

**THE ELASTIC PROPERTIES OF 17ST ALUMINUM ALLOY TUBING
INCLUDING THE EFFECTS OF PRESTRESSING**

**Thesis by
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TABLE OF CONTENTS

	Page
I Acknowledgments	1
II Summary	2
III Introduction	3
IV Experimental Investigation	4
Testing Methods and Equipment	4
Prestress Tests	6
Description of Tests	7
V Results	10
VI Discussion of Results	14
VII References	23
VIII Appendix I: Index to Tests	24

I. ACKNOWLEDGMENTS

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II. SUMMARY

The elastic properties of four different sizes of 178T aluminum alloy tubing in tension and compression are given. It was found that the yield point in compression is consistently about 7,000 lbs./sq.in. lower than the yield point in tension.

An investigation of the effect of prestressing is made and a curve is given showing the variation of yield point (in both tension and compression) as a function of the amount and direction of prestressing.

III. INTRODUCTION

Perhaps the most fundamental problem in structural design is an accurate determination of the properties of all materials used. In the theory of elasticity all material is considered isotropic and if this is so the strengths of a given material in pure compression and in pure tension should be equal. However, the fact that most aluminum alloys used in the aircraft industry are stronger in tension than in compression is just beginning to be accepted. The effect of various methods of fabrication involving alternate stressing of a material is perhaps better appreciated and understood.

It is the purpose of this paper to investigate the properties of a particular alloy, 1737, in tension and compression and then to find the effects of prestressing on these properties.

IV. EXPERIMENTAL INVESTIGATION

A. Testing Methods and Equipment

A 50,000 pound Riehle testing machine (Figure 1) having a least reading of 10 pounds was used in all tests. In making the tension tests it was necessary to slip steel plugs in the ends of the tube before insertion of the specimen in the jaws of the machine. For strain readings two Muggenberger tensometers were used and their readings were averaged. On these tensometers one division is equal to approximately 0.00017 inches per inch and they were read to 0.1 of a division. Figure 2 shows the set-up for a tension test. This method of testing the tubes in tension was very satisfactory as there were very few tube failures that occurred near the fittings, and when such failures occurred it was found that the jaws of the machine had been extended too far beyond the fittings and were crushing the tube. The fittings are shown in Figure 3, together with some typical tension failures. Tension specimens were 18" long.

The arrangement for compression tests is shown in Figure 4. Most compression specimens were 5" long and in the case of the 1" tube were only 4" long. They were cut from tubing as received and then the ends were

very carefully turned down square and smooth in a lathe. The two compression plates bore directly on the testing machine and were leveled up very accurately. At first a spherical head was inserted between the lower compression plate and the bottom of the tube. However, this spherical head was later discarded due to unsatisfactory results. The compression specimens were cut as short as possible to prevent bending failure and at the same time have no "end effect" on the tensometers. Four Huggenberger tensometers were used, as is shown in Figure 4, and the readings were averaged. By means of the four tensometers it was comparatively easy to determine if the tube was bending. Tests in which excessive bending occurred were discarded. However, it was found that tests in which slight bending occurred could be used if the four tensometer readings were averaged. This averaging was found to be valid because tests in which no bending occurred and those in which slight bending occurred gave almost identical results.

When a cylindrical shell is compressed axially symmetrical buckling may occur at a certain value of the compressive load (Reference 1). In order to make certain that this type of buckling did not occur before the yield point was reached some preliminary tests were made. A tube was loaded up to the yield point and

diameter measurements were taken at right angles and at half-inch increments measured axially. These diameter measurements were taken at four different loadings between no load and the yield point. At no time was there any appreciable increase or decrease in any diameter to indicate that symmetrical buckling was occurring. It is therefore believed that true "block compression" was obtained.

Prestress Tests

No difficulty was found in prestressing specimens in tension. The tubes were plugged at the ends, as previously described, and loaded at a constant rate until a load corresponding to the desired prestress value was reached. This load was kept constant for five minutes and then removed. Tension specimens were 18" long and after prestressing some were retained for tension tests while the rest were cut into 5" lengths for compression tests. Only two compression specimens were cut from each 18" length and they were carefully checked for straightness and constant diameter.

For prestressing the tubes in compression a special wooden guide was made up to prevent lateral bending. This set-up is shown in Figure 5. The guide consisted of two halves of wood bolted together, leaving two strips

of tubing about one-half inch wide exposed and unsupported. The guide was 18" long and the tubes were 18" in length. The ends of these tubes were very carefully turned down square on a lathe. The tube was quite free to move vertically with respect to the guide and lateral expansion was permitted at the exposed areas. The set-up was found satisfactory although slight bending occurred when the tubes were prestressed up to 45,000 lbs./sq.in. It is felt that there was no restriction of lateral expansion. After prestressing, some tubes were tested in tension and two 5" compression specimens were cut from each of the other tubes. Here special care was taken in checking the straightness of the specimens.

B. Description of Tests

(1) Tension and Compression Tests

As was already mentioned, the first part of this investigation was to compare the compressive and tensile yield strengths of a particular aluminum alloy. For this purpose four different sizes of 178T aluminum alloy tubing were selected. All of these sizes were in the class of what are known as "thick-walled cylinders." The specimens were cut from 12-foot lengths of tubing. The sizes of the

specimens and methods of testing have already been described. For each size of tubing at least two compression and two tension tests were made.

At first a series of preliminary tests were made on 1 1/8" x .065" tubing to determine such things as effects of changes in testing procedure, optimum lengths of compression specimens, number of tensometers needed, etc.

A complete index to all tests is in Appendix I.

(2) Prestress Tests

In the second group of tests 1 1/2" x .065" 17ST tubing was used throughout. Here there were two parameters to be varied. One was the type of test insofar as how the direction of prestress (tension or compression) and direction of testing (tension or compression) were combined. For this all four possible combinations, as listed below, were used.

1. Tension test of tubing prestressed in tension (T_T).
2. Tension test of tubing prestressed in compression (T_C).
3. Compression test of tubing prestressed in tension (C_T).
4. Compression test of tubing prestressed in compression (C_C).

The symbols in parentheses indicate the method of

labeling tests in the index.

The second parameter was the amount of prestress used. Three different stresses were chosen as follows: the lowest stress was one which was below the proportional limit, the second stress was one above the proportional limit but still below the defined yield point, and the third point was above the defined yield point and as high as could be conveniently taken.

The proportional limit and defined yield point, as referred to in the previous paragraph, naturally depend on the direction of prestress, and as was found from the first group of tests are lower for compression than for tension. Figure 17 shows tension and compression tests of the normal (zero prestress) tubing. The different values of prestress used (1, 2, 3, 4, 5 and 6) for each case are indicated.

All tests were done twice and in all there were 24 tubes tested. A complete index of these tests is included in Appendix I. Any additional tests are also included in the index.

V. RESULTS

The various terms used will first be defined.

The proportional limit is the maximum stress for which the stress-strain curve is still a straight line. Its value is approximate only.

The yield point is the stress which produces a permanent set of 0.2% of the initial gage length.

The elongation (where given) is based on a 4" gage length in the case of the 12" specimens, and a 3" gage length for the 13" specimens.

Young's Modulus and the ultimate strength have their usual significance.

The results of the tension and compression tests on the four different sizes of tubing are plotted in Figures 6 to 13. It will be noted that all tests are first plotted on a staggered coordinate system for clarity (Figures 6, 8, 10 and 12). Then typical sets of tension and compression curves are plotted to compare differences in the shapes of the curves (Figures 7, 9, 11, and 13). Figures 14 and 15 are composite curves to compare all the tube sizes.

Typical tension failures are shown in Figure 3, and compression failures are shown in Figure 16.

The results are in tabular form in Table I (averages of two or more tests plotted in figures mentioned previously).

TABLE I

Property		1½"x.065"	1½"x.049"	1"x.065"	1"x.049"
Ten- sion	$E \times 10^{-6} \#/\text{in.}^2$	10.3	10.4	10.0	9.7
	Proportional Limit	32800	36200	36700	27500
	Yield Point	46000	51300	47500	41400
	Ultimate Strength	65810	66680	67590	63950
	Elongation	24.4%	---	25.0%	23.8%
	$E \times 10^{-6} \#/\text{in.}^2$	10.2	10.2	10.1	9.9
	Proportional Limit	25100	23300	26000	29500
	Yield Point	38300	43900	40500	40000
	Ultimate Strength	56520	54240	56170	53350
(Tension Y.P.)-(Comp.Y.P.)		7700	7400	7200	1400
(Tension P.L.)-(Comp.P.L.)		7700	12900	10700	-2000

The results of the prestressing tests are plotted in Figures 18 to 21. Figures 22 to 25 show average curves replotted so as to indicate more clearly the effects of

prestressing. Finally, Figure 26 is a plot of yield point versus amount of prestress.

The results are also presented in tabular form in Table II.

TABLE II

Prestressed to	Properties	Tension	Compression
Zero Prestress (From Table I)	$E \times 10^{-6}$ lb./in. ²	10.3	10.2
	Proportional Limit	32800	25100
	Yield Point	46000	38300
	Ultimate Strength	65610	56520
	Elongation	24.4%	
25,000 lb./in. ² in Tension	$E \times 10^{-6}$ lb./in. ²	10.0	10.4
	Proportional Limit	33000	33000
	Yield Point	45500	44600
	Ultimate Strength	66320	57570
	Elongation	---	
42,000 lb./in. ² in Tension	$E \times 10^{-6}$ lb./in. ²	10.4	10.4
	Proportional Limit	42600	25500
	Yield Point	47000	42900
	Ultimate Strength	67610	58250
	Elongation	22.8%	
50,000 lb./in. ² in Tension	$E \times 10^{-6}$ lb./in. ²	10.3	10.4
	Proportional Limit	47000	22900
	Yield Point	53300	41500
	Ultimate Strength	67940	59060
	Elongation	21.3%	
18,000 lb./in. ² in Compression	$E \times 10^{-6}$ lb./in. ²	9.9	10.3
	Proportional Limit	55800	25000
	Yield Point	46100	38400
	Ultimate Strength	66360	56620
	Elongation	26.4%	
52,000 lb./in. ² in Compression	$E \times 10^{-6}$ lb./in. ²	10.2	10.4
	Proportional Limit	32000	30000
	Yield Point	44900	39600
	Ultimate Strength	66630	57160
	Elongation	23.2%	
45,000 lb./in. ² in Compression	$E \times 10^{-6}$ lb./in. ²	10.2	10.6
	Proportional Limit	22800	44500
	Yield Point	39200	46600
	Ultimate Strength	66725	57120
	Elongation	24.5%	

VI. DISCUSSION OF RESULTS

From an inspection of Table I it is immediately apparent that the value of the tensile yield point is higher than that of the yield point in compression. In the case of three different sizes of tubing the average difference is 7,400 lb./sq.in. However, it can be seen that the 1" x .049" tubing gives different results. Although in this case the tensile yield point is also higher than the yield point in compression the difference is only 1400 lb./sq.in. While the four different yield points in compression are approximately the same the yield point in tension is much lower for the 1" x .049" tubing than for the other three sizes. Therefore, the fact that the difference in yield point (comparing tension and compression for the 1" x .049" tubing) is too small is because the tension yield point for this size tubing is much too low. The reason for this is not definitely known, but it is highly probable that the low tensile strength is simply a characteristic of the particular tube tested. Either the heat treatment was not quite high enough or the tube drawing operations for this size are different than those for the other sizes.

In Table III is listed values of the yield point of 179F as found in various references.

TABLE III

Source	Yield Point in Tension	Yield Pt. in Compression	Remarks
Aleco Handb'k. Reference 4	37000	Not given	Typical Properties of 1732
Aleco Handb'k. Reference 4	40000	Not given	Guaranteed minimum for Tubing tested
ANG-5 Reference 5	30000	30000	Minimum acceptable value ("before stretching")
ANG-5 Reference 5	40000	36000	Minimum acceptable value ("after stretching"; i.e., "as received")
Tech. Note 618 Reference 3	44000	38000	For 2" x .083" Tubing

It will be noted that in the latest edition of the Aleco Handbook (1937) tensile values only are given. However, the newly published "ANG-5" Handbook gives values for both tension and compression. Also, since tubing "as received" has been stretched in a straightening process values are given for "after stretching" and "before stretching."

