METHODS FOR

BEND TESTING OF METALS

B.S. 1639 : 1964

Price 5/- net

BRITISH STANDARDS INSTITUTION

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First published, May, 1950
First revision, January, 1964

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The following B.S.I. references relate to the work on this standard:
Committee references, MEE/37, MEE/37/4.
Draft for comment D 63/3473.

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BRITISH STANDARD

METHODS FOR BEND TESTING OF METALS

FOREWORD

This British Standard is a revision of B.S. 1639 which was first published in 1950 to provide guidance in specifying simple, now referred to as ' single ', bend tests. During the revision the drafting Committee has taken into consideration current general practice in carrying out bend tests on ferrous and non-ferrous materials and also the corresponding recommendations of the International Organization for Standardization (ISO).

In consequence, it has been decided in the interests of unifying testing procedures that the standard should establish suitable methods of bend testing to which appropriate reference can be made in materials standards when this form of test is specified. In addition to covering single bend tests on materials of all thicknesses, the scope of the standard has been widened to include reverse bend tests and tests on thin metal sheet and strip which were formerly described in Section B of B.S. 485 : 1934.

It is acknowledged that certain requirements for the particular method to be employed will, of necessity, have to be stated in materials standards, but, in addition to describing the various methods, guidance is given regarding their application.

The standard does not apply to the bend testing of wire or tubes, nor to tests on composite or welded metals. For such tests reference should be made to the relevant standard for the material or methods of test for welded joints.

NOTE. Where metric equivalents are stated the figures in British units are to be regarded as the standard. The metric conversions are approximate and more accurate conversions should be based on the tables in B.S. 350, ' Conversion factors and tables '.

SECTION ONE : GENERAL

SCOPE

1. This British Standard describes the essential features of the principal methods for single and reverse bend testing, and indicates the usual fields of application of the several forms of test. Attention is drawn to the details in each method of test, some of which may need to be specified more exactly in individual materials standards.

PURPOSE AND VALUE OF THE TEST

2. Bend tests serve to indicate the capacity of a material for deformation. As a comparative empirical method bend testing has the advantage that either a

machined or unmachined test piece may be prepared from wrought or cast material.

SYMBOLS AND DEFINITIONS

3. *a. Symbols.* In this British Standard the following symbols apply:

Symbol	Designation
a	Thickness or diameter or test piece
b	Width of test piece
l	Length of test piece
	NOTE. For cone bend test pieces the lengths at the broad and narrow end are designated respectively by the symbols l_1 and l_2. (See Fig. 9*a*).
α	Angle of bend
θ	Angle of taper of cone bend test piece
R	Radius of supports
D/2	Radius of mandrel or radius of curvature of blocks
r	Internal radius of the bent portion of the test piece after bending
h	Distance from top of blocks to bottom face of guide
Nb	Number of bends

b. Single bend test. A test in which a straight solid test piece, generally of round or rectangular cross-section, is submitted to appreciable plastic deformation by bending without reversing the direction of flexure.

c. Reverse bend test. A test in which a test piece, held firmly in a vice or machine, is alternately bent and straightened over a mandrel of specified radius.

d. Thickness grading. For the application of the various methods of test, the thickness of materials is graded as follows:

'*Thin*' Material up to ⅛ in (3 mm) thick.

'*Medium*' Material from $\frac{1}{10}$ in to ½ in (2·5 mm to 12·5 mm) thick.

'*Thick*' Material over ⅜ in (9 mm) thick.

NOTE. These grades are included for convenience and the overlap on the thickness ranges is intended to cover the nomenclature used in different industries.

INFLUENCE OF GEOMETRICAL PROPORTIONS OF TEST PIECE

4. For a given final internal radius of bend in relation to thickness, increasing the ratio of width to thickness of the test piece increases the severity of the test.

The results of experiments indicate that the test is less severe for a round section test piece than for one of square section having the same value of *a*.

