

Comparison between the EIHP Draft Regulations and the ISO Draft Standards on liquid hydrogen fuel tanks for land vehicles as well as the compilation of comments received on both documents. Discussed at the GRPE/ISO group of experts meeting on 29 July 2002 in Munich, Germany.

GRPE/ISO N 05

2002-07-29

EIHP Draft regulations: Uniform Provisions Concerning the Approval of : I Specific Components of Motor Vehicles Using Liquid Hydrogen; II. Vehicles with Regard to the Installation of Specific Components for the Use of Liquid Hydrogen. Rev. 11 dated 29 August 2001.

ISO/DIS 13985-1 Liquid hydrogen – Land vehicle fuel tanks – Part 1: Design, fabrication, inspection and testing (2001-07-31)

ISO/DIS 13985-2 Liquid hydrogen – Land vehicle fuel tanks – Part 2: Installation and maintenance (2001-07-31)

Replaces: Document GRPE/ISO N 02

Code ¹	Clause in EIHP draft regulation	Clause in ISO draft standards	Name of expert/ Organization	Comments	Proposed change	Observations on each comment submitted
C	General	General		Both documents are designed around a factor of safety of 3.0 with a proof factor of 1.3. It is unclear; however based on the comments below, if a vessel designed to the EIHP document would meet the requirements of the ISO standard and vice versa. In some instances the ISO document is more conservative and in some cases the EIHP document is more conservative. It is this reviewer's opinion that these differences must be rectified prior to either document moving forward. ISO/DIS 13985-1 also include requirements for inner tanks made of composite materials which are not covered in the EIHP draft regulations. A decision should be made as to whether there is a need for such inner tanks.		6.2.1 will be modified in order to make other materials possible. Maybe a need for further discussion
E	2.27		EIHP	Definition of "normal operating range" should be clearer	Replace example in the second half of the definition by (see diagram 1 at the end of definition)	MAWP to be added on the diagram

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E	2.41		EIHP	A diagram of the ranges will enhance the understanding	Add after 2.41: Diagram of ranges (example)	Move the diagram to 2.10. In 2.10, the design pressure is to be replaced by the maximum allowable working pressure (MAWP). The EIHP draft regulation definition for maximum working pressure is to be deleted. Change Maximum permissible operating pressure in the ISO draft standards to MAWP.
E	2.45					Isolation to be replaced by insulation in the EIHP draft regulations
C	4.3.1	ISO/DIS 13985-1, clause 7		There is no requirements for marking of the inner tank in ISO/DIS 13985-1.		The requirements of marking of the inner tank is to be limited to the serial number. All the other markings previously listed in the EIHP draft are to be marked on the outer jacket. The ISO draft standard is to be modified accordingly.
E	4.3.1		EIHP	Date of manufacturing is important not date of approval	Replace "Year and month of approval (e.g. 2000/01)" by "Year and month of manufacturing (e.g. 2000/01)"	Agreed

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C	4.3.2	ISO/DIS 13985-1, clause 7.1		The marking requirements in the EIHP draft regulations differ from the marking requirements in ISO/DIS 13985-1.		The allowed orientation of the tank in the car is to be added as a marking requirement (double check if there is a similar requirements in the gaseous draft) The EIHP draft requirements for markings are to be incorporated in the ISO standard.
C	6.1.2	ISO/DIS 13985-1, clause 4.2		There is no reference to the hydrogen compatibility test in ISO/DIS 13985-1.		The ISO standard is to be changed to incorporate the hydrogen compatibility requirement.
C	6.1.3	ISO/DIS 13985-1, clause 4.2		There is no reference to the toughness requirements of materials in contact with cryogenic temperature in ISO/DIS 13985-1. Comment: ISO/WI 21028-1 <i>Cryogenic vessels — Toughness requirements for materials at cryogenic temperature — Part 1: Temperature below -80 °C</i> is currently in development in ISO/TC 220.		The ISO draft standard is to be changed to include the EIHP draft requirements on toughness requirements. Bob Hay is to study the differences between the EN and the ISO/TC220 equivalent. If possible, EIHP will adopt the ISO standard.
E	6.1.3		EIHP	Typing error	Delete "NF" before EN 1252-1	Agreed
E	6.2.1		EIHP	Currently the whole draft is made for steel tanks. There are no requirements for composite tanks available. Therefore we propose to open the scope also to other materials but then in cooperation with the technical service	Add the sentence: "For Hydrogen container(s) made from other material than metals, annexes 7A-1 and 7A-2 to this Regulation have to be applied analogously."	

