TESTING MATERIALS.

by

RAINEY FARIS.

TESTING MATERIALS.

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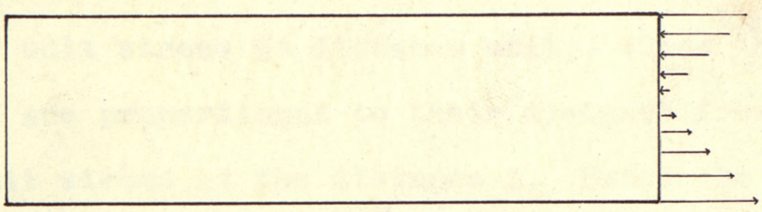
The subject of testing materials is too broad to be treated in detail in a short article such as this must necessarily be. Its breadth is such that one would have to work almost a lifetime to be able to handle it satisfactorily if one depended altogether on ones own resources. Our treatment of the subject will therefore be confined entirely to tests of timber, and we will have recourse to the publications of other experimentors for the greater part of our information.

The object of tests in general is ofcourse, to gain as great a knowledge as possible of the behavior of the different materials when subjected to stresses andstrains such as are put upon them in the various structures in which they are actually used.

A great many formulas expressing the relation between the loads applied and the stresses produced in the various materials have been arrived at, partly by experiment and partly by mathematical deduction. These formulas are only approximately correct, as they are in most cases average results of tests made on materials from one locality. Materials (and especially timbers) vary greatly in different localities and hence a formula that would be approximately correct in one place, might be entirely wrong in another.

Our object then will be, not to deduce any new formulas, but merely to investigate the correctness of those already in existence for the timber in common use in this locality.

Perhaps it might be well to show how some of the most important formulas are deduced. The two fundamental formulas, $V= AS_s$, and $M= \frac{si}{c}$ for the investigation of beams may be deduced as follows:- consider any beam loaded in any manner and cut at any section by an imaginary vertical plane. Considering the left of the section only, it is plane that the internal stresses in that section must hold in equilibrium the external forces on the left of the section.



It may easily be proved that,
Resisting shear is equal to the vertical shear, and,
Resisting moment is equal to the bending moment.
Now the resisting shear is the algebraic sum of all the vertical components of the internal stresses at the section of the beam under consideration. Hence if A be the area of the section, S_s the shearing unit stress, regarding it as uniform thruout the section, and V the vertical shear, we have the formula.

$$V = AS_s,$$

which is of great importance in case of a very short beam when the shearing force becomes greater than the bending moment.

The resisting moment is the algebraic sum of the moments of the internal horizontal stresses at any section with reference to a point in that section.

If S is the horizontal unit stress upon the fiber most remote from the neutral axis, C the shortest distance from that fiber to this axis, and Z the distance from the Neutral axis to any fiber having the elementary area A.

$\frac{s}{c}$ = unit stress at distance unity, since the horizontal stresses are proportional to their distance from the axis, and $\frac{s}{c}Z$,= unit stress at the distance Z. Hence the total stress on any fiber of area A, is $\frac{Asz}{c}$; and the bending moment of this stress about the mental axis is, $\frac{Asz^2}{c}$. Now the sum of all these moments of unit areas about the Neutral axis is, the resisting moment of the horizontal stresses and may be represented by, $\sum \frac{Asz^2}{c}$ which may be written, $\frac{s}{c} \sum Az^2$ since S and C are both constants.

But $\sum Az^2$ is the moment of enertia of the cross section with reference to the Neutral axis and may be denoted by I.

The resisting moment is equal to M, the bending moment and hence, $M = \frac{si}{c}$,

or as it is more often written,

$$\frac{M}{s} = \frac{I}{C}.$$

It should be stated however ,that these formulas do not hold if the material is stressed beyond the Elastic Limit.

Different writers give different definitions to this term "Elastic Limit" . At best it is a rather indefinite quantity for wood, but in wrot iron and steel it can be located with a considerable degree of accuracy.

