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A Study of Spliced Wooden Tie-Beams

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A STUDY OF
SPLICED WOODEN TIE-BEAMS

BY

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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

John Christopher Gustafson

ENTITLED A Study of Spliced Wooden Tie-Beams

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE

OF Architectural Engineer

N. Clifford Ricker.

HEAD OF DEPARTMENT OF Architecture

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A STUDY OF SPLICED WOODEN TIE-BEAMS.

The object of all tests of building materials should be to determine facts and develope results that may be of practical value in future designing. In order that such facts and results may have real value, three conditions are necessary; First, that the materials tested shall be identical with what is commercially available in the open market; second, that the conditions, methods, and details of construction conform exactly to those obtainable in practice; third, that the tests ~~are to~~ be conducted in a scientific manner. (Tests by the Roebling Co.)

Few tests, if any, have been made upon full-size timbers, in tension; none, so far as can be learned, have been made to decide on the efficiency of the various types of splices commonly used in joining wooden beams in tension. This investigation is made to determine these efficiencies; to decide which type of splice is strongest, which is weakest and which is most economical, with due regard to ease in construction, the amount of material used, and the nature of the material. To this end splices have been made using in one instance, wooden fish-pieces with bolts, in comparison with another type using wooden fish-pieces held together by lagscrews instead of bolts. Again, similar splices were constructed in which steel plates were substituted for the wooden fish-pieces.

The material used was identical with that commercially available in the local market. It was short leaf pine, shipped from Grandin, Mo., and supplied from stock by local dealers, Hunter, Rourke & Co., Urbana, and was a material considerably used in

this locality for structural purposes.

The splices were designed, that so far as possible, conditions, methods and details of construction should conform exactly to those found in practice. This means that they were designed just as if they were to be used in actual construction. One exception occurred, where bolts and lagscrews were used to transmit the stress; these were than designed to resist bending, only partially. They were so arranged, because of a difference of opinion, some asserting it to be necessary to calculate for bending, others holding that bending may be neglected. When the computations were made, it was found that a much greater number of bolts and lagscrews was required than good practice or common sense would demand. An average of their opinions led to the use of what was considered a safe number.

The following coefficients were taken from tables furnished by Dr.N.Clifford Ricker and were used in the design. Safe values were employed in all computations.

Short Leaf Line:-

Tension, ultimate,	9000	lbs.	per	sq.	in.	Safe,	900	lbs.
Shear, (Hor.) "	400	"	"	"	"	"	100	"
Crushing, (par.)"	6000	"	"	"	"	"	1200	"

Cast Iron:-

Tension	"	3000	"
Shear	"	2500	"
Crushing	"	10000	"

Wrought Iron:-

Shear	Safe 9000 lbs.
Tension	" 12000 "

The test pieces were framed together by an experienced carpenter; the workmanship was of good quality, equal to that required for first class construction.

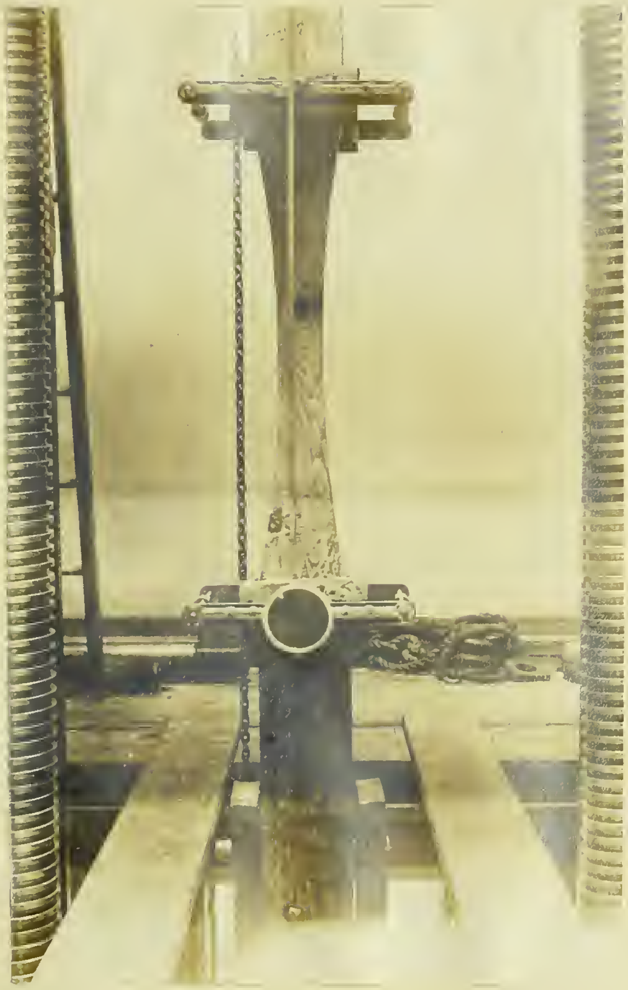
Several plans and methods suggested themselves for fixing the test pieces to the testing machine. The method finally adopted was devised and designed by Prof.Talbot. It should be stated, that the connection is far heavier than required for these special tests; but it was designed for use in future tests, and was made of strength sufficient to equal the capacity of the machine.

It consists of two eye-bars at each end, five feet long from center of pin hole to end of bar, six inches wide, and two inches thick, placed on each side of the timber, and secured to it by means of four pins, each two inches in diameter and placed nine inches on centers, with three pins one and one-half inches in diameter, placed four and one-half inches on centers. These eye-bars were in turn connected to a large eye-bolt, five feet long and four and one-half inches in diameter at shank, by means of a five inch pin. This eye-bolt passed through a hole in the head of the machine and was secured by a large nut resting against an adjustable washer. The illustrations will fully explain the connections. The material used for this connection was soft steel.

The tests were made in the laboratory of the University Experiment Station, upon the recently installed 600,000 lbs.Reihle testing machine. The stress was applied by lowering the traveling

base of the machine, the head being stationary. The elongations were taken at each increase of 5000 lbs by extensometers, made by Mann & Co. of St.Louis. The instruments are shown by photograph. These were placed at the top and bottom of the splice plates, and readings to the nearest one one-thousandth of an inch were taken on both sides of the test splice, the average of the two readings being taken in plotting the curves.

There were seven types of test pieces, six of which were spliced joints, the other a solid tension member. These types will now be considered, and the method of computations, given.



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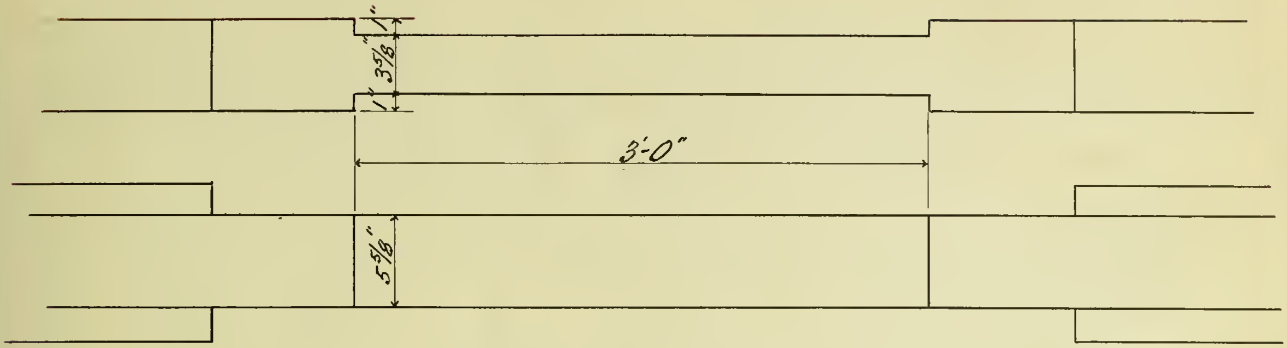

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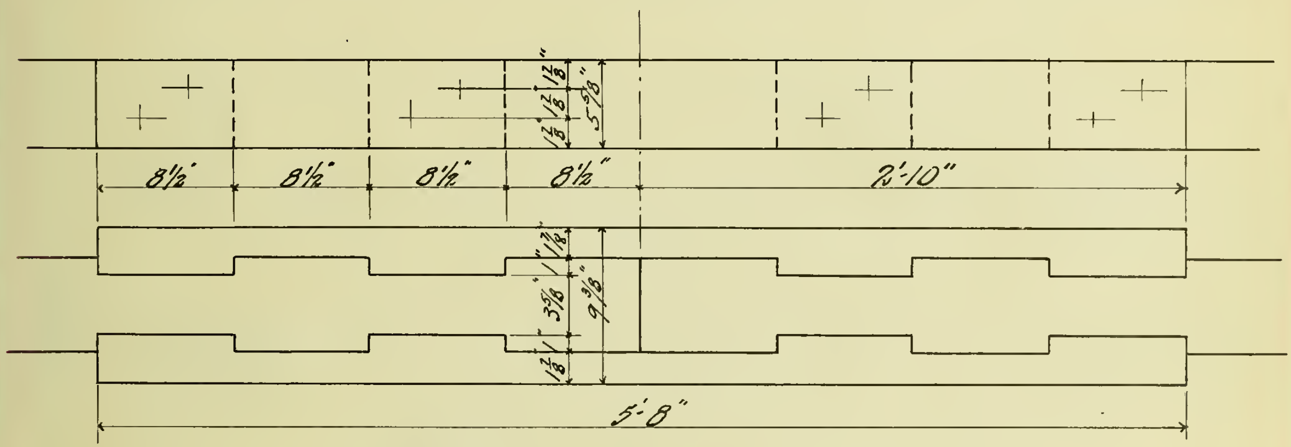

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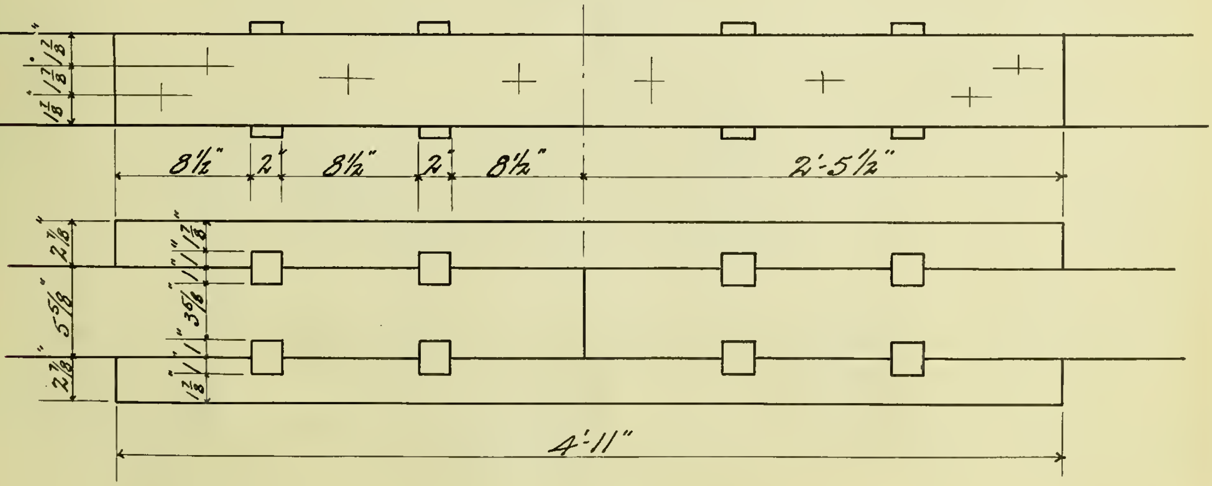

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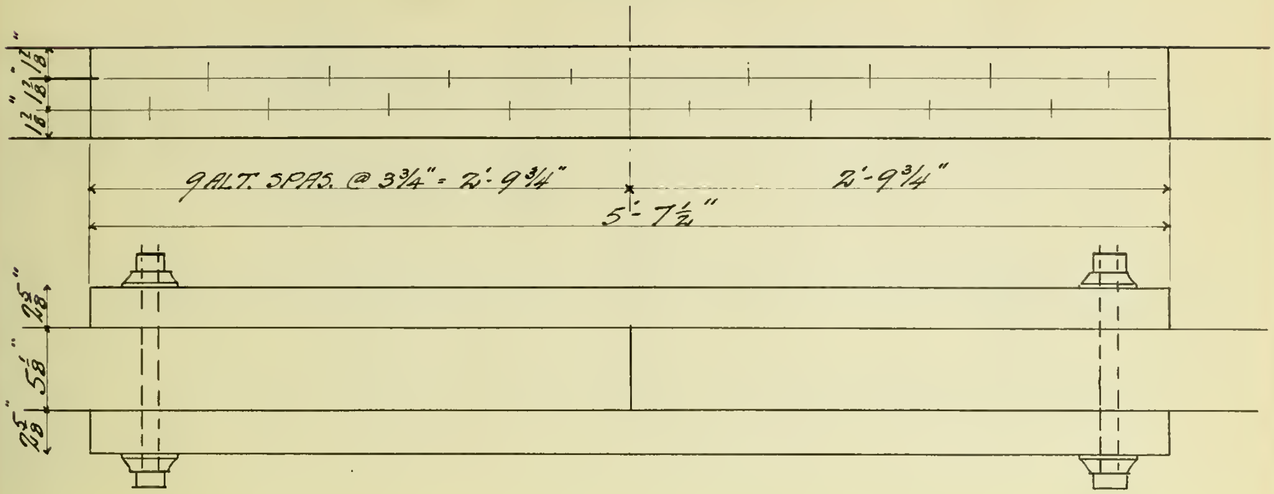

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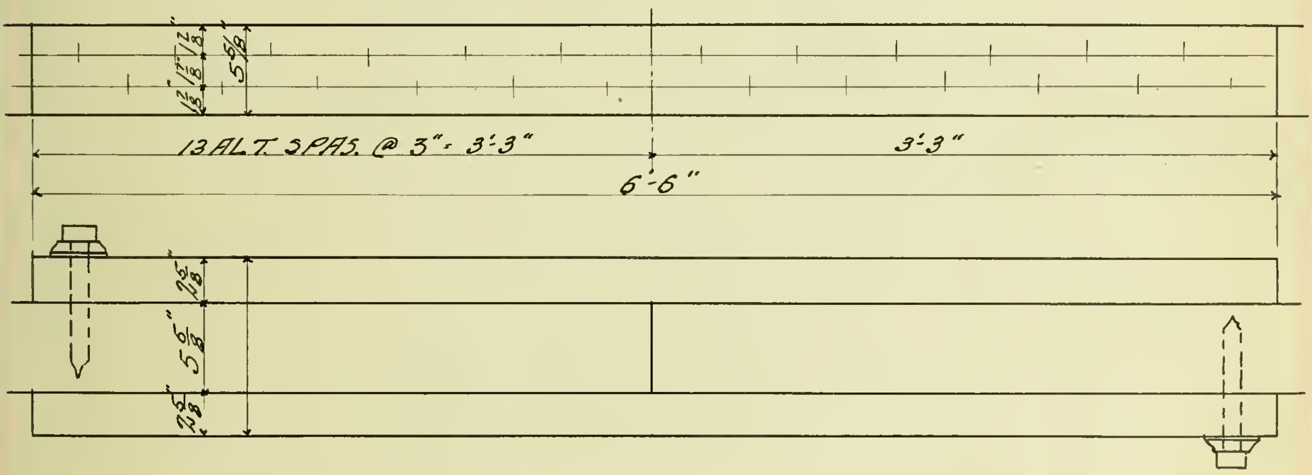

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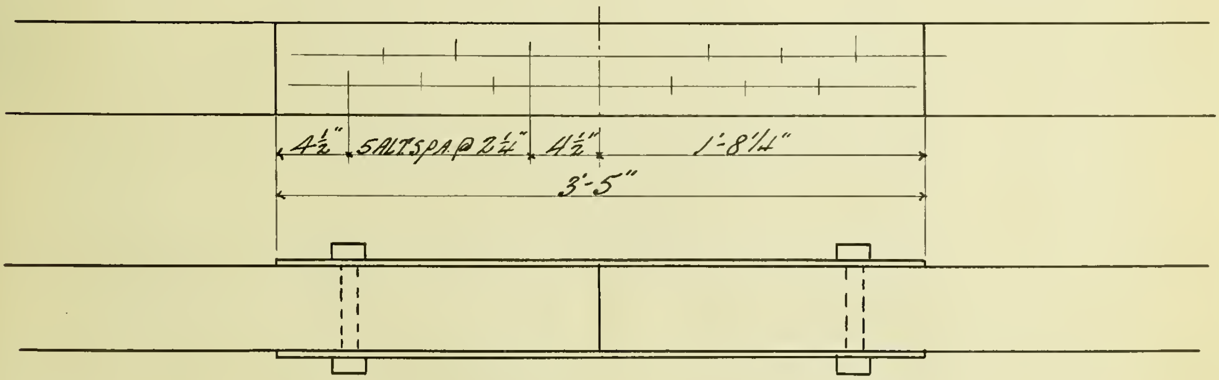

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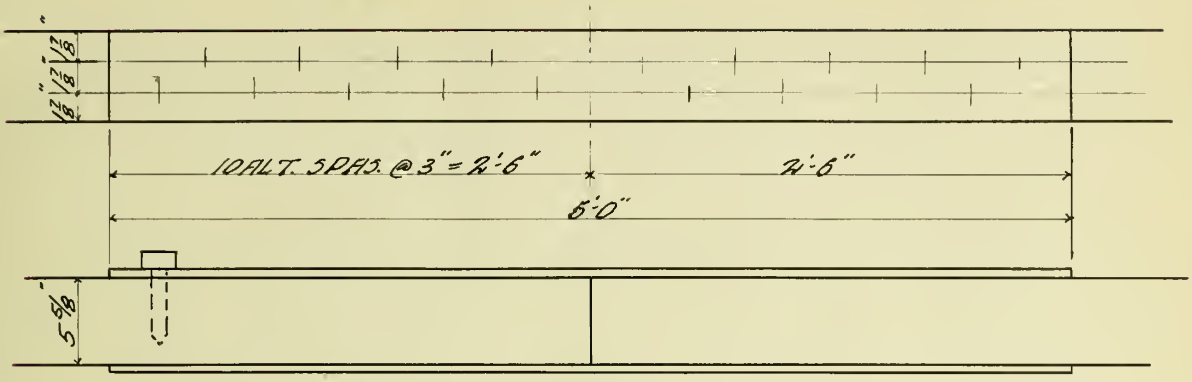


Type A.