For strict comparison of tests of different thicknesses the length and widths of the test piece and the radii to which they are bent should preferably all be in proportion to their thicknesses.

For sheet and plate material up to a thickness of ⅜ in (10 mm) the effect of variation in width is not important provided that the width is at least four times the thickness.

FORM AND PREPARATION OF TEST PIECE

5. *a. Form* (i) *Wrought bar and cast materials.* Test pieces may be unmachined.

(ii) '*Thin*' *material.* Test pieces shall be of rectangular cross-section and of the full thickness of the material under test. The width shall be not less than ¾ in (20 mm) or the full width of the strip it represents if less than ¾ in (20 mm).

(iii) '*Medium*' *material.* For thickness up to and including ⅜ in (10 mm), test pieces shall be of rectangular cross-section and of the full thickness of the material under test. The width shall be not less than 1½ in (40 mm) or the full width of the material it represents if less than 1½ in (40 mm).

(iv) '*Thick*' *material.* For thicknesses exceeding ⅜ in (10 mm), the width of the test piece should be specified in the standard for the material.

(v) *General.* In all cases the length of the test piece shall be suitable for whichever method of test is to be employed, and, where applicable, the test piece should be cut in the direction relative to the direction of final rolling of the material it represents as specified in the standard for that material.

b. Preparation. If the test piece is to be machined all over, it is recommended that, where practicable, the machining should be in the longitudinal direction of the test piece as transverse tool marks induce localization of stress and may cause premature failure.

If the longer edges of the test piece have been cut, the edges may be rounded and smoothed longitudinally so that there are no transverse burrs, scratches or marks which might adversely influence the test.

The use of a shearing machine or of a flame for cutting out the test pieces affects the structure of the metal along the cut edge. Metal thus affected may be removed from such damaged edges by longitudinal milling, planing, grinding or other method which does not use large forces or overheat the material.

METHODS OF BENDING

6. Common methods of making bend tests are described in Sections Two and Three of this standard. Unless otherwise stated in the relevant standard for the material, the supplier shall be allowed the choice of these methods.

CRITERION OF PERFORMANCE

7. Unless otherwise stated in the standard for the material, the criterion for the acceptability of the material is that, after the test piece has been bent by one of the methods described in this standard and through the specified amount, it shall be unbroken and free from cracks on the outside surface. Small cracks at

the edges of rectangular section test pieces and cracks which require magnification to be visible may be disregarded.

SEVERITY OF TEST

8. *a. Single.* In stating bend test requirements, the required severity of test for a test piece of any given shape and size should be defined in terms of the final internal minimum radius of curvature and/or the angle of bend. The standard for the material should state whether the radius, r, and/or the angle, α, are to be measured before or after bending forces and restraint have been removed.

b. Reverse. The standard for the material should state the radius of curvature and the angle of bend and number of bends, Nb.

NOTE. When the specification applies to material with a range of thickness or cross-section, the final minimum radius of curvature should be expressed as a function of the thickness or diameter of cross-section of the test piece.

TEMPERATURE OF TEST

9. Unless otherwise agreed, the test shall be carried out with the temperature of the test piece at not less than 10°C and not more than 30°C.

GENERAL

10. In the early stages of a bend test, elastic curvature is produced and complete recovery would result from removal of the bending moment. When the bending moment is increased sufficiently, plastic bending takes place and, although some elastic recovery may occur after removal of the load the test piece will remain curved.

In most tests, the test piece can conform to the straining mechanism either by curving more or less uniformly over a considerable length or by curving more sharply over a very short length. The tendency to increase the sharpness of curvature over a short length is usually called 'peaking'.

The conditions which determine the onset of peaking are frequently complex and are not easy to define. If a uniform bar or a strip of material is subjected to a bending moment which is uniform along its length, it will bend into the arc of a circle. In the usual form of test the bending moment is greatest at mid-length. If in addition some axial tension is applied, the curvature will be reduced towards the centre of the test length. Conversely, axial compression will increase curvature at mid-length. It follows that tendency to peaking may to some extent be counteracted by axial tension and will be accentuated by axial compression.

