NBS SPECIAL PUBLICATION 355

Universal Testing Machine of 12-Million-lbf Capacity at the National Bureau of Standards

U.S. DEPARTMENT OF COMMERCE
National Bureau of Standards

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FOREWORD

As a result of a number of structural failures, exemplified by the disastrous collapse of a lattice column during erection of the first Quebec bridge in 1907, the Federal Government became deeply involved in structural-material testing. In 1910 this work was consolidated at the National Bureau of Standards and expanded through the acquisition of a 10,000,000 lbf compression testing machine originally contracted for by the Geological Survey.

This large testing machine, and other facilities of the Engineering Mechanics Section of NBS, were used for extensive research into the mechanical behavior of such structural components as columns, struts, masonry walls, ship structures, and bridge members. When the NBS relocation to the Gaithersburg, Maryland, site was being planned, it was evident that the 10,000,000 lbf capacity machine was inadequate for current and projected needs. A modern machine, incorporating the technological advances of recent years, was needed to enable NBS to continue its leadership in research on large structural components and in calibration of large force measuring devices. These plans resulted in the development and construction of a unique 12,000,000 lbf capacity universal testing machine.

This machine represents a significant addition to the Nation's facilities for research and testing in the field of large structures. The National Bureau of Standards welcomes the opportunity to use this unique facility in cooperation with academic, industrial and government organizations in solving a wide variety of problems of National concern.

Lewis M. Branscomb, Director

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In view of present accepted practice in this technological area, U. S. customary units of measurement have been used throughout this paper. It should be noted that the U. S. is a signatory to the General Conference on Weights and Measures which gave official status to the metric SI system of units in 1960. Readers interested in making use of the coherent system of SI units will find conversion factors in ASTM Standard Metric Practice Guide, ASTM Designation E 380-70 (available from American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103). Conversion factors for units used in this paper are:

Length	1 in = 0.0254* meter 1 ft = 0.3048* meter
Force	1 lbf = 4.448 newton
Stress	1 lbf/in^2 = 6895 newton/meter^2
Moment	1 lbf-ft = 1.356 newton meter
Mass	1 ton = 907.2 kilograms 1 lb = 0.4536 kilograms

*Exact values

Universal Testing Machine of 12-Million-lbf Capacity at the National Bureau of Standards

Arthur F. Kirstein

A 12-million pounds-force capacity universal testing machine, which is believed to be the largest of its kind in the world, has been put into operation in the Engineering Mechanics Laboratory of the National Bureau of Standards in Gaithersburg, Maryland. This hydraulically operated machine, which has an overall height of over 100 feet, was designed to test full scale structural components and to apply the forces needed to calibrate large capacity force measuring devices. The testing machine is capable of applying axial forces of 12,000,000 lbf in compression, 6,000,000 lbf in tension, and a transverse force of 4,000,000 lbf to a flexural specimen.

Key words: Force calibration; large test facilities; structural testing; universal testing machine.

1. INTRODUCTION

For many years the National Bureau of Standards has been aware of the increasing requirements for a large force generating facility which would be suitable for tests of large full scale structural components and for calibration of large force measuring devices. To satisfy these requirements, plans were made for the design and construction of a 12,000,000 lbf capacity universal testing machine--plans which were consummated with the construction of a new large testing facility in the Engineering Mechanics Laboratory in Gaithersburg, Maryland (fig. 1).

This hydraulically operated machine is a vertical, four-screw type with the main fixed platen flush with the floor (fig. 2). It projects approximately 78 feet above the floor level, and extends about 23 feet into a pit. It is capable of applying 12,000,000 lbf in compression, 6,000,000 lbf in tension, and 4,000,000 lbf to a flexural specimen.

This new universal testing machine has replaced a 10,000,000 lbf capacity compression testing machine, which has been in service since the early nineteen-hundreds. A comparison of the features of the new machine, described in this paper, to those of the 10,000,000 lbf machine, as given in references 1 and 2, will show the many advances that have been made through the years and are incorporated in this new machine.

2. PRINICIPAL DIMENSIONS

The 12,000,000 lbf capacity universal testing machine, shown in figure 3, projects approximately 78 feet above the floor and extends about 23 feet below into a pit. The overall height of the machine is then approximately 101 feet, and its gross weight is about 2,000,000 pounds. The base of the machine is attached to its reinforced concrete foundation with a prestress force of 4,000,000 lbf. A test floor 90 feet long is an integral part of this foundation.

