DGUV Test
Prüf- und Zertifizierungsstelle
Fachausschuss Elektrotechnik

Supplementary requirements fort he testing and certification of face shields for electrical works

Date of issue: 2010-02 Revision 1 (2010-12)

Supplementary requirement
for electrical works
GS-ET 29

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Expert committee for electrical engineering
Testing and certification body
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The principles set out here will be revised and extended periodically in consideration of technical progress and the latest findings in the area of occupational safety and health. The most recent edition shall be binding for testing and certification conducted by the expert committee for electrical engineering of the testing and certification department at DGUV Test.

This is the English translation of the German test principle. The German original version is obligatory

Changes from the 2008-07 edition:

4.1.1	The transmission limits in class 1 and 2 are reduced from 65% to 50%
2.3/5.2	Correction of the date of issue of ISO 10527

The supplementary requirements apply in addition to EN 166:2001, in order for compliance with the PPE Directive 89/686/EEC to be assured.

Note 1:
The tests described in Section 4.2 of the test principles concerning thermal protection were drawn up with reference to DIN EN 61482-1-2.

Note 2:
The interval between the centre line of the electrode and the calorimeter No. 3 as per Fig. 7 of the test principles was set at 350 mm, based upon practical experience gained with work on live parts in immediate proximity to the field of vision.

Revision 1: (2010-12):

- New cover- and head Layout
- New layout with English translations, figure 7
- Insertion, figure 3
- English translations, figure 1, 2, 3, 4, 5

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1.0 General

1.1 Scope of application

The supplementary requirements apply to Face shields worn by electricians during work in which a risk of a fault arc exists.

1.2 Test and certification procedure

The test and certification procedure shall be launched once the agreement has been signed by the contracting parties. The technical documentation listed in Section 3.2 must be submitted together with the agreement.

2.0 Definitions

2.1 Face shields for electrical works

Face shields for electrical works are a form of personal protective equipment which is worn in front of the face in combination with headgear.

The face shield consists of a transparent protective filter which is either attached to the frame
or held by a surround manufactured from textile materials.

2.2 Torso

The torso is a model of the human upper body which consists of a plate of non-flammable, non-metal material.

2.3 VLT (visible light transmittance)

The stated visible light transmittance (VLT) makes allowance for the spectral sensitivity of the average human eye to daylight in accordance with ISO 10527:2006.

3.0 Requirements and tests

3.1 General rules

Unless specified to the contrary in the individual test sections, the tests shall be performed at an ambient temperature of 20 °C ± 5 K and a relative atmospheric humidity of 30% to 85%.

The tests shall be conducted in accordance with the manufacturer's rating data. The measured values shall not differ from the rating data by more than ± 5%.

3.2 Documentation to be submitted

- The following technical documentation is required for testing:
- User information, including technical data
- Parts lists
- Data sheets of the materials employed
- Product drawings, including dimensions
- Fabrication instructions

3.3 Test specimens

4 test specimens, including headgear, and 3 test specimens (200 x 200 mm) of the lens are required for the tests for each type of electrician's face shield.

4.0 Additional requirements/tests

4.1 Visible light transmittance (380 nm to 780 nm)

4.1.1 Requirements

The visible light transmittance[1] (VLT) shall be measured by means of the following light sources on each of three samples[2]:
a) Standard light type A
b) Fluorescent lamp
c) White-light LED

The lenses are divided into classes in accordance with the D65 standard light source:

Class 0:
Visible light transmittance (D65) ≥ 75%
(no information in the user information)

Class 1:
Visible light transmittance (D65) 50% ≤ VLT (D65) < 75%
(constraints must be described in the user information)

Class 2:
Visible light transmittance (D65) < 50%
(constraints must be described in the user information)

4.1.2 Testing

Measurement shall be performed by means of a spectrometer with a resolution of at least 5 nm (note: the MU rises by 1% compared to a resolution of 1 nm; an interval of 1 nm should ideally be employed).

The test arrangement for determining the three visual light transmittance (VLT) values (standard light type A, fluorescent lamp, white-light LED) is shown in Fig. 3.

The dimensions of the lens must be at least 200 x 200 mm.
The visual light transmittance shall be determined at three different positions for both the left and the right eye. The metering fields for this purpose are shown in Fig. 4.
The test specimen shall be clamped flat in the test arrangement.

Three series of measurements shall be performed for each metering field and light source.
The mean value of each series shall be employed for evaluation of the VLT.
The measurement uncertainty must be stated.

The test shall be deemed passed when the figure stated by the manufacturer for each light source lies within the tolerance (+3% / -5%) of the measured test result.

[1] Test arrangement, see Fig. 3
[2] Each lens may be re-used on each light source

4.2 Thermal protection (arc testing)

4.2.1 Test arrangement

The test arrangement shall comprise the following elements:

- Test chamber
- Torso
- Test head with calorimeter
- Electrical power supply
- Data recording system

4.2.2 Test chamber

The test chamber as shown in Fig 5 must be manufactured from non-conductive, heat-resistant material (e.g. plaster of Paris).

