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भारतीय मानक मसौदा

Draft Indian Standard

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प्रघात नलिका अधिस्फोटकों - विशीष्टि

Draft *Indian Standard*

SHOCK TUBE DETONATORS – SPECIFICATION

ICS 71.100.30

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B U R E A U O F I N D I A N S T A N D A R D S
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Explosives and Pyrotechnics Sectional Committee, CHD 26

FOREWORD

(Formal clauses shall be added later)

A detonator is a device used to trigger an explosive. Detonators are usually initiated by mechanical or electrical means or with a shock wave.

A shock tube detonator is an initiator in the form of small-diameter hollow plastic tubing used to transport an initiating signal to an explosive by means of a shock wave traveling the length of the tube. Shock tube is used to convey a detonation signal to a detonator.

In the formulation of this standard, assistance has been derived from the EN 13763 Series 'Explosives for civil uses — Detonators and relays'.

There is no ISO specification for the product.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 2022 'Rules for rounding off numerical values *(second revision)*'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Draft Indian Standard

SHOCK TUBE DETONATORS - SPECIFICATION

1 SCOPE

This standard prescribes the requirements, methods of sampling, and tests for shock tube detonators used for blasting purposes.

2 REFERENCES

The standards listed below contain provisions which through reference in this text, constitute provisions of and necessary adjuncts to this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated.

IS No.	*Title*
IS 1260 (Part 1)	Pictorial Marking for Handling and Labelling of Goods: Part 1 Dangerous Goods (*first revision*)
IS 4905: 2015	Random Sampling and Randomization Procedures (*first revision*)
IS 6609 (part 3): 1973	Methods of Test for Commercial Blasting Explosives and Accessories Part 3 Detonators, General and Permitted
IS 10081: 1981	Terms Relating to Commercial Explosives, Pyrotechnics and Blasting Practices
IS/IEC 60529: 2001	Degrees of protection provided by enclosures (IP Code)

3 TERMINOLOGY

For the purpose of this standard, the terms and definitions given in IS 10081, in addition to the following shall apply.

3.1 Shock tube – A tube usually containing a dusting of explosive charge on the inner wall capable on activation of transmitting a shock wave from one end of the tube to the other at a constant velocity and having no external explosive effect.

4 REQUIREMENTS

4.1 Drop Test

When subjected to drop test as laid down in **2.2** of IS 6609 (Part 3), none of the detonators connected to the shock tubes shall detonate nor there shall be any loose composition inside the tubes. At the end of drop test, all the test samples shall fire in the functioning test.

NOTE – *In case of electronic detonators, cut the leading wire so that 5 cm lengths left instead of 20 cm wire as prescribed in clause 2.2.1 of IS 6609 (Part 3).*

4.2 Vibration Test

When subjected to vibration test as laid down in **2.4** of IS 6609 (Part 3) and examined visually, there shall neither be any loose composition inside the tubes nor it shall come out of the tube during the testing and the shock tubes shall not explode during the test.

4.3 Strength of detonators

4.3.1 *By sand bomb method* - When the shock tube detonators are tested in sand bomb as prescribed in **2.5** of IS 6609 (Part 3), the percentage of crushed sand passing through 500-micron and 250-micron IS Sieves shall be as follows:

Strength of detonator	Percentage of sand passing through	
	500 micron IS sieve	250 micron IS sieve
No.6	≥ 35	≥ 30
No.8	≥ 50	≥ 45

4.3.2 *By lead plate method* - When the shock tube detonators are subjected to the test as prescribed in **2.6** of IS 6609 (Part 3), they shall produce dent on the lead plate corresponding to at least C-3 class [**2.6.2.2** of IS 6609 (Part 3)].

4.4 Immersion in hot oil

When tested as per the method prescribed in Annex A, the shock tube detonator shall pass in the functional test.

4.5 Water Resistance

When the shock tube detonators are subjected to water resistance test as prescribed in **2.1** of IS 6609 (Part 3), the detonators shall satisfy the following requirements;

a) After being subjected to the test, all the test samples shall fire.

b) All single values of their delay times shall be within the defined delay values.

c) All the surface connectors and non-electric detonators intended to be connected/combined with surface connectors shall detonate and all single values of their delay times shall be within the defined delay values.

4.6 Delay Time Measurement

The manufacturer shall declare the nominal and delay interval for each delay of shock tube detonators.

Delay time shall be measured as prescribed in 2.10.3.1 of IS 6609 (Part 3). In delay time measurement, the scatter of any particular delay number shall be such that not more than 10% of the shock tube detonators tested shall have delay timing overlapping with the delay timing of the adjacent numbers.

4.7 Determination of shock wave velocity

When tested according to the method prescribed in **Annex B**, the individual shock wave velocities shall be within ±10% of the shock wave velocity declared by the manufacturer.

4.8 Mechanical strength of lead-wires, shock-tubes, connections, crimps and closures

When tested as per the method prescribed in **Annex C**;

a) During the sudden and slow release, no detonator shall detonate.

b) During the sudden release test, no leading wire or shock-tube shall break and the plug/shock tube shall not be pulled out of the shell.

c) During the slow release test, no plug, shock tube or fuse-head shall pull out of the shell.

4.9 Determination of transfer capability of surface connectors, relays and coupling accessories

Transfer capability shall be determined as per the method prescribed in **Annex D**. In case of surface connectors, all the test specimen shall pass. In case of coupling accessories, requirements specified in the manufacturer's manual shall be satisfied.

5 TYPE TESTS

5.1 Thermal stability test

When the shock tube detonators are subjected to thermal stability test as prescribed in **Annex E**, there shall be no detonation.

5.2 Impact test

When tested according to the method prescribed in **Annex F**, the mean and minimum heights at which explosion is observed shall be greater than 9 m and 7 m respectively.

5.3 Resistance to abrasion

When tested as per the method prescribed in **Annex G**, all the test specimen shall be initiated and shall propagate the detonation along the entire length of the shock tube.

5.4 Resistance to cutting damage

When tested as per the method prescribed in **Annex H**, all the test specimen shall be initiated and shall propagate the detonation along the entire length of the shock tube.

5.5 Resistance of detonators to bending

When tested as per the method prescribed in **Annex J**, none of the shock tube detonators shall initiate. Also, there shall be no cracks or breaks in any of the shells.

5.6 Determination of electrical non-conductivity

When tested as per the method prescribed in **Annex K**, the shock tube detonators shall satisfy the following requirements –

a) The resistance of each test specimen shall be greater than 0.1 GΩ.

b) The flash-over distance of each test specimen shall not be greater than 20 mm.

6 PACKING AND MARKING

6.1 Packing

The shock tube detonators shall be packed as agreed to between the purchaser and the supplier. The packing shall conform to the provisions of *Explosives (Amendment) Rules*, 2019.

6.2 Marking

6.2.1 Each package shall be marked with the following information:

a) Name of the material / Product.

b) Number of pieces in the package;

c) Manufacturer's name and/or his recognized trade-mark, if any; and

d) Date of manufacture, lot number and Employee / Operator Number to enable the batch of manufacture to be traced from records.

6.2.2 The package shall also be marked with the appropriate symbol specified in IS 1260 (Part 1).

6.2.3 The marking shall further be in conformity to the provisions of *Explosives (Amendment) Rules*, 2019.

6.3 BIS Certification Marking

The product(s) conforming to the requirements of this standard may be certified as per the conformity assessment schemes under the provisions of the *Bureau of Indian Standards Act*, 2016 and the Rules and Regulations framed thereunder, and the products may be marked with the standard mark.

7 SAMPLING

7.1 Lot

7.1.1 Cases of Shock tube detonators of same grade, same type and belonging to the same batch of manufacture shall be grouped together to constitute a lot.

7.1.2 Detonators constituting the sample shall be drawn from each lot separately for deciding the conformity of the lot to the requirements of the specification.

7.2 Scale of Sampling

Number of detonators to be selected at random from the lot shall depend on the lot size and shall be in accordance with co1 2 of Table 1. In order to ensure randomness of selection, procedures given in IS 4905 may be followed.

Table 1 Scale of sampling of Shock tube detonators

No. of detonators in the lot	Sample size
(1)	(2)

Up to 10 000	100
10 001 to 25 000	200
25 001 and above	250

7.3 Number of Tests - The number of detonators taken for the determination of each characteristic shall be as given below:

Sl No.	**Test/ Characteristic**	**No. of detonators to be tested**
i)	Water resistance	5
ii)	Drop test	5
iii)	Vibration test	14
iv)	Strength test by lead plate or sand bomb method	5
v)	Mechanical strength test	5
vi)	Immersion in hot oil test	2
vii)	Delay timing test	20

7.4 Criteria for conformity - For deciding the conformity of the lot to the requirements of this specification, the test results of each characteristic shall meet the corresponding requirements specified in the relevant clauses.

ANNEX A
(*Clause* 4.5)

IMMERSION IN HOT OIL TEST

A-1 GENERAL

The purpose of this test is to determine the performance of shock tube detonators when subjected to immersion in hot oil.