The French Commission after investigating the subject in detail decided to adopt three critical points; viz:-

1. The Elastic Limit, or the unit stress beyond which a portion of the deformation remains as a permanent set.

2. The Proportional Elastic Limit corresponding to the point where the deformations cease to be proportional to the loads.

3. The Apparent Elastic Limit corresponding to the point where the deformations increase rapidly without any increase in the force exerted.

It will be seen at once that in practice these points will be difficult to locate, and that very delicate measuring instruments will be required if any acurate results are to be obtained.

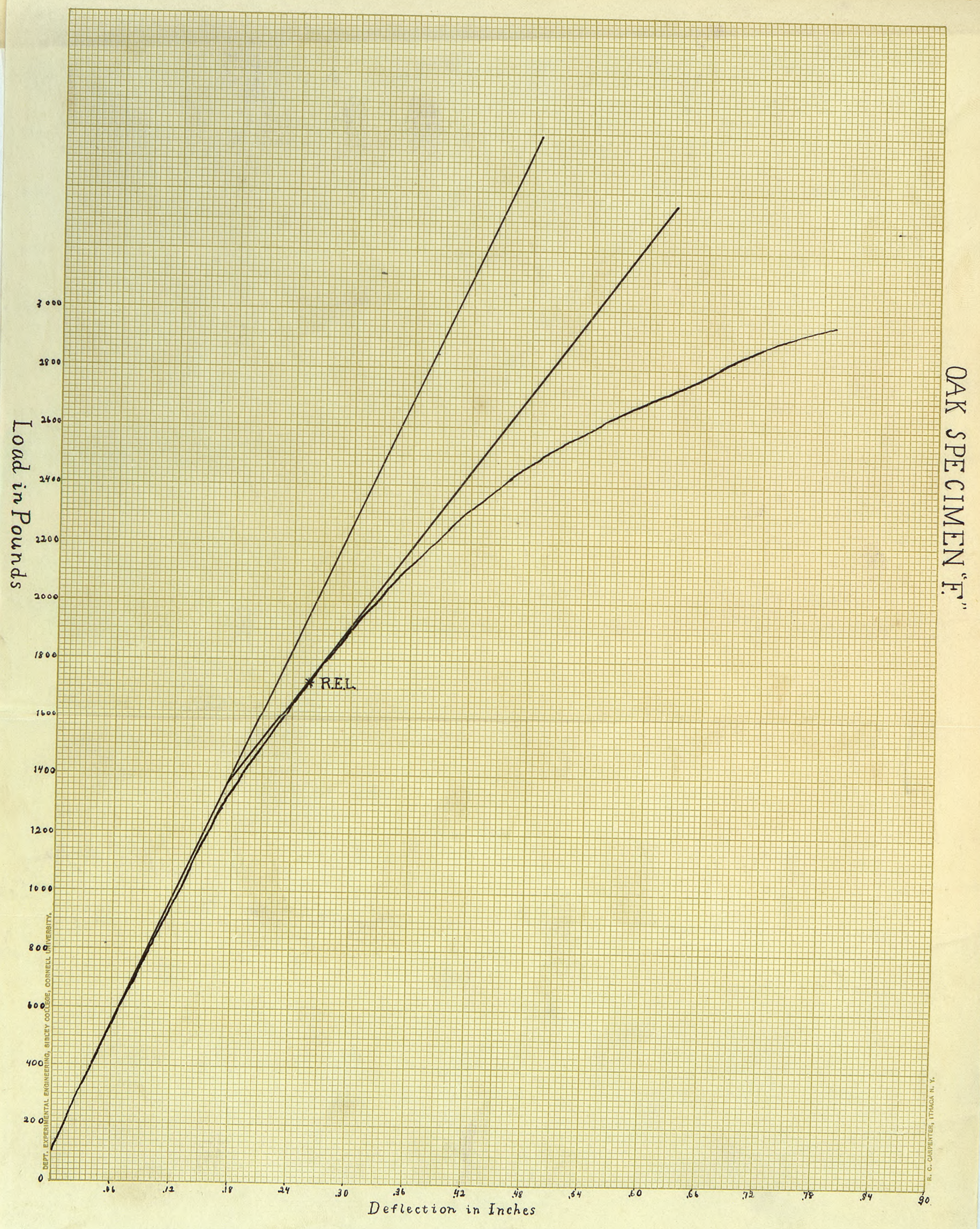
Prof. J. B. Johnson proposes the term, Relative Elastic Limit instead of the three French terms mentioned, and defines it as,the point on the stress diagram of tests in cross bending where the rate of deformation is fifty percent greater than it is at the origin. This point can be easily located and,it is a point that will determine the load the material can safely carry.

