U. S. DEPARTMENT OF COMMER
HENRY A. WALLACE, Secretary
NATIONAL BUREAU OF STANDARDS
E. U. CONDON, Director

Circular of the National Bureau of Standards C454

PROVING RINGS FOR CALIBRATING TESTING MACHINES

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[Issued August 14, 1946]

UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON : 1946

For sale by the Superintendent of Documents, U. S. Government Printing Office
Washington 25, D. C. - Price 10 cents

PREFACE

The trend in present-day engineering design is toward the use of efficient, lightweight structural elements and machine parts. Such elements have of necessity been utilized by aircraft and ordnance engineers, and their application is now being given increased attention by engineers in all fields. In the development of efficient designs it is necessary that materials be tested before being used as structural elements and machine parts to insure that they will have the required mechanical properties. Structures and subassemblies must also be tested to verify the soundness of design and point the way to still more efficient designs. This testing requires the use of accurate load-indicating testing machines. To insure the reliability of the test results obtained with load-indicating testing machines, frequent periodic calibration is recognized as being essential. A study of methods of calibrating testing machines, initiated at the Bureau some 25 years ago, showed the equipment then available to be inadequate and led to the development of the proving ring by H. L. Whittemore and S. N. Petrenko. The proving ring, because of its accuracy, constancy, and convenience, is now the most widely used device for the calibration of testing machines. Several hundred of these devices are now in service in commercial and government laboratories in this country and abroad. This Circular summarizes the Bureau's experience in the calibration and use of proving rings and makes recommendations for their proper use.

E. U. CONDON, *Director.*

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By Bruce L. Wilson, Douglas R. Tate, and George Borkowski

ABSTRACT

A description is given of the proving ring, which was developed at the National Bureau of Standards to provide an accurate portable load-measuring device for calibrating testing machines. Methods are described for calibrating proving rings by dead weights for loads up to 111,000 lb and by means of other calibrated proving rings for higher loads. Rings which complied with the specification included in the paper were subjected to tests to determine the errors introduced by variations of the conditions of use. Provided reasonable care is exercised in using proving rings, the errors are shown to be small compared to ±1 percent, the generally recognized tolerance for testing machines.

CONTENTS

I. INTRODUCTION

Experience at the National Bureau of Standards and in other laboratories in using testing machines that apply forces to engineering materials and structures has indicated the advisability of frequent periodic calibration of such machines, if reliable test results are to be obtained. To insure the accuracy of the results obtained with a machine, it is necessary that the calibration include loads up to the capacity load of the machine. Some types of low-capacity machines may be calibrated to capacity by means of standard weights or by means of standard weights and proving levers. Because these methods of calibration were not adequate for calibrating all types of small machines, and particularly, because they were inadequate for calibrating large testing machines, experiments were undertaken more than 20 years ago with portable elastic devices which could be calibrated under accurately known forces and then transported to the testing machine and used to measure the forces applied by the testing machine. These experiments led to the development of the proving ring [1, 2, 3][1] by H. L. Whittemore and S. N. Petrenko. The development and commercial production of the proving ring led to a greatly increased use of elastic calibration devices and made it necessary to provide facilities for the calibration of these devices. For calibrating devices up to 111,000 lb two dead-weight testing machines [4] have been installed at the Bureau. Methods of calibrating elastic devices for loads up to 300,000 lb by means of several 100,000-lb-capacity rings have been developed. The purpose of this paper is to describe the proving ring, its calibration, and performance under various conditions of use.

II. DESCRIPTION OF PROVING RINGS

1. DEFINITION

A proving ring is an elastic ring, suitable for calibrating a testing machine, in which the deflection of the ring when loaded along a diameter is measured by means of a micrometer screw and a vibrating reed mounted diametrically in the ring.

2. DESIGN

(a) SHAPE

A compression proving ring is shown in figure 1. Forces are applied to

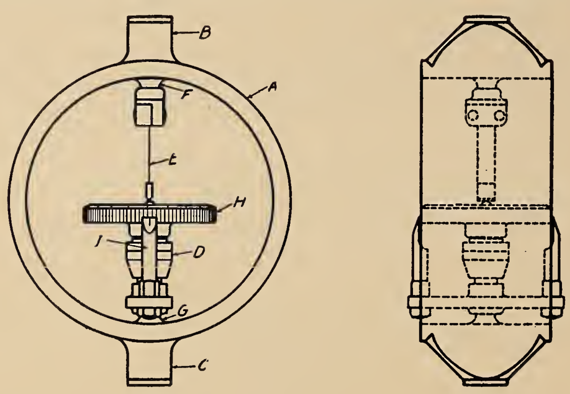

Figure 1.—*Proving ring for measuring compressive forces.*

the ring, *A*, through the integral external bosses, *B* and *C*. The resulting deflection of the ring is measured with a micrometer screw, *D*, and a vibrating reed, *E*, which are attached to integral internal bosses, *F* and *G*. By means of a graduated dial, *H*, and an index pointer, *I*, the deflection of the ring may be measured in divisions of the micrometer dial. A proving ring for measuring both tensile and compressive forces is shown in figure 2 with the tension fittings attached.

[1] Figures in brackets indicate the references given at the end of this paper.