It must be remembered that the various fabrication processes through which the tubing must go, such as drawing and stretching, are in effect prestressing operations insofar as the tension and compression tests just mentioned are concerned. Therefore, before continuing this phase of the

discussion the tests on prestressing will be taken up.

The effect of prestressing is best seen from Figure 26. It can be seen that the yield point in tension is raised by prestressing in tension and lowered by prestressing in compression. Furthermore, prestressing below the proportional limit has practically no effect on the yield point, and as the amount of prestressing is increased its effect, whether to raise or lower the yield point, is more pronounced.

It can also be seen from Figure 26 that the yield point in compression is raised by prestressing in compression. Here also prestressing below the proportional limit has very little effect on the yield point, but the effect increases as the prestress value is raised. The curve showing the variation of compressive yield point as a function of the value of prestress in tension is not similar to the previous cases. It appears that this type of prestress also has very little effect in the elastic region. However, as the tensile prestress is raised up to the proportional limit the compressive yield point is suddenly increased to a very high value, after which it decreases proportionately to the amount of prestress.

Physically, it is difficult to conceive of this sudden increase in yield point, and also, as will be seen later, this does not seem to agree with other similar

experiments made by Bauschinger (Reference 2). It would be expected that the compressive yield point would progressively decrease as the tensile prestress was increased beyond the proportional limit, and would never be above the normal compressive yield point. As a matter of fact, several check points (also plotted on Figure 28) indicate that this curve is doubtful, and further tests should be made for this case.

At this point it is perhaps best to discuss the work of other investigators.

The effects of alternate loading, which is what the prestress tests really are, were first investigated by Bauschinger in 1891 (Reference 2). He found the following:

1. When a metal is loaded above the elastic limit in tension or compression the elastic limit for stresses in the same direction is raised. Similarly, for stresses in the opposite direction the elastic limit is lowered. The latter effect is known as "the Bauschinger Effect." Also, this increase or decrease is proportional to the initial overload above the elastic limit. The elastic limit lowered in this way does not recover in any length of time.

2. If the elastic limit has been lowered it can be raised again by alternate tensile and compressive stresses which increase in amplitude, but the original elastic limit will never be reached. This higher elastic limit is called the "natural elastic limit."

3. By a great number of repeated loadings between zero and a given stress (of the same sign) the elastic limit is raised, but not indefinitely. If this given stress is so high that the elastic limit cannot be raised above it then rupture will occur.

The first law of Bauschinger is borne out in the prestress tests in three out of four of the cases. In this fourth case already mentioned, a stress of opposite sign actually causes an increase in yield point in a given range.

The other two conclusions of Bauschinger are mostly of importance in the fatigue of metals under alternate stresses.

The effect of prestressing on tubing has also been investigated by Helt and Hartmann at the Aluminum Research Laboratories (Reference 3). However, they were chiefly interested in the effect on columns and give very little data on the actual yield point in direct compression. Four points obtained from their results are replotted on Figure 26 and, as can be seen, agree very well with the curves.

The tension and compression curves of the first part will now be discussed further.

An attempt may be made to explain the differences between compression and tension tests of the tubing "as received" by closely examining the methods of fabrication,

such as drawing, annealing, heat-treating, and stretching. Undoubtedly these processes have a very definite effect on the tube properties. However, it must be remembered that this difference in yield points has also been found in cast metal, and it seems to be an actual property of the material.

In an effort to explain this yield point variation a series of photomicrographs were taken. Specimens were cut both perpendicular and parallel to the axis of loading (axis of the tube). A tube failed in compression was cut near the center, one failed in tension was cut close to the break, and a normal tube "as received" was cut, and all were polished. Six specimens in all were cut. The magnification used was 100X.

Figures 27, 28 and 29 are photomicrographs of specimens cut parallel to the tube axis. Figures 30, 31 and 32 are photomicrographs of specimens cut perpendicular to the tube axis.

It can be seen that there is no unusual distortion of the crystals in any of the photographs. It may be concluded that the reason for the variation in yield point is not apparent from the photomicrographs. However, it must be remembered that the tension specimen represents conditions at failure, and the compression specimen represents conditions at some unknown stress (since failure occurred by local buckling at the ends of the tube). Perhaps a more



Figure 27
Normal



Figure 28
Compression



Figure 29
Tension

Photomicrographs taken Parallel to the Axis of Loading



Figure 30
Normal



Figure 31
Tension

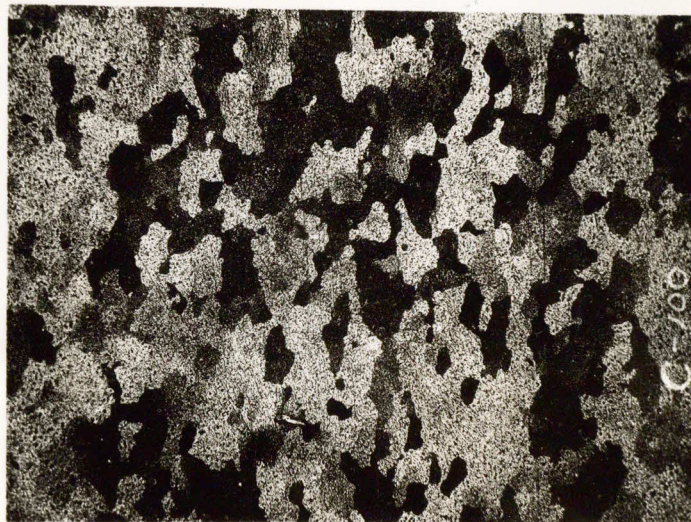


Figure 32
Compression

Photomicrographs taken Perpendicular to the Axis of Loading

thorough metallographical investigation at various stresses would reveal something of value.

Among possible explanations for the "Bauschinger effect" the following may be mentioned: a rotation of the directions of the principal stresses, a change in the three principal stresses, and a distortion of the lattice structure. The latter has been investigated recently by means of X-ray diffraction patterns.

As yet the phenomenon of the variation in yield point has not been satisfactorily explained.

One parameter which was not considered in this investigation was the effect of aging after prestressing. It will be noted that the dates of both prestressing and testing are included in the index to tests (Appendix I). An attempt was made to keep all time intervals uniform so that it is believed the effect of aging is of minor importance in the present tests.

VII. REFERENCES

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2. Bauschinger, J.: Mitteilungen aus dem Mech. techn. Labor. der T. H. München, Heft 13, München, 1881.
3. Holt, M., and Hartmann, E.C.: Increasing the Strength of Aluminum-Alloy Columns by Prestressing. N. A. C. A. Technical Note No. 618.
4. Alcoa Aluminum and its Alloys. Published by the Aluminum Company of America, Pittsburgh, Pa.
5. ANC-5: Strength of Aircraft Elements. Issued by the Army-Navy-Commerce Committee on Aircraft Requirements, January, 1938.

APPENDIX I

Index to Tests

* Indicates test has been plotted on one of the Figures.

Test No.	Date 1938	Tube Size In.	Length In.	$E \times 10^{-6}$ #/in ²	Prop. Limit	Yield Point	Ult. Strength
C O M P R E S S I O N T E S T S							
10	2/5	1 1/8x.065	8				
20	2/8	1 1/8x.065	8	10.4		41000	56980
30	2/12	1 1/8x.065	8	10.2	30300	41200	53160
40	2/12	1 1/8x.065	4 3/4	10.7	23400	38300	62200
50	2/16	1 1/8x.065	4 15/16				62550
60	2/16	1 1/8x.065	4 15/16				63050
70	2/19	1 1/8x.065	6				59700
80	2/21	1 1/8x.065	6				60200
90	3/5	1 1/8x.065	4 15/16				63000
*100	3/5	1 1/2x.065	5	10.2	26000	38900	57000
*110	3/5	1 1/2x.065	5	10.3	25800	38400	56940
120	3/23	1x.065	5				64710
130	3/23	1x.049	5				55400
*140	3/23	1 1/2x.065	5	10.2	24600	38300	56480
*150	3/28	1 1/2x.065	5	10.2	25600	38600	56530
160	3/28	1 1/2x.065	5				56600
170	3/28	1 1/2x.049	5				54050
*180	4/16	1 1/2x.049	5	10.2	25500	43900	54000
*190	4/16	1 1/2x.049	5	10.2	25000	43900	54480
*200	4/16	1x.065	4	10.1	26000	40400	66240
*210	4/16	1x.065	4	10.1	26000	20100	66090
*220	4/16	1x.049	4	9.6	30000	39900	55250
*230	4/16	1x.049	4	10.1	29000	40100	55450
*240	5/7	1 1/2x.065	5	9.9	24800	37700	55540
250	5/7	1x.049	4				57940
*260	5/18	1 1/2x.065	5	10.4	24000	37700	56630

Index to Tests (continued)

* Indicates test has been plotted on one of the figures

Test No.	Date 1938	Tube Size In.	Length In.	$E \times 10^{-6}$ #/in. ²	Prop. Limit	Yield Point	Ult. Strength	Elong. %
T E N S I O N T E S T S								
1T	3/22	1 1/8x.065	18				60440	
2T	3/22	1 1/8x.065	18				61020	
* 3T	3/31	1 1/8x.065	18	10.3	35000	46000	64300	
* 4T	3/31	1 1/8x.065	18	10.3	32400	46000	65340	
* 5T	5/2	1 1/8x.065	18	10.2	31000	46000	67290	24.4
* 6T	3/31	1 1/2x.049	18	10.4	38400	51000	66570	
* 7T	3/31	1 1/8x.049	18	10.4	38000	51500	66790	
* 8T	4/23	1x.049	18	9.5	26600	41400	62610	
* 9T	4/23	1x.065	18	9.9	36000	47000	55260	
* 10T	4/23	1x.049	18	9.6	28000	41300	62940	
* 11T	4/23	1x.065	18	9.9	38000	46900	66810	
12T	4/25	1" diam. Bar	18				61100	25.3
13T	4/25	1" diam. Bar	18				62090	25.0
* 14T	5/2	1x.065	18	10.1	36000	48500	63360	25.0
* 15T	5/11	1x.049	18	10.0	28000	41700	65300	23.8

Index to Tests (concluded)

PRESTRESSING TESTS

Test No.	Date Pre-stressed	Date Tested	Pre-stressed to	$\text{Ex}10^{-6}$ #/in. ²	Prop. Limit	Yield Point	Ult. Strength	Elong. %
TENSION TESTS, PRESTRESSED IN COMPRESSION								
1T _c	4/21	4/25	18000	9.8	36000	44800	65940	27.5
2T _c	5/5	5/11	18000	10.0	35000	45300	66780	25.3
3T _c	5/5	5/11	32000	10.2	32000	44800	66620	25.3
4T _c	5/5	5/11	32000	10.1	32000	45000	66640	25.0
5T _c	5/5	5/12	45000	10.1	23000	39200	66950	25.0
6T _c	5/5	5/12	45000	10.3	22500	39100	66500	24.0
TENSION TESTS, PRESTRESSED IN TENSION								
7T _T	4/21	4/25	25000	10.0	32000	45400	66270	
8T _T	4/21	4/25	25000	9.9	34000	45500	66370	
9T _T	5/2	5/5	42000	10.5	42600	46900	67610	22.5
10T _T	5/2	5/5	42000	10.3	42600	47000	67610	23.0
11T _T	5/2	5/5	50000	10.4	48000	53300	67890	21.3
12T _T	5/2	5/5	50000	10.2	46000	53300	67990	21.3
COMPRESSION TESTS, PRESTRESSED IN COMPRESSION								
1C _c	5/5	5/8	18000	10.2	26000	38500	56630	
2C _c	5/5	5/8	18000	10.4	24000	38300	56600	
3C _c	5/5	5/8	32000	10.3	30000	39700	57140	
4C _c	5/5	5/9	32000	10.5	30000	39500	57170	
5C _c	5/5	5/12	45000	10.6	44500	48600	57420	
6C _c	5/5	5/12	45000	10.6	44500	48600	56920	
COMPRESSION TESTS, PRESTRESSED IN TENSION								
7C _T	5/2	5/7	25000	10.4	34000	45000	58230	
8C _T	5/2	5/7	25000	10.4	32000	44100	56900	
9C _T	5/2	5/7	42000	10.4	26000	42700	58480	
10C _T	5/2	5/7	42000	10.3	25000	43000	58040	
11C _T	5/2	5/7	50000	10.4	22000	41700	59200	
12C _T	5/2	5/8	50000	10.3	22000	41200	56890	
13C _T	5/18	5/19	15000	10.5	23000	36100	57000	
14C _T	5/22	5/26	42000	10.4	22000	36400	58190	

