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THE UNIVERSITY OF NEW SOUTH WALES

WATER RESEARCH LABORATORY

Report No. 33

THE APPARENT MODULUS OF ELASTICITY OF ASBESTOS CEMENT PIPES UNDER CIRCUMFERENTIAL TENSION.

by

R. T. Hattersley

June, 1962.

The University of New South Wales
WATER RESEARCH LABORATORY

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1. Introduction

The calculation of the magnitude of the pressure developed in a closed water pipeline in which the rate of flow is suddenly restricted necessitates a knowledge of the rate at which the material of the pipeline distends in a diametral direction under the application of internal pressure.

The material from which asbestos cement pipes is made consists of a mixture of mineral asbestos fibre, filler and portland cement. By virtue of the process in which a matrix of the prepared material in wet condition is wrapped on a mandril and is rapidly cured before removal, the resulting product is dense, smooth internally, relatively light, in many ways eminently suitable as a piping material.

Pipes manufactured from this material differ from their counterparts made from iron or steel because the material is not fully isotropic. Owing to the manner in which the mineral fibres are disposed in the manufacturing process the strength properties are to some extent dependent on the disposition of the fibres. Also, because the allowable stress is lower than that for iron or steel the pipe walls of asbestos cement pipes are thicker for a given working head.

Conventional co-axial tension and compression tests which are commonly used for the determination of the properties of structural materials are considered unlikely to produce realistic figures for the elastic properties of asbestos cement used as a piping material.

2. Description of Elasticity Tests of Asbestos Cement Pipes

The series of tests reported in this document were devised to overcome the difficulties associated with the application of co-axial stress/strain tests to the calculation of the circumferential elastic deformation of asbestos cement pipes. Much of the difficulty is overcome if the diametral distension is measured on an actual pipe sample subjected to hydrostatic pressure. The stresses are then correctly aligned with respect to the mineral fibres and the effects of wall thickness are automatically taken into account.

To ascertain directly the distension in the diametral plane of a pipe sample the testing apparatus was designed so that the hydrostatic load could be applied to a representative length of the pipe with special arrangements to relieve the ends of the pipe of subsidiary strains. The subsidiary strains could be produced by the effect of the weight of water in a long horizontal pipe or by the influence of unsuitable capping arrangements to seal the ends against leakage.

The apparatus is shown in Drawing No. CE-E-2824 attached and further illustrated in the photographs of the assembled equipment, Plates Nos. 1 and 2. Sealing of the pipe ends was effected with specially prepared cup leathers backed by flat reinforced end plates. The cup leathers confined the water under pressure but allowed the pipe wall to distend freely in the circumferential direction under the influence of the applied pressure. Short samples of pipe were used measuring 2 feet long. These were tested with the axis vertical in order to remove differential effects of the weight of water in the pipe.

The free diametral distension occurring under the applied hydrostatic load was measured by two gauges each sensitive to one ten thousandth part of an inch. The gauges were mounted in diametrically opposite positions at precisely the same height above the floor. The difference of the readings taken by the gauges was recorded after each load increment as the diametral distension. Load increments were applied progressively in small steps in order to check closely the behaviour of the specimen throughout the range of the applied load. The total load applied on each specimen was kept within the limits of the test pressures listed in the Australian Standard Specification No.A41-1959 for the respective size and class of pipe under test. No destruction of the specimens was intended.

Because of the possibility of the pipe samples having been mishandled in transit and cracked, each sample was subjected to a preliminary load up to the full Australian Standard test pressure before the strain measurements were taken. This was found necessary in order to protect the sensitive gauges from possible damage.

3. Reduction of Test Results

The average stress in pounds per square inch was computed from the formula

$$\frac{p\,r}{t} = f_a$$

in which

p = applied hydrostatic pressure in pounds per square inch.

r = the radius of the internal surface of the pipe in inches.

t = the thickness of the pipe in inches.

The average diametral strain was computed by dividing the observed pipe distension in inches by the mean diameter of the pipe, also in inches. The mean diameter of the pipe was calculated from the following formula:

$$d_m = \frac{\text{internal diameter in inches + twice the wall thickness in inches}}{2}$$

The calculated values of stress (f_a) and strain ($s = x/d_m$) were plotted as shown in graphs Nos. CE-E2684A to CE-E-2684Z inclusive.

The difference in the distensions measured were of the order of fractions of one thousandth of an inch. Because of the very low order of magnitude of the strains small movements caused by the distortion in shape of the test apparatus as the load was applied were by comparison significant. This necessitated independent mounting of the strain gauges which were set up on special three point stands mounted on the solid concrete floor with screw adjustments for levelling. The specimen which was arranged vertically was mounted on a special three point support. The three point support consisted of three steel cylinders with conical points at each end mounted vertically and welded to a steel ring. This form of mounting was found necessary to prevent flexural deflection of the end plates causing alteration of the position of the specimen. Co-axial studs spaced equally around the specimen retained the end plates in position. The studs were only tightened nominal amounts to avoid compressive strain in the material of the specimen and to avoid the possibility of end restraint against the circumferential expansion of the pipe occurring through the agency of friction.

Notwithstanding the care taken in the mounting of the specimens the effect of initial load frequently showed on the strain gauges as an adjustment of the position of the specimen. The effect was worse for specimens of small diameter than for large ones. Meticulous care in preparation of the specimen ends may have eliminated some of this trouble Also, replacement of the simple three point support stand with a three screw precise levelling system controlled through a sensitive striding bubble, to correct the positional movement of the specimen, may have resulted in improvement. The scope of the present series of tests did not allow for the design or construction of this more expensive form of apparatus. The test results for the pipes of smaller diameter suffer in accuracy from these causes.

4. Test Results

The Stress/ Strain plots reproduced on Drawings CE-E-2684A to CE-E-2684Z inclusive show evidence of the specimen movements. Movement of a specimen which apparently occurred at distinct intervals had the effect of creating a discontinuity in the stress/ strain plot. This occurred two or three times during a single test in the worse cases. Other tests particularly of the larger diameter specimens suffered little from the effects of specimen movement. Once the readjustment of the specimen occurred during the test the strain readings usually resumed the apparent linear trend of the preceding points. In general the test results for the pipes of 12 inches diameter are most consistent.

If the average slopes of the stress/ strain diagrams are measured without regard to the apparent specimen movements, gross errors are possible in finding a line of best fit. If the stress/ strain graphs are first examined for consistency in slope, sets of points with similar slope will be found. The slopes so found indicate that the material behaves elastically generally over the range of the test loads.

The values of stress divided by strain obtained by the process of grouping the points with one or two exceptions tend to a single value within the limits of experimental accuracy corresponding to the pressure readings and strain measurements.

The drawings of the Stress/ Strain graphs have accordingly been adjusted on the assumption that the discontinuities appearing thereon are due to uncontrolled specimen movements. The lines of mean slope have been shown and the corresponding value of the apparent elastic constant (E) has been shown.

The values of E have been tabulated in Table I on which the values of the arithmetic mean values of 'E' for each group of specimens is also shown, together with the arithmetic mean of all specimens tested, the Standard Deviation and the Standard Error of the Mean.

5. Accuracy of Measurement

Pressure readings were taken on Bourdon Type Gauges selected to give midscale to extreme scale readings over the range of the tests. The gauges were calibrated by comparison with a Standard Dead Weight Pressure Gauge Testing apparatus. The accuracy of the gauges as read is estimated to be of the order of 5 per cent of the scale reading.

Measurements of strain reckoned in accordance with the magnitude of the distensions recorded and the scale accuracy of the gauges is estimated in accordance with the following table:-

12 inch pipes	±	1 per cent
10 " "	±	4 " "
8 " "	±	5 " "
6 " "	±	5 " "
4 " "	±	8 " "

The above table takes no account of the effects of the adjustment of the position of the specimen.

Errors in the measurement of the pipe dimensions are negligible by comparison with the strain and pressure measuring errors.

The order of accuracy of the calculated values of stress/ strain therefore varies from about ± 6 per cent for the 12 inch pipe samples up to ± 13 per cent for the 4 inch pipes, allowing for an assumption that positive and negative errors are equally likely in the measurements.

6. Conclusions

The computed Standard Error of the Arithmetic Mean value for the stress/ strain constant for all samples tested corresponds to about five per cent and is slightly less than the estimated error of measurement not allowing for the effects of specimen movement. This suggests that the procedure adopted for allowing for specimen movement does not entail significant error.

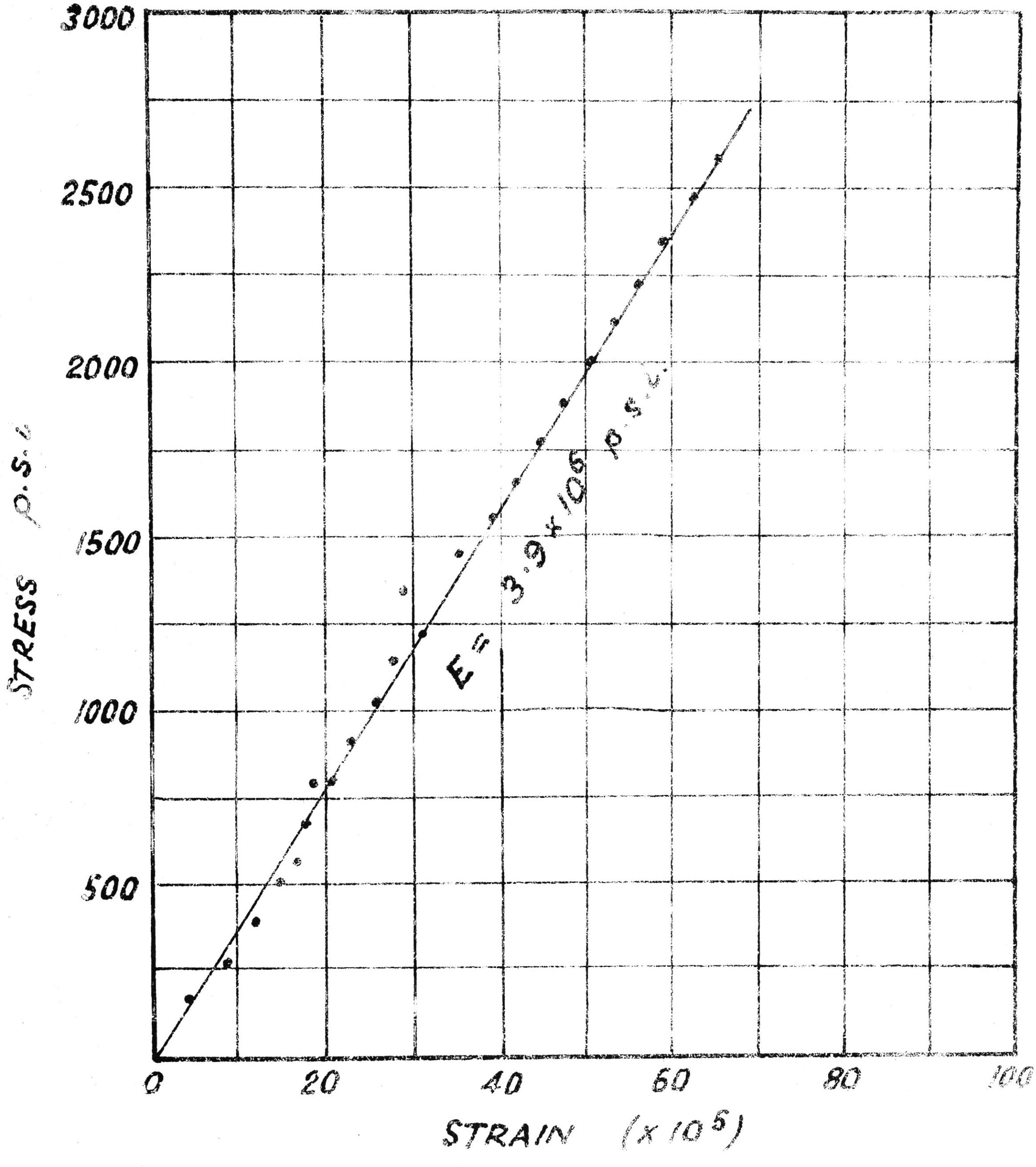
The values of the stress/ strain relationship obtained in the tests indicate that within the range of test the material of the pipes behaves elastically and the mean value of the Apparent Elastic Constant for the material is 3.9 million pounds per square inch.

TABLE I.

Specimen	Internal Diameter of Pipe in Inches	Aust. Stan. Spec. Class	Apparent Elastic Constant x 10^{-6}
1A	12	C	3.9
2A	12	C	3.8
2B	12	C	3.3
3A	12	C	2.7
4A	12	C	3.5
4B	12	C	5.2
5A	12	C	3.7 Arithmetic Mean 3.7
6	10	D	3.9
7	10	D	4.5
8	10	D	6.5
9	10	D	3.4
10	10	D	5.0 Arithmetic Mean 4.6
11	8	D	3.7
12	8	D	3.4
13	8	D	- x
14	8	D	4.4
15	8	D	3.5 Arithmetic Mean 3.8
16	6	D	3.5
17	6	D	3.5
18	6	D	3.5
19	6	D	3.5
20	6	D	- x Arithmetic Mean 3.5
21	4	D	3.6
22	4	D	4.2
23	4	D	3.0
24	4	D	- x
25	4	D	1.9 Arithmetic Mean 3.2

Arithmetic Mean of all Samples 3.85 x 10^6 pounds per square inch.
Standard Deviation of Mean 0.91 x 10^6 pounds per square inch.
Standard Error of the Mean 0.18 " " " "

x Specimens cracked during test.
Specimens 1B and 3B found damaged before test.



