LABORATORY CREEP STUDIES ON "PHEASANT" AND "EXPANDED" ALUMINUM CONDUCTORS

by

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A THESIS

submitted to

OREGON STATE UNIVERSITY

in partial fulfillment of
the requirements for the
degree of

MASTER OF SCIENCE

June 1963

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Date thesis is presented July 13, 1962

Typed by Jolene Wuest

ACKNOWLEDGEMENTS

The author is grateful to Bonneville Power Administration for sponsoring the project. He is further indebted to Professor O. G. Paasche of Oregon State University Department of Mechanical Engineering for his invaluable guidance and suggestions. He is also grateful to P. F. Winkelman of Bonneville Power Administration for his suggestions.

Finally the author wishes to express his thanks to Mrs. L. M. Wilson, his wife, for her assistance and encouragement in the writing of this manuscript.

TABLE OF CONTENTS

	Page
INTRODUCTION	1
EXPERIMENTAL WORK	8
Equipment Design	8
Equipment and Specimen Installation	12
Test Loading Procedure	25
Testing Program	27
TEST RESULTS	31
Graphical Representation	31
Short Time Creep	34
Creep Stabilization	36
Long Time Creep	37
Initial and Final Stress-Strain	40
Mathematical Form of Creep Curves	43
CONCLUSIONS	47
RECOMMENDATIONS	48
BIBLIOGRAPHY	49
APPENDIX	50

LIST OF TABLES

	Page
Test Specimens	28
Creep Testing Conditions	30
Initial Creep of X(AFC)	35
Final Creep Strain	39
Results of Analytical Treatment of Creep Data	45
Creep and Final Stress-Strain Data	50
Initial Stress Strain Data	76

LIST OF FIGURES

		Page
1.	460 KV Expanded Conductors	6
2.	Closeup of Plastic End Fitting	10
3.	Cutaway of Plastic End Fitting	11
4.	Schematic Diagram of Conductor Creep Testing Equipment	13
5.	Exterior of Conductor Creep Testing Equipment	14
6.	Interior of Conductor Creep Testing Equipment	15
7.	Take-up End of Conductor Creep Testing Equipment	17
8.	Plastic End Fitting Shown Bolted in Place in Testing Column	18
9.	Position of Leveling Chains and Leveling Devise	19
10.	Closeup of Dial Gage	21
11.	Closeup of Dial Gage Showing Tension Spring and Mounting Clamp	22
12.	Schematic Diagram of Loading System	23
13.	Loading End of Conductor Creep Testing Equipment	24
14-24.	Creep Curves for 460 KV Expanded Conductors	82
25-36.	Stress-Strain and Creep Curves for 460 KV Expanded Conductors	93
37-40.	Stress-Strain Curves for 460 KV Expanded Conductors	105

41-42. Stress-Strain Curves for ACSR Pheasant Conductors 109

43. Stress-Strain and Creep Curve for ACSR Pheasant Conductor 111

LABORATORY CREEP STUDIES ON "PHEASANT" AND "EXPANDED" ALUMINUM CONDUCTORS

INTRODUCTION

Overhead conductors for electric power transmission lines are strung between towers. There is a conductor strung for each phase. The conductors are strung so there is a certain amount of sag between towers. This sag increases due to conductor creep.

Conductor creep in power transmission lines starts the instant a conductor is put under a load and continues for the life of the conductor. In conductors under field conditions conductor creep results in an increase in sag. This increase in sag, due to conductor creep, must be considered for two cases:

1). Installation During stringing of conductors where the conductor of each phase is strung separately, the time lag and variations in tension during stringing will cause a difference in sag between phases which can result in undue power losses. This is especially true for bundle construction. By bundle construction is meant to string two equal size conductors for each phase. By this bundle method the power handling capacity of the line is more than doubled. However, the sag between the two conductors of one phase must be held constant. To hold this sag constant the two conductors must be strung so their

sag and creep rates are equal.

2). Continual Service The sag that results from conductor creep causes the vertical clearance between the conductor and the ground to be decreased. Since there is a minimum clearance required by regulations, too large a sag could result in expensive resagging. This vertical clearance problem may be compensated for by building higher towers or by placing the towers closer together to reduce tension and thereby reduce the sag. Economics dictates the optimum tower height and spacing combination.

Both cases enter into the conductor replacement problem, where the new conductor must be at the same sag level and creep rate as the existing conductors.

A contractual agreement was entered into between Bonneville Power Administration and Oregon State University (2) to determine on all-aluminum, ACSR, and expanded 460 KV conductors the following factors involved in conductor creep:

1). Effects of various combinations of pretension and pretension-hold time on conductor creep stabilization and long time creep.

2). Effects of conductor creep on the initial (E_i) and final (E_f) modulus of elasticity.

3). Cumulative effect of non-elastic elongation of a conductor from creep and from a temporary load increase involving the difference in E_i and E_f.

This work covers the results of testing selected expanded 460 KV conductors for all the above listed items and also covers item number 3 for ASCR pheasant conductors.

Metallurgical creep is defined as plastic deformation during which the applied stress remains constant. For this work, constant load will be considered as constant stress. Schroeck says: "It is an experimental fact that creep is a thermally activated process. Creep is only possible because there exist certain obstacles to deformation which can be overcome by the combined action of the applied stress and thermal fluctuations. For a given stress σ, temperature T, and structure st, the strain rate $\dot{\epsilon}$ can be expressed therefore, quite generally as

$$\dot{\epsilon} = f(\sigma, T, st) \exp -\left\{\frac{\Delta H (\sigma, T, st)}{KT}\right\} . \qquad (1)$$

ΔH is the energy of activation. The term structure describes the internal parameters such as density and arrangement of crystalline defects which change during deformation." (6, p. 200).

Usually three stages of metallurgical creep are recognized:

1). Transient Creep. The principal characteristic of transient creep is its decreasing rate. In this stage the creep

rate diminishes from some large value towards a constant value.

2). Steady State Creep. The principal characteristic of steady state creep is that the creep continues to increase, and while under a constant stress it increases at a constant rate. This stage is sometimes referred to as viscous creep.

3). Tertiary Creep. The principal characteristic of tertiary creep is that the creep rate increases rapidly until the material fractures.

The general method of measuring metallurgical creep is to load a solid rod axially and measure the extension with time. During this time the temperature and stress are held constant.

This thesis is concerned with the creep properties of a fabricated conductor made up of many wires and/or tubes and in some cases the conductor will consist of two materials. All of these factors will affect the creep properties of the conductor. Due to these factors the conductors tested will have included, along with metallurgical creep, the effects of:

1). Fabrication Method. Creep properties depend grossly on the previous mechanical history. (1, p. 177). Due to the variation in fabrication techniques between manufacturers,

similar cables from different manufacturers may show varied creep properties.

2). Conductor Design. Figure 1 shows the variation in the design of 460 KV expanded conductors of six manufacturers. This variation, although within the limits of the specifications listed in Figure 1 will cause varying creep properties for each design.

3). Strand Setting. Conductors are made up of individual layers of wires wound in reverse lay fashion around a core. The individual layers are not perfectly tight, upon loading this looseness will disappear due to strand setting and give an elongation to the conductor span.

4). Straightening. When conductors are manufactured they are wound on reels for shipment. If the curvature is too small it will cause the conductor to retain some of its reeled helical shape after unwinding. Upon loading this will disappear but will give an elongation to the conductor span.

5). Different Materials. Creep rates are different for each material. As shown in Figure 1 some conductors are made from combinations of EC aluminum and aluminum alloy wires, while others are made from combinations of EC aluminum and steel wires. These factors will alter the creep properties

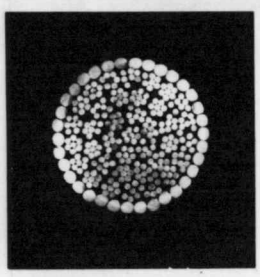
EXPANDED 460 KV EXPERIMENTAL CONDUCTORS

Specifications:

Minimum Diameter (Dia.)	2.125 inches
Minimum Cu Equivalent	1,600 MCM
Maximum Weight (Wt.)	3.28 lbs./ft.
Minimum Strength	69,000 lbs.
Minimum Strength/Weight	22,000 ft.

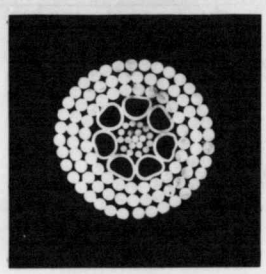
All materials shall be metallic.

ALUMINUM COMPANY OF AMERICA



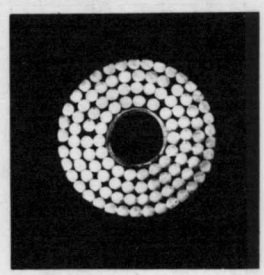
34 x .1727" EC Al
18/12/6/1 (7 x .0859") 5005 Al Alloy Rope Lay
Dia. 2.15"; Cu Equiv. 1,702 MCM;
Wt. 2.802 lbs.; RS 69,900 lbs.;
Strength/Wt. 24,900 ft.

KAISER ALUMINUM & CHEMICAL SALES, INC.



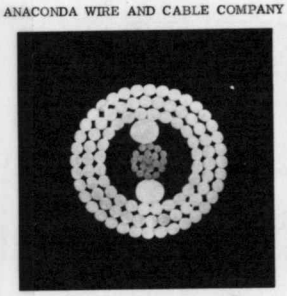
36/30/24 x .1634" EC Al
7 3/8" x .035" Al Tubes
12/6/1 x .0977" Galv. Steel
Dia. 2.125"; Cu Equiv. 1,750 MCM;
Wt. 3.075 lbs.; RS 68,800 lbs.;
Strength/Wt. 22,400 ft.

ALUMINUM COMPANY OF AMERICA



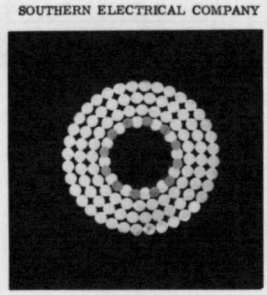
36/30/24/18 x .165" 5005 Al Alloy
1 x .825" Al Alloy Flexible Conduit
Dia. 2.145"; Cu Equiv. 1,621 MCM;
Wt. 2.881 lbs.; RS 70,600 lbs.;
Strength/Wt. 24,500 ft.

ANACONDA WIRE AND CABLE COMPANY



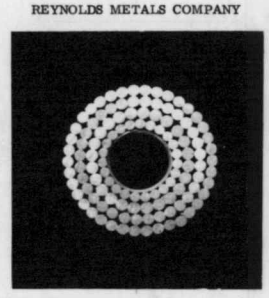
36/30/24 x .1649" EC Al
2 x .326" EC Al Spacers
12/6/1 x .1015" Galv. Steel
Dia. 2.150"; Cu Equiv. 1,600 MCM;
Wt. 3.074 lbs.; RS 69,000 lbs.;
Strength/Wt. 22,400 ft.

SOUTHERN ELECTRICAL COMPANY



36/30/24 x .1643" EC Al
12 x .1443" Galv. Steel } Core
12 Shaped EC Al Wires }
Dia. 2.136"; Cu Equiv. 1,707 MCM;
Wt. 3.268 lbs.; RS 82,800 lbs.;
Strength/Wt. 25,300 ft.

REYNOLDS METALS COMPANY



38/32 x .1591")
24 x .1706") 5005 Al Alloy
23 x .1377")
1 x .927" Al Alloy Flexible Conduit
Dia. 2.18"; Cu Equiv. 1,603 MCM;
Wt. 2.910 lbs.; RS 73,300 lbs.;
Strength/Wt. 25,200 ft.

Figure 1.

460 KV Expanded Conductors

considerably.

The combination of these five factors and metallurgical creep will be referred to as conductor creep.

Conductor creep has been recognized for many years in the design of transmission lines. The conductor sag was estimated from short time stress-strain data (sag charts). These charts are designed for the larger value of sag increase as determined by creep at design load or by the change in modulus of elasticity due to estimated ice load. (Design load is 20% of the conductor's rated strength. Ice load is figured for a conductor at 0^{o} F. covered with 1/2 in. of ice with an 8 lb/ft^2 wind blowing. For 460 KV expanded conductors, design load or stringing tension is 14, 000 lb. The combination of design, ice, and wind load, which is referred to as maximum working tension or MWT, is 27, 000 lb.) Estimation of sag from sag charts has proved inadequate as recent tests show that these elongations are cumulative. (8, p. 6-8). This fact, along with the trend to larger and larger conductors is causing conductor creep to assume greater importance as a design consideration.

EXPERIMENTAL WORK

Equipment Design

The design and construction of the test equipment was not part of this thesis, therefore, only the basic operations and purposes of the equipment will be described. A complete description of design, operation, and calibration can be found in previous work. (3, p. 2-18).

The average span length for a conductor is 1, 200 feet. To test a conductor of this length would be highly impractical. However, the conductor to be tested must be long enough to have the gage length free of end effects. Also, this gage length must be long enough to give high accuracy to the conductor creep measurements. A small error in measurements of conductor creep in a short conductor, when applied to a long span length and extrapolated to service periods of many years, would give a large error in conductor sag. With these considerations in mind a specimen length of 28 feet and a gage length of 200 inches was chosen.

Gripping of the specimen to apply the load was previously done by a gooseneck arrangement. (5, p. 11-12). Due to the fact that conductors are made from layers of small wires wrapped in

alternating helical fashion, gripping all of the wires equally was difficult and basketing at the ends occurred. For this thesis this basketing was not a problem. Bonneville Power Administration designed the plastic fitting shown in Figure 2 and Figure 3. By fraying the ends of the conductor and then molding the fitting on (9, p. 5-6) the individual strands are all gripped equally and the problem of basketing was eliminated.

In order that results of tests made at different times may be compared, controlled test conditions must prevail. The controlled test conditions for the design of the equipment used in this thesis were:

1). Temperature. A small aluminum tube, over 200 inches long, was used for the extensometer rod. Due to the difference in size between the extensometer rod and the conductor the extensometer rod is more sensitive to temperature changes than the conductor. This sensitivity to temperature would cause expansion or contraction, depending on the temperature fluctuation. This fluctuation would result in an error in the creep measurement of the conductor. To eliminate the effect of thermal expansion and contraction and to have similar test conditions for all conductors a temperature of 75^{o} F. + 2^{o} F. was maintained.

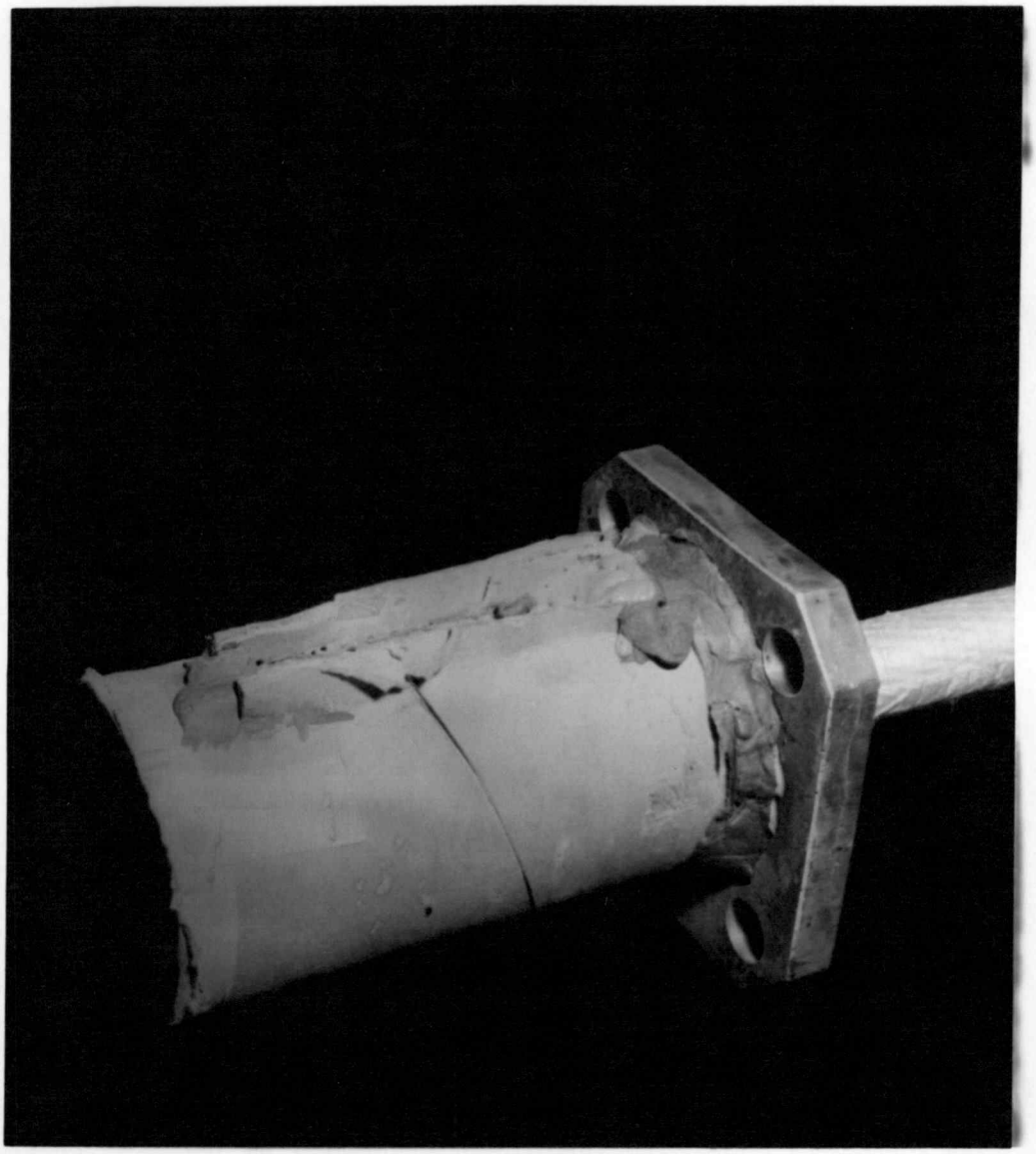


Figure 2

Closeup of Plastic Fitting

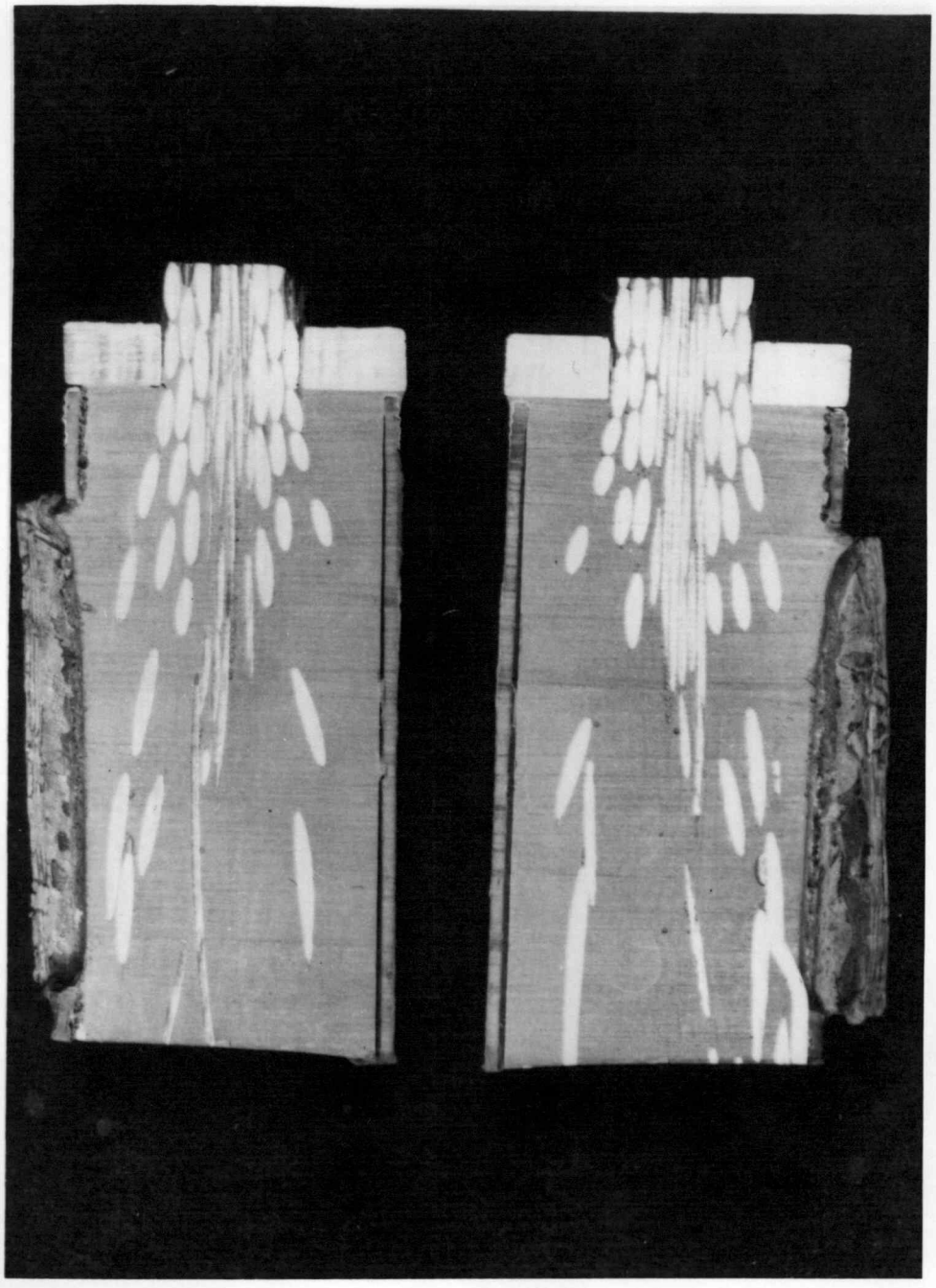


Figure 3

Cutaway of Plastic End Fitting

2). Loading. The requirements on the loading system were that the system be capable of applying a wide range of loads, that each specimen be loaded individually, of loading 28 foot lengths and that the loads be maintained within an accuracy of 1 percent.

3). Elongation Measurement. Elongation over the 200 inch gage length was required to be precise to 10^{-3} inches.

Equipment and Specimen Installation

The test specimens were tested in a temperature controlled enclosure. The loading components were external to the enclosure. Figure 4 shows schematically the general layout of the entire conductor creep testing equipment. The actual exterior and interior of the equipment is shown in Figure 5 and Figure 6.

The function of each component can best be seen by going through the procedure of installing a conductor for application of load. The conductors were received in 28 foot lengths with the end fittings in place. They were installed as follows:

1). Specimen Placement. The specimens were received completely covered to prevent scratching in shipment. With the covering still on, the specimens were fed into the horizontal loading column from the take up end. The take up mechanism,

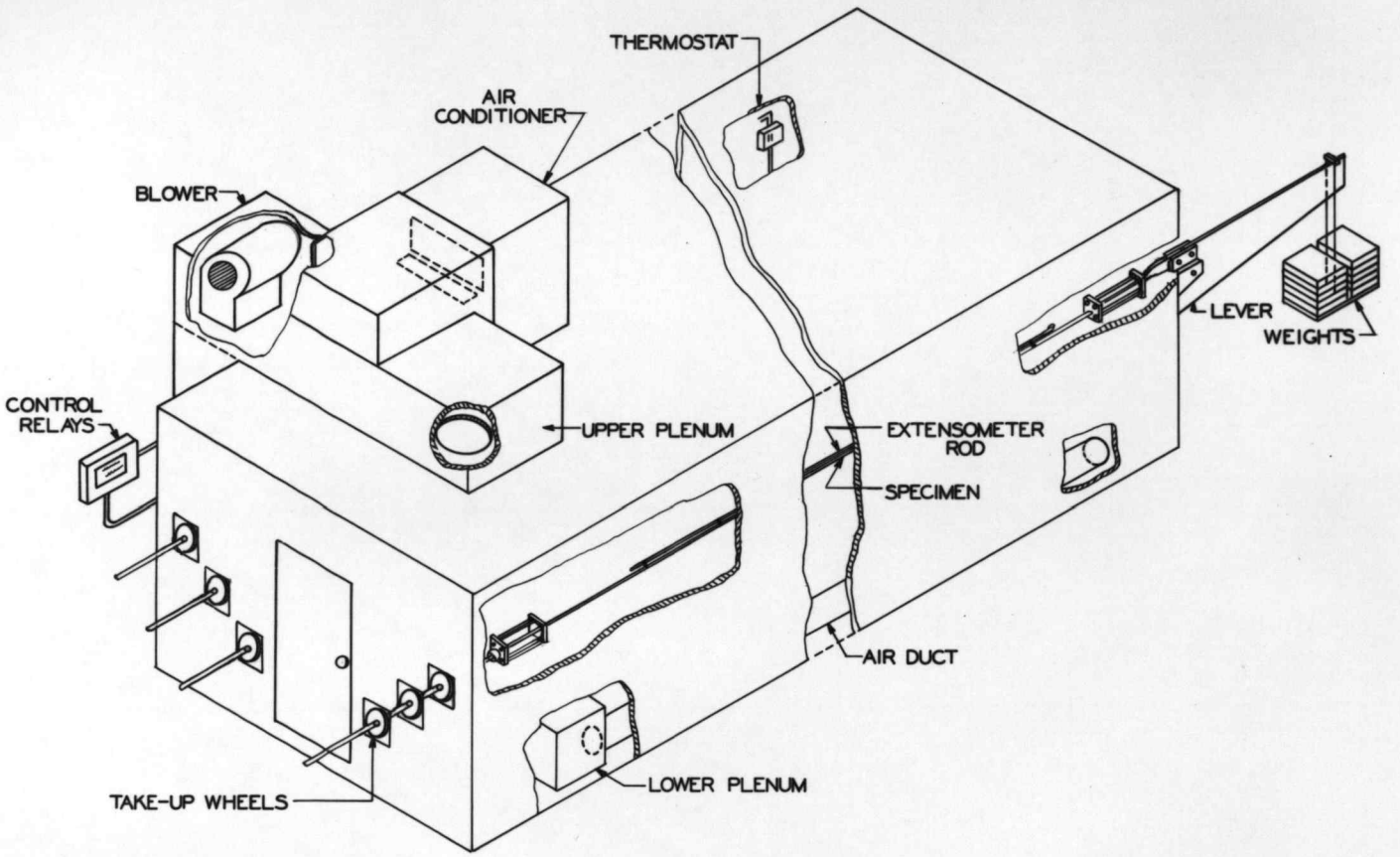


Figure 4

Schematic Diagram of Conductor Creep Testing Equipment

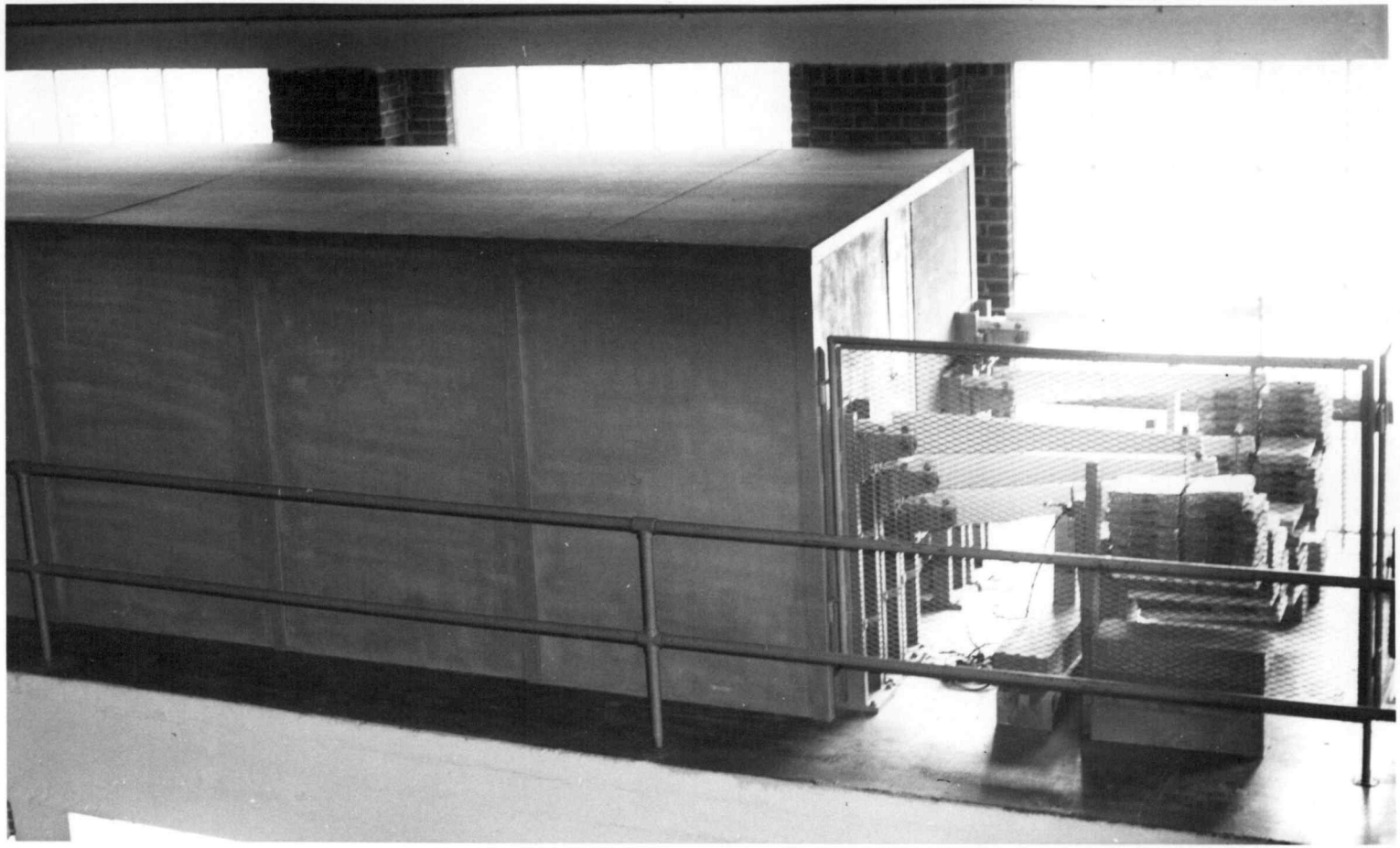


Figure 5

Exterior of Conductor Creep Testing Equipment



Figure 6

Interior of Conductor Creep Testing Equipment

shown in Figure 7 was removeable. After the specimen was in the column the covering was removed. Then the end fittings were bolted to the take up mechanism and load mechanism respectively. This connection is shown in Figure 8.

2). Specimen Leveling. To eliminate elongation, due to curvature, the specimen was held level by a series of chains, Figure 9. These chains were previously leveled as follows: A cylinder, the same diameter as the specimen with its center marked was hung in the chain. A transit was placed at the open end sighting down the channel. The center of the cylinder was brought up to level by means of the transit. The leveling device shown in Figure 9 was then placed in position. The vertical distance of the bolt above the channel was measured and marked down. After the chains were hooked around the specimen each vertical bolt height was checked to assure that the specimen was level.

