

Promotion of CRS Safety by ISO TC22/SC12/WG1 Child Restraint Systems

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ABSTRACT

This paper summarises the experience of activities for standardisation in the International Standardisation Organisation (ISO) working group on child restraint systems. Main areas covered:

- Background for the formation of the group
- Items selected for standardisation efforts
- Progress so far, regarding published International Standards and Technical Reports
- Impact on society regarding use of these standards, either voluntary or legislative
- Ongoing work on development of new standards

BACKGROUND

A BALLOT took place in 1987 among the member countries of the ISO Technical Committee 22 (TC 22), Road Vehicles, to start a specific activity regarding child restraint systems. It was decided to allocate the work to Working Group 1 (WG 1) of Subcommittee 12 (SC 12), Restraint Systems, presently reworded as "Passive safety crash protection systems" of TC 22. The convenorship and secretariat was allocated to Sweden.

WG 1 was given the title "Child restraint systems (in road vehicles)". WG 1 commenced work on child restraint systems in May 1989 and has since then had two meetings each year.

The scope of the WG, decided at the first meeting, is still valid:

"The aim of this working group should be international harmonization and standardization in the field of child restraint systems in passenger cars in order to improve safety for children in cars."

Approximately 70 experts from 17 countries participate in the work. The experts represent different areas of the child safety community, such as child restraint system manufacturers, testing laboratories, traffic safety authorities, consumer organizations and car manufacturers.

At the initial meetings, compatibility and reduction of misuse were found to be important tasks for standardization efforts. It was also stated that WG 1 should not develop new standards intended to replace existing main regulations, such as ECE R.44 or FMVSS 213.

WORK ITEMS

INITIAL SURVEY OF TASKS – At the first meetings, a list of possible work items was made, and a priority order was established. Misuse and compatibility at an early stage turned out to be the two most important tasks of the WG. Misuse is a widely recognized problem, and the increased injury risk due to misuse has been reported by several researchers in the child safety field. The compatibility of child restraints with cars is a closely related problem area, which also has appeared to be of great significance. Within these areas, several work items were selected. A detailed review of these will not be given, as they to a large extent are the same as today, although more items have been added at consecutive meetings.

PRESENT WORK ITEMS – The most important items were selected for a formal vote and approval at the ISO Technical Committee 22 (TC 22) level. These items were (ISO/TC 22, 1992):

1. Comparison of regulations and standards, including definitions
2. Reduction of misuse risk, covering:
 - Forms for the collection of data in field studies of misuse
 - Test methods for the evaluation of misuse risk: Panel evaluation and Misuse Mode and Effect Analysis (MMEA)
 - Instructions and labels
3. Standardized universal attachment to vehicle (ISOFIX)
4. Determination of adult belt anchorage location and belt length with respect to the attachment of a child restraint system to a vehicle
5. Report form for accidents involving child passengers

All these work items were approved in a voting procedure among the TC22 member countries. In addition to the above items, the following were also brought to the agenda:

- Dummies
- New group definitions (i.e. size/weight grouping of children)
- Injury criteria, neck criteria and other criteria (additional to those already used in existing regulations and standards)

- Specification of top tether attachments
- Monitoring of changes in regulations, standards, and laws affecting child restraint systems in cars
- Side impact testing
- Child restraint interaction with passenger airbags

In the following sections of this paper, the most important of the work items of the group will be discussed in more detail.

RESULTS

COMPARISON OF REGULATIONS AND STANDARDS – Although the WG, as already mentioned, had decided not to duplicate existing standards, we have undertaken to assemble a document describing and comparing the various existing regulations and standards concerning child restraint systems today. This document was first presented at the second meeting and has been extended and revised ever since. The first version was published in December 1996 as ISO Technical Report, TR 13214, to be available to the child safety community also outside ISO. It is revised and updated continuously within the WG in order to incorporate changes in regulations and standards.

