NATIONAL BUREAU OF STANDARDS REPORT

5314

TEST OF A PRESTRESSED CELLULAR SLAB

by

Arthur F. Kirstein

Report to

Bureau of Yards and Docks
Department of the Navy

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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Abstract

As a continuation of the study of the properties of prestressed cellular slabs, a nine celled unit of cement-asbestos was developed, and a slab composed of 16 of these units was tested. Since concrete cannot in itself develop high enough tensile strengths to withstand the diagonal tension encountered in slabs of this kind, cement-asbestos was used. The test results appear favorable as the load-carrying capacity of the cement-asbestos slab was found to be over 60 percent higher than comparable concrete slabs. It is of further interest that no evidence of diagonal tension cracking was observed in this slab which failed by compression. This mode of failure indicates that a still greater increase in maximum load-carrying capacity and cracking load can be realized by increasing the thickness of the flanges of the units and the amount of prestress applied to the slab.

1. INTRODUCTION

Since the study of the properties of prestressed cellular slabs was initiated, a series of nineteen 5- by 5-ft slabs have been tested. The conclusions drawn from the work presented in NBS Reports Nos. 4396, 4813, 4951, and 5212, were that the units must be bonded together to attain intimate contact between units and that the webs of the units must be able to resist higher tensile stresses if the load-carrying capacity of the slab is to be increased.

A previous attempt to increase the load-carrying capacity of the prestressed concrete block slabs was made by reinforcing the concrete block webs with steel to prevent the typical diagonal tension failure. The increase in load-carrying capacity was appreciable, but the blocks were difficult to manufacture in any sizeable quantity. Therefore, it was found necessary to consider materials other than concrete for use in manufacturing these slabs. Prestressed beam tests were made to compare concrete units having reinforced webs with units of identical size and shape made of cement-asbestos. These tests indicated that the cement-asbestos beams carried up to 45 percent more load than the beams with reinforced concrete units. This report is concerned with the prestressed slab test that was made to verify these findings.

The basic unit was redesigned with interlocking lugs to aid in the distribution of stress and to facilitate proper assembly in the field. This unit contains nine cells and four interlocking lugs and the nominal dimensions are 6- by 15- by 15 in. It is believed that these units can be mass produced efficiently and shipped to the fabrication site as individual units.

The prestressed cement-asbestos slab tests reported herein indicates that the load-carrying capacity was increased by more than 60 percent over that of comparable concrete slabs, and that a further increase is possible inasmuch as no evidence of diagonal tension cracking was observed in any of the webs.

2. DESCRIPTION OF TEST SPECIMENS

2.1 Cellular blocks

As mentioned previously, the basic cellular unit was redesigned to have outside nominal dimensions of 6- by 15- by 15-in. The unit containing nine cells and four interlocking lugs is shown in figure 1. Upon examination of figure 1, it is readily apparent that the slots of the unit and interlocking lugs of the adjoining units make the field assembly practically fool-proof.

The basic components that are used to fabricate the typical unit are shown in figure 2. The members are cemented together with epoxy resin to form the nine-cell unit. Figure 3, a photograph of the partially fabricated unit, shows how the unit is assembled in an "egg-crate" fashion. Attention is

directed to the location of the circular holes in the webs. These holes are arranged so that the prestressing tendons can be staggered above and below the midplane of the block to produce a resultant prestressing force at midplane in both directions. By cutting an oval hole in the webs these units could be made interchangeable.

Figure 4 is a detailed drawing of the components of the typical cellular unit. Upon comparing figure 4 with figure 2 it can be seen that an alteration of the interlocking lugs was made. This alteration was believed necessary because of the cutting technique employed.

The physical properties of the cement-asbestos used in this investigation were determined by tensile, compressive, and sonic tests. The tensile tests indicated that the cement-asbestos could carry an ultimate stress of 1390 psi in direct tension with a modulus of elasticity of 1.82×10^6 psi, while the compressive tests indicated an ultimate stress of 4890 psi in direct compression with a modulus of elasticity of 2.05×10^6 psi. The sonic tests gave a modulus of elasticity of 1.95×10^6 psi with a Poisson's Ratio of 0.30.

2.2 Jointing material

Care was taken to select a resin for use in bonding the cellular units together so that a premature failure of the slab would not result from a cement failure. The first test performed was a comparative test between a polyester resin and an epoxy resin. Cement joints of polyester and epoxy resin were made by butting pieces of cement-asbestos together and cementing the 3/4- by 1 13/16-in. butted cross-sections. Direct tension tests of these cemented joints revealed that the polyester resin had an ultimate tensile stress of only 432 psi, while the epoxy resin had a tensile strength of 946 psi.

From the test results reported above, it was evident that the epoxy resin with its tensile strength more than twice that of polyester resin was a more suitable cement. Further testing of the epoxy resin was carried out to determine the type and proportions of fillers necessary to make a strong workable cement. Ignited Al_2O_3 and a finely divided siliceous mineral filler were selected for testing. The final result of this testing was a cement of 100 parts epoxy resin (Epon 828), 10 parts of diethylenetriamine, and 5 parts of the finely divided siliceous filler by weight. This particular mixture was

stronger than cement-asbestos in pure shear and had the consistency of petroleum jelly with a pot life of 53 minutes. This mixture had good workability yet would not run off of a vertical surface of cement-asbestos.

2.3 Prestressing steel

The steel prestressing tendons used in the cellular cement-asbestos slab were 0.75 in. diameter "Elastuff" bars. Tensile tests of this material indicated a stress-strain relationship that was essentially linear up to 70,000 psi, and exhibited a Young's Modulus of 28.6×10^6 psi. The yield strength of the bar was found to be 105,000 psi as determined by the 0.2 percent offset method and the tensile strength was found to be 125,500 psi. The tensile stress-strain curve for this material is shown in figure 5. Although the "Elastuff" bars are made of cold-worked high carbon steel, they are fairly ductile and can be machined easily.

2.4 Description of prestressed slab

The 5- by 5-ft slab was made of 16 units that were bonded together with epoxy resin, and eight 0.75 in. diameter "Elastuff" steel bars were used to apply the 1000 psi prestress in both directions. Figure 6 shows the arrangement of the units in the slab and the placement of the prestressing tendons. The end rows of cells were filled with concrete to distribute the prestressing force over the entire area of the cement-asbestos in the direction of the span, while the concrete anchorage blocks were used to distribute the prestress in the transverse direction. The slab was assembled without the top flanges in place so that the assembly could be viewed (Figure 6), but the slab can be assembled as easily with the flanges in place.

2.5 Prestressing procedure

Approximately one-third of the prestress was applied to the slab in small increments by tightening the anchorage nuts with a wrench. The remaining prestressing force was applied by means of a hydraulic jacking rig. This final stage of the prestressing operation was accomplished by using a suitable sequence of stressing the tendons so that no unduly large differences in strain would be induced in the blocks. The hydraulic jacking rig was equipped with a dynamometer to determine the amount of prestressing that was applied to the tendons. The calibration curve for the dynamometer is shown in figure 7.