3). Measuring System Placement. The extensometer rod which can be seen in Figure 9 was placed on the specimen. The rod was held in a horizontal position parallel to the specimen by a series of clamps. These clamps allow the rod free travel in the direction of elongation. The 200 inch gage length was marked off and clamps were placed at each end of the gage

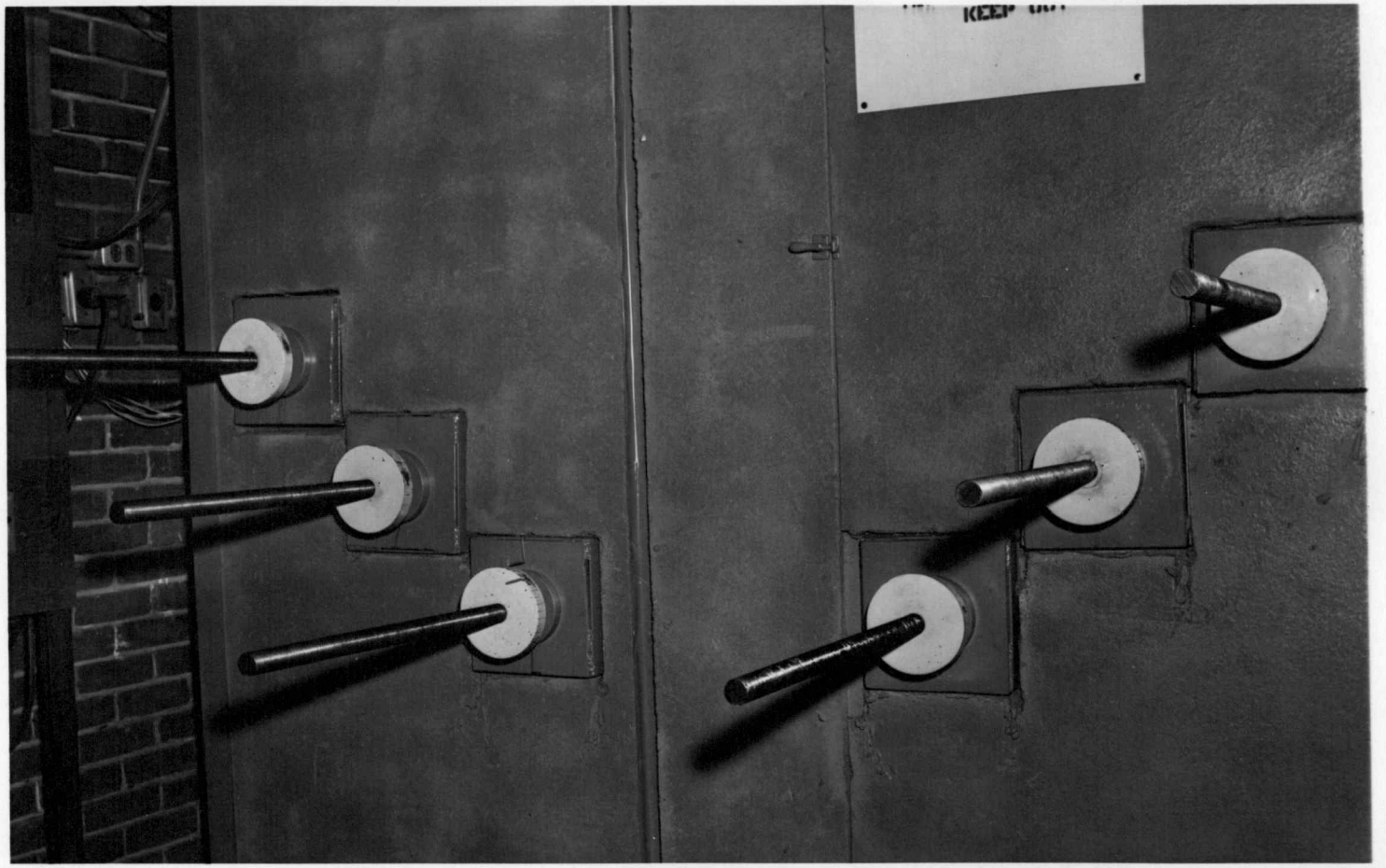


Figure 7

Take-Up End of Conductor Creep Testing Equipment



Figure 8

Plastic End Fitting Shown Bolted in Place in Testing Column

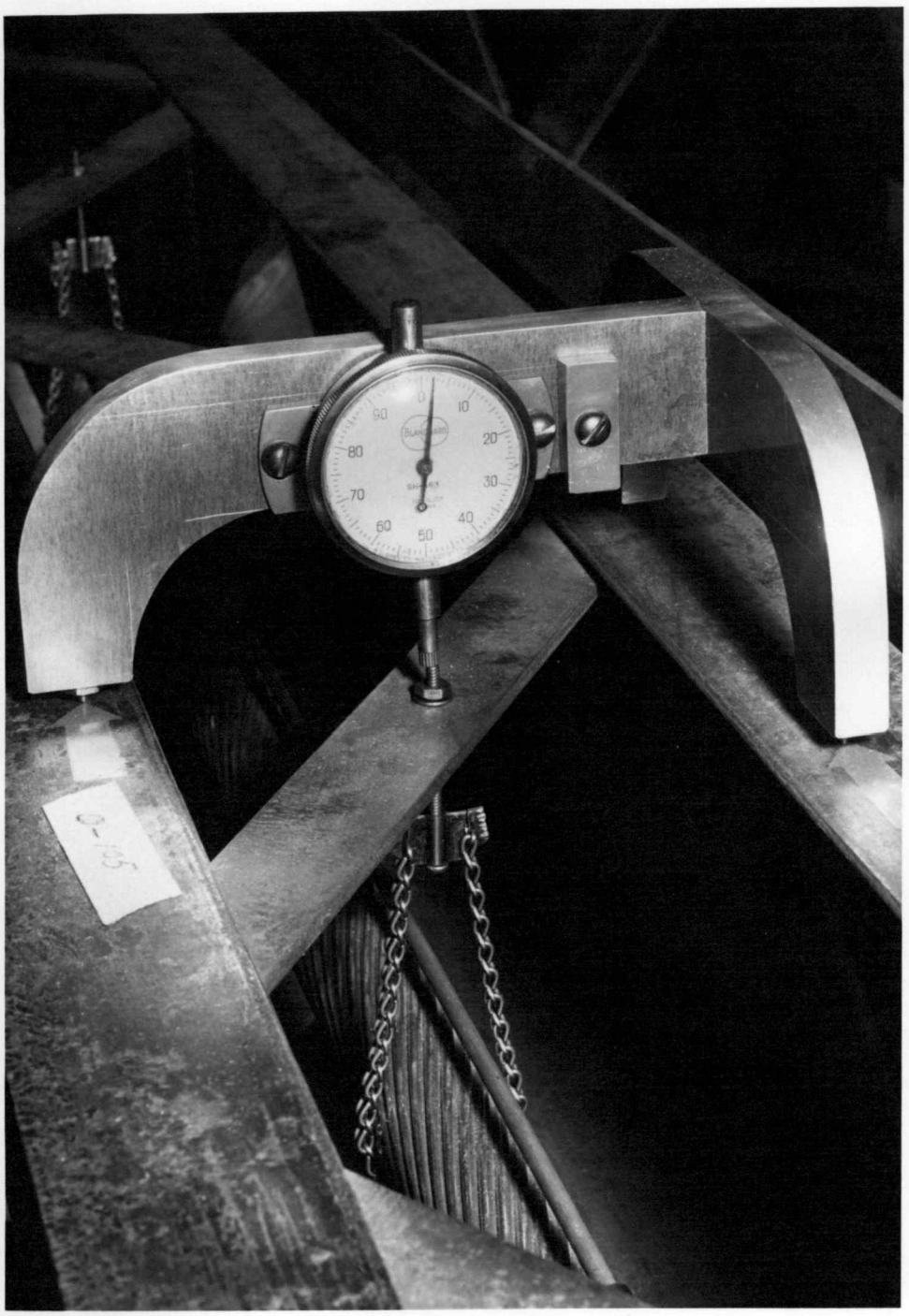


Figure 9

Position of Leveling Chains and Leveling Device

length. The clamp at one end held the rod firmly to the conductor. The clamp at the other end held the dial gage, which was connected to the extensometer rod, firmly to the conductor. The dial gage and clamp is shown in Figure 10, and Figure 11. The tension spring, shown in Figure 11 placed a slight tension on the extensometer rod so that when the conductor was being unloaded the extensometer rod followed the contraction.

4). Loading. Loading was accomplished by means of a lever arm system and weights. Figure 12 is a schematic drawing of the loading system while Figure 13 is an actual photograph of the lever system and weights. The actual loading was accomplished as follows: Known weights were placed on the loading lever, which was blocked up. A spanner wrench was used to turn the take up wheel which in turn raised the lever arm and thereby produced a known tension on the specimen. The lever arm was raised sufficiently high to allow for elongation of the specimen.

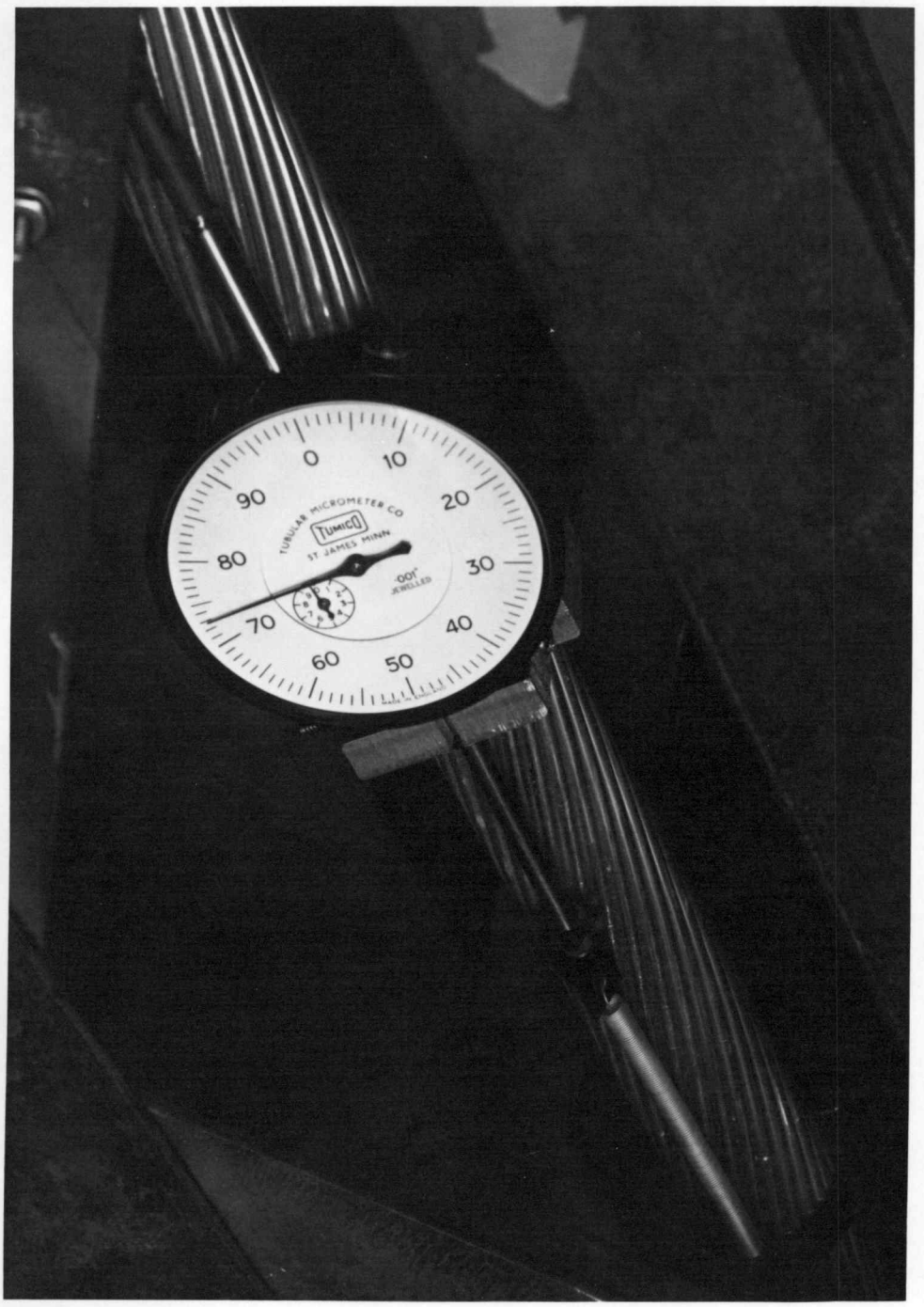


Figure 10. Closeup of Dial Gage

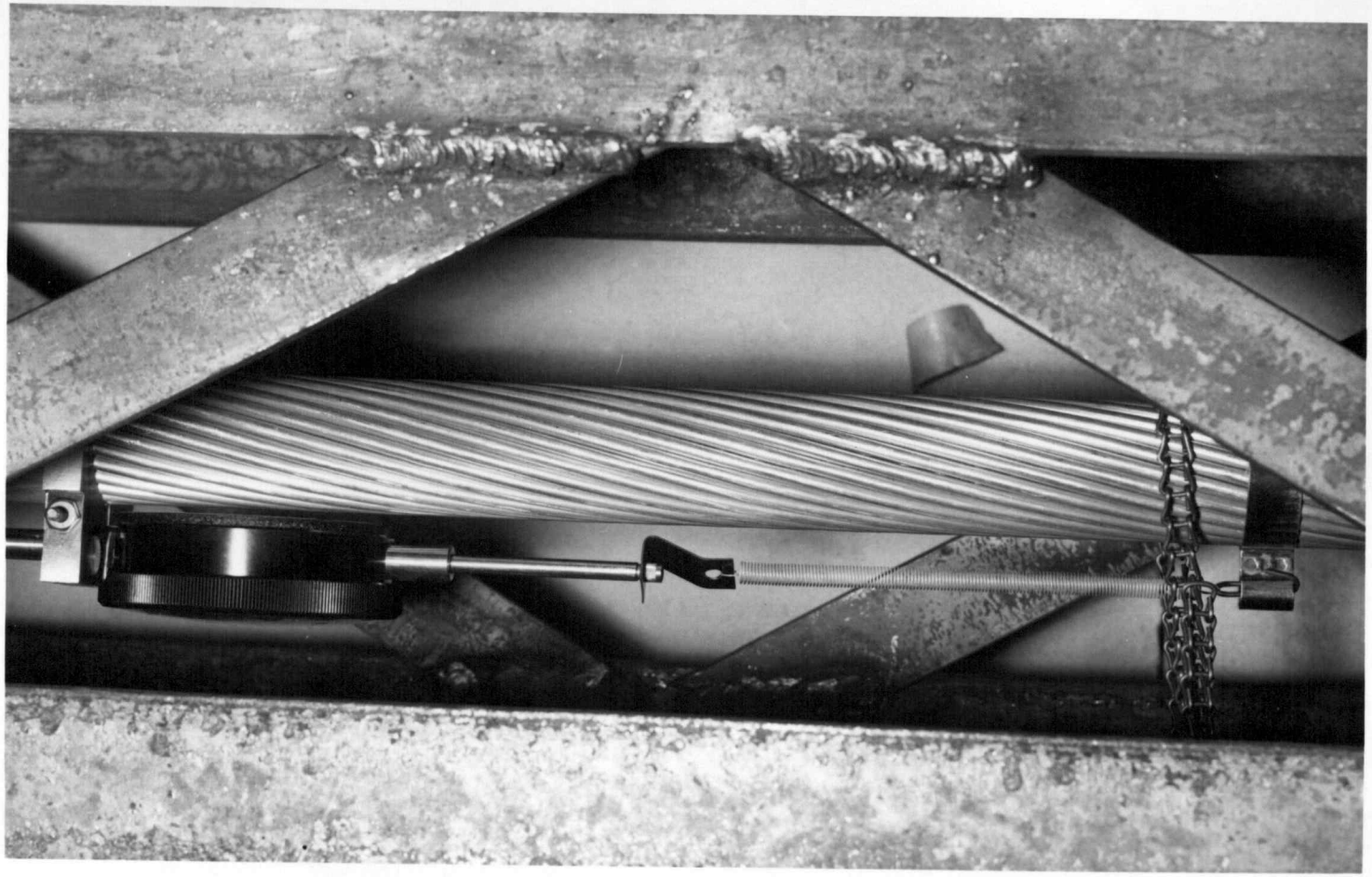


Figure 11

Closeup of Dial Gage Showing Tension Spring and Mounting Clamp

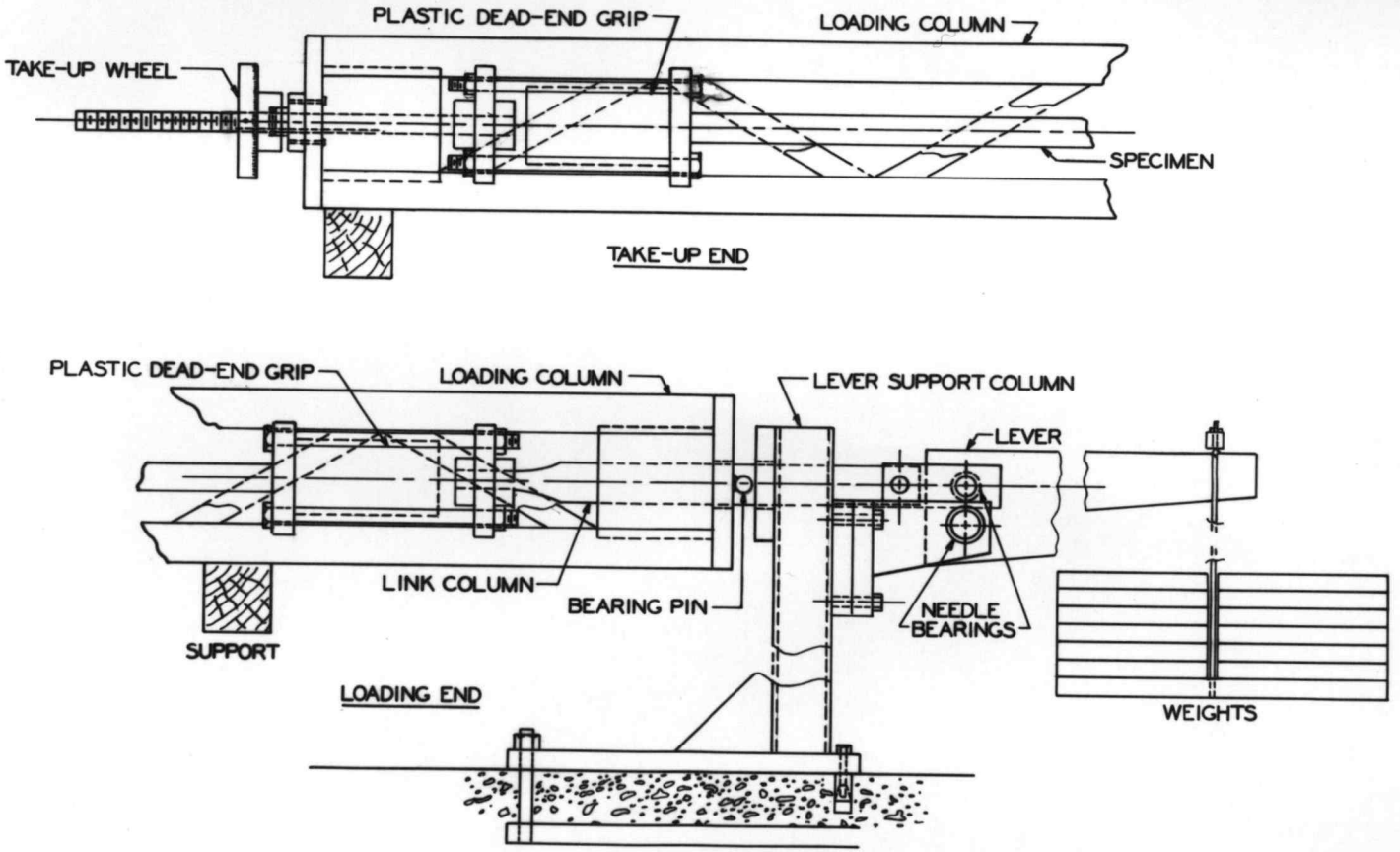


Figure 12

Schematic Diagram of Loading System



Figure 13

Loading End of Conductor Creep Testing Equipment

Test Loading Procedure

For the first creep test two procedures were used to reach pretension. By pretension is meant some prescribed tension above actual service tension. This pretension is stated in percent of service tension which will be referred to as percent of creep tension. One procedure was a slow load for determining an initial stress strain relationship. The dial gage was set at zero with the lever load on the specimen (approximately 750 lb). The load was then increased at about 2, 000 pounds (100 pounds of weight at the lever gives about 2, 000 pounds of tension. The exact tension depends on the lever arm for each loading column.) increments at intervals of 3 minutes. The dial was read 30 seconds before each load increase. The total time to reach pretension was 30 minutes. The second procedure was a fast load. The gage was set at zero for lever load. Then the lever was blocked up and the full pretension load was placed on the lever. The lever was then raised by the take up wheel so that the total pretension load was applied in 1 minute.

For the second series of creep tests two procedures were used to reach pretension. The slow rate was reduced to a total time of 15 minutes with load increments of about 4, 000 pounds at 3 minute

intervals. The fast rate was accomplished in two steps. The procedure was followed as before but instead of total pretension load being placed on the blocked up lever, about 1/2 pretension load was placed on the lever. The lever was raised as before in 1 minute. The dial gage was then read and the remaining load was applied and the lever leveled within a total elapsed time of 3 minutes. The dial gage was zeroed with lever load the same as for the first series.

For both series, after reaching pretension, dial readings were taken at 5, 10, 15, 30, 45 minutes, 1, 1 1/2, 2, 3, 4, 6, 8, 12, 16 and 24 hours, and then every 96 hours until approximately 2, 000 hours. The reason for this spacing was that when the data are plotted on log-log coordinates this sequence gives a fairly uniform distance between plotted points.

For both series, after being at pretension for the prescribed time, the conductors were unloaded to creep tension and the lever arm leveled within about 1 minute.

At the completion of the 2, 000 hours each specimen was taken through a stress strain loading as follows: Starting at creep tension, for zero final stress strain time, the load was increased at about 2, 000 pound increments in 3 minute intervals to

approximately 21, 000 pounds. The specimen was then unloaded at about 4, 000 pound increments in 3 minute intervals to lever load. The specimen was then loaded at 2, 000 pound increments in 3 minute intervals to creep tension or slightly above. This took 51 minutes and completed the test.

Initial stress strain tests were also run. The procedure for these tests was the same as for the final stress strain, except zero stress strain time was at lever load instead of creep tension load.

Testing Program

Creep Specimens. Twelve specimens (460 KV expanded conductors) were used for 2, 000 hour creep tests. Table 1. lists the 12 specimens and their main characteristics. The actual design and exact wire type and combinations is shown in Figure 1.

Stress-Strain Specimens. Four 460 KV expanded conductors were used for stress-strain test without creep. The four consisted of two X(AWR) 652 and two X(SE). Two ACSR "Pheasant" conductors, consisting of 54 aluminum and 10 steel strands, were also used for stress strain test without creep.

TABLE 1. Test Specimens

Manufacturer	Code Symbol	Number of Specimens	Rated Strength lbs	Strength/weight feet
Aluminum Co. of America	X(AWR)652	1	69, 900	24, 900
Kaiser Aluminum and Chemical Co.	X(K)	2	68, 800	22, 400
Aluminum Co. of America	X(AFC)648	5	70, 600	24, 500
Anaconda Wire and Cable Co.	X(AN)	2	69, 000	22, 400
Southern Electric Co.	X(SE)	0	82, 800	25, 300
Reynolds Metals Co.	X(R)	2	73, 300	25, 200

Tests. To identify the type of creep test that a conductor has undergone a code system has been adopted. A typical code would be X(AN)-125/1-20. The first series of letters represents the conductor; the first set of numbers represents the amount of pretension in percent of creep tension and time of pretension in hours and second set represents the test load in percent of nominal strength. The code shown indicates that the conductor is an expanded 460 KV conductor manufactured by Anaconda that has been pretensioned to 125% of creep tension for one hour and creep tested at 20% of

nominal strength. A nominal strength of 70, 000 lb. was used for all 460 KV expanded conductors. Table 1 gives the manufacturers code and Table 2 gives the test code and conditions for the twelve specimens subjected to 2, 000 hours creep tests.

To distinguish between stress-strain tests for similar conductors a number is placed after the manufacturers code symbol. Two typical codes would be X(SE)-1 and X(SE)-2.

TABLE 2. Creep Testing Conditions

Code	Pretension			Creep Tension		
	Percent of Creep Tension*	lb.	Time hr.	Percent of Nominal Strength*	lb.	Time hr.
X(AFC)-100/1-20	100	14, 000	1	20	14, 000	2, 130
X(AFC)-125/1/4-20	125	17, 500	1/4	20	14, 000	2, 114
X(AFC)-125/1-20	125	17, 500	1	20	14, 000	2, 129
X(AFC)-150/1-20	150	21, 000	1	20	14, 000	2, 132
X(AFC)-125/16-20	125	17, 500	16	20	14, 000	2, 117
X(AWR)-125/16-20-2**	125	17, 500	16	20	14, 000	2, 134
X(R)-125/1-20	125	17, 500	1	20	14, 000	2, 085
X(R)-150/1-20	150	21, 000	1	20	14, 000	2, 087
X(AN)-125/1-20-2**	125	17, 500	1	20	14, 000	2, 069
X(AN)-150/1-20	150	21, 000	1	20	14, 000	2, 083
X(K)-125/1-20	125	17, 500	1	20	14, 000	2, 070
X(K)-150/1-20	150	21, 000	1	20	14, 000	2, 069

*Based on a nominal strength of 70, 000 lbs.

**Slow load.

TEST RESULTS

Graphical Representation

Results of the tests listed in Table 2 are shown in graphical form in Figures 14 to 36. The data are represented in two forms.

The first form, Figures 14 to 24, represents the creep strain as a function of time plotted on log-log coordinates. For these curves creep strain is plotted for constant load. For this reason it was necessary to assume the time of application of full pretension as zero creep time. This can be seen by referring to Figure 26 where the data for X(AFC)125/1/4-20 are plotted. The point at 17,500 lbs. and 0.1248 percent strain is marked "1 minute = 0 minutes." This is zero creep time for the solid curve on Figure 14. This conductor was at pretension for 15 minutes and then unloaded to creep tension for the remainder of the creep test. At the time just prior to this unloading the strain had increased to 0.1251 percent strain for a net increase of 0.0003 percent strain. The conductor was then unloaded with a decrease in strain down to 0.1075 percent strain. It is assumed that the conductor has already undergone 0.0003 percent strain and that any additional creep strain will be a change from this value. The data for these changes are plotted on the portion of the curve beyond pretension time. The data for the

remaining tests are presented in similar fashion.

The creep curves for all X(AFC), Figures 14 to 17, specimens have the data from specimen X(AFC)-100/ 1-20 (actually represents no pretension treatment) dotted in. This shows the effect of different test conditions as compared to a standard condition for a particular conductor. Due to the time involved and the number of conductors to be tested it was not possible to present this type of a comparison for the other conductors.

From the plotted data of Figure 27 it can be seen that upon unloading specimen X(AFC)-125/1-20 from pretension to creep tension there was a time during which the conductor remained at a fairly constant length. This period was called the creep stabilization period or stable period. The stable period was arrived at as follows: For Figure 27 the creep strain at end of pretension was 8 microinches per inch. Knowing the slope of the straight line portion of the creep curve, a straight line was drawn back along this slope until it intersected 8 microinches per inch of creep strain. This intersection occurred, for Figure 27, at 5.8 hours which, less the 1 hour pretension, gives a stable period of 4.8 hours. The stable period for the remaining tests were determined, and are indicated, in similar fashion.

The second graphical form of presentation of test results on specimens tested in Table 2 is shown in Figures 25 to 36. In these figures the data are plotted as tension in pounds versus strain in percent, the time being indicated by numerals on the curve. These figures are a complete log of the test history of the specimen. The elapsed time from the start of the test is listed on the curve. This can be seen by referring to Figure 26 where the data for X(AFC)-125/1/4-20 are plotted. The plot was started at lever load (752 lb) for the initial point of zero minutes. To reach pretension (17,500 lb) took 1 minute, which as stated before, was taken as zero creep time. The load was held at pretension for 15 minutes and then reduced to creep tension (14,000 lb) in 1 minute as indicated. The remaining points are labeled, with the creep test ending at 2,114 hours. At this point final stress strain readings were taken. 2,114 hours is called zero final stress-strain time. The load was increased, as indicated, in 3 minute intervals to 18,509 lb. This load was held for 15 minutes. The load was then decreased to 752 lb and then increased back up to 14,000 lb. This decrease and increase was again done in three minute intervals. This completed the entire creep and final stress strain testing procedure for the specimen X(AFC)-125/1/4-20. Data for the remaining tests are presented in similar fashion.

Figures 37 to 42 present the data for stress strain tests without creep. The figures plot tension in pounds versus strain in percent. The plot was started at lever load. The load was increased to about 40% of rated strength then decreased to lever load and then increased to about 20% of rated strength. The increases and decreases were done in three minute intervals. The elapsed time for each data point from the start of the test is listed on the figures.

Short Time Creep

The initial creep data, as shown in Figures 14 to 24, has a much higher slope than the final creep rate. Some of this is due to higher (pretension) loads. However, by looking at Figure 16 and comparing X(AFC)-150/1-20 to X(AFC)100/1-20 it can be seen that the X(AFC)-100/1-20, which was not stabilized, has an initially high creep rate which decreases with time to a more or less constant rate for long time creep. This high initial rate with a decrease towards a constant value can be attributed to the factors of strand setting, straightening, and in bimetalic conductors to a transferring of the load from aluminum to steel (due to the large difference in creep rate for each material). When a constant creep rate is reached metallurgical creep should be the controlling factor.

There is only a slight difference in initial creep for the same conductors under similar conditions. This difference can be seen in Table 3.

Table 3. Initial Creep of X(AFC)

Specimen	Load lb.	Elapsed time minutes	Unit Strain microinch in.
X(AFC)-125/1/4-20	17,500	15	1,251
X(AFC)-125/1-20	17,500	15	1,306
X(AFC)-125/16-20	17,500	15	1,195

This difference in unit strain of 1,195 to 1,306 microinches per inch (8.49%) occurring under similar test conditions, could be caused by the difference in handling of the individual specimens during manufacture, assembly of end fittings, transporting, and installing for testing.

Evidence of loose stranding was quite noticeable on specimens X(K)-125/1-20 and X(K)-150/1-20 at time of specimen installation. The results of this can be seen from data plotted on Figure 23 and 24 which show a high initial creep strain of 29.5 and 53.5 microinches per inch respectively at one hour creep time.

The specimens X(AN)-125/1-20-2 and X(AN)-150/1-20 showed evidence of being taken near the end (the small diameter) of the reel as they had a slight helical shape. The results of this can be seen from the data plotted on Figures 21 and 22 which show a high initial creep strain of 39.0 and 74.0 microinches per inch respectively at one hour creep time.

From the data for the X(AFC)-100/1-20 specimen, which are dotted in on Figures 14 to 17, it can be seen that the high initial creep rate has diminished towards a constant value by 100 hours creep time. This effect can also be seen on all other creep curves. This indicates that the major effect of strand setting and conductor straightening is over by this time. It must be remembered that, even though the creep rate has reached a constant value, this initial elongation is still included in the total creep and must be taken into consideration for conductor sag.

Creep Stabilization

The method of establishing the stable period was described previously. Using this method the stable periods varied from 0.45 hours (Figure 14, X(AFC)-125/1/4-20) to 46 hours (Figure 18 X(AWR)-125/16-20-2) for the twelve specimens tested. By referring to Figures 14 to 24 it can be seen that the stable period

generally increases with an increase in pretension or pretension time.

Long Time Creep

The 2, 000 hour tests conducted on the twelve 460 KV expanded conductors are relatively long laboratory tests. However, when compared to the actual service life of a conductor in a transmission line (30-50 years) the testing period was relatively short.

