[858]

The "note" in the definition above was also reproduced in the definition of "thermal electric hybrid vehicle" in the standard EN 1986-2 (discussed in §6.2.3.2), the last phrase "in so far they do not allow a pure electric mode" changed however in

> *"in so far they do not participate in the traction"*[859]

This statement does include vehicles like the Prius, where the electric motor does participate substantially in the traction, but, to our opinion, excludes "mild hybrids" or "alternator-starter" types, which indeed cannot be considered true hybrids (although they may feature some kinetic energy regeneration). (cf. §6.1).

The problem of defining the hybrid vehicle was discussed by WG1 on its October 1998 meeting, which followed the EVS-15 symposium in Brussels. Two papers on this symposium highlighted the definition and classification of electric drivetrains, one by Dr. Victor Wouk[860], who highlighted the definitions from IEC TC69 WG5, and one by Mr. Joseph Beretta[861], who presented his structural overview which will be presented in Figure 6.5. The "Beretta" approach was favourably considered by TC301 WG1; in the following draft version, the definition of hybrid vehicle was adopted as follows:

> *"Hybrid vehicle: vehicle in which the propulsion energy is available from two or more types of on-board energy sources, creating at least one path of energy flow between an energy storage and the wheels which is reversible and at least one path of energy flow between an energy storage and the wheels which is not reversible".*[862]

The key element in this definition is the notion of a reversible energy source on board the vehicle. Such reversible energy source is invariably associated with an energy storage device.

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[857] Doc. CEN/TC301/WG1 N73, 1997-12. This is the last draft in which this definition appears.
[858] Doc. CEN/TC301 N138E, Minutes of the 13th meeting in Paris, 1998-07-09, ¶6
[859] EN 1986-2:2001, ¶3.3
[860] Victor Wouk, IEC TC69 definitions of hybrid vehicle and related terms, EVS-15, Brussels, 1998
[861] Joseph Beretta, New classification on electric-thermal hybrid vehicles, EVS-15, Brussels, 1998
[862] EN 13447:2001, ¶3.2.3; this definition first appeared in Doc. CEN/TC301/WG1 N77, Minutes of the 18th meeting in Torino, 1998-10-14/15

The issue was further discussed on the plenary TC301 meeting in January 1999[863], where the issue was raised whether not externally chargeable vehicles like the Prius would need the definition of a specific test procedure. Reference was made to the American SAE J1711 document (§6.2.4.1) that covered this particular case.

The terminology document was circulated among national committees as prEN 13447[864], and eventually approved and published as European standard EN 13447:2001 "Electrically propelled road vehicles - Terminology" in 2001.
The aim of this standard is to give definitions used in European standards for electrically propelled road vehicles, in order to permit a good understanding of these standards[865].
EN 13447 differs considerably from the corresponding international standard ISO 8713. Its 67 lemmata do not form an alphabetic glossary, but are organized by theme, with a large attention being considered to the types of electrically propelled road vehicles, of which 14 types are distinguished. These definitions are absent from ISO 8713, which states however that

> *"an appropriate definition of the expanding family of electric road vehicles requires further consideration"*[866]

Furthermore, the definitions of magnitudes in relationship with the road operating ability or the energy performances (like "maximum speed" or "energy consumption") state the references to the specific standards where test methods for these magnitudes are specified.
The definitions concerning subsystems and electrical circuits are largely equivalent to the ISO standard; EN 13447 however introduces the notion of "ancillary"[867] functions, as opposed to the non-traction related "auxiliary" functions:

> *"an ancillary function is a necessary function for the correct operation of the traction system of the vehicle. It is usually performed by actuators or sub-systems of the traction system, as cooling system, pump, but not involved in the direct traction flow"*[868].

The overall aspect of an electric traction system as presented by EN 13447 is shown in Figure 5.45, highlighting the definitions of "power train", "drive train" and "power circuit".

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[863] Doc. CEN/TC301 N146E, Minutes of the 14th meeting in Paris, 1999-01-19
[864] Doc. CEN/TC301 N156, Voting on pren 13447, 1999-12
[865] EN 13447:2001, ¶1, Scope
[866] ISO 8713:2002, ¶1, Scope
[867] "Ancillary" is erroneously spelt "ancilliary" in EN 13447:2002
[868] EN 13447:2002, ¶4.5

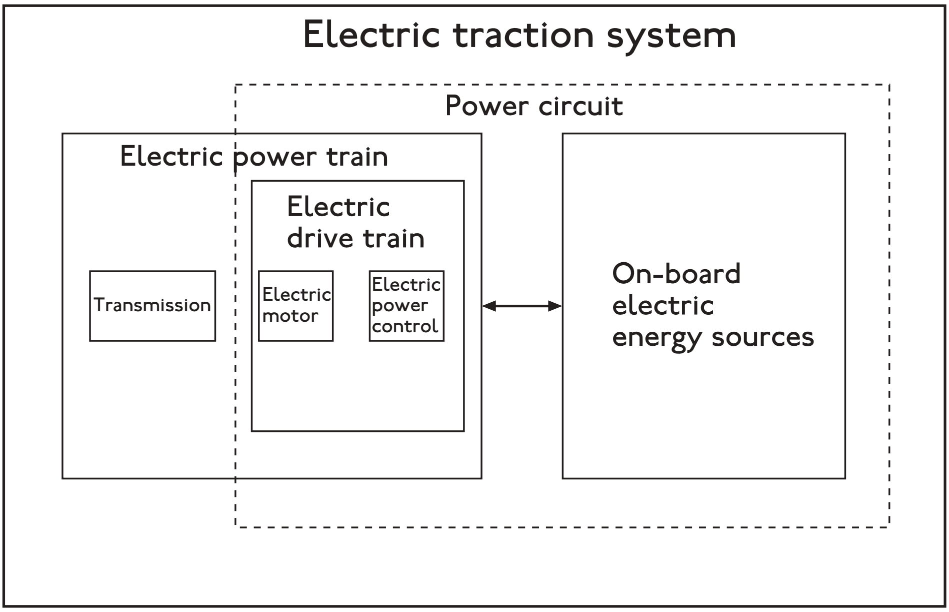

Figure 5.45: Electric traction system[869]

5.5.7 Braking: the work of TC301 WG2

The first document published by TC301 would emanate from WG2. It was a technical report[870] CR1955:1995 "Proposals for the braking of electric vehicles", taking into account the effects of regenerative braking and their potential influence on vehicle safety.

The report made a number of proposals to adapt the relevant European directive[871]:

☞ All current regulations concerning retardation and braking proportion between axles shall be respected, both in clutched and declutched positions (if any).

☞ A switch to inhibit regenerative braking shall not be allowed. Such switches were provided on a number of early electric vehicles, to overcome problems with regenerative braking on low adhesion (slippery) roads. The CEN experts were of the opinion however that

> *"it seems illusive to guarantee a correct operation of this switch."*[872]

☞ In case of failure of the braking system, a red warning light should be provided.

☞ Brake tests may have be adapted to suit electric vehicles, since standard brake test might last more than one discharge of the battery.

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[869] EN 13447:2002, Figure 3
[870] CEN CR1955:1995 Proposals for the braking of electric vehicles
[871] Council Directive 71/320/EEC
[872] CEN CR1955:1995, ¶3

☞ The control of the service braking shall remain adjustable and gradual whatever the state of the battery is.
☞ For electric vehicles fitted with an anti-lock braking system, the current regulation for ICE vehicles with anti-lock system shall be applied.
☞ For electric vehicles with a separate control device for the friction brake and the regenerative brake, current regulation for ICE vehicles fitted with an independent retarding system shall be applied.

This report would never make it into a standard however; taking into account that the subject was being covered by regulations (ECE 13, see §5.8.5), TC 301 decided to formally disband WG2 in 2001.[873]

5.5.8 The work of TC301 WG4

5.5.8.1 Liaison between vehicle and charging station

This item was the first main mission of WG4, where Dr. Sporckmann was the convenor. It was looked upon as a priority item mainly by French manufacturers, taking into account their introduction of electric vehicles in the market around 1995.[874] A draft proposal by France was circulated in December 1994[875]; a similar draft being presented in the same time to IEC TC69 WG4.[876] This document presented a data interchange based on the "Keyword Protocol 2000" described in the (then draft) international standard ISO 14230. The document was discussed on the TC301 meeting in March 1995[877]. As the subject belonged to the work programme of CENELEC TC69X, it would be further treated by that committee, an idea that was rejected by UK and German delegates who preferred it to be treated by ISO, being based on an ISO protocol.
The work would be continued by CENELEC TC69X WG1 and would emanate in the European prestandard ENV 50275-2-4 (§5.5.3.2).

5.5.8.2 Noise emissions during charging: EN 12736

Work on this subject had been initiated in 1994 by CEN TC301 WG3 (which got absorbed into WG4) and also by CENELEC TC69X WG2 (§5.5.3.3.2). From 1996, all the work got concentrated at CEN however.

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873 Doc. CEN/TC301 N175, Resolution 67 taken on the 17th meeting, Paris, 2001-02-07
874 Doc. CEN/TC301 N42E, Minutes of the 4th meeting, 1994-03-24, ¶5.3
875 Doc. CEN/TC301 N57, "Electric road vehicles - communication data link for the charging procedure" 1994-12
876 Doc. IEC/TC69/WG4 (France) 4
877 Doc. CEN/TC301 N67E, Minutes of the 7th meeting, 1995-03-30

A first document[878] was published in 1994, with the intention to publish it as a CEN technical report. It was a very short overview of the problem perceived, facing existing noise limitation in a number of countries. Its publication was rejected by the central secretariat of CEN however, and it was suggested to prepare a standard or pre-standard on the subject.[879]

WG4 drafted a proposal for a measurement method, based on the existing international standard ISO 3744 for measuring noise of industrial machines. It was not the purpose to fix any limits, as this was the job for the regulatory bodies.
This proposal presented a very complicated and extensive measuring procedure, involving not less than twenty-one microphones for vehicles up to 4 m long, or twenty-eight for vehicles up to 7 m long, as shown in Figure 5.46.

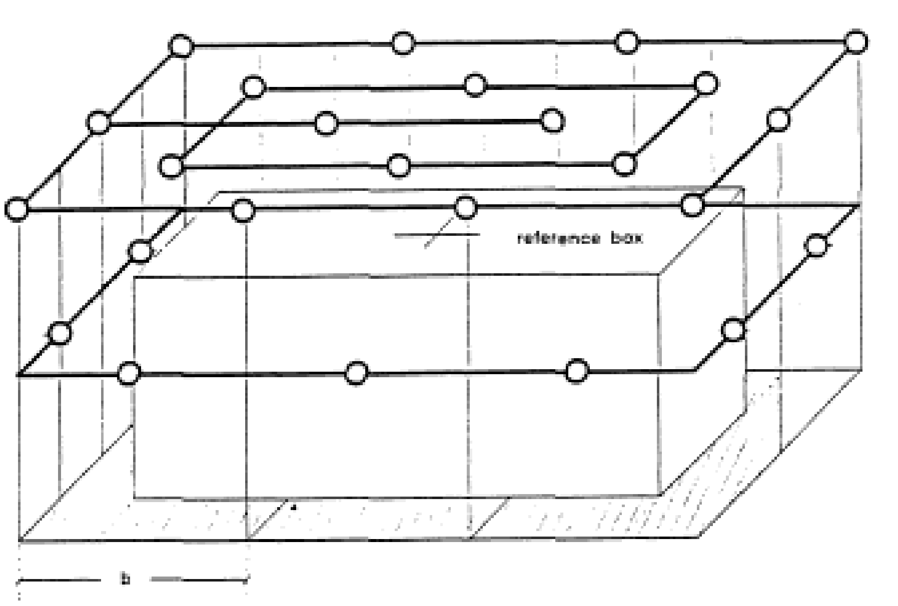

Figure 5.46: Position of microphones for noise measurement (draft prEN 12736)

The draft prEN 12736 got submitted to vote in 1997. It got negative votes[880], among others from Belgium, whose experts, P. Van den Bossche and G. Maggetto, stated,

> *"We do not support this document as EN, as we do not see the necessity of standardization in the field. The technological evolution of electric road vehicles has led to the widespread adoption of high frequency onboard chargers which have a low volume and weight. Their high frequency operation makes that the audible acoustic emissions are very low, and do not cause concern which may necessitate standardization."*[881]

[878] Doc. CEN/TC301 N41E "Limits of airborne noise from the charging of electric road vehicles", 1994-06-24

[879] Doc. CEN/TC301 N67E, Minutes of the 7th meeting in Paris, 1995-03-30

[880] Doc. CEN/TC301 N121, Voting on prEN12736, 1997

[881] Belgian comments on prEN 12736, 1997-03-14

TC301 commented on this remark by stating that the perceived noise problem from chargers was not only created by the charger itself, but rather by the ventilators which control the battery temperature[882].

Another negative comment came from France, who found the proposal much too complicated and too expensive, and who made a new draft[883], simplifying the procedure (using just one or two microphones) taking into account known and implemented test methods in the automotive field (ISO 362 and ISO 10844).
This revised draft got proposed for formal vote in 2001, and got again a negative vote from Belgium, who still saw no necessity for standardization on this subject. It can be argued in fact that this standard is an example of "overstandardization".

The European standard EN 12736[884] "Electrically propelled road vehicles - Airborne acoustical noise of vehicle during charging with on-board chargers - Determination of sound power level" was eventually published in 2002.
It specifies a procedure for measurement of noise emissions during charging, for electric vehicles fitted with on-board charger, from categories M1, M2, N1 and N2, and states, in its *informative* annex, different airborne noise limits existing in some European countries.

5.5.8.3 Ventilation of closed charging area

The problem of ventilating charging areas was also part of the work programme of WG4. A draft on this subject[885], prepared by WG4, was circulated to TC301 in 1994 for comments[886]. As no comments were received, the item was kept on stand-by[887]. The November 1995 work report of WG4 showed no progress "as the work repartition between CEN and CENELEC was not cleared"[888]. At the next TC301 meeting[889], the stand-by was noted, and the ongoing work of CENELEC TC21X indicated, which would eventually cover this subject in the standard EN 50272-3 (§5.5.3.4), removing this issue from the CEN TC301 work programme.

[882] Doc. CEN/TC301 N124, Minutes of 12th meeting in Paris, 1997-11-24
[883] Doc. CEN/TC301 N141E, French revised proposal for prEN12736
[884] EN 12736:2002 "Electrically propelled road vehicles - Airborne acoustical noise of vehicle during charging with on-board chargers - Determination of sound power level"
[885] Doc. CEN/TC301 N49
[886] Doc. CEN/TC301/N52, Resolution 28 taken on the 6th meeting, 1994-04-14
[887] Doc. CEN/TC301 N67, Minutes of the 7th meeting in Paris, 1995-03-30, ¶9.2
[888] Doc. CEN/TC301 N81, Work report of TC301 WG4, 1995-11
[889] Doc. CEN/TC301 N83, Minutes of the 8th meeting in Paris, 1995-11-28, ¶8

5.5.8.4 Charging socket

The definition of dimensional and electrical requirements for the charging socket on the vehicle (which in the correct IEC terminology is called "vehicle inlet", cf. Figure 5.28) also figured in the work programme of WG4 from as early as 1994[890]. Unlike the other types of accessories (plug, connector) this was considered a CEN item since it was part of the vehicle. Difficulties were encountered however to come up to a standard, due to the dependence on technical solutions chosen by the manufacturers[891]. Not much progress was made during the next few years, in 1996 it was recognized however that there was no urgent need for a standard, as

> *"the charging socket is a current matter of 'maturation' on a European level (between all involved parties), thus avoiding to impose a single choice from one European member"*[892]

It proved hard to reach a consensus on this matter, and WG4 had to admit no progress was made. On the 1997 meeting, it was pointed out that the target of this work item was not to standardize one specific product, but to allow all EVs to use the same charging stations.[893]

In 1998, Italy took over the convenorship of WG4 from Germany; TC301 resolved:

> *"Because the charging socket is an important integral part of the vehicle, TC301 confirms that this item should be dealt with by TC301. TC301 recognises the importance of the interface and supply network requirements. It is suggested that an inventory and analysis should be undertaken of existing trailing female hardware in order to develop proposals for a set of male vehicle socket specifications. This set should include the range of power levels, as well as single and three phase options."*[894]

WG4 would take note of the work on charging sockets being performed by CENELEC TC69X WG3[895], no document would be published however and the item figures on the work programme of CEN TC301 until to-day.

5.5.9 Safety standards: the work of TC301 WG5

5.5.9.1 Generalities

WG5, under the convenorship of Mr. Martinod, drafted three standards stating safety requirements for electric vehicles. The work in ISO on the international standard ISO 6469 lingering on, it was deemed useful to start working on an European level

[890] Doc. CEN/TC 301 N42E, Minutes of the 4th meeting, 1994-03-24
[891] Doc. CEN/TC301, N51E, Minutes of the 5th meeting, 1994-10-14
[892] Doc. CEN/TC301 N109E, Minutes of the 10th meeting, 1996-11-28, statement by Mr. Martinod
[893] Doc. CEN/TC301 N117E, Minutes of the 11th meeting, 1997-05-27
[894] Doc. CEN/TC301 N139: Resolution 59 taken at the 13th meeting in Paris, 1998-07-09
[895] Doc. CEN/TC301 N165: Minutes of the 16th meeting in Lisbon, 2000-28-06

in order to obtain a finished document in a shorter time. The proposed standard consisted of three parts, covering respectively on-board energy storage, functional safety and protection of personnel against electrical hazards.
Drafts of the documents were circulated to national committees in 1994[896], with a formal vote taking place in February 1996 for prEN 1987-1[897] and preN 1987-2[898], which showed a large support for these documents. prEN 1987-3 was circulated in September 1996, and subject to a number of comments[899] considering its discrepancy with the draft ECE 100 regulation.
The European standards would be published in 1997 and 1998 as EN 1987, four years before the international standard ISO 6469. They are virtually identical to the ISO documents (presented in §5.3.3), the main differences being the wording which differs in a number of cases, such as in the definitions, and the normative references which for the EN of course refer to European standard when appropriate. The differences however that are more relevant as to the content of the standard are discussed below.

5.5.9.2 EN 1987-1*: On-board energy storage*

- ☞ The international standard ISO 6469-1 is applicable to vehicles with a working voltage of 1500 V d.c. or 1000 V a.c.[900]; the scope of the European standard does not specify a voltage range.
- ☞ The EN does not reproduce the paragraph about "environmental and operational conditions"[901], which is very general however and does not contain any specific requirement.
- ☞ Marking of battery type: whileas the EN asks the "chemical type" of the battery to be indicated[902], the international standard refers to national or regional prescriptions such as the US National Electrical Code (see also §5.6.10) or the ECE 105 regulation on the carriage of dangerous goods.
- ☞ EN 1987-1 states a requirement about protection against direct contact (referring to EN 1987-3)[903], such requirement is not present in ISO 6469-1 (although it can implicitly be understood that it is covered by ISO 6469-3).
- ☞ Insulation resistance of the battery: the EN specifies it shall be greater than 500 Ω/V[904] for a new battery, and shall stay higher than 100 Ω/V within its

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[896] Doc. CEN/TC301 N51, Minutes of the 6th meeting in Paris, 1994-10-14
[897] Doc. CEN/TC301 N89, Voting on prEN1987-1
[898] Doc. CEN/TC301 N90, Voting on prEN1987-2
[899] Doc. CEN/TC301 N106, Comments on prEN1987-3, 1996-09
[900] ISO 6469-1:2001, ¶1, Scope
[901] ISO 6469-1:2001, ¶4
[902] EN 1987-1:1997, ¶4.2
[903] EN 1987-1:1997, ¶6.1
[904] "500 Ω/V" means a resistance of (500 x U)Ω, where U is the nominal voltage of the battery

lifetime[905]. The international standard specifies only 100 Ω/V throughout the entire lifetime of the traction battery[906]

- ☞ The maximum allowable concentrations of hydrogen in the EN are 0,8 % in case of normal running and 3,5 % in case of a first failure[907]; the ISO standard specifies values of 1 % and 2 % respectively[908].

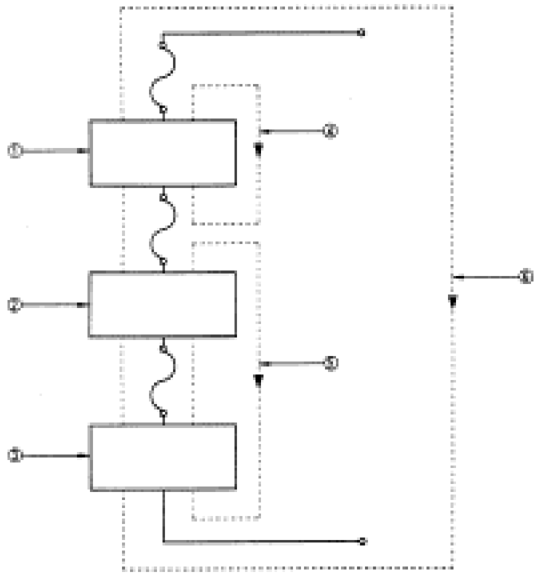

Figure 5.47: Over-current protection devices in EN 1987-1[909]

- ☞ The requirement on "inter-battery modules liaison"[910] is not present in the ISO standard. This is also a very general statement.
- ☞ Unlike ISO 6469-1, EN 1987-1 requires one over-current protection device per battery pack, as to be able to open each possible short circuit current.[911] This is shown in Figure 5.47, where the dotted lines indicate short-circuit paths.
- ☞ The EN does not specify the requirements of ISO about electrolyte leakage in case of crash[912] (max. 5 l electrolyte shall be spilled during a crash test, no electrolyte shall enter passenger compartment).
- ☞ Neither does it give the precise calculation of traction battery insulation resistance of the (informative) annex of the ISO standard.

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905 EN 1987-1:1997, ¶6.2.2
906 ISO 6469-1:2001, ¶7.1.3
907 EN 1987-1:1997, ¶6.4.2.1
908 ISO 6469-1:2001, ¶7.3.2.1
909 EN 1987-1:1997, ¶A.2
910 EN 1987-1:1997, ¶6.6
911 EN 1987-1:1997, ¶7.2
912 ISO 6469-1:2001, ¶9.2

5.5.9.3 EN 1987-2: *Functional safety means and protection against failures*

- ☞ The European standard does not include the statement that deceleration by releasing the acceleration pedal should not be greater than of a comparable ICE vehicle.[913]
- ☞ The EN does not include a reference to EMC emissions[914].
- ☞ Unintentional behaviour of the vehicle: the EN states that a failure shall not cause more than 0,1 m movement in a standing unbraked, vehicle[915], while as the ISO standard states that "the propulsion shall be cut off to prevent unintended vehicle movement"[916], i.e. allowing no movement at all.

5.5.9.4 EN 1987-3: *Protection of personnel against electrical hazards*

- ☞ In EN 1987-3, the maximum working voltage to which the standard is applicable, is 750 V d.c. or 500 V a.c.[917], against 1500 V d.c. or 1000 V a.c. in the ISO 6469-3[918]. These limits are used throughout the document.
- ☞ Insulation resistance: the EN states a single value of 1000 Ω/V[919], whileas the ISO document states against 1000 Ω/V for Class I equipment and 5000 Ω/V for Class II equipment.[920]
- ☞ Unlike the ISO document, EN 1987-3 states requirements about "protection against temperature rise".[921]
- ☞ Concerning the protection against water effects, the European standard requires an insulation resistance after the test of 250 Ω/V, and 500 Ω/V after a 24 hour rest period.[922] The international standard specifies 100 Ω/V[923]; in both cases, these measurements are taken with the power equipment connected to the battery. Furthermore, the international standard specifies that an automatic disconnection is to take place if insulation resistance drops below 100 Ω/V, when an insulation resistance monitoring system is present.[924]

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913 ISO 6469-2:2001, ¶5.2.3
914 ISO 6469-2:2001, ¶5.6.2
915 EN 1987-2:2001, ¶6.1
916 ISO 6469-2:2001, ¶6.2
917 EN 1987-3:1998, ¶1, Scope
918 ISO 6469-3:2001, ¶1, Scope
919 EN 1987-3:1998, ¶6.3.1
920 ISO 6469-3:2001, Table 2
921 EN 1987-3:1998, ¶7
922 EN 1987-3:1998, ¶8.2
923 ISO 6469-3:2001, ¶7.3.2
924 ISO 6469-3:2001, ¶7.3.1

5.5.10 National standards

With the advent of European standardization (see also §5.5.11), and the compulsory adoption of European standards as national standards, purely national standardization is gradually losing field in Europe.
Specific standardization aimed at new fields such as electric vehicle is likely to be based on European or international standardization. Only in some established fields do national standards continue to play a role (such as the German battery assembly standards described in §4.2.4.4.2).

5.5.11 Specific problems of European standardization

The standardization landscape in Europe presents some specific features deemed worth further consideration in the framework of this thesis.

5.5.11.1 *The status of European standards*

"European Standards" (EN) are regional standards resulting from the work of CEN and CENELEC. Just like international standards, they are implemented through a consensus process involving all national standardization committees within CEN or CENELEC. There is a major difference however: approval of a European standard implies for all CEN/CENELEC members the obligation to give it the status of a national standard, and to withdraw any conflicting national standard.[925]
Furthermore, national committees shall not publish new or revised national standards which are not in line with European standards which are approved or in preparation. This principle is known as "standstill"[926].
The benefits of these policies for European standardization are clear: through the CEN/CENELEC system, harmonization of national standards is effectively promoted.
Harmonization is defined as:

> *"prevention or elimination of differences in the technical content of standards having the same scope, particularly those differences that may cause hindrances to trade"*[927]

Harmonization of these standards is considered to be achieved when the products manufactured to the national standards of one country may be regarded as complying, without modification, with the standards of the other countries and vice versa. This is an essential element for the realization of a true Common Market.
One result of this policy is that the independent standardization work by individual national committees has greatly been reduced, and that they have become clearinghouses for European standards which are published as national standards through reproduction, endorsement or translation.[928] The share of national standardization activities at the German national committee DIN for example, dropped from 84% in 1984 to just 8% in 1997, with European and international standardization taking a share of respectively 56% and 36% of the work.[929]
The operating procedures and regulations of CEN and CENELEC are closely related to those in ISO and IEC; Part 3 of the CEN/CENELEC internal regulations, which states the rules and structure for the drafting of the standards, is largely identical to the ISO/IEC directives.

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[925] CEN/CENELEC Guide 1, Status of European standards, Art. 5
[926] CEN/CENELEC Internal Regulations, Part 2, ¶5
[927] Ibid., ¶2.1
[928] CEN/CENELEC Internal Regulations, Part 3, Annex ZC
[929] Schepel, H. and Falke, J., op.cit., p.50

CEN and CENELEC may also adapt ("endorse") international standards (published by ISO or IEC) as European standards, with or without (limited) modifications or European annexes.[930]

There is however one major difference that can be discerned between international and European standards, and this concerns the voting procedure. For the approval of new work items and the formal approval of standards, the procedures within CEN or CENELEC make use of a weighted vote with qualified majority system, derived from European Council practice[931]. This procedure is in stark contrast with the democratic "one member - one vote" system such as used by IEC and ISO, and one can valuably argue that this system puts small member countries (such as Belgium!) in a more disadvantaged position.

5.5.11.2 Standards and the European authorities - the New Approach

The European authorities are well aware of the significance of standards and of the work of standardization bodies in Europe. The Council keeps the subject of standardization under constant review.[932]
The EU is aware that diverging national standards can be a barrier to free trade; to this effect, a directive has been issued by the European Parliament and the Council[933], obliging member states to notify their standardization activity and draft standards to the Commission and to the European (CEN, CENELEC, ETSI) and member states' standardization committees. A standstill period is foreseen for other parties to react to the draft; the directive also gives the Commission the possibility of inviting the European standards organizations to initiate work on European standards when appropriate.
This is the same directive which grants formal recognition to the European and national standardization committees, which are non-governmental organizations (although, depending on the country, they may belong to the public or the private sector).

Furthermore, one has to consider the European legislation which is aimed at both the removal of barriers to trade within the single market and to preserve health, safety, consumer protection and environmental protection. Such legislation tends to be highly technical as it defines individual requirements for each product category, and due to its technical nature, it may relatively quickly become obsolete as technology progresses.

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930 CEN/CENELEC Internal Regulations, Part 3, Annex ZB
931 CEN/CENELEC Internal Regulations, Part 2, Annex D
932 Council conclusions of 2002-03-01 on standardization
933 Directive 98/34/EC. This directive supersedes the initial directive 83/189/EEC on the subject.

To make the regulation process smoother and more efficient, a "New Approach"[934] was conceived in the early 1980s, and laid down in a Council Resolution in 1985.[935] This resolution clearly recognizes the significance of standardization:

> *"The Council believes that standardization goes a long way towards ensuring that industrial products can be marketed freely and also towards creating a standard technical environment for undertakings in all countries, which improves competitiveness not only on the Community market, but also on external markets, especially in new technology."*[936]

The New Approach is based on the following fundamental principles:

☞ The legislative harmonization, written in the Directives, is limited to the essential requirements that products must meet to be put on the market. These essential requirements are mandatory. They define the results to be attained, or the risks to be dealt with, but do not specify in detail the technical solutions for doing so, leaving the choice how to meet them to suppliers. This means that the essential requirements can be embedded in legislation in a way that they remain valid over time, without being connected to a single technical solution which might become obsolete with technical progress. This means that the directives will not necessitate to be adapted regularly to technical progress.

☞ The task of drafting the detailed specifications to conform with the technical requirements is entrusted to the European standardization bodies, who can elaborate new EN standards or identify existing ones. These standards give a presumption of conformity to the essential requirements they are dealing with. Once such standards have been referenced by the European Commission and transposed into national standards, they are known as "harmonized standards". The principle of referring to standards highlights the use of standardization as a support to legislation. About one quarter of European standards ratified by CEN are linked to the New Approach directives.[937]

☞ These standards remain voluntary; manufacturers may choose any technical solution to comply with the essential requirements. When not following the harmonized standards however, the manufacturer has the burden of proof that the product meets the essential requirements.

☞ The standards shall not contain normative references to directives, nor contain elements of directives as normative elements. There is in fact no vote of CEN or CENELEC members on the content of the directives, the responsibility for the

[934] Guide to the implementation of directives based on the new approach and the global approach, European commission, 2000

[935] Council Resolution of 1985-05-07 on a new approach to technical harmonization and standards

[936] Council Resolution of 1985-05-07, Annex 1

[937] Schepel, H. and Falke, J., op.cit., p6

latter being in the hands of politicians, and not of standardization experts (no pun intended).[938]

- ☞ Conformity with the requirements is expressed through apposition of the CE mark (Figure 5.48) on the product. Note that the apposition of this mark is the responsibility of the manufacturer or the importer, and that it does not imply that the product has been tested by an independent organization.

Figure 5.48: CE *mark*

The New Approach has added a new dimension to standardization, and highlighted a number of issues concerning European standardization:

- ☞ Although standardization remains a voluntary process carried out by independent organizations, the standards bodies are not entirely free to decide which standards to develop, as they are required to draft a coherent set of standards to meet the essential requirements of the directives. Under the New Approach, they thus carry a larger responsibility. [939]
- ☞ The standards bodies bear the responsibility for the harmonized standards. Public authorities have not to take decisions to approve these standards, even if previously such technical aspects were subject of regulation. This means a discrepancy with existing standards legislation in Belgium, for example, where the formal approval (homologation) of a standard by Royal Decree is required to render it mandatory.[940]
- ☞ The New Approach is only feasible if the standardization system is open and transparent, if the standard is supported by all major interested parties and if it is applied in an uniform way throughout the Community. These requirements are referred to as the *accountability of European standardization.*[941]
- ☞ The European authorities are concerned with the efficiency of the standardization process, and more particularly with the timely elaboration of standards. It welcomes measures taken by CEN, CENELEC and ETSI to improve their efficiency. It had been proposed by the Council[942] that adoption of standards could be speeded up if the standardization bodies should use qualified majority vote at earlier stages in the drafting process, it should be noted however

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[938] CEN, http://www.cenorm.be/BOSS/supmat/guidance/gd026.thm Guidance on standards and regulations,

[939] CEC, Efficiency and accountability in European standardization under the new approach, Report from the Commission to the Council and the European Parliament, ¶6

[940] Schepel H. and Falke J., op.cit., p 73, 154,182

[941] CEC, op.cit., ¶8

[942] Council resolution of 1999-10-28 on the role of standardization in Europe, ¶23

that such practice will not necessarily be more efficient than the traditional consensus procedure, since early voting might hamper the standardization process by making it more political.[943]

- ☞ A merger between CEN and CENELEC, which has sometimes been suggested, is not considered to improve efficiency, due to the fact that, for historical reasons, similar structural differences exist at both national and international levels, nor is the recognition of new standards bodies on specific fields.[944]
- ☞ The EU is also concerned about the viability of the European standardization work and grants financial support to the New Approach standardization work; mainly supporting a strong infrastructure for European standardization. The central secretariats of the European standardization bodies are supported, to ensure 45% of the operational costs of CEN, and 17% for CENELEC.[945] In this framework, the fact must also be taken into account that the New Approach may lead to the erosion of one of the main sources of income of national standardization committees: the selling of standards. When standards become part of legislation through references in directives (or in the case of Belgian standards, through homologation by Royal Decree), they lose in fact their copyright protection.[946]
- ☞ The Commission, facing the role of standardization in international trade, states that international, European and national standards complement each other. International standards are to be preferred whenever possible; national standards are considered to complement the international standardization process while European standardization provides coherence for free circulation on the European market or to meet European harmonization. National standardization takes local particularities into account and strengthens the capacity of European and international standardization to reach out to local interests and to ensure a wide participation of stakeholders in the standardization process.[947]

New Approach directives deal with large families of products; examples include the Low Voltage directive (which was first introduced in 1973 marking the first example of a connection between community law and harmonized standards, and has been very influential for the drafting of the New Approach[948]) and the Machine directive or with "horizontal" risks that can be encountered in a broad range of applications, such as the EMC directive.

The New Approach is not (yet) implemented however in sectors where Community legislation was already well established, such as foodstuffs, cosmetics, or, relevant to this work, motor vehicles.

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943 CEC, op.cit., ¶17-18
944 Ibid, ¶28-29
945 CEC, op.cit., ¶34
946 Schepel H. and Falke J., op.cit., p167-171
947 CEC staff working paper: European policy principles on international standardization, SEC(2001)1296
948 Schepel H. and Falke J., op.cit., p23

The Council, in its 1999 resolution on standardization, recognizes that the New Approach has proved itself and should be further applied; it invited the Commission to examine its application to sectors not yet covered, as a means of improving and simplifying legislation whenever possible.[949]

5.5.11.3 Standards and public procurement

Purchases of equipment by the public sector, such as the acquisition of electric vans by a municipality, of hybrid buses by a government-owned public transport company, or of electric combat vehicles by the armed forces, must go through a well-defined process of open, competitive procurement to allow access to these markets by all interesting manufacturers.
In the past, public purchasers tended to rely on local suppliers, and used national standards in their product specifications.
In the framework of the European Community's evolving procurement rules, which are designed to promote the realization of the single market, and which have been expressed in directive 93/36/EEC[950], however, contracting bodies will be obliged to refer to European EN standards wherever they exist. A product which complies to EN or other recognized standards, which offers equivalent guarantees of safety and reliability, and which is lawfully produced in one country can thus not be banned in another country and should be accepted on equal footing.

This directive aims at eliminating "bespoke standards", which are implemented with the strong support of local manufacturers in order to preserve the local market for their product.
Preserving the market share of one's own product has in fact often been, and still is, a point on the hidden agenda of corporate participants in standardization committees.

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[949] Council resolution of 1999-10-28 on the role of standardization in Europe, ¶20
[950] Council Directive 93/36/EEC

5.5.12 Activities of AVERE in the field of standardization

AVERE, the European Electric Road Vehicle Association, had been founded in 1978, and is one of the premier promoters of electrically driven vehicles in Europe up to this day, being, among other things, the organizer of the well-known Electric Vehicle Symposia ("EVS"). It is a cupola organization consisting of national sections.
AVERE is to-day not directly active in standardization work (although many of its members are involved in standardization committees). From its inception however it had constituted a number of working committees, among which a Committee No.2:

> *"Study of norms and standards in liaison with existing organizations"*[951]

The Committee, chaired by Mr. Pierre Margrain, had its first meeting in Paris on April 6, 1979.
Its main task was to execute a study[952] on behalf of the CEC[953], with as object to examine motor vehicle regulations in view of their adaptation to electric vehicles. To this effect, AVERE established an overview of electric vehicle regulations in force in different member states, and proposed actions to be taken in the field. The study focused on four main topics:

- ☞ Energy storage and charging
- ☞ Vehicle mass, mass repartition, braking
- ☞ Performance requirements and test procedures
- ☞ Particular problems of on-board electricity.

Although this study was mainly focused on regulatory issues (EU directives, fiscal and taxation matters) - and thus rather outside the scope of this work, the activities of AVERE in the field also involved standardization:

> *"Il apparaît une fois de plus que les notions de normalisation et de réglementations sont recouvrantes."*[954]

The aim of the activities in the framework of AVERE was to accelerate (standardization) work, in collaboration with IEC and ISO[955].

A number of typical problems concerning standardization activities were encountered:[956]

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[951] AVERE Committees, 1978-12-13
[952] Community regulations on electric vehicles, AVERE, Brussels, 1980
[953] Contracts CEC-AVERE, signed 1979-05-17. One contract concerned cars, the other one buses and utility vehicles
[954] AVERE, Minutes of French Working Committee No.2, 1979-05-08
[955] BEC/CEB, Commission 69, Procès-verbal de la reunion 1979-06-21, Doc. PV4
[956] AVERE, Situation actuelle des comités d'études, 1979-09-20, Doc. FB/EV 7.3

- ☞ The mutual distrust between car manufacturers and electrical manufacturers, who have a quite different philosophy (see also §5.4.1 for a deeper discussion of this issue). Car manufacturers feared that the AVERE study could lead to more stringent regulations to be imposed on ICE vehicles.
- ☞ It was deemed essential to establish contacts between AVERE on one hand and ISO TC22 SC21 and IEC TC69 on the other hand.

The activities of AVERE in the framework of the European contract raised in fact some concern with the standardization committees, who regarded it as inappropriate if AVERE would undertake actual standardization work (like defining specifications) on such a short timescale as dictated by a one-year contract, the drafting of an international standard being in fact a long-term process allowing inputs and comments from all interested parties. IEC TC69 actually urged AVERE to limit its activities to those requested in the contract, i.e. reviewing of relevant legislation[957].

It was however never the intention of the AVERE Committee to prepare actual standards, but rather to identify themes where standardization work was deemed useful and where no international standards were in existence.

The AVERE committee followed up standardization work in the different international standardization bodies:[958]

- ☞ ISO TC22 SC21: the work on energy consumption standards (§5.3.4.3) with its draft test cycle (Figure 5.36) was considered, and confronted to the SAE J227 cycle (§5.6.2.1), which "had the advantage to be published and be in regular use, but which was extra-European".
- ☞ IEC TC69 WG2
- ☞ IEC TC69 WG3

The report "Community regulations on electric vehicles" was submitted to the CEC in December 1980.

In 1982, AVERE revised the structure of its working committees, constituting three technical committees in the field of "Standards", "Operations" and "Technology".

The aim of the Standards committee was not to perform mere standardization work, but rather to:

> - ☛ *Examine and to transit to the other Committees information on electric vehicle and equipments standards derived from IEC, ISO, etc.*
> - ☛ *Monitor EEC supported R&D programs on standards*
> - ☛ *Keep close contact with IEC, ISO and national organizations, as regards standardization and norms.*[959]

[957] Letter of Dr. Edwards, Chairman of IEC TC69, to AVERE, 1980-01-28

[958] AVERE Study Committee n° 2, Minutes of the meeting in Essen, 1979-11-22

[959] AVERE Committee "Standards", Aims and study areas, 1982-04-01

The chairman of IEC TC69 WG2, Dr. Brian Edwards, was appointed as chairman of the Standards committee. He informed the IEC TC69 1982 plenary meeting about the creation and scope of the committee; at this meeting it was stated that AVERE should not draft its own standards, but that it was welcome to participate in the activities of standardization bodies.[960]

One of the tasks performed by AVERE (the Technology committee, rather than the Standards committee in fact) was to prepare a document describing test specifications for "road electric vehicle batteries".[961]
The rationale behind these specifications was to define tests representing an average of European operation conditions, and to present manufacturers with simple, repeatable and relevant tests. The use of the battery on-board an electric vehicle does in fact differ from the traditional use in an industrial vehicle, as discharge rates are higher and peak powers are prolonged in time, making the traditional constant-current-discharge capacity test less relevant.
The document contained three sections:

- Section 1 "Outline specification" defines the test requirements for the qualification of lead-acid traction batteries, in order to assess the compatibility of batteries with typical electric vehicle applications and to determine general performance characteristics. The following order of tests is specified:
  - Initial inspection and leak testing
  - Shape, dimension and weight determination
  - Standard capacity determination (C_5, measured according to IEC 254-1)
  - Capacity at room temperature for different discharge rates (1,6 I_5, 2,5 I_5, 5 I_5)
  - Low temperature (0 °C) capacity, for different discharge rates
  - Discharge power determination, at different depths of discharge
  - Charge conservation test
  - Standard capacity determination
  - Final inspection
  - Shape, dimension and weight determination
- Section 2 "Specification for cycling evaluation" describes a test to be carried out in order to assess batteries' behaviour by charging and discharging in different environmental and operational conditions, which can be either related to mission and vehicle design (like temperature, discharge rate or depth of discharge) or applied by the operator (like charge current profile and charge factor - the latter being the quotient of ampere-hours charged vs. discharged). Tests are specified to show the impact of the charge factor on the deliverable capacity and thus on the vehicle range. The tests consist in submitting the

[960] IEC TC69, Minutes of the meeting in Amsterdam, 1982-10-26/28, Doc. PV2549/CE69
[961] AVERE Technology and Standard Committees, Road Electric Vehicle Batteries, Test Specifications, 1984

battery to a number of discharge/charge cycles in different conditions as to temperature and charge factor, and determining of the residual capacity after each set of five cycles.

☞ A Section 3 "Specification for the capacity evaluation and the ageing by cycling simulation" was under consideration. For this subject, it was proposed to define a capacity test under variable discharge rate; as for the issue of battery ageing, it was pointed out that there had been established no correlation between bench ageing tests and real life test, but that it was essential to define a representative bench test to be carried out on a common base, the CEC also requesting such a test.[962]

This AVERE document found its way into international standardization among others through the Belgian National Committee, which recommended it to be considered by IEC TC69 WG3. (see §5.2.4.1).

[962] AVERE Committee Standard, Minutes of the meeting in Birmingham, 1984-11-21

5.6 Regional standardization work in America

5.6.1 Introduction

In the United States, standardization activities are organized in a particular manner, different from other countries with strongly centralized standards bodies: US standardization follows a "decentralized" model, where standards are being developed by a large number of organizations, as shown in Figure 5.49. The co-ordination of standardization work is performed by the American National Standards Institute (ANSI), which approves standards as American National Standards and acts as official member of ISO and IEC.[963]

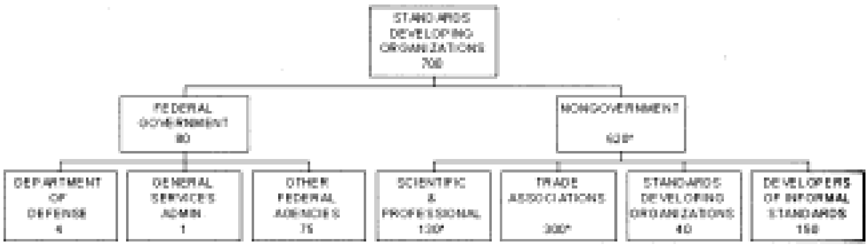

Figure 5.49: Standards developing associations in the United States[964]

In the automotive field, the main standardization body is the Society of Automotive Engineers, which has published over 4500 standards. Its early activities in the field have been highlighted in §3.3; the new electric vehicle developments towards the end of the twentieth century have created new SAE standardization work.
In this chapter, relevant SAE standards in force will be presented, classified by type; attention will be however also be given to SAE J227A, which is now withdrawn but which is of historical significance.

5.6.2 SAE electric vehicle performance standards

5.6.2.1 SAE J227a: the original SAE electric vehicle test

One of the first specific electric-vehicle related documents was the SAE recommended practice SAE J227A "Electric vehicle test procedure" which was approved in 1971 and revised in 1976.

[963] S.M. Spivak, F. C. Brenner, Standardization Essentials, P68
[964] Ibid., P134

This document SAE J227A had also provoked the interest of AVERE, whose Committee No.2 proposed in 1979 to follow the J227A test cycles, although "*légèrement européanisé*".[965]

This document establishes uniform procedures for testing battery-electric road vehicles, with the intent to provide standard tests allowing to cross-compare various performance characteristics of electric vehicles on a common base. The tests in SAE J227A address the total vehicle system rather than the components. It describes both road tests, used to establish vehicle performance specifications, and dynamometer tests which were primarily aimed to facilitate development testing.[966] The tests defined in this document are discussed in the paragraphs below.

5.6.2.1.1 Range at steady speed

These tests are to be performed at a minimum of three different test speeds, including the maximum cruise speed of the vehicle

5.6.2.1.2 Range when operating on a selected driving pattern

This test represents the first instance of a driving cycle specifically standardized for electric vehicles. The proposed cycle is of a quite simple pattern, as shown in Figure 5.50, and the authors did realize its limitations, as they state:

> *"The driving cycles defined in this procedure are not necessarily intended to simulate a particular vehicle use pattern. Rather it is the intent of this section to provide standard procedures for testing electric road vehicles so that their performance can be cross-compared when operated over a fixed driving pattern."*[967]

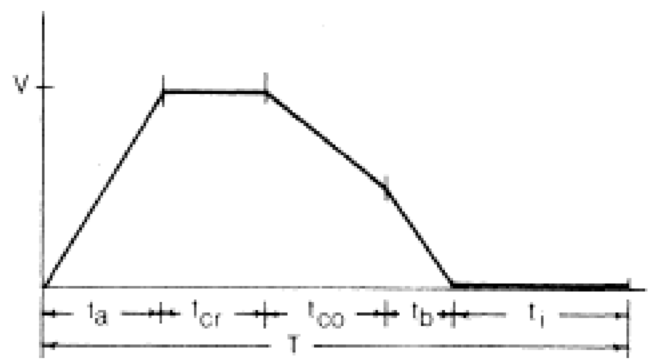

Figure 5.50: Vehicle test cycle from SAE J227a

[965] AVERE, letter by J. Voos, 1979-12-28
[966] SAE J227A, Scope - SAE handbook 1989 Vol 4 p28.01
[967] Ibid., ¶6

Four test cycles were defined, aimed at different classes and applications of the electric vehicle, consisting of an acceleration, constant-speed, coasting, braking and standstill phase, characterized by the values shown in Table 5.11. The test can be taken either on a test track on or a dynamometer bench.

	A	B	C	D
V	16 km/h	32 km/h	48 km/h	72 km/h
t_a	4	19	18	28
t_{cr}	0	19	20	50
t_{co}	2	4	8	10
t_b	3	5	9	9
t_i	30	35	25	25
T	39	72	80	122
Traffic type	Fixed route, high-frequency stop and go	Fixed route, medium frequency stop and go	Variable route, medium frequency stop and go	Variable route, typical suburban stop and go
Typical applic.	Residential postal delivery van Milk truck	Bakery truck Shuttle bus	Parcel post delivery van Retail store delivery	Commuter car

Table 5.11: Test schedule for repeatable driving pattern, SAE J227a (all times in seconds)

5.6.2.1.3 Acceleration test on a level road

In this test, acceleration curves are recorded for various initial SOC values (100 %, 60 %, 20 %) of the battery. The test can be taken either on a test track on or a dynamometer bench.

