Indian Standard

METHODS OF TEST FOR VULCANIZED RUBBERS

PART XI DETERMINATION OF REBOUND RESILIENCE

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Indian Standard

METHODS OF TEST FOR VULCANIZED RUBBERS

PART XI DETERMINATION OF REBOUND RESILIENCE

0. FOREWORD

0.1 This Indian Standard (Part XI) was adopted by the Indian Standards Institution on 31 July 1969, after the draft finalized by the Rubber Products Sectional Committee had been approved by the Chemical Division Council.

0.2 This standard covers test procedures for determining the rebound resilience of vulcanized rubbers; it employs a mechanism which has a part that strikes the rubber test piece with known mechanical energy and is then free to rebound.

0.3 The value of the rebound resilience involved during impact depends mainly on the temperature and to a certain extent on other factors like magnitude of stress, friction loss, air drag, vibration and weight and height of the fall of the indentor. The methods described in the specification are by the use of Dunlop Tripsometer and Lupke Pendulum. Even using the similar type of measuring apparatus under identical condition, the resilience values obtained will not necessarily be identical.

0.4 In Dunlop Tripsometer method, certain corrections are to be made to the observed values due to friction loss, damping and shuffle. But Lupke Pendulum method needs no correction as there is no motion of the clamped test piece to its holder and damping by air resistance and friction is negligible. However, Dunlop Tripsometer is more compact and simple for operations. At present, in this country, only Dunlop Tripsometer method is followed for determining rebound resilience. However, attempts are being made in this country to equip the laboratories with Lupke Pendulum type instrument. ISO has adopted Lupke Pendulum method as the standard method for the determination of rebound resilience. It is hoped that in future, laboratories equipping themselves with apparatus for determining rebound resilience would prefer to have Lupke Pendulum type of instruments.

0.5 While preparing this standard, assistance has been drawn freely from the following standards:

ISO/DR 1767 Determination of rebound resilience of vulcanized rubber by the Lüpke Pendulum. International Organization for Standardization.

B.S. 903 : Part A8 : 1963 Methods of testing vulcanized rubber — Determination of rebound resilience. British Standards Institution.

0.6 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 : 2-1960*. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

1. SCOPE

1.1 This standard (Part XI) prescribes methods for determining the rebound resilience of vulcanized rubbers.

2. TERMINOLOGY

2.0 For the purpose of this standard, the following definitions shall apply.

2.1 Resilience — The ability of a rubber vulcanizate to return the energy used to deform it.

2.2 Rebound Resilience — The proportion of applied kinetic energy returned in one impact cycle.

3. METHODS OF TEST

3.1 In this standard two methods have been prescribed. In Method A the Dunlop Tripsometer is used and in Method B Lüpke Pendulum is used.

4. METHOD A — DUNLOP TRIPSOMETER

4.0 Outline of the Method — The test consists in allowing a rigid mass to strike the rubber test piece from a fixed angle and measuring the angle of rebound. Tests are commonly required either on several rubbers at one temperature or on one rubber at a series of temperature (not more than 10°C apart) in order to study the temperature variations of resilience.

4.1 Apparatus

4.1.1 The Tripsometer has the following components.

*Rules for rounding off numerical values (*revised*).

4.1.1.1 The apparatus (*see* Fig. 1) consists of a solid steel disk 419·0 ± 1·3 mm in diameter, 14·3 cm thick and of mass 16 500 ± 50 g. The disc carries on its periphery, a bracket which holds a striking steel ball 400·00 ± 0·04 mm in diameter with its centre 260·0 ± 0·5 mm apart from the centre of the disc, the ball and bracket together adding an unbalanced mass of 60·0 ± 0·2 g.