By referring to Figures 14 to 17, which have the data for specimen X(AFC)-100/1-20 dotted in for comparison with other X(AFC) specimens (Series 1), the following seems to be true: For the pretension and pretension times tested the creep rate tends to return towards that of a conductor that has had no pretension. Although there is some deviation it seems reasonable to assume that pretension affects the initial creep rate considerably and the long time creep rate only slightly.

The specimen data shown in Figures 18 to 24 do not have data from a specimen without pretension dotted in. It will be observed that all the creep rates approached a constant value. By assuming that the pretension does not greatly affect the long time creep rate these specimens would be at nearly the same creep rate at 2, 000 hours if they had no pretension treatment.

Table 4 lists the final creep strain in microinches per inch and the total strain in percent for the twelve creep specimens. It will be observed from the last six specimens (Series 2) that, holding pretension time at one hour, and increase in pretension raised both the creep strain and total strain. The creep strain was raised 8.67% between the X(R) - 125/1-20 and X(R) - 150/1-20, 11.17% between the X(AN) - 125/1-20 and X(AN) - 150/1-20, and 6.13% between the X(K) - 125/1-20 and X(K) - 150/1-20 specimens.

Table 4. Final Creep Strain

Specimen	Load lb	Elapsed Time hr.	Creep Strain microinch in.	Total Strain percent
X(AFC)-100/1-20	14, 000	2, 130	79.0	0.1183
X(AFC)-125/1/4-20	14, 000	2, 114	76.5	0.1149
X(AFC)-125/1-20	14, 000	2, 129	78.0	0.1204
X(AFC)-150/1-20	14, 000	2, 132	69.5	0.1472
X(AFC)-125/16-20	14, 000	2, 117	83.8	0.1100
X(AWR)-125/16-20-2	14, 000	2, 134	213.0	0.1736
X(R)-125/1-20	14, 000	2, 085	90.5	0.0928
X(R)-150/1-20	14, 000	2, 087	98.5	0.0994
X(AN)-125/1-20-2	14, 000	2, 069	239.0	0.1064
X(AN)-150/1-20	14, 000	2, 083	269.0	0.1095
X(K)-125/1-20	14, 000	2, 070	169.0	0.1105
X(K)-150/1-20	14, 000	2, 069	180.0	0.1143

Initial and Final Stress-Strain

The modulus of elasticity E, is a measure of the stiffness of the material, E expressed by Hookes' law is

$$E = \frac{\sigma}{\epsilon}$$

where σ is stress and ϵ is strain. This is the slope of the line for a graphically represented curve of stress versus strain. It will be observed from Figures 37 to 42 that for the specimens tested the E_i and E_f are at different slopes. The E_i is the slope of the curve for the initial loading. The E_f is the slope of the curve for a reloading of the same specimen to a load equal or less than the initial loading. From these same figures it can be seen that the E_f was the same whether taken from the unloading or reloading portion of the curve. This phenomenon has been shown for various kinds of conductors (7, p. 413).

It will be observed from Figures 25 to 36 that upon unloading from pretension to creep tension the specimens followed the E_f.

As mentioned before, the creep specimens after being at creep tension for approximately 2, 000 hours were put through a stress strain cycle. This cycle is shown at the end of the curve for the above mentioned figures. The specimens follow the E_f to above the initial pretension and then they go into E_i. Upon unloading and

subsequent reloading to creep tension the specimens follow E_f. From this series of tests and also previous work (8, p. 8) it appears that creep does affect the value of E.

Due to the load limitations of the equipment the 460 KV expanded conductors were not able to be loaded to a high enough load to show clearly the change from E_i to E_f. Due to this limitation, the final stress strain curves of Figures 25 to 36 and the initial stress strain curves of Figures 37 to 40 do not show a complete picture.

Figure 43 shows how creep affects E_i and E_f and the cumulative effect of the nonelastic elongation caused by creep and the difference in the E_i and E_f for an ACSR "Pheasant" conductor. The dotted portion of the curve is from initial stress strain tests shown in Figures 41 and 42. The remaining portion is from previous work (3, p. 27).

The stress strain and creep tests for this thesis also show this effect, but not as clearly as Figure 43 (due to the load limitations mentioned previously).

From Figure 43 it can be seen that the specimen had an increase of elongation of 0.0095% at pretension load (11, 200 lb) for final loading and unloading after 2, 163 hours creep. From the dotted portion of the curve this elongation would have been 0.0180%

for a similar cycle without the effects of creep. This 0.0095% elongation occurred after 0.0280% elongation from creep. An additional elongation occurred in all the stress strain creep tests for ACSR "Pheasant" conductors.(3, p. 22-28).

To fully appreciate these results it must be recalled from the introduction that sag calculations previously were based on only the larger elongation as determined by creep or the change in E due to a momentary load increase (due to ice). The inadequacy of this type of sag calculation can be seen from the previously mentioned results. For the conductor of Figure 43, creep would have been the design criteria for sag as it was the largest value of elongation (0.0280%). By using this method of designing for sag the additional increase of 0.0095% or 34% of creep elongation would be neglected.

For this work the only conductor that was tested for both initial stress strain and creep with final stress strain was X(AWR). By referring to Figures 30, 39 and 40 it can be seen that on initial stress strain there was an elongation of 0.0060% for pretension load (17,500 lb). At the same load for final stress strain there was an elongation of 0.0010%. This elongation occurred after 0.0212% elongation from creep.

Mathematical Form of Creep Curves

As mentioned previously, the graphical representation of creep data on log-log coordinates plots as a straight line, (after an initial period). This fact indicates that the straight line portion can be expressed as

$$\epsilon = Bt^n \qquad (3)$$

where

ϵ = creep strain

t = time

B and n are constants

Equation (3) written in log form is

$$\log \epsilon = \log B + n \log t \qquad (4)$$

where n becomes the slope of the straight line of the plotted data on log-log coordinates and B becomes the intercept at t = 1 hour.

Previous work (3, p. 26; 4, p. 43) has shown that creep data for various conductors can be put in the form of equation 4.

Determination of the Slope n and Intercept B. The method of least squares was used to determine the most probable values for the constants n and B. It was assumed that the t measurements were exact and that the value of ϵ were liable to errors. This is

equivalent to saying that the deviations, the sum of whose squares is to be a minimum, are those that are directly parallel to the ϵ axis. (10, p. 240).

By representing log t by x, log ϵ by y, log B by a and n by b, the form of equation 4 is

$$y = a + bx \tag{5}$$

where the unknowns are a and b, which are found from the equations

$$a = \frac{\sum x^2 \sum y - \sum x \sum xy}{n \sum x^2 - (\sum x)^2} \tag{6}$$

$$b = \frac{n \sum xy - \sum x \sum y}{n \sum x^2 - (\sum x)^2} \tag{7}$$

where n is the number of points analyzed (10, p. 240).

Table 5 gives the values for B and n in equations 3 and 4 (corresponding to a and b in equations 6 and 7) for the specimens tested. All specimens were analyzed for the elapsed time interval of 150 to 2, 000 hours. Table 5 shows how pretension affects the slope of the creep curve and the one hour intercept. In all cases an increase in pretension or pretension time decreased the value of n and increased the value of B.

Equation 3 and 4 can be used to determine the stable period and to extrapolate creep data to times beyond the test time. The

Table 5. Results of Analytical Treatment of Creep Data

Specimen	n	B	Stable period hr.	10, 000 hr. creep strain microin/in.
X(AFC)-100/1-20	0.416	3.38	---	159.5
X(AFC)-125/1/4-20	0.390	3.65	1.01	132.5
X(AFC)-125/1-20	0.385	4.08	4.75	141.5
X(AFC)-150/1-20	0.383	4.11	3.83	140.5
X(AFC)-125/16-20	0.349	6.18	39.5	154.5
X(AWR)-125/16-20-2	0.323	17.15	40.0	343.1
X(R)-125/1-20	0.540	1.49	10.95	214.4
X(R)-150/1-20	0.474	2.65	5.63	209.5
X(AN)-125/1-20-2	0.319	21.87	3.36	414.1
X(AN)-150/1-20	0.247	41.09	9.9	400.2
X(K)-125/1-20	0.292	18.91	3.58	281.0
X(K)-150/1-20	0.252	26.31	15.7	269.0

values for the stable periods, and creep strain at 10, 000 hours are listed in Table 5. 10, 000 hours was chosen as it is recommended that extrapolations be carried out to only one cycle beyond the actual test time. Table 5 shows that at 10, 000 hours the four sets of conductors that had pretensions of 125% and 150% of creep tension for one hour vary in creep rate from 0.68% [X(AFC)] to 4.26% X(K) .

CONCLUSIONS

The following factors were determined for the 460 KV expanded conductors tested:

1. There is only a slight difference in initial creep for similar conductors under similar conditions.
2. The high initial creep rate tends to diminish towards a constant value by 100 hours creep time.
3. Loose stranding and conductor straightening cause an increase in initial creep rate.
4. The stable period generally increases with an increase in amount of pretension or pretension time.
5. An increase in pretension or pretension time decreases the slope of long time creep curve as plotted on log-log coordinates.
6. Conductors stay on E_f above their initial tension after 2, 000 hours of creep at 20% nominal strength.
7. For the conductor tested for initial stress strain and then final stress strain after creep, there is a cumulative effect for the nonelastic elongation from creep and a temporary load increase.

RECOMMENDATIONS

1. Complete an initial stress strain test on all specimens to a minimum tension of 40% of nominal strength.
2. Complete a final stress strain test on all specimens after creep to a minimum tension of 40% of nominal strength.
3. Install a clamp of some type behind the steel plate on the plastic end fitting to prevent the plate from slipping down the specimen in shipment and installation.
4. Mark off the gage length on the specimens so the dial gage is completely visible for readings.
5. Devise some type of test to separate the effects of strand setting and conductor straightening from conductor creep.

BIBLIOGRAPHY

1. Andrade, E. M. da, C. The concept of creep. In: Creep and Recovery. Cleveland, American Society for Metals, 1957. 372 p.

2. Oregon. Bonneville Power Administration. Special study authorization no. SST-73. Portland, 1961. 4 p.

3. Paasche, O. G. and L. E. Johnson. Laboratory creep studies on Pheasant conductor. Corvallis, Oregon State University. Engineering Experiment Station, 1961. 28 p. (Mimeographed).

4. Paasche, O. G. and R. D. Olleman. Creep in AAAC, 4/0, seven-strand, "Alliance" conductor at 75F without prestressing treatment. Spokane, 1958. 54 p. (Kaiser Aluminum Interim Project Report No. MS PR 58-78).

5. Prasad, P. Creep tests on aluminum and aluminum alloy conductors. Master's thesis. Corvallis, Oregon State College, 1959. 78 numb. leaves.

6. Schoeck, G. Theory of creep. In: Creep and Recovery. Cleveland, American Society for Metals, 1957. 372 p.

7. Rodee, H. H. Discussion. Transactions of the American Institute of Electrical Engineers 74 (Part 3. Power Apparatus and Systems):413. 1955.

8. Winkelman, P. F. Report on creep of overhead conductors. Portland, 1962. 12 p. (Bonneville Power Administration Report No. CSC 1-62-6)

9. Winkelman, P. F. Conductor creep and transmission line construction. Portland, 1961. 12 p. (Bonneville Power Administration Report No. CSC 6-61-15)

10. Worthing, A. G. and J. Gefner. Treatment of experimental data. New York, Wiley, 1943. 342 p.

APPENDIX

Table 6. CREEP AND FINAL STRESS STRAIN TEST DATA

SUBJECT: Creep Test of 460 KV Conductor X(AFC)-125/$\frac{1}{4}$-20
BY: O. G. Paasche, L. E. Johnson, L. M. Wilson DATE: Nov. 3, 1961
PRETENSION: 100% C.T. - 14,000 lb.
PRETENSION TIME: 1 Hour
CREEP TENSION: 20% N.T.
CREEP TENSION TIME: 2130 Hours
GAGE LENGTH: 200 inches TEMPERATURE: 75°F±2°

Elapsed Time Hr	Gage Reading 10^{-3} in	Creep Strain Microin/in	Unit Strain Microin/in
0	220.9	0	1104.5
5 min	220.8	-0.5	1104.0
10 min	220.7	-1.0	1103.5
15 min	220.8	-0.5	1104.0
30 min	221.0	0.5	1105.0
45 min	221.1	1.0	1105.5
1	221.2	1.5	1106.0
1.5	221.8	3.5	1108.0
2	221.8	4.5	1109.0
3	222.1	6.0	1110.5
4	222.2	6.5	1111.0
6	222.2	6.5	1111.0
8	222.4	7.5	1112.0
12	222.9	10.0	1114.5
16	223.2	11.5	1116.0
24	223.2	11.5	1116.0
31	223.7	14.0	1118.5
44	224.1	16.0	1120.5
68	224.2	16.5	1121.0
92	225.0	20.5	1125.0
116	225.1	21.0	1125.5
140	226.0	25.5	1130.0
188	226.8	29.5	1134.0
284	228.1	36.0	1140.5
380	229.1	41.0	1145.5
476	230.0	45.5	1150.0
572	230.1	46.0	1150.5
668	230.5	48.0	1152.5
764	230.9	50.0	1154.5
860	232.6	58.5	1163.0
956	232.8	59.5	1164.0
1052	233.2	61.5	1166.0
1148	232.6	59.5	1163.0
1244	233.8	64.5	1169.0
1340	233.1	61.0	1165.5

Table 6. (continued)

Elapsed Time Hr	Gage Reading 10^{-3} in	Creep Strain Microin/in	Unit Strain Microin/in
1436	235.0	70.5	1175.0
1532	235.0	70.5	1175.0
1628	234.8	69.5	1174.0
1724	235.9	75.0	1179.5
1820	235.9	75.0	1179.5
1916	236.0	75.5	1180.0
2012	236.5	78.0	1182.5
2130	236.7	79.0	1183.5

FINAL STRESS STRAIN

(Jan. 31, 1962)

Elapsed Time Min	Gage Reading 10^{-3} in	Conductor Tension lb.	Unit Strain Microin/in
0*	236.7	14,000	1183.5
3	262.3	16,301	1311.5
6**	282.6	18,248	1413.0
9	303.0	20,195	1515.0
12	316.2	22,142	1581.0
15	303.3	20,195	1516.5
18	265.7	16,301	1328.5
21	224.9	12,377	1124.5
24	185.8	8,488	929.0
27	142.6	4,606	713.0
30	66.6	745	333.0
33	113.4	2,682	567.0
36	140.5	4,608	702.5
39	162.9	6,569	814.5
42	184.1	8,488	920.5
45	204.2	10,435	1021.0
48	223.9	12,377	1119.5
51	240.8	14,000	1204.0

* 2130 Hours = 0 minutes

** See Note on Figure 15

Table 7. CREEP AND FINAL STRESS STRAIN TEST DATA

SUBJECT: Creep Test of 460 KV Conductor X(AFC)-100/1-20
BY: O. G. Paasche, L. E. Johnson, L. M. Wilson DATE: Nov. 3, 1961
PRETENSION: 125% C.T. - 17,500 lb.
PRETENSION TIME: 1/4 Hour
CREEP TENSION: 20% N.S. - 14,000 lb.
CREEP TENSION TIME: 2114 Hours
GAGE LENGTH: 200 inches TEMPERATURE: 75°F±2°

Elapsed Time Hr	Gage Reading 10^{-3} in	Creep Strain Microin/in	Unit Strain Microin/in
0	249.4	0	1247.0
5 min	249.6	1.0	1248.0
10 min	249.8	2.0	1249.0
15 min	250.2	4.0	1251.0
15 min	215.2	4.0	1076.0
30 min	215.2	4.0	1076.0
45 min	215.6	6.0	1078.0
1	215.8	7.0	1078.0
1.5	215.8	7.0	1079.0
2	215.8	7.0	1079.0
3	215.8	7.0	1079.0
4	216.0	8.0	1080.0
6	216.1	8.5	1080.5
8	216.6	11.0	1083.0
12	216.8	12.0	1084.0
16	217.3	14.5	1086.5
24	217.3	14.5	1086.5
34	217.8	17.0	1089.0
47	218.0	18.0	1090.0
71	218.3	19.5	1091.5
95	218.9	22.5	1094.5
119	219.5	25.5	1097.5
143	220.1	28.5	1100.5
191	220.8	32.0	1104.0
287	221.9	37.5	1109.5
383	222.5	40.5	1112.5
479	223.1	43.5	1115.5
575	223.8	47.0	1119.0
671	224.0	48.0	1120.0
767	224.9	52.5	1124.5
863	225.7	56.5	1128.5
959	226.0	58.0	1130.0
1055	226.6	61.0	1133.0
1151	226.9	62.5	1134.5
1247	227.1	63.5	1135.5

Table 7. (continued)

Elapsed Time Hr	Gage Reading 10^{-3} in	Creep Strain Microin/in	Unit Strain Microin/in
1343	227.1	63.5	1135.5
1439	227.9	67.0	1139.5
1535	228.1	68.0	1140.5
1631	228.3	69.0	1141.5
1727	229.0	72.5	1145.0
1823	229.0	72.5	1145.0
1919	229.0	72.5	1145.0
2015	229.5	74.5	1147.5
2114	229.9	76.5	1149.5

FINAL STRESS STRAIN
(Jan. 30, 1962)

Elapsed Time Hr	Conductor Tension lb	Gage Reading 10^{-3} in	Unit Strain Microin/in
0*	14,000	229.2	1146.0
3	16,536	255.4	1277.0
6	18,508	275.8	1379.0
9	18,508	275.8	1379.0
12	18,508	275.7	1378.5
15	18,508	275.7	1378.5
18	18,508	275.5	1378.0
21	18,508	275.6	1378.0
24	16,536	255.2	1276.0
27	12,590	215.2	1076.0
30	8,644	174.3	871.5
33	4,698	130.6	653.0
36	752	57.8	289.0
39	2,725	101.4	507.0
42	4,698	129.1	645.5
45	6,671	152.7	763.5
48	8,644	173.8	869.0
51	10,617	194.1	970.5
54	12,590	214.8	1074.0
57	14,000	229.9	1149.5

* 2114 hours = 0 minutes

Table 8. CREEP AND FINAL STRESS STRAIN TEST DATA

SUBJECT: Creep Test of 460 KV Conductor X(AFC)-125/1-20
BY: O. G. Paasche, L. E. Johnson, L. M. Wilson
PRETENSION: 125% C.T. 17,500 lb. DATE: Nov. 3, 1961
PRETENSION TIME: 1 Hour
CREEP TENSION: 20% N.S. 14,000 lb.
CREEP TENSION TIME: 2129 Hours
GAGE LENGTH: 200 inches TEMPERATURE: 75°F±2°

Elapsed Time Hr	Gage Reading 10^{-3} in	Creep Strain Microin/in	Unit Strain Microin/in
0	260.7	0	1303.5
5 min	260.7	0	1303.5
10 min	260.8	0.5	1304.0
15 min	261.2	2.5	1306.0
30 min	261.8	5.5	1309.0
45 min	262.0	6.5	1310.0
1	262.3	8.0	1311.5
1	226.8	8.0	1134.0
1.5	226.9	8.5	1134.5
2	227.0	9.0	1135.0
3	227.1	9.5	1135.5
4	227.0	9.0	1135.0
6	227.0	9.0	1135.0
8	227.0	9.0	1135.0
12	227.6	12.0	1138.0
16	228.0	14.0	1140.0
24	228.0	14.0	1140.0
30	228.2	15.0	1141.0
43	228.6	17.0	1143.0
67	229.0	19.0	1145.0
93	229.8	23.0	1149.0
117	230.1	24.5	1150.5
141	230.9	28.5	1154.5
189	231.3	30.5	1156.5
285	232.6	37.0	1163.0
381	233.4	41.0	1167.0
477	234.1	44.5	1170.5
573	234.2	45.0	1171.0
669	234.9	48.5	1174.5
765	235.2	50.0	1176.0
861	236.5	56.5	1182.5
957	236.6	57.0	1183.0
1053	237.5	61.5	1187.5
1149	237.2	60.0	1186.0
1245	238.0	64.0	1190.0

Table 8. (continued)

Elapsed Time Hr	Gage Reading 10^{-3} in	Creep Strain Microin/in	Unit Strain Microin/in
1341	237.9	63.5	1189.5
1437	238.7	67.0	1193.5
1533	239.0	68.5	1195.0
1629	239.0	68.5	1195.0
1725	239.9	73.0	1199.5
1821	239.9	73.0	1199.5
1917	239.9	73.0	1199.5
2013	240.4	75.5	1202.0
2129	240.9	78.0	1204.5

FINAL STRESS STRAIN
(Jan. 31, 1962)

Elapsed Time Min	Conductor Tension lb	Gage Reading 10^{-3} in	Unit Strain Microin/in
0*	14,000	240.9	1204.5
3	17,276	274.9	1374.5
6	19,321	296.3	1481.5
9	21,383	317.9	1589.5
12	23,445	341.8	1709.0
15	23,445	341.8	1709.0
18	23,445	341.9	1709.5
21	23,445	342.2	1711.0
24	23,445	342.2	1711.0
27	23,445	342.2	1711.0
30	21,383	321.7	1608.5
36	17,276	280.2	1401.0
39	13,134	237.8	1189.0
42	9,019	194.7	973.5
45	4,889	149.2	746.0
48	788	69.6	348.0
51	2,842	117.9	589.5
54	4,889	145.9	729.5
57	6,958	170.3	851.5
60	9,019	192.5	962.5
63	11,079	214.4	1072.0
66	13,134	236.2	1181.0
69	14,000	244.8	1224.0

* 2129 Hours = 0 minutes

Table 9. CREEP AND FINAL STRESS STRAIN TEST DATA

SUBJECT: Creep Test of 460 KV Conductor X(AFC)-150/1-20
BY: O. G. Paasche, L. E. Johnson, L. M. Wilson DATE: Nov. 3, 1961
PRETENSION: 150% C.T. - 21,000 lb.
PRETENSION TIME: 1 Hour
CREEP TENSION: 20% N.S. - 14,000 lb.
CREEP TENSION TIME: 2132 Hours
GAGE LENGTH: 200 inches TEMPERATURE: 75°F±2°

Elapsed Time Hr	Gage Reading 10^{-3} in	Creep Strain Microin/in	Unit Strain Microin/in
0	351.8	0	1759.0
5 min	351.8	0	1759.0
10 min	351.9	0.5	1759.5
15 min	352.3	2.5	1761.5
30 min	353.0	6.0	1765.0
45 min	353.0	6.0	1765.0
1	353.3	7.5	1766.5
1	282.1	7.5	1410.5
1.5	282.0	7.0	1410.0
3	282.1	7.5	1410.5
4	282.1	7.5	1410.5
6	282.5	9.5	1412.5
8	282.9	11.5	1414.5
12	282.9	11.5	1414.5
16	282.8	11.0	1414.0
24	282.9	11.5	1414.5
32	283.8	16.0	1419.0
45	284.1	17.5	1420.5
69	284.1	17.5	1420.5
93	284.8	21.0	1424.0
117	285.0	22.0	1425.0
141	286.0	27.0	1430.0
189	286.1	27.5	1430.5
285	287.4	34.0	1437.0
381	287.9	36.5	1439.5
477	289.0	42.0	1445.0
573	289.1	42.5	1445.5
669	289.1	42.5	1445.5
765	289.9	46.5	1449.5
861	291.0	52.0	1455.0
957	291.2	53.0	1456.0
1053	291.9	56.5	1459.5
1149	291.2	53.0	1456.0
1245	292.5	58.5	1461.5
1341	291.9	56.5	1459.5

Table 9. (continued)

Elapsed Time Hr	Gage Reading 10^{-3} in	Creep Strain Microin/in	Unit Strain Microin/in
1437	293.1	62.5	1465.5
1533	293.2	63.0	1466.0
1629	292.9	61.5	1464.5
1725	293.0	62.0	1465.0
1821	293.7	65.5	1468.5
1917	293.8	66.0	1469.0
2013	294.4	69.0	1472.0
2132	294.5	69.5	1472.5

FINAL STRESS STRAIN

(Jan. 31, 1962)

Elapsed Time Min	Conductor Tension lb	Gage Reading 10^{-3} in	Unit Strain Microin/in
0*	14,000	294.9	1474.5
3	16,892	323.8	1619.0
6	18,941	343.7	1718.5
9	20,933	364.3	1821.5
12	21,929	385.0	1925.0
15	20,933	363.8	1819.0
18	16,892	323.7	1618.5
21	12,856	283.1	1415.5
24	8,808	241.4	1207.0
27	4,772	196.0	980.0
30	769	88.3	441.5
33	2,768	157.9	789.5
36	4,772	193.2	966.0
39	6,793	218.3	1091.5
42	8,808	240.1	1200.5
45	10,821	261.9	1309.5
48	12,856	282.4	1412.0
51	14,000	293.9	1469.5

* 2132 Hours = 0 minutes

Table 10. CREEP AND FINAL STRESS STRAIN TEST DATA

SUBJECT: Creep Test of 460 KV Conductor X(AFC)-125/16-20
BY: O. G. Paasche, L. E. Johnson, L. M. Wilson DATE: Nov. 3, 1961
PRETENSION: 125% C. T. - 17,500 lb.
PRETENSION TIME: 16 Hours
CREEP TENSION: 20% N.S. - 14,000 lb.
CREEP TENSION TIME: 2117 Hours
GAGE LENGTH: 200 inches TEMPERATURE: 75°F±2°

Elapsed Time Hr	Gage Reading 10^{-3} in	Creep Strain Microin/in	Unit Strain Microin/in
0	238.2	0	1191.2
5 min	238.0	-1.2	1190.0
10 min	238.1	-0.7	1190.5
15 min	239.0	3.8	1195.0
30 min	239.1	4.3	1195.5
45 min	239.7	7.3	1198.5
1	240.1	9.3	1200.5
1.5	240.3	10.3	1201.5
2	240.9	13.3	1204.5
3	241.1	14.3	1205.5
4	241.3	15.3	1206.5
6	241.8	17.8	1209.0
8	242.2	19.8	1211.0
12	242.5	21.3	1212.5
16	243.2	24.8	1216.0
16	208.1	24.8	1040.5
24	208.0	24.3	1040.0
35	208.1	24.8	1040.5
48	208.1	24.8	1040.5
72	208.6	27.3	1043.0
96	208.9	28.8	1044.5
120	209.4	31.3	1047.0
144	210.0	34.3	1050.0
192	211.0	39.3	1055.0
288	212.0	44.3	1060.0
384	213.0	49.3	1065.0
480	213.7	52.8	1068.5
576	214.0	54.3	1070.0
672	214.4	56.3	1072.0
768	215.0	59.3	1075.0
864	216.0	64.3	1080.0
960	216.0	64.3	1080.0
1056	216.9	68.8	1084.5
1152	217.0	69.3	1085.0
1248	217.6	72.3	1088.0

Table 10. (continued)

Elapsed Time Hr	Gage Reading 10^{-3} in	Creep Strain Microin/in	Unit Strain Microin/in
1344	217.6	72.3	1088.0
1440	218.2	75.3	1091.0
1536	218.6	77.3	1093.0
1632	218.9	78.8	1094.5
1728	219.4	81.3	1097.0
1824	219.5	81.8	1097.5
1920	219.5	81.8	1097.5
2016	219.9	83.8	1099.5
2117	219.9	83.8	1099.5

FINAL STRESS STRAIN
(Jan. 30, 1962)

Elapsed Time Min	Conductor Tension lb	Gage Reading 10^{-3} in	Unit Strain Microin/in
0*	14,000	219.9	1099.5
3	16,670	247.1	1235.5
6	18,661	267.7	1338.5
9	16,670	246.8	1234.0
12	12,688	206.9	1034.5
15	8,706	166.9	834.5
18	4,724	121.6	608.0
21	741	46.9	234.5
24	2,733	92.2	461.0
27	4,724	120.1	600.5
30	6,717	143.6	718.0
33	8,706	164.5	822.5
36	10,687	185.1	925.5
39	12,688	206.3	1031.5
42	14,000	220.1	1100.5

* 2117 Hours = 0 minutes

Table 11. CREEP AND FINAL STRESS STRAIN TEST DATA

SUBJECT: Creep Test of 460 KV Conductor X(AWR) 125/16-20-2
BY: O. G. Paasche, L. E. Johnson, L. M. Wilson DATE: Nov. 3, 1961
PRETENSION: 125% C.T. - 17,500 lb.
PRETENSION TIME: 16 Hours
CREEP TENSION: 20% N.S. - 14,000 lb.
CREEP TENSION TIME:
GAGE LENGTH: 200 inches TEMPERATURE: 75°F±2°

Elapsed Time Hr	Gage Reading 10^{-3} in	Creep Strain Microin/in	Unit Strain Microin/in
0	0	719 lb*	0
3 min	37.8	1,712 lb	189
6 min	68.1	2,638 lb	340.5
9 min	116.8	4,601 lb	584.0
12 min	157.2	6,535 lb	716.0
15 min	193.7	8,408 lb	968.5
18 min	228.3	10,404 lb	1141.5
21 min	261.9	12,347 lb	1309.5
24 min	293.8	14,285 lb	1469.0
27 min	325.2	16,223 lb	1626.0
30 min	344.4	17,500 lb	1722.0
35 min	345.0	3.0	1725.0
40 min	345.7	6.5	1728.5
45 min	346.1	8.5	1730.5
1	348.1	18.5	1740.5
1 15	348.1	18.5	1740.5
1 30	349.2	24.0	1746.0
2 00	350.0	28.0	1750.0
2 30	351.3	34.5	1756.5
3	352.3	39.5	1761.5
4	353.2	44.0	1766.0
6	354.1	48.5	1770.5
8	354.7	51.5	1773.5
12	356.0	58.0	1780.0
16	357.0	63.0	1785.0
16	317.5	63.0	1587.5
24	317.6	63.5	1588.0
37	317.3	62.0	1586.5
50	318.0	65.5	1590.0
74	319.0	70.5	1595.0
98	320.1	76.0	1600.5
122	321.1	81.0	1605.5
146	322.1	86.0	1610.5
194	323.9	95.0	1619.5
290	326.1	106.0	1630.5
386	328.1	116.0	1640.5

* Slow load to zero creep time (30 min)

Table 11. (continued)

Elapsed Time Hr	Gage Reading 10^{-3} in	Creep Strain Microin/in	Unit Strain Microin/in
482	330.0	125.5	1650.0
578	330.5	128.0	1652.5
674	332.0	135.5	1660.0
770	333.1	141.0	1665.5
866	334.1	146.0	1670.5
962	335.8	154.5	1679.0
1058	337.1	161.0	1685.5
1154	337.0	160.5	1685.0
1250	339.1	171.0	1695.5
1346	339.2	172.5	1696.0
1442	340.6	179.5	1703.0
1538	341.6	184.5	1708.0
1634	342.0	186.5	1710.0
1730	343.0	191.5	1715.0
1826	343.2	192.5	1716.0
1922	343.7	195.0	1718.5
2018	344.9	201.0	1724.5
2134	347.3	213.0	1736.5

FINAL STRESS STRAIN

(Jan. 31, 1962)

Elapsed Time Hr	Conductor Tension lb	Gage Reading 10^{-3} in	Unit Strain Microin/in
0**	14,000	347.3	1736.5
3	16,237	374.3	1871.5
6	18,179	397.3	1986.5
9	16,237	376.7	1883.5
12	12,347	232.8	1664.0
15	8,474	235.7	1428.5
18	4,607	226.9	1134.5
21	725	119.7	598.5
24	2,644	175.2	876.0
27	4,607	214.1	1070.5
30	6,541	246.7	1233.5

Table 11. (continued)