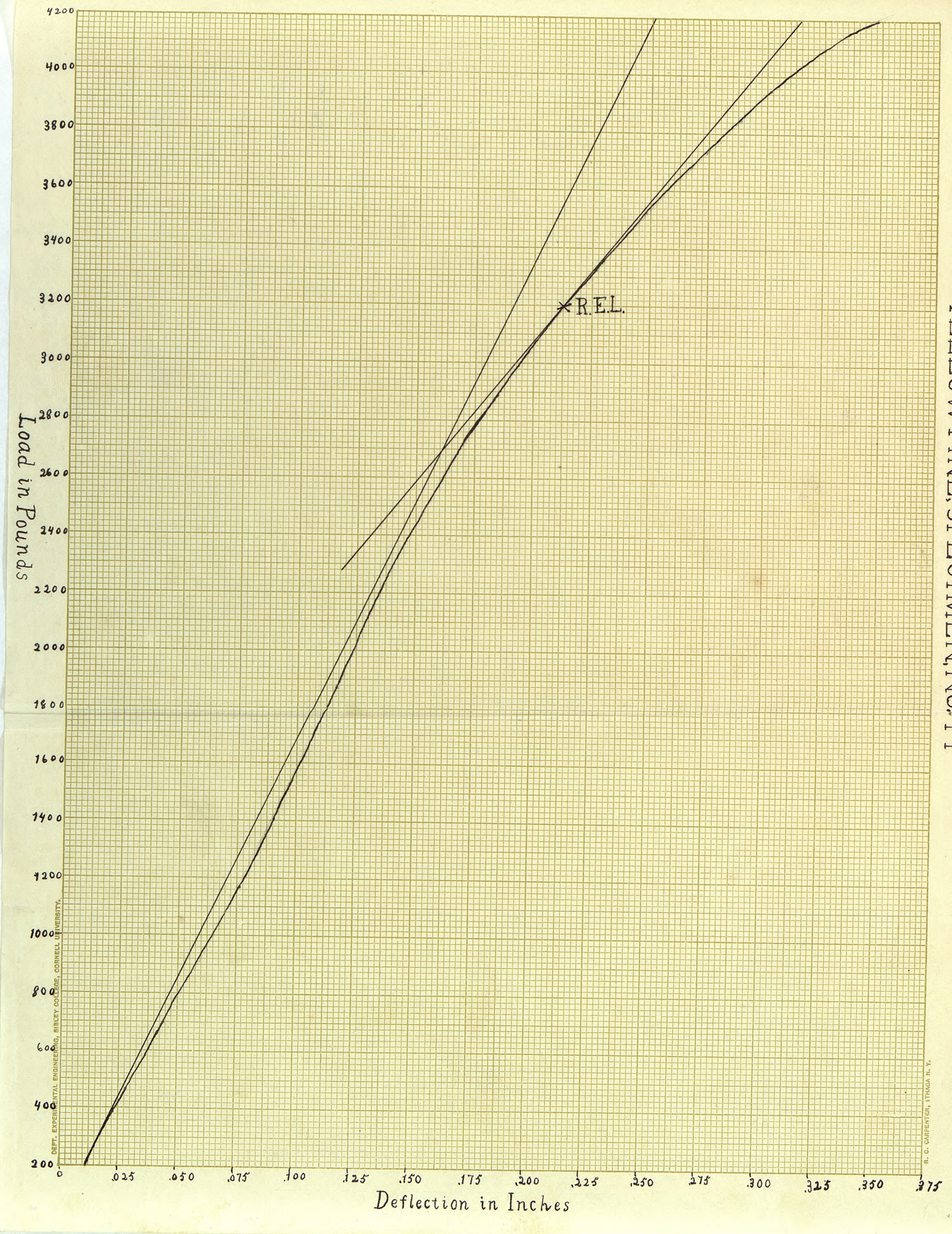
Prof. Johnson gives the following method of locating the point on the stress diagram. Draw a tangent to the stress diagram at the origin . Find the angle whose tangent is fifty percent greater than that of the original tangent line, and locate the point at which a line drawn at this new angle will be tangent to the stress diagram.

