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A COMPARISON OF THE BRITISH, U. S. FEDERAL AND A.S.T.M. STANDARD AND TENTATIVE STANDARD TEST METHODS FOR THE BRINELL, DIAMOND PYRAMID AND ROCKWELL HARDNESS TESTING OF METALS

by

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PHYSICAL METALLURGY DIVISION

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A COMPARISON OF THE BRITISH, U.S. FEDERAL AND A.S.T.M. STANDARD AND TENTATIVE STANDARD TEST METHODS FOR THE BRINELL, DIAMOND PYRAMID AND ROCKWELL HARDNESS TESTING OF METALS

by

P. J. Todkill*

ABSTRACT

As part of the work of the Tripartite Committee of the armies of the United States, the United Kingdom, and Canada on the Standardization of Methods of Test of Ferrous Materials, a survey has been made of the British, U.S. Federal and A.S.T.M. Standard and Tentative Standard test methods for the Brinell, Diamond Pyramid and Rockwell hardness testing of metals. This survey attempts to show the differences which exist in these test methods, thereby pointing out areas in which agreement must be obtained in the standardization of them.

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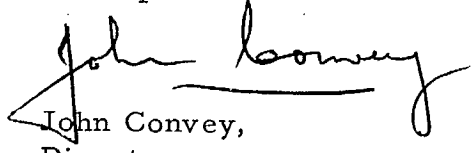
PREFACE

This comparison report has been prepared as a reference point from which discussions may proceed on the standardization of hardness test methods, a project initiated at a meeting of the Tripartite Committee of Methods of Test of Ferrous Materials held in Washington, D. C., March 16, 1950.

The British, U. S. Federal and A. S. T. M. Standard and Tentative Standard test methods for the Brinell, Diamond Pyramid and Rockwell hardness testing of metals have been reproduced herein in such a manner that the equivalent sections of each may be easily compared. The main differences upon which, it is felt, agreement must be obtained before these test methods can be standardized have been pointed out and some comments have been made upon the possible significance of these differences. However, as it is realized that standardization can only be achieved after considerable discussion on the part of the respective representatives concerned, the scope of this circular has been limited to the provision of a basis for this discussion and no proposals have been made for the acceptance of any particular test methods as standards.

It is well known that the International Organization for Standardization is actively engaged in the development of Brinell and Diamond Pyramid hardness test standards. ISO recommendations for Brinell and Diamond Pyramid hardness tests have been prepared in the form of separate proposals for Light Metals and Their Alloys (ISO/TC79), Copper and Copper Alloys (ISO/TC26), and Steel (ISO/TC17). However, as the latest drafts of these recommendations are still under review, they have not been included in this comparison.



John Convey,
Director,
Mines Branch

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INTRODUCTION

On March 16, 1950, a meeting of the Tripartite Committee on Standardization of Methods of Test of Ferrous Materials was held in the Pentagon, Washington, D. C. This meeting, which was held to determine the scope of Category Nine, Project 6.7.1., "Methods of Test of Ferrous Materials", was attended by representatives of the armies of the United States, the United Kingdom and Canada. Canada was also represented by Dr. J. Convey of the Mines Branch, Department of Mines and Technical Surveys, Ottawa.

Following a discussion which brought out that the field was a fertile one for standardization, it was agreed that the scope of the project would be limited to Methods of Test of Ferrous Materials required for production control only. No attempt would be made at that time to standardize on specialized test methods. It was decided that the total scope of the project would include the following physical (mechanical) tests:

(a) Magnetic crack detection (procedure only)
(b) Radiographic (procedure only)
(c) Bend tests
(d) Hardness - to include Brinell, Diamond, Rockwell and ASTM conversion tables
(e) Hardenability
(f) Impact - to include nicked fracture test
(g) Shear
(h) Tensile
(i) Torsion
(j) Transverse (cast iron)
(k) Welding
(l) Grain sizes

It was also agreed that the initial portion of the study would be confined to the following tests, in the priorities indicated:

(a) Hardness
(b) Tensile
(c) Impact
(d) Bend

It was further agreed that Canada should monitor the study of the standardization of hardness test methods. Certain U.S. specifications were handed to Dr. Convey, since the Mines Branch of the Canadian Department of Mines and Technical Surveys was to act as the monitoring agency.

As the United States Federal Specification QQ-M-151a, "General Specification for Inspection of Metals", was under extensive revision at the time of this meeting, work on this project was deferred pending the completion of this revision. The revised copy of the United States Federal Test Method Standard No. 151 was not received until April, 1957.

This present report contains a comparison of the British Standard Test Methods, the revised United States Federal Standard Test Methods and the American Society for Testing Materials Standard and Tentative Standard Test Methods, governing the Brinell, Rockwell and Diamond Pyramid hardness testing of metals. The following test methods have been considered in this comparison:

B.S. 240 : Part 1 : 1937, British Standard Method and Tables for Brinell Hardness Testing
B.S. 427 : 1931, British Standard Diamond Pyramid Hardness Numbers

B. S. 891 : 1940, British Standard Method for Direct Reading Hardness Testing, Rockwell Principle

Federal Test Method Standard No. 151 : 1956
Method No. 242, Brinell Hardness Test
Method No. 244, Diamond Pyramid Hardness Test
Method No. 243, Rockwell Hardness Test

ASTM Designation: E10-54T, Tentative Method of Test for Brinell Hardness of Metallic Materials
ASTM Designation: E92-57, Standard Method of Test for Diamond Pyramid Hardness of Metallic Materials
ASTM Designation: E18-57T, Tentative Methods of Test for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials

These test methods have been arranged in such a manner that equivalent sections of each can be readily compared. This arrangement shows that the ASTM standard and tentative standard test methods are much more detailed than the United States Federal Test Methods, which in turn are more detailed than the British Standard Test Methods.

A number of the more obvious differences in the standards governing each of the hardness test methods are listed below. Some of these differences, particularly in the Rockwell hardness test methods, will apply only when the particular test is used on non-ferrous metals which are actually not within the scope of Category Nine, Project 6.7.1. However, as these standards have been prepared for the testing of metallic materials, no attempt has been made to limit this comparison to those sections which are relevant to the testing of ferrous materials.

BRINELL HARDNESS TEST

An examination of the Brinell hardness test methods, British Standard B.S. 240 : 1937, Federal Test Method No. 242: 1956 and ASTM Designation E10-54T, shows that these three standards are quite similar. Probably the most outstanding differences are found in the size of balls and the magnitude of the loads accepted as standard. The Federal and ASTM test methods state that the standard ball shall be 10 mm in diameter, while the British Standard considers that 1, 2, 5 and 10 mm diameter balls are standard. The Federal and ASTM test methods also state that the standard loads are 3000 kg, 1500 kg and 500 kg; however, these loads are not mandatory. In the British Standard the standard loads are listed as 1, 4, 5, 10, 25, 30, 40, 100, 120, 125, 250, 500, 750, 1000 and 3000 kg. The significance of these differences is reduced somewhat by the fact that both the Federal and ASTM test methods make provision for the reporting of results when loads and balls other than the standard are used.

Another point of difference is in the length of time the test load is applied. The Federal and ASTM test methods specify that the full test load shall be applied for at least 15 seconds in the case of iron and steel and for at least 30 seconds in the case of other metals. In B.S. 240 it is stated that the full load shall be maintained for 15 seconds.

The ASTM test method contains a detailed description of two acceptable methods of calibrating Brinell hardness machines. The other two standards do not give any details on calibration procedure.

DIAMOND PYRAMID HARDNESS TEST

The Diamond Pyramid Hardness test methods described in British Standard B.S. 427, Federal Test Method No. 244 and ASTM Designation E92-57 are quite similar. One of the more important points of difference noted is in the recommended procedure for determining the hardness of case-hardened specimens. In B.S. 427 and Federal Method No. 244, it is stated that several impressions should be made with various loads on the diamond until two different loads will give the same hardness values. In ASTM E92 it is stated that in tests on specimens with a hardness gradient the magnitude of the test load should be stated in the test report.

ROCKWELL HARDNESS TEST

The ASTM Designation E18-57T, Tentative Methods of Test for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials, is considerably more lengthy than the British Standard 891, Direct Reading Hardness Testing, Rockwell Principle, and the Federal Method No. 243, Rockwell Hardness Test. However, it is stated in ASTM E 18 that the information in certain sections is intended to describe and define the type of test that is involved and to outline the limitations of acceptable testing machines. This descriptive material is not mandatory in connection with the test itself.

Nevertheless, there are possibly more points of difference in the specifications governing this type of test than in the specifications for the other hardness test methods mentioned above. The more obvious

differences are pointed out in the remarks column. For example, the term "major load" in B.S. 891 is used to describe the load which is added to the minor load to form the total load, whereas in ASTM E 18 and in Federal Method 243 the major load is the total load applied.

In the application and removal of the major load, B.S. 891 and Federal Method 243 state that as soon as the reading of the depth indicator or dial hand becomes steady the major load shall be gently removed. In ASTM E 18, provision is made for the case in which the material being tested exhibits plastic flow after the application of the major load. In this case, ASTM E 18 specifies that the operating lever may be brought back to its latched position at a specified elapsed time between tipping and removal of load.

In B.S. 891 the standard test is restricted to scales A, B, and C, with scales D, E, F, G, and H being included to serve as a guide. In Federal Method 243 the standard scales are A, B, C, D, E, F, G, H, and K, while in ASTM E 18 the standard scales are A, B, C, D, E, F, G, H, K, L, M, P, R, S and V. The Rockwell Superficial test is not included in B.S. 891. Federal Method 243 lists the Superficial Rockwell Scales for the diamond and 1/16 in. ball penetrators. ASTM E 18, however, contains a complete description of the Rockwell Superficial hardness test.

In B.S. 891 it is considered that test figures obtained on curved surfaces are only of comparative value. Federal Method 243 states that if indentations are made on curved specimens, the radius

of curvature shall not be less than 1/2 in. unless standard correction tables are used. ASTM E 18 contains tables of corrections to be added to readings on cylindrical specimens.

B.S. 891 does not recognize tests carried out on sheet materials in thicknesses which show a bulge or other marking on the surface opposite the impression and resulting from the application of the load. Federal Method 243 and ASTM E 18 both recognize that acceptable Rockwell readings may be obtained on sheet materials which show some bulging or marking when the detail specification requires the use of scales to thicknesses that bulge.

SUMMARY

From the foregoing comparison no conclusions have been drawn as to which test method should be accepted as standard for each of the three hardness tests considered. However, the following observations are made on the basis of this comparison. (In general, the differences in these test methods are not so fundamental that they would lead to serious discrepancies in test results. The differences are for the most part related to descriptive material, terminology, and, to some degree, scope.)

It is readily seen that the British Standards have remained unchanged for a considerable number of years, whereas the ASTM test methods are being revised almost continuously. The ASTM test methods therefore recognize that some types of materials and specimens must be treated differently than others. This is particularly noticeable

in the case of the Rockwell hardness test, where provision is made for changing the length of time the major load is applied and also for the testing of round specimens and very thin specimens. The British Standard for the Brinell test contains a large number of combinations of loads and ball diameters, while in the Federal and ASTM test methods governing the Brinell test the number of combinations of loads and ball diameters is held to a minimum. The trend is in the opposite direction in the case of the Rockwell test. There are only three actual standard scales in the British Standard for the Rockwell test, whereas there are a great number of scales accepted as standard in the Federal and ASTM test methods for this test.

METHODS COMPARISONS

BRITISH STANDARD METHOD AND TABLES FOR BRINELL HARDNESS TESTING

B.S. 240 : Part 1 : 1937

DEFINITION

1. The Brinell hardness number is the quotient of the applied load divided by the spherical area of the impression. The Brinell hardness number is given by the following formula:-

$$H = \frac{P}{\pi \frac{D}{2} \left(D - \sqrt{D^2 - d^2}\right)}$$

$$= \left(\frac{P}{D^2}\right) \left(\frac{2/\pi}{1 - \sqrt{1 - (d/D)^2}}\right)$$

where P = load (in kilogrammes),
D = diameter of ball (in millimetres),
d = diameter of impression (in millimetres),
H = Brinell hardness number.

Note: The spherical area must be calculated from the average diameter of the impression obtained by taking two readings at right angles, and not from the depth of the impression.

APPARATUS

2. a. Testing machine. The accuracy of the testing machine shall be within 0.5 per cent of the load applied to the test piece.

b. Measuring device. The micrometer microscope or other measuring device used shall be capable of measuring the diameter of the impression to within $\pm$0.5 per cent.

Note: An accuracy of measurement of $\pm$ 0.025 mm.

FEDERAL TEST METHOD STANDARD NO. 151 METHOD NO. 242 BRINELL HARDNESS TEST

1956

1. SCOPE

1.1 This method covers the test procedure for determining the hardness of metals by the Brinell hardness test.

2. DEFINITIONS

2.1 Brinell Hardness Test. The Brinell test consists of using calibrated equipment to apply a specified load to the surface of the material to be tested through a hard ball of specified diameter, and to measure the diameter of the resulting permanent indentation.