NOTE:T_c specimens are 15" longT_T specimens are 18" longC_c and C_T specimens are 5" long

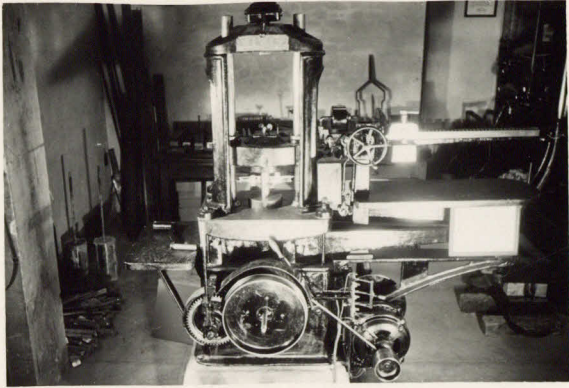


Fig. 1

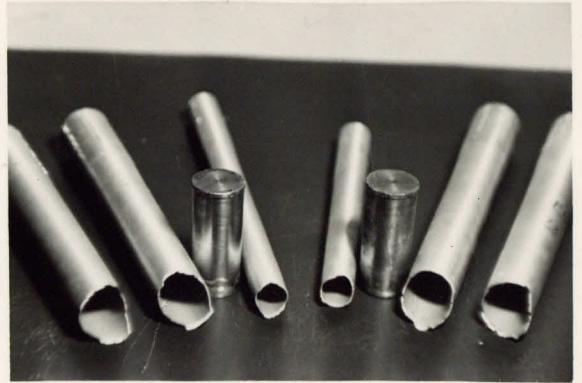


Fig. 3

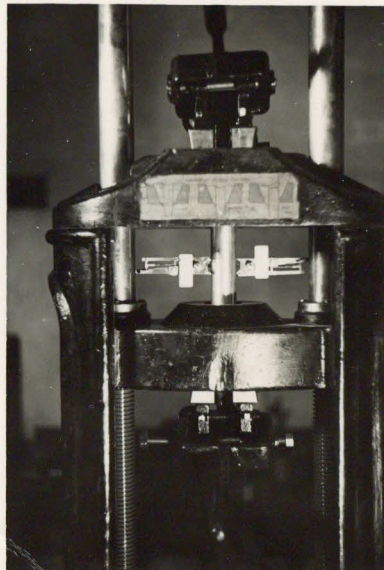


Fig. 2

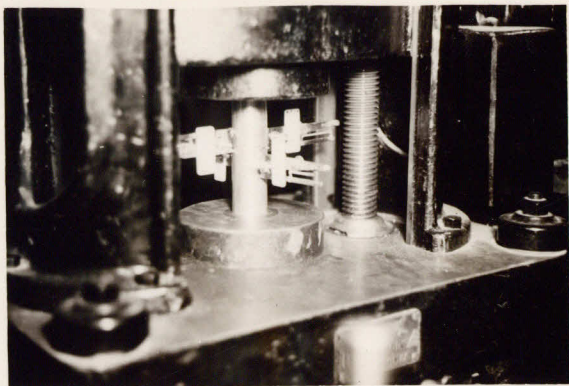


Fig. 4

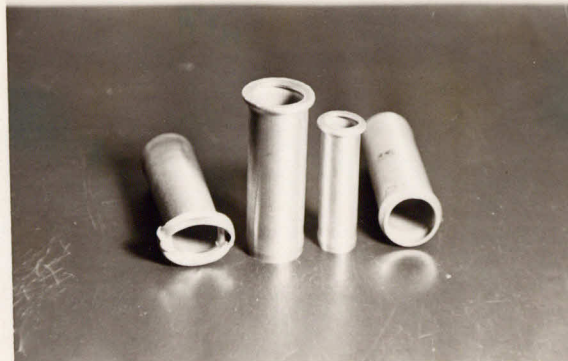


Fig. 16

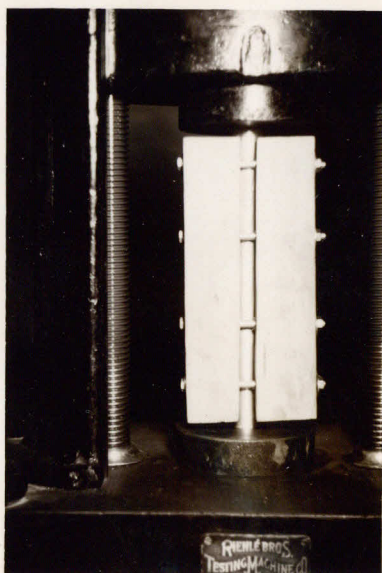
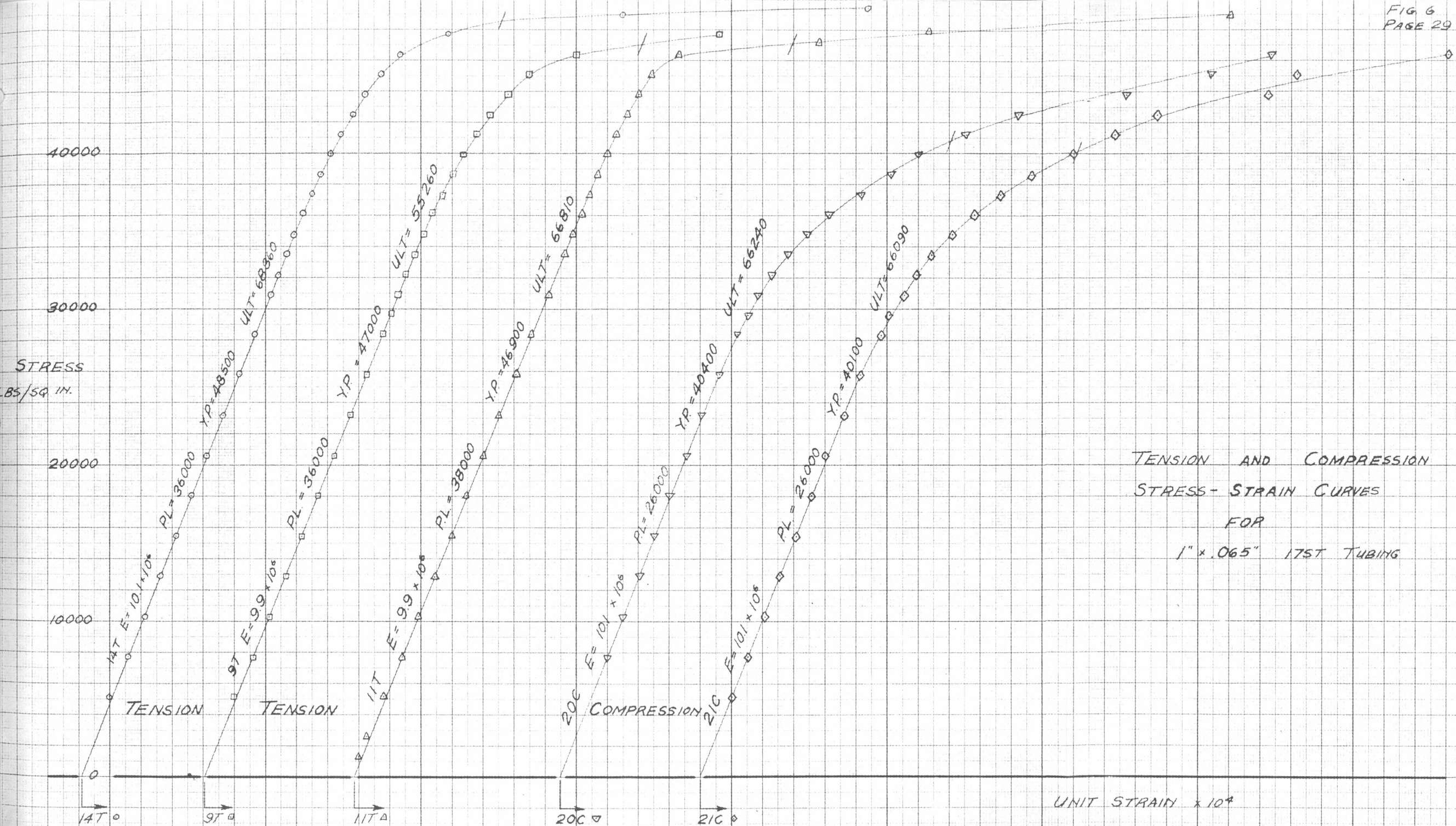
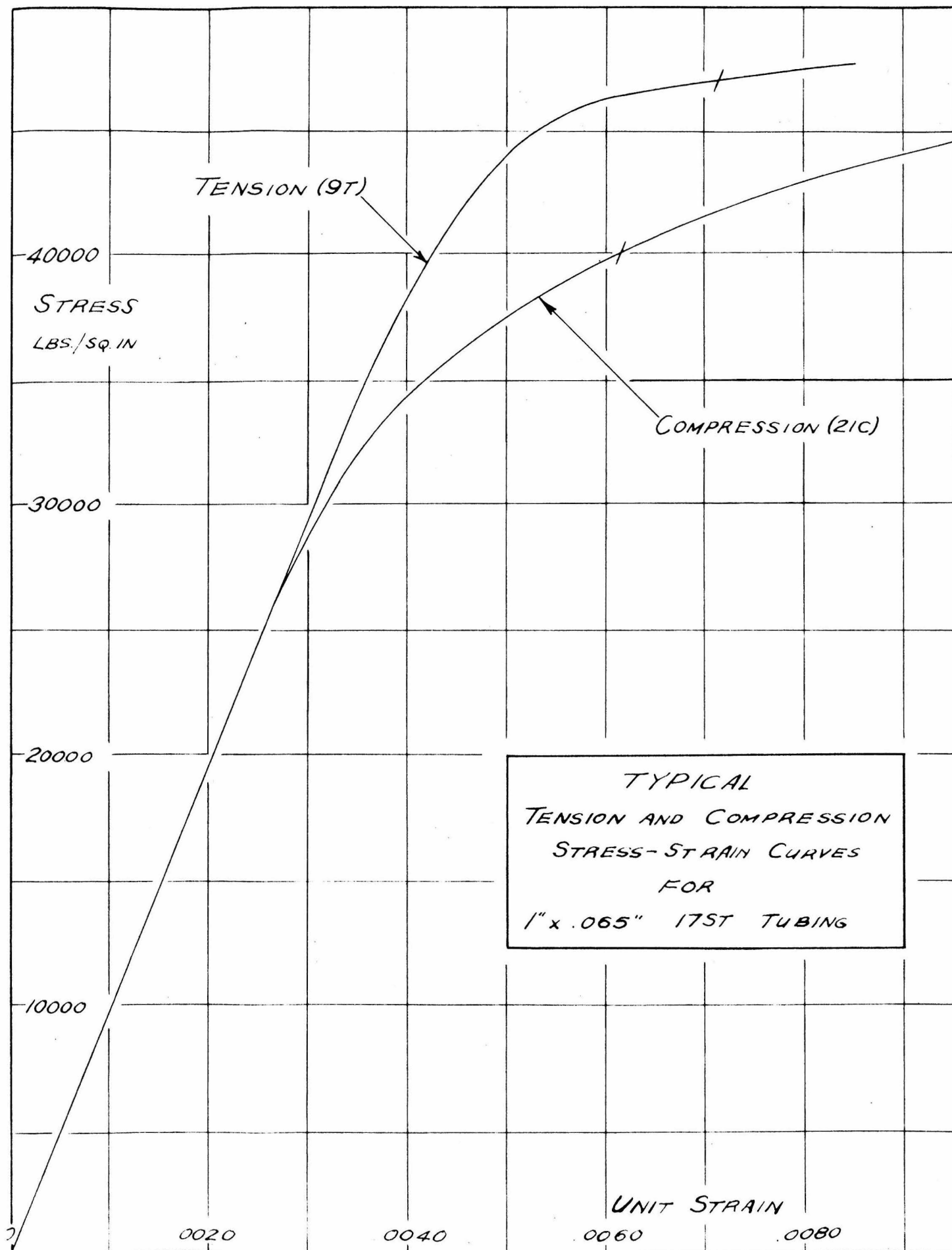
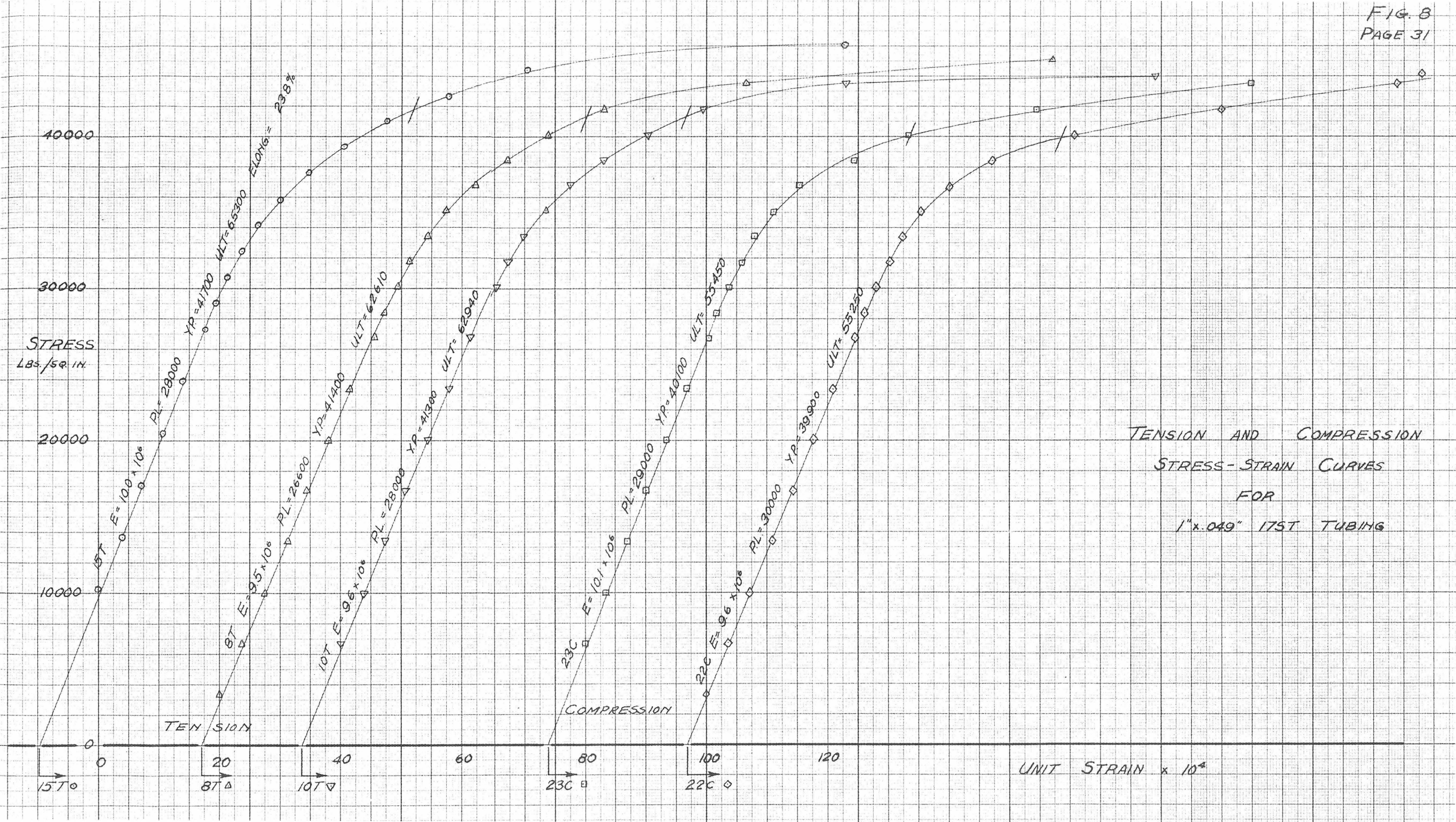