To give a better idea ofwhat the elastic limit is, and to show how poorly it is defined in wood as compared with metals, examine the curves here shown. The curve shown for mild steel is one taken from a tension test made here by the class of 1901 in our regular labratory work. Readings were taken every half minute and the curve was plotted with times as abscissas and loads as ordinates. Here you will notice,the elastic limit is clearly defined and shows a load of about 26900 pounds. Notice that the loads up to this point were proportional to the times but increased very much faster beyond it. A very similar curve would be obtained by using deformations as abscissas instead of times. No stop was made to take readings, and hence the deformations would be exactly proportional to the times.

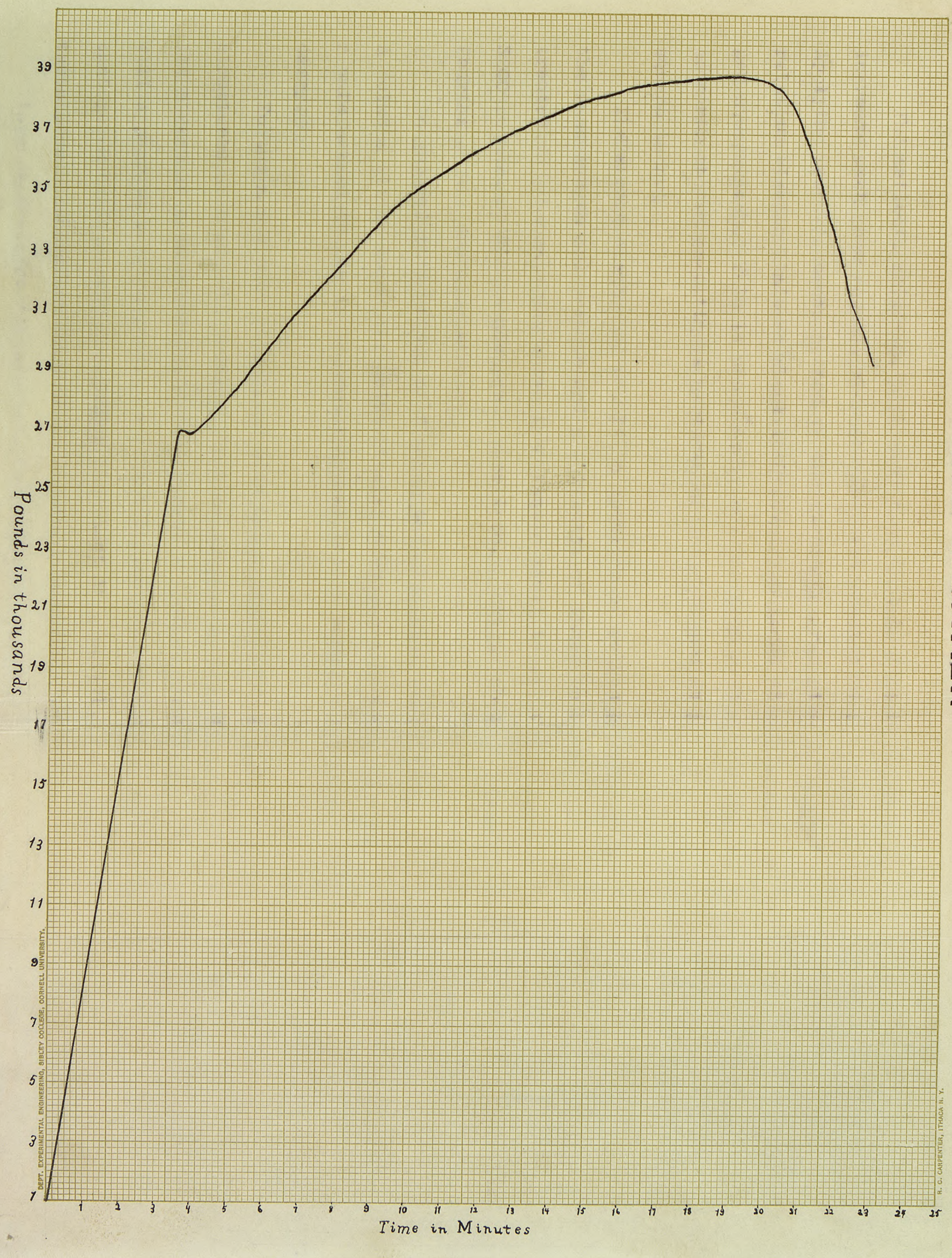
The curves here shown of timber are for cross bending and are taken from tests made expressly for this purpose.