Methods of bend testing differ in the degree to which peaking is affected by the introduction of axial load. The methods differ also in the way in which bending moment is applied and in the distribution of bending moment along the test piece.

SECTION TWO : SINGLE BEND TESTS

METHOD 1. MANDREL AND SUPPORTS

11. *a. Description.* The test piece is laid on two parallel supports and bent by pressure applied midway between the supports by means of a mandrel or hardened former, the radius of which is specified in the standard for the material.

If the radii of the supports are small (as in Fig. 1) the material of the test piece may be damaged. As bending increases, the test piece slips past the edges of the support and the frictional force results in a tensile component acting along the test piece. Increasing the radii of the supports will reduce local damage but will also reduce the tensile force opposing peaking. If the supports are free to rotate the tendency to local damage will be minimized, but the tendency to peaking will be accentuated. It is recommended that the radius of the supports should lie between 1 and 10 times the thickness of the test piece.

To accommodate different thicknesses of test piece the distance between supports should be $D + 3a \pm a/2$. Within these limits tests can be made on fixed supports by using insert rollers to accommodate test pieces of different thicknesses, as in Fig. 2.

b. Application. This method is suitable for testing 'medium' and 'thick' materials for angles of bend up to 120°.

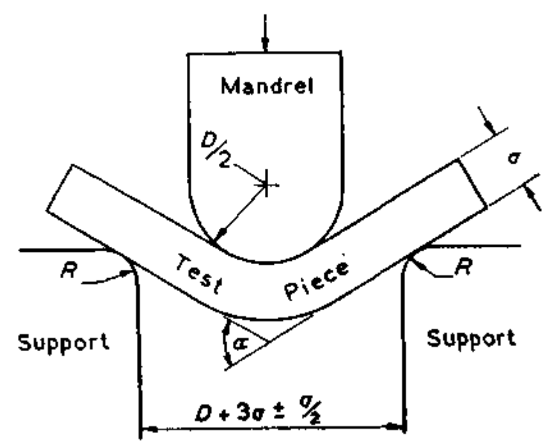


Fig. 1. Simplest method of bend test

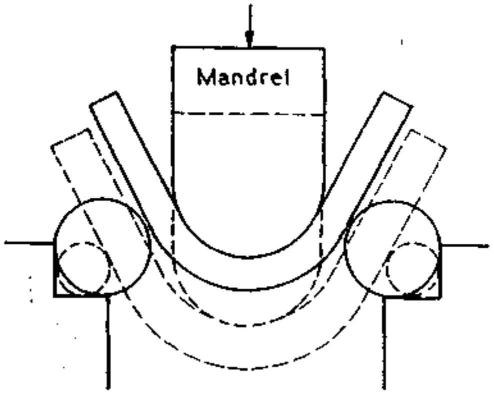


Fig. 2. Modification of method illustrated in Fig. 1 by the use of roller supports

METHOD 2. VEE-BLOCK

12. *a. Description.* The method of bending is similar to that described in Clause 11, but in this test the angle of bend is definitely limited by providing mechanical stops in the form of a vee-block as shown in Fig. 3. The vee shape between the supports does not play any part in the test until the test piece touches the sides of the vee, at which stage the test is discontinued.

The same considerations regarding the radii of the supports (see Clause 11) apply equally to the radii at the upper edges of the vee.

b. Application. This method is suitable for testing 'medium' material up to an angle of bend of 90°.