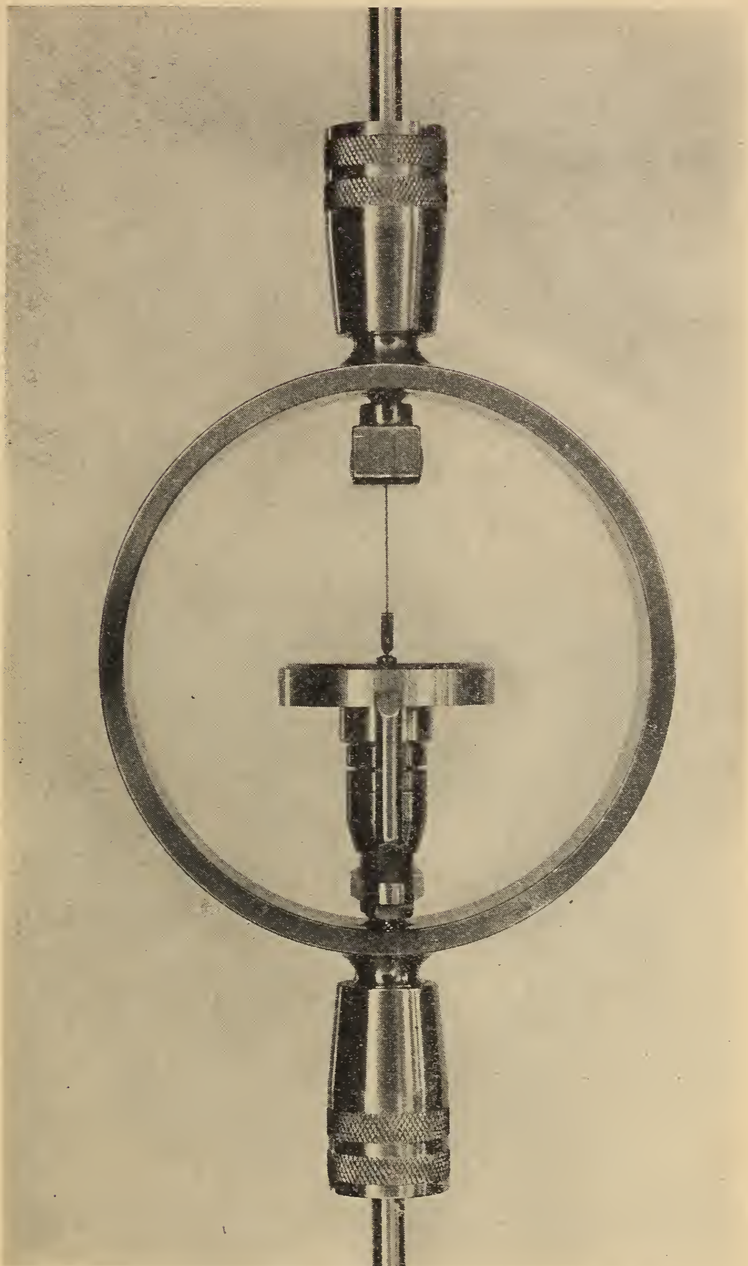

FIGURE 2.—*Proving ring for measuring both tensile and compressive forces, with tension fittings attached.*

The end of the lower external boss of a compression proving ring usually is plane and perpendicular to the axis of the bosses. The end of the upper external boss is usually convex. It is frequently made a portion of a sphere having as center the center of the end of the lower external boss and a radius equal to the over-all height of the ring. The external bosses of rings for measuring tensile forces are provided with tension fittings for applying forces to the ring. The fittings usually include spherical bearings to minimize eccentric loading of the ring.

(b) CAPACITIES

Compression rings having capacities from 300 lb to 300,000 lb, and tension rings having capacities as great as 100,000 lb have been submitted for calibration. The over-all heights of compression rings vary from about 6 in. for 2,000-lb rings to 19 in. for 300,000-lb rings. The weights of compression rings vary from about 2 lb for 2,000-lb rings to 150 lb for 300,000-lb rings.

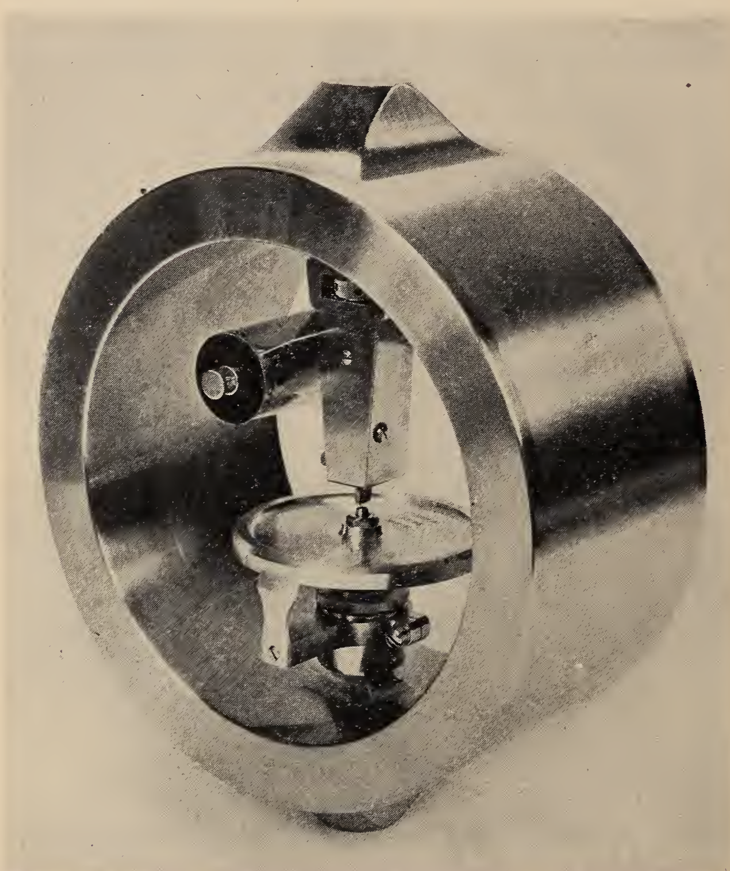

FIGURE 3.—*Proving ring equipped with electrically operated vibrating reed.*

The weights and heights of tension rings without tension fittings are a little greater than for compression rings of corresponding capacities.

(c) DEFLECTION-MEASURING APPARATUS

The vibrating reed and micrometer screw provide a sensitive and reliable means for measuring the change in diameter of the ring under load. When the reed is vibrating and the micrometer screw is adjusted so that the button on the spindle contacts the vibrating reed, a sensitive indication is produced, which varies rapidly as the button is advanced. Experience indicates that with micrometer screws having pitches varying from 40 to 64 threads per inch, as commonly supplied on most proving rings, readings may be made with a sensitivity of about one or two hundred thousandths of an inch.

Two types of vibrating reeds are used on proving rings; one type is operated manually and the other is driven electrically [5]. Figures 2 and 3 show proving rings having the two types of vibrating reeds. When reading a ring equipped with a manually operated vibrating reed, the lower end of the reed is pushed aside about ½ inch with the end of a pencil or other suitable object and released. Use of the finger is not recommended because changes in length of the reed with temperature change the reading of the ring. While the reed is vibrating, the dial is rotated, advancing the button into the path of the reed until a characteristic buzzing sound is produced, and the time required to reduce the amplitude from about ½ in. to zero amplitude is 2 or 3 seconds. Either or both of these effects may be used by the operator in setting the dial. With no contact between the reed and button, the vibration will continue from 10 to 15 seconds. An operator usually has no difficulty in obtaining reproducible readings to about ± 0.1 dial division at zero load. Different operators will obtain zero-load readings that differ by more than this amount, as will a single operator if he uses different sound intensities and different lengths of time for stopping the motion of the reed. As deflections of the ring are the differences between zero-load readings and load readings, it is important that the operator adjust the dial in the same way in making each reading. Different operators will obtain comparable deflections even though their methods of adjusting the dial differ.

With the electrically driven reed the best results are obtained by turning the dial to advance the button just far enough to interfere with the vibration of the reed. This condition can be detected better by watching the change in amplitude of the reed than by listening for the change in intensity or frequency of the sound. Readings taken by advancing the button until a large change in amplitude is produced or until the motion is nearly stopped have been found much less reliable than readings taken in the manner described above.

Experience indicates that the combination of a well-made micrometer screw and vibrating reed is about equal in sensitivity and superior in ruggedness and accuracy to dial micrometers for measuring the deflections of elastic devices. The best dial micrometers commercially available have errors several times the errors of well-made micrometer screws. For this reason, the American Society for Testing Materials [6] permits the use of devices having dial micrometers only at the test loads for which they have been calibrated.