A-2 APPARATUS AND REAGENTS

A-2.1 Water bath.

A-2.2 Stainless steel vessel with lid, having a capacity of 2 l.

A-2.3 Thermometer, having a range of 0 to 110°C.

A-2.4 Fresh lubricant or furnace oil having medium viscosity – 1 000 ml.

A-3 PROCEDURE

A-3.1 Take a test specimen of 1 m length, duly sealed at both the ends.

A-3.2 Coil the test specimen so as to fit into the vessel.

A-3.3 Pour the oil (*see* **A-2.4**) into the vessel (*see* **A-2.2**) till the coil of shock tube is completely dipped except the two sealed ends.

A-3.4 Cover the vessel with lid, ensuring that the two sealed ends of the test specimen are outside.

A-3.5 Place the vessel with oil on the water bath and turn on the water bath electrically.

A-3.6 Keep the temperature of the thermostat at 85°C.

A-3.7 Note the time of switching on the water bath.

A-3.8 Maintain the water bath temperature in the range of 75 to 80°C for 8 h.

A-3.9 Remove the shock tube and let it cool to temperature of 50°C.

A-3.10 Cut one sealed end of the test specimen and fire it. Measure the velocity of detonation. Also, examine the other end of the test specimen for confirmation of the shock wave passing through the one meter length.

ANNEX B
(*Clause* 4.7)

DETERMINATION OF SHOCK WAVE VELOCITY

B-1 APPARATUS

B-1.1 An initiating device (percussion cap, spark, etc.) or an initiating detonator provided that the shock tube and measuring equipment are protected against the fragments from the initiated detonator.

B-1.2 System equipped with two optical sensors (e.g. optical fibers, see A and B in Figure 1) and capable of measuring the time taken for the shock wave to travel between the two sensors, to an accuracy of 1 µs.

B-1.3 Conditioning chamber

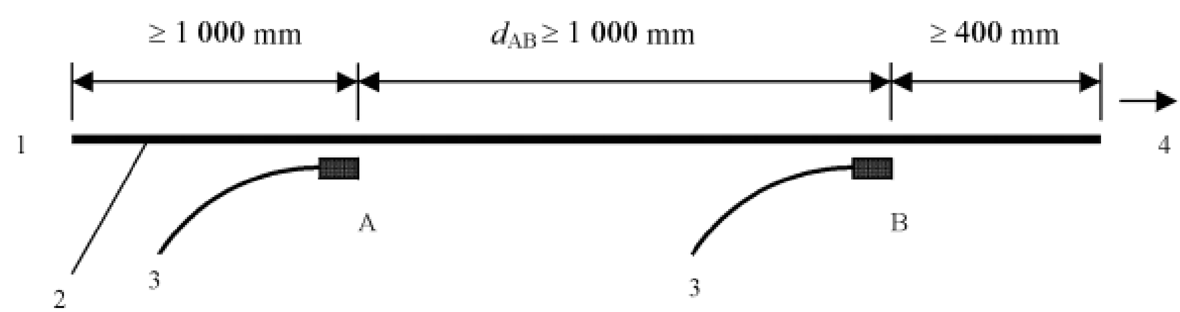
B-2 TEST PIECES

Select 20 lengths of shock tube, each at least 2.4 m long. If the shock tubes are assembled with detonators, the lengths shall be taken from 20 detonators of the same specific type. If the detonators form part of a series with different delay times select detonators with delay times distributed as evenly as possible throughout the series

B-3 PROCEDURE

B-3.1 Cut the required lengths of shock tube and immediately seal the cut ends, e.g. by adhesive tape or other suitable means. Condition the sealed lengths for at least 2 h at (20 ± 2) °C prior to testing.

B-3.2 Install the two sensors in contact with the shock tube as in Figure 1. The distance between the sensors d_{AB} shall be at least 1000 mm, measured to an accuracy of ± 5 mm. Remove the seal if necessary and initiate the shock tube.



Key

1 Initiator location
2 Shock tube
3 Optical sensors (A and B)
4 Direction of shock wave propagation

Figure 1 – Test arrangement

B-4 CALCULATION

B-4.1 Record the time t_{AB} of the shock-wave propagation from A to B.

B-4.2 Record the individual values of d_{AB} and t_{AB} for each of the 20 determinations.

B-4.3 Calculate the shockwave velocity, v expressed in meters per second (m/s), for each determination, from the following equation. Round the value in m/s to the nearest whole number.

$$v = \frac{d_{AB}}{t_{AB}}$$

B-4.4 Calculate the mean value of v in m/s and report this value, rounded to the nearest whole number, as the result of the test.

ANNEX C
(*Clause* 4.8)

MECHANICAL STRENGTH OF LEAD-WIRES, SHOCK-TUBES, CONNECTIONS, CRIMPS, AND CLOSURES

C-1 GENERAL

During normal use on site, the crimps/closures of detonators and their leading wires or shock tubes can be subjected to pulling forces. Such forces can cause a pullout of internal components of the detonator. A pullout would either cause the detonator to explode, or would render it incapable of functioning. This method determines the ability of detonator leading wires/shock tubes, and their connections into the crimp/closure or sealing arrangement, to withstand a pullout when subjected to a pulling force.

C-2 APPARATUS

The apparatus consists of the following parts as given in Figure 2:

C-2.1 Fixing point for the detonator

C-2.2 Moveable support table

C-2.3 Weights that are to be attached to the shock tubes or leading wires, capable for applying forces of 40 N or 400 N.

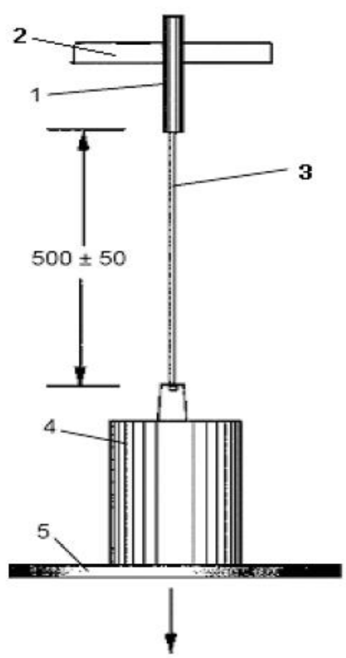


Figure 2 Test Apparatus

Key

1. Detonator

2. Fixing point for detonator
3. Leading wires or shock tubes
4. Weights
5. Moveable support table

C-3 TEST PIECES

C-3.1 Electric detonators: Select about 40 assemblies of a particular type, whose construction, shell material, dimensions, crimp/closure, construction are of the similar design but delay compositions, primary charge/base charge and fuseheads may vary.

C-3.2 Non electric detonators: Make a selection of 20 assemblies, each one of particular type, having shell material, construction, shock tube, dimensions and crimp/closure of the similar design but delay composition and primary charge/base charge may vary.

C-4 PROCEDURE

The test is to be carried out at the highest operational temperature as claimed by the manufacturer.

C-4.1 SUDDEN RELEASE TEST

C-4.1.1 ELECTRIC DETONATORS: Test for 20 assemblies. To the fixing point, attach the detonator shell and to the weights of total mass, attach the leading wires corresponding to a force of (40±0.1) N. Allow the weights to rest on the supporting table in such a way that even a small amount of tension of about 5 N, is applied such that the distance between the attachment to the weights and the detonator is (500±50) mm.

Make sure that the leading wires are attached to the weights in such a way that the force could be uniformly distributed between them. The weights are releases such that the entire load is applied instantly and the load is maintained for (120±5) sec.

Keep the record if the detonator fires during the test or not. Record if or not the leading wires break down and/or if a pullout has occurred.

C-4.1.2 NON ELECTRIC DETONATORS: Test for 20 assemblies. To the fixing point, the detonator shell is attached and to the weights of total mass corresponding to the force of (40±0.1) N, the shock tube is attached. Allow the weights to rest on the supporting table, in such a way that a small amount of tension of about 5 N is applied and such that the distance between the attachment to the weights and the detonator is (500±50) mm. The weights are released such that the entire load is applied instantly and the load is maintained for (120±5) sec.

Keep the record if or not the detonator fires during the test. Record if or not the shock tube breaks and/or if a pullout has occurred.

C-4.2 SLOW RELEASE TEST (ELECTRIC DETONATORS ONLY)

Test for 20 assemblies. To the fixing point, the detonator shell is attached and to the weights of total mass corresponding to a force of (100±1) N, shock tube is attached. Allow the weights to rest on the supporting table, in such a way that a small amount of tension of nearly 5 N is applied, and such that the distance between the attachment to the weights and the detonator is (500±50) mm.

Make sure that the leading wires are attached to the weights in such a way that the force could be uniformly distributed between them. Slowly release the weights till the entire load is applied and the load is maintained for 10 seconds. Keep a record if or not the detonator fires during the test. Record if or not the leading wires break or if a pullout has occurred.