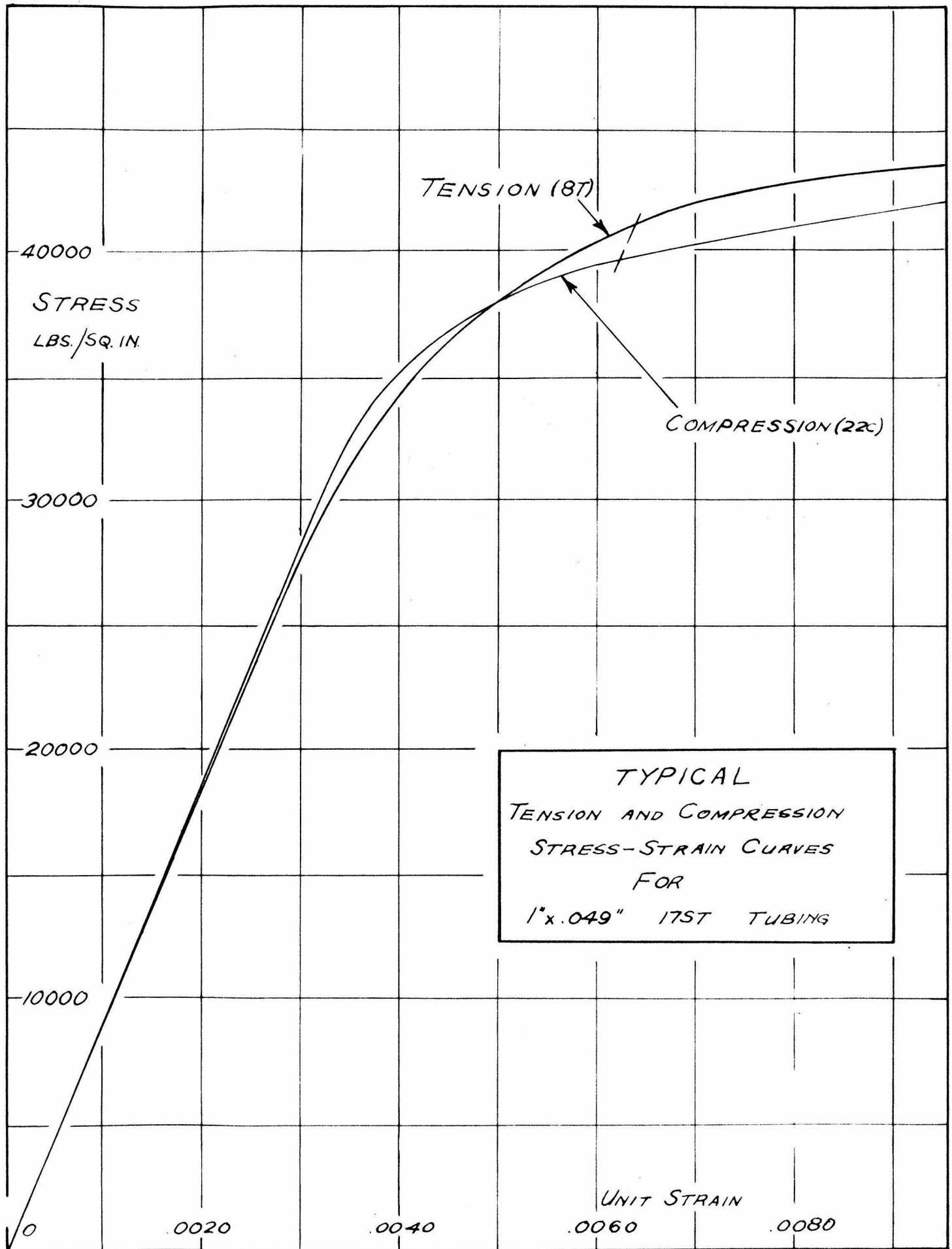
Fig. 5

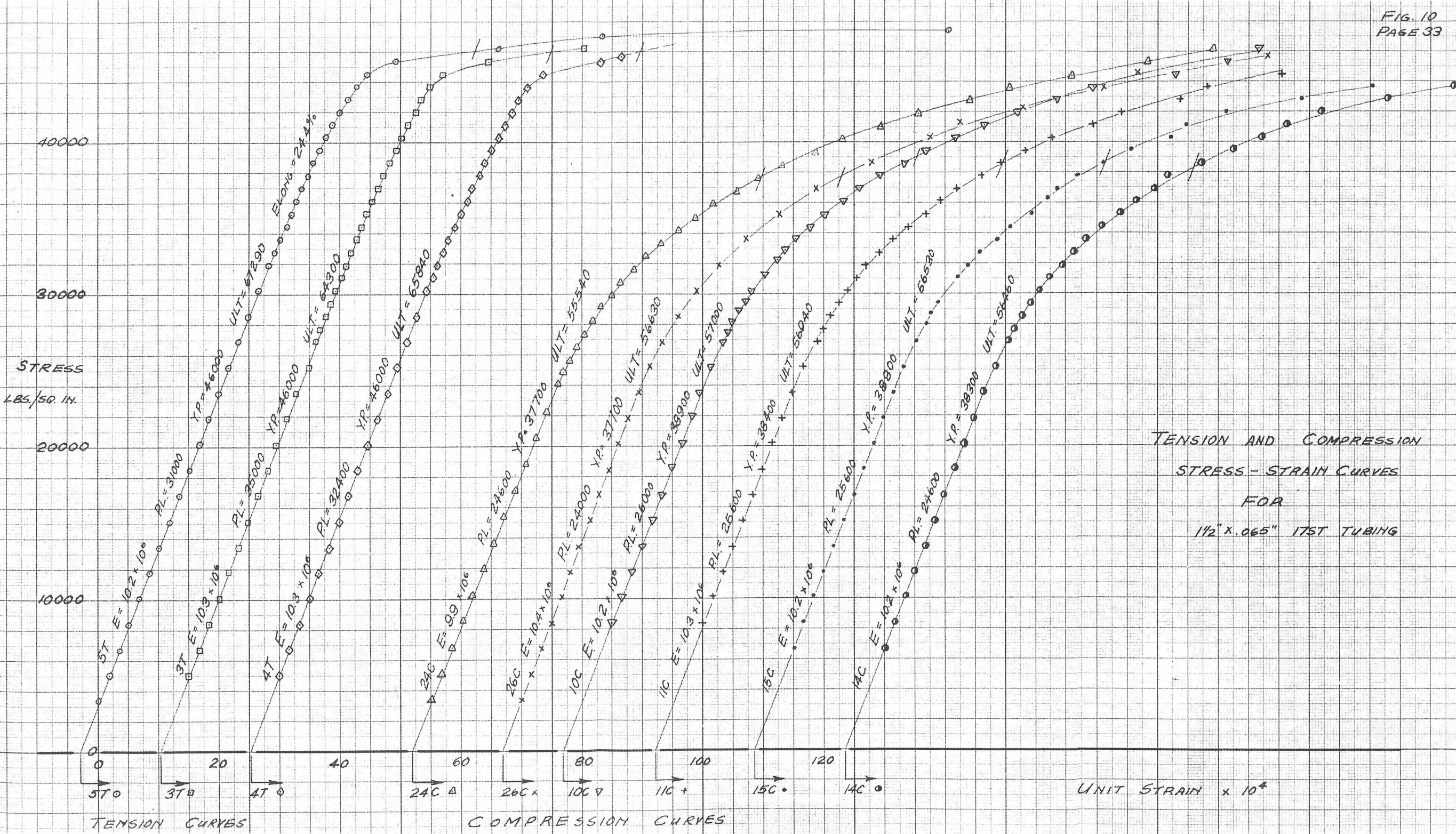


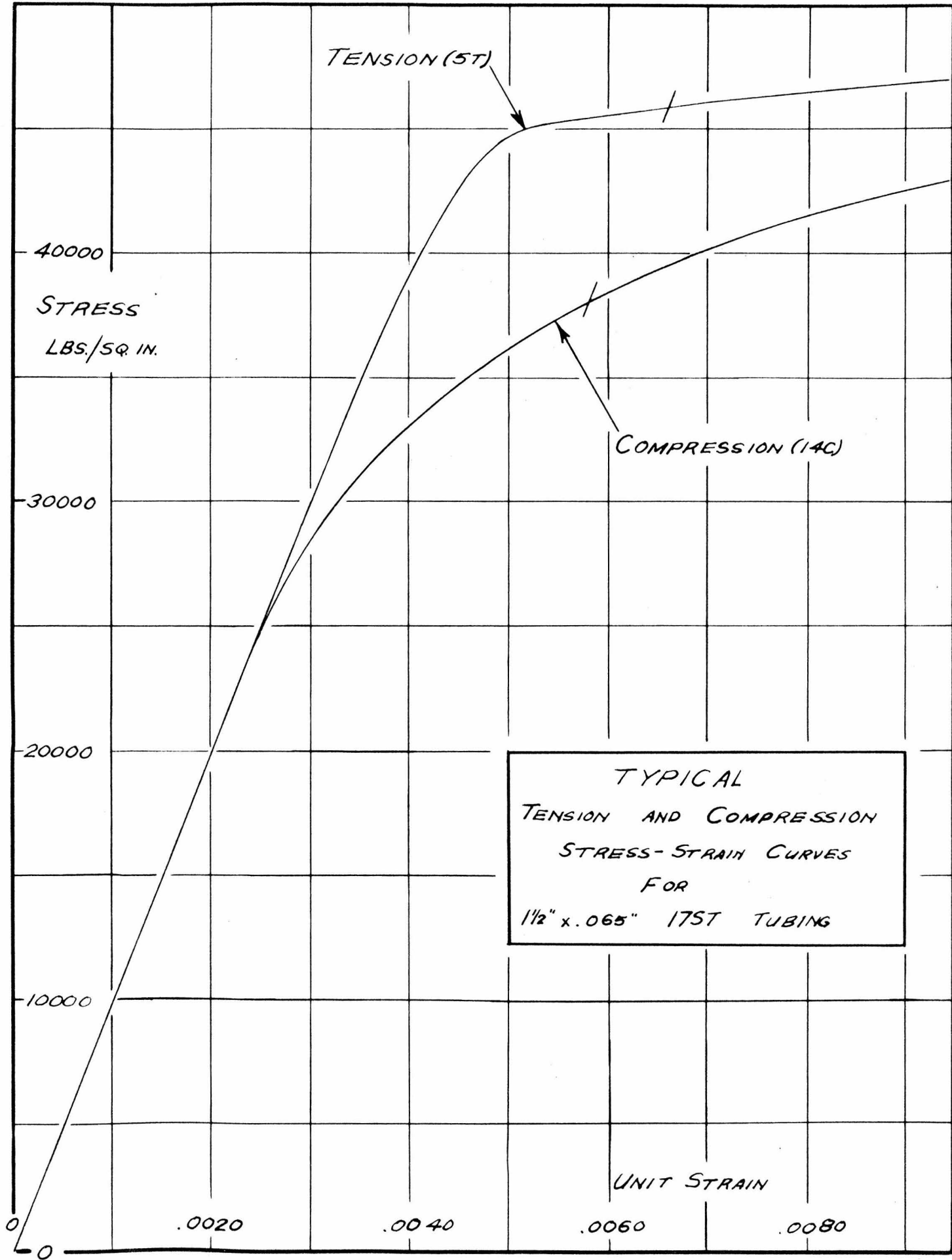
TENSION AND COMPRESSION
STRESS-STRAIN CURVES
FOR
1" x .065" 17ST TUBING

