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MIDLAND PLANT UNITS 1 AND 2
BECHTEL JOB 7220
CONSUMERS POWER COMPANY
MIDLAND, MICHIGAN

ELECTRICAL RACEWAY SUPPORT TESTS REPORT
PART 1

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ELECTRICAL RACEWAY SUPPORT TESTS REPORT

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REFERENCES

A NRC Inspection and Enforcement Information Notice 79-14

B Bechtel Meeting Notes No. 1078, issued November 9, 1979

C Calculation 31-(b) Q

D J. Heuschkel, The Expression of Spot-Weld Properties, Welding Journal (October 1952), as commented by Yu, Cold-Formed Steel Structures, McGraw Hill, NYC-1973, page 306

E Calculation 20-46(Q)

F Specification 7220-E-55(Q), Rev 5

G Drawing 7220-E-42(Q), Rev 51

H Bechtel Interoffice Memorandum; Mettallographic Examination of Midland Unistrut Spot Welds, Job 7220-001, File Number GRS-061-09, June 11, 1981

I Power Strut Catalog 20-3R, p 45 and 106

J Larson, H.J., Introduction to Probability Theory and Statistical Inference, John Wiley and Sons, New York, 1969

K Specification 7220-C-92(Q), Rev 1

L Specification 7220-C-501(Q), Rev 11

M AISI Specification, Cold-Formed Steel Design Manual, 1968 Edition

N Letter, Power Strut (L.N. Mears) to Bechtel (L.H. Curtis), 8/7/81 (Com 038848)

O Letter, Power Strut (D. Gebhardt) to Bechtel (L.H. Curtis), 8/18/81 (Com 039868)

P Calculation 31-c(Q)

R Calculation 31-d(Q)

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PART 2

1. Volume I, Power Strut Tests Samples A-E
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SUMMARY

Tests were made to verify the adequacy of electrical raceway supports, particularly Power Strut hardware and cable trays from Husky Products, Inc., subsidiary of Burndy Corporation. The tests included:

- Shear strength tests of Power Strut spot welds
- Shear strength tests of cable tray spot welds
- Yield stress tests of base metal in Power Strut members
- Yield stress tests of base metal in cable trays (channels and rungs)
- Ultimate capacity tests of Power Strut fittings

Tests were conducted in accordance with Specification 7220-C-92(Q), Rev 1. The test data are contained in Part 2 of this report.

The summary of results is presented in Table 1 for spot weld tests, Table 2 for base metal tests, and Table 3 for Power Strut fittings. Safety factors are calculated for the considered members and spot welds and are compared to the minimum required values.

On the basis of the test results, the electrical raceway supports are found to have adequate safety factors.

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1.0 INTRODUCTION

The NRC requires that the design, procurement, and installation of Class 1E electrical systems and associated support systems be treated as safety-related and Q-listed (Reference A). Until the end of 1979, only the Bechtel design and installation of the Class 1E cable support system satisfied 10 CFR 50, Criterion II, Appendix A requirements. The cable support system was procured as non-Q-listed material. Also, the installed trays and supports were not traceable to a specific batch or delivery date.

It was decided (Reference B) that samples of Husky cable trays and Power Strut hardware would be tested to determine the following capacities:

a. Ultimate tensile strength of the Power Strut and cable tray material

b. Ultimate shear capacities of the spot welds in Power Strut members and Husky cable trays

c. Ultimate capacity of Power Strut fittings

Materials and Quality Services (M&QS) in San Francisco performed tests on samples selected from the storage area at the Midland jobsite.

M&QS prepared and tested the specimens either in the M&QS San Francisco laboratory or at Anamet Laboratories, Inc., in Berkeley, California. The test program followed Specification 7220-C-92(Q), Rev 1 (Reference K). The test data are contained in Appendix C of this specification.

2.0 ITEMS TESTED

Three classes of hardware items were tested: Power Strut sections, Husky cable tray sections, and Power Strut fittings.

2.1 POWER STRUT SECTIONS

Power Strut sections are light-gage channels manufactured by cold-forming mild strip steel. These channel sections are connected to each other in various configurations, as shown in Figure 1. Connection is provided at 3-inch intervals, using a process commercially known as spot welding.

For the spot weld testing program, Power Strut sections were divided into three categories, based on the welding process. One category included channel sections welded back-to-back (PS-201, PS-151, PS-155, PS-205, and PS-101). The second category included channels welded side-to-side (PS-202, PS-152, PS-155,

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and PS-205). The third category included channel sections welded side-to-back (PS-204, PS-207, and PS-3151). Members PS-155 and PS-205 included both back-to-back and side-to-side configuration of spot welds and, consequently, were evenly divided between Categories 1 and 2. A typical sample was 11 inches long and had a minimum of three spot welds. The ends were made as indicated in the appropriate figure prior to performing the tests (see Figures 2 through 5).

For ultimate tensile strength testing, Power Strut hardware was lumped into one category regardless of section type. Test coupons were shaped in accordance with the requirements of ASTM A 370 and ASTM E 8. Figure 6 shows a typical test coupon.

2.2 CABLE TRAY SECTIONS

Cable tray sections consisted of two thin-gage channel sections connected at 6-inch intervals by tray rungs. Testing of cable tray spot welds involved testing the tray rung-to-channel connection as a unit (two spot welds). Figure 7 shows a typical cable tray sample. Samples were taken from 12-, 18-, 24-, and 36-inch width trays. A proportionate number of samples was obtained from curved cable trays. Each sample was cut into two pieces, yielding two separate test samples. Each test sample was modified as shown in Figure 8 prior to performing tests.

For tensile strength testing, cable tray sections were lumped into one batch regardless of tray width. Both cable tray channels and cable tray rungs were subject to tensile testing. Test coupons were obtained in accordance with the requirements of ASTM A 370 and ASTM E 8. Figure 9 shows a typical test coupon.

2.3 POWER STRUT FITTINGS

Five types of Power Strut fittings are used in the raceway support system. These fittings are shown in Figure 10. The fittings that include welding in their manufacturing process were tested because the welding procedure was not qualified. These fittings are made from 1/4-inch thick strip steel conforming to ASTM A 575. Based on their geometry, Power Strut fittings were separated into four categories:

a. PS-3064 (baseplate - double)

b. PS-3375 (yoke base bracket)

c. PS-3033 (baseplate - single)

d. PS-3127R and PS-3127L (angle plate)

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Only ultimate capacity tests were performed on Power Strut fittings.

3.0 SAMPLING PROCEDURE

The sampling procedure selected representative samples of material for tests. The number of samples for each type reflected the proportion of the quantity of each item to the total quantity of material in its category. In the lot from which the samples were selected, all the items were numbered. Selection was based on a computer-generated list of random numbers. Table 4 specifies the numbers of items selected in each category. No samples were selected for 9 inch cable tray channels and Power Strut fitting PS-3033. These items were not available in the jobsite warehouse.

4.0 TEST ARRANGEMENT

4.1 POWER STRUT AND CABLE TRAY SPOT WELDS

Figure 11 shows an arrangement for Power Strut sections. The test arrangement for cable tray sections is shown in Figure 12. The dial gage was placed on the test specimen, attaching it to the sample as shown in Figures 11 and 12. A tensile load was applied in increments of approximately 400 pounds. At each load increment, the deflection was recorded on the test data sheet. The load was increased until failure occurred. The failure load was recorded, and the load-deflection values were plotted on the test data sheet.

4.2 TENSILE TESTS OF CABLE TRAY AND POWER STRUT MATERIAL

The procedure for sizing test coupons and for subsequent tensile testing followed ASTM A 370 and ASTM E 8 guidelines. Test data and results were entered on the test data form.

4.3 ULTIMATE CAPACITY OF POWER STRUT FITTINGS

The following test arrangements were used:

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Power Strut Fitting	Test Arrangement (Figure)	Testing Machine Load Application Direction	Load Increment
PS-3064	13	Compression	400
PS-3375	14	Tension	400
PS-3033	(Testing not done because these items were not available in the jobsite warehouse)		
PS-3127R and L	15	Compression or Tension	400

A dial gage was placed across the opening of the testing machine to measure vertical displacement of the specimen. At each load increment, the deflection was recorded on the test data sheet. The load was increased until failure occurred, and the failure load was recorded.

5.0 TEST EQUIPMENT

Two testing machines were used: the Tinius Olsen Universal testing machine of Bechtel M&QS Laboratory, San Francisco, and the Riehle Universal testing machine of Anamet Laboratories, Inc., Berkeley. The certificates of verification and calibration are in the appendix.

6.0 ACCEPTANCE CRITERIA

Power Strut sections and Husky cable trays, ? except fittings and spot welds, were designed on the basis of an American Iron and Steel Institute (AISI) specification (Reference M). This specification uses the specified yield stength of base metal. To demonstrate the adequacy of material in Power Strut channels and Husky trays, it is sufficient to show that at least 95% of the members have yield strength equal to or larger than the specified value with a confidence level of 95%. The fifth percentiles of yield stress were determined from the tests results. A cumulative distribution function was assumed for each item. χ^2 tests were performed to check the adequacy of this assumption with the confidence level of 95%.

For spot welds and fittings, the structural acceptance criteria are contained in Specification 7220-C-92(Q), Rev 1 (Reference K). Appendix A of this specification provides the minimum required spot weld strength and the minimum required Power Strut fitting strength. It is specified that if any test sample fails to meet

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or exceed these loads during the testing procedure, then further engineering analysis is required.

The purpose of this analysis is to demonstrate, with 95% confidence, that at least 95% of the considered items are equal to or exceed the design loads. The fifth percentiles of strength were determined from the test results.

A cumulative distribution function was assumed for each item and a χ^2 test was performed to check the adequacy of this assumption, with the confidence level of 95%. Safety factors were then calculated as ratios of the strength and design load. The safety factors were compared to the minimum required values.

For spot welds AISI recommends a safety factor of 2.5 (Reference M). Specification 7220-C-501(Q), Rev 11 (which satisfies FSAR Section 3.8.6) allows a stress increase of 25% for operating basis earthquake (OBE) and 50% for safe shutdown earthquake (SSE). Based on these criteria, the minimum required safety factors for spot welds and fittings are:

2.50 - For the load combinations including dead load and live load

2.00 - For the load combinations including dead load, live load, and OBE $\left(\frac{2.50}{1.25} = 2.00\right)$

1.67 - For the load combinations including dead load, live load, and SSE $\left(\frac{2.50}{1.50} = 1.67\right)$

The load combination including dead load plus live load plus SSE produces the largest design load. Therefore, if the corresponding safety factor exceeds 2.5, it also verifies the adequacy of the other two load combinations.

6.1 POWER STRUT BASE METAL

The power strut channel manufacturer guarantees a minimum yield strength of 33,000 psi (Reference I). This value of yield stress was used in the design. Therefore, the minimum acceptable 5th percentile of yield strength is 33,000 psi.

6.2 CABLE TRAY BASE METAL

Cable tray channels and rungs have a manufacturer's guaranteed minimum yield strenth of 30,000 psi. This value was used in the design. Therefore, the minimum acceptable fifth percentile of yield strength is 30,000 psi.

6.3 POWER STRUT SPOT WELDS

The maximum design shear force for the Power Strut sections under SSE loads are given in Specification 7220-C-92(Q), Rev 1. These forces are obtained by adding the maximum static force envelope to the maximum dynamic force envelope at any location for each Power Strut section. This is conservative because the greatest dynamic shear does not necessarily occur at the same point as the greatest static shear. The maximum design load values were conservatively increased by 25%. Additional calculations were made for dead load plus live load, and dead load plus live load plus OBE loads (Reference C). The factors of safety are calculated for the considered load combinations.

6.4 CABLE TRAY SPOT WELDS

In Specification 7220-C-92(Q), the acceptance criteria for the spot weld shear strength are based on the minimum recommended strength by the AISI specification (Reference M). In the following, the maximum allowable load or the minimum acceptable shear strength per weld is calculated using the maximum cable tray width, applicable maximum seismic accelerations, and maximum cable tie spacings. Safety factors are based on these calculated strengths.

The linear safety criterion to calculate the minimum allowable shear force is:

$$\frac{v}{V} + \frac{t}{T} \leq 1$$

where

v = shear force per weld due to loading (four welds per rung)

V = allowable shear force

t = tensile force per weld due to loading (four welds for rung)

T = allowable tension

As stated in Reference D, the tensile strength was conservatively assumed to be 25% of the shear capacity:

> It can be seen that for the steel specified in the AISI specification, the tensile strength of spot welding can be conservatively taken as 25% of the shear strength.

Therefore, the safety criterion becomes:

$$\frac{v}{V} + \frac{t}{.25V} \le 1$$

$$\text{or } v + 4t \le V$$

The weight of the rungs and cables (vertical) and the seismic loads (vertical and horizontal) comprise the load.

For the four buildings involved, the maximum vertical accelerations, a_v, and horizontal accelerations, a_h, were calculated (Reference E). The results are shown below.

Building	Maximum Vertical Acceleration* (g)	Horizontal Acceleration (g)
Auxiliary building	1.188	0.62
Containment building	1.250	0.88
Diesel generator building	1.233	1.15
Service water pump structure	1.75	1.85

*Including 1g for dead load

The shear force (v) and tension force (t) equal $\frac{Pa}{4}_v$ and $\frac{Pa}{4}_h$, respectively (P equals mass of the rung and attached cables). The working load is 70 lb/ft for the 36-inch wide cable trays (see Reference F). The working load is lower for cable trays narrower than 36 inches. The safety criterion can be written as:

$$\frac{P}{4}a_v + Pa_h \le V$$

whereas

$$P = 70 \times S_{max}/g$$

where

S_{max} = spacing between cable ties connecting cables to rungs; P is divided by four to determine the force per weld. (Four spot welds connect each rung, with two welds on each end.)

Therefore, the minimum value of the allowable shear force is:

$$V = 70S_{max}\ (0.25a_v + a_h)/g$$

The maximum allowable spacings between cable ties are given below (Reference G):

Building	S_{max} Allowable Limit (ft)
Auxiliary building	4.0
Containment building	3.6
Diesel generator building	3.0
Service water pump structure	2.0

The allowable shear forces, V, corresponding to the above-listed spacings are calculated from the safety criterion:

Building	Allowable Shear Force per Weld (lb)
Auxiliary Building	257
Reactor Building	300
Diesel Generator Building	306
Service Water Pump Structure	320

6.5 POWER STRUT FITTINGS

The maximum forces (shear, axial, or moment) for Power Strut fittings are given in Specification 7220-C-92(Q). The safety factors are calculated based on these forces.

7.0 TEST DATA

The test data contained in Part 2 of this report include test records with tables of loads and deformations as well as load deformation plots. Typical load deformation plots are shown in Figures 32 to 34 for Power Strut base metal, Figures 35 to 37 for Power Strut cable tray base metal, Figures 38 to 40 for Power Strut spot wells. In most cases, as illustrated by the plots, a ductile failure mode was observed.

The three weakest spot welds in the Test Group D were subjected to metallographic examination by the Material and Quality Services Department (M&QS) in San Francisco. The results of this examination are summarized in Reference H. The photographs of welds and their cross sections exposing the fusion zone are shown in Figures 44 and 45. Reference H confirmed the relationship between weld size (fusion zone area) and its shear strength.

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Typical load deformation plots are shown in Figures 41, 42, and 43 for Power Strut fittings. The following modes of failure were observed in Power Strut fitting tests.

a. Plastic deformation of base metal and rupture of the weld for Power Strut fittings PS-3064 and PS-3375

b. In the case of PS-3127L and R, the prevailing mode of failure was buckling of plates forming the fittings.

The test results are summarized in Table 5 for Power Strut spot welds, Table 6 for Husky cable tray spot welds, Table 7 for Power Strut base metal tests, Table 8 for cable tray base metal channel tests, Table 9 for cable tray base metal rung tests, and Table 10 for Power Strut fittings.

8.0 ACCEPTANCE CRITERIA VERSUS TEST DATA

For each test group, the fifth percentile of resistance was determined. For base metal these values were compared to the minimum acceptable values. For spot welds and fittings, safety factors were calculated and compared to the minimum acceptable values.

8.1 POWER STRUT BASE METAL

The Power Strut channel manufacturer guarantees a minimum yield strength of 33,000 psi (Reference I). The distribution function of yield strength for the test samples is shown on normal probability paper in Figure 16. The fifth percentile is 42,800 psi (Reference R) and exceeds 33,000 psi. This justifies the adequacy of Power Strut base metal.

8.2 CABLE TRAY BASE METAL

Cable tray channels and rungs have a manufacturer's guaranteed minimum yield strength of 30,000 psi. The tensile tests of base metal were performed to demonstrate that the fifth percentile of yield strength exceeds this value.

8.2.1 Channels

The distribution function of base metal yield strength for the test samples is shown on normal probability paper in Figure 17. The fifth percentile is 38,800 psi (Reference R[illegible] ds 30,000 psi. This justifies the adequacy of Husky [illegible]

8.2.2 Rungs

The base metal yield strength distribution function for the test samples is shown on normal probability paper in Figure 18. The fifth percentile is 38,800 psi (Reference R) and it exceeds 30,000 psi. This justifies the adequacy of Husky rungs.

8.3 POWER STRUT SPOT WELDS

The test results indicate significant differences in the strengths of spot welds for various types of sections and welds. Generally, back-to-back spot welds are stronger than side-to-side or side-to-back welds. Spot welds connecting channels deeper than 1-5/8 inch (PS-200) show lower strength. The technological explanation for these strength variations is that longer or curved electrodes are less effective.

The shear force in a spot weld (P) is caused by the shear force in the member (V).

The following equation determines the relationship between P and V:

$$P = QVd/(In)$$

where

Q = static moment of the appropriate area

d = spacing between welds; for Power Strut members, the maximum spacing is 3 inches; d is conservatively assumed to equal 3 inches.

I = moment of inertia of the section

n = number of spot welds subject to shear in the considered plane

Table 11 lists the basic section properties for the tested Power Strut sections. The adequacy of spot welds was checked separately for various sections and welds.

8.3.1 PS-101, Back-to-Back Spot Welds, Test ID.A

Two spot welds were tested and withstood 4,080 and 790 pounds, respectively. The maximum design shear force in the section, including SSE, is 123 pounds (Reference K). To check the adequacy of spot welds, a design shear force equalling 200 pounds was used instead. The corresponding shear force per spot weld is 126 pounds (200 x 0.63). (The value 0.63 is from Table 11.)

The joint distribution function for PS-101, PS-151, and PS-201 is plotted in Figure 19. The following χ^2 test checks whether the distribution is normal. A 95% confidence level was assumed. The test data indicate the maximum likelihood estimates of the mean and standard deviation are 3,427 and 1,065 pounds, respectively. For the χ^2 test, 11 intervals were considered; j denotes intervals:

	$j_1 \leq$	1,979 pounds
1,979 pounds <	$j_2 \leq$	2,426 pounds
2,426 pounds <	$j_3 \leq$	2,756 pounds
2,756 pounds <	$j_4 \leq$	3,033 pounds
3,033 pounds <	$j_5 \leq$	3,278 pounds
3,278 pounds <	$j_6 \leq$	3,576 pounds
3,576 pounds <	$j_7 \leq$	3,821 pounds
3,821 pounds <	$j_8 \leq$	4,098 pounds
4,098 pounds <	$j_9 \leq$	4,428 pounds
4,428 pounds <	$j_{10} \leq$	4,875 pounds
4,875 pounds <	j_{11}	

According to statistical theory (Reference J), the following is a χ^2 random variable, with 8 degrees of freedom (11-2-1):

$$\sum_{j=1}^{11} \frac{(X_j - nP_j)^2}{nP_j}$$

where

X = number of spot welds with strength in interval "j"

n = 58 (number of spot welds tested)

P_j = probability of the strength to be in interval "j" if the distribution of strength was normal

From the table of χ^2 distribution function (Reference J) acceptable maximum value of χ^2 function to satisfy 95% confidence level is 15.5.