4.2.3 Torso

A torso in the form of a plate (H = 500 mm, B = 600 mm, D = min. 10 mm) manufactured from non-flammable, non-metal material shall be employed for the test.
The torso shall be arranged such that it remains in position throughout the duration of the electric arc.

4.2.4 Test head with calorimeter

The test head shall correspond approximately to the 50th percentile of male adults and shall be manufactured from non-flammable, non-metal material. Nominal dimensions and design details are stated below and in Fig. 6.

4.2.4.1 Arrangement of the sensors

The sensor shall have a diameter of 60 mm and shall comprise an insulated mounting and a calorimeter. The calorimeter shall satisfy ISO 9151 and shall consist of a round disk manufactured from electrolytic copper with a diameter of 40 mm and a mass of 18 g, and a type T thermoelement (copper-constantan). The thermoelement shall be manufactured from copper-constantan wire (type T to IEC 60584-1) and shall be attached such that the constantan wire is located in the centre of the disk and the copper wire outside the centre. The disk shall be embedded in an insulated mounting. The sensor shall be fitted into the test plate such that it is flush with the surface of the latter. The surface of the copper disk, the purpose of which is to absorb heat, shall be coated with a thin layer of optically black paint.

4.2.4.2 Sensor measured values

The measured values from the sensors for the temperature rise in °C shall be converted to thermal energy (acting energy) in units of kJ/m^2 by multiplication of the delta temperature values by a constant factor of 5.52 kJ/m^2 °C.

NOTE: The constant factor is based upon an average value for the thermal capacity of copper of C_p = 0.385 J/g °C (80 °C) within the tested temperature range.

4.2.5 Electrical power supply and electrodes

For the duration of the arc, the electrical power supply must be capable of delivering a virtually constant alternating voltage and a constant short-circuit current (symmetrical alternating current component). Alternating currents at 50 Hz and 60 Hz are permissible.

4.2.5.1 Electrical test circuit

The electrical test circuit shall be configured such that under no-load conditions, a voltage corresponding to the test voltage is generated, and a current corresponding to the test current would flow were the electrodes to be connected with no impedance (short-circuit). The arc tests shall be performed in this configuration.

4.2.5.2 Instrumentation in the electrical test circuit

The test voltage and test current shall be demonstrated by measurements.
The test current (prospective short-circuit current) shall be recorded in the form of an oscillogram showing the instantaneous values. A graphical representation shall be produced.
A circuit-breaker, which shall be monitored for the duration of the arc, shall be employed for making and breaking of the electrical test circuit.

NOTE: No particular requirements apply to making of the test circuit (the angles affecting the sine wave of the current) and the phase angle or the X/R ratio of the source impedance; the X/R ratio should if possible be between 1 and 5.

4.2.5.3 Electrodes

The electrodes shall be manufactured from electrical copper and electrical aluminium rods (with ≥ 99.5% Al or electrical Al Mg Si 2.5) (see Fig. 5).

4.2.5.4 Igniter wire

An igniter wire linking the two electrode tips shall be employed for ignition of the arc. This wire is consumed during testing. Its mass must therefore be kept low, in order to reduce the number of burns caused by liquid material. A copper wire with a nominal diameter not exceeding 0.5 mm shall be employed as the igniter wire.

4.2.6 Parameters of the electric arc

The parameters of the electric arc are defined as follows:
Test voltage: AC 400 V ± 5%

Test current/$_{arc,\ class}$: Class 1: 4 kA ± 5%
Class 2: 7 kA ± 5%

Arc duration: 500 ms ± 5%

Frequency: The test shall be performed at a frequency of (50 ± 1) or (60 ± 0.12) Hz.

These parameters must be tuned during the tests, in order for the same values to be employed for all tests within a series. The actual arc voltage and arc current shall be recorded during the arc duration in each test.

4.2.7 Data recording system

Recording of measured values and data:
The system shall be capable of recording the current and voltage of the electrical test circuit simultaneously.
The recording frequency shall be at least 5 kHz.
The actual arc current and the actual arc voltage shall be recorded for each arc test. These values shall be reproduced in graphs within the report.
In addition to the voltage and the current, the two initial values of the calorimeter shall be recorded. The temperature values must be recorded for at least 30 s with a scanning rate of at least 50 ms per channel.

4.2.8 Preparation of the test specimen

4.2.8.1 The test head shall be attached to the torso such that it is flush with the transition to the neck and remains in position throughout the duration of the electric arc (Fig. 7).

4.2.8.2 The face shield shall be stored for at least 24 hours at a temperature of between 18 and 28 °C and a relative atmospheric humidity of between 45% and 75%.

4.2.8.3 The face shield shall be fitted to the test head together with the headgear specified by the manufacturer in accordance with the information in the instruction manual.

4.2.9 Calibration

4.2.9.1 Measurement chain for recording of the temperature

The entire measurement chain, comprising calorimeter and data recording system, shall be calibrated at regular intervals.
It shall be possible to calibrate several temperature measurement points at values above 100 °C. The data recording system shall be calibrated. Owing to the characteristics of the tests, several checks of the calibration are recommended.