C-4.3 FUNCTIONING TEST AFTER SUDDEN RELEASE TEST

After carrying out the sudden release tests as given for electric detonators and non-electric detonators, fire out each of the remaining detonator of which the shock tube or leading wires are intact and no pullout has occurred, according to the instructions given by the manufacturer. Record if or not the detonators fire or not.

ANNEX D
(*Clause* 4.9)

DETERMINATION OF TRANSFER CAPABILITY OF SURFACE CONNECTORS, RELAYS AND COUPLING ACCESSORIES

D-1 GENERAL

When using non-electric initiation systems there is a need to transfer the shock-wave from one unit to another and/or to delay the signal. This can be done by means of surface connectors, relays and coupling accessories.

D-2 APPARATUS

Witness papers, initiating device for the donors, Detonating cords or shock tubes (for use as receptors or donors)

D-3 TEST PIECES

Make a selection of 25 items of similar type with similar construction and materials

D-4 PROCEDURE

D-4.1 RELAYS OR SURFACE CONNECTORS OTHER THAN THE ONES WHICH ARE DESIGNED TO BE HUNG FROM VERTICAL ROCK FACES

Connect the maximum number of receptors that are claimed by the manufacturer to the surface connector or to the relay as per the instructions given by the manufacturer.

Condition the entire assembly by submerging the assembly for 48 h at a depth of (0.5 ± 0.1) m in water. The temperature should be kept at (20±5) ^{o}C and make sure that the ends of the receptors are kept out of the water.

Unless specified by the manufacturer ensure that the surface connectors free end or relay shall remain submerged during conditioning.

After the conditioning step, remove the relay or connector from the water.

Witness papers are placed at each of the receptor’s end. Now initiate the donor by making use of the initiating device and then check the witness paper at each receptor’s end.

Record if shockwave has successfully transferred to all receptors or not.

D-4.2 RELAYS OR SURFACE CONNECTORS THAT ARE DESIGNED TO BE HUNG FROM NEAR VERTICAL ROCK FACES

If the relay or surface connector is of a type that is designed to be hung to a near vertical rock face and is not laid on the ground, from the place where it can be exposed to the puddles of water, as mentioned by the manufacturer, the procedure given in the clause **D-4.1** shall be performed with the relay or connector subjected to the ingress of the water test for IPX4as given in IS/IEC 60529, instead of the complete immersion in water.

D-4.3 COUPLING ACCESSORIES OTHER THAN THE ONES THAT ARE DESIGNED TO BE HUNG TO A NEAR VERTICAL ROCK FACES

Maximum number of receptors as claimed by the manufacturer are connected to the coupling accessory as per the instructions given by the manufacturer.

Condition the entire assembly by submerging it in water at a depth of (0.5±0.1) m for a period of 48 hours at a temperature of 20±5 ^{o}C, thereby assuming that the receptors ends are kept out of water.

After the conditioning is done, the coupling accessory is removed from water.

Witness paper is placed at the end of each receptor.

Initiate the donor by making use of initiating device and the witness paper is checked at the end of each receptor.

Record if the shock wave has successfully transferred to all the receptors or not.

D-4.4 COUPLING ACCESSORIES THAT ARE DESIGNED TO HUNG FROM THE NEAR VERTICAL ROCK FACES

In case the coupling accessory is of such a type that it is designed just to hung from a near vertical rock face and is not laid on the ground, where it could be exposed to puddles of water, as described by the manufacturer, the procedure given in the clause **D-4.3** shall be used with the coupling accessory to undergo the ingress of water test for IPX4 as given in IS/IEC 60529, in place of the total immersion in water.

D-5 TEST REPORT

It shall clearly indicate the following information:

i. Number of receptors that did no initiate during the test

ANNEX E
(*Clause* 5.1)

THERMAL STABILITY TEST

E-1 GENERAL

The method describes the determination of the thermal stability shock tubes for use with non-electric detonators by providing the heat treatment to the test pieces.

E-2 APPARATUS

Oven/heating cabinet which is capable of maintaining a prescribed temperature within ± 2 ^{0}C

Note: *The apparatus should be of such a design that it can ensure the prevention of sympathetic detonation.*

E-3 TEST PIECES

For each particular type having similar materials of construction, dimensions and chemical composition, selection of 25 pieces of shock tube is made, each with a length of (1.00±0.05) m.

E-4 PROCEDURE

In the heating cabinet, store the test pieces for 48 h at a temperature of (25±2) ^{0}C higher than the maximum safe operating temperature as given by the manufacturer but should be at least (75±2) ^{0}C.

12 of the test pieces are to be placed in a rack while keeping the base upwards and other 13 of the test pieces are to be placed in a rack while keeping their base downwards. Record any kind of incident of detonation or any evidence of reaction inside the tube (which may be audible or visible) during the test.

ANNEX F

(*Clause* 5.2)

DETERMINATION OF SENSITIVENESS TO IMPACT

F-1 GENERAL

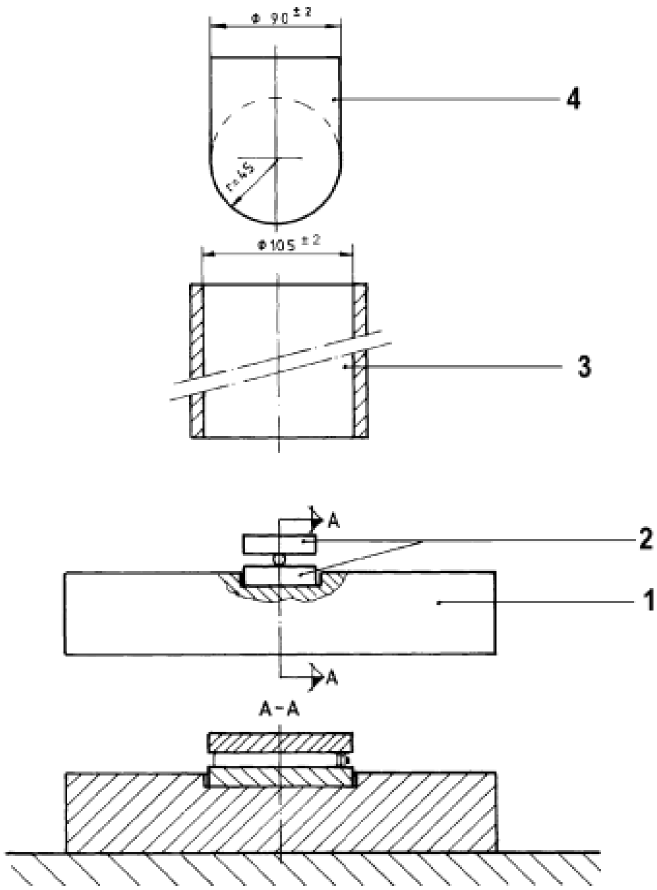
The resistance of a detonator to initiation or damage by impact gives an indication of its safety in handling, transportation and use.

F-2 APPARATUS

Impact testing apparatus, consisting of a (5.0 ± 0.01) kg steel hammer which can be dropped freely from a set height, inside a guide tube onto a steel plate and anvil containing the device to be tested. The anvil shall rest on a concrete floor.

NOTE: *Figure 3 shows the arrangement of the impact testing apparatus.*

The hammer is made of steel of type B1 100Cr6 as defined by ISO 683-17:1999. The plates are made of steel of type FE 490-2 as defined by ISO 1052:1982. The anvil is made of steel of type 46 S 20 as defined by ISO 683- 9:1988.



Key

1 Anvil
2 Plates
3 Guide tube
4 Hammer

Figure 3 – Impact testing apparatus for shock tubes

F-3 TEST PIECES

Select 25 pieces, each with a length of at least 200 mm, of a specific type of shock tube.

F-4 PROCEDURE

F-4.1 Place the shock tube piece between the two parallel steel plates and secure it by putting a thin paper tape around the plates. Place the whole assembly on the anvil so that the bottom plate fits into the recess (see Fig 3). Drop the hammer from the specified height and observe whether the shock tube ignites. Confirm the ignition at both ends of the shock tube with a witness sheet, e.g. a sheet of white paper. The mean height is calculated using the Bruceton method which is based on determining the level of stimulus at which there is a 50% probability of obtaining a positive result.

F-4.2 the Bruceton method involves the application of different levels of stimulus and determining whether or not a positive reaction occurs. The performance of the trials is concentrated around the critical region. It takes place by decreasing the stimulus in one level at the next trial if a positive result is obtained and by increasing the stimulus in one level if a negative result is obtained. Usually about five preliminary trials are performed to find a starting level in approximately the right region and then at least 25 trials are performed to provide the data for the calculations.