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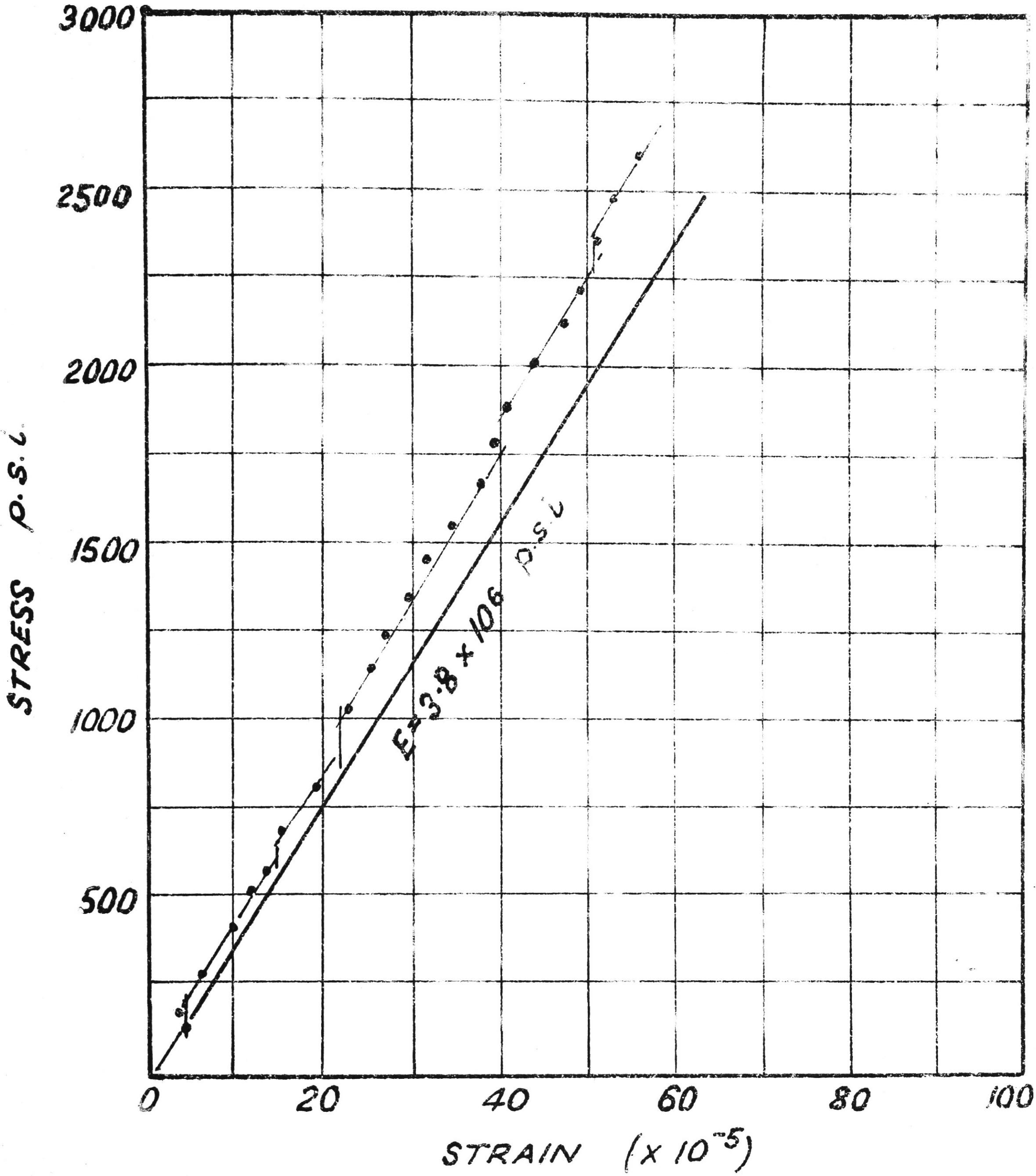
ELASTICITY OF ASBESTOS CEMENT PIPES SPECIMEN No. 1A. 12 INCH CLASS "C"	Drawn: R.T.R. Traced: J.H. Checked: R.W.	Date: 30 · 6 · 62. CE-E-2684A



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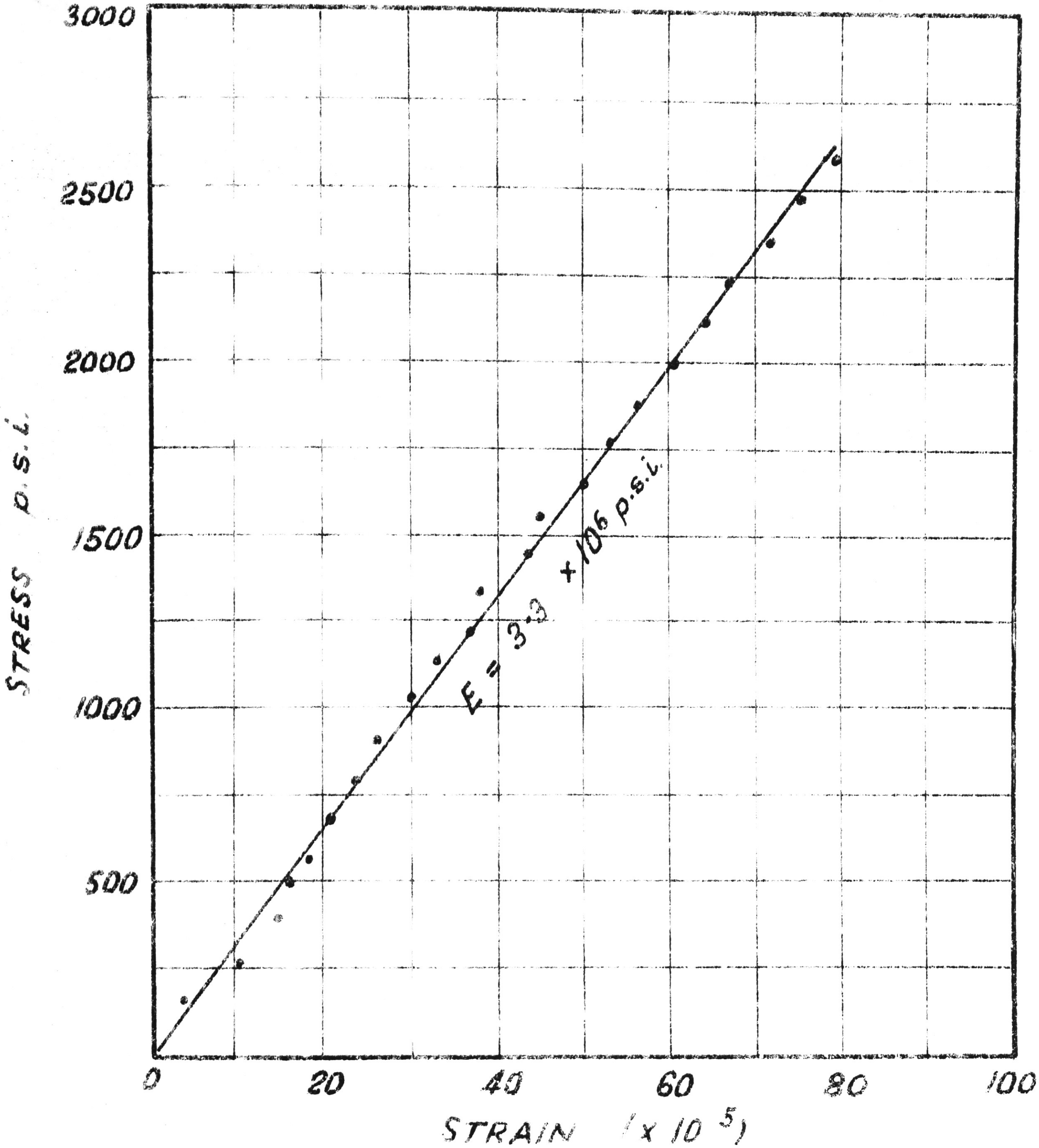
ELASTICITY OF ASBESTOS CEMENT PIPES SPECIMEN Nº2A 12 INCH CLASS "C"	Drawn: R.T.H Traced: J.H. Checked: R.H.	Date 30·6·62. CE-E-2684 B



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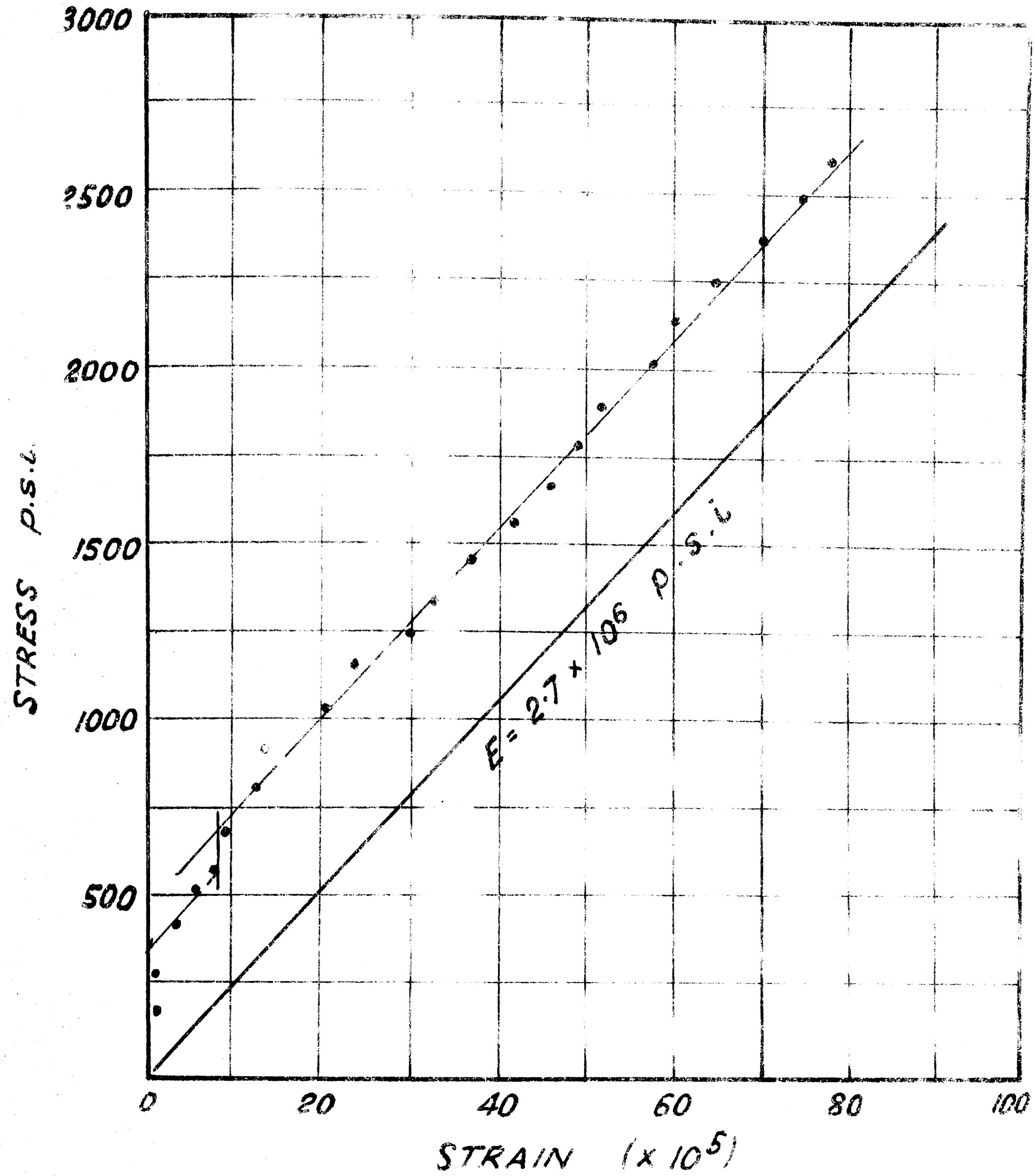

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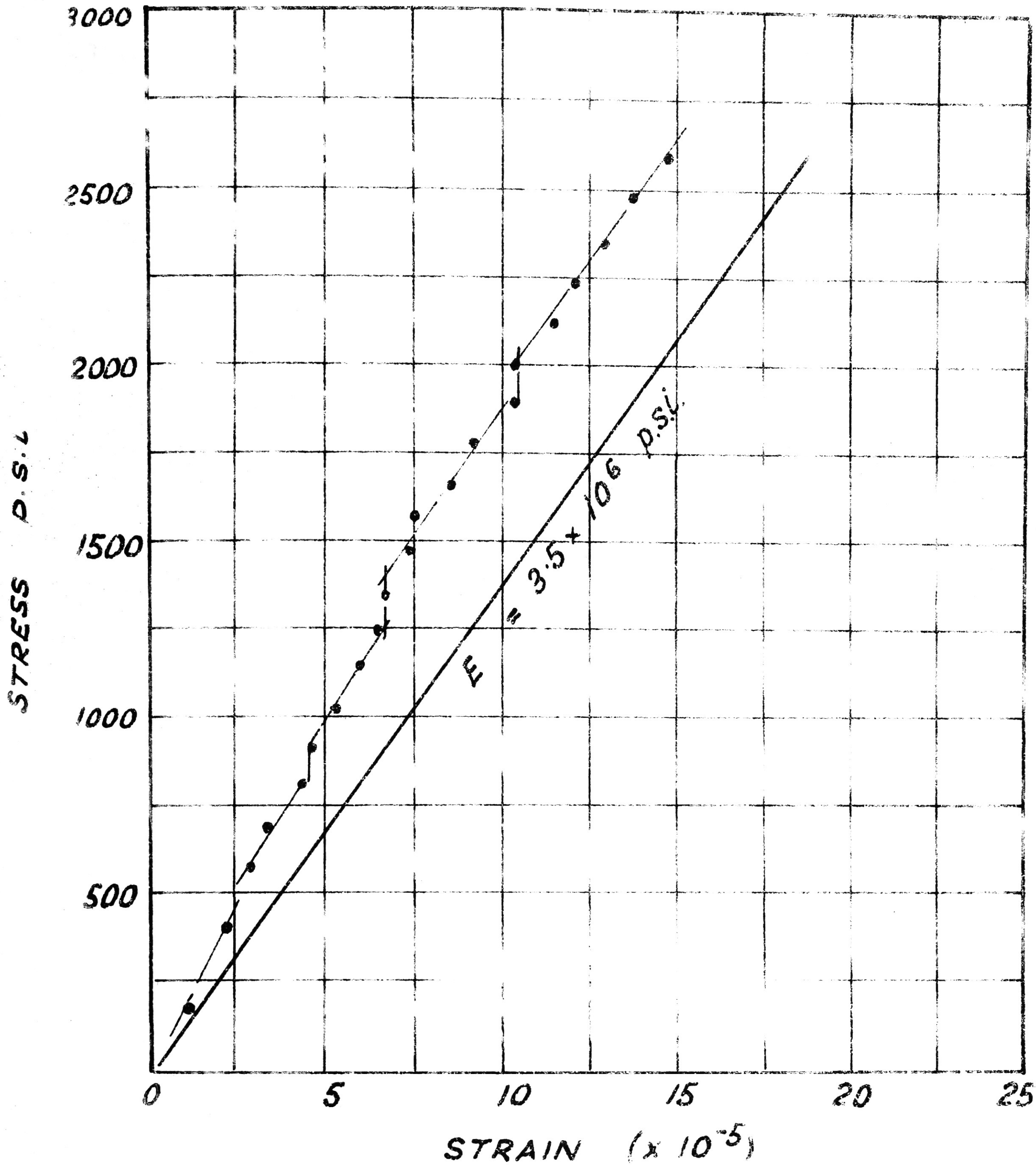
ELASTICITY OF ASBESTOS CEMENT PIPES SPECIMEN Nº 3A 12 INCH CLASS C	Drawn: R.T.H. Traced: J.H. Checked:	Date: 30-6-62 CE-E-2684^D