4.2.9.2 Calibration of the electrical test circuit and performance of the test

For demonstration of the test conditions, calibration oscillograms of the set prospective test current and of the test voltage must be recorded with unchanged test parameters at least for each series of tests.
The reference measurement shall be performed without test specimen; in this case, the directly acting energy E_{i0} is measured.
It shall be demonstrated that in accordance with Fig. 3 of DIN EN 61482-1-2, the recorded energy $E_{i0}$of each sensor on the test plate lies within the range of the double standard deviation ± 2 *s* of the mean value in accordance with Table 2.

Test current	**Mean E_{i0}**	**Double standard deviation ± 2 *s***
	kJ/m^2 (cal/cm^2)	kJ/m^2 (cal/cm^2)
Class 1: 4 kA	135 (3.2)	± 56 (1.3)
Class 2: 7 kA	423 (10.1)	± 78 (1.9)

Table 2: **Statistically validated mean values of the directly acting energy**

The value of the arc energy shall be determined for each individual test. A test shall be valid only if the arc energy W_{arc} lies within the range of the double standard deviation ±2 s of the mean value in accordance with Table 3. Otherwise, the test must be repeated.

Test current	Mean value W_{arc}	Double standard deviation ± 2 s
	kJ	kJ
Class 1: 4 kA	158	± 34
Class 2: 7 kA	318	± 44

Table 3: Values for the permissible arc energy

4.2.9.3 Confirmation of the settings of the test arrangement

The settings of the test arrangement shall be confirmed for each test. The measured values to be recorded are the arc current, arc duration, arc energy and arc voltage. The diagram of the arc current shall be recorded in order to assure the correct phase characteristics. The ambient temperature and relative atmospheric humidity shall also be recorded. Influences from wind or air currents shall be prevented.

4.2.9.4 Preparation and treatment of the chamber

The chamber shall be prepared for the test and treated.
Refer to Fig. 5 for the arrangement of the chamber.
The chamber shall be dry.
Prior to testing, the following instructions concerning preparation and treatment shall be observed:

The "plaster-of-Paris box" shall be dried in an oven for 12 hours at a temperature of approximately 60 °C. It shall be demonstrated that the weight and the electrical surface resistance have not changed by more than 5% at the end of preparations.

4.2.10 Maintenance and care of the test arrangement

4.2.10.1 Care of the sensor surface

The surface of each sensor shall be wiped immediately following each test in order for any decomposition products to be removed which have precipitated and which could subsequently give rise to faults. Should deposits have collected and appear to be thicker than a paint coating or to be uneven, the sensor surface shall be repaired. The sensor shall be cleaned carefully when cold with an acetone or petroleum solvent which permits gentle treatment. A thin coat of black high-temperature paint shall be applied to the surface. The same coating shall be applied to all sensors. It shall be ensured that the coated surface is dry prior to the beginning of testing.

4.2.10.2 Care of the torso and test head

The torso and test head must remain dry. Where testing is performed outdoors, the torso and test head must be covered during longer intervals between tests, in order to prevent solar radiation from causing excessive temperature rises.

4.2.11 Test method

4.2.11.1 Test arrangement

The test chamber, test head and torso shall be arranged as shown in Fig. 7.

4.2.11.2 Number of test specimens4 test specimens shall be tested for each face shield type.

4.2.11.3 Test parameters

The test parameters are defined for the following two characteristic test classes:

Test class	Test current kA	Test voltage V AC	Arc duration ms
Class 1	4 ± 5%	400 ± 5%	500 ± 5%
Class 2	7 ± 5%	400 ± 5%	500 ± 5%

Table 4: Test parameters

4.2.11.4 Test conditions and initial temperature

The tests shall be performed at an ambient temperature T_a of between 15 °C and 35 °C and a relative atmospheric humidity of 25% to 75%.
The initial temperature of the sensors shall be between 15 °C and 35 °C.
The ambient temperature T_a and the initial temperature of the sensors T_o shall be measured. It must be ensured that the initial temperature of the sensors (during measurement of the temperature difference by means of the thermoelements) within series of tests lies within a tolerance of $T_o = T_a \pm 2$ °C.
Decomposition products must be removed. The active surface of the sensors shall be renewed frequently by recoating with black paint.

NOTE 1: If necessary, the sensors should be cooled by means of an air jet or by contact with a cold surface. Should condensed decomposition products become thicker than the paint coating, the sensor shall be cleaned, once cool, with an acetone or mineral-oil-based solvent. The surface shall be recoated with black paint.
The same paint shall be used for all sensors.

NOTE 2: Should suitable equipment be required during outdoor tests in order to prevent the influence of wind, rain, etc., the tests shall begin not later than 5 minutes following removal of the item under test from the pretreatment atmosphere.

4.2.11.5 Performance of the test

The arc shall be ignited within five minutes of removal of the face shield from the pretreatment atmosphere.
The point at which the arc is ignited must be determined.
The curves for the temperature rise of all sensors in the test series shall be recorded for the entire exposure time of 30 seconds.
The value pairs (maximum value of the temperature rise ΔT_p at the points in time indicated in Table 5) shall be determined for each sensor.

