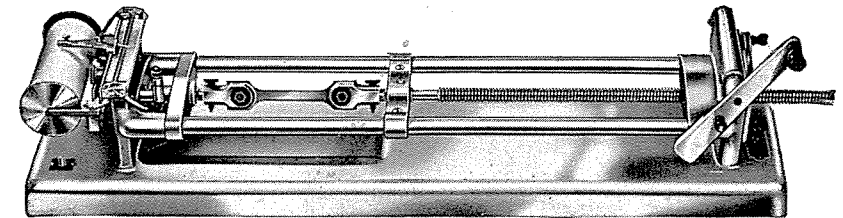


Hounsfield Tensometer

Type W



Instruction Manual

Tensometer Ltd.,
81 Morland Road,
Croydon . CR9 6HG.

Telephone: 01-654 2205

Telegrams and Cables: Hounsfield, Croydon

In all correspondence please quote serial number of machine

during adhesion and similar tests, as it responds surprisingly well to rapid changes of load. Whilst the accuracy is adequate for most normal work, careful use of the manual recorder will produce a more accurate result, provided that the rate of change of load is not too rapid. This Recorder (Code Ref. A110) can be fitted to all 'W' Type Tensometers.

4b The so-called "dumbbell", as used in a maxima thermometer, can be used to record the max. movement of the mercury. This consists of a piece of mild steel 18 gauge (.048" dia.) and $\frac{3}{8}$ " long but this is not normally found to be necessary.

5 It is no exaggeration to say that the striking success of the machine is very largely due to the admirable way in which these records show all the properties of the material at a glance.

6 The autographic records in connection with notched-bar tests in particular have opened up a new field in determining a material's ability to resist shock and stress concentration.

CONSTRUCTION

8 Reference to the figures 1 & 2 will show that the chuck attachments are spherically mounted as at 44 to ensure axial alignment, while the various chucks of simple and robust construction can be pinned to the attachments with the pins 40 after the test-piece, 39 for example, has been placed in position.

9a The ends of the spring beam 26 are carried on rollers 22; and the pull in the test-piece is transmitted through the tension head 66 to the spring beam, the deflection of which is proportional to the load, and this deflection is measured by the movement of the mercury in the glass tube 76.

10 The spring beams are made in various thicknesses to suit the strength of the material being tested. (See ¶ 321d.)

11a The end of the mercury column shows on the force scale C.178 the actual force applied with a 2-ton beam and, for example, on scale E.182 the stress in a No. 12 or 13 test-piece.

The scales are readily interchangeable with other scales graduated to suit the strength of beam and the cross-sectional area of test-piece.

11b Machines can be supplied for a range of metric test-pieces and scales with Publication 108 to be used in conjunction with this Manual.

12a The handle 49 enables the load to be applied uniformly and without effort. If this handle is turned backwards the worm becomes disengaged and the quick-acting handle 51 enables the crosshead to be brought quickly to the position required.

13a If at any time it becomes desirable to remove the load before the test-piece breaks, the knurled nut 47 can be screwed home which keeps the worm gear in engagement.

In ordinary circumstances this nut is left loose or unscrewed but can be left in position.

14 No one doing serious work will fail to take an autographic record as this can be done so easily. It is far easier and more reliable to pick out the critical points from the graph than by attempting to note the behaviour of the machine and trying to remember the loads corresponding to critical points. Furthermore critical points alone do not give the character of the material in the same way as a graph. It is also much easier to compare a series of graphs than a number of columns of figures.

15 In fact the best way to produce a real "likeness" of the material so as to be able to grasp its properties at a glance, is to plot both the tensile and notched-bar curves on the same sheet as in Fig. 12B.

16a As the extension of some of the test-pieces is very much greater than others, due to differences in both initial length and ductility, provision is made for varying the magnification

of the extension from 4 to 1, to 16 to 1. This is done by sliding the pinion 2 on its spindle 4 to engage with different geared rings on the contrate wheel 1.

16b For magnifications of 2 to 1, 1 to 1 and $\frac{1}{2}$ to 1, see ¶ 67b.

17 The recorder drum with graph attached can be instantly released by moving the trigger 20 without disturbing the driving mechanism. The removal of the blade spring 5 releases the graph paper.

18 The open end of the glass tube is covered with a pad of felt to prevent the ingress of dust and the escape of mercury, while at the same time allowing a free passage of air.

19 It will be noted from Fig. 1 that the spring 72 holds the cursor up so that the needle 70 clears the revolving drum. The pin 75 prevents this spring from touching the slide bar 74. In this position the cursor will slide endways perfectly freely, but directly the needle end is depressed the spring 72 grips the slide bar and so causes the needle to make a vertical descent.

SELECTION OF TURNED TENSILE TEST-PIECE

20 The odd numbered test-pieces Fig. 5 are more expensive to make and are necessary only for brittle materials, e.g., with a 2-ton spring beam No. 11 is suitable for hard steel over 80 ton tensile, No. 13 for cast bronzes, No. 15 for cast brass and aluminium alloys not exceeding 40 tons tensile and No. 17 for such brittle materials as hardened tin die castings and bakelite.

21 The even numbers 12, 14, 16 and 18 are suitable for all ordinary ductile materials such as steel below 80 tons tensile, drawn brass, drawn aluminium and lead respectively.

22 With a 1-ton spring beam No. 11 test-piece must be used for all steels over 40 tons tensile; No. 12 can be used for any material up to 40 tons if ductile and No. 13 if brittle.



Fig. 3 ¶ 61

CHUCKS

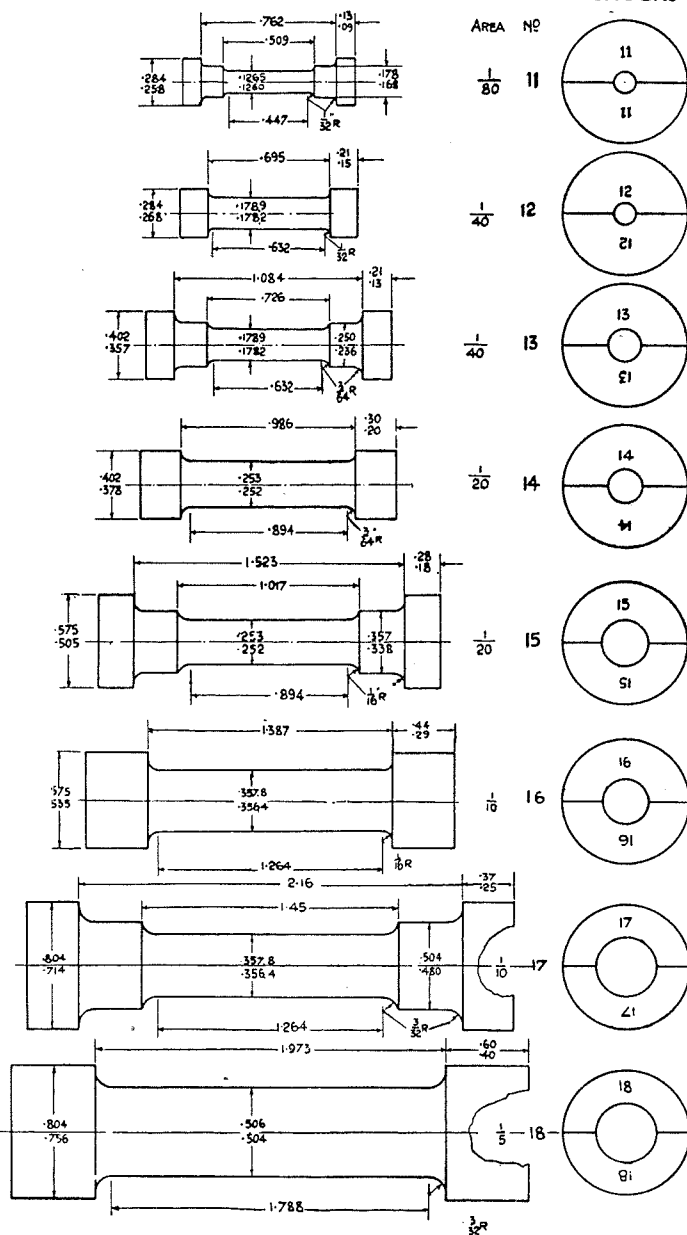


Fig. 5

23b STRESS. The following Table enables the most suitable Spring Beam to be chosen for any of the test-pieces given in Fig. 5

Column Line	1	2	3	4	5	6	7	8	9	10	11	12	13
			2-ton Spring Beam	4-ton Spring Beam	5-ton Spring Beam	6-ton Spring Beam	7-ton Spring Beam	8-ton Spring Beam	9-ton Spring Beam	10-ton Spring Beam	11-ton Spring Beam	12-ton Spring Beam	13-ton Spring Beam
A	Test-piece	Max. Stress in Test-piece	Scale No.	Graph Sheet	Stress per Graph Division	Max. Stress in Test-piece	Scale No.	Graph Sheet	Stress per Graph Division	Max. Stress in Test-piece	Scale No.	Graph Sheet	Stress per Graph Division
B	11	160 tons	E181	401	1 ton	80 tons	E182	401	$\frac{1}{2}$ ton	40 tons	E183	401	$\frac{1}{2}$ ton
C	12 & 13	80 "	E182	401	" "	40 "	E183	401	" "	20 "	E184	402	$\frac{1}{5}$ "
D	14 & 15	40 "	E183	401	$\frac{1}{2}$ "	20 "	E184	402	$\frac{1}{5}$ "	10 "	E185	402	$\frac{1}{10}$ "
E	16 & 17	20 "	E184	402	$\frac{1}{5}$ "	10 "	E185	402	$\frac{1}{10}$ "	5 "	"	402	$\frac{1}{20}$ "
F	18	10 "	E185	402	$\frac{1}{10}$ "	5 "	"	402	$\frac{1}{20}$ "	$2\frac{1}{2}$ "	"	402	$\frac{1}{40}$ "

USE GRAPH SHEET 402 FOR ALL lb. BEAMS.

<i>Column Line</i>	14	15 500 lb. Spring Beam	16 Spring Beam	17	18 250 lb. Spring Beam	19 Spring Beam	20	21 125 lb. Spring Beam	22 Spring Beam	23	24 62½ lb. Spring Beam	25	26
G	Test-piece	Max. Stress in Test-piece	Scale No.	Stress per Graph Division	Max. Stress in Test-piece	Scale No.	Stress per Graph Division	Max. Stress in Test-piece	Scale No.	Stress per Graph Division	Max. Stress in Test-piece	Scale No.	Stress per Graph Division
H	11	40,000 lb.	E501	400 lb.	20,000 lb.	E502	200 lb.	10,000 lb.	E503	100 lb.	5,000 lb.	E504	50 lb.
I	12 & 13	20,000 "	E502	200 "	10,000 "	E503	100 "	5,000 "	E504	50 "	2,500 "	E505	25 "
K	14 & 15	10,000 "	E503	100 "	5,000 "	E504	50 "	2,500 "	E505	25 "	1,250 "		12½ "
L	16 & 17	5,000 "	E504	50 "	2,500 "	E505	25 "	1,250 "		625 "	312½ "		6½ "
M	18	2,500 "	E505	25 "	1,250 "		12½ "	625 "		0½ "			3½ "

23d Example of how to calculate the stress. Suppose a No. 12 plastic test-piece breaks at 53 divisions from the bottom when using a 125 lb. beam and 402 graph, use one of the following methods:—

(a) From line J column 23 each division represents 50 lb. per sq. in., hence $53 \times 50 = 2,650$ lb. per sq. in.

From line J column 21 the max. stress = 5,000 lb. per sq. in., hence 53 per cent. of this = 2,650 lb. per sq. in.
The force = 53 per cent. of 125 lb. = $53 \times 125/100 = 66.25$ lb. and 66.25 lb./area of $1/40$ sq. in. = 2,650 lb. per sq. in.

24a Example of how to choose the spring beam and test-piece. Given a specimen believed to be about 30-ton steel.

Line D columns 1 & 2 show this can be broken with a No. 14 test-piece using a 2-ton beam, or

[illegible][illegible]

All will give the same height of graph but the first uses the largest test-piece, often preferable, 12 test-piece and a 2-ton beam may be advisable

If a No. 14 test-piece on line D has been chosen, on the same line in columns 2 and 4 the next 12 test-piece and a 2-ton beam may be advisable.

If a No. 14 test-piece on line D has been chosen; on the same line in columns 3 and 4 the scale indicated. In column 2 the max. stress is 40 tons so every 4 divisions of the 160 represent 1 ton.

indicated: in column 2 the max. stress is 40 tons, so every 4 divisions of the 160 represent 1 ton.

new to use a test to test press each time. Columns 1 to 4 give the relevant information.

25a Note. In practice it is often desirable to use a small test-piece even for weak materials in order to make the graph, though small, comparable with those obtained from similar stronger materials. A No. 12 is recommended for all steels below 80 tons per sq. in.

26 In the test-pieces shown in Fig. 5 the parallel portions of the stems are to B.S.I. proportions, they are the cheapest to make and quickest to test. (See ¶ 51.)

27 This series of test-pieces is therefore recommended for commercial testing, but if the explanation given in ¶ 52-57 is not considered satisfactory and if it is considered essential that the parallel stem should be extended each end of the gauge length as specified by the B.S.I. then the test-pieces shown in Fig. 6 are necessary. These conform to B.S.I. requirements in detail.

MAKING THE TEST-PIECE

Lathe Tools.

29 The special lathe-turning tools, Fig. 9A, greatly reduce the time taken to produce a tensile test-piece, particularly if it is in high tensile material.

30 The tool marked (11 & 12) has a cutter $1/32$ radius and is therefore suitable for test-pieces numbers 11 and 12.

The tool marked (13 & 14) has $3/64$ radius for test-pieces 13 and 14 and so on.

31 The point of the cutter should be $\frac{3}{8}$ " above the under side of the cutter holder and at "centre" height.

The front rake is 10 degrees and the top rake can readily be ground to suit the material.

31a Do not tighten the cheese-headed screw tightly.

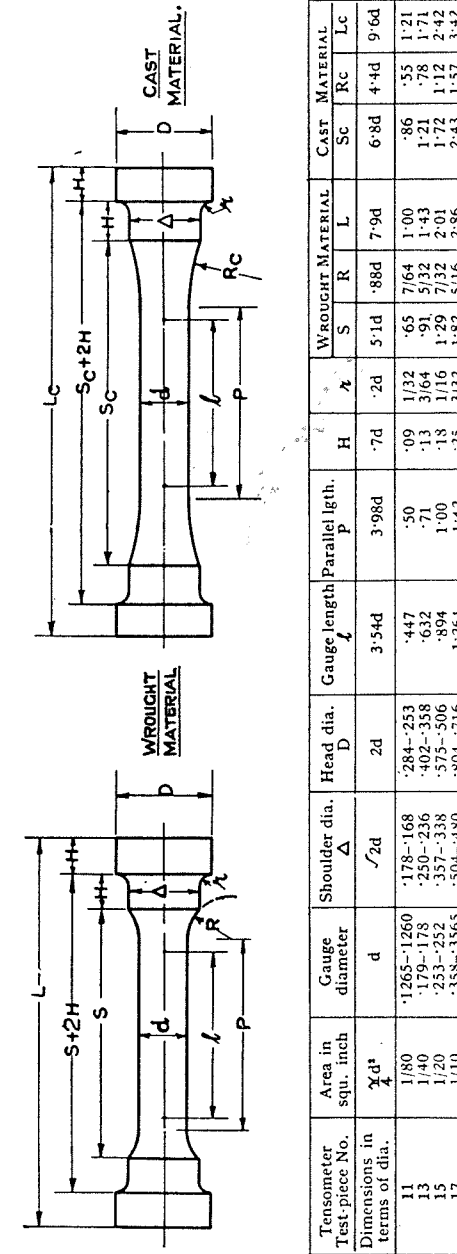


Fig. 6 ¶ 27, 42, 44, 58b

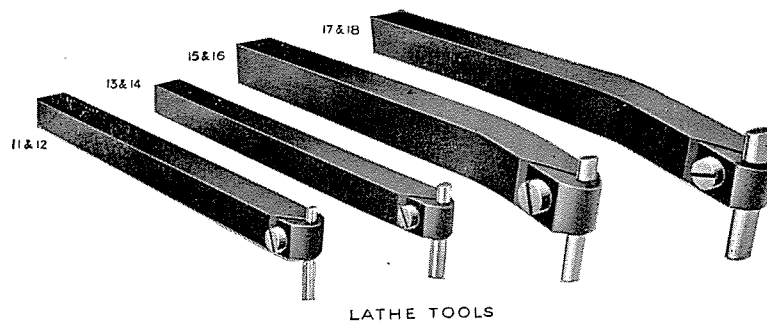


Fig. 9A ¶ 29-35e

32 In securing the cutter in the holder, no side rake should be given but the effect of side rake obtained by pointing the holder to the left when clamping it down flat on the slide rest.

