

Thesis 21100



INVESTIGATION
of the
STRENGTH OF BEEF BONE
by
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and
E. R. MONASTERIO

✓

June 1, 1920

Professor A. L. Merrill,
Secretary of the Faculty,
Massachusetts Institute of Technology.

Dear Sir:-

In accordance with the requirements for
graduation, we herewith submit a thesis entitled
"An Investigation of the Strength of Beef Bone."

Respectfully,

J. E. Cassidy.

128649

Thanks are due Professor H. W. Hayward for helpful suggestions and to Mr. G. R. Hapgood of the Brighton Dressed Meat Company, who kindly provided the specimens.

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OBJECT OF THESIS

The object of this thesis was to determine the strength of bone under different strains. The thesis was undertaken originally to investigate the resistance to strain of human bone, about which no quantitative information is available.

Human bones are relatively expensive and difficult to obtain. As a preliminary study, therefore, beef bone was used, and so original and unique was the investigation, that the whole time was spent in the investigation of beef bone.

The thesis is of more practical value than may be at first sight realized. All of the long bone obtained at the Brighton Dressed Meat Company are shipped to Japan where they are manufactured into imitation ivory articles.

Bone takes a very lustrous and beautiful polish, and the Japanese have purchased practically all obtainable in this country for the past twenty-five years.

At the Brighton Dressed Meat Company, we were shown several very ornamental as well as useful bone hooks turned out by the power saw operator. So, aside from its interest as a research study, this thesis may not be wholly without practical value.

SELECTION OF BONE USED

The strength of bone differs with the age and condition of the creature from which it is obtained. Cattle are generally about three years old when killed for beef, and the bones tested by us were selected from animals of this age.

The shin bone was selected because it is better adapted to the purposes of testing, because of its relative straightness and uniformity of section than any other.

In general appearance, the bones were hollow tubes five to six inches in length, and one to two square inches in cross sectional area.

TENSION TESTS

Bone was tested in tension in two directions just as in compression, that is parallel to the longitudinal axis and perpendicular to it.

Several interesting features were encountered. In the tests parallel to the longitudinal axis, after several unsuccessful attempts to grip the bone in its original tubular shape, the strip method was resorted to.

Strips were cut from the bone about five inches in length with the power saw. They were then filed into rectangular prisms with a reduced central section as shown in the sketch in the appendix.

Twenty-five tension tests parallel to the longitudinal axis were made in the hand tension machines in the laboratory.

In the tension tests perpendicular to the longitudinal axis, since it was impossible to grip any of the short specimens in the tension machine, it was necessary to adopt another expedient.

Specimens similar to the compression specimens were prepared, and then a small longitudinal strip removed. (See sketch in the appendix). The specimen was then supported between triangular shaped steel prisms. A groove was filed

in the two opposite contact lines and the apex of the steel prisms inserted in these grooves giving linear contact.

The specimens were then compressed in the Hand Olsen Machine and failed in tension perpendicular to the longitudinal axis of the material. Ten such tests were made.

COMPRESSION TESTS

From shin bones measuring five to six inches in length and tubular in section, a uniform hollow cylinder was cut from the middle portion.

The dimensions of the pieces tested varied from 1.00 inch to 1.75 inches in length and 1.10 square inches to 1.50 square inches net area of cross section.

The Hand Olsen Machine was used in the compression tests. The pieces were cut into the desired length with the aid of the power saw, and then the bearing surfaces were filed in order to make certain that the load would be uniformly distributed.

Surface gages were used to mark the end faces parallel. Twenty-five tests were made in this manner.

MODULUS OF ELASTICITY

In an effort to determine the modulus of elasticity for bone, six tests were made, all in compression.

Compression tests were necessary because the tension specimens were too short to permit of the use of the extensometer. (The bones were only about five to six inches in length, and four to five inches were required to insert in the jaws of the tension machine).

The specimens tested were four inches in length. A two inch Berry extensometer was bound to the specimen with wire to do away with the personal error which would arise in adjusting the instrument each time to the punched holes.

SHEARING TESTS

Bone was tested in shear in a special device used in the laboratory to determine the shearing strength of wood. A picture of this device is shown in the appendix.

The tests were made for shear in two directions: parallel to the longitudinal axis and perpendicular to it.

In the tests perpendicular to the axis, strips were used similar to those used in tension. In the tests parallel to the axis, a specially prepared specimen shown in a sketch in the appendix was used.

DENSITY

The density of the material was determined in the usual manner. Ten specimens were weighed, and then their displacement was determined.

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CONDENSED TABLE OF RESULTS
 DENSITY 128# PER CUBIC FOOT
 STRENGTH OF BEEF BONE

	Strength in Pounds Per Sq. Inch	
	Upper Limit	Lower Limit
Compression	23,100	14,800
Tension Parallel to Longitudinal Axis	15,700	11,800
Tension Perpendicular to Longitudinal Axis	10,150	6,970
Shear - Longitudinal	8,120	6,450
Shear - Across Grain	13,300	19,875
Modulus of Elasticity	4,120,000	2,720,000

- : TENSION TESTS : -

Number	B Inches	b Inches	a Inches	Area Sq.In.	Ultimate Load	Lbs. Sq. In
1	2	.218	.712	.155	1915	12350
2	"	.264	.685	.181	2390	13200
3	"	.293	.765	.224	2630	11750
4	"	.315	.785	.247	3010	12200
5	"	.347	.679	.236	3410	14450
6	"	.321	.759	.236	3160	13400
7	"	.286	.691	.198	3005	15200
8	"	.344	.736	.249	3060	12300
9	"	.379	.753	.285	3525	12450
10	"	.337	.604	.204	2510	12300
11	"	.313	.727	.227	3040	13400
12	"	.294	.773	.227	2930	12900
13	"	.362	.628	.227	3430	15100
14	"	.287	.651	.182	2440	13400
15	"	.355	.749	.266	3910	14700
16	"	.328	.726	.238	3420	14450
17	"	.281	.630	.177	2110	11900
18	"	.318	.718	.228	3050	13400
19	"	.371	.622	.231	3370	14600
20	"	.298	.643	.190	2910	15300