The test openings and the sizes of the test fixtures govern the sizes of specimens that can be tested in this machine. The vertical opening between the bedplate, which rests on the main platen (fig. 2), and the compression leveling plate assembly, which is on the sensitive crosshead, is infinitely adjustable along the screw columns to provide vertical openings up to 58 feet for compression tests. For tension tests the vertical opening from the top of the sensitive crosshead to the bottom of the tension crosshead is infinitely adjustable from zero to 53 feet. These dimensions allow for the full 5 foot power stroke of the main hydraulic cylinder. For convenience, the tension head can be located at the notched positions along the two main columns as shown in figure 3. These notches are located 32, 42, 52, 62, and 72 feet above the main platen of the machine. Both of the test openings given above can be increased by two feet if the compression leveling plate assembly and the bedplate are removed from the machine. The clear horizontal working space between the screw columns is 8 feet 4 inches, and the working surface of the main platen is 8 feet 4 inches by 15 feet. The bedplate is 7 feet in diameter and 1 foot thick. The working surface of the foundation, which extends beyond the main platen, contains a tie-down floor system that can be used to support transverse or flexural specimens up to 90 feet in length.

3. FOUNDATION AND TIE-DOWN FLOOR SYSTEM

The reinforced concrete foundation for this machine includes a tie-down floor system which provides the capability to perform transverse or flexural tests on specimens up to 90 feet in length. A plan view of the foundation is shown in figure 4. The pit through the central portion contains the hydraulic and electric equipment to operate the machine as well as the lower 23 feet of the machine. The overall dimensions of the tie-down floor are 90 feet in length and 16 feet 8 inches in width. Other pertinent dimensions of the 126 tie-down bolt locations are shown in figure 4.

The working strength values for the tie-down floor system are:

Longitudinal bending moment	12,500,000 lbf-ft
(over central 40 feet)	20,000,000 lbf-ft
Tranverse bending moment	467,000 lbf-ft/ft of width
(over central 40 feet)	750,000 lbf-ft/ft of width
Uniform bearing	940 lbf/in^2
Tensile force on anchor bolts	150,000 lbf/bolt

4. LOADING STRUCTURE

The loading structure consists of a fixed frame and a movable frame. The fixed frame is built around the main platen and includes the main platen, main columns, top tie plate, and tension crosshead (fig. 3). The movable frame is supported by the fixed frame, and includes the main hydraulic cylinder, screw columns, and sensitive crosshead. Compression tests are performed between the sensitive crosshead and the bedplate, and tension tests are performed between the sensitive and tension crossheads. Flexural tests may be performed between the sensitive crosshead and either the main platen or the tie-down floor system. In all cases the test load is applied by pressurizing the main hydraulic cylinder which pulls the screw columns through the main platen thus drawing the sensitive crosshead downward and providing the force required for compression, tension, or flexural testing.

An important feature of the loading structure is the backlash elimination system, which locks the sensitive crosshead to the screw columns. This feature prevents recoil damage to the threads of both the screw columns and drive nuts of the crosshead. It also provides for greater stability of the movable frame.

5. FORCE MEASURING SYSTEM

Two hydraulic capsules are installed in the sensitive crosshead. One of these annular cells provides the force measuring function for compression, tension, and flexural testing. The other cell provides the preloading that is required for proper operation of the force measuring cell. Pressure transducers, located within a constant temperature oven on the sensitive crosshead, sense the pressure within the force measuring cell and transform it into an electrical signal. This signal is transmitted to the control console where the applied load, in pounds-force, is displayed by analog and/or digital indicating systems. The full scale ranges of these indicating systems are:

Analog ranges lbf	Digital ranges lbf
12,000,000	12,000,000
6,000,000	1,200,000
3,000,000	120,000
1,200,000	
600,000	

All ranges have been calibrated, and generally do not exhibit errors greater than 0.5 percent of the applied load.

There are two other features incorporated in the force measuring system which are worthy of note. One device is incorporated with the analog indicator to transmit force measurement output signals directly to a data acquisition system. This records the force along with the strain and displacement measurements for future reference and study, and also provides the machine operator with a visual means to monitor and control the progress of the test. The other device provides for the use of an auxiliary (external) load cell with the analog indicating system. This feature permits the selection of a wide number of full scale ranges not available from the internal force measuring system.

6. CONTROL CONSOLE

The majority of the machine operations are controlled and monitored from the control console which is located on the floor adjacent to the testing machine (fig. 2). Auxiliary controls are provided at convenient locations on both the movable work platform and the sensitive crosshead to facilitate their operation.

The hydraulic and electric controls for the loading and unloading operations for both the main and auxiliary pumps are manipulated from the console. Two sets of valves are provided to permit the machine operator to use coarse or fine control of the flow of hydraulic fluid to and from the main cylinder. This, in effect, lets the operator select a range of combinations from needle valve control of the low flow auxiliary pump to coarse valve control of the flow from the main pump. The fine control is useful in calibration set ups, which may require maximum crosshead motions in the order of 0.035 inch to apply the full calibration force. Coarse controls are generally used for testing less rigid structures where applications of the desired test loads may require crosshead motions up to the full 5 foot power stroke of the machine.

As mentioned previously the force measuring system is monitored from the console on analog and/or digital indicating systems. These systems are conveniently located in front of the operator to aid in the manual control of the loading and unloading operation.