2.2 Brinell Hardness Number. The Brinell hardness number is the value obtained by dividing the applied load in kilograms by the surface area of the indentation in square millimeters calculated from the measured diameter of the rim of the indentation. The number is calculated from the following formula:

$$B.H.N. = \frac{P}{\pi \frac{D}{2} \left(D - \sqrt{D^2 - d^2}\right)}$$

where:
B.H.N. = Brinell hardness number in kilograms per square millimeter,
P = applied load in kilograms,
D = diameter of the ball in millimeters, and
d = diameter of the indentation in millimeters.

Table I gives the Brinell hardness numbers corresponding to various diameters of indentations with the 10 mm diameter ball at standard loads of 500, 1500, and 3000 kg, making it unnecessary to calculate for each test the value of the Brinell hardness number by the above formula.

3. APPARATUS

3.1 Brinell tests shall be made on equipment meeting the requirements herein and otherwise approved by the procuring agency.

3.2 Error in load applied by the machine shall not exceed one per cent.

3.3 The 10 mm diameter ball shall be used unless otherwise specified or approved by the purchaser. (See 6.3.) The ball, measured on any

TENTATIVE METHOD OF TEST FOR BRINELL HARDNESS OF METALLIC MATERIALS

ASTM Designation: E 10 - 54 T

SCOPE

1. This method covers the test procedure for determining the Brinell hardness of metallic materials where a high degree of accuracy is required.

DEFINITIONS

2. (a) Brinell Test. -- The standard Brinell test consists in using calibrated equipment to apply a specified load to the surface of the material to be tested through a hard ball of specified diameter, and to measure the diameter of the resulting permanent impression.

(b) Brinell Hardness Number. -- The Brinell hardness number is the value obtained by dividing the applied load in kilograms by the surface area of the impression in square millimeters calculated from the measured diameter of the rim of the impression. It is assumed that the impression is an imprint of the undeformed ball. The Brinell hardness number is calculated from the following formula:

$$BHN = \frac{P}{\frac{\pi D}{2}\left(D - \sqrt{D^2 - d^2}\right)}$$

where:

BHN = Brinell hardness number in kilograms per square millimeter,
P = applied load in kilograms,
D = diameter of the ball in millimeters, and
d = diameter of the impression in millimeters.

As it is a recognized experimental fact that the Brinell hardness number of nearly all materials is influenced by the magnitude of the indenting load, the diameter of the ball indenter, and elastic characteristics of the ball, these three quantities must be specified. In general, a standard ball 10 mm in diameter with applied loads of 3000 kg, 1500 kg, or 500 kg shall be used. (See Sections 3 (c) and 5.)

In Table I is given the Brinell hardness number corresponding to various diameters of impression for 500-, 1500-, and 3000-kg loads, making it unnecessary to calculate for each test the value of the Brinell hardness number by the above formula unless otherwise specified.

APPARATUS

3. (a) Testing Machine. -- Equipment for Brinell hardness testing usually consists of a testing machine which supports the test specimen and applies a predetermined indenting load to a ball in contact with the specimen. The magnitude of the indenting load is often limited to certain discrete values. The design of the testing machines shall be such that no rocking or lateral movement of the indenter or specimen is permitted while the load is being applied. The

REMARKS

SCOPE

B. S. 240 . . . . Scope is not stated.

DEFINITIONS

B. S. 240 . . . . Brinell hardness test is not defined.

APPARATUS

ASTM E 10 . . . . Contains a discussion on design and types of testing machines.

ASTM E 10 . . . .)Error in load applied Federal Method 242) by the machine shall not exceed one percent.

B. S. 240 . . . . . The accuracy of the

(0.001 in.) may be accepted for impressions made with a 10 mm. diameter ball, ±0.01 mm. for impressions made with a 5 mm. diameter ball, and ±0.002 mm. for impressions made with a 1 mm. diameter ball.

c. Balls. The balls used in Brinell hardness testing shall be of hardened steel complying with the appropriate requirements of B.S. 240 : Part 2, 'Steel balls for Brinell hardness testing', or shall be of some harder material.

The diameter of the ball shall not differ from the appropriate standard diameter (see Clause 3) by more than ±0.0025 mm. (0.0001 in.).

B.S. 240 : Part 2 : 1950

Hardness of Balls

1. The balls used for Brinell hardness testing shall be of hardened steel or of some harder material.

For Brinell hardness tests where the material to be tested has a hardness number not exceeding 500 the diamond hardness number of the ball used, determined as described in Clause 2, shall be not less than 900.

For Brinell hardness tests where the material to be tested has a hardness number exceeding 500 and less than 630, if the balls are of hardened steel they shall be previously work-hardened and the surface diamond hardness number, determined as described in Clause 2, shall be not less than 990.

On materials having a Brinell hardness number exceeding 630, the permanent deformation of the ball makes the Brinell hardness test unreliable and therefore for such materials it is recommended that the diamond indentation or other suitable test should be employed.

diameter, shall not deviate from the nominal size by more than 0.01 mm. Balls shall be measured periodically while in use, and shall be discarded when this tolerance is exceeded.

3.4 Steel or tungsten-carbide balls may be used for Brinell hardness values up to 450. The tungsten-carbide ball shall be used for Brinell hardness values above 450 to 630.

3.5 The device used to measure the diameter of the indentation shall permit direct measurement of the diameter to 0.01 mm and estimation of the diameter to 0.02 mm.

TEST SPECIMENS

4.a. Position of impression. The centre of the impression shall be not less than two-and-a-half times the diameter of the impression from any edge of the test specimen.

b. Thickness. The thickness of the test specimen shall be at least ten times the depth of the impression as given by the formula: *

$$\text{Depth of impression in mm.} = \frac{P}{\pi DH}$$

For some materials the requirement that the thickness of the specimen must be not less than ten times the depth of the impression may be unnecessarily high, and, in order that the test should not

4. PREPARATION OF SPECIMEN

4.1 The specimen shall be of such thickness that no bulging shall be visible on the side opposite the indentation. In any event, the thickness of the specimen shall be at least ten times the depth of the indentation. The distance of the center of the indentation from the edge of the specimen or edge of another indentation shall be at least two and one-half times the diameter of the indentations.

4.2 The surface on which the indentation is to be made shall be ground, machined, or polished with emery paper so that the edge of the indentation shall be clearly enough defined to permit the measurement of the diameter within 0.01 mm. The preparation of the test surface should be carefully

ASTM E 10

type of machine in which the magnitude of the indenting load is fixed by dead weights acting on a small piston connected to a hydraulic loading cylinder, or one in which dead weights act on a multiplying lever system, is to be preferred to those machines in which the load is indicated by an ordinary Bourdon tube gage or a dial indicator. In the use of the first two types of machines, however, precautions shall be taken to prevent a momentary overload caused by the inertia of the dead-weight system. The loading pump or hand lever shall be operated with the utmost care as the maximum value of the indenting load is approached, to prevent a large acceleration of the dead weight system.

(b) Brinell Ball. -- A ball suitable for use shall show a permanent change in diameter not greater than 0.01 mm (0.0004 in.) when pressed with a force of 3000 kg against the test specimens (Note). If a ball is used in a test of a specimen which shows a Brinell hardness number greater than the limit for the ball as detailed in Section 5 (c), the ball shall be remeasured after the test. Should the ball show a permanent change in diameter greater than that specified above, the ball shall be unsuitable for further use in a standard test (Note), and the results of the test shall be considered unreliable.

Note. -- In testing softer metals it is not, of course, necessary to have balls of this extreme hardness. However, a ball to be suitable for use shall withstand pressure against the hardest material to be tested without showing a permanent change in diameter greater than 0.01 mm.

(c) Size of Standard Ball. -- The standard ball for Brinell hardness testing shall be 10 mm (0.3937 in.) in diameter with a deviation from this value of not more than 0.01 mm (0.0004 in.) in any diameter. (See also Section 5 (a).)

(d) Micrometer Microscope. -- The divisions of the micrometer scale of the microscope or other measuring devices used for the measurement of the diameter of the impression shall be such as to permit the direct measuring of the diameter to 0.1 mm and the estimation of the diameter to 0.02 mm.

TEST SPECIMENS

4. Specimens used in Brinell hardness testing vary greatly in form since it is frequently desirable to make the impression upon a part to be used in the finished product rather than upon a sample test specimen.

(a) Thickness. -- The thickness of the piece tested shall be such that no bulge or other marking showing the effect of the load appears on the side of the piece opposite the impression. In any event the thickness of the specimen shall be at least 10 times the depth of the indentation (Appendix I). The minimum width must conform with requirements of Section 5 (d).

(b) Finish. -- The surface on which the impression is to be made shall be filed, ground, machined, or polished with abrasive material so that the edge of the impression

REMARKS (continued)

testing machine shall be within 0.5 percent of the load applied to the test piece.

ASTM E 10 . . . .) Federal Method 242) Standard ball shall be 10 mm (0.3937 in.) in diameter with a deviation from this value of not more than 0.01 mm (0.0004 in.) in any diameter.

B.S. 240 . . . . 1, 2, 5 and 10 mm diameter balls are considered as standard. The diameter of the ball shall not differ from the appropriate standard diameter by more than $\pm$0.0025 mm (0.0001 in.)

ASTM E 10 . . .) Federal Method 242) Device used to measure the diameter of the indentation shall permit direct measurement of the diameter to 0.1 mm and estimation of the diameter to 0.02 mm.

B.S. 240 . . . . The micrometer microscope or other measuring device used shall be capable of measuring the diameter of the impression to within $\pm$0.5 percent.

NOTE. An accuracy of measurement of $\pm$0.025 mm (0.001 in.) may be accepted for impressions made with a 10 mm diameter ball, $\pm$0.01 mm for impressions made with a 5 mm, diameter ball, and $\pm$0.002 mm for impressions made with a 1 mm diameter ball.

TEST SPECIMENS

be unduly restricted in its application to the testing of thin metal strip and sheet, lower values of the ratio may be permitted in some instances.

c. Surface. The surface on which the impression is to be made shall be polished° if the diameter of the ball used is 1 mm. or 2 mm. If the diameter of the ball used is 5 mm. or 10 mm. a surface finish obtained by filing, grinding, or smooth machining may be found to be adequate.

* See Appendix.

° A polish such as is obtained by the use of 000 emery paper is suitable.

Suitable precautions should be taken to ensure that the surface tested is representative of the material and that its hardness is not affected by decarburisation, carburisation, or by the method used for the preparation of the test surface.

RELATION OF BALL TO LOAD

3. The standard balls and loads used for Brinell hardness testing shall be as follows:-

Diameter of ball	Load			
	$\frac{P}{D^2} = 1$	$\frac{P}{D^2} = 5$	$\frac{P}{D^2} = 10$	$\frac{P}{D^2} = 30$
mm.	kg.	kg.	kg.	kg.
1	1	5	10	30
2	4	20	40	120
5	25	125	250	750
10	100	500	1000	3000

Note 1. In the case of materials of coarsely duplex microstructure, such as cast iron, small impressions tend to give the hardness of individual constituents, and, if the average hardness of the material is required, care should be taken to make a sufficiently large impression, and wherever possible a number of impressions should be made and an average taken.

Note 2. The same Brinell hardness number is given by tests on the same uniform material with balls of different diameters when the same value of the ratio $\frac{P}{D^2}$ is used.

MAGNITUDE OF LOAD

5. The test shall be carried out with one of the loads and ball diameters selected from the table in Clause 3 corresponding to the value of the ratio $\frac{P}{D^2}$ stated in the specification for the material under test.

Note. -- The value of the ratio $\frac{P}{D^2}$ should always be stated in the specification for the material.

controlled to avoid any alteration of mechanical properties such as softening or hardening due to tempering during grinding, or work-hardening during polishing operations.

4.3 Care shall be exercised to limit hardness readings to areas wherein indentations cannot later contribute to failure, as for example under dynamic loadings, and to limit the number of indentations to the minimum necessary for accurate determinations.

5. PROCEDURE

5.1 Unless otherwise specified or approved by the purchaser (see 6.3), one of the three standard loads shall be used as follows:

3000 kg for over 160 B.H.N.
1500 kg for 80 to 300 B.H.N.
500 kg for 26 to 100 B.H.N.

5.2 The load shall be applied to the specimen steadily, without a jerk. In equipment using weights to apply the standard load, precautions shall be taken to prevent a momentary overload caused by the inertia of the weight system. The full load shall be applied for at least 15 seconds in the case of iron and steel and for at least 30 seconds in the case of other metals. The time interval shall be of such duration as to assure uniform application of load, and minimum effects due to creep. Once established, the time interval chosen should be used for all specimens of this material.