Notice first the curve of specimen F, which was a red oak specimen two feet long between supports, two and one half inches in depth, and one and a half inches in breadth. Here there is no definite point that could be located by the eye as in the steel specimen.


OAK SPECIMEN "F"
Load in Pounds
Deflection in Inches
R.E.L.
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000
.06
.12
.18
.24
.30
.36
.42
.48
.54
.60
.66
.72
.78
.84
.90
DEPT. EXPERIMENTAL ENGINEERING, SIBLEY COLLEGE, CORNELL UNIVERSITY.
R. C. CARPENTER, ITHACA N. Y.



YELLOW PINE, SPECIMEN, NO. 14



STEEL SPECIMEN

The deflections(see data sheets) show that bending began to increase much more rapidly when the load was about 1900 pounds. Applying Prof. Johnsons method to the stress diagram gives the relative elastic limit as about 1800 pounds or about 480 pounds per square inch. This is undoubtedly not far from right as the specimen showed an ultimate strength of only 790 pounds per square inch.

The stress diagram of No. 14, a specimen of yellow pine of the same length and breadth and a thickness of three inches, treated in the same way shows the Elastic limit to be at about 3200 pounds, or 710 pounds per square inch. This is about three fourths of the breaking stress.

In general this method of finding the elastic limit gives a point a little below the point usually taken, and hence this is a safe method to use in determining what load a beam can safely carry.

To the man who is unfamiliar with the stress es in such structures as roofs and bridges the time spent in computing the stress in each member as a roof struss or other structure will appear to be time lost. He will tell you to use material that you know is strong enough for the place in question, and not waste your time performing what is to him, a useless task.

To show the erroneousness of his position, suppose a structure built according to his ideas. What is the result? Evidently this; some pieces are too light owing to his misjudgment, and others are much heavier than necessity demands.

Suppose however he happens to get all parts sufficiently heavy to stand the load they are intended to carry. He will still have pieces that are much heavier than are needed and the result is a waste of valuable material, and an unnecessary expence incurred. Consequently he will be unable to compete with wiser men, and will soon be compelled to retire from the field.

This is sufficient to show the value of an investigation of the strength of materials, and the stresses in the different members of a structure, and we will now proceed with our investigations.

Data taken from tests of our own has been used for reference tho no explanation of how the tests were made has been given. This we will now endeavor to give.

Most of our tests were in cross-bending. All specimens tested weretwo feet in length, this being the maximum length that could be tested in cross-bending on the testing machine used without a special beam.

This machine need not be described as it is similar to those explained in works on "Testing Materials", "The Materials of construction", etc.

Figure 1 will give a clearer idea of the arrangement of the specimens when being tested than could be given in any other way.