Elapsed Time Min	Conductor Tension lb	Gage Reading 10^{-3} in	Unit Strain Microin/in
33	8,474	276.2	1381.0
36	10,410	303.0	1515.0
39	12,347	328.3	1641.5
42	14,000	349.5	1747.5

** 2134 Hours = 0 minutes

Table 12. CREEP AND FINAL STRESS STRAIN TEST DATA

SUBJECT: Creep Tests of 460 KV Conductor X(R)-125/1-20
BY: O. G. Paasche, L. M. Wilson DATE: March 10, 1962
PRETENSION: 125% C.T. - 17,500 lb.
PRETENSION TIME: 1 hour
CREEP TENSION: 20% N.S. - 14,000 lb.
CREEP TENSION TIME: 2085 hours
GAGE LENGTH: 200 inches TEMPERATURE: 75°F±2°

Elapse Time Hr	Gage Reading 10^{-3} in	Creep Strain Microin/in	Unit Strain Microin/in
0	0	0	0
1 min*	113.2	0	566.0
3 min	201.0	0	1005.0
5 min	201.0	0	1005.0
10 min	201.0	0	1005.0
15 min	201.0	0	1005.0
30 min	201.5	2.5	1007.5
45 min	202.0	5.0	1010.0
1	202.2	6.0	1011.0
1	168.8	6.0	844.0
1.5	168.6	5.0	843.0
2	168.5	4.5	842.5
3	168.5	4.5	842.5
4	168.5	4.5	842.5
6	168.5	4.5	842.5
8	168.7	5.5	843.5
12	169.1	7.5	845.5
16	169.1	7.5	845.5
24	169.1	7.5	845.5
34½	169.2	8.0	846.0
48	169.5	9.5	847.5
72	169.9	11.5	849.5
96	170.2	13.0	851.0
120	171.0	17.0	855.0
144	171.6	20.0	858.0
168	172.0	22.0	860.0
264	173.3	28.5	866.5
360	175.3	38.5	876.5
456	175.6	40.0	878.0
552	176.8	46.0	884.0
648	177.5	49.5	887.5
744	178.1	52.5	890.5
840	179.1	57.5	895.5

* 9,461 lb. tension

Table 12. (continued)

Elapsed Time Hr	Gage Reading 10^{-3} in	Creep Strain Microin/in	Union Strain Microin/in
936	179.3	58.5	896.5
1032	181.0	67.0	905.0
1128	181.1	67.5	905.5
1224	181.8	71.0	909.0
1320	182.0	72.0	910.0
1416	182.6	75.0	913.0
1512	183.4	79.0	917.0
1608	183.7	80.5	918.5
1704	184.1	82.5	920.5
1800	184.8	86.0	924.0
1896	184.5	84.5	922.5
1992	185.7	90.5	928.5
2085	185.7	90.5	928.5

FINAL STRESS STRAIN

(June 5, 1962)

Conductor Tension lb	Elapsed Time Min	Gage Reading 10^{-3} in	Unit Strain Microin/in
14,000	0**	185.7	928.5
16,301	3	208.5	1042.5
18,248	6	229.1	1145.5
20,195	9	248.1	1240.5
22,142	12	270.8	1354.0
20,195	15	251.5	1257.5
16,301	18	212.8	1064.0
12,377	21	173.5	867.5
8,488	24	133.5	667.5
4,608	27	92.9	464.5
745	30	45.3	226.5
2,682	33	70.3	351.5
4,608	36	92.0	460.0
6,569	39	112.5	562.5
8,488	42	132.5	662.5
10,435	45	152.8	764.0
12,377	48	172.3	861.5
14,000	51	189.4	947.0

** 2085 hours = 0 minutes

Table 13. CREEP AND FINAL STRESS STRAIN TEST DATA

SUBJECT: Creep Test of 460 KV Conductor X(R)-150/1-20
BY: O. G. Paasche, L. M. Wilson DATE: March 10, 1962
PRETENSION: 150% C.T. - 21,000 lb.
PRETENSION TIME: 1 Hour
CREEP TENSION: 20% N.S. - 14,000 lb.
CREEP TENSION TIME: 2087 Hours
GAGE LENGTH: 200 inches TEMPERATURE: 75°F±2°

Elapsed Time Hr	Gage Reading 10^{-3} in	Creep Strain Microin/in	Unit Strain Microin/in
0	0	0	0
1 min*	137.4	0	687.0
3 min	247.2	0	1236.0
5 min	247.2	0	1236.0
10 min	247.9	3.5	1239.5
15 min	248.0	4.0	1240.0
30 min	248.1	4.5	1240.5
45 min	248.2	5.0	1241.0
1	248.5	6.5	1242.5
1	180.0	6.5	900.0
1.5	180.0	6.5	900.0
2	180.0	6.5	900.0
3	180.0	6.5	900.0
4	180.0	6.5	900.0
6	180.0	6.5	900.0
8	180.0	6.5	900.0
12	180.4	8.5	902.0
16	180.7	10.0	903.5
24	181.1	12.0	905.5
35-3/4	181.5	14.0	907.5
49	182.0	16.5	910.0
73	182.5	19.0	912.5
97	183.1	22.0	915.5
121	184.1	27.0	920.5
145	184.3	28.0	921.5
169	184.9	31.0	924.5
265	186.1	37.0	930.5
361	187.3	43.0	936.5
457	188.2	47.5	941.0
553	189.2	52.5	946.0
649	190.8	60.5	954.0
745	190.9	61.0	954.5
841	192.1	66.0	960.5

* 10,821 lb. tension.

Table 13. (continued)

Elapsed Time Hr	Gage Reading 10^{-3} in	Creep Strain Microin/in	Unit Strain Microin/in
937	192.9	70.0	964.5
1033	193.2	71.5	966.0
1129	194.0	75.5	970.0
1225	194.4	77.5	972.0
1321	195.0	80.5	975.0
1417	195.4	82.5	977.0
1513	196.1	85.0	980.5
1609	196.5	87.0	982.5
1705	197.0	89.5	985.0
1801	198.1	94.0	990.5
1897	198.1	94.5	990.5
1993	198.5	96.5	992.5
2087	198.9	98.5	994.5

FINAL STRESS STRAIN

(June 5, 1962)

Conductor Tension lb	Elapsed Time Min	Gage Reading 10^{-3} in	Unit Strain Microin/in
14,000	0**	198.9	994.5
16,892	3	228.1	1140.5
18,941	6	248.3	1241.5
20,933	9	268.8	1344.0
22,929	12	290.6	1453.0
20,933	15	270.1	1350.5
16,892	18	230.2	1151.0
12,856	21	188.3	941.5
8,808	24	148.0	740.0
4,772	27	105.2	526.0
769	29	49.7	248.5
2,768	33	78.9	394.5
4,772	36	103.2	516.0
6,793	39	125.3	626.5
8,808	42	146.3	731.5
10,821	45	167.2	836.0
12,856	48	187.8	939.0
14,000	51	199.3	996.5

** 2087 hours = 0 minutes

Table 14. CREEP AND FINAL STRESS STRAIN TEST DATA

SUBJECT: Creep Test of 460 KV Conductor X(AN)-125/1-20-2
BY: O. G. Paasche, L. M. Wilson DATE: March 10, 1962
PRETENSION: 125% C.T. - 17,500 lb.
PRETENSION TIME: 1 hour
CREEP TENSION: 20% N.S. - 14,000 lb.
CREEP TENSION TIME: 2069 hours
GAGE LENGTH: 200 inches TEMPERATURE: 75°F±2°

Elapsed Time Hr	Gage Reading 10^{-3} in	Creep Strain Microin/in	Unit Strain Microin/in
0	0	752 lb*	0
3 min	47.9-47.9	4,700 lb	239.5
6 min	94.0-94.0	8,650 lb	470.0
9 min	139.2-139.6	12,600 lb	698.0
12 min	161.1-162.0	14,550 lb	810.0
15 min	195.6-196.4	17,500 lb	982.0
20 min	198.3	9.5	991.5
25 min	199.6	16.0	998.0
30 min	200.3	19.5	1001.5
45 min	202.0	28.0	1010.0
1	203.4	35.0	1017.0
1.25	204.2	39.0	1021.0
1.25	172.9	39.0	864.5
1.45	172.4	36.5	862.0
2.25	172.3	36.0	861.5
3.25	173.9	44.0	869.5
4.25	173.9	44.0	869.5
6.25	173.9	44.0	869.5
8.25	173.9	44.0	869.5
12.25	175.1	50.0	875.5
16.25	176.2	55.5	881.0
24.25	177.9	64.0	889.5
37.45	179.1	70.0	895.5
51	180.5	77.0	902.5
75	182.2	85.5	911.0
99	184.0	94.5	920.0
123	186.1	105.0	930.5
147	187.2	100.5	936.0
171	188.2	115.5	941.0
267	191.9	134.0	959.5
363	194.1	145.0	970.5
459	196.1	155.0	980.5
555	197.9	164.0	989.5

* Slow load to zero creep time (15 minutes)

Table 14. (continued)

Elapsed Time Hr	Gage Reading 10^{-3} in	Creep Strain Microin/in	Unit Strain Microin/in
651	200.1	175.0	1000.5
747	201.1	180.0	1005.5
843	202.9	189.0	1014.5
939	203.9	194.0	1019.5
1035	205.2	200.5	1026.0
1131	206.4	206.5	1032.0
1227	206.9	209.0	1034.5
1323	208.0	214.5	1040.0
1419	208.4	216.5	1042.0
1515	209.4	221.5	1047.0
1611	210.2	225.5	1051.0
1707	211.0	229.5	1055.0
1803	212.4	236.5	1062.0
1899	212.1	235.0	1060.5
1995	213.1	240.0	1065.5
2069	212.9	239.0	1064.5

FINAL STRESS STRAIN

(June 4, 1962)

Conductor Tension lb	Elapsed Time Min	Gage Reading 10^{-3} in	Unit Strain Microin/in
14,000	0**	212.9	1064.5
16,536	3	239.5	1197.5
18,509	6	258.8	1294.0
20,482	8	278.7	1393.5
22,455	12	299.6	1498.0
20,482	15	282.3	1411.5
16,536	18	245.0	1225.0
12,590	21	205.8	1029.0
8,644	24	168.0	840.0
4,698	27	124.7	623.5
752	30	19.2	96.0
2,725	33	87.5	437.5
4,698	36	117.2	586.0

** 2069 hours = 0 minutes

Table 14. (continued)

Conductor Tension lb	Elapsed Time Min	Gage Reading 10^{-3} in	Unit Strain Microin/in
6,671	39	141.7	708.5
8,644	42	162.5	812.5
10,617	45	181.8	909.0
12,590	48	201.9	1009.5
14,000	51	217.0	1085.0

Table 15. CREEP AND FINAL STRESS STRAIN TEST DATA

SUBJECT: Creep Test of 460 KV Conductor X(AN)-150/1-20
BY: O. G. Paasche, L. M. Wilson DATE: March 10, 1962
PRETENSION: 150% C.T. - 21,000 lb.
PRETENSION TIME: 1 hour
CREEP TENSION: 20% N.S. - 14,000 lb.
CREEP TENSION TIME: 2083 hours
GAGE LENGTH: 200 inches TEMPERATURE: 75°F±2°

Elapsed Time Hr	Gage Reading 10^{-3} in	Creep Strain Microin/in	Unit Strain Microin/in
0	0	0	0
1 min*	128.8	0	644.0
3 min	231.0	0	1155.0
5 min	233.1	10.5	1165.5
10 min	235.3	21.5	1176.5
15 min	236.9	29.5	1184.5
30 min	239.4	42.0	1197.0
45 min	243.5	62.5	1217.5
1	245.8	74.0	1229.0
1	180.1	74.0	900.5
1.5	180.1	74.0	900.5
2	180.0	73.5	900.0
3	180.1	74.0	900.5
4	180.4	75.5	902.0
6	181.0	78.5	905.0
8	181.5	81.0	907.5
12	182.5	86.0	912.5
16	183.5	91.0	917.5
24	184.2	94.5	921.0
33½	185.3	100.0	926.5
47	186.6	106.5	933.0
71	188.5	116.0	942.5
95	190.0	123.5	950.0
119	191.8	132.5	959.0
143	192.9	138.0	964.5
167	194.0	143.5	970.0
263	197.1	159.0	985.5
359	200.2	174.5	1001.0
455	202.0	183.5	1010.0
551	203.9	193.0	1019.5
647	205.2	199.5	1026.0
743	207.0	208.5	1035.0
839	208.1	214.0	1040.5

* 11,079 lb. tension

Table 15. (continued)

Elapsed Time Hr	Gage Reading 10^{-3} in	Creep Strain Microin/in	Unit Strain Microin/in
935	209.0	218.5	1045.0
1031	211.2	229.5	1056.0
1127	211.6	231.5	1058.0
1223	212.8	237.5	1064.0
1319	213.6	241.5	1068.0
1415	214.5	246.0	1072.5
1511	215.5	251.0	1077.5
1607	216.2	254.5	1081.0
1703	217.0	258.5	1085.0
1799	218.7	267.0	1093.5
1895	217.9	263.0	1089.5
1991	218.8	267.5	1094.0
2083	219.1	269.0	1095.5

FINAL STRESS STRAIN
(June 5, 1962)

Conductor Tension lb	Elapsed Time Min	Gage Reading 10^{-3} in	Unit Strain Microin/in
14,000	0**	219.1	1095.5
17,276	3	250.3	1251.5
19,321	6	270.9	1354.5
21,383	9	292.2	1461.0
23,445	12	314.2	1571.0
21,383	15	296.1	1480.5
17,276	18	256.3	1281.5
13,134	21	216.3	1081.5
9,019	24	175.9	879.5
4,889	27	134.4	672.0
788	30	35.5	177.5
2,842	33	102.5	512.5
4,889	36	127.3	636.5
6,958	39	148.9	744.5
9,019	42	169.9	849.5
11,079	45	191.2	956.0
13,134	48	212.3	1061.5
14,000	51	220.3	1101.5

** 2083 hours = 0 minutes

Table 16. CREEP AND FINAL STRESS STRAIN TEST DATA

SUBJECT: Creep Test of 460 KV Conductor A(K)-125/1-20
BY: O. G. Paasche, L. M. Wilson DATE: March 10, 1962
PRETENSION: 125% C.T. - 17,500 lb.
PRETENSION TIME: 1 hour
CREEP TENSION: 20% N.S. - 14,000 lb.
CREEP TENSION TIME: 2070 hours
GAGE LENGTH: 200 inches TEMPERATURE: 75°F±2°

Elapsed Time Hr	Gage Reading 10^{-3} in	Creep Strain Microin/in	Unit Strain Microin/in
0	0	0	0
1 min*	116.0	0	580.0
3 min	217.0	0	1085.0
5 min	218.9	9.5	1094.5
10 min	219.9	14.5	1099.5
15 min	223.1	20.5	1115.5
30 min	224.1	25.5	1120.5
45 min	---	---	---
1	224.9	29.5	1124.5
1	193.1	29.5	965.5
1.5	193.0	29.0	965.0
2	193.0	29.0	965.0
3	193.6	32.0	968.0
4	193.9	33.5	969.5
6	194.4	36.0	972.0
8	195.0	39.0	975.0
12	195.0	39.0	975.0
16	196.0	44.0	980.0
24	197.1	49.5	985.5
36	198.8	58.0	994.0
50	199.9	63.5	999.5
74	201.0	69.0	1005.0
98	201.1	69.5	1005.5
122	202.8	78.0	1014.0
146	203.4	81.0	1017.0
170	204.8	88.0	1024.0
266	206.6	97.0	1033.0
362	209.6	112.0	1048.0
458	209.7	112.5	1048.5
554	211.0	119.0	1055.0
650	212.1	124.5	1060.5
746	213.0	129.0	1065.0
842	214.1	134.5	1070.5
938	214.8	138.0	1074.0

* 9,442 lb. tension

Table 16. (continued)

Elapsed Time Hr	Gage Reading 10^{-3} in	Creep Strain Microin/in	Unit Strain Microin/in
1034	216.9	148.5	1084.5
1130	217.0	149.0	1085.0
1226	217.8	153.0	1089.0
1322	217.8	153.0	1089.0
1418	218.3	155.5	1091.5
1514	219.1	159.5	1095.5
1610	219.5	161.5	1097.5
1706	220.0	164.0	1100.0
1802	220.3	165.5	1101.5
1898	220.9	168.0	1104.5
1994	221.6	171.5	1108.0
2070	221.1	169.0	1105.5

FINAL STRESS STRAIN
(June 4, 1962)

Conductor Tension lb	Elapsed Time Min	Gage Reading 10^{-3} in	Unit Strain Microin/in
14,000	0**	221.1	1105.5
16,237	3	242.8	1214.0
18,179	6	261.0	1305.0
20,117	9	283.8	1419.0
22,055	12	309.0	1545.0
20,117	15	291.2	1456.0
16,237	19	255.3	1276.5
12,347	21	219.2	1096.0
8,474	24	183.6	918.0
4,607	27	145.2	726.0
725	30	64.0	320.0
2,644	33	121.3	606.5
4,607	36	142.8	714.0
6,541	39	163.3	816.5
8,474	42	182.3	911.5
10,410	45	200.5	1002.5
12,347	48	218.8	1094.0
14,000	51	234.8	1174.0

** 2070 hours = 0 minutes

Table 17. CREEP AND FINAL STRESS STRAIN TEST DATA

SUBJECT: Creep Test of 460 KV Conductor X(K)-150/1-20
BY: O. G. Paasche, L. M. Wilson DATE: March 10, 1962
PRETENSION: 150% C.T. - 21,000 lb.
PRETENSION TIME: 1 hour
CREEP TENSION: 20% N.S. - 14,000 lb.
CREEP TENSION TIME: 2069 hours
GAGE LENGTH: 200 inches TEMPERATURE: 75°F±2°

Elapsed Time Hr	Gage Reading 10^{-3} in	Creep Strain Microin/in	Unit Strain Microin/in
0	0	0	0
1 min*	135.1	0	675.5
3 min	254.0-254.5	0	1272.5
5 min	257.2	13.5	1286.0
10 min	259.5	25.0	1297.5
15 min	260.9	32.0	1304.5
30 min	263.1	43.0	1315.5
45 min	265.1	53.0	1325.5
1	265.2	53.5	1326.0
1	203.1	53.5	1015.5
1.5	202.9	52.5	1014.5
2	203.0	53.0	1015.0
3	203.0	53.0	1015.0
4	203.1	53.5	1015.5
6	203.1	53.5	1015.5
8	203.5	55.5	1017.5
12	204.2	59.0	1012.0
16	204.6	61.0	1023.0
24	205.6	66.0	1028.0
36	206.4	70.0	1032.0
50	207.0	73.0	1035.0
74	208.1	77.5	1040.5
98	209.1	82.5	1045.5
122	210.1	87.5	1050.5
146	211.1	92.5	1055.5
170	212.0	97.0	1060.0
266	214.2	108.0	1071.0
362	216.1	117.5	1080.5
458	217.1	122.5	1085.5
554	218.2	128.0	1091.0
650	219.3	133.5	1096.5
746	220.5	139.5	1102.5
842	221.3	143.5	1106.5
938	221.9	146.5	1109.5

* 11,687 lb. tension

Table 17. (continued)

Elapsed Time Hr	Gage Reading 10^{-3} in	Creep Strain Microin/in	Unit Strain Microin/in
1034	223.3	153.5	1116.5
1130	223.6	155.0	1118.0
1226	224.3	158.5	1121.5
1322	224.8	161.0	1124.0
1418	225.8	166.0	1129.0
1514	226.3	168.5	1131.5
1610	226.8	171.0	1134.0
1706	227.4	174.0	1137.0
1802	228.3	178.5	1141.5
1898	228.2	178.0	1141.0
1994	228.8	181.0	1144.0
2069	228.6	180.0	1143.0

FINAL STRESS STRAIN
(June 4, 1962)

Conductor Tension lb	Elapsed Time Min	Gage Reading 10^{-3} in	Unit Strain Microin/in
14,000	0**	228.6	1143.0
16,670	3	252.5	1262.5
18,661	6	271.1	1355.0
20,652	9	289.3	1446.5
22,643	12	310.3	1551.5
20,652	15	293.1	1465.5
16,670	18	258.5	1292.5
12,688	21	221.8	1109.0
8,706	24	184.9	924.5
4,724	27	145.5	727.5
741	30	60.7	303.5
2,733	33	121.8	609.0
4,724	36	143.9	719.5
6,717	39	163.5	817.5
8,706	42	183.4	917.0
10,687	45	202.2	1011.0
12,688	48	220.8	1104.0
14,000	51	233.9	1169.5

** 2069 hours = 0 minutes

Table 18. INITIAL STRESS STRAIN TEST DATA

SUBJECT: Initial Stress-Strain of 460 KV Expanded Conductor X(SE)-1

BY: L. E. Johnson, L. M. Wilson DATE: Feb. 21, 1962

GAGE LENGTH: 200 inches TEMPERATURE: 75°F±2°

TIME: Time is time of load change, gage reading taken $2\frac{1}{2}$ minutes later than indicated.

Elapsed Time Min	Conductor Tension lb	Gage Reading 10^{-3} in	Unit Strain Microin/in
0	725	0	0
3	2,644	133.3	665.5
6	4,607	167.3	836.5
9	6,541	195.8	979.0
12	8,474	223.2	1116.0
15	10,410	248.3	1241.5
18	12,347	272.3	1361.5
21	14,278	295.0	1475.0
24	16,237	317.3	1586.3
27	18,179	340.1	1700.5
30	20,117	363.9	1819.5
33	22,055	387.0	1935.0
36	20,177	370.6	1853.0
39	16,237	335.6	1678.0
42	12,347	298.1	1490.5
45	8,474	256.1	1280.5
48	4,607	204.9	1024.5
51	725	122.7	613.5
54	2,644	170.9	854.5
57	4,607	198.0	990.0
60	6,541	224.6	1123.0
63	8,474	250.1	1250.5
66	10,410	273.0	1365.0
69	12,347	292.9	1464.5
72	14,000	310.2	1551.0

Table 19. INITIAL STRESS STRAIN TEST DATA

SUBJECT: Initial Stress-Strain of 460 KV Expanded Conductor X(SE)-2

BY: L. E. Johnson, L. M. Wilson DATE: Feb. 21, 1962

GAGE LENGTH: 200 inches TEMPERATURE: 75°F±2°

TIME: Time is time of load change, gage reading taken $2\frac{1}{2}$ minutes later than indicated.

Elapsed Time Min	Conductor Tension lb	Gage Reading 10^{-3} in	Unit Strain Microin/in
0	788	0	0
3	2,842	98.8	494.0
6	4,889	132.4	662.0
9	6,958	161.8	809.0
12	9,019	187.9	939.5
15	11,079	212.4	1062.0
18	13,134	236.5	1182.5
21	15,189	259.0	1295.0
24	17,276	282.0	1410.0
27	19,321	305.8	1529.0
30	21,383	330.1	1650.5
33	23,445	354.3	1771.5
36	21,383	337.2	1686.0
39	17,276	300.7	1503.5
42	13,134	260.7	1303.5
45	9,019	219.7	1098.5
48	4,889	168.2	841.0
51	788	92.8	464.0
54	2,842	133.2	666.0
57	4,889	162.3	811.5
60	6,958	189.5	947.5
63	9,019	213.4	1067.0
66	11,079	234.6	1173.0
69	13,134	255.2	1276.0
72	14,000	266.3	1331.5

Table 20. INITIAL STRESS STRAIN TEST DATA

SUBJECT: Initial Stress-Strain of 460 KV Expanded Conductor X(AWR)-1

BY: L. E. Johnson, L. M. Wilson DATE: Feb. 21, 1962

GAGE LENGTH: 200 inches TEMPERATURE: 75°F±2°

TIME: Time is time of load change, gage reading taken $2\frac{1}{2}$ minutes later than indicated.

Elapsed Time Min	Conductor Tension lb	Gage Reading 10^{-3} in	Unit Strain Microin/in
0	745	0	
3	2,682	64.6	323.0
6	4,608	113.4	567.0
9	6,569	156.7	783.5
12	8,488	194.3	971.5
15	10,435	228.7	1143.5
18	12,377	261.1	1305.5
21	14,304	292.3	1461.5
24	16,301	315.9	1579.5
27	18,248	338.7	1693.5
30	20,195	363.6	1818.0
33	22,142	391.0	1955.0
36	20,195	370.0	1850.0
39	16,301	326.5	1632.5
42	12,377	279.7	1398.5
45	8,488	227.2	1136.0
48	4,608	161.8	809.0
51	745	55.8	279.0
54	2,682	107.3	536.5
57	4,608	148.4	742.0
60	6,569	183.2	916.0
63	8,488	214.1	1070.5
66	10,435	242.9	1214.5
69	12,377	270.9	1354.5
72	14,000	293.1	1465.5

Table 21. INITIAL STRESS STRAIN TEST DATA

SUBJECT: Initial Stress-Strain of 460 KV Expanded Conductor X(AWR)

BY: L. E. Johnson, L. M. Wilson DATE: Feb. 21, 1962

GAGE LENGTH: 200 inches TEMPERATURE: 75°F±2°

TIME: Time is time of load change, gage reading taken $2\frac{1}{2}$ minutes later than indicated.

Elapsed Time Min	Conductor Tension lb	Gage Reading 10^{-3} in	Unit Strain Microin/in
0	769	0	
3	2,768	67.4	337.0
6	4,772	119.5	597.5
9	6,793	162.1	810.5
12	8,808	199.3	996.5
15	10,821	233.7	1168.5
18	12,856	267.8	1339.0
21	14,867	300.7	1503.5
24	16,892	332.8	1664.0
27	18,941	364.3	1821.5
30	20,933	393.3	1966.5
33	21,929	407.1	2035.5
36	20,933	385.7	1928.5
39	16,892	341.6	1708.0
42	12,856	292.2	1461.0
45	8,808	238.2	1191.0
48	4,772	171.1	855.5
51	769	55.3	276.5
54	2,768	113.1	565.5
57	4,772	156.8	784.0
60	6,793	193.9	969.5
63	8,808	226.0	1130.0
66	10,821	254.0	1270.0
69	12,856	281.6	1408.0
72	14,000	297.1	1485.5

Table 22. INITIAL STRESS STRAIN TEST DATA

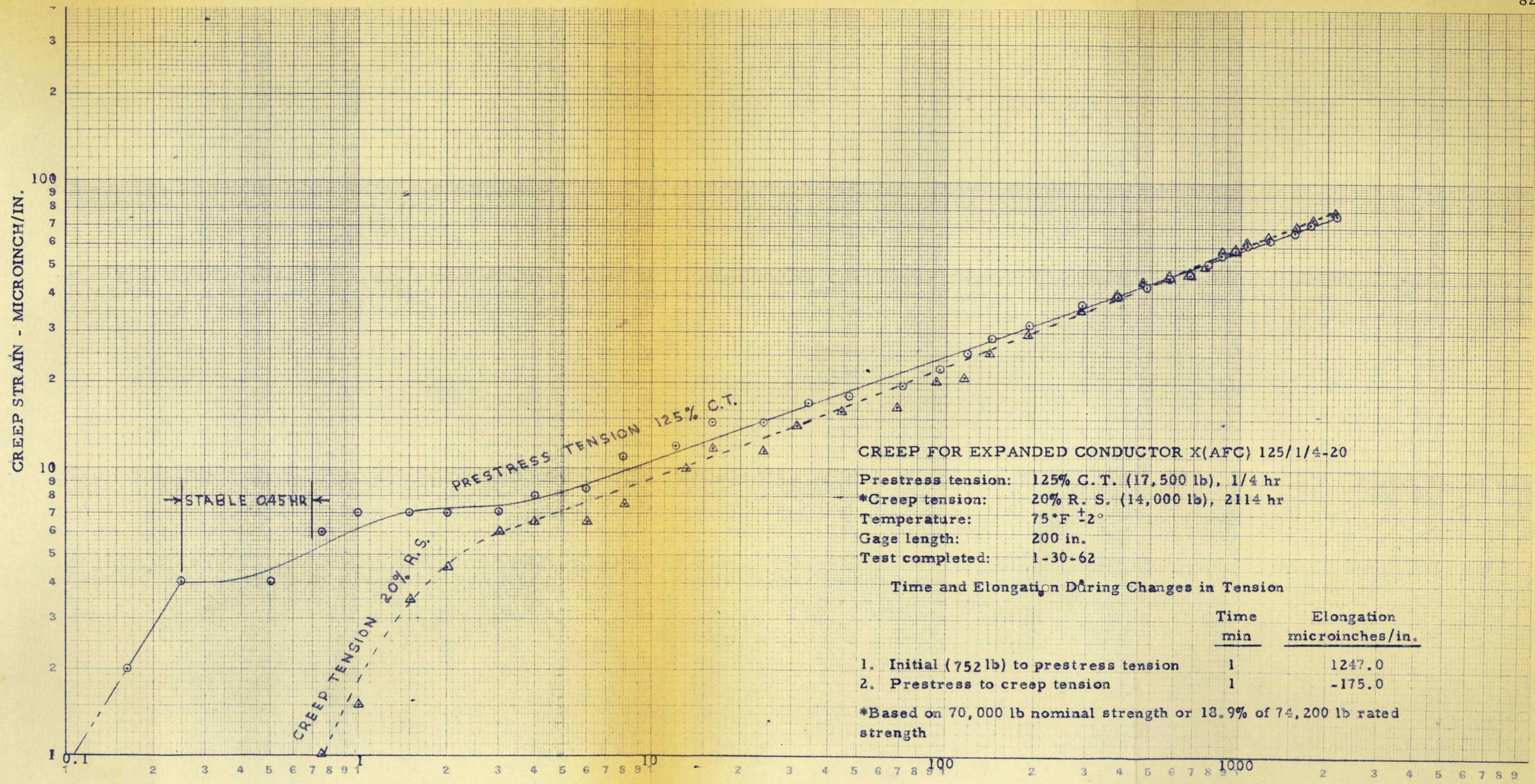
SUBJECT: Initial Stress-Strain of ACSR Pheasant Conductor P-2
BY: L. E. Johnson, L. M. Wilson DATE: Feb. 17, 1962
GAGE LENGTH: 200 inches TEMPERATURE: 75°F±3°
TIME: Time is time of load change, gage reading taken $2\frac{1}{2}$ minutes later than indicated.

Elapsed Time Min	Conductor Tension lb	Gage Reading 10^{-3} in	Unit Strain Microin/in
0	752	0	0
3	2,725	54.3	271.5
6	4,698	96.3	481.5
9	6,671	134.9	634.5
12	8,644	172.4	862.0
15	10,617	209.2	1046.0
18	12,590	246.7	1233.5
21	14,563	285.3	1426.5
24	16,536	326.0	1630.0
27	18,509	369.6	1848.0
30	16,536	338.2	1691.0
33	12,590	273.8	1364.0
36	8,644	206.6	1033.0
39	4,698	135.0	675.0
42	752	34.6	173.0
45	2,725	91.4	457.0
48	4,698	131.0	655.0
51	6,671	167.2	836.0
54	8,644	201.8	1009.0
57	10,617	235.2	1176.0

Table 23. INITIAL STRESS STRAIN TEST DATA

SUBJECT: Initial Stress-Strain of ACSR Pheasant Conductor P-3
BY: L. E. Johnson, L. M. Wilson DATE: Feb. 17, 1962
GAGE LENGTH: 200 inches TEMPERATURE: 75°F±2°
TIME: Time is time of load change, gage reading taken $2\frac{1}{2}$ minutes later than indicated.