(d) DEFLECTION

Proving rings are usually designed to have a deflection of 0.05 to 0.10 in. under capacity load. The dimensions of a ring that will have approximately a desired deflection may be computed by means of equations given in engineering textbooks. Equations for computing the deflection of plain rings loaded at opposite ends of a diameter have been published by Timoshenko, Bach and Baumann, and Larard [7, 8, 9, 10]. For a plain ring having a rectangular cross section, the equation given by Timoshenko reduces to the following:

$$d=\frac{Pr^2}{eElt}\left\{\frac{\pi}{4}-\frac{2}{\pi}\left(1-\frac{e^2}{r^2}\right)+\frac{2e}{r}\left[\frac{2}{\pi}\left(1-\frac{e}{r}\right)+0.265\pi\right]\right\},$$

where

d = deflection of the ring in the direction of the loaded diameter, in.

P = applied load, lb
r = radius of the centerline of the ring, in.
E = Young's modulus of elasticity for the material of the ring, lb/in.^{2}
l = width of the cross section of the ring, in.
t = thickness of the cross section of the ring, in.

$$e=r-\frac{t}{\log_n\dfrac{1+\frac{1}{2}\frac{t}{r}}{1-\frac{1}{2}\frac{t}{r}}}.$$

Actually, the measured deflections of proving rings are about 25 percent less than the deflections computed by means of equations derived for plain rings because of the stiffening effect of the integral bosses. As the relationship between the deflection of a proving ring and the applied load is determined by applying accurately known forces to the ring, the derivation of an equation which would take into account the stiffening effect of the bosses is unnecessary.

(e) STRESS

To obtain satisfactory elastic behavior of a ring, the maximum stress must be less than the stress required to produce an appreciable permanent set in the material. Equations for computing the maximum bending moment in a plain ring loaded at opposite ends of a diameter are given by Timoshenko, Bach and Baumann, and Larard [7, 8, 9, 10]. The following equation derived from Timoshenko's results gives the maximum stress for a ring having a rectangular cross section:

$$\sigma_{max}=\frac{Pr}{elt\pi}\left(1-\frac{e}{r}\right)\frac{\left(\frac{t}{2}-e\right)}{\left(r-\frac{t}{2}\right)},$$

where

σ_{max} = maximum fiber stress across the inner cylindrical elements passing through the load line, lb/in.^{2}
P = applied load, lb
r = radius of the centerline of the ring, in.

l = width of the cross section of the ring, in.
t = thickness of the cross section of the ring, in.

$$e = r - \frac{t}{\log_n \dfrac{1 + \frac{1}{2}\frac{t}{r}}{1 - \frac{1}{2}\frac{t}{r}}}.$$

This equation for plain rings does not apply accurately to proving rings having integral bosses (fig. 1) because the bosses influence the stress distribution in the plane containing the maximum bending moment. Experience has demonstrated that stress values calculated by the above equation are satisfactory for design purposes, provided there are adequate fillets where the bosses join the ring and no "stress raisers" are present. Breakage of some rings through holes and stamped numbers has indicated the desirability of avoiding holes, stamped numbers, tool marks, cracks, etc.

Except for rings having deflection-measuring apparatus attached by means of plugs or screws, computed working stresses as high as 150,000 to 165,000 lb/in.^{2} have been found satisfactory.

(f) MATERIAL AND FINISH

Proving rings are usually made of alloy steel, rough-machined from annealed forgings, heat treated, and then ground to size. Probably rings unpolished after heat treatment or finished by some other method would be satisfactory. One chromium-plated ring has given satisfactory service for several years at the Bureau.

Satisfactory proving rings designed along the lines indicated in the preceding sections have been made from a steel having the following chemical composition: Carbon, 0.50 percent; chromium, 1.00 percent; and nickel, 1.75 percent. This steel is heat treated to give about the following properties in tensile tests:

Yield strength (offset=0.05 percent)	210,000 lb/in.^{2}
Tensile strength	230,000 lb/in.^{2}
Elongation in 2 inches	8 percent.

III. CALIBRATION

1. GENERAL

All proving rings submitted for calibration at the National Bureau of Standards are calibrated for compliance with the performance specification given in the appendix, section VIII. This specification does not give detailed requirements for the design of proving rings, but it does include performance requirements that have been found necessary to insure that rings will maintain their calibrations satisfactorily with ordinary use and with the handling to which rings shipped by commercial carriers are subjected.

Proving rings are calibrated by determining the relationship between accurately known forces and the corresponding deflections.

2. LOADS NOT EXCEEDING 111,000 LB

Two dead-weight testing machines [4] have been installed at the National Bureau of Standards for calibrating elastic calibration devices.

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With the larger machine, compressive and tensile loads from 2,000 lb to 111,000 lb by 1,000-lb increments may be applied. With the smaller machine, loads from 200 lb to 10,100 lb by 100-lb increments may be applied. The errors of the weights do not exceed about 0.01 percent.

3. LOADS EXCEEDING 111,000 LB

Calibration loads exceeding 111,000 lb are applied to large proving rings by means of three calibrated 100,000-lb-capacity proving rings as shown in figure 4. The three nearly identical calibrated rings are placed

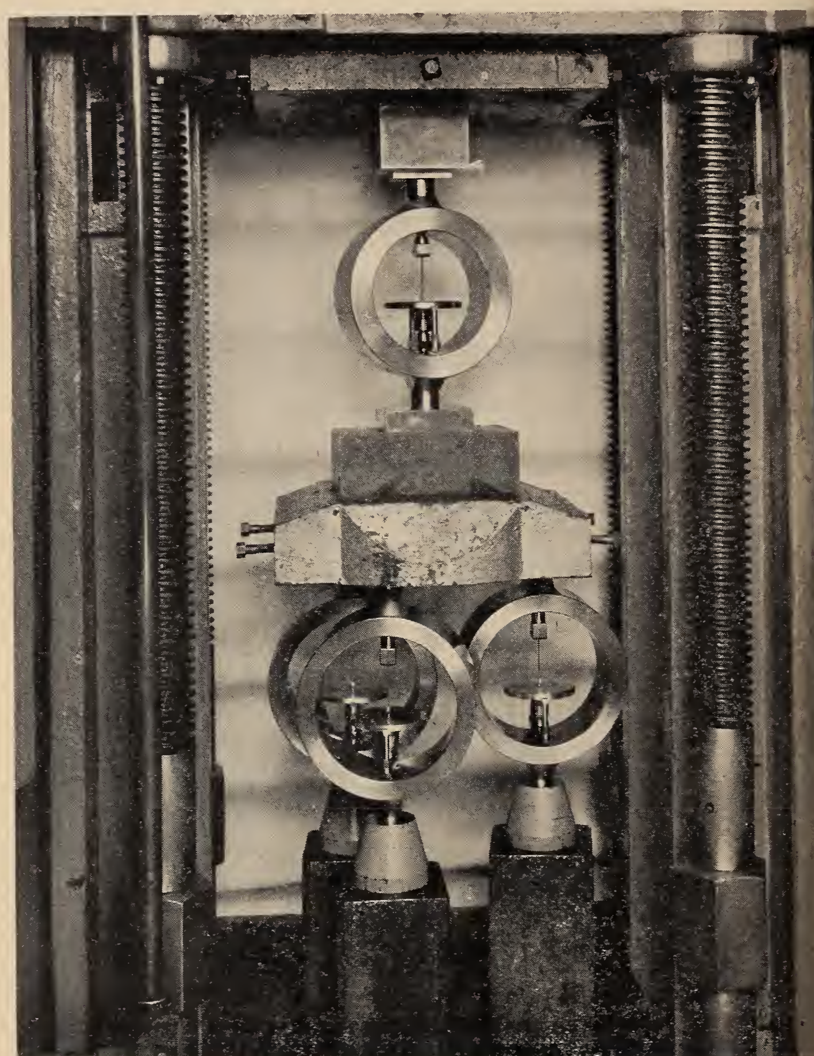

Figure 4.—*Calibration of a proving ring for loads exceeding 111,000 lb by means of three calibrated 100,000-lb-capacity proving rings.*

in a vertical testing machine at the corners of a triangle so oriented that the centroid of the triangle lies on the axis of the machine. A thick steel plate is placed over the upper bosses of the three rings. The ring to be calibrated is placed on a hardened block on the plate above the three rings and so located that when forces are applied to the rings by means of the testing machine, the deflections of the three lower rings are equalized to within about 1 percent.