33 For the finishing cuts the holder should be placed square with the lathe axis so as to finish in one setting the radius at each end of the test-piece.

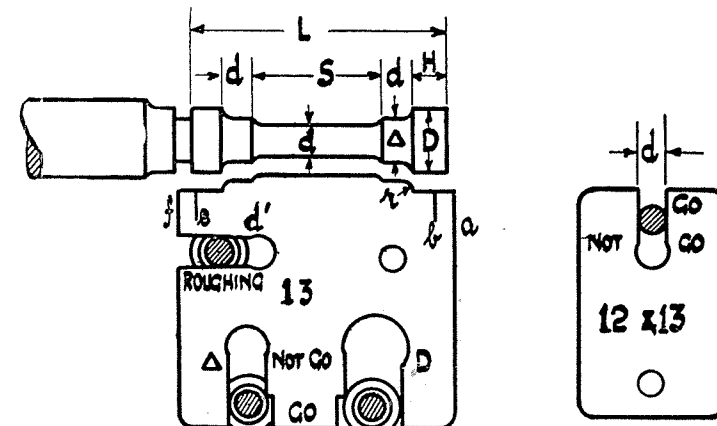
34 These cutters can be re-sharpened with the removal of the minimum of metal by stoning or grinding, and they are capable of taking remarkably heavy cuts for their size.

35 It must be borne in mind that most materials "work harden" and for this reason it is important that finishing cuts over the gauge length of the test-piece should be made with a sharp tool with plenty of top rake.

35b Rough turn a length L to the diameter D so that the first part of the gap D will go over, but not the whole of the gap.

35c Similarly turn down a length $S + 2d$ to the diameter Δ so that the end of the test-piece comes between the lines a and b .

35d Reduce the stem for a length S using the taper gap gauge d' till it passes right through the gap.



Roughing Gauge

Fig. 9c ¶ 35b-35f

Finishing Gauge

35e Finish and polish the stem to the gap d in the finishing gauge. This gauge is also very slightly tapered and effort should be made to finish the stem till it goes about half-way along the gap.

The correct radius r is produced by the lathe tool; the gauge is not supposed to be accurate in this detail.

35f Part off the test-piece so that the end comes between the line e and the edge f .

36 "Finish" of Test-piece. Although small scratches are fatal in a fatigue test, the improvement obtained by a high polish on a tensile test-piece is too small to be detected, unless the material is exceptionally brittle.

37 Accuracy. Great accuracy is not important because reasonable errors can be noted and correct results computed as follows:—

For every .001" the diameter is too *small*, *increase* the scale reading—or graph reading—by the percentage figure given in the following Table:—

Test-piece No.	11	1.6 %
	12 & 13	1.1 %
	14 & 15	.8 %
	16 & 17	.56 %
	18	.4 %

38 Example. A No. 14 test-piece is found to be .002" too small, and the maximum stress recorded is 30 tons per sq. in. As the test-piece is too small the recorded figure will be too low and must be increased by .8 per cent for each .001", i.e., by 1.6 per cent.

$$30 \times \frac{1.6}{100} = 30\frac{1}{2} \text{ tons per sq. in.}$$

39 The elongation per cent is not affected by this error and the universal reduction in area gauge takes the error into account.

40 From this it will be seen that careless errors are not serious in commercial testing and if they occur the true result can be readily computed.

41 Identification. Stamp the end of the test-piece with some mark and attach a label similarly marked, giving the material, etc., and any deviation from standard dimensions.

42 Before pulling the test-piece set the universal reduction in area gauge to the stem diameter and, if it is from the series in Fig. 5, set the elongation gauge; otherwise mark the gauge length on the stem with very small dots, as indicated at *l* in Fig. 6.

43 If the material is very brittle it is better to scratch fine lines on dabs of quick drying paint, instead of using small punched dots.

44 It will be noted that the test-pieces to complete B.S.I. proportions in Fig. 6 for brittle materials have larger radii of curvature than those for ductile materials.

MAKING A TENSILE TEST

Universal Reduction in Area Gauge

45 This gauge gives on one scale the reduction in area per cent of any test-piece.

46 Before test, the unbroken test-piece is placed at zero reading, the two arms are closed to touch it and are then locked.

47 After test a broken end is moved towards the pivot and the reading where it touches both arms is the reduction in area per cent.

Universal Elongation Gauge

48 This gauge (Fig. 11) shows on one scale the elongation per cent of the test-pieces shown on Fig. 5. The horizontal cradle is locked at the appropriate vertical distance from the arm pivot, which is proportional to the parallel length of the test-piece on which the elongation is required.

48a The left hand scale, which is $2\frac{1}{2}$ times full size, is used for test-pieces in which the parallel length is different from those given in Fig. 5.

49 Before pulling the test-piece, it is laid in the cradle, the pivoted arm is moved to the left, pushing the test-piece and left slide or abutment before it until the arm reading is zero. The left slide is then locked.

50 After test, the two ends of the broken test-piece are "fitted" together and lightly pressed against the left slide by the arm, the new reading of which gives the elongation per cent.

50a In fitting the fractured ends together in the cradle use only the thumbs for holding the test-piece heads against the abutments.

51 The following advantages are derived from using the test-pieces in the series Fig. 5:—

- (1) The whole test-piece can be roughed and finished with one lathe tool.

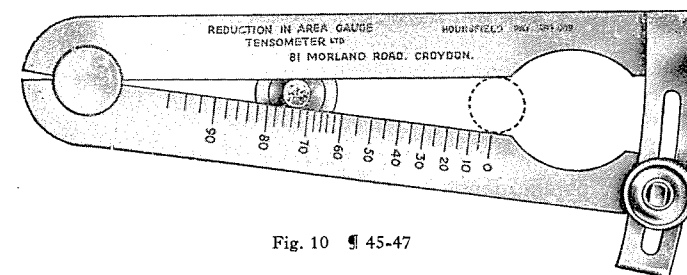


Fig. 10 45-47

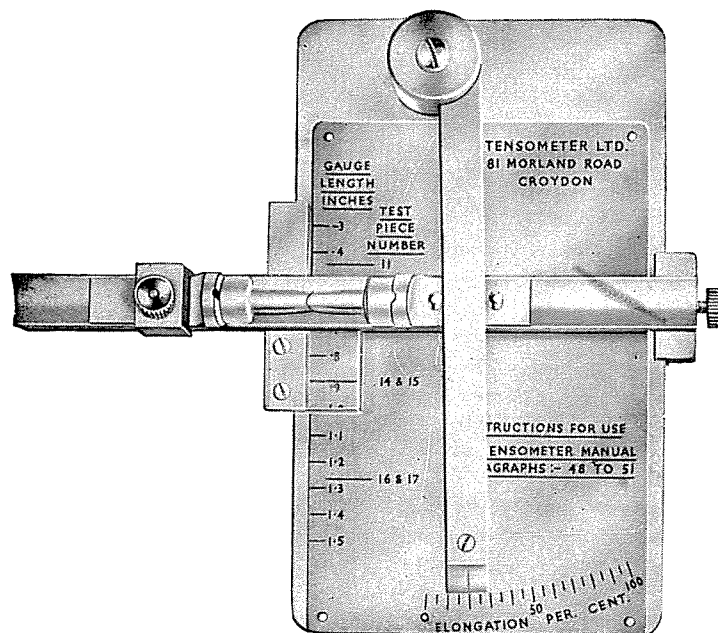


Fig. 11A ¶ 48-60

- (2) The piece is short and rigid and in most materials can be machined without the use of a back centre.

It is easy to set a lathe headstock to turn parallel, but the back centre invariably introduces errors particularly when turning short lengths.

- (3) Dots do not have to be punched on the stems and the elongation per cent can be obtained without the troublesome calculation with the possibility of arithmetical mistakes.

Justification for over-all measurements

52 It should be pointed out that the over-all length of the test-piece is immaterial because the position of the left slide does not affect the result.

53 The position of the cradle on the vertical slide being set to suit the parallel length of the test-piece means that only the extension of the parallel length is taken into account,

54 If there were no radiused fillets but sharp corners at the ends of the gauge length, then the rigidity of the heads would support the adjoining portion of the stem and prevent it from extending properly.

55 On the other hand if large radiused fillets were to be used, these fillets would extend and the total extension would be too great.

56 It has been found experimentally that if the radius of curvature is $\cdot 2$ times the diameter then the one error cancels the other and accurate results are obtained.

57 It may be thought that when double shouldered test-pieces are used the inner shouldered portion may extend and impair the results, but this inner shoulder of diameter $\sqrt{2} d$ has twice the cross sectional area of the stem, hence it will extend only in materials where the Y.P. is less than half the M.S. This may be the case in certain austenitic steels, but double shouldered test-pieces should not be made in such ductile materials.

Elongation or E

58b These three articles, although outside the scope of an instruction manual, are given to save so much correspondence on the subject of elongation.

In order to obtain the same values for $E\%$ for different sized test-pieces they must be homologous as in Fig. 5, ¶ 26, e.g., $l = 3.54d$, Fig. 6, but l may be any length, say not less than $3\frac{1}{4}$ " inside the heads when using an extensometer to obtain Proof Stress or Young's Modulus.

E can be divided into two kinds: elastic and permanent.

The former is proportional to the load, in metals, and disappears when the load is removed (represented by the slope of the tangent in Fig. 12B). It may vary from 0.0015 " per inch in 20-ton steel to 0.0075 " in 100-ton steel, while the latter remains as a permanent extension, which by convention is measured on the broken test-piece instead of on the graph.

The latter can again be divided into two components: (1) stable or uniform E , which takes place uniformly along the stem of the test-piece and gives the rising portion of the graph between Y.P. and M.S., during which time work-hardening takes place in normal materials and (2) unstable or local E , due to the necking or waisting of the stem; usually, in one place this gives the falling portion of the graph between M.S. and f .

Test-piece	Gauge Length (<i>l</i>)	Stable <i>E</i> %	Unstable <i>E</i> %	Total <i>E</i>	Total <i>E</i> %
A ₁	1"	0.1" = 10	0.4" = 40	0.5"	50
A ₅	5"	0.5" = 10	0.4" = 8	0.9"	18
B ₁	1"	0.1" = 10	0.05" = 5	0.15"	15
B ₅	5"	0.5" = 10	0.05" = 1	0.55"	11
A ₅ -4	5"	0.5" = 10	1.6" = 32	2.1"	42

This table shows the effect of different values of *l* on the total permanent *E*%. It also shows that the shorter the *l* the greater the effect of necking on *E*% for material A. With material B the total *E*% is not reduced so much by increasing *l* because the unstable *E* is relatively small.

These examples serve to show that tables of factors purporting to give the relation between *E*% for different values of *l*, regardless of the material, are fundamentally silly. For A₅ the factor would be 50/18 or 2.78, and for B₅—15/11 or 1.36.

60 The comparison is rendered still more inconsistent with long stems because sometimes necking occurs in more than one place. Prof. Haigh once obtained seven necks in a bronze alloy. The last line of the table indicates how the *E* might be affected if test-piece A₅ necked in 4 places.

Long gauge lengths are bad from the point of view of *E*% (1) because the effect of the unstable *E* diminishes as the length increases, and (2) because more than one neck may occur in a long test-piece.

Selection of Tensile Chucks

61 A set of chucks consists of 2 pairs or 4 halves; each set has two numbers, *e.g.*, the smallest chucks are numbered 11 and 12, Fig. 5. The two halves numbered 11 should go together and the two halves numbered 12 should go together.

62 The set of chucks numbered 11 and 12 is suitable for pulling either test-piece No. 11 or 12, 1/80 sq. in. or 1/40 sq. in. respectively.

63 Similarly the next size larger chucks, Nos. 13 and 14, are suitable for pulling either test-piece No. 13 or 14, 1/40 sq. in. or 1/20 sq. in. respectively.

Pulling the Test-piece

64 Take, for example, a No. 12 test-piece, Fig. 5, in mild steel. Having made this (§ 29-35f) and measured and marked

it (§ 41-43), select the suitable chucks (§ 61-63), *viz.*, Nos. 11 and 12 for a No. 12 test-piece. Assemble the two half chucks No. 11 on one end and No. 12 halves on the other end; slip the rings 43, Fig. 2, over the chucks to keep them together.

65a The machine will not give accurate results unless the mercury glass tube is practically horizontal.

Autographic Recorder

66a Choice of magnification. The greatest magnification 16 to 1, suitable for short test-pieces and non-ductile long ones, is obtained by sliding the pinion 2, Fig. 2, to the left to engage with the smallest geared ring on the contrate wheel 1.

When sliding the pinion to engage another geared ring the recorder drum should be removed to avoid damaging the small gear teeth.

67a For 4 to 1 magnification the pinion is moved to the extreme right, while the intermediate position gives 8 to 1.

67b When pulling helical springs or rubber-like materials less magnification may be required and magnifications of 2 to 1, 1 to 1 and $\frac{1}{2}$ to 1 may be obtained by the use of a cord attached at 86 to the crosshead (52 in Figs. 1 and 2) passing round the recorder drum with a half-pound weight at the end. This is shown by a dotted line in the Figs. and gives a ratio of 1 to 1. If this cord is passed round the pulley 86 and attached at 97 the ratio becomes 2 to 1; this is shown by the dotted line extended with a chain line. Similarly $\frac{1}{2}$ to 1 can be obtained, using the principle of a pulley block. When the cord is in use the pinion drive is put out of action by sliding the pinion about 3/16" to the left of the position shown in Fig. 2.

67d A suitable non-elastic non-twisting cord is Size 2, No. 808, Plaited Flax Line, made by Dutton & Co., Eastbourne, Sussex.

68a The small pinion is attached to the spindle 4 by means of a friction clutch 3, which enables the drum to be rotated at will without fear of damaging the gear teeth.

70 It will be found that 16 to 1 will be satisfactory for the test-pieces 11 to 15 in Fig. 5, and to make the graphs comparable for similar tests the same magnification should always be used.

71 The magnification chosen should be recorded on the graph paper in the place provided by crossing out the figures which do not apply.

72b **Attaching the Graph Paper.** Operate the trigger 20 to remove the drum and remove the spring 5.

Place the bottom edge of the paper against the flange of the drum with the arrow opposite the slot 19, Fig. 2.

Fold the paper round the drum so that the left-hand edge of the paper is outside or over the right-hand edge, taking care to see that the base line is continuous at the overlap.

Place the flanged end flat on the table and insert the end of the spring 5 into the slot 19 and hook the top end of the spring on to the top end of the drum and push it home as the drum is lifted from the table.