- : TENSION TESTS : -

- 2 -

Number	B Inches	b Inches	a Inches	Area Sq.In.	Ultimate Load	Lbs. Sq.In.
21	2	.370	.778	.288	3540	12300
22	"	.291	.714	.208	3270	15700
23	"	.302	.734	.222	3010	13600
24	"	.350	.748	.262	3350	12800
25	"	.369	.780	.288	3370	11800

- : COMPRESSION TESTS : -

Specimen Number	Volume in Cu. Cm.	Volume in Cu. In.	Length Inches	Area per Sq.In.	Ultimate Load	Lbs. Sq.In.
1	24	1.46	1.76	.833	16500	19800
2	30.5	1.86	1.31	1.42	22540	15800
3	35	2.14	1.76	1.22	18000	14800
4	31.75	1.93	1.11-	1.74	40030	23100
5	20	1.12	1.45	1.10	24400	22200
6	25	1.52	1.30	1.17	18870	16100
7	16.9	1.03	.87	1.19	26100	21900
8	20	1.22	.95	1.29	29900	23100
9	27.7	1.69	1.25	1.35	26300	19500
10	26.4	1.61	1.14	1.41	25100	17800
11	24.7	1.65	1.50	1.10	20200	18400
12	27.2	1.66	1.45	1.15	19900	17300
13	28.4	1.73	1.35	1.28	27200	21250
14	29.0	1.77	1.46	1.21	24900	20600
15	31.2	1.90	1.52	1.25	26500	21200
16	27.7	1.69	1.54	1.10	18500	16800
17	28.2	1.72	1.52	1.13	22300	19700
18	27.6	1.68	1.50	1.12	21500	19100
19	27.4	1.67	1.51	1.11	20300	18300
20	28.2	1.72	1.51	1.14	21300	18700

- ; COMPRESSION TESTS : -

- 2 -

Specimen Number	Volume in Cu. Cm.	Volume in Cu. In.	Length Inches	Area per Sq. In.	Ultimate Load	Lbs. Sq. In.
21	30.8	1.88	1.53	1.23	26000	21100
22	28.9	1.76	1.52	1.16	19600	16900
23	29.0	1.77	1.51	1.17	20300	17300
24	29.9	1.82	1.50	1.21	22300	18400
25	30.9	1.88	1.53	1.23	27400	22300

- : STRESS - STRAIN - COMPRESSION : -

No. 1

Load Lbs.	:	Extensiometer Reading
2000	:	0.0
2250	:	.0015
2500	:	.0034
2750	:	.0048
3000	:	.0063
3250	:	.0082
3500	:	.0095
3750	:	.0112
4000	:	.0128
4250	:	.0146
4500	:	.0161
4750	:	.0176
5000	:	.0195
5250	:	.0214
5500	:	.0232
6000	:	.0262
6500	:	.0300
7000	:	.0334
7500	:	.0375
8000	:	.0416
8500	:	.0465
9000	:	.0532
9500	:	.0607

- : STRESS - STRAIN - COMPRESSION : -

No. 2

Load Lbs.	:	Extensiometer Reading
2000	:	0.0
2500	:	.0037
3000	:	.0067
3500	:	.0101
4000	:	.0135
4500	:	.0165
5000	:	.0202
5500	:	.0240
6000	:	.0277
6500	:	.0311
7000	:	.0348
7500	:	.0394
8000	:	.0441
8500	:	.0495
9000	:	.0578
9500	:	.0674

- : STRESS - STRAIN - COMPRESSION : -

No. 3

Load Lbs.	:	Extensiometer Reading
2000	:	0.0
2500	:	.0045
3000	:	.0082
3500	:	.0123
4000	:	.0165
4500	:	.0202
5000	:	.0258
5500	:	.0292
6000	:	.0337
6500	:	.0378
7000	:	.0424
7500	:	.0483
8000	:	.0544
8500	:	.0600
9000	:	.0682

- : STRESS - STRAIN - COMPRESSION : -

No. 4

Load Lbs.	:	Extensiometer Reading
2000	:	0.0
2500	:	.0040
3000	:	.0075
3500	:	.0097
4000	:	.0150
4500	:	.0127
5000	:	.0153
5500	:	.0183
6000	:	.0210
6500	:	.0240
7000	:	.0266
7500	:	.0300
8000	:	.0334
8500	:	.0375
9000	:	.0427
9500	:	.0487

- : STRESS - STRAIN - COMPRESSION : -

No. 5

Load Lbs.	:	Extensiometer Reading
2000	:	0.0
2500	:	.0022
3000	:	.0045
3500	:	.0064
4000	:	.0090
4500	:	.0108
5000	:	.0131
5500	:	.0157
6000	:	.0180
6500	:	.0206
7000	:	.0232
7500	:	.0262
8000	:	.0292
8500	:	.0326
9000	:	.0368
9500	:	.0424

- : STRESS - STRAIN - COMPRESSION : -

No. 6

Load Lbs.	:	Extensiometer Reading
2000	:	0.0
2500	:	.0037
3000	:	.0075
3500	:	.0112
4000	:	.0150
4500	:	.0191
5000	:	.0232
5500	:	.0274
6000	:	.0322
6500	:	.0371
7000	:	.0423
7500	:	.0480
8000	:	.0540
8500	:	.0626
9000	:	.0742

MODULUS OF ELASTICITY
Compression

$$E = \frac{P L}{A d}$$

$$= \frac{(5000 - 2000) 2}{.915 \times .00195} = 3,364,000$$

	P lbs.	L ins.	A sq.ins.	d ins.	E
1:	3000	2	.915	.00195	3,364,000
2:	3000	2	1.05	.00202	2,830,000
3:	3000	2	.870	.00253	2,720,000
4:	3000	2	.950	.00153	4,120,000
5:	3000	2	1.081	.00131	3,830,000
6:	3000	2	.830	.00191	3,760,000