5.3 In the case of materials of coarse duplex microstructure such as cast iron, small impressions tend to give the hardness of individual constituents, and if the average hardness of the material is required, care should be taken to make sufficiently large indentations. Whenever possible a number of indentations should be made and an average shall be considered.

5.4 The indentation diameter shall be taken as the average of at least two mutually perpendicular diameters. In the case of a curved specimen, the diameter of indentation shall be taken as the average of the two principal diameters.

5.5 For the 10 mm diameter ball and standard loads, the Brinell hardness number shall be determined from Table I.

5.6 The applied load shall be checked period-

ASTM E 10

REMARKS (continued)

shall be clearly enough defined to permit the measurement of the diameter within 0.01 mm (0.0004 in.). Care should be taken to avoid overheating or cold working the surface.

PROCEDURE

5. (a) Magnitude of Test Load. -- The load in the standard Brinell test shall be 3000 kg, 1500 kg, or 500 kg. It is desirable that the test load be of such magnitude that the diameter of the impression be in the range 2.50 to 4.75 mm. The following table gives test loads and approximate Brinell numbers for this range of impression diameters:

3000 kg	160 to 600 BHN
1500 kg	80 to 300 BHN
500 kg	26 to 100 BHN

It is not mandatory that the Brinell test conform to the above ranges. For the purpose of obtaining a continuous scale of values it may be desirable to use a single load to cover the complete range of hardness for a given material. For softer metals, loads of 250 kg, 125 kg, or 100 kg are sometimes used. The load used shall be specifically stated in the test report, conveniently as a subscript of the hardness number (for example, 275 BHN_{3000}).

For testing very small specimens it is sometimes necessary to make hardness tests with a ball less than 10 mm in diameter. For such tests (which are not to be regarded as standard Brinell tests), the relation between the applied load P, measured in kilograms, and the diameter of the ball, D, measured in millimeters, should be:

For BHN above 160	$P = 30\ D^2$
For BHN above 80	$P = 15\ D^2$
For BHN above 26	$P = 5\ D^2$
For softer metals	$(P = 2.5\ D^2$
	$(P = 1.25\ D^2$
	$(P = D^2$

When balls smaller than 10 mm in diameter are used, both the test load and ball size shall be specifically stated in the test report (for example 190, $BHN_{120/2}$). Balls differing in size from the standard 10-mm ball should conform to the requirements for the material and the permissible variations in diameter specified for the standard ball.

PROCEDURE

ASTM E 10. . . .) Standard loads are
Federal Method 242) 3000 kg, 1500 kg, and 500 kg; however, these loads are not mandatory.

B.S. 240 . . . . . Standard loads are 1, 4, 5, 10, 25, 30, 40, 100, 120, 125, 250, 500, 750, 1000, and 3000 kg.

ASTM E 10 . . . . . When balls smaller than 10 mm in diameter are used, both the test load and ball size shall be specifically stated in the test report.

Federal Method 242. (Clause 6.3) When it is necessary or desirable to use an indenting ball other than 10 mm in diameter, or a load other than 500, 1,500, or 3,000 kg, the load and ball diameter shall be reported with the Brinell hardness number.

B.S. 240 . . . . . The diameter of the ball used and the load applied shall be stated in each case.

ASTM E 10. . . .) The full test load
Federal Method 242) shall be applied for at least 15 seconds in the case of iron and steel and for at least 30 seconds in the case of other metals.

B.S. 240 . . . . . The full load shall be maintained for 15 seconds.

ASTM E 10 . . . . The angle between the load line and the normal to

The following table is given as a broad indication of desirable values:-

Approximate hardness number	$\frac{P}{D^2}$ ratio
Above 160	30
160 to 60	10
60 to 20	5
Up to 20	1

Where the hardness of the material falls within more than one of the above ranges, one ratio only shall be used throughout. It is advisable that the ratio of the diameter of the impression to the diameter of the ball shall not generally fall below 0.25 nor exceed 0.50. For guidance in specifying an appropriate value for the ratio $\frac{P}{D^2}$ approximate values for representative materials are given below:-

Steels; cast iron	30
Copper alloys; aluminium alloy	10
Copper; aluminium	5
Lead, tin and their alloys . . .	1

APPLICATION OF LOAD

6. The load shall be applied slowly and progressively to the test specimen in a direction normal to the surface. The full load shall be maintained for 15 seconds.

METHOD OF INDICATING HARDNESS

7. The Brinell hardness shall be indicated by the Brinell hardness Number and not by the diameter of the impression. The diameter of the ball used and the load applied shall be stated in each case, e.g. H 10/3000.

ically with a proving ring, by the use of weights and levers, by an elastic calibrating device or by using a series of specimens of different degrees of known hardness values. The machine load shall be correct within one per cent. The microscope or other measuring device shall be calibrated by comparing it with a calibrated scale.

5.7 The test surface shall be normal to the axis of the indenter within 2 degrees and whenever possible shall be flat and parallel to the seating (opposite) surface.

6. NOTES

6.1 The 3000 kg Brinell load may cause too much deformation in a thin-walled tubular specimen. In this case the 500 kg load should be applied, or inside stiffening by means of an internal anvil should be used. Brinell testing shall not be applicable to tubular products less then 2 inches in outside diameter, or less than 0.200 inch in wall thickness.

6.2 Whenever practicable, hardness reading shall be taken on the type of equipment indicated by the specification or drawing and not on another type of equipment and then converted.

6.3 When it is necessary or desirable to use an indenting ball other than 10 mm in diameter, or a load other than 500, 1,500, or 3,000 kg (and such use is approved by the purchaser), the relation between the applied load, P, in kilograms and the diameter of the ball, D, in millimeters shall be:

For B. H. N. above 160 . . . $P = 30D^2$
For B. H. N. above 80 . . . $P = 15D^2$
For B. H. N. above 26 . . . $P = 5D^2$

The Brinell hardness number shall be determined from the formula in 2.2 and the load and ball diameter reported with the Brinell hardness number.

7. REPORT OF RESULTS

7.1 When a test load other than the one normally used for a particular material is used (such as 3,000 kg for steel and 500 kg for aluminum alloys), the test load shall be reported with the Brinell hardness number, for example: B. H. N. (3000) 450. The report shall refer to the contract or purchase order and shall include all other information requested by the procuring agency.

7.2 When the reported hardness value is converted from a scale or load different than that specified, the value and scale or load from which converted shall also be reported.

(b) Radius of Curvature. -- When indentations are made on a curved specimen, the minimum radius of curvature of the specimen shall be not less than 1 in. for a 10-mm ball. The diameter of the indentation shall be taken as the average of the two principal diameters.

(c) Types of Balls. -- A steel ball may be used on material having a BHN not over 450, a Hultgren ball on material not over 500, or a carbide ball on material not over 630. The Brinell test is not recommended for material having a BHN over 630.

(d) Spacing of Indentations. -- The distance of the center of the indentation from the edge of the specimen or edge of another indentation shall be at least two and one-half times the diameter of the indentation.

(e) Application of the Test Load. -- The load shall be applied to the specimen steadily without a jerk. The full test load shall be applied for at least 15 sec in the case of iron and steel and for at least 30 sec in the case of other metals.

(f) Alignment. -- The angle between the load line and the normal to the specimen shall not exceed 2 deg.

MEASUREMENT OF IMPRESSION

6. (a) Diameter. -- In the standard Brinell hardness test, two diameters of the impression at right angles to each other shall be measured and their average value used as a basis for calculation of the Brinell hardness number.

NOTE. -- When the micrometer microscope is used to measure the diameter of the impression, the sharpness of definition of the edge of the impression can be increased by the use of a movable lamp for illumination of the specimen, placing the lamp so that the contrast of light and shade will bring first one edge of the impression, then the other, into sharp definition. In testing very hard material, the sharpness of definition of the impression can be somewhat increased by the use of a ball lightly etched with nitric acid, or by the use of some pigment, such as Prussian blue, on the ball. In testing material in which there is considerable recovery of shape, the material may first be coated with a dull black pigment, such as drawing ink or a mixture of graphite and alcohol. The edge of the impression is rendered clear on a surface so coated.

CALIBRATION OF APPARATUS

7. This section gives a detailed description of two acceptable methods of calibrating Brinell machines.

the specimen shall not exceed 2 degrees.

Federal Method 242. The test surface shall be normal to the axis of the indenter within 2 degrees.

B. S. 240 . . . . . The load shall be applied in a direction normal to the surface.

APPENDIX

Minimum Thicknesses of Test Specimens

For the convenience of those carrying out tests in accordance with this standard method the following schedule of minimum thicknesses of test specimens for a selected series of ball diameters, loads, and hardness numbers (calculated in accordance with the provisions of Clause 4 (b)) is given.

Ball mm.	Load kg.	Hardness Number				
		1	5	10	15	20
		Minimum Thickness (inches)				
1	1	0.125	0.025	0.013	-	-
2	4	0.250	0.050	0.025	0.017	0.013
5	25	0.627	0.125	0.063	0.042	0.031
10	100	1.25	0.250	0.125	0.094	0.063

Ball mm.	Load kg.	Hardness Number					
		20	30	40	50	60	70
		Minimum Thickness (inches)					
1	5	0.031	0.021	0.016	0.013	0.010	-
2	20	0.063	0.042	0.031	0.025	0.021	0.018
5	125	0.157	0.105	0.076	0.063	0.052	0.044
10	500	0.313	0.209	0.157	0.125	0.104	0.089

Ball mm.	Load kg.	Hardness Number				
		80	100	120	140	150
		Minimum Thickness (inches)				
1	10	0.016	0.013	0.010	-	-
2	40	0.031	0.025	0.021	0.018	0.017
5	250	0.078	0.063	0.052	0.044	0.042
10	1000	0.157	0.125	0.104	0.089	0.083

Ball mm.	Load kg.	Hardness Number				
		150	200	300	400	500
		Minimum Thickness (inches)				
1	30	0.025	0.019	0.013	-	-
2	120	0.050	0.038	0.025	0.019	0.015
5	750	0.125	0.094	0.063	0.047	0.037
10	3000	0.251	0.188	0.125	0.094	0.075

ASTM E 10

APPENDIX

Minimum Thickness of Specimens Required for Brinell Hardness Tests

Brinell Hardness Number	Minimum Thickness of Specimen, in.
500-KG LOAD	
30	0.209
40	0.157
50	0.125
60	0.104
70	0.089
1500-KG LOAD	
80	0.235
100	0.188
120	0.157
140	0.134
160	0.117
3000-KG LOAD	
160	0.235
200	0.188
300	0.125
400	0.094
500	0.075

REMARKS (continued)

Minimum Thickness of Specimens

B.S. 240 . . . . . Contains minimum thicknesses of test specimens at various hardness levels for four different ball diameters and sixteen different loads.

ASTM E 10 . . . . . Contains minimum thickness of specimens at various hardness levels for a 10 mm diameter ball and loads of 500, 1500 and 3000 kg.
The thickness specified for 500 and 3000 kg loads are the same as those given for these loads in B.S. 240.

Federal Method 242. . Does not contain a table of minimum thickness of specimens required for Brinell hardness tests.

B. S. 240

BRINELL HARDNESS NUMBERS

TABLES 1 to 12*

Diameter of Ball = 10, 5, 2, and 1 mm.
Load = 3000, 1000, 750, 500, 250, 125, 120, 100, 40, 30, 25, 20, 10, 5, 4, and 1 kg.

* These tables are the mathematical solutions to the equation given in 1 (see page 10). Therefore, they have not been repeated here.

Federal Method 242: 1956

BRINELL HARDNESS NUMBERS

TABLE I°

10 mm diameter ball

NOTE. -- The values given in this table for hardness numbers are merely solutions of the equation given in 2.2. They do not imply that Brinell tests are feasible on materials of a hardness indicated by the highest values in the table.

° This table is not repeated here.

ASTM E 10

BRINELL HARDNESS NUMBERS

TABLE 1°

Steel ball, 10 mm in diameter.
Pressure of 500, 1500, and 3000 kg.

The values given in this table for hardness numbers are merely solutions of the equation given in the note under Section 2 (b). They do not imply that Brinell tests are feasible on materials of a hardness indicated by the highest values in the table (see Section 5 (c)).

° Table 1 is not repeated here.

REMARKS (continued)

BRINELL HARDNESS NUMBERS

B.S. 240 . . . . . Contains twelve tables showing the relationship between diameter of impression and Brinell hardness number for various combinations of load and ball diameters.

ASTM E 10. . . .) Each contains one
Federal Method 242) table showing the relationship between diameter of impression and Brinell hardness number for loads of 500, 1500, and 3000 kg and a 10 mm ball.