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	6.3.3					The ISO draft standard is to be changed to include the EIHP draft requirements on oxygen compatibility. Bob Hay is to study the differences between the EN and the ISO/TC220 equivalent. If possible, EIHP will adopt the ISO standard.
C	6.4.1.1	ISO/DIS 13985-1, clause 4.6.1.1.1		Ok ISO general requirements for pressure relief of the inner liner if it is metal. Only that the MPOP is established by manufacturer.		
E	6.4.1.1		EIHP	Inconsistency to definitions	Replace "...≤ 110% of the design pressure..." by "...≤ 100% of the design pressure..." and "...> 110% of the design pressure..." by "...> 100% of the design pressure..."	The normal operating range of the inner tank is between 0 MPa and the maximum allowable working pressure. The permissible fault range of the inner tank is between maximum allowable working pressure and 136% of MAWP for steel inner tanks. For other materials, an equivalent level of safety should be applied.
	6.4.1.2					
C	6.4.1.2	ISO/DIS 13985-1, clause 4.6.1.1.1		O.K.		

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E	6.4.1.2		EIHP	Inconsistency to definitions	Replace "...the maximum of the normal operating range..." by "...110% of the normal operating range.."	In the EIHP draft regulation, change that the primary pressure relief device for the inner tank shall limit the pressure within the tank to not more than "110 % of the maximum allowable working pressure" instead of "maximum of the normal operating range".
C	6.4.1.3	ISO/DIS 13985-1, clause 4.6.1.1.b		Difference. EIHP says secondary relief shall limit pressure within maximum permissible fault range which is not to exceed 90% of the yield strength of the vessel while ISO/DIS 13985-1 says no greater than 136% maximum permissible operating pressure. Depending on the materials selected and margins these could conflict.		It was agreed that 136% of MAWP for steel inner tanks should be used as the upper limit of the permissible fault range. <i>For other materials, an equivalent level of safety should be applied.</i>
C	6.4.1.3 6.4.1.5	ISO/DIS 13985-1, clause 4.6.1.1.a		Difference. EIHP says burst disc shall have sufficient safety margin for the inner tank, which according to 6.4.1.1 should not exceed 90% of the yield strength of the vessel. ISO/DIS 13985-1 specifies between 120% and 150% of maximum permissible operating pressure. Again, depending on materials selected and margins these could conflict.		It was agreed that the secondary pressure relief device shall operate not below 110% of the set pressure of the primary PRD and not more than 136% of the maximum allowable working pressure (to replace 6.4.1.3 of the EIHP draft regulations) 6.4.1.5 of the EIHP draft regulation is to be deleted. 4.6.1.1.1 of the ISO standard is to be revised accordingly.
C	14.3.1	ISO/DIS 13985-1, clause 4.4.2		O. K.		

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C	14.3.1	ISO/DIS 13985-2		The EIHP documents specifically disallows the placement of the tank in the engine compartment of an internal combustion engine. There is no specific restriction in ISO/DIS 13985-2.		It was agreed that the tank could be placed in the engine compartment.
E	14.3.1		EIHP	There is no need to forbid container installation in engine compartment	Delete "It shall not be installed in the internal combustion engine department"	It was agreed that the tank could be placed in the engine compartment.
C	14.3.2			No corresponding ISO statement.		Check the wording for clarity. This cannot be integrated in the ISO standard on the fuel tank.
C	14.3.3	ISO/DIS 13985-2, clause 4.1		O.K. ISO/DIS 13985-2 seems to cover this.		
C	14.3.4	ISO/DIS 13985-2, clause 4.1		The accelerations to which the fuel tank will be submitted are different. The EIHP draft regulations also include different requirements based on the category of vehicles.		The accelerations will be included in the ISO standards. If there are North American categories for cars, they will be integrated as well. (Elizabeth Pfeiffer is to look into this)
C	14.3.5			No comment without documents referenced in EIHP.		The reference to the EC directives in the EIHP draft regulations is to be deleted. There is no need to include this requirement in the ISO standard.