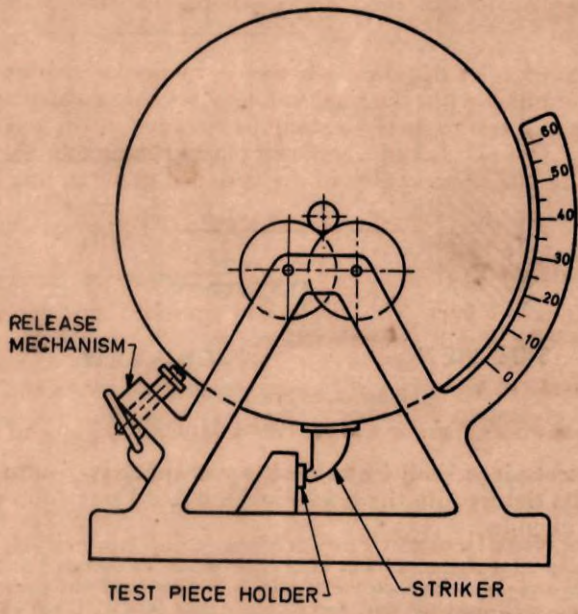


FIG. 1 DUNLOP TRIPSOMETER

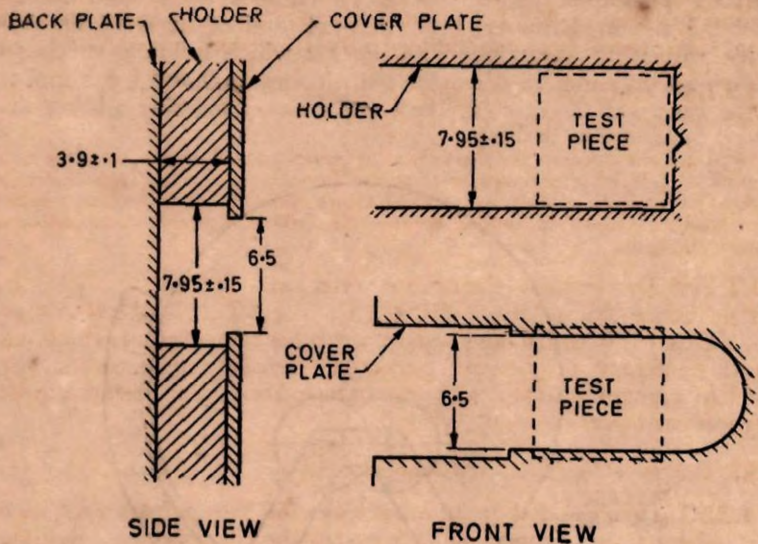
4.1.1.2 The scale is graduated in degrees to measure the angular displacement of the disk, which can be held in any desired position by closing the stops provided. On opening the stops, the disk is released instantaneously by a release mechanism.

4.1.2 The release mechanism shall not impart any impulse to the striker.

4.1.3 Provision to hold the test piece in a recessed slot into which the test piece shall fit tightly, and provision for electrically heating the holder (*see* Fig. 2) shall be made.

4.2 Test Piece

4.2.1 If fabric is attached to the sample it shall be removed before testing and the sample surface shall be flat and smooth.



All dimensions in millimetres.

FIG. 2 TEST PIECE HOLDER

4.2.2 The test piece shall be a block approximately 8 mm square but such that it fits tightly into the holder and 4·0 ± 0·1 mm thick and may be either cut or moulded.

NOTE — Losses due to transmission of energy to the instrument through the surface supporting the test piece may become serious with very hard test pieces. Hence this method shall not be used for test pieces harder than 90 IRHD* at the temperature of test.

4.3 Procedure

4.3.1 *Conditioning of Test Pieces*

4.3.1.1 Samples for test shall not be prepared during first 24 hours after vulcanization. For accurate comparisons between different rubbers, it may be necessary to ensure that these are tested at substantially the same interval after vulcanization.

4.3.1.2 Protect test pieces from light as completely as possible during the interval between vulcanization and testing.

4.3.1.3 Keep test pieces at a temperature of 27° ± 2°C (*see* IS : 196-1966†) for a period of not less than 3 hours immediately prior to the

*International Rubber Hardness Degree.
†Atmospheric conditions for testing (*revised*).

measurement and test. Test these test pieces immediately but if not tested immediately, keep at 27° ± 2°C until tested. If the preparation involves buffing, the interval between buffing and testing shall not exceed 72 hours.