3. TESTING PROCEDURE

3.1 Test setup

The slab was simply supported on two edges over a 54-in. span by 1-in. square aluminum bars that were attached to the steel frames resting on the testing machine platen. All bearing surfaces were set firmly with high-strength plaster to obtain intimate contact between individual members. The load was applied to the center of the slab through a 12- by 12-in. concrete loading block 6-in. thick.

3.2 Instrumentation

The deflection measurements of the slab were made with 0.001-in. micrometer dial gages that were attached to steel angles. These angles rested on the top surface of the slab directly over the supports, thus placing the datum plane at the supports. Figure 8 shows the test setup with the dial gages in place, and the A-1 type bonded wire strain gages connected to the strain measuring equipment. The exact locations of the gages are shown on the Instrumentation Diagram in figure 9.

3.3 Test procedure

The slab was loaded at the center of the top surface through a 6- by 12- by 12-in. concrete loading block. The load was applied in increments of 2500 and 5000 lb, and gage readings were made for each increment until the maximum load was reached.

4. TEST DATA

4.1 Deflection and load-carrying capacity of slab

Figure 10 shows the observed relationship between the applied load and center deflection of Slab No. T-1. The reciprocal of the slope of the linear or elastic portion of this curve can be considered to be a measure of the deflection sensitivity of the slab, and is expressed in terms of micro inches of deflection per pound of applied load (μ in./lb). This factor is useful in comparing the performance of similar slabs.

Table 1 shows a comparison of the deflection sensitivities and the maximum load-carrying capacities of the cement-asbestos Slab No. T-1 and the comparable concrete slabs summarized in NBS Report 5212.

4.2 Strain in cement-asbestos

The relationships between the applied load and the longitudinal strains in the top and bottom of the cement-asbestos slab are shown in figure 11. The transverse strains were of minor importance because the slab was simply supported along two edges.

4.3 Crack patterns

The first audible crack occurred at a load of 21,500 lb. This crack was formed in the epoxy resin on the bottom surface and propagated transversely across the mid-span of the slab. The formation of this crack was evidenced by the change in the relationship between the applied load and the center deflection shown in figure 10.

The transverse crack was the only crack that formed during the test until the upper flange crushed at the maximum load of 45,600 lb. When the prestressing tendons were removed after the test the slab broke in half, and upon further investigation of the slab it was discovered that no diagonal tension cracks had formed in the webs. The slab was then broken into quarters to make a more thorough inspection of the webs, but no diagonal tension cracks could be found. Figure 12 is a photograph of the broken ends of two of the quarters that clearly indicates that the webs are still intact.

5. DISCUSSION AND SUMMARY OF RESULTS

Upon examination of Table 1, it is immediately apparent that Slab No. T-1 carried over 60 percent more load than any of the comparable concrete slabs. This increase in the load-carrying capacity coupled with the fact that Slab No. T-1 failed in compression bears out the conclusion from a previous report that the webs of the units must be strengthened in tension to increase the load-carrying capacity.

Since Slab No. T-1 failed in compression, the conclusions drawn in previous reports about the need for a jointing material to ensure intimate contact between units and eliminate local stress concentrations is again substantiated.

The deflection sensitivity of the cement-asbestos slab was greater than those of the concrete slabs, but that was expected from the lower modulus material. The greater deflection of the slab displays the relative toughness of the cement-asbestos as compared to the concrete.

It is believed that the cracking load of 21,500 lb can be increased by increasing the prestress from 1000to 1500 or 2000 psi. However, it is not known how this increase in prestress will effect the maximum load-carrying capacity of the slab, since the ultimate load was reached when the upper flanges failed in compression. Possibly it may be necessary to increase the thickness of the flanges if greater prestressing forces are used.

Although the cement-asbestos material exhibits good tensile properties, little is known of its creep properties. Therefore, it would be necessary to conduct research over a period of time to ascertain whether cement-asbestos would be a suitable material to be used in prestressed units.

Table 1. Comparison of Test Results from Cement-Asbestos Slab and Comparable Concrete Slabs

Slab No.	Method of support	Arrangement of blocks	Jointing material	Type of block	Deflection sensitivity	Maximum load
					μin./lb	kips
10	2 edge	Criss-cross	None	NBS	1.57	17.0
11	2 edge	Criss-cross	Neat cement	NBS	1.27	26.25
19	2 edge	Criss-cross	Polyester resin	NBS	1.39	28.0
T-1	2 edge	Interlocked	Epoxy resin	9 unit cement-asbestos	2.31	45.6

Note: All slabs were tested over a 54-in. span, and contained a 1000 psi prestress in both directions.