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C	14.4.2	ISO/DIS 13985-2 clause 4.2		ISO/DIS 13985-2 does not specify rollover protection. ISO/DIS 13985-2 does specify relief at 120% with reset pressure defined. The Annex 7B requirement in the EIHP document which references Paragraph 6,4.2 of the EIHP document requires also a 120% setting but has no reset requirement.		In the EIHP draft regulation, the example (e.g. vehicle rolling over) is to be removed. The reset requirement should be covered in EN 13648 Part 1 (see the reference in Annex 7B). ISO is to look if there is an ISO equivalent for this EN standard so that this reference can also be included in the ISO standard. If there is an ISO equivalent, the EIHP draft regulations could refer to it as well.
C	14.4.1	ISO/DIS 13985-2, clause 14.5.2 and 14.5.3		ISO/DIS 13985-2 specifies only a single automatic shut-off valve between the tank and the remainder of the vehicle system while the EIHP document requires multiple normally closed valves to protect the system. The EIHP document could allow for a valve to be placed in-between the tank and the relief vent. The EIHP document does not address check valves (non-return valves).		The ISO draft standard is to be revised to reflect the EIHP draft regulations requirements. The EIHP draft regulations do not allow the valve to be placed between the tank and the relief vent and address check valves. (see 6.5.1, 6.5.2, 14.4.2.12 and 14.4.1.2) No change required.
C	14.5	ISO/DIS 13985-2, Clause 4.4		ISO/DIS 13985-2 specifies piping strengths while the EIHP document does not. ISO/DIS 13985-2 specifies that vacuum-jacketed or insulated lines to prevent heat soak while the EIHP document tends to concern itself with structural rigidity and mounting issues.		6.3 of the EIHP draft regulations already cover these issues. No change required.

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E	14.8.2		EIHP	Hazardous zone 1 according to IEC 60079-10 will limit the possible solutions. In IEC 60079-10 it is foreseen to evaluate of the actual situation and according to the results different measures are allowed. This is common practice and should therefore be the same in an ECE regulation.	Replace in the first sentence "applicable for the hazardous zone 1" by "evaluated" and add at the end of the first sentence "if applicable".	
C	14.9	ISO/DIS 13985-2, Clause 4.9		No differences.		
E	14.9.1.		EIHP	A boil off management system should be mandatory according to the discussion in the ad hoc working group on 19.2.2002	Delete "...vent off in a safe way or shall be..."	
E	14.9.2.		EIHP	A boil off management system should be mandatory according to the discussion in the ad hoc working group on 19.2.2002	Delete "If present the boil off system and.."	
E	14.9.4		EIHP	A boil off management system should be mandatory according to the discussion in the ad hoc working group on 19.2.2002	Delete whole paragraph	
C	14.15	ISO/DIS 13985-2, clause 6.3		More stringent than ISO/DIS 13985-2. ISO may want to consider adoption of more specific language.		
E	14.15		EIHP	The frequency of periodic inspections is differing from country to country as well as from vehicle category to vehicle category	Change "at least every 36 month" into "at a frequency in accordance with national requirements"	

