SLOVENSKI STANDARD
SIST-TP CEN/TR 16148:2011

01-junij-2011

Merila za določanje poškodbe glave in vratu, ki nastanejo zaradi udarca, opekline ali hrupa - Vodilo za odbore CEN, ki pripravljajo standarde za čelade

Head and neck impact, burn and noise injury criteria - A Guide for CEN helmet standards committees

Kriterien für Verletzungen durch Einwirkung auf Kopf und Hals, Verbrennungen und Lärmverletzungen - Leitfaden für Arbeitsgruppen, die europäische Helmnormen erarbeiten

Ta slovenski standard je istoveten z: **CEN/TR 16148:2011**

ICS:

01.120	Standardizacija. Splošna pravila	Standardization. General rules
13.340.20	Varovalna oprema za glavo	Head protective equipment

SIST-TP CEN/TR 16148:2011 **en,fr,de**

TECHNICAL REPORT

RAPPORT TECHNIQUE

TECHNISCHER BERICHT

CEN/TR 16148

March 2011

ICS 13.340.20

English Version

Head and neck impact, burn and noise injury criteria - A Guide for CEN helmet standards committees

Critères relatifs au traumatisme cervico-facial et aux lésions dues aux brûlures et au bruit - Guide destiné aux comités des normes sur les casques de protection du CEN

Kriterien für Verletzungen durch Einwirkung auf Kopf und Hals, Verbrennungen und Lärmverletzungen - Leitfaden für Arbeitsgruppen, die europäische Helmnormen erarbeiten

This Technical Report was approved by CEN on 27 December 2010. It has been drawn up by the Technical Committee CEN/TC 158.

CEN members are the national standards bodies of Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

Management Centre: Avenue Marnix 17, B-1000 Brussels

Ref. No. CEN/TR 16148:2011: E

Contents

Foreword

This document (CEN/TR 16148:2011) has been prepared by Technical Committee CEN/TC 158 “Head protection”, the secretariat of which is held by BSI.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

Introduction

Members of helmet Standards committees frequently need to define limits for test procedures. Such limits relate to test values that indicate the potential for injury and yet it is often difficult for members to know the type and severity of injury that is represented by a given test value. Over the years, criteria have been developed for different body regions and usually these have been derived from a combination of accident and casualty data, and tests on cadavers, cadaver body parts, animals and human volunteers. However, such criteria are often used by the automotive industry as pass/fail values without a clear understanding of human tolerance to injurious forces. This sometimes leads to the mistaken belief that any value below the stated limit implies uninjured and all values above imply a serious or fatal injury.

This misconception gives very little freedom to choose values that are different from the often inappropriate automotive value. This is particularly true for head injury criteria for which values for a helmeted head may be different to those for the unhelmeted head. Many accidents to wearers of helmets, which cover a wide range of activities from horse riding to downhill skiing, result in a closed head injury. This is when the brain is damaged without any skull or external tissue damage. Conversely, head injuries in automotive accidents are much more frequently open head injuries with skull fracture and soft tissue lesions.

Other misconceptions arise because of the failure to understand that human response to a given dose or injurious parameter varies across a range of the population. The dose response curve tends to be "S" (sigmoid) shaped such that as the magnitude of the injurious parameter increases so does the percent of the population that sustains an injury of a given severity. Thus, a family of "S" curves can be generated for a range of injury severity such as AIS and a measurement or criterion such as HIC, the Head Injury Criterion. Unfortunately, the data for such an analysis is generally difficult to obtain because measurements generated by test apparatus do not relate directly to injury severity because a headform for example does not respond in an impact like a human head. Hence, it is necessary to find a relationship between these test measurements and injury severity.

This paper is designed to provide information to convenors that will help in choosing test limits in relation to a particular injury type and severity. It is worth noting that accident investigators use a scale known as the Abbreviated Injury Scale, AIS (AAAM). This was developed (in the USA) so that injury severity could be recorded in databases regardless of the body region and type of injury thus avoiding lengthy medical terms that were unfamiliar and difficult to interpret. This paper begins by reviewing the AIS scale and its application to head and neck injuries and burn injuries. Thereafter, each measurement type is reviewed and the severity of injury for given values is identified where possible. A section on burn injuries and fatigue related to heat exposure has been included to assist with Standards for equipment to protect firefighters. The Appendix describes the skin structure and the category and consequence of burn injuries.