4.2.11.6 Evaluation of the measurement results

The acting energy shall be calculated by multiplication of the maximum value of the temperature rise by the sensor constant 5.52 kJ/m^2 °C (or 0.132 cal/cm^2 °C).

E_{io} = 5.52 (kJ/m^2 °C) x $\Delta T_{p.o}$ (°C)
or E_{io} = 1.132 (cal/cm^2 °C) x $\Delta T_{p,o}$ (°C)

E_{it} = 5.52 (kJ/m^2 °C) x ΔT_{p} (°C)
or E_{it} = 1.132 (cal/cm^2 °C) x ΔT_{p} (°C)

The directly acting energy E_{io} and the four values of the transferred energy E_{it} shall be determined, as shall the mean value of the four E_{it} values and their corresponding random error range of 95%.

4.2.11.7 Evaluation of the test results

The test shall be deemed passed when, following extinguishing of the fault arc:

- The combustion time of the test specimen is ≤ 5 s
- The test specimen does not fuse through
- The test specimen is not fully punctured
- The value pairs of all calorimeters of the test head lie below the relevant - values stated in Table 5

Time to reach the peak value temperature	Heat flow	Acting energy	Peak temperature (temperature rise according to the calorimeter)
s	kW/m^2	kJ/m^2	ΔT °C
1	50	50	8.9
2	31	61	10.8
3	23	69	12.2
4	19	75	13.3
5	16	80	14.1
6	14	85	15.1
7	13	88	15.5
8	11.5	92	16.2
9	10.6	95	16.8
10	9.8	98	17.3
11	9.2	101	17.8
12	8.6	103	18.2
13	8.1	106	18.7
14	7.7	108	19.1
15	7.4	111	19.7
16	7.0	113	19.8
17	6.7	114	20.2
18	6.4	116	20.6
19	6.2	118	20.8
20	6.0	120	21.2
25	5.1	128	22.6
30	4.5	134	23.8

Table 5: Resistance of human tissue to heat, second-degree burns

4.3 Additional marking

In addition to marking of the lens in accordance with Section 9.2 of DIN EN 166, the code for the resistance to fault arcs (8) shall be followed by indication of the fault arc class (1 or 2) and the visible light transmittance for the standard light type A (0 or 1 or 2), separated by dashes.

Example: 8 - 1 - 0

The test shall be deemed passed when the marking matches the values determined in accordance with Sections 4.1 and 4.2.

4.4 User information

In addition to the information required by DIN EN 166 Section 10, the following marking information must be provided:

- Explanation of the code for the fault arc class by statement of the corresponding short-circuit current (test current) and of the scope of use.

- Explanation of the code for the visible light transmittance, according to the classification in accordance with Section 4.1.1.

- In the case of light transmittance classes 1 and 2, the following additional information is required:

  - Additional explanations of the constraints, relating to the visible light transmission with the different light sources.

  - Additional information concerning the light source required at the workplace in order for a minimum illumination of 30 lux to be attained behind the electrician's face shield.

Example:
At a transmittance of 70% for standard light Type A, the value of the additional light source is at least 39 lux (calculated as follows: 1.3 × 30 lux = 39 lux).