Note: *If no explosion occurs at the maximum height of the apparatus (12 m), test the next piece at the same height. Continue the procedure until all test pieces have been tested.*

F-5 CALCULATION

In determining the level at which the probability of obtaining a positive result is 50% (H_{50}), only the positive results (+) or only the negative results (-) are used, depending on which has the smaller amount. If the numbers are equal, either may be used. The data are recorded in a Table (e.g. as in Table 2) and summarized as shown in Table 3. Column 1 of Table 3 contains the drop heights, in ascending order, starting with the lowest level for which a test result is recorded. In column 2, ‘i’ is a number corresponding to the number of equal increments above the base or zero line. Column 3 contains the number of positive results (n (-)) for each drop height. The fourth column tabulates the result of multiplying ‘i’ times ‘n’ and the fifth column tabulates the results of multiplying the square of ‘i’ times ‘n’. A mean is calculated from the following equation:

$$H_{50} = c + d \times [(A/N_S) \pm 0.5] \qquad (1)$$

Where

$N_s = \Sigma n_i$,

$A = \Sigma (i \times n_i)$,

c is the lowest drop height

d is the height interval.

If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used. The standard deviation, s, may be estimated using:

$$s = 1.62 \times d \times [((NS \times B - A^2) / N_S^2) + 0.029] \qquad (2)$$

Where

$B = \Sigma (I^2 \times n_i)$.

EXAMPLE

Using the following data from Tables 1 and 2: lowest drop height 10 cm; height interval 5 cm; sum of i.n(-) 16; sum of i^2.n(-) 12,

The mean height is given by equation (1) as:

$H_{50} = 10 + 5 \times [(16 / 12) + 0.5] = 19.2$ cm

And the standard deviation by equation (2) as:

s = [((12 x 30 - 162) / 122) + 0.029] = 6.1

The minimum height at which explosion occurred = 15 cm

Table 2 Recording Data

Drop Height (cm)																											
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	+	-
30								+																		1	
25							-		+				+				+		+							4	1
20				+		-				+		-		+		-		-		+		+				5	4
15	+		-		-						-				-						-		+		+	3	5
10		-																						-			2
																										13	12

Table 3 Summarizing data

Height (cm)		**Calculations using negatives**		
	i(-)	n(-)	i(-).n(-)	i^2(-).n(-)
25	3	1	3	9
20	2	4	8	16
15	1	5	5	5
10	0	2	0	0
Totals		N_s = 12	A = 16	B = 30

F-6 TEST REPORT

It shall clearly indicate the following information:

i. The mean height and standard deviation as calculated from the above procedure
ii. The minimum height at which the explosion occurred in at least 1 out of 25 trials.

ANNEX G

(*Clause* 5.3)

RESISTANCE TO ABRASION

G-1 GENERAL

During usage, the plastic tubing of shock tube can experience abrasive forces when drawn over a rough surface which may result in gradual wearing of the plastic material. This method determines the ability of shock tube to resist the abrasive forces that are likely to be experienced in the normal use.

G-2 PRINCIPLE

The test piece is subjected to abrasion by an abrasive surface, moving on a particular speed, while applying a particular load then its functioning is tested after immersion in water.

G-3 APPRATUS

G-3.1 ABRASION TEST APPARATUS

It comprises of Pivot (1), Hinged arm (2), Leading wire (3), weight (4), Pulley (5), Rod (7), weight (7), clamp screw (8) for attaching the test piece, clamp for attaching the test piece (9), Rotor (10).

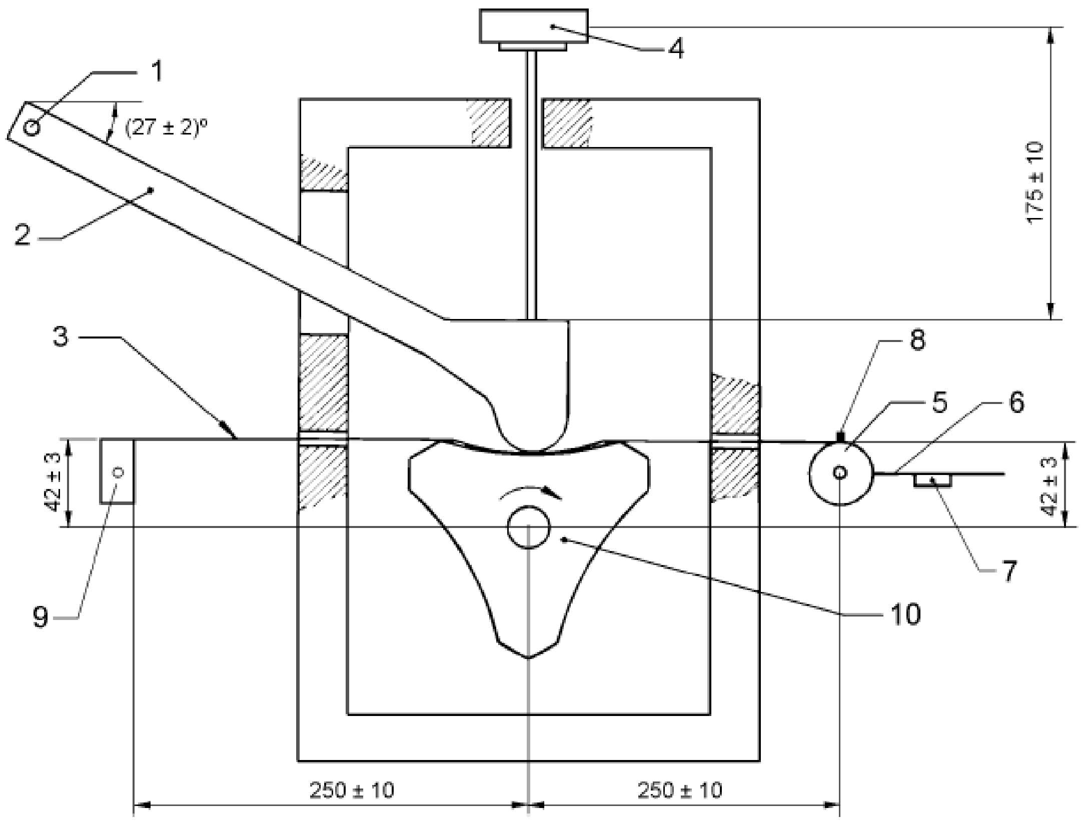
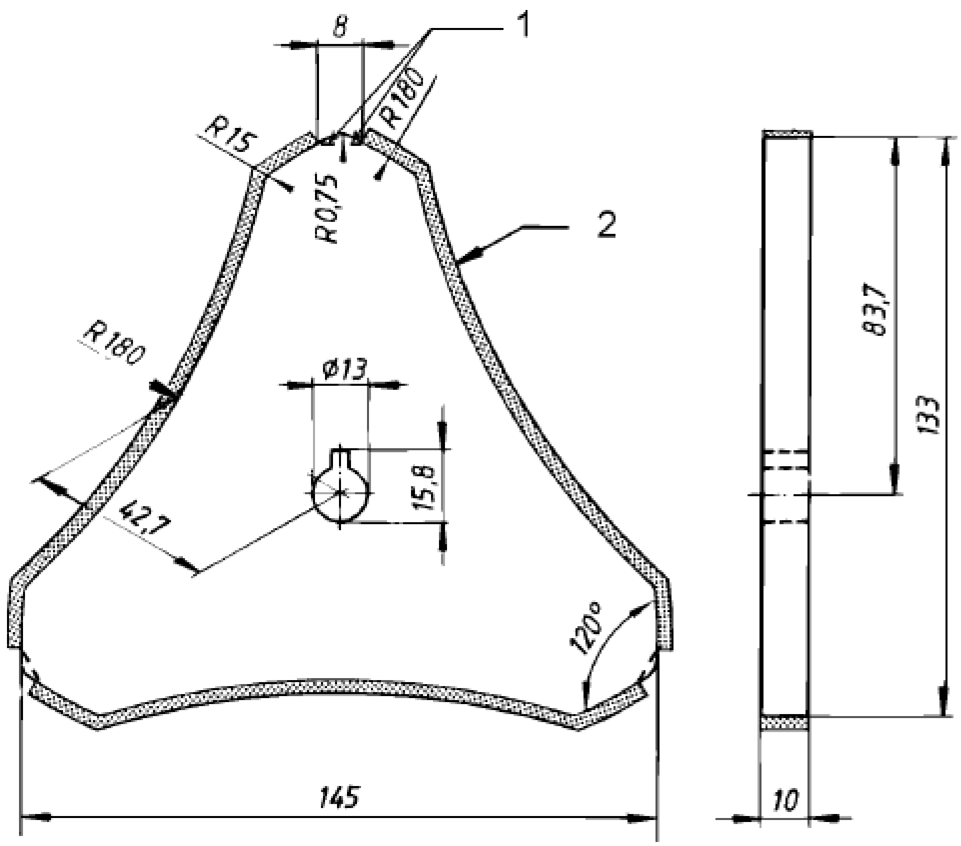


Figure 4 Abrasion test apparatus with rotor in the starting position

G-3.1.1 Steel or brass rotor: having a perimeter of (432±2) mm to which 3 abrasive are attached with the help of double sided adhesive tape or glue. It is to be ensured that the electrical contact between the rotor and the abrasive strips is made eg: at the slits on the rotor, the point where the ends of the abrasive strips are inserted (as given in Figure 5). The rotating speed of the rotor shall be around (9.96±0.18) rpm, with a mean peripheral speed of (0.075±0.001) m/s.