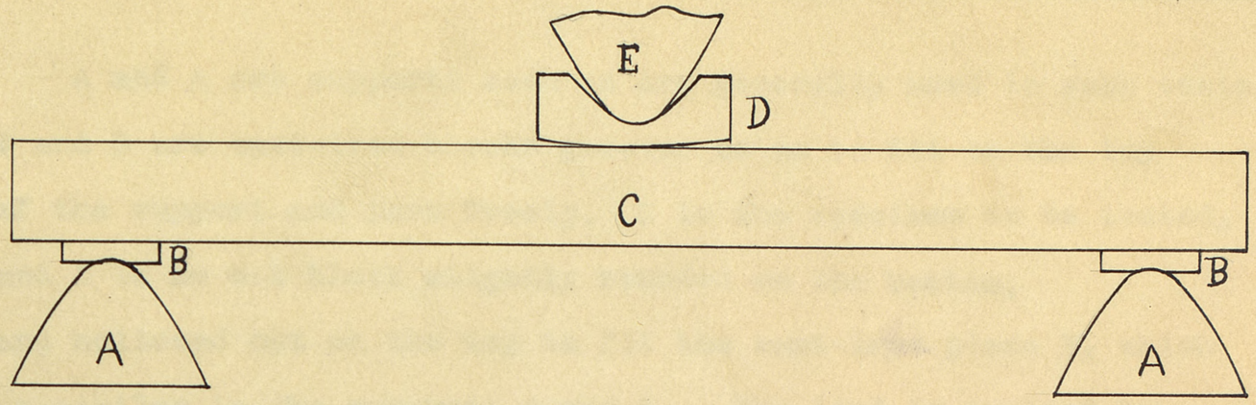


Fig. I

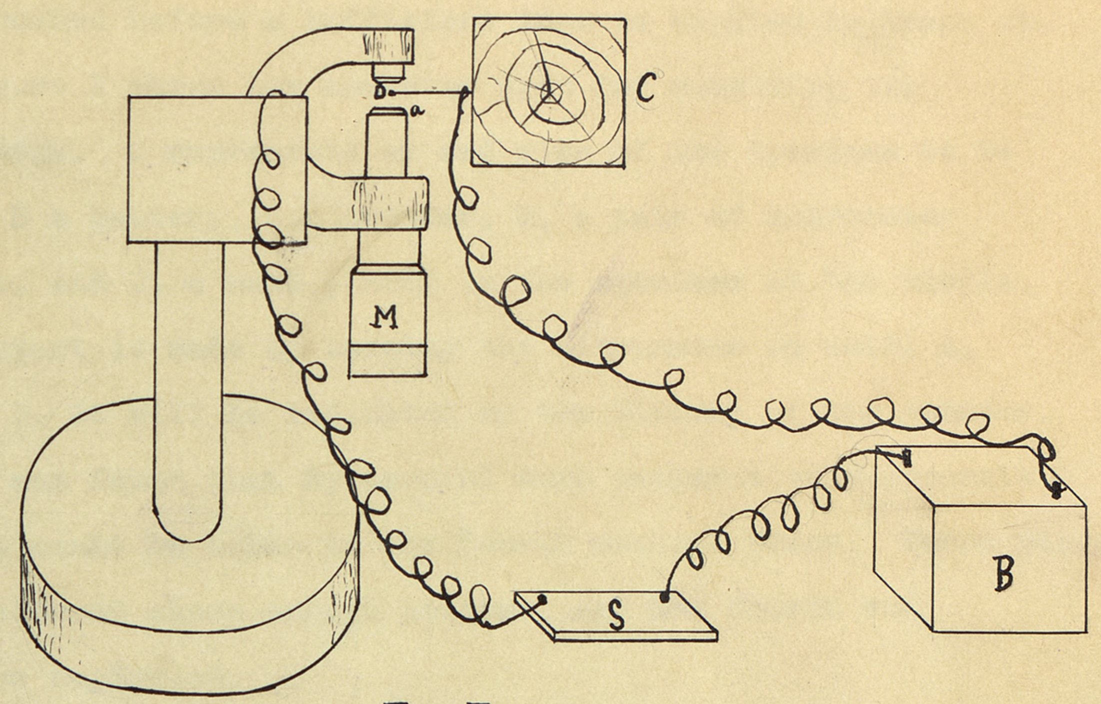


Fig. II

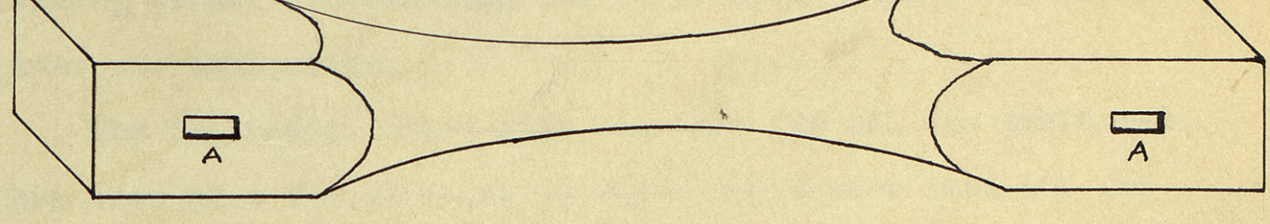


Fig. III

A and A are supports such as are generally used in such tests: B and B are cast-iron blocks grooved so as to fit on the top of the support and turn freely. C is the specimen to be tested, and D is an oak block slightly rounded on the bottom, and hollowed out on the top to fit the cast-iron piece E, which is, similar to the supports A and A. The load is applied by two screws which bring E downward.

The blocks B.B. and D. are to prevent the specimen from being crushed before a sufficient load is applied to break it.

Figure 2 shows the aparatus used for measuring the deflections. C represents an end view of the specimen to be tested, B a battery, S, a sounder, M, a pair of micrometer calipers, and D, a nail placed in the specimen at the middle. When contact is made by turning the micrometer up until A, touches D, it will be indicated by the ticking of the sounder.

It was found that by careful work comparatively accurate readings could be taken to the fourth decimal place. Three places was considered close enough however, and the fourth was therefore neglected.

In all cases an initial load was applied, then a reading of the micrometer taken, another load applied, and then another reading taken. Subtracting the first reading from the second gives the deflection.

The following tables give the data for all the tests made. They also give the ultimate Strength per square inch and the Modulus of Elasticity for each specimen tested in cross bending.