During the calibration the load indicated by the testing machine is disregarded. The four proving rings are read simultaneously while the load is held constant or increased very slowly. The force applied to the ring being calibrated is the sum of the forces measured by the three previously calibrated rings.

This method of calibration has been used for loads up to 300,000 lb, the capacity load of the largest compression ring submitted for calibration. The errors of measuring the load applied to the ring being calibrated do not exceed 0.1 percent. Calibration factors (see below) computed from results obtained in the dead-weight machine and from results obtained on the same rings by the method described fit smooth curves about equally well. The relatively smaller observational error in determining the deflection of the ring for the higher loads compensates for the greater errors of the loads measured with the three rings so that the departure of individual calibration factors is little greater for a given ring for loads exceeding 111,000 lb than for loads applied by dead weights.

4. LOADING PROCEDURE

Proving rings are calibrated by increasing the loads to the test loads. Compressive loads, except those on concave and convex bearing blocks [appendix, paragraph II-5(d)], are applied to the lower boss of a ring through a plane, hardened steel bearing block and to the upper boss either through a ball or a soft-steel block. Tensile loads are applied to a ring through pulling rods provided with the ring. The tension fittings usually include two or more spherical bearings so that the ring will not be loaded eccentrically.

Proving rings are usually calibrated for 10 approximately equally spaced loads from 10-percent-capacity load to capacity load. A preliminary preload to capacity is desirable to stabilize the no-load reading of the ring. Before and after each load reading, a no-load reading of the ring is observed. The deflection of the ring is computed as the difference between the load reading and the average of the no-load readings observed immediately before and after the application of the load. For each deflection the calibration factor, which is the ratio of the load to the corresponding deflection, is computed.

5. CALIBRATION GRAPH

The calibration factors are plotted on the calibration graph as a function of the deflection, as shown in figure 5. Well-made rings in good condition exhibit a nearly linear relationship between the calibration factors and the deflection. The calibration factor for compression rings decreases with increasing ring deflection, as shown in figure 5. The calibration factor for tension rings increases with increasing ring deflection.

In using the ring the load is computed from the ring readings by multiplying the ring deflection by the calibration factor read from the calibration graph.

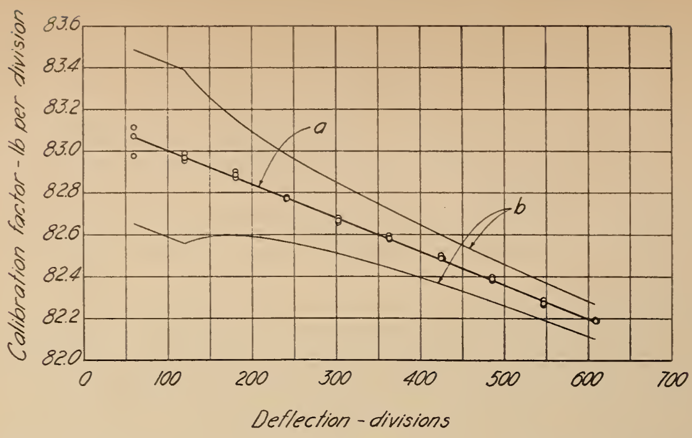

FIGURE 5.—*Calibration graph for 50,000-lb-capacity compression proving ring.*
Line "a" represents the calibration line for 70° F; line "b" represents the specification limits.

6. TEMPERATURE COEFFICIENT

Because the dimensions and the elastic properties of a ring change with temperature, the deflection of a ring for a given load varies with the temperature. The variation is not large for small temperature changes; usually it is less than 0.02 percent per degree Fahrenheit. Calibration results for proving rings are given for a temperature of 70° F. When the rings are used to calibrate testing machines and the ring temperature is different from 70° F, the results may be corrected for temperature by the formula

$$d_{70} = d_t\,[1 + K\,(t - 70)],$$

where

d_{70} = deflection of ring at a temperature of 70° F
d_t = deflection of ring at a temperature of t degrees Fahrenheit
K = temperature coefficient of the ring
t = temperature, degrees Fahrenheit, during test.

The temperature coefficient, K, depends primarily upon the temperature coefficient of Young's modulus for the material of the ring. The temperature coefficient of Young's modulus for steels depends upon the chemical composition of the steel and its heat treatment. For rings made of steels having a total alloying content not exceeding 5 percent, the value $K = -0.00015$ per degree Fahrenheit has been found sufficiently accurate. For some other steels, values of the temperature coefficient of Young's modulus of elasticity, that would result in values of K ranging from -0.00011 to -0.00024 have been observed. Most of the proving rings submitted for calibration are made of steel having a total alloying content not exceeding 5 percent.

Calibrations of proving rings in the dead-weight machines at the National Bureau of Standards are made at 70° F, whereas calibrations at loads beyond the capacity of these machines are made at room temperature, usually in the range 65° to 90° F, and then corrected to 70° F.

IV. USE

1. CALIBRATION OF TESTING MACHINES

Proving rings are used primarily for calibrating testing machines, the purpose for which they were developed. In figure 6, a 100,000-lb-capacity compression proving ring is shown in a vertical hydraulic testing machine. The ring, together with bearing blocks through which the loads are applied to the external bosses, takes the place of the specimen in the machine. When rings are used for calibrating horizontal testing machines, the no-load ring readings are taken with the rings supported by their external bosses.