5.6.2.1.4 Gradeability

The purpose of this test is to determine the maximum grade on which the test vehicle can just move forward. It is measured indirectly, through the maximum tractive force (which can be maintained for 20 s while moving the vehicle at a minimum speed of 1,5 km/h), and also in function of the battery SOC.
The gradeability is calculated as follows:

$$G_{\%} = 100 \times \tan(\arcsin \frac{P}{W}) \qquad (5\text{-}14)$$ [968]

where $G_{\%}$ is the gradeability in percent, P is the measured tractive force in kg, and W is the vehicle's gross weight in kg. (Note that the document specifies the use of the kilogram as unit of force and weight!)
This formula can easily be proven: the additional force necessary to climb a slope at road angle α with a vehicle of mass M is equal to:

968 Ibid., ¶8.3

$$F_c = M \times g \times \sin(\alpha) \qquad (5\text{-}15)$$[969]

The maximum slope that can be negotiated corresponds to the maximum tractive effort P, hence:

$$\alpha_{\max} = \arcsin\frac{P}{M \times g} = \arcsin\frac{P}{W} \qquad (5\text{-}16)$$

Given the relationship between the slope angle α and the gradeability G in %:

$$G_{\%} = 100 \times \tan(\alpha) \qquad (5\text{-}17)$$

one comes back to the initial equation *(5-14)*.

5.6.2.1.5 Gradeability at speed

The purpose of this test is to determine the maximum speed on graded roads. It can be calculated either from a dynamometer test or using the data from the acceleration test. In the latter case, values for the acceleration (in m/s) are derived from the acceleration curve. The gradeability at a certain speed is then given by:

$$G_{\%} = 100 \times \tan(\arcsin(0{,}0285 \times a)) \qquad (5\text{-}18)$$

where $G_{\%}$ is the gradeability in percent and a is the acceleration in km/h per second at that speed.

Let's prove this calculation. During the acceleration test, the following force is needed to accelerate the vehicle:

$$F_a = M \times a \qquad (5\text{-}19)$$

Note that this formula does not take into account the inertia of the rotating masses of the vehicle.

This force accelerates the vehicle. When applied at that speed, on a slope, the force would be used to climb the slope rather than to accelerate the vehicle, following formula (5-15). Equalling the force in (5-15) and (5-19) gives:

$$\sin(\alpha) = \frac{a_{\text{m/s}}}{g} = \frac{a_{\text{km/h}}}{3{,}6 \times 9{,}80655} = 0{,}0283 \times a_{\text{km/h}} \qquad (5\text{-}20)$$

[969] J. Van Mierlo, Simulation software for comparison and design of electric, hybrid electric and internal combustion vehicles with respect to energy, emissions and performances, p164

One comes back to formula (5-18). The constant 0,0285 in the latter corresponds to a rather low value of 9,75 m/s² for *g*. This is obviously a typographical error, since the constant given for an acceleration expressed in mph per second (0,0455) yields a more acceptable value of 9,81 m/s² for *g*. This has been corrected in the follow-up standard SAE J1666.

5.6.2.1.6 Vehicle road energy consumption

The purpose of this test is to determine the power and energy consumed at various speeds to overcome friction, rolling resistance and windage.
To this effect, a coast-down test is performed from maximum speed to standstill. This gives a deceleration curve, as shown in Figure 5.51.

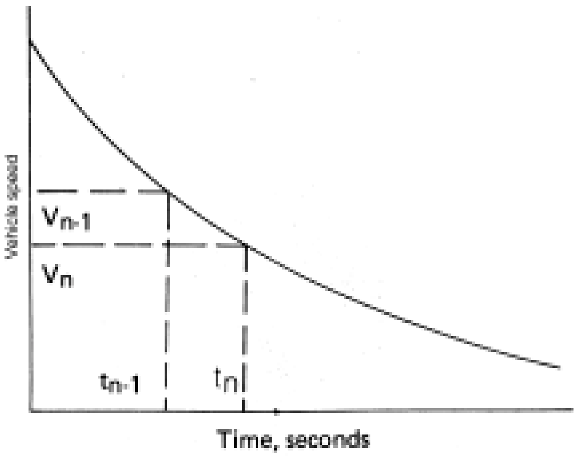

Figure 5.51: Deceleration test

To propel the vehicle at an average speed of

$$\overline{V}_n = \frac{V_n + V_{n-1}}{2} \qquad (5\text{-}21)$$

the required power can be calculated from the deceleration curve:

$$P_n = 3{,}86 \times 10^{-5} \times M \times \frac{V_{n-1}^2 - V_n^2}{t_n - t_{n-1}} \qquad (5\text{-}22)$$

where P is the power in kW and M the mass in kg; the standard however is using here the symbol W as “gross weight”.

The energy required per km to propel the vehicle at that constant speed can also be calculated from the deceleration curve:

$$E_n = 7,72 \times 10^{-5} \times M \times \frac{V_{n-1} - V_n}{t_n - t_{n-1}} \qquad (5\text{-}23)$$

where E is the energy consumption in kWh/km.

How to prove these formulas?
To propel a vehicle at a speed V_n one has overcome the drag force[970]:

$$F_v = \tfrac{1}{2}\rho S c_x \left(V_n + V_w\right)^2 \qquad (5\text{-}24)$$

where ρ is the air density, S the frontal surface, c_x the drag coefficient and V_w the wind speed,
and the friction force:

$$F_f = Mgf_f \cos(\alpha) \qquad (5\text{-}25)$$

where f_r is the friction coefficient and α the road angle.
During coasting, with no motor power applied, the vehicle will decelerate; the deceleration force which also complies to formula (5-19) will be equal to the sum of the resistive forces:

$$F_d = \left(F_v + F_f\right) = M \times d = M \times \frac{V_{n-1} - V_n}{t_n - t_{n-1}} \qquad (5\text{-}26)$$

The drive power needed to deliver this force would be equal to:

$$P = T_d \times \omega = \left(F_d \times R\right) \times \frac{\overline{V}_n}{R} = F_d \times \overline{V}_n \qquad (5\text{-}27)$$

where ω is the rotational velocity of the wheel (rad/s) and R the wheel radius. This gives, if we substitute F_d from (*5-26*) and V_n from (*5-21*):

$$P = M \times \frac{V_{n-1} - V_n}{t_n - t_{n-1}} \times \frac{V_{n-1} + V_n}{2} = \frac{1}{2} M \times \frac{V_{n-1}^2 - V_n^2}{t_n - t_{n-1}} \qquad (5\text{-}28)$$

[970] J. Van Mierlo, op.cit.

This formula is based on a speed in m/s, and yields a power in watts. To use the speed in km/h, and the power in kW, one becomes formula (5-22) again:

$$P = \frac{1}{2 \times 1000 \times 3{,}6^2} \times M \times \frac{V_{n-1}^2 - V_n^2}{t_n - t_{n-1}} = 3{,}86 \times 10^{-5} \times M \times \frac{V_{n-1}^2 - V_n^2}{t_n - t_{n-1}} \quad (5\text{-}29)$$

The energy consumption needed to cover one kilometre can be obtained by dividing the power by the speed, becoming formula (5-23) again:

$$E = \frac{P}{\overline{V}_n} = \frac{3{,}86 \times 10^{-5} \times M \times \frac{V_{n-1}^2 - V_n^2}{t_n - t_{n-1}}}{\frac{V_{n-1} + V_n}{2}} = 7{,}72 \times 10^{-5} \times M \times \frac{V_{n-1} - V_n}{t_n - t_{n-1}} \quad (5\text{-}30)$$

5.6.2.1.7 Vehicle energy economy

This test evaluates the energy consumption of the vehicle, and is performed by charging the batteries after the vehicle range test. The “energy economy”, expressed in km/kWh, is the inverse of the more generally used “energy consumption” expressed in kWh/km.

SAE J227A was eventually cancelled in May 1993, to be replaced by SAE J1634 and SAE J1666.
Some of the tests described in this document, notably the acceleration and deceleration tests and the resultant calculations, have been systematically used by CITELEC in its electric vehicle test programme, which was performed under co-ordination of the author[971].

5.6.2.2 SAE J1634: energy consumption and range test[972]

Recommended Practice SAE J1634 “Electric Vehicle Energy Consumption and Range Test Procedure” was initially published in 1993 as a report of the SAE Light-Duty Vehicle Performance and Economy Measurement Committee. It was revised in 1995 and 1999. It was intended to replace the relevant tests defined in SAE J227A.
The main change was the abandoning of the simple J227A test cycles, and replacing them with the two test cycles defined by the United States Environmental Protection Agency (EPA). These cycles are the official US test cycles, also used for emission and consumption tests on ICE vehicles.

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971 CITELEC, Vehicle test reports
972 SAE J1634:1999

☞ The UDDS cycle[973] (Urban Dynamometer Driving Schedule) which represents city driving. It consists of a series of non-repetitive idle, acceleration, cruise, and deceleration modes of various time sequences and rates. The UDDS has a duration of 1372 s and is 12 km long with an average speed of 31,5 km/h and a maximum speed of 91,2 km/h. Maximum acceleration is 1,5 m/s^2. It is shown in Figure 5.52.

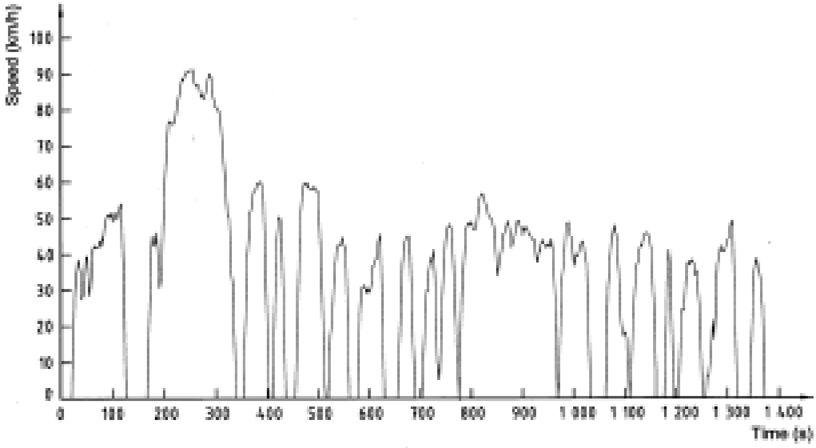


Figure 5.52: UDDS driving cycle

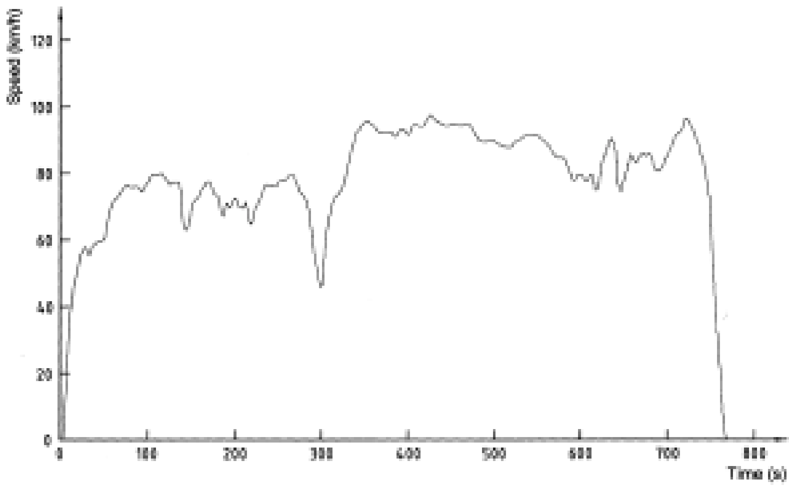


Figure 5.53: HFEDS driving cycle

☞ The HFEDS cycle[974] (Highway Fuel Economy Driving Schedule) which represents highway driving. The HFEDS is 764 s in duration and is 16,4 km

[973] US Code of Federal Regulations, Title 40, Part 86, , Appendix I
[974] US Code of Federal Regulations, Title 40, Part 600, Appendix I

long. The average speed is 77,8 km/h with a maximum speed of 96,4 km/h. Maximum acceleration is 1,44 m/s^2. It is shown in Figure 5.53.

The document also introduced the quantity "energy consumption" instead of the quantity "energy economy". It further specifies dynamometer test procedures in order to minimize the test-to-test variations inherent with track testing, and to adhere to standard industry practice for energy consumption and range testing.
SAE J1634 was cancelled in October 2002, to be replaced not by another SAE specification, but obviously by the new international standard ISO 8714 which encompasses the same US driving cycles (cf. §5.3.4). This is another example how successful international standardization can displace local standards, coming to global standards which are usable by all, and which contribute to the opening of the markets and to global understanding.

5.6.2.3 SAE J1666: acceleration, gradeability and deceleration test

Recommended Practice SAE J1666 "Electric Vehicle Acceleration, Gradeability and Deceleration" was also published in 1993 as a report of the SAE Light-Duty Vehicle Performance and Economy Measurement Committee. It was revised in 1999. It was intended to replace the corresponding tests defined in SAE J227A.

Acceleration and gradeability tests are identical to J227A.
The factor in formula *(5-18)* has been corrected to the correct value of 0,0283.
The calculation of power and energy consumption out of the deceleration test has been omitted however; the coastdown deceleration test is still performed, but its function is to determine the road load force as a function of speed, so that an accurate simulation of the road load force can be performed on a chassis dynamometer. For the actual procedure of this test, reference is made to SAE J1263:1999 "Road Load Measurement and Dynamometer Simulation Using Coastdown Techniques", a general standard applicable for all vehicles, with the (obvious) specification however that regenerative braking shall be disabled during the coastdown test.
For vehicles which can not perform the procedure of J1263, J1666 specifies an alternative "frontal area method", where the power setting on the dynamometer is determined from the dynamometer inertia weight, the vehicle reference frontal area, the vehicle protuberances and the tire type.
Also J1666 was cancelled in October 2002, the international standard ISO 8715 (§5.3.4.4) being its obvious replacement.

5.6.2.4 SAE J1711 and SAE J2711: Hybrid vehicles

SAE J1711 "Recommended practice for measuring the exhaust emissions and fuel economy of hybrid-electric vehicles" and SAE J2711 "Recommended Practice for Measuring Fuel Economy and Emissions of Hybrid-Electric and Conventional Heavy-Duty Vehicles" will be treated in the chapter on hybrids (§6.2.4).

5.6.3 SAE electric vehicle safety standards

5.6.3.1 SAE J1718: Hydrogen emissions

The SAE recommended practice J1718 "Measurement of hydrogen gas emission from battery-powered passenger cars and light trucks during battery charging" was published by the SAE Electric Vehicle Battery Standards Committee in 1994 and revised in 1997.
It is aimed at determining the concentrations of hydrogen gas emitted by an electric vehicle being charged in a residential garage, in order to know whether or not forced air ventilation is required in the garage.

The procedures described in this document are very likely to the draft international standard ISO/PWD 17374 (§6.3.3.2.5), which has obviously been inspired by this SAE J1718. However, it also provides both a high temperature (+43 °C) and a low temperature test (at -18 °C)[975], where the ISO draft, in its current version, only has a test at +40 °C[976].

5.6.3.2 SAE J1766: Battery crash integrity

SAE J1766 "Recommended practice for electric and hybrid electric vehicle battery systems crash integrity" was published in 1996 by the Electric Vehicle Battery Safety Issues Task Force of the SAE Electric Vehicle Battery System Standards Committee, and revised in 1998.
It describes modes for evaluating EV performance when subjected to various test procedures described in the US "Federal Motor Vehicle Safety Standards" (FMVSS).
SAE J1766, which is primarily intended to provide EV designers with recommended tests and performance criteria, is the first of its kind, and it is recognized that it is "*based on limited data*" and that "*test personnel should exercise extreme caution*".

[975] SAE J1718, ¶8
[976] ISO/PWD 17374, ¶7.3

To obtain type approval as road vehicles, electric vehicle must obviously meet the same safety standards as conventional vehicle regarding crash integrity. Crash tests are specified in FMVSS 571.208 (front impact), FMVSS 571.214 (side impact) and FMVSS 301 (rear impact); the latter standard also specifies a static rollover procedure. SAE J1766 requires the following performance criteria for electric and hybrid vehicles:

- ☞ No electrolyte spillage is permitted into the vehicle occupant compartment.
- ☞ Electrolyte spillage outside the occupant compartment shall be limited to 5 litres.
- ☞ Battery modules shall stay restrained throughout the test procedures. Intrusion of battery system components into the vehicle occupant compartment is not permitted.
- ☞ Electrical insulation between the traction battery system and the vehicle chassis must remain at minimum 500 Ω/V.

This last value contrasts with ISO 8715, which specifies 100 Ω/V as battery insulation resistance.

5.6.3.3 *SAE J2344: Electric vehicle safety*

The SAE information report SAE J2344 "Guidelines for electric vehicle safety" was published by the SAE Electric Vehicle Safety Committee in 1998. It was meant as a first attempt to formalize a list of essential safety features for vehicle developers; it was recognized however that

> *"automotive manufacturers, insurance companies, the repair industry, and first responders groups will need to work together to update this document as more data becomes available."*[977]

The document cites the ISO 6469 series (which were, at the moment, still in draft stage) as "related" publications (and not as "normative references"), but takes a distinct and more general approach, identifying a number of guidelines for areas where specific hazards may be present. It is clearly still an information report and not yet a standard, often stating "should" and not "shall".

Specifications are given on the following items:

- ☞ Crashworthiness (referencing to SAE J1766)
- ☞ Single point failure (which should not result in a "unreasonable safety risk"
- ☞ Electrical safety: automatic hazardous voltage disconnects, manual disconnects, interlocks, grounding, high voltage wiring assemblies (for which reference is made to specific standards SAE J1654 and SAE J1673), fusing.
- ☞ Fault monitoring and indicators of faults
- ☞ Leakage of hazardous liquids and gases
- ☞ Vehicle immersion in water

[977] SAE J2344:1998, Foreword

- EMC: referenced is made to other standards, such as SAE J551, ISO 11451, IEC 555 (which is now part of the IEC 61000 series), as well as regulations such as the European EMC directive.
- Safety labelling
- Mechanical safety
- Battery state-of-charge indicator

It is clear that this document still has a long way to go before it can be considered a real authoritative standard on the subject; strict requirements and limit values have to be defined. However, with the availability today of the international standard ISO 6469, whose three parts cover the whole of the subject, the most advisable solution is of course to adopt the international standard.

5.6.4 SAE electric vehicle battery standards

5.6.4.1 SAE J1797: Battery modules

The SAE recommended practice J1797 "Recommended Practice for Packaging of Electric Vehicle Battery Modules" was published by the SAE Electric Vehicle Battery System Standards Committee in 1997. Its mission is to provide direction for standardization in packaging of EV battery modules, as to have such modules designed to be effectively packed into an EV. It is intended as an industry guideline for battery module design.[978]

SAE J1797, which addresses only commercially available aqueous battery systems (i.e. lead-acid, nickel-cadmium and nickel-metal hydride) and defines four sizes of 12 V monoblocs, as illustrated in Table 5.12.

Type	Length	Width	Height	Mass	Ah
SAE EV1	388	116	175	≤ 21 kg	63
SAE EV2	306	173	223	≤ 30 kg	90
SAE EV3	246	123	260	≤ 13 kg	39
SAE EV4	197	165	170	≤ 15 kg	45

Table 5.12: Standard battery modules (SAE J1797; Ah values calculated)

The type SAE EV1 can also be found back in the proposals made to IEC TC69 WG3 on the subject (Table 5.1); the type SAE EV2 has nearly the same footprint than one of the standard types in Table 5.1, but is a few centimetres higher.

It is clear that the proposed sizes of battery modules do not allow for a high capacity battery, at least when using lead-acid: the typical capacity for a 12 V module (calculated in Table 5.12 using a energy density of 36 Wh/kg which corresponds to

[978] SAE J1797, Foreword and Scope

a state-of-the-art lead-acid battery) is in all cases below 100 Ah. This takes into account the evolution of technology on one hand towards higher system voltages (which need lower Ah capacity to get the same energy content), and on the other hand towards hybrid systems (where power density is paramount to energy density). As a comparison: the 6 V module shown in Table 5.1 above has a typical capacity of 180 Ah; this battery has been very popular in European electric vehicle design of the 1980s and 1990s.

SAE J1797 also states a number of guidelines for the mechanical interface (installation of the battery), ventilation interface, monitoring interface and safety.

5.6.4.2 SAE J1798: Performance rating

The "Recommended practice for performance rating of electric vehicle battery modules" SAE J1798 was published by the SAE Electric Vehicle Battery System Standards Committee in 1997. It provides for common test and verification methods to determine EV battery module performance, in order to determine what is the basic performance of EV battery modules and whether they meet minimum performance requirements specified by vehicle manufacturers.[979]

The document specifies the following battery tests:

- ☞ Static capacity test at constant current: the battery is discharged at currents of $C_1/1$, $C_2/2$ and $C_3/3$, corresponding to a discharge in one, two or three hours. This is a classical battery capacity test.
- ☞ Static capacity test at constant power: the battery is discharged in one, two and three hours, with a constant power of $P_1/1$, $P_2/2$ and $P_3/3$. This represents another approach to the capacity test, the notion of "power" is in fact more in line with the actual needs of the battery load (i.e. the vehicle), as also stated in the discussion on IEC 61982-3 (§5.2.4.8)
- ☞ Charge retention test, after 2, 14 and 30 days.
- ☞ Charge acceptance test at different temperatures (-20 °C, 0 °C, 25 °C, 45 °C)
- ☞ Peak power capability test, using 30 s discharge peaks at a current corresponding to the battery's maximum rated current, or a current equal to 80 % of the battery's rated peak power, divided by 2/3 open circuit voltage at 80 % depth of discharge, whichever the less. This test is repeated throughout a discharge cycle, since this power may be dependent on the battery SOC. The test is unique to this document, and is not used in the IEC battery standards.
- ☞ Dynamic capacity test, using the DST test profile (shown in Figure 5.11 above). This corresponds to the dynamic capacity test described in IEC 61982-3.

[979] SAE J1798, Scope

5.6.4.3 SAE J2288: Life cycle testing

"Life cycle testing of electric vehicle battery modules" is the subject of SAE J2288. It defines a standardized test method to define the life, in number of cycles, of electric vehicle battery modules. The repetitive discharge cycling in this test makes use of the dynamic discharge cycling in SAE J1798, and is thus fully comparable to the life testing in IEC 61982-3.

One could imagine that both SAE J1798 and J2288 could be replaced by international standards like IEC 61982-3 and/or IEC 61982-2. The international collaboration in standardization committees has already made possible that the US DST cycle has been implemented in IEC 61982-3; the further adoption of international standards, realized through consensus of all involved parties, can only be a major benefit.

5.6.4.4 SAE J2289: Battery pack functional guidelines

SAE J2289 "Electric Drive Battery Pack System Functional Guidelines" was published in 2000 by the SAE Electric Vehicle Battery Pack Standards Subcommittee of the SAE Electric Vehicle Battery Standards Committee. This document aims to provide guidance in designing battery systems for EV and HEV, describing common practices for design of battery systems. It lays the foundation for electric vehicle battery systems and provides information to assist in developing a robust battery system[980].
The document is principally aimed at battery system and vehicle designers and integrators. It is a "*should*" and "*may*" document and not a "*shall*" document: it does not specify acceptance criteria or compliance tests. It does refer however to other SAE publications related to batteries and electric vehicles.
SAE J2289 gives a general overview of battery system requirements, in the following fields:

- Physical requirements: mechanical retention, installation/removal from service, installation clearances.
- Durability requirements: mechanical shock, vibration, corrosion, abrasion, exposure to water, sand, dust and UV radiation.
- Electrical requirements: operational modes, electrical ratings, EMC, high power connection requirements, electrical isolation, monitoring/control system, diagnostics and service.
- Environmental requirements: operation temperature range, hazardous emissions, gas emissions management.
- Marking and labelling.

[980] SAE J2289, Scope

Although it can not be considered a real "standard", this document constitutes however a useful compilation of operational and safety requirements which the EV system designers are facing.

5.6.4.5 SAE J2380: Vibration testing

The SAE Recommended Practice "Vibration testing of electric vehicle batteries" was published in 1998 by the SAE Electric Vehicle Safety Committee.
It provides a test procedure for characterizing the effects of long-term road-induced vibration and shock on the performance and service life of electric vehicle batteries. The intent of the procedure is to assess the vibration durability of the battery.
The document is based on a test developed by the USABC. It defines vibration spectra (using swept sine wave testing) synthesized from actual rough-road measurements, and corresponding to about 100000 miles (160000 km) which are compressed in a test sequence of maximum 92 hours. Performance tests (according to SAE J1798) are done before and after the vibration test.

This is also a test which has no equivalent in the IEC standards. It seems foremostly useful for battery manufacturers in order to optimise the internal construction parameters of their batteries.

5.6.4.6 SAE J2464: Abuse testing

SAE J2464 deals with "Electric vehicle battery abuse testing" is also derived from a USABC document. It is intended as a guide toward standard practice rather than a definitive standard, being subject to change as technology advances. It describes a number of abuse tests on batteries, and does not define acceptance criteria for any of the tests since these are deemed application-dependent.[981]
SAE J2464 defines the following tests, some of which can obviously be considered as destructive tests:

☞ Mechanical abuse tests:
  - Shock test, at a "low" and "medium" level.
  - Drop test, from 10 m high.
  - Penetration test, with a pointed steel rod.
  - Roll-over test.
  - Immersion test in salt water.
  - Crush test, between a fixed surface and a textured platen.

☞ Thermal abuse tests:
  - Radiant heat test, to simulate a fire: 890 °C for 10 minutes

[981] SAE J2464, Scope

- Thermal stability test, at temperatures up to 200 °C, to verify if thermal runaway occurs
- Compromise of thermal insulation test
- Overheat/thermal runaway test, through high current cycling of the battery in a closed volume with all thermal controls disabled
- Thermal shock cycling test (+80 °C to -40 °C)
- Elevated temperature storage test (40 °C, 60 °C or 80 °C for two months)

☞ Electrical abuse tests:

- Short circuit test
- Partial short circuit test (between adjacent modules)
- Overcharge test
- Overdischarge test
- Extreme cold temperature cycling test

These tests were derived from failure mode and effect analysis, historical abuse testing and user input. It is clear that these users had quite some ideas about how to torture a battery!

One might even make the reflection that this might be a case of impending overstandardization as part of a hidden agenda against electric vehicles.

It may sound sensible of course to define requirements for on-board energy storage devices like batteries, but if one imagines for example how a gasoline tank, which is also an on-board energy storage device, and which actually stores a much higher amount of energy than a traction battery[982], would behave if subjected to the same abuse tests, one might be reminded of the biblical proverb *"different weights and different measures, both of them are alike abomination to the Lord"*.

The requirements for fuel tanks in existing vehicle regulations (for example the ECE 34 regulation[983]) are in fact not so strict.

Just like SAE J2380, the main interest of this document is as a guideline for battery manufacturers, in this case to define actual performance criteria for batteries. Since no acceptance criteria are given, this is not a standard relevant to the user.

5.6.5 SAE electrical component standards

Although SAE did not perform specific standardization work on traction-related electric vehicle components, it published a few documents on electrical cables and connectors that may be relevant for electric vehicle applications, and which are cited here for information's sake.

[982] A 50 litre tank of gasoline contains approximately 450 kWh of energy, whileas a typical EV battery contains about 15 to 20 kWh.

[983] ECE 34, Annex 5

5.6.5.1 SAE J1654: High Voltage Cables

The document SAE J1654 "High Voltage Primary Cable", issued from the SAE Cable Task Force, covers cable intended for use at a nominal system voltage higher than 60 V d.c. or 25 V a.c. but less than or equal to 600 V r.m.s. It is intended for use in surface vehicle electrical systems.

5.6.5.2 SAE J1673: High Voltage Wiring Assemblies

SAE J1673 "High Voltage Automotive Wiring Assembly Design" covers the design and application of primary on-board wiring distribution system harnesses for road vehicles, operating between 50 V and 600 V d.c. or a.c. r.m.s.

5.6.5.3 SAE J1742: High Voltage Connectors

The SAE Recommended Practice J1742 "Connections for High-Voltage On-Board Road Vehicle Electrical Wiring Harnesses - Test Methods and General Performance Requirements" defines recommended test methods and performance requirements of single-pole and multi-pole connectors for on-board electrical wiring harnesses of electric or hybrid vehicles, operating between 50 V and 600 V d.c. or a.c. r.m.s. It is aimed at connectors designed to be disconnected in case of maintenance or repair after mounting in the vehicle (e.g. not charging connectors, but battery pack or motor connectors).

5.6.6 SAE charging infrastructure standards

5.6.6.1 SAE J1772: Conductive charging

The document SAE J1772 "SAE Electric Vehicle Conductive Charge Coupler" was published in 1996. It is

> *"a recommended practice and in no manner should be interpreted as a standard of the SAE. This proposal should not be interpreted as an endorsement of conductive charging by SAE."*[984]

This first phrase of the document is a silent witness of the "charging wars" going on between major US vehicle manufacturers in the 1990s, where one major manufacturer (GM) extolled the virtues of inductive charging, while another one (Ford) preferred the conductive approach. Eventually conductive charging would

[984] SAE J1772, Foreword

be the solution of choice, due to its simplicity, low cost and excellent safety characteristics.

SAE J1772 covers the general physical, electrical and performance requirements for conductive charging couplers specifically for use in North America. It defines general system requirements, and personnel protection devices for the three "levels" of charging (which have already been cited in §5.2.5.3.2). It also defines electrical and physical requirements for the interface (vehicle inlet and coupler), as well as physical application requirements. SAE J1772 presents in appendix two examples of physical dimensions of couplers.
The constraints for personnel protection which have been introduced by SAE J1772 have had a deep influence on the IEC 61851 documents discussed in §5.2.5.2. The control pilot with ampacity control feature and the connector interface have found their way into the IEC standard. Eventually the SAE document may even be replaced by the international standard.

5.6.6.2 SAE J1773: Inductive charging

Also this document, SAE J1773 "SAE Electric Vehicle Inductively Coupled Charging" should not be interpreted as "an endorsement of inductive charging by SAE". It was first published in 1995, and revised in 1999. It establishes the minimum interface compatibility requirements for inductive charging in North America. This is the paddle-type technology also encountered in IEC 61980-2 (§5.2.5.4.3).
The 1995 version[985] featured the first version of the inductive charging coupler introduced on the US market by GM and Hughes, featuring a 138 mm paddle and a RF communication system. The industry however made the transition towards a smaller, 106 mm wide paddle and a IR communication coupling. This latter system is described in the 1999 version; the appendixes of this document contain provisions to provide compatibility between the two systems, allowing the small paddle to be used with older vehicles having the large inlet.

The contents of the 1999 version are fully parallel with the CD version of IEC 61980-2, the IEC document being in fact more than loosely based on the SAE one. The actual structure of the documents however reflects the traditions of each organization.

[985] SAE J1773:1995 "Electric vehicle inductive charge coupling recommended practice"

5.6.6.3 SAE J2293

SAE J2293 "Energy Transfer System for Electric Vehicles" consists of two parts: Part 1: "Functional Requirements and System Architectures" and Part 2: "Communication Requirements and Network Architecture", both published in 1997. These Recommended Practices are "*intended as a guide toward standard practice and are subject to change to keep pace with experience and technical advances*".

These extensive documents establish requirements for EV and off-board EVSE in North America. It defines, either directly or by reference, all characteristics of the total "EV Energy Transfer System" (EV-ETS) necessary to insure the functional interoperability of an EV and EVSE of the same physical system architecture.[986]
The ETS is the general system which converts a.c. electrical energy from the grid into d.c. electrical energy for the battery of an EV. Its location is shown in Figure 5.54.

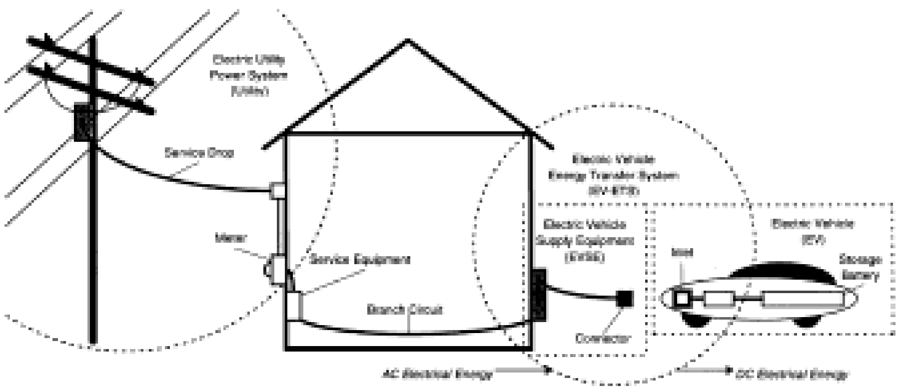


Figure 5.54: Electric vehicle energy transfer system[987]

The ETS can have different physical aspects ("architectures") depending on the style of coupling chosen:
☞ Conductive coupling to an a.c. charging station
☞ Inductive coupling
☞ Conductive coupling to a d.c. charging station
The limit between the EV and the EVSE will be dependent on this style, as shown in Figure 5.55. In each case, the considered functions, divided in four functional groups (FG) as shown, will belong to either EV or EVSE. For the physical coupling between EV and EVSE, reference is made to SAE J1772 and J1773.

Communication within the ETS complies to SAE J1850, a general standard for communication network interfaces on land-based vehicles. SAE J1850 is a Class "B"

[986] SAE J2293-1 and -2, Scope
[987] Ibid., Fig. 1

network, operating at speeds of either 10,4 Kb/s or 41,6 Kb/s. It has gained wide acceptance among American car manufacturers, being implemented in many production vehicles for data sharing and diagnostic purposes. The Controller Area Network "CAN" data bus, popular among European manufacturers, is a faster Class "C" network. It is described by the international standard ISO 11898.

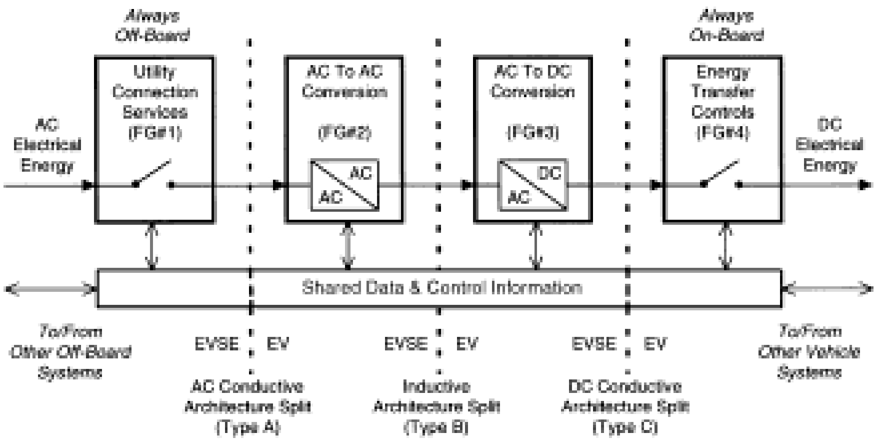


Figure 5.55: ETS structure

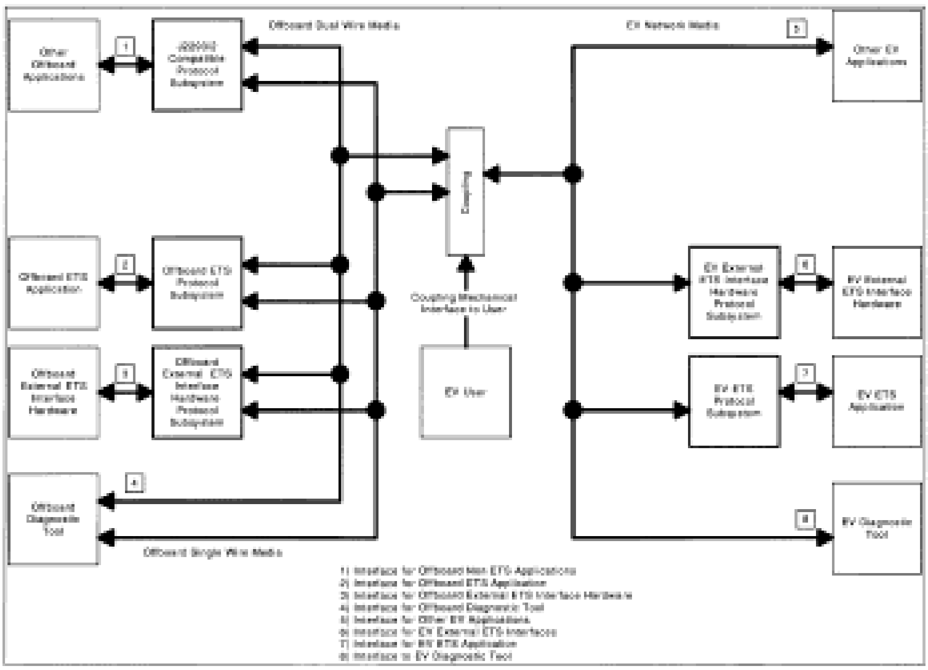


Figure 5.56: ETS network system architecture[988]

[988] SAE J2293-2, ¶7

Part 1 of SAE J2293 describes the total ETS and allocates requirements to the EV or the EVSE for the various architectures. It deals with the upper half of Figure 5.55.
This document describes in detail the functionality of the various elements of the system and the data flows that rules each of the processes.
Part 2 of SAE J2293 describes the communication network of the ETS, which exchanges information between EV and EVSE, as shown in the lower half of Figure 5.55.
It defines full system requirements and message structures for the SAE J1850-compliant ETS network, the overall architecture of which is shown in Figure 5.56.
The document also proposes the data dictionary for the communication.

5.6.7 SAE electric vehicle EMC standards

The SAE Recommended Practice SAE J551-5 "Performance levels and methods of measurement of magnetic and electric field strength from electric vehicles, broadband, 9 kHz to 30 MHz" will be discussed in the EMC chapter (§5.9.14).

5.6.8 SAE general electric vehicle standards

Information report SAE J1715 "Electric vehicle terminology" is a glossary of commonly used terminology concerning electric vehicles. It was first published in 1994[989] and revised in 2000[990].
Compared with the international standard ISO 8713 "Electric road vehicles - Vocabulary", SAE J1715 is much more extended: it presents 147 lemmata where the international standard just has 57. Furthermore, it is mainly battery-oriented.

[989] SAE J1715:1994 "Electric vehicle terminology"
[990] SAE J1715:2000 "Electric vehicle terminology"

5.6.9 Underwriters' Laboratories

Underwriters' Laboratories, Inc. (UL) is an independent, not-for-profit product safety testing and certification organization. Its involvement in electric vehicle standardization makes it worthwhile to mention in this paragraph.
UL was founded in 1894, mainly supported by the insurance sector through the National Board of Fire Underwriters. It was granted a charter in 1901 by the State of Illinois, authorizing the corporation to establish and maintain laboratories for the examination and testing of appliances and devices, and to enter into contracts with owners and manufacturers of such appliances and devices respecting the recommendations thereof to insurance organizations.[991] Today it is one of the most recognized conformity assessment providers in the world, testing products and granting them the UL safety mark.
UL has published over 800 safety standards, mostly concerning fire safety equipment, electrical installations and electric appliances. In a number of cases, it has adopted IEC publications as harmonized standards.
As a preliminary step to standardization, it also publishes so-called "outlines of investigation" An Outline is a collection of requirements based upon UL´s investigations of a few products and serves as guidelines in UL´s investigations for the product categories indicated.
A number of UL Outlines concerned electric vehicles:

☞ EV charging system equipment[992]. This extensive 1994 document proposes detailed requirements for construction, protection of users, performance testing, ratings, marking, instruction manuals, and production-line tests applicable to all ev charging equipment, either conductive or inductive, on-board or off-board, indoor or outdoor.

☞ Personnel protection systems for EV supply circuits[993]. This 1996 document covers devices and systems to reduce the risk of electric shock in circuits for charging electric vehicles. It defines protective system requirements for grounded and isolated systems.

☞ Plugs, receptacles and couplers for EV[994], a 1998 document describes requirements for plugs, socket-outlets, vehicle inlets and connectors rated up to 800 A and up to 600 V a.c. or d.c., and intended for conductive charging.

The requirements in these documents are much more detailed than is usual in international standards or similar documents. Their scope goes further in fact: the observance of the UL outlines or standards by a manufacturer is one of the conditions

[991] Underwriters' Laboratories, The Central Station, Vol8 n9 (1909-03) p200-202

[992] Underwriters' Laboratories, Subject 2202, Outline of investigation for EV charging system equipment, 1994-11

[993] Underwriters' Laboratories, Subject 2231-1, Outline of investigation for personnel protection systems for EV supply circuits, Issue 1, 1996-07

[994] Underwriters' Laboratories, Subject 2251, Outline of investigation for plugs, receptacles and couplers for EV, 1998-03 draft

for UL to cover the product and to allow the attribution of the UL mark. Organizations like ISO or IEC on the other hand do not normally perform conformity assessment activities.

Through the active participation of UL delegates, like Mr. Greg Nieminski, who is the Chairman of IEC SC23H, the activities of Underwriters' Laboratories however do contribute to international standardization.

5.6.10 The National Electrical Code

The emerging use of electricity by the end of the 19th century also created an awareness for the hazards of electricity. Rules to abate this hazard were published by various authorities, such as municipalities, fire departments and insurance companies. These rules showed a great diversity and no such thing as uniformity in practice existed. This chaotic condition made the National Electric Light Association (NELA; see also §3.2.1) to insist upon a single standard set of rules. As a result, a national conference on standard electrical rules met in New York City on March 18, 1896, where the rules of several organizations were discussed and compared: the NELA, the National Board of Fire Underwriters, the Associated Factory Mutual Insurance Companies, together with these of the Phoenix Fire Company and the Board of Trade, both of England. Following this conference, the first edition of the "National Electrical Code" was published in 1897 by the NELA.[995]

> *"The National Code is the outcome of experience. It is the result of a great amount of study and discussion. It stands to-day as the best expression of what is definitely believed by the ablest men of both insurance and electrical lines."*[996]

Since 1911, the NEC has been published by the National Fire Protection Association (NFPA), who publishes regular reviews, in principle every three years. The document, coded NFPA 70, is approved as an American National Standard. It is a model code that is adopted by local jurisdictions in both states and counties throughout the United States, frequently as written. It can be considered the American pendant of the AREI[997] in Belgium.

[995] W.H. Blood, Jr., The National Electrical Code and the Relation of the Contractor to the Central Station, Read before the National Electrical Contractors' Association, Toledo, Ohio, 1909-07-21; The Central Station, Vol9 n3 (1909-09) p31

[996] Pierce and Richardson, The National Electrical Code, An analysis and explanation of the underwriters' electrical code, intelligible to non-experts. Chicago, Charles A. Hewitt, c.1896

[997] Algemeen Reglement op de Elektrische Installaties (General Regulations on Electrical Installations)

The NEC contains hundreds of articles covering all aspects of electrical installations, from air conditioners to x-ray equipment, from pools to pipe organs.

In 1993 the SAE and the National Electric Vehicle Infrastructure Working Council proposed to include provisions for EV charging in the 1996 NEC.[998]
This led to the new Article 625 of the NEC, which deals with "Electric Vehicle Charging System", and which covers

> *the electrical conductors and equipment external to an electric vehicle, that connect an electric vehicle to a supply of electricity by conductive or inductive means, and the installation of equipment and devices related to electric vehicle charging."*[999]

NEC 625 states the requirements for the wiring methods, construction of the EVSE, and overcurrent and personnel protection. It also defines ventilation requirements for enclosed garages[1000].

[998] Infrastructure Working Council, An Overview of New NEC Article 625, 1995-06-28
[999] National Electrical Code, 1999 edition, ¶625-1, NFPA, Quincy, Massachusetts
[1000] Ibid.

5.7 *Regional standardization work in Asia*

5.7.1 The Japan Electric Vehicle Association

The Japan Electric Vehicle Association (JEVA) was founded in 1976 with the direction and assistance of government and industry bodies as an organization to conduct R&D and promotion activities in the field of electrically powered vehicles. JEVA works as a domestic deliberative organization to draft and spread standards for electric vehicles, their components and related equipment. It also works towards international standardization, participating in the activities of ISO and IEC and collaborating with SAE.

Since its inception, JEVA has published over 40 standards, most of them only available in Japanese version however. This paragraph will have a closer look however to the 20 documents that have been translated in English.

5.7.2 JEVA electric vehicle performance standards

5.7.2.1 *JEVS Z108: driving range and energy consumption*

The standard JEVS Z108 "Electric vehicle measurement for driving range and energy consumption", published in 1994, specifies dynamometer test procedures for measuring the range and the a.c. energy consumption of battery-electric road vehicles. It was also published as national Japanese standard JIS D1301.

The interesting feature of this test is that it introduces the Japanese test cycles "10-mode" and "15-mode". These names are derived from the number of driving phases in each cycle.
The 10-mode cycle (Figure 5.57) represents city traffic with a speed up to 40 km/h; one cycle is 664 m long. Maximum acceleration is 0,79 m/s^2.
The 15-mode cycle (Figure 5.58) is a 2173 m long suburban cycle with speeds up to 70 km/h. Maximum acceleration is 0,77 m/s^2.

A typical test sequence consists of three 10-mode cycles and one 15-mode cycle. For low speed vehicles, only the 10-mode cycle shall be applied. This pattern is repeated until the end-of-test criterion is reached, that is when the vehicle is deviating from the speed curves for at least 4 s. The vehicle is charged after the test to obtain the a.c. energy consumption.

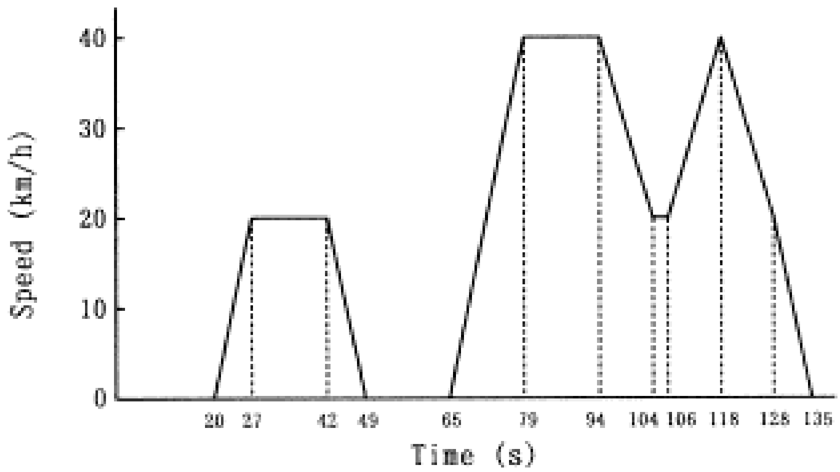


Figure 5.57: 10-mode cycle

The 10-mode and 15-mode cycles have now made it into the international standard ISO 8714[1001] (§5.3.4) which may eventually displace this Japanese standard.