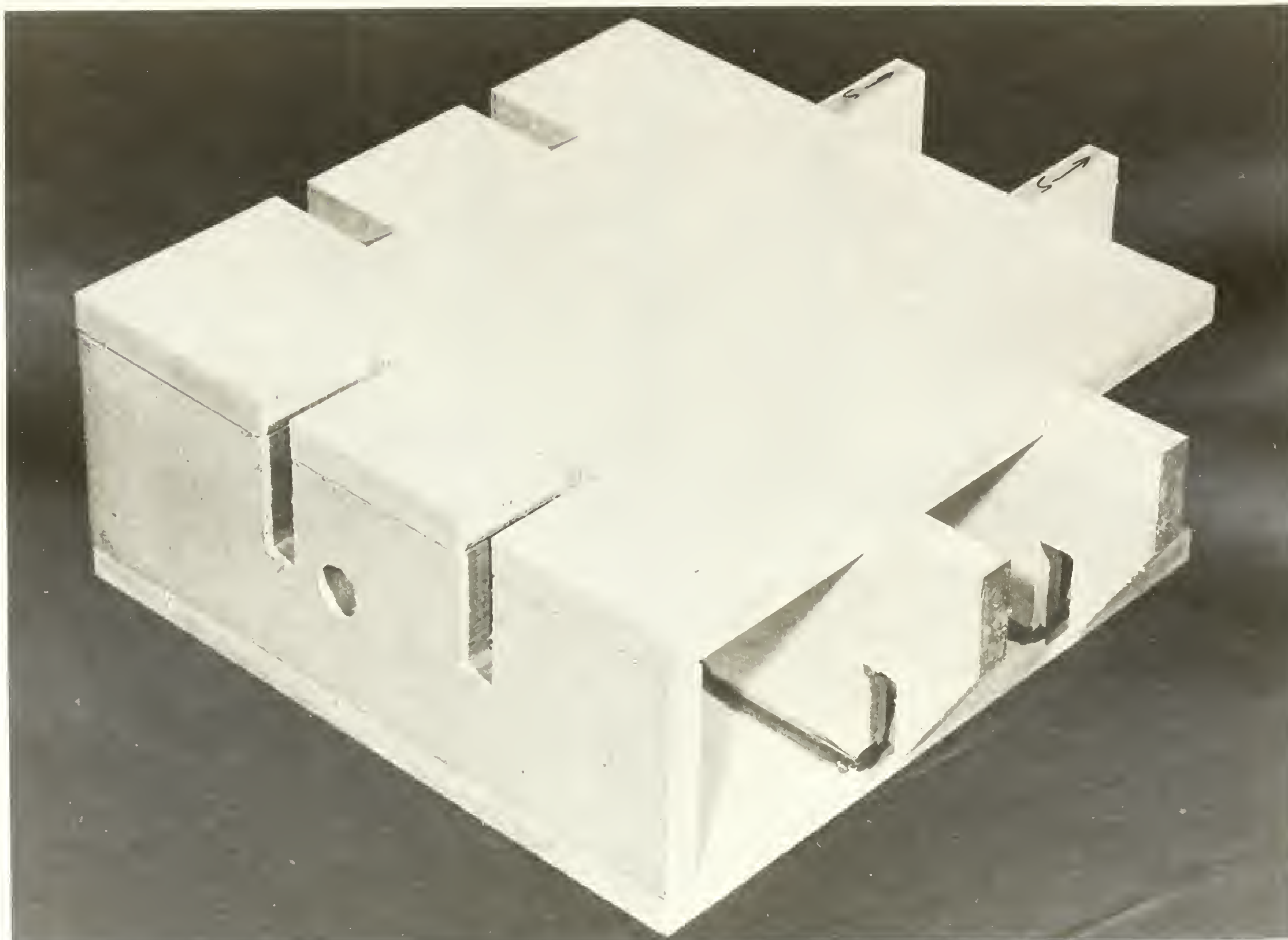


FIGURE 1. NINE-CELL CEMENT-ASBESTOS UNIT

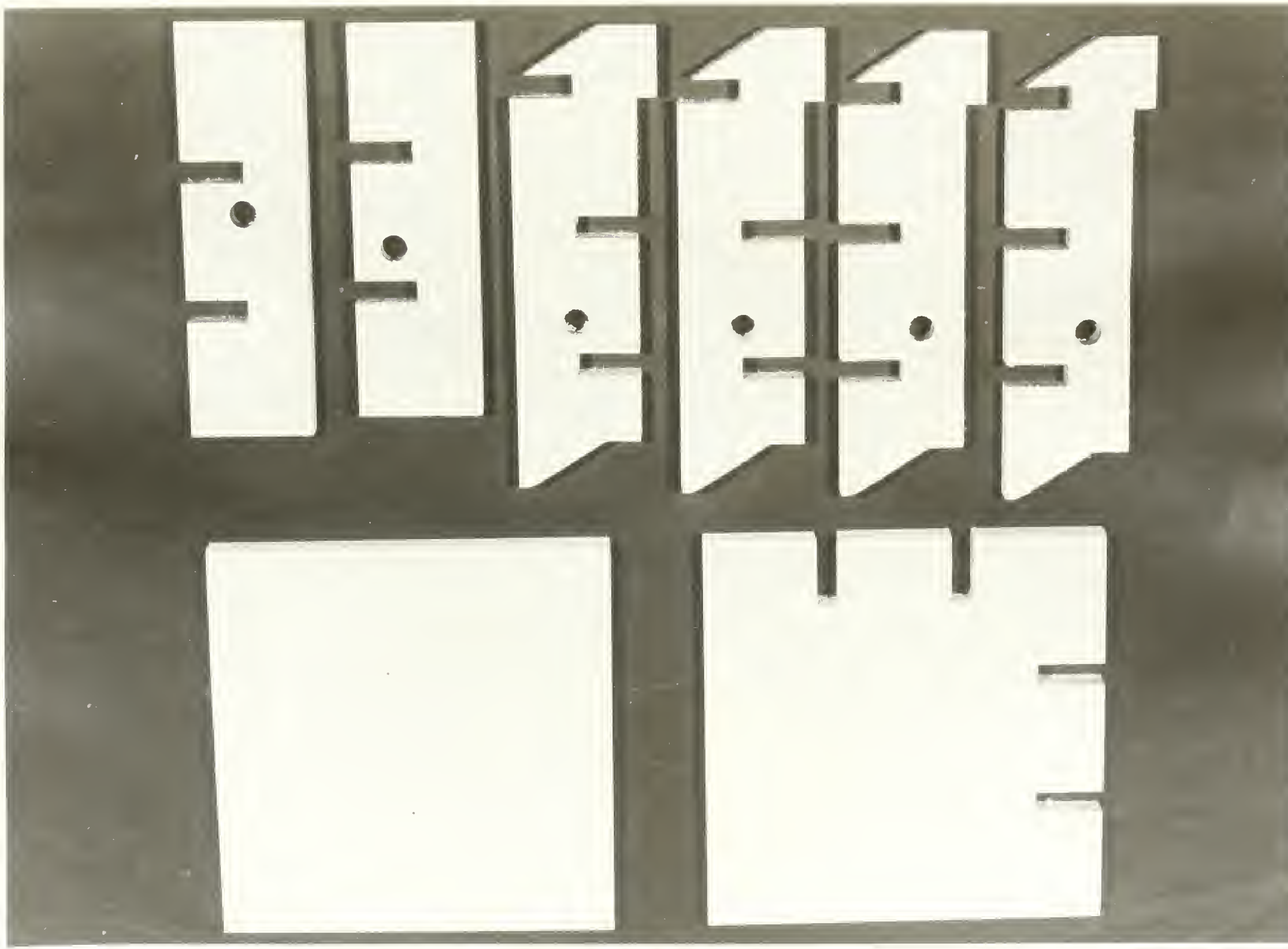


FIGURE 2. BASIC COMPONENTS OF THE CEMENT - ASBESTOS UNIT

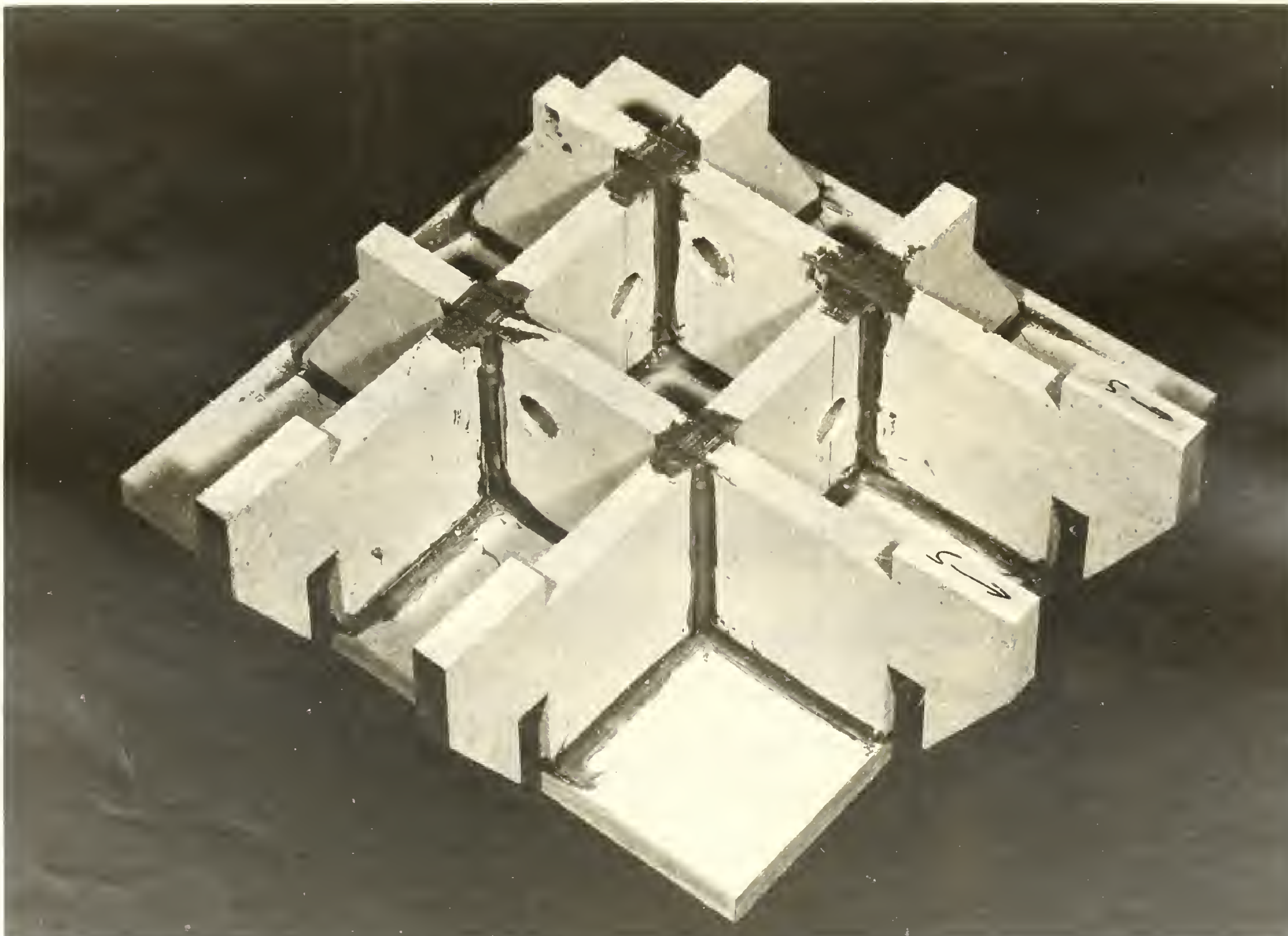
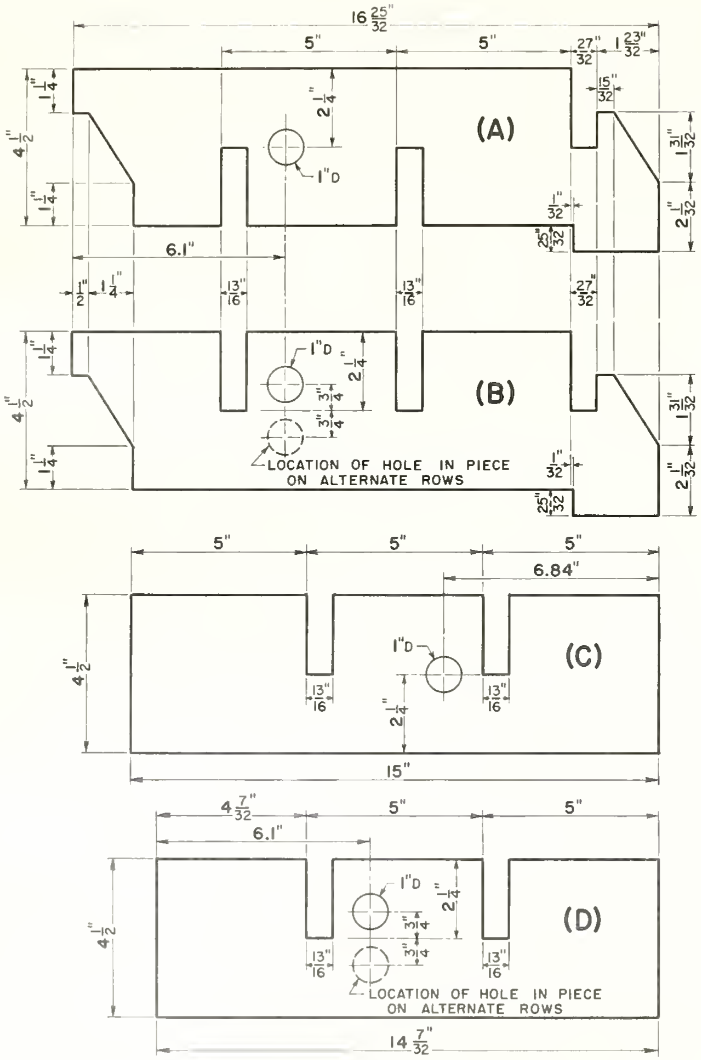
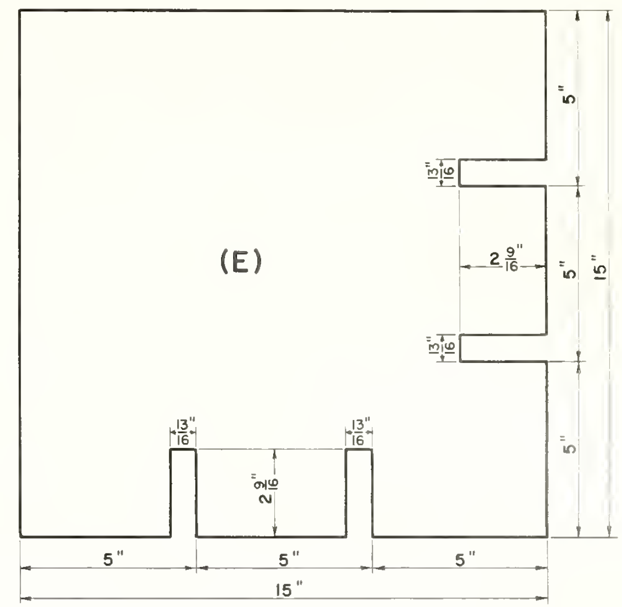


FIGURE 3. PARTIALLY ASSEMBLED UNIT



NOTE: SLOTS ON PIECES A, B, C & D ARE $2\frac{9}{32}$" DEEP.



(F). SAME AS E EXCEPT PIECE IS NOT SLOTTED.

PIECE	NUMBER REQ'D.	PIECE	NUMBER REQ'D.
A	2	D	1
B	2	E	1
C	1	F	1

FIGURE 4.
DETAIL DRAWING OF COMPONENTS OF NINE-CELL UNIT.