The document compares different aspects of safety regulations and standards applicable to children in cars. The document also has four appendices, containing the crash test deceleration pulses, the approval procedures for different countries/markets, the laws in different countries and finally a compilation of definitions from regulations and standards.

Status mid 2005:

ISO/TR 13214:1996, *Road vehicles – Child restraint systems – Compilation of safety regulations and standards*. This Technical Report, Type 3, was published in December 1996. The document has been revised to incorporate more recent changes in regulations and standards (current working document is WG 1 N 649). The document will be updated regarding the FMVSS, CMVSS and ECE regulations for universal CRS attachment systems.

REDUCTION OF MISUSE RISK – As mentioned before, misuse is a widely recognized problem, and the increased injury risk has been reported by several authors. One report from the USA estimates that the misuse rate is 50-75% (Petrucelli, 1986). Another report from the USA estimates that the injury-reducing effect of child restraints regarding fatal injuries decreases from 71 % for correct use to 44% for partial misuse. The corresponding decrease for serious injuries is from 67% to 48% (Kahane, 1986). A WG 1 ad-hoc group concerning misuse was formed in May 1990. The proposals described below have emerged from this group.

Definition of misuse – The WG has made an effort to define misuse. The first approach was to find the different types of misuse and to classify these. It was, however, found to be a very difficult task to find a common classification, as the type of misuse is very dependent upon the type of child restraint. The WG came to the conclusion that only an overall definition of

misuse was possible to achieve at this stage: *"Any deviation from the intended application and use which might reduce the protective performance of a child restraint system"*.

The following two work items are empirical methods for the evaluation of misuse risk.

Test methods for the evaluation of misuse risk: Panel method –

This method specifies the requirements and test methods for judging whether the user installed child restraints are correctly used (Bell, 1991). A panel of up to 200 adult participants is given the task of installing the child restraint to be evaluated. Two minutes are allowed for study of instructions, and five minutes for installation of the seat. After this, the supervisor records whether the child restraint was correctly installed. The requirement for approval uses the relation between correct and incorrect installations. The ISO Standard was published in November 1999.

Status mid 2005:

ISO 13215-2:1999, *Road vehicles – Reduction of misuse risk of child restraint systems – Part 2: Requirements and test procedure for correct installation (panel method)*. The ISO standard was published 1999-11-01. The standard was recently confirmed at its first 5-year review.

Test methods for the evaluation of misuse risk: MMEA, Misuse Mode and Effects Analysis – This method closely resembles the FMEA method widely used by the industry, where a team of experts evaluates the failure risk during the design phase of a product (Czernakowski, 1991). In FMEA, a Risk Priority Number (RPN) is derived by multiplying the judged occurrence, severity and detection of misuse. In MMEA, in a similar way, an RPN is obtained by multiplying occurrence and severity. Acceptance values for RPN for approval are proposed. The ISO standard was published in April 1999.

Status mid 2005:

ISO 13215-3:1999, *Road vehicles – Reduction of misuse risk of child restraint systems – Part 3: Misuse Mode and Effects Analysis (MMEA)*. The ISO standard was published on 1999-04-01. The standard was recently confirmed at its first 5-year review.

Instructions and labels – One possible reason for misuse is that the instructions and labels supplied with the child restraint systems are sometimes difficult to understand. They also differ from one child restraint system to another. The WG's approach to this is to develop a standard for symbols. This has proved to be a complicated task, and the WG has so far made an inquiry within the group concerning what should be included in labels.

A first proposal for several symbols was presented at the meeting in November 1992. These were evaluated by the members of the WG, in a clinic with over 3000 participants around the world. Very useful information came out of this study that has been used in e.g. the design of warning labels for airbag and CRS interaction.

However, regarding symbols directly generated by WG 1, the result is only one symbol, showing a generic child seat (with or without the text "ISOFIX"). The work has been handed over to the ISO working group for symbols applicable to vehicles, SC13/WG5.