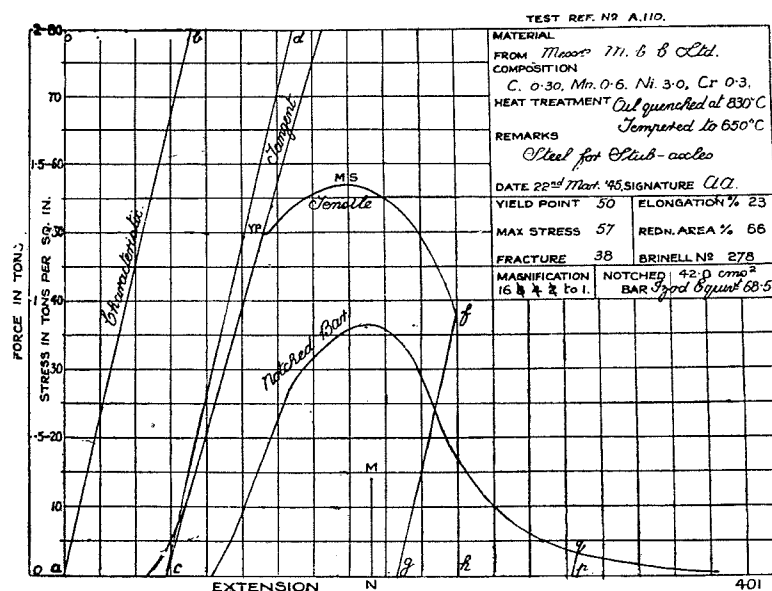


Fig. 12b § 15, 58b, 76, 120a-140

73b ¶ 23b shows which graph paper should be used for the standard tensile test-pieces shown in Fig. 5. For all other tests, e.g., Strip, Wire, Bend and Shear, the graph paper 402, giving percentages, should be used.

74 **Choice of Scales.** As a No. 12 test-piece has a cross sectional area of 1/40 sq. in. the scale E.182 is selected (¶ 23b) and inserted by putting the zero end in position first and the top end in last under the screw 77, which can be tightened on to it.

75 It will be noticed that the upper ends of the scales are provided with thumb-nail grooves to facilitate the removal of these scales.

76 Scale E.182 is graduated to 80 tons per sq. in., so the figure 80 should be written at the top left-hand corner—just above the small o. (Fig. 12b). The figure 70 should be written 20 mm. below and so on. This can be done readily by detaching the scale and placing it on the graph paper. In the same way forces can be read straight off, from the curve.

77b **Setting the Mercury to Zero.** Insert the pricker in the zero line of the graph paper, loosening the screw 71 and slide the cursor until the straight edge of the celluloid pointer 73 is at the zero line of the graduated scale. This ensures that the graph paper graduations coincide with the scale.

78a Assemble the test-piece in the chucks with the rings 43 in position and assemble the unit in the machine by advancing the chuck attachment 42 with the handle 51.

79b **Adjusting the Mercury.** Turn the mercury adjusting screw 54 anti-clockwise until the mercury is drawn out of the glass tube, then adjust it up to zero—not down to zero.

80b **Making the Record.** With the left hand on the chucks, turn the handle 51 slowly till the chucks begin to tighten and become rigid. Now rotate the drum till the needle 70 comes to any convenient starting place to the right of the spring 5 and, with the pointer 73 opposite the end of the mercury column, puncture the paper.

This is the first point of the curve, which is not on the zero line because there is a slight tension in the test-piece.

80c A frequent cause of low readings is due to the thoughtlessness of some operators who re-set the mercury to zero after applying the tightening load. This may amount to 3 tons per sq. in. on a No. 12 test-piece.

81a With the worm gear still disengaged, apply the load with the handle 51 a little at a time, follow the mercury with the pointer 73 and puncture the paper. Always cease turning while the paper is being punctured.

82a As soon as the handle 51 becomes a little hard to turn, the operating handle 49 may be used for all further load applications until fracture occurs.

83 If it is desired to release the load before fracture occurs the reversing nut 47 must be screwed in position, which enables the operating handle to be reversed without disengagement.

84b When using the cursor, place the first finger and the thumb of the left hand on both the cursor and the slide bar 74 (the finger can then be used to feed the cursor along smoothly), while the operating handle 49 is turned with the right hand, keeping the eye on the mercury column. To puncture the paper, the left hand should not be removed but just rocked to the left.

85a Increase the load and puncture the paper alternately, not simultaneously.

Make the punctures more frequent in the neighbourhood of the yield point.

85b As increments of load and punctures have to be made alternatively it is much quicker if both are made by one operator because two operators cannot keep in step so readily as the left and right hand.

86 If the mercury falls suddenly at the yield point the corresponding extension of the test-piece will have relieved the load, so turn the handle a little more before puncturing.

87a After the yield point the punctures can be widely spaced until fracture becomes imminent. During this period plastic flow is taking place, hence time has an effect and the curve will not be uniform unless the intervals of time are regular.

87b The cursor is provided with a lens which enables slight movements of the mercury to be read accurately as is necessary in determining proof stress (*see* ¶ 100b); it also enables the yield point to be determined very accurately because as soon as plastic flow commences the curved surface of the mercury will be seen to flatten when the operating handle is stopped. (This point can be conveniently recorded by moving the cursor about half an inch above the mercury and puncturing the graph paper before proceeding with the graph plotting.)

This method is very sensitive and may give yield points rather lower than those obtained with other testing machines.

For ordinary quick testing the lens need not be used.

88 Interpreting the Graph Record. The graph produced is removed from the drum by placing the flanged end flat on the table and removing the spring.

89a The general slope of the graph is called the characteristic, represented by the line *a b* in Fig. 12B, and it is dependent on three strains:—

- (1) The deflection of the spring beam which is the same for all beams;
- (2) The flexibility of the whole machine which varies with the load;
- (3) The bedding in of the grips which is small with a well-made test-piece and is represented by the first part of the graph being curved which is neglected. Then there is the actual extension of the test-piece which is the value required. All these strains have been subject to the magnification chosen.

90b Using the tensile chucks and a magnification of 16 to 1 the distance *ob* may be taken as 41 mm. with a 2-ton beam, 32 mm. with a 1-ton beam, 27 mm. with a $\frac{1}{2}$ -ton beam, and 23 mm. for the pound beams. A line drawn from *b* to the origin *a* is the characteristic.

The following two articles are chiefly of theoretical interest—

91b The actual slope of this line *a b*, would not vary if it were dependent only on the deflection of the spring beam; the distance 0 to *b* would be 22 mm. for all beams. The slope is increased by the flexibility of the

whole machine, which includes the portion of the operating screw 36 in tension, the whole length of the standards 35 in compression and particularly any strain in the chucks, which is small in the tensile chucks but considerable in the compression attachment.

All these strains are proportional to the load on the test-piece and all add to the slope of the characteristic.

92a Hence, if the true slope is required it must be plotted experimentally for the beam and chucks in question, *e.g.*, with a short No. 16 steel test-piece for tensile tests or with the compression dies Fig. 26A, butting for compression tests.

PROOF STRESS

95 According to the B.S.I. specification for Tensile Testing of Metals, "The material shall be deemed to have passed the proof test if, when the specified proof stress is applied to the test-piece for a period of 15 seconds and removed, the test-piece shall not have acquired a permanent extension greater than the specified percentage of the gauge length."

96 Assume, for example, that the specified proof stress is 45 tons per sq. in. and the permanent extension must not exceed .1 per cent of the gauge length.

97a If a No. 12 test-piece Fig. 5 were to be used, the extension would not have to exceed $.632" \times .1$ per cent, which is only .0006". Hence it is desirable to use a No. 12 test-piece with a 2" gauge length, then the permanent extension must not exceed .002" after the stress of 45 tons has been applied, as given by the scale E.182 with a 2-ton spring beam.

98 To measure this extension it is desirable to machine little pips or knobs on the ends of the test-piece for setting the micrometer to, before and after applying the specified proof stress.

99 Accuracy with regard to the length of the stem is not important because the extension is not required to an accuracy of 1 per cent.

100b If it is desired to ascertain the actual proof stress, as distinct from "passing the proof test" (*see* ¶ 95), an extensometer* must be attached to the test-piece during the application of the load and the stress/strain curve plotted on 1" squared paper to a scale of $1" = 0.001"$ extension.

* Leaflet 147 describes, with full illustrations, the Hounsfield Extensometer.

100c If the parallel length of a test-piece can be, say, $6\frac{1}{4}"$ long then the proof stress extension on the ordinary recorder graph becomes $.001 \times 6\frac{1}{4} \times 16$ magnification which is .1" which can be measured accurately enough to give the proof stress for most materials.

100d When it is impossible to obtain a long test piece, "proof stress" can be obtained from a No. 12, No. 13 or No. 14 test piece by using special Proof Stress Chucks (Code K20) and the Hounsfield Extensometer. Details will be sent on application.

NOTCHED-BAR TEST

101 The object of the notched-bar test is to determine the resistance a material is likely to offer to shock, and shows its ability to withstand stress concentration.

102 Generally speaking, the resistance to shock of a material may be guessed from its ductility—elongation and reduction in area—in the tensile test.

103 However, apart from the fact that there are many exceptions to this rule, in tempering high quality steels to give toughness or ductility the elongation and reduction in area increase as the tempering temperature increases, but there is considerable lag in the increase of the energy absorbed in breaking the notched-bar test-piece, see Fig. 18A.

This lag is very pronounced with alloy steels.

104 It will also be noticed from this Fig. that when the tempering is carried to the extreme—by annealing—the notched-bar value diminishes, sometimes very seriously.

105 Material used for all the important parts of machinery such as shafts and axles in all transport vehicles, where failure may mean loss of life, is almost invariably subjected to this test, but bolts are very frequently deficient in shock-resisting properties.

106 The manufacture of bolts involves removing or machining off a large proportion of the raw material as well as screw cutting; for both these operations free cutting steel is a great advantage, but free cutting steels generally have very low shock-resisting properties; hence if the failure of a bolt is going to

be serious, the material must be subjected to the notched-bar test.

107 The test consists of measuring the work done in bending the test-piece shown in Fig. 14, through about a right angle. The work done is the product of the force applied multiplied by the distance through which it moves and both these components are pricked on to a chart with the Autographic Recorder.

107a It should be appreciated that the notched-bar test is invaluable where a component is subject to shock or to stress concentration produced by sharp changes in section, oil holes or keyways, and if the graph shows sudden drops indicating cracks the material is not suitable for such components, hence the exact area of the diagram is not important.

On the other hand, if the diagram is very large due to the fact that the test-piece does not break and that energy is expended in bending the test-piece each side of the notch, then the test is not really applicable because the test is essentially to determine the work done in fracturing the test-piece at the notch.

Making the Test-piece

108a Although it is customary to make the diameter of the test-piece and also the depth of the notch accurate, the latter is difficult to measure and is really of little significance provided the one dimension—the root diameter of $\cdot229$ "—is correct, and this can easily be made accurate to gauge.

Accuracy on length is not important for the slow bend test, but must be correct for the impact test because the length affects the angle of bend.

108c To obtain the approximate depth of notch for the first test-piece, the depth screw should be set so that the cutter just touches the test-piece when the $5/16$ " mark is opposite

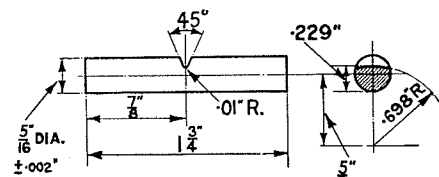


Fig. 14 ¶ 107-109a, 124c

the arrow in Fig. 14B. Try the gauge in the notch before the depth feed cam reaches its highest place then adjust the depth screw up or down till the depth is correct when the highest portion of the cam has passed.

Notching Machine for Slow Bend and Impact Test-pieces

109a Having turned a test-piece $5/16$ " diameter, Fig. 14 from the specimen to be tested, grip it in the test-piece clamp.

110a Rotate the ratchet wheel by hand till the $5/16$ mark comes opposite the arrow on the frame casting.

111a Cut the notch by turning the handle—clockwise—till the point of the depth screw drops down the steep side of the depth feed cam, applying paraffin to the notching cutter through the brush provided.

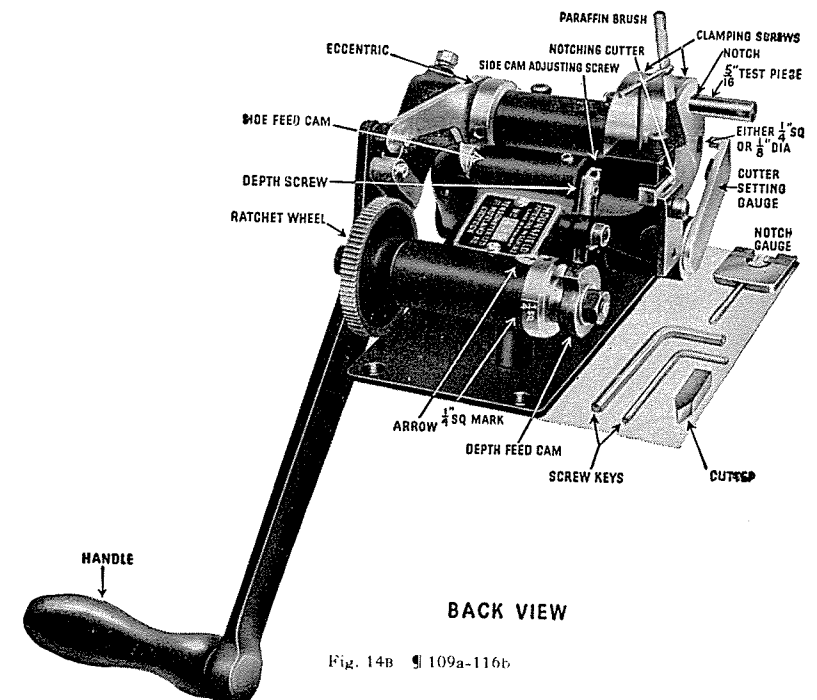


Fig. 14B ¶ 109a-116b

124e When everything is similar the same degree of accuracy cannot be obtained with the notched-bar test, whether slow or impact, as with the tensile test, and different testing machines do not always place materials in the same order, hence equivalents can only be approximate. (See ¶ 146-148b.)

124f This lack of consistency does not mean that the notched-bar test is too rough to be of value; the ability of a material to withstand concentration of stress is most important, and accuracy is not so important as in the tensile test, as the following example on a sample of heat-treated nickel chrome steel will show.

Heat treatment correct. Tensile 59 tons. Izod 62 ft. lb.*
 „ „ incorrect. „ 60 „ „ 8 ft. lb.
 This subject is dealt with more fully in Publication 120.

Explanations

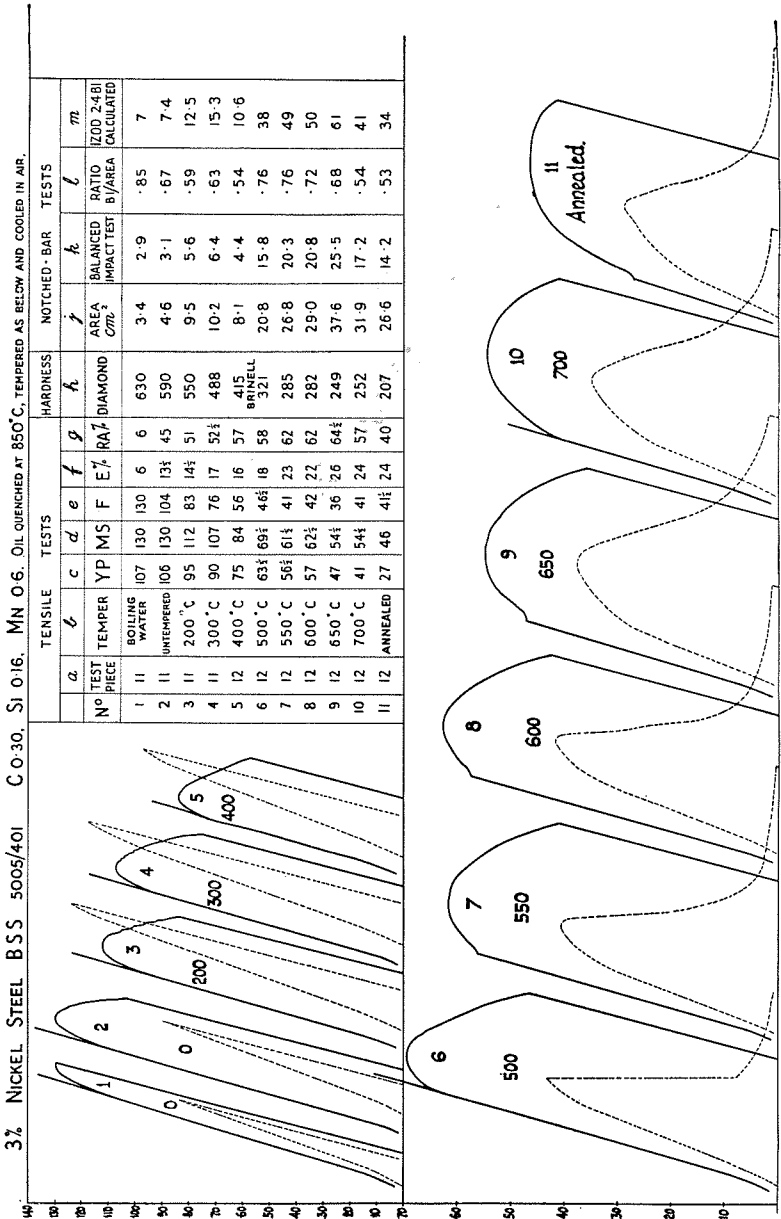
146 Fig. 18A gives the tensile (full lines) and the notched-bar (dotted lines) test curves for a nickel steel for eleven different heat-treatments or tempering temperatures.