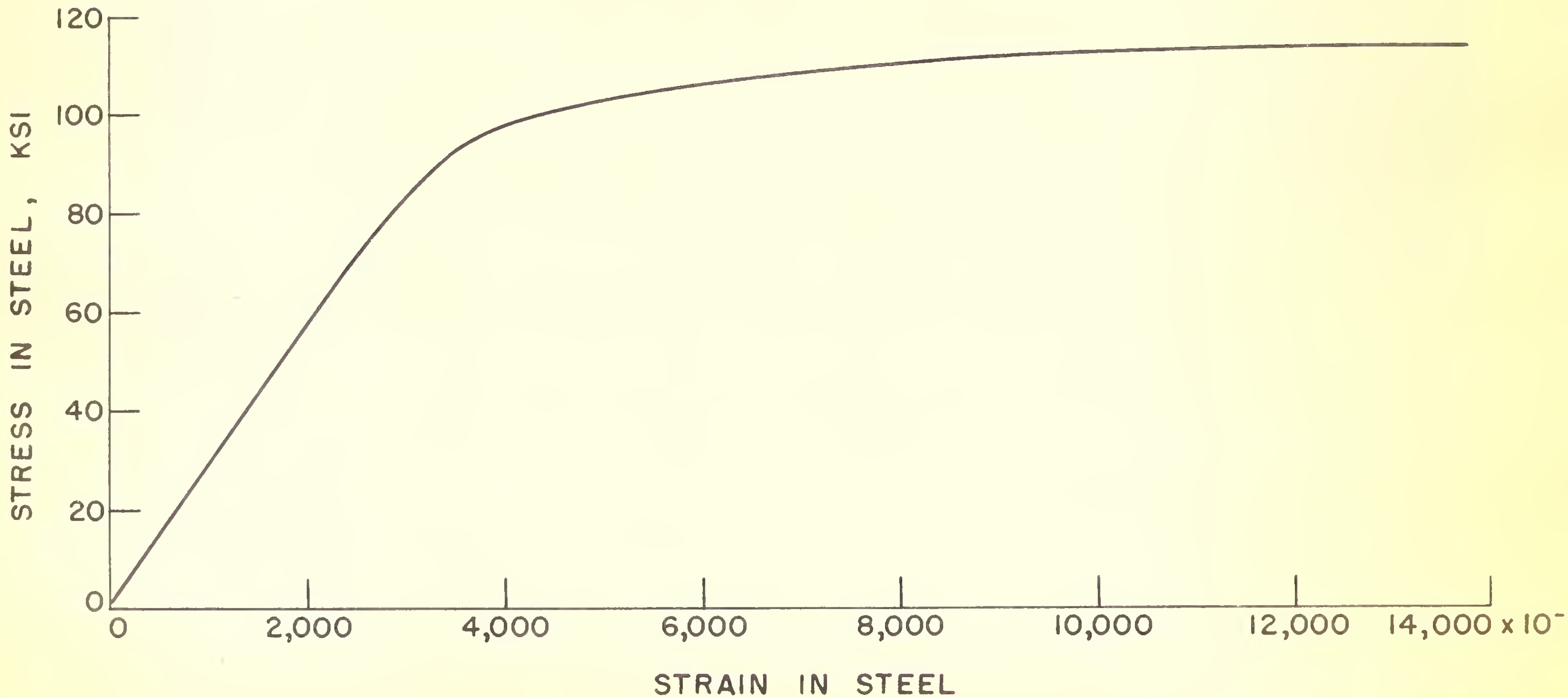


FIGURE 5. STRESS - STRAIN DIAGRAM OF PRESTRESSING STEEL

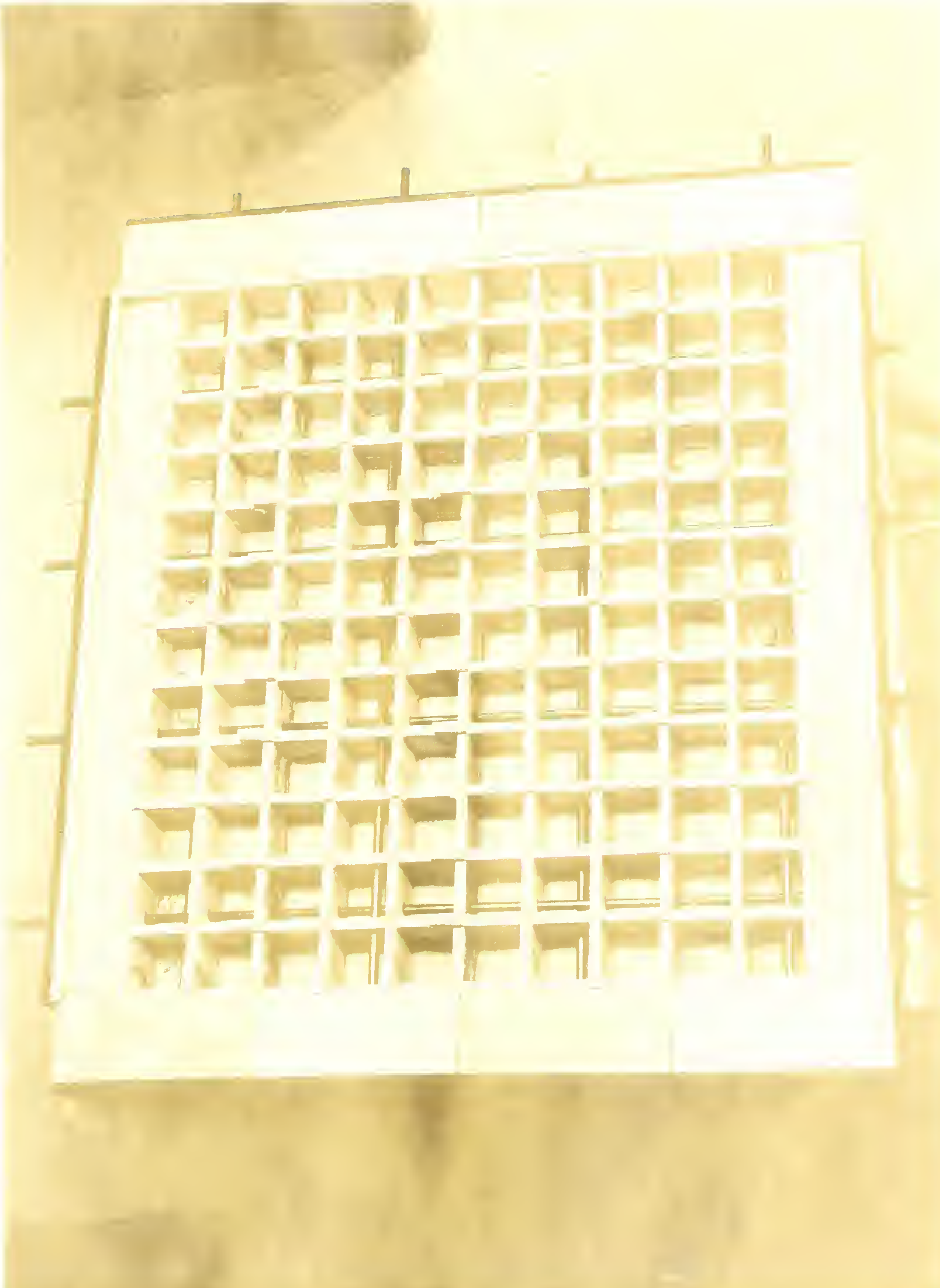