BRITISH STANDARD
DIAMOND PYRAMID HARDNESS NUMBERS
B. S. 427 : 1931

DEFINITION

2. The diamond pyramid hardness number is the quotient of the applied load divided by the pyramidal area of the impression. The diamond pyramid hardness number is given by the following formula:

$$H_D = \frac{2P \sin \frac{\Theta}{2}}{d^2}$$

where P = load (in kilogrammes)
d = diagonal of the impression (in mm.)
Θ = angle between each pair of opposite faces of the pyramidal diamond
H_D = diamond pyramid hardness number

Note: The pyramidal area must be calculated from the mean of readings taken on both diagonals and not from the depth of the impression.

APPARATUS

1. a. The diamond indenter shall be in the form of a square pyramid and have an angle between opposite faces of 136°.* The pyramidal faces shall have a good polish and be free from 'pits' or other surface blemishes. The point of the diamond shall be sharp.

b. The micrometer, microscope or other measuring device used shall be capable of measuring each diagonal of the impression to an accuracy

FEDERAL TEST METHOD STANDARD NO. 151
METHOD NO. 244
DIAMOND PYRAMID HARDNESS TEST
1956

1. SCOPE

1.1 This method covers procedures for determining the hardness of metals by the square-based diamond pyramid (Vickers) method.

2. DEFINITIONS

2.1 Diamond pyramid hardness test.--The diamond hardness test consists of applying a specified load to the surface of the material to be tested through a square-based pyramidal diamond having specified face angles and in measuring the diagonals of the resulting permanent indentation.

2.2 Diamond pyramid hardness number.--The diamond pyramid hardness number is the number obtained by dividing the applied load in kilograms by the surface area of the indentation in square millimeters computed from the measured diagonals of an accurate indentation. (See 5.1.)

3. APPARATUS

3.1 Testing Machine.-- Equipment for diamond pyramid hardness testing usually consists of a testing machine which supports the specimen and permits the penetrator and the specimen to be brought into contact gradually and smoothly under a predetermined load, which is applied for a fixed period of time. The machine shall be rigid and sturdy without any rocking or lateral movement of the penetrator or specimen while the load is being applied

STANDARD METHOD OF TEST FOR DIAMOND PYRAMID HARDNESS OF METALLIC MATERIALS

ASTM Designation: E 92-57

SCOPE

1. This method covers the test procedure for determining the diamond pyramid hardness of metallic materials.

OUTLINE OF METHOD

2. The diamond pyramid test consists in applying a specified load to the surface of the material to be tested through a square-based pyramidal diamond having specified face angles, and measuring the resulting permanent impression.

DEFINITION

3. Diamond Pyramid Hardness Number.--The diamond pyramid hardness number is the number obtained by dividing the applied load in kilograms by the surface area of the impression in square millimeters computed from the measured diagonal of the impression. It is assumed that the impression is an imprint of the undeformed penetrator.

The diamond pyramid hardness number is computed from the following formula:

$$DPH = \frac{2L \sin \frac{\alpha}{2}}{d^2} = \frac{1.8544L}{d^2}$$

where:

L = load in kilograms,
d = diagonal of impression in millimeters, and
α = face angle of diamond = 136 deg.

For practical purposes the diamond pyramid hardness number is constant when a square-based diamond pyramid with a face angle of 136 deg is used with applied loads of 1 g to 120 kg. At low test loads the diamond pyramid hardness may be load-dependent.

In Table I are given the diamond pyramid hardness numbers for a test load of 1 kg. For obtaining hardness numbers when other test loads are used, the diamond pyramid hardness number obtained from Table I is multiplied by the test load in kilograms (see Table II)

APPARATUS

4. (a) Testing Machine.--Equipment for diamond pyramid hardness testing usually consists of a testing machine which supports the specimen and permits the penetrator and the specimen to be brought into contact gradually and smoothly under a predetermined load, which is applied for a fixed period of time. The design of the machine should be such that no rocking or lateral movement of the penetrator or specimen is permitted while the load is being applied or removed. A measuring microscope is usually mounted on the

REMARKS

SCOPE

B.S. 247. . . . . Scope is not stated.

DEFINITION

B. S. 247 . . . . . Defines diamond pyramid hardness number.

ASTM E 92 . . . .)
Federal Method 244) Define diamond pyramid hardness test and number.

APPARATUS

B.S. 427 . . . . . The standard loads used for diamond pyramid hardness tests shall be 5, 10, 20, 30, 50, 100, and 120 kilograms.

ASTM E 92 . . . .) Section 6. (a)
Federal Method 244) Section 5.2. Test loads of 1 g to 120 kg may be used.

of plus or minus 0.5 per cent or plus or minus 0.001 mm.

c. The standard loads used for diamond pyramid hardness tests shall be 5, 10, 20, 30, 50, 100, and 120 kilogrammes.

*Some apparatus is equipped with a diamond having an angle between the opposite faces of 140° instead of the standard angle of 136° as given in Clause 1 a. above. If these tables are used for impressions obtained with a 140° diamond, the resulting hardness numbers will be lower than those obtained under the standard conditions. In a series of experiments it was found that the average difference in the hardness number was 2 per cent and that the difference in no case exceeded 3.5 per cent when a 140° diamond was used in conjunction with the 136° tables.

TEST SPECIMENS

3. a. The centre of the impression shall be not less than two and a half times the diagonal of the impression from any edge of the test specimen and from any other impression.

b. The thickness of the test specimen shall be at least equal to one and a half times the diagonal of the impression.

When tests are made on thin specimens, care should be taken to ensure that the under surface of the specimen is smooth and in full contact with a smooth supporting surface of hardened steel.

c. The surface on which the impression is to be made shall be flat and polished and shall be supported rigidly at right angles to the axis of the diamond indenter. (For tests on curved surfaces the figures given by the formula in Clause 2 are only of comparative value. For tests on steel balls, see B.S. 240, Part 2.)

d. Suitable precautions should be taken to or removed. A measuring microscope is usually mounted on the machine in such a manner that the indentation in the specimen may be readily located in the optical field.

3.2 Penetrator. -- The penetrator shall be a highly polished, pointed, square-based pyramidal diamond with included angle between opposite faces of 136° $\pm$ 1/2°. The four faces shall meet at a sharp point. The diamond shall be examined periodically and if it is loose in its mounting, chipped, or cracked, it shall be discarded or reconditioned. The condition of the point of the penetrator is of major importance when the test load is light and the indentation is small. It is recommended that the point be periodically checked by examining an indentation made in a polished steel block. Under a magnification of 600X or more, using a vertical illuminator, any chipping or rounding of the point can be detected and the extent of the defect measured with a filar micrometer. It is recommended that a diamond pyramid penetrator should not be used for tests in which the maximum length of such a defect exceeds 5 percent of the length of the indentation diagonal.

3.3 Micrometer microscope. -- The micrometer microscope shall be so constructed that the length of the diagonals of an indentation in a properly surface-finished specimen (see 4.3) can be measured to within $\pm$ 0.0005 mm or $\pm$ 0.5 per cent, whichever is larger. The shutters of the micrometer microscope should be checked prior to the inspection of each major lot, to ensure a zero reading on the Vickers microscope dial when the shutters are just touching.

4. PREPARATION OF SPECIMEN

4.1 General. -- The diamond pyramid hardness test is adaptable to a wide variety of test specimens ranging from large bars and rolled sections to minute pieces in the metallographic mounts. In general the backs of the specimens shall be finished and clamped to remove the possibility of their rocking or shifting under the test load.

4.2 Thickness. -- The thickness of the test specimen shall be such that no bulge or marking showing the effect of the load shall be visible on the side of the specimen opposite the indentation. In any event, the thickness of the specimen shall be at least 1 1/2 times the length of the diagonal.

4.3 Finish. -- The surface of the specimen shall be so prepared that the ends of the diagonals are clearly defined and can be read with an accuracy of $\pm$ 0.0005 mm or $\pm$ 0.5 per cent of the length of the diagonals, whichever is larger. Care should be taken in specimen preparation to avoid tempering

machine in such a manner that the impression in the specimen may be readily located in the optical field.

NOTE. -- A single machine capable of applying the complete load range (1 g to 120 kg) covered by this method is not manufactured at the present time.

(b) Penetrator. -- The penetrator shall be a highly polished, pointed, square-based pyramidal diamond with face angles of 136 deg ± 30 min. The four faces shall meet at a sharp point.

NOTE. --The diamond should be examined periodically and if it is loose in the mounting material, chipped, or cracked, it should be discarded or reconditioned.

The condition of the point of the penetrator is of considerable importance where the test load is light and the impression is small. It is recommended that the point be periodically checked by examining an impression made in a polished steel block. Under a magnification of 600X or more, using a vertical illuminator, any chipping or rounding of the point can be detected and the extent of the defect measured with a filar micrometer. It is recommended that a diamond pyramid penetrator should not be used for tests in which the maximum length of such a defect exceeds 5 percent of the length of the impression diagonal.

(c) Micrometer Microscope. -- The micrometer microscope shall be so constructed that the length of the diagonals of an impression in a properly surface-finished specimen (see Section 5 (c)) can be measured to within ±0.0005 mm or ±0.5 percent, whichever is larger.

TEST SPECIMENS

5. (a) The diamond pyramid hardness test is adaptable to a wide variety of test specimens, ranging from large bars and rolled sections to minute pieces in metallographic mounts. In general the backs of the specimens shall be so finished or the specimens shall be so clamped that there is no possibility of their rocking or shifting under the test load. The specimens should also conform to the requirements given in the following paragraphs (b), (c), and (d).

(b) Thickness. -- The thickness of the test specimen shall be such that no bulge or marking showing the effect of the load appears on the side of the specimen opposite the impression. In any event the thickness of the specimen shall be at least one and one-half times the length of the diagonal. When laminated material is tested, the thickness of the individual component being tested shall be used for the thickness-diagonal length relationship.

(c) Finish. --The surface of the specimen should be so prepared that the ends of the diagonals are clearly defined and can be read with an accuracy of ± 0.0005 mm or ±0.5 percent of the length of the diagonals, whichever is larger. Care should be taken in specimen preparation to avoid tempering during grinding, or work-hardening the surface during polishing. Specimens for tests at loads of 100 g or less require careful metallographic preparation by methods such as those outlined in the Tentative Methods of Preparation of Metallo-

ensure that the surface tested is representative of the material and that its hardness is not affected by decarbonisation, carburisation or any unsuitable machining, grinding or polishing process applied to it, unless the test is of the type referred to in Clause 4 d.

MAGNITUDE AND APPLICATION OF LOAD

4. a. In order to obtain the greatest accuracy the load should be as large as possible consistent with the dimensions of the test sample. Loads of 100 kg. and above are, however, liable to fracture the diamond if used on hard materials. In the case of materials of coarsely duplex microstructure, such as cast iron, small impressions tend to give the hardness of individual constituents and, if the average hardness of the material is required, care should be taken to use a sufficiently large load (see Note to Clause 1).

In order to unify testing procedure, the standard loads given in Clause 1c shall be employed wherever possible.

b. The load shall be applied slowly and progressively to the test specimen.

c. The full load shall be maintained for 15 seconds.

d. Where diamond pyramid hardness tests are carried out to ascertain the hardness of the case in case-hardened materials, or in similar circumstances, it is recommended that several impressions shall be made with various loads on the diamond (e.g. 10, 20 and 30 kg.). If the results are unaffected by the 'core' of the sample, the same hardness number will be given by each impression. Should the values progressively increase or decrease, lower loads must be employed until two such loads give the same value.

during grinding, or work-hardening the surface during polishing. Specimens for tests at loads of 100 g or less require careful metallographic preparation.

4.4 Alignment. -- The specimen shall be prepared or mounted so that the surface is normal to the axis of the penetrator within $\pm 1°$. This can be readily accomplished by surface grinding or otherwise machining the opposite side of the specimen to be parallel with the side to be tested.

4.5 Radius of curvature. -- Unless the exterior surface is significant, any radius of curvature should be removed prior to testing. Until investigative work is accomplished to determine the effect of the radius of curvature on readings, due caution should be used in interpreting or accepting the results of tests made on cylindrical surfaces.

4.6 Location of indentations. -- Care shall be exercised to limit hardness readings to areas wherein indentations cannot later contribute to failure, as, for example, under dynamic loadings, and to limit the number of indentations to the minimum necessary for accurate determinations.

5. PROCEDURE

5.1 The diamond pyramid hardness number is computed from the following formula:

$$\text{D.P.H.} = \frac{2L \sin \frac{136}{2}}{d^2} = 1.8544 \times \frac{L}{d^2}$$

where:

L = load in kilograms

d = diagonal of indentation in mm.

The diamond pyramid hardness numbers for a test load of 1 kg are given in Table I. To obtain hardness numbers when other test loads are used, the diamond hardness number obtained from Table I is multiplied by the test load in kilograms. (See Table II.)

5.2 Magnitude of test load. -- Test loads of 1 g to 120 kg may be used, depending on the requirements of the test. Although tests on homogeneous materials indicate that the diamond pyramid hardness number is nearly independent of the test load, this condition will not be present in cases where there is a hardness gradient from the specimen surface to the interior of the specimen. The latter condition is present when ascertaining the hardness of the hardened layer in the surface of a hardened material. Several impressions should then be made with various loads on the diamond until two different loads will give the same hardness values.

graphic Specimens (ASTM Designation : E 3)[3] and with observance of all precautions mentioned in Methods E 3.