4.3.1.4 Condition test pieces and the test piece holder at the test temperature before testing.

NOTE — To compensate for loss of heat by radiation, conduction, etc, it is necessary to work at slightly higher temperature on the thermometer, or the Tripsometer shall be covered with a thick glass casing or shall be suitably located in a constant temperature room where it is free from ambient temperature, effects of drafts, doors, windows and other equipment.

4.3.2 *Test Temperature* — Carry out tests at − 70° ± 1°C, − 55° ± 1°C, − 40° ± 1°C, − 25° ± 1°C, − 10° ± 1°C, 0° ± 1°C, 27° ± 1°C, 50° ± 1°C, 70° ± 1°C and 100° ± 1°C and also at any other temperature which may be deemed necessary in view of particular service requirements. Where resilience changes quickly with the temperature, for research purposes closer intervals may be used.

4.3.3 *Determination of Rebound Resilience*

4.3.3.1 Turn the disk in an anti-clockwise direction through an angle of 45° where it is clamped by a cam-release mechanism. Release the mechanism. On release, the striking ball is carried down and rebounds from the test piece, the angular displacement of the rebound being measured at the end of the rebound swing.

4.3.3.2 Subject the test piece to a number of impacts in rapid succession (4 to 6 are usually sufficient) until a constant reading is maintained for three consecutive impacts. Use this constant reading in the calculation of the results.

4.3.3.3 Test two test pieces and average the results. Repeat the test if results are not within 5 percent of the mean.

4.3.3.4 In tests at a series of temperatures not more than 10°C apart, keep the test piece in the holder for 10 minutes after each change of temperature of the holder.

NOTE — Any suitable angle may be chosen but experience has shown 45° to be the convenient for most rubber compounds.

4.4 Expression of Results

4.4.1 Express the results as percentage rebound resilience calculated from the following expression.

4.4.1.1 *Determination of rebound resilience*

$$\text{Rebound resilience, percent} = \frac{1 - \text{Cos}\ (\theta + \delta_2 + \sigma)}{1 - \text{Cos}\ (\varphi - \delta_1)} \times 100$$

where

θ = rebound angle,

δ_2 = damping correction for angle θ,

σ = shuffle correction,

φ = angle of drop (45°), and

δ_1 = damping correction for angle φ.

4.4.1.2 *Determination of damping* — Determine damping by removing the test piece holder and allowing the disk and attachments to oscillate freely, noting the amplitude of successive swings in the same direction, measured as angular displacement. Repeat the procedure at several different amplitudes covering the required range of resilience values.

4.4.1.3 *Determination of shuffle correction* — Determine shuffle correction as the difference between the rebounds from:

a) a normal test piece, and

b) a test piece with a piece of copper foil stuck on the back to prevent shuffle.

Determine the same for several materials covering a wide range of resilience values.

4.4.1.4 On the average damping correction of 0·2° (independent of resilience between 25 and 100 percent) and shuffle correction of 0·5° is the usual order of magnitude of the corrections. However, it is probable that shuffle corrections may vary from one test piece to another and that a satisfactory shuffle correction figure cannot be determined.

4.5 Reports

4.5.1 The report shall include the following information:

a) Rebound resilience, percent;

b) Temperature of test; and

c) Number of test pieces used from the same batch.