FIGURE 6. SLAB NO. 7-1 WITHOUT TOP FLANGES IN PLACE

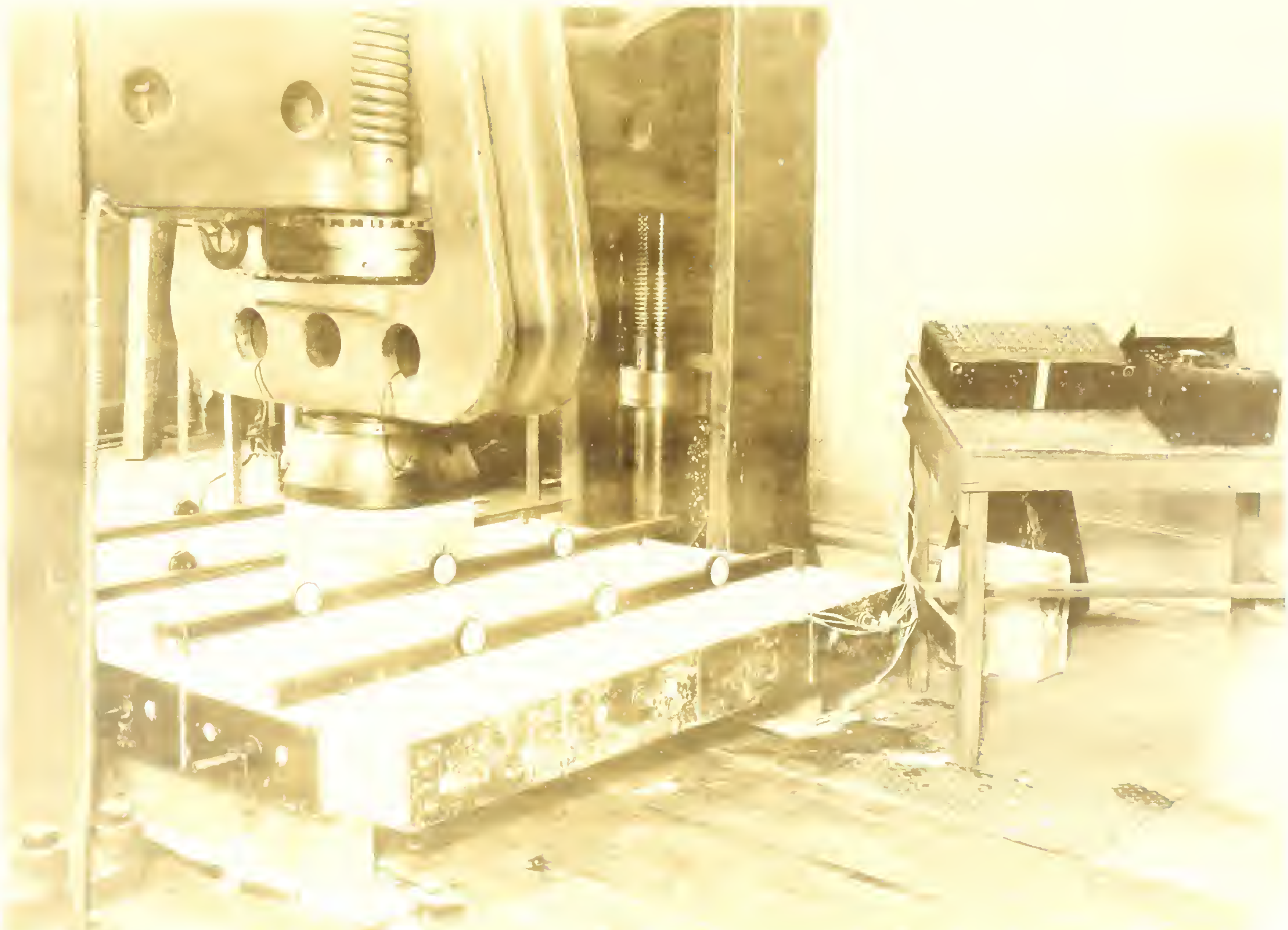
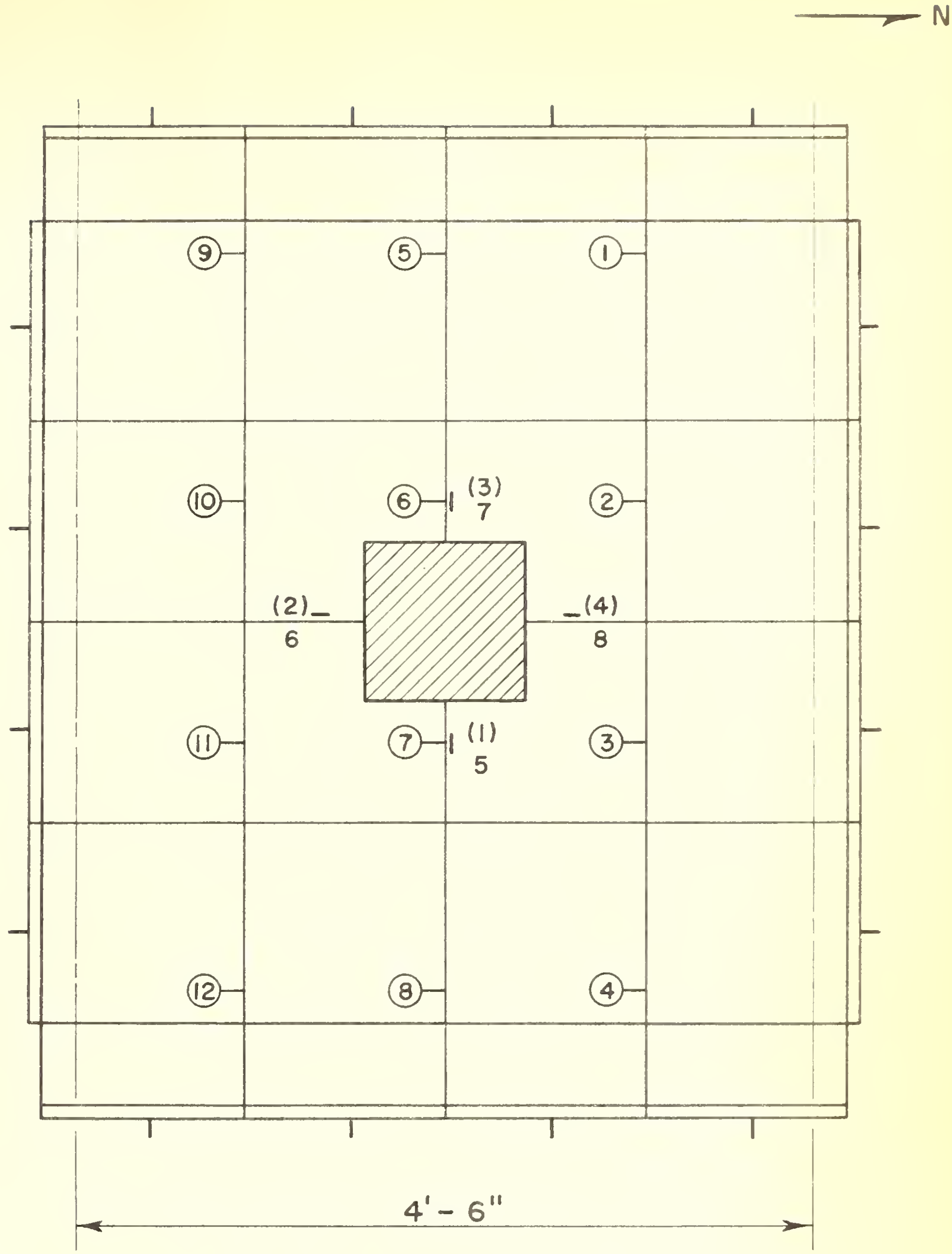