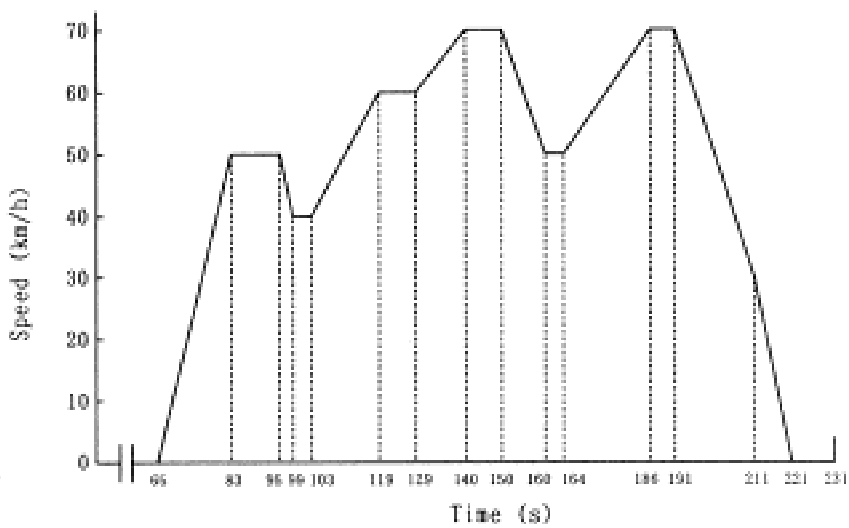


Figure 5.58: 15-mode cycle

[1001] ISO 8714:2002, Annex C

5.7.2.2 *JEVS Z109: Acceleration measurement*

JEVS Z109 "Electric vehicle - Measurement for acceleration" specifies a test procedure for measuring the acceleration of electric road vehicles. The test is performed on a level road.

5.7.2.3 *JEVS Z110: Maximum cruising speed*

JEVS Z110 "Electric vehicle - Measurement for maximum cruising speed" specifies test procedures for measuring the maximum *practical* speed of electric road vehicles. Two speeds are defined:[1002]

☞ The maximum 30-minute cruising speed

☞ The maximum practical speed over 1 km distance.

These two tests are also prescribed by the international standard ISO 8715.[1003]

5.7.2.4 *JEVS Z111: Travelling energy consumption*

JEVS Z111 "Electric Vehicle - Measurement for Reference Energy Consumption" aims to measure the "travelling energy consumption" of electric passenger road vehicles. The "travelling energy consumption" is defined as the energy consumption (expressed in Wh) measured at the battery terminals, including both energy discharged from the battery and recharged through regenerative braking.[1004] The test is performed using the same driving cycles (10-mode and 15-mode) as JEVS Z108, and can be performed together with it.

This way of measuring energy is not found back in the international standard ISO 8714. However, measuring the energy at the battery terminals is an interesting feature of electric vehicle testing. It is performed for example systematically in the tests performed by CITELEC, although it is there generally expressed in Ah (as battery discharge) and called "instantaneous consumption". If performed in different traffic conditions and with different drivers, the instantaneous energy consumption provides interesting feedback on the influence of traffic and driving style on the energy consumption.

[1002] JEVS Z110, ¶3

[1003] ISO 8715:2001, ¶9

[1004] JEVS Z111:1995, ¶5.2

5.7.2.5 *JEVS Z112: Hill climbing ability*

JEVS Z112 "Electric vehicle - Measurements of hill climbing ability" describes a steep slope test for determining the maximum gradient that can be climbed and a long slope test for determining the cruising speed of hill climbing.
The tests present some differences compared to the international standard ISO 8715: in JEVS Z112, the maximum gradient is attacked from a launching track at low speed (5 km/h)[1005] whileas ISO 8715 measures the hill starting ability from speed zero[1006]. For the hill climbing speed, it is done in JEVS Z112 at 12 % on a road (or on a bench)[1007]; the international standard only specifies dynamometer tests, performed on 4 or 12 % slope.[1008]

5.7.3 JEVA electric vehicle battery standards

5.7.3.1 *JEVS D001*

The standard JEVS D001 "Dimensions and construction of valve regulated lead-acid batteries for electric vehicles" defines two standard sizes of 12 V lead-acid monobloc batteries, as well as some constructional requirements.

Type	Length	Width	Height
A	295	130	200
B	388	116	175

Table 5.13: Battery sizes from JEVS D001 (mm)[1009]

The proposed sizes, shown in Table 5.13, can be compared with the sizes proposed by SAE J1797 (Table 5.12) and by those proposed to IEC TC69 WG3 (Table 5.1). One can see that both sizes were proposed to WG3, type "A" being identical to type SAE EV1.

5.7.3.2 *JEVS D701*[1010]*: Battery capacity*

JEVS D701 "Capacity test procedure for lead-acid batteries of electric vehicles" specifies test procedures for vented and valve-regulated lead-acid batteries for electric

[1005] JEVS Z112:1996, ¶3.2
[1006] ISO 8715:2001, ¶9.8
[1007] JEVS Z112:1996, ¶3.3
[1008] ISO 8715:2001, ¶9.7
[1009] JEVS D001:1995, Table 1
[1010] JEVS D701:1994 "Capacity test procedure for lead-acid batteries of electric vehicles"

vehicles. These are based on a constant-current discharge at the three-hour current (i.e. a current in amps equal to the rated capacity at three-hour rate divided by three), down to a test voltage of 1,65 V.[1011]
This cut-off voltage is logically located between the cut-off voltages specified in IEC 60254-1 for constant-current discharge tests on lead-acid batteries: 1,70 V for a five-hour discharge [1012]and 1,60 V for a one-hour discharge[1013].

5.7.3.3 JEVS D702: Energy density

The standard JEVS D702 "Energy density test procedure for lead-acid batteries of electric vehicles" defines energy density with respect to mass (Wh/kg) or volume (Wh/l). The energy content in Wh is defined by multiplying the three-hour capacity from the JEVS D701 test with the average voltage measured during the discharge test.

5.7.3.4 JEVS D703: Power density

JEVS D703 "Power density test procedure for lead-acid batteries of electric vehicles" measures the power density (W/kg) of lead-acid batteries at 50 % SOC according to JEVS D701.
The current used for this test is derived from a preliminary test that evaluates the relationship between discharge current and voltage drop, at test currents of ⅓ C_3, C_3, 3 C_3 and 6 C_3. This curve is extrapolated to obtain a value for the discharge current equivalent to ⅔ of the open circuit voltage. This discharge current is then applied during 30 s; the average voltage during this discharge gives the average power for the power density calculation.
This test is comparable to the maximum power test described in IEC 61982-3 (§5.2.4.9), with the difference however that JEVS D703 actually performs the measurement, whileas the IEC test prescribes a theoretical calculation of the maximum battery power, recognizing that the actual test may overstress the battery.

5.7.3.5 JEVS D704: Cycle life test

JEVS D704 "Cycle life test procedure of valve-regulated lead-acid batteries for electric vehicles" specifies a life cycle test using the discharge pattern cycle shown in Figure 5.59. This cycle is comparable in shape to the cycles defined in IEC 60254-1 (Figure

[1011] JEVS D701:1994, ¶3.2
[1012] IEC 60254-1:1997, ¶4.2.5
[1013] IEC 60254-1:1997, ¶6.1.2.5

5.8) and IEC 61382-1 (§5.2.4.3), but has a maximum current of 1,8 C_3 (which can be equivaled to 2 to 3 C_5), whileas IEC 60254-1 specifies 8 C_5, and IEC 61382-1 only 1,6 C_5.

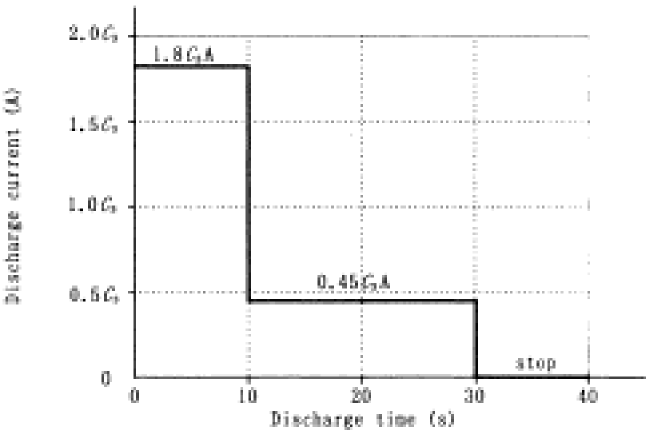


Figure 5.59: JEVS D704 discharge cycle[1014]

5.7.4 JEVA electric vehicle component standards

5.7.4.1 JEVS E701: electric motors and controllers

The document JEVS E701 "Combined power measurement of electric motors and controllers for electric vehicles" specifies procedures for measuring the combined power characteristics of electric motors and controllers. This "motor-controller" approach reflects technological evolutions and was also considered by IEC TC69 WG2 (§5.2.3.6). It makes reference to the standards JEVS Z101 and JEVS Z107 (both of which only exist in Japanese however), and to JIS C4004, a general Japanese standard on rotating electrical machines.
Tests described in this document include:

☞ Continuous power rating test
☞ Short-time rating test, recommended durations are 30 s, 1, 3, 5, 10 and 15 min.

The permissible temperature rises for the different insulation classes are given in Table 5.14. One should note that these values are lower than those specified in other motor standards like BS 1727 (Table 4.3) or IEC 60349[1015]. JEVS E701 prefers the temperature measurement using a thermometer or embedded thermometer[1016], whileas the other standards prefer the resistance measurement for those windings

[1014] JEVS D704:1997, Figure 1
[1015] IEC 60349-1:1991, ¶6.1
[1016] JEVS E701:1994, ¶5.3

where it is practicable. Permissible temperature rises measured by thermometer are usually 10 to 15 degrees lower than measured by resistance; this on itself does not cover the differences however; another consideration might be the fact that JEVS E701 also addresses controllers.

Insulation Class	Temperature rise °C
A	65
E	80
B	90
F	110
H	135

Table 5.14: Permissible temperature rise (JEVS E701)[1017]

5.7.4.2 *JEVS E702: Power measurement*

JEVS E702 "Power measurement of electric motors equivalent to the on-board state for electric vehicles" is a companion standard to JEVS E701, describing the test procedure for motor-controllers, combined as they are on-board the EV, in order to draw torque, power and efficiency curves in function of the speed.

5.7.5 JEVA electric vehicle infrastructure standards

5.7.5.1 *The Eco-Station concept*

5.7.5.1.1 Introduction

The availability of fast charging for electric may increase their flexibility and use potential. However, fast charging stations exert a high power demand on the distribution network, typically 36 kVA per vehicle. At peak times, such load can be very expensive. To this effect, a concept was developed in Japan in 1992, involving a fast charging station featuring a large stationary battery, which was charged overnight and which debited high current in electric vehicles visiting this "Eco-Station" to be charged. This concept has also been considered for other locations, such as the charging station for the hybrid-electric buses of the "LuxBus" project in Luxembourg, G.D. Luxembourg[1018], where the technical evaluation was performed by CITELEC.

[1017] JEVS E701:1994, Table 2

[1018] Thermie Project TR153/94 "LuxBus - Hybrid electric city bus for the Grand Duchy of Luxembourg"

In 1993, JEVA published a number of standards on the issue, which were also circulated among the members of IEC TC69 WG4. The applicable standards are shown on the schematic diagram of the Eco-Station in Figure 5.60.

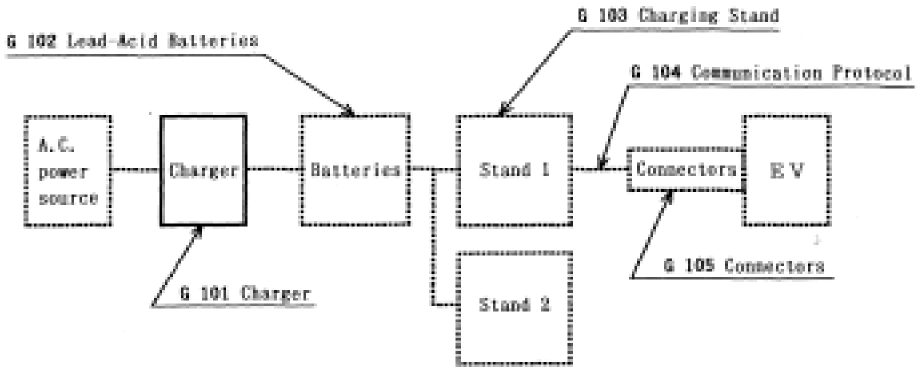


Figure 5.60: Eco-Station scheme[1019]

5.7.5.1.2 JEVS G101

JEVS G101 "Chargers applicable to quick charging system at Eco-Station for electric vehicles" defines the specifications of the charger used to charge the stationary battery in the Eco-Station: operation procedure, electrical performances, functional specifications.

5.7.5.1.3 JEVS G 102

The document JEVS G102 "Lead-acid batteries applicable to quick charging system at Eco-Station for electric vehicles" specifies assembled batteries for energy storage under the "Eco-Station" concept.
These are stationary batteries. The document contains specifications for installations and ventilations and describes a charging test and voltage variation test.

5.7.5.1.4 JEVS G 103

JEVS G103 "Charging stands applicable to quick charging system at Eco-Station for electric vehicles" defines physical and electrical specifications for the quick charging stand that is the interface between the EV and the Eco-Station. Ratings are 10 to 150 A d.c. output, at a voltage of 48 to 500 V d.c., in order to cover a wide range of electric vehicles.

5.7.5.1.5 JEVS G 104

JEVS G104 "Communications protocol applicable to quick charging system at Eco-Station for electric vehicles" describes the control and communications interface that

[1019] JEVS G101:1993, Appendix

rules the function of the Eco-Station. Both the physical layer and the data structures are covered.
It could be considered as the Japanese pendant of the European prestandard ENV 50275-2-4, with which it is not compatible however.

5.7.5.1.6 JEVS G 105
JEVS G105 "Connectors applicable to quick charging system at Eco-Station for electric vehicles" defines physical specifications for a connector rated 150 A d.c. for the Eco-station. This is used in a Case "C" configuration (cf. Figure 5.18), and contains only high-power d.c. and communication contacts; this interface is thus not usable for connection to the a.c. network.

5.7.5.2 TG G101: AC 200 V Charging system

JEVA TG G101 "AC 200 V charging system for electric vehicles", issued in 1997, is a "technical guideline" rather than a standard. It is thus intended to be a temporary document to provide guidance in an area where "data acquisition and verification have not completed and discussions have not matured to make the standards". In this case, this means of course the standard IEC 61851 (§5.2.5.2).
JEVA TG G101 aims to offer design and production guidance in realizing a 200 V single phase a.c. charging system, defining physical and electrical requirements of the charging interface, as well as proposing a physical design for the connector rated 50 A a.c. (Figure 5.61). This is a Mode 3 device fitted with a control pilot.

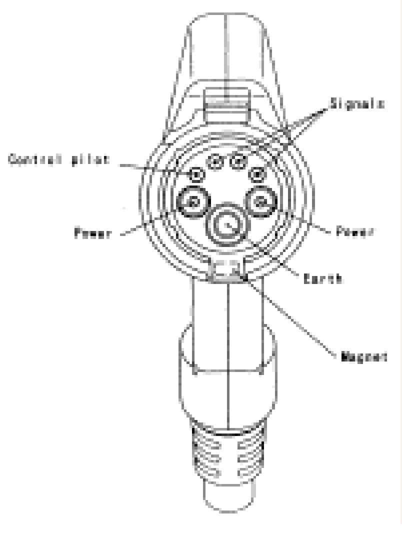


Figure 5.61: Connector from JEVA TG G 101

The publication of this guideline by the Japanese can be compared to the publication of ENV 50275 (§5.5.3.2) by CENELEC in Europe: in both cases, the slow

progress of international standardization work in IEC pushed the local standardization committee to provide a preliminary document (technical guideline or prestandard) in order to cover immediate needs from the industry for a guidance document.
With the adoption of IEC 61851 as an international standard covering all requirements, this document can obviously be slated for replacement.

5.7.6 JEVA general electric vehicle standards

5.7.6.1 JEVS Z804: Symbols and indicators

The standard JEVS Z804 "Electric vehicles – Symbols for indicators, controls and telltales" defines a number of symbols for informing the EV driver. These are indicated in Table 5.15.

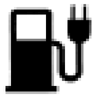
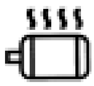
SOC of main batteries	Motor overheat	Charge coupling	Electric brake	Operation ready	System malfunction	Reduced power mode
				READY		

Table 5.15: Symbols for controls, indicators and telltales[1020]

This standard is to be seen as a complement to other standards defining similar symbols for conventional vehicles such as the Japanese JIS D0032 or its international equivalent ISO 2575. This work has also been input to ISO TC22 SC21.[1021]

5.7.6.2 JEVS Z901: Standard Specification for EV

JEVS Z901 "Electric vehicle – Standard form of specification (Form of main specification)" specifies standard forms, items and entering procedures for the specifications of electric vehicles. It merely lists all data that have to be entered in the vehicle specification sheets.

[1020] JEVS Z804, Table 1
[1021] Doc.ISO/TC22/SC21 N224E – Graphic symbols – Collection of information, 1997-07

5.7.7 JEVA standards in Japanese

A number of JEVA standards are only available in Japanese edition and we have thus been unable to analyse their contents; they are listed here for information however.

- ☞ JEVS C601:2000: Plugs and receptacles for EV charging
- ☞ JEVS D002:1999: Capacity/Dimension/Structure for NiMH batteries
- ☞ JEVS D705:1999: Capacity test procedure for NiMH batteries
- ☞ JEVS D706:1999: Energy density test procedure for NiMH batteries
- ☞ JEVS D707:1999: Power density test procedure for NiMH batteries
- ☞ JEVS D708:1999: Cycle life test procedure for NiMH batteries
- ☞ JEVS D709:1999: Dynamic capacity test procedure for NiMH batteries
- ☞ JEVS E901:1985: Nameplates of electric motor and controller for EV
- ☞ JEVS G106:2000: Inductive charging - General requirements (based on IEC 61980-1)
- ☞ JEVS G107:2000: Inductive charging - Manual connection (based on SAE J1773)
- ☞ JEVS G108:2001: Communication protocol (based on SAE J1773)
- ☞ JEVS G109:2001: Conductive charging - General requirements (based on IEC 61851-1)
- ☞ JEVS Z101:1987: General rules of running test method of EV
- ☞ JEVS Z102:1987: Maximum speed test method of EV
- ☞ JEVS Z103:1987: Range test method of EV
- ☞ JEVS Z104:1987: Climbing hill test method of EV
- ☞ JEVS Z105:1988: Energy economy test method of EV
- ☞ jEVS Z106:1988: Energy consumption test method of EV
- ☞ JEVS Z107:1988: Combined test method of motors and controllers for EV
- ☞ JEVS Z805:1998, JEVS Z806:1998, JEVS Z807:1998, JEVS Z808:1998: Terminology (also registered as JIS D0112, D0113, D0114 D0115)

The presence of a number of standards about NiMH batteries shows the interest of Japanese manufacturers for this type of battery.

5.7.8 Electric vehicle standardization in the Republic of Korea

The involvement of industry in the Republic of Korea in EV and HEV manufacturing has created the need to prepare Korean standards (KS). Specific activities in this field started in 1996, mostly performed by the Korea Automotive Technology Institute (KATECH), and categorized in four fields: electric vehicle, interface/infrastructure, battery, and motor/controller/charger.

For the "electric vehicle", the following test standards have been published[1022]:
- ☞ KS R 1133: General rules of running test method of electric vehicles
- ☞ KS R 1134: Coastdown test method of electric vehicle
- ☞ KS R 1135: Energy consumption and range test procedure of electric vehicles
- ☞ KS R 1136: Acceleration and maximum test measurement of electric vehicles
- ☞ KS R 1137: Maximum climbing test method of electric vehicles
- ☞ KS R 1138: Climbing test method of electric vehicles
- ☞ KS R 1139: Brake test method of electric vehicles

The contents of these documents is mainly influenced by SAE and JEVS standards.

For performance tests on HEV, a draft version has been established based on SAE J1711; it only addresses however HEVS with a battery as RESS and it does define the components for the exhaust emission test.
This procedure has been verified through tests on a Toyota Prius hybrid vehicle. Test results based on the Korean draft procedure were very comparable with those performed by the US EPA.[1023]

As what concerns infrastructure standardization, the international standards IEC 61851-1, IEC 61851-21 and IEC 61851-22 have been adopted as KS. [1024]

Standards for batteries have been focused on performance and safety evaluation nickel-metal hydride and lithium-ion batteries.[1025]

Extensive work is being performed in the field of component standardization. From 1999, a number of standards for motor and controller have been developed and proposed in 2001 for adoption as KS[1026]:
- ☞ KS G7-MC01: Test procedure for electric motor for electric vehicle
- ☞ KS G7-MC02: General test procedure for controller for electric vehicle
- ☞ KS G7-MC03: Combined test for motor and controller for electric vehicle

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1022 Rhee, Meung-ho and Hahn, Chang-su, Standardization of testing methods for EV&HEV in Korea, EVS-19, Busan, 2002 (Paper and dialogue presentation poster)
1023 Ibid.
1024 Chung, Gyo-Bum and Oh, Sung-Chul, Standardization activity on EV motor, controller and charger in Korea, EVS-19, Busan, 2002 (Paper and dialogue presentation poster)
1025 Kim, Ki-won, Rhee, Meung-ho and Hahn, Chang-su, Standardization of performance and establishment of test methods for EV batteries, EVS-19, Busan, 2002
1026 Chung, op.cit.

5.8 ECE regulations relevant to electric vehicles

5.8.1 Introduction

It could be stated that the subject of this paragraph falls outside the scope of the work, since "regulations" are not the same as "standards". However, some of these regulations cover the same subjects as existing international or European standards. Since there may be a certain confusion on this matter, we thought it to be useful to give some attention to it, under form of a brief historical introduction and an analysis of relevant regulations in force.

The first confusion that often arises is about the nature of the ECE. Unlike what one might think at first sight of the acronym, the ECE has nothing to do with the "European Commission". Its full name is UNECE[1027]: it is in fact the "United Nations Economic Commission for Europe", set up in 1947 as one of five regional commissions of the United Nations. Its primary goal is to encourage greater economic cooperation among its member States, focusing on economic analysis, environment and human settlements, statistics, sustainable energy, trade, industry and enterprise development, timber and transport.
Activities include policy analysis, development of conventions, regulations and standards, and technical assistance. It has 55 member states (all European countries and the former USSR republics, and Israel); over 70 international professional organizations and other non-governmental organizations take part in UNECE activities. There are also a number of observer countries, like the USA and Japan.
In the field of transport, UNECE has established international technical regulations for road vehicles, and their equipment and parts. Over 100 regulations established by UNECE provide for equal safety and environmental requirements, for governments and vehicle manufacturers in 32 countries. These regulations reduce manufacturing and research costs, and remove obstacles to the international trade of motor vehicles, allowing for easier type approval of motor vehicles between countries.

In the automotive trade, these regulations are often referred to as "Geneva regulations", the UNECE being based in Geneva, Switzerland. This gives another source of confusion as Geneva is also the seat of IEC and ISO, making this Swiss city the "standardization and regulation capital of the world".

All these regulations are considered addenda to the

> *"Agreement concerning the adoption of uniform technical prescriptions for wheeled vehicles, equipment, and parts which can be fitted and/or be used on wheeled vehicles and the conditions for reciprocal recognition of approvals granted on the basis of these prescriptions"*

[1027] http://www.unece.org

which, in its original form, was done in Geneva on March 20, 1958.
At this moment, there are 113 ECE regulations on vehicles published. They cover a wide amount of subjects such as vehicle lighting, safety devices, collision safety, braking, noise, and polluting emissions. Their layout can be compared to that of an international standard (scope, definitions, specifications, etc...) although they also contain a number of administrative clauses regarding type approval and definition of approval marks.
ECE regulations are not automatically mandatory unless taken into national legislation. Within the EU, it has been agreed that the ECE will act as the lead body for vehicle harmonization and type approval, and the EU acts as a single body (with 15 votes) in the ECE.
Within UNECE, vehicle specification and type approval are looked after by Working Party 29. Within WP29, a number of working groups are active on different topics.

5.8.2 ECE and electric vehicles: historical developments

With the appearance on the market of traffic-compatible electric vehicles, "aimed to compete with ICE vehicles" in the late 1970s, the necessity of adopting specific regulations for this class of vehicles was considered by ECE.
On the 57TH session of the expert group on vehicle construction, which was held in Geneva in March 1979[1028], the issue of electrically driven vehicles was put on the agenda.
A document[1029] was presented, which had been communicated by the UK Government, stating the rationale that traffic-compatible electric vehicles, unlike slow vehicles such as milk floats, must comply to the same safety rules than other road vehicles. It examined the regulations that were in force, dividing them in three groups:

- ☞ Regulations applicable to all vehicles, which could be adopted as such for electric vehicles. Examples include: headlights, safety belts, etc.
- ☞ Regulations applicable to all vehicle, which would need minor adaptations in text or in test procedures to take into account electric vehicles. Examples include: braking (to take in account regenerative braking)or crashworthiness (to take into account the battery mass)
- ☞ Regulations which would require specific test procedures for electric vehicles.

The ECE also took note of the standardization work being performed by ISO and IEC, and of the division of work being convened among these committees (cf. §5.4)

[1028] UNECE, Agenda of the 57th session, 1979-03-05, Doc. TRANS/SC1/WP29/46
[1029] UNECE, Doc. TRANS/SC1/WP29/R.178, 1978-11-28

5.8.3 ECE and electric vehicles: current regulations

At this moment, a number of regulations can be identified which contain explicit provisions referencing to electric vehicles and which have merit further study taking into account their relevance for this work:

- ☞ ECE 12: Uniform provisions concerning the approval of vehicles with regard to the protection of the driver against the steering mechanism in the event of impact.
- ☞ ECE 13: Uniform provisions concerning the approval of vehicles of categories M, N and O with regard to braking.
- ☞ ECE 51: Uniform provisions concerning the approval of motor vehicles having at least four wheels with regard to their noise emissions.
- ☞ ECE 68: Uniform provisions concerning the approval of power-driven vehicles including pure electric vehicles with regard to the measurement of the maximum speed.
- ☞ ECE 85: Uniform provisions concerning the approval of internal combustion engines or electric drive trains intended for the propulsion of motor vehicles of categories M and N with regard to the measurement of the net power and the maximum 30 minutes power of electric drive trains.
- ☞ ECE 100: Uniform provisions concerning the approval of battery electric vehicles with regard to specific requirements for the construction and functional safety.
- ☞ ECE 101: Uniform provisions concerning the approval of passenger cars equipped with an internal combustion engine with regard to the measurement of the emission of carbon dioxide and fuel consumption and of categories M1 and N1 vehicles equipped with an electric power train with regard to the measurement of electric energy consumption and range.

The "categories" of vehicles referenced to are derived from the European directive: [1030]

- ☞ Category M are "motor vehicles with at least four wheels used for the carriage of passengers":
  - ☛ M1 are "vehicles used for the carriage of passengers and comprising no more than eight seats in addition to the driver's seat" (i.e. cars and minibuses).
  - ☛ M2 are "vehicles used for the carriage of passengers, comprising more than eight seats in addition to the driver's seat, and having a maximum mass not exceeding 5 tonnes"

[1030] Council Directive No 92/53/EEC

- M3 are "vehicles used for the carriage of passengers, comprising more than eight seats in addition to the driver's seat, and having a maximum mass exceeding 5 tonnes"

- Category N are "motor vehicles with at least four wheels used for the carriage of goods":
  - N1 are "vehicles used for the carriage of goods and having a maximum mass not exceeding 3,5 tonnes"
  - N2 are "vehicles used for the carriage of goods and having a maximum mass exceeding 3,5 tonnes but not exceeding 12 tonnes"
  - N3 are "vehicles used for the carriage of goods and having a maximum mass exceeding 12 tonnes"

- Category O are trailers (including semi-trailers):
  - O1 are "trailers with a maximum mass not exceeding 0,75 tonnes"
  - O2 are "trailers with a maximum mass exceeding 0,75 tonnes but not exceeding 3,5 tonnes"
  - O3are "trailers with a maximum mass exceeding 3,5 tonnes but not exceeding 10 tonnes"
  - O4 are "trailers with a maximum mass exceeding 10 tonnes".

5.8.4 ECE 12

Regulation No. 12 "Uniform provisions concerning the approval of vehicles with regard to the protection of the driver against the steering mechanism in the event of impact" - revision 3 - amendment 1 - entered into force on December 12, 1996. It was prepared by the working group GRSP on passive safety.

It applies to the behaviour of the steering mechanism of motor vehicles of category M1 and N1, with a maximum permissible mass less than 1500 kg, with regard to the protection of the driver in a frontal collision.[1031]

The document specifies the behaviour of the steering column in case of a crash. Amendment 1 to this regulation introduces some requirements for electric vehicles[1032]:

- The crash test shall be carried out with the propulsion battery master switch in the "on" position.
- The battery monoblocs shall remain fixed in their places.
- No liquid electrolyte shall leak into the passenger compartment; a limited leakage is permissible, however, only to outside the vehicle, provided that the

[1031] ECE 12, Rev.3, ¶1, Scope

[1032] ECE 12, Rev.3, Amend.1, ¶5.1.1

leakage which occurs during the first hour after the test does not exceed 7 per cent of the total of the liquid electrolyte in the propulsion battery.

5.8.5 ECE 13

Regulation No. 13 "Uniform provisions concerning the approval of vehicles of categories M, N and O with regard to braking", Revision 4, entered into force on August 1, 2000. It was prepared by the working group GRRF on brakes and running gear.
It applies to the braking of power-driven vehicles individually and of trailers individually of categories M, N and O[1033].

This regulation defines specifications for braking systems, taking into account two types of electric regenerative braking: [1034]

☞ "Category A" regenerative braking which is not part of the service braking system.
For light vehicles (categories M1 and N1), this shall only be actuated by the accelerator control and/or the gear selector neutral position.
For vehicles categories N2 (< 5t) and M2, the control can be a separate switch or lever.[1035] This corresponds to a "retarder" switch often found on heavy-duty vehicles.
This case corresponds to the configuration present on several electric vehicles on the market today, where regenerative braking is initiated by releasing the accelerator pedal. This configuration mimics the "engine braking" on an ICE vehicle, and is thus considered an element of "driveability" by a number of automobile manufacturers; one must recognize however that this solution is not the optimal one if viewed from an energy economy standpoint, since it eliminates the "coasting" phase where energy consumption is effectively zero. The combination of coasting ability, with regenerative braking (actuated e.g. via the brake pedal) allows for the best fuel economy if the driver is skilled in their use[1036].

☞ "Category B" regenerative braking system which is part of the service braking system.
This corresponds to the control of regenerative braking through the braking pedal.

[1033] ECE 13, Rev. 4, ¶1, Scope
[1034] ECE 13, Rev. 4, ¶2.20
[1035] Ibid., ¶5.2.1.25.1
[1036] This issue has been investigated by CITELEC, cf. Test report on Peugeot 106 électrique, 1996

> In this case, the service braking system shall have only one control device, and it shall not be possible to manually disconnect partially or totally one part of the service braking system.[1037] This requirement goes back to the CEN TC301 WG2 report on the issue (§5.5.7).

ECE 13 also adapted its braking tests in function of the presence of regenerative braking, including failure tests[1038]:

- ☞ For a total failure of the electric component of the service braking.
- ☞ In the case where the electric component delivers the maximum braking force when a failure of the electric transmission occurs.

The last case corresponds to a short-circuit of the motor armature through the power controller, which causes a very high braking torque which may have unwanted consequences.

5.8.6 ECE 51

Regulation No. 51 "Uniform provisions concerning the approval of motor vehicles having at least four wheels with regard to their noise emissions" entered into force on May 5, 1996. It was prepared by the working group GRB on noise.
It contains a measurement methodology for noise emitted by motor vehicles having at least four wheels.
This regulation makes the following statements concerning electric vehicles:

- ☞ Noise emission of electric vehicles must only be measured when the vehicle is moving, no measurement on stationary vehicles is necessary[1039].
- ☞ The speed at which the noise has to be measured is ¾ of the maximum speed, or 50 km/h, whichever is the lower.[1040]

5.8.7 ECE 68

Regulation No. 68 "Uniform Provisions concerning the approval of power-driven vehicles with regard to the measurement of the maximum speed" entered in force on May 1, 1987 and was amended on November 30, 1996 to include battery-electric vehicles. It was prepared by the working group GRPE on pollution and energy.
It applies to the approval of power driven-vehicles including pure electric vehicles of categories M1 and N1 with regard to the measurement of the maximum speed indicated by the manufacturer[1041].

[1037] Ibid., ¶5.2.1.25.2
[1038] Ibid., Annex 4, ¶2.2.6
[1039] ECE 51, Rev. 1, ¶6.2.1.1
[1040] ECE 51, Rev. 1, ¶3.1.2.2, ¶3.1.2.3
[1041] ECE 68, Amend. 1 ¶1, Scope

This document should be compared side by side with the European standard EN 1821-1 "Electrically propelled road vehicles - Measurement of road operating ability - Part 1: Pure electric vehicles"

For electric vehicles, ECE 68 defines:

- ☞ The "maximum speed", as the "highest average value of the speed which the vehicle can maintain twice over a distance of 1 km"[1042]. This definition is in line with the definition in EN 1821-1[1043].
- ☞ The "maximum 30 minute speed", as "the average value of the maximum speed which the vehicle can maintain for 30 minutes"[1044]. Also this definition is in line with EN 1821-1[1045].

As for the test procedures, the requirements for test track (¶5.3 in ECE 68, ¶6.3 in EN 1821-1), test load (¶5.2.1.3 in ECE 68; ¶3.3 in EN 1821-1), battery pre-charge (¶5.2.2.2 in ECE 68; ¶7.1 in EN 1821-1) and vehicle warm-up (¶5.5.1.2.2 in ECE 68, ¶7.3 in EN 1821-1) also are comparable between the two documents.

As for the actual test, there are some small differences however:

- ☞ For the maximum speed test, ECE 68 requires a distance covered of at least 2000 m for electric vehicles[1046], whileas EN 1821-1 specifies a distance of 1000 m[1047].
- ☞ The formula used to calculate the maximum thirty minute speed is different in both documents, although both formulas yield the same result[1048].

It is clear that there is a close concordance between the European standard and the ECE regulation in this case. Such concordance can only be lauded, since any discordance would greatly reduce the usability of any of these documents.

5.8.8 ECE 85

Regulation No. 85 "Uniform provisions concerning the approval of internal combustion engines or electric drive trains intended for the propulsion of motor vehicles of categories M and N with regard to the measurement of the net power and the maximum 30 minutes power of electric drive trains" entered into force on

[1042] Ibid., ¶2.2.2
[1043] EN 1821-1:1996, ¶9.3.1
[1044] ECE 68, Amend. 1, ¶2.3
[1045] EN 1821-1:1996, ¶9.1
[1046] ECE 68, Amend. 1, ¶5.5.5
[1047] EN 1821-1:1996, ¶9.3.1
[1048] ECE 68, Amend. 1, ¶5.5.6 vs. EN 1821-1:1996, ¶9.1

September 15, 1990 and was amended to take into account electric drive trains on July 9, 1996. A further amendment went into force on May 14, 1998, but this one is only relevant for LPG or CNG fuelled vehicles. It was prepared by the working group GRPE on pollution and energy.

It applies:

> *"to the representation of the curve as a function of engine or motor speed of the power at full load indicated by the manufacturer for internal combustion engines or electric drive trains and the maximum 30 minutes power of electric drive trains intended for the propulsion of motor vehicles of categories M and N"*[1049]

The electric drive trains considered are composed of controllers and motors used for propulsion of vehicles as the sole mode of propulsion[1050]. Parallel and combined hybrid structures are thus not covered by this regulation.

The ECE 85 distinguishes two levels of drive train power:

☞ the "30 minute power", which is defined as

> *"the net power of an electric drive train (...), which a drive train can deliver over a period of 30 minutes as an average"*[1051]

☞ the "net power", which is defined as the power measured at the motor shaft on a test bench, at full setting of the power controller (i.e. full throttle) with a defined number of auxiliaries connected, with measurements taken at a sufficient number of motor speeds to define a correct power curve between zero and the highest motor speed recommended by the manufacturer. The whole test shall be completed within 5 minutes.[1052]

These definition differ somewhat from those proposed in an earlier draft of the amendment to ECE 68[1053], which did not mention the 30-minute power, and which defined the net power (which had to be measured at the electric motor "crankshaft"!) as the average power during a three-minute test, at maximum throttle, in a speed range from near zero to the maximum speed of the motor.

The choice of a 30-minute rating is in concordance with the "maximum 30-minute speed" as defined in ECE 68 above.
At this moment, there are no international standards on this subject, except the old documents IEC 785 and IEC 786 (§ 5.2.3.4). These documents have a traditional electrotechnical approach to power testing, and are very general, referring to IEC 60349 for detailed test procedures.

[1049] ECE 85, Amend. 1, ¶1 Scope
[1050] Ibid., ¶1.3
[1051] Ibid., ¶2.4, and ¶5.3.2
[1052] Ibid., ¶2.3, ¶5.3.1, and Annex 5
[1053] Proposal for draft amendment to regulation no.85, 1994-05-05, Doc. TRANS/WP.29/GRPE/R.234/

ECE 85 addresses the motor and controller to be tested as one unit (as indeed built into the vehicle). This approach seems also desirable for any new standard to be written on this subject, as has been reflected in the forthcoming evolutions of the IEC TC69 WG2 activities (§ 5.2.3.7).

The choice for a "thirty minute rating" as typical rating for an electric vehicle motor/controller, together with a three- or five-minute rating corresponding to the "net power test" gives a good guideline for ratings to be considered in any such new standardization.

5.8.9 ECE 100

5.8.9.1 Introduction

Regulation No. 100 "Uniform Provisions concerning the approval of battery electric vehicles with regard to specific requirements for the construction and functional safety" entered into force on August 23, 1996, and was amended on February 21, 2002. It was prepared by the working group GRPE on pollution and energy.

It applies to safety requirements with respect to all battery-electric road vehicles of categories M and N, with a maximum design speed exceeding 25 km/h[1054].

It is interesting to compare this document with the European and international standards of the EN 1987 (cf. § 5.5.4) and ISO 6469 (cf. § 5.3.2) series, which treat the same subject. In both documents, three areas of electric vehicle safety are treated: traction battery safety, functional safety and protection against electrical hazards. The ECE regulation does not make any reference to these standards however.

5.8.9.2 Traction battery requirements

The corresponding European and international standards in the field are EN 1987-1:1997 and ISO 6469-1:2001 respectively.
The initial version of ECE 100 gives some very general requirements about traction battery safety[1055]:

☞ Installation of the battery in the vehicle shall not allow any potential dangerous accumulation of gas pockets (¶5.1.1.1)
☞ Battery compartments shall be safely ventilated (¶5.1.1.2)

[1054] ECE 100, ¶1 Scope
[1055] Ibid., ¶5.1.1

Number of cells	Volt V	Permissible overcharge Ah over 5h	Permissible end of charge current A	Permissible overcharge in case of failure Ah over 30 min	Permissible failure current A
Pb cells					
36	72	91,9	18,4	30,9	61,8
48	96	68,9	13,8	23,2	46,3
110	220	30,1	6,0	10,1	20,2
300	600	11,0	2,2	3,7	7,4
NiCd cells					
100	120	33,1	6,6	11,1	22,2
140	168	23,6	4,7	7,9	15,9
180	216	18,4	3,7	6,2	12,4
500	600	6,6	1,3	2,2	4,4

Table 5.16: Permissible overcharge (calculated from ECE 100 Amend. 1)

☞ The traction battery and the power train shall be protected by properly rated fuses or circuit breakers (¶5.1.1.3).

No definition of permissible hydrogen levels or ventilation requirements are given in this document.

The 2002 amendment to ECE 100[1056] added extensive requirements and tests (including calibration procedure)[1057] concerning hydrogen emissions during charging. It imposes actual limits on hydrogen emissions, which must not be more than 125 g during a five hour normal charge (¶5.3.3), or than 42 g in case of charger failure, the duration of the failure must be limited to 30 minutes (¶5.3.4).

Furthermore, it gives some additional requirements such as that the charger must operate fully automatically (¶5.3.5) and that anomalies must be signalled to the driver (¶5.3.8). The ECE regulation also presents a detailed (but complicated and expensive, involving full-size gas-tight measurement chambers) measurement method for hydrogen emissions.

The standards take a different approach towards this issue. They do not give actual mass limits on hydrogen emissions, but state:

☞ That the manufacturer shall determine the maximum flow rate of gases exhausted by the traction battery, both in normal operation as in case of a first failure, in order to determine ventilation requirements for the charging room.[1058] A proposal for measurement of hydrogen emissions is under consideration by ISO.

☞ That no potential dangerous accumulation of gas shall be allowed[1059]; maximum values of hydrogen concentrations are specified to be 0,8 % in case of normal operation and 3,5 % in case of a first failure in EN 1987-1; in ISO 6469-

[1056] ECE 100, Amend. 1, ¶5.3

[1057] Ibid., Annex 7

[1058] EN 1987-1:1997, ¶5 and ISO 6469-1:2001, ¶6

[1059] EN 1987-1:1997, ¶6.4 and ISO 6469-1:2001, ¶7.3

1, these values are 1 % and 2 % respectively[1060] (4 % being the lower explosion limit for hydrogen). ISO 6469-1 specifies the same limits during driving the vehicle[1061], but states that these values apply

"until internationally accepted test methods are developed"[1062]

What is the real meaning of the hydrogen emission limits in ECE 100?
Each battery cell electrolyses 0,34 g of water for each ampere-hour overcharge[1063]; this corresponds to 0,0378 g of hydrogen.

One thus comes to the values in Table 5.16, which gives, for some typical battery voltages in both lead-acid and nickel-cadmium (or nickel-metal-hydride) batteries, the permissible overcharge in ampere-hour, both in normal charge (125 g emission limit over 5 h) and failure (42 g emission limit over 30 min). In each of these cases, a value is given for the corresponding current; it should be stated however that these current values are purely theoretical.

For batteries with a limited number of cells, these values seem reachable with current charger technology, particularly when taking into account the typical capacities of cells used: for the 120 V, 100 Ah NiCd battery assembly which is used today in a popular electric car, the permissible overcharge of 33,1 Ah would mean a 33% overcharge, which is a quite high value.
For high-voltage batteries such as used in buses however the presented values become more strict. Such vehicles fall indeed within the scope of ECE 100, which addresses all vehicles of categories M and N, not only M1 and N1. Compliance to the regulation for a heavy-duty vehicle would thus require a very critical design of the charger.

However, the procedure described in the regulation (which involves the vehicle inside its measurement chamber) only addresses on-board chargers:

The procedure excludes all types of external chargers[1064]

Since heavy-duty vehicles in many cases do use external chargers, it is not clear to which extent the proposed limits apply in this case.

The approach of EN 1987-1, which defines maximum hydrogen *concentrations* for safe operation, seems more useful and straightforward. It is in fact the concentration, and not the actual mass, of hydrogen that determines the safety hazard. Furthermore, the hydrogen mass emission is in fact calculated from concentration

[1060] EN 1987-1:1997, ¶6.4.2.1 and ISO 6469-1:2001, ¶7.3.2.1
[1061] ISO 6469-1:2001, ¶7.3.2.2
[1062] ISO 6469-1:2001, ¶7.3.2.1
[1063] EN 1987-1:1997, Annex B
[1064] ECE 100, Amend.1, Annex 7, ¶5.1.2

measurements[1065], since the measurement of the actual emitted hydrogen mass is not practicable.

One could ask where the limit value of 125 g hydrogen emission comes from. Taking into account the molar norm volume of an ideal gas[1066], and the fact that 125 g of H_2 equals 62,5 mol, one becomes the corresponding volume (at 0 °C and atmospheric pressure):

$$V = 62{,}5 \text{ mol} \times 22{,}41 \frac{\text{dm}^3}{\text{mol}} = 1401 \text{ dm}^3 \tag{5-31}$$

In a typical garage of 50 m^3, this corresponds to a concentration of 2,8 % of hydrogen; this value is below the 4 % lower explosion limit, but is higher than the 0,8 % specified in EN 1987-1.
With the 42 g hydrogen emission in case of failure added, one comes to a total hydrogen emission of 167 g; the corresponding volume becomes 1872 dm3, giving a concentration of 3,75 % in the garage, just under the explosion limit.

As for insulation resistance, ECE 100 specifies a value of 500 Ω/V of the nominal voltage[1067]. This tests obviously refer to a new vehicle. EN 1987-1 states 500 Ω/V for a new battery, value which shall stay higher than 100 Ω/V within its lifetime[1068]. ISO 6469-1 on the other hand finds a value of 100 Ω/V over the lifetime of the battery sufficient[1069].

Unlike the standards, ECE 100 states no requirements for creepage distance.`

5.8.9.3 Functional safety

The corresponding European and international standards in the field are EN 1987-2:1997 and ISO 6469-1:2001 respectively.
ECE 100 specifies a number of requirements, all of which can be found back in the standards; the concordance between paragraphs is given in Table 5.17.
The concordance between the regulation and the standards is thus very good: any vehicle which complies to the standards will also comply to the regulation. This greatly enhances the usability of the standards as reference documents.

[1065] Ibid., ¶6
[1066] Cf. W. Taveirne, op.cit, p 373
[1067] ECE 100, ¶5.1.2.3.2
[1068] EN 1987-1:1997, ¶6.2.2
[1069] ISO 6469-2001, ¶7.1.3

	ECE-100	EN 1987-2	ISO 6469-2
power-on procedure	5.2.1	5.1	5.1
running and stopping indication	5.2.2.1	5.1	5.1
minimum state of charge	5.2.2.2	5.2.2	5.2.2
unintentional behaviour	5.2.2.3	6.1	6.2
leaving the vehicle	5.2.2.4	5.4	5.4
reversing	5.2.3	5.3	5.3
emergency power reduction	5.2.4	5.2.1	5.2.1

Table 5.17: Functional safety measures

5.8.9.4 Protection against electric hazards

The corresponding European and international standards in the field are EN 1987-3:1998 and ISO 6469-3:2001 respectively.

In accordance with these standards[1070], ECE-100 states that for voltages below 60 V d.c. or 25 V a.c., no specific protection is needed.[1071]
Concerning requirements for protection against direct contact at higher voltages, ECE 100 requires a protection degree of at least IP XXD in passenger and load compartments and at least IP XXB in other areas; in the "engine" (i.e. electric motor - the redaction of this document always reflects its ICE background!) compartment the access to live parts shall only be possible with "voluntary action"[1072].
ECE 100 even incorporates an extract from the international standard IEC 60529 concerning protection against direct contact[1073].
The standards are much more detailed on this issue, defining several types of enclosures/barriers. Furthermore, they are a bit stricter in the matter, imposing IP XXD protection degree for all parts that are directly accessible, independent from their location (thus also outside of the passenger/load compartment. IP XXB protection degree is only sufficient for equipment fitted underneath the vehicle, providing the ground clearance is less than 30 cm[1074].

Protection against indirect contact shall be ensured by using insulation and by galvanic connection of exposed conductive parts[1075]. The standards discuss this more

[1070] EN 1987-3:1998, ¶5.1 and ISO 6469-3, ¶5
[1071] ECE 100, ¶5.1.2.1
[1072] ECE 100, ¶5.1.2.1.3 - ¶5.1.2.1.5
[1073] ECE 100, Annex 3
[1074] EN 1987-3:1998, ¶5.2 and ISO 6469-3, ¶6.3
[1075] ECE 100, ¶5.1.2.2.3

in detail, mentioning the notion of Class I and Class II (double insulated) electrical equipment[1076].

The potential equalization resistance between any two exposed conductive parts shall be lower than 0,1 Ω[1077]. This is in line with the requirements of the standards[1078]. There is however a significant difference on the measurement of this resistance: whileas ECE 100 states that the measurement current shall be at least 0,2 A, the standards provide a measurement current of 1,5 times the maximum current of the power circuit (which could mean a few hundred amps!), or 25 A, whichever is the greater. This difference can be explained through a different approach to the problem: the small current is considered as a leakage current, the high one as a fault current. The use of a very high current may be difficult to implement in the framework of a non-destructive measurement procedure; the value of 25 A can be considered a compromise solution.