5. METHOD B — LÜPKE PENDULUM

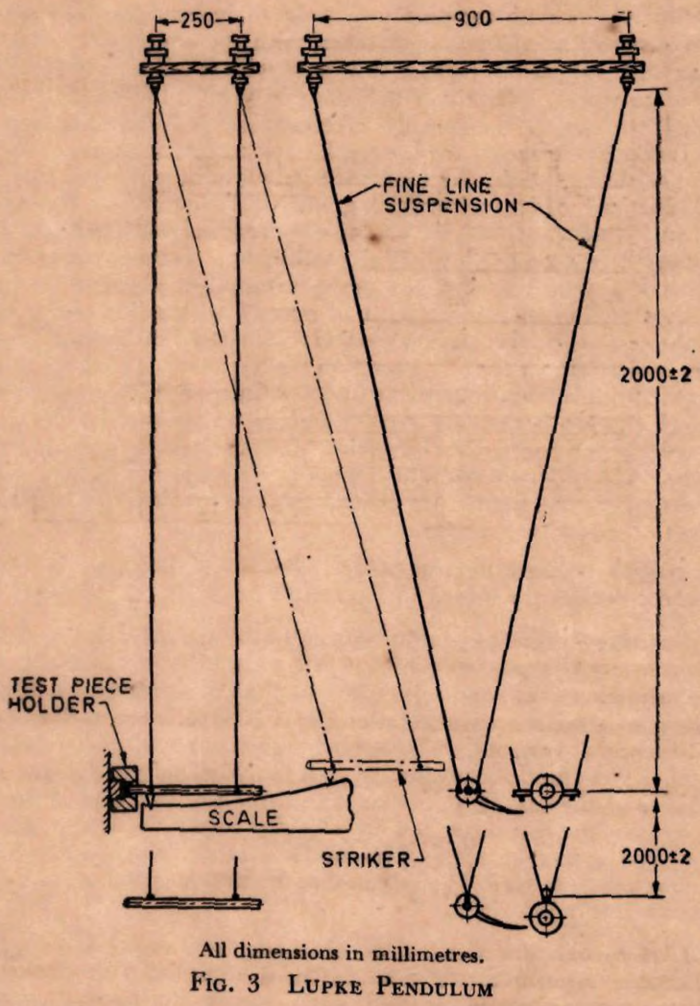
5.1 Principle of the Method — In this test a certain part of the input energy is dissipated as heat and is thus not returned as mechanical energy during the rebound; the greater the heat dissipation in the rubber, the smaller will be the rebound. Owing to the wide variety of possible service conditions no general correlation between the rebound resilience and the energy dissipated as heat during service operation can be given. The value of the rebound resilience for a given material is not a fixed quantity but varies with temperature, time of indentation and rebound, and, in the case of filler-loaded polymers, with the amplitude of the deformation, as well. This variation of resilience with conditions is an inherent property of polymers, which can therefore only be fully evaluated if tests are carried out over a wide range of conditions. If another apparatus than the Lupke Pendulum is used, even having a similar range of time and amplitude of deformation, the resilience values obtained will not necessarily be identical. If tests involving greatly differing impact times and/or different amplitudes are used, for example a dropping steel ball, the results are likely to differ considerably. This method applies to vulcanized rubber the hardness of which at the test temperature lies between 30 and 85 IRHD. Losses due to transmission of energy to the instrument frame through the test piece may become serious with very hard test pieces, and for this reason an upper limit is placed on the hardness of rubbers that may be tested. It is also very important that the frame and its supports should be rigid. Tests are commonly required *either* on several rubbers at one temperature, *or* on one rubber at series of temperatures (not more than 10 deg apart) in order to study the temperature variation of the resilience. For these two purposes different procedures are specified for bringing the test piece to the test temperature.

5.2 Apparatus — The apparatus consist of the pendulum and the test piece holder whose details are shown in Fig. 3 to 7.

5.2.1 *Pendulum* — The pendulum consists of a rod of a mass of 350·00 ± 0·25 g, the striking end of which is a hemisphere of 12·50 ± 0·25 mm diameter, suspended by four thin cords so that it maintains a horizontal position when describing an arc of a circle of 2 000 ± 2 mm radius. When the pendulum is at rest, the tip just touches the centre of the surface of the test pieces. The pendulum swings from a specified height Y depending on the thickness of the test piece above the position of rest and strikes horizontally against the test piece, which is held securely by a suitable holder against a rigid or heavy anvil. The release mechanism should not impart any impulse to the striker. The rebound of the striker is measured by means of a suitable graduated scale.