Premature deafness because of high noise levels and the converse problem of over attenuation of auditory warnings was also considered. Suggested levels have been included with details of test methods in Annex A.

1 Abbreviated injury scale, AIS

This is a scale that extends from 0 to 6 where 0 is uninjured and 6 is unsurviveable. Each level can be applied to any body region according to a coding manual developed by the Association for the Advancement of Automotive Medicine (AAAM). Tables 1 and 2 give the scale and injury severity and an indication of the head and neck injuries that would be classified at each level. Table 3 gives similar information for burn injuries by degree, surface area and region of the body.

Table 1 — AIS scale with head injury severity

	AIS 0 uninjured	AIS 1 minor	AIS 2 slight	AIS 3 moderate	AIS 4 serious	AIS 5 severe	AIS 6 unsurviveable
Scalp							
superficial abrasions, contusions, lacerations		X					
major laceration or minor blood loss			X				
blood loss >20% or total scalp loss				X			
Intracranial vessels (arteries)							
laceration					X	X	
Cranial nerves							
contusion, laceration, loss of function			X				
Brain							
swelling, contusions, haemorrhage				X			
haematoma, large >15cc contusion					X		
massive >30cc contusions, diffuse axonal injury, large haematoma						X	
crush, penetrating injury							X
Loss of consciousness							
< 1 hour			X				
1 - 6 hours or < 1 hour with neurological deficit				X			
6 – 24 hours, or 1-6 hours with neurological deficit					X		
> 24 hours, or 6-24 hours with neurological deficit						X	
Skull Fracture							
simple			X				
compound				X			
complex, open, loss of brain tissue					X		

Table 2 — AIS scale with neck injury severity

	AIS 0 uninjured	AIS 1 minor	AIS 2 slight	AIS 3 moderate	AIS 4 serious	AIS 5 severe	AIS 6 unsurviveable
Whole area							
Skin							
superficial abrasions, contusions, lacerations		X					
major laceration or minor blood loss			X				
blood loss >20%				X			
Decapitation							X
Vessels (arteries)							
carotid, jugular and vertebral laceration minor			X				
carotid jugular and vertebral laceration major				X			
Nerves							
vagus injury		X					
phrenic injury			X				
Spine							
hyoid fracture			X				
cord contusion				X			
incomplete cord syndrome					X		
complete cord syndrome or laceration C-4 or below						X	
complete cord syndrome or laceration C-3 or above							X
disc injury without nerve root damage			X				
disc injury with nerve root damage				X			

Table 3 — AIS scale with burn injury severity

	AIS 0 uninjured	AIS 1 minor	AIS2 slight	AIS 3 moderate	AIS 4 serious	AIS 5 severe	AIS 6 unsurviveable
1st degree							
unspecified		X					
2nd degree							
< 10% TBS (Total Body Surface)		X					
3rd degree							
< 10% TBS			X				
< 10% TBS with face, hand or genitalia involvement				X			
2nd or 3rd degree							
10% to 19% TBS			X				
10% to 19% TBS with face, hand or genitalia involvement				X			
20% to 29% TBS				X			
20% to 29% TBS with face, hand or genitalia involvement					X		
30% to 39% TBS					X		
30% to 39% TBS with face, hand or genitalia involvement						X	
40% to 89% TBS						X	
≥ 90%							X
TBS = Total Body Surface							

2 Peak linear acceleration (A.3.1 & A.4)

This is the most frequently used parameter in helmet testing and is derived usually from a tri-axial accelerometer mounted in the headform unless the headform is rigidly supported and then the source is a single axis accelerometer. In both types, the helmet is mounted onto the headform and then the apparatus allowed to fall unimpeded onto a rigid anvil.

Table 4 is a scale published by Newman (1980) and is supported by research that is more recent.

Table 4 — Peak acceleration and typical AIS Equivalent

Peak Acceleration	AIS
< 50 g	AIS 0
50 g – 100 g	AIS 1
100 g – 150 g	AIS 2
150 g – 200 g	AIS 3
200 g – 250 g	AIS 4
250 g – 300 g	AIS 5
> 300 g	AIS 6

Although not specifically stated in the original research paper it should be considered that the above values represent 50th percentile, which means that 50 percent of the population would sustain an injury of a given AIS severity for the corresponding range of acceleration. It is interesting to note that historically, values have been set which correspond to AIS 5 and that this has resulted in helmets that have given reasonable protection.