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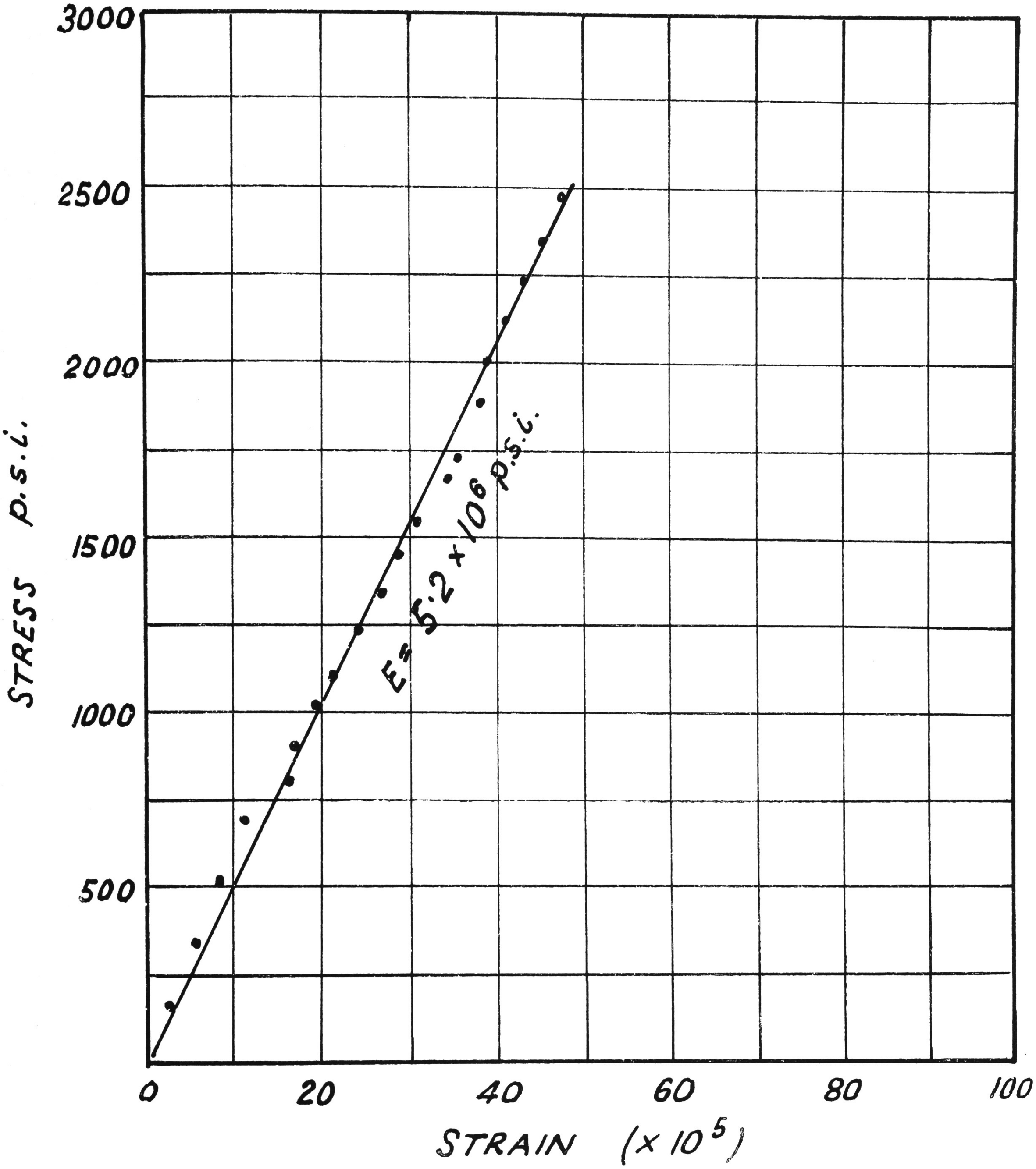

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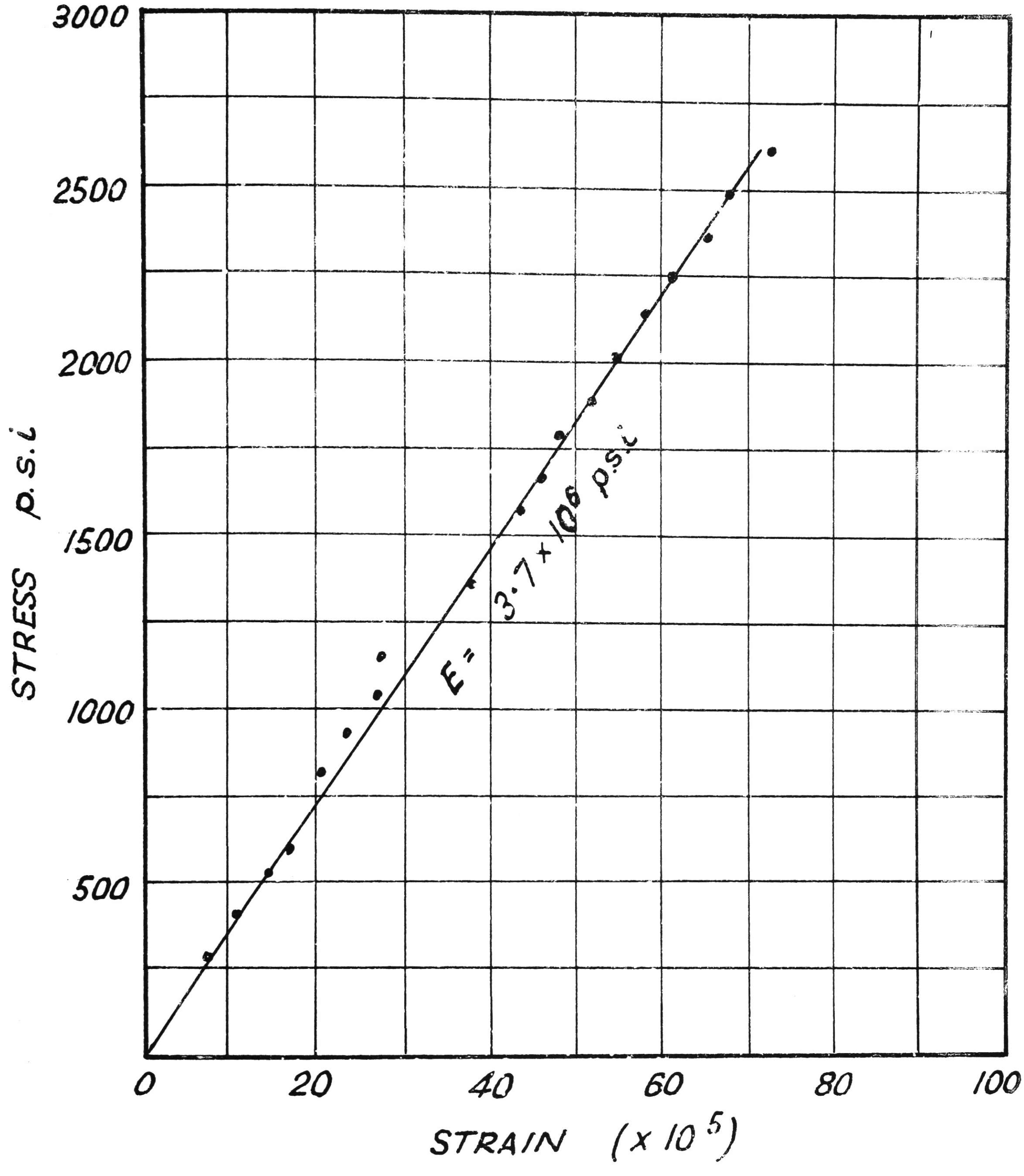

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ELASTICITY OF ASBESTOS CEMENT PIPES	Scale:	Date 30 · 6 · 62
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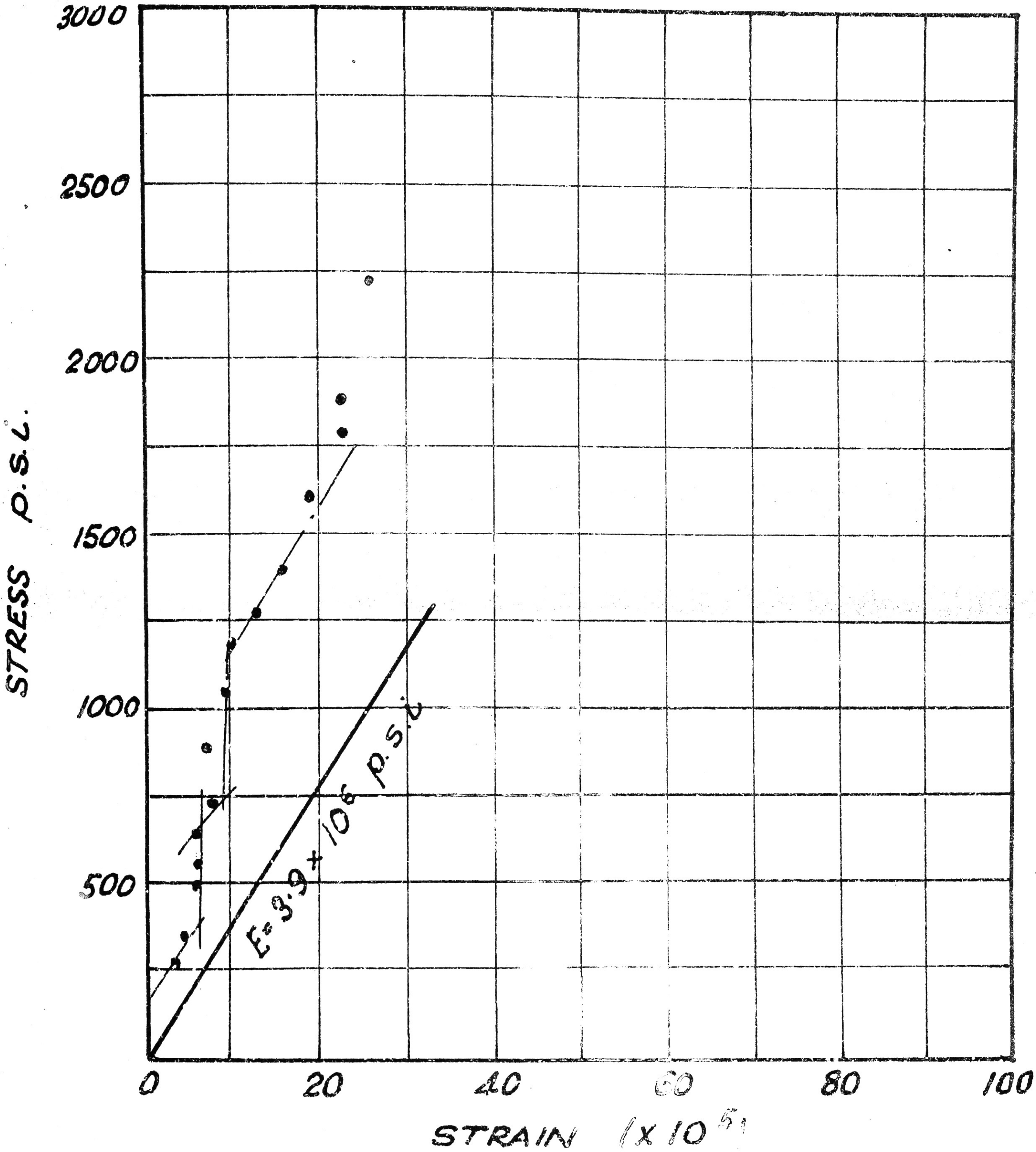

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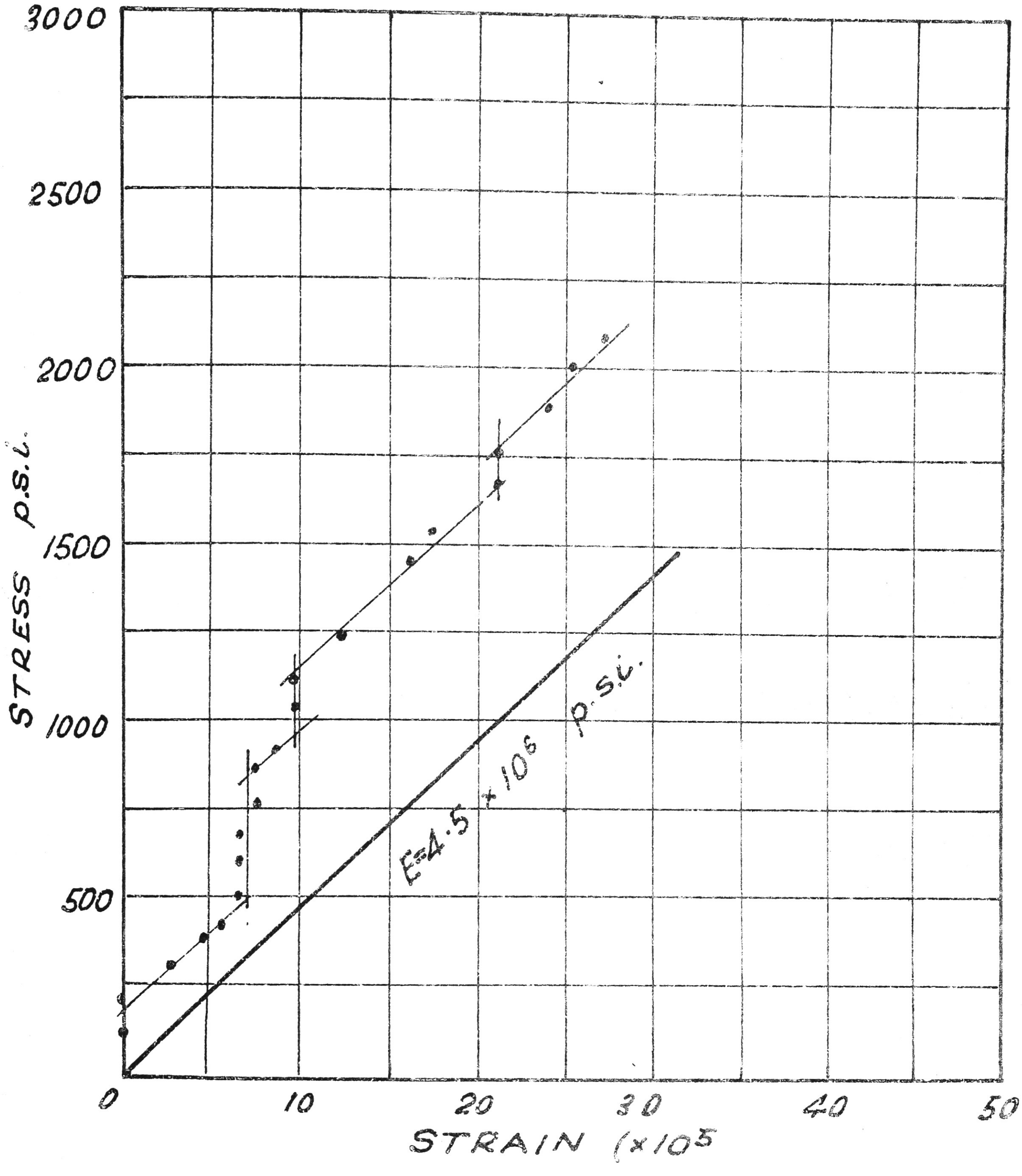
ELASTICITY OF ASBESTOS CEMENT PIPES SPECIMEN Nº 6 10 INCH CLASS "D"	Drawn: R.T.H Traced: J. H. Checked: RJH.	Date: 30 · 6 · 62 CE-E-2684H