5.2.2 *Holder* — Suction holder may be used. For composed test pieces a special holder is needed. The holder should not exert any lateral restraint on the circumference of the test piece. A minimum clearance of 1·5 mm between the circumference of the test piece and the inside surface of the holder is necessary. The rigidity of the holder and of the anvil should be sufficiently high. The anvil should be connected to a rigid structure or, if the anvil is free, it should have a mass of as least 200 times the mass of the striker. Provision may be made for heating or cooling the test piece for tests at series of different temperatures.

5.2.1.1 *Mechanical holder* — The force exerted on the edge of the test piece by the clamp shall be 3 to 5 kgf.

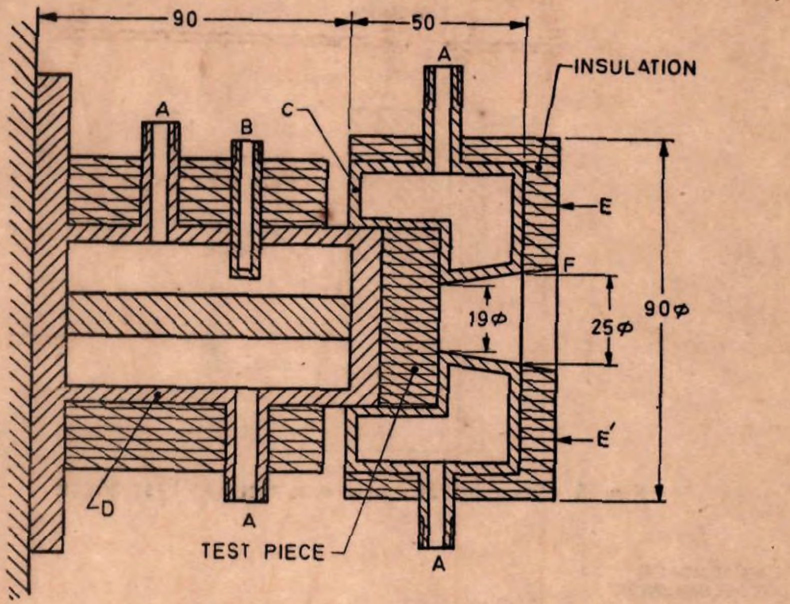


All dimensions in millimetres.

FIG. 3 LUPKE PENDULUM

5.2.1.2 *Suction holder for single test piece* — The solid test piece is held against the anvil by suction acting through grooves in the periphery of the test piece.

5.2.1.3 *Suction holder for composed test piece* — The test piece or pieces built up to obtain the proper thickness are heated in an air oven in the centre part of the clamp. After having reached the test temperature, this part is placed in the preheated base and covered with the air curtain which blows air over the samples at the test temperature.



A — Inlet or outlet for temperature control fluid.

B — Thermometer pocket.

F — The clearance between outside diameter of striking hammer and inner diameter of the circular chamber must be > 1 mm.

The circular chamber *C* is a sliding fit on the end of tube *D* and is held in position by two spring loaded levers *E*, *E′*.

All dimensions in millimetres.

FIG. 4 MECHANICAL HOLDER

5.2.1.4 *Special suction holder with provisions for heating or cooling* — This holder enables measurements to be made at any of the recommended test temperatures by circulating suitable liquids heated or cooled to the appropriate temperature.

5.3 Test Piece — The standard test piece is a disc of 12·5 ± 0·5 mm thickness and a diameter, preferably, of 29·0 ± 0·5 mm. Test pieces with larger diameter may be used in a suitably sized holder.

5.3.1 Alternatively a test piece with a lesser thickness, but not less than 3·8 mm, may be used provided the drop height is adjusted as described in **5.4.5.1**.