- : LONGITUDINAL SHEAR TESTS : -

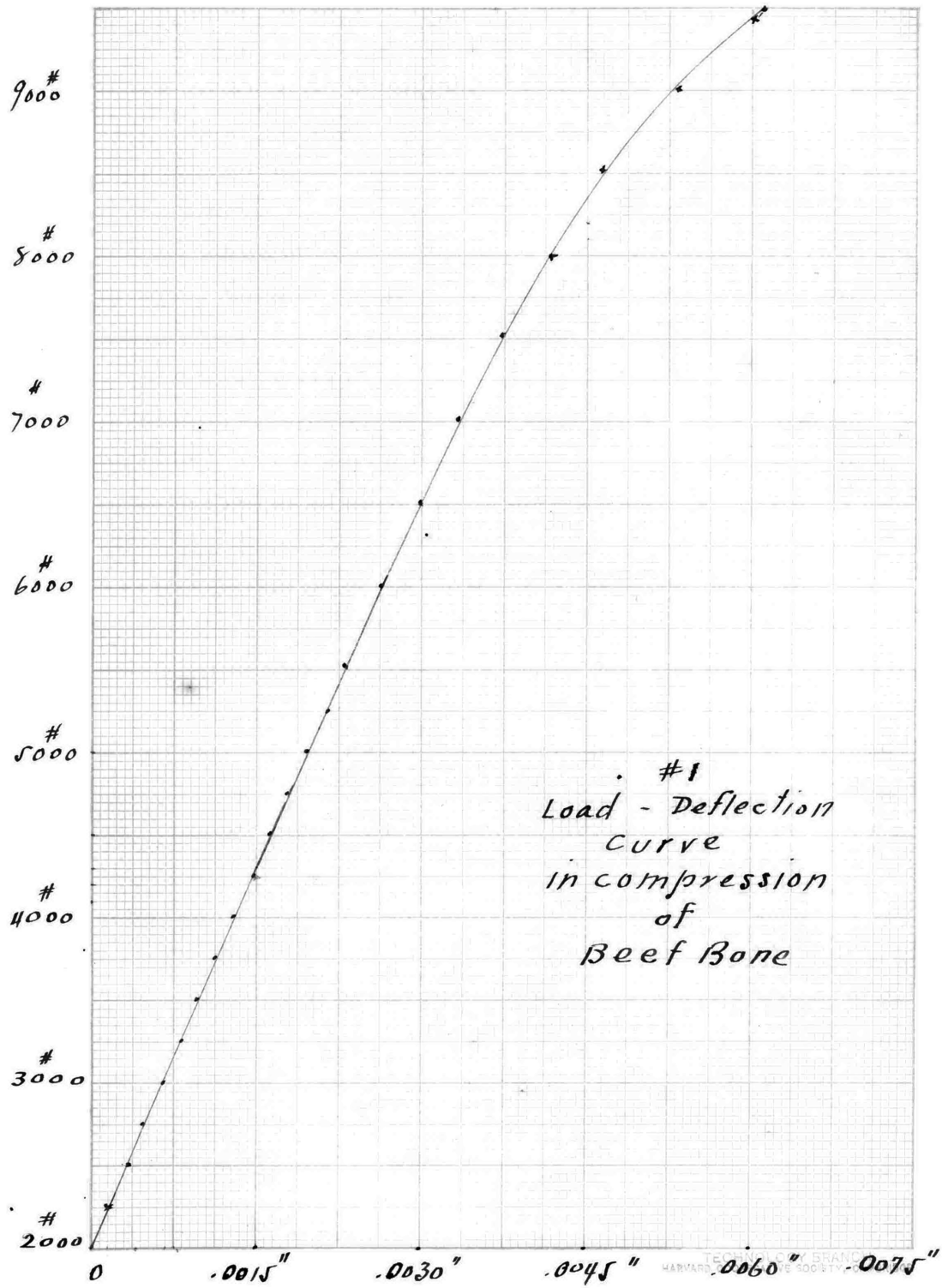
No.	Area	Shear Load	Lbs. Sq. In.
1	.696	5190	7430
2	.415	3360	8100
3	.360	2410	6700
4	.315	2190	6950
5	.542	3550	7720
6	.481	3620	7530
7	.732	5890	8050
8	.398	2780	6450
9	.479	3650	7610
10	.388	2890	7460
11	.686	4960	7230
12	.377	3060	8120
13	.424	3130	7385
14	.661	4620	6985
15	.684	4160	7115