On the other hand, using a measurement current of 0,2 A on a resistance of 0,1 Ω would mean that the voltage to be measured is only 0,02 V; the accurate measurement of such a small voltage can be difficult, which would justify the choice of a higher measurement current.

Unlike the standards[1079], ECE 100 does not specify requirements or tests for protection against water effects.

It states however some requirements about the connection of the vehicle to the mains network.[1080]

There are no corresponding requirements in EN 1987 or ISO 6469 on this matter, since the connection of the vehicle to the charging network is covered by electrotechnical standards (cf. division of labour IEC/ISO, §5.4).

So let's refer to the international standard IEC 61851.

The requirements of ECE 100 are as follows:

- ☞ The vehicle shall not be capable to move by its own means when connected to the network or to off-board charger (¶5.1.2.4.1). This corresponds to the "drive train interlock" specified in the IEC standard[1081].
- ☞ The components used when charging the battery from an external power source shall allow the charging current to be cut in case of disconnection without physical damage (¶ 5.1.2.4.2).
- ☞ The coupling parts likely to be live shall be protected against any direct contact in all operating conditions (¶5.1.2.4.3). On this subject, the IEC standard

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1076 EN 1987-3:1998, ¶6 and ISO 6469-3, ¶5.3, ¶6

1077 ECE 100, ¶5.1.2.3.3

1078 EN 1987-3:1998, ¶ 6.2.1.2.3 and ISO 6469-3:2001, ¶6.4

1079 EN 1987-3:1998, ¶7 and ISO 6469-3, ¶8

1080 ECE 100, ¶5.1.2.4

1081 IEC 61851-21, ¶10.1

requires specific IP protection measures: IP55 in road position; IP44 when charging, also for the connector and the socket-outlet when not in use[1082].

☞ All exposed conductive parts shall be linked through a conducting wire plugged to earth when charging (¶5.1.2.4.4). This is also specified in the IEC standard[1083].

5.8.10 ECE 101

Regulation No. 101 "Uniform provisions concerning the approval of passenger cars equipped with an internal combustion engine with regard to the measurement of the emission of carbon dioxide and fuel consumption" entered into force on January 01, 1997 and was amended on August 10, 1997 to include electrically driven vehicles, its title becoming "Uniform provisions concerning the approval of passenger cars equipped with an internal combustion engine with regard to the measurement of the emission of carbon dioxide and fuel consumption and of categories M1 and N1 vehicles equipped with an electric power train with regard to the measurement of electric energy consumption and range". It was prepared by the working group GRPE on pollution and energy.
Amendments 2 (May 14, 1998) and 4 (September 12, 2001) are only relevant to LPG and CNG fuelled vehicles; amendment 3 (February 05, 2000) is editorial.

This Regulation applies to the measurement of the emission of carbon dioxide (CO_2) and fuel consumption for M1 category vehicles, or to the measurement of electric energy consumption and range of categories M1 and N1 vehicles.[1084] In the frame of this work, only the aspects concerning electric vehicles will be covered.
Annex 6 to this regulation describes the measure of electric energy consumption.

The test sequence for the range consists of four elementary urban cycles and one extra-urban cycle. This sequence is run twice, giving a total distance of 22,044 km covered in 39 min 20 s.
These test cycles, as well as the detail of the test procedure, are identical to those specified in the European standard EN 1986-1 (cf. §5.5.4).
The European standard also gives the possibility to use a test cycle consisting of twenty-eight elementary urban cycles, this to cater for lower speed vehicles[1085]. The ECE 101 regulation does not provide this however; for the test to be applied on low speed vehicles, it states:

[1082] IEC 61851-1, ¶9.9
[1083] IEC 61851-21, ¶7.2
[1084] ECE 101 Amend.1, Scope
[1085] EN 1986-1:1997, ¶5.5.2

> *"Over 50 km/h, it is accepted to go beyond tolerances provided the accelerator pedal is fully depressed."*[1086]

The specifications for the calibration of the chassis dynamometer to carry out the tests are also identical; the European standard in fact referring to the ECE regulation.[1087]

A method for measuring the range of the electric vehicle is described in Annex 7 to ECE 101. Also this procedure is identical to that in EN 1986-1[1088].

5.8.11 ECE work on hybrid vehicles

ECE working group GRPE has also started activities on type approval of hybrid passenger cars. It will prepare amendments to ECE regulations 83 (which deals with emission measurement), 85 and 101. It is foreseen to approve a procedure by 2004.[1089]

5.8.12 ECE work on fuel cell vehicles

The forthcoming emergence of fuel cell vehicles has also been noted by the UNECE, where working group GRPE focuses on regulation work which might be impending, particularly in the field of hydrogen storage safety on board vehicles. An ad-hoc working group "Hydrogen vehicles - Onboard storage systems" was set up; its activities were performed in close collaboration with other standardization bodies involved such as ISO, SAE and JEVA.[1090]

5.8.13 Conclusions

In most cases reviewed above, the concordance between (European or international) standards and ECE regulations proved rather close. Without such concordance, either document set would be unworkable. Furthermore, due to the legal ramifications of the ECE regulations (compliance to these regulations being conditional for international type approval of a vehicle), vehicle manufacturers will

1086 ECE 101 Amend. 1, Annex 6, ¶1.4
1087 ECE 101 Amend. 1, Annex 6, Appendix 1 and EN 1986-1:1997, Annex A
1088 ECE 101 Amend. 1, Annex 7 and EN 1986-1:1997, ¶6
1089 R. Smokers, "Hybrid Vehhicles in Relation to Legislation, Regulations and Policy", EVS-19, Busan, 2002
1090 Doc. ISO/TC22/SC21 N335E, UNECE GRPE ad-hoc WG, Minutes of the meeting, 2002-11-14/15

rather have to stick to the regulation when this conflicts with the standard. In such case, the practical usefulness of the standard becomes doubtful.
Concordance between EN standards and ECE regulations can only be achieved through close collaboration between the bodies responsible for these documents. Often the same experts from automotive sector figure on the board, furthermore, the drafting of CEN standards in particular is influenced by ECE regulations (as has been seen for example with EN 1986-1 in §5.5.6.3).
There remain some differences however; the best way to resolve these in the future seems to be to adapt a "New Approach", similar to the one taken with EU directives (cf. §5.5.11), where the regulations would be limited to essential requirement stated in general terms, and the detailed technical specifications formulated in standards drafted by standardization bodies.
This way, standardization work would benefit regulative and legislative bodies, and thus the whole society consisting of government, producers and end users. Such implementation would involve some political difficulties since the ECE regulations are not an EU but a UNECE competence.

5.9 *EMC standardization and regulation problems relevant to electric vehicles*

5.9.1 EMC and the electric vehicle

Electric vehicles make use of electromagnetic power conversion, and thus are subject to EMC issues, particularly when considering the use of high switching frequency power electronic devices. The electric vehicle is in fact a source as well as a potential receiver of electromagnetic energy, either through radiation as through conduction, the latter phenomenon restricted however to when the vehicle is connected for charging on the grid.

☞ Source: the electric vehicle can cause electromagnetic interference with other electronic equipment such as telecommunication devices or other apparatus. Furthermore, personnel can be exposed to electromagnetic fields.

☞ Receiver: the electric vehicle can be influenced by electromagnetic emissions from other sources.

The EMC phenomena surrounding electric vehicles have been considered in a number of studies[1091,1092,1093] and have of course had their impact on standardization matters.

The impact of regulation in this matter has been quite considerable; to this effect, relevant European directives have also be taken into account in this paragraph.

5.9.2 EMC standardization in IEC

Within the IEC, EMC standardization activities are organized as illustrated in Figure 5.62[1094].

The co-ordination of the work is performed by the Advisory Committee on Electromagnetic Compatibility (ACEC).

Technical Committee 77, founded in 1973, is a technical committee with a horizontal function mainly responsible for developing basic and generic EMC standards relating to immunity (in the whole frequency range) and emissions (in the low frequency range up to 9 kHz).

[1091] A. Buonarota et al., Electromagnetic impact of the electric vehicle

[1092] EVIAC, op.cit.

[1093] Kevin Selleslags, Normalisatie van EMC aspecten van elektrische voertuigen, VUB-ETEC, 2002

[1094] IEC Guide 107 "Electromagnetic compatibility - Guide to the drafting of electromagnetic compatibility publications" - 2.ed. 1998-01, p19

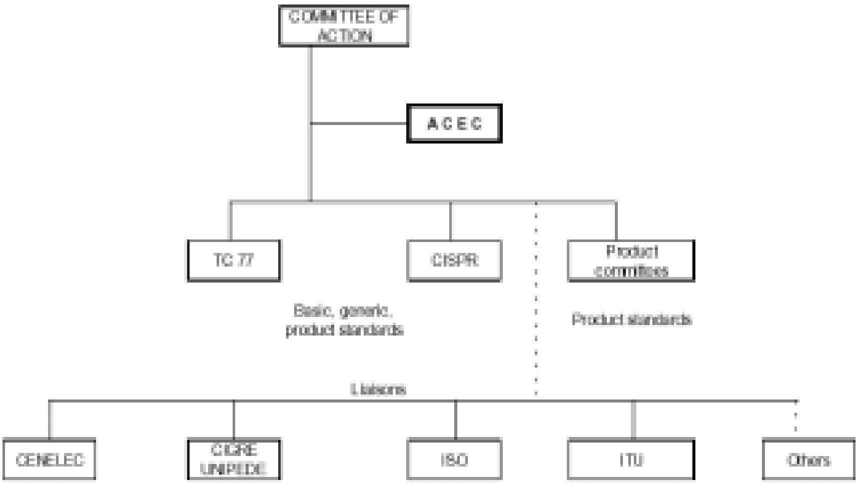

Figure 5.62: Organization of the work on EMC in the IEC

The IEC's EMC standards are grouped together in the IEC 61000 series; they can be divided in four major categories[1095]:

☞ "Basic" EMC publications, which give the general and fundamental conditions or rules for the achievement of EMC and serve as reference documents for the product committees. These are standards or technical reports of a general character, not dedicated to specific product families or products.

☞ "Generic" EMC standards apply to products operating in a particular environment for which no dedicated product family/product EMC standards exist. They specify a set of essential requirements, test procedures and generalized performance criteria applicable to such products or systems operating in this environment.

☞ "Product family" EMC standards, which define specific electromagnetic requirements and test procedures dedicated to particular product families. They should indicate the relevant installation and operating conditions, and also give precise performance criteria, taking into account the purpose of the equipment where possible. These standards should apply the basic EMC standards and be coordinated with the generic EMC standards to the extent practicable.

☞ "Product" EMC standards relate to a particular type of product for which specific conditions should be considered. The same rules apply as for the product family EMC standards.

For what concerns the electric vehicle, a liaison between IEC TC 69 on one hand and TC 77/CISPR on the other hand has been established.

[1095], Ibid., p13

5.9.3 The International Special Committee on Radio Interference

The International Special Committee on Radio Interference (CISPR) is primarily responsible for the radio frequency range above 9 kHz. Besides basic and generic standards for radio frequency emissions, it also develops product and product family emission standards for protecting radio communications services and immunity standards for receivers.

CISPR was founded in 1934 in order to secure infirmity in the method of measurement and definition of limits for radio interference and to avoid difficulties in the exchange of goods and services. The first standard CISPR measuring set was built by the Belgian Electrotechnical Committee in 1939.
The frequency range on which CISPR was active was gradually extended over the years, and limits for various application fields were defined.
Since 1984, much attention has been concerned with refining the measurements methods and the limits for information technology equipment. In principle, this is any equipment that uses a microprocessor and switching frequencies or clocks above 9 kHz[1096]. Electronic systems on electric vehicles such as power converters or chargers may thus fall into this definition.

It is interesting to consider the founding dates of these two committees, TC77 and CISPR. The first technical area where problems with electromagnetic interference were encountered was in fact radio broadcasting and receiving, hence the early creation of CISPR. For general electrotechnical applications, electromagnetic interference became a more tangible reality with the introduction of power electronics and their distorted waveforms, hence the creation of TC77.

5.9.4 The EMC situation of the electric vehicle

To position the electric vehicle facing the existing EMC standards and regulations, one should take into account two cases:

☞ When the vehicle is charging, it is coupled to the grid and can be considered as an electrical appliance; the EMC regulations for electrical apparatus are in force, and both radiation and conduction phenomena have to be taken into account. Here, the general European EMC directive (Council Directive 89/336/EEC) is applicable. IEC and CISPR standards are available to check compliance. There are no specific ISO standards applicable in this case.

☞ When the vehicle is on the road, it is a vehicle, and automotive standards may apply. Only radiation has to be taken into account. Here the situation is not

[1096] CISPR 16-3/TR:2000, ¶5.1.1, ¶5.1.3

unequivocal, as there are several directives to be followed, and as there may exist some mutual differences.
The main directive in this field is the Automotive Directive (Commission Directive 95/54/EC).
Furthermore, there are ISO vehicle standards and CISPR standards for radiation emissions.
Standards on electric vehicle EMC emissions have also been produced by regional organizations such as SAE.

5.9.5 The European Automotive Directive 95/54/EC

5.9.5.1 Generalities

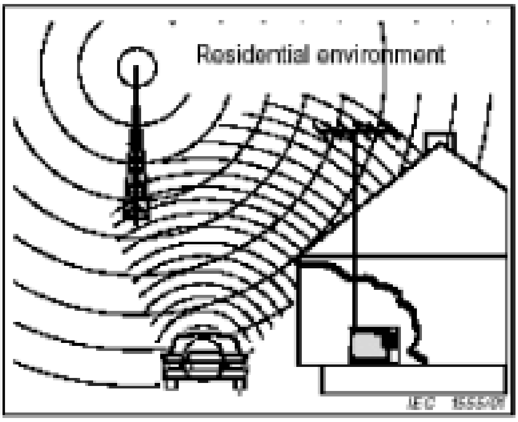

Figure 5.63: Radio interferences caused by radiations from a motor vehicle

The main scope of this directive is the suppression of radio interference between 30 MHz and 1 GHz, caused by vehicle engines with electric ignition (Figure 5.63). Emission and immunity aspects of both vehicles and electric/electronic subassemblies are treated. This directive entered into force on October 1, 2002 and is a key element of the European type approval procedure for vehicles.
Although electric vehicles are not explicitly covered in the scope, one can state that they too are covered by the directive. This will be further discussed in §5.9.5.2.
At this moment, there is no specific European EMC directive for electrically driven vehicles.

The automotive directive emanates from the following documents:
☞ February 6, 1970: introduction of EC type approval procedure for motor vehicles and trailers: Council Directive 70/156/EEC on the approximation of the laws of the Member States relating to the type-approval of motor vehicles and their trailers, amended by Commission Directive 93/81/EEC

- ☞ June 20, 1972: Council Directive 72/245/EEC on the approximation of the laws of the Member States relating to the suppression of radio interference produced by spark-ignition engines fitted to motor vehicles, amended by Commission Directive 89/491/EEC
- ☞ May 3, 1989: Council Directive 89/336/EEC on the approximation of the laws of the Member States relating to electromagnetic compatibility, which states that its general specifications do not apply on apparatus falling under "special directives"; amended by Council Directive 93/68/EEC
- ☞ October 31, 1995: adaptation of directive 72/245/EC to technical progress; directive 95/54/EC.

It is likely that adaptations to this document will be implemented, under the influence of the concerned industrial sectors.

The new automotive EMC directive 95/54/EC is considered a complementary directive to the general EMC directive 89/336/EC; the latter is thus not applicable anymore to vehicles covered by 95/54/EC.

The main statement of the automotive directive is the following:

> *"A vehicle (and its electrical/electronic system(s) or ESA(s)) shall be so designed, constructed and fitted as to enable the vehicle, in normal conditions of use, to comply with the requirements of the Directive."*[1097]

The document states limit values and test methods for narrowband and broadband emissions of both vehicles and electrical/electronic sub-assemblies (ESAs).
It allows the manufacturer to obtain type approval, either of the vehicle as a whole or of separate ESAs.

5.9.5.2 The automotive directive and the electric vehicle

Article 2 of the automotive directive states:

> *"For the purpose of this Directive, "vehicle" means any vehicle as defined in Directive 70/156/EEC"*[1098]

Which directive states in turn:

> *"For the purposes of this Directive, "vehicle" means any motor vehicle intended for use on the road, with or without bodywork, having at least four wheels and a maximum*

[1097] Directive 95/54/EC, annex 1, ¶6.1.1
[1098] Directive 95/54/EC, art. 2

design speed exceeding 25 km/h, and its trailers, with the exception of vehicles which run on rails and of agricultural tractors and machinery."[1099]

It seems thus clear that electric road vehicles are covered by this directive, unlike industrial vehicles and agricultural machines.
However, 95/54/EC, in its title, refers to

"the suppression of radio interference produced by spark-ignition engines fitted to motor vehicles"

The origin for this regulation is in fact that spark-ignition engines are likely to cause substantial radio interference if proper measures are not taken, and that these were thus the original object of the regulation. The ignition system is the main source of radiation in such vehicles; other components become secondary emission sources.
The directive however has been extended to vehicles with diesel engines. It makes a distinction between two kinds of electromagnetic radiation:

☞ "broadband" radiation, which has a bandwidth greater than that of a particular measuring apparatus or receiver[1100]. Examples of broadband radiation sources are the electrical ignition system, or rotating machines such as the alternator or the ventilator

☞ "narrowband" radiation, which has a bandwidth less than that of a particular measuring apparatus or receiver[1101]. This are typically oscillators above 9 kHz; examples are microprocessor systems for engine management.

For an electric vehicle, the absence of an ignition system and the presence of power electronic components makes that the EMC situation is fundamentally different compared with thermal vehicles. It can be stated that most of these components will generate narrowband radiation: a chopper for example will have an emission peak at its operating frequency.
In some cases it can be somewhat difficult to determine whether one has to do with broadband or narrowband radiation. To this effect, a flowchart has been draught by CISPR. (Figure 5.64)

[1099] Directive 70/156/EC, art. 1

[1100] ISO 11451-1:2001, ¶3.9

[1101] ISO 11451-1:2001, ¶3.8

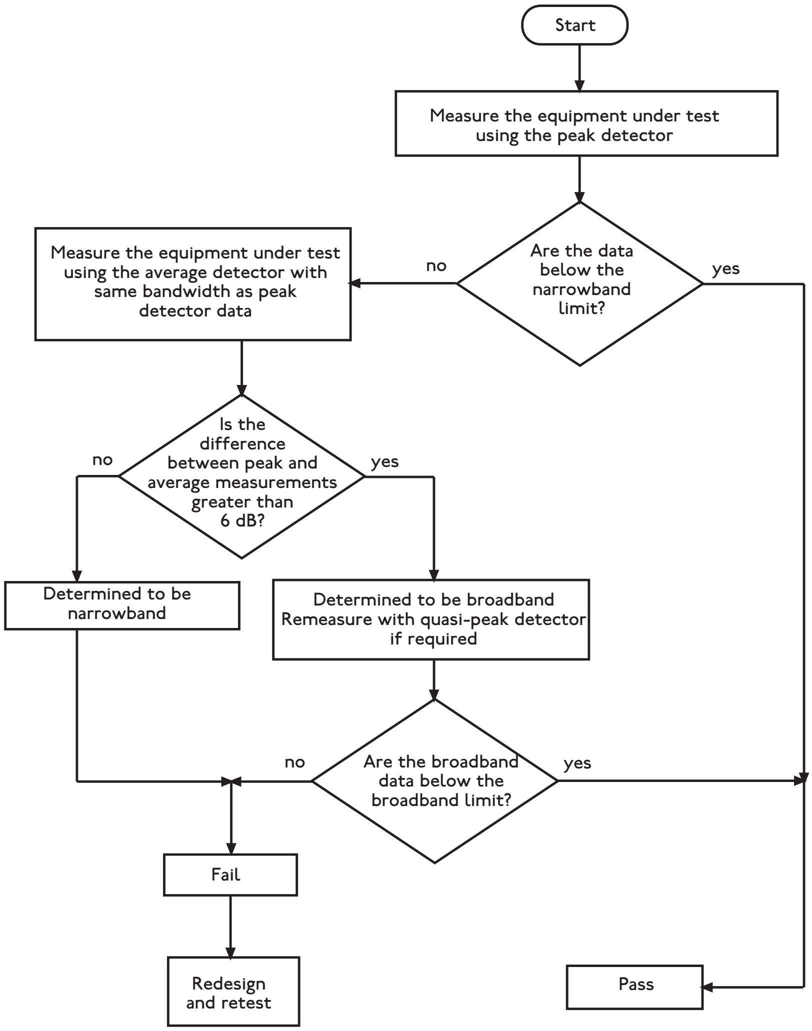

Figure 5.64: Method to determine emission limits[1102]

To determine immunity aspects, the automotive directive uses the "off-vehicle radiation source method", where a test field is emitted by an external antenna. This test field is calibrated with the so-called "substitution method", which is described in detail in ISO 11451. The Directive however never refers to this international standard.

[1102] CISPR 12:2001, p15

5.9.6 The international standard ISO 11451

The standard ISO 11451 "Road vehicles - Vehicle test methods for electrical disturbances from narrowband radiated electromagnetic energy" describes test methods which can be used for the evaluation of vehicle immunity characteristics.
ISO 11451 is not intended as a product specification, and it thus does not specify values for the test severity level.[1103]

Part of ISO 11451	Applicable frequency range MHz	Coupling to:	Test severity parameter and unit	Provisions	
11451-2	Off-vehicle radiation source	0,1 to 18 000	Device under test and wiring harness	Electric field (V/m)	Absorber-lined shielded enclosure required
11451-3	On-board transmitter simulation	1,8 to 1 300	Device under test and wiring harness	Power (W)	Absorber-lined shielded enclosure recommended
11451-4	Bulk current injection(BCI)	1 to 400	Wiring harness	Current (mA)	Shielded enclosure recommended

Table 5.18: Main characteristics of test methods in ISO 11451[1104]

The test methods, procedures, test instrumentation and levels specified in ISO 11451 are intended to facilitate vehicle specification for electrical disturbances by narrowband radiated electromagnetic energy. A basis is provided for mutual agreement between vehicle manufacturers and component suppliers intended to assist rather than restrict[1105].
A single standard test may not reveal all the needed information about the device under test. It is thus necessary for users of ISO 11451 to anticipate the appropriate test conditions, select applicable parts of ISO 11451 and define function performance objectives. The main characteristics of each test method in ISO 11451-2 to ISO 11451-4 are presented in Table 5.18.

The standard also defines classes of "function performance status classification, which are also referred to in IEC immunity standards:

[1103] ISO 11451-1:2001. Scope.
[1104] ISO 11451-1:2001, Table 1
[1105] ISO 11451-1:2001 - Part 1: General and definitions. ¶4

- ☞ Class A: all functions of a device or system perform as designed during and after exposure to a disturbance.
- ☞ Class B: all functions of a device or system perform as designed during exposure; however, one or more of them may go beyond the specified tolerance. All functions return automatically to within normal limits after exposure is removed. Memory functions shall remain class A.
- ☞ Class C: one or more functions of a device or system do not perform as designed during exposure but return automatically to normal operation after exposure is removed.
- ☞ Class D: one or more functions of a device or system do not perform as designed during exposure and do not return to normal operation until exposure is removed and the device or system is reset by a simple "operator/use" action.
- ☞ Class E: one or more functions of a device or system do not perform as designed during and after exposure and cannot be returned to proper operation without repairing or replacing the device or system.[1106]

5.9.7 EMC issues in IEC 784, IEC 785 and IEC 786

The reports IEC 784 (§5.2.3.3), IEC 785 (§5.2.3.4) and IEC 786 (§5.2.3.5) make some brief reference concerning EMC issues (called EMI in these documents).
None of these documents give any limit values for EMC or make reference to measurement methods however.

IEC 784 states that

> *"Instrumentation whose performance is critical to vehicle operation should not be affected adversely by the EMI generated on or outside the vehicle"*[1107]

IEC 785 states that

> *"since the motor may be a source of EMI it should be designed and constructed so that EMI from the motor does not affect the operation of the vehicle"*[1108]

IEC 786 gives the following statement about interference:

> *"Electromagnetic interference - Since the controller may be a source of EMI, it should be designed, constructed or installed so that the EMI from the controller does not affect the operation of the vehicle.*
> *Interference to equipment outside the vehicle - The controller should be designed in conjunction with the rest of the vehicle in such a way that in normal operation no unwanted radiations are generated.*

[1106] ISO 11451-1:2001, Appendix A
[1107] IEC 784:1984, ¶4.2
[1108] IEC 785:1984, ¶4.5

Controller resistance to external electrical interference - The controller should be designed in such a way that electrical interference generated remotely by other equipment on or off the vehicle does not adversely affect controller operation."[1109]

IEC 786 furthermore describes a test for electromagnetic radiation

"to ensure that the electromagnetic radiation generated as a result of controller operation does not exceed the limits as defined in sub-clause 4.2.5"[1110]

which clause does not state any specific quantitative limits however.

It further states that the controller should be immune to all transients associated with its own operation or with any other load on the traction battery[1111], or to any transients in other vehicle harnesses.[1112] No quantitative requirements are specified however which would enable to test these requirements.

5.9.8 EMC issues in IEC 61851 - Conductive charging

The IEC standards about conductive charging, the 61851 series, have been discussed in §5.2.5.

These documents contain specifications on both immunity and emissions.

During the review process for IEC 61851, the IEC ACEC, CISPR and IEC TC77 have requested to be consulted on emc matters to ensure that the requirements specified in this standard are correct and aligned with common requirements.[1113]

5.9.8.1 IEC 61851-21: electric vehicle requirements

This standard defines requirements for a number of immunity issues, with specific performance criteria[1114].

☞ Immunity to low-frequency conducted disturbances[1115]:
  - Supply voltage harmonics (performance criterion A)
  - Supply voltage dips (performance criterion B)
  - Immunity to voltage unbalance in three phase network (under consideration)
  - Immunity to d.c. components in the a.c. supply (under consideration)

[1109] IEC 786:1984, ¶4.2.5

[1110] IEC 786:1984, ¶6.2.6

[1111] IEC 786:1984, ¶4.2.3.1

[1112] IEC 786:1984, ¶4.2.3.2

[1113] IEC TC69, Letter by secretary Craig Toepfer, 2002-10-01

[1114] IEC 61851-2 defines performance criteria A, B, and C, which are equivalent to the performance classes A, B and D presented in ISO 11451 (§5.9.6)

[1115] IEC 61851-21:2001, ¶9.1.2

- ☞ Immunity to high-frequency conducted disturbances:[1116]
  - ☚ Fast transient bursts due to switchgear (performance criterion B)
  - ☚ Voltage surges caused by switching phenomena or lightning (performance criterion C)
  - ☚ Immunity to electrostatic discharges (performance criterion B)
  - ☚ Immunity to radiated electromagnetic disturbances in the 80 MHz to 1 GHz band:
    - performance criterion A for 3 V/m
    - performance criterion B for 10 V/m

In all cases, reference is made to the measurement techniques described in the IEC 61000-4 series of standards.

IEC 61851-21 also specifies limits for generated electromagnetic disturbances. For low-frequency conducted disturbances, it is stated that the distortion caused by the electric vehicle systems "shall not be excessive". Reference is made to IEC 61000-3-2 for harmonics limits where the rated current is less than 16 A; for higher rated currents, the limits are under consideration[1117].

The requirements for high-frequency conducted and radiated disturbances are also "under consideration", some values are already given however[1118]:

- ☞ Specifications are given for conducted disturbances at the a.c. input connections, in the 150 kHz - 30 MHz band for both "unrestricted" (domestic) and "restricted" (industrial) environments; limits are under consideration for the 9 kHz - 150 kHz band and no limits are specified above 30 MHz.
- ☞ Limits are also defined for conducted disturbances at signal I/O and control connections. These limits are comparable with those of the "restricted" environment for the a.c. input connections.

For the measurements, reference is made to CISPR 14 and CISPR 16
The fact that this standard still has "under consideration" clauses makes it however not appropriate to be published as a harmonized standard under the European EMC directive.
Furthermore, the CENELEC EMC consultant stated that the added value of the immunity requirements compared with the generic standards were low, as no specific performance criteria are given in this standard.[1119]

[1116] IEC 61851-21:2001, ¶9.1.3
[1117] IEC 61851-21:2001, ¶9.2.1
[1118] Ibid., ¶9.2.2
[1119] Doc. CLC/TC69X(Sec)46, 2001-06

5.9.8.2 IEC 61851-22: AC electric vehicle charging station

This standard specifies immunity requirements which are virtually identical to those in IEC 61851-21[1120].
For emitted low-frequency conducted disturbances, the a.c. electric vehicle charging station shall comply to IEC 61000-3-2 when no load is connected, otherwise the distortion cause shall "not be excessive".[1121]
The limits given for high-frequency conducted disturbances are comparable with the "unrestricted" levels of IEC 61851-21, but are much lower for the signal I/O and control terminals, as can be seen in Table 5.19, where the limit levels are given for a frequency of 1 MHz.

Standard	Quasi-peak limit (1 MHz)
EV (61851-21) a.c. input Restricted environment	73 dB µV/m
EV (61851-21) a.c. input Unrestricted environment	56 dB µV/m
EV (61851-21) Signal I/O and control	73 dB µV/m
a.c. station (61851-22) input	56 dB µV/m
a.c. station (61851-22) Signal I/O and control	30 dB µV/m

Table 5.19: Conducted emission limits at 1 MHz

For radiated emissions, magnetic fields (150 kHz - 30 MHz) are under consideration; limit values are defined for electric fields (30 MHz - 1 GHz): 29 dB µV/m up to 230 MHz, 37 dB µV/m above.
Compliance is checked in according to CISPR 22 and CISPR 16.

5.9.8.3 IEC 61851-23: DC electric vehicle charging station

This standard is not yet published; it is interesting however to look at the specification given in the latest draft version[1122].
The immunity and emission requirement in this document are identical to those in IEC 61851-22.
For low-frequency conducted emissions however, reference is made to the document IEC 61000-3-4, as d.c. electric vehicle charging stations will most likely have a rated current exceeding 16 A.

[1120] IEC 61851-22:2001, ¶11.3.2
[1121] Ibid., ¶11.3.3
[1122] IEC 61851-23, Committee Draft, Doc. 69/113/CD, 1999-05

5.9.9 EMC issues in IEC 61980 - Inductive charging

The forthcoming IEC standards about inductive charging, the 61980 series, have been discussed in §5.2.5.4.
These documents contain specifications on both immunity and emissions. They are not yet published as standards, but the latest available draft versions have been used here.

5.9.9.1 IEC 61980-1 - General requirements[1123]

Immunity requirements in this standard are identical to those in IEC 61851-22; the immunity required against supply voltage dips is a bit more lenient however (criterion C instead of B for voltage dips 50% or lower).

For emitted disturbances, reference is made to IEC 61000-3-2 for low-frequency conducted and to CISPR 14 for high frequency conducted and for radiated electric fields. Magnetic fields (150 kHz - 30 MHz) remain under consideration.
No specifications have been defined for magnetic fields below 150 kHz; the operating frequency of inductive charger systems can well be below this range however.

5.9.9.2 IEC 61980-2 - Paddle type[1124]

This document describes a particular type of inductive charger, which operates in the frequency range 130 to 360 kHz.
As for EMC issues, it is stated that the inductive interface is part of the complete inductive charging system, and any EMC testing shall be performed on a complete system.
In addition to the general requirements of IEC 61980-1, this document states particular requirements about the EMC shield contact zone, which is used to connect the vehicle chassis ground to the charger ground for purposes of EMC shielding when the inductive connector is fully inserted into the vehicle inlet[1125].

[1123] IEC 61980-1, Committee Draft, Doc. 69/125/CD, 2000-11
[1124] IEC 61980-2, Committee Draft, Doc. 69/126/CD, 2000-11
[1125] Ibid., ¶5.4.1.6, 5.4.1.7, 5.4.2.3, 5.4.2.4

5.9.10 EMC issues in ISO 6469-2

This standard, which has been described more in detail in §5.3.2, contains some concise references to EMC matters.

For electromagnetic susceptibility, ISO 6469-2 states that the electric road vehicle shall be tested for susceptibility according to ISO 11451-2. The reference field strength shall be a minimum of 30 V/m r.m.s. or according to national standards or regulations.[1126]
As for emissions, reference is made to national standards or regulations and international standards such as CISPR 22[1127].

5.9.11 CISPR 12

The document CISPR 12 "Vehicles, boats, and internal combustion engine driven devices - Radio disturbance characteristics - Limits and methods of measurement for the protection of receivers except those installed in the vehicle/boat/device itself or in adjacent vehicles/boats/devices." applies to the emission of broadband and narrowband electromagnetic energy in the frequency band 30 MHz to 1 GHz which may cause interference to radio reception and which is emitted from vehicles, propelled by either ICE engines or electric motors.
Experience has shown that compliance with this standard may provide satisfactory protection for receivers of other types of transmissions when used in the residential environment, including radio transmissions in frequency ranges other than that specified.[1128]

CISPR 12 is explicitly applicable on electric and hybrid road vehicles, as follows from the chart in Figure 5.65.

The measurement methods and the limits for broadband and narrowband radiation stated in Directive 95/54 are mainly based on the specifications of CISPR 12.

[1126] ISO 6469-2:2001, ¶5.6.1
[1127] ISO 6469-2:2001, ¶5.6.2
[1128] CISPR 12:2001. Scope.

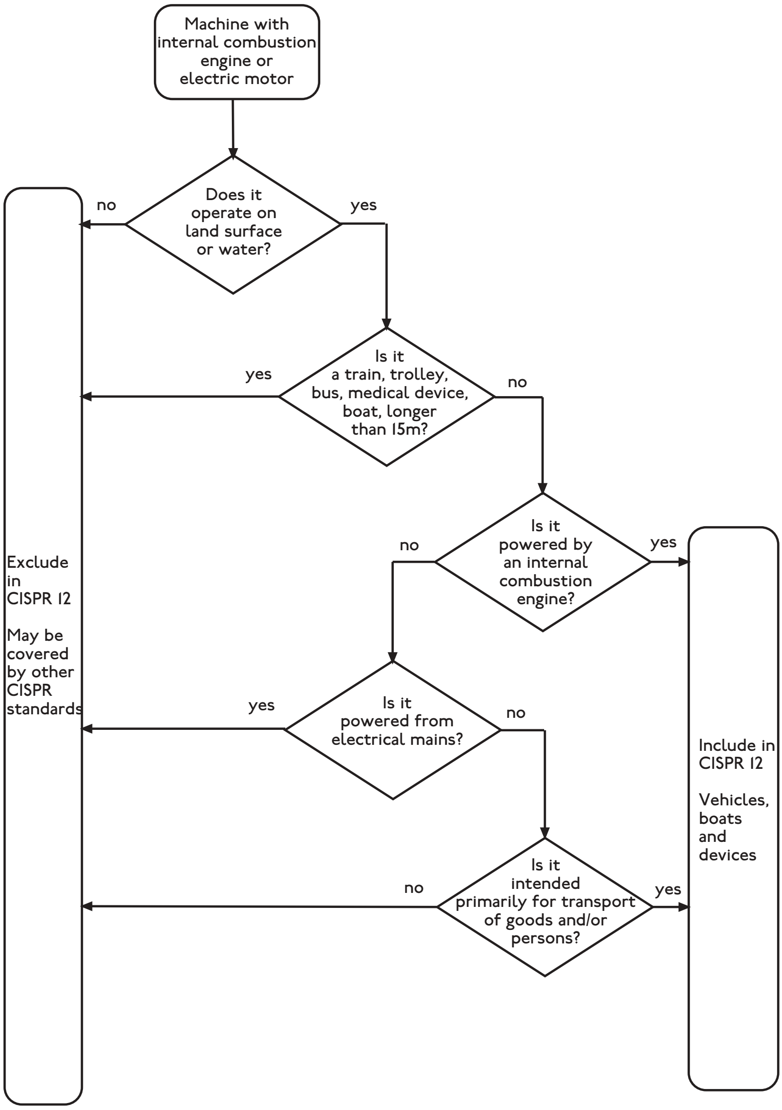

Figure 5.65: Applicability of CISPR 12[1129]

[1129] CISPR 12:2001, p99

5.9.12 CISPR 16

Both the automotive directive and international standards refer to CISPR 16 "Specification for radio disturbance and immunity measuring apparatus and methods", a document consisting of three parts:

☞ Part 1: Radio disturbance and immunity measuring apparatus[1130].
CISPR 16-1 is a basic standard, which specifies the characteristics and performance of equipment for measuring of radio disturbance voltages, currents and electromagnetic fields in the frequency band 9 kHz to 18 GHz, taking into account broadband and narrowband disturbances. Furthermore, requirements are specified for specialized equipment for discontinuous disturbance measurements.
Nearly every directive or standard about EMC measurements will refer to CISPR 16-1.

☞ Part 2: Methods of measurement of disturbances and immunity[1131].
CISPR 16-2 specifies the methods of measurement of EMC phenomena in the frequency range 9 kHz to 18 GHz, considering both emission and immunity measurements. These methods are the general base of most EMC measurements; although specific measurement methods described in a other directives of standards are based on the principles of CISPR 16-2, there are few direct references made to it.

☞ Part 3: Reports and recommendations of CISPR[1132]
This document is a "technical report": its contents is purely informative and it is not to be regarded as an International Standard.
CISPR 16-3 contains recommendations on statistics of disturbance complaints, on the significance of CISPR limits, on determination of CISPR limits and other specific reports.

[1130] CISPR 16-1:1999
[1131] CISPR 16-2:1996+A1:1999
[1132] CISPR 16-3/TR:2000

5.9.13 CISPR 22

CISPR 22 "Information technology equipment - Radio disturbance characteristics - Limits and methods of measurement" is mentioned here as it is specifically referred to in ISO 6469-2[1133] and SAE J551-5[1134].

CISPR 22 gives procedures for the measurement of the levels of spurious signals generated by the equipment and limits are specified for the frequency band 9 kHz to 400 GHz. Its intention is to establish uniform requirements for radio disturbance level, to fix limits of disturbance, to describe methods of measurement and to standardize operating conditions and interpretation of results.[1135]

In the framework of CISPR 22, information technology equipment (ITE) is defined as any equipment[1136]:

- ☛ *which has a primary function of either (or a combination of) entry, storage, display, retrieval, transmission, processing, switching, or control, of data and of telecommunication messages and which may be equipped with one or more terminal ports typically operated for information transfer;*
- ☛ *with a rated supply voltage not exceeding 600 V.*

It includes, for example, data processing equipment, office machines, electronic business equipment and telecommunication equipment.

An electric vehicle, as such, is of course not a piece of information technology equipment; it can be stated however that it contains a number of ESAs which are covered by CISPR 22. In fact, a more general definition of information technology equipment states that "in principle, this is any equipment that uses a microprocessor and switching frequencies or clocks above 9 kHz"[1137].

Furthermore, the fact that it is referenced in other standards proves the usability of its techniques for electric vehicle applications.

[1133] ISO 6469-2:2001, ¶5.6.2
[1134] SAE J551-5:1997, ¶2.1.2
[1135] CISPR 22:1997 ¶1 Scope
[1136] Ibid., ¶3.1
[1137] CISPR 16-3/TR:2000 ¶5.1.3

5.9.14 SAE J551-5

The Automotive directive 95/54/EC defines limit values and measurement procedures for radiation emission in the 30 MHz to 1 GHz band. For emissions below 30 MHz, there is for the moment no European directive, neither an international IEC or CISPR document which is specifically applicable on electric vehicles.

The Society of Automotive Engineers in the United States however has published the recommended practice SAE J551-5, which gives test procedures and limit values for electromagnetical emission of electric vehicles, in the following frequency bands:
☞ 9 kHz to 30 MHz for radiated emissions when the vehicle is on the road
☞ 450 kHz to 30 MHz for conductive emissions when the vehicle is charging.

The conducted emission measurements in SAE J551-5 are only applicable for vehicles where the switching frequency of the charger exceeds 9 kHz, and for conductive charging. It only gives reference values and measurement methods for broadband emissions.

Requirements for narrowband emissions and for the frequency band 30 MHz - 1 GHz are given in SAE J551-2.
This document applies to electromagnetic emission which may cause interference to radio reception and which is emitted from a vehicle propelled by IC engines, electrical means or both; it is thus to be considered equivalent to CISPR 12.

5.9.15 ISO 14982

5.9.15.1 Introduction

Taking into account the fact that the applicability of the automotive directive 95/54/EC on the electric vehicle is not straightforward, it has been deemed interesting also to consider the international standard ISO 14982. This standard was prepared by Technical Committee ISO/TC 23, "Tractors and machinery for agriculture and forestry", and has also been adopted as European standard.

ISO 14982 specifies test methods and acceptance criteria for evaluating the electromagnetic compatibility of tractors and all kinds of mobile (including hand-held) agricultural machinery, forestry machinery, landscaping and gardening machinery. It is applicable to machines and ESAs.[1138]

[1138] ISO 14982:1998, Scope

This International Standard has been established as a means of achieving conformity with the requirements of the European EMC Directive (89/336/EEC) and the EMC requirements of the Machine Directive (Council Directive 89/392/EEC). The elaboration of ISO 14982 is based upon the Automotive Directive 95/54/EC. This procedure was chosen due to the large conformity of the disturbance phenomena in many domains, similar operation and ambient conditions and the possibility of using the same measuring apparatus.

In accordance with the status of this document as an International Standard, the measuring procedures described in Directive 95/54/EC have been replaced by equivalent internationally standardized measuring procedures, referring to standards like ISO 11451 for vehicles and ISO 11452 for ESAs.
However, there were no appropriate International Standards for radiated broadband and narrowband electromagnetic disturbances from machines and for radiated broadband and narrowband electromagnetic disturbances of ESAs.[1139]
The standard thus describes the necessary procedures in its annexes, and states that international standardization of the measuring procedures for all types of machines would be desirable for the future.

In contrast to the directive 95/54/EC, ISO 14982 includes requirements for electrostatic discharge and conducted transients (along 12 and 24 V onboard supply systems), which are deemed relevant for agricultural machines.

5.9.15.2 Application to electric vehicles ?

The scope of ISO 14982 - agricultural machines - is located on the fringe between "vehicles" and "machines": tractors, combined harvesters and the like may be able to drive on the road, but they are also "machines" having to comply to the machine directive 89/392/EC.
This directive is also applicable to industrial electric vehicles like fork lift trucks, but not on electric road vehicles.
As for radiation emission and immunity, the limit values and test procedures of ISO 14982 are akin to these in the automotive directive; ISO 14982 thus does not offer much new added value interesting for the electric road vehicle.

[1139] ISO 14982:1998, Introduction

5.9.16 Overview of EMC standardization for electric vehicles

When studying the electromagnetical phenomena which occur in an electric vehicle, and when analysing the existing standardization and regulation issues, the flowchart of Figure 5.66 can be presented which summarizes the EMC situation of the electric vehicle. Standards printed in italic are specifically applicable to electric vehicles.

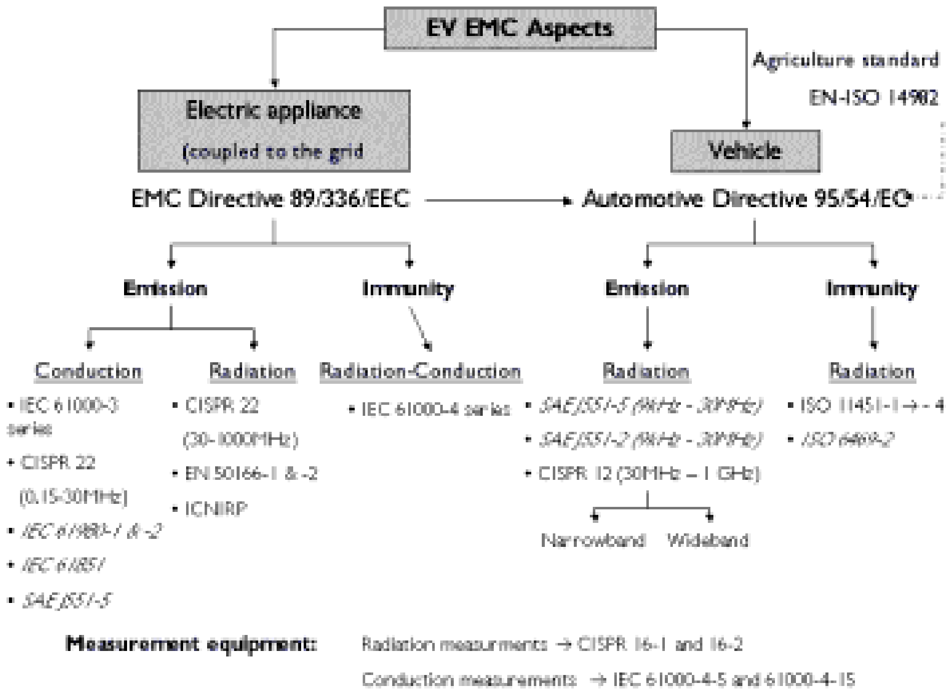

Figure 5.66: Standardization of EMC aspects[1140]

5.9.16.1 The electric vehicle as electrical appliance

When coupled to the grid, the vehicle must comply to the general EMC directive 89/336/EC. Both conduction and radiation phenomena will occur.
The reference levels and measurement procedures for measuring conductive disturbance when charging the batteries are described in a number of IEC and CISPR documents.
The radiation problems for information technology equipment (ITE) between 30 MHz and 1 GHz is described in CISPR 22. There are no specific standards

[1140] cf. K. Selleslags, op.cit.

however defining reference levels for low frequency magnetic fields generated by a vehicle.
For these limits, one can however refer to the ICNIRP guidelines[1141], which define maximal magnetic and electric field strengths for exposure of personnel.
ICNIRP, the International Commission on Non-Ionising Radiation Protection, is a formally recognized non-governmental organization in non-ionising radiation for the World Health Organization and the International Labour Office. Its functions are to investigate the hazards that may be associated with the different forms of non-ionising radiation, develop international guidelines on exposure limits, and deal with all aspects of non-ionising radiation protection.
The European prestandard ENV 50166 is largely based on these guidelines.

As for immunity, the requirements for the vehicle whilst charging are fully covered by the documents of the IEC 61000-4 series. This series consist of a number of standards each describing one specific immunity test.

5.9.16.2 The electric vehicle on the road

When the vehicle is driving on the road, it has to comply to all requirements of Automotive Directive 95/54/EC, which replaces, for automotive vehicles, the general directive 89/336/EC.

Concerning the radiation aspects, one can distinguish three frequency bands.
In the low-frequency band between 25 Hz and 9 kHz, the emitted radiation is quite low[1142], and there is no need to impose specific standardization.
For the frequency band between 9 kHz and 30 MHz, there are for the moment no European or international standards available. The radiation of ICE vehicles in this band is low in fact, so there was no need for specific standards to be issued.
For electric vehicles however, the radiation emitted in this frequency band can be significant, since it corresponds to the working frequency of most power converters.

One can however refer to two standards published by SAE for electromagnetic emissions of electric vehicles in the 9 kHz - 30 MHz band: SAE J551-2 treats narrowband emissions while SAE J551-5 treats broadband emissions.

The radiation in the frequency band above 30 MHz is fully described in CISPR 12, which also distinguishes between wide and narrowband radiation.
The limit values and measurement methods of the European automotive Directive are fully based on this document.

[1141] ICNIRP, Guidelines for limiting exposure to time-varying electric, magnetic and electromagnetic fields (up to 300 GHz), Health Physics, Vol74 n4, 1998, p494-522
[1142] Cf. measurements performed at ETEC and described in K. Selleslags, op.cit., app6

The immunity of a vehicle exposed to external magnetic fields is the province of ISO. The documents ISO 6469-2 and ISO 11451 can be used to describe all immunity issues of electric vehicles.