[3] 1955 Book of ASTM Standards, Part 2.

(d) Alignment. -- The specimen should be so prepared or mounted that the surface is normal to the axis of the penetrator within ± 1 deg of angle. This can readily be accomplished by surface grinding (or otherwise machining) the opposite side of the specimen to parallelism with the side to be tested.

(e) Radius of Curvature. -- Until investigative work is accomplished to determine the effect of the radius of curvature on readings, due caution should be used in interpreting or accepting the results of tests made on cylindrical surfaces.

PROCEDURE

6. (a) Magnitude of Test Load. -- Test loads of 1 g to 120 kg may be used, depending on the requirements of the test. Although tests on homogeneous materials indicate that the diamond pyramid hardness number is nearly independent of the test load, this condition will not be present in cases where there is a hardness gradient from the specimen surface to the interior of the specimen. The magnitude of the test load should therefore be stated in the test report.

(b) Application of Test Load. -- The test load shall be applied and released smoothly without shock or vibration. The time of application of the full test load shall be at least 15 sec, unless otherwise specified.

(c) Spacing of Indentations. -- The center of the impression shall not be closer to any edge of the test specimen or to another impression than a distance equal to two and one-half times the length of diagonal of the impression. When laminated material is tested, a bond surface shall be considered as an edge for spacing of indentation calculations.

MEASUREMENT OF IMPRESSION

7. Both diagonals of the impression shall be measured and their average value used as a basis for calculation of the diamond pyramid hardness number. It is recommended that the measurement be made with the impression centered as nearly as possible in the field of the microscope.

CALIBRATION OF APPARATUS

8. (a) Micrometer Microscope. --The micrometer microscope or other device for measuring the diagonals of the impression shall be calibrated against an accurately ruled

MAGNITUDE OF TEST LOAD

B.S. 247 . . . . . Where diamond pyramid hardness tests are carried out to ascertain the hardness of the case in case-hardened materials, or in similar circumstances, it is recommended that several impressions shall be made with various loads on the diamond. If the results are unaffected by the 'core' of the sample, the same hardness number will be given by each impression. Should the values progressively increase or decrease, lower loads must be employed until two such loads give the same value.

Federal Method 244 . . Although tests on homogeneous materials indicate that the diamond pyramid hardness number is nearly independent of the test load, this condition will not be present in cases where there is a hardness gradient from the specimen surface to the interior of the specimen. The latter condition is present when ascertaining the hardness of the hardened layer in the surface of a hardened material. Several impressions should then be made with various loads on the diamond until two different loads will give the same hardness values.

ASTM E 92 . . . . . Although tests on homogeneous materials indicate that the diamond pyramid hardness number is nearly independent of the test load, this condition will not be present in cases where there is a hardness gradient from the specimen surface to the interior of the specimen. The magnitude of the test load should therefore be stated in the test report.

CALIBRATION OF APPARATUS

ASTM E 92 . . . . Describes the procedure specified for calibrating the micrometer microscope and hard-

B.S. 427 : 1931

METHOD OF SPECIFYING DIAMOND PYRAMID HARDNESS

5.a. The diamond pyramid hardness shall be specified by the diamond pyramid hardness number and not by the diagonal of the impression.

b. The load employed shall be stated in every case, e.g.,

$$H_D/20=$$

Note:

The impression produced by the pyramidal indenting tool as viewed under the measuring microscope may not be square.

Variations in the shape of the impression may, on certain materials, give useful indications of the work-hardening properties of such materials. Where the sides of the impression are drawn in (or concave), a capacity for cold work may be indicated, and, alternatively, where the sides of the impression are more or less bulged (or convex), the indication may be that the material has little further capacity for cold work.

Federal
Method No. 244 : 1956

5.2.1 In the case of coarsely duplex microstructure, such as cast iron, small indentations tend to give the hardness of individual constituents. If the average hardness of the material is required, care shall be taken to use a sufficiently large load, and whenever possible a number of indentations shall be made with an average taken.

5.3 Application of test load. -- The test load shall be applied and released steadily without shock or vibration. Unless otherwise specified, application of the full test load shall be for at least 15 seconds.

5.4 Spacing of indentations. -- The center of indentations shall not be closer to any edge of the test specimen nor to another indentation than a distance equal to two and one-half times the length of the diagonal of the indentation.

5.5 Measurement of indentation. -- Both diagonals of the indentation shall be measured and their average value used as a basis for calculation of the diamond pyramid hardness number. It is recommended that the measurement be made with the indentation centered as nearly as possible in the field of the microscope.

6. NOTES

6.1 Whenever practicable, hardness readings shall be taken on the type of equipment indicated by the specification or drawing, and not on another type of equipment and then converted.

7. REPORT OF RESULTS

7.1 The test load shall be reported with the diamond pyramid hardness number. For example: 223 D.P.H. for 50 kg test load. Reports shall be made on forms either furnished or approved by the Government inspector. The report shall refer to the contract or purchase order and shall include all information requested by the procuring agency.

7.2 When the hardness value reported is converted from a scale or load different than that specified, the value and scale or load from which converted shall also be reported.

line scale (stage micrometer). The errors of the line scale shall not exceed 0.00005 mm (0.05 micron) or 0.05 percent of any interval, whichever is greater. The micrometer microscope shall be calibrated throughout its range of use and a calibration factor chosen such that the error shall not exceed ±0.5 percent. It may be necessary to divide the complete range of the micrometer microscope into several subranges, each having its own factor.

(b) Comparison Impression Method. -- The load application of a diamond pyramid hardness testing machine may be checked by making a series of adjacent impressions with a standardized machine interspersed between impressions made with the machine being checked (Note). The diagonals of all impressions shall be measured with one calibrated micrometer microscope. The error shall be determined from the relative values of the average diagonal lengths for the machine being checked and the standardized machine.

Note. -- Standard load-calibrating devices of suitable capacity and design are not commercially available. Test blocks for use in the comparison impression method are usually obtained by arrangement with testing machine manufacturers or other agencies equipped to make load calibrations using specially constructed dead weights and proving levers, or other calibration devices, in the manner described in the Tentative Methods of Verification of Testing Machines (ASTM Designation: E 4).

(c) Comparison Specimens. -- When the comparison impression method of checking the load application of a diamond pyramid hardness testing machine is used, the specimen shall be selected to be as homogeneous as possible. The surface on which the comparison impressions are to be made shall be prepared so as to minimize spurious effects caused by tempering, work hardening, or irregularities in contour. The lighter the test load at which the machines are to be compared, the greater the care that shall be exercised in finishing the test block. The impressions shall be spaced such that the centers of the adjacent impressions are not less than five diagonal lengths apart. Although it is not necessary to use specimens of different hardness, impressions should be made at test loads spaced throughout the range of the machine. The maximum allowable difference between the average diagonal lengths for the two machines at a given load shall not exceed ± 1.0 percent of the diagonal length obtained with the standardized machine, or ± 0.001 mm, whichever is larger.

(d) Reproducibility of Results. -- If the measured diagonal of any impression either for the machine being checked or for the standard machine, differs by more than ±0.002 mm or ± 2 percent, whichever is larger, for the mean of the group of impressions made with that machine, it is recommended that the measurement of the diagonal be discarded. If two measurements differ by more than ± 0.002 mm or ± 2 percent, whichever is larger, from the mean, the whole series should be discarded.

ness testing machine.

B. S. 427 : 1931

TABLE I

Table I gives hardness numbers for diagonals of impressions measured to thousandths of a millimetre obtained with loads of 5, 10, 20, 30, 50, 100, and 120 kg.

This table is the mathematical solution to the formula given in section 2; hence, it is not repeated here.

Federal
Method No. 244 : 1956

TABLE I

Table I gives hardness numbers for diagonals of impressiums measured to ten-thousandths of a millimeter obtained with a load of 1 kg. As stated in 5.1, to obtain hardness numbers when other test loads are used, the diamond pyramid hardness number obtained from Table I is multiplied by the test load in kilograms.

TABLE II is a decimal point finder used with Table I.

TABLE I

Table I gives hardness numbers for diagonals of impressions measured to ten thousandths of a millimeter obtained with a load of 1 kg. As stated in 3, to obtain hardness numbers when other test loads are used, the diamond pyramid hardness number obtained from Table I is multiplied by the test load in kilograms.

TABLE II is a decimal point finder used with Table I.

BRITISH STANDARD METHOD FOR
DIRECT READING HARDNESS TESTING
ROCKWELL PRINCIPLE

B. S. 891 : 1940

DESCRIPTION OF TEST

1. The principle of the test is illustrated graphically in the diagram, Figs. 1, 2 and 3.

A minor load is applied (Fig. 1) to a penetrator and causes an indentation in the test specimen.

While the minor load is still operating, it is augmented (Fig. 2) by a major load with resulting increase in the depth of indentation.

The major load is then removed (Fig. 3), still retaining the minor load; this operation effects a partial recovery in the depth of the indentation as compared with Fig. 2 and eliminates the indication of the deflection in the structural members during application of the major load.

Two alternative forms of penetrator are used: (a) a diamond cone with rounded point, or (b) a hardened steel ball.

FEDERAL TEST METHOD STANDARD NO. 151
METHOD NO. 243
ROCKWELL HARDNESS TEST

1956

SCOPE

1. 1 This method covers procedures for determining the hardness of metals by the Rockwell Standard and Rockwell Superficial Hardness Tests.

2. DEFINITIONS

2. 1 Rockwell hardness test. -- The Rockwell hardness test consists of determining the depth of penetration of an indenter into the specimen under certain arbitrarily fixed conditions of test.

2. 2 Rockwell hardness number. -- The Rockwell hardness number is a value derived from the increase in depth of impression as the load on an indenter is increased from a fixed minimum value to a higher value and then returned to the minimum value. Rockwell hardness numbers are always quoted with a prefix representing the Rockwell scale corresponding to a given combination of load and indenter.

TENTATIVE METHODS OF TEST FOR ROCKWELL HARDNESS AND ROCKWELL SUPERFICIAL HARDNESS OF METALLIC MATERIALS

ASTM Designation : E 18 - 57 T

REMARKS

SCOPE

1. (a) These methods cover the test procedures for determining the Rockwell hardness (Sections 2 to 7) and the Rockwell superficial hardness (Sections 8 to 12) of metallic materials.

(b) The information in Sections 2, 3, 4, 8, and 9 is intended to describe and define the type of test that is involved and to outline the limitations of acceptable testing machines. This descriptive material is not mandatory in connection with the test itself.

SCOPE

B.S. 891 . . . . . Scope is not stated.

DEFINITION

2. Rockwell Hardness Number. -- A number derived from the net increase in depth of impression as the load on a penetrator is increased from a fixed minimum load to a higher load and then returned to the minimum load. Penetrators for the Rockwell test include steel balls of several specified diameters and a diamond cone penetrator having an included angle of 120 deg with a spherical tip having a radius of 0.2 mm. Rockwell hardness numbers are always quoted with a scale symbol representing the penetrator, load, and dial used.

DEFINITION

B.S. 891 . . . . . Does not contain a definition of the Rockwell hardness test or the Rockwell hardness number.

ASTM E 18 . . . . Defines Rockwell hardness number.

Federal Method 243 . Defines Rockwell hardness test and Rockwell hardness number.

GENERAL DESCRIPTION OF ROCKWELL HARDNESS METHOD

APPARATUS

3. (a) The tester for making Rockwell hardness determinations is essentially a machine that measures hardness by determining the depth of penetration of a penetrator into the specimen under certain arbitrarily fixed conditions of test. The penetrator may be either a steel ball or a diamond sphero-conical penetrator. The hardness value, as read from the dial, is an arbitrary number which is related to the depth of indentation caused by two superimposed impressions, and since the scales are reversed, the number is higher the harder the material. A minor load of 10 kg is first applied which causes an initial penetration which sets the penetrator on the material and holds it in position. The dial is set at zero on the black-figure scale, and the major load is applied. This major load is the total load applied and the depth measurement depends solely on the increase in depth due to increase from minor to major load.