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C	Annex 7A-1 2.2.1.1	ISO/DIS 13985-1, clause 5		Difference. EIHP specifies a mechanical stresses at $1.3x(P_{design} + 0.1 \text{ Mpa})$, control of materials, and testing per Annex 7A – 2. ISO/DIS 13985-1, clause 4.3.2 specifies a 4:1 factor of safety in design of the inner vessel (25% of UTS in any plane normal to the wall). ISO/DIS 13985-1 specifies qualification test including pressure cycling tests and burst tests. The test requirements in the ISO document are much more involved and would tend to lead to a more conservative design. In particular the ISO document addresses impact damage to the vessel which is not addressed in the EIHP document.		It was agreed that the ISO draft standard would be changed to use the EIHP draft regulation approach. This approach is also being used by ISO/TC 220 in their draft standards. In the EIHP draft regulation, P_{design} is to be replaced by MAWP. $P_{test} = 1,3 (MAWP + 0,1)$ The pressure cycling test is to be removed from the ISO draft standard. Impact test could not be found in the ISO draft standard.
E	Annex 7A-1, 2.2.2.1		EIHP	If outer jacket has an additional safety device, it shall be allowed that the outer jacket is designed according to the set pressure of these additional safety device.	Delete “..but at least 0.05 MPa” at the end of the sentence.	
C	Annex 7A-1 2.2.2.2	ISO/DIS 13985-1, clause 4..4.3		Difference. EIHP specifies resisting an outer pressure of 0.1 MPa. ISO/DIS 13985-1 specifies a minimum collapsing pressure of 200 kPa differential pressure.		
C	Annex 7A-1 2.2.3	ISO/DIS 13985-2		There is no requirements for the outer supports in ISO/DIS 13985-2.		
C	Annex 7A-1 2.2.4	ISO/DIS 13985-2		There is no requirements for the inner supports in ISO/DIS 13985-2.		

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E	Annex 7A-1, 2.2.4 and 2.2.5		EIHP	The performance of the outer supports can be also proofed by crash tests	Renumber 2.2.4.2 into 2.2.5, 2.2.4.1 is now 2.2.4, renumber 2.2.5 into 2.2.6 Change in 2.2.5 (new) "2.2.4.1" into "2.2.3 and 2.2.4"	
C	Annex 7A-1 2.3			No equivalent ISO specification for EIHP "Design temperature". In addition the design temperature as specified is in conflict with the specification temperature in clause 14.1.7 of the EIHP draft regulation.		
C	Annex 7A-1 2.4.1 and 2.4.2	ISO/DIS 13985-1, clause 4.4.2		Ok. EIHP "Chemical compatibility" is similar to ISO/DIS 13985-1.		
C	Annex 7A-1 2.4.3	ISO/DIS 13985-1, clause 4.2		There is no requirement for the compatibility of materials with atmosphere enriched with oxygen in ISO/DIS 13985-1. Comment: ISO/WI 21010 <i>Cryogenic vessels — Gas/material compatibility</i> is currently in development in ISO/TC 220.		
C	Annex 7A-1 3.1-3.3	ISO/DIS 13985-1, clause 4.4.2		Ok. EIHP "Materials" is similar to ISO/DIS 13985-1.		
C	Annex 7A-1 3.4	ISO/DIS 13985-1		There is no reference to the toughness requirements of materials in contact with cryogenic temperature in ISO/DIS 13985-1. I Comment: ISO/WI 21028-1 <i>Cryogenic vessels — Toughness requirements for materials at cryogenic temperature — Part 1: Temperature below -80 °C</i> is currently in development in ISO/TC 220.		

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C	Annex 7A-1 4.	ISO/DIS 13985-1, clause 6		Difference. Manufacturing and mounting of the Container. EIHP specifies in 4.1 appropriate equipment, manufacturing equipment, certified personnel, a manufacturing and inspection plan, quality assurance with traceability of parts and materials. 4.7 calls out inspection and testing of containers per Annex 7-2. Annex 7-2 is design validation by calculation and manufacturing operations per prEN 1251-2 “Cryogenic vessels – Transportable vacuum insulated vessels of not more than 1000 liters volume – Part 2 Design Fabrication and Testing”. While we don’t have this specification to examine, we did have ISO/CD 21029-1 with the same title. The ISO document, ISO/CD 21029-1 does specify batch tests with radiographic inspection but the protocol and the criteria appear different from what ISO/DIS 13985-1 specifies. ISO/DIS 13985-1 gives specific instructions on non-destructive testing of batch lots using radiographic, ultrasonic or acoustic means. Void size specifications are given.		
C	Annex 7A-1 5.2.3 Annex 8A 2	ISO/DIS 13985-1, Clause 4.5		The EIHP document in paragraph 5.2.3 requires a 15 minute fire resistance test while the ISO/DIS 13985-2 requires a 30 minute fire exposure test. The EIHP requires a 24 hour holding time at 20 °C for insulation while the ISO/DIS 13985-2 requires a time specified by the manufacturer (marked holding time) at 65 °C.		It was agreed that ISO would change its requirements to reflect the EIHP draft regulations requirements. Paragraph 5.2.1 is to be removed from the EIHP draft regulations. The requirements on the rated holding time is to be removed from ISO draft standard.