Other operations which can be controlled from the console are raising and lowering the movable work platform, locking and unlocking the backlash elimination system, and positioning both the tension and sensitive crossheads prior to testing.

7. ACCESSORIES

The machine is equipped with basic accessories such as compression and tension test fixtures, specimen restraining structures, a movable work platform, and load-handling equipment to facilitate the installation of test specimens in the machine.

A compression leveling plate assembly is mounted on the underside of the sensitive crosshead to accommodate nonparallel ends of compression specimens. This assembly, which can bear the full 12,000,000 lbf compression capacity of the testing machine, can be tilted as much as 0.5 inch, in a 60 inch diameter, toward any point of the compass.

To apply the full 6,000,000 lbf tension capacity to specimens, the machine is supplied with assemblies consisting of wedge blocks, nuts, spherical washers, tension rods, and either threaded couplings or clevis fixtures. One of each of these fixtures is shown in figure 5. Threaded couplings are available with 11-3ACME-2G and 15-3ACME-2G general purpose threads. Each pair of couplings is equipped with right and left hand threads to facilitate assembly. The clevis fixtures have 16 inch diameter pins, a 25 inch throat, and 12 inches clear between lugs to accommodate the tab ends of test specimens. In addition the machine is presently equipped with both flat and V-type wedge grips (fig. 5) which are capable of transmitting 3,000,000 lbf in tension to flat and round specimens, respectively. The flat grips can accommodate plate specimens up to 24 inches wide by 4 inches thick. The V-type grips can accommodate round specimens from 2.75 to 8 inches in diameter.

In the testing of large structural components, there is the ever present danger that the sudden release of energy due to abrupt specimen failure could cause considerable damage by expelling part or all of the specimen from the machine. In order to lessen this danger the machine is equipped with basic restraining structures, recoil assemblies, and other retaining devices which can be assembled into the machine as required.

Other accessories for the machine, which are independent of the testing equipment, are a movable work platform and load-handling equipment. These accessories are shown in figure 2. The movable work platform operates vertically along the four guide columns and is raised or lowered by electric motors which can be controlled from either the platform or from the testing machine control console. A ladder on one of the guide columns, which extends to the full height of the machine, provides convenient access to the platform at all positions above floor level. In order to facilitate the placement of test specimens in the machine, both the tension and the sensitive crossheads are equipped with load-handling equipment. This equipment consists of pairs of monorails and hoists which are mounted on the underside of each crosshead as shown in figure 2. Each hoist on the tension crosshead can handle loads up to eight tons while each of those on the sensitive crosshead has a twelve ton capacity. Test specimens are raised from the floor or are transferred from a thirty-ton capacity overhead crane to these monorail hoists, and are then transported into the machine along the monorails.

8. RESEARCH AND FORCE CALIBRATION

For the first time it is possible to load large column sections up to 12,000,000 lbf. The heavy stub column shown in position between the bedplate and the sensitive crosshead of the machine in figure 6 has an estimated yield load of 7,200,000 lbf. The test of this 23H681 stub and its 36-foot long companion column have awaited the completion of this machine as no other existing machine offered the necessary size and load capacity.

Other tests of fabricated columns, large eye bars, large diameter drill rod for undersea drilling operations, heavy specimens of wire rope, and structural configurations of column and beam connections are planned as future work for this unique testing machine.

This machine is also capable of applying forces for the calibration of force measuring devices having capacities up to 12,000,000 lbf. Calibrations of large elastic force measuring devices are made in this machine using a configuration similar to that shown in figure 7. Here a large capacity load cell is compared with a group of smaller cells, each of which was calibrated previously against known force standards such as the NBS deadweight machines.

9. SUMMARY

Recognizing needs for a new large testing facility for large force calibrations and for full scale tests of large structural components, NBS has planned, developed, and placed in service a unique 12,000,000 lbf capacity universal testing machine which is believed to be the largest in the world. To extend the versatility of this machine the reinforced concrete foundation incorporates a floor tie-down system which will accommodate flexural test specimens up to 90 feet in length.

The use of this machine makes it possible to obtain information on the strength and behavior of structural components which because of their size and load capacity could not be tested previously. Plans discussed in the preceding section for force calibration and for tests of large structural components show the impact that the machine has on NBS programs.

10. REFERENCES

1. Mosley, T. J. and Griffith, J. H., What Our Large Testing Machines Have Accomplished, Engineering News-Record, 78, 4, April 26, 1917.

2. Griffith, J. H., and Bragg, J. G., Tests of Large Bridge Columns, Bureau of Standards Tech Paper No. 101, June 27, 1918.

Figure 1. Engineering Mechanics Laboratory.