The final test is:

$$\sum_{j=1}^{11} \frac{(X_j - nP_j)^2}{nP_j} = \frac{(3 - 5.04)^2}{5.04} + \frac{(6 - 5.03)^2}{5.03} + \frac{(8 - 5.26)^2}{5.26} + \frac{(5 - 5.30)^2}{5.30} + \frac{(9 - 5.14)^2}{5.14} + \frac{(3 - 6.46)^2}{6.46} + \frac{(2 - 5.14)^2}{5.14} + \frac{(5 - 5.30)^2}{5.30} + \frac{(5 - 5.26)^2}{5.26} + \frac{(8 - 5.03)^2}{5.03} + \frac{(4 - 5.04)^2}{5.04}$$

$$= 11.12 < 15.5$$

Therefore, the strength of back-to-back spot welds can be considered as normally distributed with the mean 3,427 pounds and standard deviation of 1,065 pounds. The confidence level is 95%. The 5th percentile of this distribution, $F_{0.05}$, is calculated as follows:

$$F_{0.05} = 3,427 - 1,065\,\Phi^{-1}(0.05)$$

where

$\Phi^{-1}(0.05)$ = inverse of standard normal distribution for 0.05; from a table of standard normal distribution, $\Phi^{-1}(0.05) = 1.645$

therefore

$F_{0.05}$ = 1,675 pounds

The safety factor for A type weld is 13.29 (1,675 divided by 126). This justifies the adequacy of these welds.

8.3.2 PS-151, Back-to-Back Spot Welds, Test ID.B

Four spot welds were tested and withstood 3,040; 3,960; 4,160; and 4,760 pounds. The maximum design shear force in the section, including SSE, is 27 pounds (Reference K). To check the adequacy of spot welds, a design shear force equalling 200 pounds was used. The corresponding shear force per spot weld is 168 pounds (200 times 0.84).

The fifth percentile of strength, which was taken from the joint distribution for PS-101, PS-151, and PS-201 (see Section 8.3.1), is 1,675 pounds. The safety factor for B type weld is 9.97 (1,675 divided by 168). This justifies the adequacy of these welds.

8.3.3 PS-155, Back-to-Back Spot Welds, Test ID.C

One specimen with two spot welds was tested and withstood 6,860 pounds for two spot welds, or 3,430 pounds per spot weld. The maximum design shear force in the section, including SSE, is 1,435 pounds (Reference K). The corresponding shear force per spot weld (two spot welds in a section) is 603 pounds (1,435 X 0.42). The fifth percentile of spot weld strength (taken from the joint distribution for PS-101, PS-151, and PS-201, see Section 8.3.1) is 1,675 pounds. The safety factor for C type welds is 2.78 (1,675 divided by 603). This justifies the adequacy of these spot welds.

8.3.4 PS-155, Side-to-Side Spot Welds, Test ID.C

Eight specimens with two spot welds each were tested, resulting in the following shear force per weld: 3,330; 3,840; 4,190; 4,608; 5,100; 5,600; 6,100; and 7,000 pounds.

The strength distribution function is plotted on normal probability paper in Figure 20. Because the sample size is small, the fifth percentile of weld strength cannot be determined from the tests of PS-155 members. Instead the analysis is based on test data for PS-152, which are made of two identical channels welded side to side. In Reference R, it is shown that the cumulative distribution function of shear strength for I tests can be approximated by a normal function with the mean 3,755.5 pounds and standard deviation 1,606 pounds. In a PS-155 section, there are two statistically independent side-to-side spot welds. Therefore, the shear strength per weld in a PS-155 section is also normally distributed with the mean the same as in I tests, 3,755.5 pounds, and the standard deviation is equal to 1,606 $\div \sqrt{2}$ = 1,135.5 pounds. The fifth percentile of shear strength per weld of side-to-side welds in PS-155 is

$$F_{0.05} = 3,755.5 - 1,135.5\Phi^{-1}(0.05)$$

where

$\Phi^{-1}(0.05)\Phi^{-1} = 1.645$, as defined in Section 8.3.1,

and therefore,

$$F_{0.05} = 1,887 \text{ pounds}$$

The maximum design shear force due to dead load and live load is 609 pounds (Reference C). The corresponding shear force per spot weld is 329 pounds (609 times 0.54). The safety factor is 5.74 (1,887 divided by 329).

The maximum design shear force due to dead load, live load, and SSE is 1,435 pounds (Reference K). The corresponding shear force per spot weld (two spot welds in a section) is 775 pounds (1,435 times 0.54). The safety factor is 2.44 (1,887 divided by 775).

These safety factors satisfy the minimum requirements specified in Section 6.0, which justify the adequacy of these spot welds.

8.3.5 PS-201, Back-to-Back Spot Welds, Test ID.D

PS-201 is the most common type of section used in electrical raceway supports. The distribution function of strength of back-to-back spot welds, which was obtained from the tests, is shown in Figure 19. Power Strut PS-201 members are welded by four different electrodes so that each of any four consecutive welds are statistically independent (References N and O).

The distribution of strength of back-to-back spot welds for PS-201 can be approximated by a normal distribution function with a confidence level of 95% (see Section 8.3.1).

The minimum number of spot welds in electrical raceway supports is three (Reference G). Any four consecutive welds in PS-201 are statistically independent. Therefore, the shear capacity of a

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system of three spot welds can be derived from the basic theory of probability (Reference J) as follows.

The strength of a single weld in PS-201 is normally distributed, with a mean 3,427 pounds and a standard deviation of 1,065 pounds. The joint strength of three welds is also normally distributed, with the mean equalling the sum of the means for single welds, 3 x 3,427 = 10,281 pounds, and the variance equalling the sum of variances, or standard deviation equalling $(3 \times 1{,}065^2)^{1/2}$ = 1,845 pounds. The strength per single weld (in a set of three) is also normally distributed with the mean equalling 10,281 ÷ 3 = 3,427 pounds and the standard deviation equalling 1,845 ÷ 3 = 615 pounds. For comparison, Figure 21 shows the normal distributions of weld strength for a single weld and for a weld in a set of three independent welds.

The fifth percentile of D type welds ($F_{0.05}$) is calculated as follows:

$$F_{0.05} = 3{,}427 - 615\Phi^{-1}(0.05)$$

where

$\Phi^{-1}(0.05) = 1.645$, as defined in Section 8.3.1

therefore: $F_{0.05}$ = 2,415 pounds

The maximum design shear force due to dead load and live load is 703 pounds (Reference C). The corresponding shear force per spot weld is 865 pounds (703 times 1.23). The safety factor is 2.79 (2,415 divided by 865).

The maximum design shear force due to dead load, live load, and OBE is 789 pounds (Reference C). The corresponding shear force per spot weld is 970 pounds (789 times 1.23). The safety factor is 2.49 (2.415 divided by 970).

The maximum design shear force due to dead load, live load, and SSE is 1,090 pounds (Reference K). The corresponding shear force per spot weld is 1,340 pounds (1,090 times 1.23). The safety factor is 1.80 (2,415 divided by 1,340).

The above safety factors satisfy the minimum requirements specified in Section 6.0, which justifies the adequacy of these spot welds.

8.3.6 PS-202, Side-to-Side Spot Welds, Test ID.E

The distribution function of strength is shown on normal probability paper in Figure 22. The fifth percentile is 3,800 pounds (Reference R).

The maximum design shear force per member, including SSE, is 645 pounds (Reference K). The corresponding shear force per spot weld is 716 pounds (645 times 1.11). The safety factor is 5.31 (3,800 divided by 716). This justifies the adequacy of these spot welds.

8.3.7 PS-204, Side-to-Back Spot Welds, Test ID.F

The strength distribution function is shown on normal probability paper in Figure 23. The 5th percentile is 1,400 pounds (Reference R).

The maximum design shear force per member, including SSE, is 115 pounds (Reference K). To check the adequacy of the spot welds, a design shear force equalling 200 pounds was used. The corresponding shear force per spot weld is 250 pounds (200 times 1.25) The safety factor is 5.6 (1,400 divided by 250). This justifies the adequacy of these spot welds.

8.3.8 PS-207, Side-to-Back Spot Welds, Test ID.G

There are three spot weld connections in a PS-207 section. Two spot welds were tested simultaneously. The resulting distribution function is shown on normal probability paper in Figure 24. The number of tested samples of this item does not allow direct determination of the fifth percentile of the shear strength of spot welds. The side-to-back spot welds in PS-207 are similar to those in PS-204. Therefore, the fifth percentile shear strength per weld of Section PS-204 is taken for PS-207 (Section 8.3.7); therefore, $F_{0.05}$ = 1,400 pounds. This value is conservative because in PS-207 sections there are two statistically independent welds.

The maximum design shear force per member, including SSE, is 270 pounds (Reference K). The corresponding shear force per spot weld is 149 pounds (270 times 0.55). The safety factor is 9.52 (1,400 divided by 149). This justifies the adequacy of these spot welds.

8.3.9 PS-205, Back-to-Back Spot Welds, Test ID.H

One specimen with two spot welds was tested and withstood 2,655 pounds per weld. The maximum design shear force per member, including SSE, is 25 pounds (Reference K). A design shear force of 200 pounds was used to check adequacy of spot welds. The corresponding shear force per spot weld is 124 pounds (200 times 0.62).

The fifth percentile of spot weld strength, 1,675 pounds, was taken from the joint distribution for PS-101, PS-151, and PS-201 (see Section 8.3.1). The safety factor is 13.51 (1,675 divided by 124). This justifies the adequacy of these spot welds.

8.3.10 PS-205, Side-to-Side Spot Welds, Test ID.H

Seven specimens with two spot welds were tested and each weld withstood the following: 4,700; 4,800; 5,600; 5,600; 6,000; 7,800; and 8,000 pounds. The distribution function is plotted on normal probability paper in Figure 25. The size of the sample does not allow for direct calculation of the fifth percentile of shear strength of a spot weld with a confidence level of 95%. Therefore, the test data for PS-202 were used. PS-202 is made of identical channels connected by side-to-side spot welds. From Reference R, the fifth percentile is 3,800 pounds.

The maximum design shear force per member, including SSE, is 25 pounds (Reference K). To check the adequacy of spot welds, a design shear force of 200 pounds was used. The corresponding shear force per spot weld is 110 pounds (200 times 0.55). The safety factor equals 34.5 (3,800 divided by 110). This justifies the adequacy of these spot welds.

8.3.11 PS-152, Side-to-Side Spot Welds, Test ID.I

The strength distribution function is shown on normal probability paper in Figure 26. The fifth percentile is 1,114 pounds (Reference R).

The maximum design shear force per member, including SSE, is 270 pounds (Reference K). The corresponding shear force per spot weld is 289 pounds (270 times 1.07). The resulting safety factor is 3.85 (1,114 divided by 289). This justifies the adequacy of these spot welds.

8.3.12 PS-3151, Side-to-Back Spot Welds, Test ID.J

The strength distribution function is shown on normal probability paper in Figure 27. The fifth percentile is 3,471 pounds (Reference R).

The maximum design shear force per member, including SSE, is 1,369 pounds (Reference K). The corresponding shear force per spot weld is 1,054 pounds (1,369 times 0.77). The safety factor is 3.24 (3,417 divided by 1,054). This justifies the adequacy of these spot welds.

8.4 CABLE TRAY SPOT WELDS

The test results are plotted on normal probability paper in Figure 28. The [illegible]fth percentile of shear strength per spot weld is 1,536 [illegible]ference R). To check the adequacy of the spot welds connec[illegible]ngs to the channels, maximum design shear forces per weld (Section 6.4) were compared with 1,536 pounds (fifth percentile of strength). The results are as follows:

Building	Required Strength Including SSE (lbs)	Safety Factor
Auxiliary Building	257	5.97
Reactor Building	300	5.11
Diesel Generator Building	306	5.02
Service Water Pump Structure	320	4.79

Spot welds connecting the rungs to the channels in 9 inch cable trays were not tested because these items were not unavailable in the jobsite warehouse. The spot welds in 9 inch cable trays are identical to the spot welds in wider cable trays. The working load for the 9 inch-wide cable tray is 18 lb/ft against 70 lb/ft for 36 inch-wide cable tray. Thus, the spot welds in 9 inch cable trays satisfy the minimum requirements.

This justifies the adequacy of spot welds connecting rungs to channels in cable trays.

8.5 POWER STRUT FITTINGS

8.5.1 Power Strut Fitting PS-3064

The maximum design compression force per fitting, including SSE, is 1,090 pounds (see Reference P). Figure 29 shows the ultimate capacity distribution. The fifth percentile is 31,340 pounds (Reference R). The resulting safety factor is 28.75 (31,340 divided by 1,090), which justifies the adequacy of these fittings.

8.5.2 Power Strut Fitting PS-3033

No samples were tested because these items were unavailable in the jobsite warehouse. The Power Strut fittings PS-3064 and PS-3033 are similar (Figure 10). Hence, the fifth per centile strength for PS-3033 is based on PS-3064.

The length of the weld in PS-3033 is 5.90625 inches, and 7.53125 inches in PS-3064 (Page 45, Reference I). Fifth percentile strength for PS-3064 is 31,340 pounds (Reference R). Therefore, fifth percentile strength for PS-3033 is $31,340 \times \frac{5.90625}{7.53125} = 24,578$ pounds. The maximum design force for PS-3033 is 4,150 pounds (Reference P). The resulting safety factor is 5.92 (24,578 divided by 4,150). This justifies the adequacy of these fittings.

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8.5.3 Power Strut Fitting PS-3375

The maximum design tensile force per fitting, including SSE, is 4,320 pounds (see Reference P). The accelerations for SSE are tabulated in Section 6.4. The lowest acceleration due to SSE is the vertical component for the auxiliary building, 0.188 g. Therefore, for PS-3375, it is assumed that the maximum design load due to dead and live load is 4,320 1.188 = 3,636 pounds.

Figure 30 shows the distribution of ultimate capacity. The fifth percentile is 9,200 pounds, (Reference R) and the safety factor is 2.53 (9,200 divided by 3,636), for dead and live load condition and 2.13 (9,200 divided by 4,320) for dead load, live load, and SSE loading condition which justifies the adequacy of these fittings.

8.5.4 Power Strut Fitting PS-3127 L and R

The maximum design compression load per fitting is 1,179 pounds (Reference P). According to Specification 7220-C-92(Q), the direction of load application (tension or compression) for PS-3127R&L fittings was to be based on four initial tests: two in tension and two in compression. The remaining fittings were to be tested following the governing mode. However, this procedure was not followed in selection of the test mode. Only two specimens were tested, one in tension and one in compression. The results of these initial tests were: 7,900 pounds in compression and 7,600 pounds in tension. Despite these results, 62 fittings were tested in compression.

The tests were arranged so that two fittings (one left and one right) were loaded simultaneously. The resulting capacity is the capacity of two fittings. The test results are shown on normal probability paper in Figure 31.

The fifth percentile of a single fitting capacity was determined in Reference R. The distribution for fittings was approximated by a normal distribution function, with a mean of 9,397 pounds and a standard deviation of 627 pounds. These values represent the parameters for double fittings. For single fittings, the distribution of capacity is also normal, with the mean 4,698 pounds ($9,397 \div 2$) and a standard deviation equal to 443 pounds ($627 \div \sqrt{2}$).

The corresponding normal distribution for single fittings is also shown in Figure 31. The fifth percentile of the single fitting capacity is:

$$F_{0.05} = 4,698 - 443\,\Phi^{-1}(0.05)$$

where

$\Phi^{-1}(0.05) = 1.645$, as defined in Section 8.3.1, and therefore,
$F_{0.05} = 3,969$ pounds.

The resulting safety factor is 3.37 (3,969 divided by 1,179), which justifies the adequacy of these fittings.

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46538 **LABORATORY CERTIFICATE**

EXHIBIT PS-1E

Anamet Laboratories, Inc.

ANALYTICAL
CHEMICAL
METALLURGICAL

HIGH TEMPERATURE
APPLIED RESEARCH
PHYSICAL TESTING

2827-7th STREET · BERKELEY CALIFORNIA 94710 · 841-5771

December 18, 1979

BLN: 1279-5
M&QS Log #JCG 1279-34
Job #531/-/0002
P.O. #OS1-8-00096

LABORATORY NUMBER: 1279.242 A

SAMPLE: Calibration of Dial Calipers

MARK: 6" Dial Micrometer S/N 16
Brown & Sharpe No. 579/1

DATE SUBMITTED: December 18, 1979

REPORT TO: Bechtel National, Inc.
P.O. Box 3965
San Francisco, California 94119
Attn: Mr. R. T. Dillon

REPORT

True Length	Measured Length
0.0000"	0.000"
0.1600"	0.159(5)"
0.2500"	0.249(7)"
0.5000"	0.499(7)"
1.0000"	1.001(4)"
2.0000"	1.999(5)"
3.0000"	2.999(5)"
4.0000"	4.001"
5.0000	4.999(5)"

Used Jo blocks and End standards, calibrated by Ultralab on 4/24/79, traceable to NBS 232.12/216449, 25 May 1977, and NBS 213.12/218345, 11 April 1978, NBS 213.12/216449, 25 May 1977.

Respectfully submitted,

ANAMET LABORATORIES, INC.