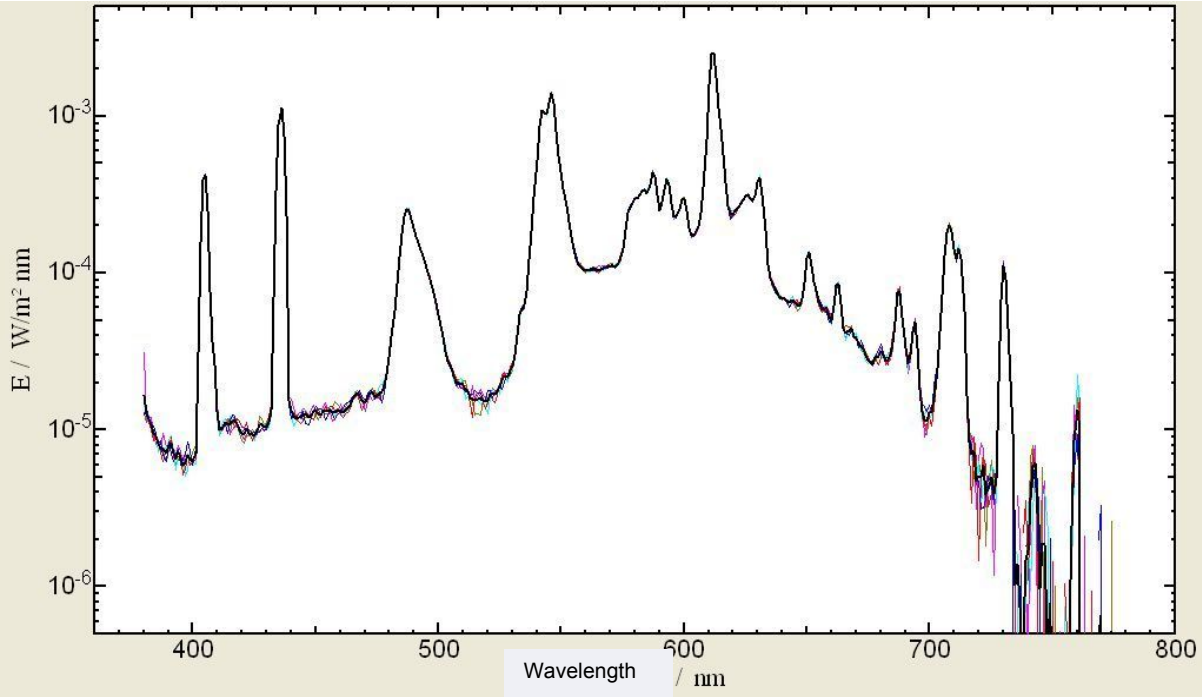

Fig 1: Spectrum (fluorescent lamp)

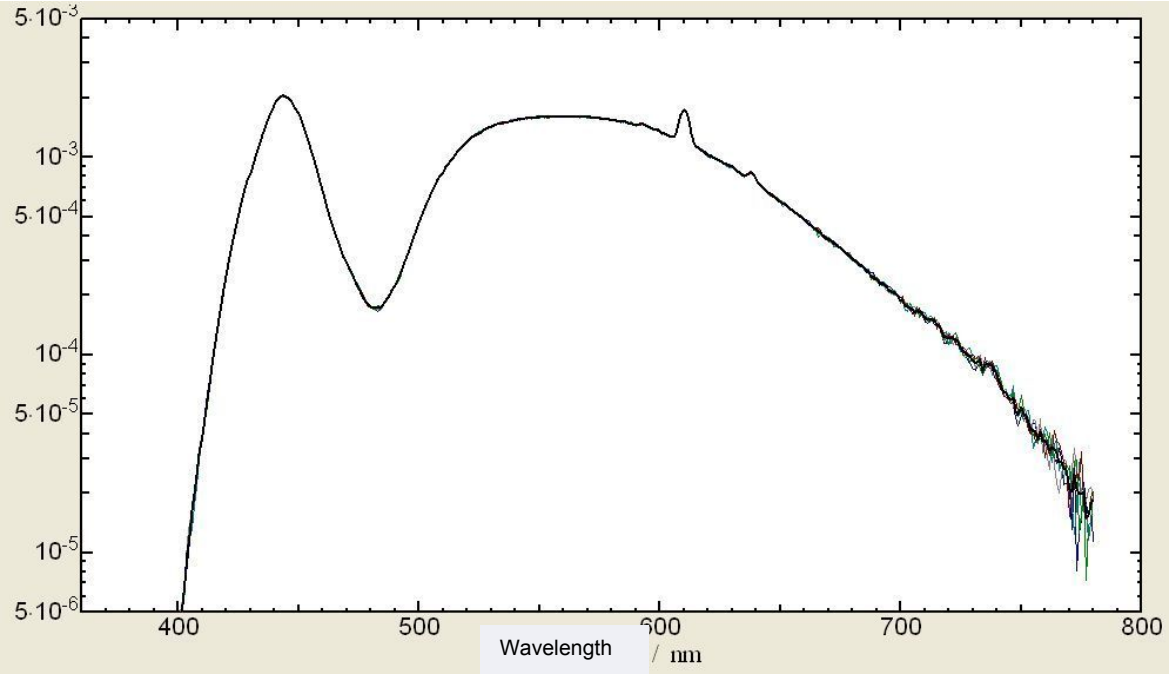

Fig 2: Spectrum (white light LED)