Figure 1. ISO 2575 child seat symbols

Status mid 2005:

ISO/WD 13215-4, *Road vehicles – Reduction of misuse risk of child restraint systems – Part 4: Instructions and labels*. ISO 2575:2000 and Amendment 1 2001-03-15 have been published, including the following child restraint symbols and signs: Child seat prohibition, Generic child seat, Child seat lower anchorage/attachment (with or without the text "ISOFIX"), and Child seat upper tether anchor.

SC 12 has asked for a close communication and agreement between SC12/WG1 and SC13/WG5 on this subject.

The WG 1 work item on symbols will be maintained until it can be assured that no other activities within WG 1 (e.g., space classification, usability criteria) will generate a further need for instructions and labels.

Forms for collection of data from field studies of misuse – One approach of the WG is to develop a standardized form for misuse studies in actual traffic environment. One problem with such studies is that they are not performed in a similar way. Thus it might be difficult to compare the results of different studies. A standardized form for such studies was first proposed in September 1991. This document is close to being submitted for final voting. It has appeared very difficult and time consuming to complete the document so that it is representative of the different types of child restraints around the world.

Status mid 2005:

ISO/DIS 13215-1, *Road vehicles – Reduction of misuse risk of child restraint systems – Part 1: Forms for field studies of misuse*. The DIS voting ended 2004-04-20. The DIS was approved; Approval by 12 countries, disapproval from 1 country, comments from 3 countries. The comments have been treated by the secretariat, and a Final DIS version will be issued for voting.

ISOFIX - STANDARDIZED ATTACHMENT OF CRS TO VEHICLE –

At the meeting in May 1990, a report was presented concerning the installation in vehicles, listing problems in the interface between vehicle and child restraint systems. Problems were indicated regarding for example top tether non-use, harness and belt non-use, incorrect routing of belts, etc. Comments were also made about "oversized" child restraint systems, the position and design of attachment points, insufficient belt length, buckle positioning etc.

One important cause for misuse is that the attachment systems differ between different child restraint systems. Furthermore, for some child restraints, these systems are complicated and difficult to use. One apparent solution to this is a standardized attachment system, and this was chosen as the WG's main approach against misuse.

A decision was made to start work on separate attachment systems. It was also decided to try to improve the situation for existing attachment methods (see section "Adult belt length and anchorage point location" below).

At the meeting in November 1990, the first proposal for a standardized attachment system was presented. The proposal consisted of two attachment points in the vehicle seat in the intersection between the seat back and seat cushion. The name "ISOFIX" was proposed as a working name for these systems. Several applications were suggested, for rearward and forward facing child seats, for booster cushions and also for a pet box, a table, and a luggage container.

At a meeting in April 1991, the first two prototypes were presented, built into two different child seats and in two different cars.

At the following meetings, more prototypes were developed. An alternative solution, with a third attachment point in front of the seat cushion, was presented at the meeting in November 1991. The third point had the intention to improve the stability of the CRS.

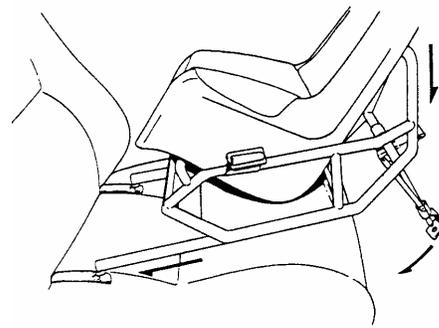
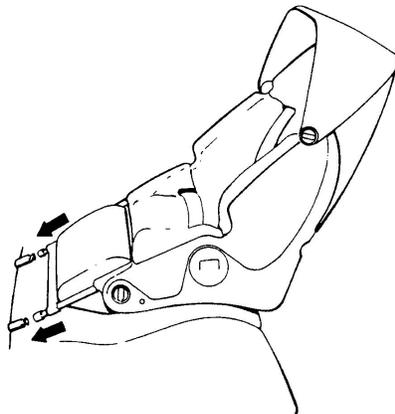


Figure 2. Principle of first prototypes Figure 3. Three-point principle

It was found that vehicle seats in general were not strong enough to support the third front centre attachment. The next step was to have two forward attachment points, giving in total four attachments. This concept was presented under the name UNIFIX.