This was the solid piece. In order to make the sectional area of the stick less than that through the connection it was reduced in section as shown.

Design of Joint A.

Solid timber. No splice.

Depth of cut one inch.

Net area of splice = 5-5/8" x 3-5/8" = 20.4 sq.in.

Tensile strength = 20.4x 900 = 18360 lbs.

Type B.

This type is shown in the sketch. All the timbers and fish-pieces were of the same material. In order to hold the splice piecesin position and to prevent them separating under stress, 5/8" bolts were inserted as shown. In calculating the strength of the splice, no attention was paid to the resistance of these bolts.

Design of Joint B.

Depth of notch = 1"

Depth of timber = 5-5/8" = 5.625"

Net depth of timber = 3-5/8" = 3.625.

" " " splice = 3.625 ÷ 2 = 1.8125" = 1-7/8"

Effective area of timber = 5.625 x 3.625 = 20.4 sq.in.

Tensile strength of " = 20.4 x 900 = 18364 lbs.

Tensile " per splice = 18364 ÷ 2 = 9180 "

To find number of notches:-

Bearing area req.= 9180 ÷ 1200 = 7.65 sq.in.

" " per notch = 5.625 sq.in.

Hence use two notches per splice.

To find distances between notches:-

Use 5/8" bolts.

Shear area req. = 9180 ÷ 100 = 91.8 sq.in.

" " " per notch = 45.9 " "

Add 2-5/8" bolt holes = 2 x .3068 = 0.613 sq. in.

Total shear area = 46.513 " "

Hence length of cut = 46.513 ÷ 5.625 =8-1/2"

Type C.

Consists of wooden fish-pieces and cast iron keys. This piece also has 5/8" bolts as shown, to hold the splice plates in position.

Design of Joint C. with Cast Iron Keys.

Depth of cut = 1"

" " timber = 5.625"

Net depth of timber = 3.625"

" " " splice = 3.625 ÷ 2 = 1.8125" = 1 7/8"

Tensile strength of timber =20.4 x 900 = 18360 lbs.

" " per splice = 18360 ÷ 2 = 9180 "

To find no. of keys:-

Bearing area req.= 9180 ÷ 1200 = 7.625 sq.in.

" " per key = 5.625 sq.in.

Hence use 2 keys per splice.

To find distance apart of keys:-

Use 5/8" bolts.

Shear area req.= 9180 ÷ 1000 = 91.8 sq.in.

Shear area req. per key =91.8 ÷ 2 = 45.9 sq. in.

Add 2-5/8" bolt holes = 2 x 3.68 = 0.613 " "

Total area required = 46.573 sq.in.

Hence distance between keys = 46.513 ÷ 5.625 = 8-1/2".

Type D.

Consists of wooden fish-pieces and 1 inch bolts, which are designed to transmit the stress from the timber to the splice plate. In some preliminary tests made to ascertain the action of bolts in timber, it was found that when cut washers were used, the bolts bent considerably, causing the washers to crush into the sides of the timber so badly as to split it. To over come this tendency, both as to splitting the fish-pieces, due to the crushing of the washers, and also to resist the bending of the bolts, cast iron washers were used instead of the usual cut washers. These washers were 3-3/4" diameter and 7/8" thick. The calculations were made to include crushing of the bolts against the wood, shear of wood in front of the bolt, and also bending of the bolts.

Design of Joint D.

Using wooden fish pieces and 1" bolts.

Gross area of timber = 5-5/8 x 5-1/8 = 28.828 sq.in.

Deduct 1 hole 5-1/8" x 1" = 5.125 " "

Net area of section = 23.703 " "

Stress in timber = 23.703 x 900 = 21330 lbs.

Net area of splice plate = 11.85 sq.in.

Thickness " " " = 2-5/8 inches.

Gross area of " " = 2-5/8 x 5-5/8 = 14.765 sq.in.

Deduct 1 hole 2-5/8 x 1 = 2.625 " "

Net area of splice plates = 12.14 " "

To find no. of bolts:-

Stress in member = 21300 lbs.

Safe bearing per bolt = 5.125 x 1000 = 5125 lbs.

Hence no. of bolts = 21300 ÷ 5125 = 5

Bending:-

M = 10665 x 1.50 = 16000 in. lbs.

Allow M = 2210

Hence no. of bolts = 8.

Spacing of bolts:-

Shear = 100 lbs. per sq.in.

Shear per bolt= 10665 ÷ 8 = 1333 lbs.

Shear area req. = 1333 ÷ 100 = 13.33 sq.in.

Length in front of bolt = 13.33 ÷ 5.125 = 2-7/16 ins.

Hence ctoc of bolts = 2-7/16"+ 1" = 3-7/16", say 3-3/4 ins.

Type E.

Consists of wooden fish-pieces and lagscrews 3/4" diamater 8 inches long, which, like the bolts in type D, are assumed to

transmit the stress to the fish-pieces, and thence beyond the joint into the timber again. Cast iron washers 3 3/4 inches diam. and 3/4 inch thick were used.

Design of Joint E.

Using wood fish-pieces, with 3/4" lagscrews, 8" long.

Gross area of timber = 5-5/8" x 5-5/8" = 31.64 sq.in.

Deduct 2 holes 5-5/8 x 3/4 = 8.43 " "

Net area of section = 23.21 " "

Stress in member = 23.2 x 900 = 20880 lbs.

" " splice plate = 10440 "

Area per splice plate req. = 11.605 sq.in.

Splice Plate 2-5/8"

Area of splice plate = 5-5/8 x 2-5/8 = 14.765 sq.in.

Deduct 1 hole 2-5/8 x 3/4 = 1.969 " "

Net area of splice plate = 12.796 " "

To find no. of lagscrews:-

Use an 8" lagscrews. Diam. base of thread = .60 inches.

Bearing area req. per splice plate = 10440 ÷ 1000 = 10.44 square inches.

Bearing area per lagscrew = 2.625 x .75 = 1.97 sq. in.

Hence no. of lagscrews = 10.44 ÷ 1.97 = 6.

To resist bending:-

M = 10440 x 1.59 = 16599 in.lbs.

$M = \frac{s\pi d^3}{32} = s \times .098\ d^3 = 25000 \times .098 \times 3/75 = 1035$ in.lbs.

Hence no. of lagscrews = 16.

Distance lagscrews c. to c. using 12 lagscrews.

Stress in splice = 10895 lbs.

Shear area = 108.95 sq.in.

Shear area per lagscrews = 108.95 ÷ 12 = 9.08 sq.in.

Hence length between lagscrews = 9.08 ÷ 5.5 = 1-3/4"

Hence dist. c to c = 1-3/4 + 3/4 = 2-1/2 Say 3"

Type F.

This type of splice is similar to type D; it consists of 1" bolts and 3/8" steel fish-plates. The bolts, as before, are calculated to resist shear, bearing, and bending.

Design of Joint F.

Using steel fish plate and 1" bolts.

Gross area of timber = 5-5/8 x 5-1/8 = 28.825 sq.in.

Deduct 1 hole 5-1/8 x 1 = 5.125 sq.in.

Net area of timbers = 23.703 " "

Stress in timber = 23.7 x 900 = 21330 lbs.

To find no. of bolts:-

Bearing area per bolt = 5.125 sq.in.

Bearing per bolt = 5125 lbs.

Hence no. of bolts = 21330 ÷ 5125 = 4.

To resist bending:-

M = 10440 x 1.42 = 14825 in.lbs.

Allow M = 2210 in. lbs.

Hence no. of bolts = 6

Bolts spaced 4-1/2" centers.

Type G.

Similar in design to Type E; but differing in that 3/8" steel fish plates were used instead of the wooden ones in the previous type. The lagscrews were 3/4" diam. and 5" long.

Design of Joint G.

Using steel fish plates with 3/4" lagscrews 5" long.

Gross area of timbers = 31.68 sq.in.

Deduct 2 holes 5 x .75 = 7.50 " "

Net area of section = 24.20 " "

Stress in timber = 24.2 x 900 = 21780 lbs.

To find no. of lagscrews:-

Bearing area per lagscrew = 2.55 sq.in.

" per lagscrew = 2.55 x 1000 = 2550 lbs.

Hence no. of lagscrews = 5.

To resist bending:-

M = 11550 x 1.4 = 16170 in. lbs.

Hence no. of lagscrews = 16170 ÷ 1035 = 15.

We shall use 8 lagscrews per splice plate.

Stress per lagscrew = 11550 ÷ 8 = 1444 lbs.

Shear area necessary per lagscrew = 14.40 sq.in.

Length between lagscrews = 1-3/4

Dist. c to c = 1-3/4 x 3/4 = 2-1/2. Say 3"

A study will now be made of the actual test pieces, and the causes of failure.

Type A.

Joint A1.

This piece was a good stick of timber with but few knots, these all at one end, as clearly shown in the picture.

The failure was due to longitudinal shear, on one side only. It started at the shoulder and extended toward the connection until stopped by a knot, where it broke across in tension. The sheared surface shows that there was a defect in the interior of the wood, namely a place about ten inches long containing dry resin, which separated the wood fibers, and thus greatly aided the piece to shear at this point.

Joint A 2.

This is the same as joint A 1, namely a solid tension piece without splice, reduced in section to 5-5/8" x 3-5/8", with a net area of 20.4 sq,in. Season checks extended the full length of the piece on the 3-5/8" face;these season checks were not large ones, nevertheless, in order to reduce the tendency to shear a - long the line of pins, three half-inch bolts were inserted, one between the last two 2" pins, one between the third and fourth 2" pins, and one between the first two 1-1/2" pins. There were no knots of such size or character as to be harmful. Dry rot exist- ed in the lower half of the timber, and well up into the reduced section. It may be noted that the carpenter, in looking over the lumber before making the test pieces, considered this stick the best in the entire pile; there was no indication of defect on the outside, and it was only when the piece had been cut into that dry rot was revealed.

Failure took place in the lower connection, it shearing out along the line of pins, and extending to the shoulder of the reduced section. The shear, within the connection, followed the season checks. There is no doubt that the piece would have stood the test considerably better had there been no dry rot.

Joint A 3.

Similar in design to the two preceding. There were two knots in the reduced section, one at each end, about five inches from the shoulder. In the lower connection there was a large knot at the third large pin and also a smaller one at the second large pin. At these places there was some cross grain. Season checks extended the full length of the piece on the 5-5/8" face.

Failure took place in the lower connection, because of shear along the line of pins. The manner of failure was peculiar. The piece sheared off between the last two inch pin, and the end; this failure was followed by a loud report, and immediately the wood sheared along the line of the remaining pins. As in the previous case 1/2" bolts were inserted in the connections.

An examination of the ruptured end, revealed dry rot in the interior of the piece along the neutral axis. Between the first and second 2" pins the wood was so badly rotted as to leave a cavity fully 2" in diameter. The dry rot extended well down in to the 1-1/2 inch hole and up toward the next 2" hole. It was evidently caused by a small hole in the knot at this place. A similar, although not so serious a defect, was found in the other end of the timber also caused by the presence of a small hollow knot. The holes in these knots were very small, and were discovered only after careful examination.

Type B.

Joint B 1.

This piece was of good sound material, having a few slight season checks, but not of such a character as seriously to lessen the strength of the stick. There were no knots in the lower half; there was a bad one in the upper half about twenty inches above the joint. The splice pieces were in excellent condition.

The lower half of the splice shows very little effect of the stress to which it was subjected, other than a few cracks at the shoulders, showing that there was a tendency to shear along the plane from shoulder to shoulder.

Failure took place in the upper half of the splice, due to shear of the shoulders on the north splice piece and the timber. These having sheared the shoulder of the stick, directly opposite sheared also. There was a great amount of bearing against the shoulders.

The bolts in the splice were badly bent, showing that, although not calculated to carry any of the stress, they were subject to considerable of it. It is most likely that the greater part of this bending was caused after failure due to shear had

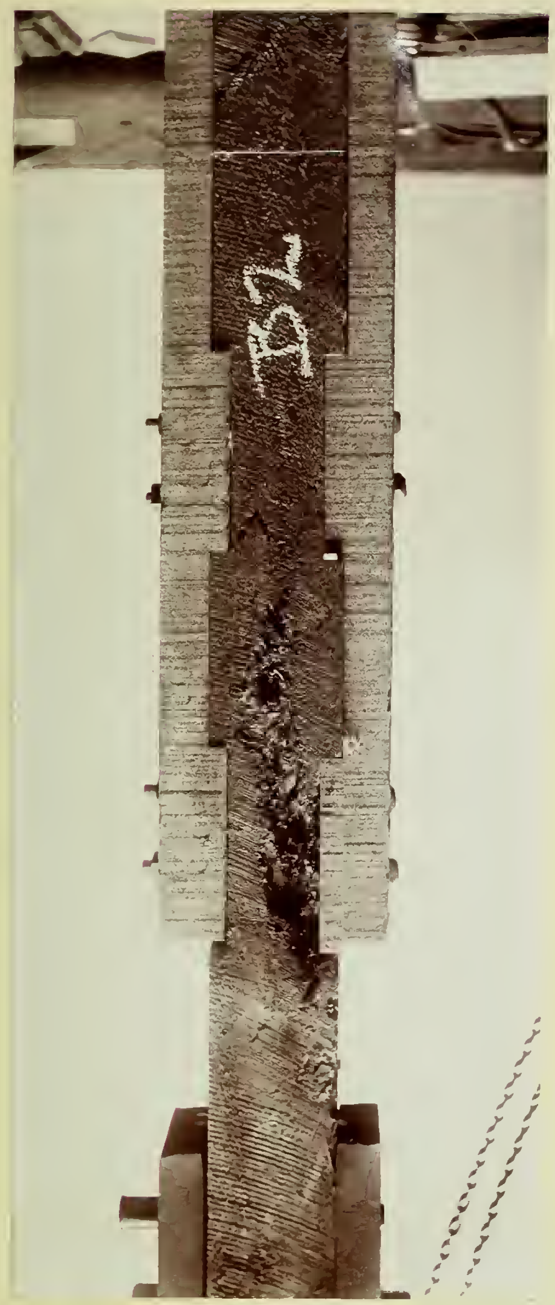
begun. So badly were these bolts bent that the cut washers were pulled into the wood, crushing and splitting the ends of the splice-plates. The shear followed the grain of the wood, and presents a clean even cut.

The fibers in front of the bolts were badly injured, and presented a wedge like appearance. This wedge action of the fibers is greatly marked and undoubtedly accounts for the condition of the splice, the fibers of which were twisted, torn and, as may be seen in the cut, curled back upon each other.

Joint B 2.

The condition of this piece maybe best understood by a glance at the picture, which shows a bad defect in the upper half, varying in depth from 1/4 to 3/4 of an inch, 3" wide, about 12" long, and filled with dry resin. In addition to this defect there is a long oval knot about 2-1/2 x 1-1/2 inches diameter, 8-1/2" above the joint, but extending partially through the stick. The splice pieces are of good clear material, of straight grain, and with but a few small knots.

Failure took place in the upper half of the splice due to shear and tension. The first failure took place in the upper shoulder of the south splice piece, this shearing off completely; then shear began at the lower end of the top shoulder of the stick itself, extended for a few inches, then broke across in tension on a 45 degree line, and finally sheared off on the upper end of the opposite shoulder. The appearance of the fracture is rough and jogged. See picture.



East View.

West View.

Joint B 3.

In this there was a bad knot one foot above, and, also a small sound knot two feet above the joint. There was also a bad knot at the top pin in the lower connection; some slight season checks and cross grain also existed. The splice plates were of excellent material, containing no knots, no season checks and no cross grain.

Failure was caused by horizontal shear of the shoulder in the splice plates. The lower shoulder on the north splice plate failed first, and was then followed by the shearing off of the one above on the same side; shortly after, the two shoulders above the joint on the other plate gave way. There was considerable crushing on the shoulder of the stick itself. The bolts in the splice were considerably bent, with same great crushing of the washers into the splice plates. The failure of this piece is very much like that of Joint B 1.

Type C.

Joint C 1.

Contained a bad knot 30 inches above the joint; and was season checked the full length of the piece. There was also cross-grain 14 inches above and 20 inches below the joint.

The piece failed in shear at the first key above the lower end of the south splice plate, the shear following along the cross grain, and finally breaking in tension at the first small pin in the lower connection. The bolts in the splice were but slightly bent; there was no crushing or pulling in of the washers, and no crushing or splitting of the splice-plates, which, with the except-

ion of some very slight crushing due to the keys, appear as before the test. The holes for the keys present a remarkably good appearance; there is little crushing of the fibres; and the sides of the holes in the splice plates and in the stick, the lower ones excepted, are in the same horzontal line. Considerable tendency of the keys to rotate was noticed while the load was being applied. This tendency was seen almost directly stress was applied and continued until final failure, when the keys returned to their original positions.

Joint C 2.

In this the stick itself was in good condition, having but a few season checks, and only one small knot in the lower

half of the splice, just below the lowest key on the south side. The splice pieces were not of proper material; a glance at the picture will show the defects.