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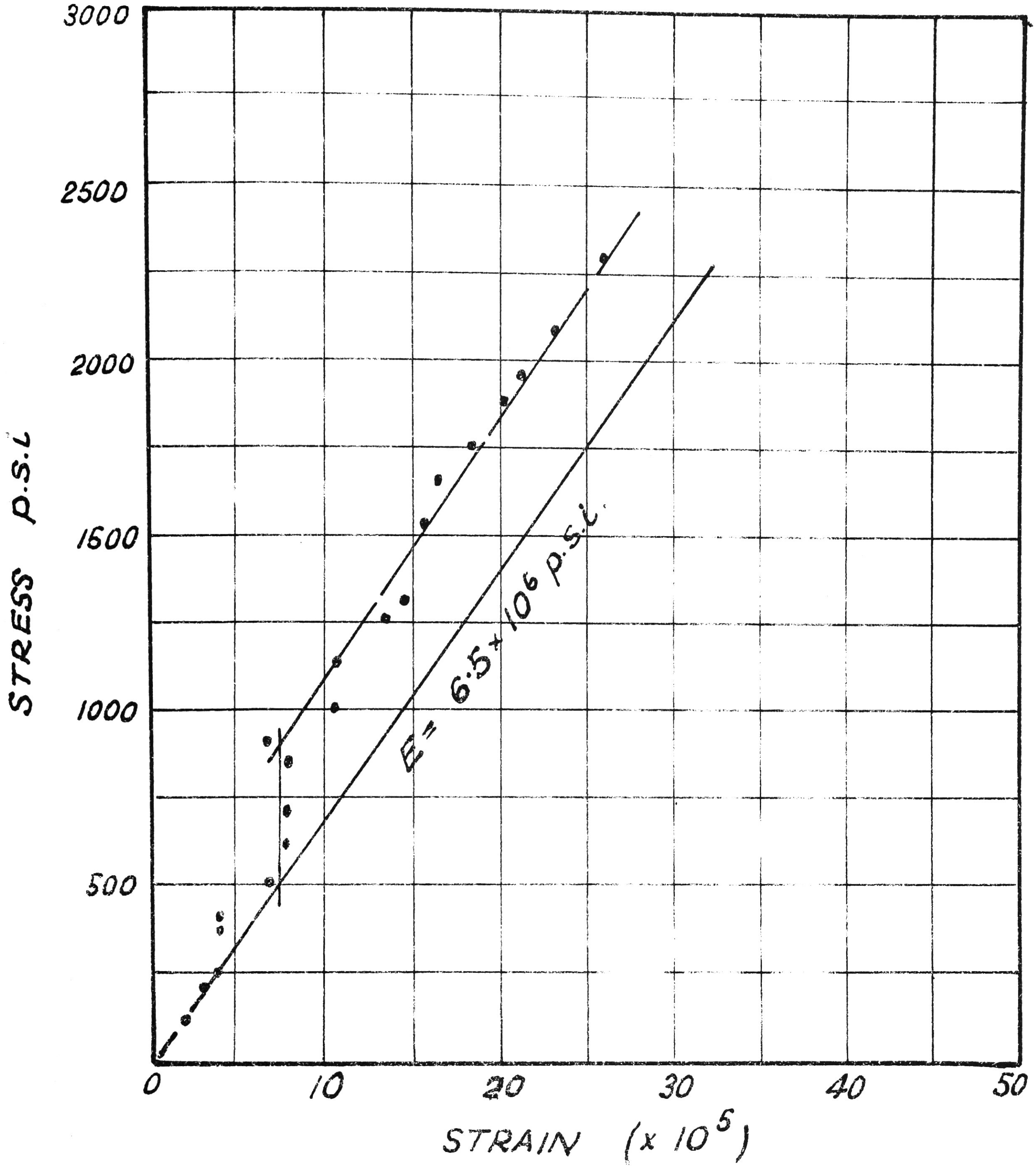

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ELASTICITY OF ASBESTOS CEMENT PIPES		Date 30·6·62
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SPECIMEN Nº 8 . 10 INCH CLASS "D"	Traced: J.H	
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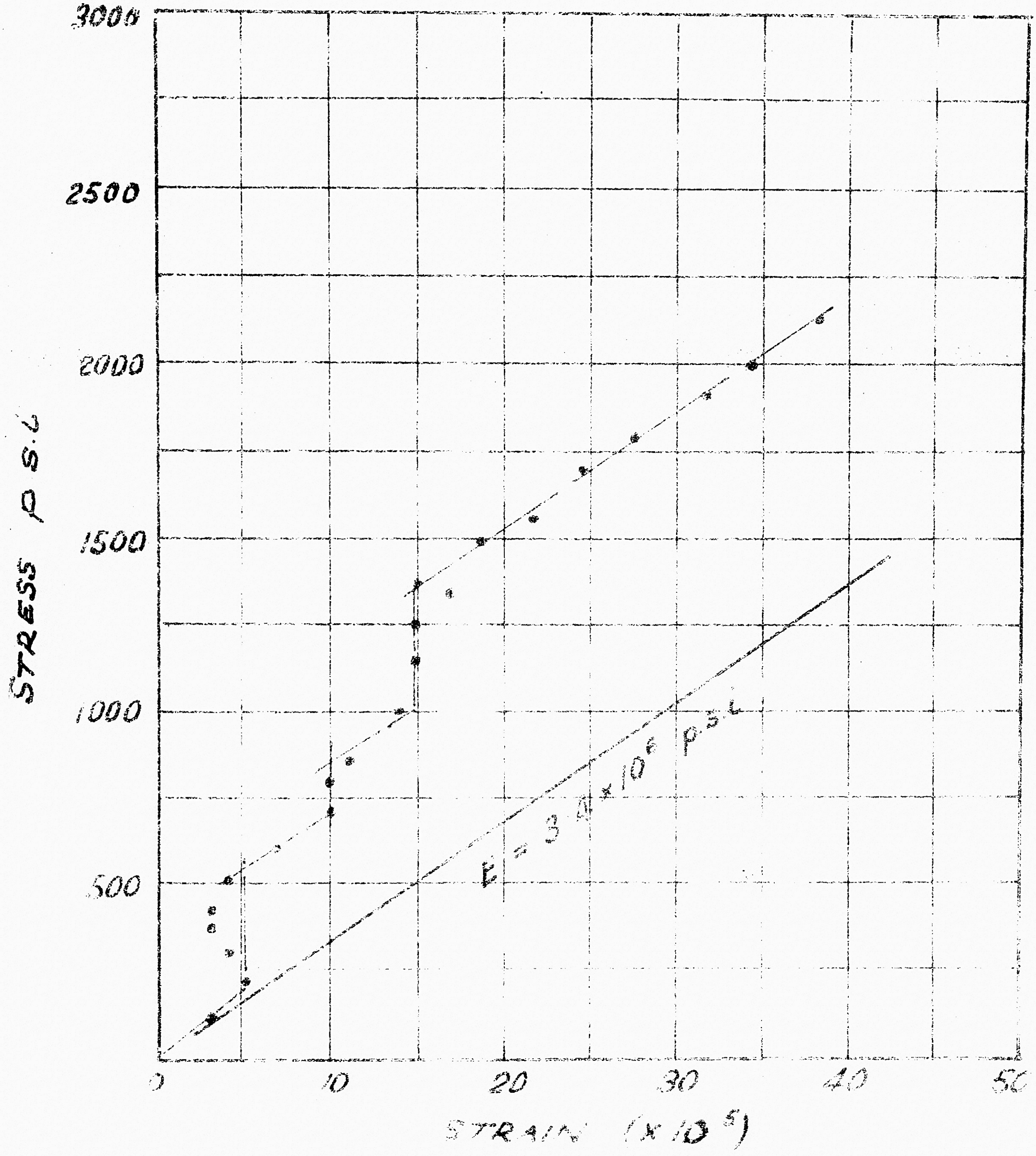

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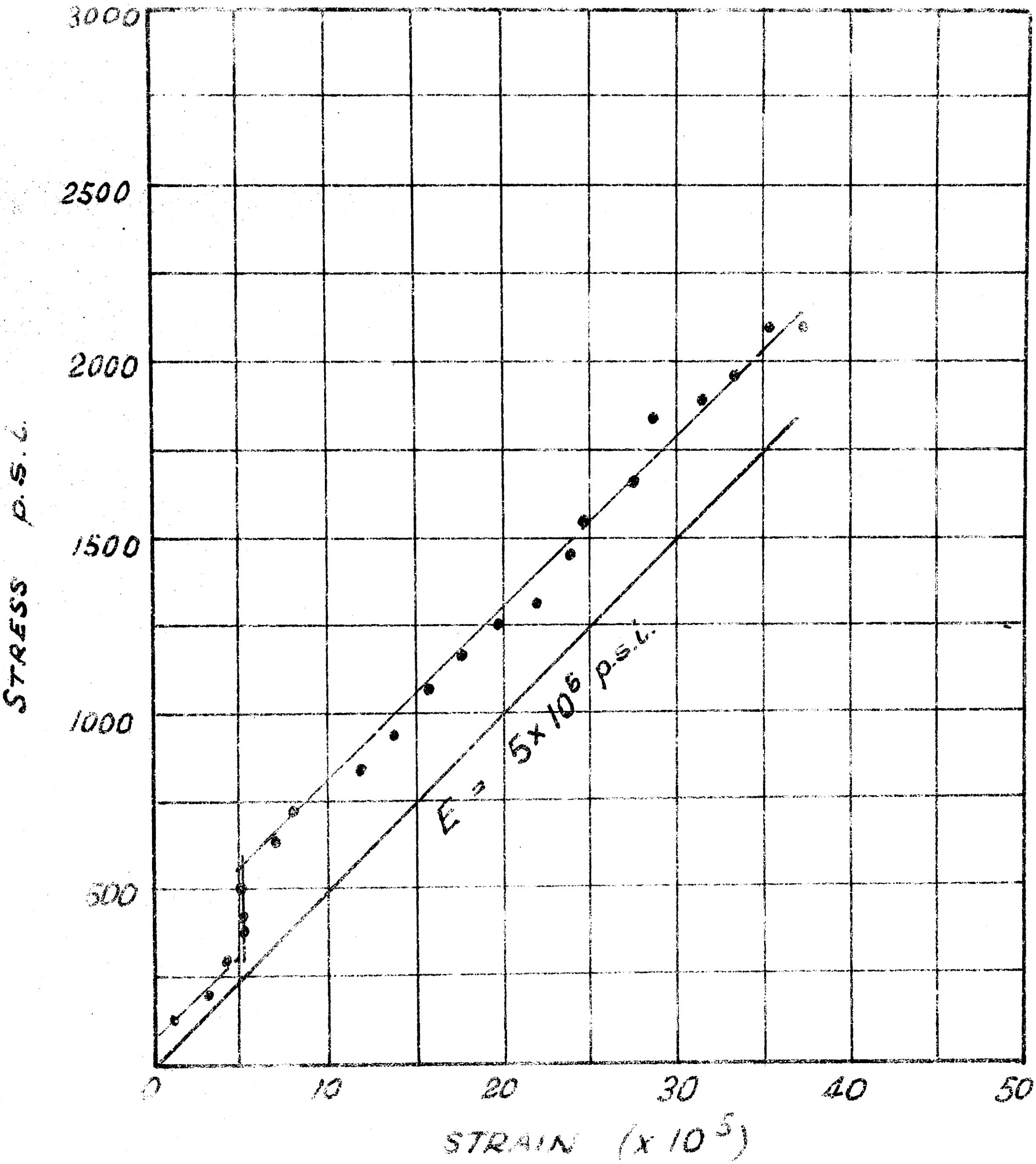