In some standards, the helmet is mounted onto a fixed headform and then a mass is dropped onto the helmet. Values given in Table 4 may be used with caution provided the falling mass is approximately 5 kg and the headform is attached to an appropriate neck. Replacing the fixed headform test by a falling headform, guided or free-fall, should be considered.

3 Head injury criterion HIC (A.4)

Annex A gives details of the derivation of HIC and the formula is given below.

$$HIC = \left[\left(\frac{1}{t_2 - t_1} \cdot \int_{t_1}^{t_2} a_{res} dt \right)^{2,5} \cdot (t_2 - t_1) \right]_{max}$$

The benefit of HIC over peak linear acceleration is that HIC is related to time and it is known that pulses with the same peak value but different duration can give a different injury outcome. Unfortunately, HIC and AIS values have never been satisfactorily correlated. Although, recent research (COST 327) has provided tentative values for AIS 2 and AIS 3, see below. Nevertheless, researchers have provided an assessment of the probability of death for HIC ranges. A summary of the various findings is given in Table 5.

Table 5 — Probability of death for HIC ranges

HIC	Probability of death	AIS (where known)
1000	10 % - 15 %	2
1500	35 %	3
2000	35 % - 50 %	
3000	55 %	
4000	60 % - 65 %	

It should be noted that where a range is given, this is indicative of more than one source. It should also be noted that HIC is derived from the GSI (Gadd Severity Index) (see A.4.2) used in some Standards. GSI and HIC are potentially interchangeable but only for regular pulse shapes. Therefore, it is recommended that GSI be replaced by HIC.

4 Rotational motion (A.2.6, A.3.2 & A.4.3)

4.1 Peak Rotational Acceleration

This is a parameter that is known to contribute substantially to brain injury but the relationship with injury is difficult to quantify. It is also a parameter that is considered by test authorities to be difficult to measure because it requires a nine-accelerometer array in the headform and complex interpretation. Nevertheless, the research shows, Table 6, that concussion AIS 1-2 can occur at 5 000 rad/sec^2 and fatal injury AIS 5-6 can potentially occur at 10 000 rad/sec^2. This correlates with data that indicates that there is a 35 % risk of a brain injury of AIS 3 - 6 at 10 000 rad/sec^2.

Table 6 — Probability of brain injury

Peak rotational acceleration	AIS	Probability of injury
5 000 rad/s^2	1 - 2	
10 000 rad/s^2	3 - 6	35 %

4.2 Tangential force at the helmet surface

This parameter is measured in motorcycle helmet Standards BS 6658 and Regulation.22-05. It is not directly related to rotational acceleration at the centre of a headform but is a function of helmet geometry. Thus, the following information in Table 7 which was obtained from motorcycle accident reconstruction data needs to be interpreted with care.

Table 7 — Injury related to peak tangential force on a motorcycle helmet

Peak tangential force	AIS	Probability of injury
1 000 N	1	-
2 000 N	2	-
3 500 N (Reg 22-05)	3	< 50 %
4 000 N	3	50 %
7 000 N	4	-

5 Skull crushing and penetration force (A.2.2 & A.3.3)

5.1 Crushing force

Resistance to crushing and a means of measuring the crush force transmitted to the skull are frequently discussed in helmet Standards committees. Below in Table 8 is a dynamic force that is typically required to fracture the facial bones and the skull. The information is from different sources hence the range and suggested tolerance values.

Table 8 — Typical fracture forces

Bone	Fracture Force Range (N)	Mean Tolerance Value (N)
Zygoma	614 - 3 470	1 000
Zygomatic arch	925 - 2 110	1 500
Maxilla	623 - 1 980	900
Mandible centre	1 890 - 4 110	3 000
Mandible lateral	818 - 3 405	1 900
Mandible midbody	1 290 - 1 445	NA
Skull tempero parietal (rigid impactor) dynamic tests	4 670 - 14 950	8 500
Skull tempero parietal (rigid impactor) static tests	3 430 - 7 830	5 070
Frontal static rigid	3 910 - 11 790	6 360
Frontal dynamic rigid	5 420 - 7 870	6 400
Frontal dynamic padded	5 340 - 15 100	11 260

The above results show that the force required to crush a human skull varies. However, analysis indicated that when the skull was crushed between two rigid plates the value was typically 5 000 N, and 10 000 N when the plates were lined with energy absorbing material such as is used for helmet liners. Hence a limit of 10 000 N is suggested for a helmet type fitted with an energy absorbing liner and 5 000 N for a helmet type that comprises a hard shell without an energy absorbing liner.