147b The shape and the area of the notched-bar diagram are the important points in estimating the quality of the material; for example, the vertical descent in curve 6 is indicative of cracking. The crack condemns the material, hence the area of the diagram is of no interest if N/B. value is a consideration.

148b The curve 5 shows that this test-piece, like the previous ones, snapped in half and the area of the N/B. diagram is very small, while the test-piece for curve 6 snapped nearly in half and that very little work was apparently required to finish the fracture.

The area of the diagram has increased from 8.1 to 20.8 cm², and the impact test shows a similar increase from 4.4 to 15.8 foot pounds, which facts indicate that in this particular case the slow bend test is more reliable because it shows the critical condition. It is true that the nature of the fracture may show that condition 6 is undesirable, but the appearance of a fracture is difficult to chronicle.

* Philpot, "Inst. Auto. Eng. Proc.," Vol. XII, p. 323.



Column 1 shows that the relation between the slow bend and the impact values is erratic for brittle test-pieces.

148c From the foregoing it will be seen that for ordinary purposes the shape of the diagram (*i.e.*, whether it indicates cracks or not) is more important than the exact area, and the area can be measured with a Planimeter or obtained approximately by counting the number of square centimetres covered by the diagram on graph sheet W.401.

First count the complete squares, then for fractions of squares those over half of a square should be counted as one each and those less than half should be neglected using a little intelligence if, for example, there are many squares less than half.

HEAT TREATMENT

149 Although this subject is outside the scope of this Manual, it must be remembered that the rate of cooling caused by quenching or air cooling depends on the mass of the specimen, which means that if the customary cooling treatment is applied to small finished test-pieces the effect will be more drastic.

As a rule, oil quenching will have the same effect on small parts as cold water quenching on larger parts. A No. 12 test-piece in 0.4 carbon steel quenched from 850° C. in cold water may sometimes crack, but can be safely quenched in oil or boiling water, previous to tempering.

PLATE OR STRIP TEST

161 The British Standards Institution has standardized two test-pieces for testing strip, one with a gauge length of 2" as shown in Fig. 20 and an alternative form for use in exceptional cases with a gauge length of 8", Fig. 21.

Making the Test-piece

162 The gauge length portion of the test-piece should be finished by filing to avoid the effects of work-hardening resulting from punching, shearing or the use of blunt cutters. (*See ¶ 35.*)

163 The maximum pull of 2 tons will give stresses up to :—
 120 tons per sq. in. in a plate $\frac{3}{8}$ " thick by $\frac{1}{2}$ " wide.
 60 " " " " $\frac{1}{16}$ " " "
 30 " " " " $\frac{1}{8}$ " " "

hence if these stresses need to be exceeded, the width of the gauge length must be suitably reduced.

164a Having made the test-piece, dot punch or pencil the gauge length and insert the finished dimensions on the label. (*See ¶ 41.*)

Pulling the Test-piece

165 When assembling the test-piece in the strip chucks place the roughened surfaces of the dies D Fig. 22 next to the test-piece, hold the bolt head H in the vice and tighten the nut. The thicker the plate the tighter the nuts should be screwed up.

166a The rest of the test is carried out in the same way as the round tensile tests, ¶ 79a–85a, using a magnification of 8 to 1 or 4 to 1, preferably on graph 402.

167 To ascertain the elongation per cent, arrange the broken ends with the fracture "fitted" as well as possible and, with one point of the dividers (set to 2" as used in spacing the dots) in one dot-mark, scratch a line on the portion carrying the other dot-mark.

168 Measure the distance between this line and the dot.

This extension divided by 2 and multiplied by 100 gives the elongation per cent.

169 Example. If the extension is .75" :—

$$\text{Elongation per cent.} = \text{Extension} \times \frac{100}{2}$$

$$\frac{.75 \times 100}{2} = 37\frac{1}{2}$$

To Calculate the Stress

170

$$\text{Stress} = \text{Force} \div \text{Area.}$$

$$= \text{Reading on Force Scale} \div (\text{breadth} \times \text{thickness}).$$

171 Example. If the highest force recorded is 1.5 tons in breaking a test-piece .5" wide and .06" thick,

$$\text{Max. Stress} = \frac{1.5}{.5 \times .06} = 50 \text{ tons/in}^2.$$

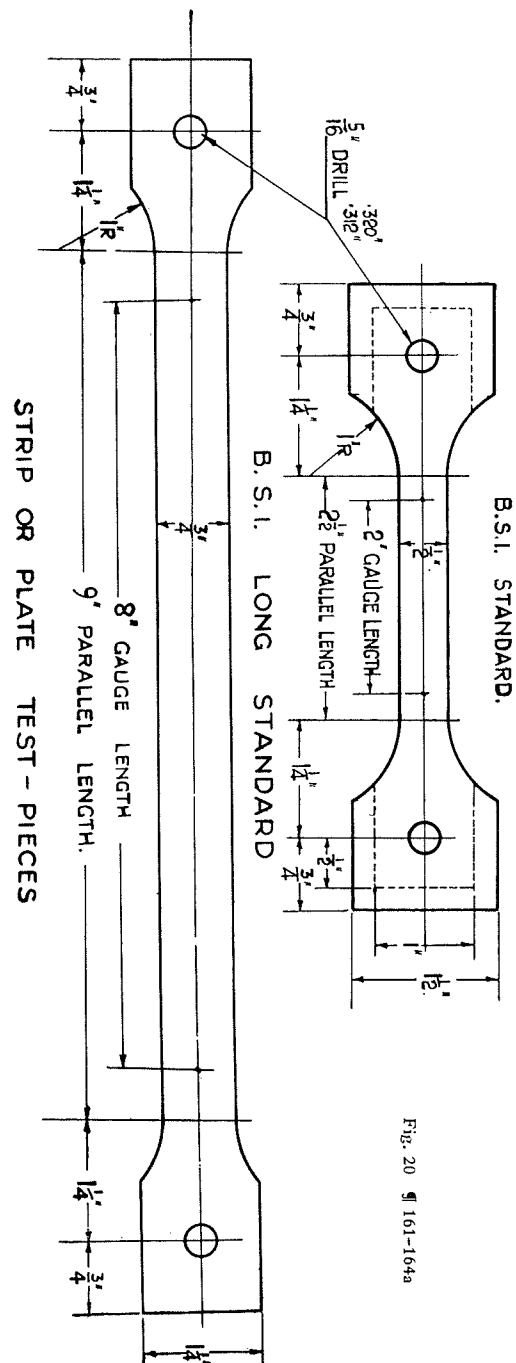


Fig. 20 9 161-164a

173 For serious testing it is advisable not to use a dot punch but having painted the stem of the test-piece matt black, make pencil lines across the stem every half inch, using a steel rule and trammels.

Choice of Grips

174 Strip up to $\frac{5}{8}$ " wide can also be tested in the chucks mentioned in ¶ 181c to 183B and Fig. 25c, using the wedges ·08·16, which saves the trouble of making shaped test-pieces.

174b The 1" wide wedge grips shown in Fig. 25d can be used for wider strip but these deeply machined chucks are not so strong as in Fig. 25c and the load must not exceed 1 ton unless bridge pieces are fixed to the chucks to prevent bursting.

175 These chucks are self gripping, are quick to use, and
do not have to be removed from the machine for each test.

176 Their self-tightening properties make them particularly suitable for gripping strip and wire in material with Austenitic properties which has a tendency to contract and draw out of most grips.

177 The windlass chucks, Figs. 24A and B, are suitable for testing thin metal ribbon or fabric up to $1\frac{3}{8}$ " wide, without making shaped test-pieces.

They are suitable for hard rolled metal up to .025" thick and soft metal up to .032" thick.

178 The end of the ribbon is held in the chuck as illustrated and is then wound on by turning the handle in a clockwise direction through $1\frac{1}{4}$ revolutions when the handle, used like a door bolt, prevents unwinding.

179 These chucks are particularly suitable for soft metal ribbon which, when gripped in rigid chucks, such, for example, as Figs. 34 and 39, reduces in width as its length increases and tears at the grips at a force far below its actual strength.

WIRE TEST

Choice of Grips

181c The most satisfactory chucks for gripping wire are the Quick Grip Chucks shown in Fig. 25c and 25f. The test-piece should be about 5" longer than the chosen gauge length of 2" or 8" to enable the full 2" to be held in each chuck as required by B.S.I. specification 18-1950.

182b Four sets of wedge grips are provided.

Those marked .04 to .08 are for gripping hard wires between these sizes and the absence of teeth prevents the wires from being nicked.

The wedges marked .08 to .16 are suitable for gripping wires between these sizes and for strip material up to $3/16$ " thick.

The wedges marked .16 to .31 are for large soft wire, as hard wires in this range are not likely to break with a pull of 2 tons.

The thin wedges will grip material up to nearly $5/16$ " thick.

183b Having assembled the chucks in the machine the turn buttons should be turned outwards to take the weight of the chucks.

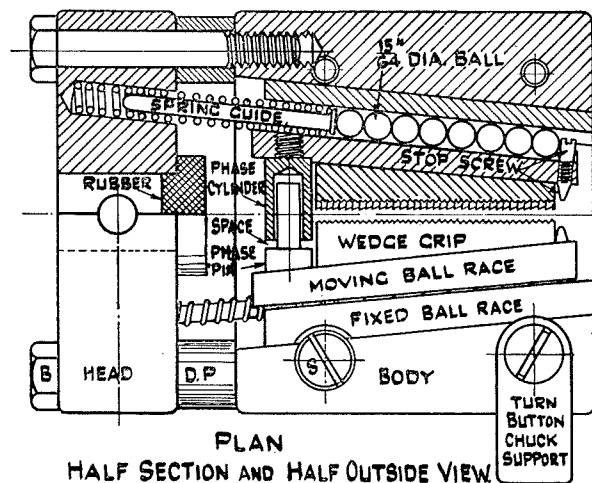


Fig. 25f 184b

184b The construction of these chucks is shown in Fig. 25f to make the object of each part clear. The phase pin and cylinder cause the moving portions to move together or in phase, a space between them is essential because if they touch

during a test, the grip is taken off the test-pieces. They should touch only when the moving ball race has reached the end of its travel. Further movement would allow the balls to escape round the end of the fixed ball race. Carelessness in allowing the full load of 2 tons, multiplied by the wedge action, will compress the phase cylinder and allow the balls to escape.

In certain cases contact may be inevitable, then a piece of a post-card $\frac{5}{8}$ " wide \times 2" long may be inserted between each wedge grip and the moving ball race.

184c Circumstances may occur when the wedges do not separate sufficiently to admit a particular test-piece. The separation can be increased by removing the rubber, but this must be replaced before the test is completed, otherwise the chucks may be damaged by the fly-back at fracture of the test-piece.

184d If the sample of wire is not dead hard the simpler vee wire grips shown in Fig. 23b will meet most requirements. The wire has its end secured in the anchor post, is passed round the groove and is prevented from unwinding by the keep pin being pushed up. These grips are suitable for soft wires up to $\frac{1}{8}$ " diameter and smaller wires in hard material.

185f Small soft wires and very fine steel wires can be tested with the disc chucks shown in Fig. 23A. The gripping discs should be softer than the wire to be tested, *e.g.*, copper or aluminium discs for steel wire, vulcanized fibre for hard brass wire and lead discs for copper wire.

Autographic Record

186 If the exposed length is about 1", 16 to 1 magnification is satisfactory; for increased lengths less magnification may be required.

187a Whatever type of chuck is used, movement of the wire will take place in the chuck and therefore the elongation per

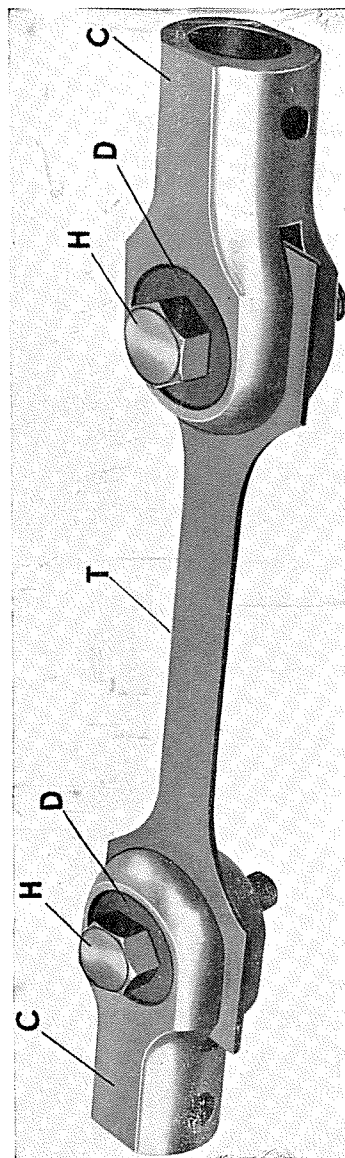


Fig. 22 ¶ 161-164, 257

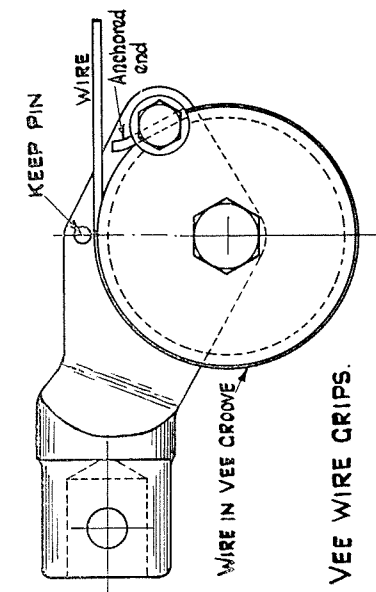


Fig. 23b ¶ 184d

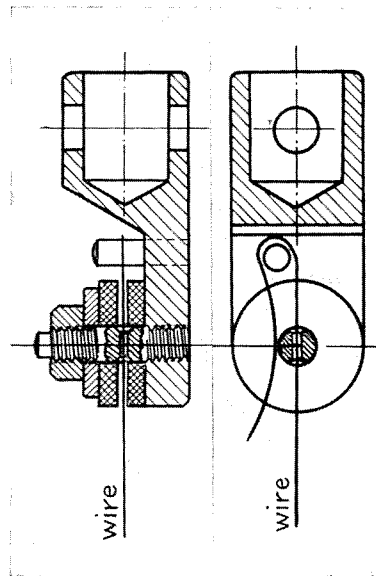


Fig. 23A ¶ 185f

cent must be obtained from marks on the gauge length (¶ 173). Although the movement in the chucks is recorded on the graph the yield point is usually indicated distinctly.

188 The rest of the test is carried out in the same way as the round tensile test, ¶ 79a-85a.

To calculate the Stress

189

$$\text{Stress} = \text{Force} \div \text{Area.}$$

$$= \text{Reading on Force Scale} \div \frac{\pi}{4} d^2$$

where d = the diameter of the wire in inches.