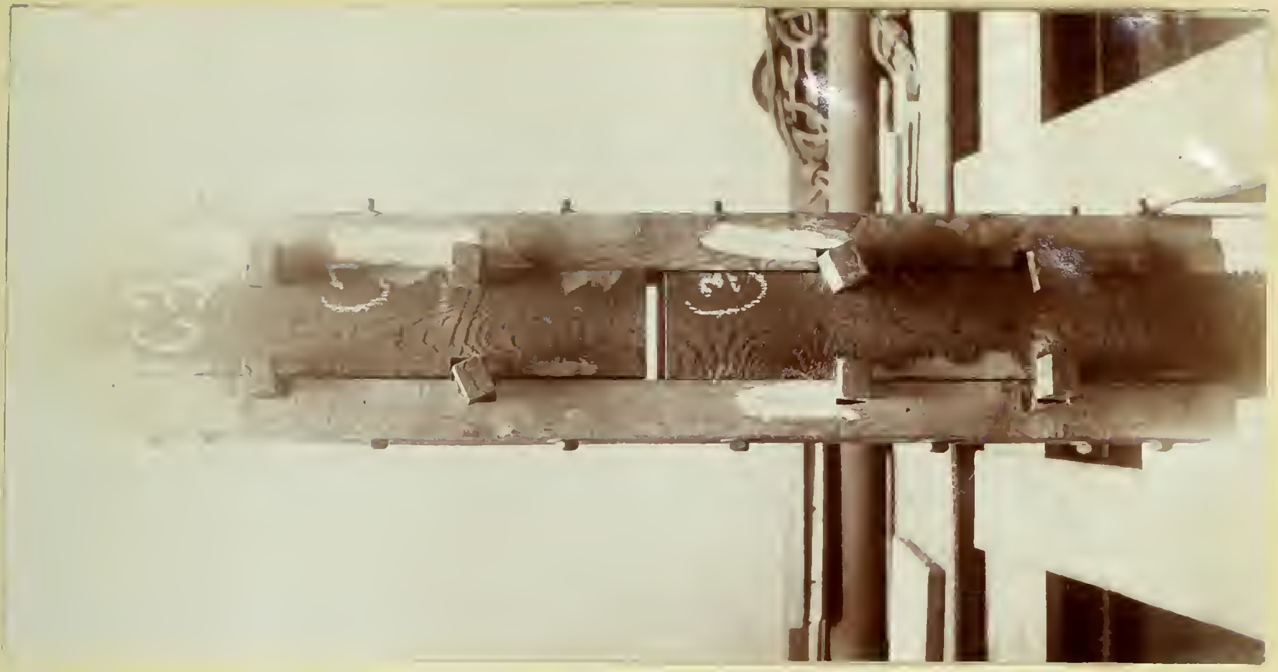
Failure in this case was due to shearing of the shoulders on the splice plate. The first failure took place by the shearing off of the top shoulder on the south plate. This plate showed signs of weakness under a load of 10000lbs. when it was noticed that a crack started at the key directly below the joint. It was not until under a load of 49000 lbs. that failure of the north splice plate was noticed, when it sheared at the key below the joint, then broke in tension at the first bolt below the joint. At 35000 lbs. there were continued cracking sounds, and bending of the test piece toward the north; the splice plates also drew away from the timber at both ends. The keys began to rotate as early as 10000lbs., which rotating in this case was excedingly great, consquently there was considerable crushing of the fibers at the sides and edges of the holes. It may be noted that the two upper keys on the south side, and the two lower keys on the north side rotated the most, the rotation of both pairs being about equal; comparatively little rotation took place on the other two sets of keys.

Joint C 3.

Contained some slight season checks in the lower half, and a small knot at the lower key. The upper half of the stick was in fair condition, there being only a few small, sound knots.

The failure was due to shear and to rotating of the keys. Shear took place at the lower shoulder of the north, and also at the upper shoulder of the south splice plate. At the other shoulder cracks appeared. The shear planes, instead of being clear and clean cut as in the previous cases, were rough and uneven, due probably to the presence of the bolts. The end bolts were bent considerably; the washers were crushed into the splice plates so badly as to split them to the end. The keys rotated badly; and again those keys in the lower north, and the upper south sides show the worse condition; the holes were badly distorted and out of line, while the remaining four were in fair condition.

This piece also bent; but toward the south instead of the north , as in Joint C2; this bending was noted at about 50000lbs. The rotating of the keys was first noted at 10000lbs. Because of this rotating of the keys the splice plates were pushed away from the main member fully 1/8 of an inch . The joint was opened to 15/16 of an inch, and so remained.



Showing condition of keys at end of test.

Showing condition of holes. Keys removed.

Type D.

Joint D.

Contains a small sound knot at the second bolt from the lower end of the splice, in the 6x6, and on the 10" face;on the other side there was also a knot 1 inch in diameter 14 inches above the joint, and likewise another at the edge of the 6x6 near the end of the splice plate.

The piece failed in tension at the first bolt from the end of the splice piece, the failure occuring in the 6x6. The fracture revealed dry rot in the main member, which rot existed at the point of fracture and for some six or eight inches up into the timber.

The motion of the extensometer was, for the most part, unsteady, at first moving slowly and evenly, then increasing in motion uneven and irregular. The bolts showed signs of bending at 40000lbs., as evidenced by the appearance of the bolt heads against the washers. An examination of the bolts after the test, showed them to be but slightly bent; it also showed that the greatest bending occurred at the bolt nearest the end of the splice, the bending decreasing toward the joint.

Joint D 2.

This piece, in the lower half, was a fairly good stick; in the upper half, there was a large knot a few inches below the first small pin, and also another large bad knot above the first 2" pin. At these knots there was considerable cross-grain. The piece was also badly season checked, as were also the splice plates.

The failure occurred at the knot near the first pin in the top connection, breaking there, and then shearing along the line of pins to the knot at the first 2" pin, where it broke in tension. The piece further failed by shear along the pins in the lower connection.

Joint D 3.

This stick was of good material, but slightly season checked, and with but few small sound knots. It failed in the lower connection, due to shear and bearing, and the pins pulling out through the timber. The fractured end shows uneven bearing of

the pins against the wood, one side of the holes being badly crushed, the other showing only small signs of crushing. The wedge like action spoken of above, is very marked; the fibers are twisted, torn, and curled back one upon another. The three half-inch bolts, put in the connection to strengthen it against shear, were badly bent; the washers were pulled into the sides of the piece causing cracks to open at those places.

D 3, incorrectly marked E 3, showing condition of failure.

The above picture shows the condition of the bolts after the test.

As seen the bolts are slightly bent, even more than in the preceding tests; it also shows, that the greatest bending was at the bolt nearest the joint; and that maximum bending occurred in the center of the 6x6.

Type E.

Joint E 1.

This piece was quite good, above the joint, but below, contained some bad knots. A few inches below the splice plates, there were two large knots, which extended through the stick, weakening it at this place. In the connection there was another knot slightly smaller. Cross grain existed at these places

Failure was caused by the piece breaking at the two large knots below the splice plates; and then shearing along the line of pins to the knot in the connection, and breaking off completely at this point.

The indicator moved very slowly and steadily at first readings, but soon began to move more rapidly, with sudden jumps and jerks. The sounds were peculiar, and were as if the threads on the lagscrew tended to pull out of their places and take a new hold on the wood. The lagscrews are bent but little, such bending taking place at about the neutral axis of the piece. They appear to have tilted slightly away from the joint.

E 1 Showing condition of failure.

E 1 Showing condition of lagscrews after failure.

Joint E 2.

The upper half of this piece was good clear material without knots, nor cross-grain. The lower half had a small knot at the edge of the joint, also one and three-fourth of an inch in diameter, on the center line 18 inches and another 23 inches below the joint. There was some gross-grain.

Failure took place in the lower connection, shearing along the line of pins, and breaking at the first small pin. The shear lay in the same plane, was clear and even, and followed mostly the grain of the wood.

The lagscrews bent very little as is shown in the above cut.

Joint E 3.

This was a fairly good piece of wood, containing only a few knots, as shown in the cut. The piece failed in the upper connection at the first small pin, then shearing between the first and second small pins, broke at the second, and finally sheared along the annular rings to the joint. The failure is best seen by the examination of the cuts.

The appearance of the lagscrews after failure is the same as in the two preceding tests.

E 3. Showing failure of test piece.

E 3. Showing character of failure.

E 3. Showing condition of lagscrews after failure.

Type F.

Joint F 1.

On the edge of the face containing the splice plates there was a large knot about four inches above the top of the plates; and also another on the other face about the same distance above the plate. There was also a small knot about 1-1/2" from the first bolt above the joint.

Failure took place in the splice, tearing out at the first and second bolts from the lower end of the splice plates, then shearing along the annular rings to the joint. It was impossible to tell much of the condition of the bolts, because they had been removed before they could be examined.

Joint F 2.

The upper half of piece contained a large oval knot 3 x 1-1/2 inches in diameter, just above the last bolt in the splice , which knot diminished on the opposite side to 1/2 inch in diameter In other respects the stick was a good one.

It failed in tension at this last bolt, and then sheared along the bolts to the joint. The sheared surface is not clean and smooth, but rough and uneven, as if both shear and tension were acting at the same time. There was considerable bearing of the bolts against the wood, as evidenced by the distorted appearance of the holes, in both the fractured section and in the lower half of the splice.

Joint F 3.

Short season checks existed along the center of the upper half on one side; there were no knots in this half. Below the joint on the same side, about 15 inches below, was a large knot, extending from the center to the south edge. Otherwise the stick was very good indeed.

It failed in tension between the first and second bolts from the end of the splice -plate, breaking across between the bolts on a 45 degree line, and then following the annular rings to a point eleven inches above the first bolt.

The motion of the indicator throughout was steady; in the beginning the motion was slow, but increased gradually until breaking.

The bolts in the splice were bent to a noticable degree; those on the"head-side," so to speak, ran straight a short distance and then bent up toward the joint. It was also noted that the greatest bending occurred at the bolt nearest the end of the plate, the bending decreasing toward the joint. The bolt nearest the joint was not bent, but inclined upward toward the joint; the one below was straight from the head for about 2 inches, and then bent upward gradually until the other end was 1/4 inch above the "head-end;" the next below was straight for an inch and a half, and then bent up 1/4 inch.

Type G.

Joint G 1.

This was a good clean stick, with few defects, namely a small knot 10 inches below the first pin in the upper connection. It contained some slight season checks and cross-grain.

It failed by shear along the line of lagscrews to a knot where it broke in tension on the opposite side. The shear surface was quite fibrous , and showed the wedgeing of the fibers when any obstacle, such as a bolt or lagscrew interferes with the shearing.

The cut shows the condition of the fracture.

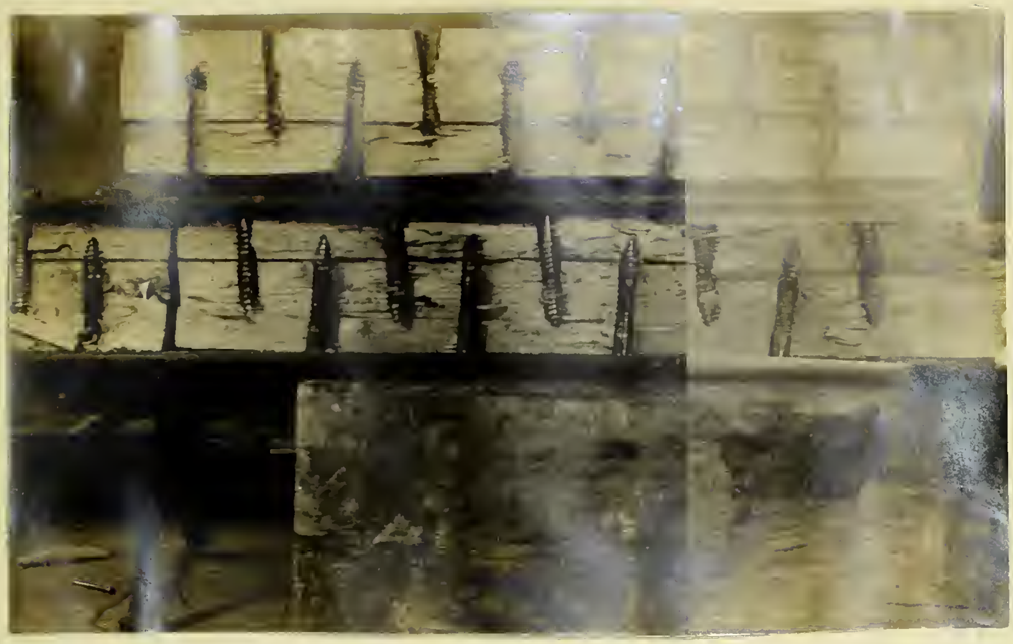
Joint G 2.

This piece broke in the connection, breaking in tension between the first and second small pins. There were two knots above the pin at which the failure first began.

There was evidently considerable crushing of the screws against the wood, the holes being distorted into a slight oval, the long diameter being 3/32 to 1/8 of an inch longer than originally. Slight cracks also appeared along the line of lagscrews.

Joint G 3.

Was a good clear stick, with few knots and little cross grain. It failed in the splice due to the shearing out of the wood in front of the lagscrews in the lower half. The lagscrews bent considerably at the plate, but within the wood were straight and pulled over diagonally. They crushed considerably against the wood as may be seen by the cut.



Conclusions.

Types B and C.

Both of these pieces failed in the splice because of longitudinal shear at the shoulders. Type B - while it did not sustain such a high maximum load as did type C, is stiffer, and the loads sustained are more closely in accord with each other. As to which is the better there is little choice and with proper designing and good workmanship both are to be recommended as equally good.

Type D and E.

These, with one exception, D 1, failed in the connection, due to defects in material, or possibly to defects in workmanship. Type D is the stiffer. The curves show three changes of curvature; it rises, showing slight elongations, in a straight line to 20000 lbs., it then abruptly changes direction, and again continues in a straight line to about 50000 lbs., where it again breaks suddenly and continues until failure.

The lagscrews, while not greatly bent, have injured the wood to a marked degree; in rotating they compress the fibers in front of them, forming a wedge, which greatly aids longitudinal shear to which there is always a tendency. In addition to the wedge action, the rotating of the lagscrews themselves tends to split the piece.

Type F and G.

These failed in the splice, at less loadings than did the two preceding types. The preceding remaks apply here as well. Both the lagscrews and the bolts have bent considerably

more, than in the other types, due undoubtedly to the greater stiffness and rigidity of the steel plates. The injury to the fibers, because of the rotating lagscrews, is also far greater than in type D.

These tests show positively that lagscrews can not be recommended and used in first class construction.Not only for the reasons here stated, but also on account of the increased expense, both in material and labor. More lagscrews are required than bolts to transmit, the stress; and also from two to four times as many holes must be bored for each screw, also half of these holes are of different diameters.

Again, were there no differences in amount of material and labor, the lack of stiffness would be sufficient to prohibit their use.

The results also show the need of tests of full size pieces and also the unreliability of timber for structural purposes, unless used in small sticks, of such sizes and dimensions that the material may be carefully selected and entirely free from knots and other defects. Wood is non-homogeneous and deceptive in its character; it is unreliable and uncertain in its action, and hence it must give away to such materials as steel, and concrete, the composition of which is known definitely.

The coefficients used in the design of these test pieces were taken from well known authorities, but are here shown to be too large; or the factors of safety are too small. In no case, did the pieces possess their calculated ultimate strength. As an example, piece A 4, the solid stick reduced in section to 5-5/8"

x 3", with a net area of 16.9 sq.in. and a calculated ultimate strength of 152,100 lbs. failed in tension at 69,240 lbs. Only 45 percent of its computed ultimate strength and less than 2-1/4 times the safe computed working stress. This shows a factor of safety 2-1/4, whereas all tables give a factor of safety of ten for short leaf line in tension.

The coefficients for longitudinal shear are also too large and it is evident that higher factors of safety should be used, and that the tables now employed should be revised.

In using cast iron keys, they should be made wider, at least, twice their depth, to overcome the tendency to rotate.

In making the following comparison of efficiences, joint A 4 was taken as the standard. In order to make the comparisons, its unit stress was found, and the net areas of each splice multiplied by this unit stress. It is shown by the following data, that the efficiences vary from 55 to 69 percent. The test pieces with keys, type C, wooden splice pieces and lagscrews, type E, and steel fish-plates with lagscrews, type G, show the highest efficiences. This is due to their elasticity and to the rotating of the keys and lagscrews. The other types show greater rigidity, and hence are to be recommended for use, in preference to any of the three types showing the higher percentages of efficency.

The wooden fish-pieces with bolts is the best type of splice all things considered; it is economical, and easily constructed. It looks clumsy and awkard, however, and it may sometimes be necessary to use the steel fish-plates, for appearances, al-

though the tests show this to be inferior in strength and stiffness. Splices with notched wooden fish-pieces, type B, would be placed next in order of preference; keys should not be used unless made wide in comparison with depth; whereas lagscrews should not be used under any circumstances.

JOINT	SECTION	NET AREA	SPLICE PL'TS. LENGTH	SPLICE PL'TS. SECTION	BOLTS NUMBER	BOLTS DIAM.	LAG SCREWS. NUMBER	LAG SCREWS. DIAM.	LAG SCREWS. LENGTH	SAFE COMP. STRENGTH	ULTIMATE STRENGTH	COMP. ULT. STRENGTH @ 4100 #	EFFICIENCY.	AV. EFFICIENCY.	ELONGATION AT MAX. LOAD.	PIECE FAILED IN
A1	5 5/8 x 3 5/8	20.4								18360	46200				.012"	in conn.
A2	"	"								"	53280				.122	" "
A3	"	"								"	70000				.176	" "
A4	5 5/8 x 3	16.9								15210	69240		100%		.108	" red. section
A5	"	"								"	52370				.102	" " "
B1	5 5/8 x 3 5/8	20.4	5'-8"	5 5/8 x 1 7/8	4	5/8"				18360	59460	83640	71.09		.260	" splice
B2	"	"	"	"	"	"				"	44500	"	63.24	60.17	.382	" "
B3	"	"	"	"	"	"				"	47000	"	56.20		.380	" "
C1	"	"	4'-11"	"	"	"				"	63760	"	76.23		.370	" "
C2	"	"	"	"	"	"				"	49000	"	58.59	67.30	.453	" "
C3	"	"	"	"	"	"				"	56000	"	67.08		.372	" "
D1	5 5/8 x 5 1/8	23.7	5'-7 1/2"	5 5/8 x 2 5/8	8	1"				21330	60000	97170	61.75		.361	" "
D2	"	"	"	"	"	"				"	65800	"	67.72	67.87	.250	" conn.
D3	"	"	"	"	"	"				"	72000	"	74.10		.350	" "
E1	5 5/8 x 5 5/8	23.2	6'-6"	"			12	3/4"	8"	20880	71300	95120	74.96		.490	" "
E2	"	"	"	"			"	"	"	"	59200	"	62.22	68.93	.450	" "
E3	"	"	"	"			"	"	"	"	66200	"	69.60		.520	" "
F1	5 5/8 x 5 1/8	23.7	3'-5"	5 5/8 x 3/8	6	1"				21330	48000	97170	49.40		.150	" splice
F2	"	"	"	"	"	"				"	49000	"	50.42	55.19	.366	" "
F3	"	"	"	"	"	"				"	64000	"	65.75		.316	" "
G1	5 5/8 x 5 5/8	24.2	5'-0"	"			9	3/4"	5"	21780	66310	99220	66.82		.600	" "
G2	"	"	"	"			"	"	"	"	60500	"	60.98	62.42	.500	" conn.
G3	"	"	"	"			"	"	"	"	59000	"	59.46		.428	" splice.