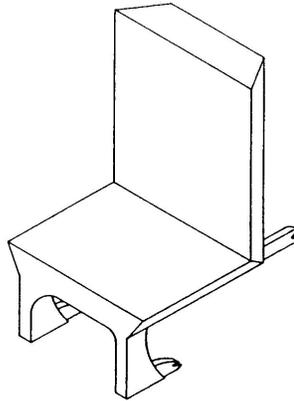


Figure 4. UNIFIX four-point principle

At the meeting in October 1992, a first outline of a specification was presented, based on a systematic evaluation of different principles. The specification was developed, and the four-point solution was chosen for the ISOFIX specification. The standard was developed gradually, and several difficult issues were discussed and solved.

At this stage, legislators in Europe and USA became interested in ISOFIX. It became apparent that ISOFIX might eventually become a legal requirement. This considerably increased the interest from some car manufacturers who had not been so involved before.

The four-point concept was opposed by some parties because of cost and complexity. An alternative concept was developed by General Motors and some US CRS manufacturers. This concept consisted of only two attachment points, but in contrast to the original two-point idea with a rigid connection between CRS and vehicle, the alternative solution had a flexible webbing and buckle type connection. It also had an upper tether, similar to the existing legal requirement in e.g. Canada. The concept was called UCRA, Universal Child Restraint Anchors.

A long and difficult discussion had started, and lasted for some years. In 1996, several petitions were sent to NHTSA, either for ISOFIX or UCRA. A first NPRM (Notice of Proposed Rulemaking) was published by NHTSA in February 1997. This was similar to the UCRA proposal.

In October 1997, NHTSA arranged a workshop regarding ISOFIX/UCRA. In April 1998, NHTSA arranged a user clinic in the USA, evaluating different concepts.

The ISOFIX standard was modified back to only two attachments, but in contrast to UCRA, the vehicle anchorages were rigid. The CRS attachments were also rigid, with the option to be flexible. A long debate whether or not to include the top tether or not took place in the ISO group. Eventually, it was decided to have a top tether specification in a separate part of the standard. The ISOFIX draft (lower anchorages/attachments) was sent for the first voting in January 1998.

During this time, the term LATCH, Lower Anchors and Tethers for Children, was given to the US version of ISOFIX, and has been used since then in USA.

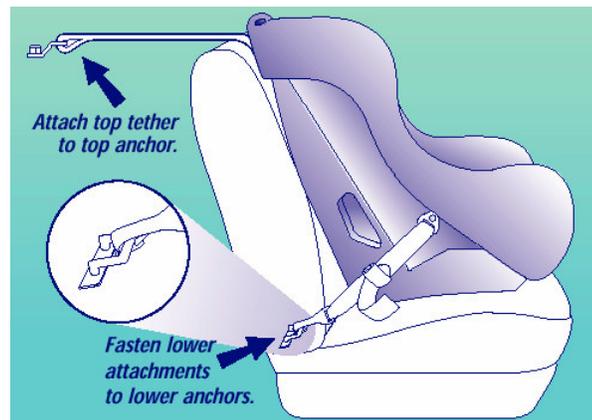


Figure 5 .The LATCH system (courtesy of NHTSA)

In February 1999, NHTSA published a Final Rule, with an amended version published in August 1999. In comparison with the NPRM, the final rule was considerably modified in the respect that the vehicle anchorages were rigid like in the ISOFIX standard. The CRS attachments were allowed to be either flexible or rigid. Top tether was also included in the requirement. A phase-in of the legal requirement between September 2000 and September 2002 was specified.

A similar, but not identical, legal requirement was introduced in Canada at about the same time. In Canada the acronym UAS is used (Universal Anchorage System).