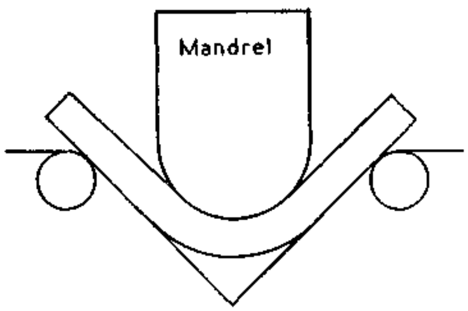


Fig. 3. Bending on a vee-block

METHOD 3. BLOCKS OF SOFT MATERIAL

13. *a. Description.* The test consists in pressing the test piece into a block of lead or other suitable plastic matrix (see Fig. 4) by means of a hardened mandrel.

The soft material may be regarded as a distributed support taking the place of the two localized supports in the tests described in Methods 1 and 2. The soft material immediately in front of the moving mandrel provides some support to the test piece and helps to prevent peaking.

b. Application. This method is suitable for testing 'thin' materials for angles of bend up to 90°. For greater angles of bend the legs of the test piece may be closed by applying pressure with the fingers or by means of a mallet.

NOTE. This method is not recommended for testing high tensile materials having a thickness greater than 1/16 in (1·5 mm) as peaking may occur. Difficulties may also be encountered in testing soft materials unless the applied load is sufficiently low.

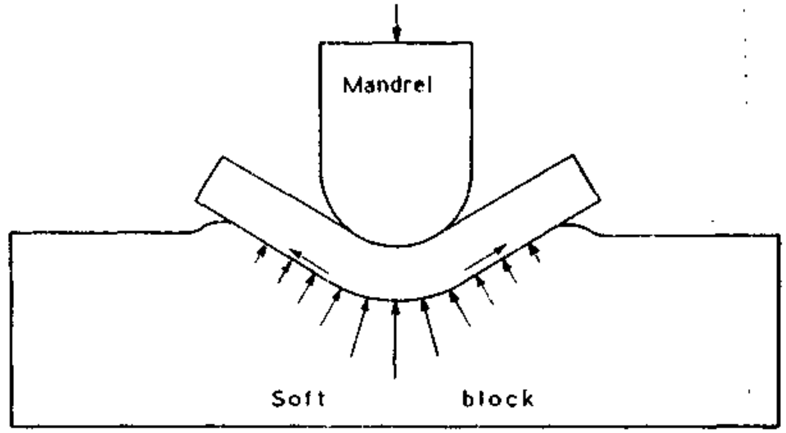


Fig. 4. Bending on a block of soft material

METHOD 4. BENDING ROUND MANDREL

14. *a. Description.* The test piece is held against a suitably shaped mandrel in a vice or other form of clamping device. The test piece is then bent around the mandrel by applying a force at right angles to the surface of the test piece using either a bending machine as shown in Fig. 5, by steady pressure such as can be exerted by the fingers, or by applied blows with a mallet, Fig. 6. The method of loading should be stated in the standard for the material.

If a bending machine is used, the force shall be applied at a distance of not greater than 2*a* from the last line of contact of the test piece on the mandrel.

b. Application. This method is suitable for testing 'thin' and 'medium' materials for angles of bend up to 180°.

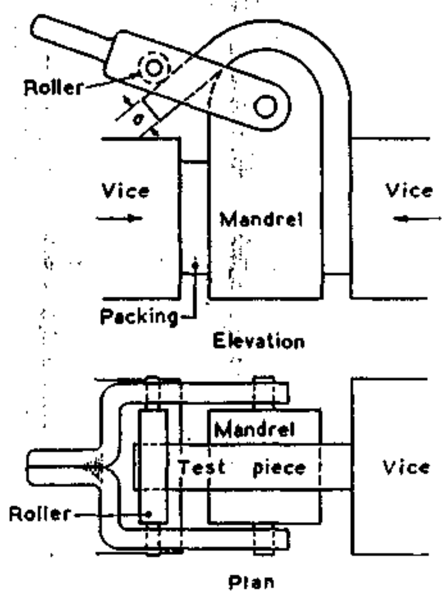


Fig. 5. Bend test machine

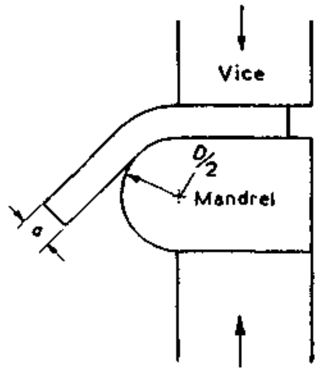


Fig. 6. Bending round a mandrel

METHOD 5. FREE BEND

NOTE. This test is difficult to control and attention is drawn to accident hazards that might arise.