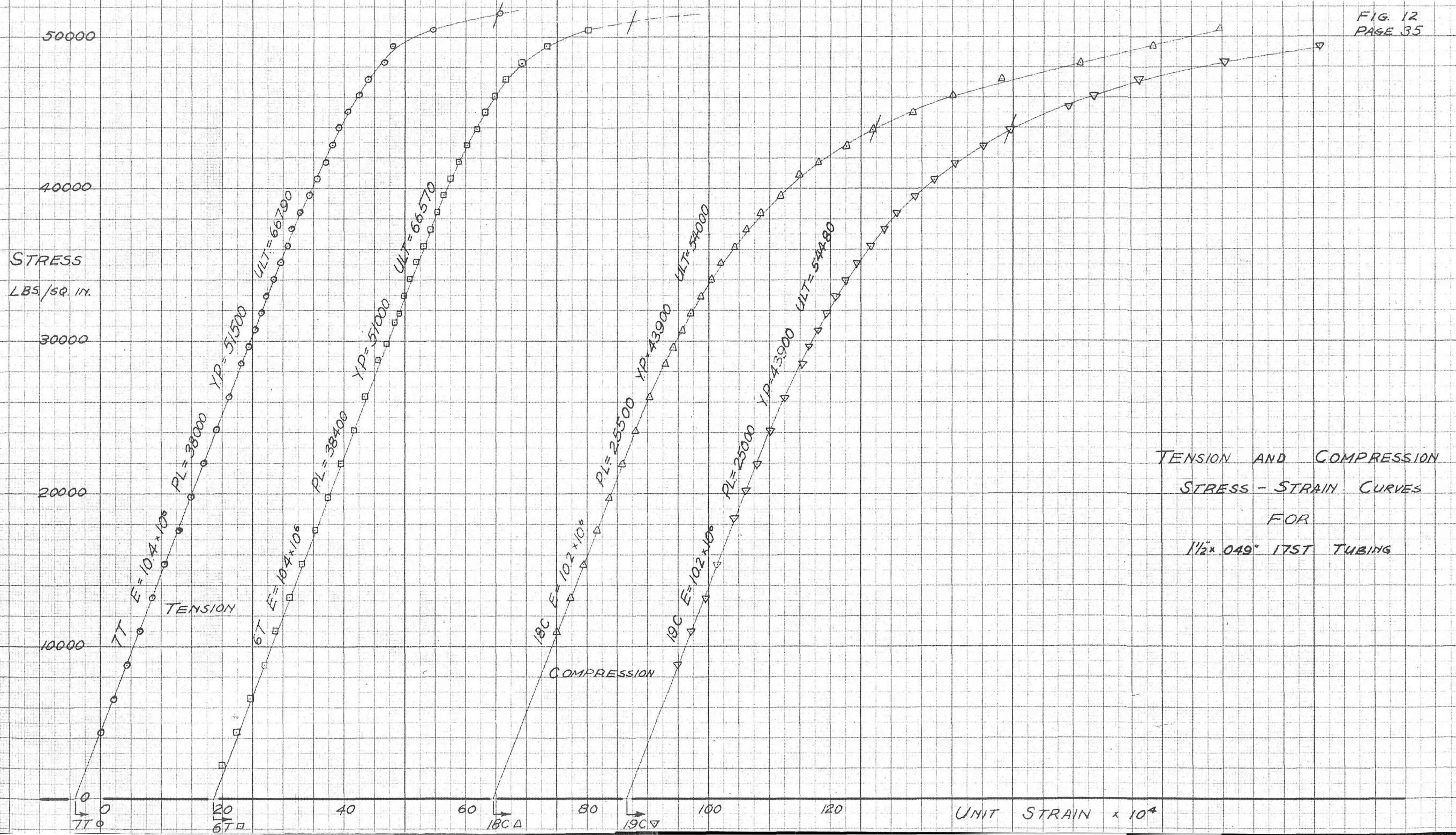


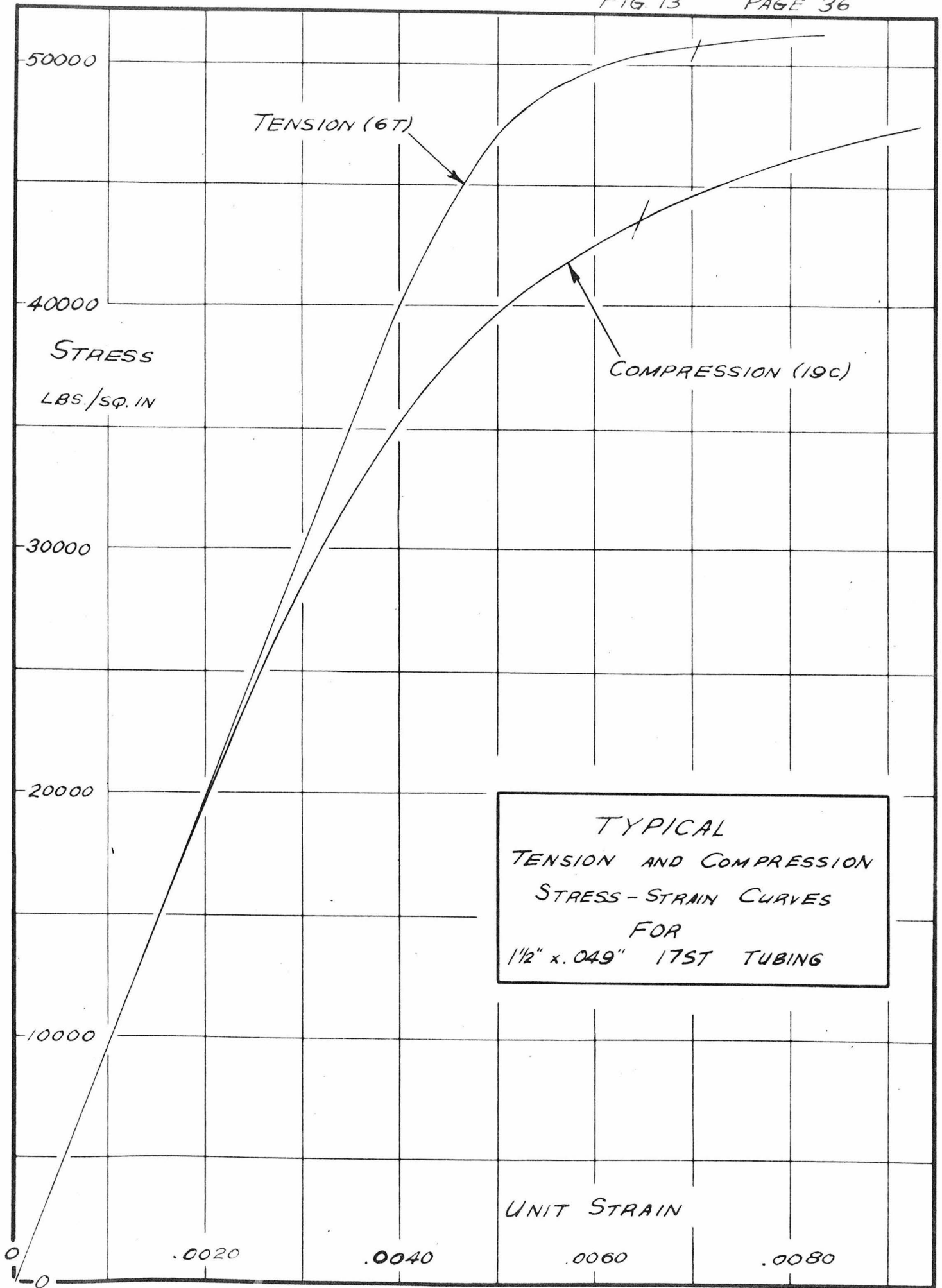


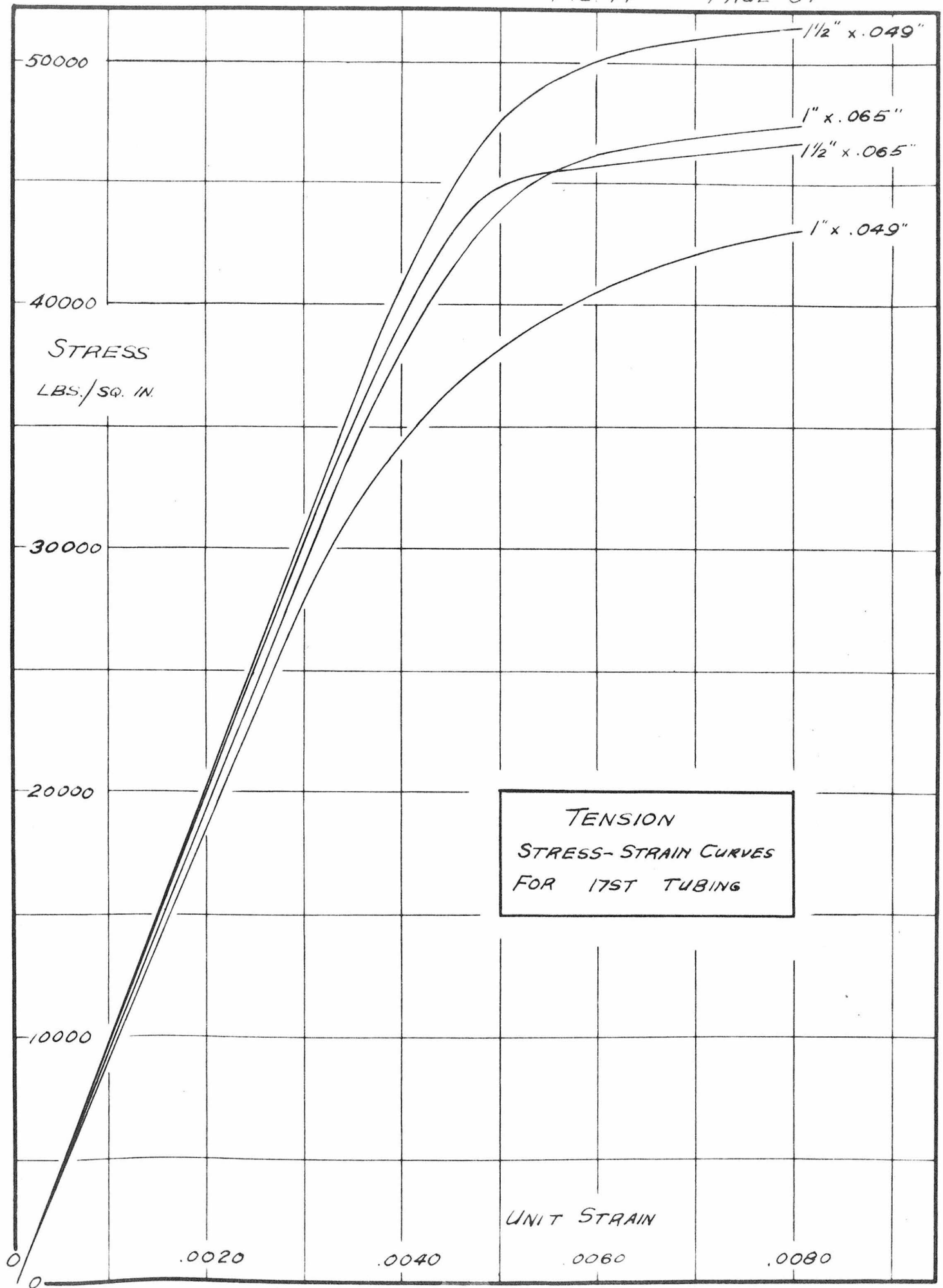


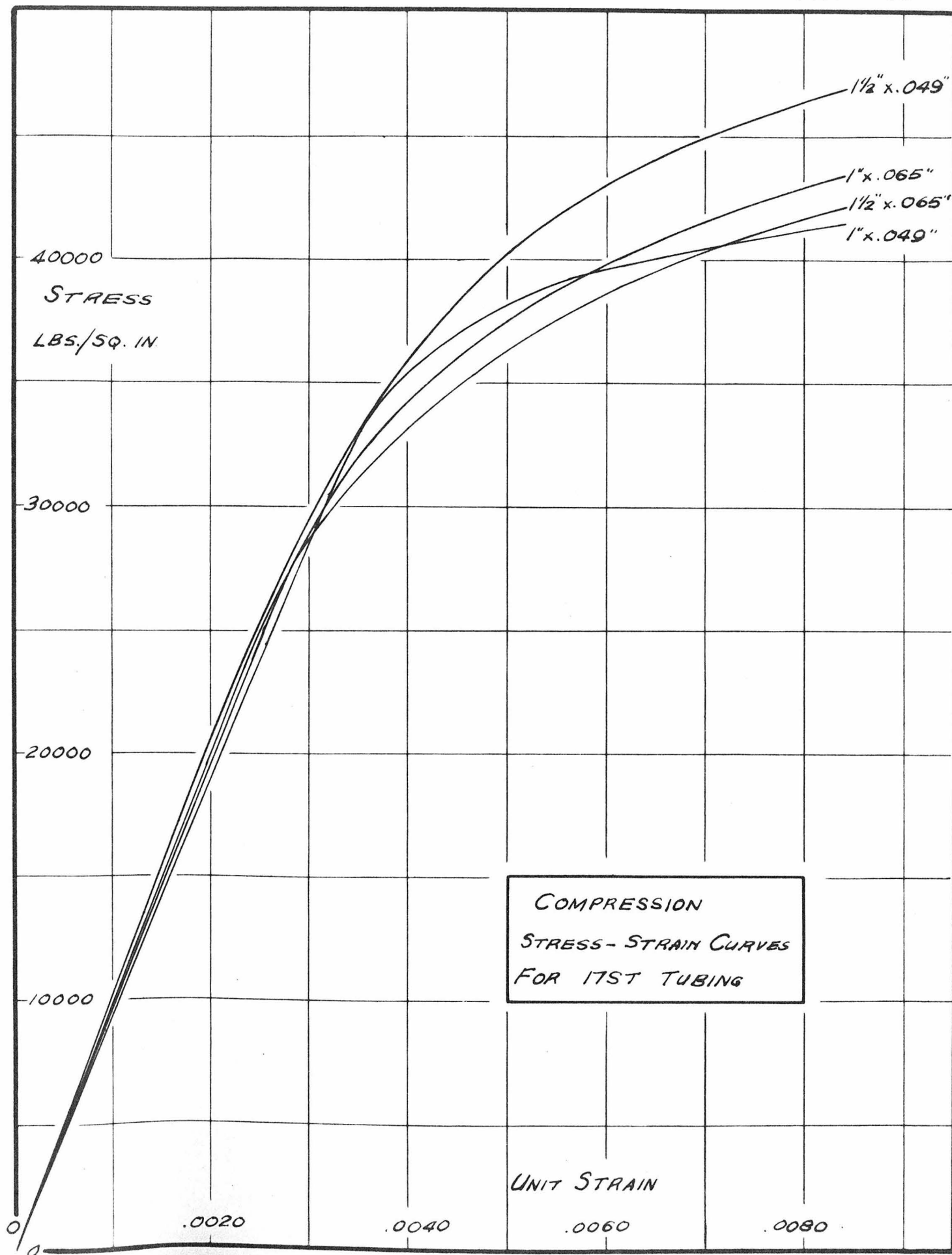


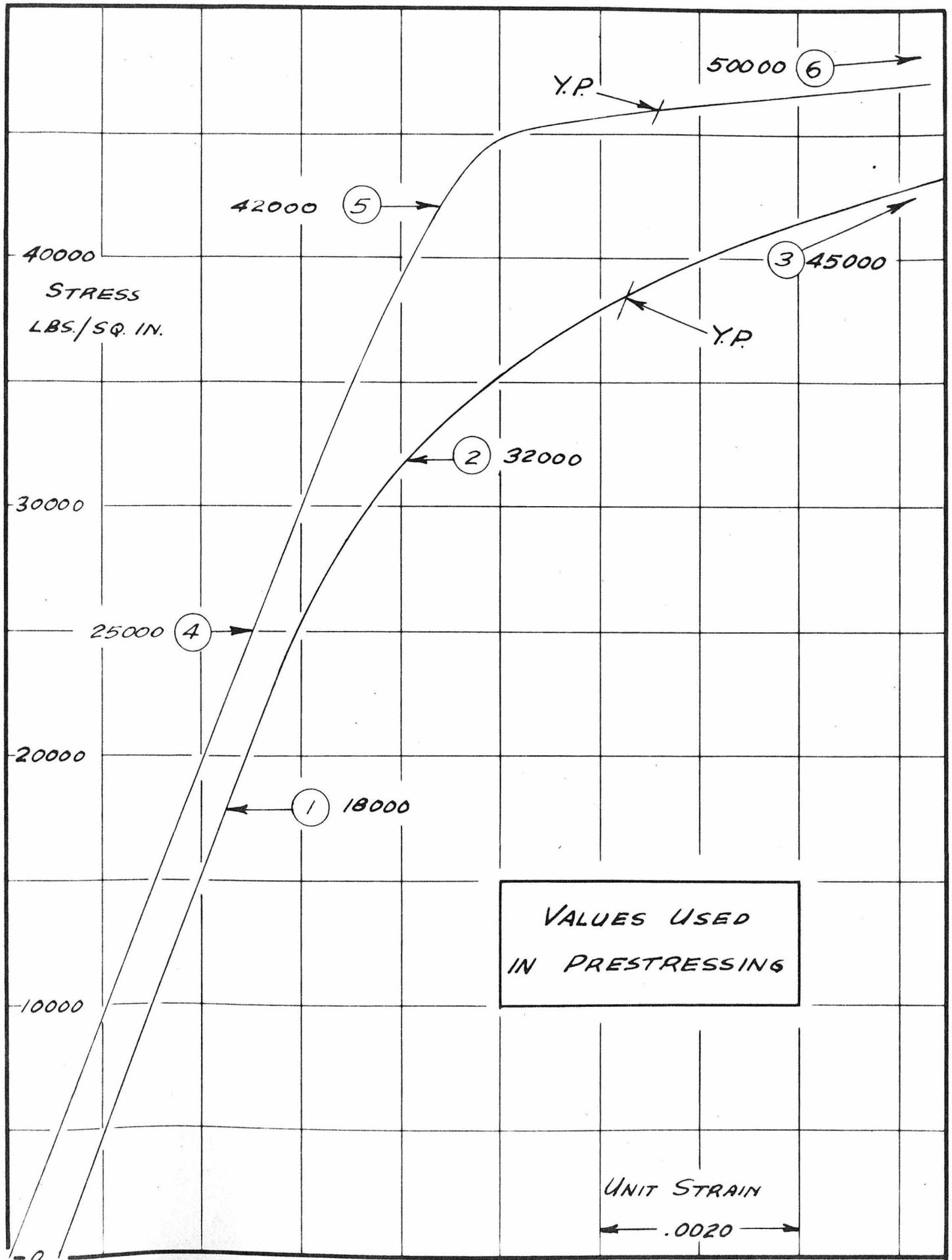