Note: *Depending upon the principle of attachment (i.e. tape or glue) of the abrasive strip to the rotor, the abrasive strip have to be carefully bent by making a use of a suitable tool so as to fit properly against the rotor surface.*



Key

1. Slit for the end of the abrasive strip
2. Abrasive strip

Figure 5 Rotor

G-3.1.2 Motor: able to maintain a constant speed of rotation whatever load is applied to the rotor.

G-3.1.3 Load: It is applied to the test piece with the help of hinged arm.

G-3.1.4 Hinged arm: it should be made of brass or steel as given in Figure 6. At the start point, the hinged arm shall apply a load of (8.35±0.05) N to the test piece.

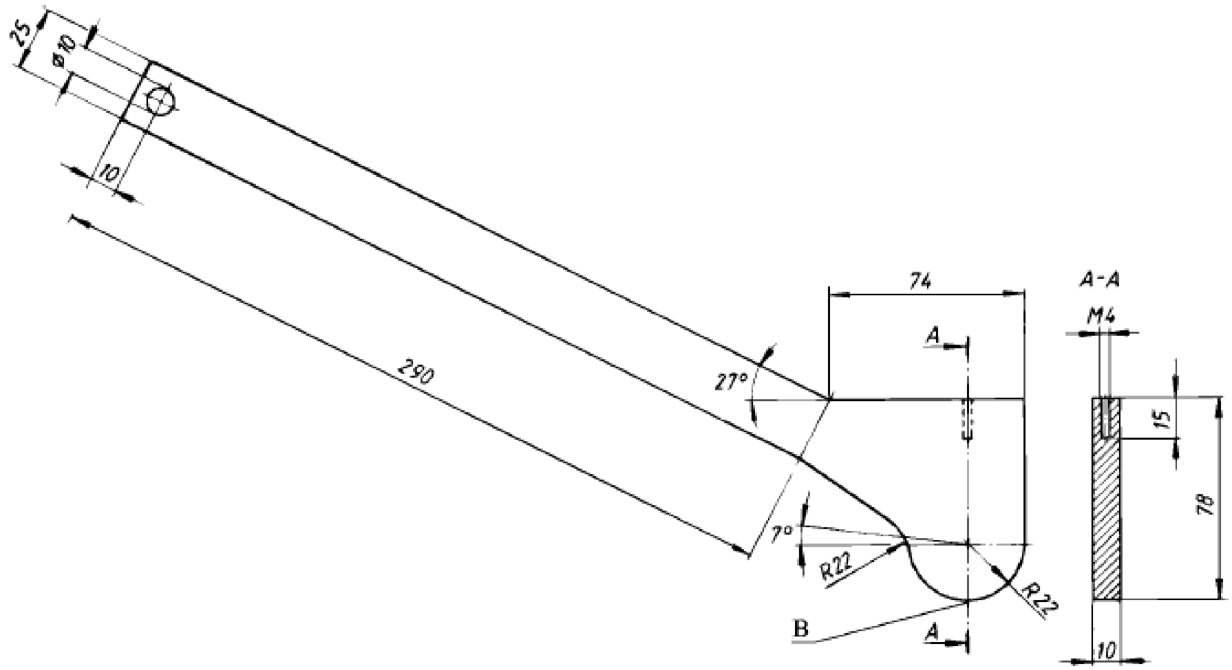


Figure 6 Hinged Arm

G-3.1.5 Abrasive strips: 3 pieces with the approximate dimensions of 10 mm X 145 mm each, made from grinding steel.

G-3.1.6 Pulley: with a diameter of (70±1) mm, sufficient for the application of a tensile load of (8.1±0.5) N to the test piece, with a rod and a weight.

Note 1: *A DC motor having an output power of at least 500W and with a separate speed control can be used.*

The rotor should be capable of rotation in 0.6 s after starting.

Note 2: *This requirement can be verified by the use of two electrodes which are 20 mm apart and each of them is adjusted to provide an electrical contact to the tips of the rotor during the process of rotation. To a digital counter, electrodes are connected by counting elapsed time between the pulses from 2 electrodes when they are being touched at the tips of the rotor.*

In between the elapsed time, comparison is made during a continuous run at a particular speed and the time elapsed is 0.6 sec after start. Initially, the rotor is manually rotated to an appropriate position such that the tip of the rotor reaches the second electrode after 0.6 sec.

Also, the electrode can be used for calibration of a particular speed of rotation, eg: by calculating the time for a single revolution. In such case, use of a single electrode is needed.

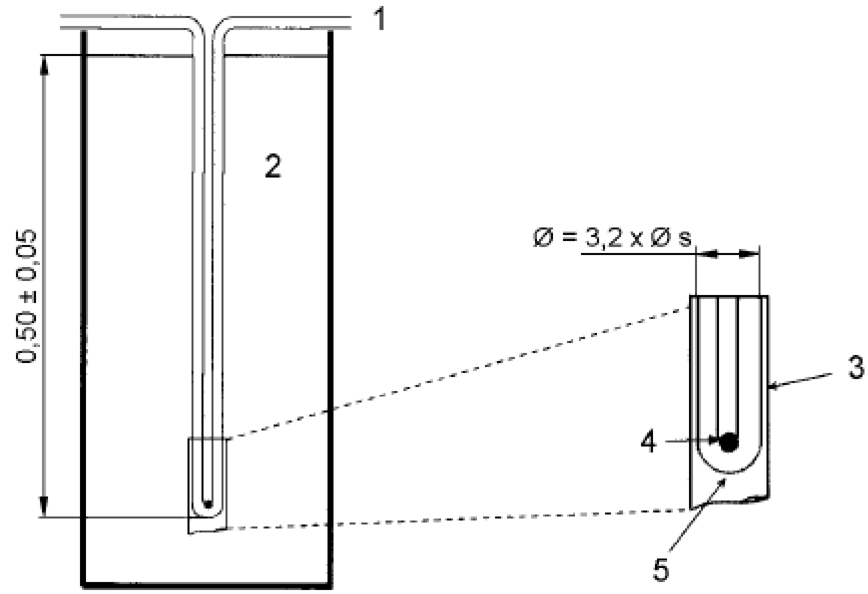
G-3.1.7 Digital timer with relay output capable of:

- A setting of predetermined time in (0 to 10) sec ± 0.1 sec range.

- Start when hinge arm is lifted by the piece under test.
- Stopping the rotor automatically when the predetermined tie has elapsed (needed for shock tube testing).
- Stopping the rotor automatically when the electric point of contact is made in between the abrasive strip or the rotor and the leading wire.

G-3.2 IMMERSION TEST APPARATUS

It should consist of the following components.



Key

1. Shock tube
2. Water
3. Cylindrical bending rig
4. Rod with a diameter equal to the diameter of the shock tube
5. Abraded surface of the shock tube on the outer radius

Figure 7 Water tank and bending rig

G-3.2.1 Tank of water: It should be deep enough to permit the abraded surface of shock tube to immerse to (0.50 ± 0.05) m.

G-3.2.2 Cylindrical bending rig: It should be capable of maintaining and bending the test pieces of shock tube in a U form with the radius of bending region around (1.6 ± 0.1) times the diameter of the shock tube.

G-3.2.3 Conditioner chamber: It should be capable of maintaining the maximum temperature by ± 2 ^{0}C as claimed by the manufacturer.

G-4 TEST PIECES

Make a selection of 10 lengths of shock tube, with each one being (3.0±0.5) m long, from 10 detonators having similar shock tube composition, constructions and dimensions. Selection of test pieces can be made from the detonators from which the pieces can be cut or from the shock tubes having the similar specification as supplied by the detonator's manufacturer.

G-5 PROCEURE

G-5.1 Conditioning of the test pieces is carried out inside the conditioning chamber at the highest temperature as claimed by the manufacturer. Set at least 2 h before testing.

G-5.2 As given in Figure 4, attach each test piece to the attachment points by suitably clamping so as to safeguard the test piece from any kind of damage at the attachment points.

G-5.3 Position the rotor as given in Figure 4 that shows the starting position.

G-5.4 Hinged arm should be lift up (72±2) mm above the rotor centre and it should be fixed in that position by using a retaining pin or similar arrangement.

G-5.5 The tensile load is adjusted to 8.1 N.

G-5.6 The hinged arm is loaded with (12.20±0.02) N [by excluding the load adjusted due to the hinged arm itself].

G-5.7 The test is carried out at the upper limit of temperature as given by the manufacturer ±2 ^{0}C.

G-5.8 Now start the motor.

G-5.9 As the test piece lifts up the hinged arm, the timing mechanism shall be started automatically.

G-5.10 The retaining pin is then removed.

G-5.11 After the timing mechanism of (6.50±0.05) s. the rotor shall be automatically stopped.