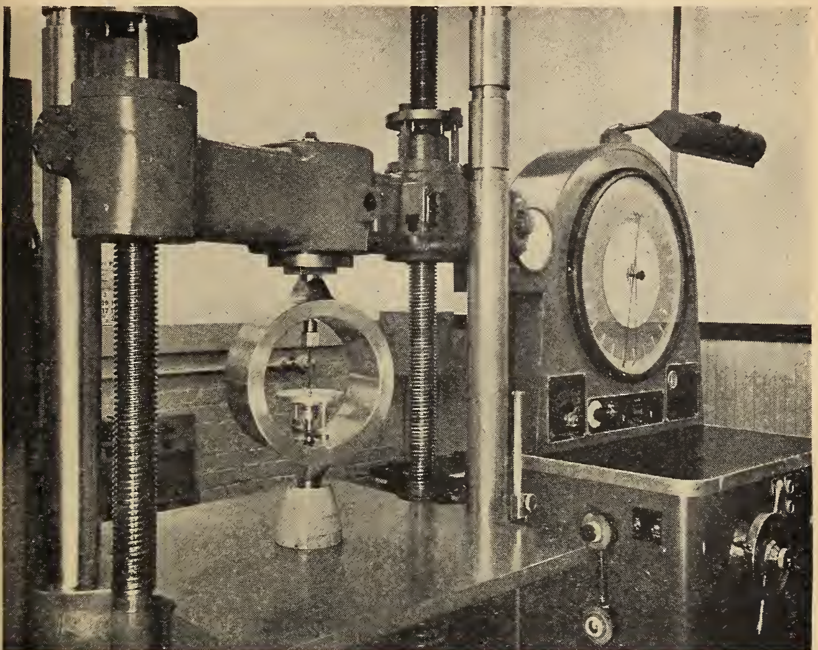

FIGURE 6.—*Proving ring in testing machine ready for the calibration of the testing machine in compression.*

In carrying out a calibration, two operators are required to read the indicated load of the testing machine and the ring simultaneously. The temperature of the air near the ring is recorded so that the proper temperature corrections may be applied.

A sample data sheet for the partial calibration of one scale range of a testing machine is given in table 1.

The results in the first three columns of table 1 were observed during the calibration. The results in the fourth column were obtained by subtracting from each load reading the average of the no-load readings taken before and after the load reading. The ring load was computed by multiplying the ring deflection for 70° F by the corresponding calibration factor. The error in pounds was computed by subtracting the ring load from the machine reading.

TABLE 1.—*Data sheet for the partial calibration of 200,000-lb scale range of hydraulic testing machine with a 100,000-lb-capacity proving ring*

Machine reading	Temperature	Ring reading	Ring deflection	Ring[a] deflection for 70° F	Calibration factor[b]	Ring load	Error of testing machine	Percentage error of testing machine
lb	*° F*	*div.*	*div.*	*div.*	*lb/div.*	*lb*	*lb*	
0	79	32.1						
60,000		442.7	410.6	410.05	145.85	59,806	+194	+0.32
0		32.1						
80,000		581.2	549.05	548.31	145.58	79,823	+177	+ .22
0		32.2						
100,000		719.6	687.4	686.47	145.31	99,751	+249	+ .25
0		32.2						
60,000		442.8	410.6	410.05	145.85	59,806	+194	+ .32
0		32.2						
80,000		580.8	548.6	547.86	145.58	79,757	+243	+ .30
0		32.2						
100,000		719.4	687.4	686.47	145.31	99,751	+249	+ .25
0	79	31.8						

[a] Ring deflection for 70° F = Ring deflection for 79° F (1 − 9 × 0.00015)
[b] Read from the calibration curve or calculated from the equation:
Calibration factor = 146.66 − 0.00197 × deflection for 70° F.

To obtain information concerning the reproducibility of the readings of a testing machine the errors are frequently determined for two or more

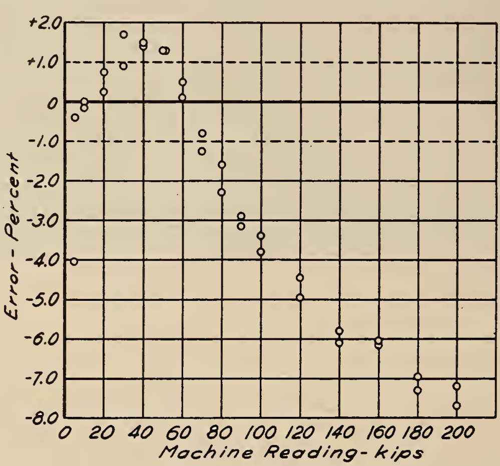

FIGURE 7.—*Calibration results obtained on a 200,000-lb-capacity testing machine in need of repairs.*

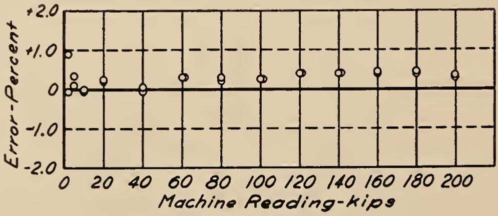

FIGURE 8.—*Calibration results obtained on a 200,000-lb-capacity testing machine in good condition.*

applications of the same indicated testing-machine loads. The results of complete calibrations of two testing machines are given in figures 7 and 8 to illustrate results for machines in unsatisfactory and satisfactory conditions. The American Society for Testing Materials [6] tolerance lines of ±1 percent are shown by the dashed lines. The machine found to be unsatisfactory (fig. 7) had been in regular use prior to its calibration.

Several rings may be used together, as shown in figure 9, to calibrate machines having capacities exceeding the capacity of a single ring. The

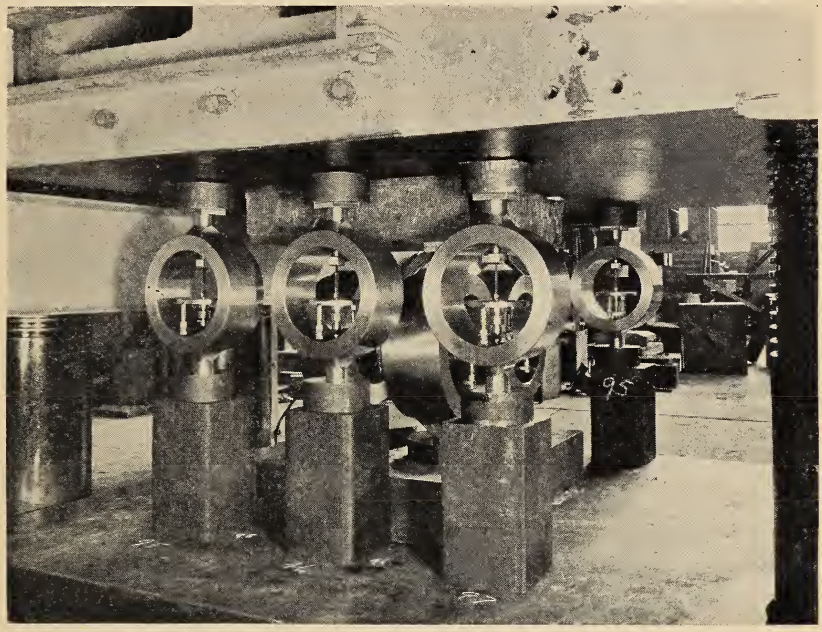

FIGURE 9.—*Eight compression proving rings arranged to be loaded in parallel to obtain test loads equal to the sum of the forces applied to the individual rings.*

indicated load of the testing machine and the rings are read simultaneously, and the ring load is computed as the sum of the loads carried by the individual rings. By this method, calibrations have been made with proving rings for loads up to about 2 million pounds.

2. OTHER USES

Proving rings have also been used as dynamometers, for weighing elevator cars, and for weighing bridge reactions [11].