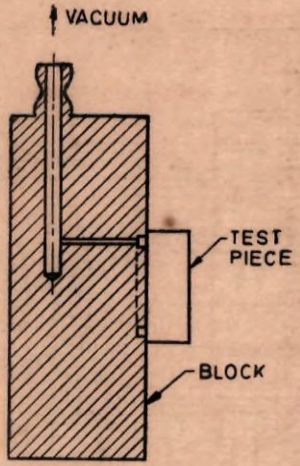


FIG. 5 SUCTION HOLDER FOR SINGLE TEST PIECE

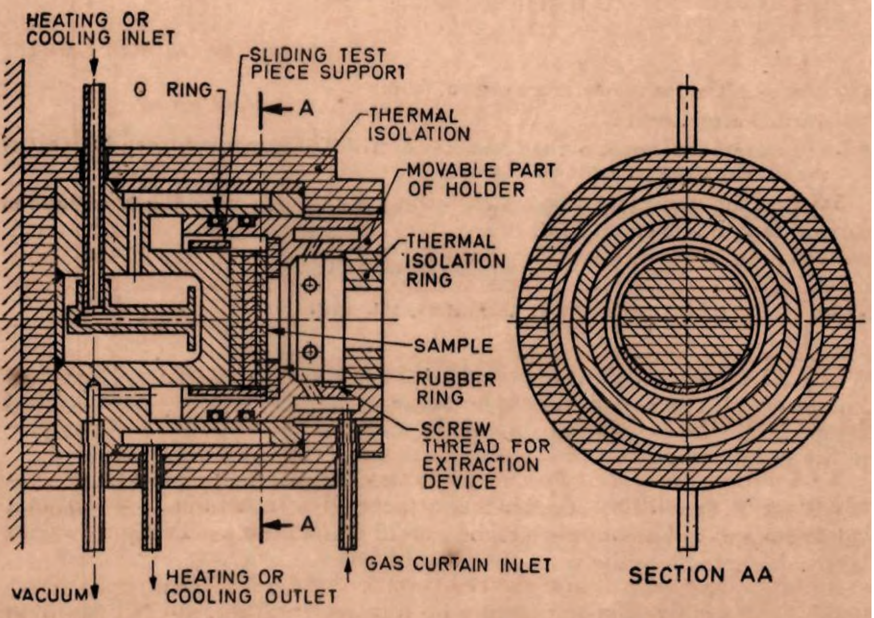


FIG. 6 SUCTION HOLDER FOR COMPOSED TEST PIECE

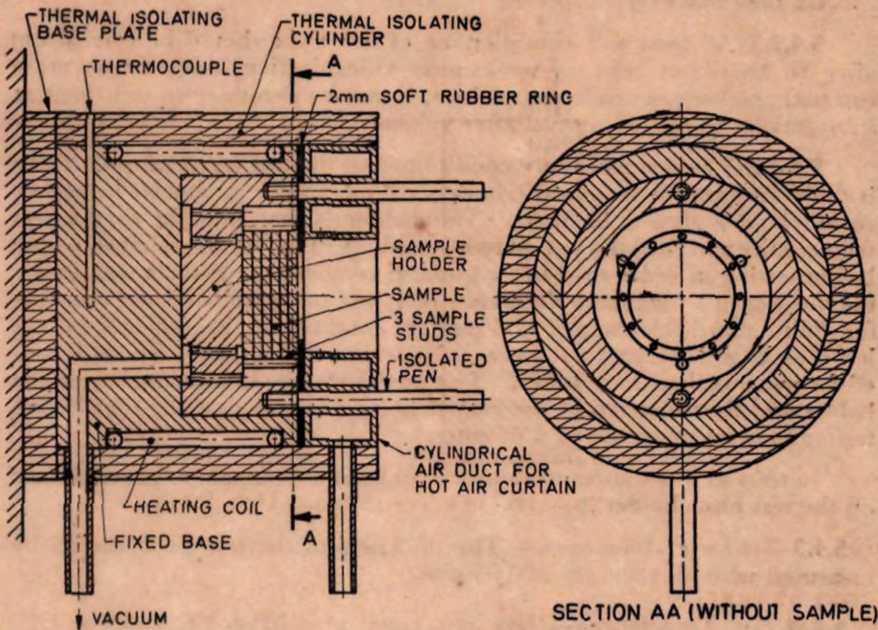


FIG. 7 SPECIAL SUCTION HOLDER WITH PROVISIONS FOR HEATING OR COOLING

5.3.2 *If the material to be tested is thinner than* 3·8 mm, the test may be carried out on a stack of discs of any thickness with a minimum of 3·8 mm, mounted in a special vacuum holder. All layers shall be of the same composition and the same state of cure. The thickness and procedure followed for comparative tests should be the same.