5.9.16.3 Measurement apparatus

For all radiation measurements on the flowchart of Figure 5.66, the specifications of CISPR 16-1 and CISPR 16-2 apply.
For conduction measurements, IEC standards are available such as IEC 61000-4-5 for harmonics and IEC 61000-4-15 for conductive transients.

5.10 Standards for "small" electric vehicles: wheelchairs and two-wheelers

5.10.1 International standards for electric wheelchairs

5.10.1.1 Introduction

The availability of compact electric drive systems and their associated controllers has allowed to use electric drive technology for power wheelchair applications.
These vehicles may represent the lower end in the panoply of electric traction, but they are a prime example of the humanitarian nature of electricity since they restore mobility to people that are physically impaired.
Standardization has followed the technical development, both on international and regional level.

The International Standard ISO 7176 is a family of standards concerning wheelchairs, prepared by Technical Committee ISO/TC 173, Technical systems and aids for disabled or handicapped persons, Subcommittee SC1, Wheelchairs.
It consists of over 20 parts concerning several aspects of the application, some of which refer specifically to electrically powered devices:

- Part 2: Determination of dynamic stability of electric wheelchairs
- Part 4: Energy consumption of electric wheelchairs and scooters for determination of theoretical distance range
- Part 6: Determination of maximum speed, acceleration and retardation of electric wheelchairs
- Part 9: Climatic tests for electric wheelchairs
- Part 10: Determination of the obstacle-climbing ability of electric wheelchairs
- Part 14: Power and control systems for electric wheelchairs - Requirements and test methods

These documents apply to electrically powered wheelchairs including scooters[1143] with a maximum nominal speed not exceeding 15 km/h, intended to carry one person.
Part 21 "Electromagnetic compatibility of powered wheelchairs and motorized scooters - Requirements and test" is now under preparation[1144].

Part 22 "Set-up procedure", describes the procedure to prepare a wheelchair for the test. It is referenced to by the performance and testing standards.

[1143] In the framework of this standard, "scooters" are to be understood as small three- or four wheel vehicles for the transport of a seated person, and not as two-wheelvehicles.
[1144] FDIS stage (50.00) at 2002-06-24

5.10.1.2 ISO 7176-2

ISO 7176-2:2001 "Determination of dynamic stability of electric wheelchairs" specifies test methods for determining the dynamic stability of electrically powered wheelchairs.[1145]
The principle of the test is to subject the wheelchair to a number of driving tests simulating normal use of a wheelchair while its movements are observed for the occurrence of a range of defined conditions of instability.[1146]

Dynamic stability is tested for rearward, forward and lateral directions, by making a set of prescribed manoeuvres (starting, stopping, braking, travelling on a step transition or a slope, driving in circles,...). Performance criteria are defined according to a scoring table[1147].

5.10.1.3 ISO 7176-4

ISO 7176-4:1997 "Energy consumption of electric wheelchairs and scooters for determination of theoretical distance range" specifies a method for determining the energy consumption, expressed as a theoretical distance range, of electric wheelchairs and scooters[1148].
The principle underlying the consumption test is quite simple: the wheelchair is driven around the test track at maximum speed (according to ISO 7176-6) 10 times clockwise and 10 times anticlockwise, and the ampere-hours used are measured[1149].

The standard states instructions on how to prepare the wheelchair for the test, how to perform the test and how to report on it.
The range of the wheelchair is calculated as follows:

$$R = \frac{C \times D}{E \times 1000} \tag{5-32}$$

where:

R is the theoretical distance range, in kilometres;
C is the capacity of the battery, in ampere hours, at a five-hour rate of discharge as declared by the battery manufacturer;
D is the distance covered during the test, expressed in metres;
E is the electric charge, in ampere hours, used during the test[1150].

[1145] ISO 7176-2:2001, Scope
[1146] Ibid., ¶4
[1147] Ibid., Annex A
[1148] ISO 7176-4:1997, Scope
[1149] Ibid., ¶4
[1150] Ibid., ¶7.11

It becomes clear that this test is based on a linear discharge of the battery based on its nominal five-hour rate, and that such a test will only be an approximation of the range of the wheelchair in real conditions, where the momentary energy consumption of the vehicle will be dependent on factors such as ambient temperature, topography of the route, driving conditions, tire pressure and battery condition.

This is even more clear since the typical use of a wheelchair, particularly when used indoors, will be characterized by a large number of stop-and-go movements (with a consequently higher energy consumption) rather than by prolonged running at maximum speed such as described in the test.

The test described in ISO 7176-4 will thus not indicate an accurate estimate of range of a particular wheelchair; it can only be used as a standardized test and a basis for comparison between different vehicles. This particularity is recognized by the authors of the document, and a word of warning is given in the introduction. [1151]

5.10.1.4 ISO 7176-6

ISO 7176-6:2001 "Determination of maximum speed, acceleration and deceleration of electric wheelchairs" specifies test methods for determining the maximum speed, acceleration and deceleration of electrically powered wheelchairs, including scooters.[1152]

These tests are demanded by other standards in the ISO 7176 series, but they have also a direct utility for the user: on one hand, the maximum speed of the wheelchair may determine its class according to vehicle regulations (such as which part of the road it has to use), and on the other hand, the speed is a factor in selection of the appropriate wheelchair, since some users may prefer a higher speed then others. The maximum acceleration and deceleration are primarily of concern with regard to the comfort of the user.[1153]

The standard, like all documents of the ISO 7176 series, also describes the format of the test report and the information which should be disclosed to the public in the manufacturer's specification sheets; the last point is even the subject of a special standard: ISO 7176-15 "Part 15: Requirements for information disclosure, documentation and labelling".

As for ISO 7176-6, the information to be disclosed to the public is limited to the maximum forward speed on horizontal plane[1154]. It is interesting to note that this

[1151] Ibid., Introduction

[1152] ISO 7176-6:2001, Scope

[1153] Ibid., Introduction

[1154] ISO 7176-6:2001, ¶10

speed should be specified in kilometres per hour, a unit easily understood by the general public, whileas for the official test report[1155], meters per second are to be used, the official speed unit in the SI system, and one which seems more practical for a vehicle like a wheelchair which is typically used in a short distance environment.

5.10.1.5 ISO 7176-9

ISO 7176-9:2001 "Climatic tests for electric wheelchairs" specifies requirements and test methods to determine the effects of rain, condensation, and temperature on the functioning of electric wheelchairs. It does not include requirements for resistance to corrosion.[1156]

The aim of these tests is to simulate climatic conditions which occur around the world. The sequence of tests includes:

- ☞ Rain test, using the IEC 60529 spray method (¶7.3)
- ☞ Cold operating conditions, -25°C (¶7.4)
- ☞ Hot operating conditions, +50°C (¶7.5)
- ☞ Cold storage conditions, -40°C (¶7.6)
- ☞ Hot storage conditions, +65°C (¶7.7)

After each test, a functional check of the wheelchair is performed, consisting of driving the wheelchair along a prescribed path as in Figure 5.67. The size of this test track is 4 by 3 metres.

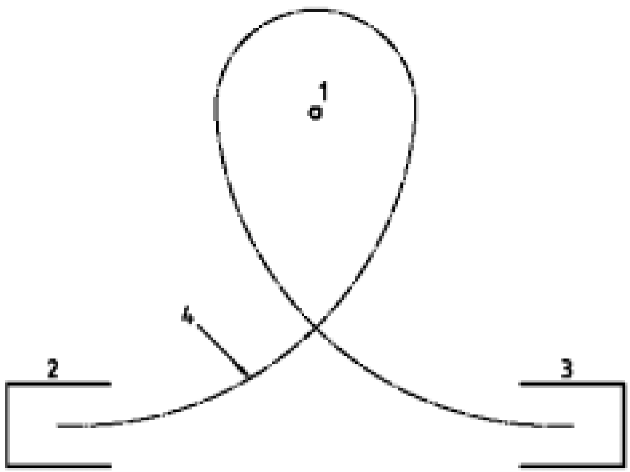

Figure 5.67: Test path for wheelchair[1157]

[1155] Ibid., ¶9

[1156] ISO 7176-9:2001, Scope

[1157] ISO 7176-9:2001, p6

5.10.1.6 ISO 7176-10

ISO 7176-10:1988 "Determination of obstacle-climbing ability of electric wheelchairs" describes a number of tests for determination of the ability of electric wheelchairs to negotiate obstacles such as kerbs and steps.
The wheelchair must be able to climb a rectangular step as shown in Figure 5.68, the height of which can vary from 20 to 200 mm.

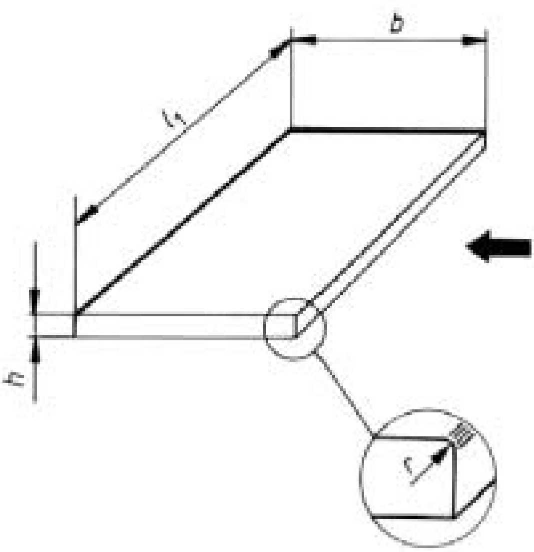

Figure 5.68: Test obstacle for wheelchair[1158]

The wheelchair is driven at a 90° angle towards the obstacle, in both forward and reverse directions, and with and without a 0,5 m run-up[1159]. The highest step the wheelchair can negotiate (i.e. fully climb, with its four wheels, upon the obstacle) in any of these four cases shall be recorded.

5.10.1.7 ISO 7176-14

Unlike the parts of ISO 7176 described in the paragraphs above, which described performance requirements, ISO 7176-14:1997 "Power and control systems for wheelchairs - Requirements and test methods" is more of a safety standard, specifying requirements for the power and control systems of wheelchairs, including

[1158] ISO 7176-10:1988, p2
[1159] Ibid., ¶7

battery chargers. It sets minimum requirements for the protection of the user during normal use and some conditions of abuse and failure. It also specifies methods of measurement of the forces necessary to operate the controls and sets limits on the forces needed for some operations.[1160]
It does not apply however to mains-powered battery chargers which are built in as an integral part of the wheelchair, nor does it address EMC issues.[1161]

ISO 7176-14 defines a comprehensive number of tests concerning the safety of the system for the user. Although the battery voltage levels used on wheelchairs are typically of a safe level (12 or 24 V), the energy stored in the battery may cause hazardous conditions such as in a short circuit. Therefore, the standard specifies such things as colour codes of wires (¶6.2), electrical isolation (¶6.3), fuses (¶6.4), interchangeability of connectors (¶6.5), wiring practices (¶6.6), protection from non-insulated parts (¶6.7) and short-circuit protection (¶6.8). The necessity for strict requirements here is strengthened due to the fact that wheelchair users are people with restricted abilities (such as poor manipulative skills), whom need to be suitably protected against hazards.
Safe operation also includes that the wheelchair shall not be able to operate during charging (¶6.9) and that the charger itself operates safely (¶9).
No dangerous conditions shall occur when the battery is reverse connected (¶6.10), that it shall withstand overvoltage conditions (¶6.11), and that it shall come to a safe stop in case of controller signal or device failures (¶6.12 and ¶6.13), or when the power is switched off or lost during operation (¶6.15). No damage shall occur to the motor when the wheelchair is stalled (¶6.14).
Since many wheelchairs are now fitted with microprocessor controllers, a "watchdog" circuit shall be provided to ensure safe operation in case of microprocessor failure (¶6.16).
Furthermore, the wheelchair shall not exhibit unsafe responses when its battery is depleted (¶6.17), and it shall be able to be moved easily (by an attendant) when the power is off (¶7).
Moving parts shall not create pinch points or other hazards to the user (¶8).
The standard also defines a test (¶10) for measuring the forces needed to operate control devices, the knowledge of which may be needed to determine the suitability of the wheelchair for certain types of users.

Like all standards in the ISO 7176 series, ISO 7176-14 defines a format for the test report (¶11), and for the information to be disclosed to the public as specified in ISO 7176-15 (¶12).

[1160] ISO 7176-14:1997, Scope
[1161] Ibid., Scope, and ¶3.9, Note

5.10.2 European standards

The European standard EN 12184:1999 "Electrically powered wheelchairs and their chargers - Requirements and test methods" has been prepared by CEN Technical Committee CEN/TC293 "Technical aids for disabled persons" under a mandate given by the European Commission and the EFTA, supporting essential requirements of the EU Directive 93/42/EEC concerning medical devices.
Wheelchairs are thus explicitly considered medical devices.

EN 12184 specifies requirements and test methods for electrically powered wheelchairs and scooters, as well as for their battery chargers[1162]. It is a comprehensive document also covering general mechanical requirements such as static, impact and fatigue strength (¶8.1), brake requirements (¶8.2), driving characteristics (¶8.4), and the like.

For the electrical characteristics, reference is made to ISO 7176-14. Since this standard, as stated in ¶5.10.1.7, does not cover wheelchairs with on-board battery chargers, EN 12184 states[1163] that these shall conform to the international standard for electrical medical devices IEC 60601-1.
The European standard defines however some additional requirements not explicitly covered by ISO 7176-14:

- ☞ Provision shall be made for the user to switch the controller on and off (¶9.2).
- ☞ A power indicator shall be provided (¶9.3).
- ☞ The driving circuit shall be protected against excessive current (¶9.4).
- ☞ It shall not be possible to drive the wheelchair with its own drive system if the automatic brakes are disengaged (¶9.5 - this overrides part of ¶7.2 of ISO 7176-14).
- ☞ Intermediate connections between battery cells shall not be used to supply power (¶9.6).

Battery chargers (¶9.7) shall comply with ¶9 of ISO 7176-14, with additional requirements that:

- ☞ A charging indicator shall be provided.
- ☞ The charger shall be capable of charging a battery discharged to 70 % of its nominal voltage.
- ☞ Trickle charging current shall not exceed 500 mA.
- ☞ Battery chargers shall operate without the need for intervention or supervision.

EN 12184 also specifies criteria for EMC (¶9.8).

[1162] EN 12184:1999, Scope
[1163] Ibid., ¶9.1

Concerning electromagnetic emission in the 30 MHz to 1 GHz range, the wheelchair shall conform the requirements for "Class B" equipment, as defined in EN 55022, which is the European pendant of CISPR 22 (cf. §5.9.13).
Class B equipment is intended primarily for use in the domestic environment; the latter being defined as "an environment where the use of broadcast radio and television receivers may be expected within a distance of 10 m of the apparatus concerned"[1164].

As for electromagnetic immunity, no undesired operation shall occur during the test, which is done for both a standing and a driving wheelchair, according to the specifications of IEC 61000-4-3, with a test level of 10 V/m.
For electrostatic discharge test, the procedure of IEC 61000-4-2 is followed. Two test methods are described: the "human body model test" and the "charged frame test".

The (informative) annexes to EN 12184 state further recommendations on design, including electrical features (Annex A), seating design (Annex B), ease of operation (Annex C), lighting (Annex D), and resistance to corrosion (Annex E).
Annex F makes an interesting recommendation from an EMC point of view: it urges manufacturers to advise in the instruction manuals that the power source of the wheelchairs is switched off while mobile telephones are used. Concerns are indeed expressed concerning the immunity against electromagnetic radiation of GSM mobile phones, which operate in the 900 MHz and 1,8 GHz bands; the latter frequency band being outside the frequency range (26 MHz to 1 GHz) covered by the EMC immunity tests described in the standard.

EN 12184 is to be considered a typical European standard, which addresses a number of requirements or other provisions of an EU directive. The correspondence between the standard and the corresponding directive are detailed in its Annex Z.
The standard thus becomes a useful tool to help manufacturers to comply with the directive, the latter being a legally binding document. This interaction between standardization and legislation is typical for European standardization; it has already been seen with the standard EN 1175-1 on industrial trucks discussed in §4.2.6.2. This situation will be further treated in §5.5.11.

[1164] CISPR 22:1997, ¶4.1

5.10.3 Electric bicycles

5.10.3.1 Introduction

The electric power-assisted cycle (EPAC)[1165] is a type of two-wheel electric vehicle that is rapidly gaining popularity. Its use is actively being promoted through international projects like E-TOUR[1166] and national programs like NewRide[1167] in Switzerland. However, standardization work has not yet caught up with this: at this day, there are no international or European standards specifically covering the electric pedal-assisted bicycle.

5.10.3.2 Bicycle standards

There are however a number of international and national standards concerning (pedal) bicycles. As these standards do not specifically refer to electrically driven bicycles, their discussion falls beyond the scope of this thesis and they will just be briefly summed up here. It is interesting to note however that there is a concordance between some parts of these national standards on one hand and international standards on the other hand.

Table 5.20 gives an overview of international (ISO) standards applicable to bicycles, and their counterparts in national (British and German) standardization. BS and DIN standards have been considered here because in those countries the most extensive number of documents on bicycles have been published. In most cases these national standards are reproducing the ISO ones identically; where this is not the case however, the number of the national case is set in cursive. It is to be noted that the German version of the bicycle safety standard (DIN 79100) has also been adapted as a Belgian national standard (NBN).

[1165] In some countries, this type of bicycle is also known as "Pedelec"

[1166] E-TOUR, Electric Two-Wheelers on Urban Roads, European project NNE5-1999-409, http://www.etourproject.org

[1167] http://www.newride.ch

International standards		British standards	German standards
ISO 4210:1996	Cycles - Safety requirements for bicycles	*BS 6102-1:1992*	*DIN 79100:2000*
ISO 5775-1:1997	Cycles - Specification for bicycle tire designations and dimensions	BS 6102-5:1998	*DIN 7800:1996*
ISO 5775-2:1996 (AMD2001)	Bicycle tyres and rims - Part 2: Rims	BS 6102-6:1997	*DIN 7815:1996*
ISO 6692:1981	Cycles - Marking of cycle components	BS 6102-7:1982	DIN ISO 6692:1989
ISO 6693:1981	Cycles - Cotter pin and assembly of the axle/cotter pin/crank		DIN ISO 6693:1989
ISO 6695:1991	Cycles - Pedal axle and crank assembly with square end fitting - Assembly dimensions	BS 6102-14:1991	
ISO 6696:1989	Cycles - Screw threads used in bottom bracket assemblies	BS 6102-9:1990	
ISO 6697:1994	Cycles - Hubs and freewheels - Assembly dimensions		
ISO 6698:1989	Cycles - Screw threads used to assemble freewheels on bicycle hubs	BS 6102-8:1990	DIN ISO 6698:1989
ISO 6699:1990	Cycles - Stem and handlebar bend - Assembly dimensions	BS 6102-11:1991	
ISO 6701:1991	Cycles - External dimensions of spoke nipples	BS 6102-15:1991	
ISO 6742-1:1987	Cycles - Lighting and retro-reflective devices - Photometric and physical requirements - Part 1: Lighting equipment	*BS 6102-2:1982*	
ISO 6742-2:1985	Cycles - Lighting and retro-reflective devices - Photometric and physical requirements - Part 2: Retro-reflective devices	*BS 6102-3:1986*	
ISO 7636:1984	Bells for bicycles and mopeds - Technical specifications		DIN ISO 7638:1986
ISO 8090:1990 (AMD1992)	Cycles - Terminology	BS ISO 8090:2000	DIN ISO 8090:2000
ISO 8098:2002	Cycles - Safety requirements for bicycles for young children	BS ISO 8098:2002	*DIN 79110:1980*
ISO 8488:1986	Cycles - Screw threads used to assemble head fittings on bicycle forks	BS 6102-10:1987	
ISO 8562:1990	Cycles - Stem wedge angle	BS 6102-12:1991	
ISO 9633:2001	Cycle chains - Characteristics and test methods		
ISO 10230:1990	Cycles - Splined hub and sprocket - Mating dimensions	BS 6102-13:1991	
ISO 11243:1994	Cycles - Luggage carriers for bicycles - Concepts, classification and testing	BS ISO 11243:1994	*DIN79121:1986*

Table 5.20: International standards for bicycles

Other BS or DIN standards for bicycles have also been published as national standards only:

☞ BS 6102-16:1997 - Cycles. Specification for replacement brake blocks

☞ DIN 79105:1985 - BMX-Fahrräder; Begriffe, Sicherheitstechnische Anforderungen, Prüfungen

☞ DIN 79011:1960 - Gewinde für Fahrräder und Mopeds; Auswahl, Verwendung

☞ DIN 79012:1960 - Gewinde für Fahrräder und Mopeds; Theoretische Werte, Gewindegrenzmaße

☞ DIN 79120:1989 - Kindersitze für Fahrräder; Begriffe, Sicherheitstecnische Anforderungen und Prüfung

Furthermore, the following European standard refers to the safety of bicycle accessories:

☞ EN 1078:1997 - Helmets for pedal cyclists and for users of skateboards and roller skates

Another European standard (prEN 14344) concerning safety requirements and tests for bicycle child seats is under preparation.

All these standards represent two of the main classes of standards: dimensional standards on one hand and safety standards on the other hand.

The main safety standard, ISO 4210 "Cycles - Safety requirements for bicycles" aims to ensure that bicycles are as safe as is practically possible. Tests are provided to ensure the strength and durability of individual parts as well as of the bicycle as a whole. Its scope has been limited to safety considerations, and not to standardization of components.[1168]

5.10.3.3 *Overview of national regulations for EPAC*

In the framework of this thesis however it seems useful to consider the national regulations which exist about electric pedal-assisted bicycles.
These regulations are about the classification of the vehicle: should it be considered a bicycle or a motorcycle? This classification of course has a direct interest for the user: motorcycles come in fact with special legal requirements such as driving licenses, compulsory insurance policies, crash helmets and the like; furthermore, the classification of a vehicle determines its place on the public thoroughfare (bicycle path or highway?).

Table 5.21 gives an overview of the current regulations concerning electric power-assisted bicycles in a number of European countries.
In most countries, the EPAC is considered a bicycle, which is quite logical since this type of vehicle needs pedal operation to go forward. Electric two-wheelers who can ride "on their own" are always classified as mopeds and fall outside the scope of these regulations.
Type approval is not needed (in fact, there are no type approval regulations for EPACs), in Germany and UK however, reference is made to national standards for (pedal) bicycles, which were presented in §5.10.3.2.

[1168] ISO 4210:1996, Introduction

Country	Legal status	Type approval	Speed limit	Motor output limit	Insurance	Helmet	Age Limit
Austria	bicycle	no	25 km/h	n.a.	no	no	no
Belgium	bicycle	no	no	300 W	no	no	no
Denmark	bicycle	no	25 km/h	250 W	no	no	no
Finland	bicycle	no	25 km/h	250 W	no	no	no
France	bicycle	no	25 km/h	500 W	no	no	no
Germany	bicycle	no (2)	24 km/h	250 W	no	no	no
Holland	bicycle (1)	no	25 km/h	250 W	yes (3)	no	no
Italy	bicycle	no	no	no	no	no	no
Luxembourg	bicycle	no	no	no	no	no	no
Spain	bicycle	no	25 km/h	500 W	no	no	no
Sweden	moped	yes	30 km/h	no	yes	yes	15
Switzerland	moped	yes	no (4)	500 W	yes	no	14
UK	bicycle	no (2)	15 mph	200 W	no	no	14

(1) based on a gentlemen's agreement between the industry and the national government and only for as long as the European Commission does not rule otherwise

(2) Germany: vehicles should comply with the DIN-standard for bicycles

UK: homologation according to British standard for bicycles

(3) moped insurance

(4) without pedal assistance: 20 km/h

Table 5.21: Current regulations for EPAC[1169]

There are more notable differences however when concerning the maximum power of the motor and the maximum authorized speed for the power-assisted mode.

The power limit for the motor varies from 200 to 500 W, with some countries imposing no limit. It can be stated however that a power of 250 to 300 W is sufficient for a reasonable EPAC operation.

Figure 5.69: EPAC test bench at VUB

[1169] E-TOUR Project Report

The maximum speed in assisted mode is typically 25 km/h in most countries. Some countries, like Belgium or Switzerland however, have no limit; it is clear that the absence of such a limitation makes the EPAC much more attractive for the market, since it will appeal to a larger group of potential users. The speed-limited EPAC is in fact rather perceived as "a bicycle for elderly people", and is marketed towards people with reduced mobility capacity due to health or age.
The power distribution between the power-assist system and the cyclist has been extensively studied in the framework of the E-TOUR project[1170], where a dedicated test infrastructure has been developed by the VUB, shown in Figure 5.69. This project could constitute an excellent base to define measurement procedures for a future standard on EPACs.

5.10.3.4 The European directive 2002/24

Some clarification in these different national regulations might be brought by the new directive 2002/24 relating to the type-approval of two or three-wheel motor vehicles.
This Directive defines the administrative rules for type approval of

> *"all two or three-wheel motor vehicles, whether twin-wheeled or otherwise, intended to travel on the road, and to the components or separate technical units of such vehicles"*[1171].

It does not apply however to:

> *"cycles with pedal assistance which are equipped with an auxiliary electric motor having a maximum continuous rated power of 0,25 kW, of which the output is progressively reduced and finally cut off as the vehicle reaches a speed of 25 km/h, or sooner, if the cyclist stops pedalling"*[1172]

such vehicles thus being exempt from type approval procedure.

It is clear that the latter paragraph refers specifically to EPACs, which continue to be considered "bicycles" for which no type approval is necessary. The limitations presented in the Directive are thus clear:

☞ The power of the motor shall not exceed 250 W, which is comparable to the power levels presented in Table 5.21. One should note however that the directive text specifies this power as a "continuous rated power", and not as a "peak power"; it would thus be acceptable to have a higher peak power level during limited time. Any definition of "rated power" becomes quite "hollow" if no reference is made to standards describing how this rating is to be defined

[1170] J. Cappelle, Ph. Lataire, "Characterisation of Electric Bicycle Performances", EVS-19, Busan, 2002
[1171] Ibid., Article 1
[1172] Ibid., Art. 1 (h)

measured.

In the directive 2002/24, as for measuring the maximum power, reference is made to directive 1995/1, which defines procedures for measuring maximum output power. These procedures only refer to internal-combustion engined mopeds and motorcycles, and are of no use for electrically powered vehicles.

☞ The maximum speed up to which assistance is applied shall be 25 km/h. Also in line with most national regulations from Table 5.21, this limitation, as stated above, is a serious hamper for the expansion of the EPAC market. Its relevance to safety can be questioned, since trained cyclists on conventional bicycles routinely exceed this speed; the need for type approval of conventional bicycles has never been raised however.

5.10.4 Electric motorcycle standards

5.10.4.1 International standardization

The electric scooter represents the other class of electric two-wheeler. Most electric scooters on the market fall within the "moped" class; these vehicles are limited (at least in Europe) to a speed of 45 km/h and do not require a special motorcycle driving license.

At this moment, there are no international standards however concerning electric two-wheelers.

Within ISO TC22, SC23 is responsible for mopeds. On its 2000 plenary meeting, this sub-committee focused its attention on electric mopeds, and it requested ISO TC22 SC21 for a formal liaison.[1173] This request was agreed upon by SC21.[1174]

5.10.4.2 Standardization in Asia

National standardization of electric motorcycles has been developed in Asian countries, where the use of such vehicles is much more widespread.

In Taiwan[1175], the Bureau of Standards, Metrology and Inspection (BSMI) began preparing electric motorcycle standards in 1998. Early standards covered only charging facilities, safety requirements, symbols and labels, inspection and testing of lead-acid batteries, performance testing, and a glossary of terminology etc. In 1999, however, the Automotive Research & Testing Centre (ARTC) began preparing 14 draft standards for electric motorcycles, based on international standards including

[1173] Doc. ISO/TC22/SC23 N274, Resolution 198 taken at the 23th meeting, 2000-11-14

[1174] Doc. ISO/TC22/SC21 N321E, Minutes of the 14th meeting, 2002-05-03

[1175] Jan-Ku Chen, Liang-Jyi Fang and Iao-Huei Pan, "The Status of Electric Motorcycles in Chinese Taipei", EVS-19, Busan, 2002

ISO, SAE, JIS, JASO, JEVS, UL, ECE, EN etc. These standards are shown in Table 5.22.
The Japanese standards referred to in this table are the general standards for electric vehicles, as discussed in §5.7.1.

Subject	Reference document
General rules of testing	CNS 3105 & 3107, JEVS E101
Methodology for testing maximum speed	JEVS E102
Methodology for testing acceleration	CNS3107
Methodology for testing climbing ability	CNS3111, JEVS Z104
Methodology for testing range	CNS3105, JEVS Z103
Methodology for measuring energy consumption	CNS3105, JEVS Z106, JEVSZ111
Methodology for testing energy economy	CNS 3105, JEVS Z105
Methodology for testing life cycle of batteries	
Methodology for testing specific power and power density of batteries	JEVS D103
Methodology for testing specific energy and energy density of batteries	JEVS D702
Methodology for testing capacity of batteries	JEVS D701
Methodology for measuring the combined power of electric motors and controller	JEVS E701
Methodology for measuring electric motors equivalent to the on-board state for electric vehicles	JEVS E701,E702
Test limits and methodology for measuring electromagnetic interference of charging and discharging	SAE J1113, J551

Table 5.22: Electric motorcycle standards being developed in Taiwan[1176]

[1176] Ibid.

5.11 *Standardization for military and dual-use vehicles*

5.11.1 The "dual use" approach

The end of the Cold War caused a considerable change in the global strategic situation. Furthermore, many countries have dramatically cut down their defence budget. In this framework, a new approach to military research, development and acquisition has been devised: whileas many solutions have spun off from military research towards civilian applications (e.g. the Internet or the global positioning system GPS), the military are now more actively looking to the commercial market and are striving to adopt commercial off-the-shelf technology (COTS) where appropriate, particularly when considering "dual-use" technologies, which are defined as "technologies that have both a military utility and sufficient commercial potential to support a viable industry base"[1177].

The interaction between military and civilian application fields is the underlying premise of this "dual-use" approach, which is deemed beneficial for all parties involved:

- ☞ The forces can make substantial savings in acquisition and logistical costs through the use of commercial products and the adoption of commercially developed technology rather than designing specific technology for military use.
- ☞ The civilian sector, through incorporating defence considerations into commercial designs, can get a leverage of R&D funding, allowing a more efficient development and deployment of new technologies for all applications.

The electrically driven vehicle is considered a typical application field of "dual-use" technology. Its benefits for military applications are obvious, as stated below; most R&D efforts in electric vehicle technology however have up to now been performed in the civilian sector. Further development to consider electric vehicles for military applications can give a considerable thrust to the development of the technology, compensating the economical drawback that electric vehicles unfortunately continue to suffer on the market compared with ICE vehicles.

The electric combat vehicle represents the best available technology for our armed forces and thus contributes to our overall security. Through the "dual-use" approach, its development can also be a factor towards the deployment of electric vehicle technology in the civilian market and bring benefits to society as a whole. It should therefore be considered a highly commendable activity.

[1177] US DOD Dual Use Science and Technology Program

5.11.2 The electrically driven military vehicle

The potential of electric propulsion for defence applications has gained considerable interest during the past few years.
Design considerations of military vehicles are based on a number of fundamental requirements: mobility, lethality and survivability. Electrically driven vehicles do present several tactical and technological benefits, the most tangible of which can be summarized as follows[1178]:

- ☞ Fuel economy: in a (series) hybrid vehicle configuration, the engine operation can be optimised for efficient constant-power output, resulting in significant savings of fuel (and thus a reduction in required fuel transportation capacity, which is a main advantage for forward-deployed theatre operations), and reduced exhaust emissions and thermal signature.
- ☞ Power availability: the availability of both a generator set and a storage battery can meet the demand of all electric power users in the vehicle. This is very interesting due to the increasing demand of electric power for on-board systems. Power supply can be continuous, to provide hotel load in the order of 30 to 50 kW, or can be pulsed power in the gigawatt range to supply electric weapons such as electric guns or directed energy weapons. Furthermore, the availability of on-board electric supply directly reduces the logistical burden of the fleet by eliminating the towed generators necessary to provide electric power to the field.
- ☞ Silent watch and silent mobility: the energy storage can be sized to meet silent watch requirements for extended periods of time for various missions such as surveillance and reconnaissance. Silent mobility over a limited distance is also achievable where the vehicle can move in or out a hostile territory without being detected.
- ☞ Flexibility: the hybrid electric drives have a modular structure, giving the vehicle designers freedom of design. Components can be arranged and integrated in the vehicle for the optimum utilization of the available space.
- ☞ Enhanced prognostics and diagnostics, through monitoring systems reducing the operation and maintenance costs over the life of the vehicle and thus to help offset the acquisition cost which at the current level of maturity exceeds that of the conventional systems.

These advantages have prompted several nations to consider the "All Electric Combat Vehicle" (AECV); within the NATO, this issue is dealt with by the Applied Vehicle Technology Panel AVT-047, of which the author is a member.

A schematic view of an AECV can be seen in Figure 5.70.

[1178] NATO AVT-047

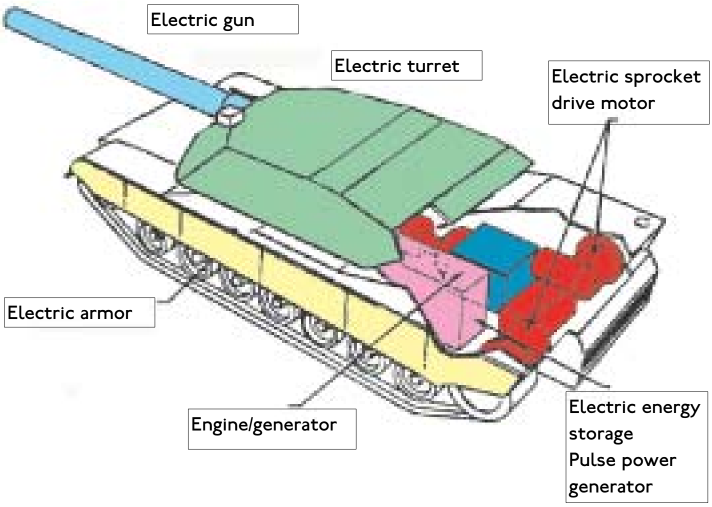

Figure 5.70: Schematic view of an AECV[1179]

A long-term scientific study performed by the NATO Research and Technology Organization[1180] stated that the introduction of electrical technologies in military vehicles was “unavoidable”, and that in the long term “electric drives will provide better operational performances with potential savings in life cycle costs”.

Figure 5.71: Hybrid HMMWV[1181]

[1179] Lee, H.G. et al., Developmental Concept of Hybrid Electric Propulsion Systems for Future Combat Vehicles, EVS-19, Busan, 2002
[1180] Baudoin Y, Life cycle cost of all-electric combat vehicles, NATO RTO, Doc. RTO-TR-13, 1999
[1181] Winters, K., and Khalil, G., Testing experiences with a hybrid electric HMMWV, 4th AECV conference, Noordwijkerhout, 2002

Electrically driven military vehicles are being developed in several countries; examples include wheeled vehicles such as the US HMMWV (High Mobility Multipurpose Wheeled Vehicle) shown in Figure 5.71 and Figure 5.72, and the UK HERO (Hybrid Electric Realised Off-Road) based on the Land Rover.

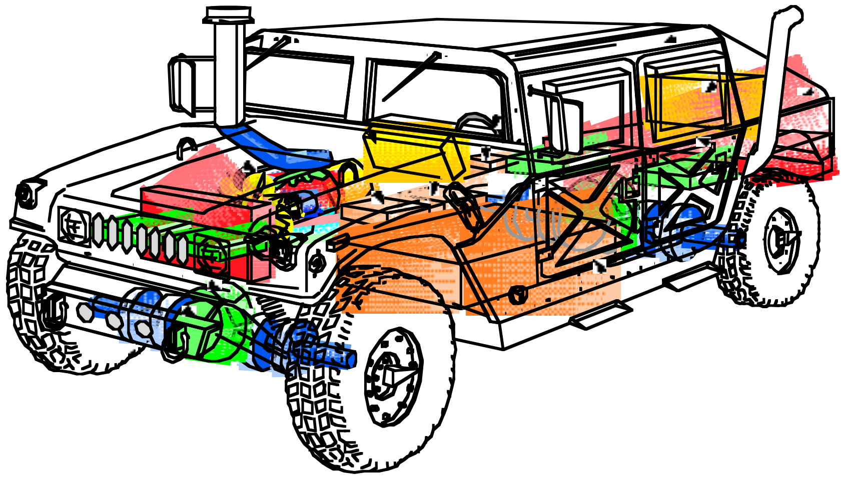

Figure 5.72: Structure of hybrid HMMWV[1182]

Tracked vehicles have also been fitted with electric drives, such as the "Wiesel", a German light airtransportable armoured vehicle (Figure 5.73), and a hybrid electric version of the popular M113 APC developed in the US.

Figure 5.73: Hybrid tracked vehicle "Wiesel"[1183]

[1182] Ibid.

5.11.3 Standardization and the military

5.11.3.1 NATO *military standardization*

As the world's largest security and defence alliance, NATO strongly relies on standardization as a means to increase the effectiveness of the military forces of the Alliance. Within NATO, standardization is defined as:

> *"the process of developing concepts, doctrines, procedures and designs to achieve and maintain the most effective level of standardization in the fields of operations, administration and materiel."*[1184]

NATO standardization is a broad process which may be applied to any NATO activity. NATO standards are generally classified into one of three groups:[1185]

☞ Operational standards, which affect military practice, procedures or formats. Examples are concepts, doctrine, tactics, techniques, training, reports, maps and charts.
☞ Materiel[1186] standards, which affect the characteristics of materiel, including complete systems, subsystems, assemblies, components, spare parts and consumables.
☞ Administrative standards, primarily concerning terminology, as well as non-military related administration aspects.

Four levels of standardization can be discerned, in ascending order:[1187]

☞ Compatibility: *"the capability of two or more items or components of equipment or materiel to exist or function in the same system or environment without mutual interference"*.
☞ Interoperability: *"the ability of systems, units or forces to provide services to, and accept services from, other systems, units or forces and to use the services so exchanged to enable them to operate effectively together"*.
☞ Interchangeability: *"a condition which exists when two or more items possess such functional and physical characteristics as to be equivalent in performance and durability, and are capable of being exchanged one for the other without alteration of the items themselves, or of adjoining items, except for adjustments, and without selection for fit and performance"*.
☞ Commonality: *"the state achieved when groups of individuals, organizations or nations use common doctrines, procedures or equipment"*.

Within NATO, standardization matters are treated by the NATO Standardization Organization (NSO), which comprises the NATO Committee for Standardization

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[1183] NATO AVT-047
[1184] NATO Logistics Handbook, 1997, ¶1705
[1185] NATO Logistics Handbook, 1997, ¶1711
[1186] Materiel (not "material"): a general NATO term covering equipment stores, supplies and spares
[1187] UK MOD, INT DEF STAN 00-00 (Part 1)/3, ¶12.3.2

(NCS), the NATO Standardization Staff Group (NSSG), and the NATO Standardization Agency (NSA).[1188]

Standardization documents issued by NATO are mostly under the form of Standardization Agreements (STANAGs). A STANAG is defined as:

> *"The record of an agreement among several or all the member nations to adopt like or similar military equipment, ammunition, supplies and stores; and operational, logistic or administrative procedures. National acceptance of a NATO Allied Publication issued by the Military Agency for Standardization may be recorded as a Standardization Agreement."*[1189]

STANAGs have no authority in the individual countries, unless implemented by reference or by the publication of an appropriate national document.[1190] Nations ratify and implement STANAGs on a voluntary basis.
Another type of NATO standards are Allied Publications (AP), documents which all or some NATO nations agree to use as a common implementing document.

NATO will make maximum use of existing standards: STANAGs will only be developed when the respective requirements are not covered by recognized civilian or already existing military standards; adoption of existing standards needs to be reflected in STANAGs.[1191]

Military standards are also issued by individual nations; the following paragraphs will cite the US and the UK as example.

5.11.3.2 US military standardization

The tendency of the armed forces towards standardization (which has been cited already in §3.3.1) has nowhere been more clearly expressed than in the United States: of the 93000 American standards which are now active, not less than 34000 are issued by the Department of Defense, which is thus by far the largest standards developer in the United States. Only about 8000 of these standards define strictly military commodities and practices, the remainder defining subjects which are also used in the commercial sector.[1192] The military also played a pioneer role in the definition of procedural and quality management standards: the well-known ISO 9000 quality standard for example can be traced back to the US military standard MIL-Q-9858 of 1959.[1193]

[1188] NATO Handbook, 2001, p 318
[1189] NATO AAP-6, NATO Glossary of Terms and Definitions
[1190] UK MOD, INT DEF STAN 00-00 (Part 1)/3, ¶15.1.1
[1191] NATO Logistics Handbook, 1997, ¶1708
[1192] S. M. Spivak, F.C. Brenner, op.cit., p139
[1193] Ibid, p 102

The US DOD approach on military standardization went through a major reform however since 1994, when Secretary of Defense William Perry issued a memorandum[1194] directing that performance-based specifications and standards or nationally recognized non-governmental standards (such as IEC or ISO standards) be used in future acquisitions, referring to military specifications and standards only as a last resort when no acceptable non-government standards are available (e.g. for weapon systems and the like).

5.11.3.3 UK military standardization

A similar policy is pursued for the military standardization in the UK. The UK MOD pursues to make the maximum use of standards in all its design and procurement activities whereby civil standards are preferred, because they reduce barriers to international trade and increase competitiveness. Military standards should only be used when there are no suitable civil standards available.
The hierarchy for the selection of standards for UK MOD procurement is as follows:[1195]

1. European standards (CEN - CENELEC - ETSI), due to the obligations of the MOD for public procurement contracts, cf. §5.5.11.
2. International standards (ISO - IEC - ITU)
3. British national standards (BS)
4. NATO standardization agreements (STANAG)
5. UK MOD defence standards (DEF STAN)
6. UK MOD departmental standards and specifications (e.g. Naval Engineering Standards)
7. Other nation's military standards
8. Recognized industry standards

UK Defence Standards (DEF STAN) are produced only when no suitable civil standard is available and when they have a clear advantage, which may be operational (e.g. NATO compatibility and interoperability) or logistic. The two main types of DEF STAN are Performance Standards and Procedural Standards.[1196]

Other international military standards are the Quadripartite Standardization Agreements (QSTAG) produced by the ABCA countries (America, Britain, Canada, Australia).

[1194] The Secretary of Defense, William J.Perry, "Specifications & Standards - A New Way of Doing Business", 1994-06-29
[1195] UK MOD, INT DEF STAN 00-00 (Part 1)/3, 1999-06-04, ¶26
[1196] UK MOD, INT DEF STAN 00-00 (Part 1)/3, 1999-06-04, ¶28

5.11.4 Standards for electric and hybrid vehicles

As seen in the paragraph above, the general tendency in military standardization is to adopt civilian standards where available and appropriate. Particularly in a (at least for the military) new field such as electrically driven vehicles, it is likely that the civilian standards, which have been discussed elsewhere in this work, are to be adopted.
Military standards are however in existence covering a number of aspects which concern the vehicle, the main areas being voltage, battery and vehicle standards.

5.11.4.1 Military standardization for voltage

One of the main tasks of the electric power plant (APU + battery) on board the military vehicle will be to provide electric power to subsystems, which are now supplied from towed generator sets. Voltage levels for such subsystems are specified in NATO STANAG 4133[1197]:

- ☞ d.c. system: 2 DC 28 V
- ☞ Single phase a.c. systems:
  - ☚ 1/N/PE AC 50 Hz or 60 Hz 230 V
  - ☚ 1/N/PE AC 60 Hz 115 V
- ☞ Three phase a.c. systems:
  - ☚ 3/N/PE AC 50 Hz or 60 Hz 400/230 V
  - ☚ 3/N/PE AC 60 Hz 200/115 V
  - ☚ 3/N/PE AC 400 Hz 208/120 V
  - ☚ 3/N/PE AC 400 Hz 416/240 V

These voltage levels will also have to be supplied by the electrically driven vehicles; one should note that, with the exception of the medium-frequency 400 Hz supplies which are most typical for aeronautic applications, the voltages specified in this military standard are comparable with the voltages in common use by electric utilities in most parts of the world, specified in IEC 60038.[1198]
There will thus no major problem in adapting these voltages.

5.11.4.2 Military standardization for batteries

The armed forces are large users of batteries, ranging in size from small button cells to large submarine batteries of up to 10000 Ah. The US military for example has

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[1197] STANAG 4133:1992, "Method of specifying electrical power supplies : standard types of electrical power"

[1198] IEC 60038:1983+A1:1994+A2:1997, Table 1. For the three-phase 60 Hz network however, the most recent version of the IEC standard specifies a voltage of 120/208 V and not 115/200 V about 3800 types of battery in use; and this is one of the domains where standardization efforts have allowed to improve design and performance and to lower cost.[1199] The use of military or commercial standardized batteries has been mandated by a US Department of the Army memorandum from 2002.[1200]

A considerable number of standards for military batteries have been published; most of these however refer to battery types designed for specific applications such as aircraft batteries or submarine batteries.

There are also a number of generic battery specifications issued by the military. The British DEF STAN 61-9[1201] for example states qualification approval procedures, and also describes a number of tests to be performed. Supplements to this standard define dimensional requirements and test procedures for specific types of batteries that are standardized for military use, e.g. a 6 V, 170 Ah type.[1202]

New applications such as electric vehicles, where new types of batteries are implemented, will have to refer to civilian standards like those published by IEC.

5.11.4.3 Military standardization for vehicles

A number of nations have published general documents for the requirements of military vehicles. The British DEF STAN 23-6[1203] for example gives guidance to the common technical requirements of military vehicles. This document makes extensive reference to other standards which are applicable, covering both NATO STANAGs, ISO standards, BS standards, DEF STANs and other documents.
This type of documents will of course also be applicable when the vehicles are fitted with electric drives.

[1199] Defense Standardisation Program Case Study, Aircraft Batteries and Components, Defense Standardisation Program Office

[1200] Development, Acquisition and Fielding of Weapon and Information Systems with Batteries, Department of the Army memorandum, 2000-01-04

[1201] DEF STAN 61-9(Part 1)/4:1993: Generic specification for batteries, rechargeable, secondary - Part 1: General requirements

[1202] DEF STAN 61-9 (part1)/3 Supp. 2 Issue 2: 1973: Specification for battery, secondary - portable lead-acid type 6 V 170 Ah (fully dry charged) - NATO stock no. 6140-99-910-1545

[1203] DEF STAN 23-6:2000, Guide to the common technical requirements for military logistic vehicles and towed equipment

6 ELECTRICALLY DRIVEN VEHICLES FOR THE FUTURE

Welch Licht leuchtet dort?
Richard Wagner, Götterdämmerung, NORNEN-*Szene*

6.1 Introduction

As we have seen in §3.1.6 above, the idea of hybrid vehicles is not new. Although diesel-electric transmissions became widespread for heavy-duty applications such as railway locomotives, the real hybrid, i.e. the one which integrates several energy *sources* in one vehicle, became a far-flung idea; the interest however was renewed in the early 1970s, prompted by the oil crisis. An interesting experimental HEV was built by Dr. Victor Wouk, who has been rightly nicknamed "*the grandfather of electric and hybrid vehicles in the United States*":

> *"During this time, I and a partner, Charles Rosen, built an HEV using my own funds and those of an investor. We outfitted the vehicle, a converted Buick Skylark, with eight heavy-duty police-car batteries, a 20-kilowatt direct-current electric motor and an RX-2 Mazda rotary engine. In 1974 it was tested at the Environmental Protection Agency's emissions-testing laboratories in Ann Arbor, Mich. The vehicle was optimised for low pollutant emissions, not for good fuel economy. Still, on the highway and with the batteries discharging, the vehicle got nearly 13 kilometres per liter - more than twice the fuel economy of the vehicle before it was converted. The vehicle's emission rates (per kilometre) of 1,53 grams of carbon monoxide, 0,5 gram of nitrogen oxides and 0,21 gram of hydrocarbons were only about 9 percent of those of a gas-powered car from that era. The project showed that a pair of determined individuals could use readily available and proved technologies to build quickly an HEV that met the requirements of the Clean Air Act of 1970. (As it happened, Detroit's conventional automobiles did not meet these requirements until 1986)."*[1204]

The concept of hybrid vehicles was initially not well accepted by electric vehicle organizations such as AVERE and its sister regional associations. The interest from manufacturers would also be quite low until the mid-1990s, when several hybrid projects were being proposed.