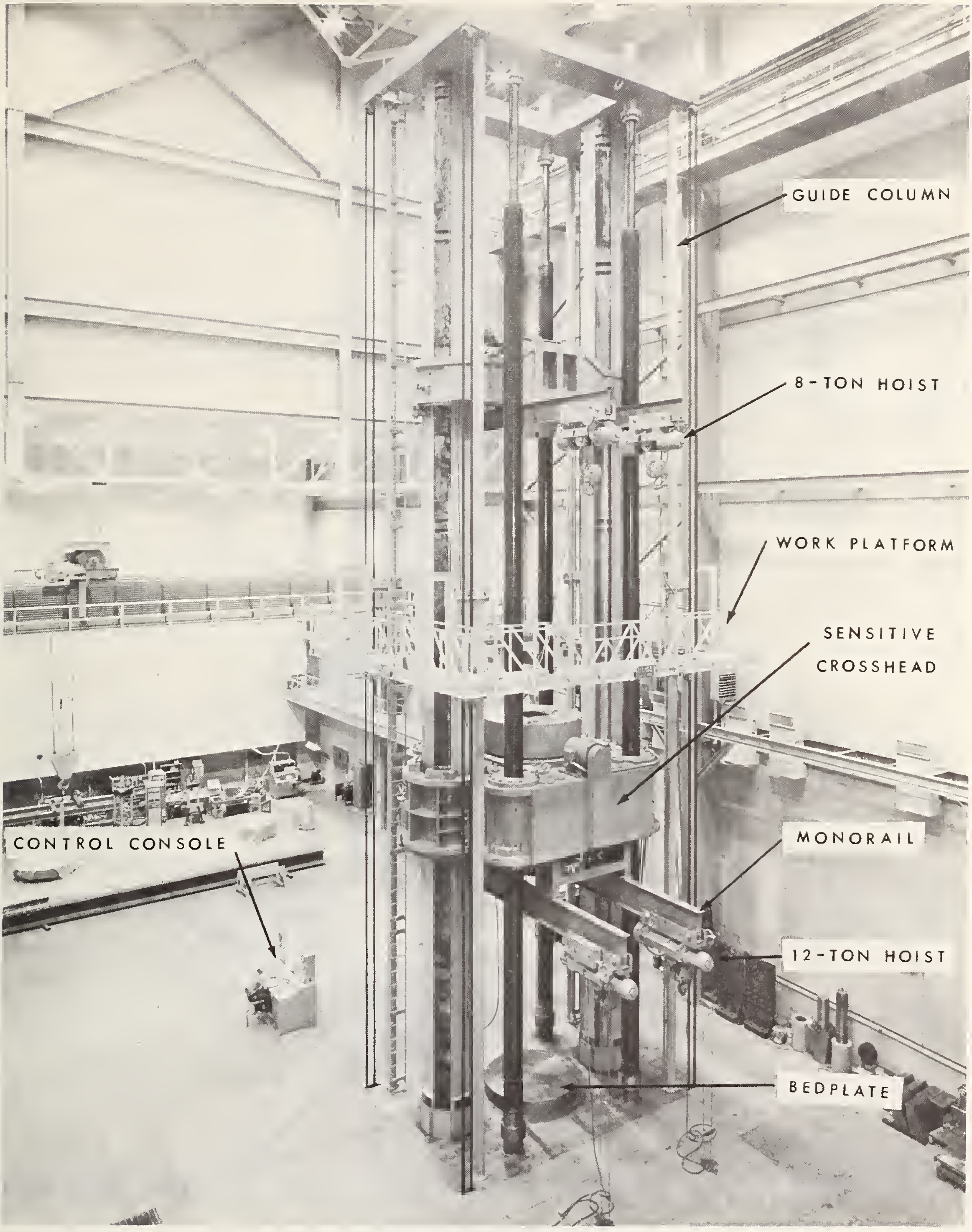

Figure 2. Universal testing machine of 12,000,000 lbf capacity.