During the development of the ISOFIX idea, several user evaluations were made. The first was made in 1992 in Sweden, using a panel of 46 parents (Berg, 1992). Three identical seats with different attachment systems were tested. The seats were ISOFIX in the original two-point version, the three-point version and a seat with conventional attachment. The results were overwhelmingly in favour of the ISOFIX system, both considering safety and ease of use. Of all participants, almost 90% were willing to change to the new system even at a substantial cost. Subsequent user clinics have had similar positive results.

and different concepts stages that the standard has evolved through, the difficulties in uniting all involved parties, the considerable opposition from parts of the car industry, and the simultaneous legislative process, it must be realised that such a complex process must take some time. It is afterwards easy to forget all these steps and difficulties.

It is the firm belief of the experts in WG 1, who were involved in the development that ISOFIX is a great step forward for child safety.

Status mid 2005 (several items related to ISOFIX):

ISO 13216-1:1999, *Road vehicles – Anchorages in vehicles and attachments to anchorages for child restraint systems – Part 1: Seat bight anchorages and attachments (ISOFIX)*. The standard was recently subjected to its first voting for the first 5-year review. SC 12 has agreed to a revision, taking into account the experiences since the publication.

ISO 13216-1:1999/DAM 1, *Road vehicles – Anchorages in vehicles and attachments to anchorages for child restraint systems – Part 1: Seat bight anchorages and attachments – Draft Amendment 1: CRF reduced height specifications*. The specification refers to the positioning fixture for seating positions that cannot accommodate the full-size CRF fixture. A second DIS was circulated with a target date of 2005-04-07. This document was unanimously approved.

ISO 13216-1:1999/DAM 2, *Road vehicles – Anchorages in vehicles and attachments to anchorages for child restraint systems – Part 1, Draft Amendment 2, Tolerance and co-linearity of the ISOFIX seat bight anchorages*. A revised version should be submitted for CD voting, following finalisation of new drawings.

ISO 13216-1:1999/DAM 3, *Road vehicles - Anchorages in vehicles and attachments to anchorages for child restraint systems – Part 1, Draft Amendment 3, Specifications for the detection of use of ISOFIX CRS in road vehicles*. The DIS version voting was closed on 2005-07-07. The DIS version was approved. Comments have been treated, and the FDIS version has been sent for initiation of the FDIS procedure.

ISO/FDIS 13216-2, *Road vehicles – Anchorages in vehicles and attachments to anchorages for child restraint systems – Part 2: Top tether anchorages and attachments*. The ISO standard was published in December 2004.

ISO/CD (DIS) 13216-3, *Road vehicles – Anchorages in vehicles and attachments to anchorages for child restraint systems – Part 3: Classification of child restraint dimensions and vehicle space*. The DIS version voting period was closed on 2005-05-30. The DIS was approved. Comments from the voting will be discussed at the WG1 meeting in November 2005. Following agreement of this issue, the standard will be sent for publication.

REPORT FORM FOR ACCIDENTS INVOLVING CHILD

PASSENGERS – The discussion of accident data was one of the first questions raised in the group. It was in some respects found to be difficult to compare accident studies made by different researchers. A proposal was made to develop a common form for field studies. This is one of the official work items of the group. A first proposal for a form was presented in May 1990. The ISO standard was published in August 1998. Unfortunately, it seems that the ISO standard is not very much used in accident studies.

Status mid 2005:

ISO 13218:1998, *Road vehicles – Child restraint systems – Report form for accidents involving child passengers*. The ISO standard was published on 1998-08-01, and was confirmed at its first 5-year review.

SIDE IMPACT TESTING – This item was on the agenda at the first meetings, but then rested until it was brought up again at the meeting in May 1992. At the following meeting in October 1992, it was reported that side impact is a common configuration in severe accidents with children. A

proposal for a test method was also reported (Tingvall, 1991). Side impact was considered to be an important work item and an ad-hoc group was formed under the leadership of Professor Langwieder. At the meeting in April 1993, the ad-hoc group reported, and it was decided to carry out further studies concerning accident data, possible counter-measures and test methods.