The Modulus of Elasticity is the ratio of the stress to the deformation and may be found by the formula,

$$E = \frac{Pl^3}{48\Delta I},$$

where E is the modulus of elasticity or Young's Modulus, P, the total load, l, the length in inches, Δ the total deformation in inches, and I, the moment of enertia of the cross section.

This formula is only true for stresses below the elastic limit and hence our results will be somewhat erroneous as we took the deformation up to the breaking point in most of the pine specimens.

In the oak wherethe elastic limit was more clearly defined, We took only to where there began to be a decided increase in the deformations.

These data show some very interesting results. The ultimate strength in compression is from eight to twelve times that shown for cross bending. The compression tests, being made from specimens cut off the ends of the cross-bending specimens, give a true comparison of strength if the relative length be taken into consideration. The compression specimens ranged from about three to five inches in length.

Steel Specimen.

Readings every half minute.

No.	Load	No.	Load	No.	Load.
1	1000	19	33710	37	38830
2	2700	20	34460	38	38990
3	5340	21	34840	39	38080
4	9050	22	35400	40	38930
5	13960	23	35730	41	38900
6	19410	24	36020	42	38490
7	23610	25	36520	43	38720
8	26960	26	36850	44	37000
9	26850	27	37070	45	35490
10	27290	28	37390	46	33020
11	28180	29	37660	47	30640
12	28750	30	38020	48	29360
13	29750	31	38030		
14	30140	32	38270		
15	31060	33	38480		
16	31720	34	38575		
17	32440	35	38660		
18	33050	36	38740		

Pine Specimens No. 14. 1 1/2" X 3".