5.3.3 Two test pieces should be prepared and tested.

5.4 Procedure

5.4.1 *Preparation of Test Piece* — The test piece may be prepared either by moulding or by cutting. If fabric is attached to the sample it is removed before testing. The sample surface should be flat and smooth.

If it is necessary to buff the test surface of the test piece in order to remove the outer skin, finishing with an abrasive equivalent to No. 60 to 80 grit is recommended if this has not already been done during the preparation of the sample.

5.4.2 *Conditioning of Test Pieces*

5.4.2.1 All tests and condition ing of test slabs should be carried out after 16 hours but before 4 weeks after vulcanization, and, for accurate comparisons between different rubbers, it may be necessary to test them at substantially the same interval after vulcanization.

5.4.2.2 The test pieces are conditioned at the test temperature. If this is different from the standard laboratory temperature, a special heated or cooled holder should be used. The holder is first brought to the test temperature and then the test piece inserted. A sufficient time should elapse before testing in order to reach a uniform temperature distribution inside the test piece, a maximum difference of 1 deg being allowed; for example for the standard thickness of 12·5 mm the conditioning time should be not less than 20 minutes and test pieces thinner than 8 mm should be conditioned for not less than 10 minutes. Test pieces may be heated apart from the holder and then inserted in the heated holder; in this case the time before testing may be shortened to 5 minutes.

In tests at low temperature provision should be made to prevent frost on the test piece holder.

5.4.3 *Thickness Measurement* — The thickness of the test piece should be measured with an accuracy of 0·05 mm.

5.4.4 *Test Temperature* — Carry out tests at $-70° \pm 1°C$, $-55° \pm 1°C$, $-40° \pm 1°C$, $-25° \pm 1°C$, $-10° \pm 1°C$, $0° \pm 1°C$, $27° \pm 1°C$, $50° \pm 1°C$, $70° \pm 1°C$ and $100° \pm 1°C$ and also at any other temperatures which may be deemed necessary in view of particular service requirements. Where resilience changes quickly with the temperature, for research purposes closer intervals may be used.

5.4.5 *Determination of Rebound Resilience* — Clamp the test piece to the holder move the striker to the desired drop height above the level of the point of impact and allow to fall. Measure the horizontal displacement after the rebound on the scale. Subject the test piece to a number of impacts in rapid succession until a constant reading is maintained for three consecutive impacts. Use this constant reading in the calculation of results.

5.4.5.1 *Drop height* — For a standard test piece with a thickness of 12·5 mm, the standard drop height is 100 mm. In order to obtain approximately comparable rebounds when using non-standard test pieces with reduced thickness, the energy applied to the sample should be related to its thickness, which can be done by adjusting the drop height and using the relation that the ratio between the velocity of the bar at the moment of impact and the thickness of the test piece is kept constant (*see* Appendices A and B).

5.4.5.2 Take the average of the results obtained from two test pieces.

5.5 Expression of Results — Express the result as percentage rebound resilience. Calculate from the following expression (*see* Fig. 8):

Rebound resilience, percent $= 100\, y/Y$

$$= \frac{100}{Y}\left(2\,000 - \sqrt{2\,000^2 - x^2}\right)$$

where

y = rebound height in millimetres,
Y = drop height in millimetres, and
x = horizontal rebound deviation in millimetres.

NOTE — To reduce calculations, the use of an appropriate scale on which the drop height and the rebound height can be read, is recommended (*see* Appendix B and Appendix C).