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E	Annex 7A-1, 5.2.3		EIHP	Thermal autonomy should be 5 minutes (see also comments to Annex 8A, 2.2.4.4)	Change "15 minutes" into "5 minutes"	
C	Annex 7A-1 6.	ISO/DIS 13985-1, clause 6		Difference. EIHP "Tests and Inspection" specifies a pressure test to 1.3x(Pdesign + 0.1 Mpa) by hydraulic or other means. Verification tests include a 10% He fluid leak tests, verification of inner vessel dimensions, visual inspection, and Destructive and non-destructive tests of welding seams per 7A-2. ISO/DIS 13985-1 gives specific instructions on non-destructive testing of batch lots using radiographic, ultrasonic or acoustic means. Void size specifications are given. The comparison should be made in more detail; however, this effort has been delayed. Additional comments are to be provided as soon as possible.		
E	Annex 7A-1, 6.1		EIHP	The reference to paragraphs should be corrected	For the approval samples of the container shall be subjected to the tests according to 6.3.7 to 6.3.10 of this annex and shall be witnessed by the Technical Service. A crash test according to 6.3.11 shall be....	
E	Annex 7A-1, 6.3.8		EIHP	Head line should be corrected in order to be in line with annex 8A	Thermal autonomy test under fire	
E	Annex 7A-1, 6.3.9		EIHP	Head line should be corrected in order to be in line with annex 8A	Thermal autonomy test during normal operation	
C	Annex 7A-1 7	ISO/DIS 13985-1		There is no equivalent requirements in ISO/DIS 13985-1.		

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ISO/DIS 13985-1 Liquid hydrogen – Land vehicle fuel tanks – Part 1: Design, fabrication, inspection and testing (2001-07-31)

ISO/DIS 13985-2 Liquid hydrogen – Land vehicle fuel tanks – Part 2: Installation and maintenance (2001-07-31)

Replaces: Document GRPE/ISO N 02

Code ¹	Clause in EIHP draft regulation	Clause in ISO draft standards	Name of expert/ Organization	Comments	Proposed change	Observations on each comment submitted
C	Annex 7A-2			The comparison should be made with the applicable parts of ISO/CD 21029-1 <i>Cryogenic vessels — Transportable vacuum insulated vessels of no more 1000 l volume - Part 1: Design, fabrication, inspection and testing</i> currently in development in ISO/TC 220. However, this comparison is a fairly extensive effort. It will be performed as soon as possible. .		
E	Annex 7A-2		EIHP	prEN 1251-2 is now published as EN 1251-2	Replace "prEN 1251-2" by "EN 1251-2" and "3/1999" by "3/2000"	
C	Annex 7B	ISO/DIS 13985-1, Clause 4.6.1		The reference pressure for the two documents is different. The ISO/DIS 13985-1 document references the maximum permissible operating pressure while the EIHP document references the maximum working pressure. ISO/DIS 13985-1 allows the primary relief to be 110% of the maximum permissible operating pressure while the EIHP document requires that it not be greater than the maximum working pressure. The set pressures for the secondary relief are not specified in the EIHP document and the flow capacities are not specified.		
E	Annex 7B, 1		EIHP	Issue dates are missing	Add "11/2001" at the end of both referenced standards	
E	Annex 7B, 4.2		EIHP	It should be aligned with 6.4.1.1	Change "yield strength" into "90% of the yield strength"	
C	Annex 7C	ISO/DIS 13985-1 Clause 4.6.4		The EIHP document calls out specific test procedures for valves while the ISO/DIS 13985-1 document only specifies a single leakage test.		
E	Annex 7C, 1		EIHP	PrEN is now released	Delete "pr" add at the end "from 03/1999"	

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Replaces: Document GRPE/ISO N 02