Loads.	Δ	Loads.	Δ	Loads.	Δ	Loads.	Δ
100 *		1100	.005	2100	.004	3100	.013
200	.012	1200	.006	2200	.004	3200	.008
300	.004	1300	.006	2300	.007	3300	.010
400	.008	1400	.010	2400	.008	3400	.010
500	.005	1500	.002	2500	.005	3500	.010
600	.007	1600	.005	2600	.006	3600	.011
700	.007	1700	.006	2700	.008	3800	.026
800	.011	1800	.007	2800	.009	4000	.026
900	.005	1900	.005	2900	.006	4200	.039
1000	.007	2000	.006	3000	.009	4250---Broke.	

Oak Specimens No. F 1 1/2" X 2 1/2"

Loads	Δ	Loads	Δ	Loads	Δ	Loads	Δ
200 *	.020	1000	.010	1800	.022	2600	.047
300	.017	1100	.021	1900	.021	2700	.076
400	.010	1200	.018	2000	.027	2800	.047
500	.012	1300	.013	2100	.027	2900	.059
600	.013	1400	.016	2200	.028	2950	.053
700	.015	1500	.018	2300	.032	2980	----Broke
800	.016	1600	.022	2400	.038		
900	.014	1700	.020	2500	.044		

* Initial Load 100 Pounds.

No.	Material & Dimensions	Ultimate strength per square inch Cross-bending	Compression	Modulas for Crossbending.
5	Yellow Pine 1 1/2"X 1 1/2"	510	6880	1588300
6	" " " X "	580	7050	1751600
10	" " 3"X 1 1/2" flat	455	812o	1561200
4	" " 1 1/2"X 1 1/2"	510	6890	1329600
9	" " " X "	590	8620	1744900
14	" " 1 1/2"X 3"Onedge	940	7190	1044900
8	" " 1 1/2"X 1 1/2"	470	7090	1538300
3	" " " X "	440	8380	1614700
7	" " " X "	470	7050	1079000
12	" " 3"X1 1/2"flat	550	8540	1486500
11	" " 1 1/2"X3" Onedge	1000	9350	1350500
13	" " " X " " "	990	8390	1336100
4	Red Oak 1 1/2"X 1 1/2"	330	3790	1778600
5	" " " X "	355	3420	1308900
9	" " 3 1/2"X 1 1/2"flat	310	3460	830600
10	" " 1 1/2"X 3 1/2"Onedge	685	3840	838300
A	" " 1 1/2"X2 1/2" " "	810		3043500
B	" " 1 1/2"X 1 1/2"	510		1498700
C	" " " X "	460		1479400
D	" " 2 1/2"X 1 1/2"flat	500		1304800
E	" " " X " "	510		1397700
F	" " 1 1/2"X 2 1/2"On edge	790		2356800

Notice that numbers 14,11, and13, in pine, and numbers 10, A, and F, in oak, which were tested on edge show a much higher ultimate strength than the same sized specimens tested flat.

This would seem to indicate that, the length and thickness being constant, the strength of a beam per square inch increases as the depth increases. There is likely a limit to this however and it would probably be found at about the ultimate compressive strength of the material. This increase in strength may have been due to the shortness of the beam, however,and without experimenting on longer beams we would not feel safe in asserting that this is true for all cases.

Comparing our results with those generally quoted for yellow pine and red oak shows that we have a very excellent grade of pine lumber on the market here, and a poor grade of oak.

Oak specimens 4,5,9, and 10, were green and do not represent the true strength of our oak timber. Those specimens when subjected to cross-bending crushed on the upper side, instead of breaking on the lower, as dry specimens would have done. The results are interesting however, in that they show the weakening effect of moisture on the strength of timber.

One pine and three or four oak specimens were tried in tension. They were cut in the usual form for tension tests, (Fig.3) and were held by flatpins placed in the holes A,A, as shown in the figure.

The pine showed a tensil strength of 10720 pounds per square inch.

No satisfactory results were obtained with the oak specimens in tension failure occuring in each case by shearing out the holes.

The unseasoned conditions of the specimens probably accounts for the low shearing stress.

The conclusion might be drawn from these failures by shear that in designing a tension member of wood great attention should be given to the fastenings, and the shearing strength, for with most woods at least, the shearing strength is much less than the tensil.