By E. A. Foreman
E. A. Foreman
Manager, Quality Control

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TABLE 1

SUMMARY OF SPOT WELD TEST RESULTS

Item	Type of Weld	Strength (lb) (per weld) Average	Strength (lb) (per weld) Fifth Percentile	Design Load (per weld) (lb)	Loading Condition	Calculated[2] Safety Factor
PS-201	Back-to-back	3,427	2,415	865	D+L	2.79
				970	D+L+E	2.49
				1,340	D+L+E'	1.80
PS-101	Back-to-back	3,427	1,675	126	D+L+E'	13.29
PS-151	Back-to-back	3,427	1,675	168	D+L+E'	9.97
PS-205	Back-to-back	3,427	1,675	124	D+L+E'	13.51
PS-155	Back-to-back	3,427	1,675	603	D+L+E'	2.78
PS-152	Side-to-side	3,756	1,114	289	D+L+E'	3.85
PS-202	Side-to-side	5,063	3,800	716	D+L+E'	5.31
PS-155	Side-to-side	4,808	1,887	329	D+L	5.74
				775	D+L+E'	2.44
PS-205	Side-to-side	5,644	3,800	110	D+L+E'	34.50
PS-204	Side-to-back	3,732	1,400	250	D+L+E'	5.60
PS-207	Side-to-back	3,578	1,400	149	D+L+E'	9.52
PS-3151	Side-to-back	5,631	3,417	1,054	D+L+E'	3.24
Cable Tray	Rung-to-Channel	2,227	1,536	320	D+L+E'	4.79

Notes:

1. In the above table, D, L, E, and E' denote:
   D - Dead load
   L - Live load
   E - Operating Basis Earthquake (OBE)
   E' - Safe Shutdown Earthquake (SSE)

2. Required factor of safety:
   D+L 2.5
   D+L+E 2.0
   D+L+E' 1.67

3. Factor of safety is not computed for D+L and D+L+E loading conditions for those items where safety factor for D+L+E' loading condition is more than 2.5

4. Factor of safety is not computed for D+L+E loading condition for those items where FS for D+L+E' is more than 2.0

TABLE 2

SUMMARY OF BASE METAL TEST RESULTS

Item	Yield Stress (psi) Average	Yield Stress (psi) Fifth percentile	Design Yield Strength (psi)
Power Strut channels	47,268	42,800	33,000
Cable tray channels	43,091	38,800	30,000
Cable tray rungs	47,923	38,800	30,000

TABLE 3

SUMMARY OF POWER STRUT FITTINGS TEST RESULTS

Item	Strength (lb) Average	Strength (lb) Fifth Percentile	Design Load (lb)	Loading Condition	Calculated(2) Safety Factor
PS-3064	34,209	31,340	1,090	D+L+E'	28.75
PS-3033(5)	-	24,578	4,150	D+L+E'	5.92
PS-3375	13,211	9,200	3,636	D+L	2.53
			4,320	D+L+E'	2.13
PS-3127 L&R	4,698	3,969	1,179	D+L+E'	3.37

Notes: 1. In the above table, D, L, E, and E' denote:

D - Dead load
L - Live load
E - Operating Basis Earthquake (OBE)
E' - Safe Shutdown Earthquake (SSE)

2. Required factor of safety:

D+L 2.5
D+L+E 2.0
D+L+E' 1.67

3. Factor of safety is not computed for D + L and D + L + E loading conditions were safety factor for D + L + E' loading condition is more than 2.50.

4. Factor of safety is not computed for D + L + E loading condition where safety factor for D + L + E' loading condition is more than 2.0.

5. For strength evaluation of PS-3033, see Section 8.5.2.

TABLE 4

NUMBER OF SAMPLES SELECTED FOR TESTS

Category	Item	Total Job Quantity (at Time of Sampling)	Sample I.D.	Number of Samples	Remarks
Power Strut spot welds, back-to-back	PS-201	147,000 ft	D	52	
	PS-151	12,500 ft	B	4	
	PS-101	5,250 ft	A	2	
	PS-155	3,350 ft	C	1	Double weld
	PS-205	2,700 ft	H	1	Double weld
Power Strut spot welds side-to-side	PS-202	10,100 ft	E	25	
	PS-152	8,100 ft	I	20	
	PS-155	3,350 ft	C	8	Double weld
	PS-205	2,700 ft	H	7	Double weld
Power Strut spot welds, side-to-back	PS-204	11,440 ft	F	16	
	PS-207	8,000 ft	G	12	Double weld
	PS-3151	22,200 ft	J	32	
Cable tray spot welds	9-inch*	1,008 ft			
	12-inch	2,796 ft	12S	3	Double weld
	18-inch	7,104 ft	18S	8	Double weld
	24-inch	30,876 ft	24S	37	Double weld
	36-inch	3,600 ft	36S	4	Double weld
Power Strut base metal tension tests	PS-201	147,900 ft	D	37	
	PS-151	12,500 ft	B	3	
	PS-101	5,250 ft	A	1	
	PS-155	3,350 ft	C	2	
	PS-205	2,700 ft	H	1	
	PS-202	10,100 ft	E	3	
	PS-204	11,440 ft	F	3	
	PS-207	8,000 ft	G	2	
	PS-152	8,100 ft	I	2	
	PS-3151	22,200 ft	J	6	
Cable tray channels, base metal tension tests	9-inch*	1,008 ft			
	12-inch	2,796 ft	12S	2	
	18-inch	7,104 ft	18S	5	
	24-inch	30,876 ft	24S	21	
	36-inch	3,600 ft	36S	3	
Cable tray rings, base metal tension tests	9-inch*	1,008 ft			
	12-inch	2,796 ft	12S	2	
	18-inch	7,104 ft	18S	5	
	24-inch	30,876 ft	24S	21	
	36-inch	3,600 ft	36S	3	

Table 4 (continued)

Category	Item	Total Job Quantity (at Time of Sampling)	Sample I.D.	Number of Samples	Remarks
Power strut fittings	PS-3064	950		39	
	PS-3375	2,200		40	
	PS-3127 L&R	3,531		62	Two fittings at a time
	PS-3033*	700			

*No samples were selected because the items were unavailable in the jobsite warehouse. For strength evaluation of 9-inch cable trays and PS-3033 fittings, see Sections 8.4 and 8.5.2.

TABLE 5

POWER STRUT SPOT WELD TEST RESULTS

Type of weld	Item	Sample ID No.	Actual Shear Strength per Weld (lb)	No. of Welds per Test
Back-to-back	PS-101	A-1	4,080	One
		A-2	790	
Back-to-back	PS-151	B-1	3,040	One
		B-2	3,960	
		B-3	4,160	
		B-4	4,760	
Back-to-back	PS-155	C-1	3,430	Two
Back-to-back	PS-201	D-1	4,410	One
		D-2	4,780	
		D-3	4,720	
		D-4	2,920	
		D-5	4,020	
		D-6	3,220	
		D-7	3,240	
		D-8	2,570	
		D-9	2,170	
		D-10	2,610	
		D-11	3,080	
		D-12	3,650	
		D-13	5,220	
		D-14	3,180	
		D-15	1,120	
		D-16	4,540	
		D-17	3,210	
		D-18	3,200	
		D-19	2,740	
		D-20	4,780	
		D-21	2,780	
		D-22	3,370	
		D-23	4,310	
		D-24	3,590	
		D-25	6,030	
		D-26	3,250	
		D-27	2,350	
		D-28	2,120	
		D-29	4,770	
		D-30	2,680	
		D-31	3,470	
		D-32	3,270	

Table 5 (continued)

Type of weld	Item	Sample ID No.	Actual Shear Strength per Weld (lb)	No. of Welds per Test
		D-33	2,630	
		D-34	4,420	
		D-35	5,180	
		D-36	2,600	
		D-37	4,780	
		D-38	3,900	
		D-39	2,630	
		D-40	2,150	
		D-41	1,960	
		D-42	4,130	
		D-43	2,080	
		D-44	3,850	
		D-45	2,830	
		D-46	2,900	
		D-47	2,980	
		D-48	2,000	
		D-49	2,630	
		D-50	3,320	
		D-51	4,730	
		D-52	4,910	
Back-to-back	PS-205	H-1	2,655	Two
Side-to-side	PS-152	I-1	2,820	One
		I-2	1,600	
		I-3	1,100	
		I-4	3,150	
		I-5	2,400	
		I-6	4,680	
		I-7	6,230	
		I-8	3,200	
		I-9	4,000	
		I-10	3,680	
		I-11	6,080	
		I-12	4,820	
		I-13	4,950	
		I-14	3,900	
		I-15	1,350	
		I-16	4,840	
		I-17	4,130	
		I-18	1,000	
		I-19	5,460	
		I-20	5,720	

Table 5 (continued)

Type of weld	Item	Sample ID No.	Actual Shear Strength per Weld (lb)	No. of Welds per Test
Side-to-side	PS-155	C-2	5,600	Two
		C-3	3,840	
		C-4	7,000	
		C-5	4,190	
		C-6	6,100	
		C-7	3,330	
		C-8	5,100	
		C-9	4,680	
Side-to-side	PS-202	E-1	4,002	One
		E-2	5,320	
		E-3	5,400	
		E-4	7,620	
		E-5	5,550	
		E-6	4,560	
		E-7	3,980	
		E-8	5,400	
		E-9	4,240	
		E-10	4,140	
		E-11	6,800	
		E-12	3,800	
		E-13	5,000	
		E-14	6,030	
		E-15	6,740	
		E-16	4,180	
		E-17	4,740	
		E-18	5,380	
		E-19	4,770	
		E-20	4,660	
		E-21	5,280	
		E-22	5,720	
		E-23	4,030	
		E-24	4,480	
		E-25	4,760	
Side-to-side	PS-205	H-2	4,800	Two
		H-3	5,600	
		H-4	6,000	
		H-5	8,000	
		H-6	7,800	
		H-7	4,700	
		H-8	5,600	

Table 5 (continued)

Type of weld	Item	Sample ID No.	Actual Shear Strength per Weld (lb)	No. of Welds per Test
Side-to-back	PS-204	F-1	1,600	One
		F-2	3,120	
		F-3	3,200	
		F-4	3,880	
		F-5	4,440	
		F-6	4,220	
		F-7	4,460	
		F-8	4,580	
		F-9	3,900	
		F-10	3,500	
		F-11	3,570	
		F-12	6,270	
		F-13	3,970	
		F-14	2,170	
		F-15	3,580	
		F-16	3,250	
Side-to-back	PS-207	G-1	2,010	Two
		G-2	4,440	
		G-3	3,620	
		G-4	4,400	
		G-5	2,550	
		G-6	4,220	
		G-7	3,310	
		G-8	3,600	
		G-9	2,910	
		G-10	3,490	
		G-11	4,600	
		G-12	3,780	
Side-to-back	PS-3151	J-1	7,120	One
		J-2	5,400	
		J-3	4,400	
		J-4	4,700	
		J-5	9,280	
		J-6	5,720	
		J-7	5,820	
		J-8	8,000	
		J-9	5,460	
		J-10	5,430	
		J-11	5,130	
		J-12	3,670	

Table 5 (continued)

Type of weld	Item	Sample ID No.	Actual Shear Strength per Weld (lb)	No. of Welds per Test
		J-13	5,040	
		J-14	6,640	
		J-15	7,680	
		J-16	6,520	
		J-17	5,710	
		J-18	6,170	
		J-19	5,550	
		J-20	5,260	
		J-21	5,460	
		J-22	3,030	
		J-23	5,520	
		J-24	6,000	
		J-25	6,650	
		J-26	6,170	
		J-27	6,350	
		J-28	5,380	
		J-29	2,800	
		J-30	3,920	
		J-31	4,760	
		J-32	5,460	

TABLE 6

HUSKY AND BURNDY CABLE TRAY SPOT WELD TEST RESULTS

Cable Tray Width (in.)	Sample ID No.	Actual Shear Strength per Weld (lb)
12	12S-71	2,350
	12S-89	2,310
	12S-94	2,200
18	18S-6	2,350
	18S-8	2,375
	18S-18	1,825
	18S-22	2,415
	18S-27	2,500
	18S-29	2,400
	18S-32	2,100
	18S-36	2,125
24	24S-1	2,800
	24S-12	2,370
	24S-18	2,400
	24S-28	2,730
	24S-35	1,[illegible]00
	24S-44	2,860
	24S-51	2,860
	24S-52	2,900
	24S-63	2,060
	24S-74	2,720
	24S-80	2,440
	24S-82	2,290
	24S-87	2,500
	24S-116	2,340
	24S-118	1,100
	24S-132	2,150
	24S-156	2,550
	24S-161	2,390
	24S-181	1,100
	24S-186	1,650
	24S-195	1,750
	24S-205	2,520
	24S-214	2,300
	24S-223	2,060
	24S-237	2,125
	24S-244	2,130
	24S-258	2,310
	24S-263	2,350
	24S-264	2,270
	24S-267	2,220

TABLE 6 (continued)

Cable Tray Width (in.)	Sample ID No	Actual Shear Strength per Weld (lb)
	24S-291	1,200
	24S-309	2,170
	24S-321	2,520
	24S-324	2,330
	24S-342	2,080
	24S-374	2,160
	24S-394	1,440
36	36S-30	2,370
	36S-37	2,175
	36S-39	2,285
	36S-44	2,700

TABLE 7

POWER STRUT BASE MATERIAL TENSION TEST RESULTS

Item	Sample ID No.	Actual Yield Strength (psi)
PS-101	A-1	45,565
PS-151	B-1	46,332
	B-2	57,340
	B-3	46,332
PS-155	C-6	52,885
	C-7	47,297
PS-201	D-1	45,059
	D-2	45,585
	D-3	46,000
	D-4	45,110
	D-5	44,715
	D-6	45,142
	D-7	46,337
	D-8	45,214
	D-9	46,906
	D-12	44,508
	D-13	45,040
	D-15	45,309
	D-16	46,414
	D-17	45,635
	D-19	47,177
	D-20	49,899
	D-21	47,337
	D-22	41,284
	D-23	44,355
	D-26	49,495
	D-27	46,365
	D-29	43,515
	D-30	44,578
	D-31	46,625
	D-33	45,996
	D-34	45,491
	D-36	44,862
	D-37	46,573
	D-38	45,749
	D-39	45,565
	D-41	43,788
	D-42	49,903
	D-43	50,100
	D-44	49,513
	D-46	48,000

TABLE 7 (continued)

Item	Sample Id. No.	Actual Yield Strength (psi)
	D-51	51,935
	D-52	46,392
PS-202	E-26	50,625
	E-27	50,891
	E-28	54,082
PS-204	F-9	49,808
	F-11	49,705
	F-12	50,803
PS-207	G-7	43,595
	G-8	42,214
PS-205	H-9	51,650
PS-152	I-19	42,945
	I-20	44,311
PS-3151	J-33	52,713
	J-34	48,466
	J-35	55,970
	J-36	44,074
	J-37	52,998
	J-38	44,016

TABLE 8

CABLE TRAY BASE MATERIAL CHANNEL TEST RESULTS

Cable Tray Width (in.)	Sample ID No.	Actual Yield Strength (psi)
12	12S-96C	47,672
	12S-106C	48,768
18	18S-3C	41,962
	18S-4C	44,101
	18S-15C	42,520
	18S-25C	41,667
	18S-34C	42,105
24	24S-33C	44,032
	24S-58C	47,170
	24S-62C	38,120
	24S-77C	41,444
	24S-88C	41,417
	24S-102C	39,889
	24S-131C	38,251
	24S-150C	42,541
	24S-153C	40,437
	24S-167C	43,646
	24S-173C	42,781
	24S-234C	45,902
	24S-247C	39,617
	24S-270C	40,000
	24S-295C	41,322
	24S-338C	42,703
	24S-343C	43,407
	24S-351C	45,179
	24S-362C	43,597
	24S-370C	44,205
	24S-393C	44,444
36	36S-7C	44,687
	36S-10C	46,900
	36S-40C	45,355

TABLE 10

POWER STRUT FITTING TEST RESULTS

Item	Sample ID. No.	Ultimate Strength (lb)
PS-3064	1	34,600
	2	34,150
	22	33,800
	35	32,275
	53	35,900
	68	36,050
	84	34,300
	99	32,350
	102	32,950
	122	31,050
	144	31,400
	156	38,150
	159	35,150
	170	35,350
	226	36,850
	258	36,300
	314	36,050
	354	32,150
	363	34,200
	381	37,100
	400	32,100
	419	33,800
	455	34,050
	462	32,800
	477	35,950
	504	32,725
	513	32,900
	515	33,025
	523	34,400
	570	34,250
	605	35,900
	628	35,800
	633	33,900
	668	34,400
	732	30,650
	769	36,250
	65	33,125
	230	33,050
	304	34,950
PS-3375	1	13,700
	35	13,700
	55	14,700
	83	15,000
	102	10,800

TABLE 10 (continued)

Item	Sample ID. No.	Ultimate Strength (lb)
	107	13,600
	133	12,600
	156	15,000
	161	12,800
	193	11,000
	228	13,000
	247	15,700
	253	15,700
	270	15,400
	358	13,500
	364	13,300
	409	14,700
	483	12,400
	497	15,000
	498	13,700
	534	14,100
	562	15,000
	575	12,600
	604	14,000
	634	12,700
	664	14,450
	690	14,000
	733	15,000
	757	13,560
	799	12,800
	814	7,670
	817	13,000
	829	10,000
	904	9,500
	959	10,700
	996	15,440
	1005	11,600
	1060	12,500
	1161	12,000
	1221	12,500
PS-3127 L&R	2L/1331R	9,000
	56L/1552R	9,900
	137L/479R	9,099
	175L/632R	9,020
	219L/1500R	9,340
	257L/980R	8,800
	265L/1507R	9,300
	294L/330R	10,040
	315L/111R	8,580
	318L/1092R	9,650
	376L/645R	8,630

TABLE 10 (continued)

Item	Sample ID. No.	Ultimate Strength (lb)
	393L/1630R	9,800
	407L/2R	8,950
	444L/621R	9,900
	591L/215R	9,440
	601L/209R	10,180
	780L/968R	9,340
	796L/142R	9,880
	820L/1421R	9,340
	854L/136R	9,880
	880L/1R	9,820
	995L/317R	9,040
	996L/1456R	9,140
	1045L/887R	9,400
	1095L/751R	9,140
	1194L/847R	9,300
	1209L/1221R	10,570
	1260L/423R	9,950
	1317L/1417R	10,440
	1347L/239R	10,420
	1367L/305R	9,600
	1382L/541R	9,300
	1582L/178R	10,000
	1642L/1343R	9,540
	1657L/1535R	9,140
	1730L/547R	9,440
	1748L/487R	9,180
	1797L/1068R	8,480
	1851L/714R	10,000
	1916L/1088R	8,860
	2011L/1022R	8,550
	2014L/666R	8,780
	1138L/46R	8,950
	416L/73R	9,640
	926L/232R	8,060
	1L/255R	8,680
	766L/258R	9,390
	1507L/337R	9,300
	167L/360R	9,790
	90L/363R	8,330
	1342L/665R	9,050
	1754L/692R	8,370
	1249L/768R	9,100
	674L/807R	10,410
	391L/922R	10,780
	948L/1108R	9,640
	821L/1120R	9,780
	447L/1208R	10,140

TABLE 10 (continued)

Item	Sample ID. No.	Ultimate Strength (lb)
	1490L/1282R	9,997
	1894L/1402R	7,670
	667L/1632R	9,990
	521L/1012R	9,400