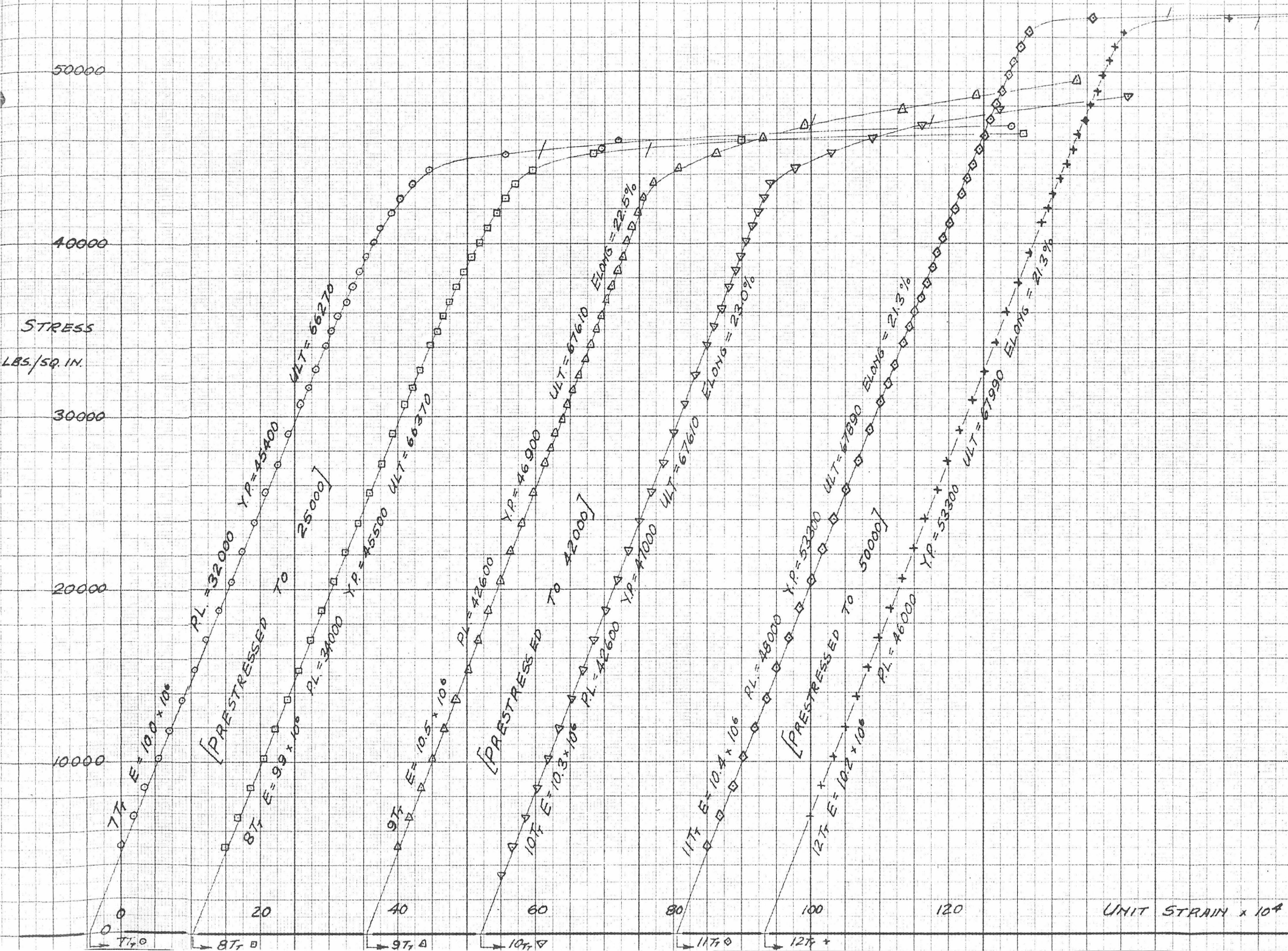




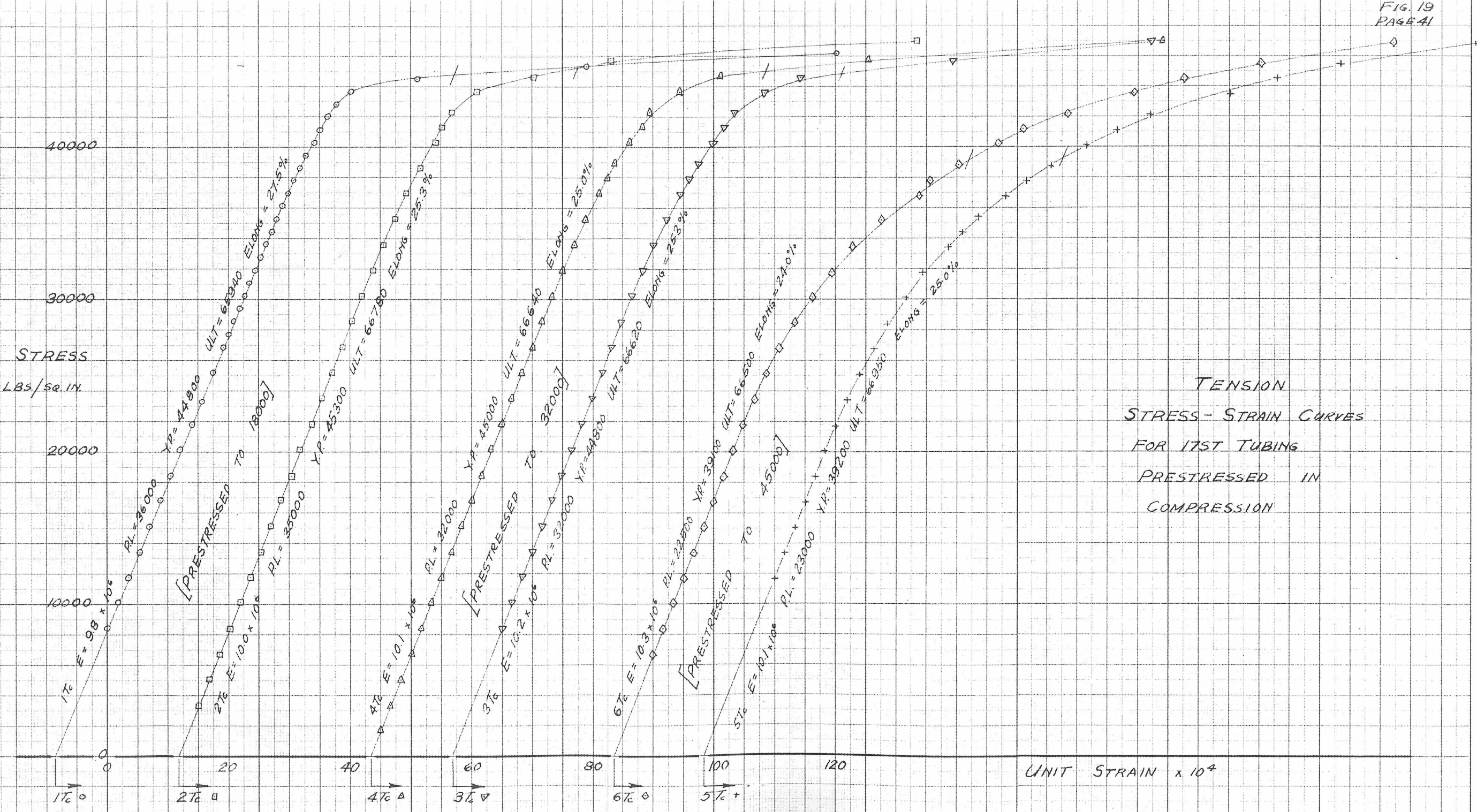








TENSION
STRESS- STRAIN CURVES
FOR 17ST TUBING
PRESTRESSED IN
TENSION



STRESS
LBS/SQ. IN.