G-5.12 From the apparatus, remove the shock tube. Note: Clean the abrasive strip after each test, for eg: by using a brush having plastic bristles. The strip should be changed at several intervals on the basis of the degradation of the strip and can be used for several tests. In order to determine the degradation of the strip, it can be monitored in routine by periodically testing a new set of ten category II leading wires which are known to give a mean time failure of 5 sec with an abrasive strip.

G-5.13 To the U shaped bending ring, attach the shock tube such that the surface which is abraded is on the outer radius of the bend.

G-5.14 Into the tank of water, put the shock tube and the bending rig such that the free ends are above water and the surface that is abraded is (0.50 ± 0.05) m below the water (as given in Figure 7).

G-5.15 At a temperature of (20±5) ^{0}C, store for 24 h.

G-5.16 After storage in water, the shock tube is removed and attempts are made to initiate it using the manufacturer’s recommended imitating device.

G-5.17 Record if the tube initiates or not. In case the tube initiates, record if it propagates along its entire length or not.

ANNEX H
(*Clause* 5.4)

RESISTANCE TO CUTTING DAMAGE

H-1 GENERAL

During usage, the plastic tubing of shock tube can experience cutting forces when drawn over a sharp edge which may result in tearing of the plastic material. This method determines the ability of shock tube to resist the cutting forces that are likely to be experienced in the normal use.

H-2 APPARATUS

H-2.1 CUTTING DAMAGE APPARATUS

It comprises of following components as shown in Figure 8:

H-2.1.1 Pulley A (with a diameter of 43.0±0.5) mm,

H-2.1.2 Pulley B (with a diameter of 33.0 ± 0.5) mm,

H-2.1.3 Tungsten carbide edge that have a cutting edge of 90^o radiused to (0.07 ± 0.02) mm.

H-2.1.4 Electrical device, to detect when the point of electrical contact is made in between the cutting edge and the conductor in the leading wire.

H-2.1.5 Electric motor: having a gearbox which is capable of rotating pulley B at $0.125_{0}^{+0.008}$ r/s and its final position is also maintained when the power is switched off to the motor.

H-2.1.6 Spring balance or any kind of alternative arrangement which is capable of applying a gradual increasing force by indicating its value.

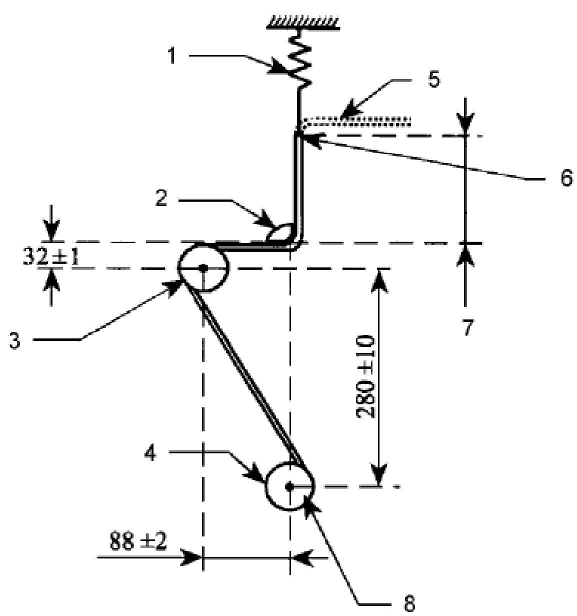


Figure 8: Principle of test apparatus

Key

1. Spring balance
2. Tungsten carbide edge
3. Pulley A
4. Pulley B
5. Remaining shock tube/leading wire
6. Suitable attachment to the shock tube/leading wire
7. (375±20)mm at start of the test
8. Suitable attachment to the shock tube/leading wire

Figure 9 illustrates an example of an apparatus having an equivalent alternative arrangement for recording and applying the maximum value of applied force.

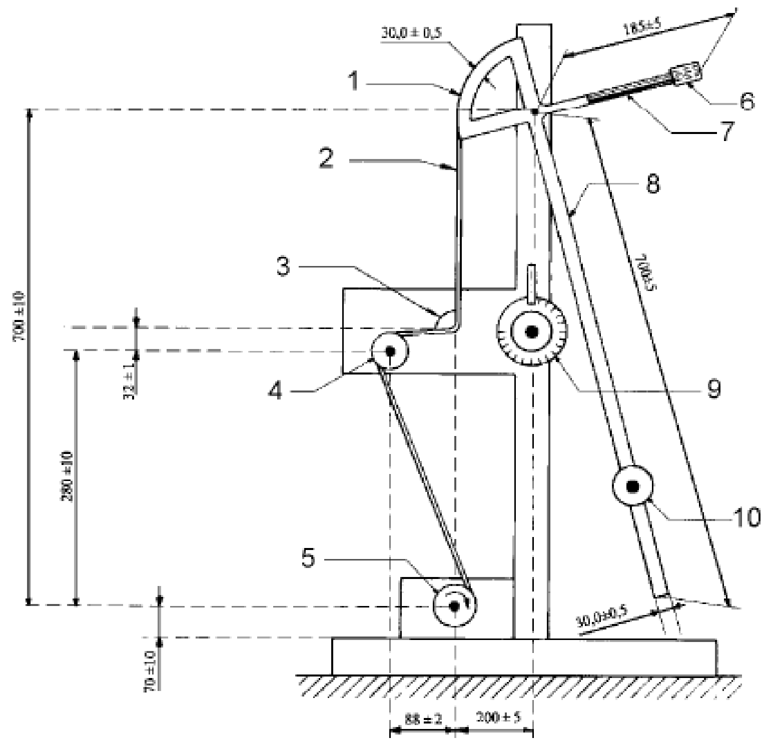


Figure 9: Example of a test apparatus

Key

1. Internal radius 200 mm
2. Shock tube/leading wire
3. Tungsten carbide edge
4. Pulley A
5. Pulley B
6. Movable balance weight of (860±10)g
7. Diameter (12±0.2) mm
8. Arm of a lever on steel with thickness of (8.5±0.2) mm

9. Protractor
10. Movable load

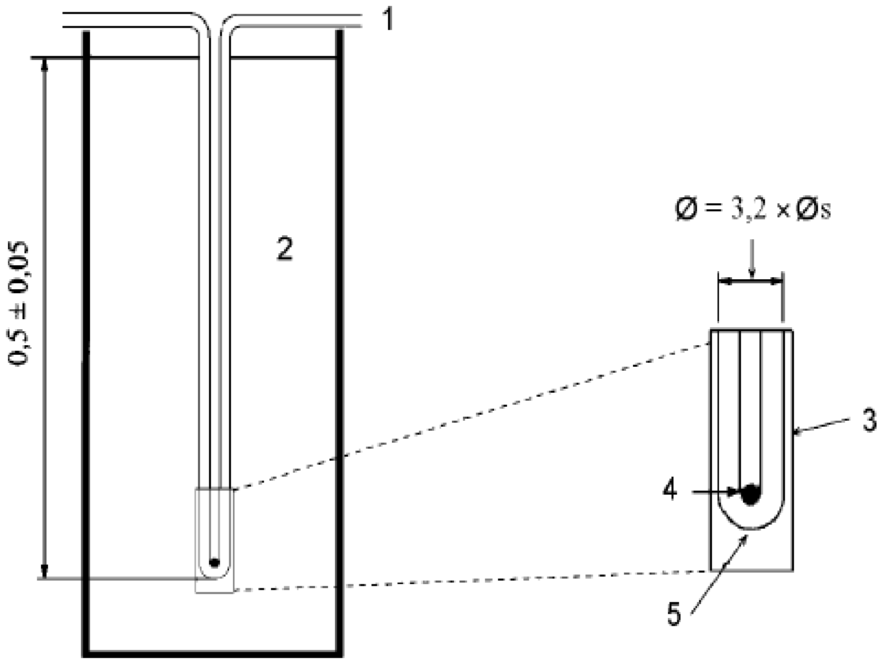


Figure 10: Water tank and bending rig

Key

1. Shock tube
2. Water
3. Cylindrical bending ring
4. Rod with a diameter equal to the diameter of the shock tube
5. Cut surface of shock tube on the outer radius

H-2.2 IMMERSION TEST APPARATUS

It is shown in Figure 10, and comprises of following components:

H-2.2.1 Tank of water which is deep enough so as to allow the cut portion of shock tube to be immersed to (0.50 ± 0.05) m.

H-2.2.2 Cylindrical bending ring: which is capable of maintaining and bending the test pieces of shock tube in a U form having a bending radius of (1.6 ± 0.1) times the shock tube diameter.

H-2.2.3 Conditioning chamber: which is capable of adjusting the maximum temperature as claimed by the manufacturer.

H-3 TEST PIECES

Make a selection of 20 lengths of shock tube, each (3.0 ± 0.5) m long, from 20 detonators of a particular type which have the similar shock tubing type, dimensions and composition. The selection of the test pieces can be made from the detonators from which the pieces are cut or from shock tubes provided by the manufacturer of the detonator.