POWER STRUT SECTION DESIGNATIONS

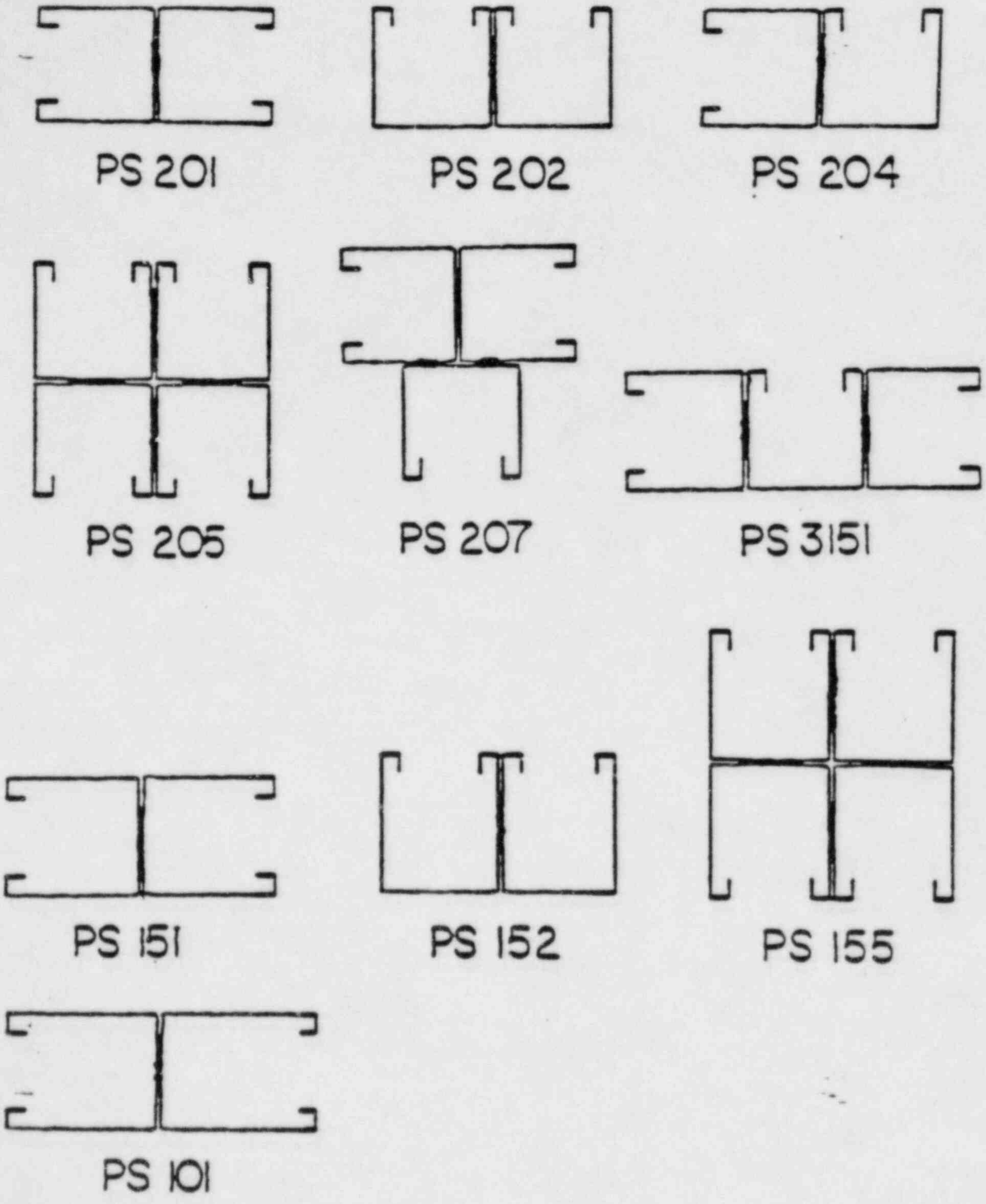
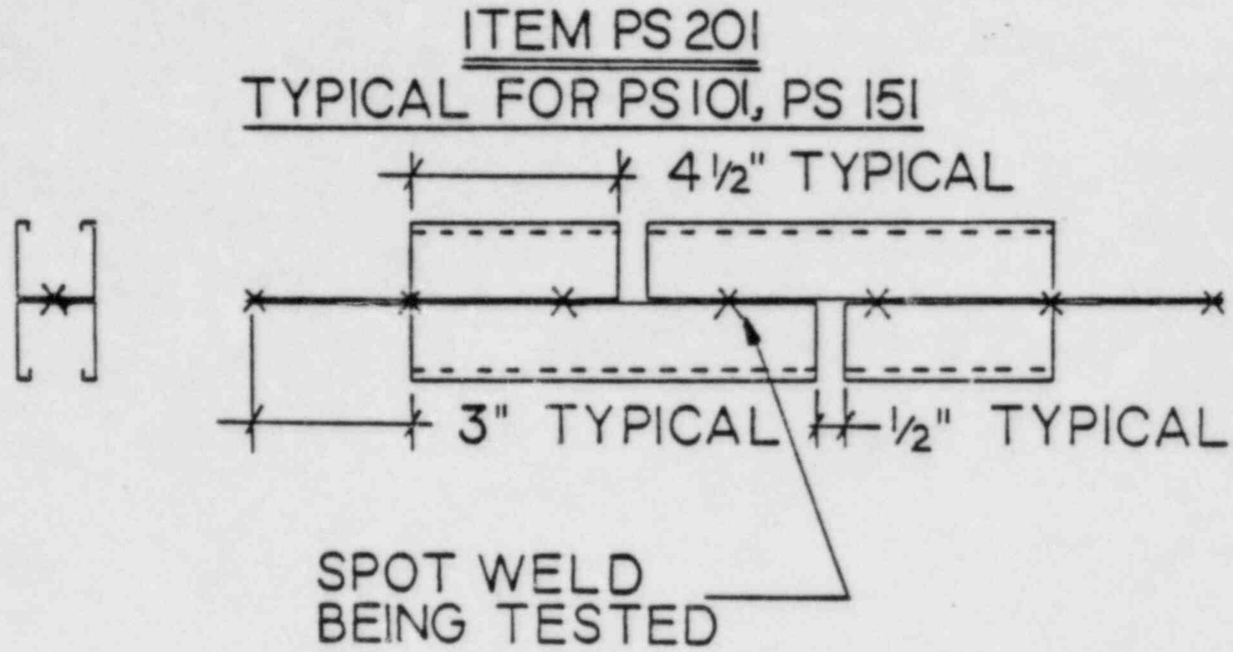


FIGURE 1

0505

TEST SAMPLE CONFIGURATIONS



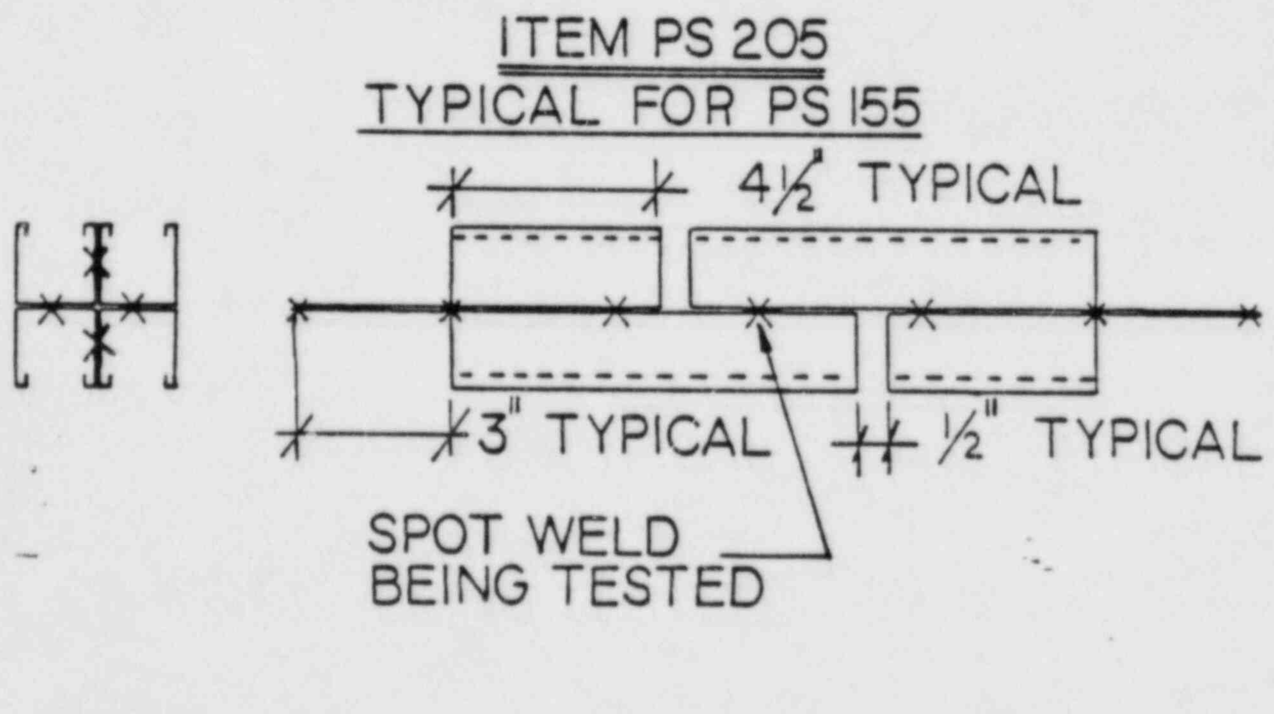


FIGURE 2

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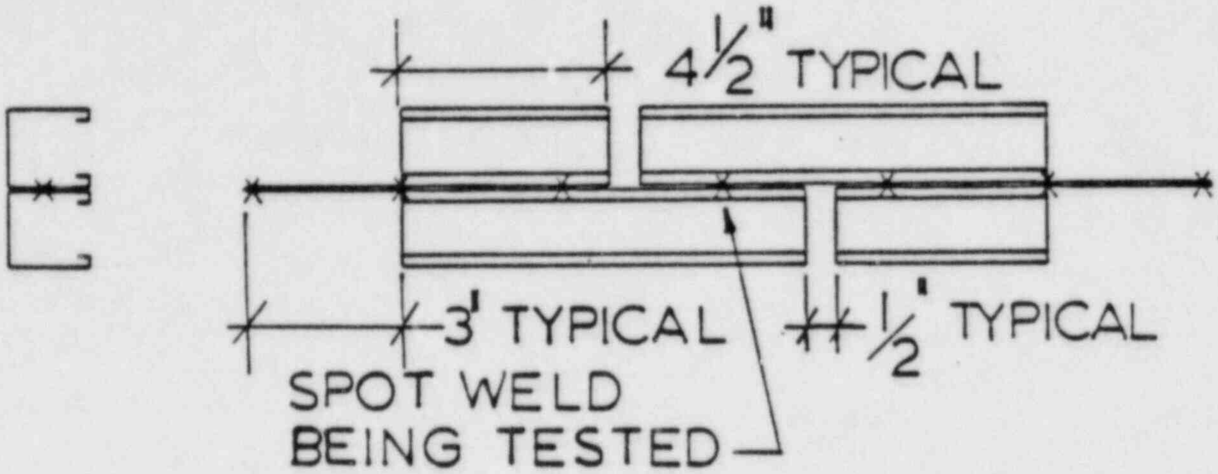
TEST SAMPLE CONFIGURATIONS