Example

190 If the diameter of the wire is .18" and the highest force recorded is 1.6 tons :—

$$\text{Stress} = 1.6 \div \left(\frac{\pi}{4} \times .18^2 \right) = 63 \text{ tons.}$$

192a Table showing the maximum stress obtainable with a 2-ton Spring Beam :—

Imperial Wire Gauge	Diameter in Inches	Maximum Stress
3	.252	40
4	.232	47
5	.212	57
6	.192	69
7	.176	82
8	.160	99
9	.144	123
10	.128	155

Fracture at Grips

193 Many people expect too much from test-piece grips and complain that their specimens break in the grips.

194 If this condition were not general there would be no necessity to incur the expense of such test-pieces as shown in Figs. 5, 6, 20-22 and 42, all of which have reduced stems, or are waisted.

195 There is a second category of grips, e.g., Figs. 25c and d, 34 and 37, for which waisting is preferable but not essential.

196 In the third category are grips specially designed for tests where waisting is considered impracticable, *e.g.*, Figs. 24A and B, 38 and all the wire chucks. Such textiles as webbing and ribbon will not stand waisting and it is unnecessary to waist canvas test-pieces because reliable results can be obtained from parallel strips. (*See* ¶ 292a.)

197 Brittleness and ductility alone do not determine the necessity for waisting. It is true that the odd numbers in Fig. 5 for brittle materials must have double shoulders, otherwise the heads will come off before the strength of the stem is reached, but brittle strip material like clock springs and plastic films will usually break between the grips without having to be waived. Ductile foil and films, on the other hand, will tear at the vice-grips in ordinary chucks, and in order to try to avoid this they have to be held in wind-on chucks such as Figs. 24A and B or 38, if waisting is considered too costly. The reasons for these phenomena are outside the purview of this manual.

198 Unwaisted test-pieces, such as wire, cannot be gripped without the introduction of a more or less considerable transverse compressive force which produces additional local stresses. This means that the tensile stress at the grips is greater than along the test length; therefore, if the material is uniform it will fail at the grips.

199 In order to prevent undue increased localisation of stress in unwaisted test-pieces the nipping stress must be reduced as much as possible by spreading the load over a long length.

If the length in the grips can be 30 or 40 times the diameter then no teeth in the grips are necessary; but if the ratio is brought down to 8 times the diameter, the teeth which then become necessary are likely to reduce the strength seriously. It is sometimes desirable to oil-stone away the tops of the teeth at the mouth-end of the grips.

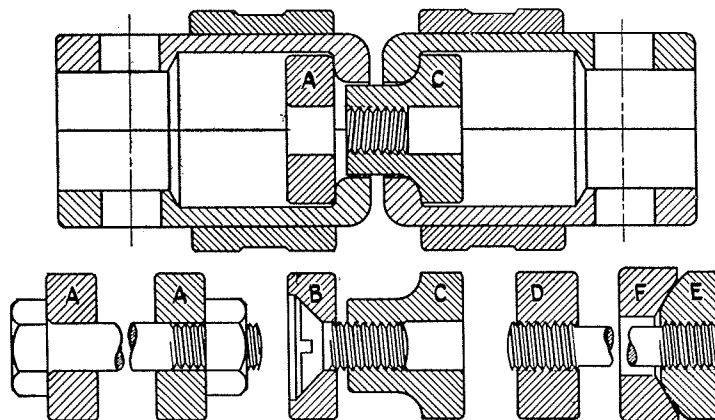


Fig. 25E ¶ 200

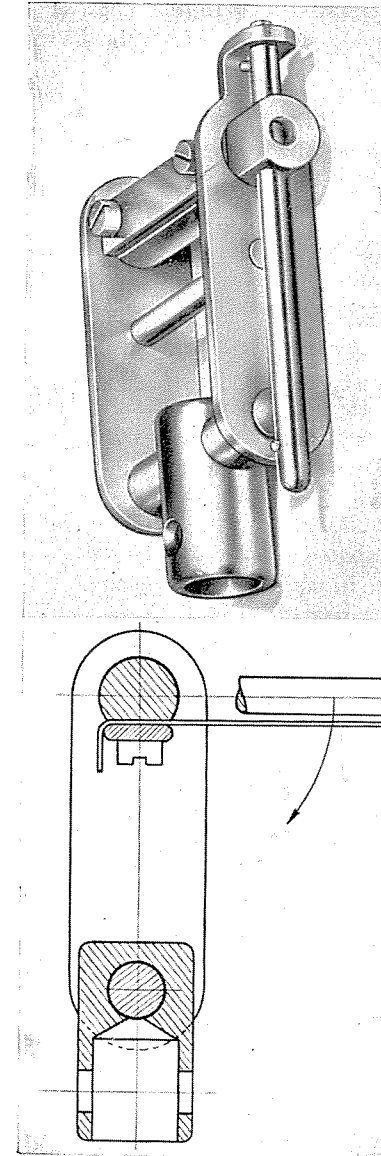


Fig. 24A ¶ 177-179, 196-197

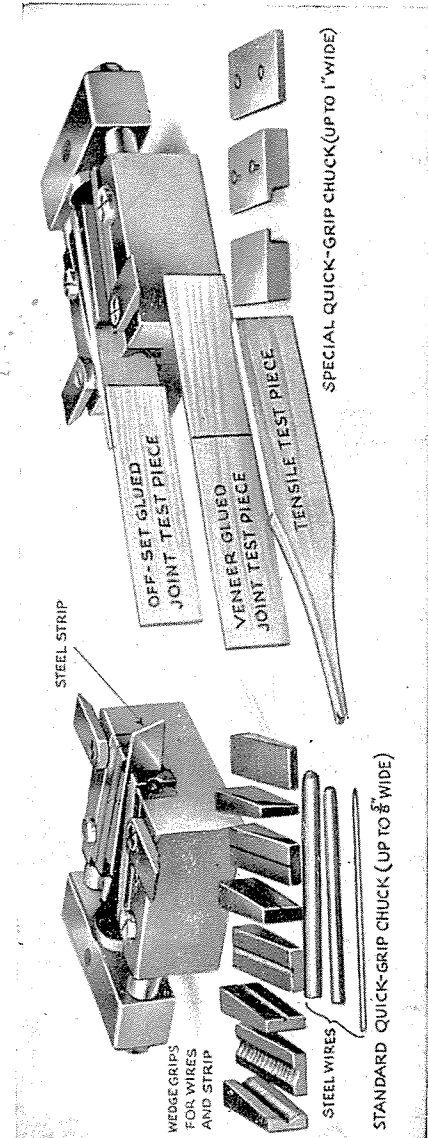


Fig. 25c ¶ 174 181c 195

Fig. 24b

Fig. 25d ¶ 174a, 195, 295

Screws and Bolts

200 As the notched-bar test (recommended in ¶ 106) is not practicable with small bolts and screws such parts can be tested in tension with simple dies (Fig. 25E) in the standard tensile chucks.

The maximum load of 2 tons will give a stress of 40 tons/in² in a 5/16 B.S.F. screw, 28 tons in a 3/8 B.S.F. screw, and 30½ tons in a 3/8 Whit. screw.

INDENTOR TESTS

Brinell Hardness

201 The Brinell test is useful for the following purposes: As a measure of hardness, as an indication of tensile strength, for checking supplies and as an indication as to whether a more reliable test should be applied.

202 For comparative work, to show if uniformity is being maintained in production, *e.g.*, if a batch of parts is made from the same material, the Brinell test gives a check on the heat-treatment; or if a batch of stampings is given the same heat-treatment the Brinell test is a check on the material.

203 As a quick and ready means for indicating suitable heat-treatment, *e.g.*, if a batch of stampings is found to be too soft or too brittle for the purpose intended, one stamping can be Brinelled (*a*) as supplied, (*b*) quenched and (*c*) annealed.

204 If one of the changes in hardness indicates that the desired result has been obtained, then this may be checked with tensile and notched-bar tests, but if an intermediate result is required, tempering is indicated.

205 The load applied to the ball should depend on the hardness of the material being tested, as the diameter of the impression should preferably be between one half and one quarter the diameter of the ball.

206a As a 5 mm. ball has one-quarter the area of a 10 mm. ball the usual Brinell loads of 3,000, 1,000 and 500 kg. for a 10 mm. ball become 750, 250 and 125 kg. respectively for a 5 mm. ball as marked on the force scales C.178, D.193 and D.194.

207a

This table gives the Load to be used with a 5 mm. Ball.

Materials of similar hardness to the following	Suitable Spring Beam	Actual Load		Equivalent Load on a 10 mm. Ball
		k.g.	Tons or Pounds	
Steel	1 ton	750	0.74	3,000 k.g.
Copper Alloys	½ "	250	0.246	1,000 "
Copper	500 lb.	125	275.6	500 "
Lead and Tin	62½ "	25	55.1	100 "

208 Unfortunately, different Brinell hardness figures on the same material are obtained when using different pressures, therefore to obtain comparable results the same load should be used.

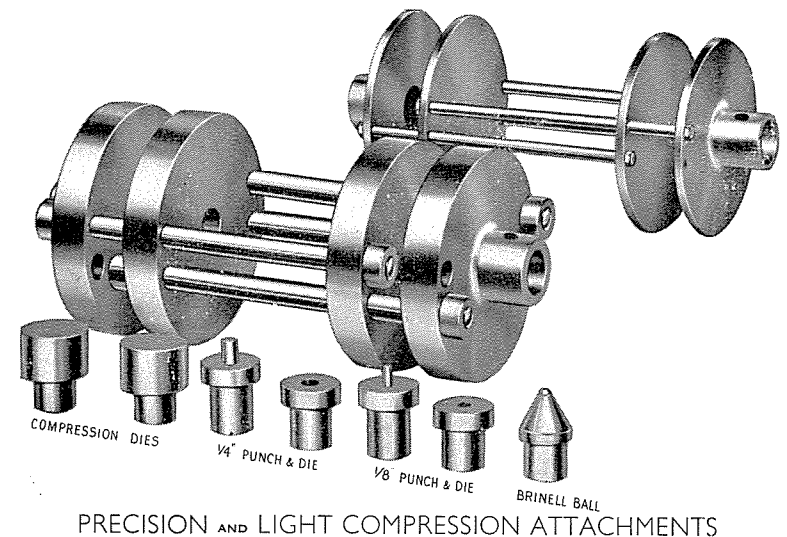


Fig. 26A ¶ 209-256

To Make a Brinell Test

209 Make a flat place on the specimen and polish this place.

Having assembled the compression attachment, Fig. 26A, in the machine and inserted one compression die and the Brinell ball bolster, adjust the mercury *up to* zero, hold the polished place against the Brinell ball and begin applying the load with the quick-acting handle 51, Fig. 2.

210 Turn the handle 49 till the mercury reaches—for steel—the 750 kg. graduation.

Keep the mercury up to this mark for 15 seconds.

211 Any movement of the specimen during this time will enlarge the impression and give a lower hardness figure.

212 Having obtained the desired impression, remove the specimen from the machine and measure the diameter of the impression with the Brinell reading Microscope and obtain the corresponding Brinell Hardness Number from the appropriate Table, ¶ 213–215.

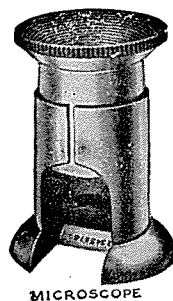


Fig. 26B ¶ 140, 212–212a

212a Apart from measuring the diameter of the Brinell ball impression, ¶ 212 *et. seq.*, and the distance O P, ¶ 140, the microscope has many other uses, *e.g.*, measuring the screen of a half-tone block, counting the wefts per inch in fabrics, the appearance of fractures, detection of cracks and general inspection work. The middle of the scale should be used for small measurements.

213*

Steels

Actual load on Ball (5 mm. dia.) = 750 KG. = .74 ton.†

Diameter of Impression mm.		.01	.02	.03	.04	.05	.06	.07	.08	.09
1.00	945	926	908	890	873	856	840	824	809	794
1.10	780	765	752	738	725	712	700	688	676	665
1.20	653	643	632	621	611	601	592	582	573	564
1.30	555	547	538	530	522	514	507	499	492	485
1.40	477	471	464	457	451	444	438	432	426	420
1.50	415	409	404	398	393	388	383	378	373	368
1.60	363	359	354	350	345	341	337	333	329	325
1.70	321	317	313	309	306	302	298	295	292	288
1.80	285	282	278	275	272	269	266	263	260	257
1.90	255	252	249	246	244	241	239	236	234	231
2.00	229	226	224	222	219	217	215	213	211	209
2.10	207	204	202	200	198	197	195	193	191	189
2.20	187	185	184	182	180	179	177	175	174	172
2.30	170	169	167	166	164	163	161	160	158	157
2.40	156	154	153	152	150	149	148	146	145	144
2.50	143	141	140	139	138	137	135	134	133	132
2.60	131	130	129	128	127	127	125	124	123	122
2.70	121	120	119	118	117	116	115	114	113	112
2.80	111	110	110	109	108	107	106	105	105	104
2.90	103	102	101	101	99.9	99.2	98.4	97.7	96.9	96.2
3.00	95.5

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† See ¶ 207a.

To obtain equivalent tensile strength, see ¶ 219–221a.

Actual Load on Ball (5 mm. dia.) = 250 KG.

Diameter of Impression mm.		.01	.02	.03	.04	.05	.06	.07	.08	.09
1.00	315	309	303	297	291	285	280	275	270	265
1.10	260	255	251	246	242	237	233	229	225	222
1.20	218	214	211	207	204	200	197	194	191	188
1.30	185	182	179	177	174	171	169	166	164	162
1.40	159	157	155	152	150	148	146	144	142	140
1.50	138	136	135	133	131	129	128	126	124	123
1.60	121	120	118	117	115	114	112	111	110	108
1.70	107	106	104	103	102	101	99.5	98.3	97.2	96.1
1.80	95.0	93.9	92.8	91.8	90.7	89.7	88.7	87.7	86.8	85.8
1.90	84.9	83.9	83.0	82.1	81.3	80.4	79.5	78.7	77.9	77.1
2.00	76.3	75.5	74.7	73.9	73.2	72.4	71.7	71.0	70.2	69.5
2.10	68.8	68.2	67.5	66.8	66.2	65.5	64.9	64.2	63.6	63.0
2.20	62.4	61.8	61.2	60.6	60.1	59.5	59.0	58.4	57.9	57.3
2.30	56.8	56.3	55.8	55.3	54.8	54.3	53.8	53.3	52.8	52.3
2.40	51.9	51.4	51.0	50.5	50.1	49.6	49.2	48.8	48.3	47.9
2.50	47.5	47.1	46.7	46.3	45.9	45.4	45.1	44.8	44.4	44.0
2.60	43.7	43.3	42.9	42.6	42.2	41.9	41.5	41.2	40.9	40.5
2.70	40.2	39.9	39.6	39.2	38.9	38.6	38.3	38.0	37.7	37.4
2.80	37.1	36.8	36.5	36.3	36.0	35.7	35.4	35.1	34.9	34.6
2.90	34.3	34.1	33.8	33.6	33.3	33.1	32.8	32.6	32.3	32.1
3.00	31.8

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214a If it is desired to use a 10 mm. ball for materials softer than steel, then the diameter of the ball being doubled, the area and therefore the load will be four times, and the diameter of the impression will be doubled.

E.g., for bronze, load = 250 kg. $\times 4 = 1,000$ kg. or .984 ton.

If the diameter of impression is 3.6 mm. then $\frac{3.6}{2} = 1.8$ which, according to the table 214 gives a hardness of 95.

Actual Load on Ball (5 mm. dia.) = 125 KG. = .123 ton.