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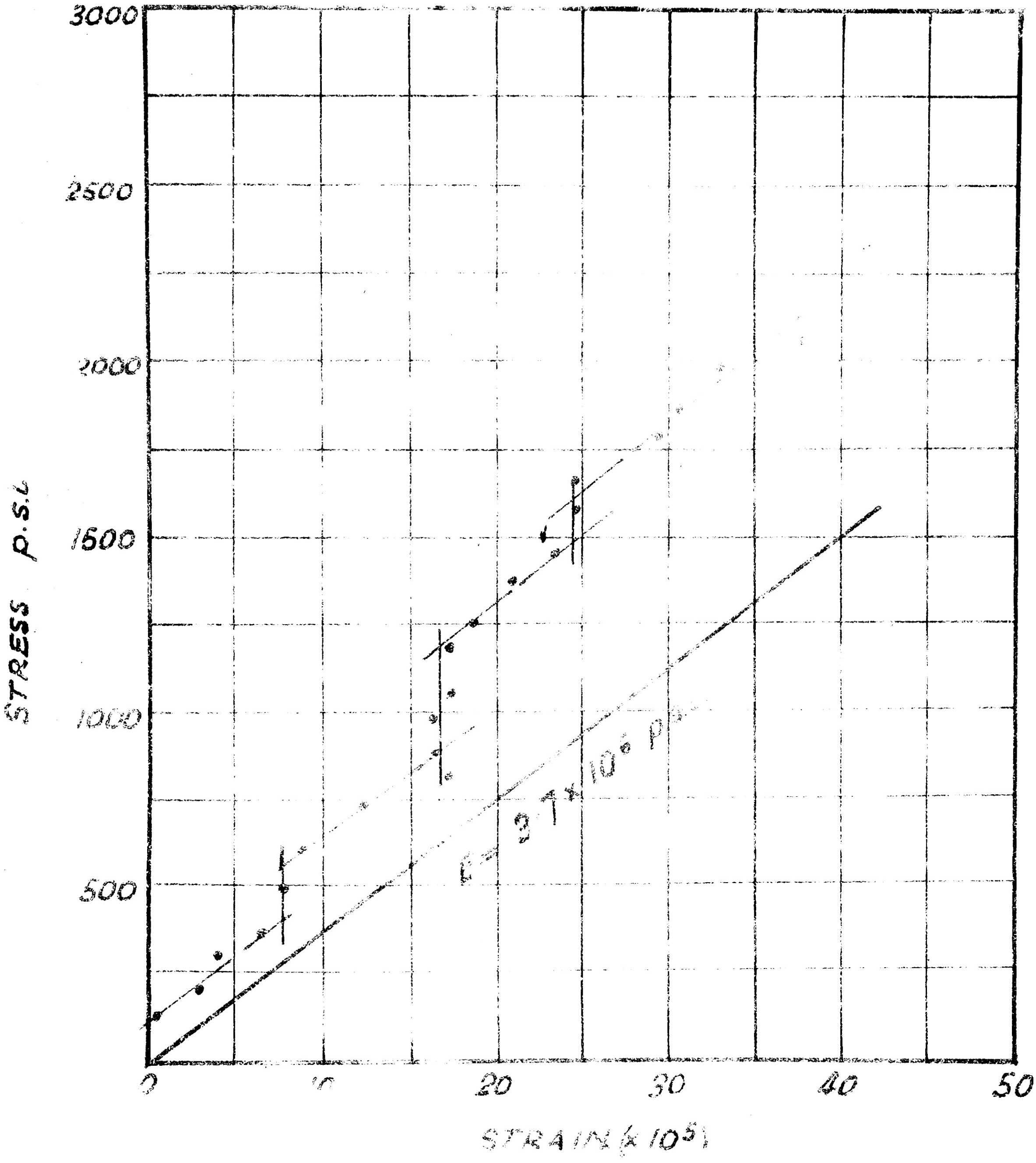
ELASTICITY OF ASBESTOS CEMENT PIPES SPECIMEN Nº10. 10 INCH CLASS "D"	Scale: Drawn: R.T.H Traced: J.H Checked R.H.	Date: 30.6.62 CE-E-2684M



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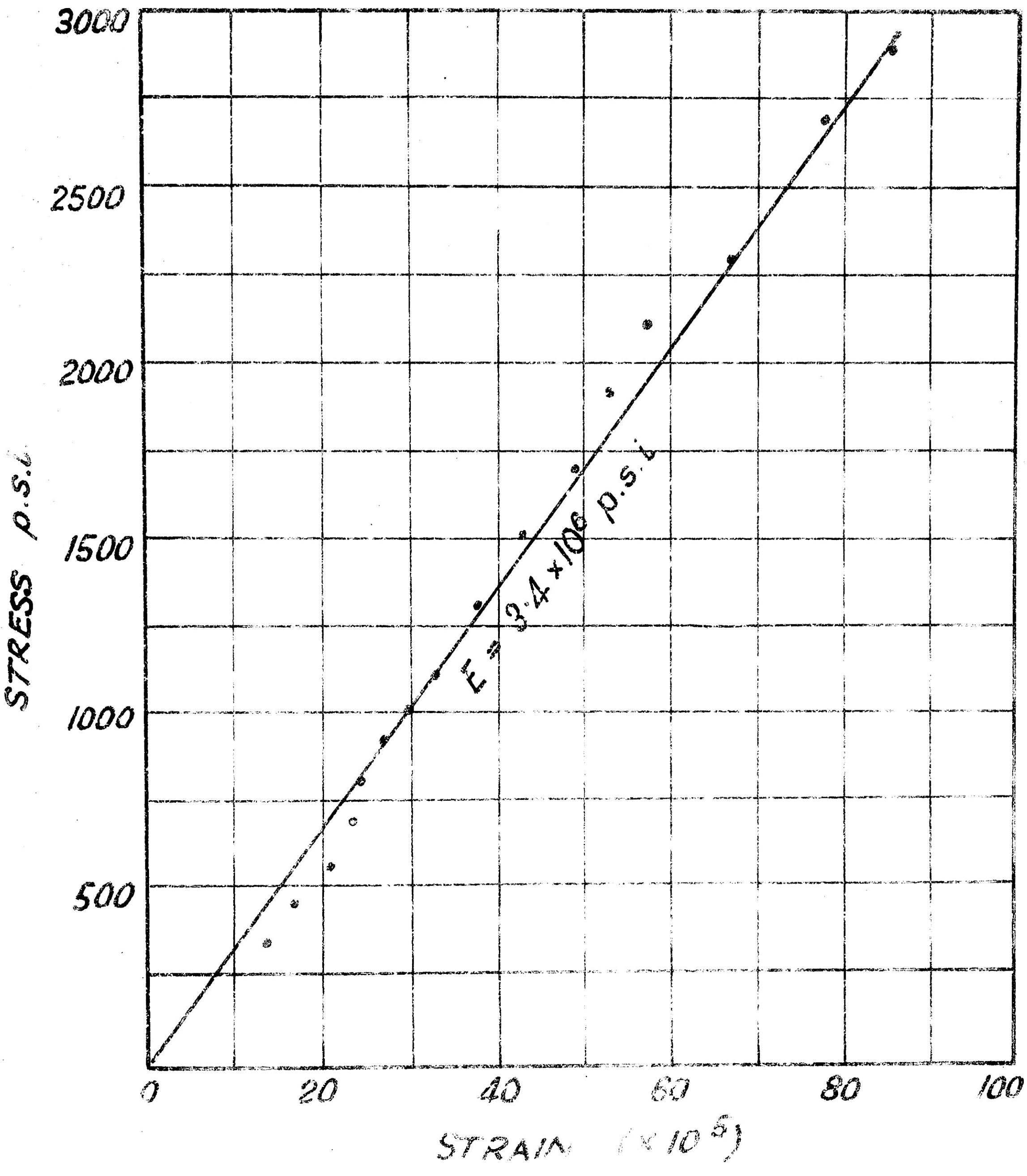

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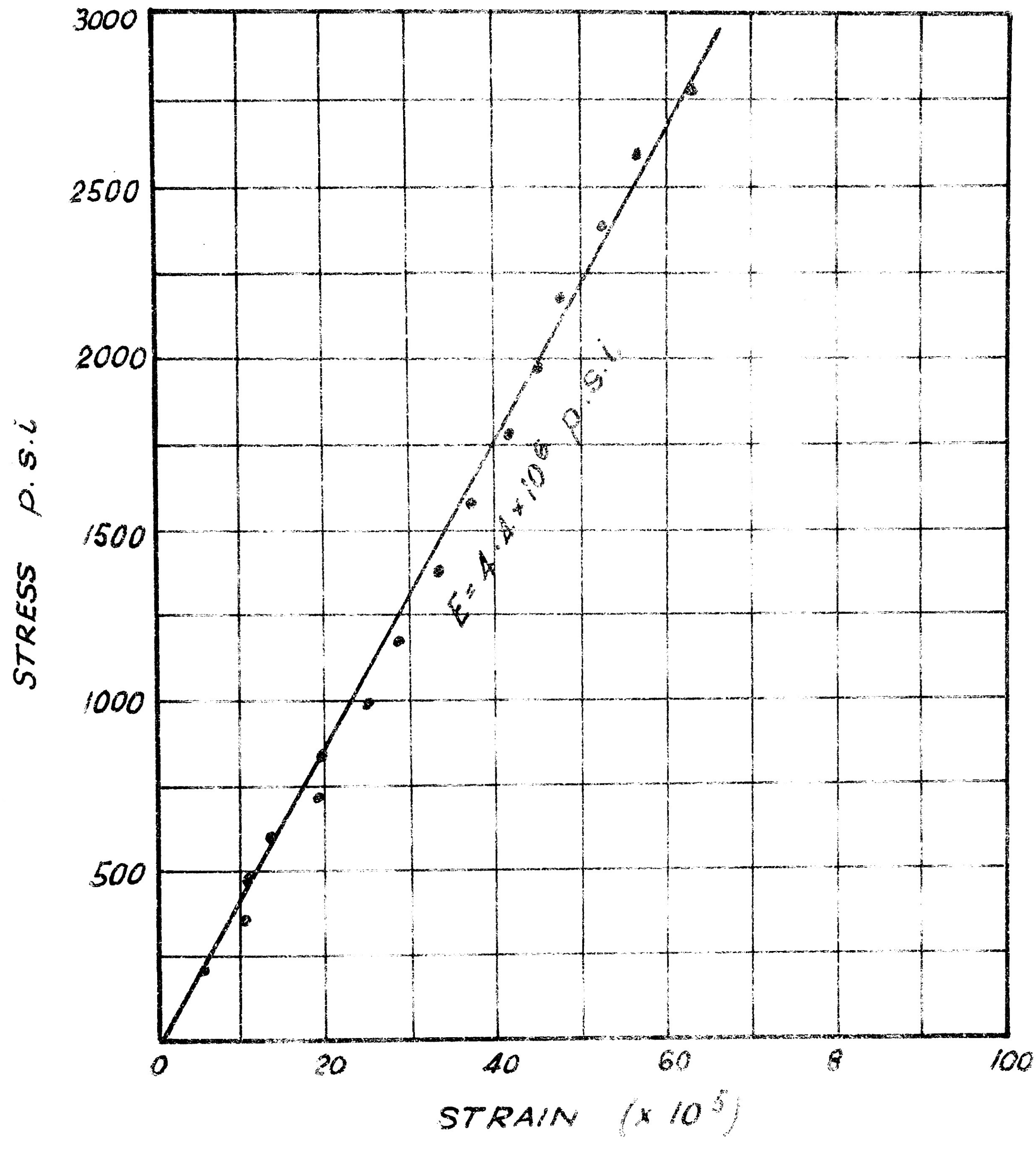

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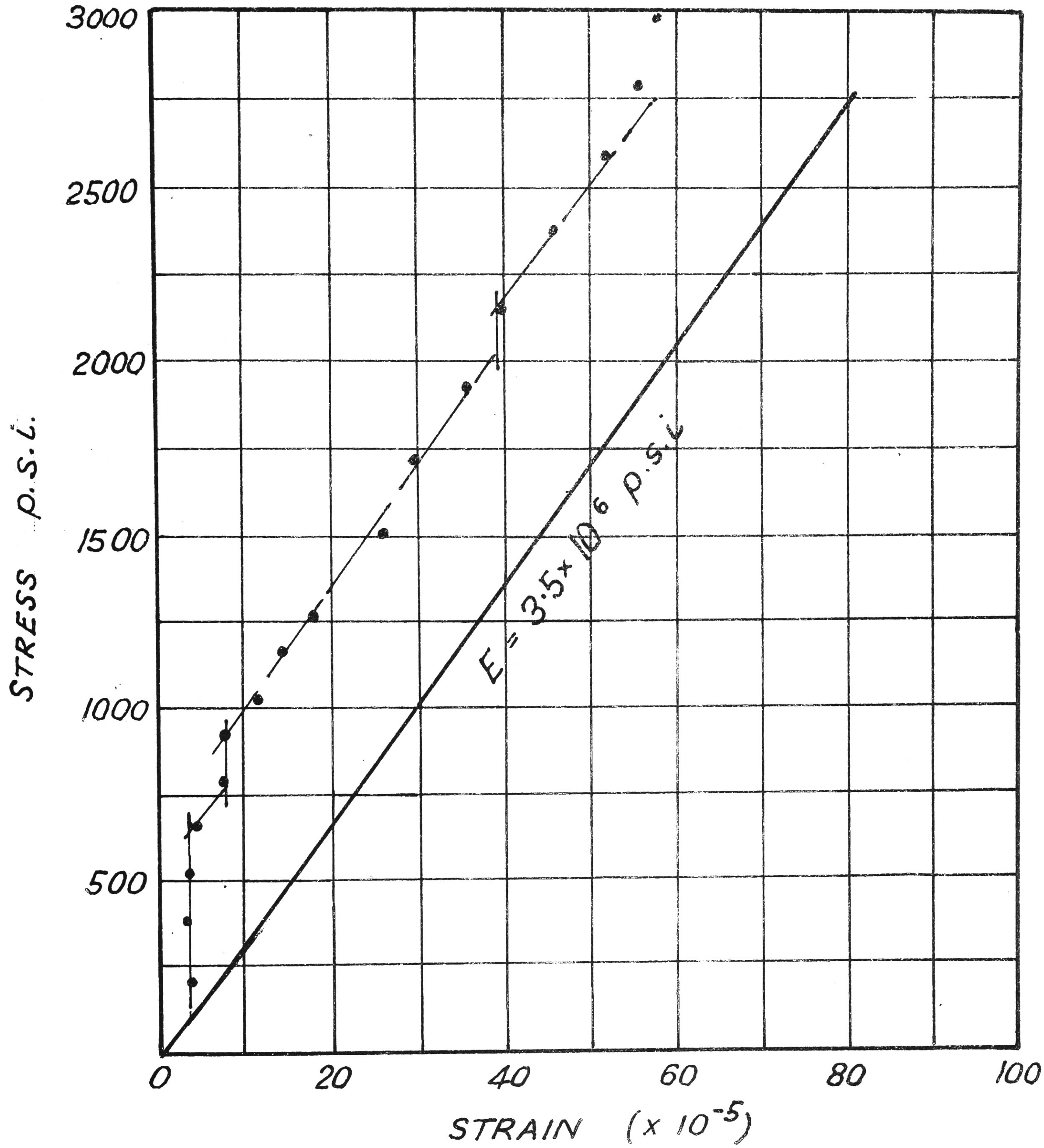