After the major load is applied and removed, according to standard procedure, the reading is taken while the minor load is still in position. The major load is customarily 60 kg or 100 kg when a steel ball is used as a penetrator, but other loads may be used when found necessary, and usually 150 kg when a diamond sphero-conical penetrator is employed. The ball penetrator is 1/16 in. in diameter normally but other

B. S. 891 : 1940

FEDERAL
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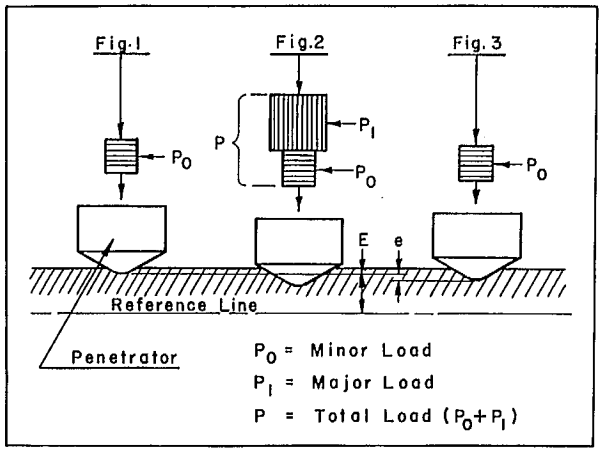

The reference line represents zero hardness on the particular scale used (see Clause 26).

Rockwell hardness numbers are read directly on an indicator and are derived from measurement of the depths of the impressions in the following manner:

$$H_R = E - e$$

where e is the difference between the depths of penetration before and after the application of the major load, and while the minor load is in operation in both cases.

The value of e is expressed in units of 0.002 mm.

E is an arbitrary constant. Its value depends on the form of penetrator used, as indicated in Clause 2 b.

H_R is the Rockwell hardness number.

APPARATUS

2. Penetrators:

a. (i) The conical penetrator shall be a diamond with an angle of 120° to an accuracy of plus or minus 0.1° in any axial plane.

The point of the penetrator shall be rounded to a radius of 0.20 mm. and the profile shall conform to the radius of 0.20 mm. within an accuracy of plus or minus 0.005 mm.

The round and conical surfaces shall join in a truly tangential manner.

The penetrator shall be clean, have a good polish, and be free from cracks and surface blemishes, and shall be solidly mounted in a suitable holder.

(ii) The ball penetrator shall be of hardened steel complying with the appropriate requirements of B.S. 240, Part 2, 'The Hardness of Steel Balls

3. APPARATUS

3.1 A Rockwell testing machine shall be used with either a steel ball or a diamond spheroconical penetrator. One of the combinations of penetrator and load as given in Tables I and II shall be used in either the standard type of testing machine (for heavy loads) or the superficial type of testing machine (for light loads).

3.2 Periodic examination of penetrators under magnification shall be made. Penetrators shall be discarded if signs of deformation, chipping, or cracking are observed or if discrepancies in hardness values obtained on a standard test block are traceable to the penetrator.

3.3 The Standard Rockwell and Superficial Rockwell tests are made on separate machines, identical in principle but differing as to initial minor load and applied major load. Superficial Rockwell

penetrators of larger diameter such as 1/8, 1/4, or 1/2 in. may be employed for soft metals. A variety of loads and penetrators are thus provided and experience decides the best combination for use.

(b) Rockwell Hardness Scales. -- Rockwell hardness values are usually determined and reported according to one of the standard scales specified in Table I. There is no Rockwell hardness value designated by a figure alone, because it is necessary to indicate which penetrator and load have been employed in making the test. In all cases the minor load is 10 kg and the dial is adjusted after applying the minor load so that the pointer reads at "SET" (C O or B 30).

The use of ball penetrators for materials which give readings greater than 100 is not recommended, because of lack of sensitivity and possible flattening of the ball. The diamond cone penetrator is not recommended for materials giving readings below 20.

For the Rockwell hardness test one Rockwell number represents 0.002 mm (0.00008 in.) movement of the penetrator.

Typical applications of the various scales are shown in Table I. There may be cases in which more than one scale could be used. It is desirable to employ the smallest ball that can properly be used, because of the loss of sensitivity as the size of the penetrator increases. An exception to this is when soft non-homogeneous material is to be tested in which case it may be preferable to use a larger ball which makes an impression of greater area, thus obtaining more of an average hardness.

While the choice of scales is optional, the scale symbol for the combination of penetrator, load, and dial used should be as listed in Table I.

(c) Penetrators. -- The standard penetrators, as have been mentioned in Paragraph (b), are the diamond spheroconical penetrator and steel balls 1/16 in., 1/8 in., 1/4 in. and 1/2 in. in diameter. The shape of the diamond spheroconical penetrator shall be a cone forming a 120-deg angle with a spherical apex of 0.2-mm radius. The steel balls used should be free from surface imperfections. The diameter of the balls shall not deviate from the nominal value by more than $\pm$0.0001 in. and the diameter of any ball measured at various points shall be constant within a permissible variation of $\pm$0.00002 in. An occasional check of the penetrator's contour should be made by examination with a magnifying glass. This will reveal any chipping of the diamond or flattening of a ball penetrator. If either of these conditions is discovered the penetrator should be replaced.

Dust, dirt, grease, and scale should not be allowed to accumulate on the penetrator as this will affect the results.

(d) Anvils. --An anvil should be used which is suitable for the specimen to be tested. Cylindrical pieces should be tested with a V-notch anvil which will support the specimen with the axis directly under the penetrator, or on hard, parallel, twin cylinders properly positioned and clamped to their base. Flat pieces should be tested on a flat anvil which has a smooth flat bearing surface whose plane is perpendicular to the axis of the penetrator. For thin materials or specimens

B.S. 891 . . . . . .Term major load is used to describe the load which is added to the minor load to form the total load.

ASTM E 18 . . . . .) Major load is the
Federal Method 243) total load applied.

B.S. 891 . . . . . The accuracy of the applied loads shall be within plus or minus 0.5 percent.
ASTM E 18 . . . . .) Accuracy of loads
Federal Method 243) is not stated.
B.S. 891 . . . . . The major load shall be applied gradually in from four to five seconds.
ASTM E 18 . . . (6. (a))
Federal Method 243. (5 Procedure))
The dash pot on the Rockwell tester shall be so adjusted that the operating handle completes its travel in from 4 to 5 seconds with no specimen in the machine and with the machine set up to apply a major load of 100 kg.
B.S. 891 . . . . . As soon as the reading of the depth indicator becomes steady the major load shall be gently removed.
ASTM E 18 . . . . . (5 i) Remove the major load within 2 seconds after

for Brinell Hardness Testing[1].

The diameter of the ball shall be 1/16 in. (1.588 mm.) and its diameter at any point shall not differ from the standard diameter by more than plus or minus 0.0001 in. (0.0025 mm.).

b. Magnitude and Application of Loads. The standard test shall be carried out in accordance with one or other of the scales A, B and C* defined as follows:

Scale	Penetrator	Minor load	Major load	Total load	Value of E
		kg.	kg.	kg.	
A	Diamond cone	10	50	60	100
B	1/16 in. (1.588 mm.) steel ball	10	90	100	130
C	Diamond cone	10	140	150	100

*For a note with regard to the use of these scales, see Appendix A.

The accuracy of the applied loads shall be within plus or minus 0.5 per cent.

The minor load shall be applied gradually and progressively to the specimen in a direction normal to its surface and axially to the penetrator.

Without removing the minor load and with the position of the test specimen undisturbed, the major load shall then be additionally applied gradually and progressively in from four to five seconds.

As soon as the reading of the depth indicator becomes steady, the major load shall be gently removed, the minor load being retained and the test specimen remaining undisturbed.

c. Measurement of Depth of Penetration. The measuring device shall be capable of measuring the depth of the impression to within plus or minus 0.001 mm. (corresponding to plus or minus 0.5 of the scale unit).

The depth shall be ascertained as the difference of readings taken before and after the application of the major load and with the minor load in operation at both readings.

° It is convenient to use a sliding scale which can be set at zero following the first application of the minor load thus enabling the difference in depth to be ascertained directly in a single reading.

d. Support of the Test Material. The support or anvil for the test specimen shall be of steel, or other material of hardness and rigidity sufficient to prevent its deformation in use.

It shall be firmly supported symmetrically under the penetrator in such a manner that its reactive pressure is directly and not obliquely opposed to the loads.

hardness tests are usually made only where the material or surface layer of interest is of insufficient thickness for the Standard Rockwell test.

3.4 Rockwell type tests shall be made on equipment meeting the requirements herein and otherwise approved by the procuring agency.

3.5 Although hardness determinations shall normally be made on the type of equipment and scale specified (see 6.1), the following table shall apply when it is necessary to convert from one Rockwell scale to another for softer metals, except when separate tables have been developed for a particular material as for steel in method 241 of this standard, and as for cartridge brass in ASTM E 33.

Hardness values obtained by conversion shall be so labeled, indicating the scale and hardness value from which converted.

TABLE I. -- STANDARD ROCKWELL SCALES

Hardness Scale	Penetrator	Major° load (kg)	Dial Figures	Application of Scale
A	Diamond cone	60	Black	Extremely hard materials, such as tungsten carbide, which might chip indenter at higher load; also for hard sheet too thin for heavy loads.
B	1/16 inch steel ball	100	Red	Materials of B 0 to B 100 hardness.
C	Diamond cone	150	Black	Materials of C 20 to C 70 hardness.
D	Diamond cone	100	Black	Sometimes used on case-hardened material.
E	1/8 inch steel ball	100	Red	For testing very soft materials such as bearing metals.
F	1/16 inch steel ball	60	Red	Substitute for the E scale.
G	1/16 inch steel ball	150	Red	
H	1/8 inch steel ball	60	Red	
K	1/8 inch steel ball	150	Red	

°This is also the total load since it includes the minor load which is 10 kg for all standard scales

which are not perfectly flat, this flat anvil shall have an elevated "spot" about 1/4 in. in diameter and about 3/4 in. in height. This spot shall be polished smooth and flat and shall be free from pits and heavy scratches. This spot shall have a Rockwell hardness of at least C 60.

If the provisions of Section 4 on thickness of specimen are complied with, there will be no danger of indenting the anvil, but if the specimen is so thin that the impression will show through on the under side, it is possible that the anvil may be damaged. Damage may also occur from accidental contacting of the anvil with the penetrator. If the anvil is damaged from any cause, it should be replaced. Anvils showing the least perceptible dent will give inaccurate results on thin material.

Very soft material should not be tested on the "spot" anvil because the applied load may cause the penetration of the anvil into the under side of the specimen, regardless of its thickness.

(e) Test Blocks. -- Test blocks meeting the requirements outlined should be used in periodic checking of the tester. Test blocks used for checking the accuracy of the Rockwell tester shall be of uniform material, thick enough to be free from "anvil effect", of smooth surface on both top and bottom sides, and of not more than 4 sq in. surface area on the test surface. They shall be prepared to a reasonably fine finish and inspected for freedom from any major surface defects or imperfections that might affect the hardness readings. The hardness value of a test block shall be determined by making five impressions with a Rockwell tester of accepted accuracy, using the procedure described in Section 5. In the calibration of the test blocks, five readings shall be taken either at the four diagonal corners and one at the center, or at 4 points approximately 90 deg apart on the periphery and one at the center. The total spread of these five hardness values shall not be more than two hardness numbers for blocks of B 30 or greater hardness, nor more than three hardness numbers for blocks softer than B 30. Blocks for other scales shall have these same limits above and below the converted hardness value equivalent to B 30. The average of the five readings shall be taken as the true Rockwell hardness of the test block. The test blocks shall be marked with a range of values which will include all five of the readings.

(f) Checking Calibration with Test Blocks. -- It has been found practicable to keep Rockwell testers within plus or minus two hardness numbers of the correct readings over the range B 35 to B 70, but a somewhat wider range prevails for softer materials. When machines in everyday production inspection testing are calibrated and adjusted once a month, it has been found that they very seldom deviate more than this amount. Daily checking of such machines assures the operator that the penetrator is in good condition and the machine is operating properly.

(g) Precautions - - General

(1) Protection Against Vibration. -- If the bench or table on which the Rockwell hardness tester is mounted is subject to vibration, such as experienced in the vicinity of other

its motion has stopped or:
(1) In the case of materials which do not exhibit plastic flow after application of the major load, the operating lever may be brought back to its latched position immediately after the pointer stops.
(2) In the case of materials which exhibit plastic flow after application of the major load, the pointer will continue to move after the operating lever stops, and in this case the operating lever may be brought back to its latched position at a specified elapsed time between tipping and removal of load.

Federal Method 243. (5.2) When the dial hand has completed its travel and becomes stationary, the load shall be slowly released to prevent jerking and the dial read.

B.S. 891 . . . . . The measuring device shall be capable of measuring the depth of the impression to within plus or minus 0.001 mm.

ASTM E 18 . . . . . .) Accuracy of
Federal Method 243. .) measuring device is not stated.

B.S. 891 . . . . . .(Appendix A). The standard test is restricted to scales A, B and C. However, scales D, E, F, G and H are included to serve as a guide.

Federal Method 243.) Standard scales are: A, B, C, D, E, F, G, H, and K.

ASTM E 18 . . . . . .(APPARATUS), Standard scales are A, B, C, D, E, F, G, H, K, L, M, P, R, S, and V.

B.S. 891 . . . . . .(Appendix A). The

Rods, cylinders, tubes and hollow articles shall be supported sufficiently to ensure their rigidity under the loads.