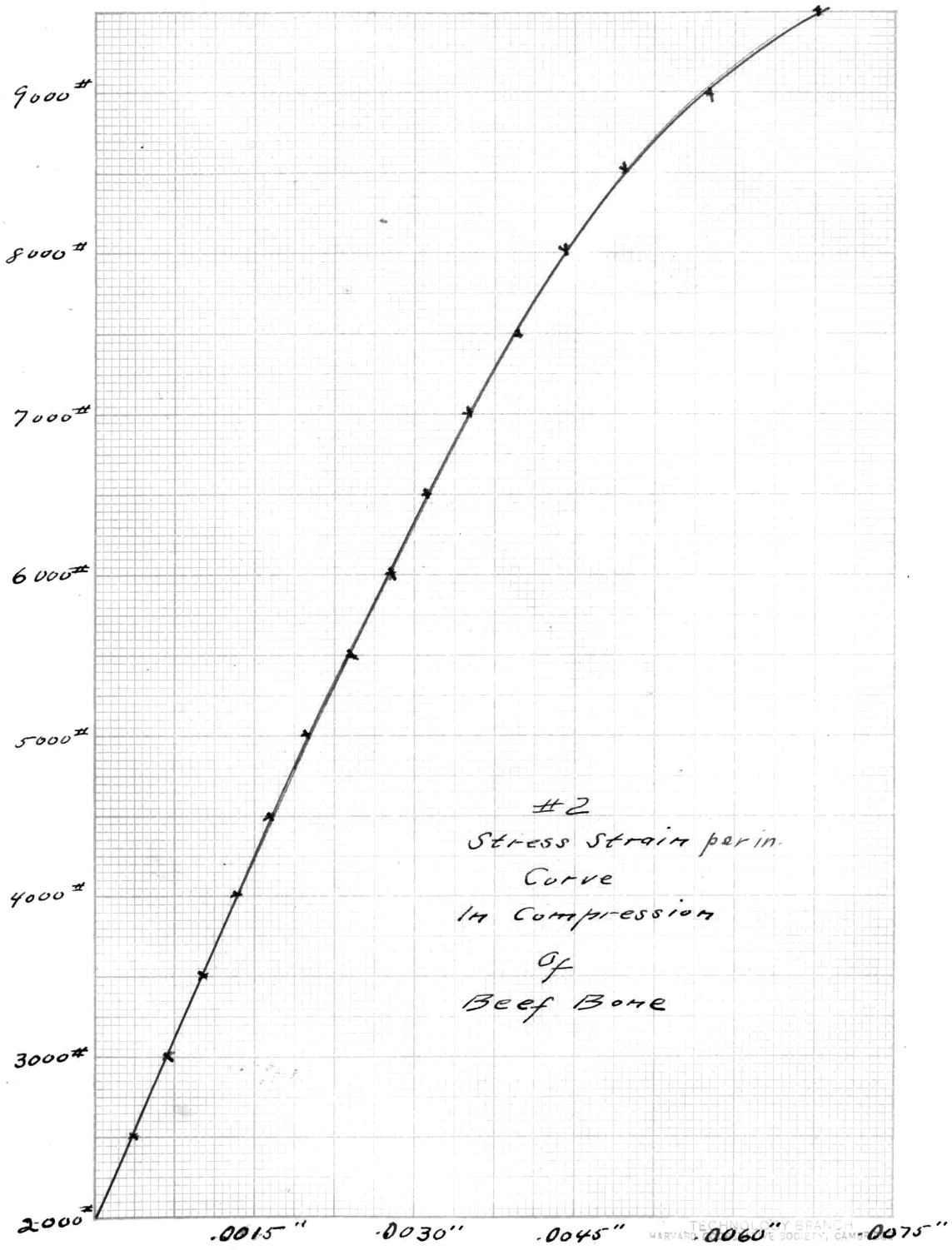
- : SHEAR ACROSS GRAIN : -

No.	Area	Shear Load	Lbs. Sq. In.
1	.160	2050	12800
2	.250	3150	12600
3	.218	2680	12300
4	.175	2290	13100
5	.223	2430	10900
6	.185	2070	11200
7	.195	2590	13300
8	.167	2050	12270
9	.245	2660	10875
10	.286	2790	9875
11	.231	2390	10350
12	.187	2120	11475
13	.209	2590	12400
14	.220	2770	12580
15	.235	3080	13100