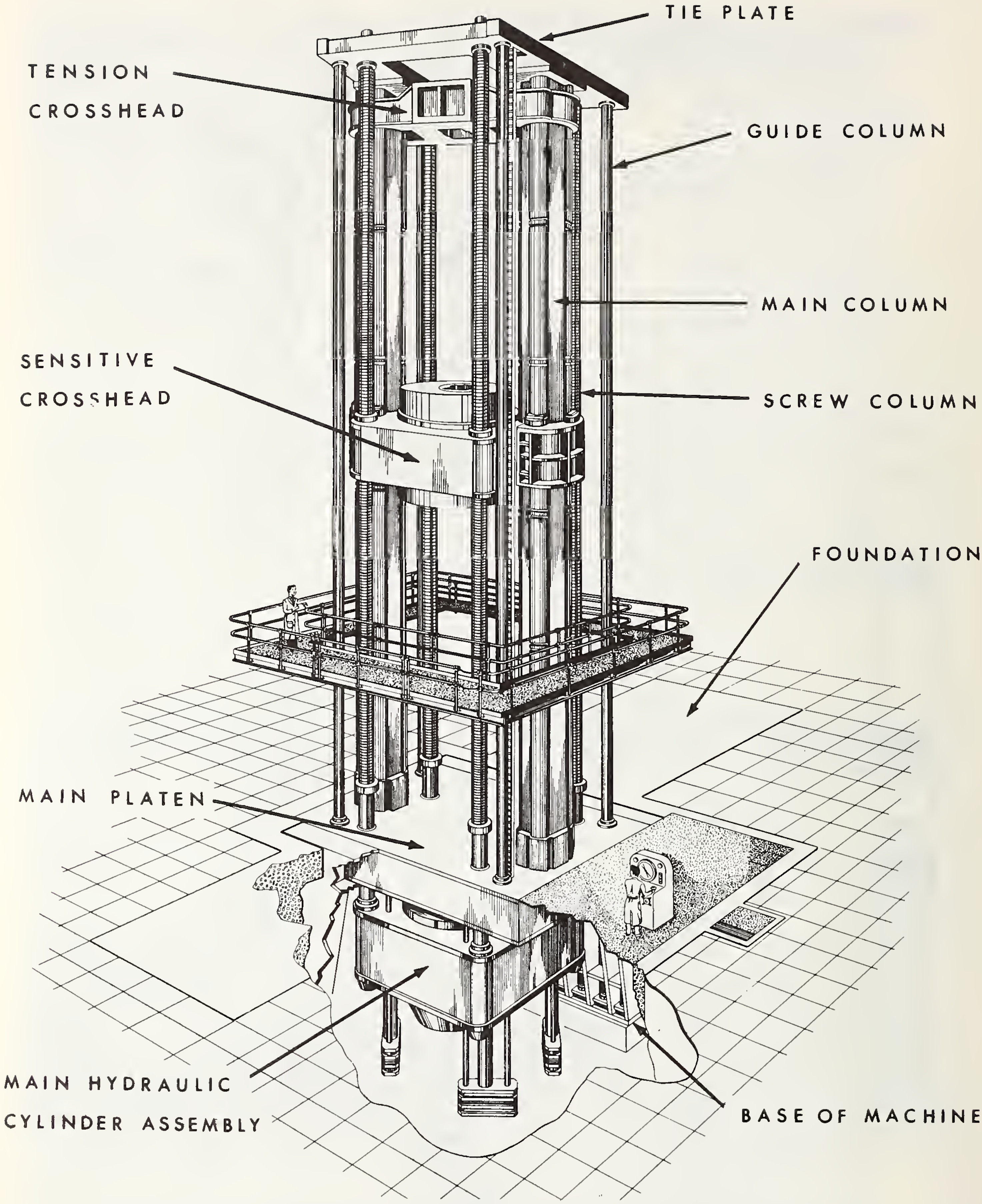

Figure 3. Drawing of the 12,000,000 lbf capacity universal testing machine.