The ad-hoc group has since then developed a draft standard for side impact sled testing. The main target has been to reproduce the ECE full size side impact test. This is a 90° impact with a deformable barrier. The objective is to create a test that reliably and with repeatability tests the ability of a child restraint system to minimise injuries in lateral impacts.

The draft standard has been prepared on the basis of accident data. Therefore, the standard addresses the struck side impact conditions which from the research data are shown to be the conditions that in real accidents produce the majority of the fatalities and serious injuries.

The standard has been developed through a progression of tests from full-scale vehicle impacts, via double sled dynamic tests, to a single sled with a hinged door.

The data from the full size tests was in the first step replicated on two sled rigs in which one sled represents the struck vehicle and the second sled represents the striking vehicle and the intruding side structure. The data from this method was analysed and used to develop a close approximation of the side impact event on a single sled. In this procedure, the intruding side structure is represented by a pivoted door panel that is rotated in relation to the test seat at a relative velocity within a band of velocities measured in full scale tests. The movement represents the deformation of the inner side structure of the passenger compartment relative to the non-struck side of the vehicle.

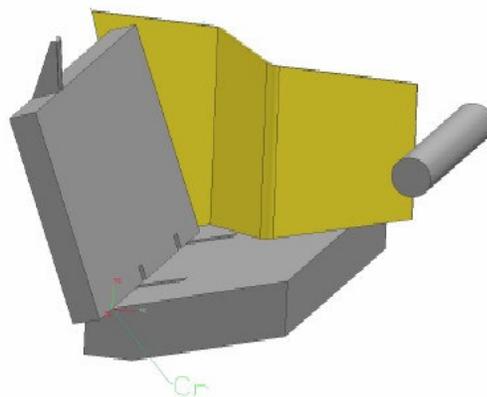


Figure 7. Side impact test rig

A major challenge has been to define the geometry of the pivoted door panel, and to define the motion of it. Great effort has been given to evaluate the proposed test method in real testing. A number of iterations have been

carried through, and was continued after the first voting carried out during 2001. The draft standard was submitted to DIS voting during autumn 2003.

In short, the test method consists of a sled moving at 25 km/h. As the sled is decelerated, the door swings inward to simulate the door intrusion. Two alternative hinge positions can be used, one forward of and one rear of the vehicle seat bench. The two hinge positions represent the respective worst case condition for forward facing and rearward facing CRS.

Status November 2005:

ISO/DIS 14646, Road vehicles – Side impact test method for child restraint systems

The DIS voting ended 2004-04-20, and the DIS was disapproved. The comments have been reviewed by WG 1 and by the side impact ad hoc group. Action items involve a further validation testing to confirm the parameters used in the method. Another action was to divide the standard in two parts, one for rear facing CRS and one for forward facing CRS. Due to ISO time restrictions, only the rear facing part was subject to the second DIS voting. The second DIS voting ended 2005-10-04 and the DIS was disapproved also this time. A decision how to go forward needs to be taken at the WG 1 meeting in November 2005. The document has to be published by ISO by April 2006 in order to avoid cancellation of the whole project. – For forward facing CRS, a draft has been prepared and is intended for later publication as an ISO Technical Specification. Also this part has to meet the ISO April 2006 deadline for publication.

CRS INTERACTION WITH AIRBAGS (I) – The interaction between passenger airbags and child restraint systems mounted in the front passenger seat is recognized by the group to be a serious problem. Several aspects of this problem were discussed. At the meeting in April 1993, an ad-hoc group was formed, and it was decided to ask TC 22 for an approval as an official work item. The ad-hoc group was asked to present recommendations to reduce the risk associated with the use of child restraints in vehicles with passenger airbags.

One effect of the group's work is that the WG's concern about the airbag and child restraint interaction problem was expressed in a resolution that was transmitted to ECE with the effect of an immediate change in Regulation 44 concerning warning labels for passenger airbags on child restraints (Turbell, 1993a).