For flat specimens the support shall have a flat, smooth bearing surface.

Specimens which are not flat shall be supported on an anvil having a flat, smooth and polished protuberance, free from pits and scratches, of hardness about 62 units on the C scale, and about 3/16 in. (4.76 mm.) diameter and about 1/8 in. (3.18 mm.) in height.

e. Structural features. The framework of the testing apparatus shall be sufficiently rigid to prevent the possibility of strains in its members from affecting the magnitude or direction of the loads.

Where the depth measuring device operates through the framework, its rigidity shall also be sufficient to prevent strains from causing errors in the depth measurement.

TABLE II. --SUPERFICIAL ROCKWELL SCALES[1]

Hardness Scale	Penetrator	Major load[2] (kg)	Dial Figures
15-N	Diamond cone	15	Black
30-N	Diamond cone	30	Black
45-N	Diamond cone	45	Black
15-T	1/16 inch steel ball	15	Black
30-T	1/16 inch steel ball	30	Black
45-T	1/16 inch steel ball	45	Black

[1] The Superficial Rockwell N scales shall be used for material that would be tested with the C scale if of sufficient thickness. The Superficial Rockwell T scales shall be used for material that would be tested with the B scale if of sufficient thickness.

[2] This is also the total load since it includes the minor load which is 3 kg for all Superficial scales.

machines, the tester should be mounted on a metal plate on sponge rubber at least 1 in. in thickness or any other type of mounting that will effectually eliminate vibration from the machine. Otherwise the penetrator will penetrate farther into the material than when such vibrations are absent.

(2) Specimens employed for hardness determinations shall be prepared with care. Should sheet metal be employed, special care should be taken with material that is curved. The concave side of the curved metal should face toward the penetrator. If such specimens are reversed, an error will be introduced due to the flattening of the metal on the anvil.

(3) Specimens which have sufficient overhang so that they do not balance themselves on the anvil shall be properly supported.

(4) The penetrator and anvil should not be brought together without a test piece between them, otherwise the anvil will be indented and the ball flattened.

(5) The dial gage plunger shall move freely without appreciable change of friction in any position.

TABLE I. --ROCKWELL HARDNESS SCALES

Scale Symbol	Penetrator	Major Load (kg)	Dial Figures	Typical Applications of Scales
B	1/16-in. ball	100	Red	Copper alloys, soft steels, aluminum alloys, malleable iron, etc.
C	Diamond cone	150	Black	Steel, hard cast irons, pearlitic malleable iron, titanium, deep case hardened steel, and other materials harder than B 100.
A	Diamond cone	60	Black	Cemented carbides, thin steel, and shallow case hardened steel.
D	Diamond cone	100	Black	Thin steel and medium case hardened steel and pearlitic malleable iron.
E	1/8-in. ball	100	Red	Cast iron, aluminum and magnesium alloys, bearing metals.
F	1/16-in. ball	60	Red	Annealed copper alloys, thin soft sheet metals.
G	1/16-in. ball	150	Red	Phosphor bronze, beryllium copper, malleable irons. Upper limit G 92 to avoid possible flattening of ball.
H	1/8-in. ball	60	Red	Aluminum, zinc, lead.

Continued...

Rockwell superficial test is not included in this specification.

Federal Method 243. (Table II) Lists the superficial Rockwell scales for the diamond and 1/16 in. ball penetrators.

ASTM E 18 . . . . . Contains a complete description of the Rockwell superficial hardness test.

B. S. 891 : 1940

FEDERAL
METHOD NO. 243 : 1956

TEST SPECIMENS

3. The surface on which the impression is to be made shall be flat. Test figures obtained on curved surfaces are only of comparative value. The surface on which the impression is made, as well as the surface in contact with the support, shall be smooth, clean and dry, and free from oxide scale and pits.

Suitable precautions should be taken to ensure that the surface tested is representative of the material and that its hardness is not affected by decarburisation, carburisation or any unsuitable machining, grinding or polishing process applied to it, unless it is desired to test the hardness of a surface layer.

The thickness of the specimen shall be sufficient to avoid any bulge or other marking on the surface opposite the impression and resulting from the application of the loads.

The centre of the impression shall be not less than two-and-a-half times the diameter of the impression from any edge of the test specimen and from any other impression.

All tests shall be made on a single thickness of the material: that is, no additional material of the same or another kind may be interposed between the specimen and the support.

4. SPECIMEN

4.1 The specimen shall be of such thickness that no bulge or marking showing the effect of the load shall be visible on the side opposite the indentation, except when the detail specification requires the use of scales to thicknesses that bulge. Rockwell indentations shall be at least 2 1/2 indentation diameters from the edge of the specimen, and the distance between indentations shall be 5 indentation diameters for ball tests and 2 1/2 indentation diameters for diamond cone tests.

4.2 The test surface shall be free from scale, oxide films, pits, and foreign material that may affect the results. The preparation of the test surface shall be carefully controlled to avoid any alteration of mechanical properties due to tempering during grinding or work-hardening during polishing operations.

4.3 If indentations are made on curved specimens, the radius of curvature shall not be less than 1/2 inch unless standard correction tables are used. Cylindrical pieces shall be tested with a V-notched anvil or double-cylinder support directly under the penetrator. The specimen shall have a seating surface such that no permanent vertical deformation occurs during the test, such as would result from burrs or dirt. An anvil shall be used which is suitable for the specimen to be tested. For thin materials or specimens which are not perfectly flat, a flat anvil shall be used having a small elevated spot about 1/4 inch in diameter and about 3/4 inch high. The spot shall be polished smooth and flat and free from pits and heavy scratches.

4.4 Care shall be exercised to limit hardness readings to areas wherein indentations cannot later contribute to failure, as for example, under dynamic loadings, and to limit the number of indentations to the minimum necessary for accurate determination, except as indicated in 5.3.

TABLE I. -- ROCKWELL HARDNESS SCALES (concluded)

Scale Symbol	Penetrator	Major Load (kg)	Dial Figures	Typical Application of Scales
K	1/8-in. ball	150	Red)	
L	1/4-in. ball	60	Red)	Bearing metals and
M	1/4-in. ball	100	Red)	other very soft or thin
P	1/4-in. ball	150	Red)	materials. Use small-
R	1/2-in. ball	60	Red)	est ball and heaviest
S	1/2-in. ball	100	Red)	load that does not give
V	1/2-in. ball	150	Red)	anvil effect.

TEST SPECIMENS

4. (a) Specimens used in Rockwell hardness testing vary greatly in form, since it is frequently desirable to make the impression upon a part to be used in the finished product rather than upon a sample test specimen. It is recognized that all the many conditions of test pieces, size, preparation, etc., cannot be covered specifically, and the following paragraphs are intended only as a general guide in the selection of test pieces.

(b) Surface conditions have a marked effect on the readings obtained on thin materials and due to the fact that the thickness of such specimens may influence the results, it cannot be assumed that the indications on the standard blocks furnish any reliable measure of the errors to be expected when testing thin material. Standard blocks are always thick enough to eliminate the effect of the underlying anvil, but it must be remembered that errors of unknown magnitude may occur when tests are made on material which is thin enough for the impression to show through on the reverse side. The standard test blocks will indicate the errors of the machine when used to test specimens of similar size, shape, and surface condition, but there is at the present time no satisfactory way of checking the accuracy of the readings taken on thin material nor of evaluating the anvil effect when this is present.

(c) Rockwell tests of the highest accuracy are made on pieces of sufficient thickness so that the Rockwell reading is not noticeably affected by the supporting anvil. Absence of a bulge or other marking on the surface of the test piece opposite the impression is an indication that the piece is sufficiently thick for precision testing.

Commercially acceptable Rockwell readings may be obtained on sheet materials which show some bulging or marking, and in some specifications the sheets to be tested are of a thickness and hardness such that anvil effect will be present. Tables of limiting thicknesses at various hardness levels for selected Rockwell and Rockwell superficial scales using the 1/16-in. diameter ball and the diamond cone indenters are given in Tables II and III. Rockwell and Rockwell superficial tests on sheet metals are acceptable for hardness specification purposes when the tests are made on thicknesses in accordance with these tables and using methods defined in this designation.

REMARKS (continued)

TEST SPECIMENS

B.S. 891 . . . . . Test figures obtained on curved surfaces are only of comparative value.

Federal Method 243. If indentations are made on curved specimens, the radius of curvature shall not be less than 1/2 in. unless standard correction tables are used.

ASTM E 18 . . . . . (Procedure, 5 (g) Readings on cylindrical specimens are subject to a correction; see Tables V and VI, appendix.

B.S. 891. . . . . The thickness of the specimen shall be sufficient to avoid any bulge or other marking on the surface opposite the impression and resulting from the application of the loads.

Federal Method 243.. The specimen shall be of such thickness that no bulge or marking showing the effect of the load shall be visible on the side opposite the indentation, except when the detail specification requires the use of scales to thicknesses that bulge.

ASTM E 18 . . . . . Commercially acceptable Rockwell readings may be obtained on sheet materials which show some bulging or marking, and in some specifications the sheets to be tested are of a thickness and hardness such that anvil effect will be present. Tables of limiting thicknesses at various hardness levels for selected Rockwell and Rockwell superficial scales, using the 1/16-in.diameter ball and the diamond cone indenters,

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In specifications in which the Rockwell or Rockwell superficial hardness is used as an approximation of the tensile strength (Note 1), Tables II and III do not apply. In these cases the relations between the specification limits for tensile strength and hardness have been established for certain specified thickness limits, hence anvil effects due to testing thin sheets are incorporated in the relationship.

To obtain Rockwell values completely independent of anvil effect, minimum thicknesses greater than those given in Tables II and III may be required, and the piece should be free of marking on the side opposite the impression.

The manufacturers of Rockwell testers state that for the E scale, material harder than E 60 may be tested as thin as 1/8 in., but if softer than E 60, the minimum thickness should be 3/16 in.

(d) The preparation of the test material shall be carefully controlled to avoid any alterations in hardness, such as may be caused by heating during grinding or by work hardening during machining and polishing operations. The test surface of the specimen shall be such that the load can be applied normal to it. The surface shall be clean, dry, free from scale, pits and foreign material that might crush or flow under the test pressure and so affect the results. If etching of the test surface is required, it should be no deeper than necessary for metallographic study. The surface in contact with the anvil shall be clean, dry, and free from any condition which may affect results.

In testing coated materials, if a hardness value for the base metal is desired, the coatings should be thoroughly removed before determining the hardness and this should be done in such a manner that the base metal is not affected.

(e) An error may result if an indentation is spaced closer than 2 1/2 diameters from its center to the edge of the specimen, or 3 diameters from another indent measured center to center.

are given in Tables II and III. Rockwell and Rockwell superficial tests on sheet metals are acceptable for hardness specification purposes when the tests are made on thicknesses in accordance with these tables and using methods defined in this designation.

In specifications in which the Rockwell or Rockwell superficial hardness is used as an approximation of the tensile strength, Tables II and III do not apply. In these cases the relations between the specification limits for tensile strength and hardness have been established for certain specified thickness limits, hence anvil effects due to testing thin sheets are incorporated in the relationship.

B.S. 891 . . . . . .The centre of the impression shall be not less than two-and-a-half times the diameter of the impression from any edge of the test specimen and from any other impression.

Federal Method 243. Rockwell indentations shall be at least 2 1/2 indentation diameters from the edge of the specimen, and the distance between indentations shall be 5 indentation diameters for ball tests and 2 1/2 indentation diameters for diamond cone tests.

ASTM E 18 . . . . . An error may result if an indentation is spaced closer than 2 1/2 diameters from its center to the edge of the specimen or 3 diameters from another indent measured center to center.

(PROCEDURE)
Method of Indicating Hardness.

4. A Rockwell hardness number shall be preceded first by the designation H_R and then by the appropriate letter indicating the scale to which it refers, e.g.--H_R C 40, which defines a Rockwell hardness of 40 units determined on the C scale.

APPENDIX A

NOTE WITH REGARD TO THE USE OF SCALES A, B AND C.

Materials for which the undermentioned scales are used:

Scale Symbol	Penetrator	Total load	Materials for which scale is used
A	Diamond cone	60 kg.	Thin hardened steel strip. Other extremely hard materials when small impressions are required.
B	Steel ball 1/16 in. (1.588 mm.) diameter	100 kg.	All mild and medium carbon steels; sheet steel and soft steel bars.
C	Diamond cone	150 kg.	Hardened steels, hardened and tempered steels, alloy steels, and materials harder than B 100.

Special care is necessary in the testing of surface hardened pieces, particularly those treated by the case hardening process. Where any doubt exists that the accuracy of a test conducted on such material in accordance with scale C is affected by the underlying softer material, resort should be made to scale A.