46500

ITEM PS 202
TYPICAL FOR ITEM PS 152



ITEM PS 204

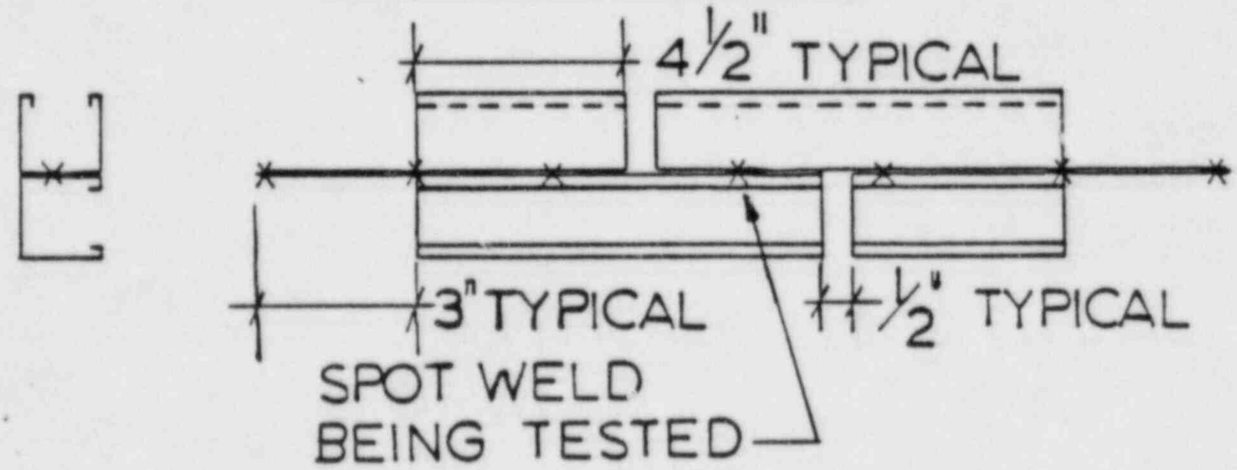


FIGURE 3

050561

TEST SAMPLE CONFIGURATIONS

4653

ITEM PS 3151

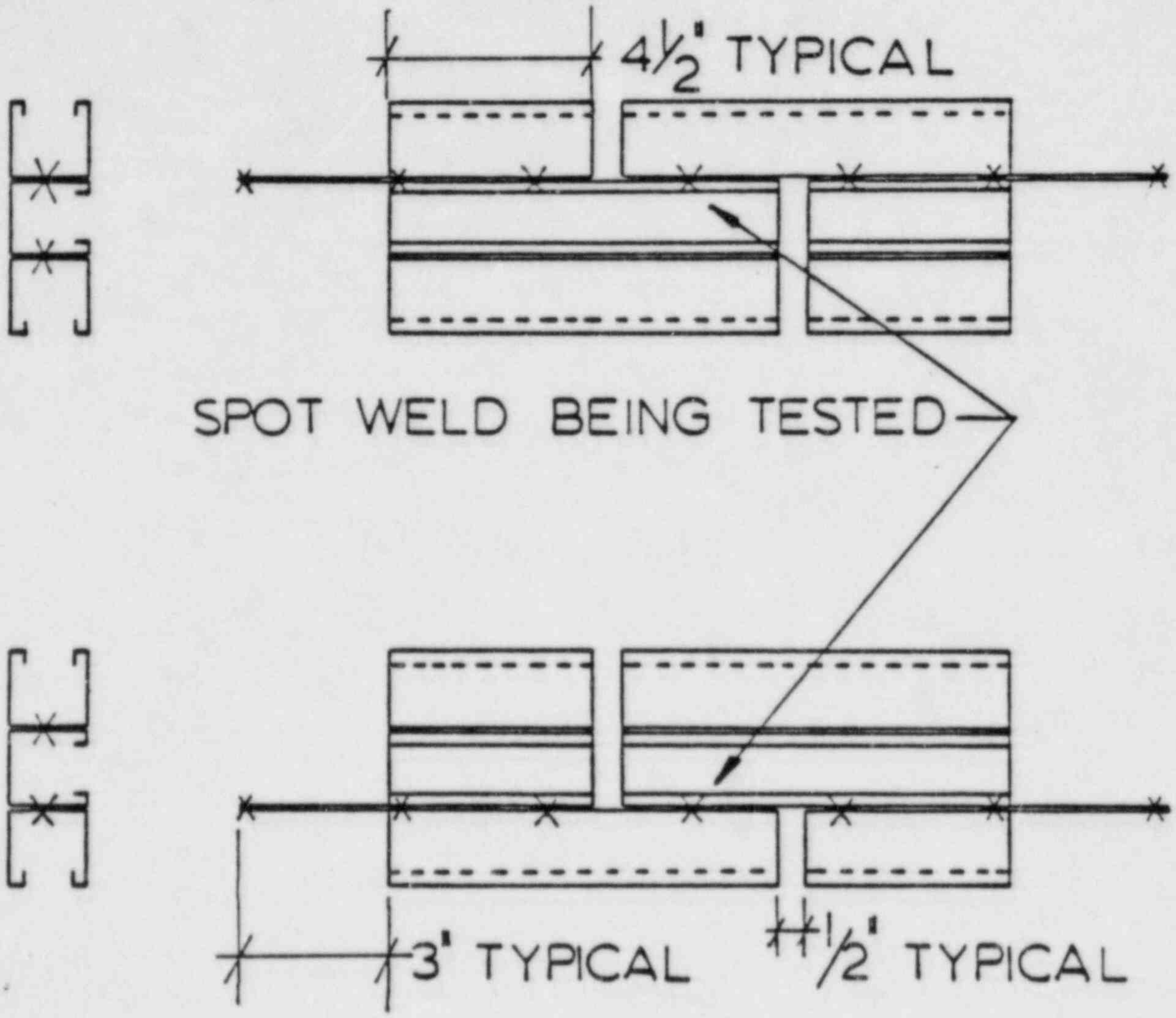


FIGURE 4

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TEST SAMPLE CONFIGURATIONS

6538

ITEM PS 207

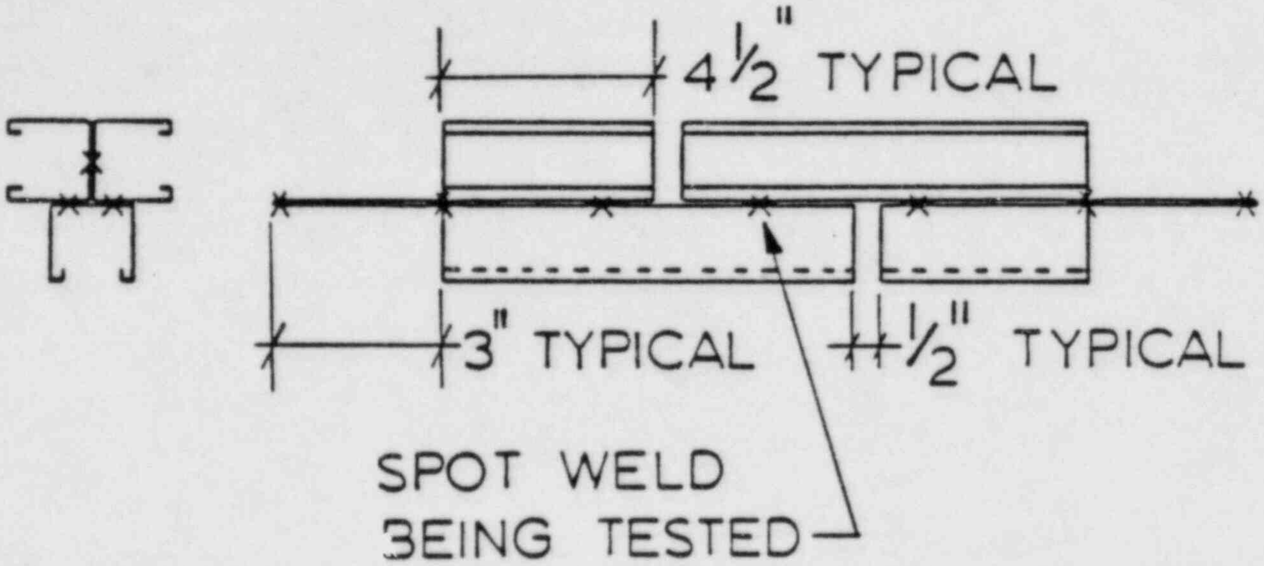

FIGURE 5

TYPICAL POWER STRUT TEST COUPON

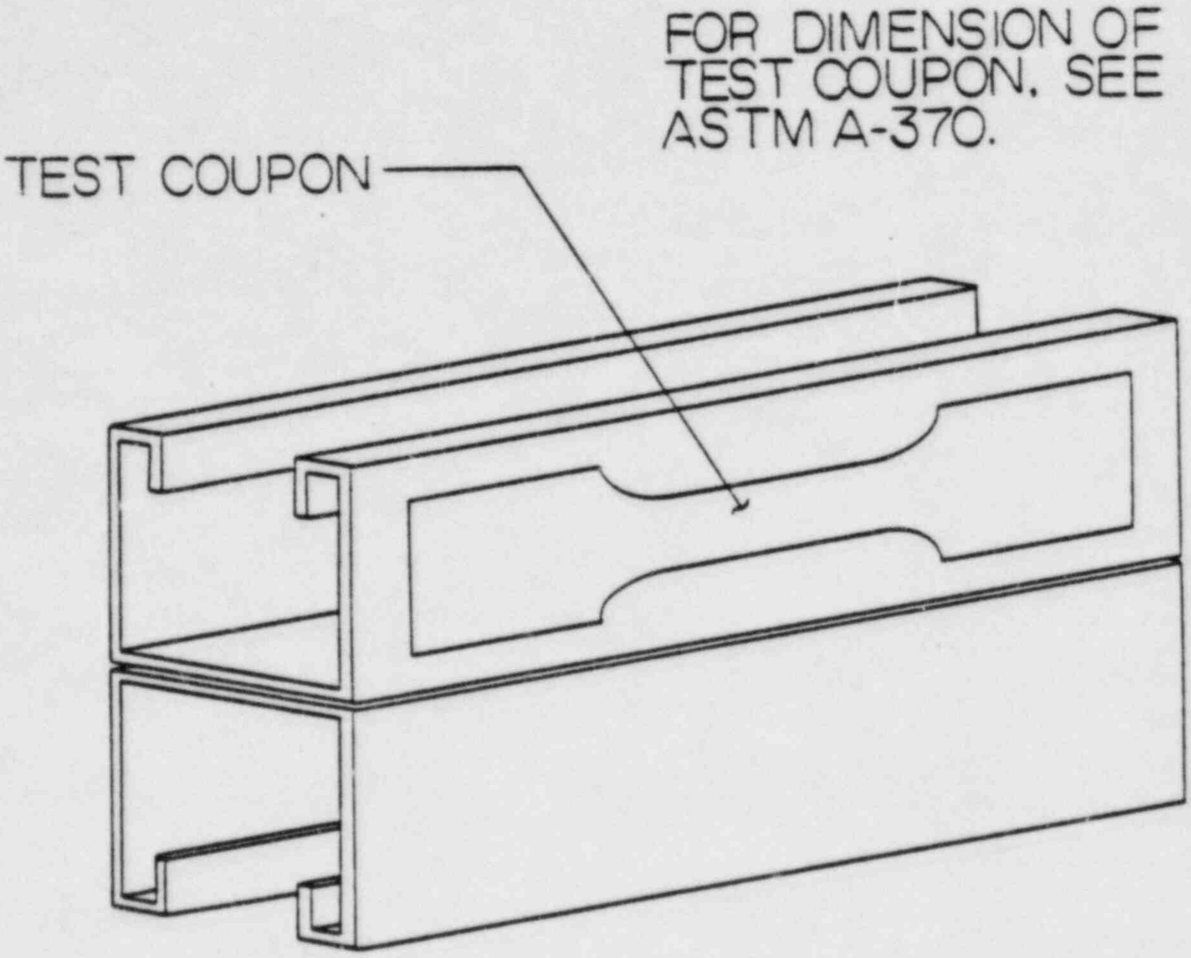

FIGURE 6

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TYPICAL CABLE TRAY SAMPLE

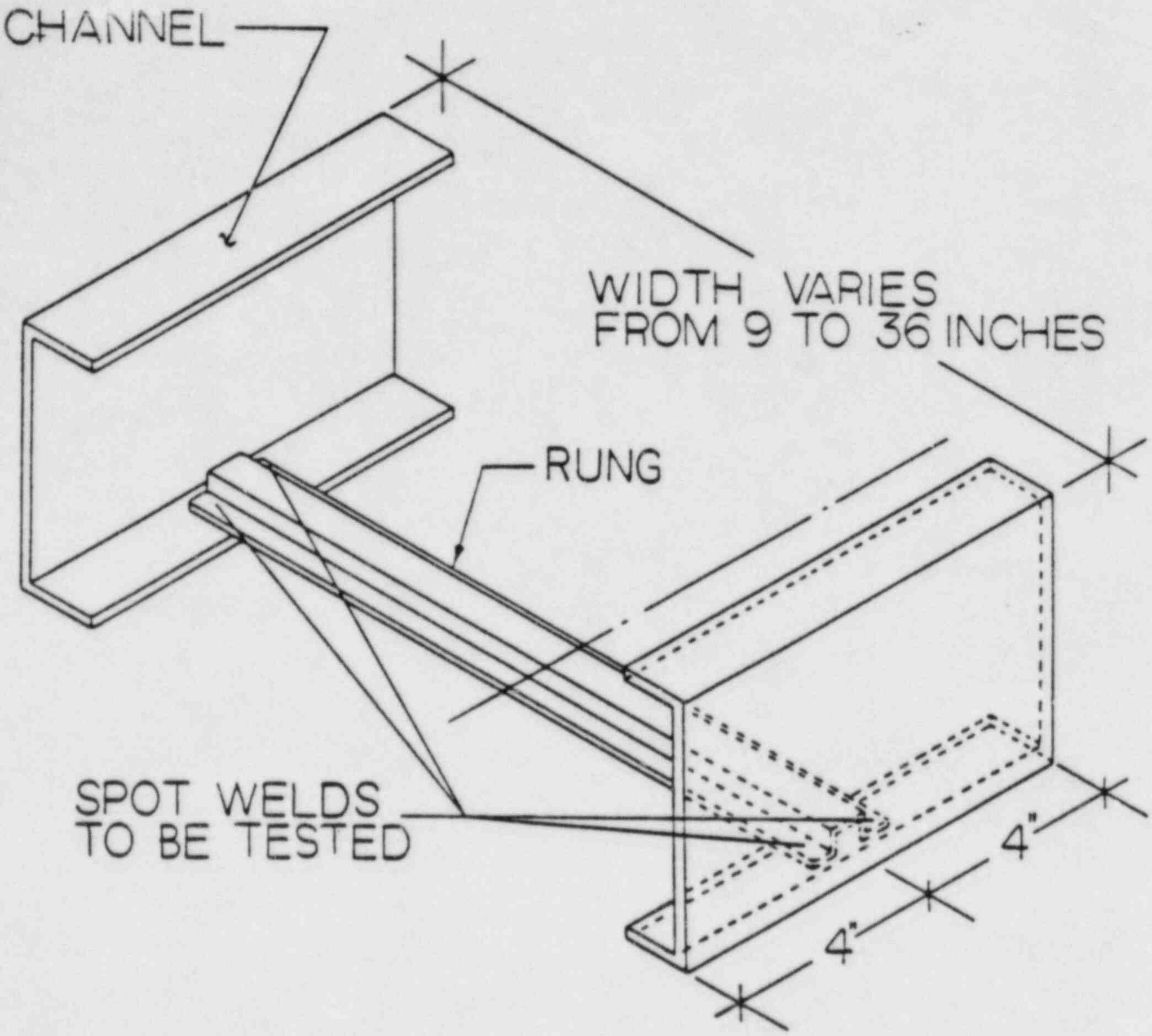

FIGURE 7

050561

TEST SAMPLE CONFIGURATION

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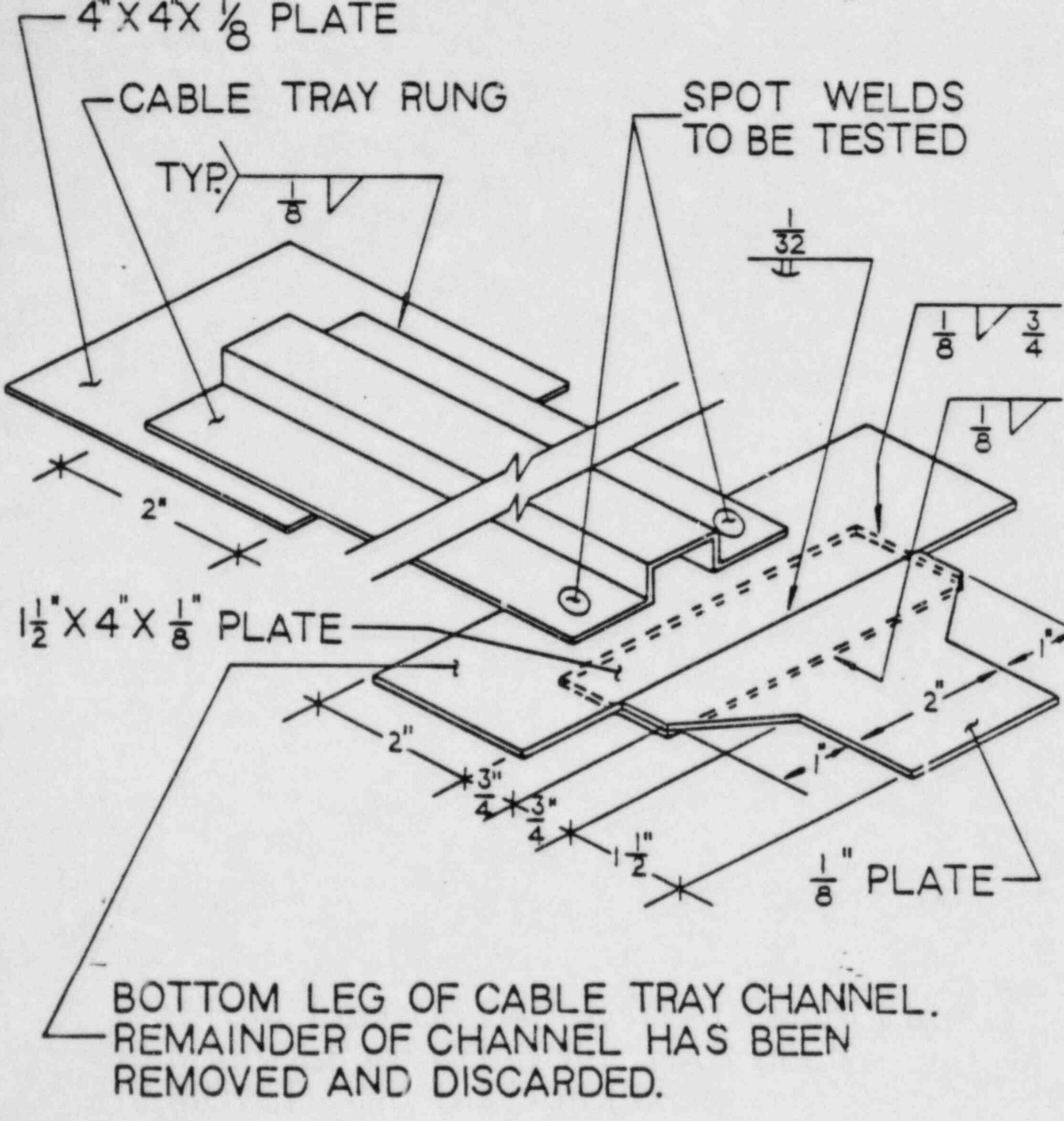

FIGURE 8

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TYP CABLE TRAY TEST COUPON

146538

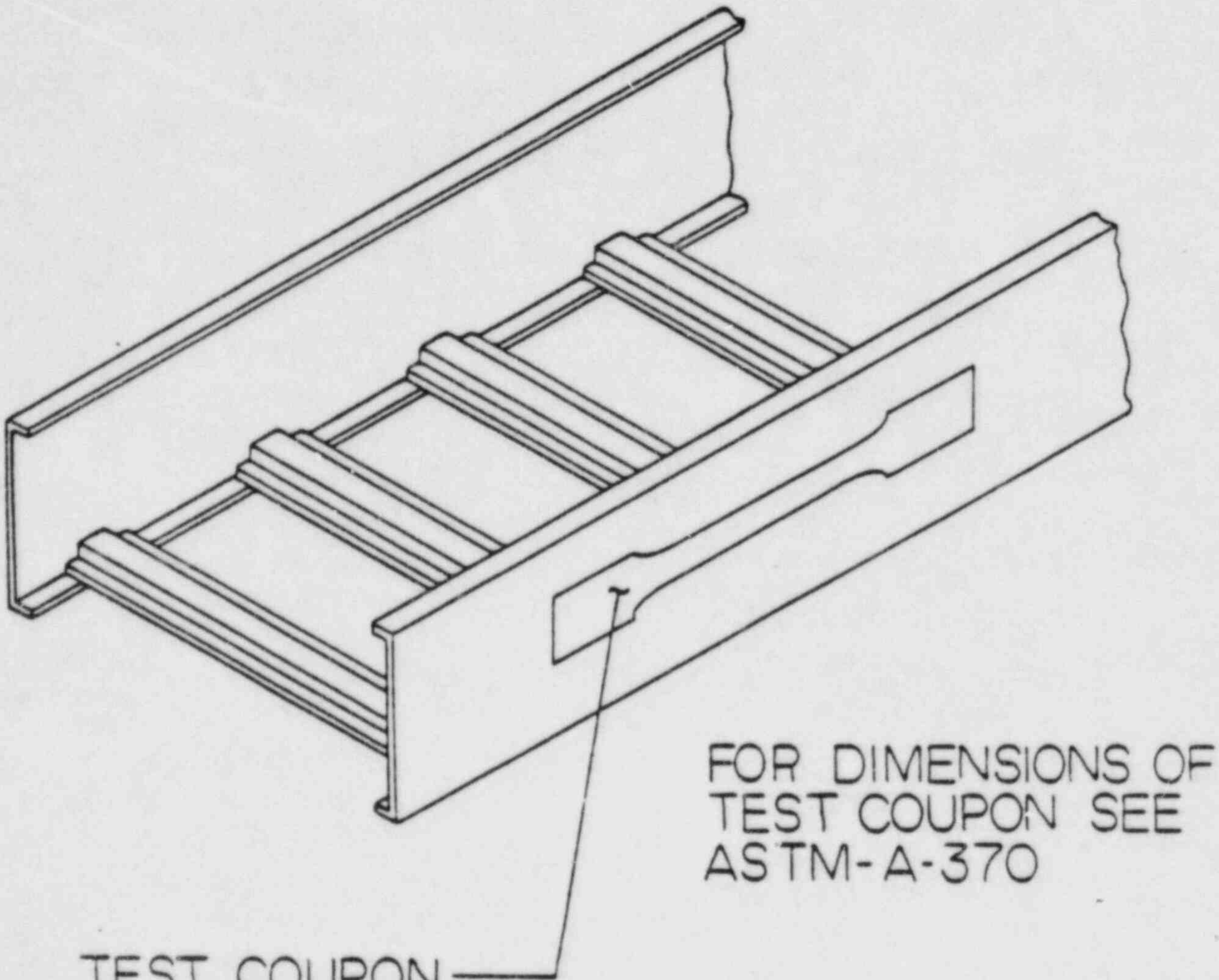
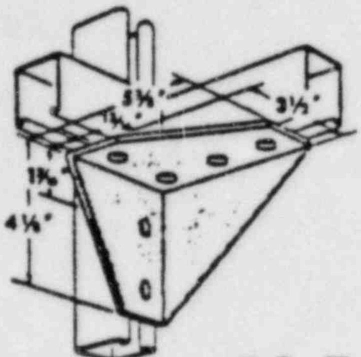
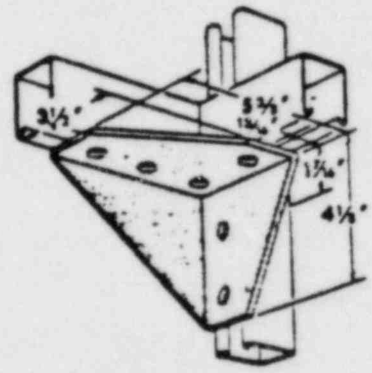


FIGURE 9

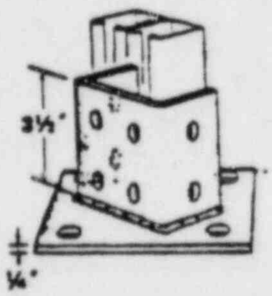
POWER STRUT FITTINGS



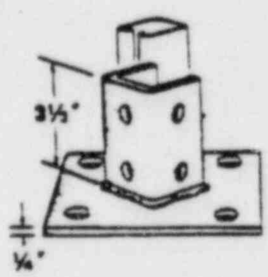
PS 3127R



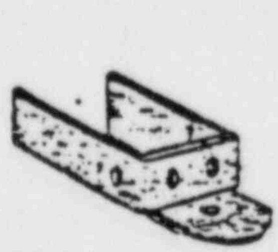
PS 3127L



PS 3064



PS 3033



PS 3375

FIGURE 10

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TYP. POWER STRUT TEST ARRANGEMENT