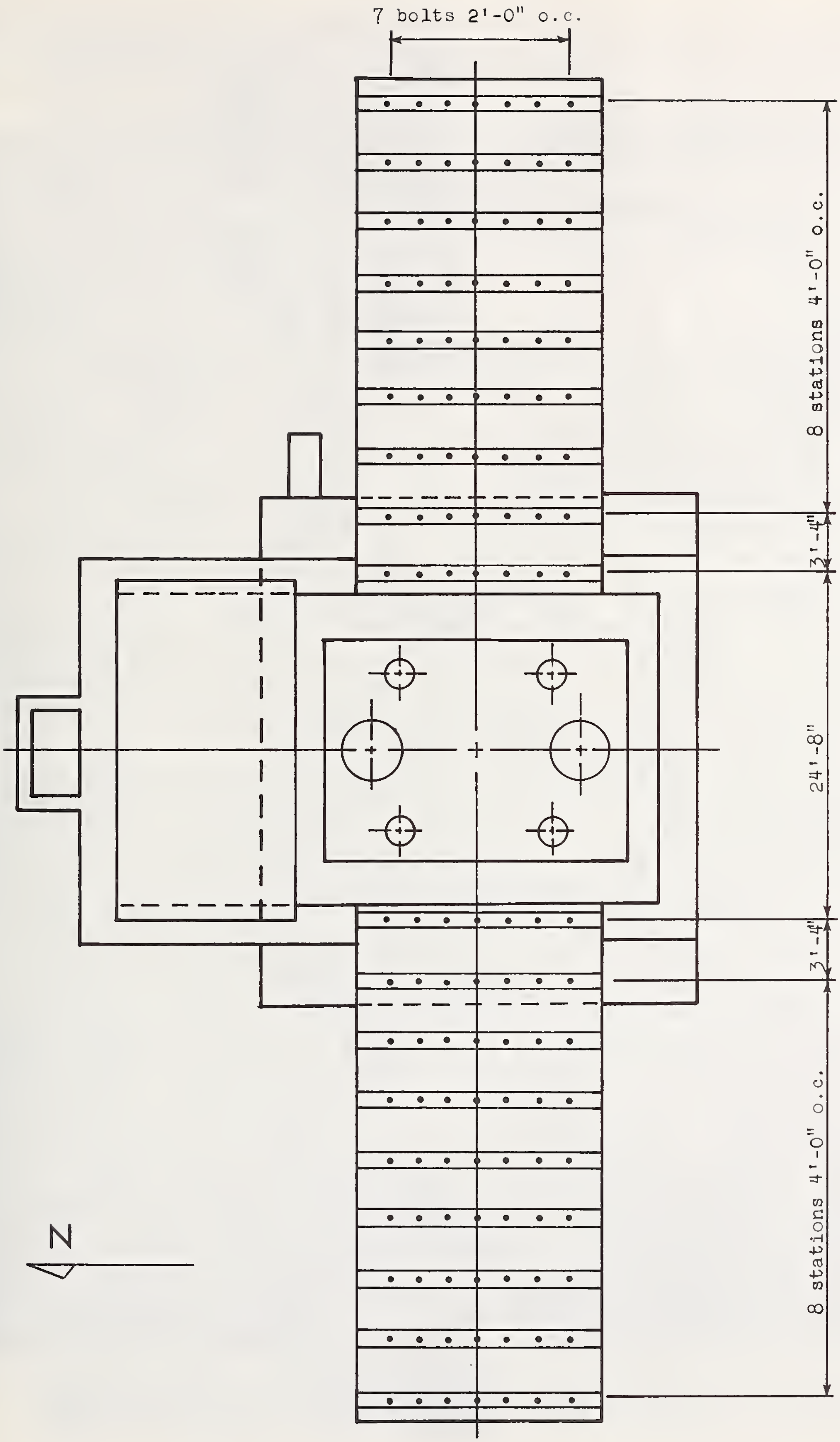

Figure 4. Foundation and tie-down floor system.