FIGURE [illegible]. TEST SETUP OF SLAB NO. [illegible]



GAGES (1) THROUGH (12) ARE DIAL GAGES
GAGES (1) THROUGH (4) ARE SR-4 GAGES ON BOTTOM SURFACE OF SLAB.
GAGES 5 " 8 " " " " TOP " " "

FIGURE 9. INSTRUMENTATION DIAGRAM FOR SLAB NO. T-1

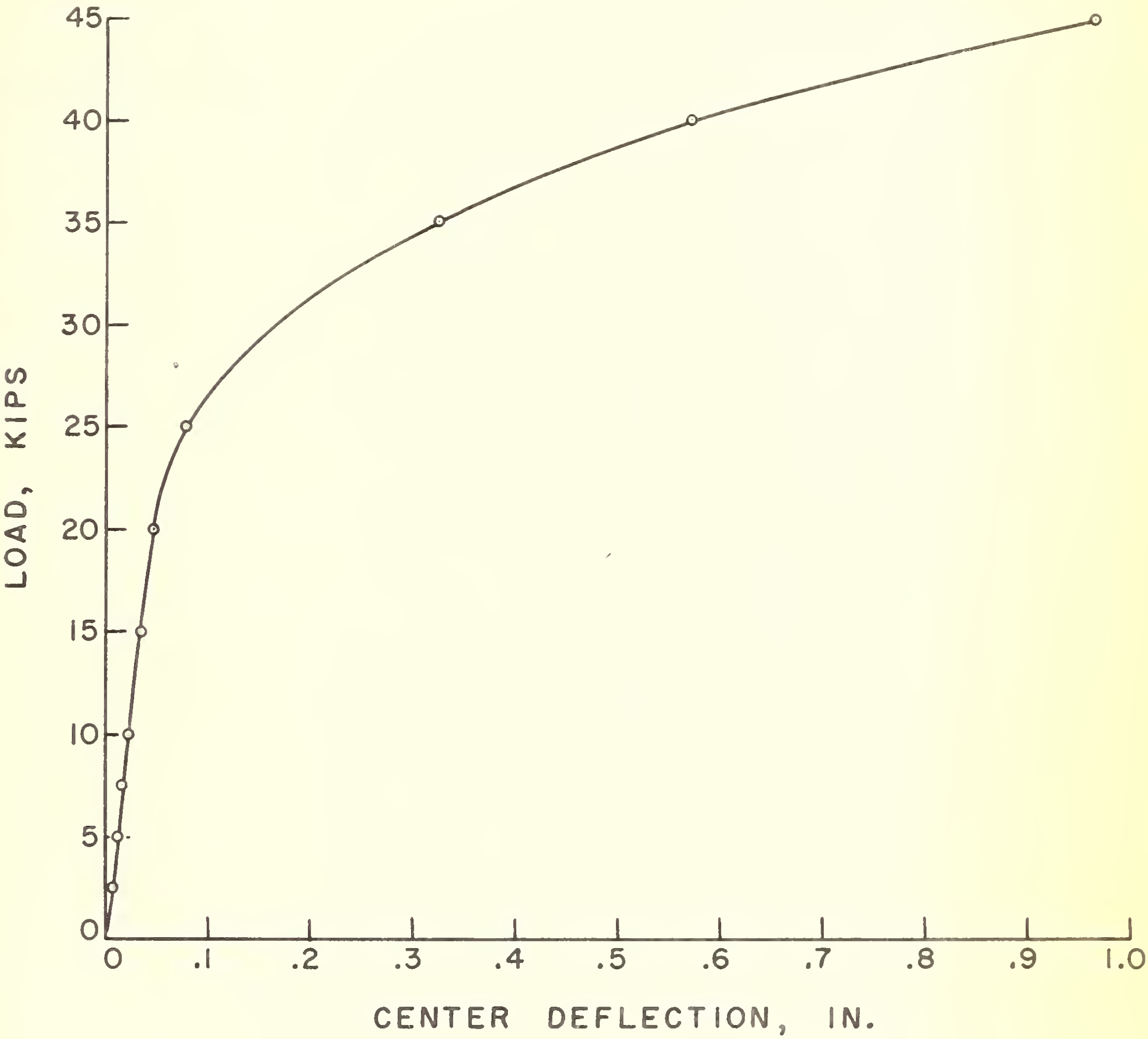


FIGURE 10. RELATIONSHIP BETWEEN LOAD AND CENTER DEFLECTION OF SLAB NO. T-1.