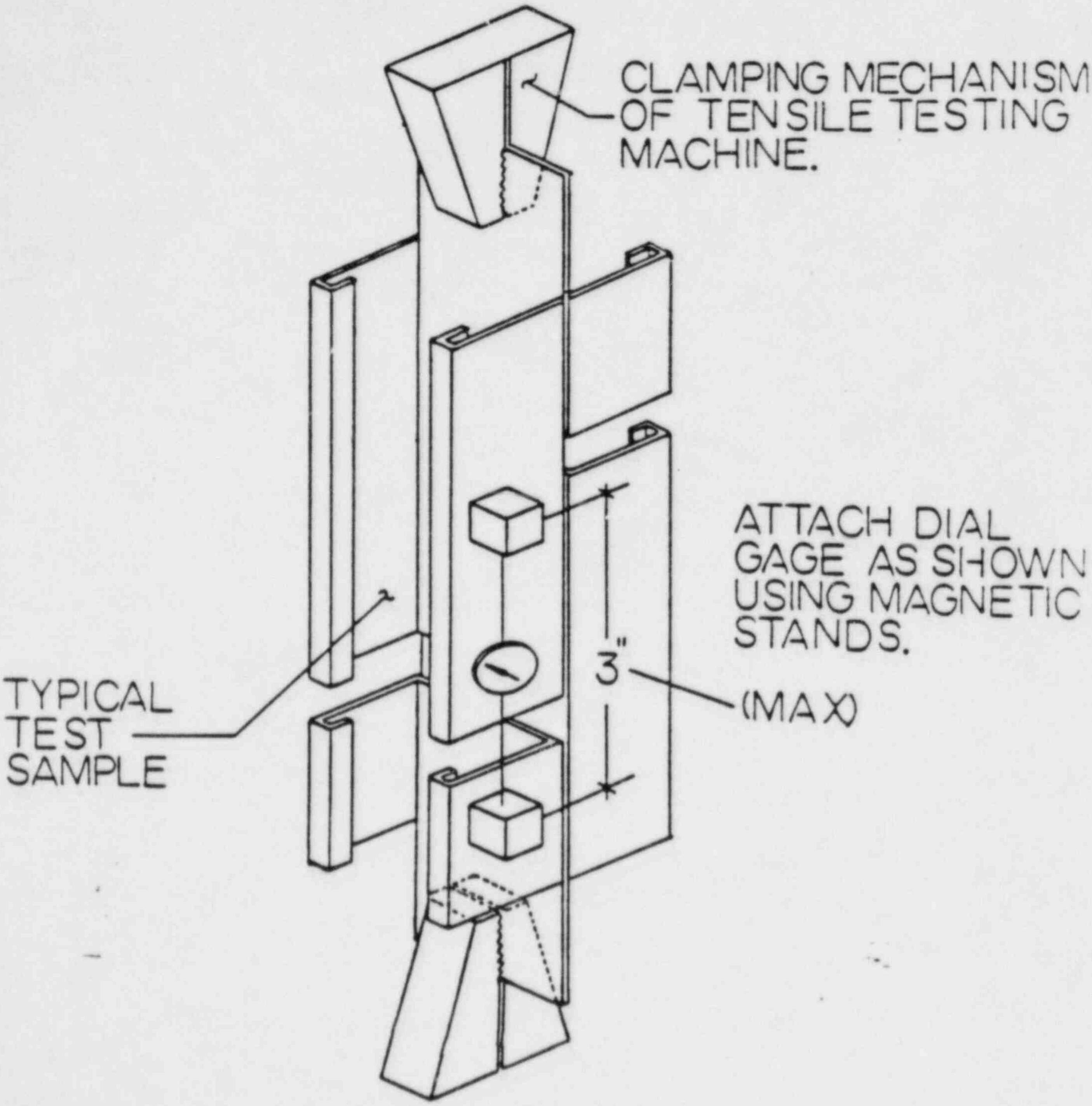

FIGURE 11

1-50561

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CABLE TRAY TEST ARRANGEMENT

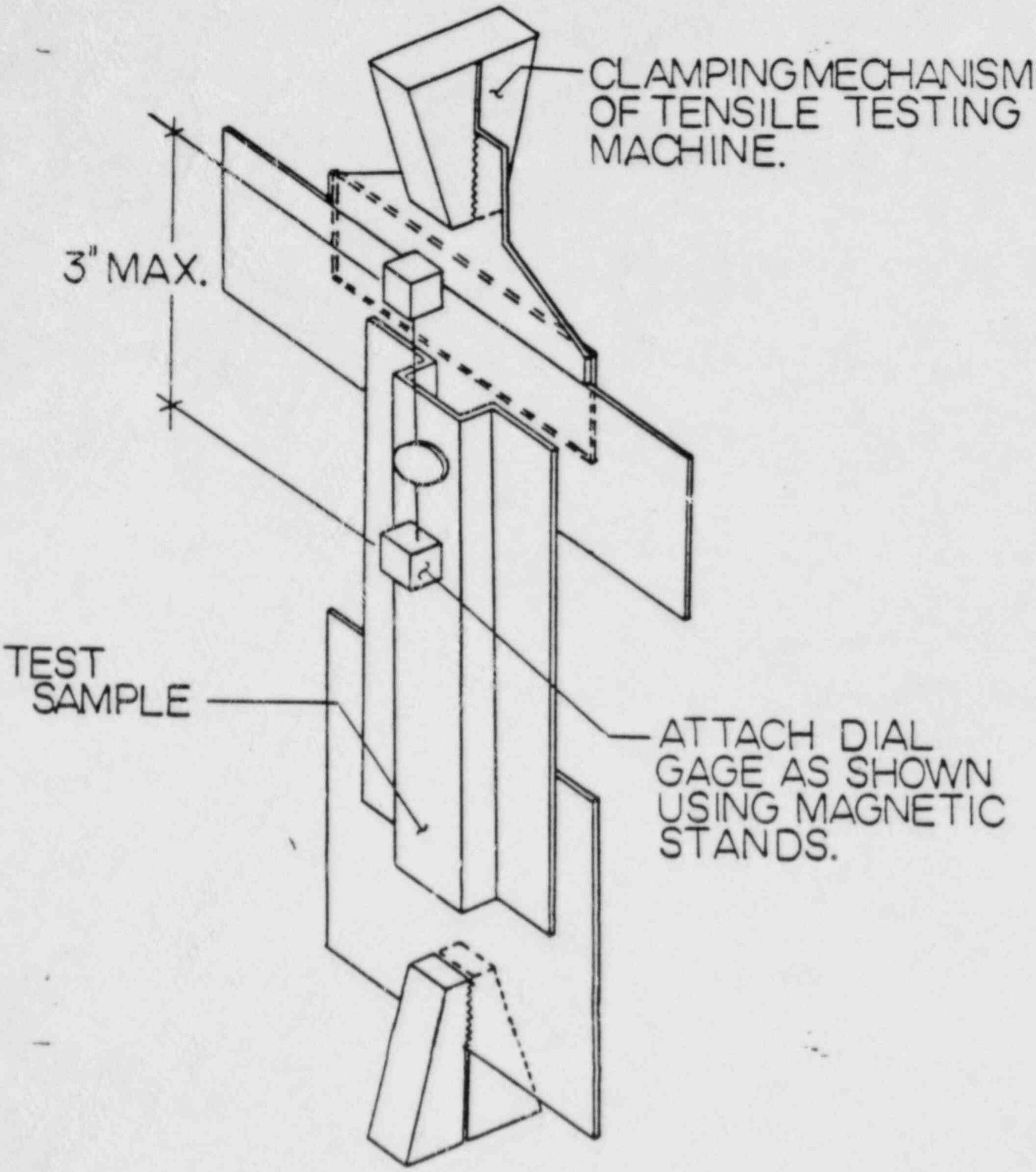

FIGURE 12

POWER STRUT FITTING TEST ARRANGEMENT

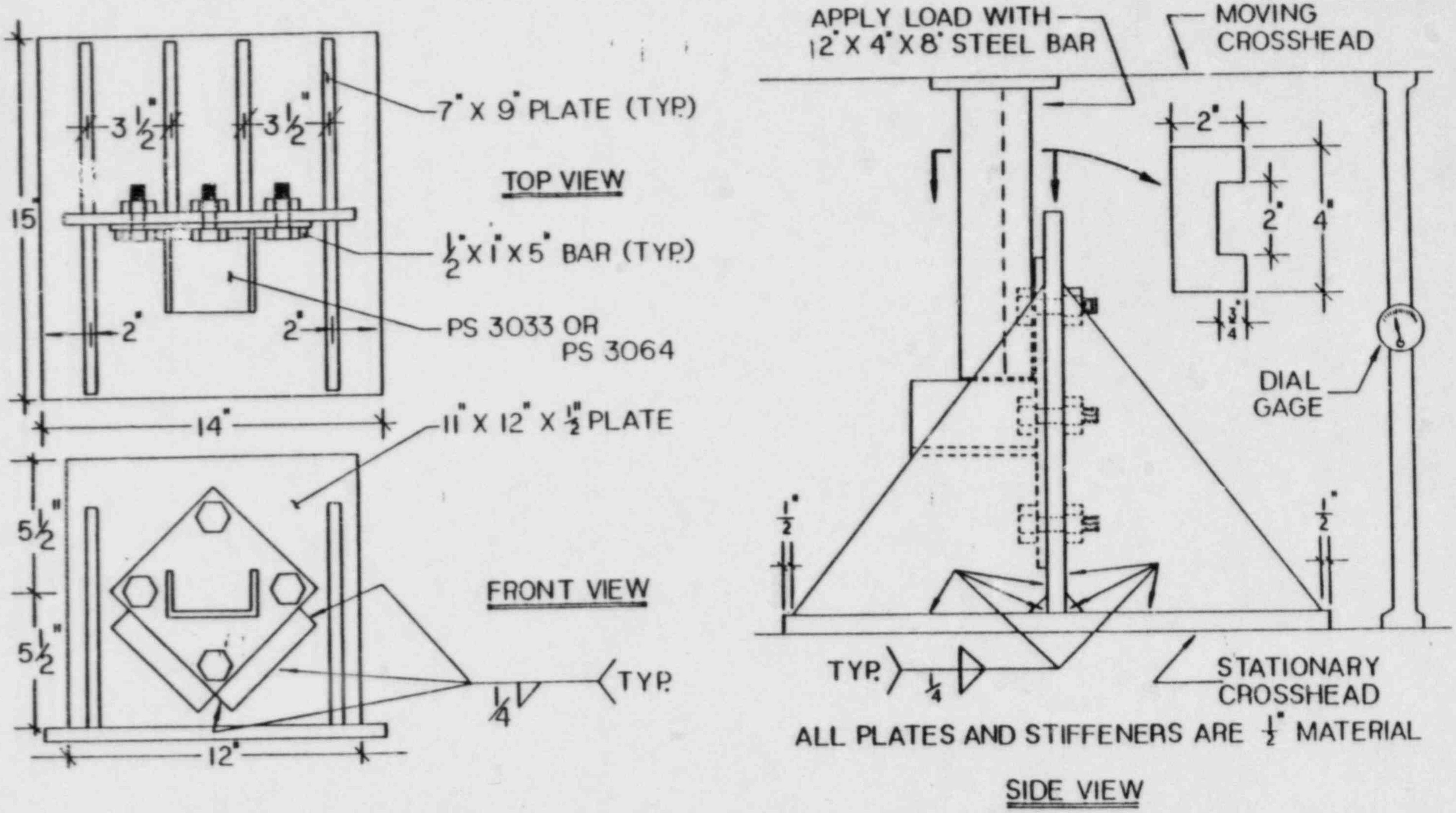

FIGURE 13

C50561

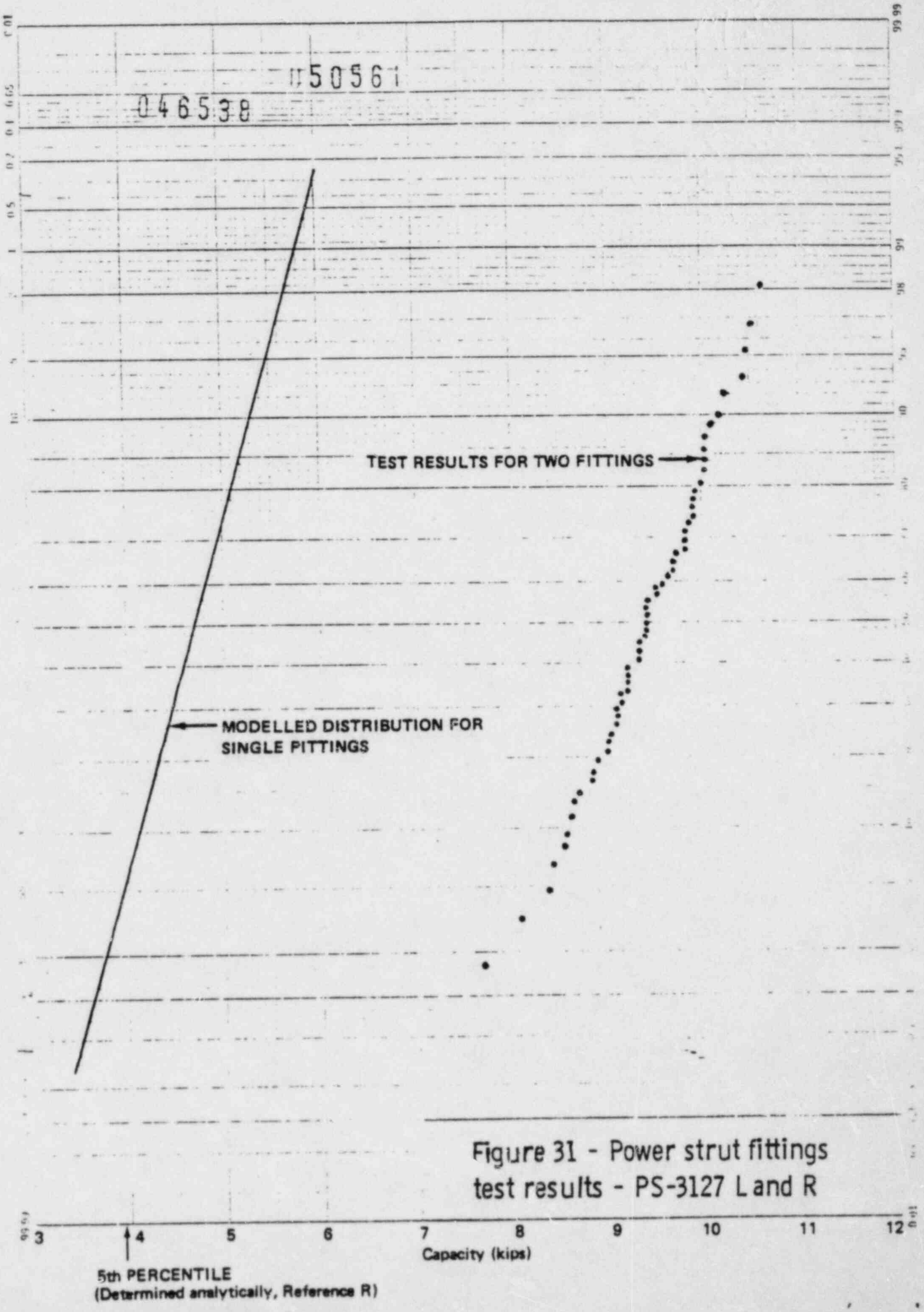

Figure 31 - Power strut fittings test results - PS-3127 L and R

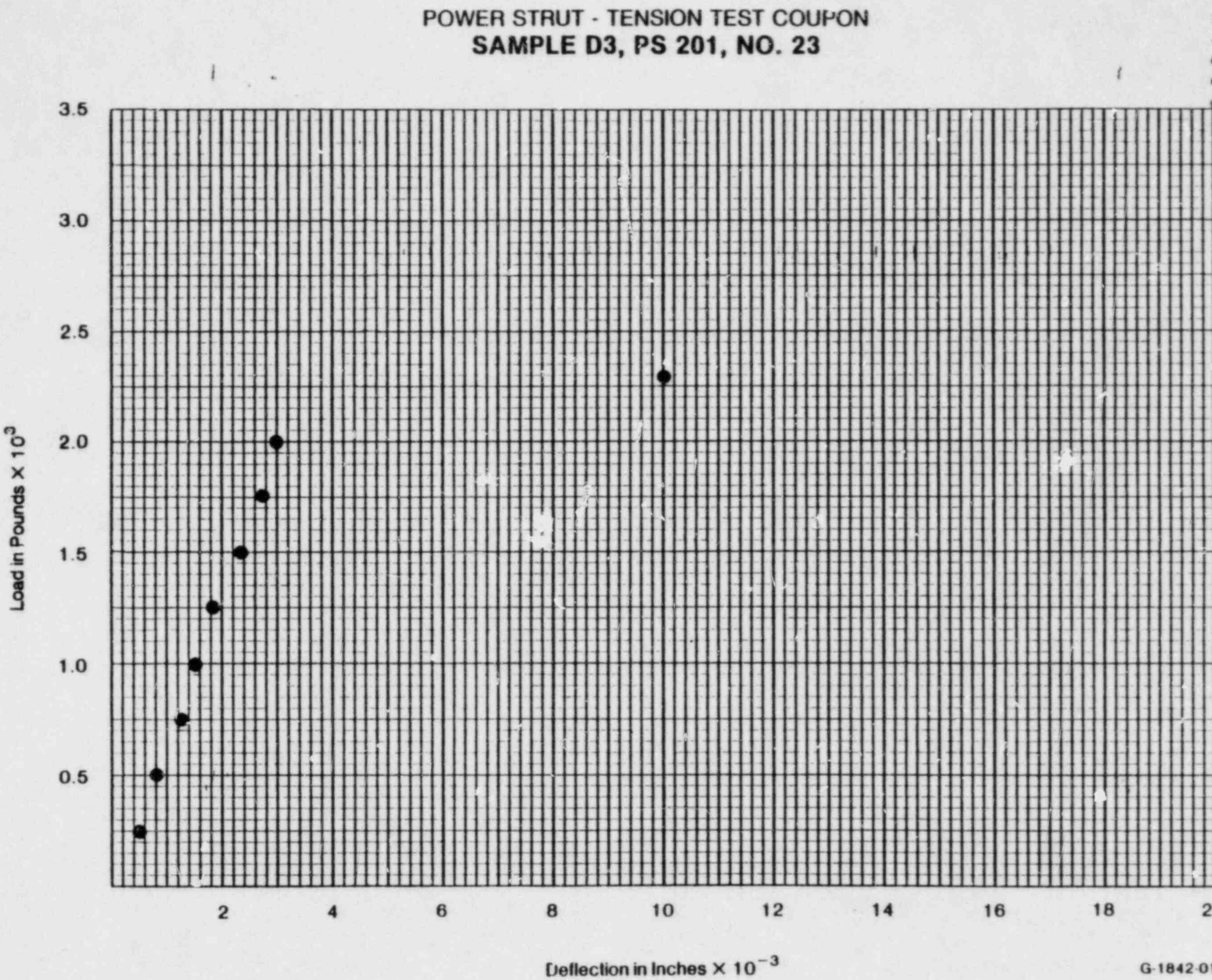

Figure 32 - Load-deformation plot for PS-201, Power Strut base metal.

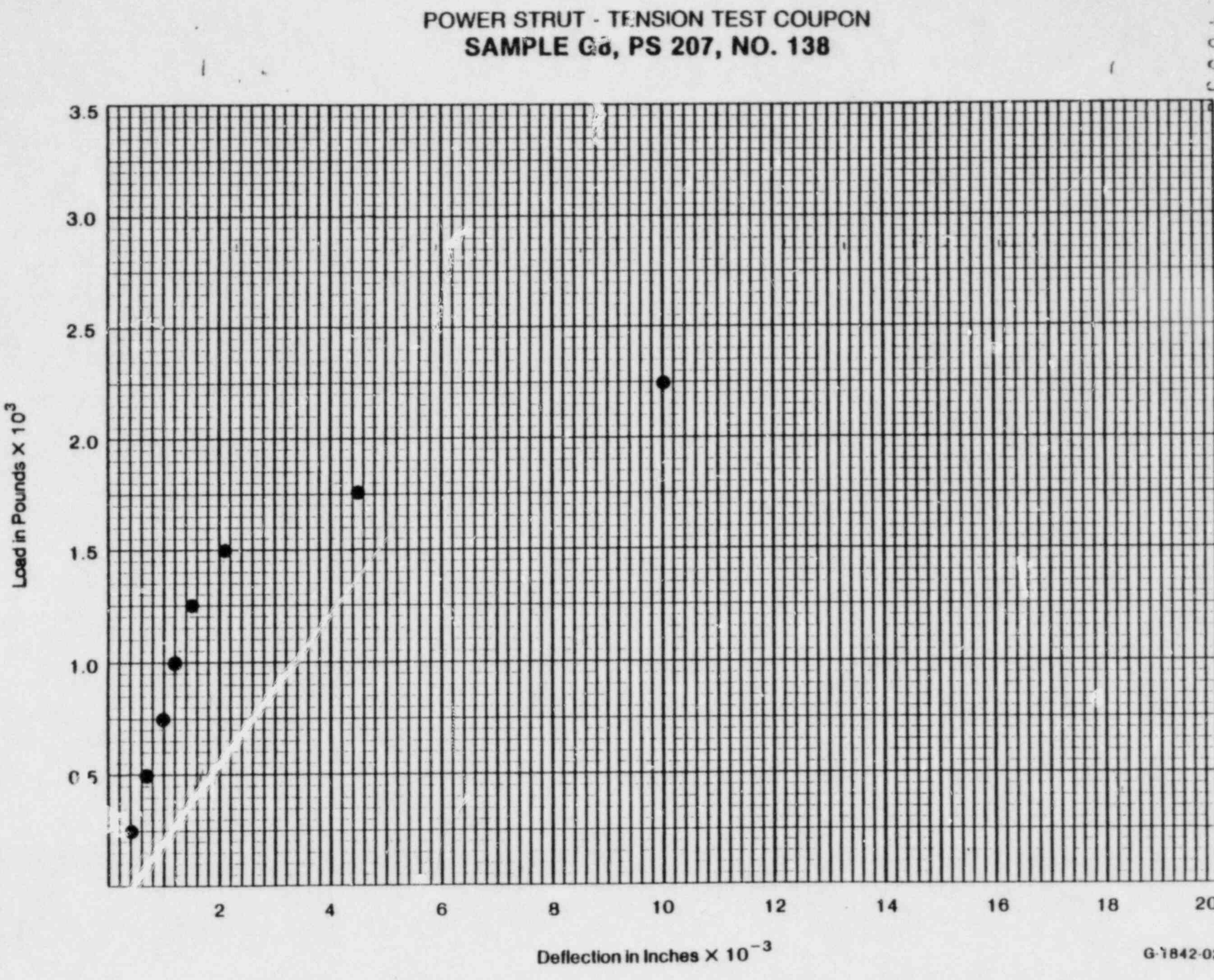

Figure 33 - Load-deformation plot for PS-207, Power Strut base metal.