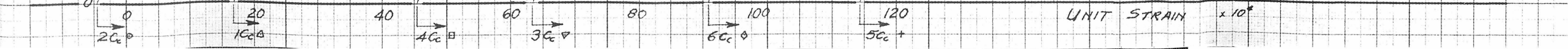
50000

10000

30000

20000

10000



COMPRESSION
STRESS-STRAIN CURVES
FOR 17ST TUBING
PRESTRESSED IN
COMPRESSION

UNIT STRAIN $\times 10^6$

50000

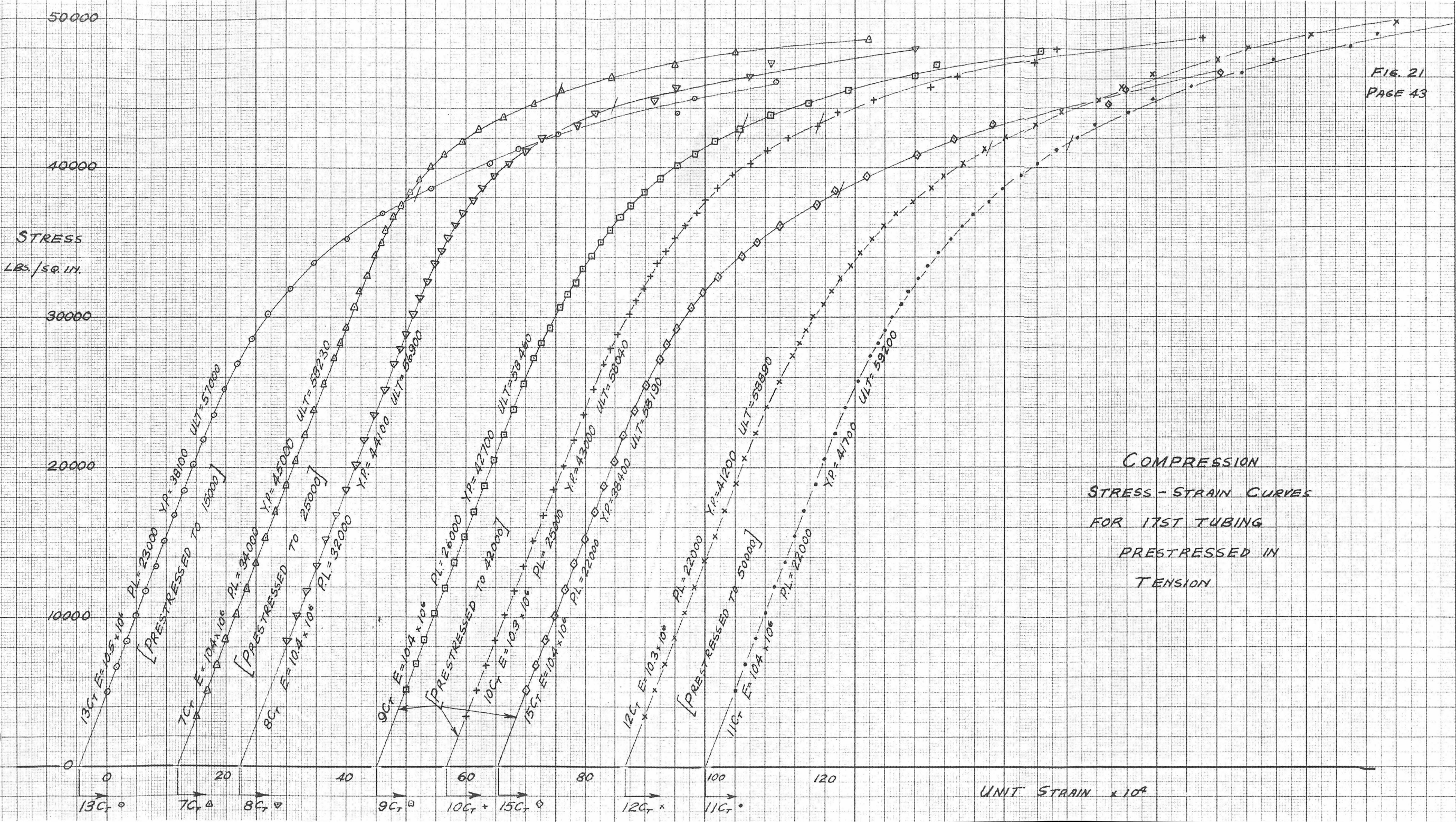
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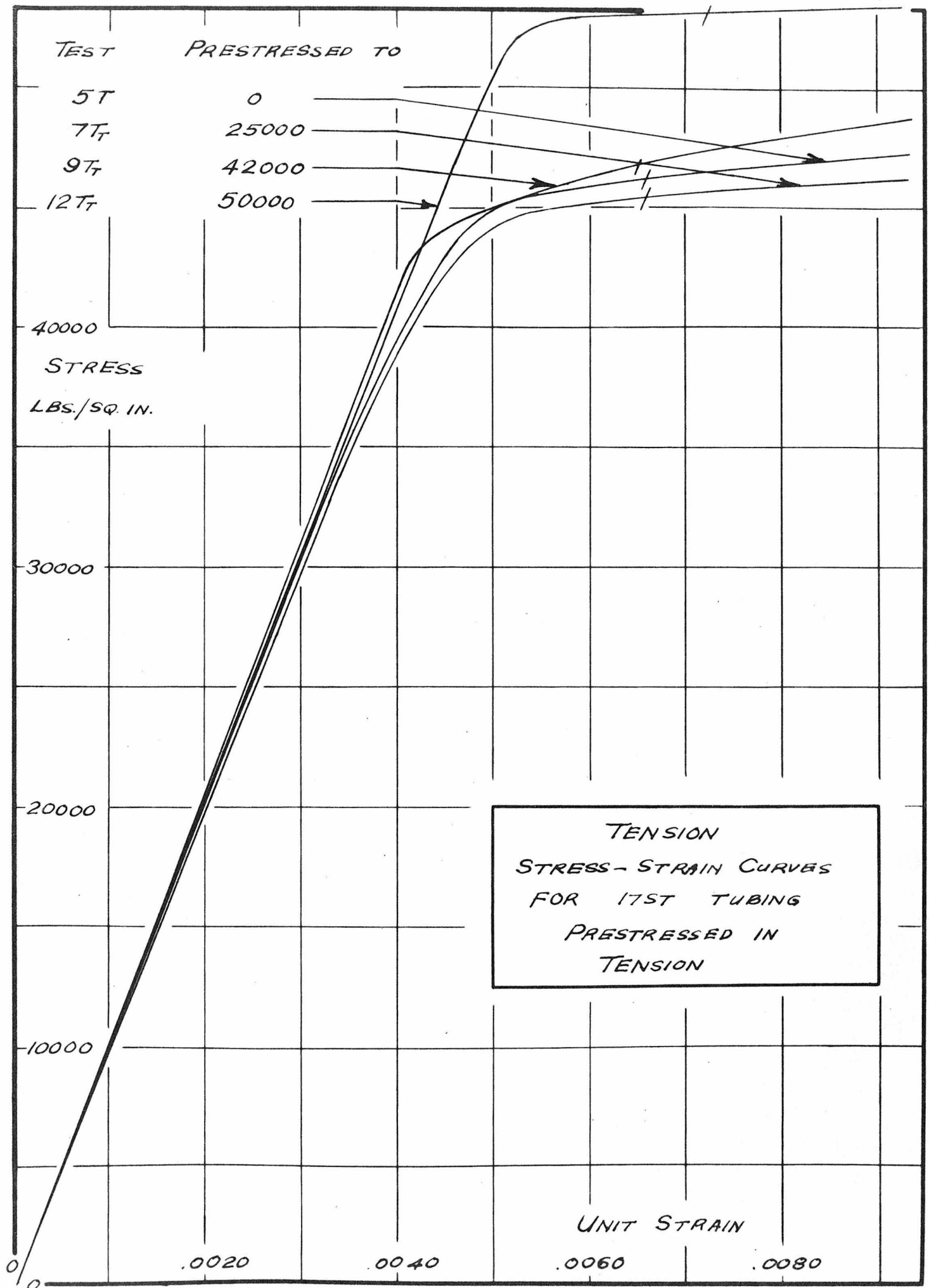
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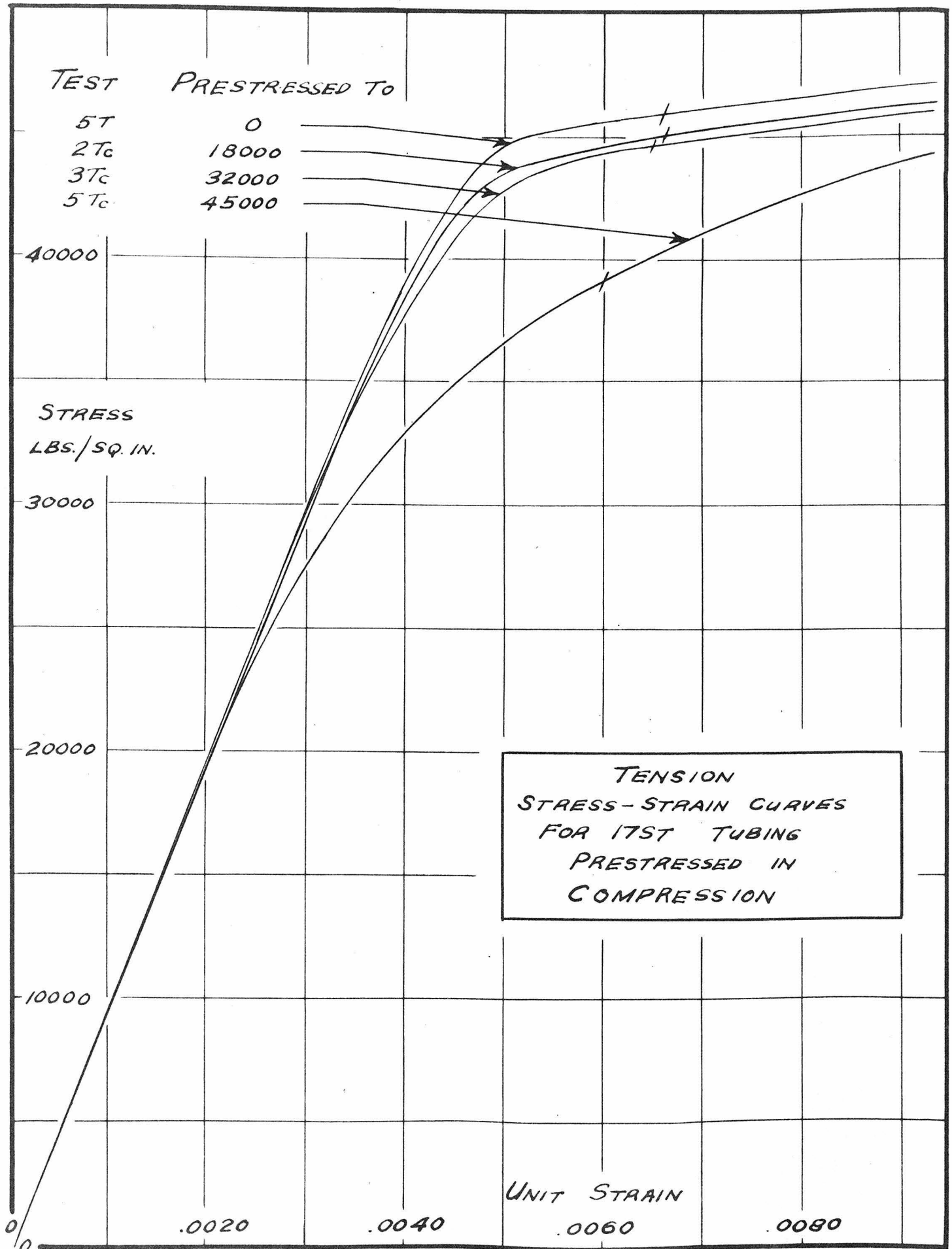