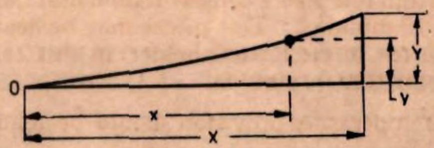


FIG. 8 PRINCIPLE OF REBOUND RESILIENCE MEASUREMENT

5.6 Report — *The report shall include the following:*

a) Rebound resilience, percent;
b) Test temperature;
c) Diameter of test piece, thickness and number of discs if it was built up;
d) Type of test piece holder; and
e) Drop height.

APPENDIX A

(*Clause* 5.4.5.1)

DROP HEIGHT

A-1. DROP HEIGHT ADJUSTMENT

A-1.1 The drop height adjustment is based on the principle that the ratio of the velocity of the striker (v) at the moment of impact to the thickness of the test piece (t) is constant:

$$\frac{V}{t} = \frac{V_o}{t_o} \qquad \text{............(1)}$$

The relation between the velocity and the drop height is:

$$V = \sqrt{2\,g\,Y} \qquad \text{............(2)}$$

where

g = acceleration due to gravity, and
Y = drop height.

From the equations (1) and (2) follows:

$$Y = \frac{t^2}{t_0^2} Y_o \qquad \text{............(3}$$

The standard drop height (Y_o) and test piece thickness (t_o) are 10
mm and 12·5 mm, respectively.

Substituting these numerical values in the foregoing formula an
simplifying the result, we obtain:

$$Y = 0{\cdot}64\ t^2 \text{ mm}$$

where t is the figure indicating the sample thickness in millimetres (*se*
Appendix B).

APPENDIX B

(*Clause* 5.4.5.1)

TEST PIECE THICKNESS, DROP HEIGHT AND HORIZONTAL DISPLACEMENTS

TABLE 1 FIGURES FOR CORRESPONDING SAMPLE THICKNESS, DROP HEIGHT AND HORIZONTAL DISPLACEMENTS

Thickness of Test Piece	Drop Height Y	Horizontal Displacement X	Thickness of Test Piece	Drop Height Y	Horizonta Displace ment X
(1)	(2)	(3)	(1)	(2)	(3)
mm	mm	mm	mm	mm	mm
3·8	9·2	192	8·6	47·3	433
4·0	10·2	202	8·8	49·6	442
4·2	11·3	212	9·0	51·8	452
4·4	12·4	222	9·2	54·2	462
4·6	13·5	232	9·4	56·6	472
4·8	14·8	242	9·6	59·0	482
5·0	16·0	252	9·8	61·5	492
5·2	17·3	263	10·0	64·0	502
5·4	18·7	273	10·2	66·6	512
5·6	20·1	283	10·4	69·2	522
5·8	21·5	293	10·6	71·9	531
6·0	23·0	303	10·8	74·7	541
6·2	24·6	313	11·0	77·4	551
6·4	26·2	323	11·2	80·3	561
6·6	27·9	332	11·4	83·2	571
6·8	29·6	343	11·6	86·1	581
7·0	31·4	353	11·8	89·1	590
7·2	33·2	363	12·0	92·2	600
7·4	35·1	373	12·2	95·3	610
7·6	37·0	383	12·4	98·4	620
7·8	38·9	393	12·6	101·6	629
8·0	41·0	403	12·8	104·9	639
8·2	43·0	413	13·0	108·2	649
8·4	45·2	423			

APPENDIX C

(*Clause* 5.5)

RELATION BETWEEN VERTICAL AND HORIZONTAL DISPLACEMENT

The relatio between the vertical and horizontal displacements of the triker is given by the formula (*see also* Fig. 8):

$$Y = 2\,000 - \sqrt{2\,000^2 - X^2}$$

and $$y = 2\,000 - \sqrt{2\,000^2 - x^2}$$

where

Y = original vertical displacement in millimetres,

X = original horizontal displacement in millimetres,

y = rebound vertical displacement in millimetres, and

x = rebound horizontal displacement in millimetres.