For determining the hardness of the very thin case produced by the nitriding process, shallow case hardening, decarburisation, surface cold working, or by other means, none of the above scales is suitable. Special tests based on the same principle and using very light loads are available for this purpose but are not included in this Specification.

Additional Scales. -- The standard test has been restricted to scales A, B and C, as it was ascertained that the use of these in industry is sufficient

5. PROCEDURE

5.1 Machines shall be properly situated to be free of vibration. The minor load shall be applied steadily through the penetrator to the surface under test, avoiding impact loading. The last movement of the elevating or lowering screw shall always be in a direction which will bring penetrator and work together. Next, the scale shall be adjusted to the set point, and the major load applied gradually by releasing handle slowly, avoiding impact. The major load is also known as the total load since it includes the minor load. The dash pot on the Rockwell tester shall be so adjusted that the operating handle completes its travel in from 4 to 5 seconds without a specimen on the machine and with the machine set up to apply a major load of 100 kg. The dash pot on the Rockwell superficial tester shall be so adjusted that the operating handle completes its travel in 6 to 7 seconds without a specimen on the machine and with the machine set up to apply a major load of 30 kg.

5.2 When the dial hand has completed its travel and becomes stationary, the load shall be slowly released to prevent jerking and the dial read. Because the accuracy of the hardness determinations is a function of the depth of penetration, particular care shall be taken to seat the penetrator and anvil firmly. Generally, the first reading will be inaccurate due to seating of the specimen, anvil, etc., and shall be disregarded. Any vertical movement at these points results in additional depth being registered on the dial gage and, therefore, causes a false reading.

5.3 The performance and accuracy of the machine shall be checked frequently by standard hardness test blocks which are supplied by the manufacturer of the machine. If the hardness value differs from that of the standard hardness test block, the machine shall be adjusted to read correctly. In case of materials of coarsely duplex microstructure, such as cast iron, small indentations tend to give the hardness of individual constituents. If the average hardness of the material is required, care should be taken to make sufficiently large indentations, and, whenever possible, a number of indentations should be made and an average shall be considered.

5.4 The test surface shall be normal to the axis of the indenter and whenever possible shall be flat and parallel to the seating (opposite) surface.

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PROCEDURE

5. (a) Before using the machine, determine its accuracy as described in Section 7.

(b) Adjust the machine according to the methods described in Section 6.

(c) Select a suitable scale and use the proper load and penetrator in accordance with Section 3(b) and (c) and Section 4(c).

(d) Select a suitable anvil in accordance with Section 3(d).

(e) All Rockwell hardness tests shall be made on a single thickness of the material, regardless of its thickness. Experience has shown that tests made on more than one thickness of material are unreliable.

(f) The penetrator should be normal to the surface to be tested.

(g) Readings on cylindrical specimens are subject to a correction; see Tables V and VI, Appendix.

(h) Minor Load Application. --Place the piece to be tested on the anvil and apply the minor load gradually until the proper dial indication is obtained. This shall be understood to be when the pointer has made the proper number of complete revolutions and stands within $\pm$ 5 divisions of the "SET" position at the top of the dial. The proper number of complete revolutions shall be indicated either by a reference mark on the stem of the gage or by an auxiliary hand on the dial. In bringing the penetrator and work into contact avoid all impact, and the last movement of the elevating or lowering screw shall always be in a direction which will bring penetrator and work together. If the proper setting is over-run, remove the minor load and select a new spot for the test. After the minor load has been applied, set the dial pointer at zero on the black-figure scale.

(i) Major Load Application. --Apply the major load by tripping the operating lever without shock. Remove the major load by bringing the operating lever back to its latched position within 2 sec after its motion has stopped, or according to one of the following alternate methods:

(1) In the case of materials which do not exhibit plastic flow after application of the major load, the pointer will come to rest before the motion of the operating lever stops, and in this case the operating lever may be brought back to its latched position immediately after the pointer stops, to reduce possible errors due to externally caused vibration.

(2) In the case of materials which exhibit plastic flow after application of the major load, the pointer will continue to move after the operating lever stops, and in this case the operating lever may be brought back to its latched position at a specified elapsed time between tripping and removal of load (Note 2). In this case the specified elapsed time shall be recorded with the Rockwell number.

Note 2. -- For materials requiring the use of this alternate method the time for application of the major load should be specified in the product specification.

(j) Reading Scale for Rockwell Hardness. --Take the Rockwell hardness as the reading of the pointer on the proper dial figures after the major load has been removed and while

REMARKS (continued)

PROCEDURE

B.S. 891 . . . . . (Apparatus). The major load shall be additionally applied gradually and progressively in from four to five seconds.

Federal Method 243. The minor load shall be applied steadily through the penetrator to the surface under test, avoiding impact loading. The last movement of the elevating or lowering screw shall always be in a direction which will bring penetrator and work together.

ASTM E 18 . . . . . In bringing the penetrator and work into contact avoid all impact, and the last movement of the elevating or lowering screw shall always be in a direction which will bring penetrator and work together. If the proper setting is over-run, remove the minor load and select a new spot for the test.

to justify standardisation. In particular instances, however, it may be desirable to use some other scale, and the following additional scales are included to serve as a guide:

Scale	Penetrator	Minor load	Major load	Total load	Value of E
		kg.	kg.	kg.	
D	Diamond cone	10	90	100	100
E	1/8 in. (3.175 mm.) steel ball	10	90	100	130
F	1/16 in. (1.588 mm.) steel ball	10	50	60	130
G	1/16 in. (1.588 mm.) steel ball	10	140	150	130
H	1/8 in. (3.175 mm.) steel ball	10	50	60	130

(Calibration)

APPENDIX B
CHECKING THE ACCURACY OF THE APPARATUS

The apparatus may conveniently include a calibrated specimen on which a check test may be made.

(a) The calibrated test specimen should comply with all the requirements of Clause 3 and with the following additional requirements:--

Its thickness should be not less than 3/16 in. (4.76 mm.).

Only one surface should be used for tests, its area not exceeding 4 sq. in. (2581 sq. mm.).

Its hardness, as determined by a competent authority, should not vary at five points comprising the centre and corners by more than 1 unit for a

6. NOTES

6.1 Whenever practicable, hardness readings shall be taken on the type of equipment indicated by the specification or drawing, and not on another type of equipment and then converted.

7. REPORT OF RESULTS

7.1 Results shall be reported on forms either furnished or approved by the Government inspector. The report shall refer to the contract or purchase order and shall include all information requested by the procuring agency.

7.2 The hardness number reported shall indicate the scale used; for example, Rockwell C60 or Rockwell 15-N 90.

7.3 When the hardness value reported is converted from a scale or load different than that specified, the value and scale or load from which converted shall also be reported.

Table III.--This table shows the conversion among Rockwell scales for softer metals.

the minor load is still applied. These readings are sometimes estimated to one-half of a division or to one-tenth of a division, depending on the material being tested.

(k) Reporting Rockwell Hardness Results. --All reports of Rockwell test readings shall indicate the scale used, as described in Section 3. Unless otherwise specified, all readings are to be reported to the nearest whole number, rounding off to be in accordance with Recommended Practice for Designating Significant Places in Specified Limiting Values (ASTM Designation: E 29).[3]

Adjustment of Apparatus

6. (a) Speed of Load Application. --Adjust the dash pot on the Rockwell tester so that the operating handle completes its travel in from 4 to 5 sec with no specimen on the machine and with the machine set up to apply a major load of 100 kg.

(b) Index Lever Adjustment. --Make the following tests (and adjustments, if necessary): Place a piece of material on the anvil and turn the capstan elevating nut to bring the material against the penetrator. Keep turning to elevate the material until the hand feels positive resistance to further turning, which will be felt after the 10-kg minor load has been picked up and when the major load is encountered. When excessive power would have to be used to raise the work higher, take note of the position of the pointer on the dial, after setting the dial so that C O and B 30 are at the top. Then if the pointer stands between B 50 and B 70 no adjustment is necessary; if the pointer stands between B 45 and B 50, adjustment is advisable; and if the pointer stands anywhere else, adjustment is imperative. As the pointer revolves several times when the work is being elevated, the readings mentioned above apply to that revolution of the pointer which occurs either as the reference mark on the gage stem disappears into the sleeve or as the auxiliary hand on the dial passes beyond the zero setting on the dial. The object of this adjustment is to see that the elevation of the specimen to pick up the minor load shall not be carried so far as to cause even a partial application of the major load, which to make a proper test, shall be applied only through the release mechanism.

Calibration with Test Blocks

7. (a) Select a test block as near as possible to the hardness of the material being tested (preferably within $\pm$ 5 hardness numbers for the C scale or scales using the diamond penetrator, and $\pm$ 10 hardness numbers for the B scale or scales using the ball penetrators). Make five impressions on the test surface of the block and compare the average thereof with the average of the five readings made in establishing the hardness value of the block. Take the difference between these two averages as the error of the machine. If the error is more than $\pm$ 2 hardness numbers (Section 3(f)), condition the machine and bring into adjustment until it comes within this limit before it is used.

(b) In the case of reinspection of material by the manufacturer and the purchaser (Note 3), they shall agree upon the standard test blocks to be used in checking and calibrating the Rockwell machines used.

REMARKS (continued)

B.S. 891 . . . . . (Appendix B). Hardness of calibrated specimen, as determined by a competent authority, should not vary at five points comprising the centre and corners by more than 1 unit for a specimen tested on the A and C scale, or more than 2 units for a specimen tested on the B scale. The hardness number of the calibrated specimen should be taken as the average of all five readings. It should be marked with two hardness numbers representing one unit above and below the average for a specimen tested on the A and C scales, one unit above and below the average for a specimen of 30 units, or greater hardness, on the B scale, and 2 units above and below the average for a specimen of less hardness than 30 units on the B scale.

Federal Method 243. The performance and accuracy of the machine shall be checked frequently by standard hardness test blocks which are supplied by the manufacturer of the machine.

ASTM E 18 . . . . . The hardness value of a test block shall be determined by making five impressions with a Rockwell tester of accepted accuracy, using the procedure described in Section 5. In the calibration of the test blocks, five readings shall be taken either at the four diagonal corners and one at the centre, or at four points approximately 90° apart on the periphery and one at the center. The total spread of these five hardness values shall not be more than two hardness numbers for blocks of B 30 or

specimen tested on the A and C scale or more than 2 units for a specimen tested on the B scale.

The hardness number of the calibrated specimen should be taken as the average of all five readings. It should be marked with two hardness numbers, representing one unit above and below the average for a specimen tested on the A and C scales; one unit above and below the average for a specimen of 30 units, or greater hardness, on the B scale; or 2 units above and below the average, for a specimen of less hardness than 30 units on the B scale.

No further methods of preparation, such as by machining, grinding or polishing, should be applied to the surface of the specimen after calibration.

(b) The hardness of the calibrated specimen used for the purpose of checking should be within five units of the hardness number determined for the material under test on the same scale.

(c) The accuracy of the apparatus may be considered satisfactory if five readings taken in the check test all lie within the range marked on the calibrated specimen.

Note 3.--When referee tests are to be made, the machine should be carefully gone over and all adjustments checked before calibrating it as described above. If readings of high accuracy are necessary, the machine may be calibrated before and after making the tests. If the machine has the same error both times, it can be safely assumed that the correction for this error will give the true Rockwell hardness, except under the conditions described in Section 4 (b).

(c) Test blocks shall be used only on the test surface because this is the only one that has been checked on the machine of accepted accuracy. Moreover, each impression has a small ridge around it, and if the block is tested on its reverse side, these ridges tend to be flattened under the pressure of the major load and may result in a low reading. Blocks should not be reground or otherwise resurfaced after they have been used up, because it is the top surface that was originally standardized and this may be of a different hardness from the new surface. The impressions work-harden the block to a considerable depth and this may result in the new test surface being in a work-hardened condition and not of the same hardness as the original test surface.

(d) When checking a complete range, the Rockwell range to be considered verified is that which exceeds the maximum and minimum test blocks values by plus or minus 5 points for the C scale or scales, using the diamond penetrator, and by plus or minus 10 points for the B scale or scales, using the ball penetrators.

Note 1. (Section 4)--In this note reference is made to a number of non-ferrous product specifications.

TABLE III. This table is a selector chart, based on specimen thickness and hardness, for scales using the diamond penetrator.

GENERAL DESCRIPTION OF ROCKWELL SUPERFICIAL HARDNESS METHOD

Sections 8, 9, 10, 11 and 12 deal with the Rockwell superficial hardness method in the same manner as the sections 1 to 7 deal with the Rockwell hardness method.

APPENDIX Table V and VI list corrections to be added to Rockwell values obtained with the diamond penetrator on cylindrical specimens of various diameters.

greater hardness nor more than three hardness numbers for blocks softer than B 30. Blocks for other scales shall have these same limits above and below the converted hardness value equivalent to B 30. The average of the five readings shall be taken as the true Rockwell hardness of the test block. The test blocks shall be marked with a range of values which will include all five of the readings.

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