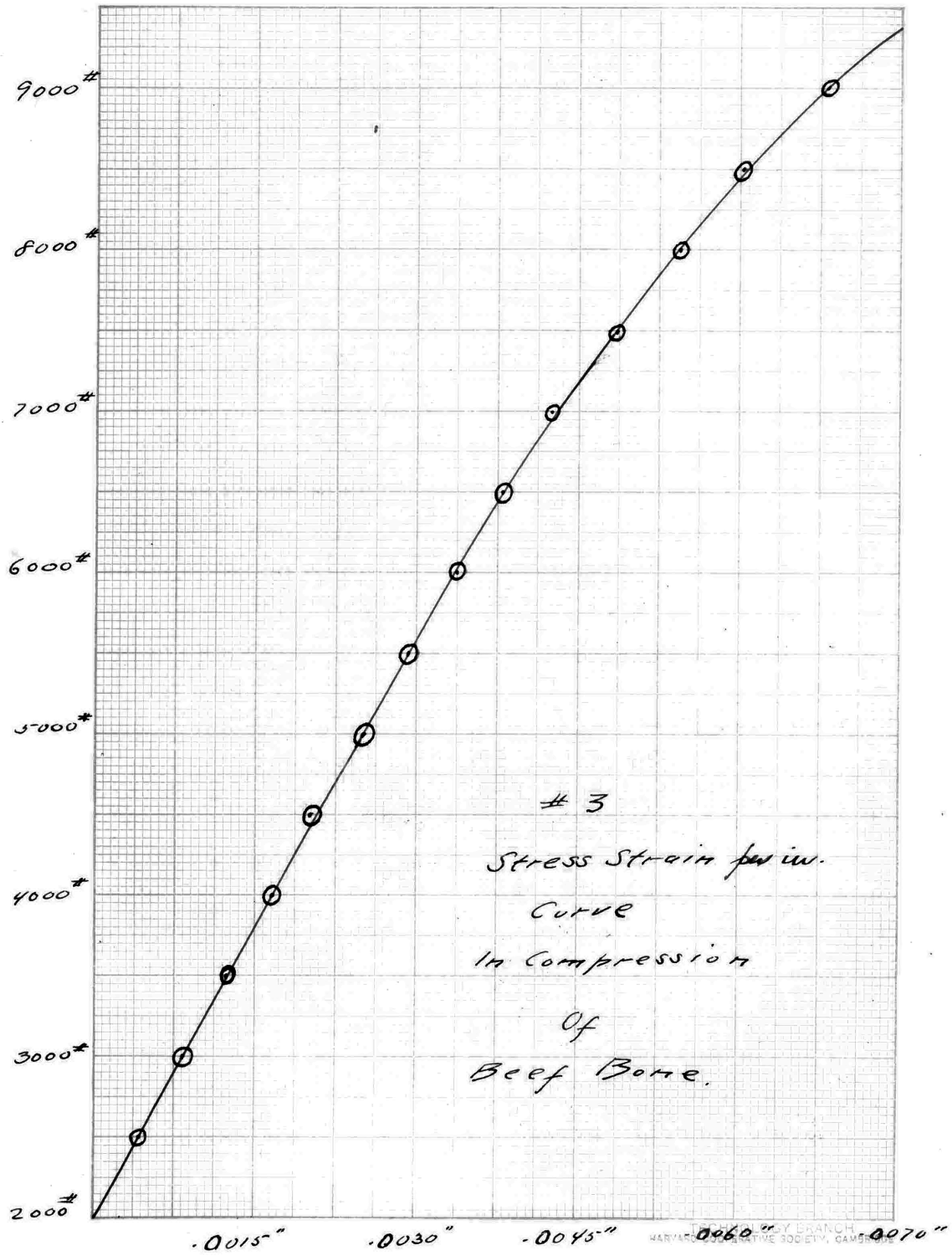
DENSITY

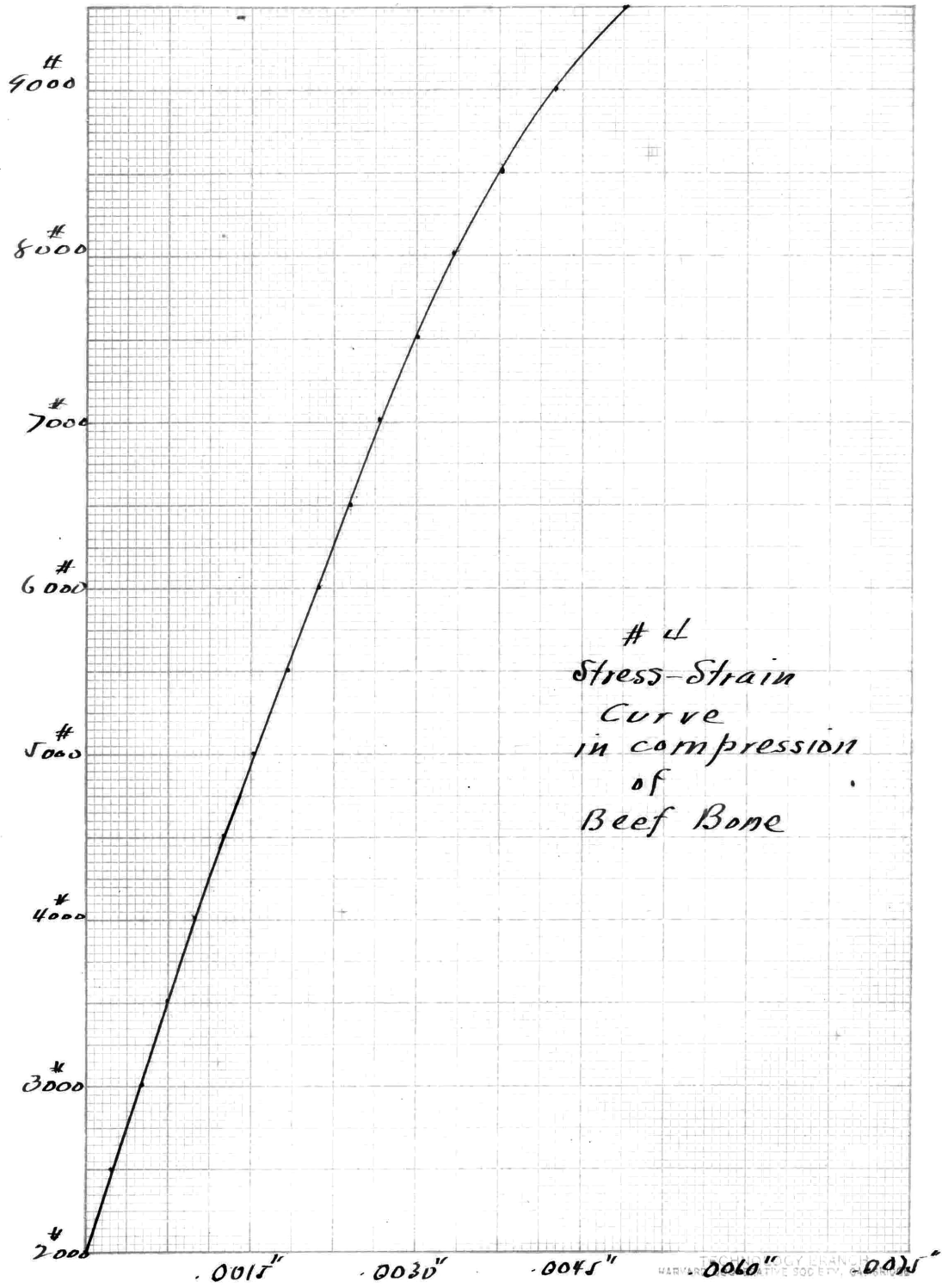
Weight of 10 specimens = 1930 grams
Displacement of 10 specimens = 925 cu. cms.
Specific Gravity = 2.09
Density = 131 lbs. per cu. ft.