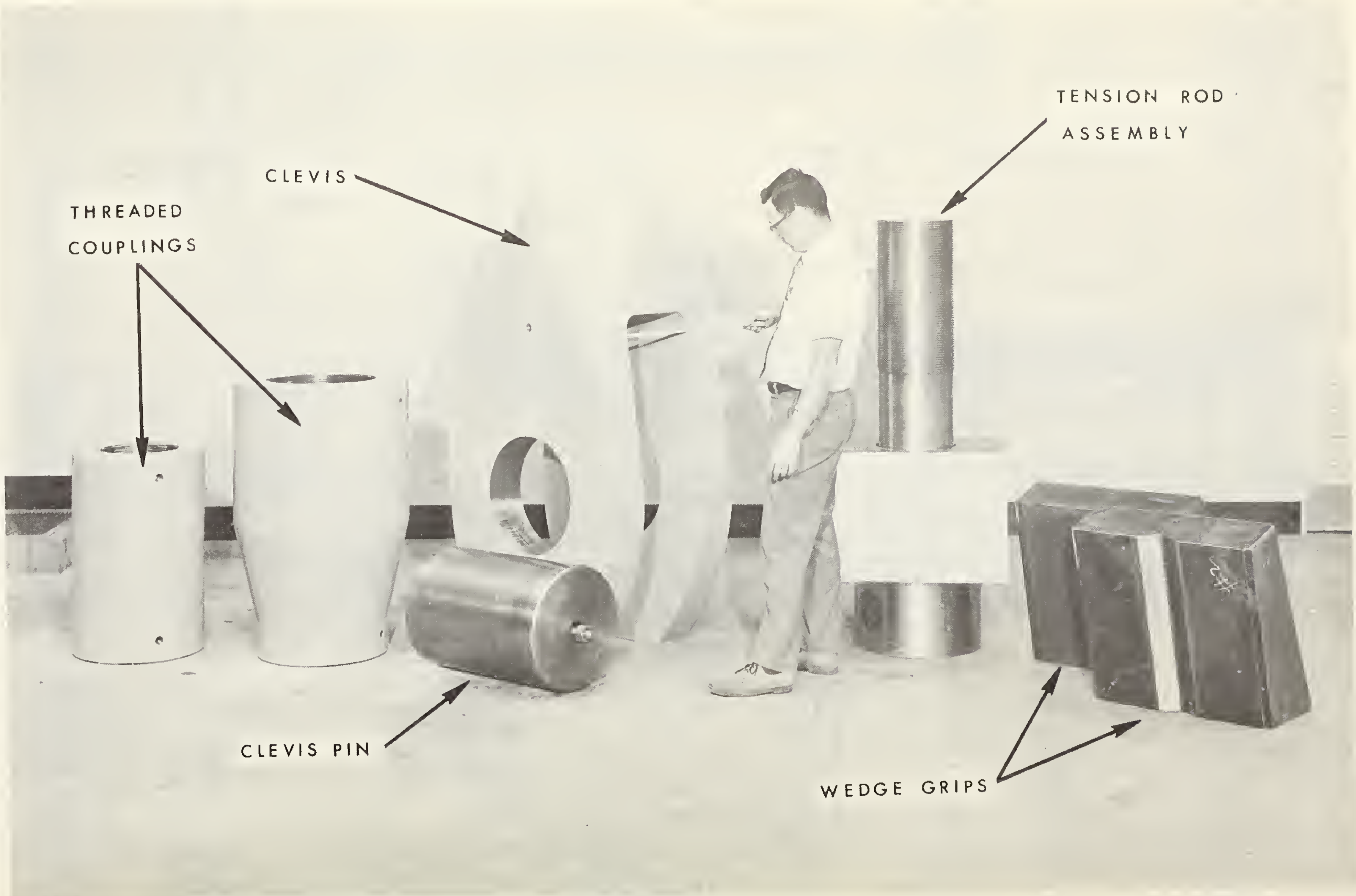

Figure 5. Tension test fixtures.

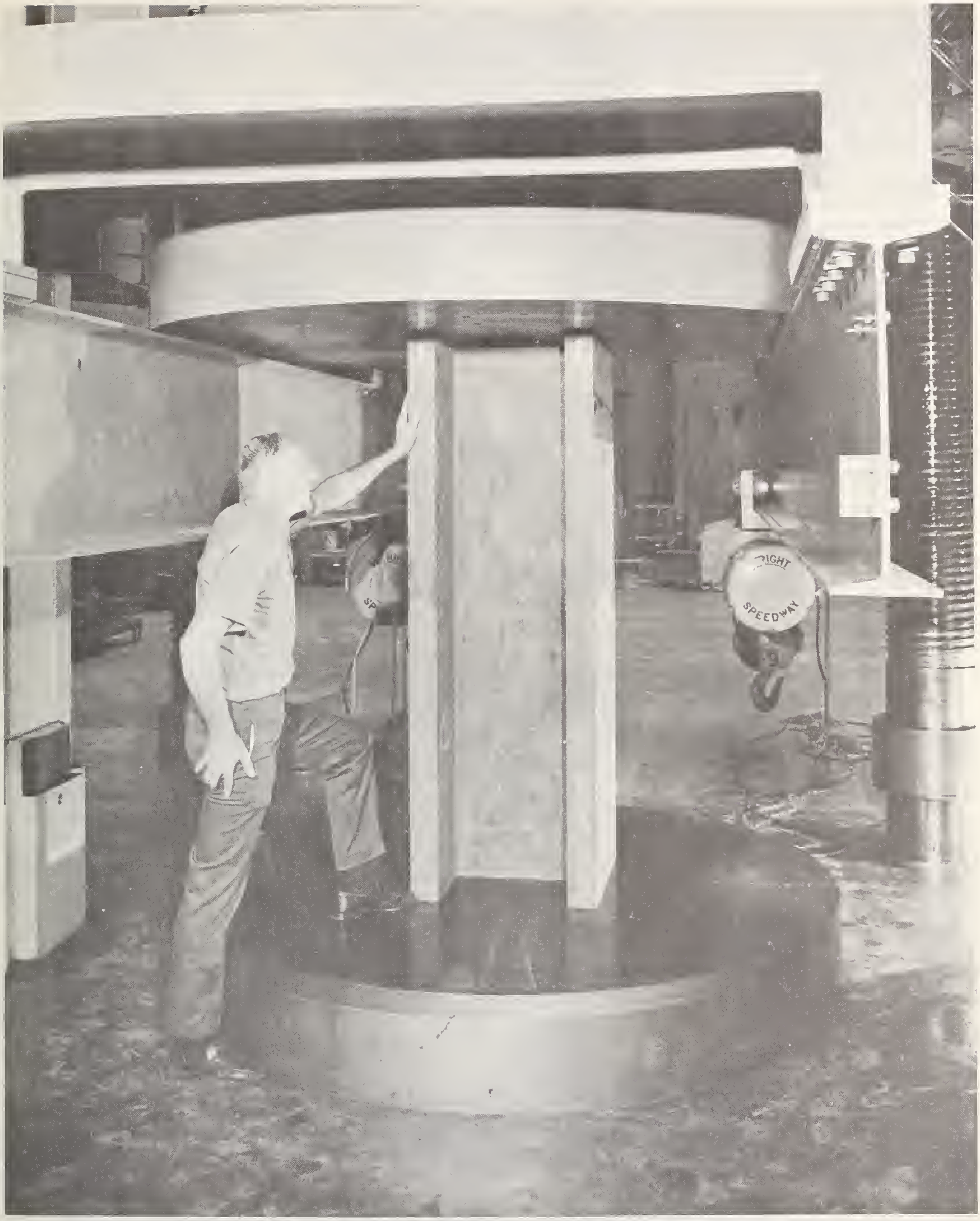

Figure 6. Heavy stub column in the 12,000,000 lbf capacity universal testing machine.