One of the most successful hybrid vehicles is the Toyota Prius (Figure 6.1), of which more than 50000 have been sold, most of them in Japan and the US. This vehicle is a "non-depleting" hybrid: the battery is never recharged from an external source. The contribution of electric traction through the hybrid drivetrain grants this vehicle a fuel consumption which is considerably lower than conventional cars of this class. The drivetrain of this vehicle is of a combined hybrid structure.

[1204] Victor Wouk, Hybrid Electric Vehicles, Scientific American, 1997-10, p70-74

Figure 6.1: Toyota Prius hybrid passenger car

Another type of hybrid is the "range extender": this is a series hybrid structure with a small ICE-powered generator whose scope it is to extend the useful range of the vehicle, in the case where longer displacements have to be made. Such a vehicle is a "battery-depleting" hybrid: its batteries are mainly charged from the mains, like a battery-electric vehicle. The Renault Kangoo Elect'road (Figure 6.2), an example of this configuration, was launched in 2002.

Figure 6.2: Renault Kangoo with range extender (series hybrid)[1205]

[1205] Renault

The hybrid technology proved particularly attractive for heavy-duty vehicles. For city buses, a series hybrid structure featuring a small combustion engine delivering a constant power, with peak power for acceleration being delivered by the battery, allows considerable reduction of fuel consumption and emissions compared with conventional diesel-powered vehicles, while maintaining a limited zero-emission range.
One of the most remarkable developments in the field has been the "Altrobus", developed by Altra of Genova, Italy, and marketed by Irisbus/Iveco. Over 100 vehicles, of 6 and 12 m size, are now in revenue-earning service, mostly in Italian cities. Figure 6.3 shows a prototype Altrobus fitted with a CNG engine; this vehicle has been evaluated by CITELEC in the framework of European research[1206].

Figure 6.3: "Altrobus" hybrid city bus

For other heavy-duty applications, where inner-city zero-emission driving is combined with highway driving, parallel hybrids are deployed. Figure 6.4 shows a Mercedes Atego hybrid truck used by the ELCIDIS project in Stockholm, Sweden.[1207]

[1206] APAS-TAUT 0007, Development and on-road testing of a natural gas-electric hybrid city bus with extra low emissions.
[1207] ELCIDIS, final report

Figure 6.4: Mercedes Atego hybrid truck

The multitude of hybrid structures that can be imagined, and the varied options in defining a hybridisation rate (the ratio between the APU power and the drive train power) allow various options to be chosen. These are shown in a graphic way in Figure 6.5, which we due to Mr. Joseph Beretta of PSA.[1208]

On the top of the figure, one has the ICE-powered vehicle, with no traction battery present. Going down, an electric power component is gradually added, and a parallel hybrid structure is present: a combination of drive trains, with both the ICE and the electric motor delivering power to the wheels. The smallest parallel hybrids are the "alternator-starter" types; in this case, the electric motor does not serve real traction purposes, although they may feature kinetic energy recovery during braking. These vehicles cannot really be considered as hybrid electric vehicles in the true sense of the word; the denomination "mild hybrid" which is often conferred to them by manufacturers is to be looked upon as a mere sales pitch.

The centre of the figure shows the battery-electric vehicle: the ICE has vanished, and all traction power is delivered by the battery.

In the lower part of the figure, the wheels are driven exclusively by the electric motor. An on-board electricity generator (which can be a fuel cell or an ICE-powered APU) is now added; this is the series hybrid, a combination of energy sources. When the generator is small (as shown at the top of the field), one has the range extender. At the bottom, where the traction battery is fully eliminated, one has

[1208] J. Beretta, New classification on thermal-electric vehicles, EVS-15, Brussels, 1998 the electric vehicle without battery: pure fuel cell vehicle or diesel-electric transmission.

This figure thus encompasses most practical hybrid vehicle structures, both series and parallel. "Combined" hybrid drive trains, such as used on the Toyota Prius, are of a higher order (the order of hybridization being defined as "the number of different systems necessary to build the drivetrain"[1209] - a standard series or parallel hybrid is second order while a combined hybrid is third order) and do not strictly fit in the plane of this graph; for practical purposes however they can be considered as parallel hybrids.

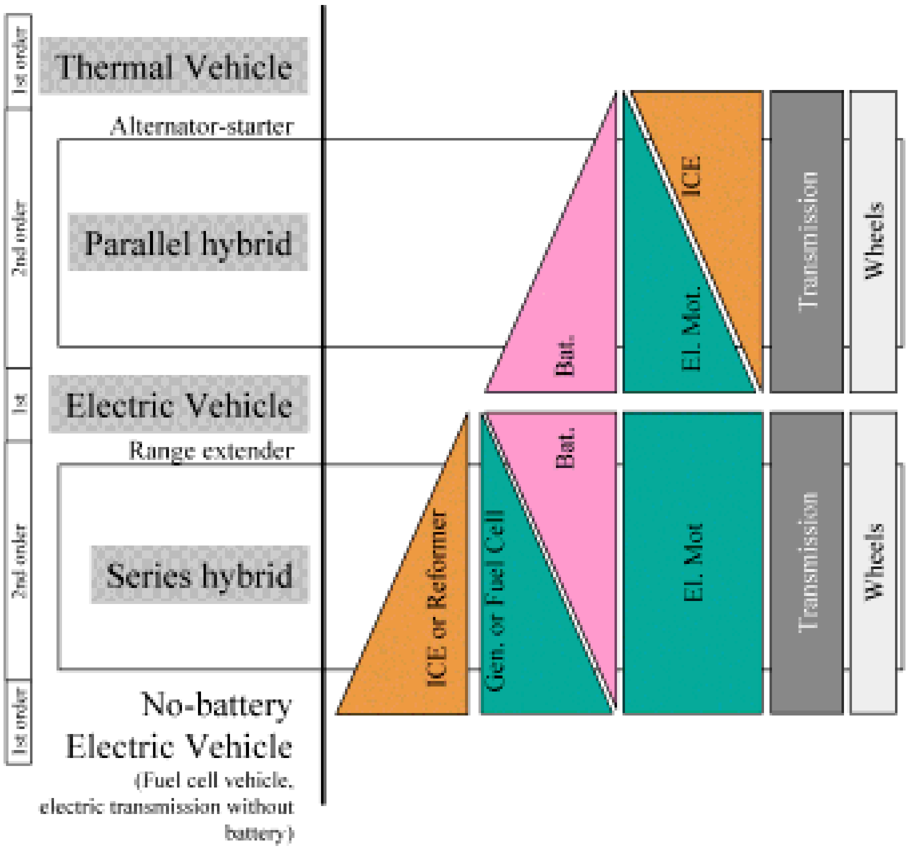

Figure 6.5: Hybrid vehicle classification

[1209] J. Van Mierlo, op.cit., ¶3.2

6.2 The standardization of the hybrid vehicle

6.2.1 IEC standardization on hybrid vehicles

The interest of IEC TC69 in hybrid vehicles started in 1978, when it was proposed, on the initiative of Dr. Victor Wouk, to convene a working group, IEC TC69 WG5, on "Electric hybrid road vehicles".[1210] It first met on an ad-hoc basis in 1980 in Essen, Germany, and received official status within TC69 in 1982.
Initial work of WG5 concentrated on the definition of the "hybrid", as well as on performance standards. One of the issues that arised was the definition of "bi-mode" vehicles (which had gained a certain interest in the 1980s, one of the most known projects involving them being the COST303 programme[1211]) with respect to hybrids; the difference being that in a bi-mode vehicle the propulsion energy generally comes from one energy source at a time, whileas in the original proposed WG5 definition of a hybrid, at least two sources could be used simultaneously. It was agreed to develop a new definition encompassing multi-mode vehicles.[1212]

The establishing of testing standards for hybrid vehicles proved to be a complicated issue, as explained in a 1985 paper by Victor Wouk[1213], which stated that the performance characteristics to be measured are mission-oriented:

- ☞ If the hybrid is designed as basically an electric vehicle with occasional assistance by the ICE, test procedures specified for EV would apply.
- ☞ If the hybrid is designed to be basically an ICE vehicle with occasional electric assistance, test procedures for conventional vehicles would apply.
- ☞ If the mission is "undefined", the test procedure and the definition of "energy consumption" becomes more complicated. The influence of the drive train strategy, which can be optimised for minimizing either ICE use or total energy consumption becomes imminent.

The appropriateness of testing the range of a hybrid was also considered, since for battery-depleting hybrids it might be limited by the capacity of the battery, rather than by the capacity of the fuel tank.

WG5 had proposed a test procedure in 1981[1214], involving several operational modes:

- ☞ Electric vehicle operational test (without on-board ICE converters being used, i.e. in pure electric mode), based on SAE J227A (§5.6.2.1).

[1210] IEC TC69, Minutes of the meeting in Amsterdam, 1982-10-26/28, Doc. PV2549/CE69

[1211] Fabre F., Klose A. (ed.), COST303 Technical and economic evaluation of dual-mode trolleybus national programmes, CEC, 1987, Doc. EUR10993EN

[1212] IEC TC69 WG5, Minutes of the 7th meeting, 1985-10-03 (annex to RM3108/TC69)

[1213] Wouk V., "Unresolved problems in establishing testing standards for electric vehicles", Drive Electric conference, Sorrento, 1985

[1214] IEC TC69 WG5, Minutes of the 3rd meeting, 1981-09-17/18 (quoted in Wouk, Unresolved problems, Appendix III

- ☞ Hybrid vehicle operational test, using both off-board energy sources and on-board ICE converters, and making use of consumption and emission tests for ICE vehicles, operating the vehicle in all modes as prescribed by the manufacturer.
- ☞ Data collection based on the above measurements, using a calculation procedure taking into account the manufacturer's specified operating conditions, i.e. applying appropriate weighting factors for the various tests.

Overall little progress was made by WG5 on establishing meaningful test standards for hybrids however, also because there were no pressing commercial or political requirements to make such standards, no hybrid vehicles being present on the market.[1215] In 1985[1216], TC69 recommended that WG5 work would be suspended, with the exception of definitions; the work continued on this item, and attempts were made to define the various types of test cycle, though not necessarily the actual tests to be used[1217].

In 1992, TC69 decided however to reactivate WG5[1218], due to the revamped interest in hybrids and the specific requirements for low and zero emission vehicles for certain urban areas.[1219] A number of potential NWIP were proposed on the TC69 meeting at EVS-11 in Florence:[1220]

- ☞ Definition of hybrid electric vehicle: classification of types, control strategies, definition of power-source types.
- ☞ Test method standardization: energy consumption, emissions, noise (electric and acoustic).
- ☞ Driver information and controls.

These work items would never be realized however: at the next TC69 meeting (which coincided with EVS-12 in Anaheim), two years later, it was decided however that the work previously within the domain of WG5 should be abandoned, hybrid vehicles being considered the province of ISO[1221].
This standpoint does not take into account however that certain types of hybrids will need a connection to the mains for charging purposes, where the relevant IEC standards might be of application.

1215 Wouk, op.cit.
1216 IEC TC69 WG5, Minutes of the 7th meeting, 1985-10-03 (annex to RM3108/TC69)
1217 IEC TC69, Minutes of the meeting in Stockholm, 1988-06-01/02, Doc. RM3108/TC69
1218 IEC TC69, Minutes of the meeting in Florence, 1992-09-30/10-01, Doc. RM3556/TC69
1219 IEC TC69, Strategic policy statement, 1992-01, Doc. 69(Sec)33
1220 IEC TC69, Doc. RM3556/TC69, Appendix 9
1221 IEC TC69, Minutes of the meeting in Anaheim, 1994-12-07/08, Doc. 69/50/RM

6.2.2 ISO standardization on hybrid vehicles

Hybrid vehicles were already mentioned as future work items on the second meeting of ISO TC22 SC21 in 1993[1222], where the specific need for hybrid vehicle standards was highlighted. Due to the various types of hybrids, definitions would be required before starting discussion on consumption standards. SC21 took note of the start of work on the subject in CEN TC301[1223], but it would not be before 1999 that a first NWIP was entered by the US committee for "Measuring the exhaust emission and fuel economy of hybrid vehicles", based on SAE J1711 (§6.2.4.1).[1224] The SAE document was submitted to SC21 together with a Japanese proposal for hybrid vehicle consumption test[1225], as well the draft of the CEN standards on the matter, EN 1986-2 (§6.2.3.2) and EN 13444-1 (§6.2.3.3). SC21 WG2 was requested to review and combine these documents and to prepare a draft in order to make a final NWIP.[1226]

The initial Japanese proposal distinguished between cold mode and hot mode testing. It also took into account the variation in SOC of the on-board energy storage, stating that the relationship between fuel consumption and ampere-hour variation could be estimated by linear interpolation (cf. the methodology of SAE J2711, §6.2.4.2). For such calculation to be effective, both negative and positive ampere-hour data should be available, and it was recognized that the ampere-hour efficiency of the battery can influence the procedure[1227].

A further draft was presented by JEVA in November 2001[1228]. This document was largely based on SAE J1711, (§6.2.4.1). Through actual measurements on several hybrid vehicles sold on the Japanese market, JEVA had further invesitgated the relationship between fuel consumption and the variation of SOC, finding out that linear interpolation could be used here in a satisfactory way. Concerning the effect of SOC variation on emissions however, no correlation could be found, leading to the conclusion that this effect could be negligible. [1229]

For the measurement of the SOC variation in HEV that are not recharged from the mains, three methods were proposed in the draft:

☞ Linear interpolation between several tests[1230]; this method is time-consuming, but the data is reproducible.

[1222] Doc. ISO/TC22/SC21 N113, Minutes of the 2nd meeting, 1993-03-18/19, ¶10
[1223] Doc. ISO/TC22/SC21 N148E, Minutes of the 4th meeting, 1994-05-09/10, ¶12
[1224] Doc. ISO/TC22/SC21 N271E, 1999-06-15
[1225] Doc. ISO/TC22/SC21 N280E, 1999-11
[1226] Doc. ISO/TC22/SC21 N285, Resolution 87 taken at the 11th meeting, 1999-11-15
[1227] Doc. ISO/TC22/SC21 N280E, ¶5.7.3
[1228] Doc. ISO/TC22/SC21/WG2 N102, 2001-11
[1229] Doc. ISO/TC22/SC21/WG2 N105, Background document for N102, 2002-01
[1230] Doc. ISO/TC22/SC21/WG2 N102, Annex F

☞ Correction of data using correction factors obtained before the test (through pre-performed tests by the manufacturer). This procedure can also yield reproducible results, but is dependent on externally supplied data.

☞ If the variation of SOC is sufficiently close to zero, test data are valid without any corrections. The reproducibility of such test however was perceived a problem.

In externally rechargeable HEV, the battery isalways to be restored to its initial SOC using an external electricity source.

The terminology of hybrid vehicles was also mentioned as a preliminary work item[1231]. A contribution to this issue was presented to SC21 by the ubiquitous Victor Wouk[1232], who highlighted the proliferation of terms that were being used on the subject, and who urged:

> *"Let's ALL speak the same language on EVs and HEVs [even if the language is (unfortunately) English]"*

He pointed out the diagram presented by Joseph Beretta (Figure 6.5) as an excellent starting point for the discussion.

On the SC21 meeting in November 2002, it was decided to set up a task force (TF3) within WG2 to deal with "Thermal/Electric Hybrid road vehicles performance"[1233]. At this moment, the work items for energy performance and emissions of hybrid vehicles are under development by ISO TC22 SC21 WG2 TF3. No ISO work item exists however for road operating ability of hybrid vehicles.

6.2.3 European standardization on hybrid vehicles

CEN TC301 is dealing with "electrically propelled road vehicles"; this includes a wide range of electric road vehicles. As stated in §5.5.6.1, TC301 made the division between "thermal electric vehicles" and "other hybrid vehicles".

Vehicles fitted with an electric transmission (diesel-electric vehicles) were within the scope of CEN TC301, but are considered as conventional vehicles with a specific transmission type, and no special standards are to be developed for them. The work performed by TC301 WG1 on the subject includes standards on road performance, energy consumption and emissions of thermal electric hybrid vehicles, as well as the definition of hybrid in the terminology standard EN 13447, which has been discussed in §5.5.6.5.

[1231] Doc. ISO/TC22/SC21 N309E, Minutes of the 13th meeting, 2001-11-16, ¶8.2

[1232] Doc. ISO/TC22/SC21 N279E, 1999-11

[1233] Doc. ISO/TC22/SC21 N332E, Minutes of the 15th meeting, 2002-11-08, ¶6.2

6.2.3.1 EN 1821-2: Road performance

The standardization work of CEN TC301 on hybrid vehicles started as early as 1994, with work items for hybrid vehicles included in the work programme (cf. §5.5.6.1). At first, "thermal electric hybrid vehicles" were considered. A first draft of the documents for road performance and energy consumption[1234] was discussed on the August 1994 meeting of TC301 WG1[1235], and during the subsequent meetings of WG1. It was decided[1236] to circulate this document among TC301 by the end of 1995[1237]; target dates for standardization of other types of hybrid vehicles were relaxed however, since the technologies were considered "not enough advanced" to warrant short term standardization[1238].
No comments were received, and the document was forwarded to six-month inquiry among national committees on the next TC301 meeting[1239]. This version gave rise to more comments however, basically concerning the test procedure which was to be spread over two days and which was deemed to complex. A revised version was proposed for formal vote in 1998[1240]; this received a negative vote from the German committee, who stated:

> "Die Veröffentlichung dieser EN-Norm wird abgelehnt, da hybride Elektrofahrzeuge noch nicht (mit einer Ausnahme) auf dem Markt sind, sondern in Entwicklungsstadium. Die Veröffentlichung der EN-Norm stellt deshalb ein Entwicklungshemmnis dar."[1241]
>
> *[The publication of this European standard is rejected, since hybrid vehicles (with one exception) are not on the market yet, but are in development phase. The publication of the European standard is thus a hamper for development.]*

To understand this opinion, one has of course to take into account the fact that no hybrid developments were being pursued by German manufacturers, and that the "one exception" was a Japanese product…
The German statement should thus be interpreted as merely political.

The European standard EN 1821-2 "Electrically propelled road vehicles - Measurement of road operating ability - Part 2: Thermal electric hybrid vehicles" was eventually published in March 1999.

It specifies the principles, conditions and procedures of the test methods to measure the road operating performances of hybrid vehicles of categories M1, M2, M3, N1, N2,

[1234] Doc. CEN/TC301/WG1 N26, N27
[1235] Doc. CEN/TC301/WG1 N30, Minutes of the meeting in Helsinki, 1994-08-30/31
[1236] Doc. CEN/TC301 N84E, Resolution 37 taken at the 8th meeting, 1995-11-28
[1237] Doc. CEN/TC301 N86E, Draft of prEN1821-2, 1995-12
[1238] Doc. CEN/TC301 N83E, Minutes of the 8th meeting in Paris, 1995-11-28
[1239] Doc. CEN/TC301 N101, Resolution 46 taken at the 9th meeting, 1996-04-19
[1240] Doc. CEN/TC301 N138E, Minutes of the 13th meeting in Paris, 1998-07-09, ¶5.2
[1241] Doc. CEN/TC301 N148, Voting on prEN 1821-2, 1999-01-05

N3 and to motor tricycles and quadricycles. "Road performances" encompass speed, acceleration and hill climbing ability.[1242]

Test conditions in EN 1821-2 are similar to those in the standard EN 1821-1 for battery-electric vehicles. The test sequence however is adapted to the hybrid character of the vehicle; a comparison of the defined tests in both standards is shown in Table 6.1.

An "hybrid mode" is defined as a driving mode where "all the on-board energy sources are available to participate in the propulsion of the vehicle, according to the management system logic"[1243].

The test procedures are obviously directed at hybrid vehicles which have both a hybrid and a pure electric mode; the standard however encompasses all hybrid vehicles. For vehicles with only one driving mode, the tests in pure electric mode are of course not applicable; this is not explicitly mentioned in the document though.

Test	EN 1821-1	EN 1821-2
Maximum speed, pure electric mode	✓	✓
Maximum speed, hybrid mode		✓
Maximum 30 min. speed, electric mode	✓	
Maximum 30 min. speed, hybrid mode		✓
Acceleration 0-50 km/h, electric mode	✓	✓
Acceleration 50-80 km/h, electric mode	✓	
Acceleration 0-100 km/h, hybrid mode		✓
Speed uphill, 4%, pure electric mode	✓	✓
Speed uphill, 12%, pure electric mode	✓	
Speed uphill, 4%, hybrid mode		✓
Hill starting ability, pure electric mode	✓	✓
Hill starting ability, hybrid mode		✓

Table 6.1: Road performance tests

6.2.3.2 EN 1986-2: Energy consumption

The topic of energy consumption and emissions for hybrid vehicle was also treated by WG1; this would develop in two separate standards, although first one unique draft had been made with independent annexes as for the consumption and the emissions[1244]. This separation was meant to facilitate test expenditure.[1245] A draft was sent to national committees for six-month enquiry by early 1998[1246]. The discussion

[1242] EN 1821-2:1999, ¶1 Scope
[1243] EN 1821-2:1999, ¶3.5
[1244] Doc. CEN/TC301 N117E, Minutes of the 11th meeting in Paris, 1997-05-27, ¶5.3
[1245] Doc. ISO/TC22/SC21 N286E, Minutes of the 11th meeting in Naples, 1999-11-15, ¶10.2
[1246] Doc. CEN/TC301 N125E, Resolution 57 taken at the 12th meeting, 1997-11-14

on this draft at TC301 level[1247] noted the progress on the American document SAE J1711 (§6.2.4.1), which was deemed worth further consideration. Furthermore, the Italian committee considered the adaptation of the test procedures for M3 category vehicles, i.e. buses. To this effect, TC301 instructed WG1 to study a test method for buses[1248], and expertise in the field was sought by WG1.

The draft standard was circulated for voting in 1999[1249], and received negative comments from Italy and Austria, the latter committee stating that since hybrid vehicles were hardly represented on the market, the introduction of an (expensive) extra test procedure would be an impediment to the market, and proposing to use the existing European directives for ICE vehicles for vehicles which only had a thermal operation mode.

The European standard EN 1986-2 "Electrically propelled road vehicles - Measurement of road operating ability - Part 2: Thermal electric hybrid vehicles" was eventually published in April 2001.
It aims to define the range in pure electric driving mode and the consumption measurements for thermal electric hybrid road vehicles from M1, N1 or M2 category, and for tricycles and quadricycles from the motorcycle types. It is thus not applicable to heavy-duty vehicles. It applies to the vehicles whose range and consumption can be tested following provisions already laid down for ICE vehicles from the equivalent categories.[1250] This statement obviously refers to vehicles having one hybrid driving mode.

The range and the electric energy consumption in pure electric mode are measured referring to the corresponding standard EN 1986-1 (§5.5.6.3). An alternative end-of-test criterion for the range test is presented however: the automatic switching on of the thermal engine[1251]. Furthermore, taking into account that the effective range in electric mode of a hybrid vehicle may be smaller than for a pure electric vehicle, a shorter test sequence may be foreseen for the energy consumption measurement. If the range in pure electric mode is smaller than one test sequence n° 1 (consisting of four basic urban cycles as shown in Figure 5.43, i.e. ca. 4 km), the measurement procedure of the electric energy consumption is not applicable[1252].

For the measurement of fuel consumption, if a pure thermal mode can be selected by the driver, the test shall be performed in the same way as for a conventional ICE

[1247] Doc. CEN/TC301 N138E, Minutes of the 13th meeting in Paris, 1998-07-09, ¶5.3
[1248] Doc. CEN/TC301 N147E, Resolution 60 taken at the 14th meeting, 1999-01-19
[1249] Doc. CEN/TC301 N154, Voting on prEN 1986-2, 1999-12 BIN
[1250] EN 1986-2:2001, ¶1 Scope
[1251] Ibid., ¶4
[1252] Ibid., ¶5

vehicle, i.e. according to the applicable European directive 80/1268/EEC; in this case, no test procedure in hybrid mode is required.
Otherwise the test is to be conducted in hybrid mode, according to EN 1986-2. The test cycle used is the sequence n° 2, consisting of four basic urban cycles and one extra-urban cycle (cf. EN 1986-1)[1253].
The vehicle shall start the test with a fully charged battery, or with the SOC recommended by the car manufacturer in the case of a vehicle which is not externally chargeable[1254]. If the vehicle allows several hybrid modes, one mode ("recommended by the vehicle manufacturer") should be chosen for the whole test procedure. It shall drive a distance equal to that of the range in pure electric mode, and a further complete cycle.
Although the choice of one single mode simplifies the test procedure (and reduces its expense), it has to be recognized that a full assessment of the hybrid vehicle's performance necessitates a measurement to be performed in the various operating modes (cf. the procedures in SAE J1711, §6.2.4.1),also taking into account the fact that the actual mode in which the vehicle will be used not necessarily corresponds with the "manufacturer recommendation".

An externally chargeable vehicle shall be fully recharged from the mains; a non-chargeable vehicle shall be operated according to the manufacturer's recommendations to recharge the battery to the initial level, taking into account that the associated distance covered is zero[1255].
The measurement of fuel consumption is performed by analysis of the exhaust gases, based on the procedures of European directive 80/1268.[1256]
Unlike the American standard SAE J2711 (§6.2.4.2), EN 1986-2 contains no provisions to calculate an equivalence between electric consumption (Wh/km) and fuel consumption (l/100 km). It states however that fuel consumption could be expressed in grams carbon dioxide per km, taking into account forthcoming regulations on carbon dioxide emission values[1257].

6.2.3.3 EN 13444-1: Emissions

The development of the companion standard of emission measurement for hybrid vehicles largely went parallel with the development of EN 1986-2. Its draft was also circulated in 1999[1258], receiving similar comments, and the standard EN 13444-1

[1253] Ibid., ¶6.2
[1254] Ibid., ¶6.6.3
[1255] Ibid., ¶6.7
[1256] Ibid., Annex A (normative)
[1257] Ibid., Annex E (informative)
[1258] Doc. CEN/TC301 N155, Voting on prEN 13444-1, 1999-12 BIN

"Electrically propelled road vehicles - Measurement of emissions of hybrid vehicles - Part 1: Thermal electric hybrid vehicles" was also published in April 2001.

The measurement technique proposed is based on the European directive 70/220, following the same test cycle as specified in EN 1986-2. This test cycle is longer than the range of the vehicle in pure electric mode, thus implying at least one cold start of the thermal engine[1259]. The results of the emission test are the following (in g/km)[1260]:

☞ hydrocarbon emission
☞ carbon monoxide emission
☞ nitrogen oxides emission
☞ particulate emission (for compression ignition engines only).

The standard provides two methods for the calculation of the emissions[1261]:

☞ constant volume sampler (CVS) with gas storage method
☞ continuous analysis method (CAM)

6.2.4 SAE standards on hybrid vehicles

6.2.4.1 SAE J1711

SAE J1711 "Recommended practice for measuring the exhaust emissions and fuel economy of hybrid-electric vehicles" establishes uniform dynamometer test procedures for on-road hybrid vehicles.

Since the lack of a broadly applicable and widely accepted test procedure for hybrid vehicles was felt as an obstacle for the development of commercial hybrid vehicles, the SAE Light Duty Vehicle Performance Measurement Standards Committee set out a task force in the fall of 1992 to develop a recommended practice for this application, following the effort done for electric vehicles through SAE J1634 (§5.6.2.2). The document, which was eventually published in 1999, was the result of a consensus effort among several parties: vehicle manufacturers, national laboratories, government agencies. The draft document resulted of an analytical evaluation of several previous proposals, and was tested to practice using three hybrid vehicles built for the SAE HEV Challenge student competition, and evaluated by the National Renewable Energy Laboratory with the help of a vehicle simulation program.

[1259] EN 13444-1:2001, ¶4.1

[1260] Ibid., ¶4.8

[1261] Ibid., Annex A (normative)

The overall goal of SAE J1711 is to allow the testing of any HEV on a fair and comparable basis with conventional ICE vehicles, EVs and other HEVs. Following requirements were used in developing the document:[1262]

- *The document shall provide a recommended practice to measure the exhaust emissions and fuel economy of any type of HEV design or control strategy.*
- *Determination of representative exhaust emissions and fuel economy shall account for the driver's usage of off-vehicle charging and the usage of driver-selected operating modes, if applicable.*
- *EVs and conventional vehicles tested on this document shall yield the same results as if tested on the test procedures currently established for such vehicles.*
- *Measurement methods and driving schedules shall be consistent with those used in existing test procedures for EVs and conventional vehicles.*
- *Testing shall not require defeating or otherwise forcing a vehicle's control system to perform differently from how it would perform in the driver's hands.*
- *This document shall provide a technical foundation to assist government regulatory agencies in developing emissions and fuel economy certificates and compliance tests for hybrid-electric vehicles.*
- *This document shall be as short and simple as possible.*

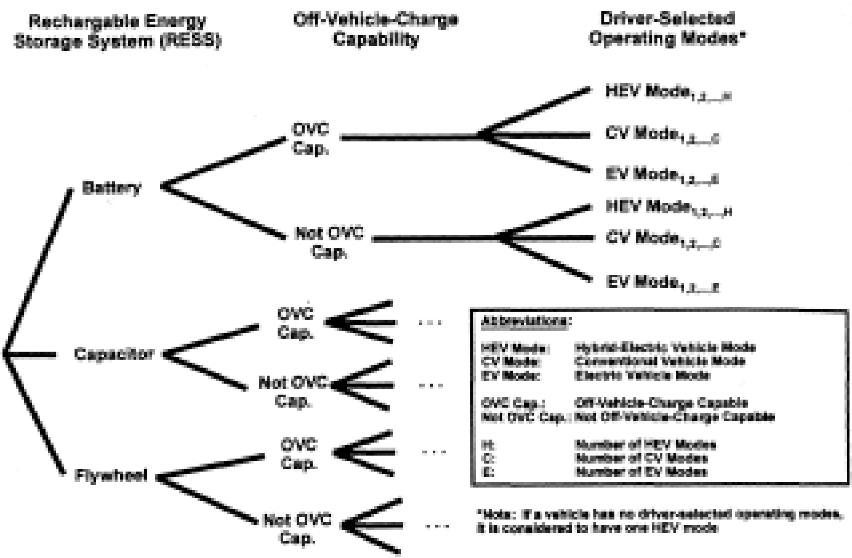

Figure 6.6: Hybrid electric vehicle classification (SAE J1711)

The last point has proven difficult to realize however: the document has become quite heavy and complex, and much more extended than EN 1986-2 for example. It wants in fact to address all possible types of hybrids, using several rechargeable energy storage systems (RESS) as shown in Figure 6.6.

[1262] SAE J1711, ¶1.1

The document presents detailed description of the test procedures and conditions for different driver-selected operating modes:[1263]

☞ Hybrid electric vehicle (HEV) operation mode, where:
    - It is possible that consumable fuel be expended for vehicle propulsion or for any other reason.
    - It is possible for some propulsion energy to be derived from the rechargeable energy storage system (RESS).

☞ Conventional vehicle (CV) operation mode, where:
    - Propulsion energy is only derived from the consumable fuel and never from the RESS.
    - The RESS may be used to supply accessories, does not have a net change in SOC over repeated driving cycles.
    - Regenerative braking is not used.

☞ Electric vehicle (EV) operation mode, where:
    - The consumable fuel is never expended for any reason.
    - Propulsion energy is always taken from the RESS.

It is clear that not every hybrid vehicle will have all modes available. Furthermore, when the choice in propulsion mode is automatically performed by the system as a result of the drivetrain strategy, this is considered as one single HEV mode. The modes can further be recharge-dependent (RD) or recharge-independent (RI). In RD modes, the operation of the vehicle may become disabled if the RESS is fully discharged. EV operating modes in HEVs which accept external charge are always considered RD; HEV operating modes that are RD are not covered by the scope of J1711.

Besides the UDDS and HFEDS driving schedules (cf. §5.6.2.2), J1711 makes use of two other US-defined cycles:

☞ The US06 driving schedule, (Figure 6.7) which is used to represent aggressive vehicle driving at heavy speeds and acceleration.

☞ The SC03 driving schedule (Figure 6.8), which is used to represent vehicle operation immediately following startup, in 95 °F ambient conditions with the vehicle air conditioning on.

[1263] SAE J1711, ¶3.11

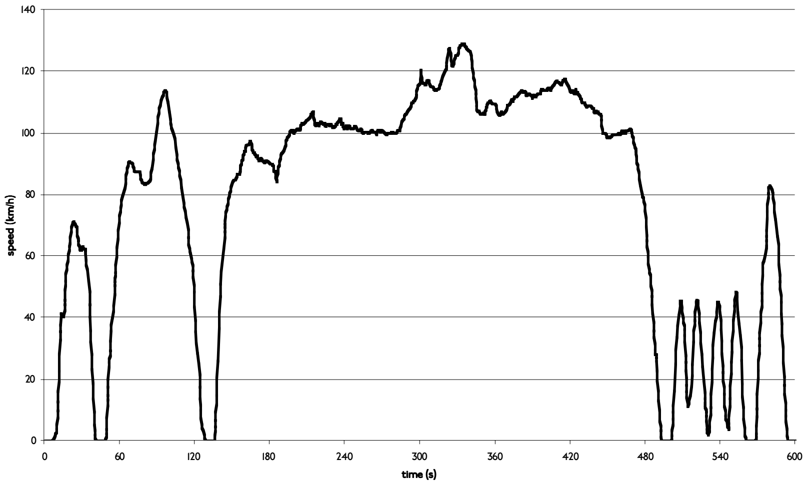

Figure 6.7: US06 driving schedule[1264]

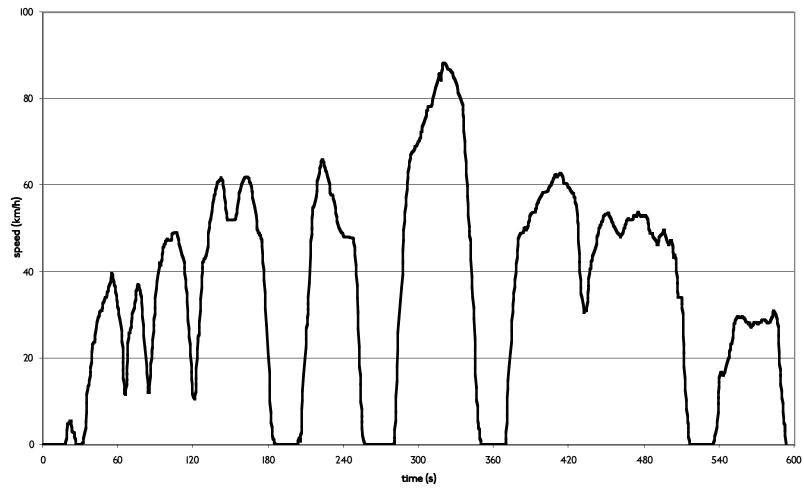

Figure 6.8: SC03 driving schedule[1265]

There are two types of emission and consumption tests specified: the "partial charge test" (PCT), which starts with a partially charged RESS, and the "full charge test" (FCT) which starts with a fully charged RESS. The PCT has a variation for HEV and CV modes while the FCT has a variation for HEV and EV modes. This gives four combinations which are described in due detail:

[1264] US Code of Federal Regulations, Title 40, Part 86, Appendix I

[1265] Ibid.

☞ The PCT-HEV, which represents the charging habits of a driver who never supplies external charge to the vehicle.
☞ The FCT-HEV, which represents the driver who every day recharges the RESS from an off-vehicle source.
☞ The PCT-CV, which considers the vehicle used in CV mode.
☞ The FCT-EV, which considers the vehicle used in EV mode.

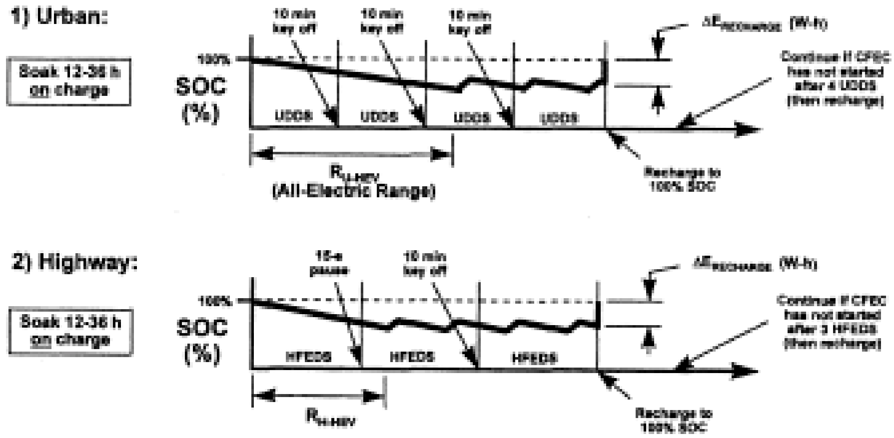

Figure 6.9: FCT-HEV test (SAE J1711)

It is clear that not all these tests are applicable to all HEVs. For the Toyota Prius for example, only the PCT-HEV will be relevant; the Renault Kangoo Elect'road on the other hand, will be subjected to the FCT-HEV and the FCT-EV.
Figure 6.9 gives as an example the organization of a FCT-HEV test. It is interesting to consider the end-of-test criterion for this test: when after the standard number of cycles the "consumable fuel energy converter" (CFEC, i.e. the APU) has not started (because the RESS is not sufficiently discharged for example), the test shall be continued until this happens. After the test, the RESS is fully recharged from an external source.

The PCT-HEV test on the other hand has to take into account a more thorough evaluation of the SOC evolution during the test. To this effect, a tolerance of SOC change during the test is defined. The main reasoning is to limit the change of the stored electrical energy in the RESS to less than ± 1 % of the total fuel energy consumed over the same cycle:

$$\left|\frac{\Delta\text{Stored Electrical Energy}}{\text{Total Fuel Energy}}\right| \leq 1\% \qquad (6\text{-}1)$$ [1266]

[1266] SAE J1711:1999, Eq. 1

This tolerance is claimed to correspond with a value for fuel consumption within ± 3 % of the vehicle's true representative fuel consumption on any given partial-charge test, based on limited analysis and test experience; to define these tolerances in a more robust way, more practical experience with hybrids would be needed[1267].

When a battery is used as RESS, the tolerance on SOC becomes:

$$\left|\Delta_{SOC}\right| \leq 0{,}01 \times \left|\frac{NHV_{fuel} \times m_{fuel}}{V_{system} \times K_1}\right| \qquad (6\text{-}2)$$[1268]

where:

Δ_{soc} is the variation in SOC over the test
NHV_{fuel} is the net heating value of the used fuel (J/kg)
m_{fuel} is the total mass of fuel consumed during the test (kg)
V_{system} is the battery's nominal d.c. system voltage
K_1 is a conversion factor (3600 s/h)

The variation in SOC is measured through a variation in ampere-hours charged and discharged from the battery with an ampere-hour meter; this instrument should have an integration period of less than 0,05 s in order to accommodate abrupt changes of current[1269]. Whileas for certain types of batteries (such as the Zebra battery), the measurement of ampere-hours gives an accurate value of the SOC, i.e. the ampere-hour efficiency for these batteries is 100 %. This is not necessarily the case for batteries with aqueous electrolyte (such as lead-acid or alkaline batteries), due to the use of ampere-hours for the decomposition of water in the end-of-charge phase. When considering the use of the battery in a partial SOC condition in a hybrid vehicle which is never fully recharged from the grid, the end-of-charge phase is rarely attained and the ampere-hour balance can be used as an acceptable approximation of the actual change in SOC.
For other types of RESS, the SOC is considered based on magnitudes which are (quadratically) proportional to the stored energy: the voltage for capacitors and the speed for flywheels.

[1267] Ibid., ¶3.7
[1268] Ibid., Eq. 6 (absolute value taken)
[1269] Ibid., ¶4.2

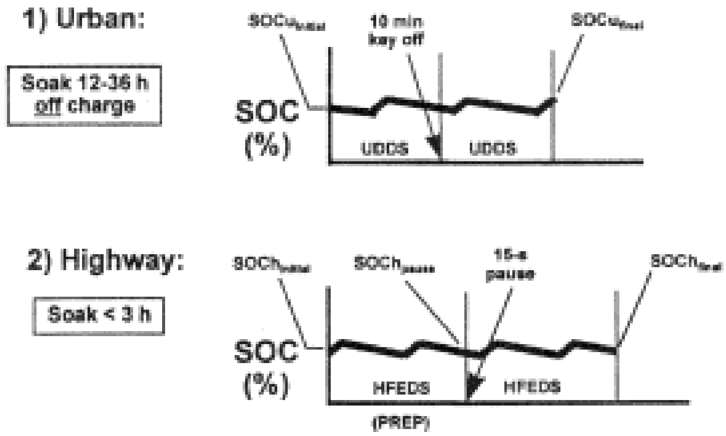

Figure 6.10: PCT-HEV test (SAE J1711)

The PCT-HEV test, as illustrated in Figure 6.10, requires that the initial SOC equals the final SOC, within the tolerances of (6-2). To this effect, the initial SOC shall be adjusted attempting to achieve a difference between initial and final SOC within this tolerance, according to the manufacturer's recommendations.

Furthermore, SAE J1711 defines a methodology for calculating exhaust emissions, taking into account several factors like cold and hot-start test phases (by weighting of subsequent cycles), the effect of charging habits and different driver-selected operating modes.
Through its comprehensive approach, SAE J1711 has aimed to be a very complete document.

6.2.4.2 SAE J2711

SAE J2711 "Recommended Practice for Measuring Fuel Economy and Emissions of Hybrid-Electric and Conventional Heavy-Duty Vehicles" was issued in 2002 by the SAE Truck and Bus Hybrid and Electric Vehicle Committee, which collaborated with the Northeast Advanced Vehicle Consortium on its development. It defines procedures for emission and fuel consumption testing on the dynamometer bench of heavy-duty vehicles and aims to provide the heavy-duty hybrid industry with a suitable measurement protocol. The document is to be viewed as a starting point for standardizing heavy duty HEV testing, and will need to be reviewed as the technology matures. It is interesting to note however that the proposed test procedures are also to be applied to conventional vehicle designs, in order to make a comparative assessment of ICEV vs. HEV possible.

SAE J2711 document builds upon SAE J1711, the light-duty vehicle procedure which was discussed in the paragraph above, using the same basic structure for the hybrid vehicle.
The driving cycles used however are chosen in function of the intended heavy-duty vehicle operation. Three cycles are defined:

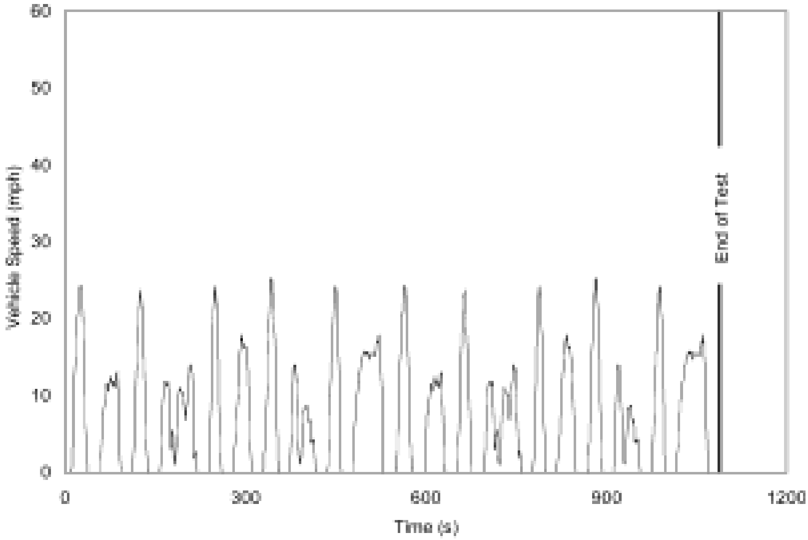

Figure 6.11: Manhattan test cycle

☞ The "Manhattan" cycle, representing low-speed operation of a transit bus in city service. It was developed from actual data logged from buses in New York City.

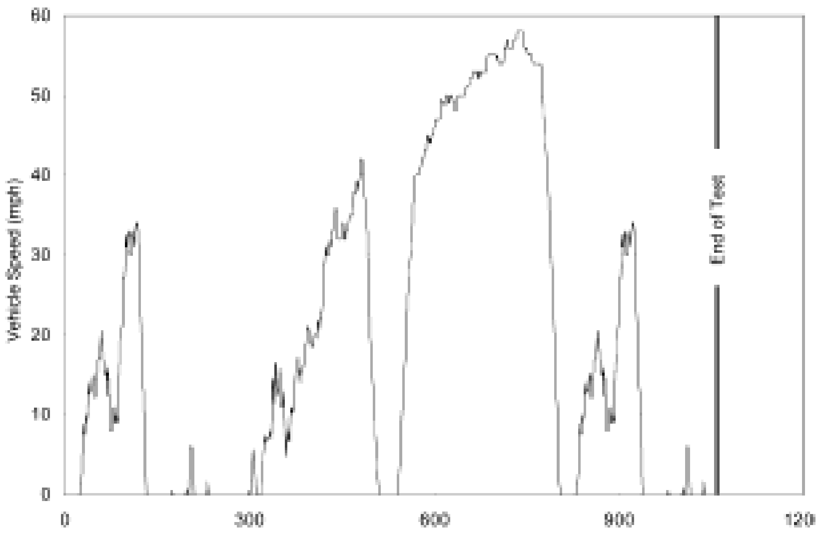

Figure 6.12: Heavy duty UDDS cycle

☞ The heavy-duty UDDS cycle (also known as "Test D", and not to be confounded with the light-duty UDDS cycle shown in Figure 5.52), which was calculated as a Monte-Carlo simulation[1270] of behaviour of trucks and buses under freeway and non-freeway operation. This cycle mimics higher speed operation.

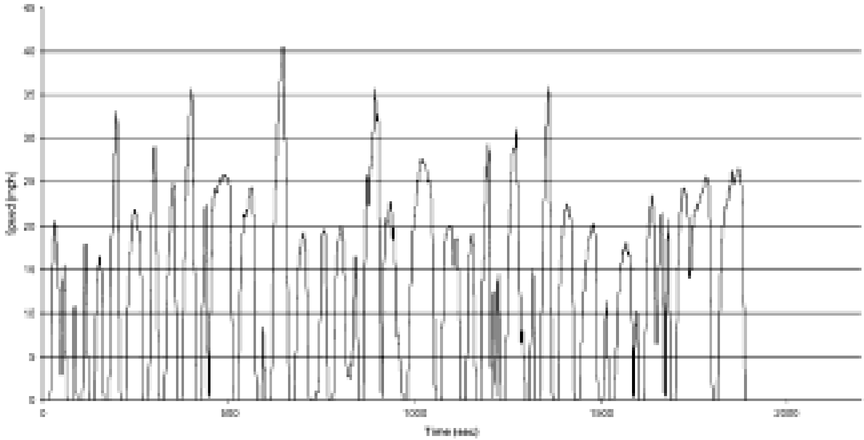

Figure 6.13: Orange County test cycle

☞ The "Orange County" cycle, representing mid-speed heavy-duty vehicle operation. It was developed from actual bus operation in Orange County, California.