Diameter of Impression mm.		.01	.02	.03	.04	.05	.06	.07	.08	.09
1.00	158	154	151	148	146	143	140	137	135	132
1.10	130	128	125	123	121	119	117	115	113	111
1.20	109	107	105	104	102	100	98.6	97.1	95.5	94.0
1.30	92.6	91.1	89.7	88.4	87.0	85.7	84.4	83.2	81.9	80.8
1.40	79.6	78.4	77.3	76.2	75.1	74.1	73.0	72.0	71.0	70.1
1.50	69.1	68.2	67.3	66.4	65.5	64.6	63.8	62.9	62.1	61.3
1.60	60.5	59.8	59.0	58.3	57.5	56.8	56.1	55.4	54.8	54.1
1.70	53.4	52.8	52.2	51.5	50.9	50.3	49.7	49.2	48.6	48.0
1.80	47.5	46.9	46.4	45.9	45.4	44.9	44.4	43.9	43.4	42.9
1.90	42.4	42.0	41.5	41.1	40.6	40.2	39.8	39.4	38.9	38.5
2.00	38.1	37.7	37.3	37.0	36.6	36.2	35.8	35.5	35.1	34.8
2.10	34.4	34.1	33.7	33.4	33.1	32.8	32.4	32.1	31.8	31.5
2.20	31.2	30.9	30.6	30.3	30.0	29.8	29.5	29.2	28.9	28.7
2.30	28.4	28.1	27.9	27.6	27.4	27.1	26.9	26.6	26.4	26.2
2.40	25.9	25.7	25.5	25.3	25.0	24.8	24.6	24.4	24.2	24.0
2.50	23.8	23.6	23.4	23.2	23.0	22.8	22.6	22.4	22.2	22.0
2.60	21.8	21.6	21.5	21.3	21.1	20.9	20.8	20.6	20.4	20.3
2.70	20.1	19.9	19.8	19.6	19.5	19.3	19.2	19.0	18.9	18.7
2.80	18.6	18.4	18.3	18.1	18.0	17.8	17.7	17.6	17.4	17.3
2.90	17.2	17.0	16.9	16.8	16.7	16.5	16.4	16.3	16.2	16.0
3.00	15.9

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216 Many experience difficulty in measuring the diameter of the impression and practice is necessary to obtain accurate results.

The following practice is helpful: If possible choose a bright diffused daylight (a north window) in preference to sun or artificial light, and hold the microscope so that plenty of light falls on the impression.

217 Focus the scale of the microscope before placing it on the specimen.

218 It is also helpful to "grain" the polished surface before making the impression. This is done by polishing in one direction at the finish. If a specimen so treated be rotated under the microscope, a position will be found where the edges of the impression show up sharply.

Thickness of Plate for Brinell Tests (all materials)

218a Many Brinell tests show the materials to be harder than they really are because too large a ball has been used for the thickness of the plate, which means that the hardened table or anvil has reduced the penetration of the ball.

If there is any doubt after the diameter d of the impression has been measured, the appropriate formula in line 2 below should be applied to see if the minimum thickness has been passed.

218b

Line 1	Diameter D of the ball ...	10	5	$2\frac{1}{2}$	1
„ 2	Minimum thickness T of plate	$0.19d^2$	$0.37d^2$	$0.75d^2$	$1.9d^2$
„ 3	Average dia. d of impression	4	2	1	0.4
„ 4	Min. T for above average ...	3	1.5	0.75	0.3

All dimensions are in millimetres.

218c The example in lines 3 and 4 must not be used thoughtlessly because it will be noted from ¶ 213-215 that for a 5 mm. ball the permissible range of impressions is from 1 to 3 mm. diameter giving an average of 2 mm., which represents a 50 ton steel, but for a 20 ton steel the diameter

of the impression would be 3 and the corresponding minimum thickness would be 3.3 instead of 1.5 mm.

219 To Calculate the Tensile Strength from the Brinell Hardness

The Brinell Hardness $\times 0.22$ = stress in tons per sq. in.
 „ „ „ $\times 493$ = „ lb. per sq. in.
 „ „ „ $\times .3465$ = „ k.g. per sq. mm.

220 *E.g.*, if Brinell hardness = 229.

The calculated stress = $229 \times .22$ = 50.4 tons per sq. in.
 229×493 = 113,000 lb. per sq. in.
 $229 \times .3465$ = 79.5 k.g. per sq. mm.

221a The ratio between the strength and the hardness is not always .22, particularly in the case of cold worked or austenitic steels.

Changing the Brinell Ball

222 If the test is used on very hard material the ball may become damaged and must be changed. The old ball may be dislodged by tapping a 1/16" diameter steel rod through the hole provided in the bolster.

223a Diamond Pyramid Hardness. If the material is harder than 450 Brinell or 100 ton tensile it will cause undue deformation of the steel ball and a flattened ball will give an impression of greater diameter which is equivalent to a lower Brinell hardness.

Hence for materials much harder than this a diamond indenter should be used, but the impression is small and difficult to measure without a travelling microscope or the like.

223b For instance, a diamond hardness of 1,000 gives an impression of only 0.237 mm. diameter with a 30 kg. (66.14 lb.) load, and this load should not be exceeded for hardnesses above 1,000 because the harder the material the smaller the impression and therefore the greater the stress on the diamond for a given load. The load may have to be still further reduced for thin sheets because the diameter of the impression must not exceed the thickness of the sheet.

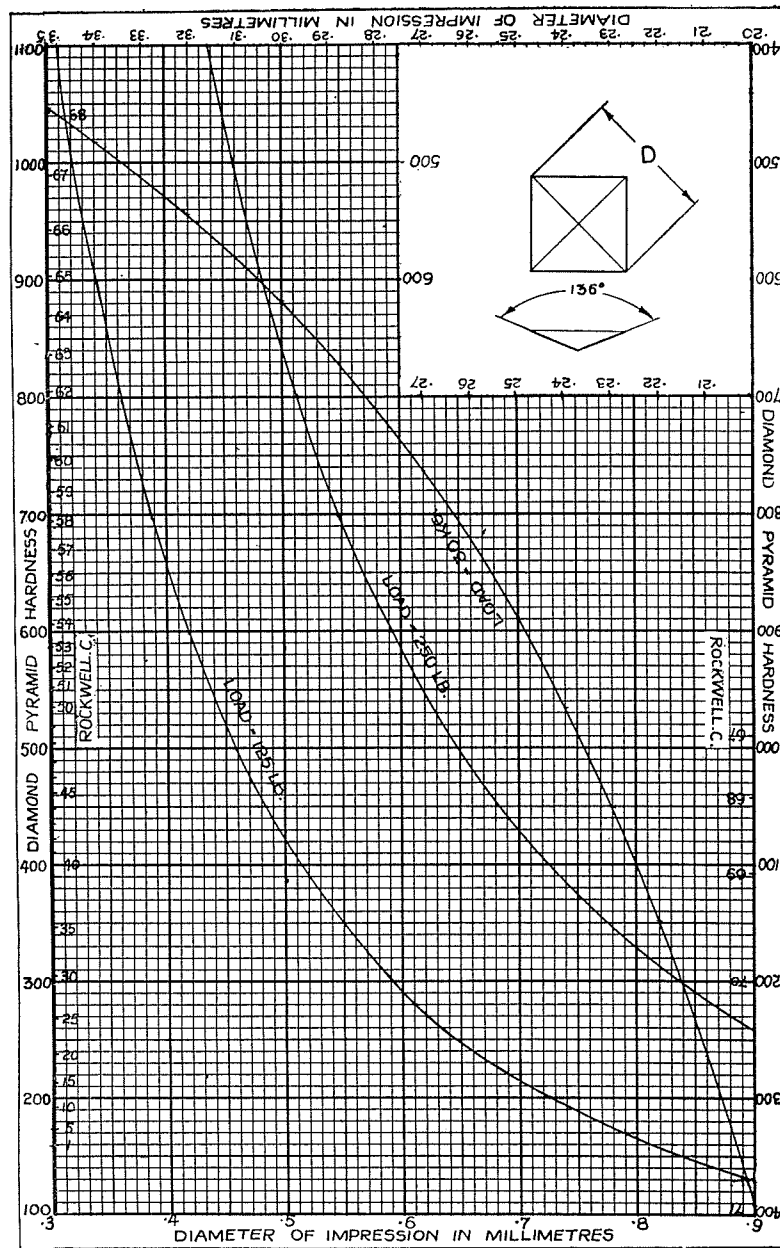


Fig. 26F 223e and f

223c Larger impressions can be obtained with softer materials by increasing the load and it is sometimes useful—when the specimen is too small either in width or thickness for a Brinell test—to use a diamond on relatively soft materials, *e.g.*, if the hardness is 300 (about 66 tons tensile) a load of 250 lb. gives an impression of 0.837 mm., which can be measured approximately with the Brinell microscope.

223d Care must be taken to see that the specimen cannot rock when the load is applied. If the indentation indicates that the point of the diamond is not dead sharp it should be re-ground provided, of course, it is not cracked.

223e The curves in Fig. 26F show the relation between the diameter *D* of the impression and the hardness for three loads *P*; they have been plotted to the equation:—

$$\text{Hardness} = \frac{\text{Load in kg.}}{\text{Area}} = \frac{2 P \sin \frac{\theta}{2}}{D^2} \text{ where } \theta = 136^\circ$$

$$\begin{aligned} &= 210 \cdot 28 / D^2 \text{ when } P = 250 \text{ lb.} \\ &= 105 \cdot 14 / D^2 \quad \quad \quad \text{,,} \quad \quad \quad \text{,,} = 125 \text{ lb.} \\ &= 55 \cdot 63 / D^2 \quad \quad \quad \text{,,} \quad \quad \quad \text{,,} = 30 \text{ kg. (66} \frac{1}{2} \text{ lb.)} \end{aligned}$$

As the last curve has had to be plotted to a different scale the chart has been inverted for this graph.

223f Accurate equivalents should not be expected between different tests, but as it sometimes becomes necessary to make comparisons the approximate Rockwell (C scale, 150 kg. diamond cone) is given next to the diamond pyramid scale, *e.g.*, Rockwell 35 = Pyramid 347.

COMPRESSION TEST

231 This test in its simple form is of little use for testing materials like steel, but is valuable for testing composite substances such as bakelite, cements, etc., using the compression dies (Fig. 26A).

It, however, has many uses apart from ordinary strength testing.

232 It may be required to know the relative pressures necessary to compress various jointing materials by a given amount or to ascertain the effect of different softening solutions on such materials,

233 In constructing an automatic manufacturing machine it may be necessary to know the curve connecting force and movement in snapping a rivet head, so that a suitable cam may be designed for the purpose; or the force necessary to make a plastic substance fill a mould or the force required to imprint a trade mark on a metal object.

If the force required exceeds 2 tons a *portion* of the engraved die can be tested and the total force calculated.

The Punch Shear Test

241 This test enables the shear strength of sheet material to be determined.

The $\frac{1}{8}$ " diameter punch, Fig. 26A, can be used on hard or thick sheets and the $\frac{1}{4}$ " punch used on soft or thin sheets.

242 In commerce it is not often that the actual shear stress is of interest, but the relative force necessary to blank or shear plates of different thickness or of different material or the increased force necessary to blank two plates at once may be required.

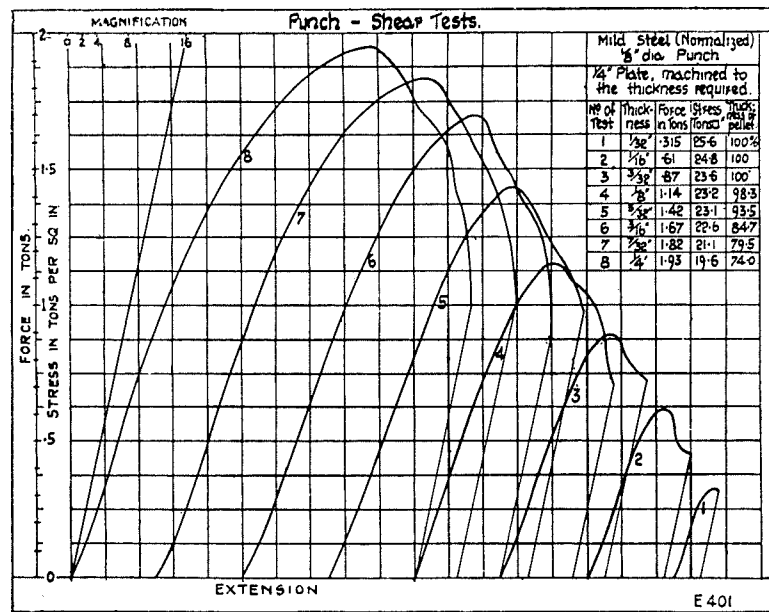


Fig. 27 ¶ 241-249g

243 Fig. 27 shows the maximum force and the work done in punching plates in the same material where the thickness varies from $1/32$ " to $1/4$ ".

244 As the maximum force is proportional to the length of the cutting edge, the force necessary for a large blanking tool can be calculated from the graph obtained from this test on the same material.

245 Probably this test is most valuable to the manufacturer engaged on quantity production, using high-class blanking and pressing dies.

246 Having found the most suitable material for his speciality he takes a graph record with the punch test.

Fresh supplies of sheet material can quickly be tested and the graphs compared with the ideal.

247 In this way damage to expensive dies can be avoided by the detection of hard plates, or if the material is too soft the production of a quantity of useless pressings is avoided.

248 In this application the strip test, ¶ 161 *et seq.*, as a single test, may give more information, but it is relatively a more expensive test and can be resorted to if the punch test casts doubt on the material.

249a As the punch die is free in the bolster and tight in the punched plate it remains in the latter and it can be placed over a hole in the bench or other piece of hard wood and tapped out with a nail.

Compression Attachment and Special Shop Tests

251 This attachment, in addition to the foregoing specific tests, can be used for such shop tests as are frequently devised to detect unsuitable material.

252 The following are a few examples :—

Users of metal tubing may cut off short lengths and drive a taper punch through.

253 This test may detect a faulty tube, but if the drift is pushed through with the compression attachment it enables a graph to be drawn and a standard of quality established

which may enable the manufacturer to use a cheaper source of supply.

254 It is more difficult to obtain steel tube of consistent quality for case-hardening than steel bar.

Short measured lengths of each tube can be cut off, numbered, heat treated and crushed, then the graph and the fracture will enable unsuitable tubes to be returned.

255 If such case-hardened tubes give trouble in snapping, suitable sample lengths may be cut off, heat treated and bent in bending dies made to suit the compression attachment, or in one of the bending attachments (§ 289a).

256 Cupping tests on sheet metal can also be made.

257 A better method for ascertaining whether sheet metal is suitable for deep drawing is to make two strip tests §162-164a, one in the direction of rolling and the other at right angles to it. The elongation per cent should be good in both directions.

CAST IRON BEND TEST

261 Generally speaking, it is undesirable to test brittle specimens or materials with coarse crystalline structure as tensile test-pieces.

262 The bend test gives more consistent results, but these are only comparative.

The test-piece is also cheaper to make.

263 The test-piece, Fig. 28, is so proportioned that the *tensile* strength for cast iron is fifty times that recorded on the appropriate force scale (for any spring beam).

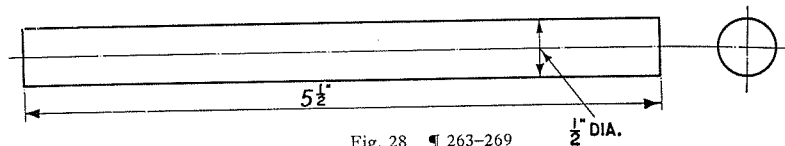


Fig. 28 ¶ 263-269

264 It is therefore convenient to use, with a 2-ton spring beam, scale E.185, then the mercury reading, on this scale, multiplied by ten, gives the tensile strength.

265 Test-pieces to Fig. 28 in most materials other than cast iron, tested in this way, will give results considerably below their tensile strengths.

266 Whether test-pieces should be cast on or cast separately is a matter of opinion and of convenience, but the cross section of the cast test-piece should be reasonably representative of the average thickness of the casting itself. See B.S.I. (Spec. No. 18-1950, or B.S.I. Spec. No. 1452-1948.)

267 Hence, a large test-piece for checking large castings must be machined down to $\frac{1}{2}$ " diameter, but with thin castings the test-piece may be cast to size.

267a Precautions must be taken to see that the rate of cooling of this test-piece is also representative of that of the casting, because chilled test-pieces are, of course, useless.

268 When a test-piece is machined out of a large piece of cast iron the distance from the surface is important because the material from the centre portion will give a less maximum stress and a greater deflection than material taken from the outside.