5.2 Penetration force

Assessment of resistance to penetration is included in a number of Standards. The following values are based upon an impactor with a flat circular plate 25,4 mm diameter. This may not be representative of a typical object causing a penetration injury but it is helpful information.

Skull region	Fracture force range (N)	Mean tolerance value (N)
Tempero parietal	2 500 – 10 000	5 200

6 Neck injury

Neck injury potential is assessed against shear, tension and extension (and sometimes compression) measured using transducers in a dummy neck. Cumulative plots of these values against time are required because injury potential is also a function of time. The following values (except compression) represent a greater than 50 % probability of a neck injury of AIS ≥ 3 (Hobbs *et al* 1999). Compression is based upon values given by Yamada (1970).

Shear	3,1 kN	1,5 kN for 25 ms to 35 ms	1,1kN for 45 ms or greater
Tension	3,3 kN	2,9 kN for 35 ms to 59 ms	1,1 kN for 60 ms or greater
Extension	57 Nm		
Compression	3,7 kN		

7 Noise (Appendix section A5.0)

Details of potential test methods to evaluate helmet noise attenuation to prevent premature deafness without over attenuation of auditory warning signals are given in Annex A, A 5.

For the purposes of the European Directive 2003/10/EC the exposure limit values and exposure action values in respect of daily noise exposure levels and peak sound pressures are fixed at:

a) exposure limit values: $L_{EX.8heq}$, = 87dB(A) and P_{peak} = 200 Pa;

b) upper exposure action values: $L_{EX.8heq}$, = 85dB(A) and P_{peak} = 140 Pa;

c) lower exposure action values: $L_{EX.8heq}$, = 80dB(A) and P_{peak} = 112 Pa.

Table 9 gives values for maximum exposure times as recommended by the UK Royal Aerospace Establishment.

Table 9 — Maximum exposure time for different noise levels

Noise level dB(A)	Maximum continuous exposure period (hours)
95	3
96	2
99	1
103	0,33
109	0,08 (5 min)
113	0,033 (2 min)
140	0

8 Heat: burns and fatigue (A.6)

8.1 Burns

This section was included for the benefit of those defining Standards for firefighting equipment although it may be used for other applications. Studies have recommended that the range of environment in which firefighters operate is categorised by three levels as follows:

— Level 1: Routine conditions - air temperatures up to approximately 100 °C and a radiant heat source of up to approximately 1,25 kW/m^2.

— Level 2: Hazardous conditions - air temperatures up to approximately 250 °C and a radiant heat source of up to approximately 8 kW/m^2.

— Level 3: Emergency conditions - air temperatures up to and above 800 °C and radiant heat sources from 80 kW/m^2 up.

Table 10 gives the burn injury degree for a range of temperature and exposure time for air and surface contact, and water. The table is compiled from a range of sources with full details in A.6.4. Table 11 gives the burn injury degree for thermal energy and time, and radiation.

Table 10 — Burn injury degree for a range of temperature and exposure time for air and surface contact, and water

Temp.°C	Time s – second m - minute	Contact substance					
		Air or surface contact			Water		
		Burn injury degree			Burn injury degree		
		1st	2nd	3rd	1st	2nd	3rd
100	15 s		X				X
82	30 s		X				X
71	60 s		X				X
68	1 s		NK		X		
64	2 s		NK		X		
60	5 s	X1					X
56	15 s		NK		X		
53	1 m		NK		X		
51	3 m		NK		X		
49	5 m	X					X
38	NS		safe			safe	
<0	NS				≥ X		

NS = not specified; NK = not known; 1= time not specified for air/surface contact

Table 11 — Burn injury degree for thermal energy and time, and radiation

Thermal Energy/unit area cal/cm2 (kJ/m^2) (average for a range of subjects)	Time sec	Radiation kW/m2 (average for a range of subjects)	Injury
3,2 (7,6)	0,5	3,8	1st Degree burn
3,13 (7,5)	0,5	4,0	2nd Degree burn
4,15 (9,9)	0,5	4,5	3rd Degree burn

8.2 Heat fatigue

Equipment to protect from heat may be available but the greater the temperature against which it is designed to protect the more of an encumbrance it becomes and the greater the fatigue when it is worn. This dichotomy