Cycle	Distance (m)	Max speed (km/h)	Avg. speed (km/h)	Max. accel. (m/s^2)	Max. decel. (m/s^2)	Time (s)	Idle time (s)	# Stops
Manhattan (2x)	6641	40,7	11,0	1,78	2,56	2178	786	41
UDDS (2x)	17848	93,3	30,3	1,87	2,01	2121	706	27
Orange County	10516	65,3	19,8	1,81	2,29	1909	406	30

Table 6.2: Test cycles from SAE J2711[1271]

The comparison between the cycles is shown in Table 6.2. These cycles replace the formerly-used "Central Business District" (CBD) cycle, which was a quite simple cycle with all cruising phases at 20 mph.

[1270] The "Monte-Carlo" simulation technique is based on a repeated random generation of values for uncertain variables to simulate a model.

[1271] SAE J2711, Table 1 (Converted in metric units)

The document covers both charge-sustaining HEV and charge-depleting HEV.
For the charge-sustaining type, provisions are provided to account the variation of RESS SOC during the test. A variation of the net energy change compared with the total cycle energy (cf. equations (6-1) and (6-2)) lower than 1 % is considered acceptable; if this variation exceeds 5 %, the test should be considered invalid.
For values between 1 % and 5 %, a correction procedure is proposed[1272], in contrast with SAE J1711 which does not foresee correction procedures, rejecting any variation over 1 %[1273]. The methodology is based on a methodology developed in a 2000 SAE paper[1274], which stated that the SOC correction of fuel consumption and emission levels is possible by fitting a line to the data of several test runs. An example is shown in Figure 6.14, where the emissions corrected to zero change in SOC are given by the intersection of a line fit to the results of a number of tests (each ending with a particular change in SOC) and the vertical zero SOC line. For the purposes of SAE J2711, the accuracy of the data is considered acceptable if the linear regression value of the data is at least 0,80[1275].
The application of this technique to exhaust emissions will however only be accurate for those emissions which can be considered as being roughly proportional to fuel consumption.

SAE J2711 states that charge-sustaining HEV evaluation requires longer test runs to increase the probability of a small SOC change between initial and final values, and to facilitate the detection of emissions produced at threshold limits. The upper limit for the length of an individual test run is however limited to about two hours due to potential problems with analyser drift, increased driver fatigue and measurement systems limitations.[1276]

[1272] sIbid., ¶4.4
[1273] SAE J1711, ¶3.7
[1274] Clark, N.N. et al., Hybrid Diesel-Electric Heavy Duty Bus Emissions: Benefits of Regeneration and Need for State of Charge Correction, SAE Paper 2000-01-2955
[1275] SAE J2711, ¶4.4.2
[1276] Ibid., ¶5.2

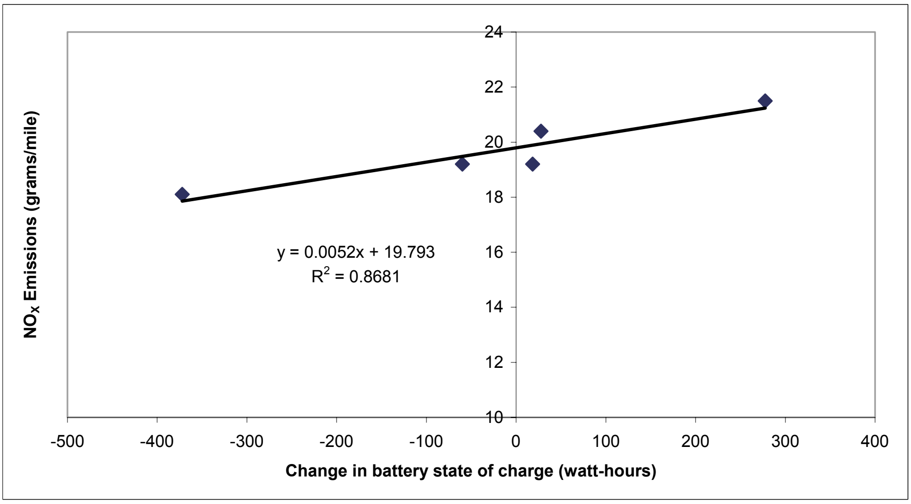

Figure 6.14: SOC correction for NO_x for a hybrid bus over five repeat runs[1277]

For testing charge-depleting HEV, the electric energy recharged from the grid is calculated back to a diesel equivalent, using the following formula:

$$FE_e = \frac{HV_{FuelOil} \times E_G \times E_T \times E_C}{E_U \times K_3} \qquad (6\text{-}3)$$[1278]

where:

- FE_e is the electric fuel economy in diesel equivalent (miles per gallon)
- $HV_{FuelOil}$ is the lower calorific value of diesel fuel (128000 Btu/gallon)
- E_G is the electricity generation efficiency (35 %)
- E_T is the electricity transmission efficiency (90 %)
- E_C is the charging efficiency (accounts for battery efficiency and standing losses) (70 %)
- E_U is the electric energy consumption measured at the grid (kWh/mile)
- K_3 is a conversion factor (3412 Btu/kWh)

[1277] Clark, op.cit., Fig. 8
[1278] SAE J2711, ¶8.1.1

One should recognize however that this formula will give a much too low value for the energy economy:

☞ the electricity generation efficiency E_G used in this calculation is at 35 % on the low side: state-of-the-art electric power plants can easily have efficiencies up to 55 %.

☞ the charging efficiency E_C should be deleted from the formula: since the electricity consumption E_U is measured at the grid, upstream from the charger, the losses in the charger and the battery are already included in the electricity consumption measure.

The standard states however that

> *"Alternatively, if the fossil electric generating rate for the region is known, this rate may be applied directly to the a.c. kWh consumption".*[1279]

which would allow a more realistic value to be considered.

Emission values from the electricity consumption are traced back to the electricity generator and added to the exhaust emissions. Taking into account local utility emissions will yield different results in each location, and is not a straightforward process since it is not evident to link a consumer of electricity (e.g. EV or HEV charging) to a specific power plant, in order to make a precise calculation of primary energy consumption and emissions, due to the interconnection on the electric grid.
SAE J2711 proposes an alternative method that will give a consistent value, by determining the APU output emissions on a given cycle, and by applying these values as if the vehicle RESS was recharged from the APU only, like in a charge-sustaining HEV.[1280]
This approach is also likely to give too high results, due to the in nearly all cases lower efficiency of the on-board APU compared to an electric power plant.

Several approaches to this problem of linking electricity consumers to power plants have been made in recent studies performed at the VUB.[1281] The most interesting solution is a corollary of the ongoing liberalization of the (European) electricity market, which allows the consumer to choose a supplier and enables the specific purchase of "green" current from renewable sources, which is then effectively zero-emission.

[1279] Ibid.

[1280] SAE J2711, ¶8.2.2

[1281] ETEC-VUB, CEESE-ULB, Report of the study "Clean Vehicles" (Schone Voertuigen) for the Brussels Capital Region, 2002-01

6.2.5 Hybrid vehicle performance standards: recommendations

6.2.5.1 Introduction

It has been seen from our research of the ISO, CEN and SAE documents above that the definition of a universal performance standard for a HEV is not a straightforward issue.
A first point is the possible availability of different operation modes in the same vehicle. To get an overall assessment, it is essential that all available modes (for as far as they are compatible with test cycles) are measured, cf. the approach taken by SAE J1711.
For "pure-electric" (with the APU switched off) ore "pure thermal" (with the electric drive train not intervening in traction) modes, if any, relevant measuring procedures for respectively electric and ICE vehicles should be used, with however the same speed cycles to be used where applicable to allow comparison among all modes.

For the hybrid driving modes however, the main issue is the consideration of the SOC of the on-board RESS during the test. The evolution of the SOC is strongly dependent on the configuration of the HEV and its control strategy.
One can make the distinction between several possible cases:
☞ whether or not the HEV is externally chargeable;
☞ whether or not the APU is designed to deliver a constant output power;
☞ what is the typical application profile for the vehicle.

6.2.5.2 Externally chargeable hybrid

The externally chargeable HEV presents the following application profiles:
☞ Battery-electric vehicle with "range extender" APU; for such vehicle, electric operation will be the principal mode, with hybrid mode used occasionally when the need arises to cover a longer distance.
☞ Hybrid vehicle with zero-emission capability; for such vehicle, hybrid operation will be the principal mode, with electric mode used for example in city centers.

Test procedures for these types of HEV should take into account both electric and hybrid operation modes:

☞ For electric operation, without APU use: measurement of the range and energy consumption can be performed according to the procedures for battery-electric vehicles (ISO 8714, §5.3.4.3). The RESS should be fully charged at the beginning of the test, and recharged from the grid after the full range has been covered.

☞ Hybrid operation. The test to be performed here can be based to the FCT-HEV test from SAE J1711[1282], with the initial SOC at 100 % and with the RESS recharged from the grid at the end of the test. This is a practical hypothesis since it may be reasonably expected that the user of an externally chargeable HEV will charge the vehicle from the grid overnight, using energy which is cheaper and more environmentally friendly than when recharging from the APU.

6.2.5.3 Non-externally charged hybrid

For non-externally chargeable HEV, the most critical point in the testing procedure is the SOC balance over the test. Due to the variety of drive train structures and control strategies envisageable, it is difficult to put forward one standard procedure which would fit for all.
The main issues to be considered here is the evolution of the RESS SOC during the test. It is thus necessary to measure the energy flows going in and out of the RESS. For the latter, the correction techniques presented in SAE J1711 and SAE J2711 can be envisaged; the most accurate choice being to limit the acceptable energy change to ± 1 %, taking into account the following issues:

☞ When the SOC change after performing the prescribed test cycle is consistently too high, this may be due to the "time constant" of the energy balance strategy embedded in the drive train control system. It could be envisaged to extend the test cycle with additional basic cycles until the desired level is achieved.

☞ The choice of the initial SOC level may also influence the outcome of the test. For this type of vehicle, it is most likely less than 100 % (cf. the PCT-HEV test in SAE J1711). The influence of the initial SOC is also dependent of the drive train strategy; and unless one wants to extend the number of tests (and hence their expense) considerably, it seems acceptable to start the test with a SOC level stated by the manufacturer, which could be between certain limits however (e.g. between 40 % and 80 %).

6.2.5.4 APU bench testing

Heavy-duty vehicles like buses and trucks represent a large application field of hybrid drive technology. Testing procedures for consumption and emission of hybrid heavy-duty vehicles are not so straightforward however: whileas for light-duty vehicles they can be derived using existing test cycles for conventional vehicles, this does not apply for heavy-duty vehicles, where the standard test methods for

1282 SAE J1711:1999, ¶4.3.2

conventional vehicles are based on static bench tests of the engine (e.g. the European Stationary Cycle 13-mode test, illustrated in Figure 6.15, introduced by directive 96/96/EC, which replaced the 13-mode cycle from regulation ECE-49), which can not be meaningfully applied to hybrid vehicles, since in these vehicles the instantaneous behaviour of the engine is decoupled from the instantaneous road load, and the standard set of measuring points and their weighting may not apply.[1283]

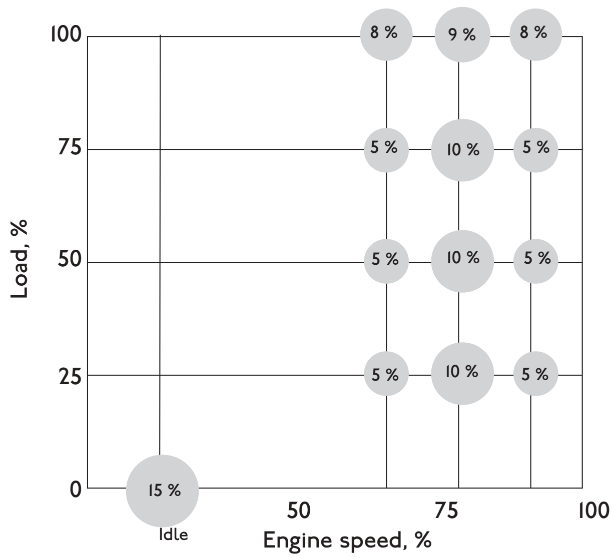

Figure 6.15: European Stationary Cycle 13-mode test

According to the drive train strategy, the following cases can be distinguished, taking into account the output power and set point of the APU[1284]:

☞ APU delivering a constant power
This is typically the case for series hybrid city buses; this configuration allows the APU to be operated at is optimal point, minimizing energy consumption.. Since the APU output power (and hence its consumption and emissions) is constant, it can be easily characterized on an engine test bench. A vehicle test however is recommendable to show the concordance between APU behaviour on and off the vehicle. Furthermore, the behaviour of the APU with a fully charged RESS (and thus a reduction of the APU output power) should be investigated.

[1283] Cf. R. Smokers, "Hybrid vehicles in relation to legislation, regulations and policy", EVS-19, Busan, 2002
[1284] Cf. J. Van Mierlo, op.cit., ¶3.4

☞ APU having a limit number of operating points
Also this case can be easily described by a bench test focusing on the pre-set operating points.

☞ APU delivering a dynamic power
This is a more complicated case; a reliable test in this case would necessitate the knowledge of the typical operation of the APU. This necessitates performing a cycle test corresponding to an actual road cycle in order to know the dynamic operation range in order to define relevant points for bench testing the APU. A quite simple procedure for this could be to start with the operating points of the 13-mode (or a similar) test, adapting the weighting of the individual operating points according to their relevance in the use cycle of the considered APU.

It is clear that the tests to be performed will have to be customized for each vehicle in order to be representative taking into account the underlying drive train strategy. This customizing however requires a thorough knowledge of the control strategy and the underlying parameters, knowledge which vehicle manufacturers usually consider as proprietary and anxiously guard. A legal obligation, such as the conformity to type approval regulations, will be necessary to have such information disclosed.
One could state that the use of customized engine tests would disallow a valid comparison between engines. However, taking into account that the use of the engine will be specific for each HEV and that the generic engine test (designed for ICE vehicle) is ill-suited for testing HEV engines, it is clear that the engine should be tested in a mode of operation which mimics its actual use in the vehicle.

6.2.5.5 Fuel and electricity consumption

As stated in §6.2.4.2, it is not evident to calculate electricity consumption back to fuel consumption, due to the variety in the electricity production mix. It thus seems more advisable not to try to combine fuel and electricity consumption in one overall consumption figure, except in singular cases where the origin of the electricity used is fully known (e.g. renewable energy sources).
Furthermore, the juxtaposition of an electricity consumption figure (kWh/km) with a fuel consumption figure (l/100 km) is more interesting for the vehicle user, who acquires these energies from different sources and is thus enable to assess the economic impact (i.e. consumption cost) of the vehicle.

6.3 Technology for the future: the fuel cell vehicle

6.3.1 Introduction

The "fuel cell" is an electrochemical device which converts the chemical energy of a fuel (which is supplied to the cell from an external source) directly into electrical energy without making use of thermodynamical processes.
The basic theory of the fuel cell was published by Christian Friedrich Schonbein and Sir William Grove as early as 1839[1285] - that is twenty years before Gaston Planté invented the lead-acid battery - but it is only in recent years that its large-scale commercial application is being envisaged.
Fuel cells are considered a key element for the future development of electrically driven vehicles. The fuel cell-powered vehicle, which can be either a "pure fuel cell" vehicle or a "fuel cell hybrid" (i.e. with a buffer battery) is often regarded as "the vehicle of the future". Prototype vehicles are being demonstrated to-day, whileas series production is expected to start in the 2010-2020 period. The fuel cell vehicle is the subject of several international research and demonstration programmes, such as the ELEDRIVE[1286] thematic network.

This emergence of a completely new technology presents a considerable challenge on the field of standardization development. Fuel cells are likely to be used in a variety of applications: stationary, on-board vehicles or portable power units. Existing standards may include certain aspects of these applications; specific standards covering the fuel cell system itself do not exist however.
As for the fuel-cell powered vehicle, one should consider that, with respect to its traction system, it is basically an electric vehicle, on which relevant electric vehicle standards are applicable.
The fuel cell technology is now in transition from a R&D to a commercial stage: this is a key phase to elaborate international standards to facilitate commercialisation, international trade and approval procedures for fuel cell systems. Care should be taken however not to restrict further development of this young technology through too restrictive standards: initial standardization efforts should be aimed at safety and interface issues rather than at design aspects.
This chapter will give an overview of ongoing activities on automotive fuel cell standardization by the international standardization organizations.

1285 SAE J2574, ¶3
1286 http://www.eledrive.org

6.3.2 Fuel cell standardization at IEC

6.3.2.1 Inception of IEC TC105

The "fuel cell" can be quite rightly considered an "electrical device" since it generates electricity; its standardization would thus be a task of the IEC.
In 1996 the IEC's President Advisory Committee for future Technology (PACT) established an ad-hoc working group to study the potential of IEC work in the fuel cell field. This led to the founding of IEC Technical Committee 105 "Fuel Cell Technologies" in October 1998[1287], in charge of preparing international standards regarding fuel cell technologies for all applications.
TC105 held its first meeting in Frankfurt am Main, Germany, in February 2000, where the initial work programme was discussed, and where delegates from ISO TC22 SC21 were present[1288]. The collaboration between TC105 and SC21 was deemed essential due to the application of fuel cells for automotive purposes.

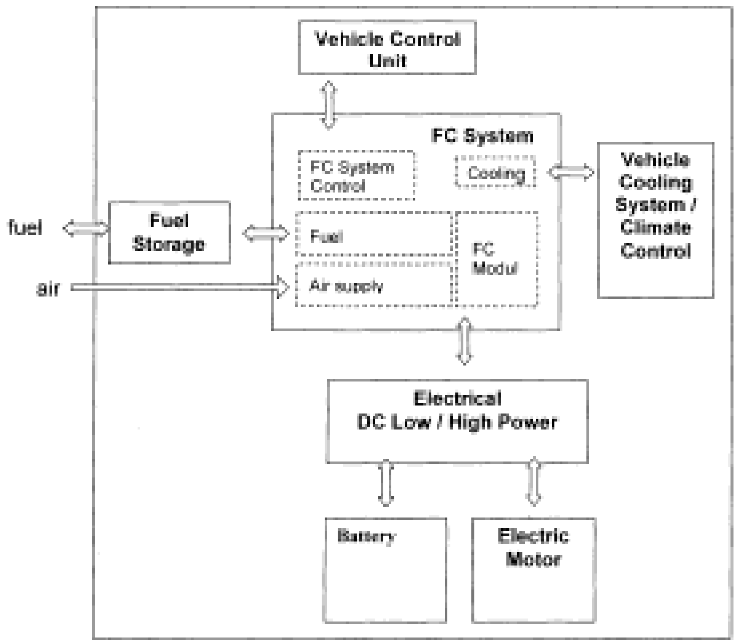

Figure 6.16: Scheme of fuel cell system for road vehicle propulsion[1289]

The point of view of ISO TC22 was to consider the fuel cell system as a "black box" delivering electricity, to be compared with the battery on a battery-electric vehicle,

[1287] IEC TC105, Doc. 105/5/DC, 1999-10
[1288] IEC TC105, Doc. 105/7/RM, Minutes of the meeting in Frankfurt, 2000-02-23/24
[1289] IEC TC105, Doc. 105/12/INF, Agreements of co-operation with ISO TC22 SC21 and ISO TC197

and it saw its job in the integration of the fuel cell into the vehicle. A schematic view of this concept is shown in Figure 6.16.

A formal liaison between the two committees was thus proposed, and undersigned by both parties in August 2000. IEC TC 105 and ISO TC22 SC21 agreed

> *"to co-operate with each other to make a positive contribution to the standardization of the integration of fuel cell systems into road vehicles"* [1290]

Furthermore, both committees agreed on the principle of creating the minimum number of standards.

The collaboration would be based on a "Mode 4" liaison. In this system, one organization takes the lead in the activities, but work sessions and meetings receive delegates, with observer status (i.e. with the right to intervene in the debates but not to vote), from the other one, who observe the liaison[1291]. The work would be divided as follows: [1292]

- ☞ ISO TC22 SC21was to take the lead in the standardization activities with respect to the integration of fuel cell systems into road vehicles; the activities would be integrated in the existing SC21 structure.
- ☞ IEC TC105 was to take the lead in the standardization activities concerning fuel cells for propulsion in its WG6.
- ☞ A joint steering committee would co-ordinate the allocation of work to either of the committees.

It is clear that the realization of such collaboration agreement, before the actual start of the standardization work, has been a key step in making a fruitful collaboration possible, without any hitches that might have occurred otherwise.

A similar agreement was signed with ISO TC197, which deals with "Hydrogen", and which in the framework of the fuel cell standardization would be responsible for all hydrogen infrastructure issues.

Furthermore, at the first TC105 meeting, the activities of other bodies involved with electric vehicle standardization, such as IEC TC69 and SAE, were presented. The co-operation of TC105 with SAE was assured via both ISO TC22 SC21 and the participation of US delegates in TC105. At the 2002 meeting of TC105, a "Category D" liaison between TC105 WG6 and SAE was announced.[1293] This type of liaison means that SAE has indicated a wish to participate in the work of WG6, and that SAE experts will be informed and invited to meetings by the convenor.[1294]

[1290] Ibid.
[1291] IEC/ISO Directives, 4th ed. 2001, Part 1, Annex B, ¶B.4.2.2 (equivalent to ¶A.4.2.2 in 3rd ed.)
[1292] IEC TC105, Doc. 105/12/INF
[1293] IEC TC105, Doc. 105/38/RM, Item 19
[1294] IEC/ISO Directives, 4th ed. 2001, ¶1.17.2

IEC TC105 defined the following working groups:

- ☞ WG1: Definitions and terminology
- ☞ WG2: Fuel cell Modules
- ☞ WG3: Stationary fuel cell power plants - Safety
- ☞ WG4: Stationary fuel cell power plants - Performance
- ☞ WG5: Stationary fuel cell power plants - Installation
- ☞ WG6: Fuel cell systems for propulsion and auxiliary power units
- ☞ WG7: Portable fuel cell systems
- ☞ WG8: Regenerative fuel cell systems

TC105 started its work on these aspects; the new standards on fuel cells to be drafted will form the IEC 62282 family of international standards.

6.3.2.2 Fuel cell modules: IEC 62282-2

A NWIP on the subject "Fuel cell modules: safety, quality assurance and environmental aspects of fuel cell modules in all applications" was circulated[1295] in December 2000 and accepted[1296] in May 2001. CDS of this document, IEC 62282-2, were circulated in February[1297] and August[1298] 2002. The CDV was circulated in December 2002[1299], due to be voted in parallel CEN/CENELEC enquiry by May 2003. This document will be the general standard for fuel cell modules, providing the minimum requirements for safety and performance of different types of fuel cell modules:

- ☞ Alkaline
- ☞ Proton exchange membrane (including direct methanol)
- ☞ Phosphoric acid
- ☞ Molten carbonate
- ☞ Solid oxide

As such, the document is of course also relevant for automotive applications.

The term "fuel cell module" is understood as a sub-assembly including "slightly more" than the fuel cell stack proper, e.g. sensors, enclosure, but not its peripheral devices, electrical output beyond d.c., or fuel storage and delivery, as shown in Figure 6.17.

The main issue of this draft is "safety": conditions that can yield hazards to personnel and damage outside the fuel cell module.

[1295] IEC TC105, Doc. 105/11/NP
[1296] IEC TC105, Doc. 105/16/RVN
[1297] IEC TC105, Doc. 105/25/CD
[1298] IEC TC105, Doc. 105/36/CD
[1299] IEC TC105, Doc. 105/42/CDV

IEC 62282-2 is drafted out of a general safety strategy, referring to risk assessment procedures as defined in particular IEC standards like IEC 60812 "Analysis techniques for system reliability - Procedure for failure mode and effects analysis", IEC 61025 "Fault tree analysis" and IEC 61508-1 "Functional safety of electrical / electronic / programmable electronic safety-related systems".

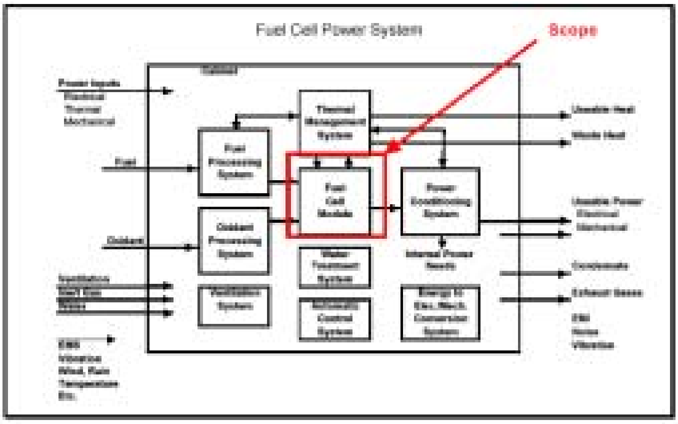

Figure 6.17: "Fuel cell module"[1300]

This IEC 61508 standard is an "IEC basic safety publication" covering all safety-related systems that are electrotechnical in nature.
IEC 61508 uses a risk-based, approach to determine the required performance of safety-related systems, specifying safety integrity levels and covering all safety lifecycle activities. It is a generic document that can be used directly as a standalone standard, but which is also used frequently as a basis for developing other standards. [1301]

The general safety strategy for the fuel cell module is based on the quantity of stored energy in the module, and is established in the following sequence:[1302]

- *Eliminate hazards outside the fuel cell module when such energy is released nearly instantaneously, or*
- *Passively control such forms of energy (e.g. burst disks, release valves, thermal cut-off devices) to ensure a release without endangering the ambient, or*
- *Actively control such forms of energy (e.g. by electronic control equipment). In this case, the remaining risk due to failures of this control equipment shall be investigated in detail. Alternatively, the hazard may be communicated to the fuel cell system integrator, or*
- *Provide appropriate safety markings, concerning the remaining risks or hazards.*

[1300] Ibid., figure 1
[1301] IEC, Functional safety and IEC 61508 - a basic guide, 2002-11
[1302] IEC TC105, Doc. 105/36/CD, ¶4.1

Hazards to be considered include mechanical, electrical, EMC, thermal, fire and explosion, malfunction, dangerous substance, waste disposal and environmental hazards.

One can see that the hazard control measures are classified in a hierarchical way as key element of the safety strategy.
It is thus clear that the implementation of such safety strategy will have a profound influence on the whole of the system design process, and that the imposition of this policy in a standard will be a guidance to system manufacturers to come to a safe product.
This overall approach to safety, stressing on *design strategy* and *design philosophy* is typical for present-day system standards writing, more particularly for a general system standard like the future IEC 62282-2.

The draft for IEC 62282-2 also states design requirements addressing following issues[1303]:

☞ Behaviour at normal and abnormal operating conditions
☞ Leakage
☞ Pressurized operation
☞ Fire and ignition
☞ Safeguarding
☞ Piping and fittings
☞ Electrical components
☞ Terminals and electrical connections
☞ Live parts
☞ Insulating materials and dielectric strength
☞ Equipotential bonding
☞ Shock and vibration
☞ Monitoring.

It finally features a battery of type tests (covering both normal and abnormal operating conditions) and routine tests, the latter being limited to the gas tightness test and the dielectric strength withstand test, and states requirements for marking and documentation.

6.3.2.3 Towards a vehicle fuel cell standard: IEC 62282-4

In September 2001, a NWIP was circulated in TC105 on "Fuel cell system for propulsion and auxiliary power units (APU)".[1304] It was aimed at performance,

[1303] Ibid., ¶4.2
[1304] IEC TC105, Doc. 105/23/NP

safety, EMC, quality assurance and environmental aspects of fuel cell systems for propulsion and auxiliary power units in automotive applications.
To consider as a starting point, the NWIP contained draft specifications:

- ☞ "Fuel cell systems for propulsion - General safety requirements", prepared by US delegates and referring mainly to SAE publications.
- ☞ "Draft fuel cell vehicle safety specification part 1-3", the draft documents of ISO TC22 SC21 presented here by JEVA

The NWIP was accepted in March 2002.[1305] This will become IEC 62282-4.
The definition of the work to be performed to draft a standard useful enough to provide worldwide coverage, particularly in view of avoiding double work with ISO, led to the necessity to extend the timing of the work; the new target date for the CD is October 2003, as decided on the third meeting, which took place in Montréal in June 2002[1306].

The strategic policy statement of IEC TC105 foresees the following activities for WG6[1307]:

- ☞ Transportation fuel cell system - propulsion unit: safety and performance tests (timeline: 2004)
- ☞ Transportation fuel cell system - auxiliary power unit: safety and performance tests (work not yet started)
- ☞ Fuel cell system integration into vehicle: safety and performance tests (timeline: 2004, also dependent on ISO TC22)

6.3.2.4 *Other work by IEC TC105*

Other items included in the work programme of IEC TC105 include:

- ☞ Terminology (IEC 62282-1 TR), for which a first CD has been circulated in March 2002[1308], with a second CD in February 2003[1309]. At a later stage, this will be included in the IEV. WG1 is responsible for this work.
- ☞ Safety of stationary fuel cell power plants (IEC 62282-3-1): this project, executed by WG3, is at ANW stage; a CD is expected for October 2003.
- ☞ Test methods for the performance of stationary fuel cell power plants (IEC 62282-3-2), the work of WG4, which circulated a CD in February 2002
- ☞ Installation of stationary fuel cell power plants (IEC 62282-3-3), the work of WG5. This is in ANW stage, target date for the first CD is June 2004.
- ☞ Safety and performance of portable fuel cell appliances (IEC 62282-5), a CD for this item is expected October 2003, prepared by WG7.

[1305] IEC TC105, Doc. 105/29/RVN
[1306] IEC TC105 Doc. 105/38/RM, Minutes of the meeting in Montréal, 2002-06-13/14
[1307] IEC TC105, Doc.SMB/2318/R, 2002-07
[1308] IEC TC105, Doc. 105/28/CD
[1309] IEC TC 105, Doc. 105/43/CD

6.3.3 Fuel cell standardization at ISO

6.3.3.1 Generalities

The topic of fuel cell vehicles first appeared within ISO TC22 SC21 in 1998, with the idea to start working on safety requirements for fuel cell vehicles being forwarded by the chairman of SC21, Dr. Sahm. The production of water by the fuel cell stack was in fact perceived as a potential problem for the system electrical insulation, to be considered in standards like ISO 6469. Several national committees declared that their industry had started the development of fuel cell vehicles. One main point of the discussion was whether it would not be premature to start standardization work at this early level of development; Sahm stated however that:

> *"Relevant standardization should not be retarded to avoid unnecessary debates at later work."*[1310]

The PWI on safety requirements for fuel cell vehicles was distributed by the German committee in 1999.[1311] It states the baselines of a possible safety strategy for fuel cell vehicles, which should have both basic safety provisions and first failure safety provisions.

Furthermore, the number of standards developed should be the minimum necessary for new car developments. The proposed policy of SC21 was to create only one international standard for safety, only one standard for performance aspects and only one standard for exhaust gas emissions. If one of the last two topics were already covered by existing standards for EV or HEV, no new standard should be worked out.

SC21 accepted this PWI, and charged WG1 to consider the document together with input from the SAE Fuel Cell Forum and to get feedback from automobile manufacturers, in order to prepare a NWIP.[1312]

At the same occasion, WG2 was asked to begin preparation of a draft for fuel cell terminology, as a PWI for material to be added to ISO 8713.[1313]

6.3.3.2 ISO TC22 SC21 WG1: System and safety standards

As stated in the co-operation agreement with IEC TC105 (§6.3.2.1), ISO TC22 SC21 will deal with vehicle-related aspects of fuel cell standardization within its existing working group structure.

[1310] Doc. ISO/TC22/SC21 N248E, Minutes of the 10Th meeting, 1998-11-19, 10.2

[1311] Doc. ISO/TC22/SC21 N275E, 1999-10

[1312] Doc. ISO/TC22/SC21 N285, Resolution 88 taken at the 11th meeting, 1999-11-15

[1313] Ibid., Resolution 89

WG1 deals with "Vehicle operating conditions, safety and energy storage installation", and is thus also responsible for fuel cell vehicle safety.
It considered a number of drafts (from Germany, Japan and the USA), and chose the four-part Japanese draft as basis for its further development on the standard "Fuel cell powered road vehicles - Safety specifications":[1314]

☞ Part 1: Vehicle functional safety
☞ Part 2: Fuel cell system integration
☞ Part 3: Protection against hydrogen hazards
☞ Part 4: Protection of persons against electrical hazards

Further work concerned the measurement of hydrogen emissions from vehicles at standstill.
These drafts[1315] were discussed at the WG1 meetings in Rome, Italy (May 2002)[1316], where the US delegates presented new versions[1317], and Sacramento, California (November 2002)[1318].
On this last meeting, WG1 recognized unanimously the advantage to develop ISO standards referring to "minimum safety requirements" for fuel cell powered road vehicles, in view of their adoption by the relevant national or international regulatory bodies.[1319]
New versions of these drafts were published in January 2003 for revision. It is expected to present a draft to ISO TC22 as official NWIP by the end of 2003.

The main content of these documents is as follows:

6.3.3.2.1 Vehicle functional safety[1320]

Part 1 of the draft standard specifies requirements of the functional safety of fuel cell powered road vehicles in respect to hazards caused by the operational characteristics of the fuel cell system and the electrical propulsion.
It should be compared to the equivalent standard for battery-electric vehicles which is ISO 6469-2:2001 (cf.§5.3.3.3).
The proposed draft is virtually identical to this standard, except for the following points where significant (i.e. more than editorial) changes occur:

☞ Operational safety (¶5.1): the draft states that a main switch function shall be provided to allow the operator to disconnect traction power sources, shutdown the fuel cell system and shut off the fuel supply, thus "switching off" the whole vehicle. The fuel cell system however shall remain able to perform certain functions such as purging.

[1314] Doc. ISO/TC22/SC21 N304E, Report of WG1 to SC21, 2001-11-16
[1315] Doc. ISO/TC22/SC21/WG1 N102REV to N105REV, 2002-01
[1316] Doc. ISO/TC22/SC21/WG1 N117E, Minutes of the 11th meeting in Rome, 2002-05-06/07
[1317] Doc. ISO/TC22/SC21/WG1 N111 to N114, 2002-05
[1318] Doc. ISO/TC22/SC21/WG1 N130E, Minutes of the 12th meeting in Sacramento, 2002-11-04/05
[1319] Ibid., Resolution 3
[1320] Doc. ISO/TC22/SC21/WG1 N132E, 2003-01

Furthermore, for the power-off procedure, it is specified that only one action shall be required to go from the "driving enabled" to "power-off" mode".

- ☞ No specifications are given for "indication of low SOC of the traction battery" and "decelerating by releasing the accelerator pedal", since (at least the first one) is not applicable for fuel cell vehicles.
- ☞ General vehicle safety (¶6.1): these safety measures apply to hazards caused by "first failures" in systems, subsystems and components. Their design shall consider "fail-safe" design principles, with for example electrical switches to open and fuel shutoffs to close when the control signal is interrupted.
- ☞ Disconnection of connectors (¶6.3): also mechanical connectors (e.g. fuel supply lines) have been taken into account.
- ☞ "Auxiliary electric circuits" and "Overcurrent cut-off device" (¶6.4): these clauses have been moved to Part 4.
- ☞ The (informative) annexes A and B to the draft

6.3.3.2.2 Fuel cell system integration[1321]

Part 2 of the draft standard specifies minimum necessary requirements of the integration of fuel cell systems into fuel cell powered road vehicles for the protection of personnel and the environment of the vehicle.

The January 2003 draft, applicable to vehicles using compressed gaseous hydrogen, presents some very general requirements for fuel cell system safety (¶6), referring however to relevant other standards:

- ☞ component requirements: the documents in preparation by IEC TC105 WG6 (i.e. IEC 62282-4)
- ☞ hydrogen-related requirements: ISO TC 197
- ☞ hydrogen related hazards of the fuel cell system integrated in the vehicle: part 3 of the draft standard
- ☞ electrical hazards of the fuel cell system integrated in the vehicle: part 4 of the draft standard

The draft also states some basic requirements for collision protection of the fuel cell system (¶7).

This approach shows a reduction of specifications compared with earlier drafts[1322], in the spirit of the collaboration with IEC TC105[1323]. As all specific requirements in this document have been shifted to the other parts, the utility to maintain part 2 has been put to question[1324].

[1321] Doc. ISO/TC22/SC21/WG1 N133E, 2003-01
[1322] Doc. ISO/TC22/SC21/WG1 N103REV, 2002-01
[1323] Doc. ISO/TC22/SC21/WG1 N117E, Minutes of the 11th meeting, ¶6
[1324] Doc. ISO/TC22/SC21/WG1 N136E, 2003-01

6.3.3.2.3 Protection against hydrogen hazards[1325]

Part 3 of the draft standard specifies the minimum necessary safety requirements of fuel cell powered road vehicles in regard to hydrogen hazards, when compressed gaseous hydrogen is used as raw fuel for propulsion.

It prescribes the following safety equipments to be used in the hydrogen system, which consists of a high-pressure and a low-pressure section as shown schematically in Figure 6.18:

- ☞ A tank valve and pressure relief device, for each tank used.
- ☞ A main shut off valve that shall be closed when electric power is lost.
- ☞ An excess flow valve that shuts off the gas flow at an excessive flow rate (e.g. when a pipe is broken).
- ☞ A hydrogen concentration monitoring and shut-off system.

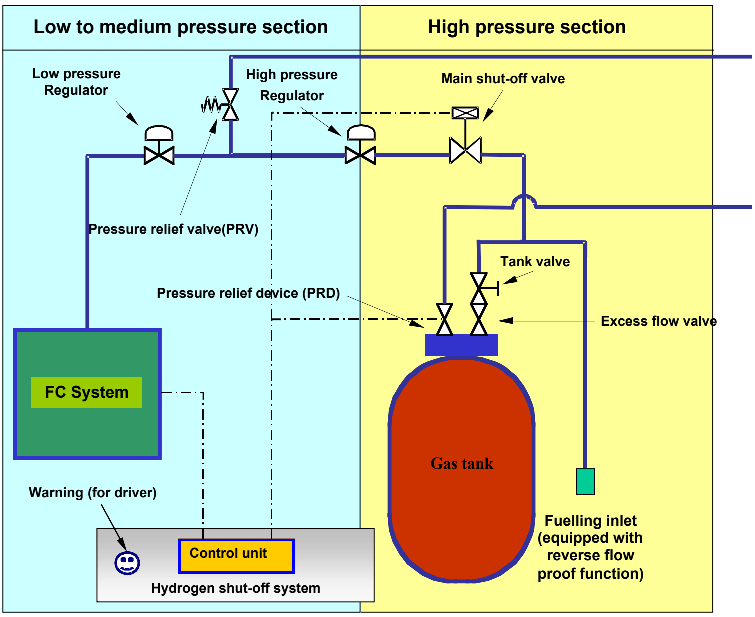

Figure 6.18: Example of hydrogen fuel supply system in fuel cell vehicle[1326]

Furthermore, this document states requirements for the equipment to be installed and the way of installing them, for the lay-out of the installation as to separate potential hazards, for ventilation and hydrogen purging, and for fuelling and defuelling.

[1325] Doc. ISO/TC22/SC21 WG1 N134E, 2003-01

[1326] Ibid., annex A

Informative annexes to this draft provide additional information on the expected discharge of flammable gases during normal operation, the management of potentially hazardous conditions within vehicle compartments (i.e. control of potentially flammable atmospheres on one hand and of potential ignitions sources on the other hand), and the monitoring of the fuel system.

For the complete drafting of this standard, the liaison with ISO TC197 will be essential, also because this standard refers to other standards (e.g. the ISO 15869 hydrogen tank standard) which are part of TC197 work programme.

6.3.3.2.4 Protection of persons against electrical hazards[1327]

Part 4 of the draft standard specifies requirements of fuel-cell powered road vehicles for the protection of persons against electrical hazards, when the vehicles are not connected to an external power supply (in the latter case, IEC 61851-21 applies).
This document is largely based on the standard ISO 6469-3:2001 (cf.§5.3.3.5), except on the following points:

- ☞ The notion of "electrical hazards" is understood not to cover electric shock hazards only.
- ☞ Voltage sources (batteries, fuel cell stacks, capacitors) shall be marked with the warning symbol shown in Figure 5.35 (¶6). This clause has been taken from ISO 6469-1[1328]. Furthermore, wiring harnesses containing high-voltage, i.e. Class B (> 60 V d.c. or 25 V a.c.) cables shall be marked in orange. This requirement emanates from a US comment on an earlier version of the draft[1329].
- ☞ The notion "protection against direct contact" has been replaced by "protection agains electric shock" (¶7.2), cf. §5.3.4.2).
- ☞ A clause has been added "protection under fault conditions of barriers/enclosures" (¶7.2.3.2), since barriers/enclosures can become faulty as well as basic insulation can.
- ☞ Protection against overcurrent and overvoltage is described (¶7.3), cf. relevant clauses in ISO 6469-1[1330] and ISO 6469-2[1331].
- ☞ The test procedures for insulation resistance take into account the option of connecting one pole of a voltage class B circuit to the vehicle chassis (¶8.2.2). It is however clearly recognized that

  "the higher potential for electric shock when chassis-connected requires higher expenditure to obtain the same level of safety".

[1327] Doc. ISO/TC22/SC21 WG1 N135E, 2003-01
[1328] ISO 6469-1:2001, ¶5.1
[1329] Doc. ISO/TC22/SC21 WG1 N121, US comment on N105
[1330] ISO 6469-1:2001, ¶8
[1331] ISO 6469-2:2001, ¶6.4

The issue of galvanic connection between power circuits and the vehicle chassis was discussed at the WG1 meeting in Rome.[1332] Although all experts agreed that the chassis shall not be used as a conductor for the propulsion system, it is hard to avoid a galvanic connection between the fuel cell system and the vehicle chassis due to functional constraints, e.g. cooling and piping systems.

- ☞ Minimal insulation resistance values (¶8.2.4) for Class 1 vehicles during the life of the vehicle are stated as 125 Ω/V for the fuel cell stack, 100 Ω/V for the battery (if any), 500 Ω/V for the balance of the power system (excluding fuel cell and battery), and 100 Ω/V for the whole circuit.
- ☞ Continuity test for exposed conductive parts (¶8.4.2): as the proposed test current of 1,5 times the maximal current was considered very high (cf. §5.3.3.5 and §5.8.9.4), it was proposed to adopt a value of 25 A for the test current[1333], which seems a reasonable value that could also be adopted in the general EV standard (cf. §5.3.3.5 and the discussion on this issue in §5.8.9.4).
- ☞ As a number of these ideas are also applicable to battery-electric vehicles, it was proposed to consider them for the next revision of ISO 6469, which will be performed by ISO TC22 SC21 WG1 after the completion of the fuel cell vehicle safety standard.[1334]

6.3.3.2.5 Hydrogen emission

WG1 is also working on a document on the "measurement of hydrogen emissions at standstill of the vehicles"[1335]. This document, ISO/PWD 17374, is aimed both at battery-electric and fuel cell vehicles, and is an enlargement of scope of an earlier work item[1336], which only covered battery-electric vehicles. It was proposed by the USA and is largely inspired on SAE J1718 (§5.6.3.1).

The presence of a world-wide standard for hydrogen emission measurement was also deemed useful because requirements for hydrogen concentrations were defined in other standards like ISO 6469-1 (§5.3.3.3).

It should be taken into account however that, with respect to potential hydrogen emissions, there is a significant difference between battery-electric vehicles, where hydrogen emissions are a side-effect of the charging process, and fuel cell vehicles, which have a much greater quantity of hydrogen stored on board.

The measurement procedure described in this document is applicable to the charging process of battery-electric vehicles on one hand, and on the release of hydrogen from fuel cell vehicles at power-off mode on the other hand. The purpose

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[1332] Doc. ISO/TC22/SC21 WG1 N117E, ¶6

[1333] Doc. ISO/TC22/SC21/WG1 N130, Minutes of the 12th meeting in Sacramento, 2002-11-04/05, ¶6.5

[1334] Doc. ISO/TC22/SC21/WG1 N136E, 2003-01

[1335] Doc. ISO/TC22/SC21 WG1 N106E, Preliminary working draft ISO/PWD 17374, 2002-03

[1336] Doc. ISO/TC22/SC21 WG1 N69E

is to determine what concentrations of hydrogen gas the vehicle can generate in a sealed test chamber, under normal and abnormal (i.e. first failure) conditions.
Systems and components subject to specific legal requirements (e.g. hydrogen storage cylinders) or which are tested to any other regulation or standard concerning hydrogen emissions are not covered.
Two reference test volumes are provided: 50 m^3 for small vehicles, and 200 m^3 for large vehicles such as buses.
The volume of 50 m^3, which accommodates most passenger cars, can be considered as a typical garage; the aim of the test is thus to determine whether hazardous concentration of hydrogen do occur when the vehicle is located in a closed garage, either charging (battery-electric vehicle) or parked (fuel cell electric vehicle).
The test procedure described in this document can be compared with the hydrogen emission test in the regulation ECE 100 (§5.8.9.2). Both are performed in a sealed measurement chamber; the proposed ISO document has hydrogen concentrations as output, whileas the ECE regulation specifies hydrogen mass emission. As stated above, it is the hydrogen concentration which may pose a hazard, so the ISO approach seems to be a much more sensible one in this case.

6.3.3.3 ISO TC22 SC21 WG2: Performance standards and terminology

In 2001, the Italian NC submitted six NWIP to TC22, which were unanimously accepted, and allocated the following project numbers:

- ☞ ISO/AWI 22918: Electrically propelled road vehicles - Measurement of road operating ability - Fuel cell electric hybrid vehicles - Hydrogen based[1337]
- ☞ ISO/AWI 22919: Electrically propelled road vehicles - Measurement of road operating ability - Pure fuel cell electric vehicles - Hydrogen based[1338]
- ☞ ISO/AWI 22920: Road vehicles - Energy performance - Fuel cell electric hybrid vehicles[1339]
- ☞ ISO/AWI 22921: Road vehicles - Energy performance - Pure fuel cell vehicles[1340]
- ☞ ISO/AWI 22922: Road vehicles - Emission of hybrid vehicles - Fuel cell electric hybrid vehicles[1341]
- ☞ ISO/AWI 22923: Road vehicles - Emission of hybrid vehicles - Pure fuel cell vehicles[1342]

[1337] Doc. ISO/TC22 N2271, also ISO/TC22/SC21 N311E, 2001-11-22
[1338] Doc. ISO/TC22 N2272, also ISO/TC22/SC21 N312E, 2001-11-22
[1339] Doc. ISO/TC22 N2273, also ISO/TC22/SC21 N312E, 2001-11-22
[1340] Doc. ISO/TC22 N2274, also ISO/TC22/SC21 N313E, 2001-11-22
[1341] Doc. ISO/TC22 N2275, also ISO/TC22/SC21 N314E, 2001-11-22
[1342] Doc. ISO/TC22 N2276, also ISO/TC22/SC21 N315E, 2001-11-22

To perform this work, a new WG2 was formed in TC21, with a specific Task Force (TF1) [1343] under the chairmanship of Dr. Brusaglino. TF1 met in October 2002 in Tokyo to define its work programme.[1344]

A second task force (TF2) would focus on terminology, led by Mr. Nieminski.