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E	Annex 7E, 1		EIHP	Issue date is missing	Add at the end "from 12/2001"	
C	Annex 7F	ISO/DIS 13985-1		We could not find a parallel requirement in the ISO/DIS 13985-1 or –2 documents.		
E	Annex 7H, 1		EIHP	Issue date is missing	Add at the end "including amendment AC from 02/2001"	
C	Annex 8A 1.	ISO/DIS 13985-1, clause 5.4		<p>Difference. EIHP "Inner tank burst test" specifies a hydraulic water test to destruction as follows: Either: 3.25x (maximum working pressure + 0.1 Mpa) or 1.5 x Rm/Rp (maximum working pressure + 0.1 Mpa) Where Rm=minimum ultimate tensile strength and Rp=minimum yield strength There is no differentiation between possible liner types. However ISO/DIS 13985-1 specifies for different liner types:</p> <ul style="list-style-type: none"> • Welded metallic inner vessels: 3 x max possible permissible operating pressure • Seamless steel inner vessels: 2.25 x max possible permissible operating pressure • Glass: 3.65 x max possible permissible operating pressure • Aramid: 3.1 x max possible permissible operating pressure • Carbon: 2.35 x max possible permissible operating pressure <p>EIHP document has no section with the text equivalent to ISO/DIS 13985-1, clause 5 that specifies pressure cycling tests as part of the approval for a new design.</p>		

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Replaces: Document GRPE/ISO N 02

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C	Annex 8A 2.	ISO/DIS 13985-1, clause 5.5		Difference. EIHP Thermal autonomy under fire is less stringent. EIHP: 15 minutes under fire (at least 650 C) not to exceed 1.1 x the maximum working pressure ISO/DIS 13985-1: 30 minutes under fire (at least 900 C) not to exceed 1.2 x the maximum working pressure.		It was agreed that 1,36 of the MAWP is to be used in both the EIHP draft regulations and the ISO draft standard. The EIHP draft regulation temperature requirements are to be included in the ISO draft standard.
E	Annex 8A, 2.1.1.		EIHP	15 minutes for the thermal autonomy under fire is too long. Remark: a conventional fuel tank is 2 minutes exposed to fire according to ECE R 34.	Replace "...be greater than 15 minutes.." by "...not less than 5 minutes.."	
E	Annex 8A, 2.1.2		EIHP	Criteria is missing for safety against bursting	Add at the end "...and the tank must not burst."	
E	Annex 8A, 2.2.4.1		EIHP	Inconsistency in the requirement	Replace text of the paragraph by: "The tank is filled with liquid hydrogen so that the quantity of liquid hydrogen measured by the mass measurement system shall be half of the maximum allowed quantity that may be contained in the inner vessel."	
E	Annex 8A, 2.2.4.4		EIHP	15 minutes for the thermal autonomy under fire is too long. Remark: a conventional fuel tank is 2 minutes exposed to fire according to ECE R 34. The second sentence is not necessary	Replace "15 minutes" by "5 minutes". Delete second sentence.	
E	Annex 8A, 2.2.4.5		EIHP	It is not necessary to measure the pressure	Delete "...and the pressure in the tank is fallen to 0,01MPa.."	
E	Annex 8A, 2.2.4.5		EIHP	Criteria is missing for safety against bursting	Add at the end "...and the tank must not burst."	

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C	Annex 8A 3.	ISO/DIS 13985-1, clause 5.6		Difference. EIHP Thermal autonomy during normal operation is specified for 24 hours before a safety device is opened. ISO defines this as "holding time" and does not specify a time, but a procedure for measuring the time. ISO conditions are more stringent with a test temperature of 65 C as opposed to the EIHP temperature of 20 C.		
C	Annex 8A 4.	ISO/DIS 13985-1		There is no equivalent requirement in ISO/DIS 13985-1.		
E	Annex 8B, 7.1		EIHP	Leakage test is not applicable for all components	Add after 3 and 4 above "..., if applicable.."	
E	Annex 8B, 10.		EIHP	Wrong reference to tests	Replace "...paragraphs 5,6 and 7.." by "...paragraphs 3 and 4..."	

Acknowledgements: The comparison of the EIHP draft regulation and the ISO draft standard was performed with the help of Mr. Stephen S. Woods, Honeywell Technology Solutions Inc. at White Sands Test Facility and Mr. Harold Beeson, NASA White Sands Test Facility in cooperation with the ISO/TC 197 Secretariat. We would like to thank them for their contribution to this work.

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