Elapsed Time Min	Conductor Tension lb	Gage Reading 10^{-3} in	Unit Stress Microin/in
0	741	0	0
3	2,733	58.8	294.0
6	4,724	108.0	540.0
9	6,717	150.9	754.5
12	8,706	190.9	954.5
15	10,687	230.9	1154.5
18	12,688	271.4	1357.0
21	14,679	312.8	1564.0
24	16,670	356.1	1780.5
27	18,661	401.5	2007.5
30	16,670	369.2	1846.0
33	12,688	301.7	1508.5
36	8,706	232.1	1160.5
39	4,724	158.0	790.0
42	741	30.6	158.0
45	2,733	105.7	528.5
48	4,724	152.9	764.5
51	6,717	191.2	956.0
54	8,706	227.2	1136.0
57	10,687	262.8	1314.0



CREEP FOR EXPANDED CONDUCTOR X(AFC) 125/1/4-20

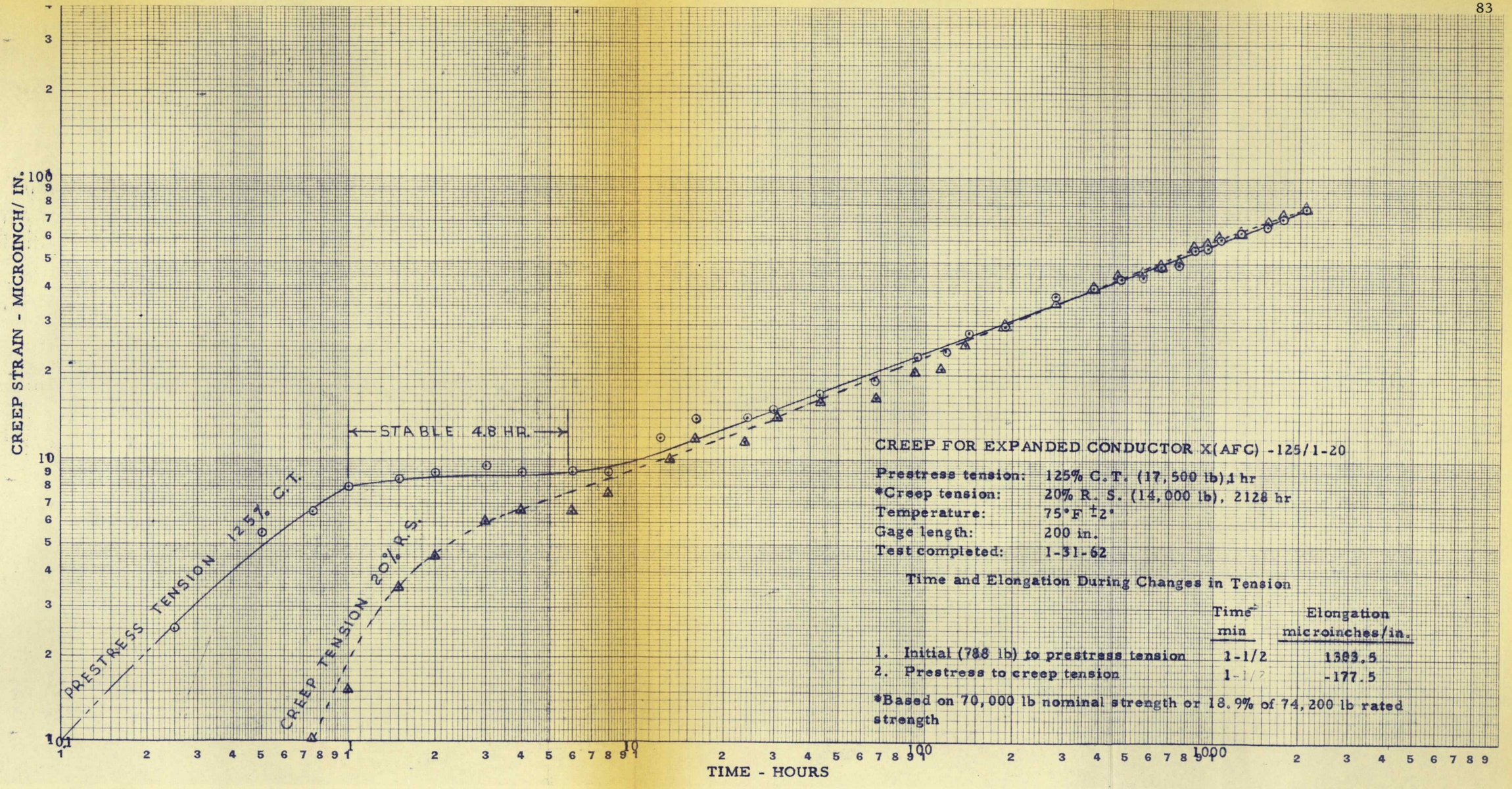
Prestress tension:	125% C.T. (17,500 lb), 1/4 hr
*Creep tension:	20% R.S. (14,000 lb), 2114 hr
Temperature:	75°F ±2°
Gage length:	200 in.
Test completed:	1-30-62

Time and Elongation During Changes in Tension

	Time min	Elongation microinches/in.
1. Initial (752 lb) to prestress tension	1	1247.0
2. Prestress to creep tension	1	-175.0

*Based on 70,000 lb nominal strength or 18.9% of 74,200 lb rated strength

Figure 14



CREEP FOR EXPANDED CONDUCTOR X(AFC) -125/1-20

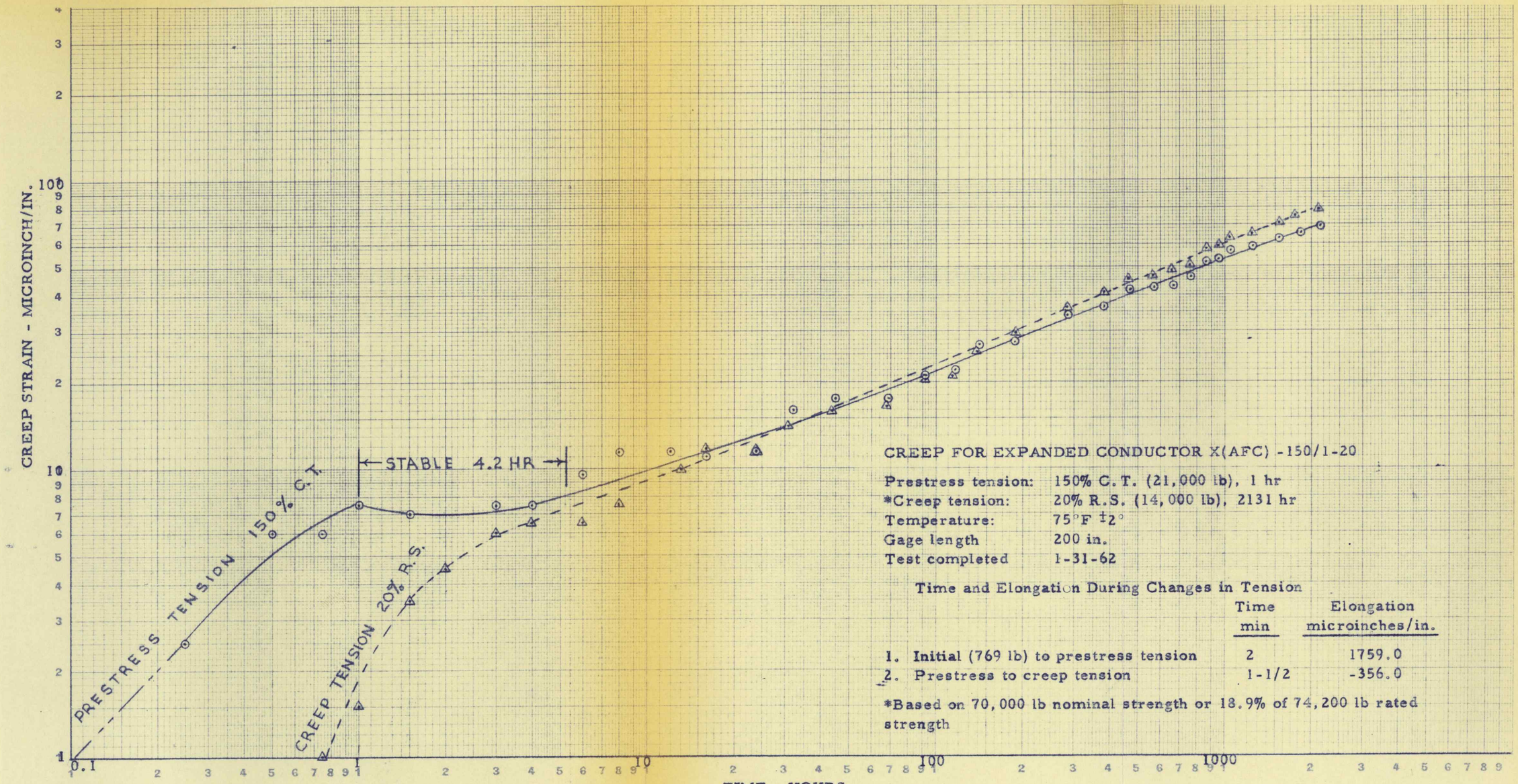
Prestress tension:	125% C. T. (17,500 lb), 1 hr
*Creep tension:	20% R. S. (14,000 lb), 2128 hr
Temperature:	75°F ±2°
Gage length:	200 in.
Test completed:	1-31-62

Time and Elongation During Changes in Tension

	Time min	Elongation microinches/in.
1. Initial (788 lb) to prestress tension	1-1/2	1383.5
2. Prestress to creep tension	1-1/2	-177.5

*Based on 70,000 lb nominal strength or 18.9% of 74,200 lb rated strength

Figure 15



CREEP FOR EXPANDED CONDUCTOR X(AFC) -150/1-20

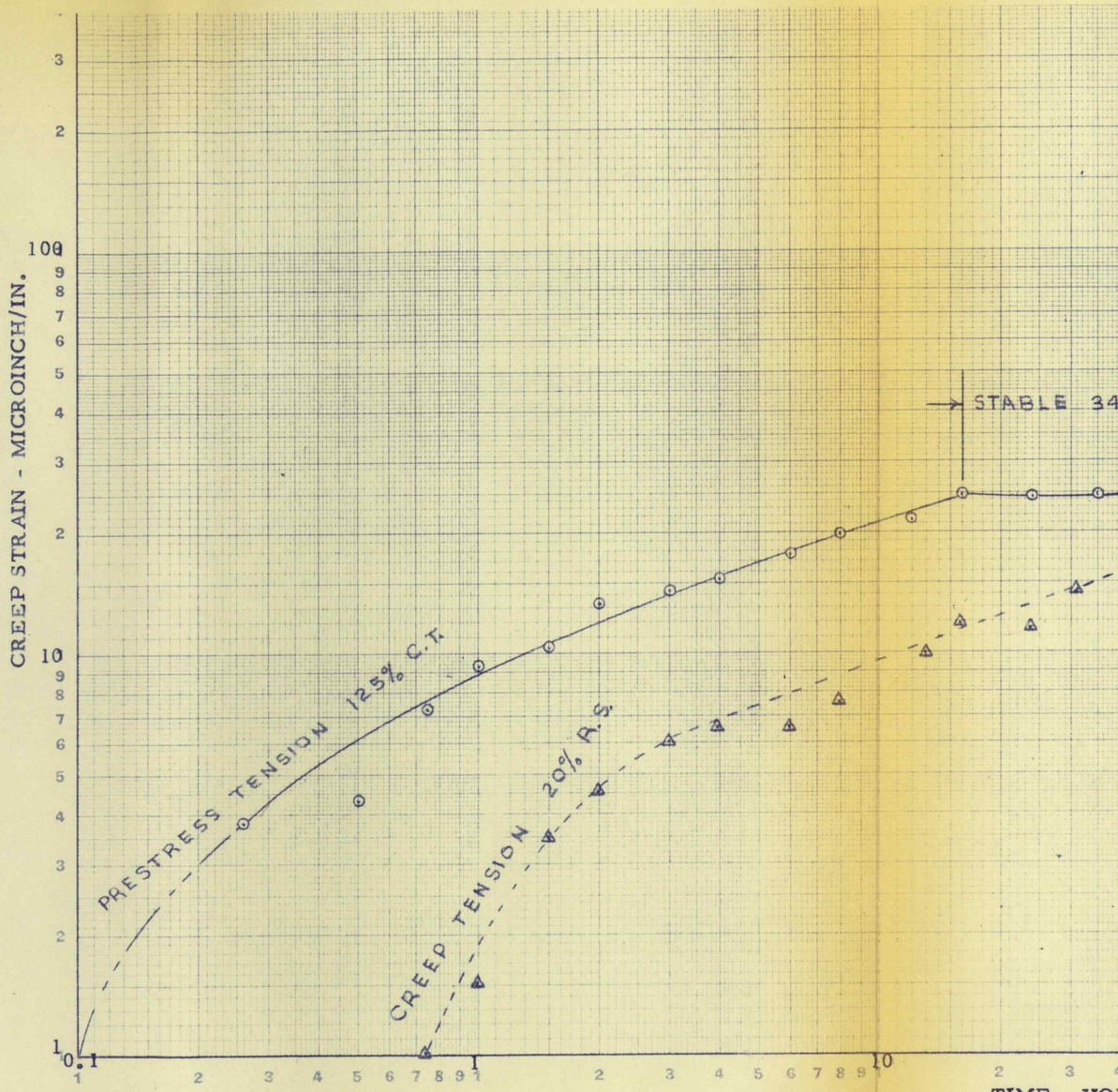
Prestress tension:	150% C.T. (21,000 lb), 1 hr
*Creep tension:	20% R.S. (14,000 lb), 2131 hr
Temperature:	75°F ±2°
Gage length	200 in.
Test completed	1-31-62

Time and Elongation During Changes in Tension

	Time min	Elongation microinches/in.
1. Initial (769 lb) to prestress tension	2	1759.0
2. Prestress to creep tension	1-1/2	-356.0

*Based on 70,000 lb nominal strength or 18.9% of 74,200 lb rated strength

Figure 16



CREEP FOR EXPANDED CONDUCTOR X(AFC) 125/16-20

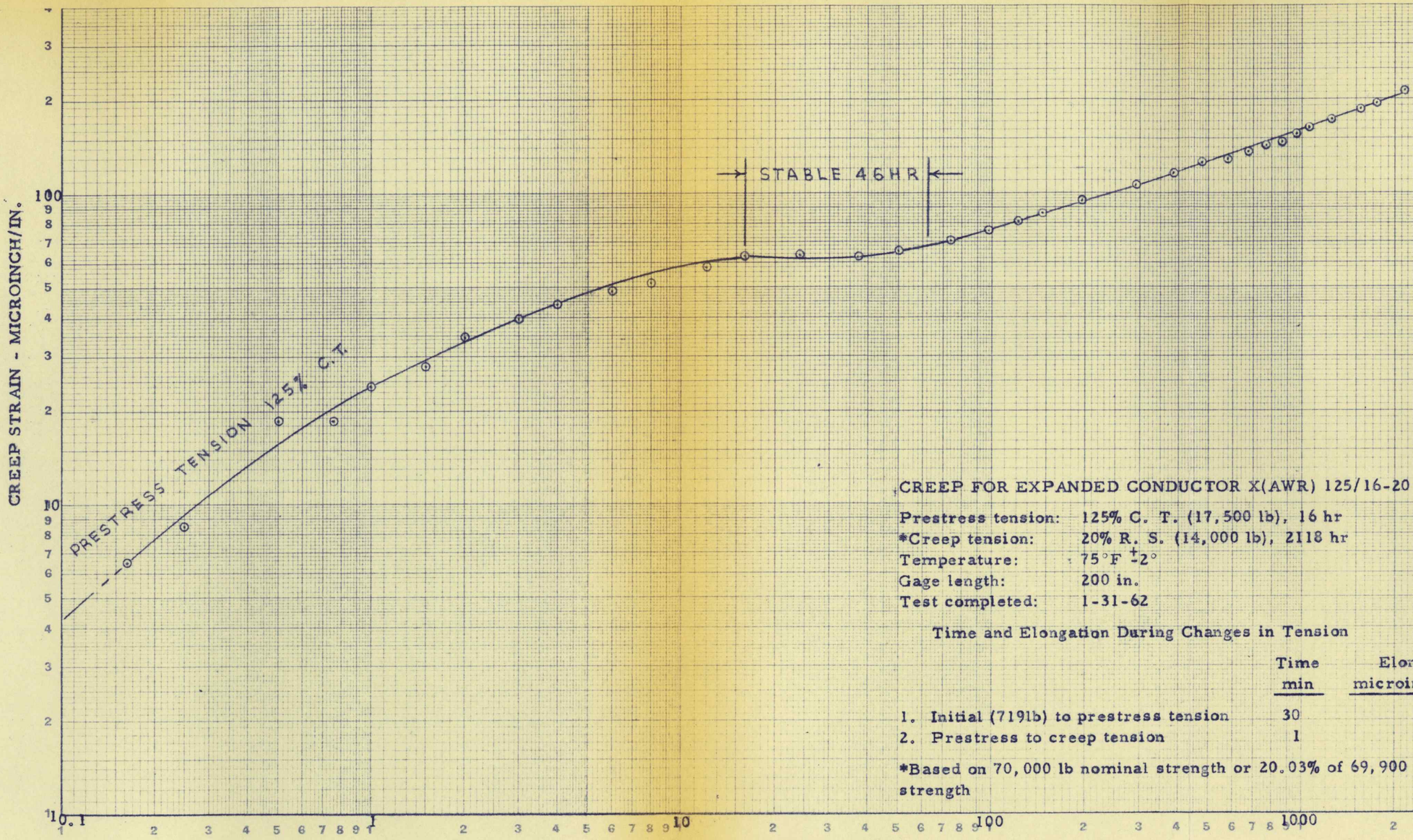
Prestress tension:	125% C. T. (17,500 lb), 16 hr
*Creep tension:	20% R. S. (14,000 lb), 2101 hr
Temperature:	75°F ±2°
Gage length:	200 in.
Test completed:	1-30-62

Time and Elongation During Changes in Tension

	Time min	Elongation microinches/in.
1. Initial (741 lb) to prestress tention	1	1191.2
2. Prestress to creep tension	1	-175.5

*Based on 70,000 lb nominal strength or 18.9% of 74,200 lb rated strength

Figure 17



CREEP FOR EXPANDED CONDUCTOR X(AWR) 125/16-20-2

Prestress tension:	125% C. T. (17,500 lb), 16 hr
*Creep tension:	20% R. S. (14,000 lb), 2118 hr
Temperature:	75°F ±2°
Gage length:	200 in.
Test completed:	1-31-62

Time and Elongation During Changes in Tension

	Time min	Elongation microinches/in.
1. Initial (719lb) to prestress tension	30	1722.0
2. Prestress to creep tension	1	-197.5

*Based on 70,000 lb nominal strength or 20.03% of 69,900 lb rated strength

Figure 18

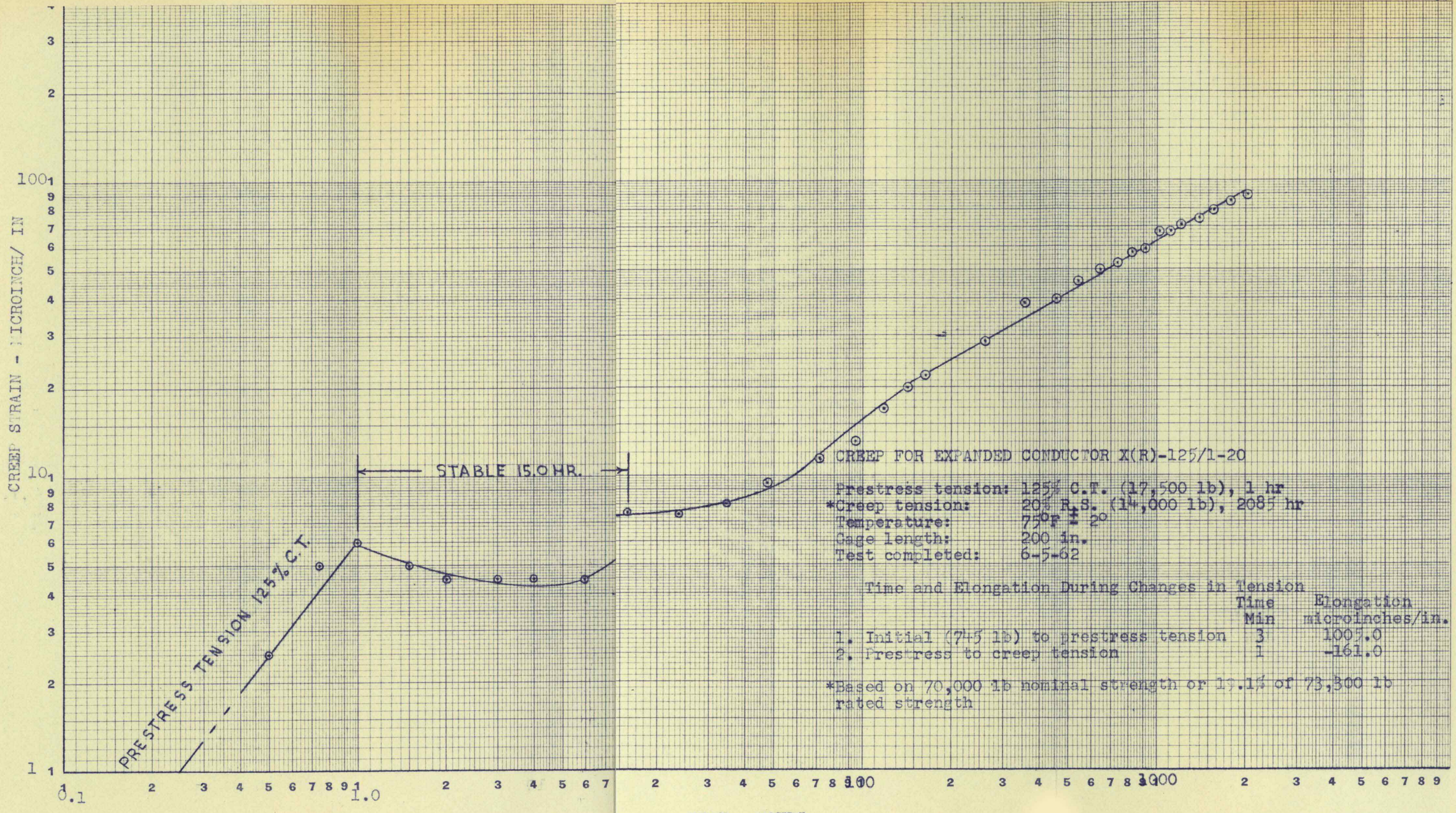
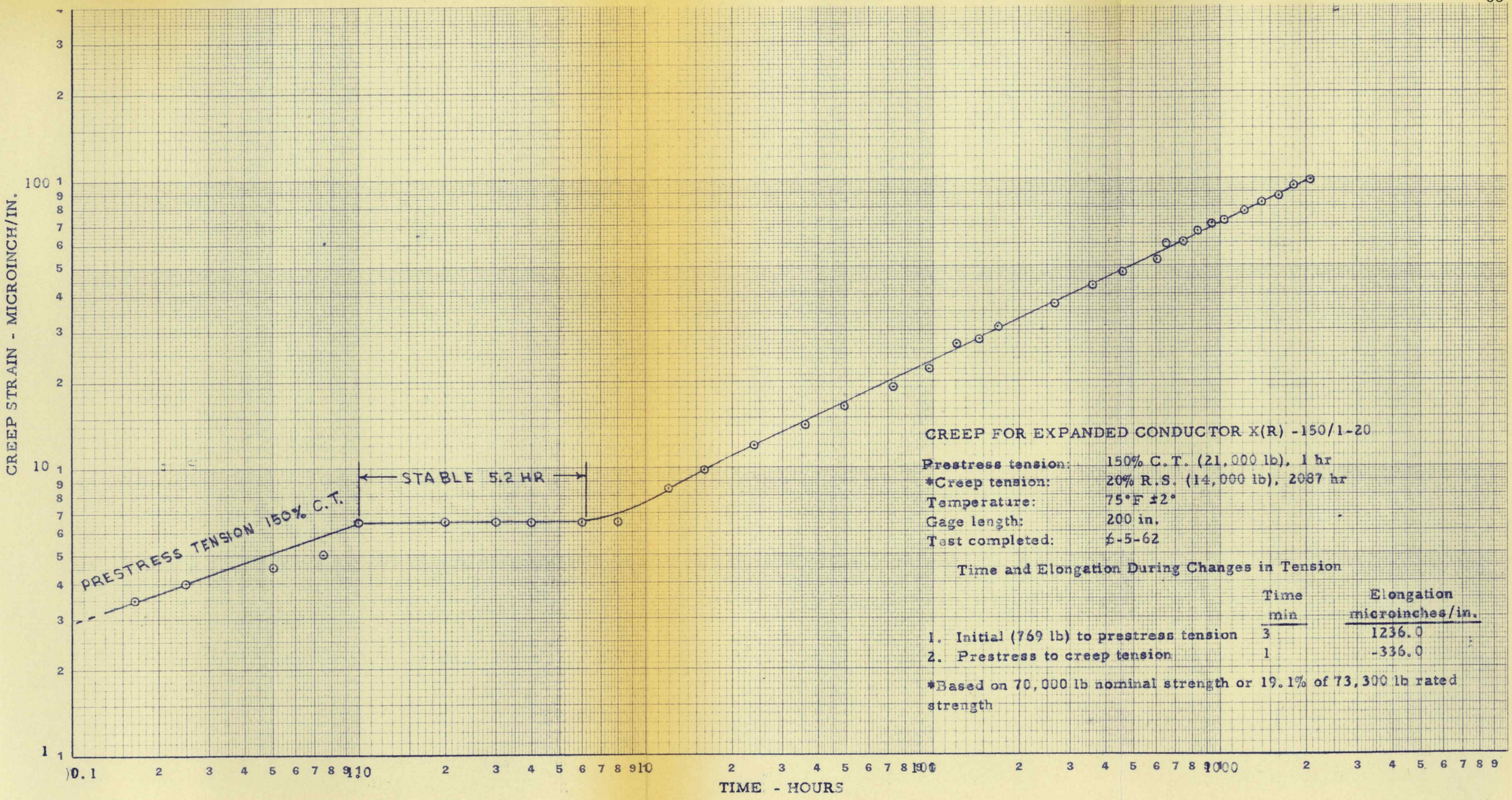

CREEP STRAIN - MICROINCH/ IN
100
10
1
STABLE 15.0 HR.
PRESTRESS TENSION 125% C.T.
0.1
1.0
10
100
1000
TIME - HOURS
CREEP FOR EXPANDED CONDUCTOR X(R)-125/1-20
Prestress tension: 125% C.T. (17,500 lb), 1 hr
*Creep tension: 20% R.S. (14,000 lb), 2085 hr
Temperature: 75°F ± 2°
Cage length: 200 in.
Test completed: 6-5-62
Time and Elongation During Changes in Tension
Time Min
Elongation microinches/in.
1. Initial (745 lb) to prestress tension 3 1007.0
2. Prestress to creep tension 1 -161.0
*Based on 70,000 lb nominal strength or 19.1% of 73,300 lb rated strength

Figure 19



CREEP FOR EXPANDED CONDUCTOR X(R) -150/1-20

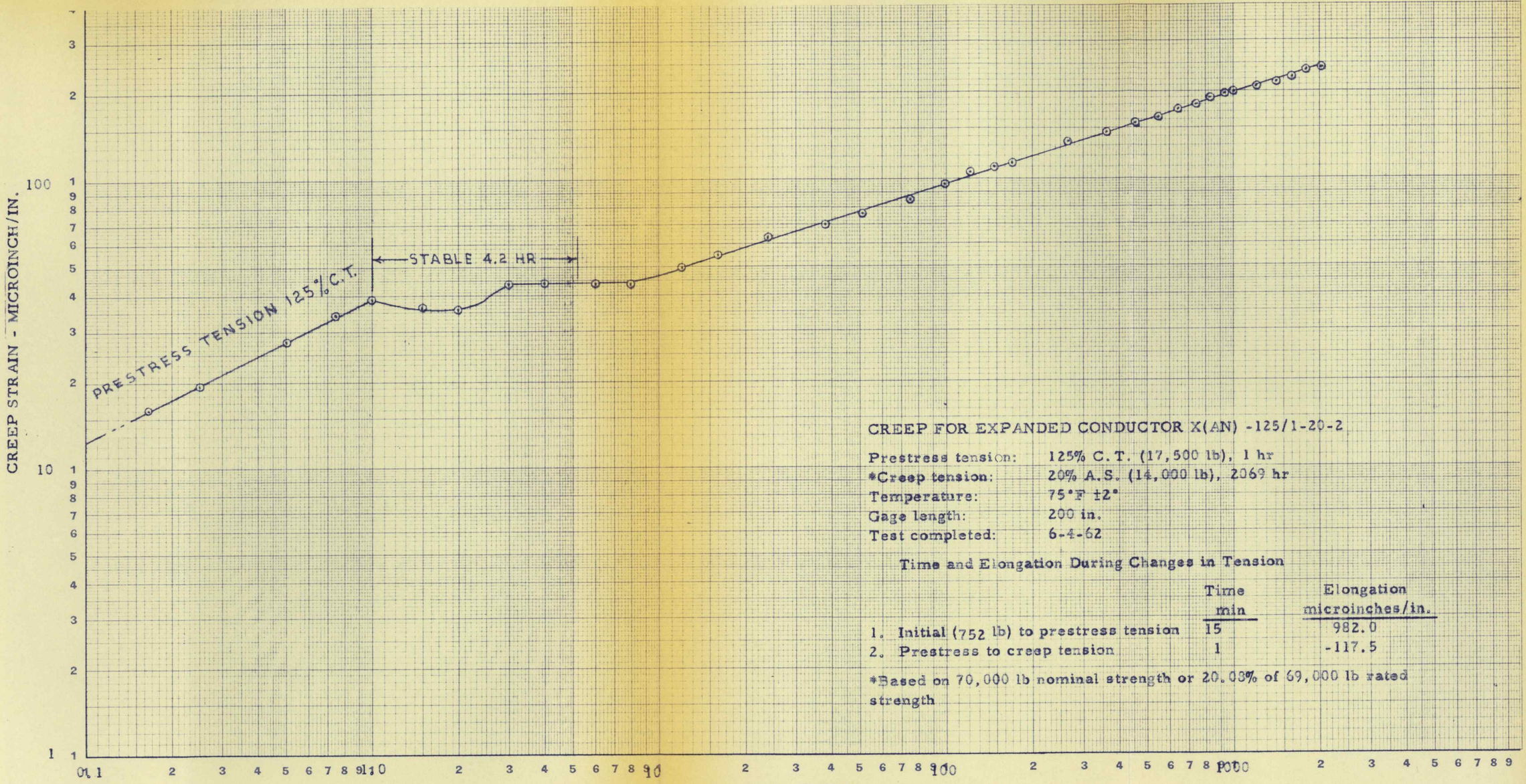
Prestress tension:	150% C.T. (21,000 lb), 1 hr
*Creep tension:	20% R.S. (14,000 lb), 2087 hr
Temperature:	75°F ±2°
Gage length:	200 in.
Test completed:	6-5-62

Time and Elongation During Changes in Tension

	Time min	Elongation microinches/in.
1. Initial (769 lb) to prestress tension	3	1236.0
2. Prestress to creep tension	1	-336.0