H-4 PROCEDURE

H-4.1 In the conditioning chamber, the test pieces are conditioned for 2 h at the maximum temperature as claimed by the manufacturer.

H-4.2 For all the 20 test pieces, one end of the shock tube is attached to the spring balance and the other end is attached to the pulley B (as driven by the motor) such that it passes over the pulley A and the tungsten carbide cutting edge (as given in Figure 8).

H-4.3 The test is carried out at the maximum temperature as claimed by the manufacturer within ± 2 ^{0}C.

H-4.4 In order to draw the shock tube over the cutting edge, start the electric motor and apply the load which is gradually increasing.

H-4.5 Stop the apparatus, when the spring balance or similar arrangement reads (7.0 ± 0.5) N and then remove the shock tube. Cool it down to (20±2) ^{0}C before it is inserted in the bending rig.

H-4.6 Into the bending rig, insert the shock tube such that the tube is bent into a U tube shape having its cut surface on the outer radius of the bend. Put the bending rig and the shock tube into the tank of water such that its free ends are above water while its cut surface is below water at a depth of (0.50±0.05) m. Store it for 24 h at a temperature of (20±5) ^{0}C.

H-4.7 Keep it in the bending rig after storing in water. Then attach a witness paper to one end and within 1 hour make an attempt to initiate it at the other end by making a use of manufacturer’s recommended initiating device. Record if or not the tube initiates. In case the tube initiates, record using witness paper, if or not it propagates along its entire length.

ANNEX J
(*Clause* 5.5)

RESISTANCE OF DETONATORS TO BENDING

J-1 GENERAL

During use on site, detonators shells can be subjected to bending during the loading of boreholes. This test determines the ability of detonator shell to resist the bending forces likely to be experienced in normal use.

J-2 APPARATUS

J-2.1 Weights that have the capability of applying a force of (50±0.1) N with a wire attachment.

J-2.2 Steel block: as given in Figure 11, has a hole (A) of at least 30 mm in length. The hole diameter should not exceed the detonator diameter by higher than 0.1 mm. The radius of the hole edge shall be (2±0.1) mm.

Figure 11: Steel block

Key
A the diameter of the hole
L the length of the hole, minimum 30 mm

J-2.3 Steel rings: They are tightly fitted to each end of the detonator. Illustration has been given in Figure 12.

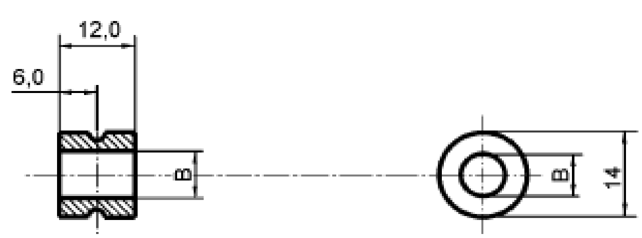


Figure 12: Ring

Key

B the inner diameter of the ring, tightly fitting each end of the detonator

J-2.4 Removable support table that is capable of supporting the weights. The illustration has been given in Figure 13 and 14.

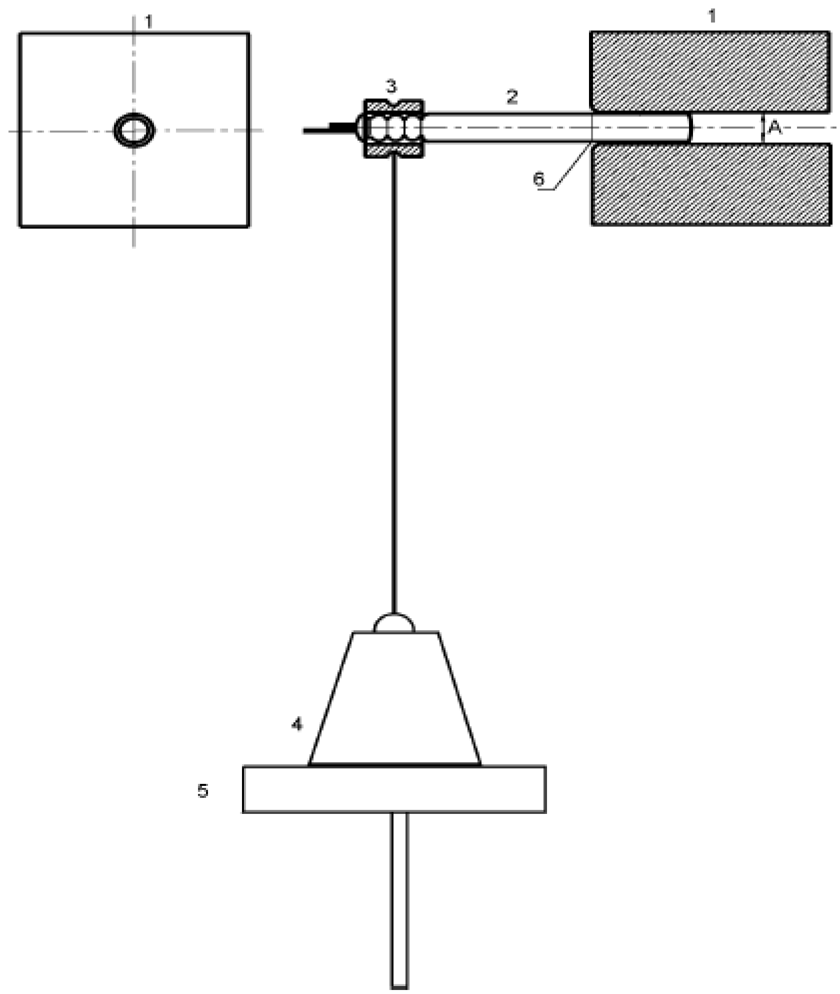


Figure 13: Assembly with detonator supported at the base

Key

1. Steel Block
2. Detonator (shown as an electric detonator)
3. Ring
4. Weight
5. Supoort table
6. Approx position of the end of the delay element or the base charge
7. Diameter of the hole

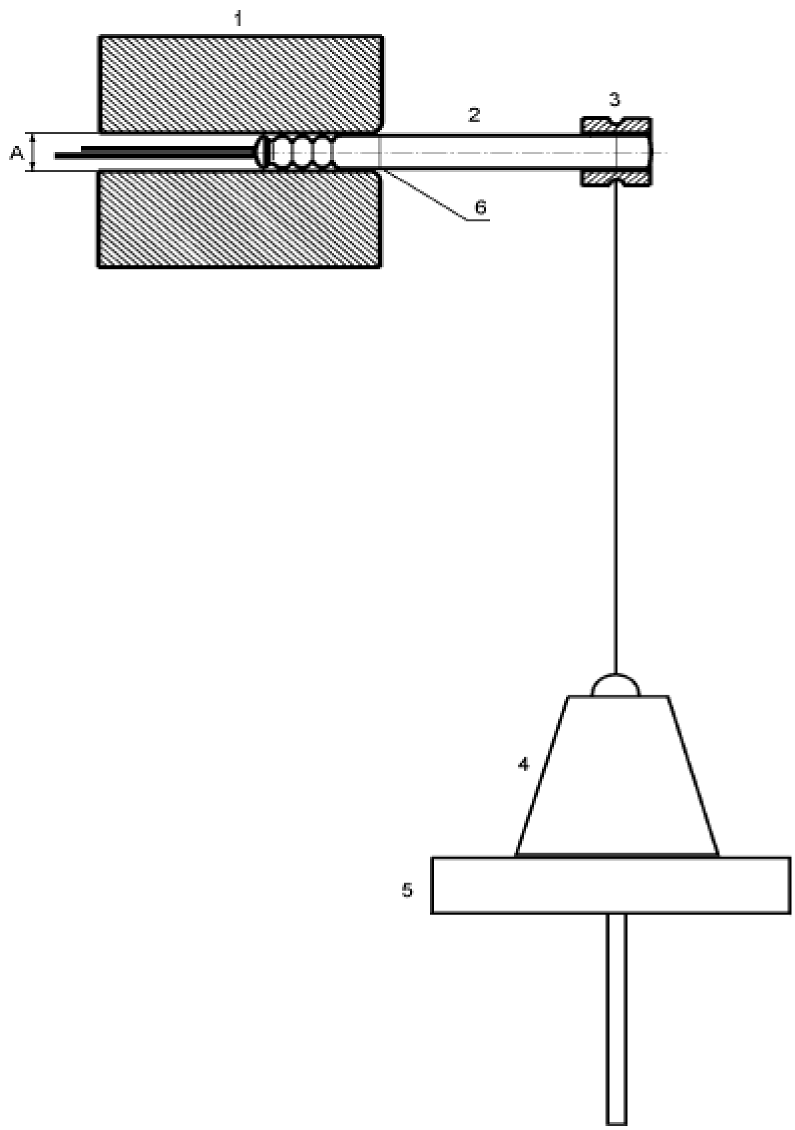


Figure 14: Assembly with detonator supported at the top

Key

1. Steel Block
2. Detonator (shown as an electric detonator)
3. Ring
4. Weight
5. Support table
6. Approx position of the end of the delay element or the base charge
7. Diameter of the hole

J-3 TEST PIECES

Select 26 detonators having a longest shell form a particular type with the similar compositions and design.