15. *a. Description.* The test piece which has been initially slightly bent by Method 1 or 2 as appropriate is subjected to compressive loading (see Fig. 7) so that it bends at mid-length under a combination of bending moment and compressive stress. Loading is continued until the angle of bend attains the specified value.

To measure the internal radius or the angle of bend, the test may be discontinued and the test piece removed.

b. Application. This method is suitable for testing 'medium' and 'thick' materials for angles of bend up to 180°. As the radius of bend is not under control, the method is not considered suitable for obtaining specified values of minimum radius.

METHOD 6. PRESSURE BEND

16. *a. Description.* The test piece which has been previously bent to an angle of approximately 90° by Methods 1, 2, 3 or 4, as appropriate, is further bent by steady compressive loading until the requirements in the standard for the material are met.

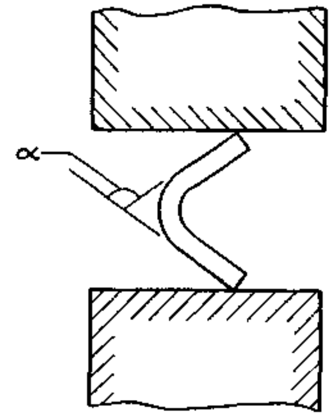


Fig. 7. Free bend test

The legs of the test piece may be brought:

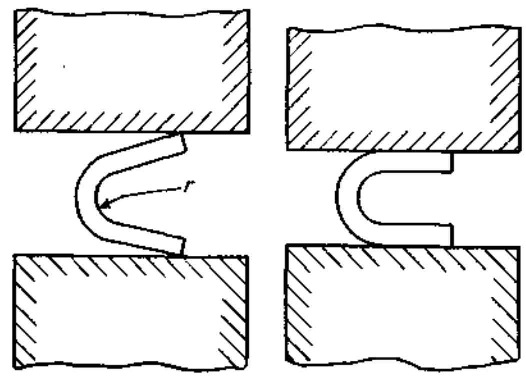
(i) to a specified angle (Fig. 8*a*),

(ii) parallel to each other at a given distance apart (Figs. 8*b* and *c*),

(iii) into contact with each other (Fig. 8*d*).

Alternatively, when the bend is carried out by Methods 1, 2, 3 or 4 up to an angle of 90°, the legs of the test piece may be bent by applying pressure with the fingers or by means of a mallet until they are parallel.

b. Application. This method is suitable for testing all thicknesses of material for angles of bend from 90° to 180°.