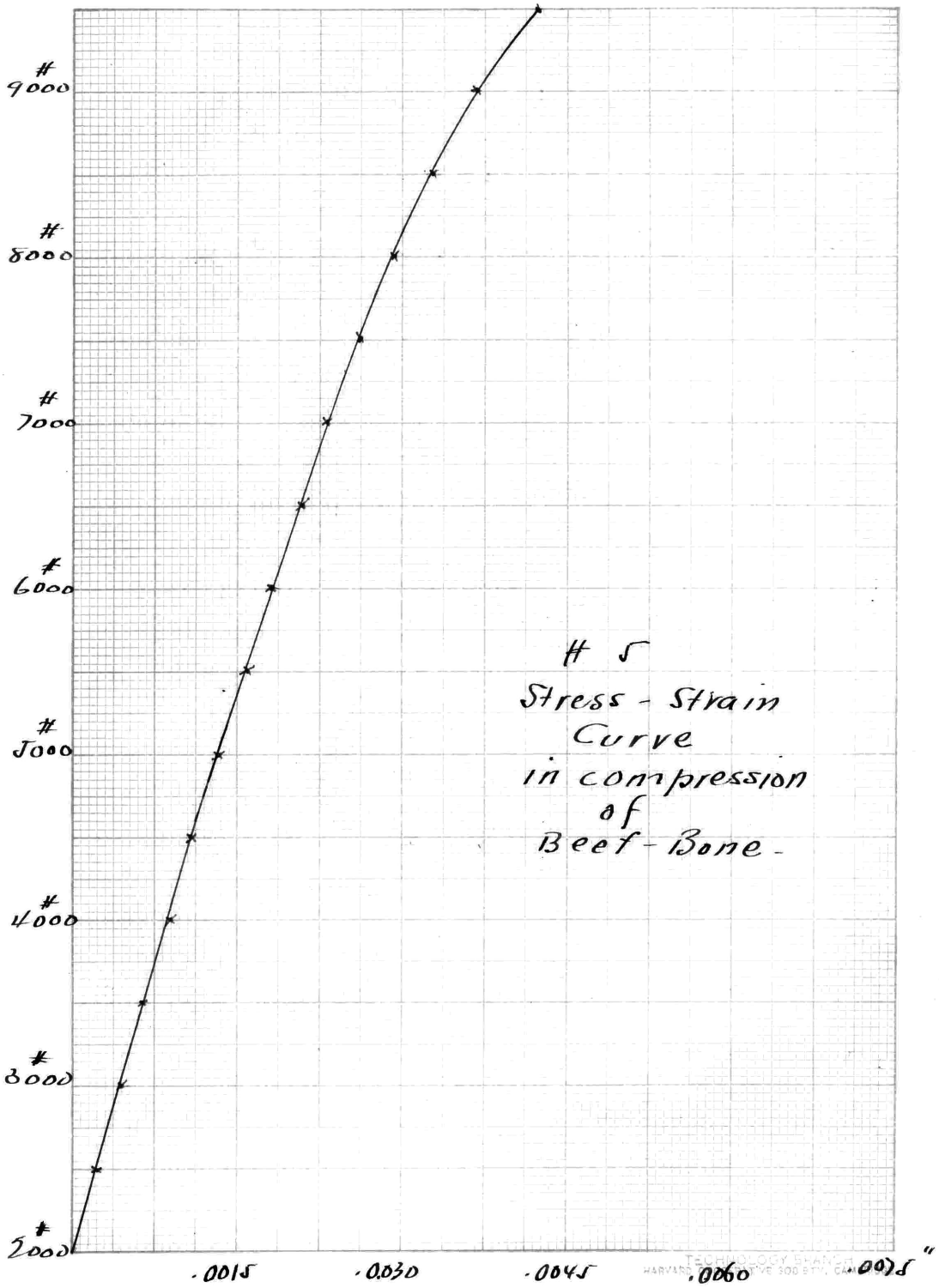


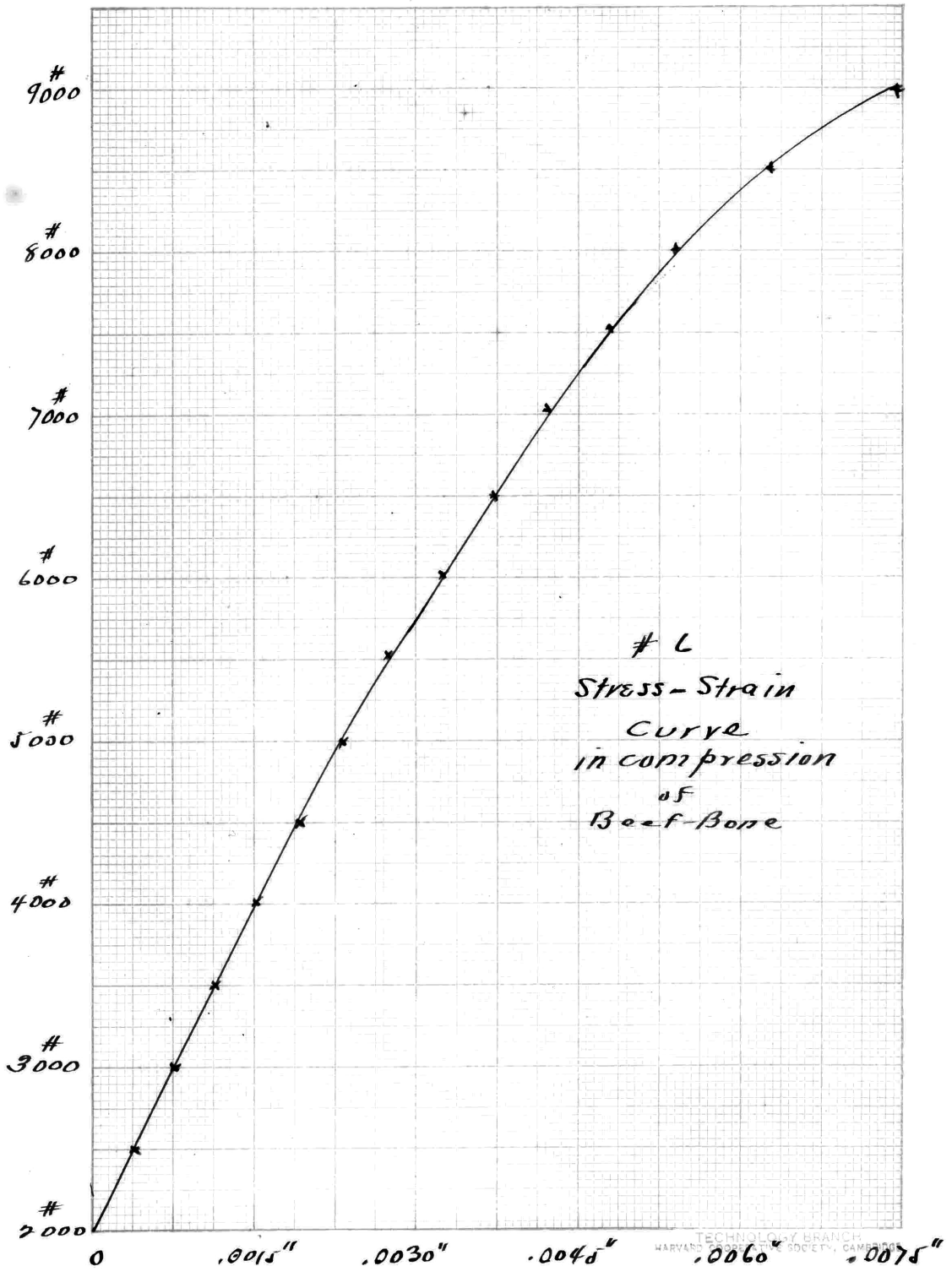


TECHNOLOGY BRANCH
 HARVARD ENGINEERING SOCIETY, CAMBRIDGE

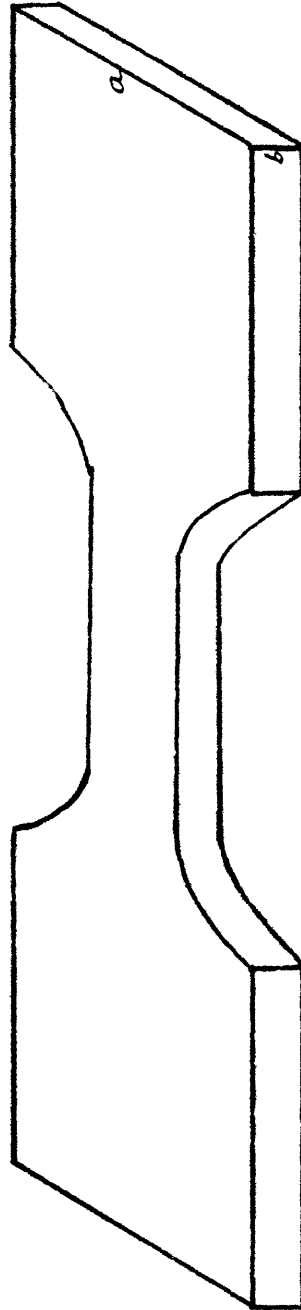