6.3.3.4 ISO TC197: Hydrogen standards

ISO TC197 "Hydrogen technologies" is responsible for standardization in the field of systems and devices for the production, storage, transport, measurement and use of hydrogen. The activities of this TC are of course of high relevance for the fuel cell vehicle. TC197 has established liaisons with several other TCs in ISO, such as TC58, which deals with "Gas cylinders", but also with TC22 "Road vehicles".[1345]
Although the hydrogen technology which is treated in the work of TC197 falls largely beyond the scope of this work, it is nevertheless interesting to give an overview of ongoing hydrogen standardization which may be relevant to the fuel cell vehicle application.

Up to now, TC197 has produced two international standards:
- ☞ ISO 13984:1999 "Liquid hydrogen - Land vehicle fuelling system interface", which specifies the characteristics of liquid hydrogen refuelling and dispensing systems on land vehicles of all types It describes the system intended for the dispensing of liquid hydrogen to a vehicle, including that portion of the system that handles cold gaseous hydrogen coming from the vehicle tank, that is, the system located between the land vehicle and the storage tank. [1346] This standard states technical requirements for the interface, and even defines the necessary qualifications for the personnel, but does not define a dimensional standard for the interface.

- ☞ ISO 14687:1999 "Hydrogen fuel - Product specification" which defines quality requirements for hydrogen intended to be used as a fuel.

TC197 has various running projects at various stages of evolution.
- ☞ DIS stage (Draft International Standard)
  - ☛ ISO/DIS 13985-1 "Liquid hydrogen - Land vehicle fuel tanks - Part 1: Design, fabrication, inspection and testing"
  - ☛ ISO/DIS 13985-2 "Liquid hydrogen - Land vehicle fuel tanks - Part 2: Installation and maintenance"

[1343] Doc. ISO/TC22/SC21 N321E, Minutes of the 14th meeting, 2002-05-03
[1344] Doc. ISO/TC22/SC21 N327E, Summary report of TF1 to WG2, 2002-11-07
[1345] Doc. ISO/TC22 N2306, also ISO/TC197 N236, Draft agreement between TC22 and TC197, 2002-06
[1346] ISO 13984:1999, Scope

- CD stage (Committee Draft)
    - ISO/CD 15869-1: "Gaseous hydrogen and hydrogen blends - Land vehicle fuel tanks - Part 1: General requirements". (The 15869 series of standards is developed by a joint working group TC197/TC58.)
    - ISO/CD 15869-2: "Gaseous hydrogen and hydrogen blends - Land vehicle fuel tanks - Part 2: Particular requirements for metal tanks"
    - ISO/CD 15869-3: "Gaseous hydrogen and hydrogen blends - Land vehicle fuel tanks - Part 3: Particular requirements for hoop wrapped composite tanks with a metal liner"
    - ISO/CD 15869-4: "Gaseous hydrogen and hydrogen blends - Land vehicle fuel tanks - Part 4: Particular requirements for fully wrapped composite tanks with a metal liner"
    - ISO/CD 15869-5: "Gaseous hydrogen and hydrogen blends - Land vehicle fuel tanks - Part 5: Particular requirements for fully wrapped composite tanks with a non-metallic liner"
- WD stage (Working Draft):
    - ISO/WD TR 15916: "Basic considerations for the safety of hydrogen systems"
    - ISO/WD 17268: "Gaseous hydrogen - Land vehicle filling connectors"
    - ISO/WD 22734: "Hydrogen generators using water electrolysis process"
- AWI stage (Accepted Work Item):
    - ISO/AWI 16110: "Hydrogen generators using fuel processing technologies" - i.e. reformers
    - ISO/AWI 16111: "Transportable gas storage devices - Hydrogen absorbed in reversible metal hydride"

      A first draft of this document was distributed to ISO TC22 SC21.[1347] It shall apply to refillable transportable gas storage devices with a metal hydride hydrogen storage system, stating safety requirements and defining a series of type tests to be performed both on the storage tank itself and on the canister in which contains the complete hydrogen storage system.

[1347] Doc. ISO/TC22/SC21 N334E, also ISO/TC197 N239, 2002-08-13

6.3.4 Fuel cell standardization in Europe

CEN TC301 followed up the activities of ISO in the field[1348], and resolved to complete the standards of the EN 1821, 1986 and 13444 series (cf. §5.5.6) with parts covering fuel cell hybrid vehicles, pure fuel cell vehicles and other electrically propelled vehicles.[1349]

Work is being pursued on these items within CEN TC301 WG1, starting with the document EN 1821-3 on the road operating ability of fuel cell hybrid electric vehicles, with a distinction being made between "hydrogen-based" and "carbon-based" (i.e. with methanol reformer) fuel cell. This will then become documents EN 1821-3-1 and EN 1821-3-2.[1350] No drafts of these documents have been circulated too national committees yet though.

6.3.5 Fuel cell standardization at SAE

6.3.5.1 Generalities

In the United States, large-scale actions on automotive fuel cell standardization have been launched by SAE in the framework of the "SAE Fuel Cell Initiative", which was formed in 1999 to facilitate and accelerate the development of standards, codes and recommended practices for fuel cell powered vehicles, with the following scope:[1351]

> *"Establish standards and test procedures for fuel cell powered vehicles."*

and mission:

> *The standards will cover the safety, performance, reliability and recyclability of fuel cell systems in vehicles with emphasis on efficiency and environmental impact. The standards will also establish test procedures for uniformity in test results for the vehicles/systems/components performances, and define interface requirements of the systems to the vehicle."*

To this effect, a Fuel Cell Standards Committee has been set up, with members from vehicle manufacturers, fuel cell manufacturers, component suppliers, energy providers, government agencies and other organizations involved.

The committee liaised with ISO TC22 SC21 in order to build an effective standardization landscape for the fuel cell vehicle industry, as shown in Figure 6.19.

[1348] Doc. CEN/TC301 N160, Minutes of the 15th meeting in Paris, 2000-01-12

[1349] Doc. CEN/TC301 N165, Resolution 63 taken at the 16th meeting, 2000-08-2

[1350] Doc. CEN/TC301 N175, Minutes of the 17th meeting in Paris, 2001-02-0

[1351] http://www.sae.org/about/mar02bb.htm
http://www.sae.org/technicalcommittees/navigator/fuelcell.htm

An uncoordinated approach by the different standardization bodies would in fact create the risk of unharmonized drafts, dual standards, and the resulting confusion when it comes to type approval of the vehicles.

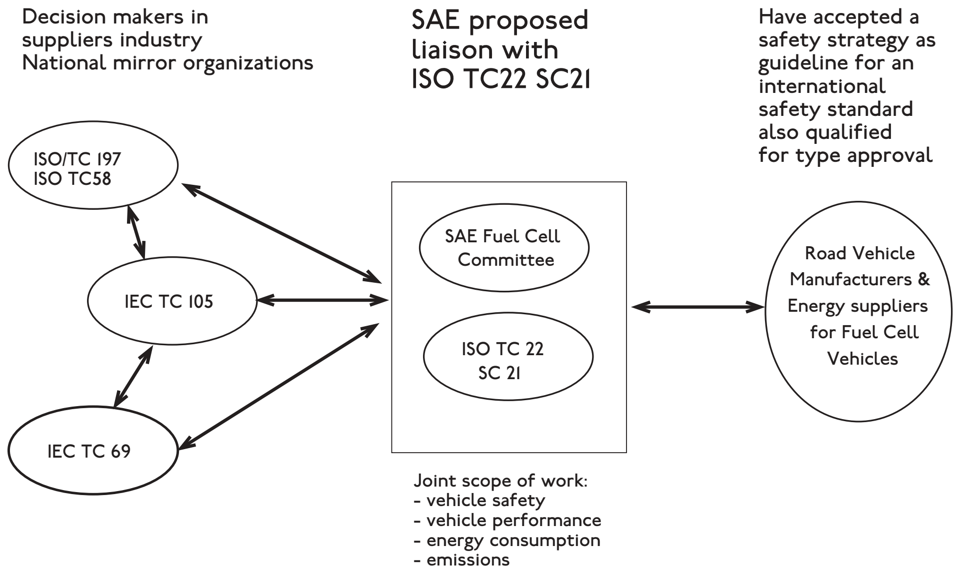

Figure 6.19: Fuel cell standardization landscape[1352]

The SAE Fuel Cell Standards Committee is constituted of six working groups, which will be discussed in the following paragraphs.

6.3.5.2 WG *Emissions and fuel consumption*

The mission of this WG is to establish standards and test procedures for measuring emissions and fuel consumption. Its goal is to define methodologies for uniformity in test results for all designs of fuel cell vehicles, and to allow a comparison with conventional vehicles.
The WG is working on a first draft document, and will in the future tackle vehicles fitted with a reformer.

☞ SAE J2572, "Fuel consumption and range" for fuel cell vehicles using compressed hydrogen from an off-board source and stored as a compressed gas onboard, including hybrid versions (i.e. with an on-board storage battery). This document is still under development.

[1352] Doc. ISO/TC22/SC21 N297E, Recommended Landscape Making Standards, 2000-08

6.3.5.3 WG *Interface*

This WG aims to develop standards to coordinate between fuel suppliers and vehicle manufacturers to ensure safe, efficient and customer friendly delivery of fuel to fuel cell powered vehicles. Topics covered include fuel supply, infrastructure, fuel storage, fuel processor and vehicle interface.
The interface WG has the following standards on its work programme:

☞ SAE J2600: "Compressed Hydrogen Vehicle Fuelling Connection Devices". This standard was published in October 2002, and was presented to ISO TC22 SC21 for review in the framework of the liaison between the committees.

SAE J2600 applies to design, safety, and operation verification of compressed hydrogen surface vehicle refuelling connection devices (nozzle and receptacle)[1353]. Working pressures considered are 25, 35, 50 and 70 MPa (250, 350, 500 and 700 bar). The nozzles and receptacles considered shall:

- prevent vehicles from being refuelled by dispenser stations with working pressures higher than the vehicle fuel system working pressure;
- allow vehicles to be refuelled by dispenser stations with working pressures equal to or lower than the vehicle fuel system working pressure;
- prevent vehicles from being refuelled by other compressed gases dispensing stations;
- prevent other gaseous fuelled vehicles from being refuelled by hydrogen dispensing stations.

☞ SAE J2601: "Compressed Hydrogen Vehicle Fuelling Communication Devices", which will define different fuelling strategies and document their advantages and disadvantages. It will also develop the strategies and protocols for refuelling with and without communications, and focus on the most effective communication technology. This draft standard is targeted for publication mid-2003.

6.3.5.4 WG *Performance*

The mission of this WG is to develop procedures for testing PEM fuel cell system and its major subsystems for automotive applications. It has defined performance and measured parameters for three test subjects: PEM fuel cell system, fuel processor and PEM fuel cell stack.

1353 SAE J2600:2002, Scope

6.3.5.5 WG *Recyclability*

This WG wants to identify recyclability issues associated with fuel cells in End of Life vehicles. It only deals with the PEM Fuel cell stack and its ancillary components, and is developing a guidance document incorporating and summarizing existing recyclability measurement techniques and recycling guidelines.

6.3.5.6 WG *Safety*

The Safety WG recommends design and construction, operation, emergency response, and maintenance practices for the safe use of fuel cell vehicles by the general public. Its work programme includes the following standards:

☞ SAE J2578: "General Fuel Cell Vehicle Safety", which provides criteria for integration for fuel systems into the vehicle. It contains the guidelines for design and construction, operations, emergency procedures and maintenance. Areas of concern include classifications, failures (enclosed areas), fail-safe actions when vehicle is moving and safety labelling.

☞ SAE J2579: "Fuel systems for Fuel Cell Vehicles", which provides criteria for systems containing or processing fuel or other hazardous materials. It contains information including design and construction, general mechanical requirements, operation, emergency procedures and maintenance. Areas of concern include fuel storage, processing, stacks, and other systems handling hazardous fluids. This document will consider all types of fuel cell systems.

The final versions of these standards are expected for the end of 2002.

6.3.5.7 WG *Terminology*

This WG defines the terminology for fuel cell powered vehicles. It has published an information report in March 2002:

☞ SAE J2574 Surface Vehicle Information Report "Fuel Cell Vehicle Terminology" which contains definitions for hydrogen fuel cell powered vehicle terminology, and which is intended to be a resource for the drafting of other fuel cell vehicle standards.

6.3.6 Other Relevant Standards

There are a number of other standards available which may be relevant to vehicle fuel cell applications.

6.3.6.1 NASA Hydrogen Safety Standard

Space applications have been a key area for fuel cell development and application. Furthermore, hydrogen is used as a fuel for rocket engines. To this effect, NASA has published a general standard on hydrogen applications: NASA NSS1740.16 "Safety standard for hydrogen and hydrogen systems"
The scope of this standard is to define guidelines for safely storing, handling and using hydrogen.
It defines specifications on the following topics:
☞ Basic hydrogen safety guidelines
☞ Properties and hazards of hydrogen
☞ Materials for hydrogen service
☞ Hydrogen facilities
☞ Hydrogen storage vessels
☞ Hydrogen and hydrogen fire detection
☞ Operating procedures
☞ Transportation
☞ Emergency procedures

The NASA document is very detailed and extensive, and takes into account a number of issues which are more relevant for space applications than for road vehicles. It contains however a number of general issues which can be applied to automotive applications, and which have actually been used as a base for SAE standardization work in the field.

6.3.6.2 The European Pressure Equipment Directive

The European Directive 97/23/EC defines requirements for pressure vessels. The directive is reflected in the harmonized European standard EN 13445:2002, which consists of the following parts:
☞ EN 13445-1:2002 - Unfired pressure vessels - Part 1: General
☞ EN 13445-2:2002 - Unfired pressure vessels - Part 2: Materials
☞ EN 13445-3:2002 - Unfired pressure vessels - Part 3: Design
☞ EN 13445-4:2002 - Unfired pressure vessels - Part 4: Fabrication
☞ EN 13445-5:2002 - Unfired pressure vessels - Part 5: Inspection and testing

- ☞ EN 13445-6:2002 - Unfired pressure vessels - Part 6: Requirements for the design and fabrication of pressure vessels and pressure parts constructed from spheroidal graphite cast iron
- ☞ CR 13445-7:2002 - Unfired pressure vessels - Part 7: Guidance on the use of the conformity procedures.

Its scope however states that is not applicable on devices mounted on vehicles.
Its only usefulness for automotive applications would be stationary hydrogen storage devices, which can find the following uses:

- ☞ Hydrogen refuelling stations
- ☞ Stationary fuel cell generators for supplying battery-electric vehicles.

The detailed discussion of such stationary applications however falls out of the scope of this work.

7 GENERAL PROOFS - CONCLUSIONS

Travaille hardiment, car tu sais ce qu'il faut savoir.
Marc-Antonio Crassellame, La lumière sortant par soi-même des ténèbres.

7.1 *Evolution of standards development: general findings*

Throughout this work, we have followed the evolution of electric vehicle standardization over a period of nearly one hundred years. From the first attempts to standardize plugs, voltage levels and batteries, we have seen standards develop, extending on the same subjects and embracing new topics to keep abreast with technological and societal evolutions. Throughout this evolution, the fundamentals of standardization however have remained remarkably constant. The main issues encountered in the course of this work give rise to the following assessments which allow to appraise the evolution in the field and to state our recommendations based on the experience we have gained from this work:

☞ Standardization work, however interesting it may be, will not and should not be performed for the sake of standardization only. There must be a clear demand perceived by the stakeholders. Standardization on a certain subject will thus reflect the underlying economic activity in the concerned sector.
We have seen that electric road vehicle standardization work vanished after the First World War, to be revived only with the renewed interest in electric vehicles in the 1970s. The activity level during the following years went up and down however, according to the interest of the moment in electric vehicles, as has been seen for example with the activity level of ISO TC21 SC22 (§5.3.2). The current state of IEC TC69 (§5.2.1), which has been virtually dormant during the last four years, its last plenary meeting being held in 1999, can be explained as well by the decreased interest from vehicle manufacturers for the battery-electric road vehicle with the advent of hybrids and fuel cells. As will be seen in §7.2 below, there are however interesting future work items left for this committee.

☞ Standardization does serve an useful purpose, but it should be introduced wisely and appropriately. The drafting of standards on non-critical subjects, such as the noise emissions of battery chargers (§5.5.8.2), or the definition of excessively demanding requirements may hamper development and deployment of a technology rather than assist it.
Such overstandardization can be caused by apprehension when confronted with a new and unknown technology, but it can also be implemented deliberately in an evil attempt to thwart new developments.

☞ The main enemies of effective standards are other standards that are contradictory. They bring confusion for the user and undermine the authority of the standardization bodies and eventually of standardization itself.
The need for close collaboration between standardization bodies remains a paramount issue on all levels.

☞ On the sectoral level, such as between IEC and ISO, the division of work between standardization bodies shall be performed on the basis of collaboration and not of competition, taking into account the specific know-how existing in the respective committees. The mutual understanding of the dissimilar approach that different sectors may take towards standardization and technological development, the recognition of reciprocal work and the multidisciplinary constitution of standardization committees will prove to be essential elements in ensuring such a collaboration to be effective.
The establishment of a single body in charge of international standardization (i.e. merging IEC and ISO, and cf. the proposals to merge CEN and CENELEC in Europe - §5.5.11.2) could provide a setting in which these collaboration issues would be resolved more smoothly. Such a merger doesn't seem very likely to occur in the short term though, due to the firmly established traditions in both organisations and due to the fact that they represent different industrial sectors with their own spheres of interest.
The evolution of technology however, with electric and electronic sub-assemblies being integrated in virtually every type of product, will lead to a further intertwining of electrotechnics within other fields of technology, thus posing further challenges to the organisation of standardization activities, which necessitate an effective policy of collaboration and liaison between the committees involved.
The standardization landscape that has developed around the fuel cell (Figure 6.19) constitutes a good example of a collaboration scheme aiming at bringing out the best in every committee involved and allowing for the most efficient standardization work.

☞ On the regional level, standardization will have to take into account differences that exist due to historical reasons, such as the organization of electricity distribution in various countries, as well as local traditions that are reflected in standardization and regulation.
It is clear however that the endorsement of international standards on regional and national level is to be preferred wherever possible; the drafting of such international standards which can be accepted worldwide is dependent on the global participation in the international committees. A good example of such a standard is the ISO 8714 (§5.3.4.3), which defines a common measurement procedure that can applied globally, while proposing specific speed cycles for each continent, reflecting local conditions and regulations.

The adoption of an international standard on a global scale does not imply the imposition of a bland uniformity; on the contrary, it can highlight richness and diversity by promoting intercultural exchanges.

☞ The constitution of standardization committees shall also reflect the variety of interested parties: manufacturers, suppliers and users. A balance between these partners is necessary to ensure that the standard reflects all interests concerned and becomes a document of global societal value, rather than a bespoke document imposed by a single group to serve its own benefits.
When considering the present constitution of the standardization committees however, it becomes clear that nearly only manufacturers are present The personal participation of the author in standardization work, who represented electric vehicle users through the association CITELEC, and who also reflected an academic research point of view through the VUB, has been a prime occasion to witness the leading position of manufacturers and the need to balance the presence of different interest groups in the committees.
The active participation in the work of an international standardization committee constitutes however a considerable investment in time and money, which may represent a heavy burden for actors like SMEs, public bodies, research institutions or user organisations. A balanced constitution of the committees will thus necessitate the access to adequate funds to support participation by these parties. The value of an investment in standardization work should not be underestimated since its impact on society as a whole.
For countries not having a manufacturing base, participation in international standardization remains interesting to have an input in the standards they will adopt as users and consumers (particularly in the case of European standards which are mandatorily converted to national standards), and a support to allow participating in, or at least actively following up, the work of the committees seems fully justified.
The balanced constitution of standards committees is a statutory requirement in a number of standardization bodies such as the ASTM[1354], in order to avoid that the standardization process is dominated by manufacturers only.

☞ National committees active in international standardization will be likely to push forward standpoints that favour the interests of their own economy. This may lead one one hand to the support of specific solutions as an international standard (such as the US paddle-type inductive charger, §5.2.5.4.1), or to the holding back of standardization work when the own economy is not deemed ready for it (such as the German standpoint on the European hybrid performance standard, §6.2.3.1). In order to avoid the standardization process to be dominated by the largest and strongest economies only, the democratic voting process ("one member - one vote") that always has been the main

[1354] S.M. Spivak, F.C. Brenner, op.cit., p35 characteristic of international IEC and ISO standardization is a key element that should be retained.

☞ The consensus model, which has been the keystone of standardization since its early years, shall remain the preferred path to the approval of standards. It is the best way to ensure that all voices which have something to say can be heard and that all stakeholders in the standardization process can participate on an equal footing. The main drawback of the consensus model however is that much more time may be needed to align diverging opinions and to agree on a common solution, which will always be a compromise solution. The history of IEC TC69 WG4, where lingering discussions over a basic notion such as the definition of charging modes (§5.2.5.3.2) have kept the working group occupied during several multi-day meetings, is a typical illustration of this phenomenon. Although reaching a consensus may be more time-consuming, particularly in an international standardization committee with members from all over the world, the end result will be more acceptable for everyone: when a standard is being enforced by one party, it is not necessarily the appropriate solution for other parties concerned.
The concept of other methodologies for standards development, for example the introduction of qualified majority voting at an early stage of the standardization process (cf. §5.5.11.2), should be carefully considered to know whether the benefits outweigh the drawbacks.

☞ Certain areas of society tend to be more and more controlled by government-issued regulations. This is particularly the case concerning for example safety issues. However, as much now as one century ago, as stated above (§2), standardization drafted by legislature may yield "unusable, inadequate or foolish specifications", and standards should be developed by experts who are competent in the matter, and be based on technical knowledge rather than political viewpoints.
The "New Approach" (§5.5.11.2), where legislation defines a basic set of essential requirements, with the technical details being covered in harmonized standards drafted by standardization bodies, is a good example of the complementarity of regulation and standardization, and it would be commendable to extend the implementation of this principle to areas where it is not yet implemented such as road vehicles. This will help to eliminate the confusion that can be caused by the discrepancy which in some fields exists between standards and regulatory documents such as ECE regulations (§5.8.13). A "New Approach" in the field would displace the technical specifications in ECE regulations by references to European standards. This evolution, however desirable it may seem, will however necessitate a difficult political decision process, since the ECE regulations emanate from the UN and are thus beyond the mere jurisdiction of the EU.

Furthermore, a "New Approach" can help to avoid the restriction of technological development through obsolete technical specifications enshrined in legislation on one hand, and through overspecification by overzealous legislators on the other hand.
The voluntary character of standards adopted by consensus remains a vital element of personal and societal freedom which is the foundation of scientific, technological and social progress.

☞ Standardization bodies should improve the knowledge of "standardization" and its backgrounds among the general public and among training and teaching bodies such as engineering schools on different levels. International standards and their impact are rarely known and understood. A notorious example is the ISO 9000 quality management standard, which is often misunderstood as a product quality standard, also due to its publicitary use by corporations.
A further responsibility lies with the press, who systematically but erroneously uses the word "standard" or "norm" to refer to legislative documents such as EU directives and the like, thus misleading the public and creating confusion about the true nature of standardization. The word "standard" should only be used for documents emanating from proper standardization committees (IEC, ISO, CENELEC, CEN, etc.).

7.2 *Where do we go from here?*

7.2.1 Introduction

During the last decennium, the committees active on electric vehicles have made impressive accomplishments, with standardization work being performed on both international and regional levels, and a comprehensive array of standards being published, concerning both battery-electric, hybrid and fuel cell vehicles.
The study of the evolution of these activities as made in the framework of this thesis allows to make a critical appraisal of the work done and to identify the areas where we perceive problems that are still to be resolved.

7.2.2 The battery-electric vehicle

For the battery-electric vehicle, for both road and industrial applications, major issues have now been covered by standards.
A number of issues are still outstanding however and merit further work:

☞ The electric drive train, consisting of motor and controller, does not benefit from a up-to-date standard to rely on. The evolution of technology in the field of power electronics, the influence of power electronics on electric motor design, and the potential of direct interaction between the drive train and the electric distribution network make the availability of such a standard desirable however. It is thus considered essential that the activities of IEC TC69 WG2 (which is convened by the author) could resume (§5.2.3.7), in order to prepare a standard describing all relevant aspects of the on-board power equipment, including safety, EMC issues and ratings, which would be useful to both vehicle manufacturers and component suppliers for electrically driven vehicles, including battery-electric, hybrid and fuel cell vehicles.
To this effect, IEC TC69 and the IEC/ISO Joint Steering Group (§5.4.3) should resume their activities in the field, and convene a multidisciplinary working group consisting of both representatives from the automotive and electrotechnical industries in order to tackle this highly interesting issue.

☞ An inclusive set of conductive charging infrastructure standards have been published (§5.2.5.2, §5.2.6). There is not yet a common ground however regarding the physical layout of the connector interface. The "universal" interfaces as defined in IEC 61851-1 (§5.2.5.3.5) suit in principle all requirements, but it can be stated that they are quite complicated to see practical widespread use.
As for the standardization of plugs and sockets, progress has been made on regional (CENELEC) level (§5.5.3.5.2), where it can be deplored however that

some national committees have put forward a proprietary national solution, thus letting pass the chance to come to an international standard of intermateable accessories. The demand for an international standard solution is clearly present from an user's point of view, as has been made clear for example in the study of charging infrastructures for the Brussels Capital Region (§5.2.8.4)
The standardization of the vehicle inlets is still pending (§5.5.8.4), which can also be ascribed to the fact that this issue is dealt with by a different (CEN) committee. This issue clearly needs the establishement of a collaboration between CEN TC301 WG4 and CENELEC TC69X WG3 on the matter.

☞ Concerning inductive charging, the low commercial interest in the field to-day is unlikely to promote standardization activities. The IEC 61980 inductive charging standard (§5.2.5.4), which is now lingering in a CD stage, will most probably be abandoned, making all the work devoted to it a vain effort; such work which eventually proves to be useless is the sad fate of standardization committees facing a change in technologies favoured by the market and preferred by vehicle manufacturers.
One can state however that the principle of inductive connection to the mains continues to be a preferable solution for those applications where this connection has to be established in a systematic and repetitive way, such as in opportunity charging for captive fleet operations like buses, taxis, goods delivery vans or car sharing vehicles, where the availability of an automatic inductive connection will offer an unprecedented safety and user-friendliness while eliminating handling as well as wear and tear problems.

☞ On-board chargers, which are now not described by standards, nevertheless present a number of issues, such as energy efficiency measurement, that would merit further work (cf. §5.2.5.3.8). The nature of the charger as "on-board power equipment" and its possible integration with the drive train equipment implies that this should be a work item for IEC TC69 WG2, with of course the necessary collaboration with IEC TC69 WG4 on infrastructure issues and ISO TC22 SC21 on infrastructure issues.

☞ Battery performance standards (the IEC 61982 series; §5.2.4.7 to §5.2.4.9) have been specifically drafted for the battery-electric vehicle application - these standards can be considered as successful developments of their kind and will be of use to both battery and vehicle people.

☞ Dimensional battery standards are only well-defined for the proven technology of industrial lead-acid traction batteries (§4.2.4.8). For advanced electric vehicle batteries however, the evolution of the technology is such that the definition of dimensional standards would still be premature at this time. Once such technologies will have evolved enough to yield mature commercial products however, it is advisable to draft dimensional standards in order to allow a competitive market to develop, just as is the case with lead-acid batteries. Proprietary or non-standard batteries will in fact always be expensive batteries.

☞ Also, the standardization of voltage levels has only been established for industrial electric vehicles (§4.2.3.7), where in fact the need for standard voltages is more present due to the common use of off-board chargers and the swapping of batteries. Electric road vehicles fitted with on-board chargers on the other hand are "closed systems" where the standardization of battery voltage seems to be a lesser requirement at first sight. One must recognize however that the recognition of standard voltage levels would be a great benefit for suppliers of sub-assemblies such as traction inverters or battery chargers. An effort to standardize such voltage levels would consist a welcome evolution for the future, taking into account however the ongoing developments in the field of power electronics, which tend to raise system voltages to higher levels; many electric road vehicles currently come with battery voltages exceeding 300 V. Considering the operating voltage for on-board auxiliary systems, it is likely that electrically driven vehicles will also make use of the 36/42 V system which is now being developed to replace the 12/14 V system in ICE vehicles; this will have a considerable influence on the design of auxiliary components which will have to be either conceived for the higher voltage or supplied through converters; the technological and economical impacts of these choices are still to be investigated.

☞ Vehicle performance standards have been prepared by both regional (§5.5.6.3, §5.6.2.2, §5.7.2.1) and international (§5.3.4.3) level. The new international standard ISO 8714 has the advantage to encompass several local drive cycles, and furthermore to measure energy consumption after a full discharge cycle, allowing for objective measurements for each electric vehicle design.

☞ Safety standards for electric vehicles have been published on both international (§5.3.3) and regional level (§5.5.9, §5.6.3), covering various aspects involved. Although the international standards ISO 6469 can be considered as comprehensive documents, it is to be foreseen that further revisions of this standard take into account the findings from relevant work in the field of fuel cell vehicles (cf. §6.3.3.2.4).

7.2.3 The hybrid vehicle

☞ Hybrid vehicle performance standards have been published on regional level (§6.2.3, §6.2.4), but not yet on international level. Due to the various hybrid structures possible and the plethora of drive train control strategies which can be implemented, the definition of suitable test procedures for hybrid vehicles and their drive trains is not a straightforward issue and merits further consideration. Various options have been discussed in §6.2.5.

☞ Battery performance standards for hybrid vehicles shall take into account the specific use pattern of the battery, which is fundamentally different from a battery electric vehicle due to the presence of an on-board energy source; this is particularly the case for non-externally-chargeable hybrids. Specific battery test cycles should be developed, preferably mimicking the usage of the battery in the vehicle test cycles.

☞ For externally-chargeable hybrids, which are designed to be connected to the electric supply network, relevant standardization for battery-electric vehicles should apply of course, and the scope of standards like IEC 61851 should be expanded to include hybrid (and fuel cell) vehicles where applicable, as well as considering these vehicle applications in the next edition of IEC 61851.

7.2.4 The fuel cell vehicle

The development of the fuel cell technology has created new challenges for standardization. The construction of an appropriate standardization landscape for this new application has allowed the structuring of effective collaboration and interaction between different standardization committees involved, avoiding double work which might lead to conflicting standards.
Although most work on fuel cell standards is still on the working group level at the time of writing, an interesting outcome can be expected.

For what concerns the standardization of test procedures for fuel cell vehicles, which may or may not be equipped with an on-board rechargeable energy storage system, the same viewpoints expressed above for the hybrid vehicle apply.

7.2.5 Conclusions

The availability of comprehensive standards covering all aspects of the electrically driven vehicle will be of great benefit to all parties concerned:

☞ Reliable performance measurement standards are a key factor allowing the user, and more in particular the fleet user, to assess the value of the electric vehicle products which are made available on the market. Validated standard procedures for performance measurement will undo performance claims which are given on an arbitrary basis, for publicity reasons.

Furthermore, clear standards for performance measurement, particularly concerning energy consumption and emissions are of essential value to vehicle manufacturers to design their vehicles and to prepare them for type approval.

- ☞ Infrastructure standardization will be a key element to allow a wide market for the electric vehicle, removing its captivity and giving the user flexibility for deploying the vehicle for various missions.
- ☞ For the vehicle manufacturer good standards are to be guidelines which allow them to develop products that are acceptable for the market. Such standards should be clear and unambiguous, but not too restrictive as to constrain the manufacturer's creativity and quest for technical progress. More in particular for the small and medium sized enterprise which heavily relies on external component suppliers, well-defined component standards will enable a better view on the market in order to make the best design choices. Also, the availability of standardized components will open up the market for competition and allow for lower prices.
- ☞ The availability of and the adherence to international standards for safety will also allow vehicle manufacturers to present their products on a global market. The compliance to known and accepted standards will presume conformity to essential safety requirements and allow to gain user confidence in the product and to develop a wide market for the electric vehicle.

Standards are thus essential for the electric vehicle to corroborate its position as the efficient, safe, reliable, energetically and ecologically sound transportation means of the future.

The electrically driven vehicle is a good thing for humanity, and so is standardization.
Through our continuous efforts in the field of standardization we will strive to contribute to the deployment of electrically driven vehicles, abiding by the Electric Vehicle Creed cited above:

We Believe in the Electric Vehicle !

7.3 Synoptic overview of existing standards

The following tables give an overview of current published international and regional published standards which have electric and/or hybrid vehicles in their scope, and which have been referenced in this work.

7.3.1 Terminology standards

	International	Europe	USA	Japan
Terminology	ISO 8713	EN 13447	SAE J1715	JEVS Z805 JEVS Z806 JEVS Z807 JEVS Z808
Terminology (Fuel Cell)			SAE J2574	

Table 7.1: Overview of terminology standards

7.3.2 Battery standards

	International	Europe	USA	Japan
Battery performance, lead-acid	IEC 60254-1	EN 60254-1		JEVS D701 JEVS D702 JEVS D703 JEVS D704
Battery size, lead-acid cells	IEC 60254-2	EN 60254-2		
Battery size, lead-acid, monobloc			SAE J1797	JEVS D001
Opportunity charging, lead-acid	IEC 61044	EN 61044		
Battery performance, NiCd	IEC 61382-1			
Battery performance, NiMH				JEVS D705 JEVS D706 JEVS D707 JEVS D708 JEVS D709
Battery size, NiMH			SAE J1797	JEVS D002
Battery performance, general	IEC 61982-2 IEC 61982-3		SAE J1798 SAE J2288	
Battery, general			SAE J2289 SAE J2380 SAE J2464	

Table 7.2: Overview of battery standards

7.3.3 Electric vehicle safety standards

	International	Europe	USA	Japan
Battery safety	ISO 6469-1	EN 1987-1 EN 50272-3		
Functional safety	ISO 6469-2	EN 1987-2		
Protection against electric hazards	ISO 6469-3	EN 1987-3		
Battery crash safety			SAE J1766	
Electric vehicle safety (general)			SAE J2344	
Hydrogen emissions		prEN 50276	SAE J1718	

Table 7.3: Overview of safety standards

7.3.4 Electric vehicle infrastructure standards

	International	Europe	USA	Japan
Conductive charging - General	IEC 61851-1	ENV 50275-1	SAE J1772	JEVS G109
Conductive charging - EV requirements	IEC61851-21	ENV 50275-2-1		
Conductive - a.c. charging station	IEC61851-22	ENV 50275-2-2		
Conductive - d.c. charging station	IEC61851-23 (CD)	ENV 50275-2-3		
Communication protocol		ENV 50275-2-4	SAE J2293-1 SAE J2293-2	JEVS G108
Plugs and receptacles	IEC 62196 (CD)	CENELEC R069/001		JEVS C601 JEVA TG G101
Charging noise		EN 12736		
Inductive - general requirements	IEC 61980-1 (CD)			JEVS G106
Inductive coupler	IEC 61980-2 (CD)		SAE J1773	JEVS G107
Eco-station				JEVS G101 JEVS G102 JEVS G103 JEVS G104 JEVS G105

Table 7.4: Overview of infrastructure standards

7.3.5 Electric vehicle component standards

	International	Europe	USA	Japan
Wiring and connectors	IEC 783			
Instrumentation	IEC 784			JEVS Z804
Rotating machines	IEC 785 IEC 60349			JEVS E702 JEVS E901
Controllers	IEC 786			JEVS Z107 JEVS E701

Table 7.5: Overview of component standards

7.3.6 Electric vehicle performance standards

	International	Europe	USA	Japan
Road operating characteristics	ISO 8715	EN 1821-1	SAE J1666	JEVS Z101 JEVS Z102 JEVS Z104 JEVS Z109 JEVS Z110 JEVS Z112
Energy consumption and range	ISO 8714	EN 1986-1	SAE J1634	JEVS Z103 JEVS Z105 JEVS Z106 JEVS Z108 JEVS Z111
Vehicle specifications				JEVS Z901

Table 7.6: Overview of electric vehicle performance standards

7.3.7 Hybrid vehicle performance standards

	International	Europe	USA	Japan
Road operating characteristics		EN 1821-2		
Energy performance		EN 1986-2	SAE J1711 SAE J2711	
Emissions		EN 13444-1	SAE J1711 SAE J2711	

Table 7.7: Overview of hybrid vehicle performance standards

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8.1 *Sigla*

The following sigla[1355] are used as to note the location of the referenced documents:

8.1.1 Academic libraries

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JCL	John Crerar Library, The University of Chicago, Chicago, Illinois
LHL	Linda Hall Library, Kansas City, Missouri
VUB	Centrale Bibliotheek, Vrije Universiteit Brussel, Brussels, Belgium

8.1.2 Libraries of standardization organizations

BEC	Belgisch Elektrotechnisch Comité, Brussels, Belgium
BIN	Belgisch Instituut voor Normalisatie, Brussels, Belgium
BSI	British Standards Institute, London, England
FAKRA	Normenausschuß FAKRA beim DIN, Frankfurt/Main, Germany

8.1.3 Others

AVERE	Archives of AVERE, Brussels, Belgium
SEC	Secondary references; these are documents quoted in other documents or otherwise not directly consulted
VDB	Documents in possession of the author
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[1355] Concept of "sigla", cf. A Gerlo and R. De Smet, Marnixi Epistulae, Brussels, University Press, 1990

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8.5 Standardization working documents and reports

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8.9 Stage codes

Stage codes are used by standardization committees to show the status of a document. ISO uses the four-digit "international harmonized stage codes", whileas IEC and CEN/CENELEC have their own alphanumeric system. These are shown in Table 8.1, Table 8.2 and Table 8.3.

STAGE	SUB-STAGE						
	00	20	60	90 Decision			
	Registration	Start of main action	Completion of main action	92 Repeat an earlier phase	93 Repeat current phase	98 Abandon	99 Proceed
00 Preliminary stage	00.00 Proposal for new project received	00.20 Proposal for new project under review	00.60 Review summary circulated			00.98 Proposal for new project abandoned	00.99 Approval to ballot proposal for new project
10 Proposal stage	10.00 Proposal for new project registered	10.20 New project ballot initiated	10.60 Voting summary circulated	10.92 Proposal returned to submitter for further definition		10.98 New project rejected	10.99 New project approved
20 Preparatory stage	20.00 New project registered in TC/SCWORK programme	20.20 Working draft (WD) study initiated	20.60 Comments summary circulated			20.98 Project deleted	20.99 WD approved for registration as CD
30 Committee stage	30.00 Committee draft (CD) registered	30.20 CD study/ballot initiated	30.60 Comments/ voting summary circulated	30.92 CD referred back to Working Group		30.98 Project deleted	30.99 CD approved for registration as DIS
40 Enquiry stage	40.00 DIS registered	40.20 DIS ballot initiated: 5 months	40.60 Voting summary dispatched	40.92 Full report circulated: DIS referred back to TC or SC	40.93 Full report circulated: decision for new DIS ballot	40.98 Project deleted	40.99 Full report circulated: DIS approved for registration as FDIS
50 Approval stage	50.00 FDIS registered for formal approval	50.20 FDIS ballot initiated: 2 months. Proof sent to secretariat	50.60 Voting summary dispatched. Proof returned by secretariat	50.92 FDIS referred back to TC or SC		50.98 Project deleted	50.99 FDIS approved for publication

60 Publication stage	60.00 International Standard under publication		60.60 International Standard published				
90 Review stage		90.20 International Standard under periodical review	90.60 Review summary dispatched	90.92 International Standard to be revised	90.93 International Standard confirmed		90.99 Withdrawal of International Standard proposed by TC or SC
95 Withdrawal stage		95.20 Withdrawal ballot initiated	95.60 Voting summary dispatched	95.92 Decision not to withdraw International Standard			95.99 Withdrawal of International Standard

Table 8.1: International harmonized stage codes[1356]

[1356] ISO Stage codes, http://www.iso.ch/iso/en/widepages/stagetable.html

Code	Meaning	Equivalent harmonized stage code
1CD	1st Committee Draft	30.20
2CD	2nd Committee Draft	32.35
3CD	3rd Committee Draft	32.35
A2CD	Approved for 2nd Committee Draft	30.99
A3CD	Approved for 3rd Committee Draft	35.92
ACDV	Draft approved for Committee Draft with Vote	35.99
ADIS	Approved for FDIS circulation	40.99
ADISSB	FDIS manuscript subcontracted to CO	40.95
AMW	Approved Maintenance Work	20.00
ANW	Approved New Work	20.00
APUB	Draft approved for publication	50.99
APUBSB	PUB manuscript subcontracted to CO	50.95
BPUB	Publication being printed	60.00
BWG	Draft returned to Working Group	30.92
CAN	Draft cancelled	20.98
CCDV	Draft circulated as Committee Draft with Vote	40.20
CDIS	Draft circulated as FDIS	50.20
CDM	Committee Draft to be discussed at Meeting	35.95
CDPAS	Circulated Draft for Publicly Available Spec.	50.20
CDTR	Circulated Draft Technical Report	50.20
CDTS	Circulated Draft Technical Specification	50.20
CDVM	Committee draft with vote for meeting	40.91
DEC	Draft at Editing Check	40.99
DEL	Deleted items	20.98
DELPUB	Deleted Publication	99.60
DREJ	Draft rejected	30.98
MERGED	Merged project	30.97
NADIS	FDIS not approved	40.93
NCD	CCDV not approved	50.92
PNW	Proposed New Work	10.00
PPUB	Publication issued	60.60
PWI	Potential new work item	00.00
RDIS	Text for FDIS received and registered	50.00
SPE	Special Handling	99.99
SRP	Publication under Systematic Review	95.92
WPUB	Publication withdrawn	95.99

Table 8.2: IEC Stage Codes[1357]

[1357] IEC Stage Codes, http://www.iec.ch

Stage Codes	Definition
	0. Work Definition
08	Work item registered (title)
09	Work item described (title and scope)
10	Proposal for new work circulated for approval
11	Work allocated to a technical body
12	Work already in technical body scope
13	Reference document submitted to BT
14	PQ decided by BT
15	UQ to be launched
16	RD to be submitted to Formal Vote (EN, CEN/TS)
	2. Questionnaire procedure
20	Document available for PQ/UQ
21	PQ/UQ circulated. Standstill started
22	Submission of PQ/UQ results to BT
23	PQ/UQ results in formal vote (EN, CEN/TS)
25	Task referred to Technical Body
27	Work stopped, standstill maintained
28	Work stopped, standstill released
	3. Technical Body stage
31	Working documents expected from Technical Body
32	Working documents circulated to Technical Body
33	CEN enquiry decided
34	Formal vote decided (EN, CEN/TS)
37	Work stopped, standstill maintained
38	Work stopped, standstill released
39	Situation report submitted to BT
	4. CEN /CENELEC enquiry
40	Document available for CEN enquiry
41	CEN enquiry and CDL started
42	Second CEN enquiry decided
43	Second CEN enquiry started
44	Vote decided, and technical editing, no deviation
45	Vote decided, and technical editing, with deviations
46	Results of CEN enquiry established
47	Work stopped, standstill maintained
48	Work stopped, standstill released
49	Document available for formal vote
	5. Formal voting
50	Preparatory vote
51	Formal vote launched (EN,CEN/TS)
52	Voting report established
53	Ratified. Publication decided
54	Complementary (or second) formal vote launched
55	Task referred to technical body

57	Work stopped, standstill maintained
58	Work stopped standstill released
59	Results reported to AG/CA
60. Finalization and printing	
63	EN, CEN/TS, CEN/TR being finalized
64	EN available
65	CEN/TR available
66	CEN/TS available
70. National implementation	
72	CEN/TS implemented
73	EN implemented
74	Proposal of EN referred to ISO/IEC

Table 8.3: CEN-CENELEC *stage codes*[1358]

[1358] CEN/CENELEC stage codes, http://www.cenorm.be/BOSS/prodpro/stages/oldstagecd.htm www

8.10 The birth of a standard

To further illustrate the genesis process of a standard, Figure 8.1 shows the various steps in the development of an IEC standard.

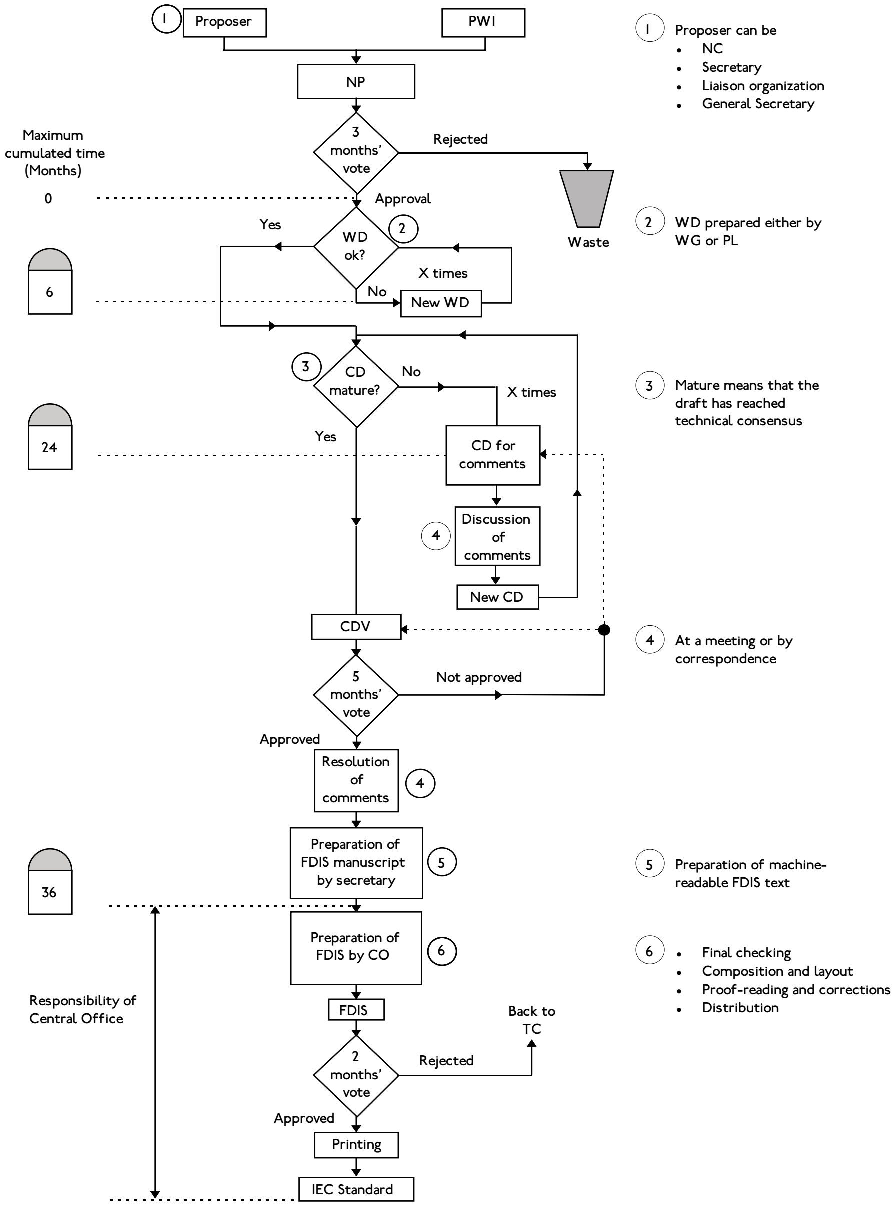

Figure 8.1: Development of an IEC standard[1359]

[1359] IEC, Guidance for convenors of working groups and project leaders, 1997-09-23

9 INDICES

9.1 Index of persons

9.2 Index of standards

This index lists all the standards listed in this work, irrespective of their current status (draft, active or deleted). IEC documents are referred to by their new number in the 60000 series.

LHOON