*Based on 70,000 lb nominal strength or 19.1% of 73,300 lb rated strength

Figure 20



CREEP FOR EXPANDED CONDUCTOR X(AN) -125/1-20-2

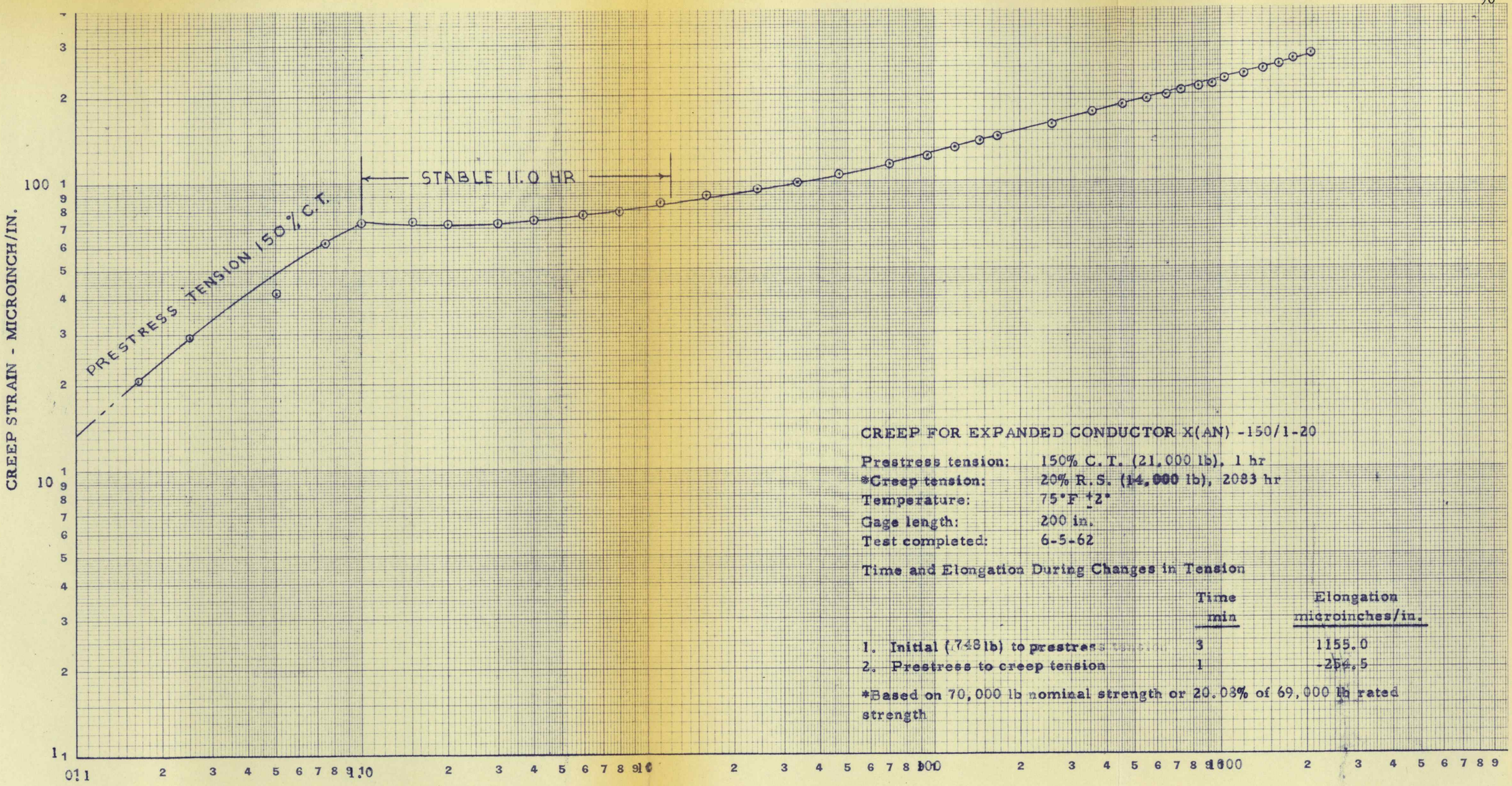
Prestress tension:	125% C.T. (17,500 lb), 1 hr
*Creep tension:	20% A.S. (14,000 lb), 2069 hr
Temperature:	75°F ±2°
Gage length:	200 in.
Test completed:	6-4-62

Time and Elongation During Changes in Tension

	Time min	Elongation microinches/in.
1. Initial (752 lb) to prestress tension	15	982.0
2. Prestress to creep tension	1	-117.5

*Based on 70,000 lb nominal strength or 20.03% of 69,000 lb rated strength

Figure 21



CREEP FOR EXPANDED CONDUCTOR X(AN) -150/1-20

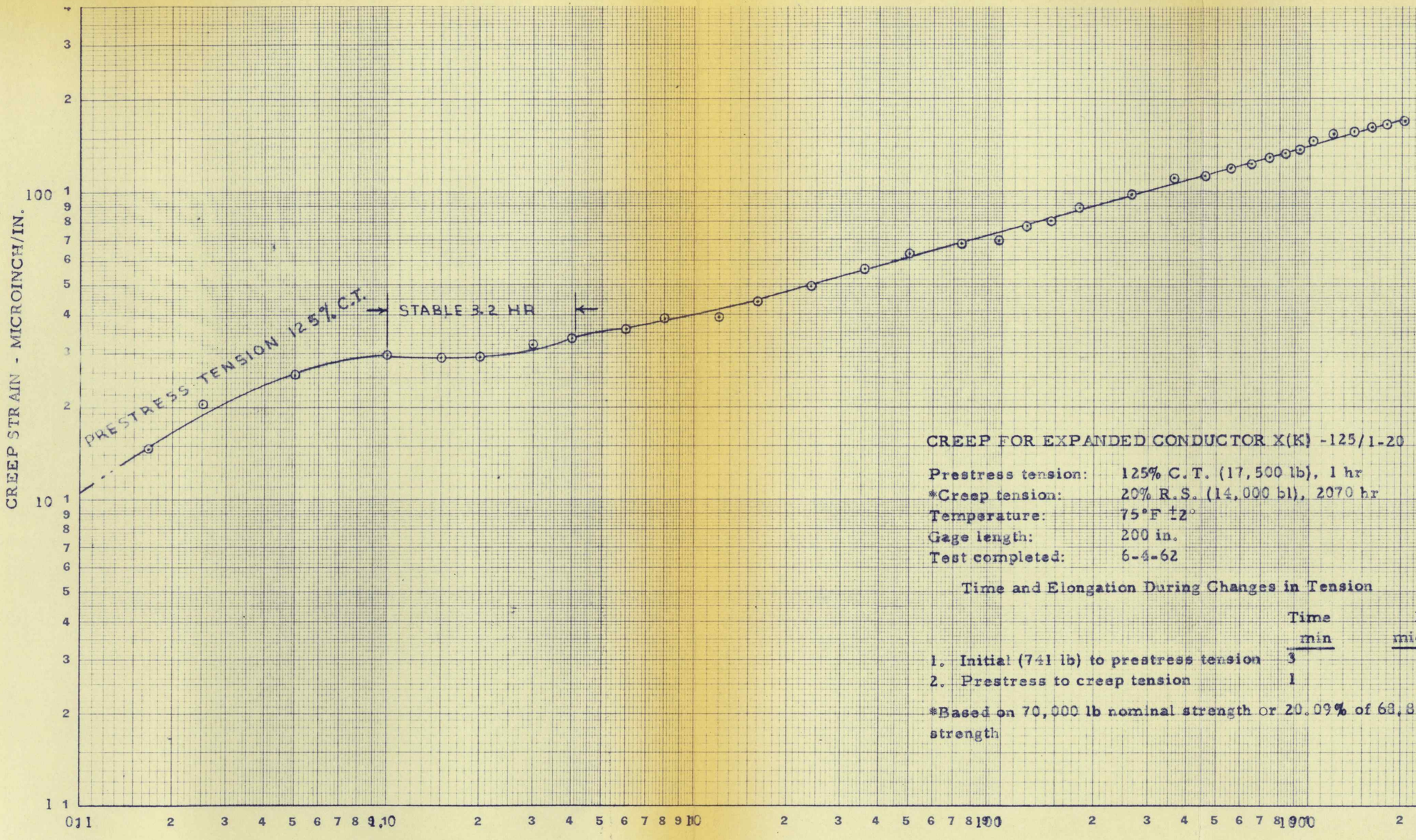
Prestress tension:	150% C.T. (21,000 lb), 1 hr
*Creep tension:	20% R.S. (14,000 lb), 2083 hr
Temperature:	75°F ±2°
Gage length:	200 in.
Test completed:	6-5-62

Time and Elongation During Changes in Tension

	Time min	Elongation microinches/in.
1. Initial (748 lb) to prestress tension	3	1155.0
2. Prestress to creep tension	1	-256.5

*Based on 70,000 lb nominal strength or 20.03% of 69,000 lb rated strength

Figure 22



CREEP FOR EXPANDED CONDUCTOR X(K) -125/1-20

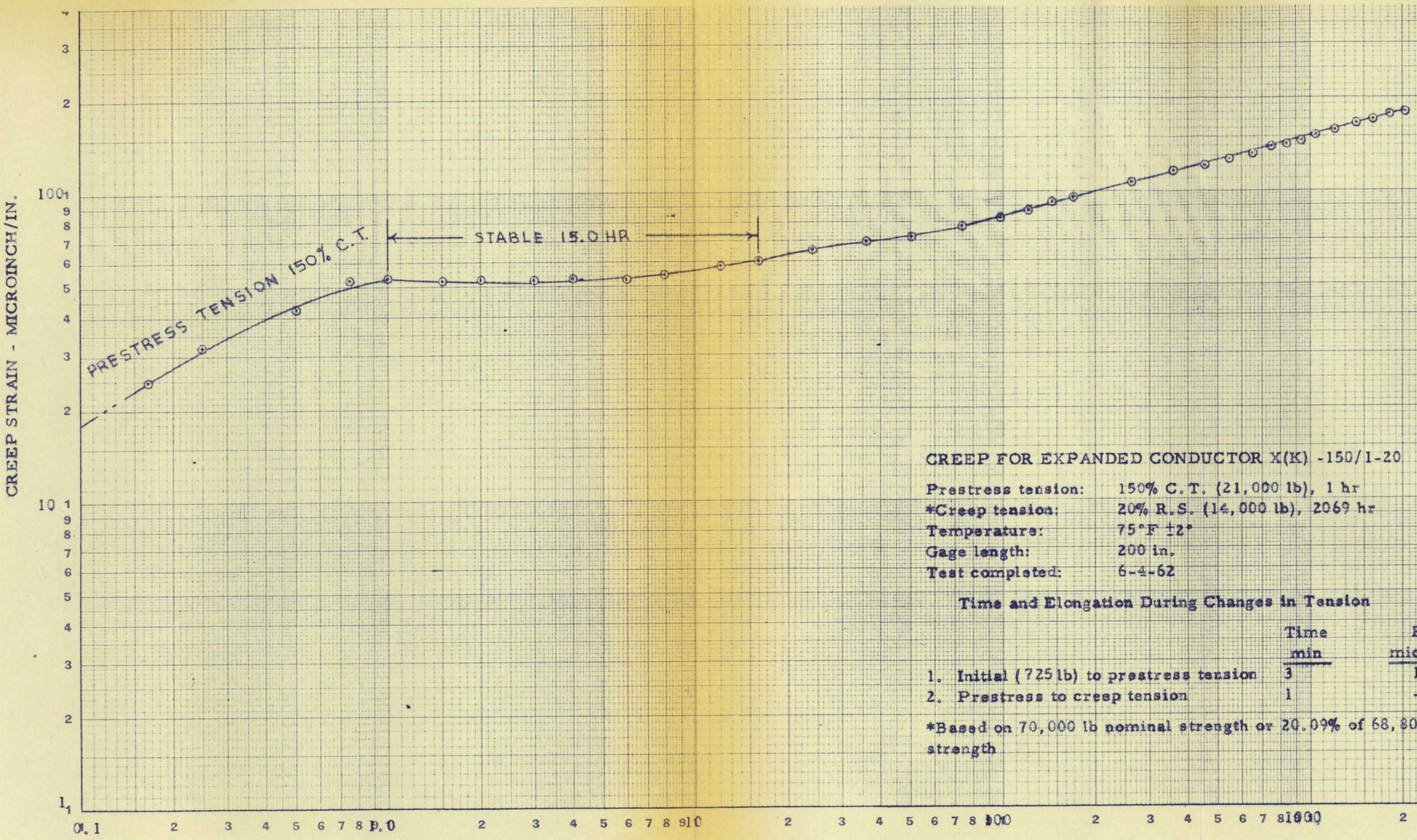
Prestress tension:	125% C.T. (17,500 lb), 1 hr
*Creep tension:	20% R.S. (14,000 bl), 2070 hr
Temperature:	75°F ±2°
Gage length:	200 in.
Test completed:	6-4-62

Time and Elongation During Changes in Tension

	Time min	Elongation microinches/in.
1. Initial (741 lb) to prestress tension	3	1085.0
2. Prestress to creep tension	1	-119.5

*Based on 70,000 lb nominal strength or 20.09% of 68,800 lb rated strength

Figure 23



CREEP FOR EXPANDED CONDUCTOR X(K) -150/1-20

Prestress tension:	150% C.T. (21,000 lb), 1 hr
*Creep tension:	20% R.S. (14,000 lb), 2069 hr
Temperature:	75°F ±2°
Gage length:	200 in.
Test completed:	6-4-62

Time and Elongation During Changes in Tension

	Time min	Elongation microinches/in.
1. Initial (725 lb) to prestress tension	3	1272.5
2. Prestress to creep tension	1	-257.0

*Based on 70,000 lb nominal strength or 20.09% of 68,800 lb rated strength

Figure 24

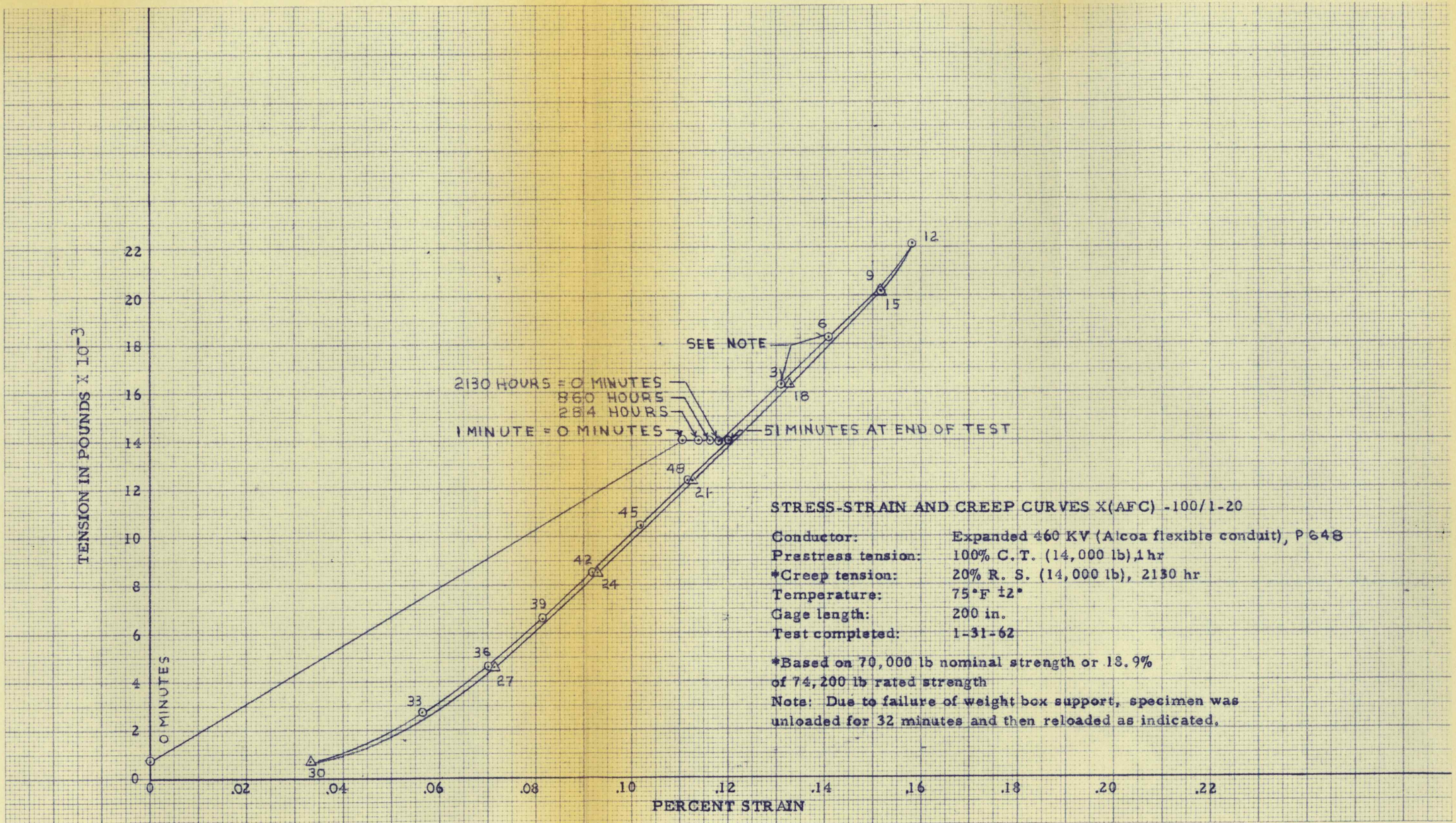

TENSION IN POUNDS X 10-3
22
20
18
16
14
12
10
8
6
4
2
0
0
.02
.04
.06
.08
.10
.12
.14
.16
.18
.20
.22
PERCENT STRAIN
0 MINUTES
2130 HOURS = 0 MINUTES
860 HOURS
284 HOURS
1 MINUTE = 0 MINUTES
51 MINUTES AT END OF TEST
SEE NOTE
STRESS-STRAIN AND CREEP CURVES X(AFC) -100/1-20
Conductor: Expanded 460 KV (Alcoa flexible conduit), P 648
Prestress tension: 100% C.T. (14,000 lb), 1 hr
*Creep tension: 20% R. S. (14,000 lb), 2130 hr
Temperature: 75°F ±2°
Gage length: 200 in.
Test completed: 1-31-62
*Based on 70,000 lb nominal strength or 18.9% of 74,200 lb rated strength
Note: Due to failure of weight box support, specimen was unloaded for 32 minutes and then reloaded as indicated.

Figure 25

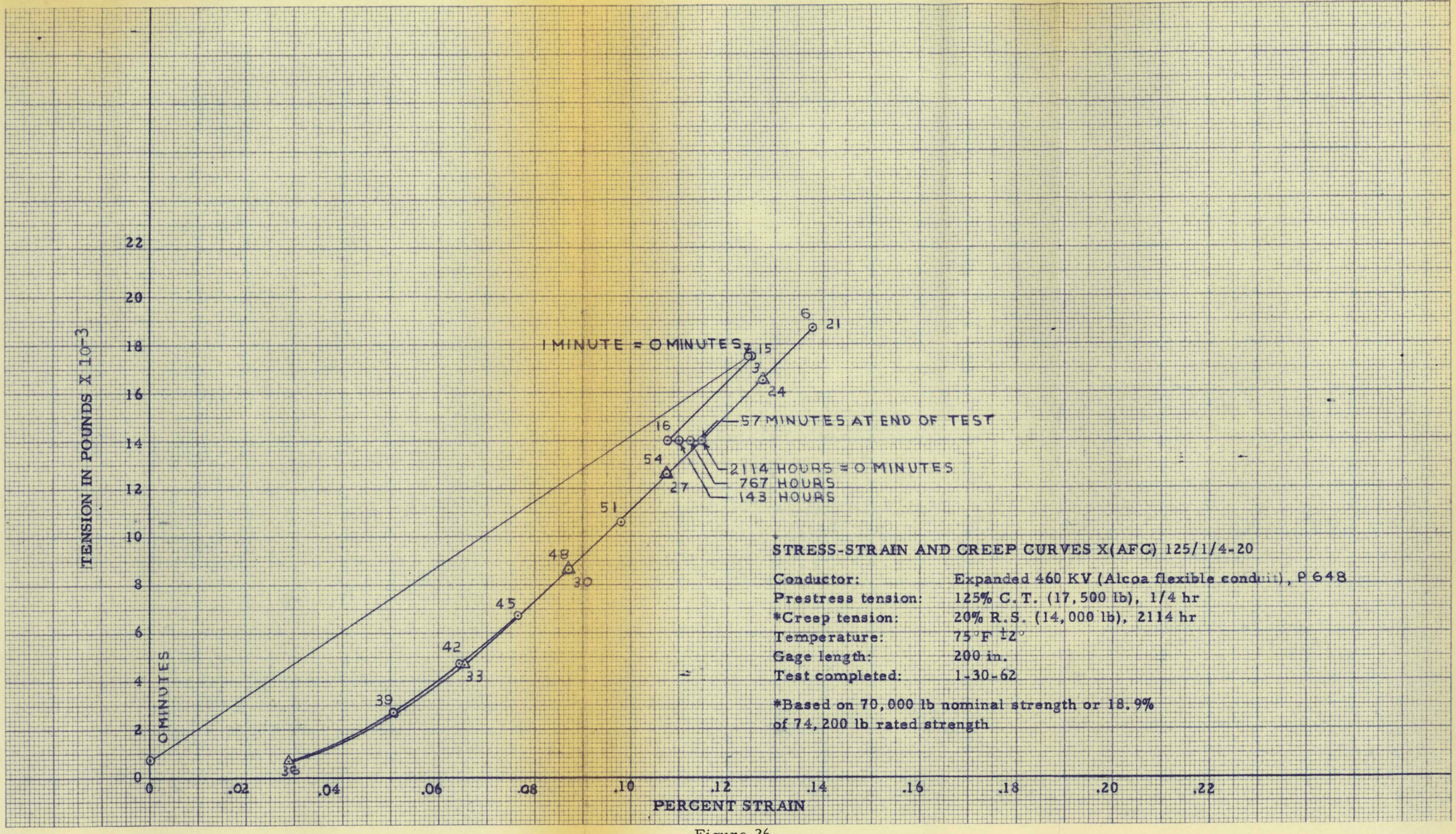

TENSION IN POUNDS X 10-3
PERCENT STRAIN
0
2
4
6
8
10
12
14
16
18
20
22
.02
.04
.06
.08
.10
.12
.14
.16
.18
.20
.22
1 MINUTE = 0 MINUTES
57 MINUTES AT END OF TEST
2114 HOURS = 0 MINUTES
767 HOURS
143 HOURS
0 MINUTES
STRESS-STRAIN AND CREEP CURVES X(AFC) 125/1/4-20
Conductor: Expanded 460 KV (Alcoa flexible conduit), P 648
Prestress tension: 125% C.T. (17,500 lb), 1/4 hr
*Creep tension: 20% R.S. (14,000 lb), 2114 hr
Temperature: 75°F ±2°
Gage length: 200 in.
Test completed: 1-30-62
*Based on 70,000 lb nominal strength or 18.9% of 74,200 lb rated strength

Figure 26

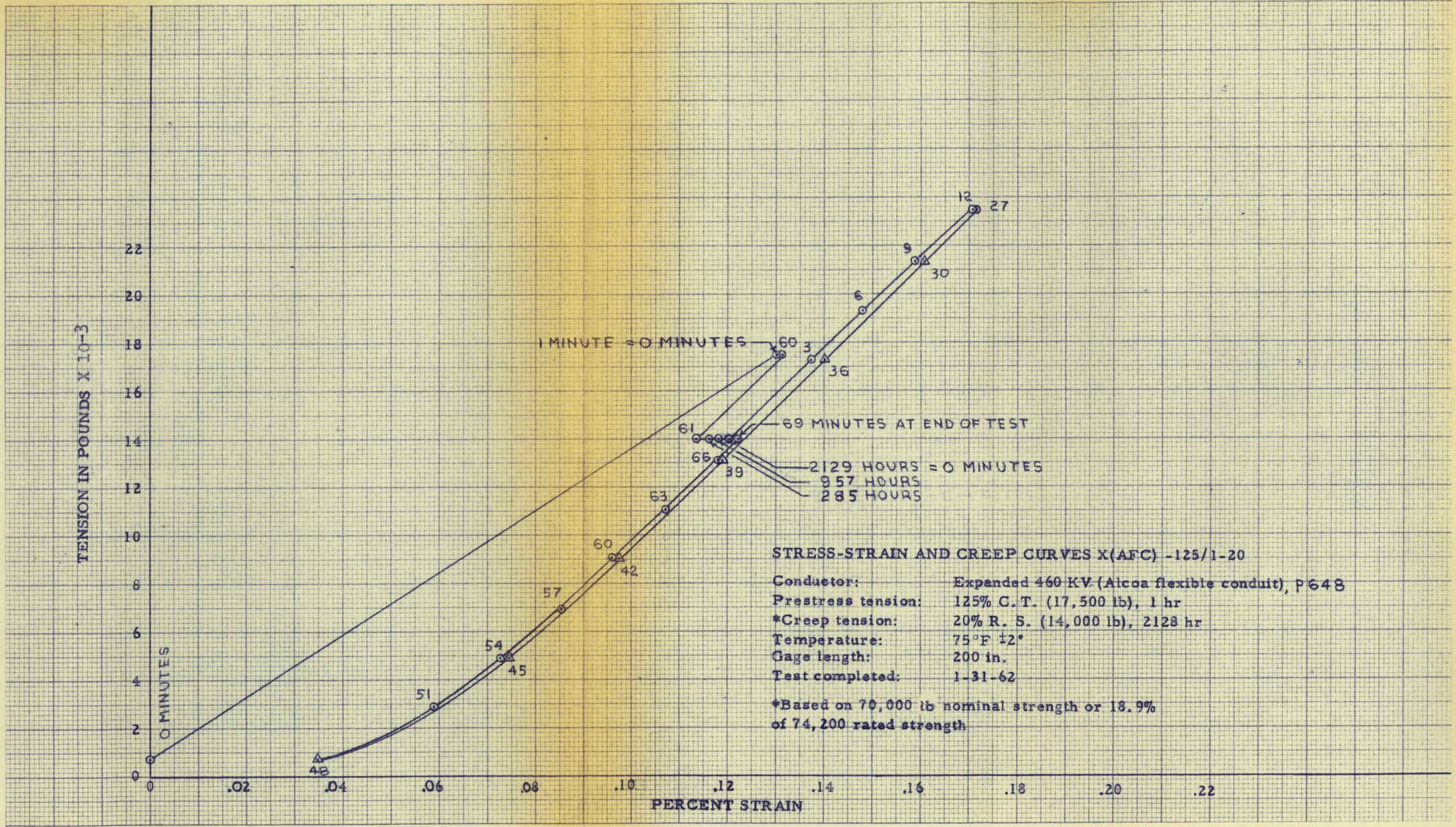

TENSION IN POUNDS X 10-3
0
2
4
6
8
10
12
14
16
18
20
22
0 MINUTES
1 MINUTE = 0 MINUTES
69 MINUTES AT END OF TEST
2129 HOURS = 0 MINUTES
957 HOURS
285 HOURS
0
.02
.04
.06
.08
.10
.12
.14
.16
.18
.20
.22
PERCENT STRAIN
STRESS-STRAIN AND CREEP CURVES X(AFC) -125/1-20
Conductor: Expanded 460 KV (Alcoa flexible conduit), P648
Prestress tension: 125% C.T. (17,500 lb), 1 hr
*Creep tension: 20% R.S. (14,000 lb), 2128 hr
Temperature: 75°F ±2°
Gage length: 200 in.
Test completed: 1-31-62
*Based on 70,000 lb nominal strength or 18.9% of 74,200 rated strength

Figure 27

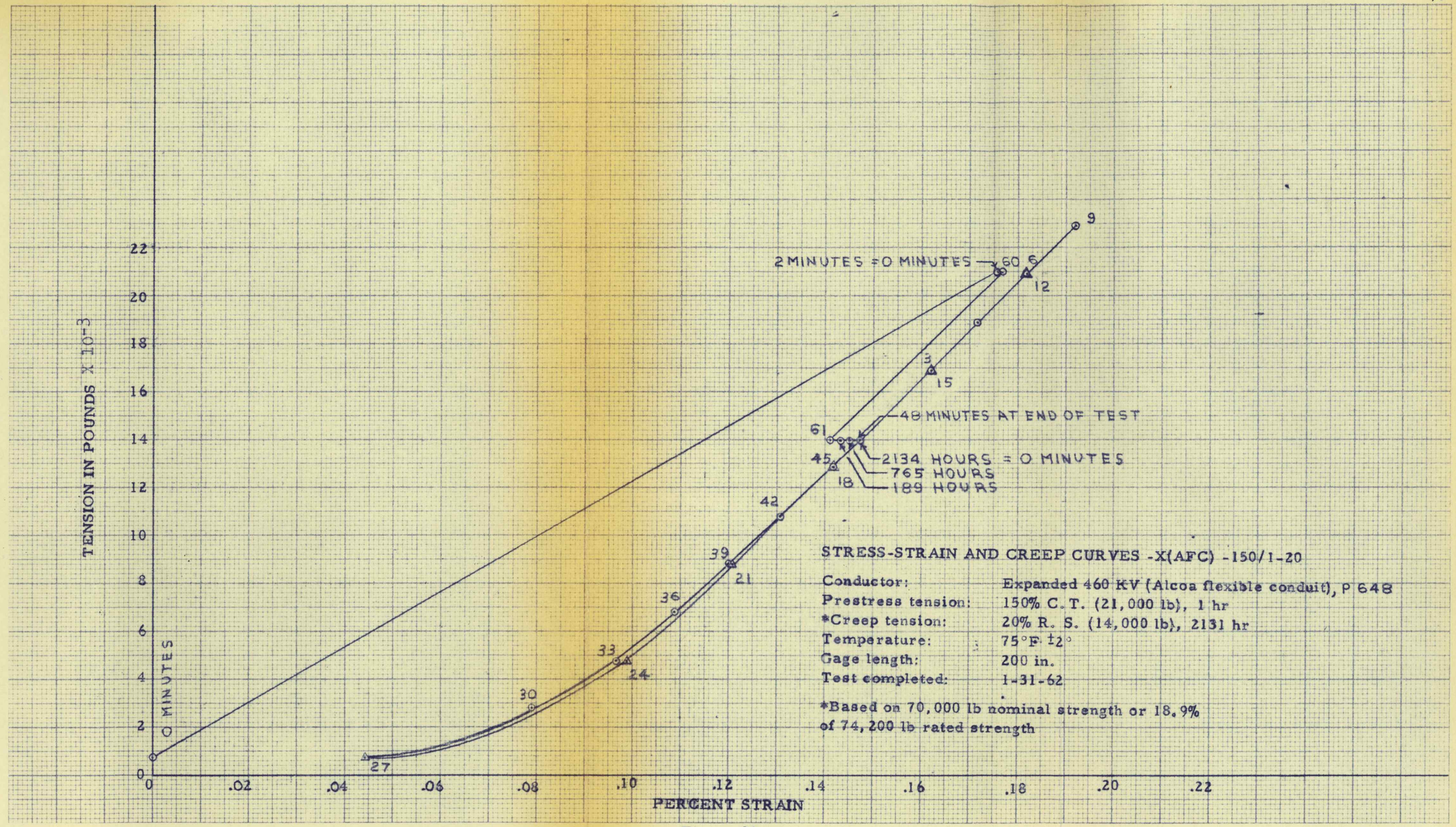
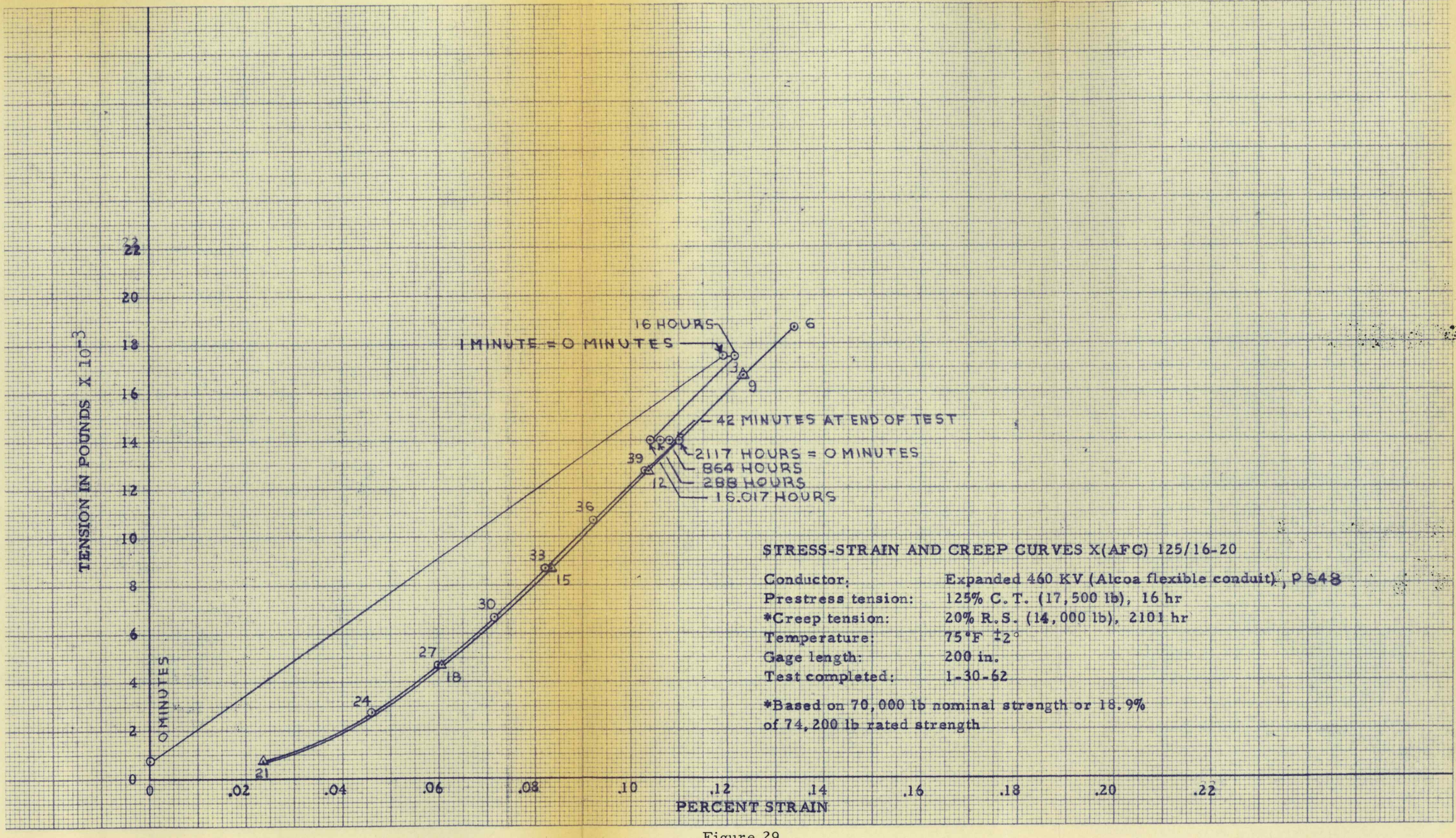