J-4 PROCEDURE

J-4.1 General

Determine the weakest point of the detonator as shown in the figure 15.

Note: *It is the point from where the outer shell will break when subject to a 90 degree angle pulling force.*

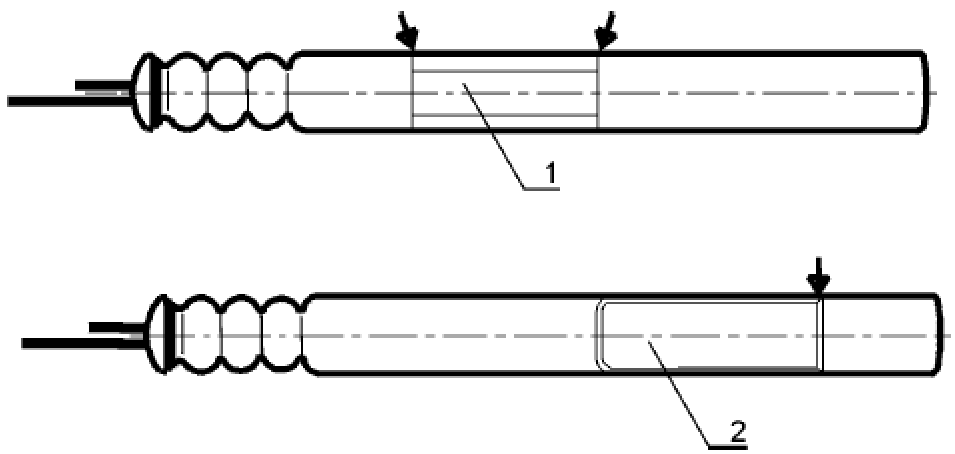


Figure 15: Principle of finding weakest points of the detonator

Key

1 Delay element
2 Primary charge cap

 The weakest points

J-4.2 Non electric detonators at the base:

Take 13 detonators for the test and the mark the weakest point at its base (Figure 15). Insert the detonator by keeping its base first into the steel block to the weakest point. On the support table, rest the weight such that no force is applied on the detonator. Now, to the end of the protruding part of the detonator, attach the ring and the wire as given in Figure 13. Lower the support table gradually such that a downward force is applied. Continue to lower down the table till the detonator is completely supporting the weight. The load is maintained for a minimum of 5 seconds. Record any cracking or breaking of the shell and any initiation of the detonator.

J-4.3 Non electric detonators at the top:

J-4.3.1 Take 13 detonators for the test. Select the length of insertion as follows:

J-4.3.1.1 If other than shock tube, there is no pyrotechnical material or other explosive above the delay element, the length is from the two mm above the delay element to the top of the shell.

J-4.3.1.2 In case there is a pyrotechnic composition above the delay element, the length is up to the middle of this composition from the top of the shell.

J-4.3.2 At the top, mark the weakest point. Insert the detonator by first keeping its top into the steel block while keeping the chosen length inside the hole. On the support table, rest the weight such that no force is applied to the detonator. To the end of the protruding part of the detonator, attach the wire and the ring as in Figure 14. Lower the support table gradually such that the force in downward direction is applied. Continue to lower down the table till the detonator is completely supporting the weight. Maintain the load for a minimum of 5 seconds.

J-4.3.3 Record the cracking or braking of the shell and any initiation of the detonator.

ANNEX K
(*Clause* 5.6)

DETERMINATION OF ELECTRICAL NON CONDUCTIVITY

K-1 GENERAL

This method determines the electrical insulation resistance (non-conductivity) and the electrical flash-over distance of shock tubes for use with non-electric detonators.

K-2 APPARATUS

K-2.1 DETERMINATION OF ELECTRICAL INSULATION RESISTANCE

K-2.1.1 Meter for measuring electrical insulation resistance having the required sensitivity and accuracy.

K-2.1.2 Voltage source, capable of applying at least 500 V D.C. with no more than 2 % deviation.

K-2.1.3 Conditioning chamber, capable of being maintained at (20 ± 2) °C and (50 ± 5) % relative humidity.

K-2.2 DETERMINATION OF ELECTRICAL FLASH-OVER DISTANCE

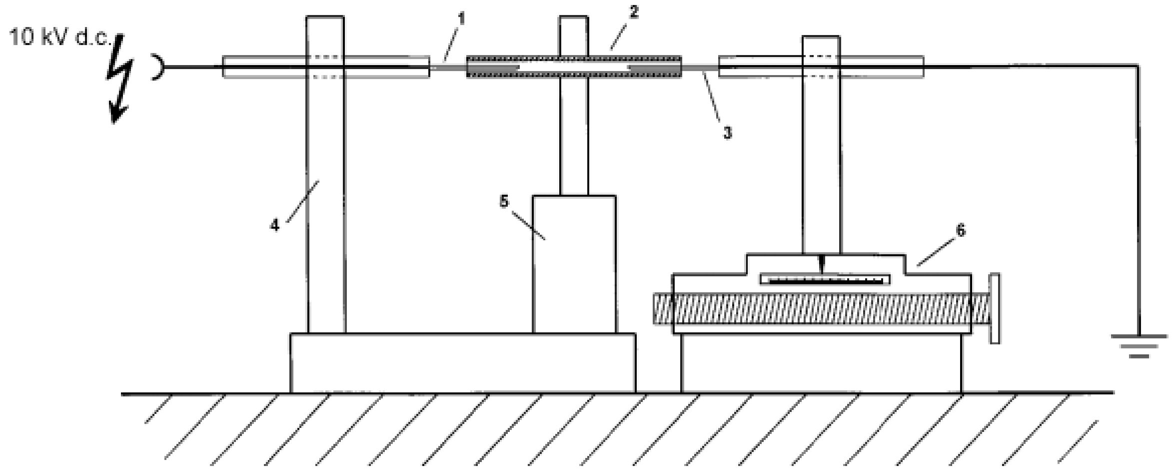
K-2.2.1 Voltage source, capable of applying 10 kV D.C. with no more than 3 % deviation and with the current output limited to no more than 5 mA.

K-2.2.2 Sensing device, to detect when an electrical flash-over has occurred.

K-2.2.3 Two needle electrodes, with a diameter of 60 % to 80 % of the shock tube's internal diameter, made from stainless steel and having rounded ends.

NOTE: *The rounded ends are needed to avoid corona discharges, but do not need precise specification.*

K-2.2.4 Test rig, comprising an electrically insulated mounting arrangement to hold the test piece in position, a fixed support for one needle electrode and a moveable support with a linear measuring scale for the other needle electrode, as shown in Figure 16.



Key

1 Fixed electrode
2 Test piece
3 Movable electrode
4 Electrode support
5 Test piece support
6 Movable electrode support

Figure 16 – Test Rig

K-3 TEST PIECES

K-3.1 DETERMINATION OF ELECTRICAL INSULATION RESISTANCE

Select 30 lengths of shock tube each of (100 ± 10) mm. If the shock tubes are assembled with detonators, the lengths shall be taken from 30 detonators of the same specific type. If the detonators form part of a series with different delay times, select the test pieces from 30 detonators with delay times as evenly distributed throughout the series as possible.

K-3.2 DETERMINATION OF ELECTRICAL FLASH-OVER DISTANCE

Select 30 lengths of shock tube each of (100 ± 10) mm. If the shock tubes are assembled with detonators, the lengths shall be taken from 30 detonators of the same specific type. If the detonators form part of a series with different delay times, select the test pieces from 30 detonators with delay times as evenly distributed throughout the series as possible.

NOTE: *Alternatively, the length of the test piece can be determined by a preliminary test to determine the maximum flashover distance, in which case the length of the test piece should be at least 10 mm longer than this distance.*

K-4 PROCEDURE

K-4.1 PREPARATION OF TEST PIECES

Condition the test pieces for 24 h at (20 ± 2) °C and (50 ± 5) % relative humidity.

K-4.2 DETERMINATION OF ELECTRICAL INSULATION RESISTANCE

Measure and record the insulation resistance of the test pieces according to IEC 60167:1964 [It has been withdrawn and replaced by IEC 62631-3-3: 2015] by using conducting paint electrodes and by applying a voltage of at least 500 V D.C.

K-4.3 DETERMINATION OF ELECTRICAL FLASH-OVER DISTANCE

Place the test piece in the mounting arrangement and insert a needle electrode at least 5 mm into each end as shown in Figure 16. Apply the test voltage of 10 kV to the needle electrodes. Slowly decrease the distance between the needle electrodes by inserting the movable electrode further into the test piece. Stop moving the needle electrode as soon as electrical flash-over occurs. Record the "flash-over distance" between the inserted ends of the needle electrodes in millimeters.