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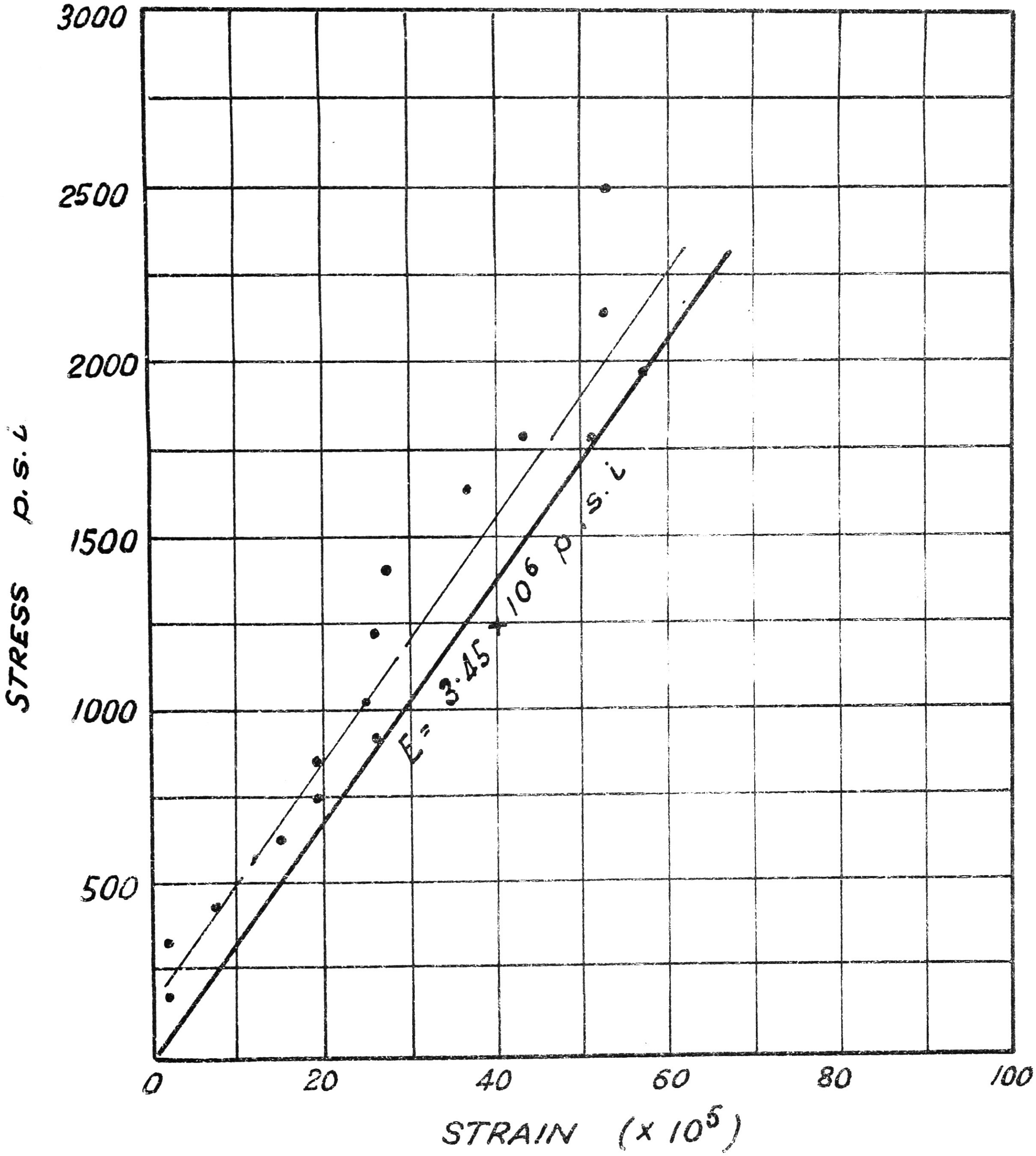

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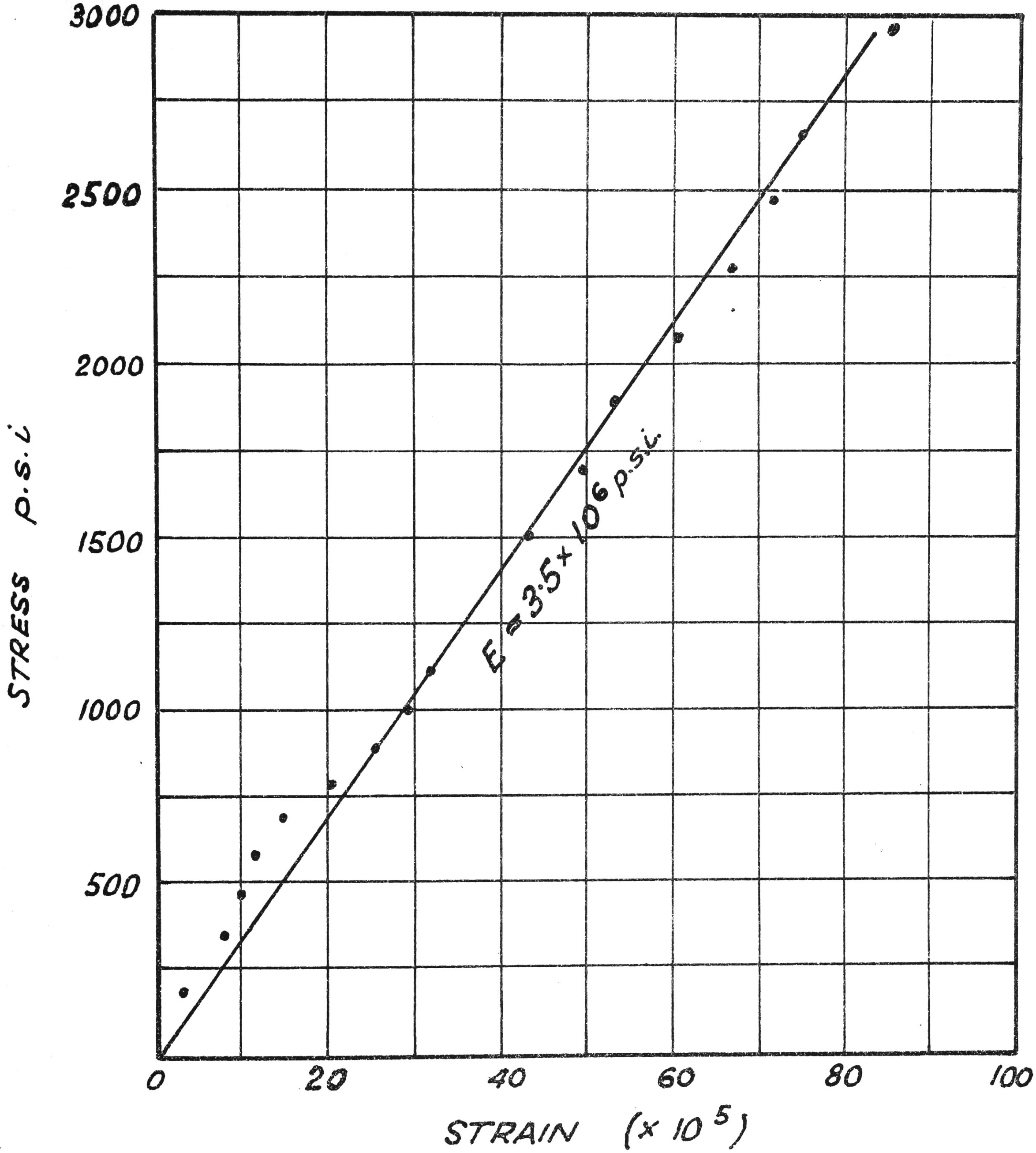

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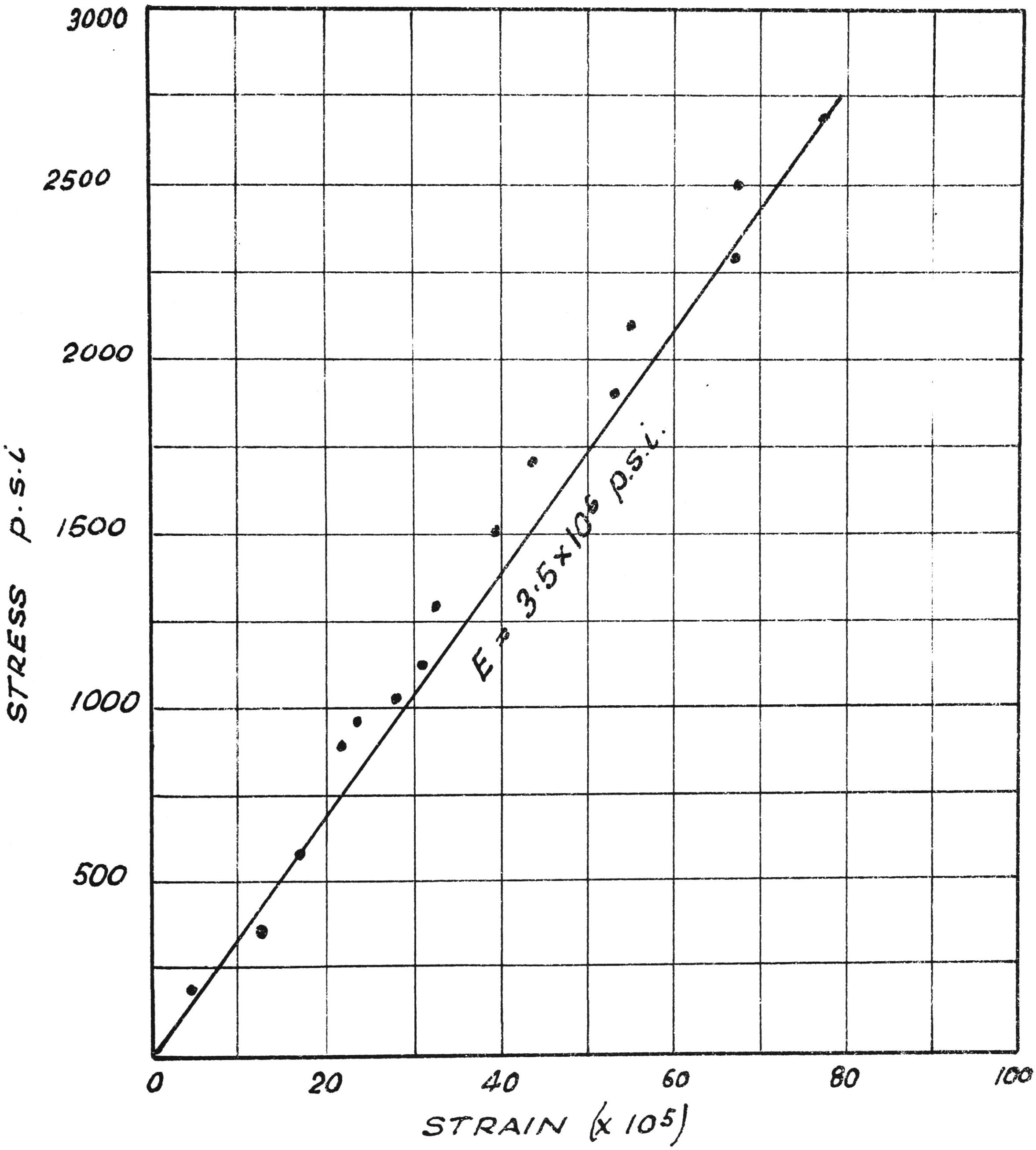

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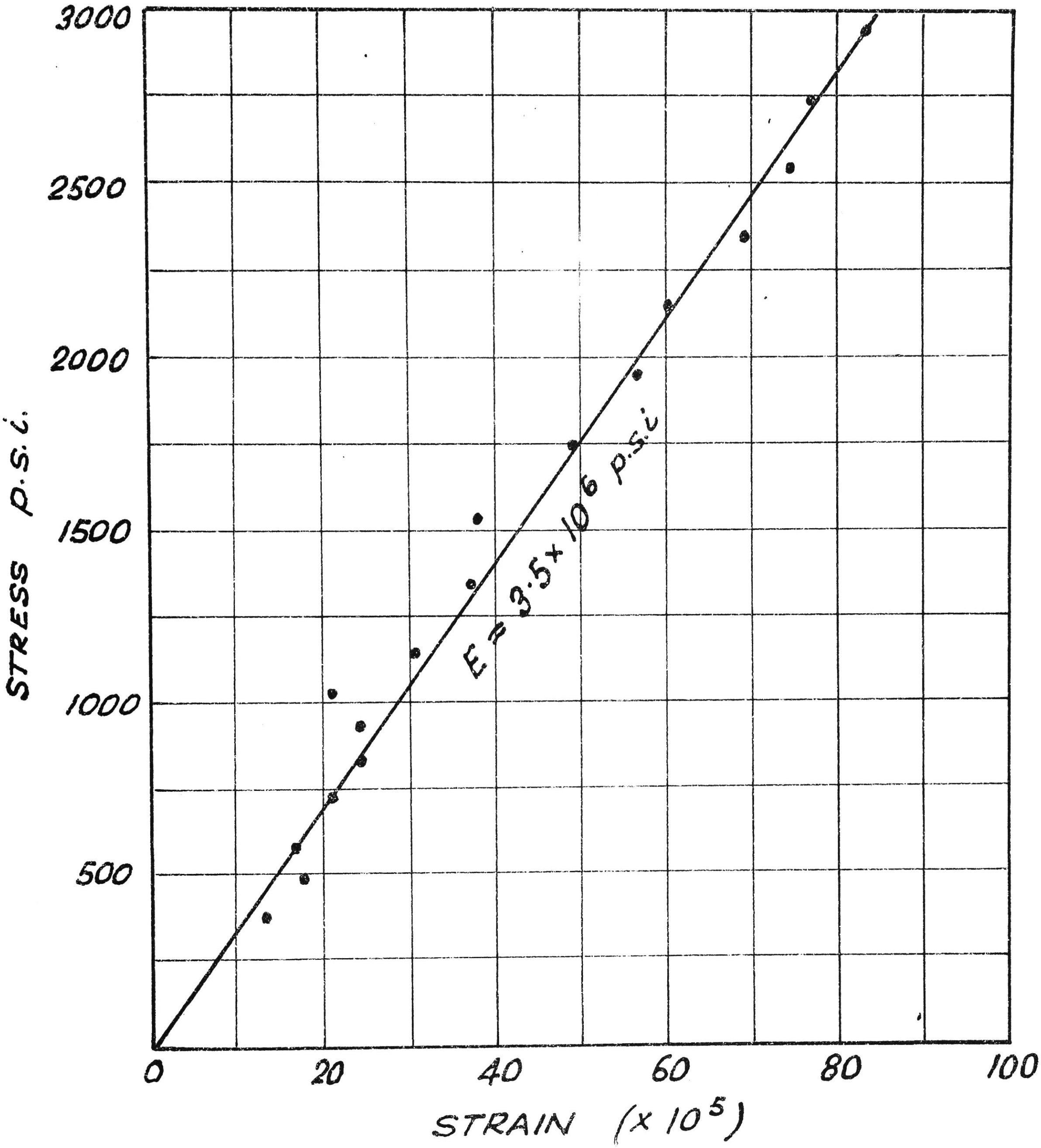