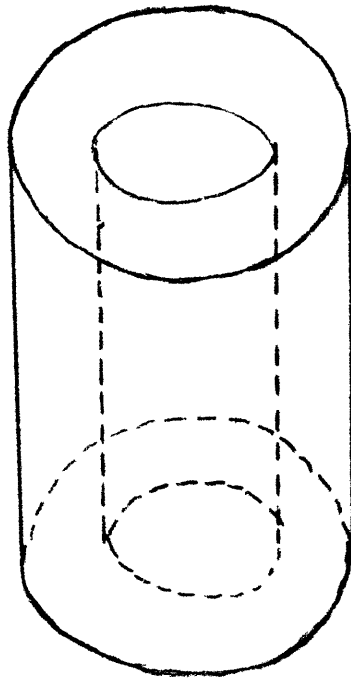




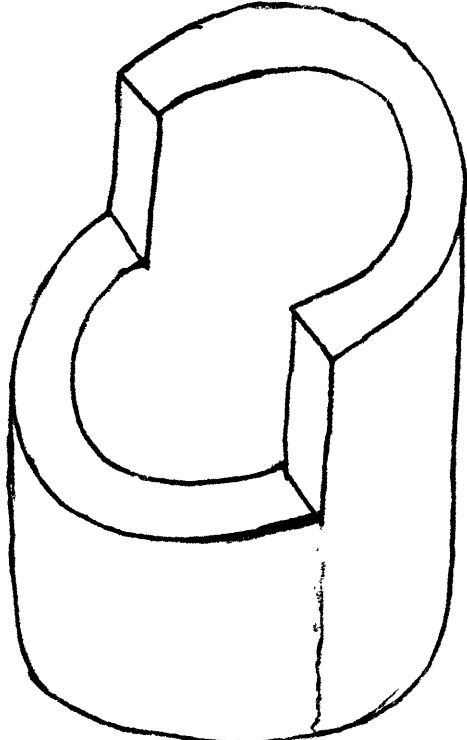
Sketch of
TENSION SPECIMEN



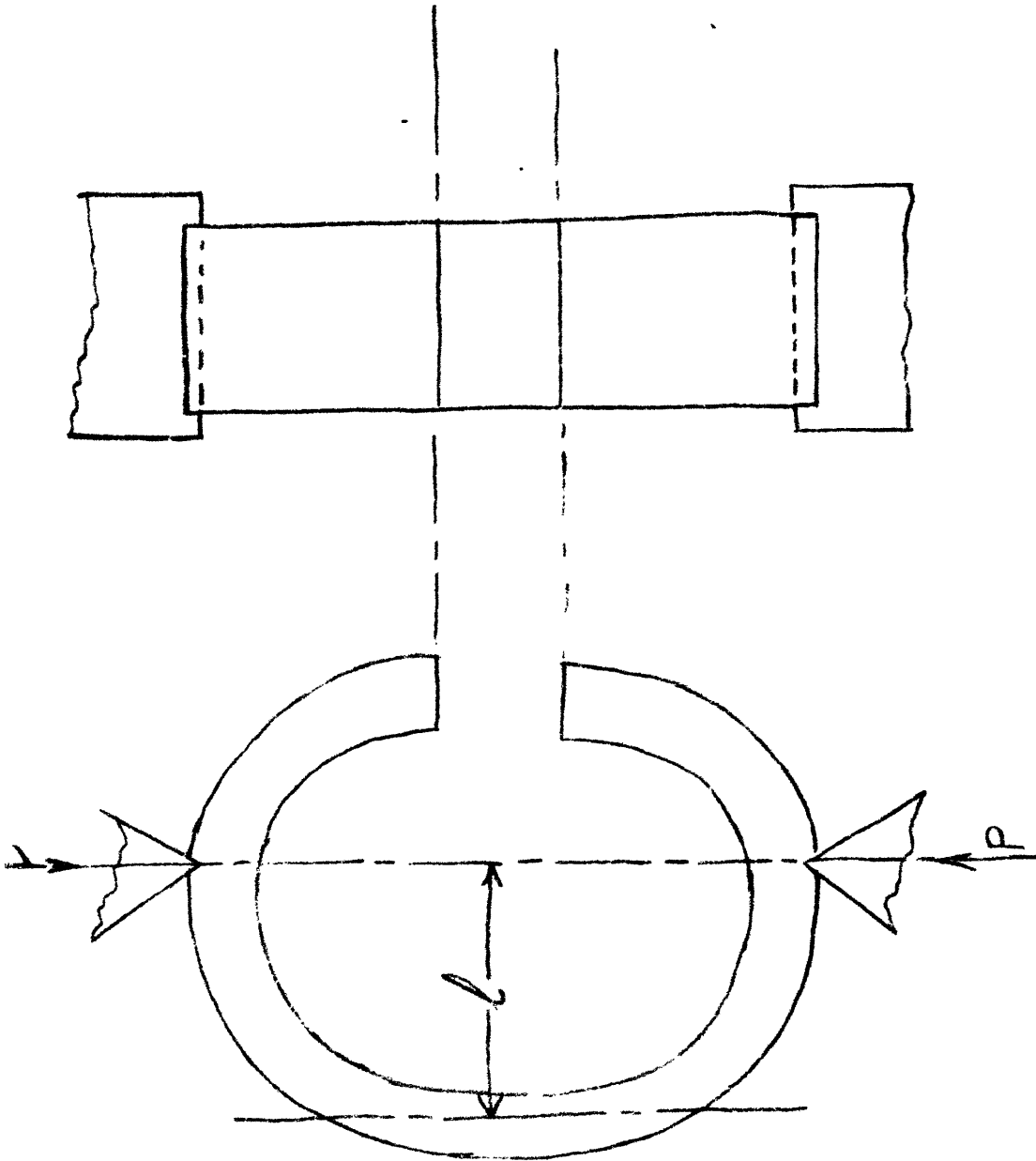
Sketch of
COMPRESSION SPECIMEN



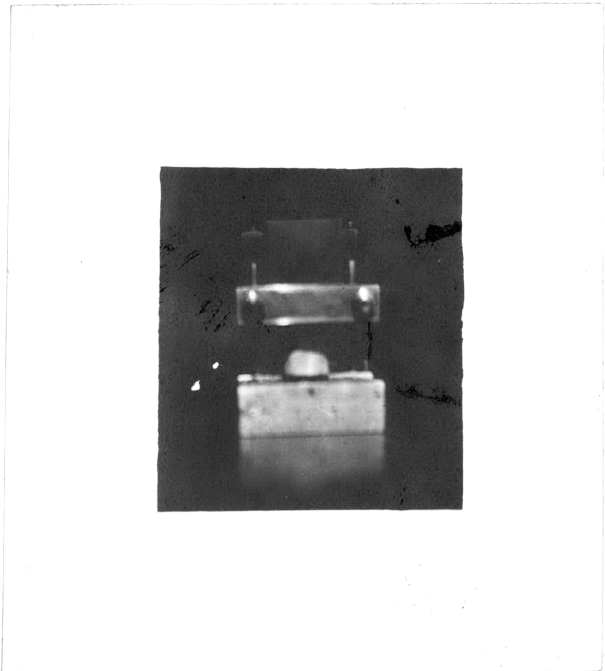