V. ERRORS

1. ERRORS DUE TO VARIATIONS IN LOADING SCHEDULE

During calibration proving rings are read within a few seconds after the load is applied or removed and a no-load reading is observed before and after each load reading. It is not always possible to follow such a time schedule in using proving rings, and it is sometimes necessary to use them for measuring decreasing as well as increasing loads. To determine the errors that might result from such variations in the conditions of use, dead-weight tests at 70° F were made on three rings having capacities of 3,000 kg, 20,000 lb, and 100,000 lb. Each of the rings had been calibrated and found to comply with the requirements of the specification given in the appendix.

After having been unloaded for more than 24 hours, each ring was loaded to capacity and kept under capacity load for 3 hours. Ring readings were observed as soon as possible after the load was fully applied and again after intervals from ½ minute to 3 hours after application. The maximum observed creep under capacity load for the 3-hour period was 0.05 division, or 0.01 percent of the capacity load.

After each ring had remained under capacity load for 3 hours, the load was completely removed. The no-load reading of the ring was observed as soon as possible and again after intervals from ½ minute to 3 hours after removal of the load. In every case the no-load reading changed during the first half-hour of the 3-hour period. The maximum observed zero shift was 0.4 division, or 0.06 percent of the capacity deflection. Within 32 minutes for the 3,000-kg and 20,000-lb rings and within 64 minutes for the 100,000-lb ring, the no-load readings equalled the no-load reading observed before the application of the capacity load.

The hysteresis at half-capacity load was determined for each ring by computing the difference between the ring readings at half-capacity load observed before and after the application of capacity load. The results indicated a hysteresis of 0.10 percent for the 3,000-kg and 100,000-lb rings and 0.15 percent for the 20,000-lb ring.

2. ERRORS DUE TO INSTANTANEOUS TEMPERATURE EFFECT

When a proving ring is loaded, both tensile and compressive stresses are set up in the material of the ring. An increase in temperature occurs in the material subjected to compressive stresses, and a decrease in temperature occurs in the material subjected to tensile stresses [12, 13]. Consequently, the reading of a suddenly loaded (or unloaded) proving ring changes as the temperature throughout the material of the ring becomes equalized. This equalization occurs so rapidly that it may be ignored without significant error in rings not exceeding 100,000-lb capacity. For larger rings, errors due to this cause become negligible if readings are taken no sooner than 30 seconds after removal of load. No delay in taking readings under load is necessary because with ordinary testing machines the time required to apply and adjust the test load and read the ring is great enough to permit nearly complete temperature equalization.

3. ERRORS DUE TO ANGLE OF LOAD LINE

If a proving ring is loaded through suitable bearing blocks or tension fittings in a testing machine whose platens are plane and parallel, the load line will be very nearly coincident with the axis of the bosses of the ring. For compression rings a lack of parallelism of the heads of the testing machine may result in an inclination of the load line with respect to the axis of the bosses of the ring.

To determine the magnitude of the error introduced by an inclination of the load line, a 100,000-lb-capacity compression proving ring was loaded in the 111,000-lb-capacity dead-weight machine through 2- and 4-degree wedges, as shown in figure 10. The errors resulting from these

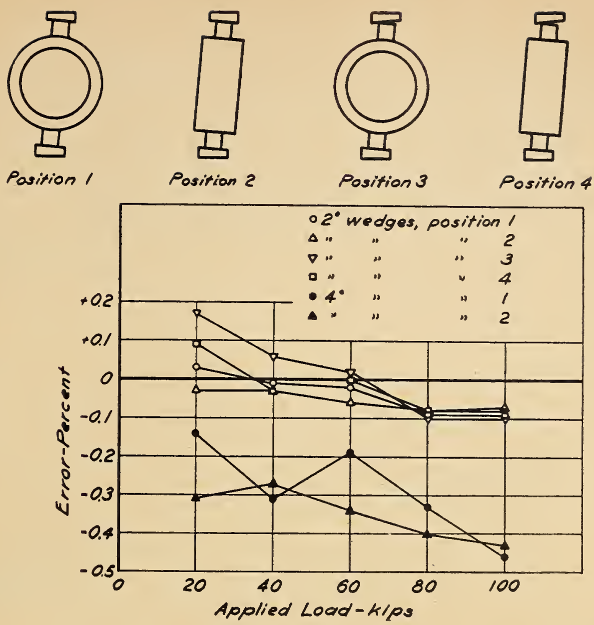

FIGURE 10.—*Effect of the angle of the load line on the calibration of a 100,000-lb-capacity proving ring.*

conditions of loading are plotted in percent as a function of the applied load. The maximum errors introduced by the 2-degree wedges were about 0.17 percent at 20-percent-capacity load and 0.1 percent at capacity load, values which do not exceed the tolerances of 0.5 percent and 0.1 percent, respectively, given in the Bureau specification for proving rings. The maximum error introduced by the 4-degree wedges was about 0.46 percent at capacity load.

As an angle of less than 2 degrees can easily be detected by inspection, there is no reason for the occurrence of appreciable errors due to inclination of the load line.

4. ERRORS DUE TO CHANGE OF CALIBRATION WITH TIME

The relationship between the deflection of a proving ring and the applied load depends not only upon the dimensions of the ring but also upon the elastic constants of the material of the ring. Provided the dimensions are not altered by removing material or by plating the surface, and provided a ring has not been overloaded or subjected to sufficient wear to introduce errors from these causes, a study of the constancy of the calibration with time may be expected to indicate the magnitude of any change in elastic constants with time.

Experience indicates that there is no appreciable aging effect for rings made of the steel described on page 7. The results of a study of the calibrations of three 300,000-lb-capacity rings for a 12-year period are given in figure 11. Each ring was calibrated seven times during this