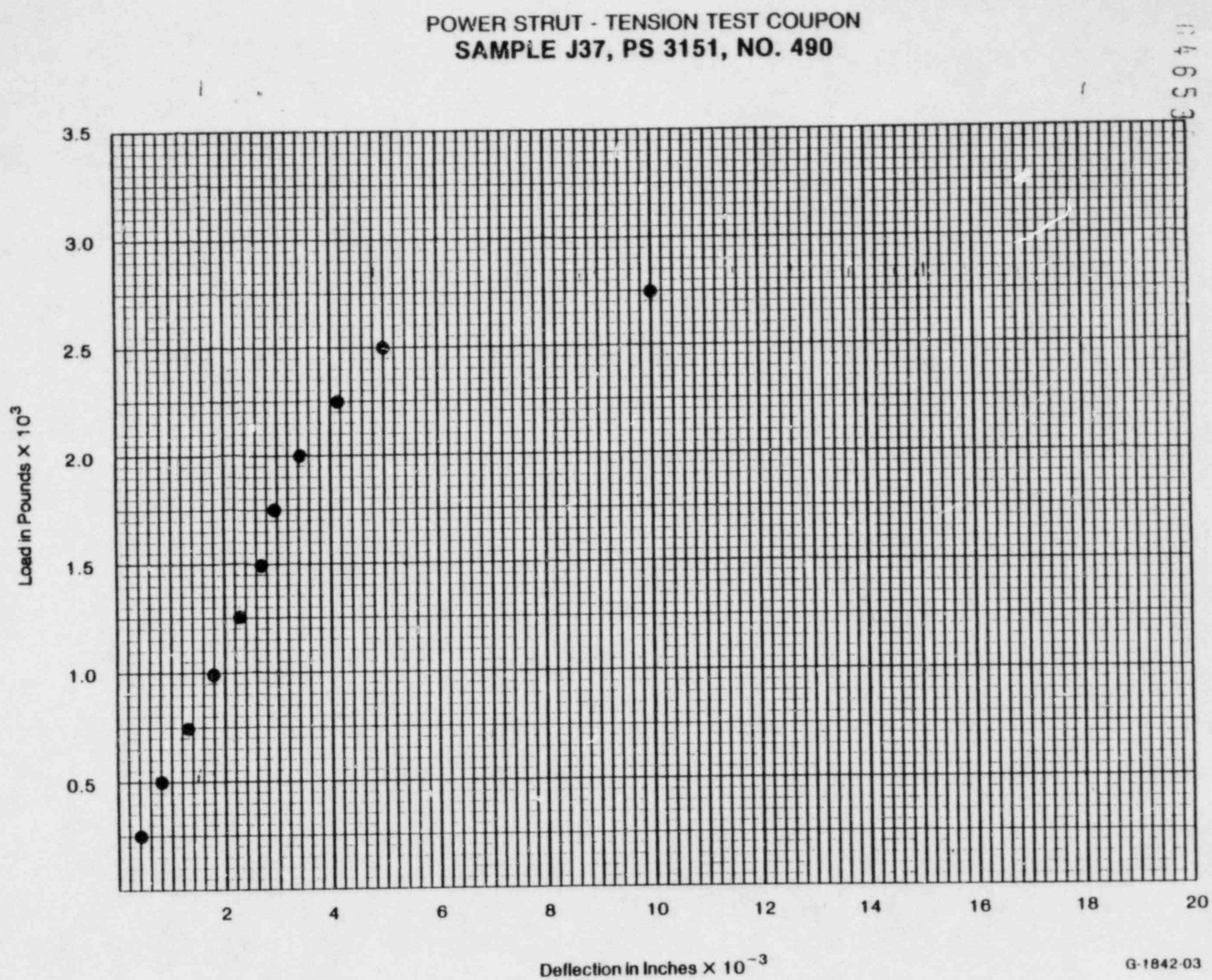

Figure 34 - Load-deformation plot for PS-3151, Power Strut base metal.

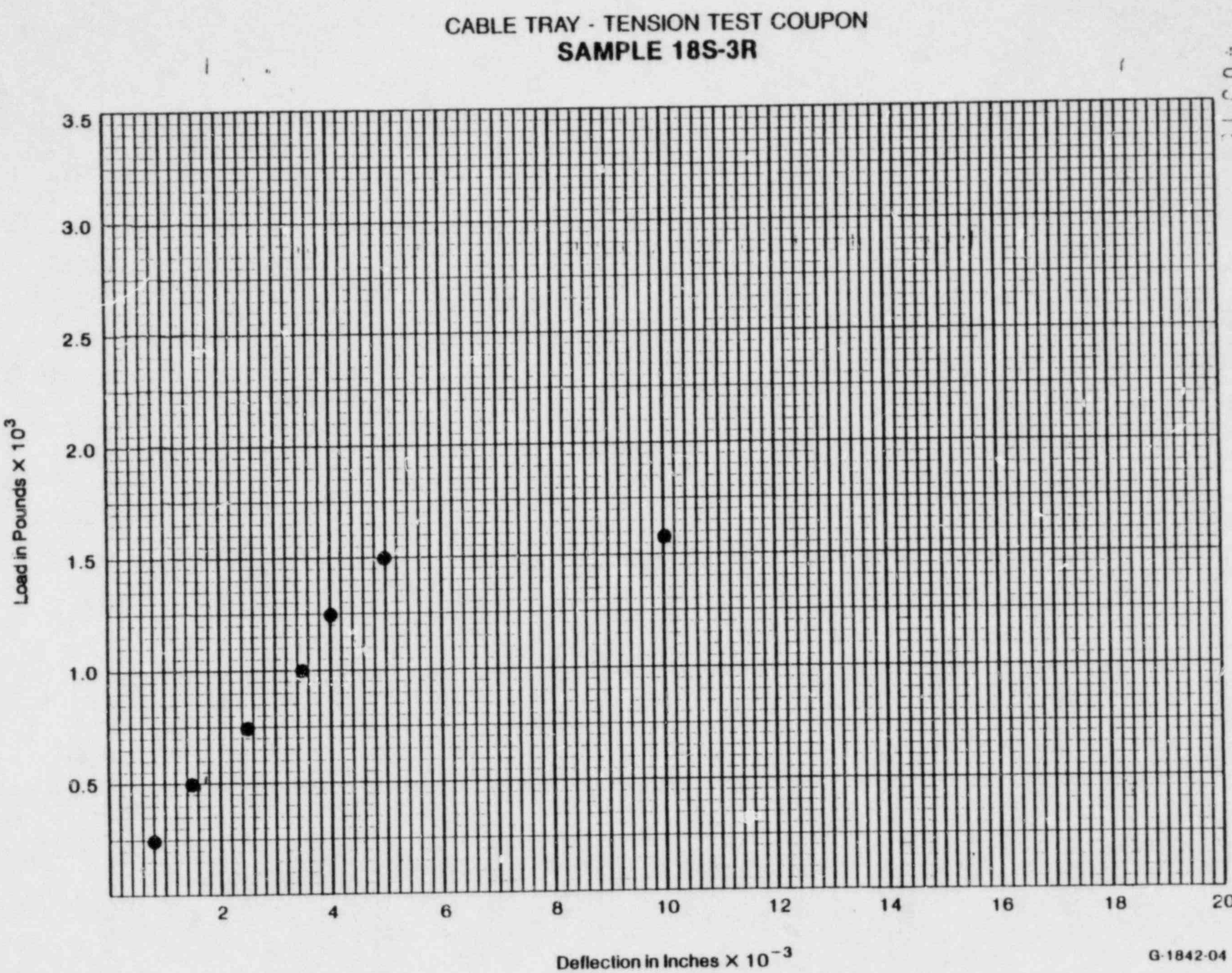

Figure 35 - Load-deformation plot for Cable Tray base metal.

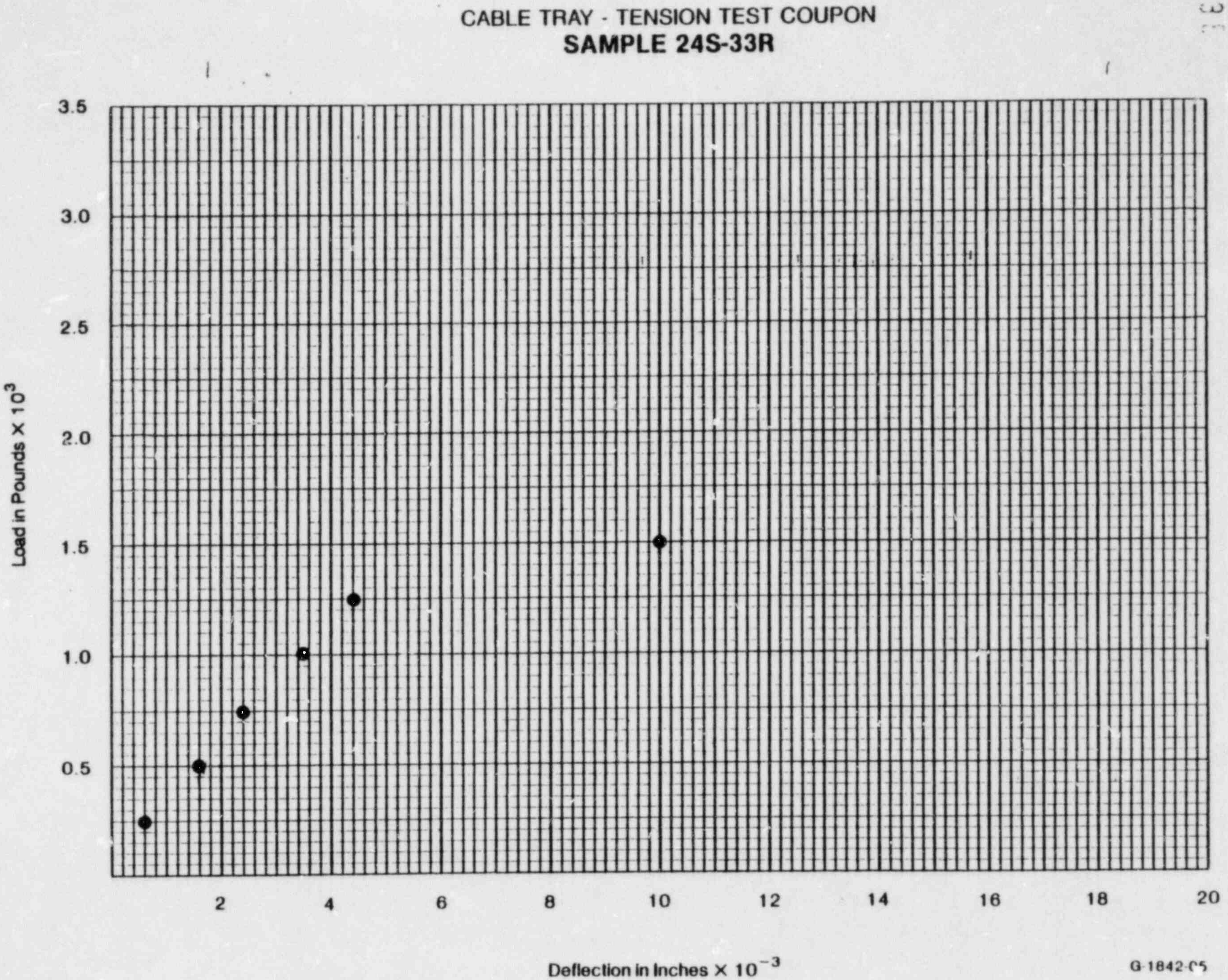

Figure 36 - Load-deformation plot for Cable Tray base metal.

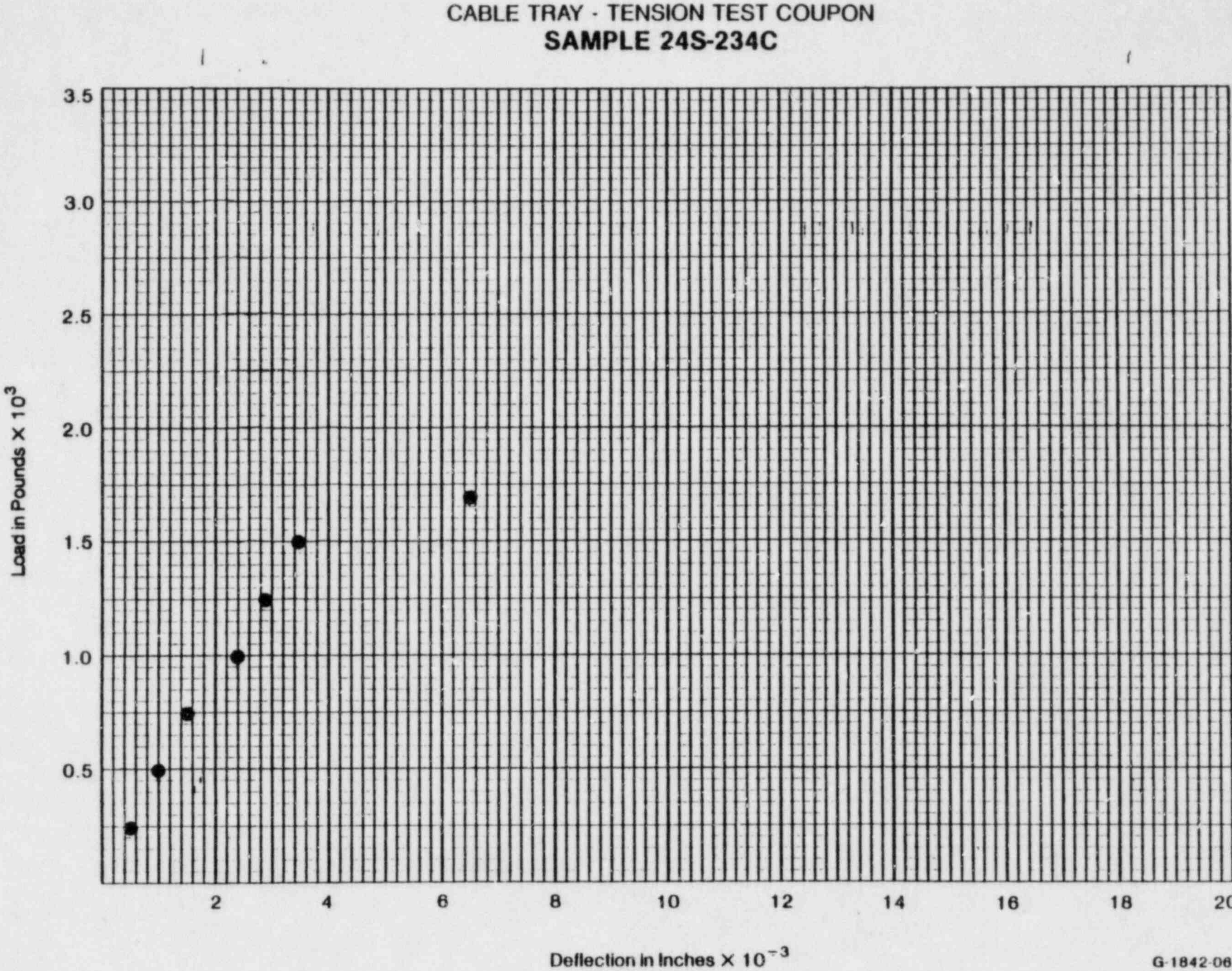

Figure 37 - Load-deformation plot for Cable Tray base metal.

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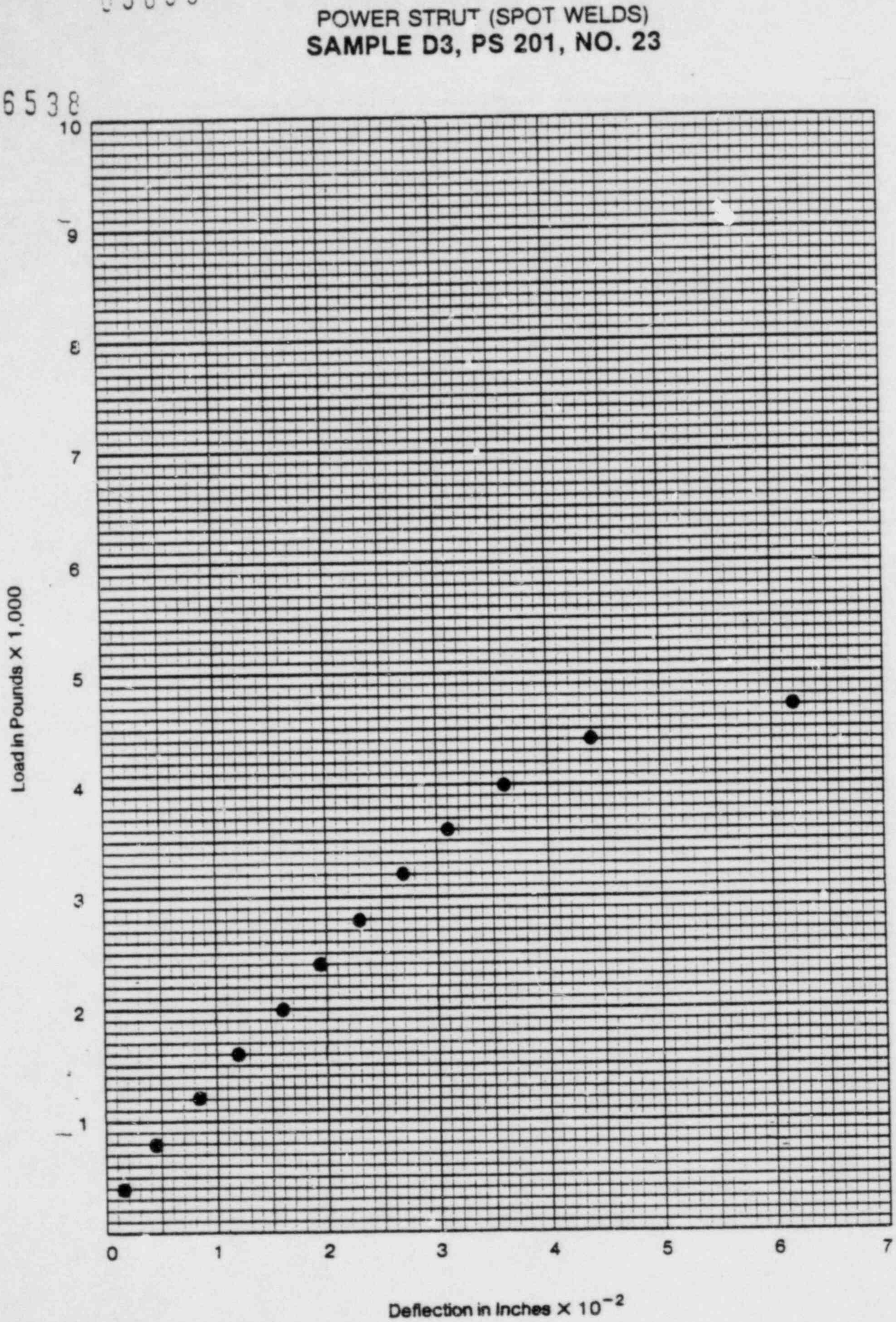

Figure 38 - Load-deformation plot for PS-201, Power Strut spot weld.