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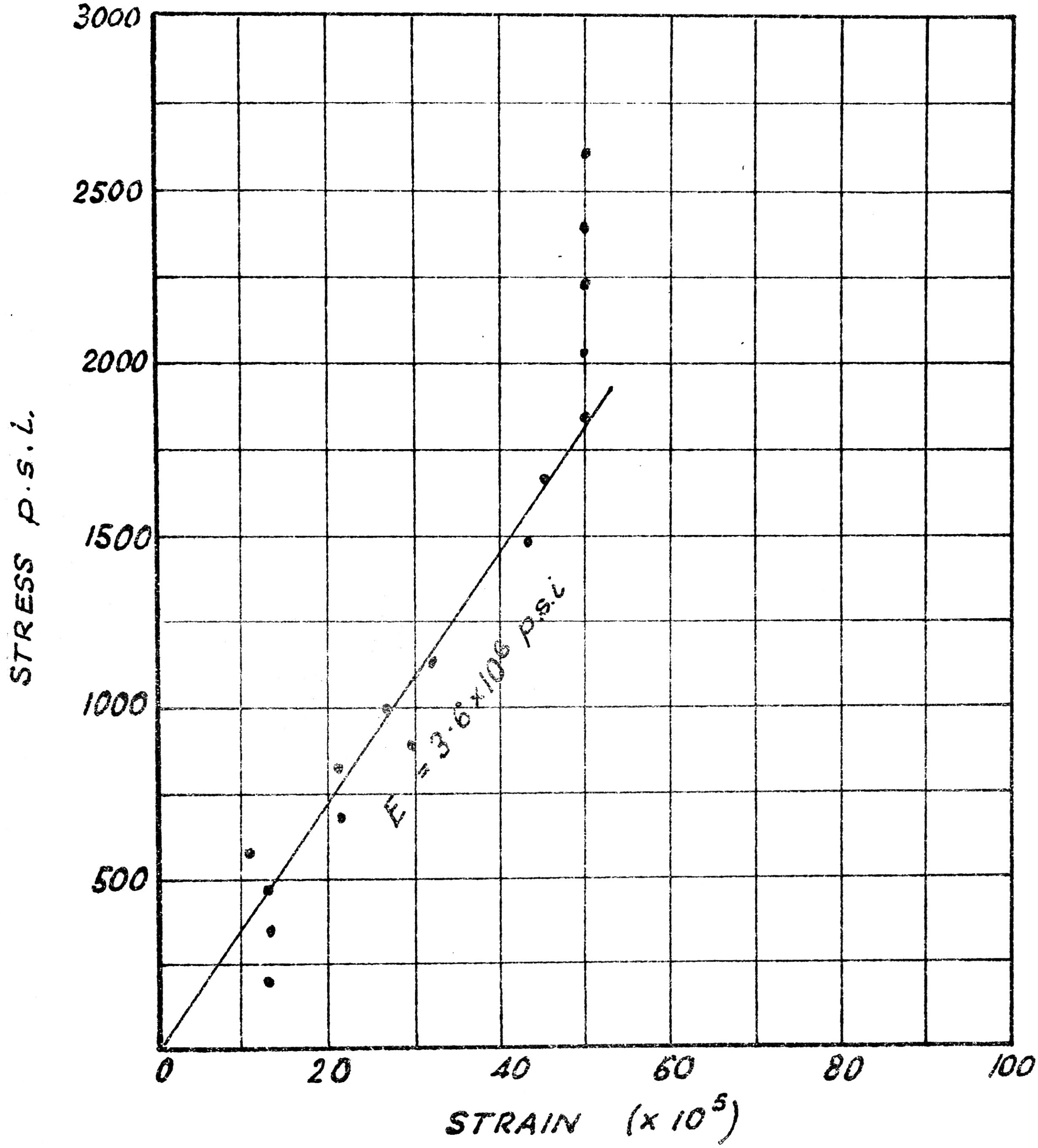
ELASTICITY OF ASBESTOS CEMENT PIPES SPECIMEN Nº19 . 6 INCH CLASS "D".	Drawn: R.T.H Traced: J.H Checked: RH	Date: 30·6·62 CE-E-2684 V



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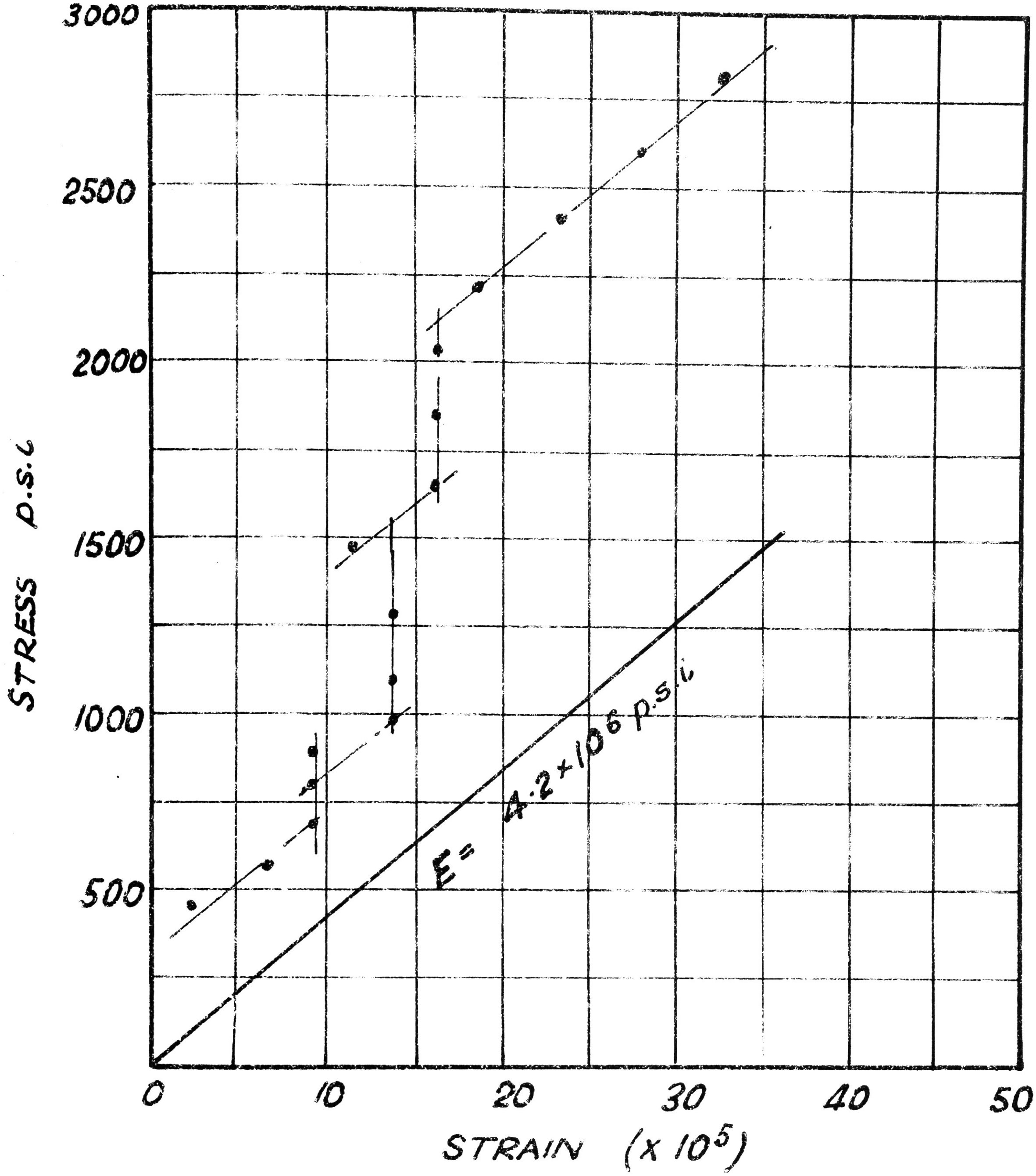
ELASTICITY OF ASBESTOS CEMENT PIPES SPECIMEN Nº 21. 4 INCH CLASS "D".	Drawn: R.T.H Traced: J.H. Checked R.a.H	Date: 30·6·62 CE-E-2684W



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ELASTICITY OF ASBESTOS CEMENT PIPES		Date: 30 · 6 · 62
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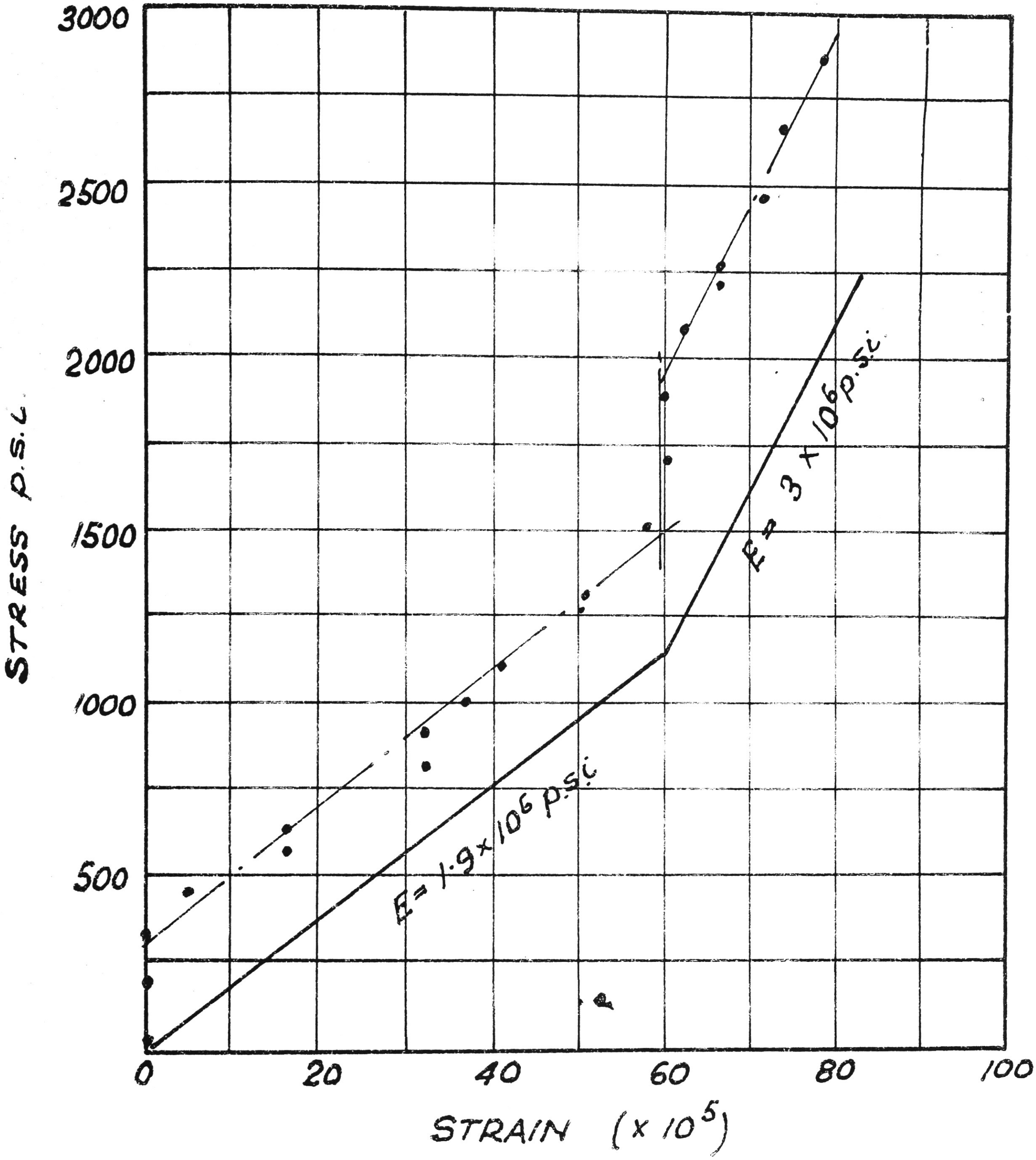
	Traced: J. H	CE-E-2684^x
SPECIMEN Nº 22. 4 INCH CLASS "D".	Checked: [illegible]	