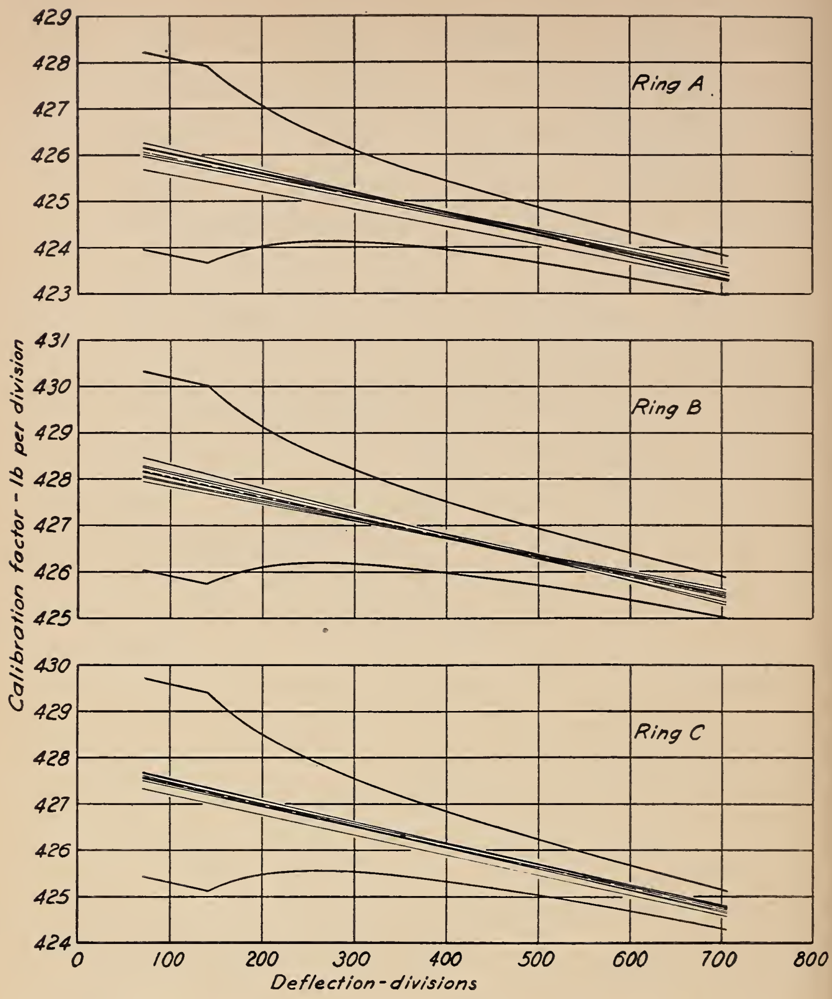

FIGURE 11.—*Effect of time and use on the calibrations of three proving rings for calibrations spaced over a period of years.*

The dashed line represents the average of the individual calibration lines indicated by the light lines which were drawn to represent experimental points not shown. The curved lines are the specification limits corresponding to the average calibration line.

period. The individual lines drawn to represent each calibration are shown as solid lines. An "average" calibration line for each ring is shown by a dashed line. Specification limits corresponding to the dashed line, computed as defined in the appendix, are shown for each ring. It is evident that the changes in calibration with time are small compared to the tolerances for constancy. Furthermore, the small changes observed indicated no progressive trend but were apparently random changes of a magnitude about equal to the experimental error of determining a given calibration line. Experience with other capacities of rings is in accord with the results given for the 300,000-lb rings.

5. ERRORS DUE TO WEAR

Each time the reading of a proving ring is observed, the end of the vibrating reed repeatedly strikes the button on the spindle of the micrometer screw, tending to wear the contacting surfaces. Although the rate at which metal is worn away varies with the operator and frequency of use, ultimately the alteration in the shapes of the surfaces leads to errors in the measured deflections of the ring.

Errors of this type generally may be observed as a cyclic departure of the calibration points from the straight line of the calibration curve,

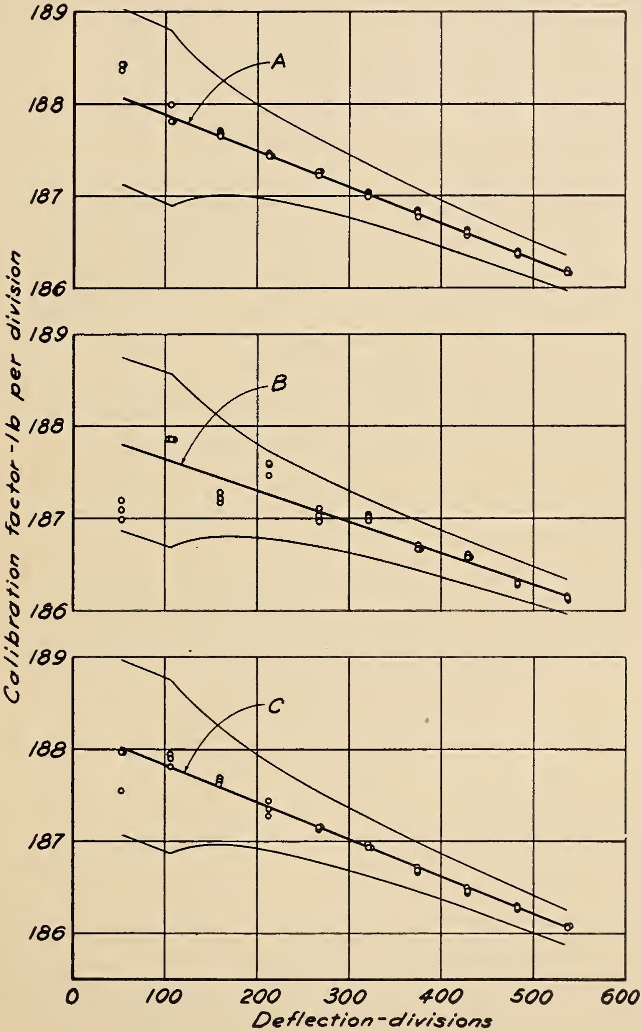

FIGURE 12.—*Effect of wear on the calibration results.*

A, Original calibration of a new ring; *B*, calibration of the same ring after considerable use; and *C*, calibration of the same ring after reconditioning of the worn surfaces of the deflection-measuring apparatus after the calibration marked *B*.

as shown in figure 12. In this figure, *A* shows the original calibration of a 100,000-lb-capacity ring, *B* shows the calibration made after considerable use, and *C* shows the calibration made after the worn surfaces of the deflection-measuring apparatus had been refinished. Experience indicates that for rings used frequently the worn surfaces should be refinished at intervals of 2 or 3 years.

The calibration of a ring that has been overloaded sufficiently to produce a set is permanently changed, and the ring should be recalibrated after any necessary repairs. A considerable number of rings have been recalibrated after having been overloaded and reconditioned and have shown satisfactory performance.

VI. CONCLUSIONS

Proving rings that comply with the specification included in the appendix are suitable for determining the errors of the indicated loads of testing machines. Such rings, provided they are not overloaded, subjected to excessive wear or otherwise damaged, maintain their calibrations without significant change over periods as long as 12 years. However, it is recommended that rings be recalibrated after intervals of from 1 to 2 years. Even under unusual conditions of use the errors of proving rings certified to comply with the specification given in the appendix are small compared to the generally recognized tolerance of ±1 percent for testing machines.

VII. REFERENCES

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VIII. APPENDIX

NATIONAL BUREAU OF STANDARDS SPECIFICATION FOR PROVING RINGS FOR CALIBRATING TESTING MACHINES

(Letter Circular LC 822, April 15, 1946)

INTRODUCTION

The National Bureau of Standards has had more than twenty-five years of experience in calibrating testing machines which apply forces to engineering materials. This experience has indicated the advisability of frequent periodic calibration of such machines, if reliable test results are to be obtained. It also indicated the need for a calibrating device which would be sufficiently accurate for the purpose and at the same time more readily portable and convenient in use than the devices previously available. Proving rings were developed at the National Bureau of Standards to meet this need.

This specification is the result of over 20 years' experience in the development of proving rings and in calibrating them periodically in dead-weight calibrating machines. It contains requirements which have been found necessary to insure that proving rings complying with them will be satisfactory, reliable instruments for calibrating testing machines.

These technical requirements are identical with those in Letter Circular 657, which this specification supersedes. The simplified procedure for the recalibration of rings previously certified is justified by the experience of the past 7 years.