a *b*

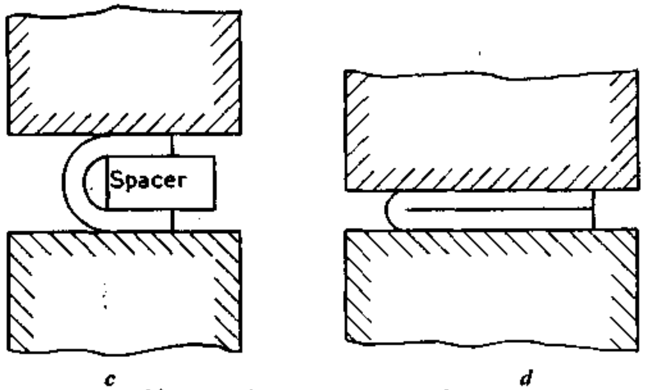


Fig. 8. Variants of pressure bend test

METHOD 7. FREE CONE BEND

17. *a. Description.* A test piece, in the form of a symmetrical trapezium (see Fig. 9*a*), having dimensions specified in the standard for the material, is subject to compressive loading along its tapered edges (see Fig. 9*b*). This loading produces buckling and bending to a progressively decreasing radius from the broad to the narrow end. The dimensions of the test piece are chosen so that the radius at the narrow end is less than the limiting radius of bend of the material under test and thus cracking occurs as illustrated in Fig. 9*c*. Measurement of the internal radius at the tip of crack provides the limiting value for the material.

The bend formed by this method in the central region at any point along the length of the test piece has been found very closely to follow a true circular arc.

NOTE. With certain materials the crack may extend beyond the limiting radius of bend as determined by Method 3. The ratio of the limiting radii of bend determined by the two methods provides an indication of the susceptibility of the material under test to crack propagation.

b. Application. This method is suitable for testing ' thin ' and ' medium ' materials through angles of bend up to 90°.

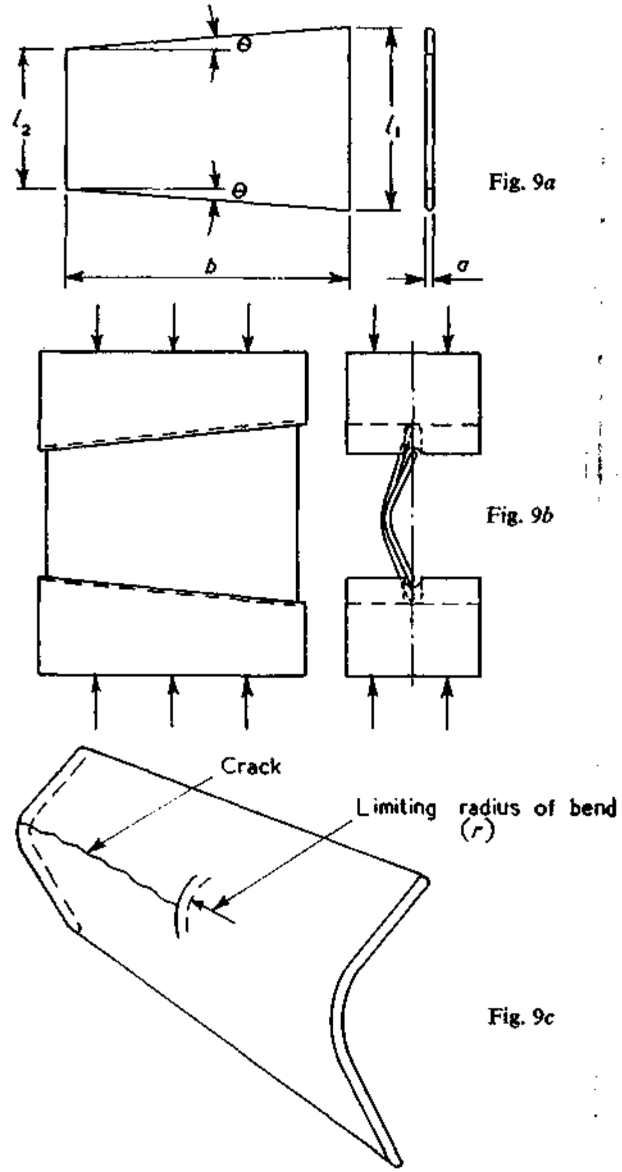


Fig. 9. Cone bend test

SECTION THREE : REVERSE BEND TEST

METHOD 8. REVERSE BEND

18. *a. Description.* One end of a rectangular section test piece is held between hardened supports, the inner edges of the supports having a specified radius. The free end of the test piece is bent through 90°, in opposite directions, over the rounded edge of the supports.

One 'reverse bend' consists of bending the test piece through an angle of 90° and then returning it to its original position (see Fig. 10).