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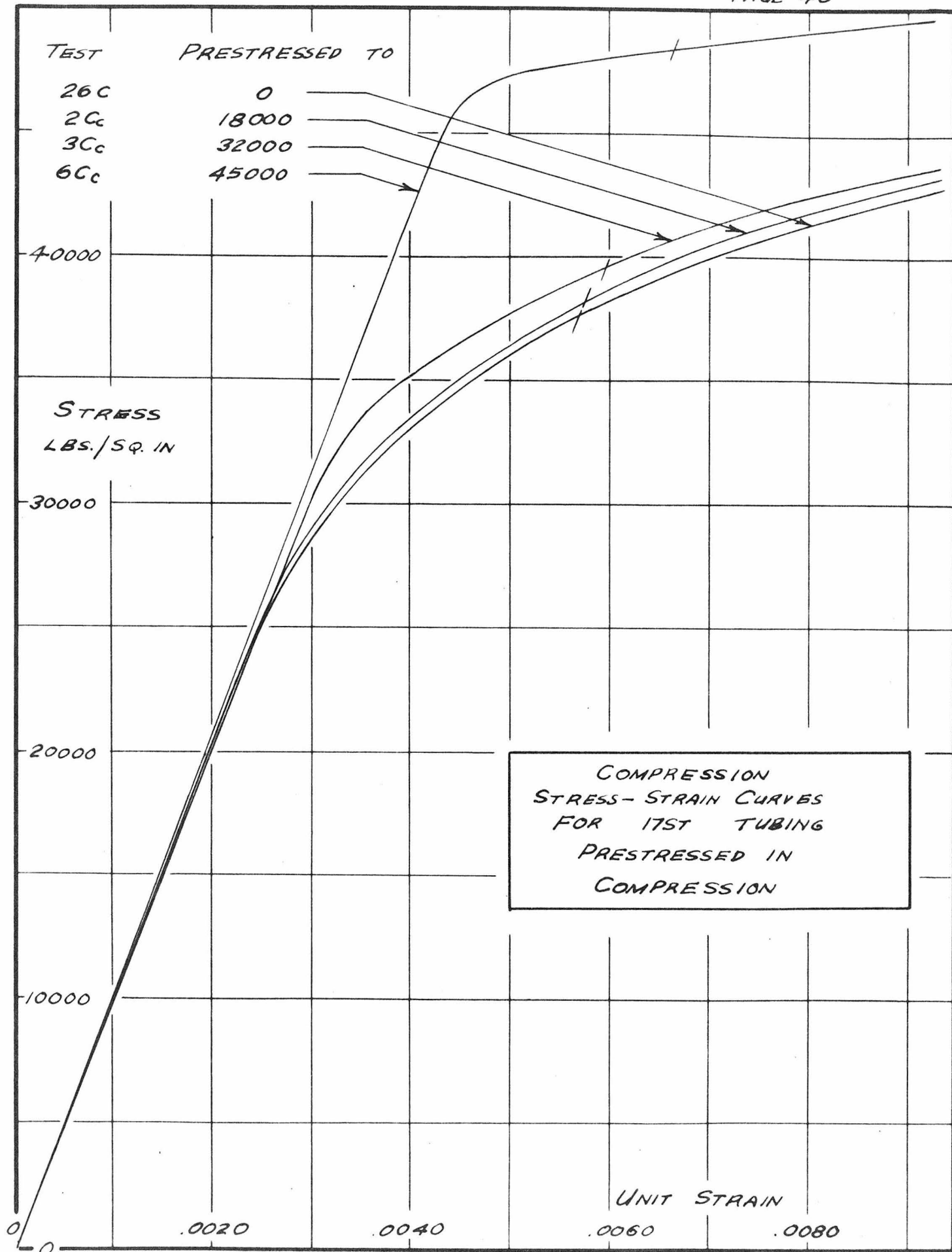
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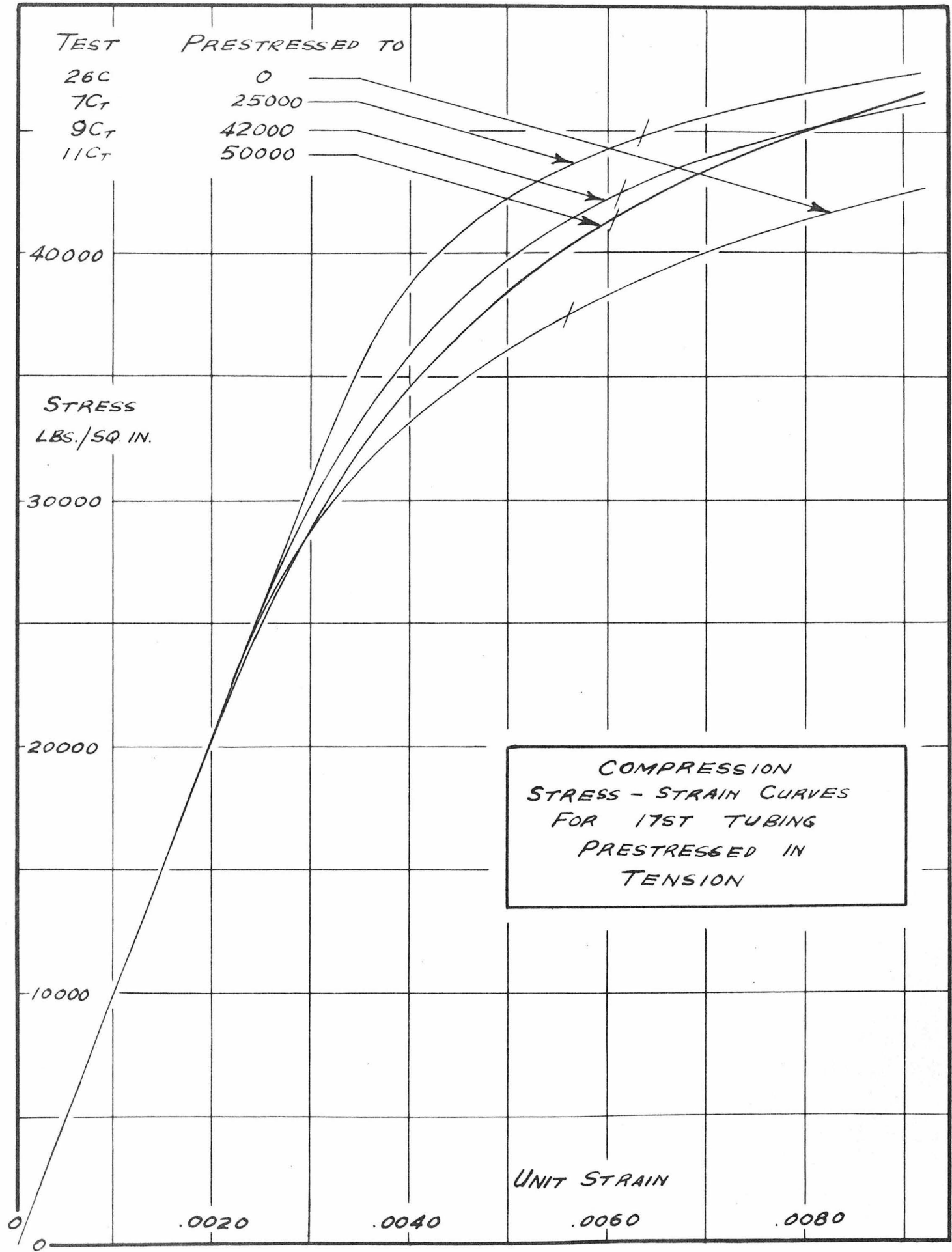
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STRESS
LBS./SQ. IN.FIG. 21
PAGE 43COMPRESSION
STRESS - STRAIN CURVES
FOR 17ST TUBING
PRESTRESSED IN
TENSION









EFFECT OF PRESTRESSING

FIG. 26
PAGE 48

(Δ, σ - FROM TN 618)