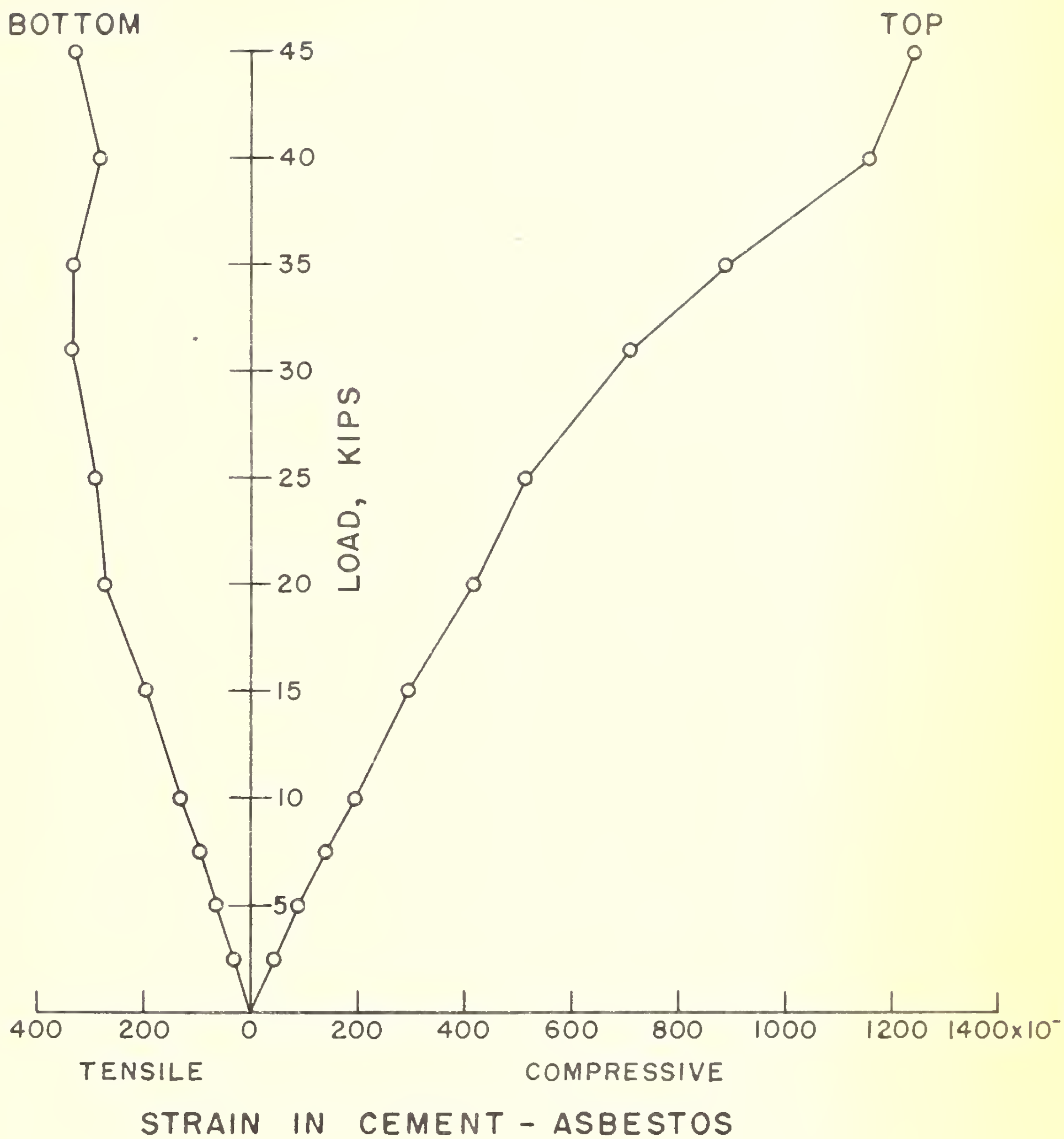


FIGURE 11. LONGITUDINAL STRAIN ON TOP AND BOTTOM SURFACE OF SLAB.

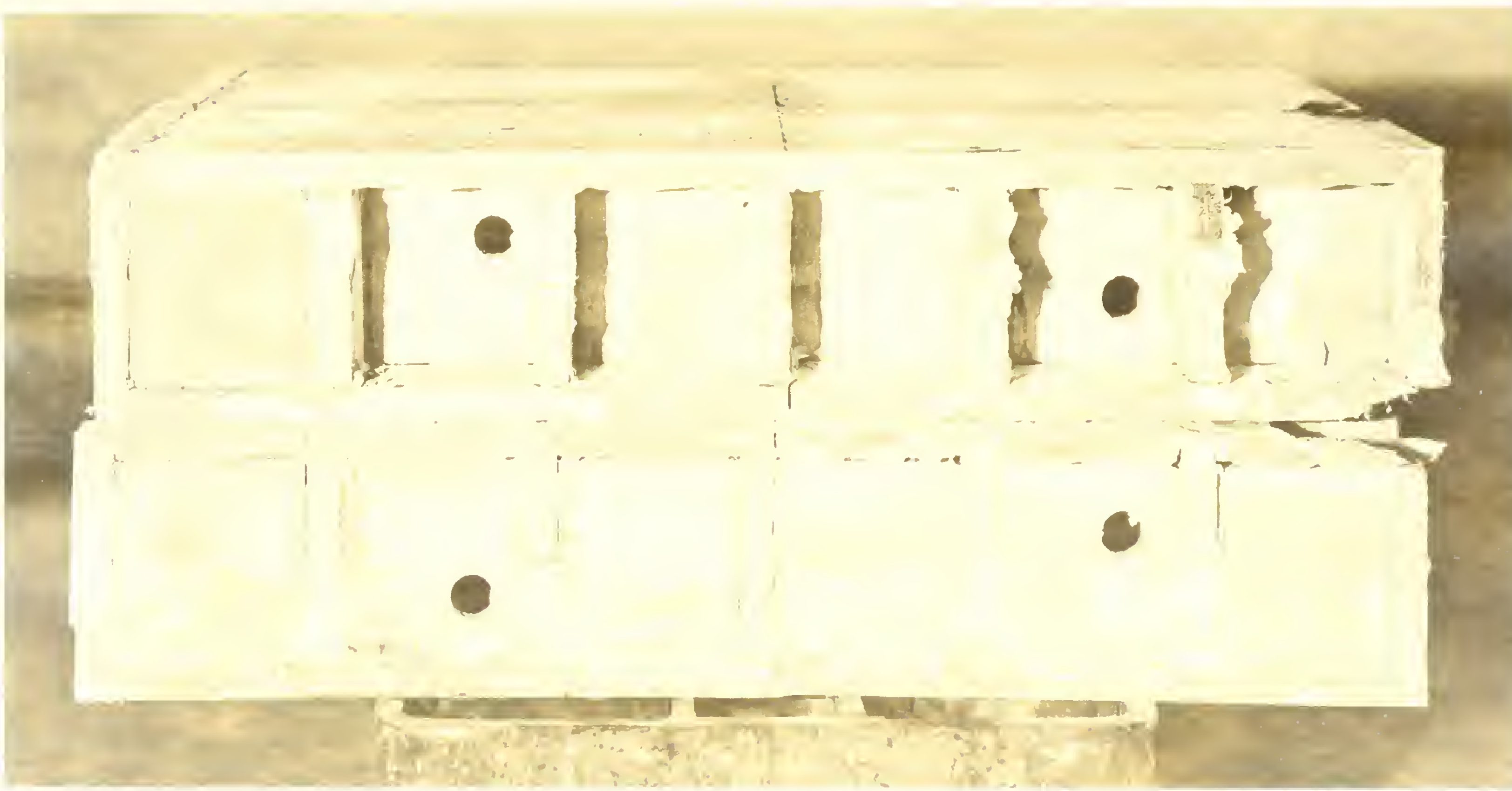


FIGURE 12. VIEW OF UNDAMAGED WEBS IN CENTER SECTION

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Sinclair Weeks, *Secretary*

NATIONAL BUREAU OF STANDARDS
A. V. Astin, *Director*

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Optics and Metrology. Photometry and Colorimetry. Optical Instruments. Photographic Technology. Length. Engineering Metrology.

Heat and Power. Temperature Physics. Thermodynamics. Cryogenic Physics. Rheology and Lubrication. Engine Fuels.

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