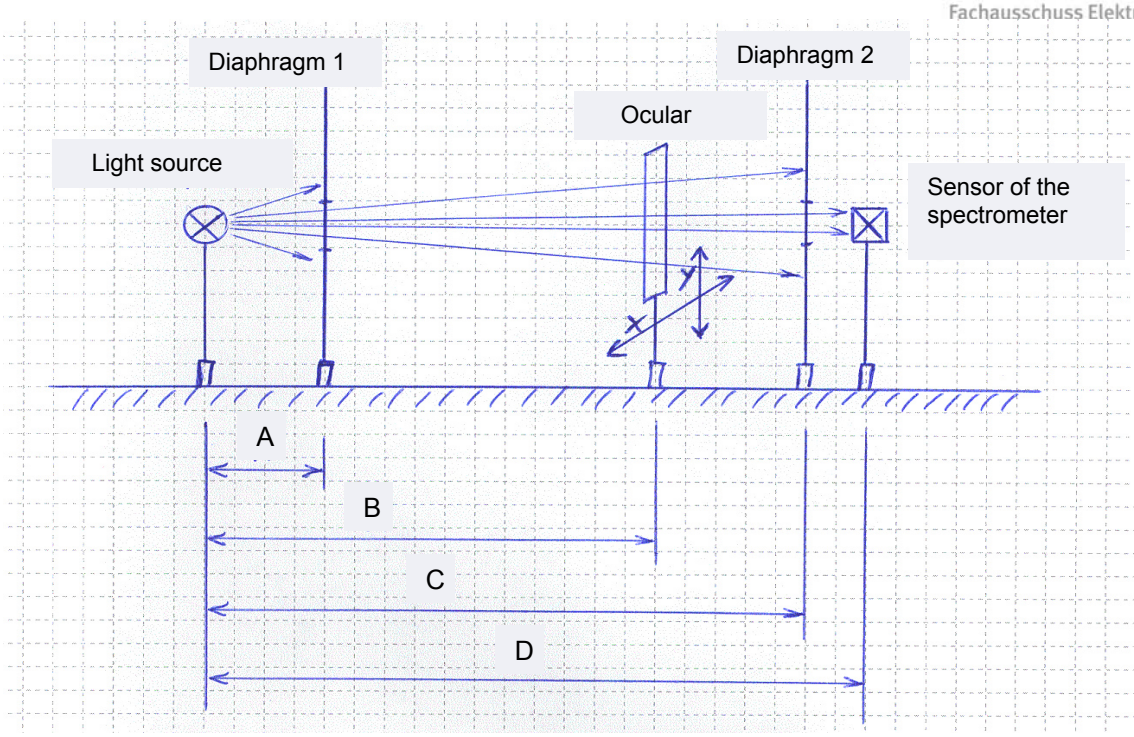

Fig 3 Arrangement for measurement of the visible light transmittance

Where light type A is employed (standard light type A in accordance with DIN 5033):
* D > 20 times the filament diameter, at least 1 m
* B ≈ ⅔ of D
* A and C shall be positioned such that no reflexes are produced on the sensor

Where the fluorescent lamp is used
(typical example: daylight spectrum, manufacturer: OSRAM, type: L/827; see Fig. 1):
* D at least 0.75 m
* B ≈ ⅔ of D
* A and C shall be positioned such that no reflexes are produced on the sensor

Where LED lighting is used
(typical example: manufacturer: LINUS, type: Luxion STAR 065150000 with condenser and diffusing panel; see Fig. 2):
* D at least 0.5 m
* B ≈ ½ of D
* A and C shall be positioned such that no reflexes are produced on the sensor
(if necessary, panel A may be omitted)

Once selected, the intervals are mandatory for the entire series of measurements, and must be documented.