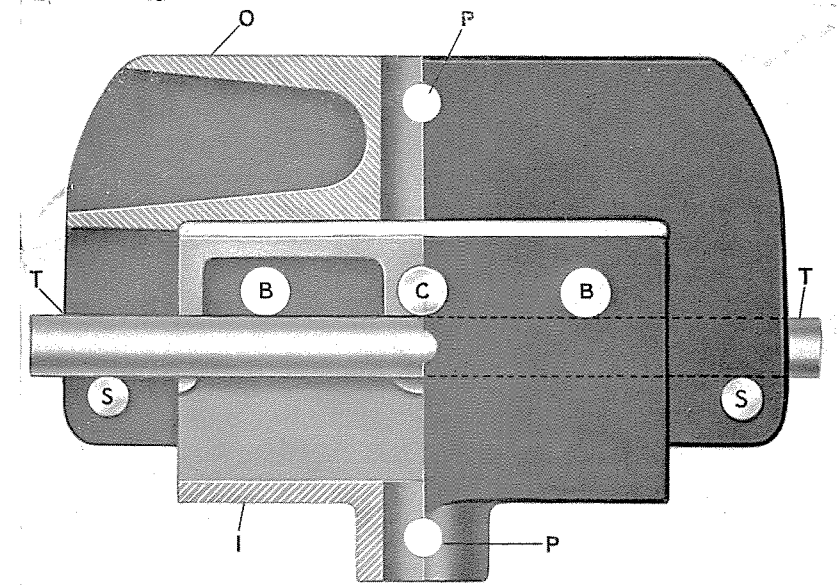


Fig. 29 ¶ 270-280a

269 If it is desired to use cast-on test-pieces, an addition is made to the pattern, which will produce a bar $\frac{1}{2}$ " diameter and $5\frac{1}{2}$ " long, on every casting, Fig. 28.

270 This can be sawn off the casting and tested as indicated in Fig. 29 with a pin in the hole C.

271 When a small load has been applied make a pencil circle on the test-piece through the window under C in Fig. 29 so that if necessary the position of the test-piece in the fixture may be determined after fracture.

272 Cover the ends of the test-piece with a duster to prevent them from "flying" when fracture occurs.

273 If an autographic record is to be made use a magnification of 16 to 1. (See ¶ 66a.)

274 If no record is taken, the exact load at fracture may be missed, owing to the operator's attention being momentarily diverted; to prevent this from occurring it is advisable for him to announce the readings aloud, *e.g.*, ten, ten-and-half, eleven, eleven-and-half and so on till fracture occurs.

275 It is necessary to machine only the middle two inches to the correct diameter.

Miniature Cast Iron Bend Test

277 The test-piece shown in Fig. 31 may be made from a new casting or from one which has failed in service and may be tested in the notched-bar chucks, Fig. 15.

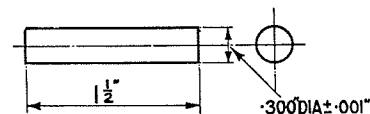


Fig. 31 ¶ 277

278 The proportions of this test-piece, like those of the larger test-piece, are such that the force-reading at fracture multiplied by 50, gives the *tensile* strength approximately.

The Uniform Bending Moment Test

279 The three-point bend test is not reliable when the material is not homogeneous because the greatest stress occurs at the centre point, which may not be the weakest point—particularly in inferior plastics or in porous materials.

280a The uniform bending moment or four-point test with the pins at BB in Fig. 29 gives a uniform stress between the two points B & B and is therefore more likely to reveal defects or folds in the material, but the force reading multiplied by 25 does not give the *tensile* stress. This test has the advantage of subjecting about half the material to the stress instead of about 1 per cent, but the breaking load is not simply related to the tensile stress.

The Bend Test Generally

281 For checking supplies, particularly of small bar material where academic figures are not required, the bend test has a very large field of use.

282 A piece of the bar to be tested can be cut off $1\frac{3}{4}$ " long for use in the Notched-bar Chucks or 6" long for use in the Cast Iron Bend Chucks (depending on the size of the material) and a graph taken.

283 Similar graphs from fresh supplies of the same sized material can be compared for uniformity or if it first material proves to be unsatisfactory for the lack of some property the graph will indicate what alteration in composition or heat treatment is required.

284 With non-ferrous castings it may be desirable to have rectangular bars cast, to be tested in this way.

289a The following bend test attachments can be supplied :—

Materials	Span	Width	Depth	Loading	Max. Load
Plastics	1" to 6"	1"	$\frac{1}{2}$ "	3-point	3,000 lb.
Cast Iron	5"	$\frac{5}{8}$ "	$\frac{5}{8}$ "	3- or 4-point	1 ton
Timber	28 cm.	2 cm.	2 cm.	3-point	1,000 lb.
Wallboard, etc. ...	4"	2"	1"	3-point	1,000 lb.
Sintered Metals ...	$1\frac{1}{4}$ "	$\frac{3}{16}$ " dia.		3-point	2 ton
Chipboard, etc. ...	6" to 12"	4"	1"	3-point	1,000 lb.
Various	4", $2\frac{1}{2}$ " and $1\frac{1}{2}$ "	1"	$\frac{1}{2}$ "	3- or 4-point	500 lb.

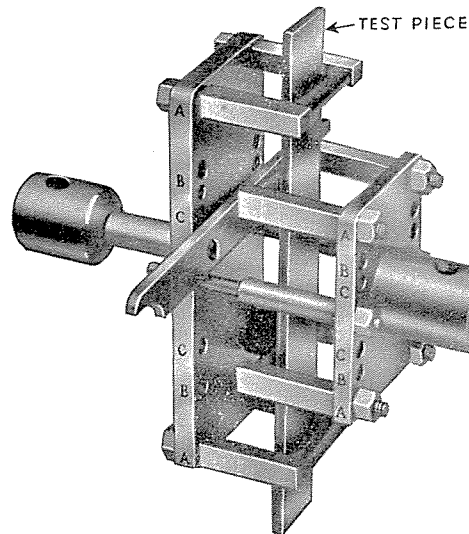


Fig. 30 UNIVERSAL BENT TEST ATTACHMENT
(Max. Load 500 lb.)

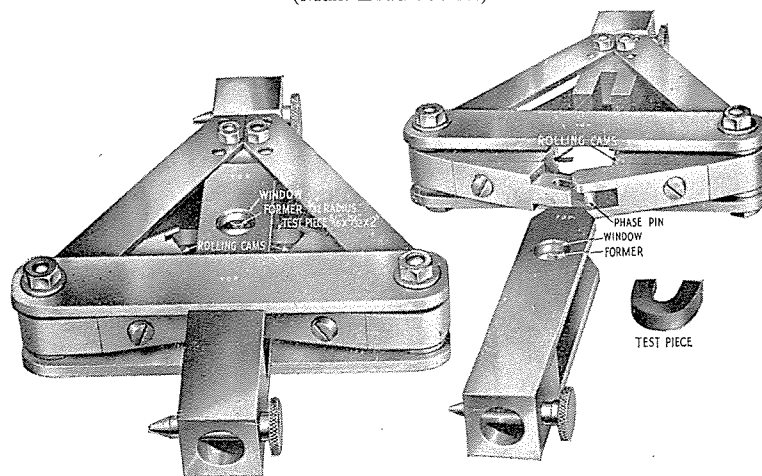


Fig. 31A 180° BEND TEST ATTACHMENT

289c This is one of the oldest tests used to judge the quality of wrought iron. It is now one of the chief tests for welded joints. Various methods have been adopted to produce the bend, but it is believed that this is the only device which makes the bend in one operation with negligible external friction so that the diagram plotted by the autographic recorder gives a true record of the work done. The test-piece is $\frac{5}{16}$ " \times $\frac{15}{32}$ " \times 2", usually welded in the centre.

NON-METALLIC SHEET MATERIALS

290 The different types of chucks which have been made for gripping sheet materials of various compositions cannot all be illustrated.

291a The grips shown in Fig. 34 enable such sheet materials as canvas, plastics, plywood, belting, leather, etc., to be tested.

292a If, say, the warp is being tested in a woven fabric, the test-piece should be cut rather full in width and the warp threads at both cut edges removed one at a time till the correct width is obtained, usually one inch.

This should ensure that the remaining warp threads go from end to end.

294 To grip the material effectively it may be desirable to face the chucks with some material like canvas or sheet rubber attached with bees-wax or solution so that it can, if necessary, be easily removed.

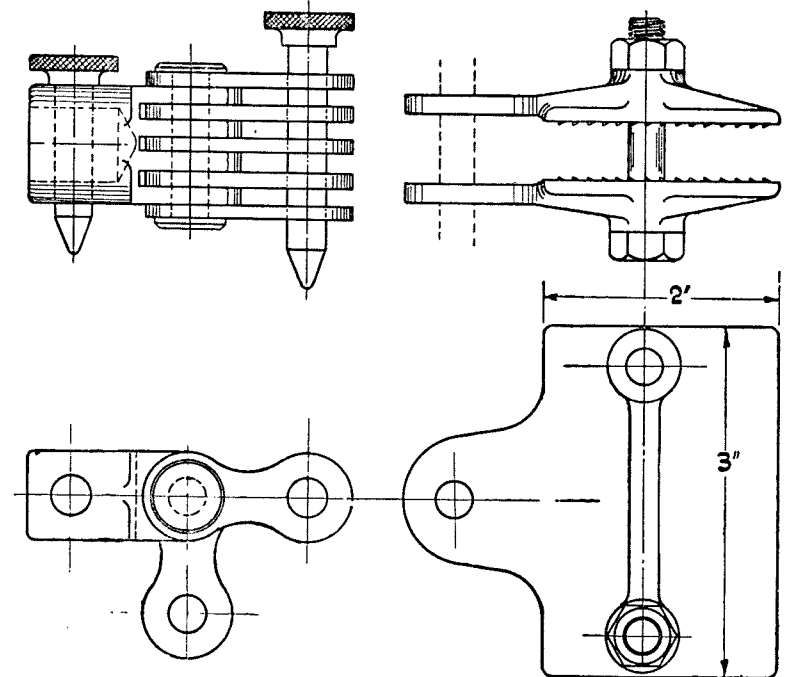


Fig. 33A 294a

Fig. 34 291a & 294b

294a

LINK ADAPTER

The most difficult problem in testing is in the design of grips which will hold a reasonably simple test-piece without impairing its strength. Then these grips have to be connected to the testing machine with some kind of adapter. The figure shows an adapter suitable for many forms of grips where 2 or 3 of the 5 links can be brought into use and the others turned to one side.

294b GRIPS FOR PLASTICS, FABRICS, THICK FELTS AND PLYWOOD (Fig. 34.)

These grips can be used in conjunction with the link adapter for thick materials up to 2" wide without drilling, or 3" wide if drilled. It is generally necessary to waist the test-piece.

295 Strip 1" wide by $\frac{1}{4}$ " thick, or less, can be pulled in chucks, Fig. 25D, provided the maximum pull does not exceed 1 ton.

296 LOCK-JAW GRIPS FOR FABRIC, FELT, FILM, FOIL AND FUSTIAN

A powerful grip is obtained by the toggle action of the links B and C, which when brought into line by the lever L, lock in the closed position. The adjusting screw A can be adjusted to suit the thickness of the material to be tested and can be locked in the correct position with the nut N for repeat tests.

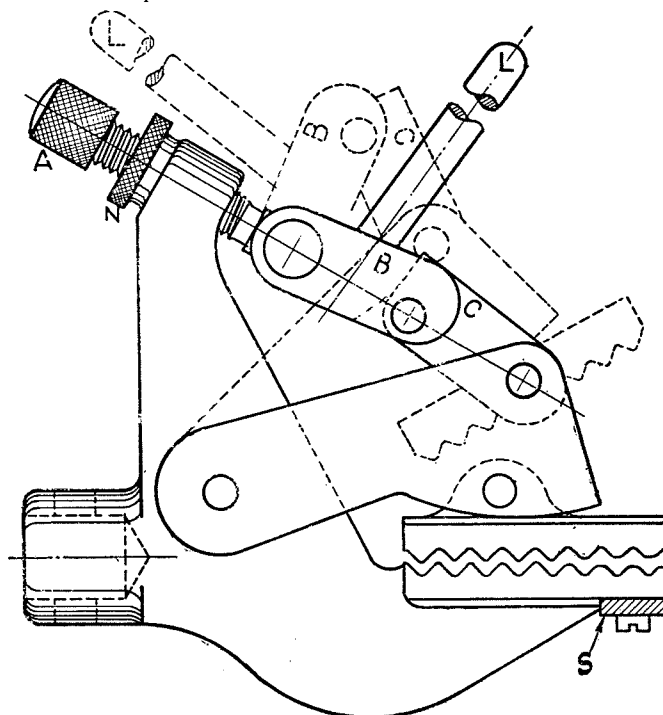


Fig. 37 ¶ 296

The teeth of the jaws are sharper at the back than at the front and greater pressure is exerted at the back of the palates, which are 3" wide and 2" from front to back.

The dotted lines show how the movement of the lever to the left opens the jaws wide, yet its action is almost instantaneous. The weight of the grips is taken by the support S.

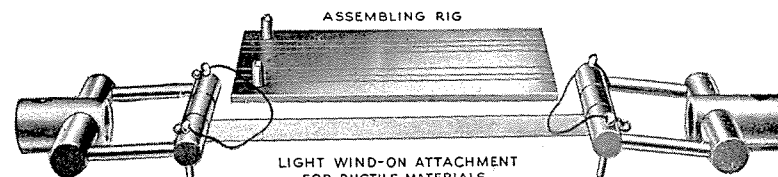


Fig. 38 ¶ 297

297 The attachment shown in Fig. 38 is suitable for thin textiles, foils, films, tapes and ribbons, where waisting is either not possible or undesirable, which elongate and reduce in width and which would therefore tear at the grips if held in vice-like grips such as Figs. 34 or 39.

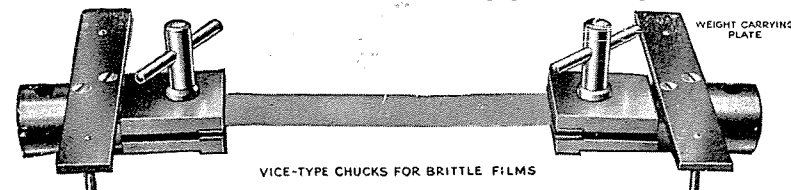


Fig. 39 ¶ 298

298 The grips, Fig. 39, are suitable for thin foils and films which are fairly brittle and do not reduce in width when pulled.

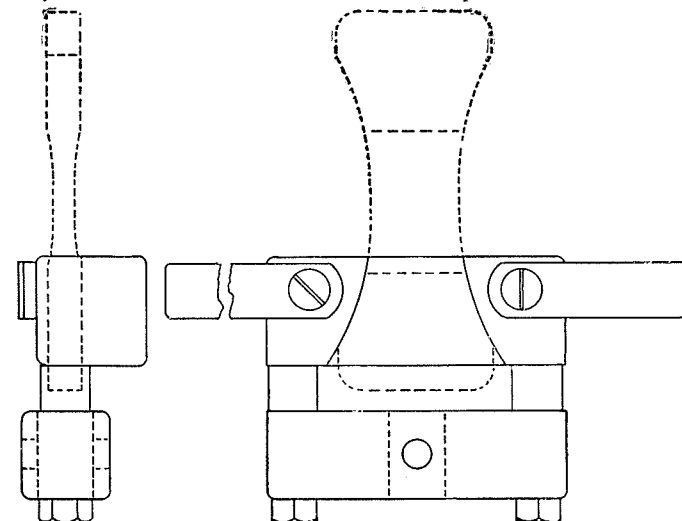


Fig. 42A ¶ 299

294a

LINK ADAPTER

The most difficult problem in testing is in the design of grips which will hold a reasonably simple test-piece without impairing its strength. Then these grips have to be connected to the testing machine with some kind of adapter. The figure shows an adapter suitable for many forms of grips where 2 or 3 of the 5 links can be brought into use and the others turned to one side.