Thanks to the work of another ISO group (SC 10/WG 3) two ISO Technical reports on evaluation of CRS interaction with airbags have been published; ISO/TR 14645 (Interaction with front airbags) and ISO/TR 14933 (Interaction with side airbags).

CRS INTERACTION WITH AIRBAGS (II) – A German initiative to bring an existing solution for airbag deactivation to ISO standardisation was approved as a new work item within ISO in May 2004. The work is carried out in a task force of WG 1, with the purpose to result in a future ISO standard no. 22239.

Status mid 2005:

ISO/NP 22239, *Road vehicles – Child seat presence and orientation detection (CPOD) system*. Result of NWI voting within ISO/TC 22 was in favour, with 5 actively participating countries. The task force has already had several meetings.

USABILITY

A task force on usability has been active for some time within WG 1. The objective is to develop methods and criteria for usability evaluation of child restraint systems and their interface with vehicle anchorage systems. The focus is on ISOFIX type systems.

The usability of a child restraint system in terms of ease of both correct installation and of day-to-day use is of utmost importance to ensure that a child restraint system is used in accordance with the manufacturer's intentions, and to ensure that it will provide a proper function in a crash situation. This refers to both a correct installation of child restraint systems in various vehicles with ISOFIX or LATCH attachments, and possibly also of the day-to-day use with a child (securing, harnessing, adaptation for a growing child, etc). An international agreement on usability criteria and measurements is also beneficial for consumers, as it provides guidelines for choosing an appropriate child restraint system, and also for manufacturers as a development tool.

The group is developing a usability evaluation form. The form has been refined in several steps. During this process, it has been evaluated in a number of clinics. This has proven to be a very powerful tool in developing the standard. Together with the form, a manual and a terminology list are also developed.

Hopefully, not so much work remains until the draft can be subject for the first voting within the ISO organization.

Status mid 2005:

ISO/NP xxxx *Road vehicles - Methods and criteria for usability evaluation of child restraint systems and their interface with vehicle anchorage systems*. The ad-hoc group on usability criteria for CRS has held several workshops and prepared a Working Draft. New versions of the rating forms, completed with a scoring system, manual and a terminology, are under development and evaluation at workshops. These are now compiled in a WD. Following agreement in WG 1, it will be sent for voting to make this an official ISO work item.

DISCUSSION

The WG has covered several aspects of child restraint systems in vehicles. The major part of the work is done in the area of misuse and compatibility, where few standards existed before.

The following projects are already finished and have been published:

- Compilation of regulations and standards (ISO/TR 13214)
- Requirements and testing procedures for correct installation (panel method) (ISO 13215-2)
- Misuse Mode and Effect Analysis (MMEA) (ISO 13215-3)
- Report form for accidents with children in vehicle (ISO 13218)
- Anchorages in vehicles and attachments to anchorages for child restraint systems - Part 1: Seat bight anchorages and attachments (ISOFIX) (ISO 13216-1)
- Anchorages in vehicles and attachments to anchorages for child restraint systems - Part 2: Top tether anchorages and attachments (ISO 13216-2)

The following are judged to be close to finalization:

- Anchorages in vehicles and attachments to anchorages for child restraint systems - Part 3: Classification of child restraint dimensions and vehicle space (ISO 13216-3)
- Forms for collection of data from field studies of misuse (ISO 13215-1)
- Side impact test method (ISO 14646)

Among the other work items presently developed by WG 1, the following are considered to be of great importance:

- Usability
- CPOD (ISO 22239)

Bringing together the knowledge and experience several experts in the child safety field has given positive results, and will hopefully continue to do so in the future. The findings in the group have had substantial effect outside of ISO. The most important example of this is the impact on legislation related to the ISOFIX standard.

It is our belief that the working group has, to a great extent, reached the goal set up in the scope already at the first meeting: "The aim of this working group should be international harmonization and standardization in the field of child restraint systems in passenger cars in order to improve safety for children in cars."

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