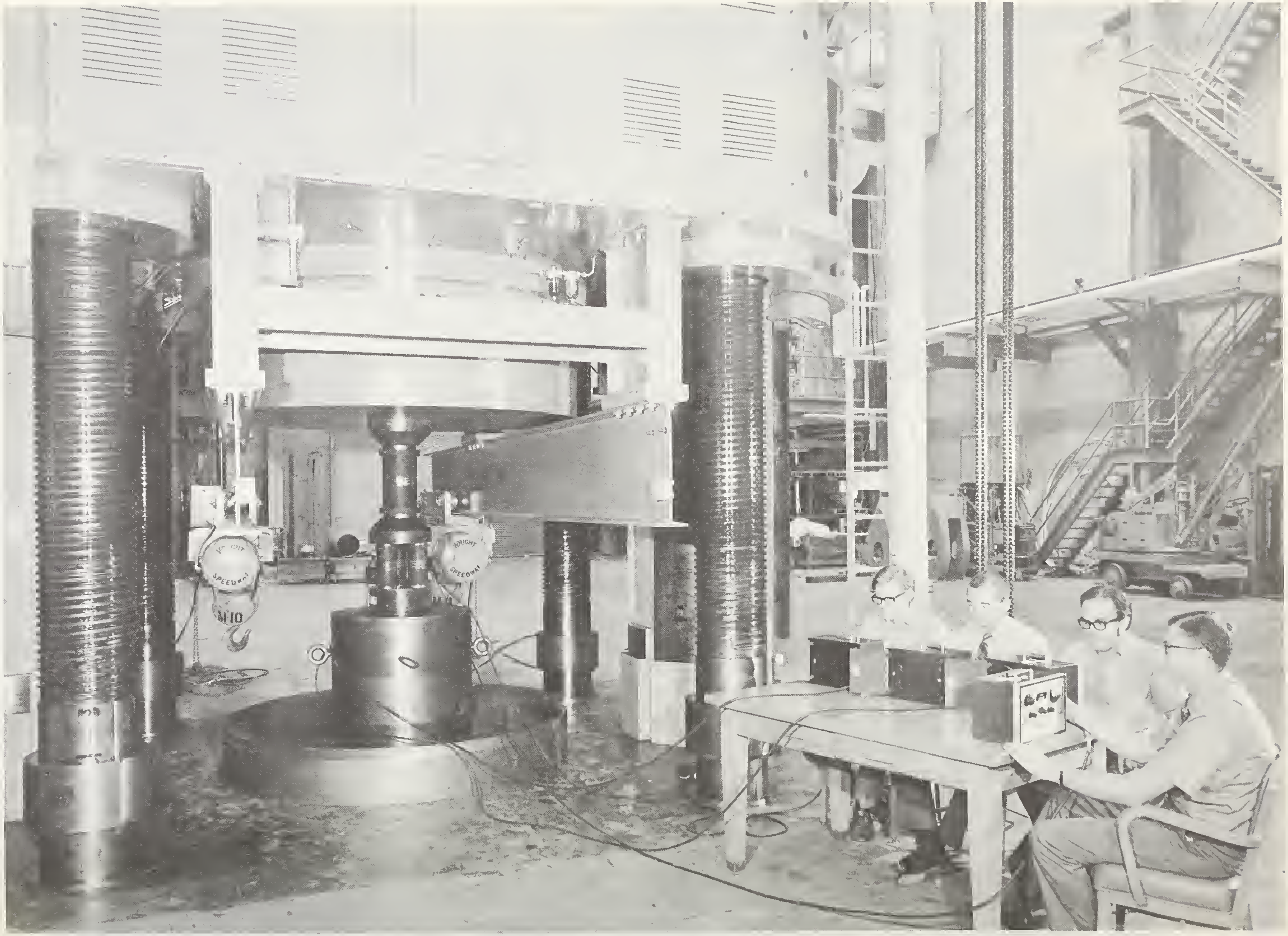

Figure 7. Calibration of a large elastic force measuring device.

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15. SUPPLEMENTARY NOTES

16. ABSTRACT (A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)

A 12-million pounds-force capacity universal testing machine, which is believed to be the largest of its kind in the world, has been put into operation in the Engineering Mechanics Laboratory of the National Bureau of Standards in Gaithersburg, Maryland. This hydraulically operated machine, which has an overall height of over 100 feet, was designed to test full scale structural components and to apply the forces needed to calibrate large capacity force measuring devices. The testing machine is capable of applying axial forces of 12,000,000 lbf in compression, 6,000,000 lbf in tension, and a transverse force of 4,000,000 lbf to a flexural specimen.

17. KEY WORDS (Alphabetical order, separated by semicolons)

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