TENSION IN POUNDS X 10-3
0
2
4
6
8
10
12
14
16
18
20
22
0 MINUTES
0
.02
.04
.06
.08
.10
.12
.14
.16
.18
.20
.22
PERCENT STRAIN
2 MINUTES = 0 MINUTES
60
6
12
9
3
15
48 MINUTES AT END OF TEST
61
45
2134 HOURS = 0 MINUTES
765 HOURS
18
189 HOURS
42
39
21
36
33
24
30
27
STRESS-STRAIN AND CREEP CURVES -X(AFC) -150/1-20
Conductor: Expanded 460 KV (Alcoa flexible conduit), P 648
Prestress tension: 150% C. T. (21,000 lb), 1 hr
*Creep tension: 20% R. S. (14,000 lb), 2131 hr
Temperature: 75°F ±2°
Gage length: 200 in.
Test completed: 1-31-62
*Based on 70,000 lb nominal strength or 18.9% of 74,200 lb rated strength

Figure 28



STRESS-STRAIN AND CREEP CURVES X(AFC) 125/16-20

Conductor:	Expanded 460 KV (Alcoa flexible conduit), P 648
Prestress tension:	125% C. T. (17,500 lb), 16 hr
*Creep tension:	20% R.S. (14,000 lb), 2101 hr
Temperature:	75°F ±2°
Gage length:	200 in.
Test completed:	1-30-62

*Based on 70,000 lb nominal strength or 18.9% of 74,200 lb rated strength

Figure 29

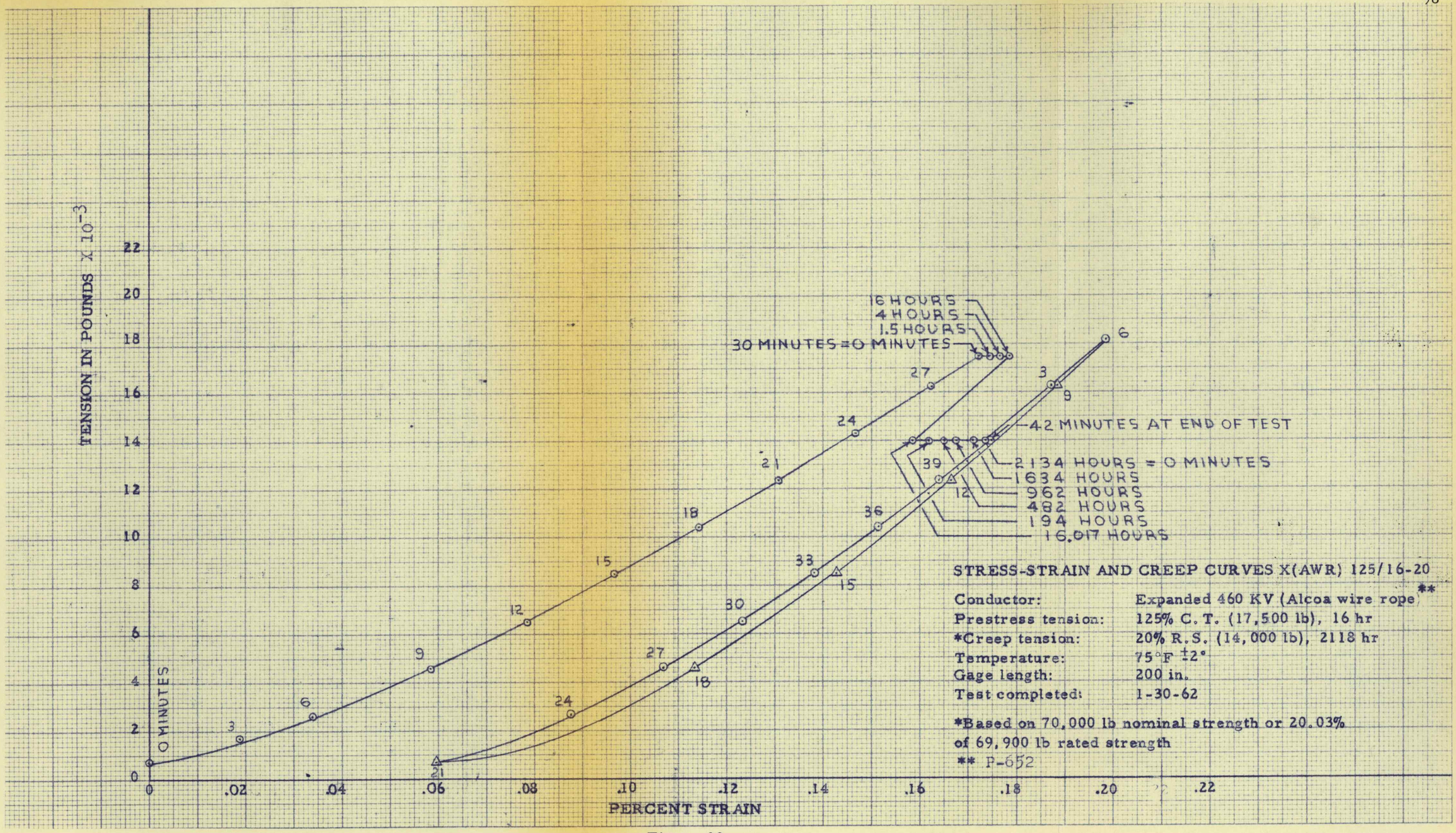

TENSION IN POUNDS X 10^{-3}
22
20
18
16
14
12
10
8
6
4
2
0
0
.02
.04
.06
.08
.10
.12
.14
.16
.18
.20
.22
PERCENT STRAIN
0 MINUTES
16 HOURS
4 HOURS
1.5 HOURS
30 MINUTES = 0 MINUTES
42 MINUTES AT END OF TEST
2134 HOURS = 0 MINUTES
1634 HOURS
962 HOURS
482 HOURS
194 HOURS
16,017 HOURS
STRESS-STRAIN AND CREEP CURVES X(AWR) 125/16-20
Conductor: Expanded 460 KV (Alcoa wire rope **
Prestress tension: 125% C. T. (17,500 lb), 16 hr
*Creep tension: 20% R.S. (14,000 lb), 2118 hr
Temperature: 75°F ±2°
Gage length: 200 in.
Test completed: 1-30-62
*Based on 70,000 lb nominal strength or 20.03% of 69,900 lb rated strength
** P-652

Figure 30

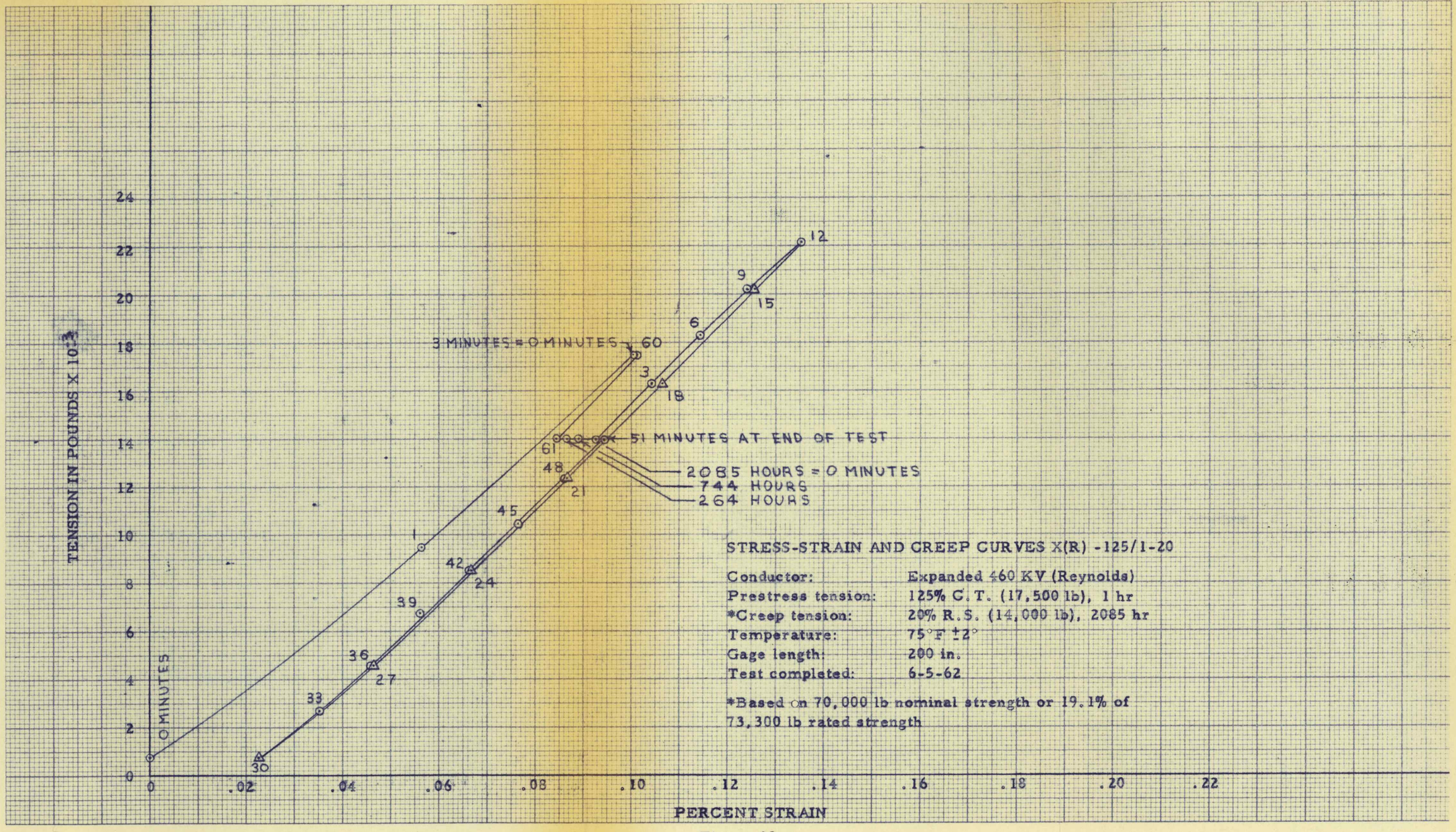

TENSION IN POUNDS X 10⁻³
PERCENT STRAIN
0
2
4
6
8
10
12
14
16
18
20
22
24
.02
.04
.06
.08
.10
.12
.14
.16
.18
.20
.22
0 MINUTES
3 MINUTES = 0 MINUTES
51 MINUTES AT END OF TEST
2085 HOURS = 0 MINUTES
744 HOURS
264 HOURS
60
3
18
12
9
15
6
61
48
21
45
1
42
24
39
36
27
33
30
STRESS-STRAIN AND CREEP CURVES X(R) -125/1-20
Conductor: Expanded 460 KV (Reynolds)
Prestress tension: 125% C.T. (17,500 lb), 1 hr
*Creep tension: 20% R.S. (14,000 lb), 2085 hr
Temperature: 75°F ±2°
Gage length: 200 in.
Test completed: 6-5-62
*Based on 70,000 lb nominal strength or 19.1% of 73,300 lb rated strength

Figure 31

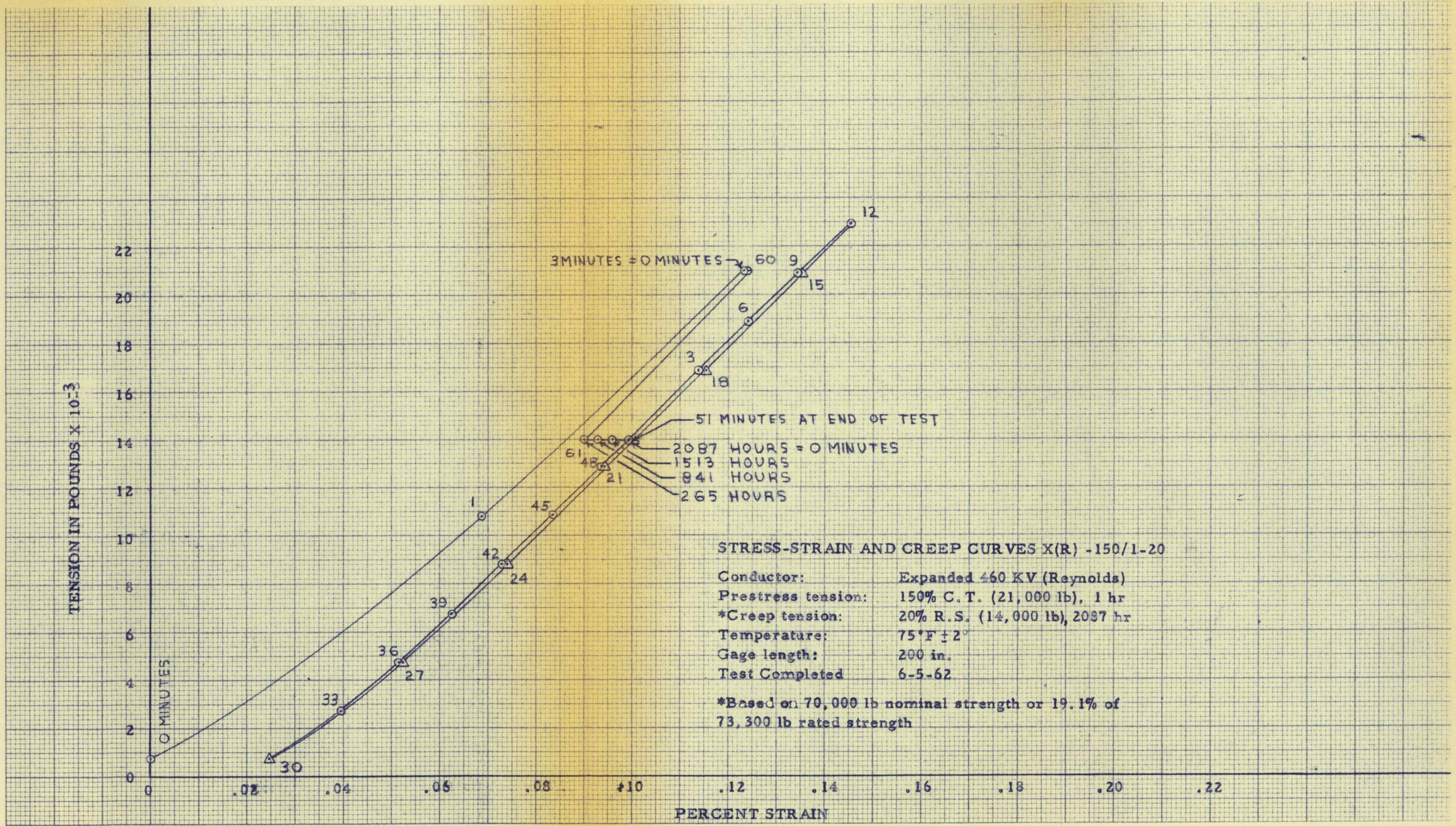

TENSION IN POUNDS X 10-3
PERCENT STRAIN
0
2
4
6
8
10
12
14
16
18
20
22
.02
.04
.06
.08
.10
.12
.14
.16
.18
.20
.22
0 MINUTES
3 MINUTES = 0 MINUTES
51 MINUTES AT END OF TEST
2087 HOURS = 0 MINUTES
1513 HOURS
841 HOURS
265 HOURS
1
3
6
9
12
15
18
21
24
27
30
33
36
39
42
45
48
51
60
61
STRESS-STRAIN AND CREEP CURVES X(R) -150/1-20
Conductor: Expanded 460 KV (Reynolds)
Prestress tension: 150% C.T. (21,000 lb), 1 hr
*Creep tension: 20% R.S. (14,000 lb), 2087 hr
Temperature: 75°F ± 2°
Gage length: 200 in.
Test Completed 6-5-62
*Based on 70,000 lb nominal strength or 19.1% of 73,300 lb rated strength

Figure 32

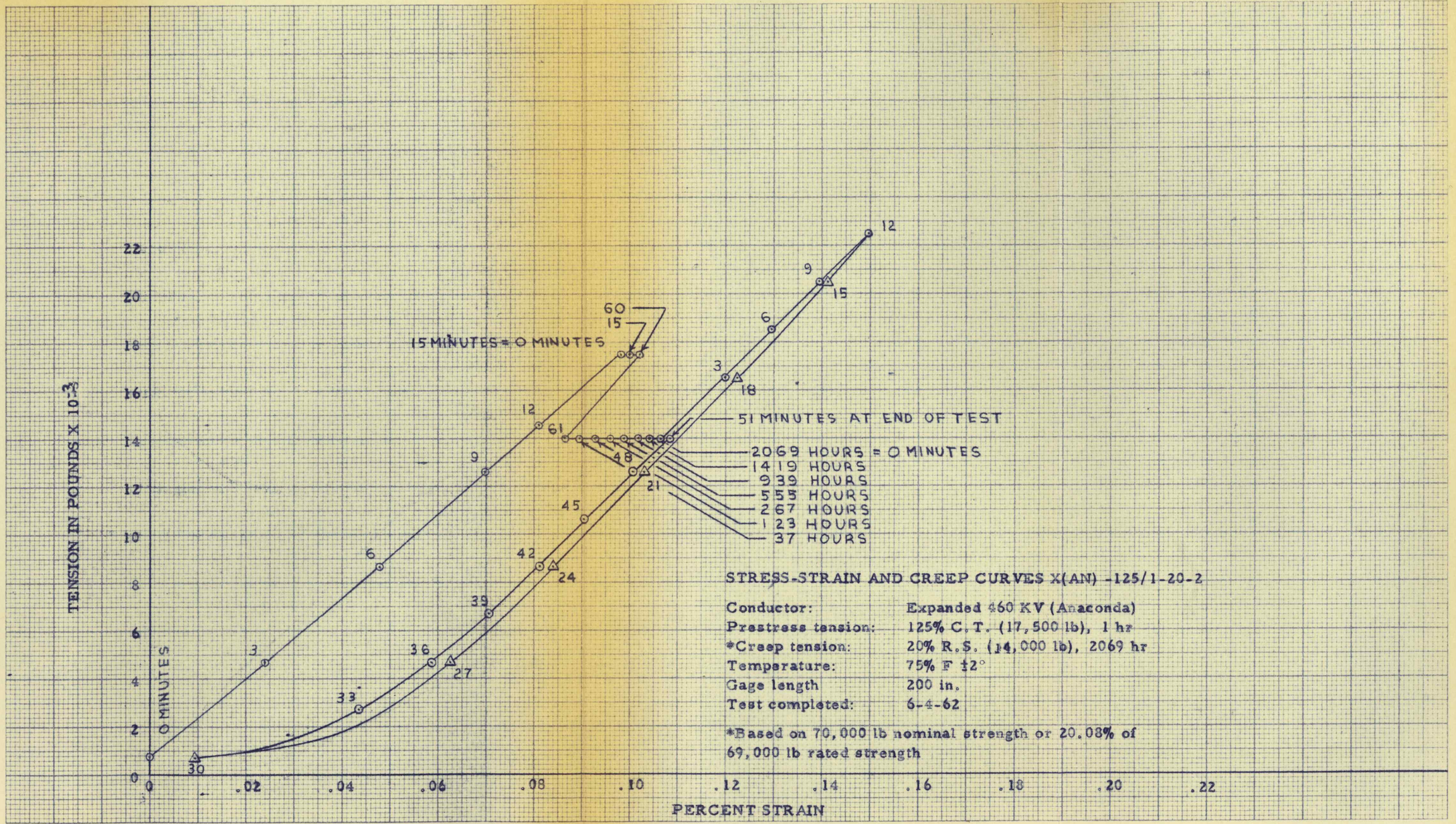

TENSION IN POUNDS X 10-3
0
2
4
6
8
10
12
14
16
18
20
22
0
.02
.04
.06
.08
.10
.12
.14
.16
.18
.20
.22
PERCENT STRAIN
0 MINUTES
15 MINUTES = 0 MINUTES
51 MINUTES AT END OF TEST
2069 HOURS = 0 MINUTES
1419 HOURS
939 HOURS
555 HOURS
267 HOURS
123 HOURS
37 HOURS
STRESS-STRAIN AND CREEP CURVES X(AN) -125/1-20-2
Conductor: Expanded 460 KV (Anaconda)
Prestress tension: 125% C.T. (17,500 lb), 1 hr
*Creep tension: 20% R.S. (14,000 lb), 2069 hr
Temperature: 75% F ±2°
Gage length 200 in.
Test completed: 6-4-62
*Based on 70,000 lb nominal strength or 20.08% of 69,000 lb rated strength

Figure 33

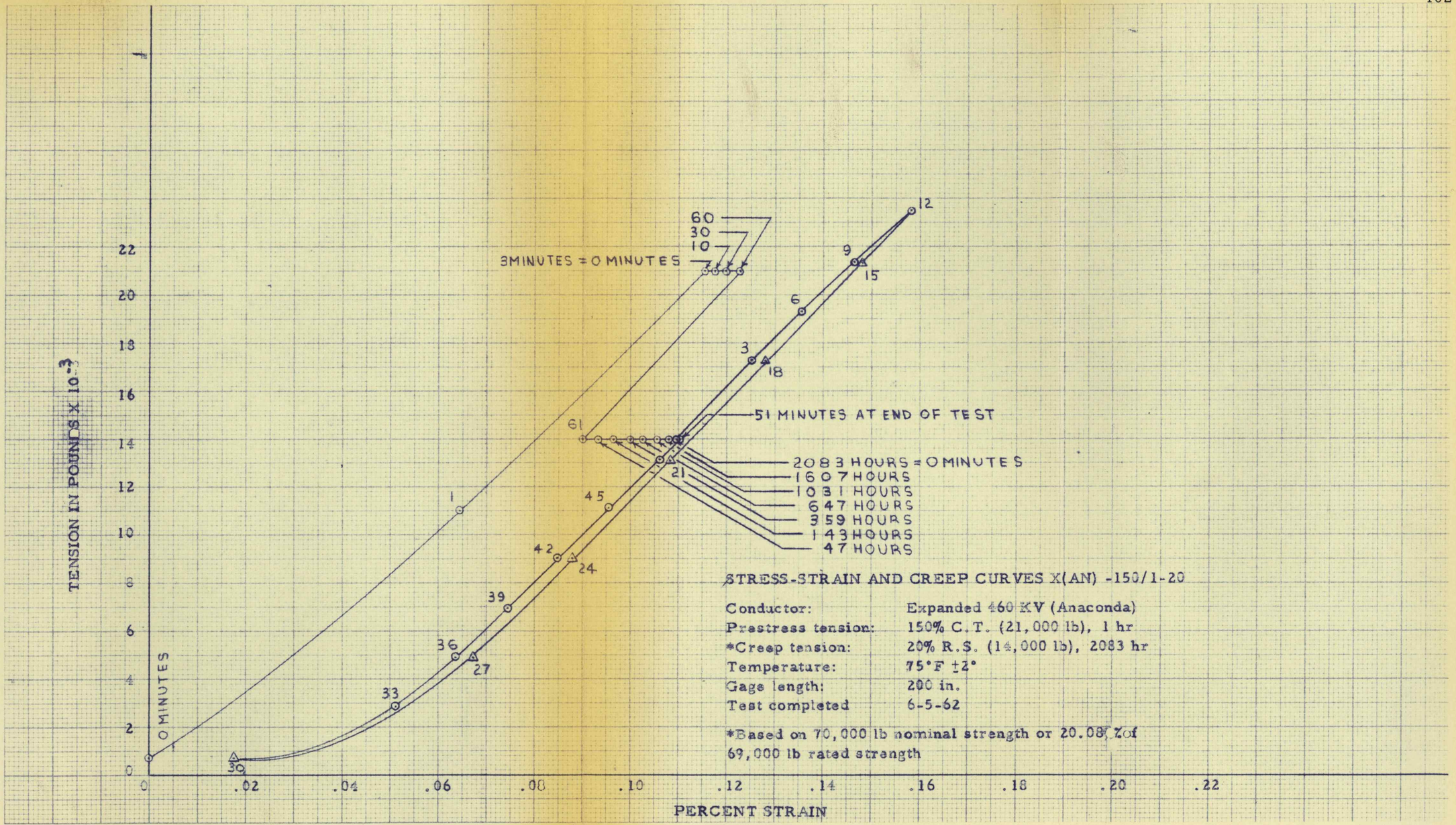

TENSION IN POUNDS X 10-3
PERCENT STRAIN
0
2
4
6
8
10
12
14
16
18
20
22
.02
.04
.06
.08
.10
.12
.14
.16
.18
.20
.22
0 MINUTES
3 MINUTES = 0 MINUTES
60
30
10
1
3
6
9
12
15
18
21
24
27
30
33
36
39
42
45
51 MINUTES AT END OF TEST
61
2083 HOURS = 0 MINUTES
1607 HOURS
1031 HOURS
647 HOURS
359 HOURS
143 HOURS
47 HOURS
STRESS-STRAIN AND CREEP CURVES X(AN) -150/1-20
Conductor: Expanded 460 KV (Anaconda)
Prestress tension: 150% C.T. (21,000 lb), 1 hr
*Creep tension: 20% R.S. (14,000 lb), 2083 hr
Temperature: 75°F ±2°
Gage length: 200 in.
Test completed 6-5-62
*Based on 70,000 lb nominal strength or 20.08% of 69,000 lb rated strength

Figure 34

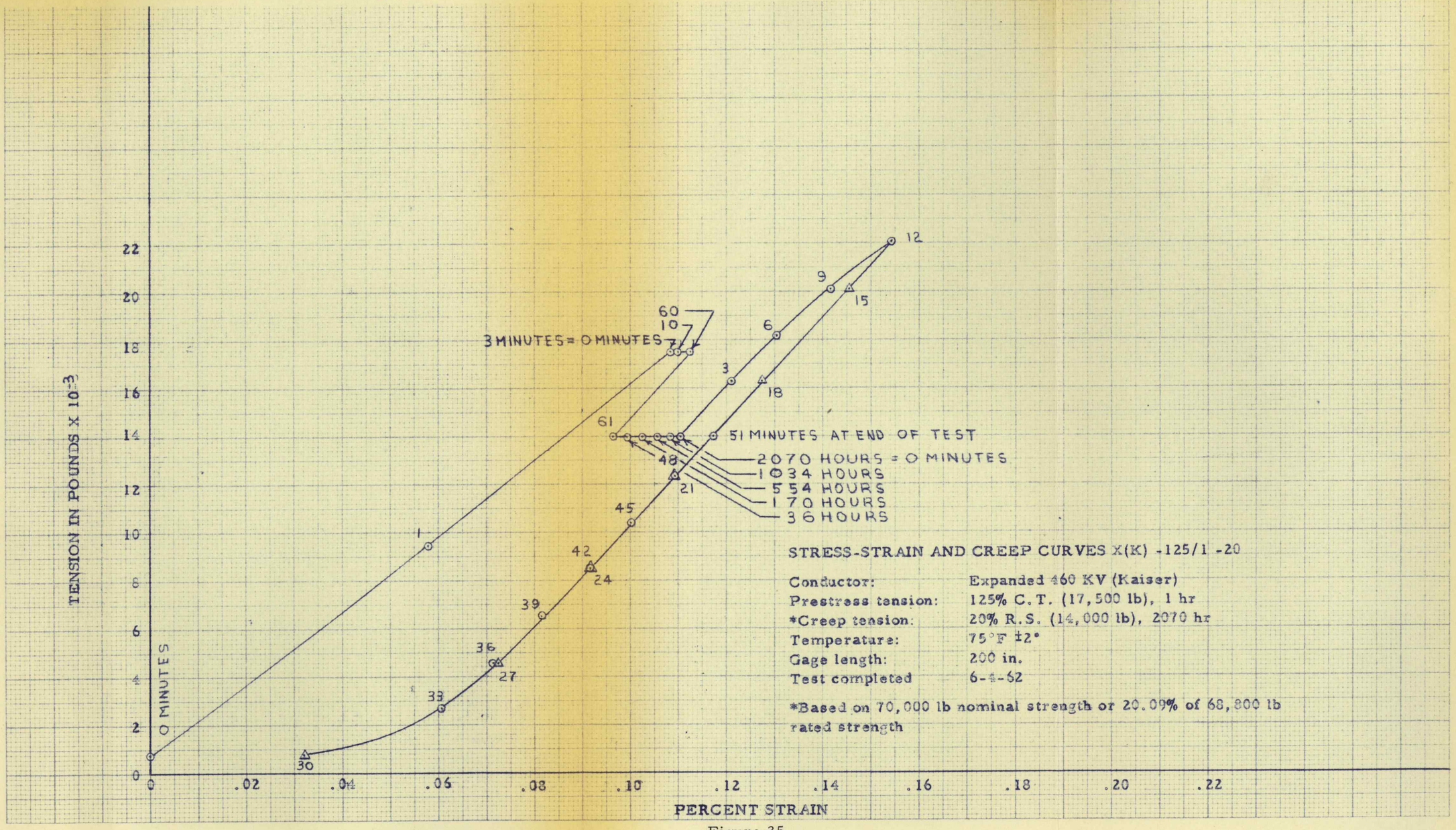

TENSION IN POUNDS X 10-3
PERCENT STRAIN
0
2
4
6
8
10
12
14
16
18
20
22
.02
.04
.06
.08
.10
.12
.14
.16
.18
.20
.22
0 MINUTES
3 MINUTES = 0 MINUTES
51 MINUTES AT END OF TEST
2070 HOURS = 0 MINUTES
1034 HOURS
554 HOURS
170 HOURS
36 HOURS
STRESS-STRAIN AND CREEP CURVES X(K) -125/1 -20
Conductor: Expanded 460 KV (Kaiser)
Prestress tension: 125% C.T. (17,500 lb), 1 hr
*Creep tension: 20% R.S. (14,000 lb), 2070 hr
Temperature: 75°F ±2°
Gage length: 200 in.
Test completed 6-4-62
*Based on 70,000 lb nominal strength or 20.09% of 68,800 lb rated strength