ALL READINGS IN 1/1000 INCHES.

JOINT A1.

LOAD	READINGS			REMARKS.
0	0	0	0	
10000	2	2	2	
20000	3	5	4½	first cracking
30000	5	7	6	
40000	6	10	8	indicator fell back 2 points, then jumped forward
46200	7	18	12½	loud cracking and failure.

JOINT A2

LOAD	READINGS.			REMARKS.
0	0	0	0	
5000	4	8	6	steady motion
10000	12	18	15	" "
15000	23	32	27	" "
20000	25	39	32	loud crack in lower connection
25000	30	46	38	
30000	34	52	45	top pin lower conn. crushing timber.
35000	42	67	54	loud crack in top conn.
40000	50	79	64	" " " bottom "
45000	65	89	77	top pin lower conn. crushing badly.
50000	93	102	97	loud snapping, splitting sounds
53280	100	145	122	sheared off in lower conn. to shoulder.

JOINT A3.

LOAD	READINGS			REMARKS.
0	0	0	0	
5000	14	16	15	steady motion
10000	19	27	23	" "
15000	30	37	33	" "
20000	38	43	40	slight cracking sound
25000	46	53	49	pins in lower conn. crushing in
30000	54	63	58	continuous cracking - very indistinct.
35000	65	70	67	
40000	73	80	76	loud crack
45000	86	89	87	" " in lower conn.
50000	105	98	106	continuous sounds of tearing
55000	124	107	115	
60000	142	128	135	loud report - indicator stopped.
65000	156	130	143	indicator jumped forward.
70000	195	156	176	piece failed.

JOINT A4

LOAD	READINGS			REMARKS
0	0	0	0	
5000	4	6	5	advance of indicator very steady
10000	9	13	11	" " " "
15000	17	20	18	" " " "
20000	22	24	23	
25000	28	30	29	
30000	34	35	34	
35000	39	40	40	first cracking sounds
40000	46	44	45	loud crack
45000	53	49	56	continued cracking
50000	59	58	59	loud crack + split at lower end of reduced section.
55000	64	70	67	Broke at lower knot - tearing sounds.
60000	70	78	74	loud crack.
65000	78	80	79	
69240	95	120	108	Broke a little below middle.

JOINT A5

LOAD	READINGS			REMARKS.
0	0	0	0	scarcely any movement of indicator
5000	7	8	8	
10000	11	16	14	
15000	19	24	22	
20000	23	26	25	
25000	28	30	29	slight cracks
30000	35	42	38	motion of indicator very unsteady
35000	43	61	47	loud crack
40000	45	62	52	cont. cracking - failing at top, due to knot.
45000	55	71	63	loud + cont. cracking
50000	75	93	84	loud report.
52570	—	102	—	failed in upper half of section.

JOINT B1

LOAD	READINGS.			REMARKS.
0	0	0	0	motion very slow
5000	2	9	5	" " steady
10000	12	20	16	" " "
15000	23	36	29	
20000	44	64	54	
25000	58	81	69	
30000	75	100	88	
35000	91	120	105	
40000	103	149	126	
45000	110	157	133	first cracking sound in upper half.
50000	126	178	152	another " " " " .
55000	148	200	174	
57240	195	225	260	Sheared on north side upper half.
59460	—	260	—	split two pieces off upper "
54470	—	380	—	other side split off.
36480	445	392	418	
39000	490	442	466	
42000	585	540	563	
43330	637	590	613	

JOINT B2.

LOAD	READINGS			REMARKS.
0	0	0	0	
5000	12	19	15	
10000	30	40	35	
15000	51	64	57	first cracking - loud - load went back
20000	101	109	105	to 13000
25000	124	127	124	more cracks - stick split in top conn.
30000	—	155	—	bad split at upper end south splice plate
35000	169	180	175	" " " lower " " " "
40000	194	207	200	
45000	223	238	230	large crack appeared.
44500	348	275	382	broke in tension - load went back to 14700

JOINT B3.

LOAD	READINGS			REMARKS.
0	0	0	0	
5000	15	15	15	
10000	40	40	40	
15000	63	60	61	
20000	88	86	87	
25000	110	110	110	
30000	137	136	136	slight cracking sounds.
35000	161	160	160	cont. " " splice plates pulling
40000	212	186	199	out at bottom.
45000	330	244	272	big crack at top.
47000	387	—	—	lower shoulders on north plate sheared.
26000	425	370	388	

JOINT C1

LOAD	READINGS			REMARKS.
0	0	0	0	
5000	20	26	23	
10000	52	68	55	keys tend to rotate
15000	78	84	81	slight cracking sounds
20000	105	104	104	
25000	127	124	125	cracking in top conn.
30000	147	132	155	" " " "
35000	170	148	159	
38000	185	152	168	Keys tend to pry splice plates away
45000	220	168	194	loud snap
50000	247	184	216	cracked at lower south key
55000	281	215	248	
63760	378	—	—	broke between lower conn. and splice plate.

JOINT C2.

LOAD	READINGS.			REMARKS.
0	0	0	0	
5000	20	20	20	
10000	53	53	53	
15000	90	90	90	keys begin to rotate
20000	133	134	134	south splice plate splitting at 2nd. key from bottom
25000	165	167	166	bad cracking in lower conn. Keys rotating
30000	200	202	201	badly - bad crack in top conn.
35000	235	238	236	Cont. Cracking sounds.
40000	280	281	280	
45000	340	340	340	bad crack
49000	440	466	453	splice plates sheared at shoulders
47700	538	543	540	north splice broke at 2nd key from bottom.

JOINT C3

LOAD	READINGS			REMARKS.
0	0	0	0	
5000	25	18	22	
10000	51	40	45	keys rotating
15000	78	60	69	top of plates spreading out
20000	103	83	93	slight cracks above
25000	117	98	108	
30000	137	117	127	
35000	162	140	150	crack at lower key south side
40000	187	165	176	cracking sounds
45000	220	200	210	" "
50000	265	243	250	loud crack
55000	332	308	320	bad crack at top
56000	384	360	372	loud crack
51000	440	420	430	" "
53000	500	480	490	bending toward south - breaking at first
46000	635	600	617	key below joint - sheared at lower end
48000	725	700	713	north side.
49200	905	860	883	

JOINT D1.

LOAD	READINGS			REMARKS.
0	0	0	0	
5000	9	5	7	indicator moving slowly
10000	18	12	15	
15000	30	20	25	
20000	46	35	40	" very unsteady
25000	72	57	65	cracking sounds.
30000	100	83	92	" "
35000	136	117	127	
40000	178	159	170	
45000	220	200	210	loud crack
50000	266	242	254	main stick splitting at bottom bolt
55000	322	289	305	
60000	383	339	361	shear + tension below joint.

JOINT D2.

LOAD	READING			REMARKS.
0	0	0	0	
5000	11	4	8	
10000	20	12	16	
15000	31	23	27	
20000	36	30	33	
25000	43	40	42.	
30000	58	62	60	cracking sounds
35000	80	89	85	Knot in lower pin splitting badly
40000	104	118	111	loud crack
45000	133	143	138	splitting in upper conn.
50000	161	178	120	
55000	192	215	204	loud crack.
60000	212	268	240	
65800	244	—	—	broke + Sheared in top conn.

JOINT D3.

LOAD	READINGS			REMARKS.
0	0	0	0	
5000	7	7	7	
10000	14	18	16	
15000	31	40	35	
20000	44	53	49	splitting in lower conn.
25000	64	75	69	
30000	86	97	97	loud crack in lower conn.
35000	118	120	119	Cont. cracking
40000	132	143	138	
45000	158	170	264	x
50000	183	200	192	loud crack
55000	210	223	216	" " in lower conn.
60000	242	257	250	
65000	277	300	288	
70000	315	347	332	
72000	340	360	350	timber splitting badly
56000	318	330	324	
47600	288	310	299	pins in lower conn pulling out through
44400	282	-	-	timber.
39700	270	-	-	

JOINT E1

LOAD	READINGS			REMARKS.
0	0	0	0	indicator moving steadily
10000	42	49	46	slight crack
20000	106	112	109	joint open 1/8 inch
30000	166	169	168	crack -
40000	231	216	224	loud crack -
50000	291	291	291	cont cracking + snapping
60000	458	434	446	tearing, ripping sounds
70000	495	482	484	
71300	-	472	-	failed at knot in lower conn - joint open 1/4"

JOINT E2

LOAD	READINGS			REMARKS
0	0	0	0	
5000	8	10	9	steady advance of indicator.
10000	35	36	35	slight cracking
15000	73	78	75	" " in lower end of splice
20000	109	115	112	
25000	138	150	144	cont. slight snapping
30000	163	183	173	splice plate slipping
35000	198	220	209	
40000	238	260	249	Cont. cracking sounds
45000	278	297	278	
50000	322	335	333	
56000	375	384	380	loud crack and snapping
59200	430	-	-	lower member split.

JOINT E3

LOAD	READING			REMARKS.
0	0	0	0	
5000	8	8	8	
10000	35	25	30	slight crack
15000	93	83	88	
20000	120	109	115	
25000	153	140	147	split in lower conn.
30000	187	170	179	loud snap
35000	222	208	215	sounds, as if lag screws were pulling out.
40000	261	243	252	
45000	280	288	284	splitting at 1st pin - upper conn. -
50000	360	338	349	loud crack
55000	412	380	395	" "
60000	468	433	450	" "
65000	525	487	506	cracking + split at top.
66200	—	—	—	broke in tension on east side - sheared along
				weather crack to end.

JOINT F1.

LOAD	READING			REMARKS.
0	0	0	0	sudden jump of indicator
10000	19	29	24	slight crack.
20000	82	99	90	" " in conn.
30000	110	148	129	frequent cracking at top.
40000	123	170	146	loud crack joint open 1/4 inch
48000	—	—	—	sudden jump - broke joint open 1/8 inch.

JOINT F2

LOAD	READINGS			REMARKS
0	0	0	0	
5000	15	11	13	
10000	57	38	48	slight cracking sounds
15000	112	80	96	
20000	140	98	169	cracking in lower splice.
25000	178	122	150	
30000	208	145	177	loud snap at top
35000	240	168	204	splitting at knot in lower plate.
40000	270	193	237	shear at knot, upper conn.
45000	256	225	240	loud snap just below upper conn.
49000	392	340	366	broke at lower bolt upper conn - sheared
				to joint.

JOINT F3

LOAD	READINGS			REMARKS.
0	0	0	0	
5000	4	6	5	
10000	9	13	11	
15000	24	30	27	
20000	36	43	40	
25000	57	66	62	crack
30000	80	88	84	"
35000	104	112	108	sharp crack
40000	126	135	130	" " in splice
45000	152	160	156	loud crack
50000	180	193	186	tearing sounds in splice
55000	210	225	218	" " repeated
60000	246	285	265	rapid motion - cont. loud cracking & tearing.
64000	272	360	316	

JOINT G1

LOAD	READINGS			REMARKS.
0	0	0	0	
5000	7	7	7	cracks as if lag screws were pulling out
10000	26	28	27	
15000	57	63	60	cracking sounds
20000	78	85	82	" "
25000	104	112	108	" "
30000	123	—	—	" "
35000	151	160	155	
40000	176	186	181	loud sharp crack - repeated.
45000	204	215	250	
50000	271	250	260	cont. cracking
55000	316	286	301	
60000	—	342	—	" "
65000	394	462	428	bottom timber split
66310	—	610	—	broke at knot near upper conn. - then
				sheared on line of holes.

JOINT G 2

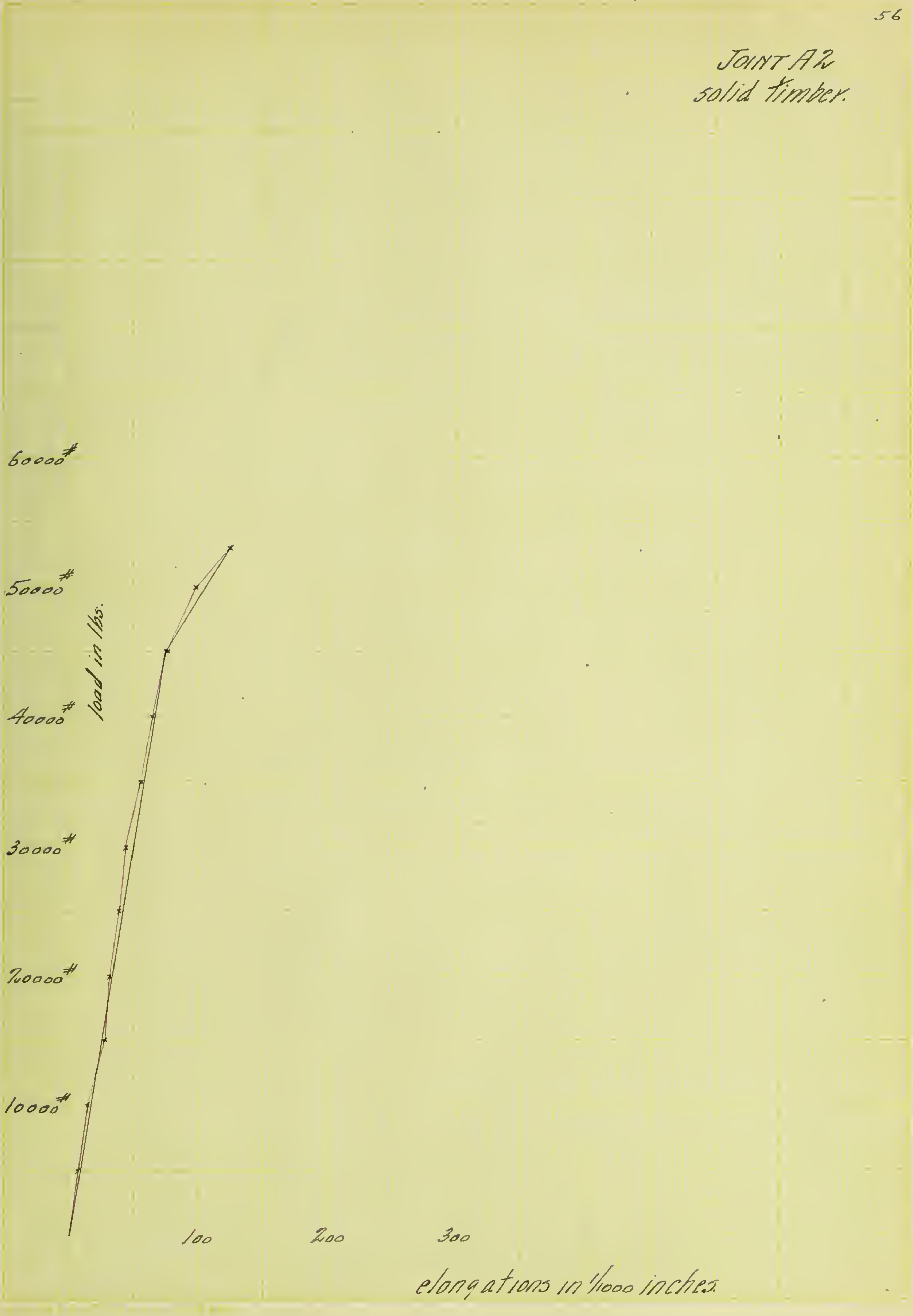
LOAD	READING			REMARKS.
0	0	0	0	
5000	18	13	15	
10000	48	40	44	slight cracking
15000	83	72	78	" "
20000	108	93	100	" " at lower end
25000	132	113	123	" " " " "
30000	158	135	147	cracks appear in knot at lower S.W. side.
35000	184	156	170	sharp crack
40000	210	180	195	continuous snapping-
45000	241	203	222	loud crack in splice
50000	275	235	250	" tearing sounds
55000	318	285	297	" " " in lower half - tearing sounds
60500				increase - loud report.