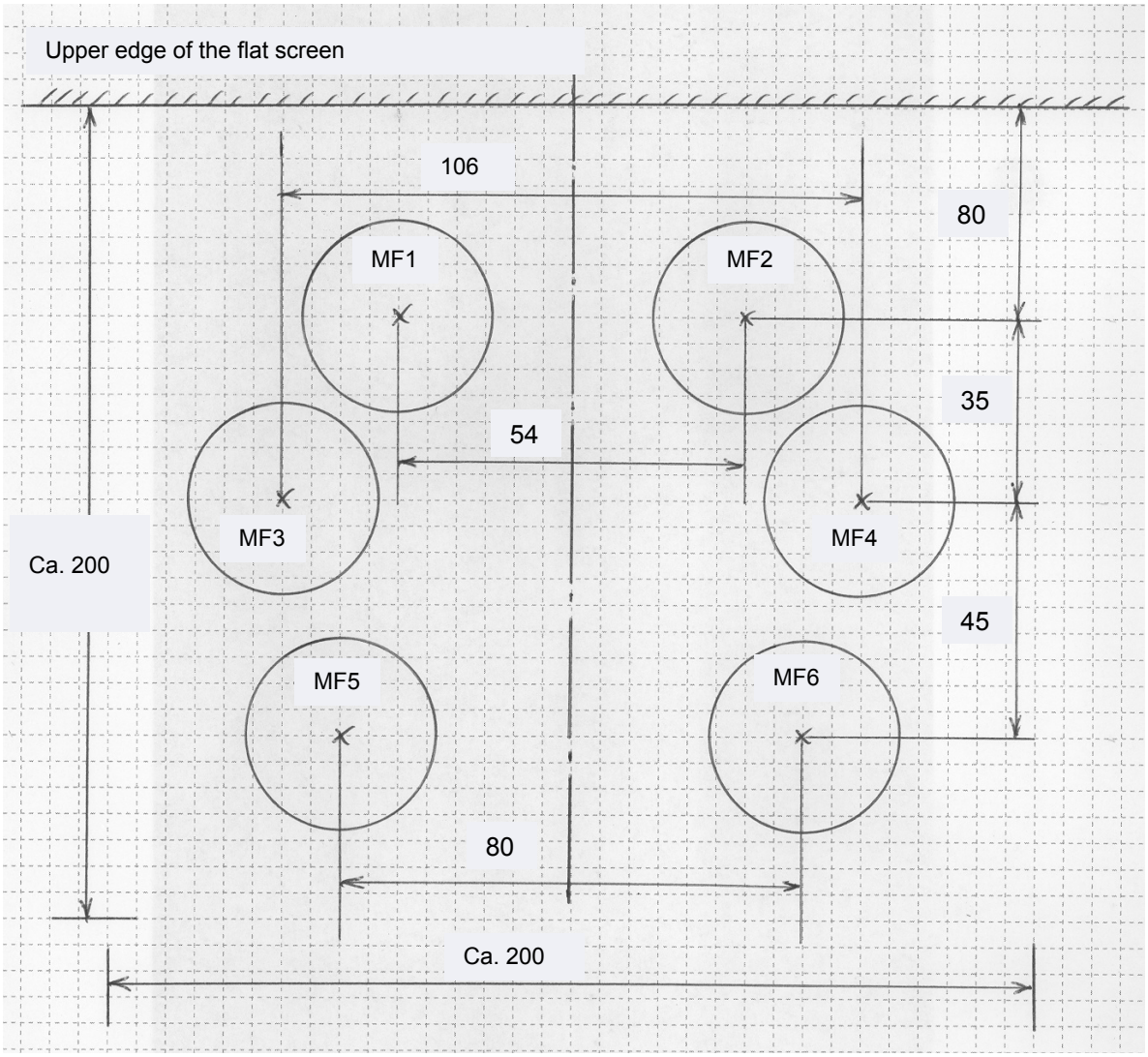

Fig. 4: Metering fields (dimensions in mm)

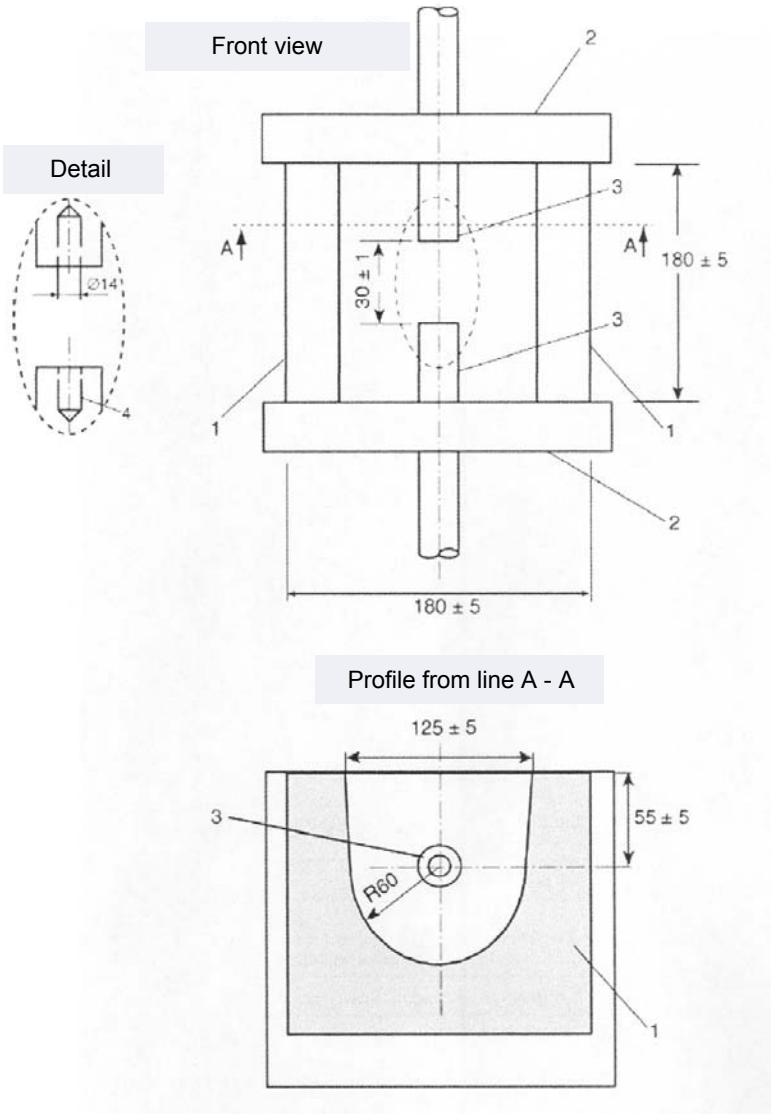

Fig 5: Test chamber

Dimensions in mm

Legend

1 Non-conductive heart-resistand material (e.g. plaster-of-Paris box)
2 Insulating plate, thickness > 15
3 Electrodes diameter 25 (top aluminium, bottom copper)
4 Holes diameter 14, depth 20