294b GRIPS FOR PLASTICS, FABRICS, THICK FELTS AND PLYWOOD (Fig. 34.)

These grips can be used in conjunction with the link adapter for thick materials up to 2" wide without drilling, or 3" wide if drilled. It is generally necessary to waist the test-piece.

295 Strip 1" wide by $\frac{1}{4}$ " thick, or less, can be pulled in chucks, Fig. 25d, provided the maximum pull does not exceed 1 ton.

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A powerful grip is obtained by the toggle action of the links B and C, which when brought into line by the lever L, lock in the closed position. The adjusting screw A can be adjusted to suit the thickness of the material to be tested and can be locked in the correct position with the nut N for repeat tests.

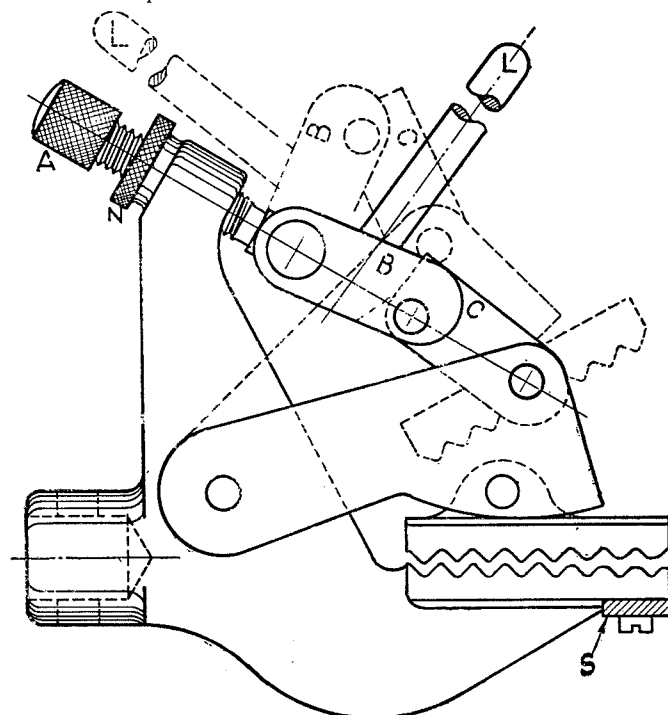


Fig. 37 ¶ 296

The teeth of the jaws are sharper at the back than at the front and greater pressure is exerted at the back of the palates, which are 3" wide and 2" from front to back.

The dotted lines show how the movement of the lever to the left opens the jaws wide, yet its action is almost instantaneous. The weight of the grips is taken by the support S.

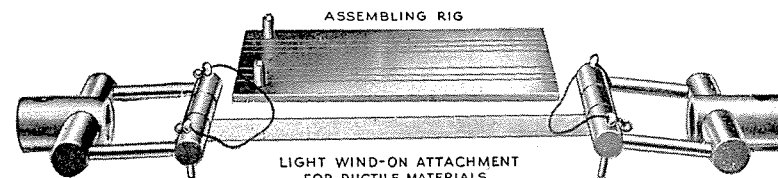


Fig. 38 ¶ 297

297 The attachment shown in Fig. 38 is suitable for thin textiles, foils, films, tapes and ribbons, where waisting is either not possible or undesirable, which elongate and reduce in width and which would therefore tear at the grips if held in vice-like grips such as Figs. 34 or 39.

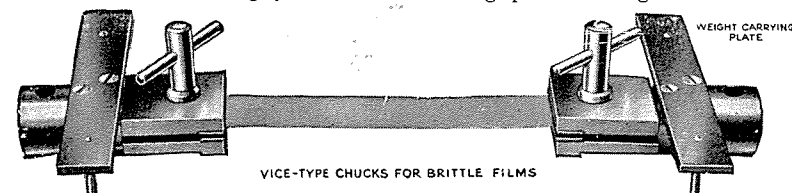


Fig. 39 ¶ 298

298 The grips, Fig. 39, are suitable for thin foils and films which are fairly brittle and do not reduce in width when pulled.

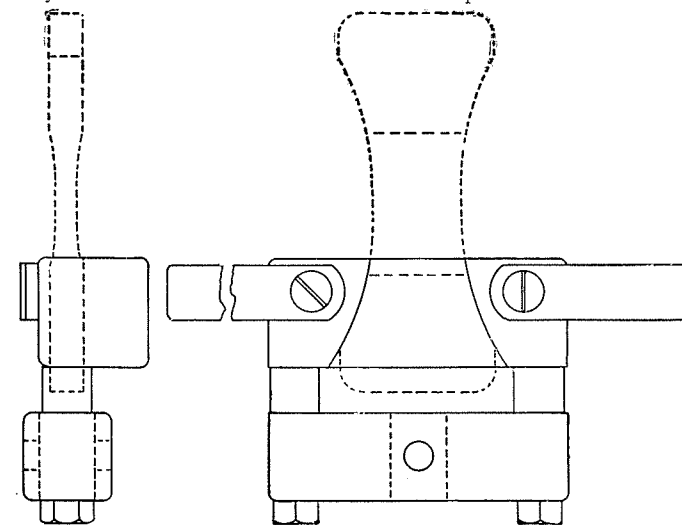
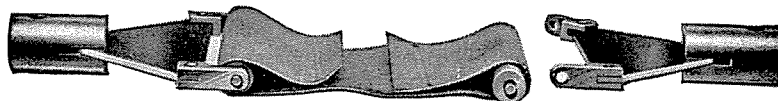


Fig. 42A ¶ 299

299 The grips, Fig. 42A, are suitable for pulling the test-piece given in B.S. Specification 771/48, Synthetic Resin.



ATTACHMENT FOR TESTING STITCHING

Fig. 45 ¶ 300

300 The attachment, Fig. 45, is for testing stitching.

The technique for ascertaining the size of thread, pitch of stitch and number of rows for the most economical "machine" work will be sent on application.

CARE AND ATTENTION

301 **Adding the Mercury.** The machine is sent out dry, and the mercury chamber must be filled with the mercury provided, which is poured into the chamber through the orifice left after removal of the mercury adjusting screw 55, Fig. 1. Add sufficient mercury to enable the column to be sent up to the end of the scale when the adjusting screw is screwed right down.

302 Do not use spilt or dirty mercury again ; it may be collected to be subsequently cleaned, but should not be returned to the instrument. It does not matter if the mercury column becomes divided by a small bubble of air.

303 To prevent the mercury from escaping the box containing the machine should be kept or carried with the carrying handle upwards. If the machine is screwed to the bench the cover can be replaced and locked.

304 **Caution.** As mercury amalgamates with and rots nearly all metals, particularly gold, silver, tin and brass, it is important to brush away all globules of spilt mercury.

305 **Caution.** The mercury must not be allowed to rise from zero to above the graduated portion of the scale while making a test, or the spring beam will be overstressed.



306 The gear box of the machine is packed with High Melting Point Grease and does not require further lubrication

307a **Lubrication.** A drop of clock or sewing machine oil should be allowed to run down the hole 63 provided above the main mercury piston 59, Fig. 1, and all screw threads and other moving parts should be lubricated occasionally.

308b When the machine is out of use the glass tube should be left empty by withdrawing the mercury right down into the perspex block.

309a If the machine is to be sent by rail the mercury system can be drained into the lid of a small cardboard box by removing the screw 57 in Fig. 1.

311c To remove the glass tube for cleaning push the far end perspex block away from the tube which can then be lifted out.

It will be observed that the spring-loaded perspex end contains a felt pad, while the other end of the tube is pressed against a rubber washer $\frac{1}{4}$ " outside diameter with a $\frac{1}{16}$ " hole.

311d The tube can be cleaned with a little cotton wool twisted on to the nylon filament used dry, or if necessary soaked with any of the usual solvents, or if dilute nitric acid has to be used it must be washed well afterwards.

311e Records are kept of glass tube sizes and if a replacement is required the Tensometer Serial Number must be quoted. It has not been found possible to guarantee the accuracy of a replacement tube nearer than \pm or $-$ 1 per cent. If greater accuracy is required the machine must be returned for re-calibration.

312 If too much oil has been put on the felt plunger of the adjusting screw 54, Fig. 1, it should be removed and thoroughly washed in benzol or other grease solvent.

If the plunger becomes clogged with oil, air cannot pass through it readily; bubbles may become imprisoned under it which may escape during a test and give an apparent yield point and a too low maximum stress, etc.

312a If mercury escapes past the felt plunger the felt may be tightened by removing the screw 55, slackening the nut 53 and tightening the screw holding the felt plunger.

312b It is easier to replace a felt plunger than clean it and a new plunger will always be sent without charge if requested.

315 Filtering Mercury. Mercury gathers dust readily and then it fouls the glass tube and gives trouble.

The dust can be removed by filtering as follows:

316 Connect a length of glass tube, about $\frac{1}{8}$ " bore and 2' long, to a glass funnel with rubber tubing.

Plug the bottom end with cotton wool and pour the mercury through into a clean bottle or beaker.

SPRING BEAMS

321d Selection of Spring Beam. The load capacity of the machine depends on the stiffness of the spring beam 26, Figs. 1 & 2.

The following table gives the beams supplied, with the corresponding force scales:—

2-ton spring beam	...	C178
1 " " "	...	D193
$\frac{1}{2}$ " " "	...	D194
500 lb. " "	...	D500
250 " " "	...	D511
125 " " "	...	D512
$62\frac{1}{2}$ " " "	...	D513

The force scales given above and the stress scales given in ¶ 23b are readily interchangeable.

The Effect of Variables on Calibration

326a Each machine is calibrated to suit a master spring beam and each beam is then calibrated to suit its own machine; hence every beam should suit every machine but in practice it is found that an error of + or — 1 per cent may occur if a beam is used on a machine other than its own.

327a The relative position of the parts 60, 61, 64 and 65 in Fig. 1 are important, hence the screws 91, 92 and 93 should not be unscrewed.

To Change the Spring Beam

332b Remove the recorder drum and draw the mercury down into the perspex block by raising the mercury adjusting screw 54 in Fig. 1 right up.

333b With the fingers of the left hand right round the top of the casting 84, press the left thumb on the washers 7 one at a time so that the turn plates 8 can be disengaged from the retaining pins 9 and the recoil blocks 10 removed.

Then remove the knurled nuts 28 and the bridge piece 29. (If the right hand be used there is a danger of gripping the mercury tube 79.)

334b Assemble the spring beam with the stepped ends against the rollers 22 in Fig. 2, so that the bridge piece 29 applies the load to the transverse ridge across the beam and the engraved title is outwards and the right way up.

335c Having changed the spring beam 26, assemble in the reverse order by putting the bridge piece in position first and tightening the nuts 28 till they are felt to come to a definite stop, *i.e.*, only finger tight.

336b Replace the recoil blocks 10 using the left hand again.

337a Changing the spring beam will necessitate changing the scale as indicated on the instruction plate C.177 on the left of the glass tube. (See ¶ 321d.)

MOTOR DRIVE

347c Although in most circumstances hand operation of the Tensometer is preferable, the machine can be motor driven when a constant rate of extension is essential or where materials with unusually large extensions have to be tested.

348d The standard motor drive unit (Code A80) consists of a cast base plate which is located at the back of the Tensometer base by two dowels. A $\frac{1}{4}$ H.P. 230 volt Single Phase, 1,430 r.p.m. A.C. Motor fitted with a 3-step pulley can be adjusted to give correct alignment and tension in the belt for driving a 9" pulley fitted to the drive shaft 30 on the Tensometer. This gives crosshead speeds of 2", 1" and $\frac{1}{2}$ " per minute. A countershaft assembly (Code A90) may be mounted on the base plate to give reduced crosshead speeds of $\frac{1}{4}$ ", $\frac{1}{8}$ " or 1/16" per minute. Alternatively special pulleys can be supplied to suit individual requirements and will provide for speeds up to a maximum of 10" per minute.

349a The motor is controlled by a switch mounted in a small metal box at the end of a flexible cable. The switch can be mounted in the most suitable position on the machine or bench. Forward and reverse limit switches are provided which clip on to the rear standard and stop the motor at predetermined positions of the crosshead. Incidentally, these switches act as a safety device which prevents the machine being damaged by driving beyond the normal travel of the crosshead.

CONVERSION CONSTANTS

351a

- 1 ton = 2,240 lb. = 1,016 k.g.
- 1 k.g. = 2.2046 lb.
- 1 ton per sq. in. = 1,016 k.g. per sq. in. = 1.575 k.g. per sq. mm.
- 1,000 k.g. (a metric tonne) = 0.9842 ton = 2,204.6 lb.
- 1 sq. in. = 6.45 sq. cm.
- 1 ft. lb. = 0.1382 metre kilograms.

ENQUIRIES

361 Particulars with regard to chucks, grips and attachments for special purposes, *e.g.*, cement, glued joints, stitched fabrics, screw threads, cupping, double shear, paraboloid indentors, tensile tests at elevated temperatures, motor drive, etc., will be sent on application.

Enquiries with regard to new tests or tests on new materials are welcome.

362 Full particulars should be given because it is almost invariably necessary to write for further detailed information or more material for testing.

363 Various impact machines can be supplied, also the Hounsfield Extensometer, which is believed to be the most accurate of the commercial type and like the Tensometer it is approved by the A.I.D.

ATTENTION TO OR SERVICING THE TENSOMETER

401 If it is thought that the machine is not giving reliable results the following points should be looked to as possible sources of trouble, although most of these are very improbable.

Mercury System

402 The commonest sources of trouble are : dirty or cracked tubes, dirty mercury and unlubricated mercury pistons.

402a The felt plunger on the mercury adjusting screw is liable to become rigid with oil and dirt. (*See ¶ 312a and b.*)

403 The glass tube should look clean and the mercury should move along it with an undeformed meniscus. (*See ¶ 308a-311b.*)

404 The presence of dust will prevent the column from filling the bore of the tube. (*See ¶ 302, 315-316.*)

405 A trace of zinc, tin or lead dissolved in the mercury will make it plastic instead of mobile. (*See ¶ 304.*)

406 The mercury column should respond instantly to any quick movement of the adjusting screw 54; any appreciable bouncing indicates the presence of imprisoned air in the system. (See ¶ 312.)

407a If the column becomes broken with air bubbles, withdraw the mercury right down into the perspex block. If bubbles reappear persistently the rubber washer at the near end of the glass tube may not be making an air-tight joint. The same defect is indicated if the column cannot be withdrawn.

408a Each glass tube is carefully calibrated for the capacity of the bore which is recorded, it is also checked for uniformity of bore.

This enables broken tubes to be matched. (See ¶ 311e.)

410 The mercury cup adjuster—from 55 downwards—should be quite rigid.

411 Adjust the mercury *up* to zero before making a test. (See ¶ 79a.)

412 It is desirable to apply a slight load before commencing to plot the graph, but the mercury must not be re-set to zero with this slight load on. (See ¶ 80b.)

413 Although the piston 59 in the mercury cylinder 58 has been known to remain free for years on the original oil, a drop of fresh oil should be put in the hole 63 every two or three months. (See ¶ 307a.) If the piston has been dry for months it will not become free directly oil is added. A sticky mercury piston is the chief cause of irregularity.

Other Parts

417 The spring beam 26 must be the right way round, *i.e.*, with the stepped ends against the rollers 22 in Fig. 2.

419 The ring rubber buffer 37 will not be nipped by the flange of the tension head 66 if everything is assembled properly.

Recorder Drum

423a The drive to the recorder drum takes place from the worm wheel 34, Fig. 2, through the quick return wheel through the spindle 13 to the gear wheel 12 to the spindle 4, through the clutch 3 to the pinion 2 on to the contrate wheel 1 to the drum. Hence, if the drum is suspected of slipping, hold it in the left hand, turn the handle 51 and follow through the above sequence to see where the slip is taking place. It should be at the safety clutch between 4 and 3, but the nut 67 or the nut 14 may have become loose. If the clutch is too free to transmit the drive it can be removed by removing the bracket 69 and the nut 6, then the four fingers can be gently closed in.

Possibly the gate 21 requires only to be pushed home.

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