Sketch of
LONGITUDINAL SHEAR SPECIMEN



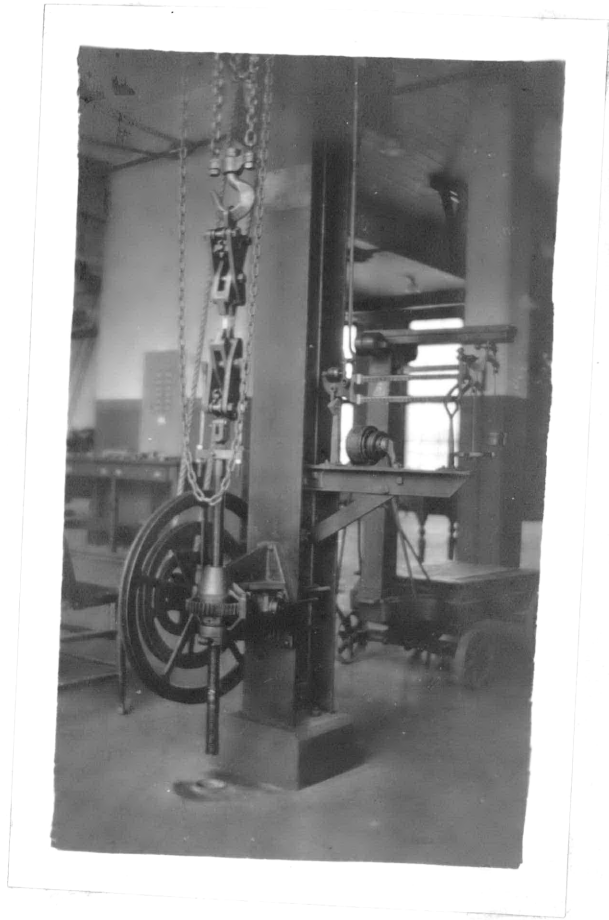
Sketch of
HOOK TENSION SPECIMEN



DEVICE USED FOR SHEARING.



HAND TENSION MACHINE



HAND COMPRESSION MACHINE