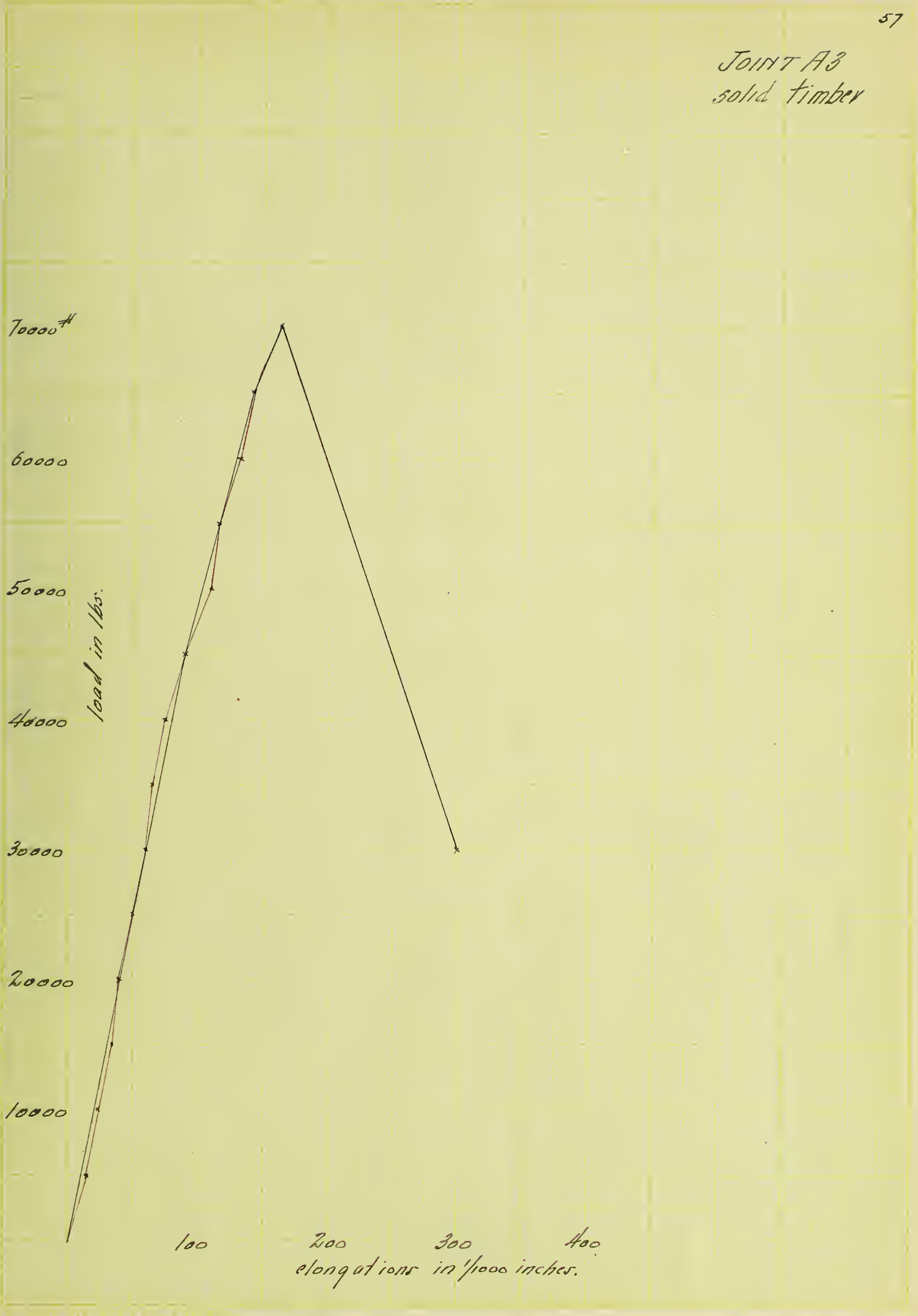
JOINT G 3

LOAD	READINGS			REMARKS
0	0	0	0	
5000	6	6	6	
10000	38	40	39	
15000	65	70	68	slight cracking
20000	88	95	91	" sounds of lag screws pulling out
25000	110	118	114	cracking
30000	132	140	136	"
35000	154	165	160	"
40000	177	193	185	loud crack
45000	207	230	218	" sharp crack - tearing sounds
50000	247	275	261	repeated " " " "
55000	319	350	335	" " "
59000	460	415	428	" " "
57000	560	630	545	loud crack in top
54200	625	585	605	" " " "
52700	685	665	675	" " " "

JOINT A1.

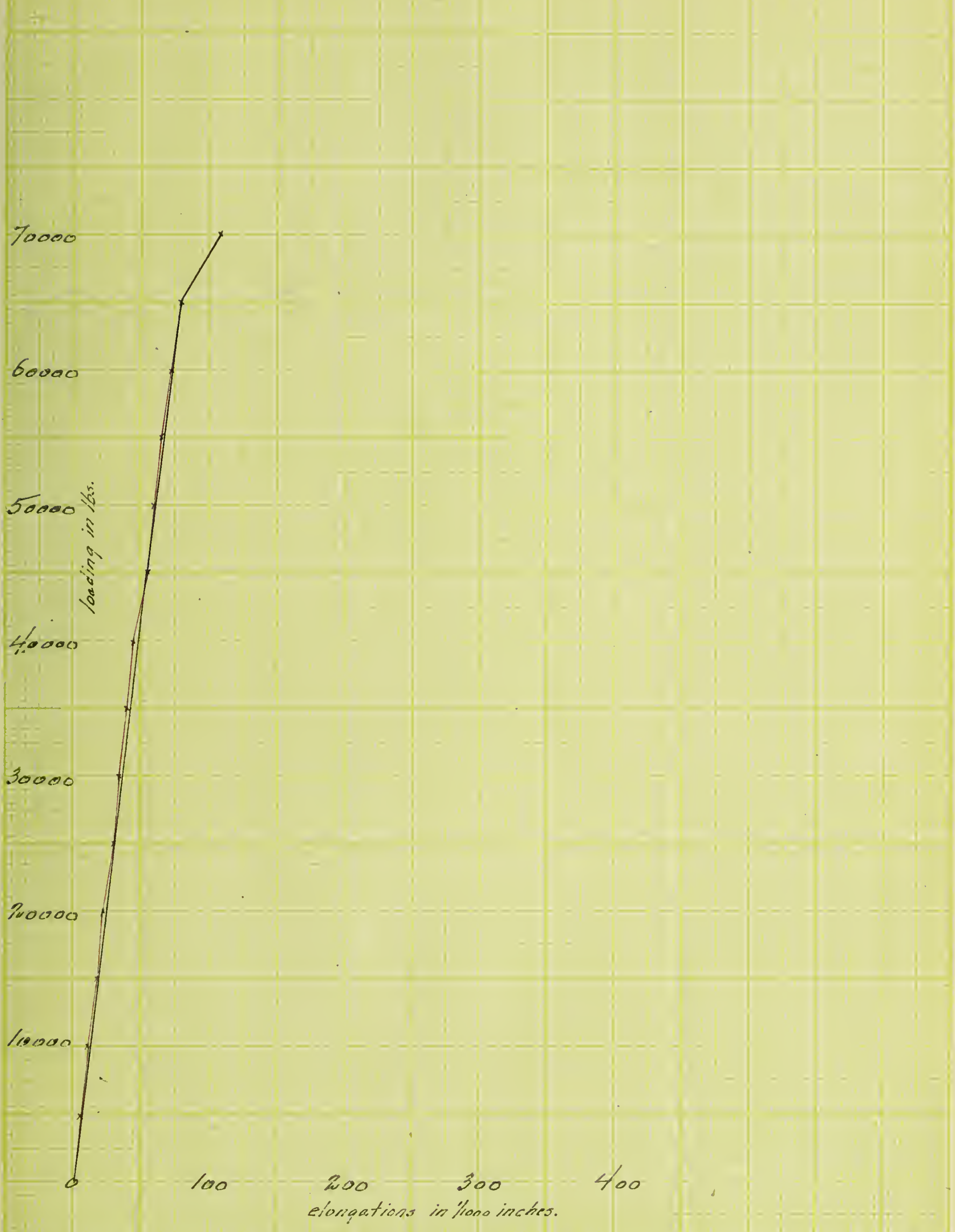

50000#
40000#
30000#
20000#
10000#
load in lbs.
0
100
200
300
400
elongations in 1/1000 inches.

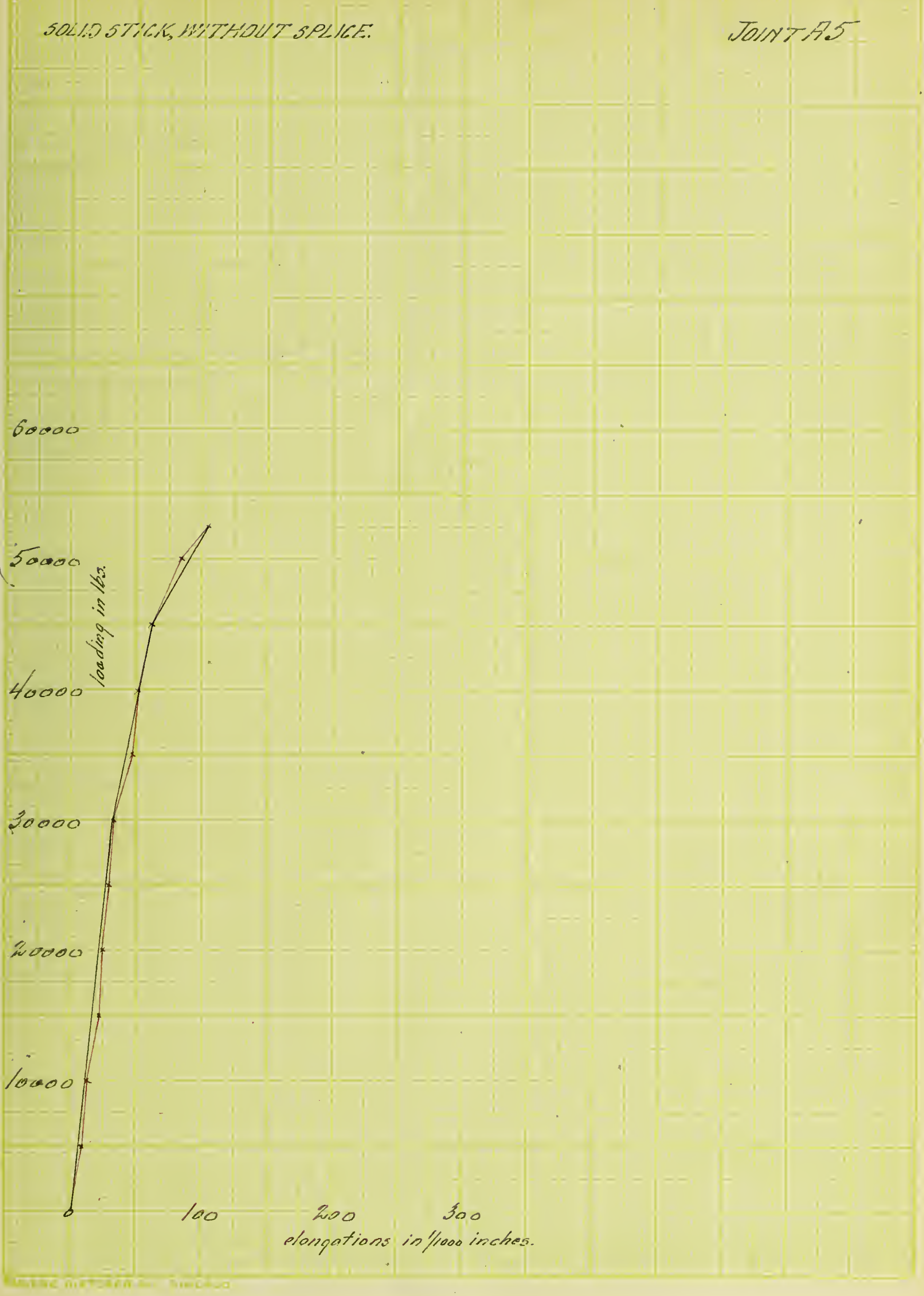

JOINT A2
solid timber.
60000#
50000#
40000#
30000#
20000#
10000#
load in lbs.
100
200
300
elongations in 1/1000 inches.

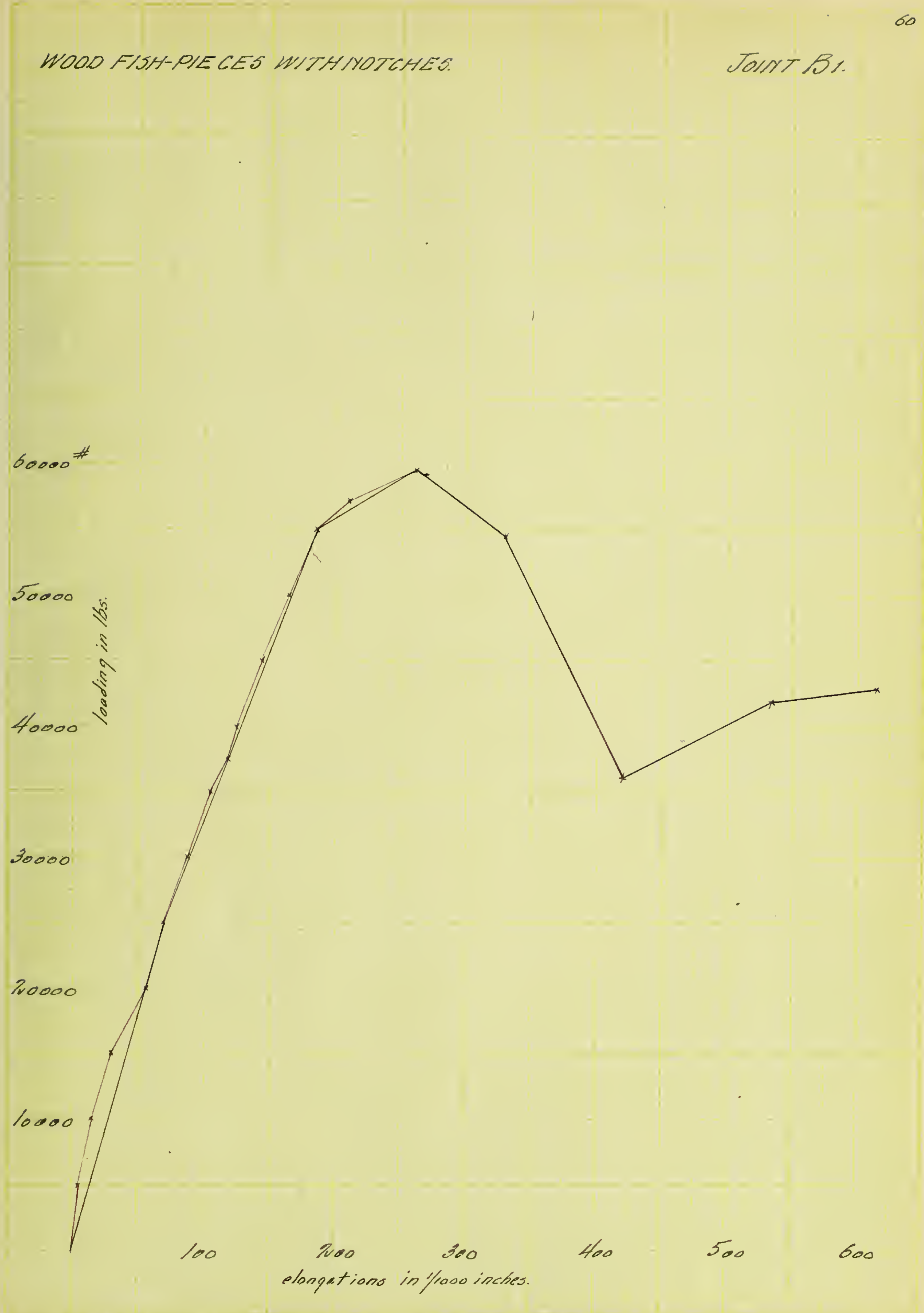

JOINT A3
solid timber
70000#
60000
50000
40000
30000
20000
10000
load in lbs.
100
200
300
400
elongations in 1/1000 inches.

SOLID STICK WITHOUT SPLICE.