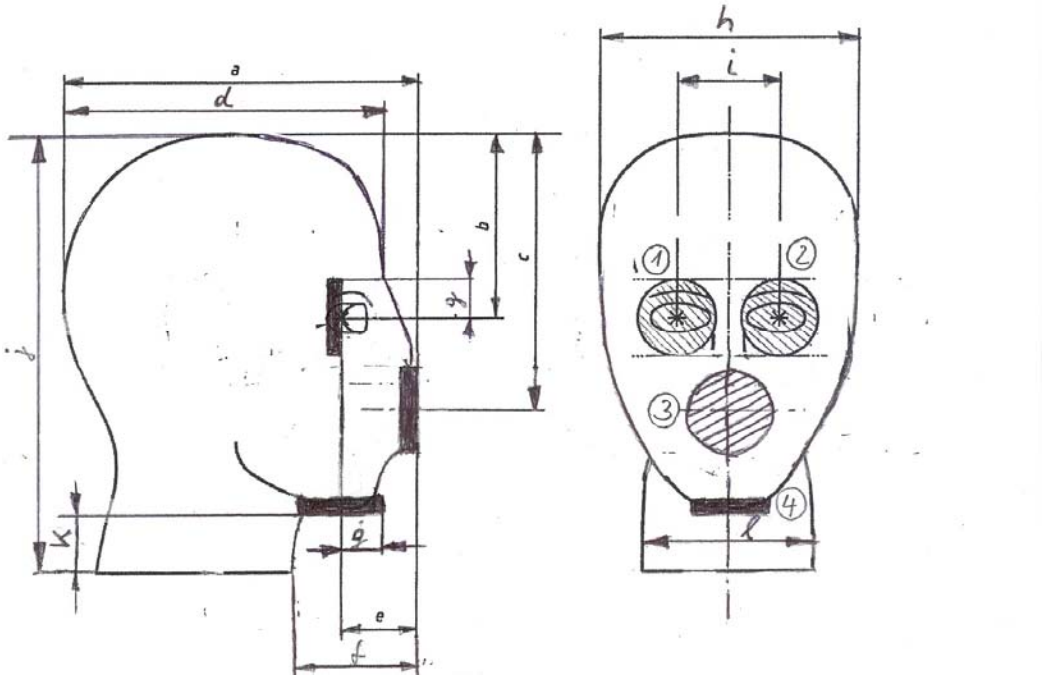

Fig. 6: Test head

Dimensions in mm; tolerance: ± 1.5

Dimension	Values [mm]
a	218
b	111
c	175
d	200
e	35
f	93
g	30
h	160
i	80
j	261
k	35
l	105

NOTE: *All head dimensions which are not defined may be selected freely; they should however be oriented towards the 50th percentile of male adults.*

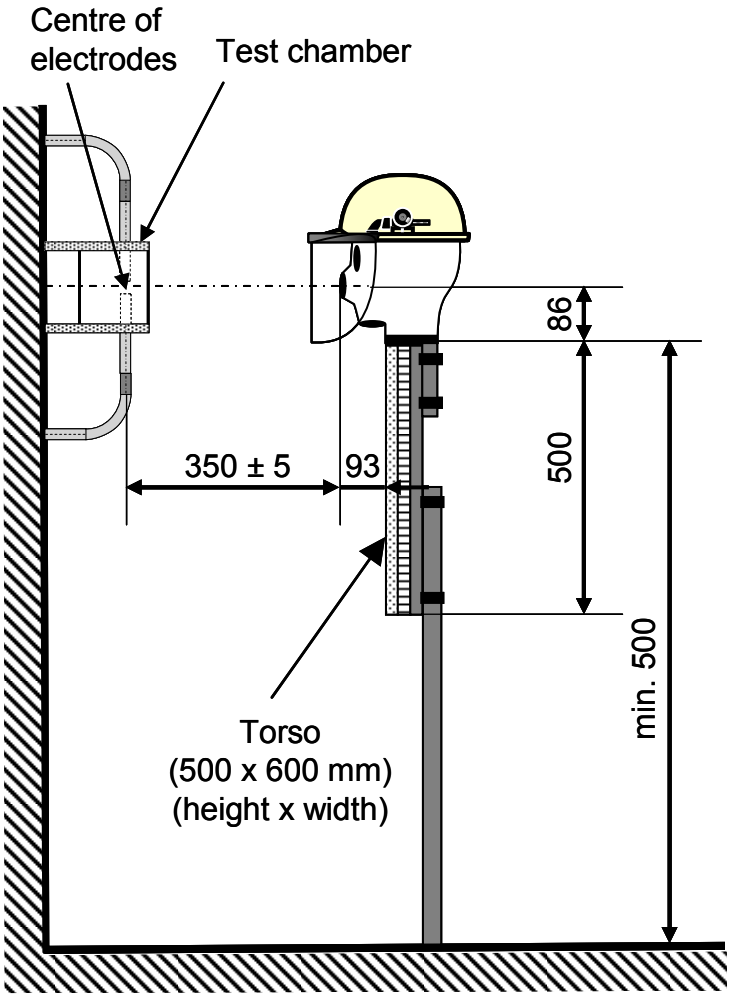

Fig. 7: Test arrangement (dimensions in mm)

5.0 Annexes

5.1 Directives

Council Directive 89/686/EEC of 21 December 1989 on the approximation of the laws of the Member States relating to personal protective equipment

5.2 Standards

EN 166:2001	Personal eye protection - Requirements
ISO 9151:1995-05	Protective clothing against heat and flame - Determination of heat transmission on exposure to flame
IEC 60584-1:1995-09	Thermocouples Part 1: Reference tables
EN 61482-1-2:2007-01	Live working - Protective clothing against the thermal hazards of an electric arc Part 1-2 Test methods - Method 2: Determination of arc protection class of material and clothing by using a constrained and directed arc (box test).
ISO 10527: 2006	CIE standard colorimetric ob