Figure 35

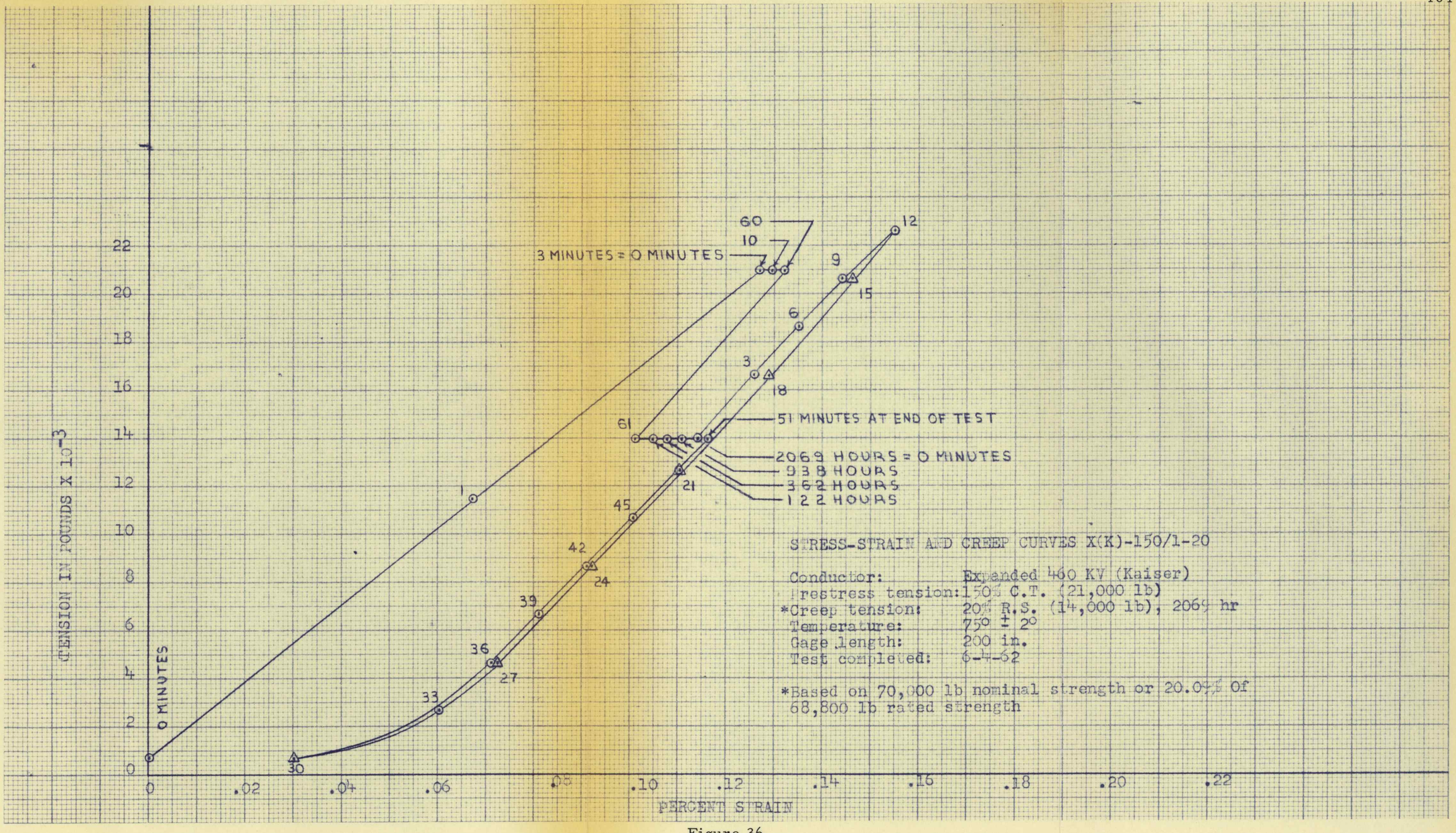

TENSION IN POUNDS X 10-3
PERCENT STRAIN
0 MINUTES
3 MINUTES = 0 MINUTES
51 MINUTES AT END OF TEST
2069 HOURS = 0 MINUTES
938 HOURS
362 HOURS
122 HOURS
STRESS-STRAIN AND CREEP CURVES X(K)-150/1-20
Conductor: Expanded 460 KV (Kaiser)
Prestress tension: 15% C.T. (21,000 lb)
*Creep tension: 20% R.S. (14,000 lb); 2069 hr
Temperature: 75° ± 2°
Gage length: 200 in.
Test completed: 6-4-62
*Based on 70,000 lb nominal strength or 20.0% of 68,800 lb rated strength

Figure 36

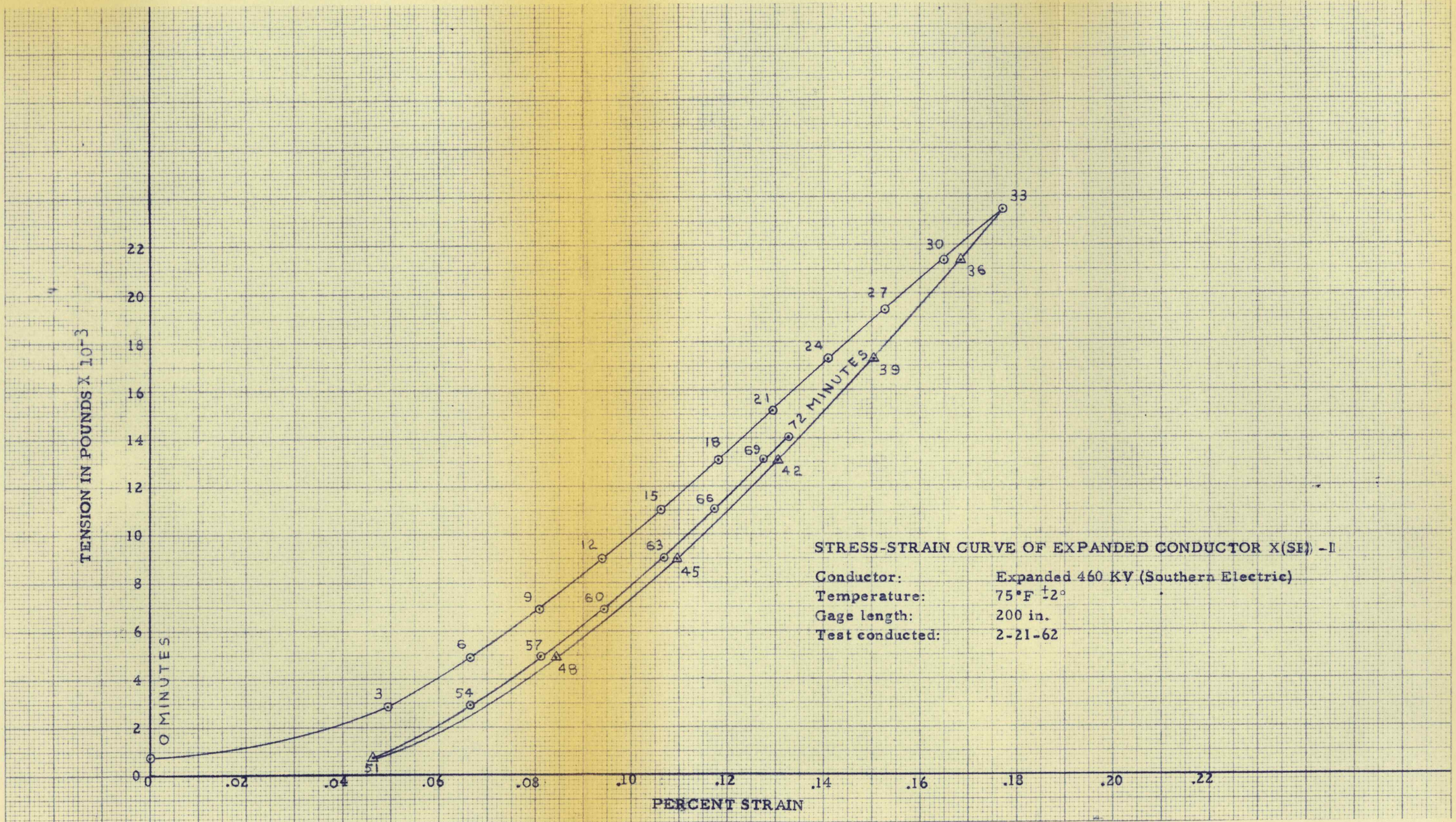

TENSION IN POUNDS X 10³
0
2
4
6
8
10
12
14
16
18
20
22
0 MINUTES
72 MINUTES
0
.02
.04
.06
.08
.10
.12
.14
.16
.18
.20
.22
PERCENT STRAIN
STRESS-STRAIN CURVE OF EXPANDED CONDUCTOR X(SE) -I
Conductor: Expanded 460 KV (Southern Electric)
Temperature: 75°F ±2°
Gage length: 200 in.
Test conducted: 2-21-62

Figure 37

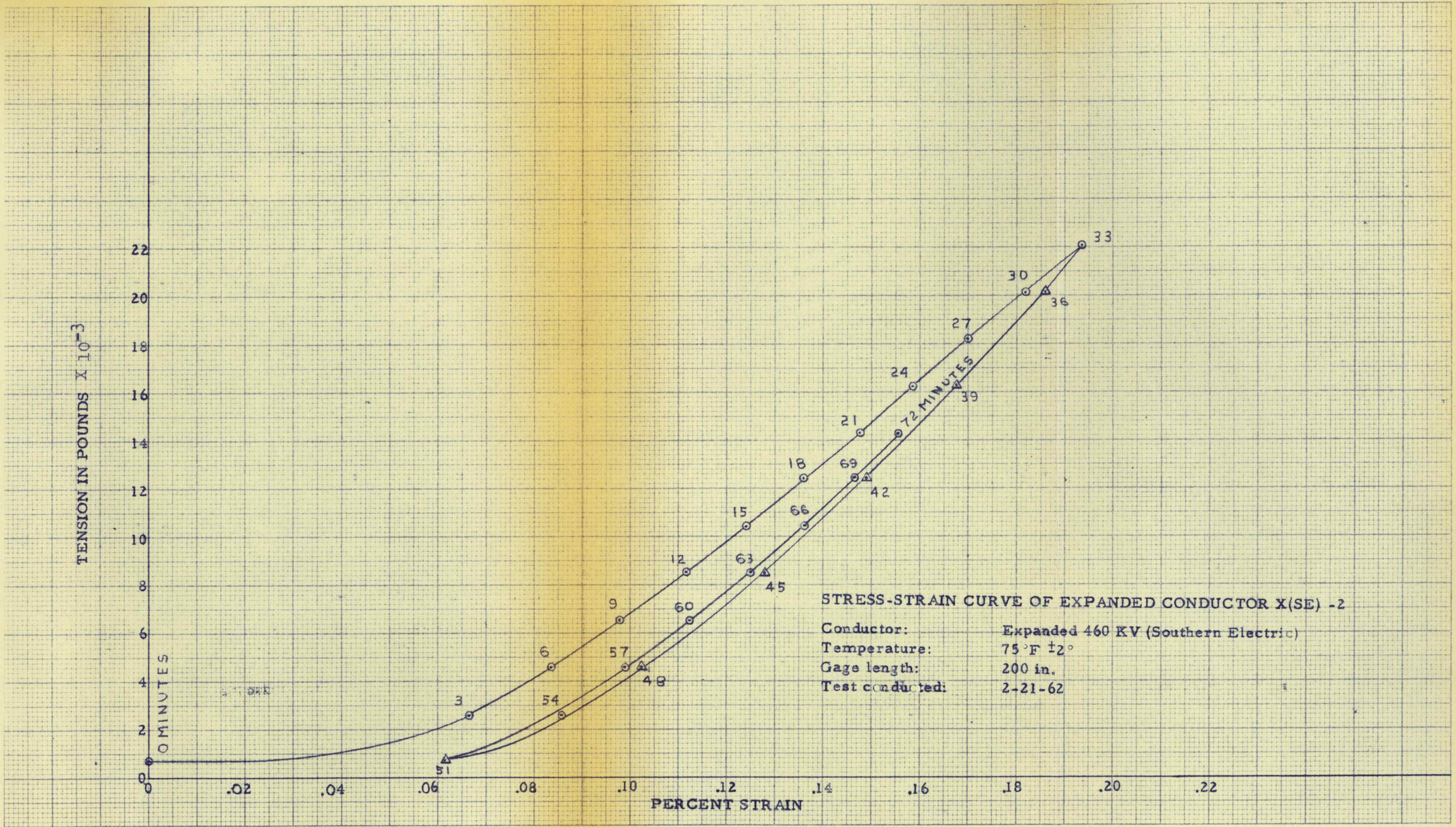

TENSION IN POUNDS X 10-3
22
20
18
16
14
12
10
8
6
4
2
0
MINUTES
0
.02
.04
.06
.08
.10
.12
.14
.16
.18
.20
.22
PERCENT STRAIN
72 MINUTES
STRESS-STRAIN CURVE OF EXPANDED CONDUCTOR X(SE) -2
Conductor: Expanded 460 KV (Southern Electric)
Temperature: 75°F ±2°
Gage length: 200 in.
Test conducted: 2-21-62

Figure 38

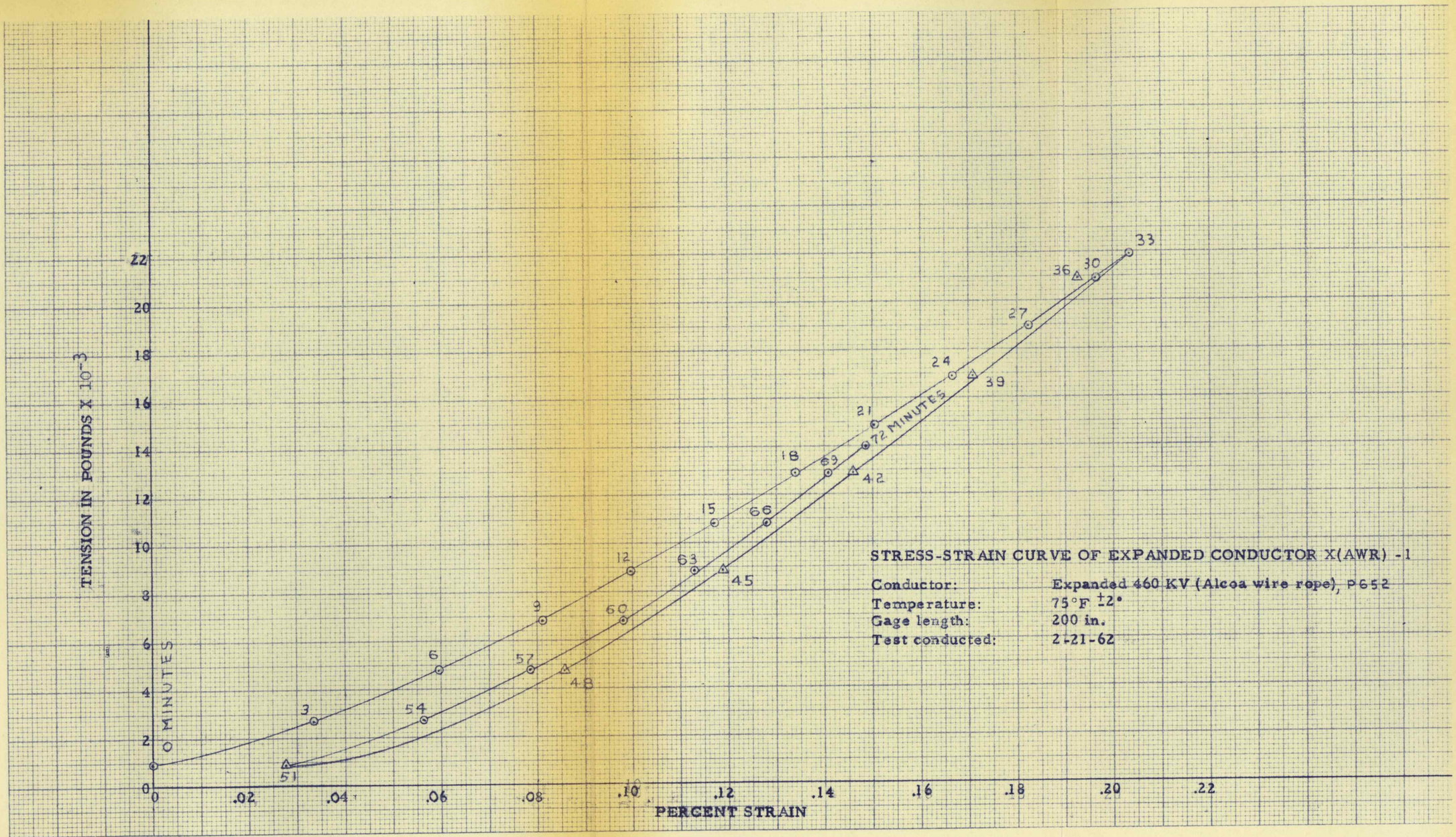

TENSION IN POUNDS X 10-3
22
20
18
16
14
12
10
8
6
4
2
0
0
.02
.04
.06
.08
.10
.12
.14
.16
.18
.20
.22
PERCENT STRAIN
0 MINUTES
72 MINUTES
0
3
6
9
12
15
18
21
24
27
30
33
36
39
42
45
48
51
54
57
60
63
66
69
STRESS-STRAIN CURVE OF EXPANDED CONDUCTOR X(AWR) -1
Conductor: Expanded 460 KV (Alcoa wire rope), P652
Temperature: 75°F ±2°
Gage length: 200 in.
Test conducted: 2-21-62

Figure 39

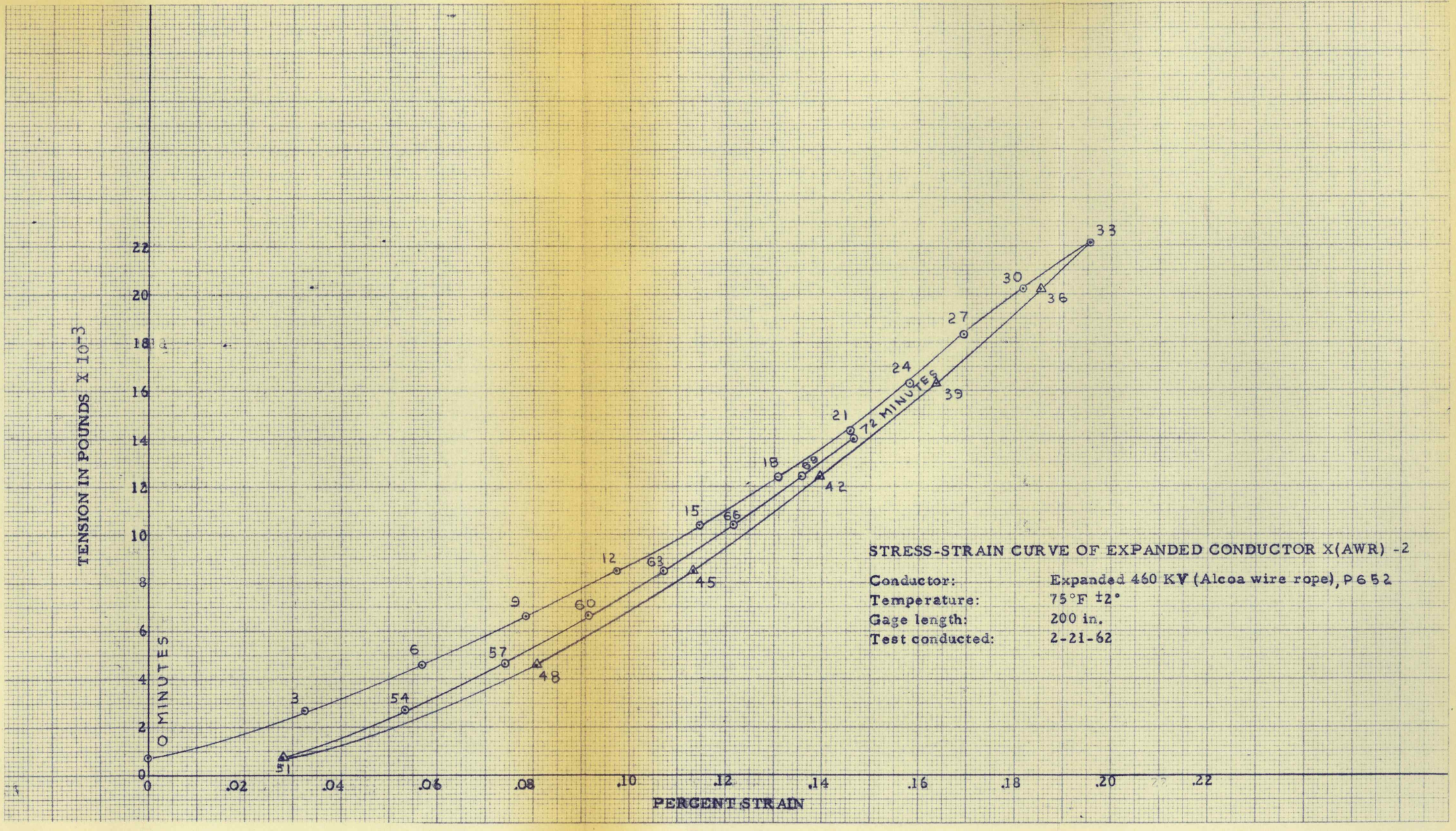

TENSION IN POUNDS X 10-3
PERCENT STRAIN
0 MINUTES
72 MINUTES
STRESS-STRAIN CURVE OF EXPANDED CONDUCTOR X(AWR) -2
Conductor: Expanded 460 KV (Alcoa wire rope), P652
Temperature: 75°F ±2°
Gage length: 200 in.
Test conducted: 2-21-62

Figure 40

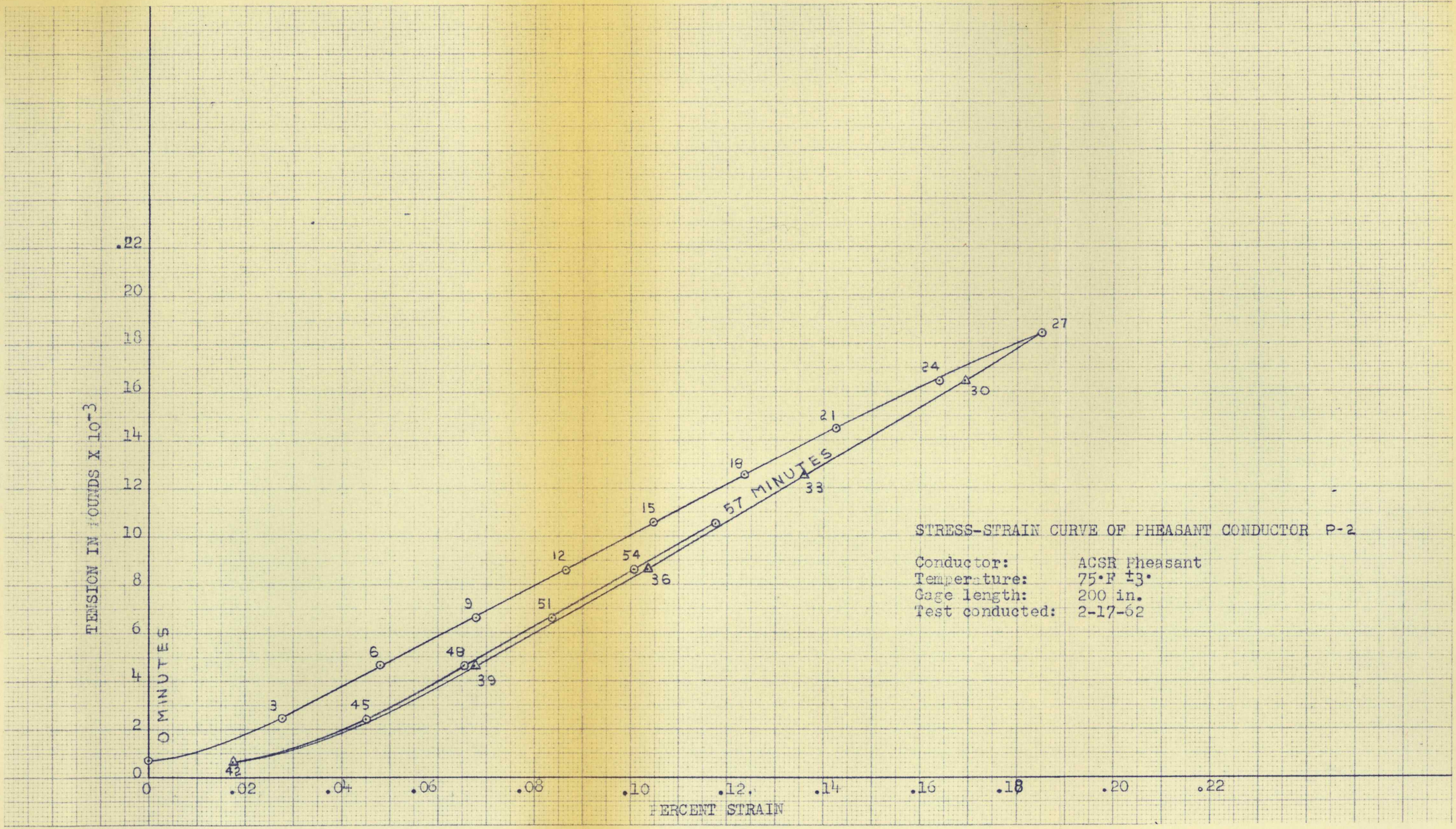

TENSION IN POUNDS X 10-3
PERCENT STRAIN
0
2
4
6
8
10
12
14
16
18
20
22
.02
.04
.06
.08
.10
.12
.14
.16
.18
.20
.22
0 MINUTES
57 MINUTES
3
6
9
12
15
18
21
24
27
30
33
36
39
42
45
48
51
54
STRESS-STRAIN CURVE OF PHEASANT CONDUCTOR P-2
Conductor: ACSR Pheasant
Temperature: 75°F ±3°
Gage length: 200 in.
Test conducted: 2-17-62

Figure 41

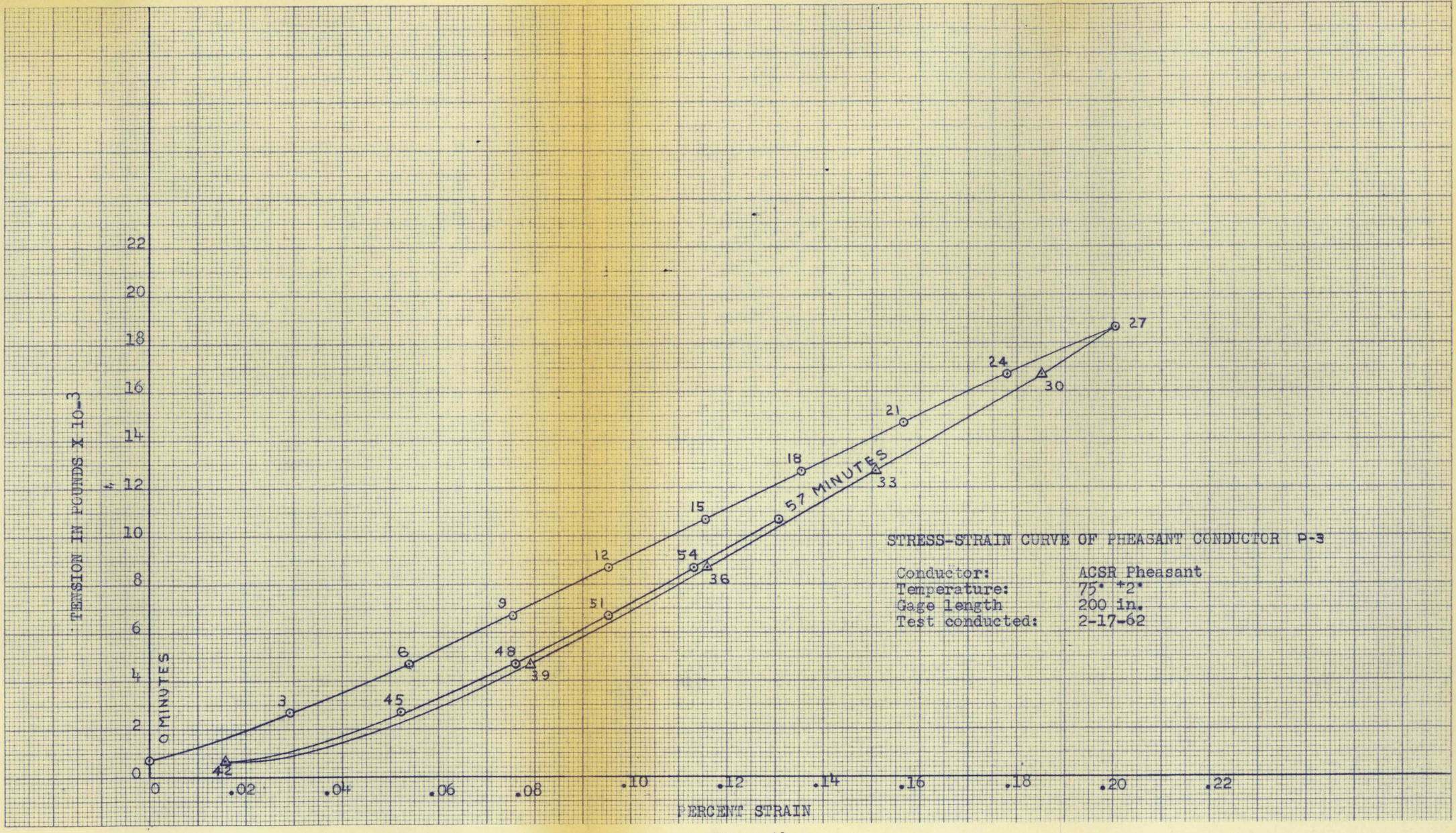

TENSION IN POUNDS X 10-3
0
2
4
6
8
10
12
14
16
18
20
22
0
.02
.04
.06
.08
.10
.12
.14
.16
.18
.20
.22
PERCENT STRAIN
0 MINUTES
57 MINUTES
3
6
9
12
15
18
21
24
27
45
51
54
57
30
33
36
39
42
48
STRESS-STRAIN CURVE OF PHEASANT CONDUCTOR P-3
Conductor: ACSR Pheasant
Temperature: 75° ±2°
Gage length 200 in.
Test conducted: 2-17-62

Figure 42