To ensure continual contact between the test piece and the supports during the test, some form of constraint is applied. This may be in the form of tension applied along the longer axis of the test piece as illustrated in Fig. 11*a*, or by rollers or guides as in Figs. 11*b* and *c*. The distance, *h*, is the minimum consistent with obtaining a smooth bend over the rounded edges of the supports, and in no case should be greater than 5*a*.

b. Application. This method is used for testing 'thin' materials until a specified number of bends has been achieved or until the test piece fails.

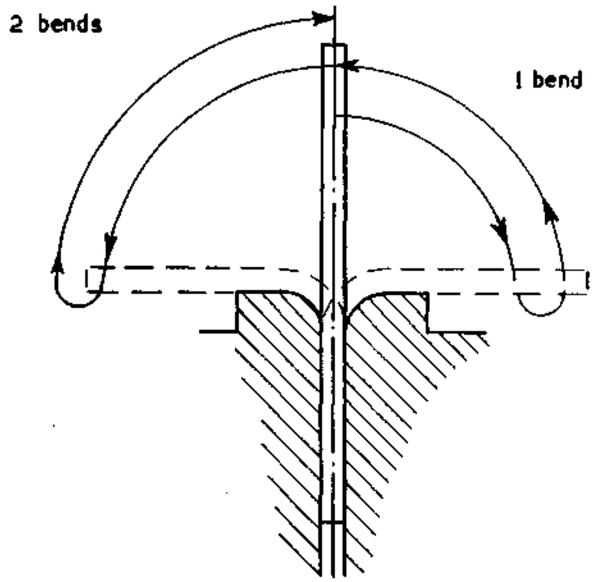


Fig. 10. Method of counting reverse bends

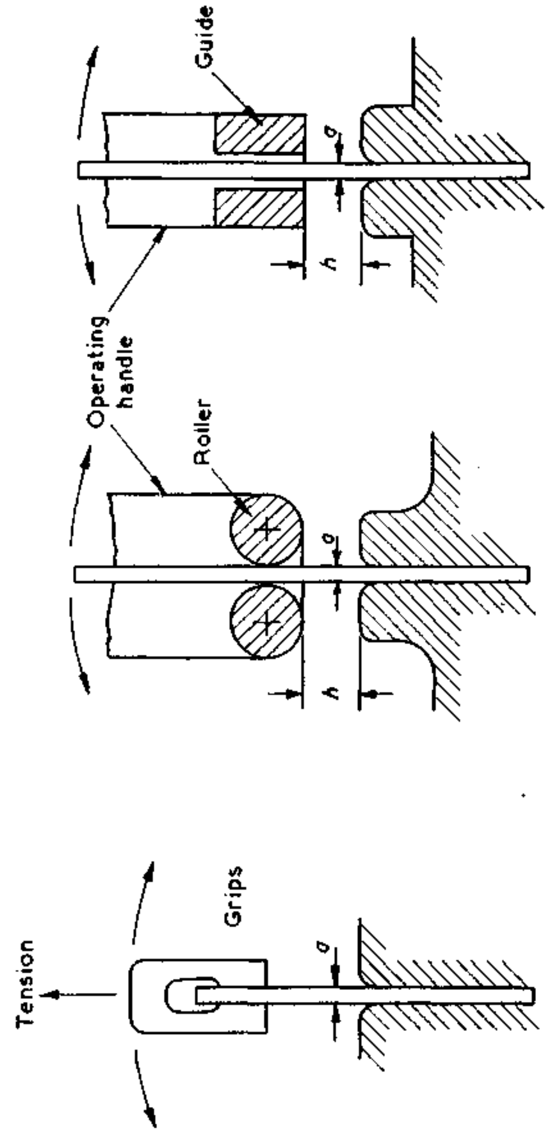


Fig. 11*c*

Fig. 11*b*

Fig. 11*a*

Fig. 11. Reverse bend

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