I. DEFINITIONS

1. PROVING RING

A proving ring is an elastic ring, suitable for calibrating a testing machine, in which the deflection of the ring when loaded along a diameter is measured by means of a micrometer screw and a vibrating reed mounted diametrically in the ring.

2. READING

A reading is the value indicated by the micrometer dial when it has been adjusted to contact the vibrating reed.

3. DEFLECTION

The deflection of the ring for any load is the difference between the reading for that load and the reading for no load.

4. CALIBRATION FACTOR

The calibration factor for a given deflection is the ratio of the corresponding load to the deflection.

II. COMPLETE CALIBRATION

1. MARKING

The maker's name, the capacity load, and the serial number of the ring shall be legibly marked upon some part of the instrument.

2. MICROMETER DIAL

(a) The dial of the micrometer shall be of the uniformly graduated type. When successive graduation lines on the dial are set to one fixed index line, the positions of successive graduation lines nearly diametrically opposite referred to another fixed index shall differ from each other by not more than 1/20 of the smallest division of the dial.

(b) The smallest division of the dial shall be not less than 0.05 inch and not more than 0.10 inch.

(c) The width of any graduation line on the dial shall not exceed one-tenth of the average distance between adjacent graduation lines.

(d) The width of any index line shall be not less than 0.75 and not more than 1.25 times the average width of the graduation lines on the dial.

3. OVERLOAD

The ring shall be overloaded repeatedly to a load of not less than 9 percent nor more than 10 percent in excess of the capacity load. The difference between the no-load reading after the first overload and the no-load reading after any subsequent overload shall not exceed one-tenth of one percent of the deflection of the ring under capacity load.

4. STIFFNESS

Under the capacity load the ring shall deflect not less than 0.040 inch.

5. CONSTANCY

(a) *Range 1/10 to 2/10-Capacity Load.*—The observed deflection of the ring, for an applied load of not less than one-tenth nor more than two-tenths of the capacity load, shall differ from the average of at least three successive observations for the same applied load by not more than one-half of one percent of the deflection for the applied load.

(b) *Range 2/10 to Capacity Load.*—The observed deflection of the ring, for any applied load not less than two-tenths nor more than the capacity load, shall differ from the average of at least three successive observations for the same applied load by not more than one-tenth of one percent of the deflection for the capacity load.

(c) *Disassembling.*—The difference between the deflections of the ring, observed before and after the deflection-measuring apparatus is removed and then replaced, shall be not greater than the maxima specified in paragraphs II-5(a) and II-5(b) of this specification, under the loads there specified.

(d) *Bearing Blocks.*—A compression proving ring shall be loaded through plane, concave, and convex bearing blocks. The deflections of the proving ring for the minimum load and for the maximum load applied by dead weights during the calibration shall be determined when the load is applied to the lower boss of the ring through concave and convex bearing blocks. The difference between the average deflections observed using the concave bearing block and the average deflections observed using a plane bearing block for the same loads shall not exceed the maxima specified in paragraphs II-5(a) and II-5(b) of this specification. The differences between the average deflections observed using the convex bearing block and the average deflections observed using a plane bearing block for the same loads shall not exceed the maxima specified in paragraphs II-5(a) and II-5(b) of this specification. The concave and convex bearing blocks shall comply with the following requirements:

(1) They shall be steel.
(2) The Brinell numbers shall be not less than 400 and not more than 600.
(3) The radii of curvature of the spherical surfaces shall be not less than 9 feet and not more than 10 feet.

III. RECALIBRATION

1. CONSTANCY

(a) *Range 1/10 to 2/10-Capacity Load.*—The observed deflection of the ring, for an applied load of not less than one-tenth nor more than two-tenths of the capacity load, shall differ from the average of at least three successive observations for the same applied load by not more than one-half of one percent of the deflection for the applied load.

(b) *Range 2/10 to Capacity Load.*—The observed deflection of the ring, for any applied load not less than two-tenths nor more than the capacity load, shall differ from the average of at least three successive observations for the same applied load by not more than one-tenth of one percent of the deflection for the capacity load.

(c) *Comparison with Last Calibration.*—The observed deflections of the ring during recalibration shall differ from the deflections observed at the time of the last calibration by not more than the maxima specified in paragraphs III-1(a) and III-1(b) of this specification, under the loads there specified.

(d) *Alternative Procedure.*—If the ring fails to comply with the requirements of paragraph III-1(c) of this specification, the deflection-measuring apparatus shall be removed and then replaced. The difference between the deflections observed before and after this is done shall be not greater than the maxima specified in paragraphs III-1(a) and III-1(b) of this specification, under the loads there specified.

IV. METHOD OF CALIBRATION

1. COMPLETE CALIBRATION

The proving ring shall be calibrated in accordance with the requirements given in section II, Complete Calibration:

(a) If the ring has not been calibrated by the National Bureau of Standards since the revision of this specification on April 4, 1934.

(b) If the ring was not certified when last calibrated by the National Bureau of Standards.
(c) If the ring has been repaired or modified since its last calibration by the National Bureau of Standards.

2. RECALIBRATION

Except as provided in paragraphs IV-1(a), IV-1(b), and IV-1(c), Complete Calibration, a ring shall be recalibrated in accordance with the requirements given in section III, Recalibration.

3. LOADS NOT EXCEEDING 110,000 LB

For loads not exceeding 110,000 lb the proving ring shall be calibrated by applying dead weights known to within 0.02 percent.

4. LOADS EXCEEDING 110,000 LB

For loads exceeding 110,000 lb the applied load shall be known to within 0.1 percent.

5. LOADING PROCEDURE

The proving ring shall be calibrated under increasing loads. Compressive loads, except as provided in paragraph II-5(d), shall be applied to the lower boss of the ring through a plane, hardened-steel bearing block and to the upper boss either through a ball or a soft-steel block. Tensile loads shall be applied to the ring through the pulling rods provided with the ring.

6. TEMPERATURE CORRECTION

To compensate for temperature changes which occur during calibration, the deflections of the proving ring shall be corrected for temperature using the formula

$$d_{70} = d_t\,[1 + K\,(t - 70)],$$

where

d_{70} = deflection of ring at a temperature of 70° Fahrenheit

d_t = deflection of ring at a temperature of t degrees Fahrenheit

K = temperature coefficient

t = temperature, degrees Fahrenheit, during test.

The coefficient K depends upon the chemical composition of the steel of which the ring is made and its heat treatment. For steels having a total alloying content not exceeding five percent, the value $K = -0.00015$ per degree Fahrenheit is sufficiently accurate. For some other steels, values of K have been found ranging from -0.00011 to -0.00024. When the proving ring is submitted for calibration, the value of K shall be furnished this Bureau by the person submitting the ring or by the manufacturer of the ring.

V. METHOD OF REPORTING RESULTS

1. CERTIFICATES OF CALIBRATION

For a ring which complies with the requirements of this specification, a certificate of calibration will be issued including a calibration graph showing the calibration factor as a function of the ring deflection.

2. REPORTS

For a ring which does not comply with the requirements of this specification, a report will be issued giving the results in the form of a table and stating wherein the ring fails to comply.

WASHINGTON, March 25, 1946.

☆ U. S. GOVERNMENT PRINTING OFFICE: 1946—697580