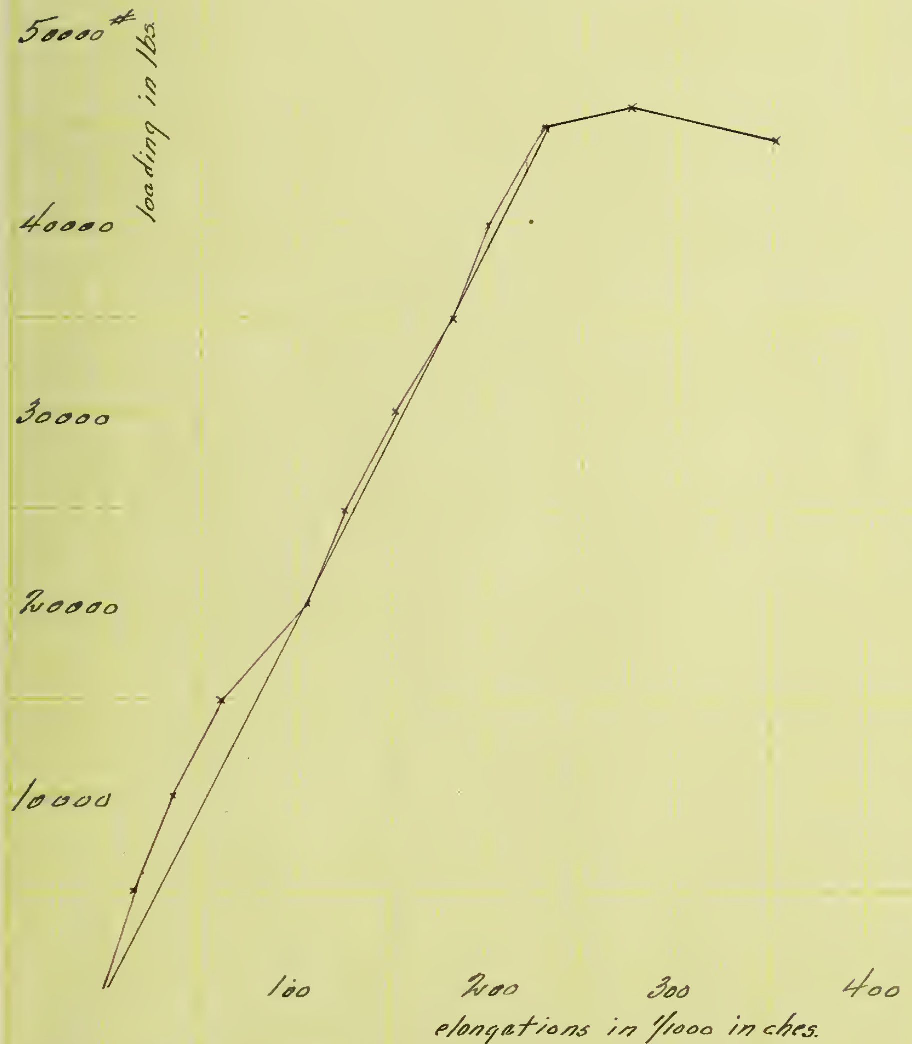
JOINT A4

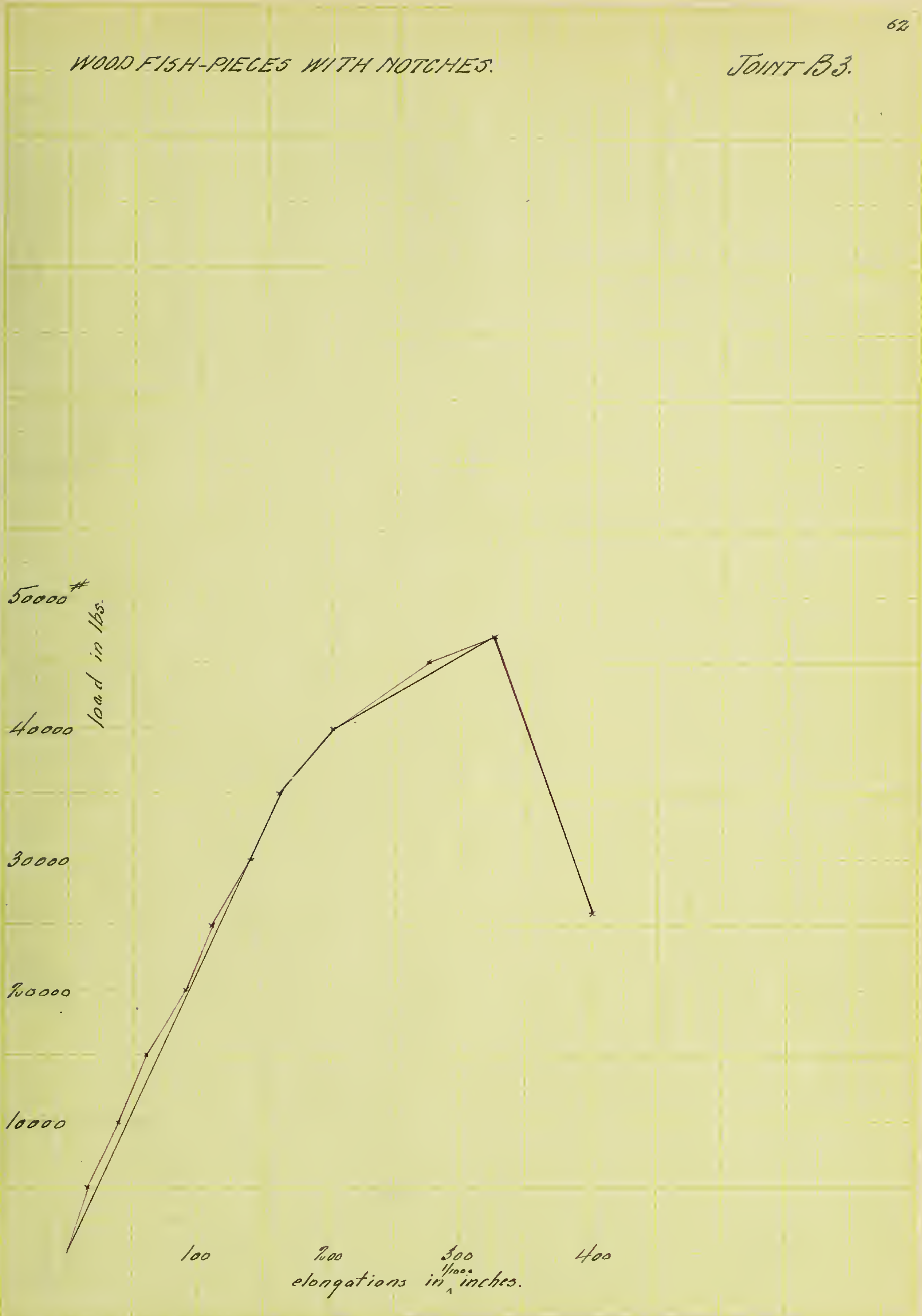


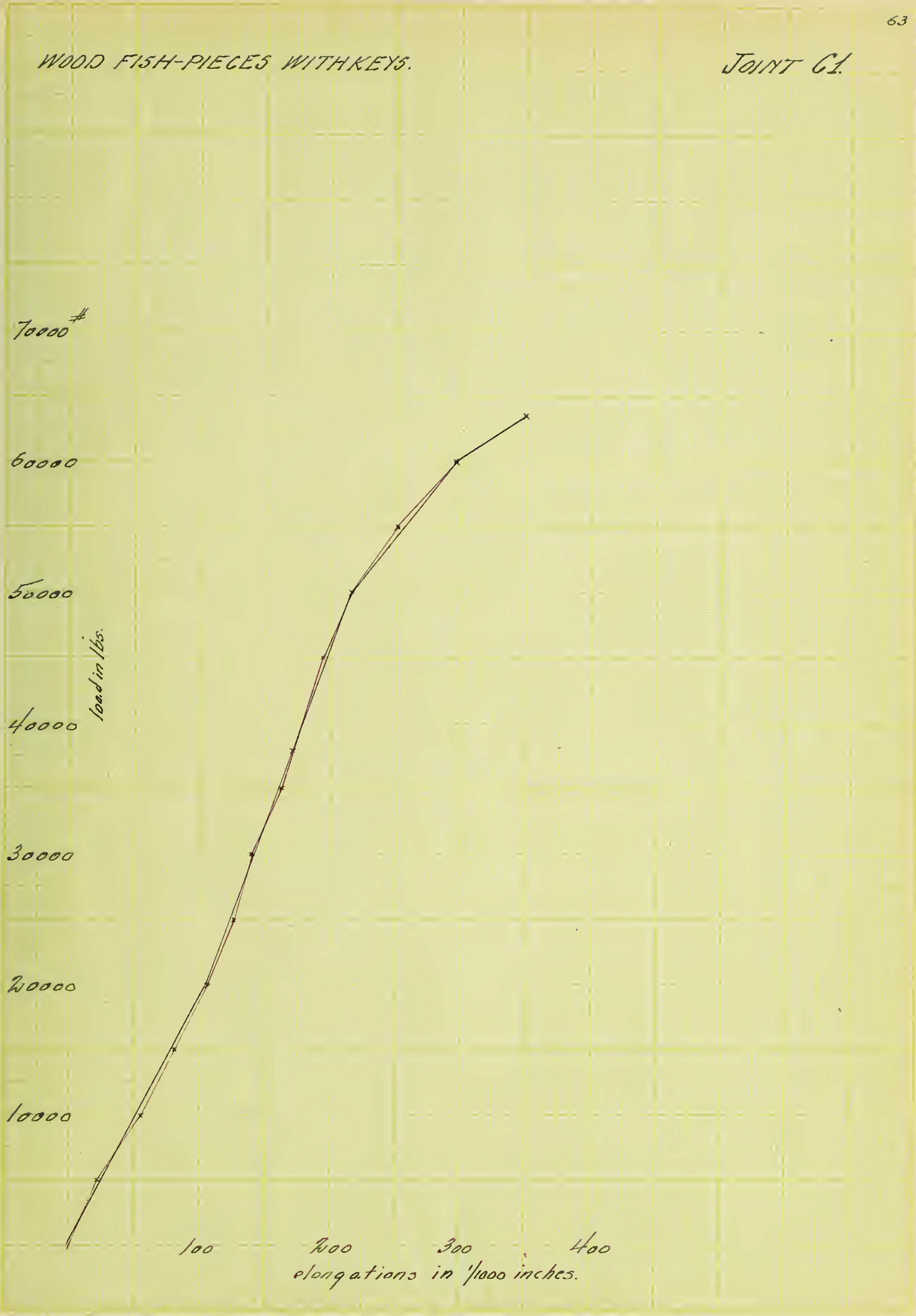

SOLID STICK, WITHOUT SPLICE.
JOINT A5
60000
50000
40000
30000
20000
10000
0
loading in lbs.
100
200
300
elongations in 1/1000 inches.

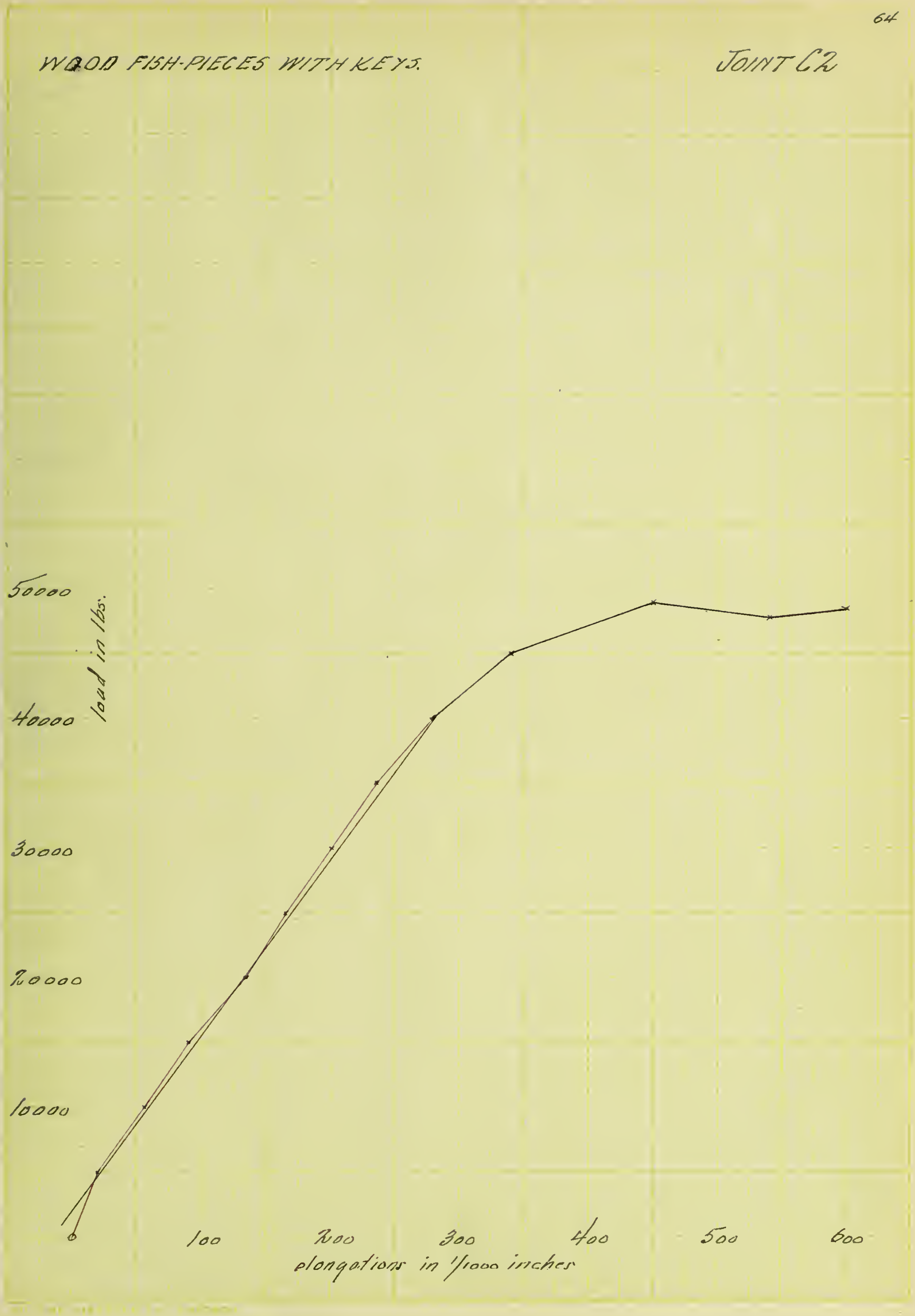

WOOD FISH-PIECES WITH NOTCHES.
JOINT B1.
60000#
50000
40000
30000
20000
10000
loading in lbs.
100
200
300
400
500
600
elongations in 1/1000 inches.

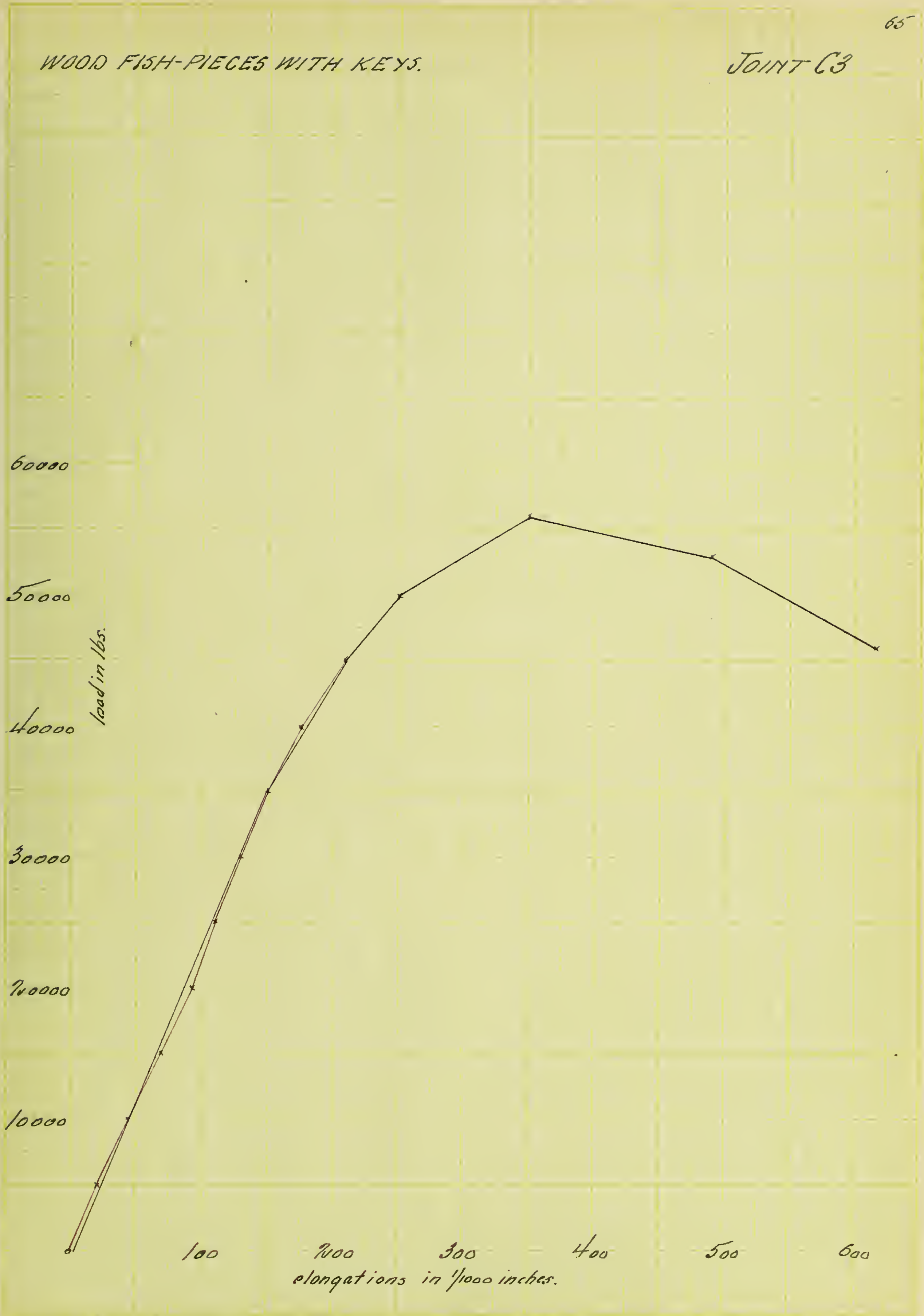
WOOD FISH-PIECES WITH NOTCHES. JOINT B2



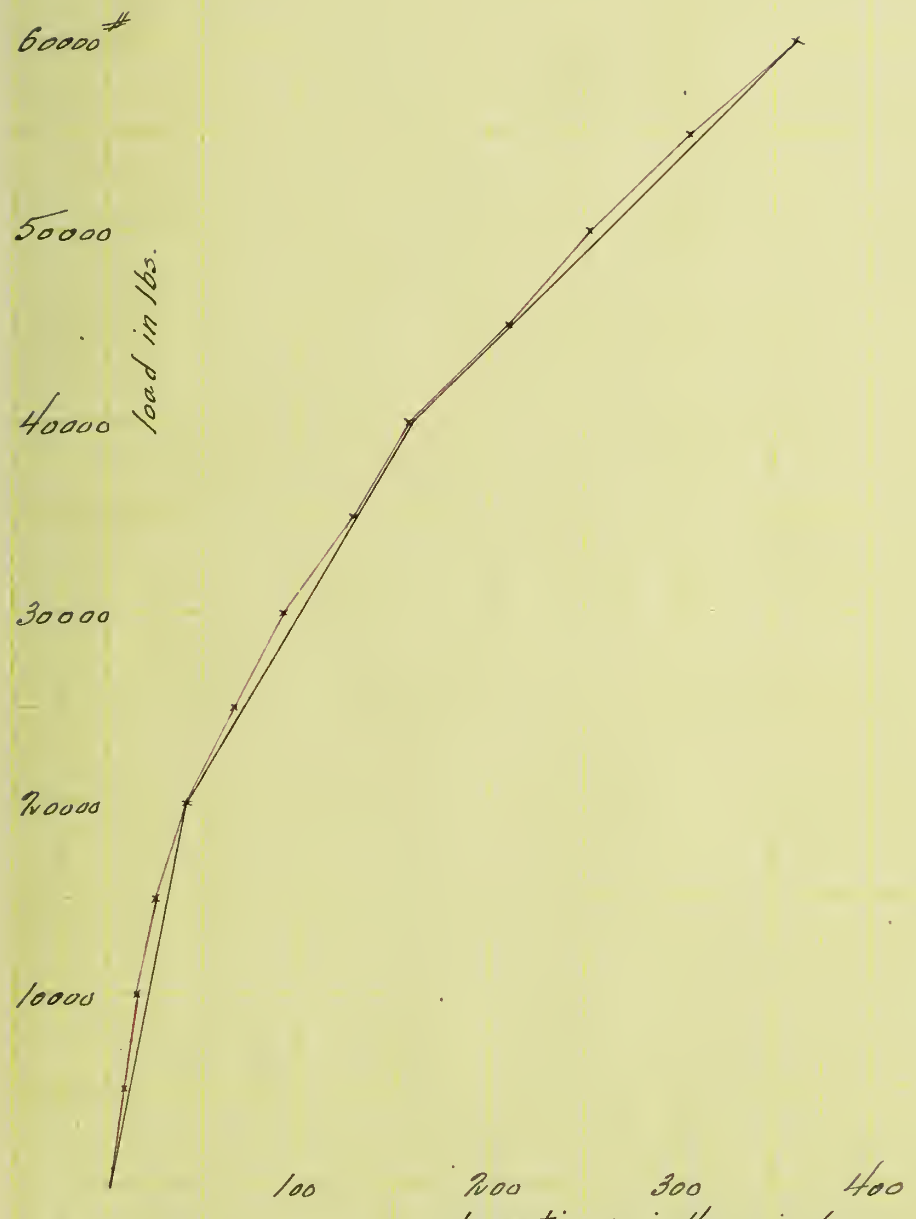

WOOD FISH-PIECES WITH NOTCHES.
JOINT B3.
load in lbs.
50000#
40000
30000
20000
10000
100
200
300
400
elongations in 1/1000 inches.