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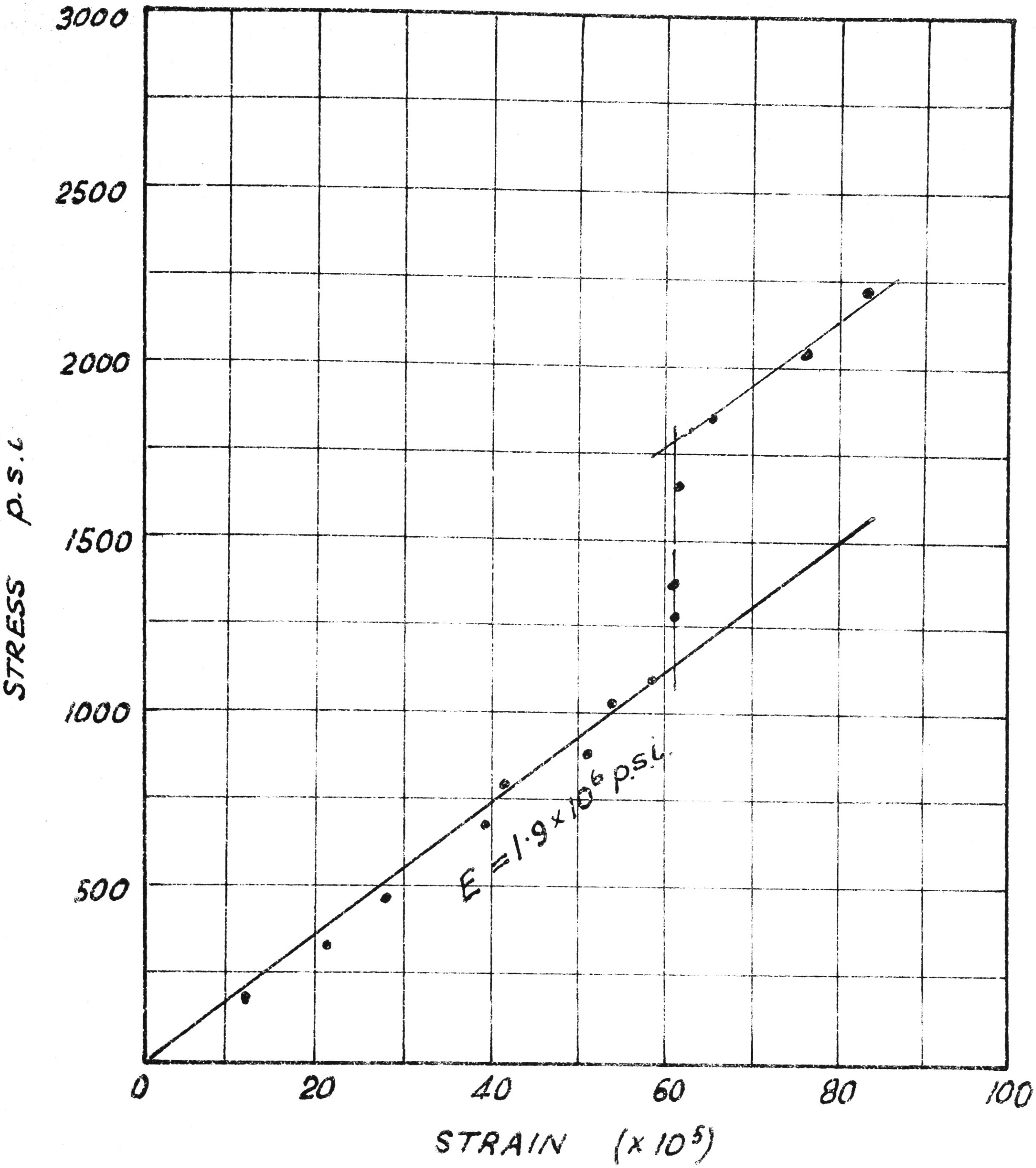
ELASTICITY OF ASBESTOS CEMENT PIPES SPECIMEN Nº 23. 4 INCH CLASS "D"	Drawn: R.T.H Traced: J.H. Checked: RdH	Date: 30·6·62 CE-E-2684Y



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ELASTICITY OF ASBESTOS CEMENT PIPES		Date: 30 · 6 · 62
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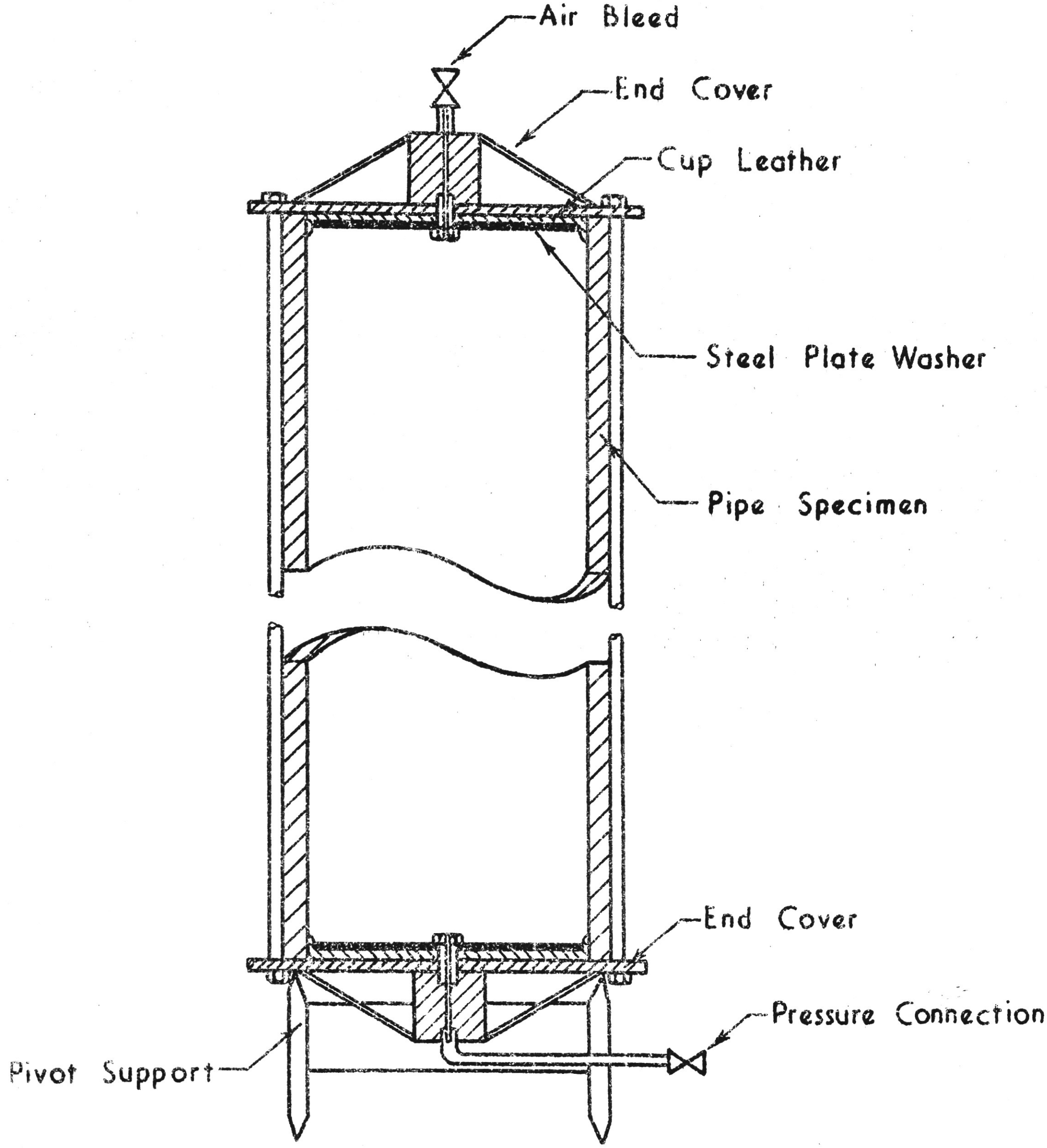
SPECIMEN Nº 25 4 INCH CLASS "D"	Traced: J.H	
	Checked R.T.H.	



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TEST RIG FOR ELASTICITY OF ASBESTOS CEMENT PIPES.	Scale: 1/8" = 1"	Date: 19·6·63	
	Drawn: R.T.H.	CE-E-2824	
	Traced: P.A.		
	Checked: RJH.		

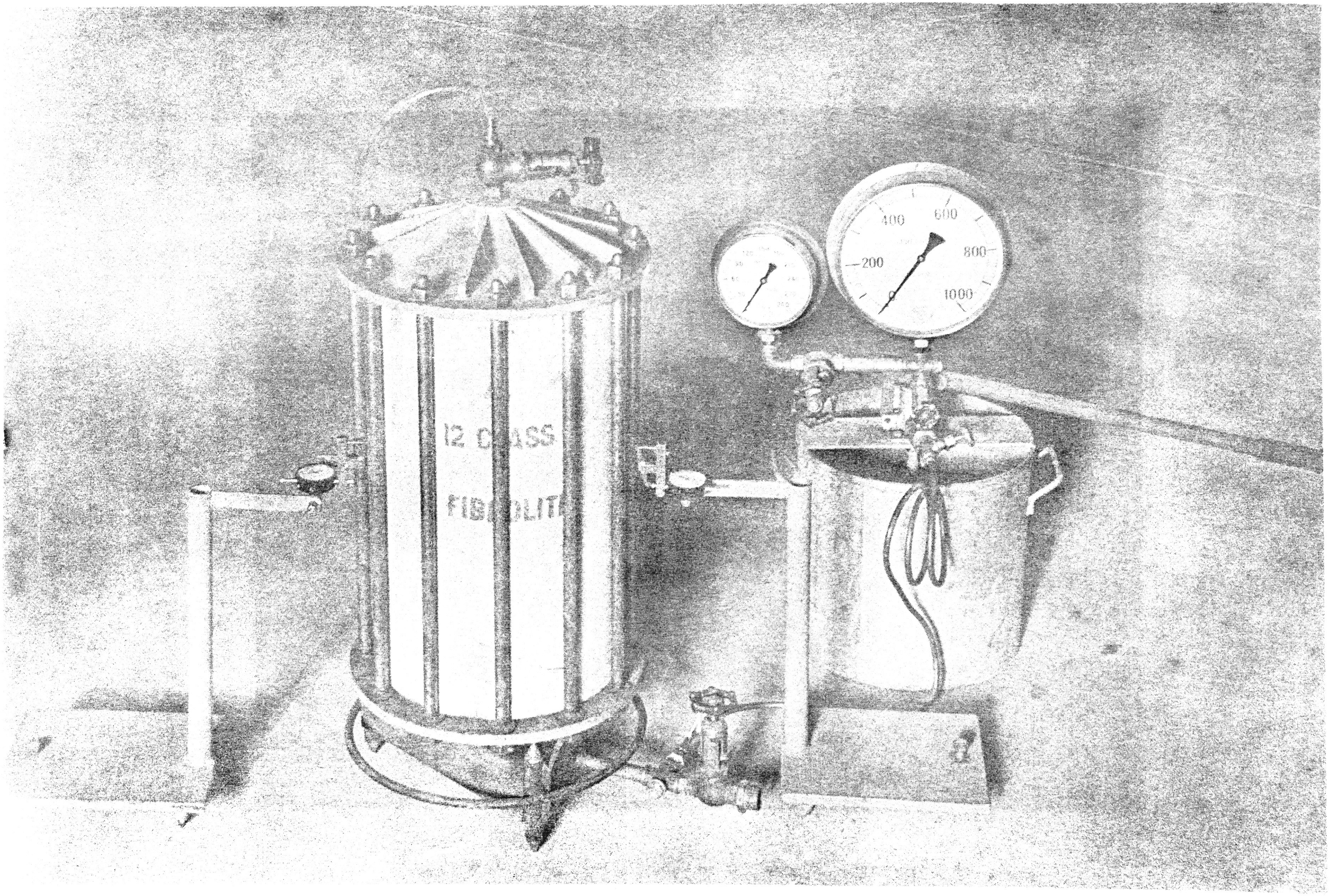

PLATE 1

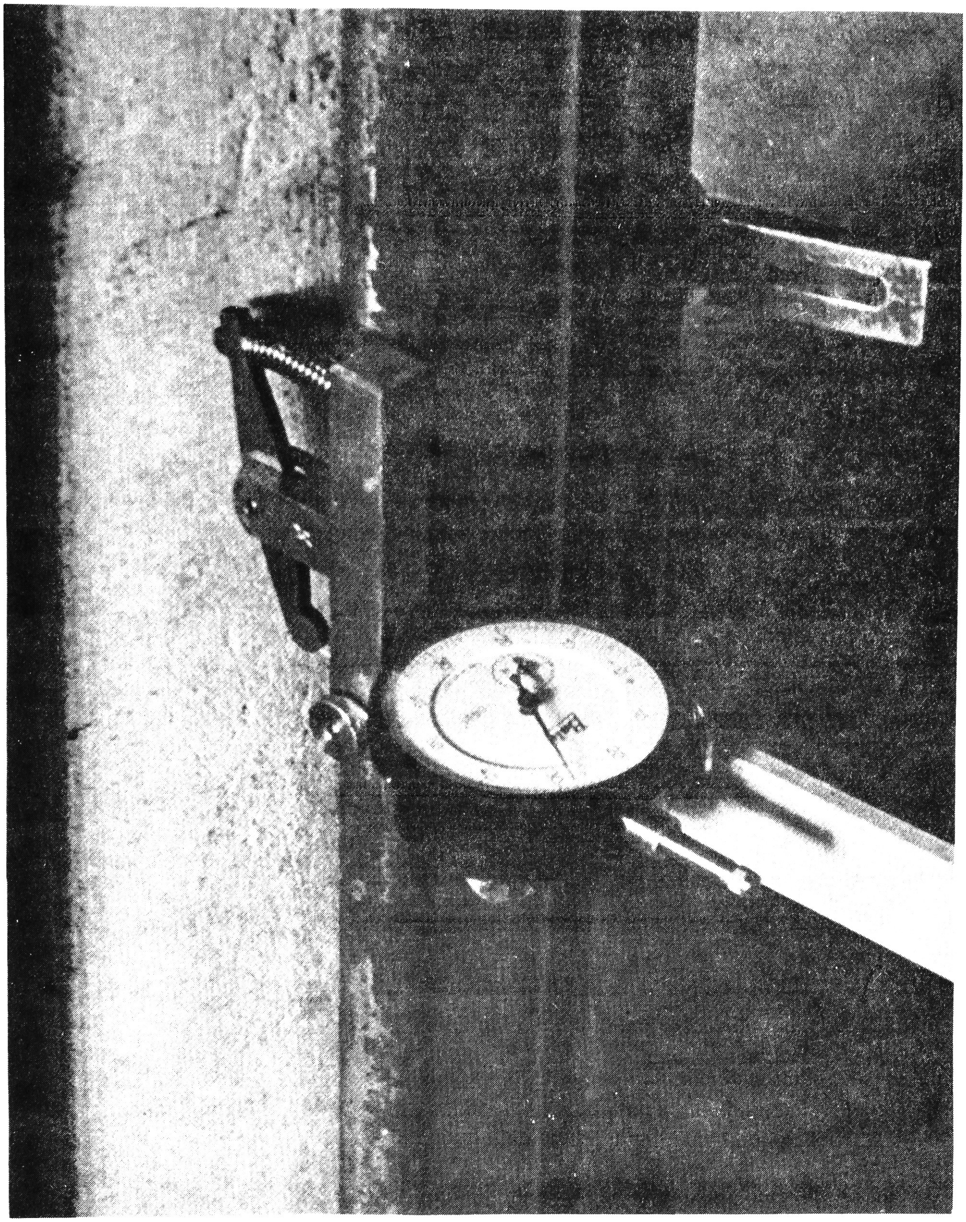

PLATE 2.