WOOD FISH-PIECES WITH KEYS.
JOINT C1.
70000#
60000
50000
40000
30000
20000
10000
load in lbs.
100
200
300
400
elongations in 1/1000 inches.


WOOD FISH-PIECES WITH KEYS.
JOINT C2
50000
40000
30000
20000
10000
load in lbs.
0
100
200
300
400
500
600
elongations in 1/1000 inches


WOOD FISH-PIECES WITH KEYS.
JOINT C3
60000
50000
40000
30000
20000
10000
load in lbs.
100
200
300
400
500
600
elongations in 1/1000 inches.

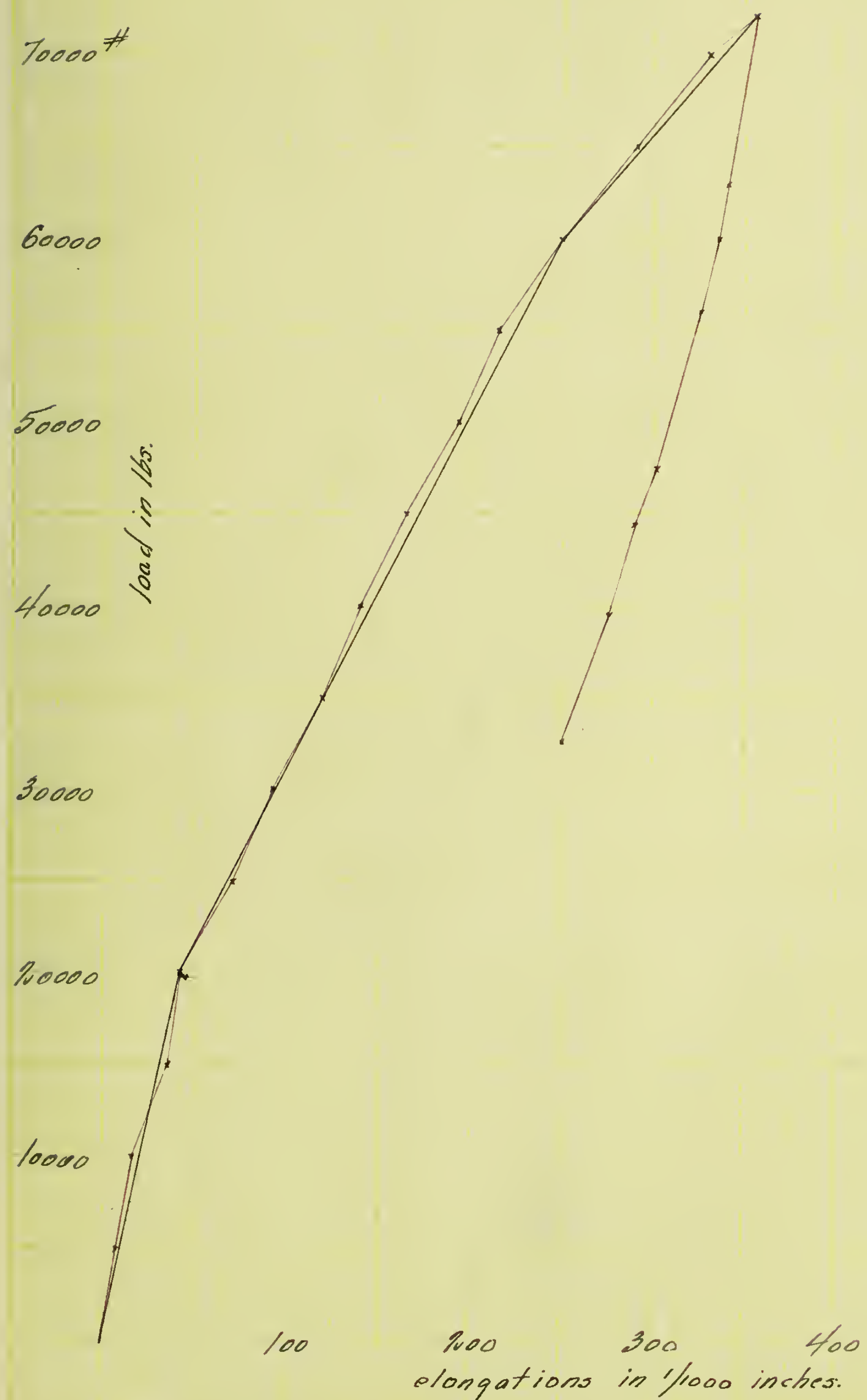
WOOD FISH-PIECES WITH 1" BOLTS. JOINT D1



WOOD FISH-PIECES WITH 1" BOLTS. JOINT D2

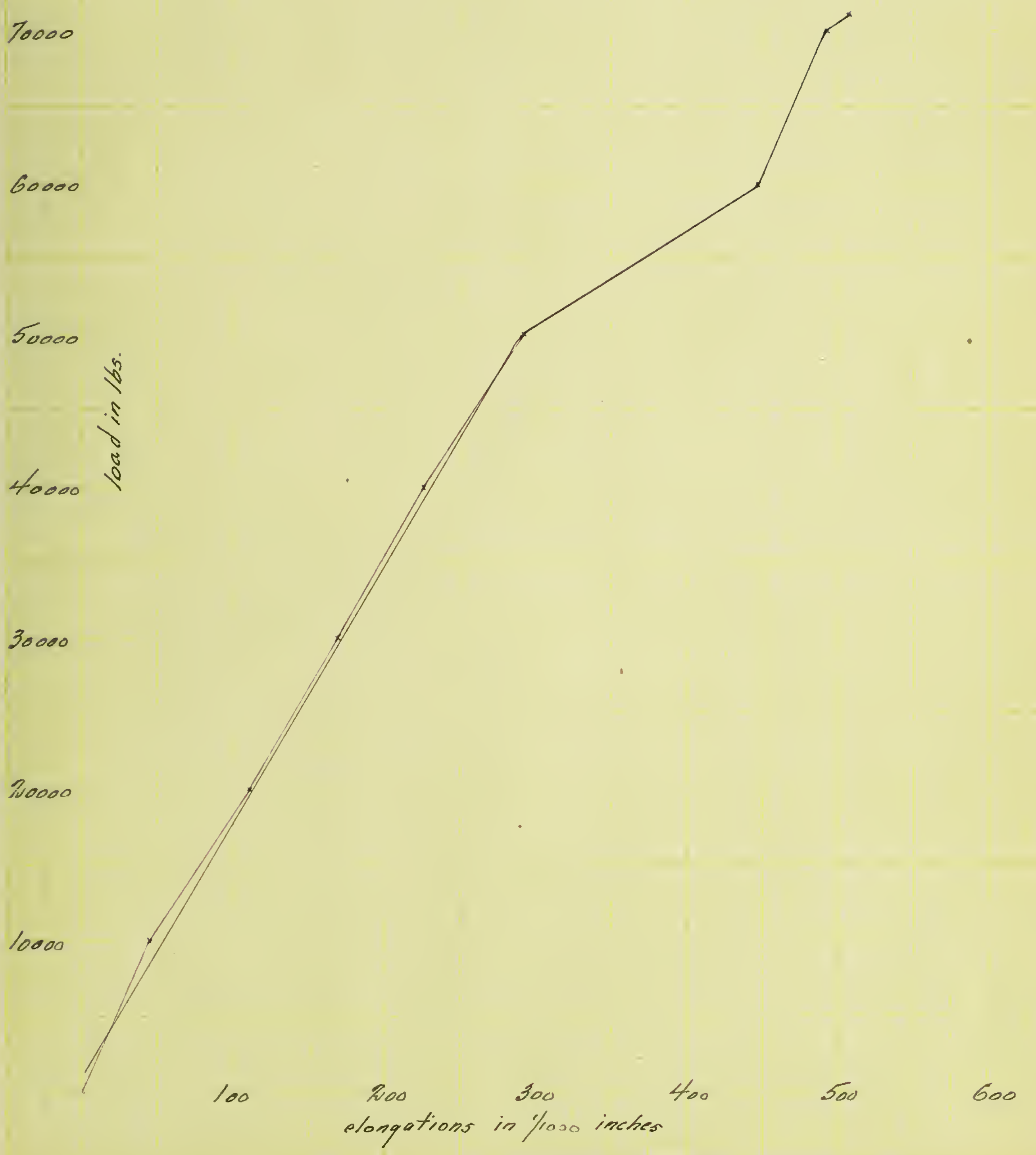
WOOD FISH-PIECES WITH 1" BOLTS.

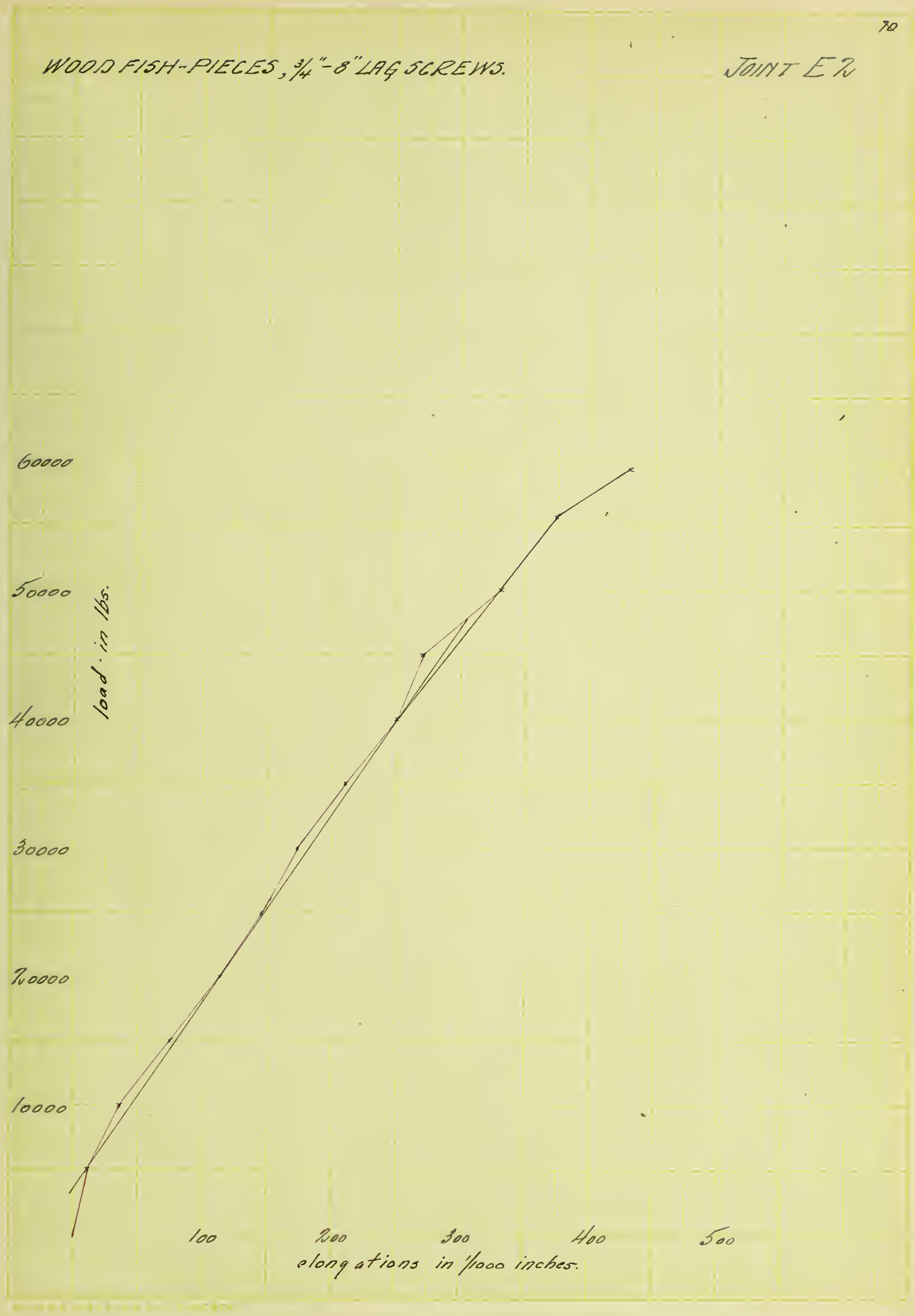
JOINT D3



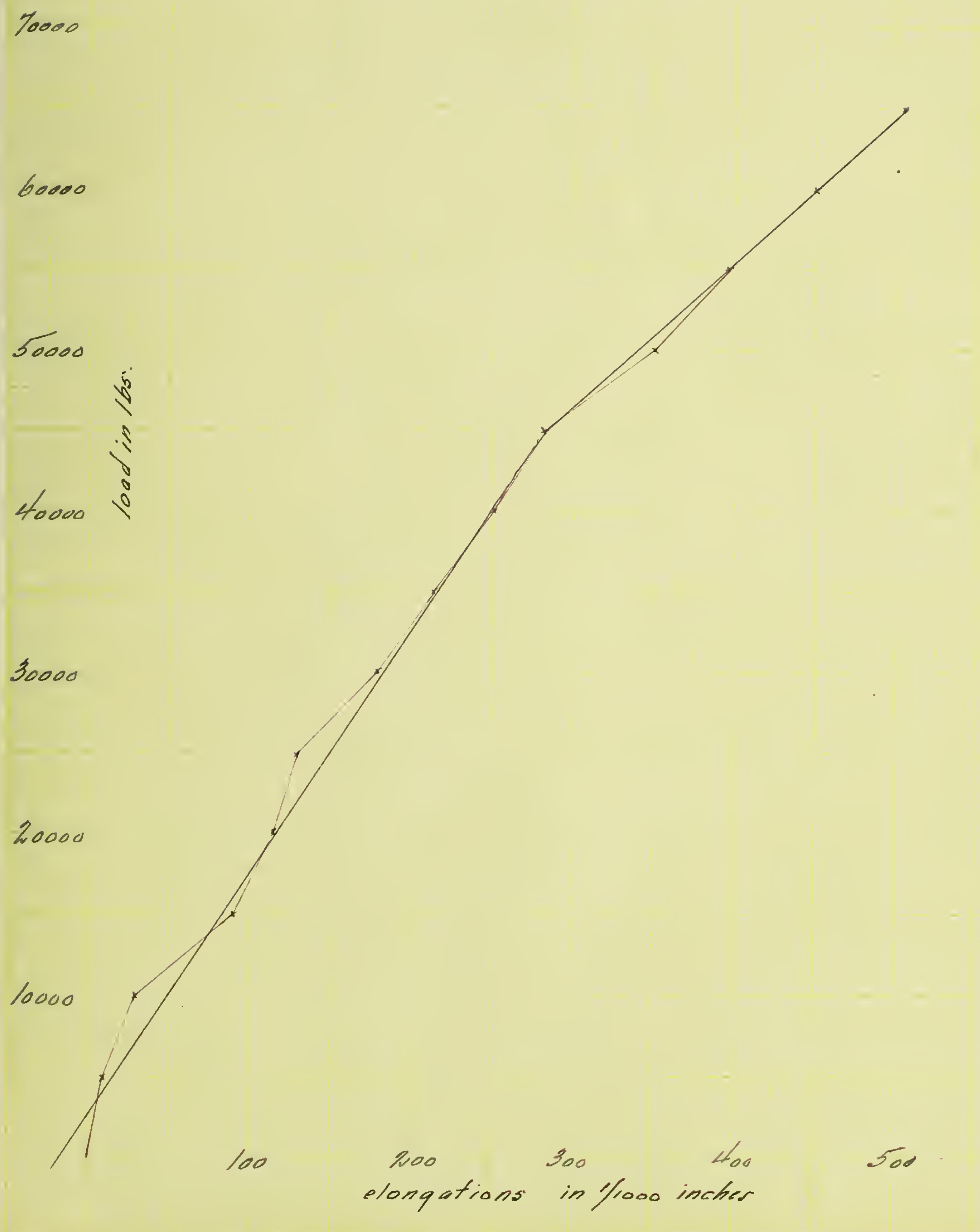
WOOD FISH-PIECES, 3/4"-8" LAG-SCREWS.

JOINT E1.

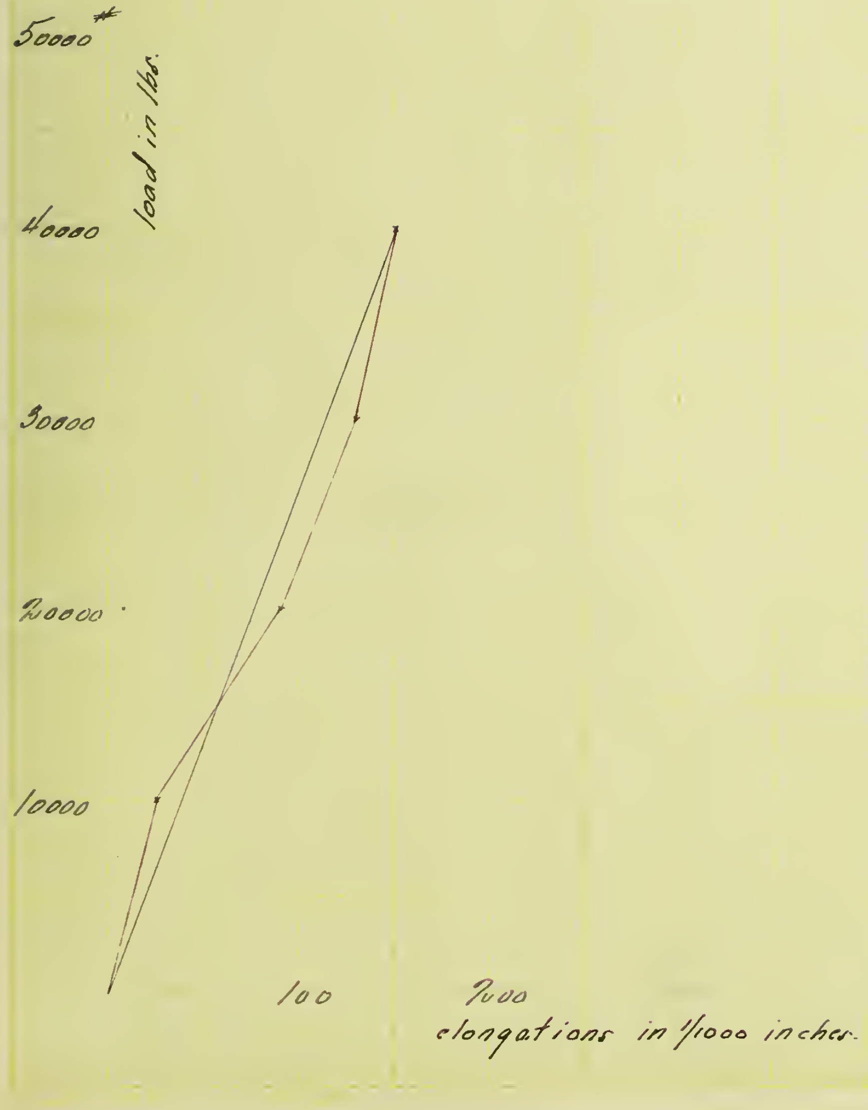



WOOD FISH-PIECES, 3/4"-8" LAG SCREWS.
JOINT E2
load in lbs.
60000
50000
40000
30000
20000
10000
100
200
300
400
500
elongations in 1/1000 inches.

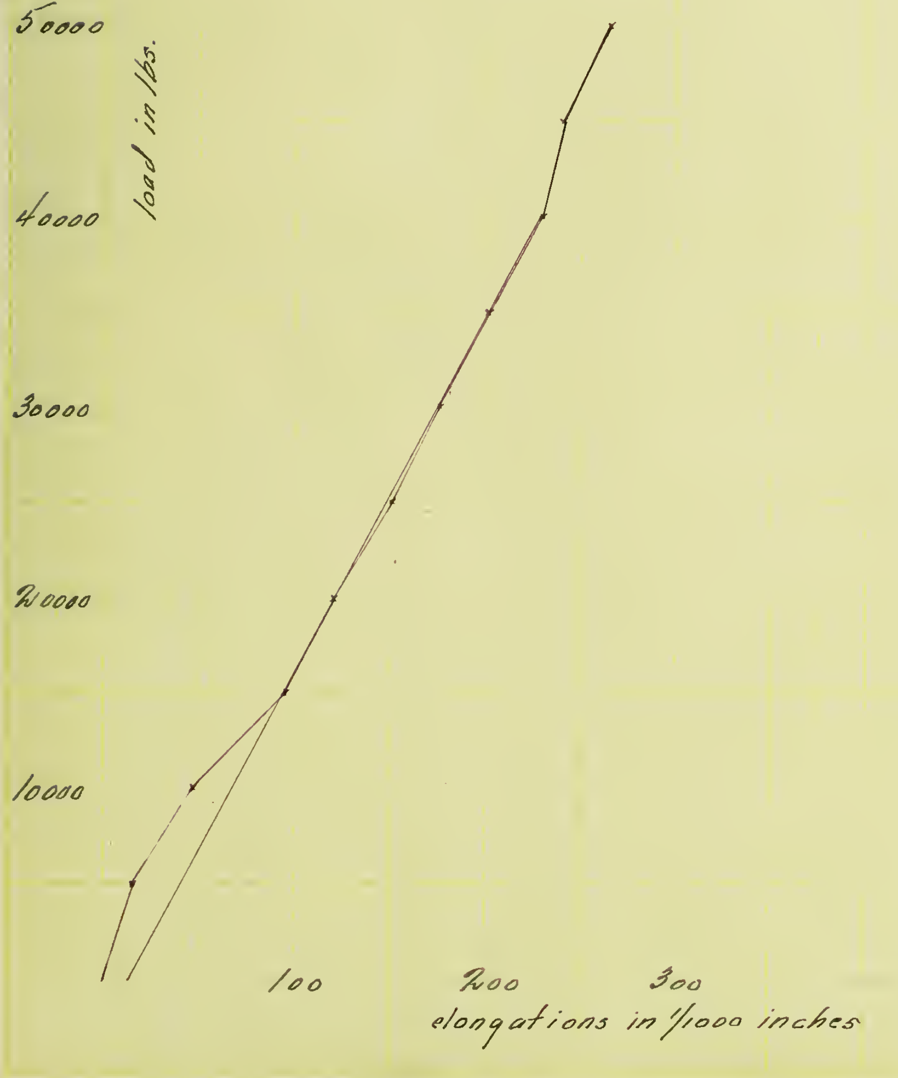
WOOD FISH-PIECES, 3/4"-8" LAG SCREWS. JOINT E3



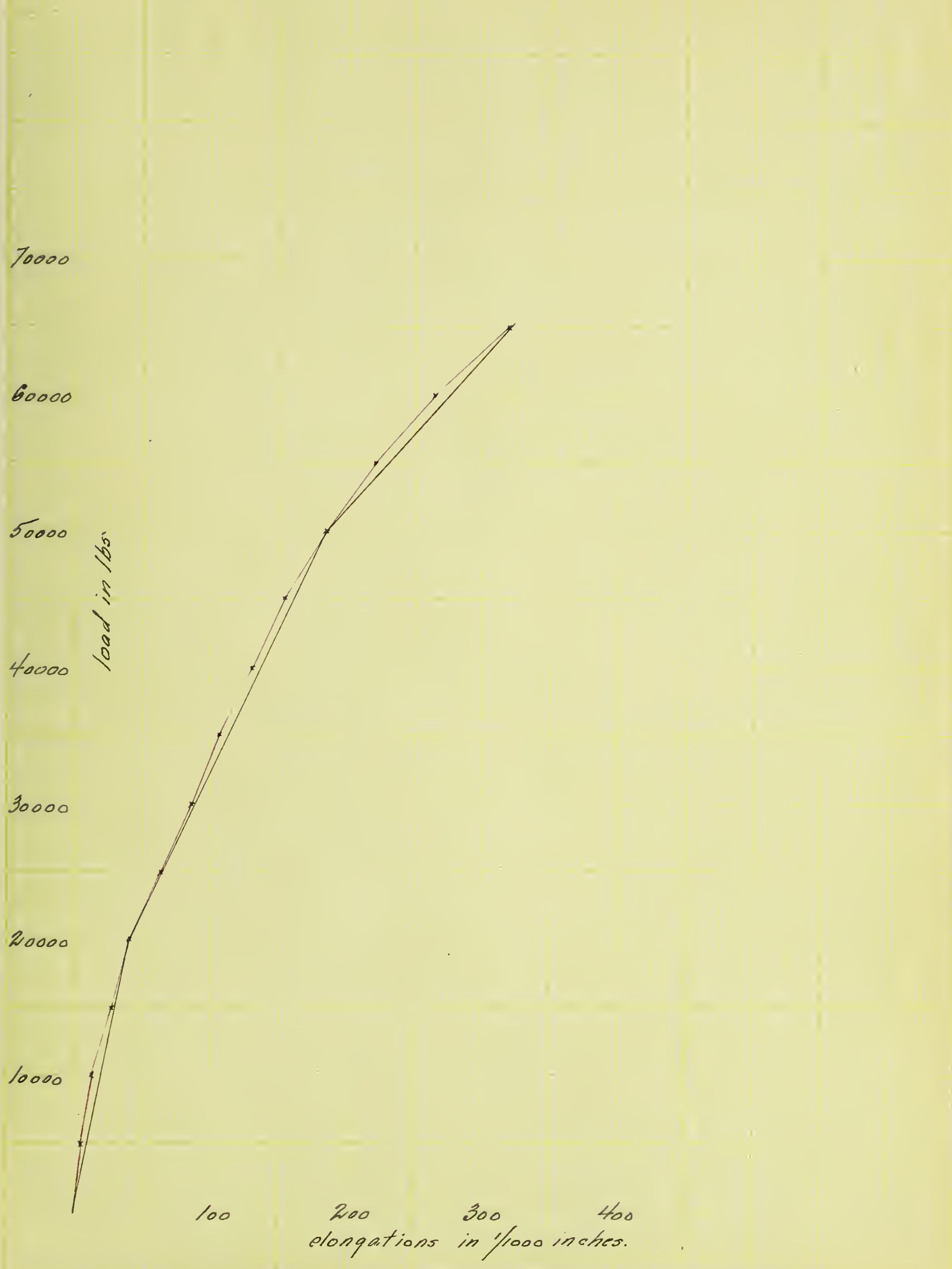
STEEL FISH-PLATES, 1" BOLTS. JOINT F1.

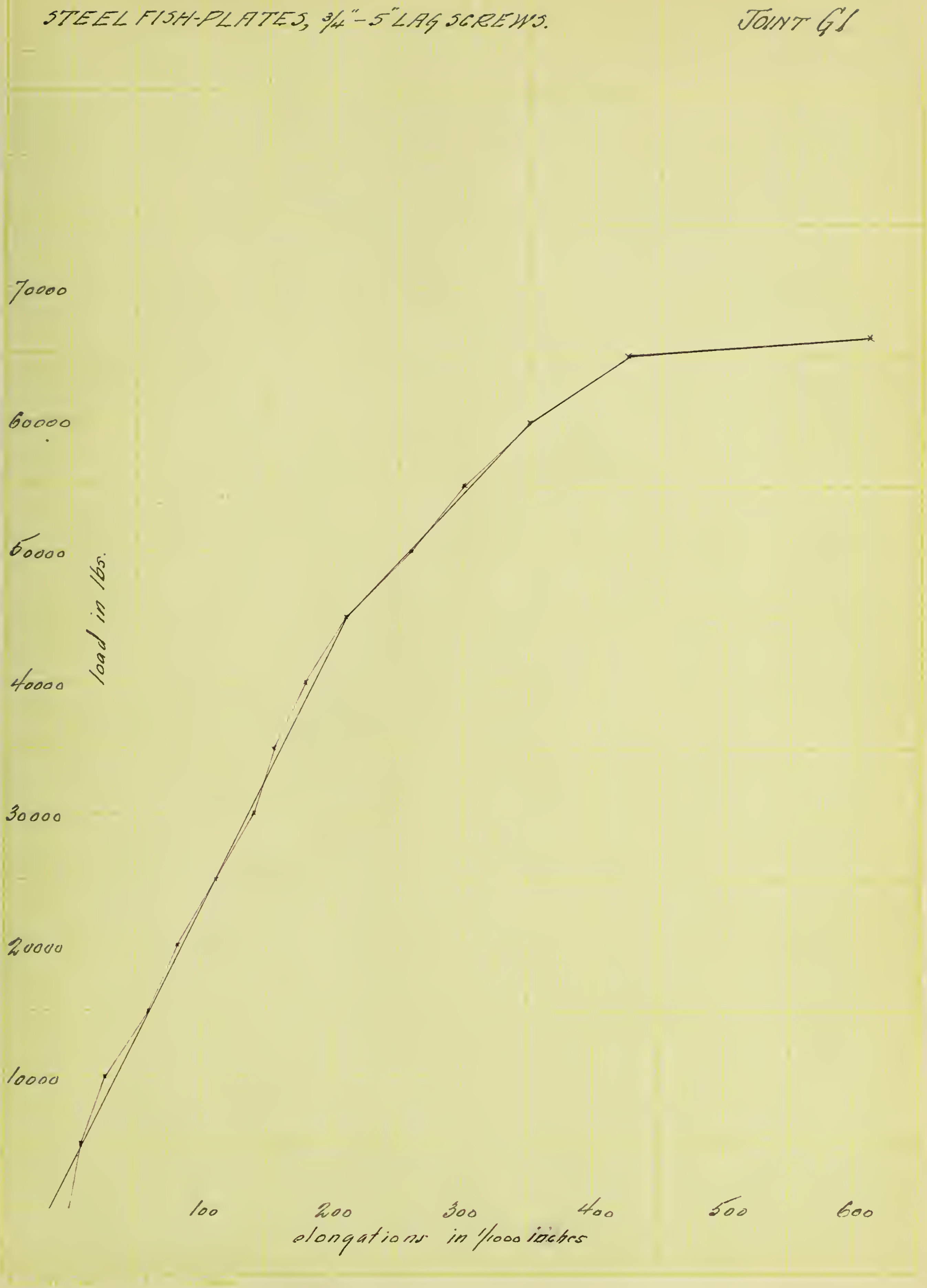


STEEL FISH-PLATES, 1" BOLTS. JOINT F2

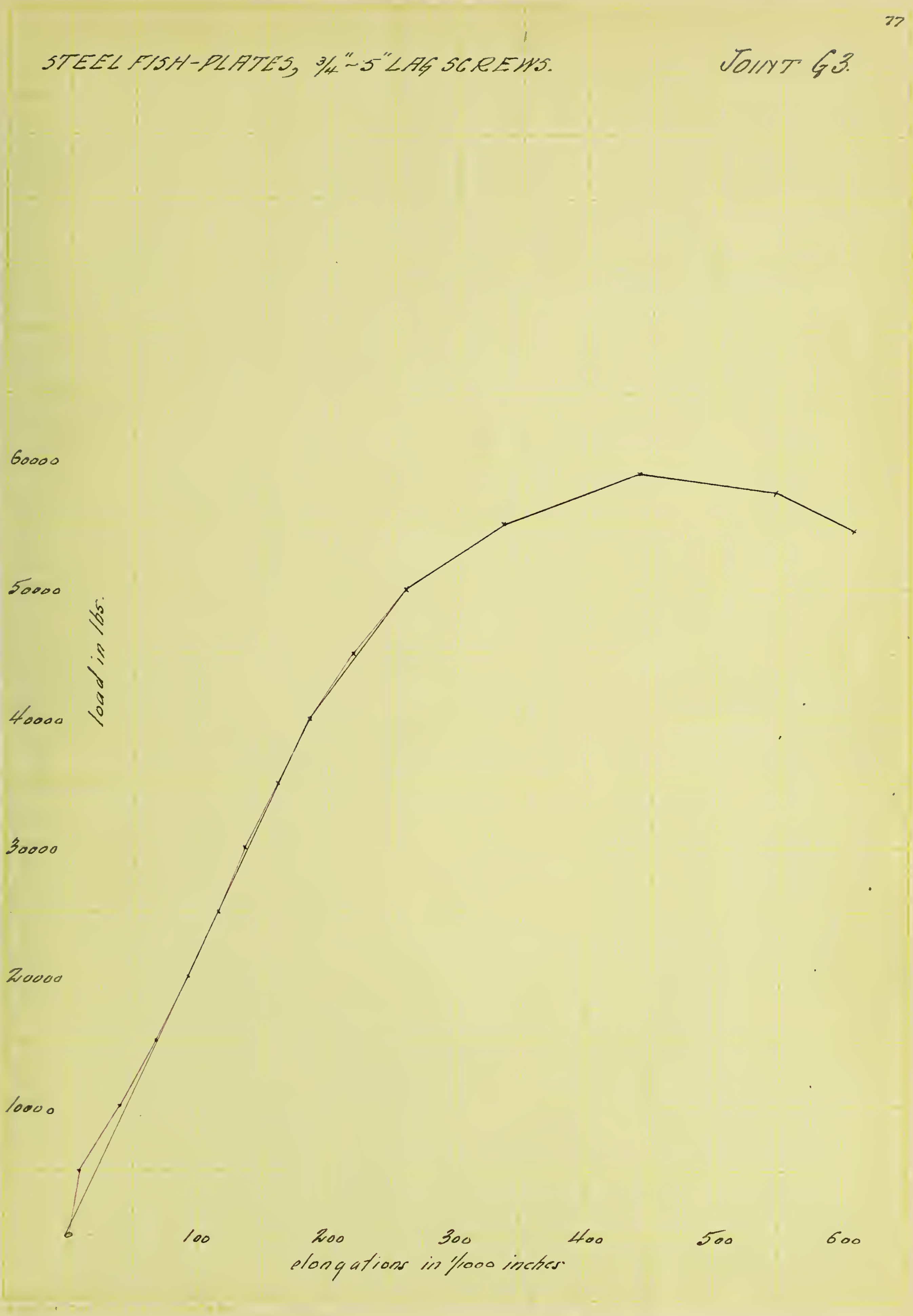


STEEL FISH-PLATES, 1" BOLTS. JOINT F3




STEEL FISH-PLATES, 3/4"-5" LAG SCREWS.
JOINT G1
70000
60000
50000
40000
30000
20000
10000
load in lbs.
100
200
300
400
500
600
elongations in 1/1000 inches

STEEL FISH-PLATES, 3/4"–5" LAG SCREWS. JOINT G2


STEEL FISH-PLATES, 3/4"-5" LAG SCREWS.
JOINT G3.
60000
50000
40000
30000
20000
10000
0
load in lbs.
100
200
300
400
500
600
elongations in 1/1000 inches