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POWER STRUT (SPOT WELDS)
SAMPLE D13, PS 201, NO. 92

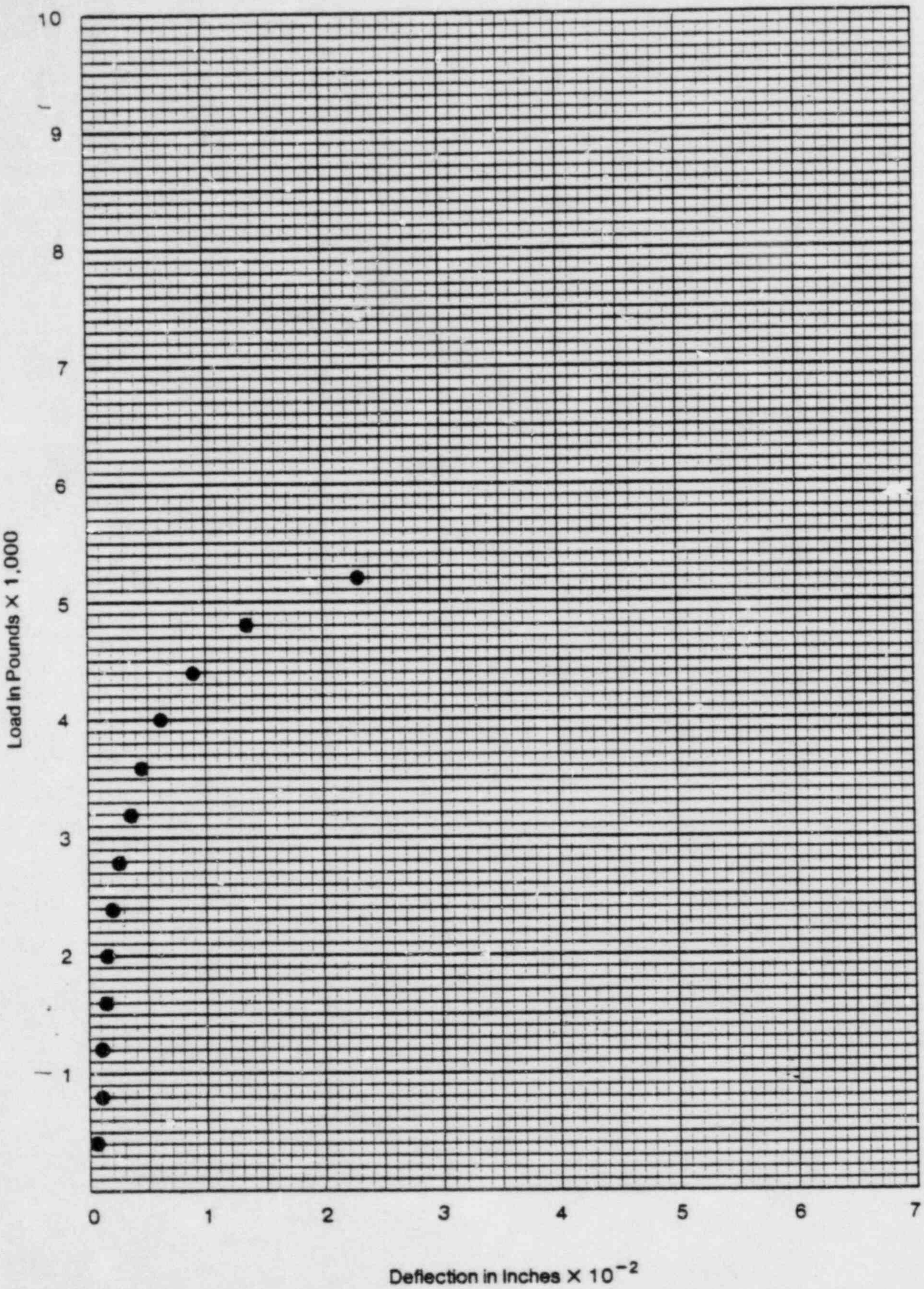

Figure 39 - Load-deformation plot for PS-201, Power Strut spot weld.

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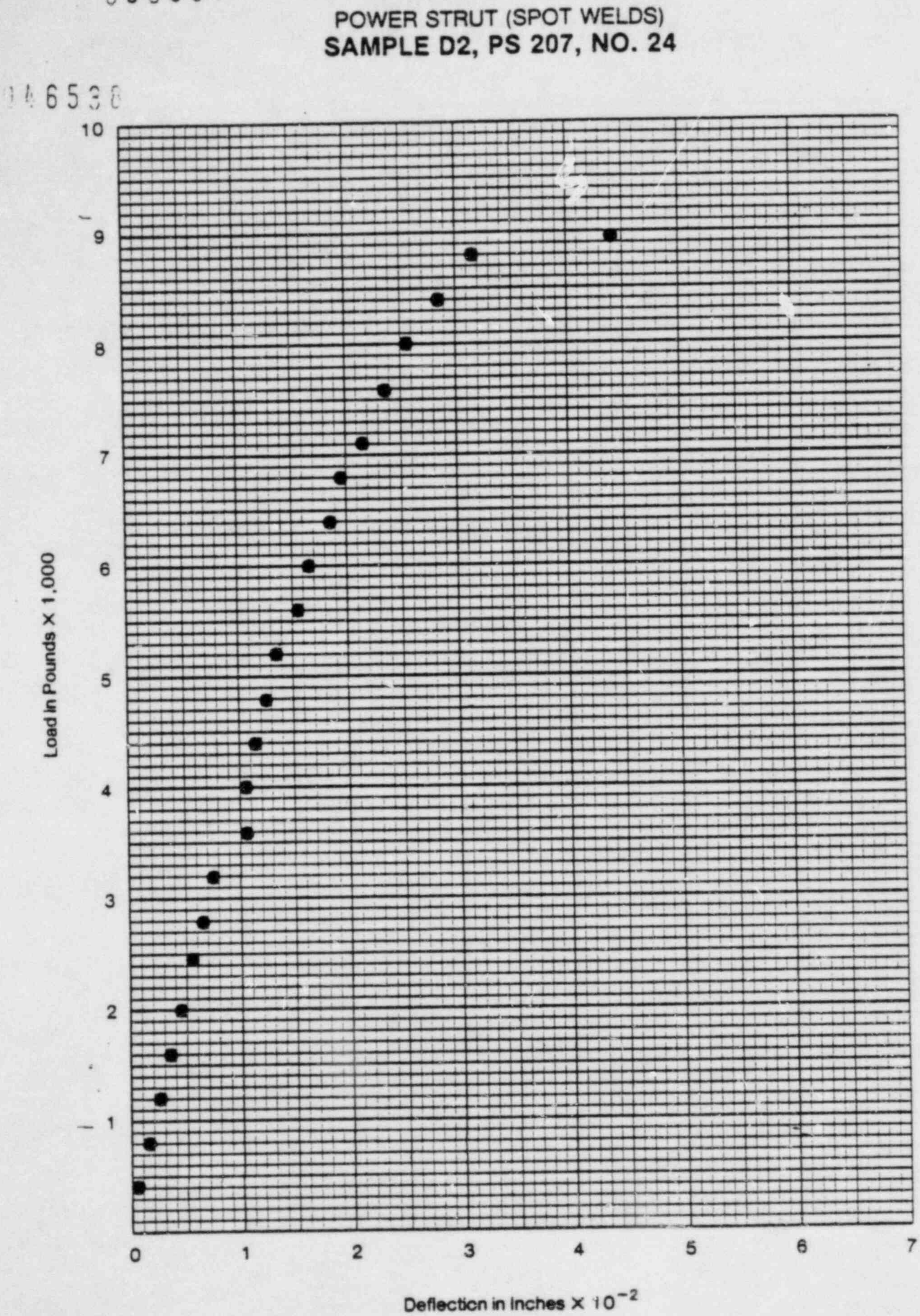

Figure 40 - Load-deformation plot for PS-207, Power Strut spot weld.

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POWER STRUT FITTING PS 3375 TENSILE TEST
SAMPLE 102

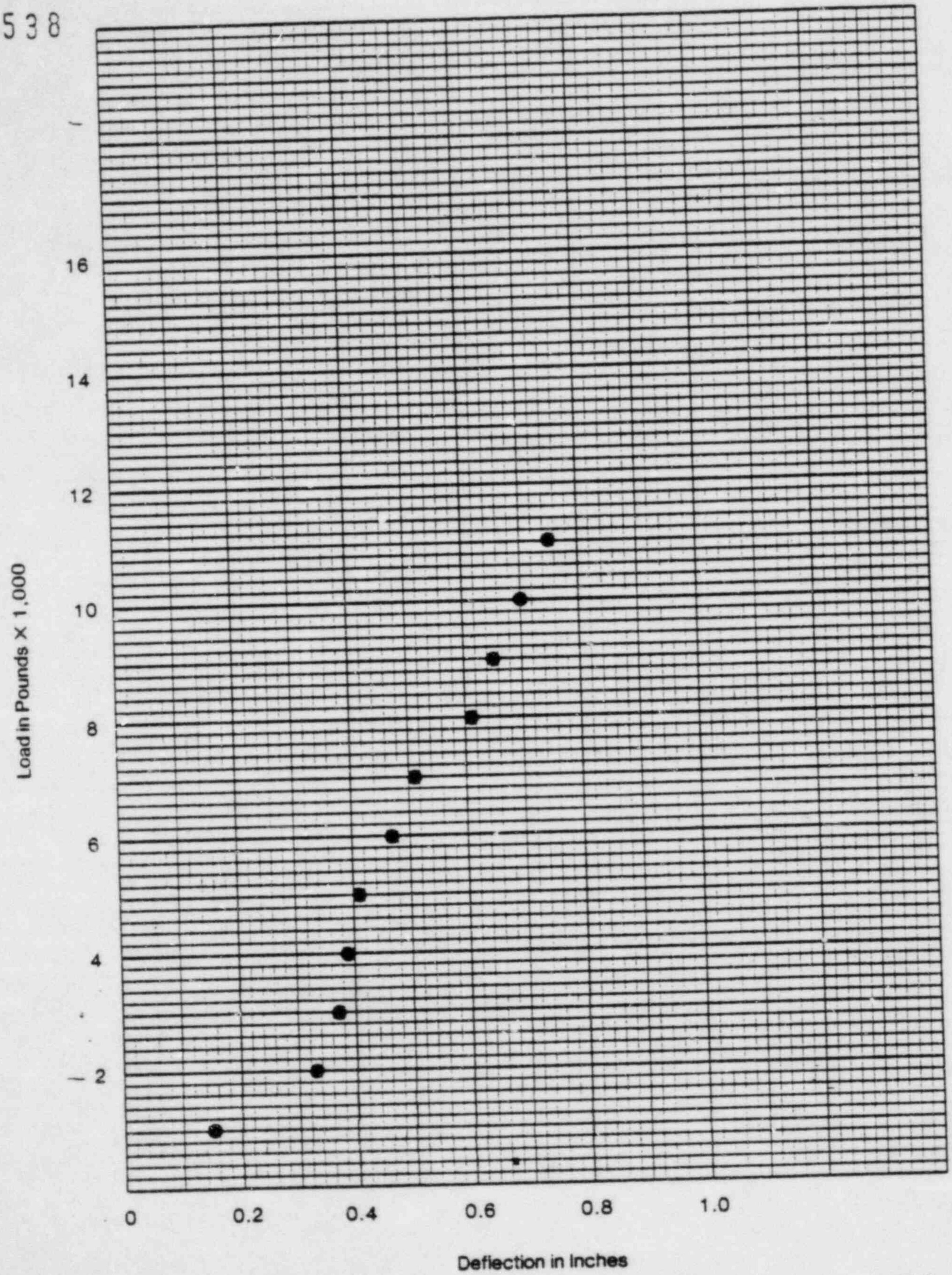

Figure 41 - Load-deformation plot for PS-3375, Power Strut fitting.

G-1842-10

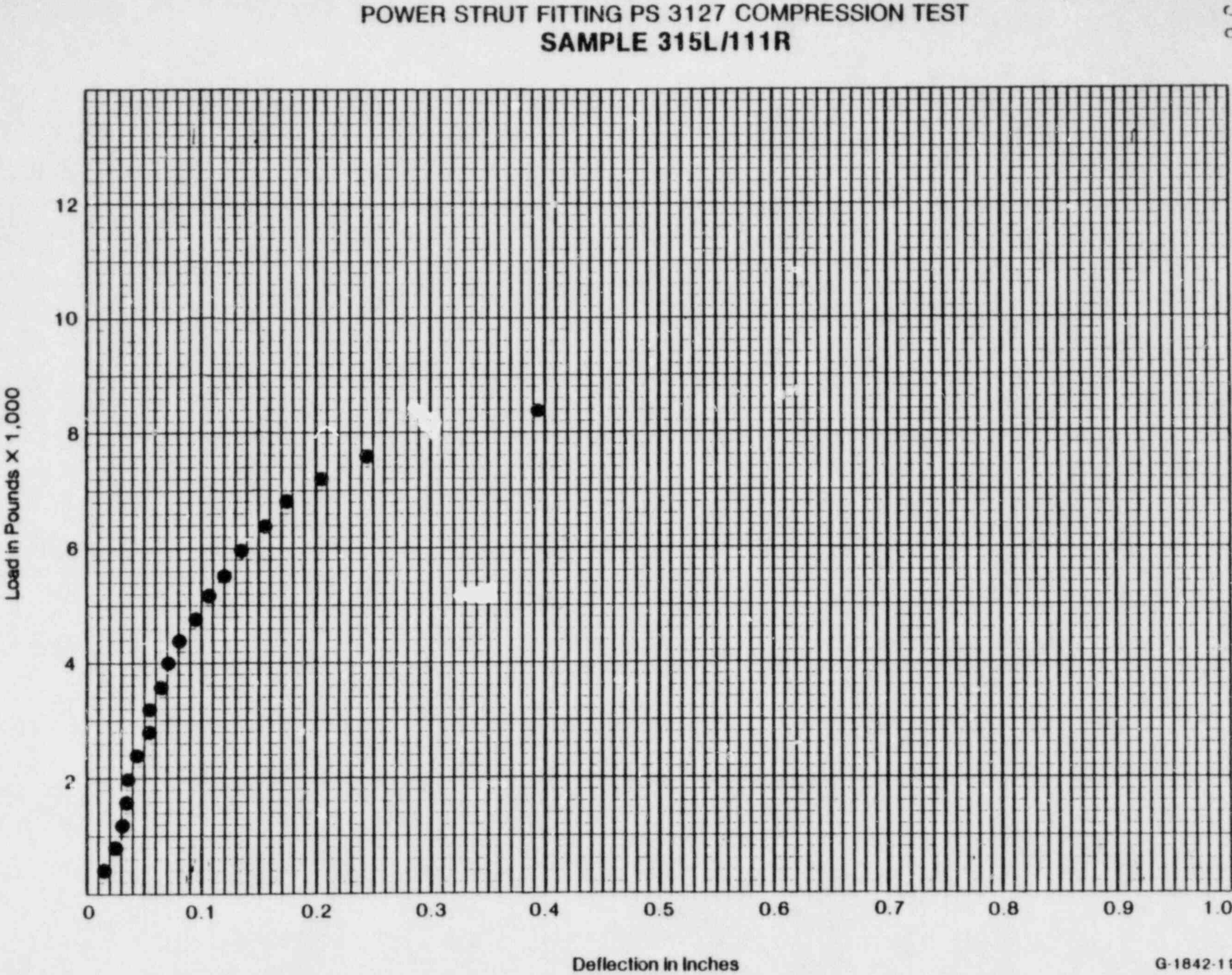

Figure 42 - Load-deformation plot for PS-3127, Power Strut fitting.

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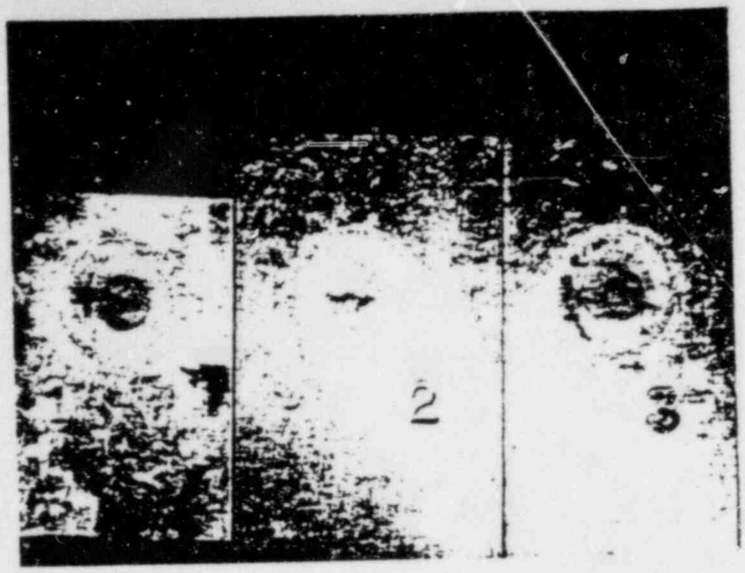
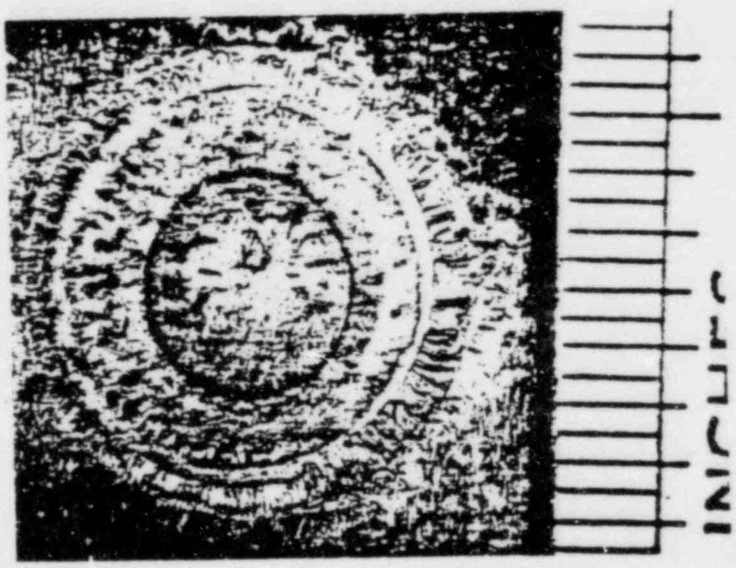


COMPARISON OF SPOT WELDS (1X)

SPOT WELD 1 (5X)



SPOT WELD 2 (5X)

SPOT WELD 3 (5X)

G-1842-13

FIGURE 14 — Fusion zones of Power Strut spot welds.

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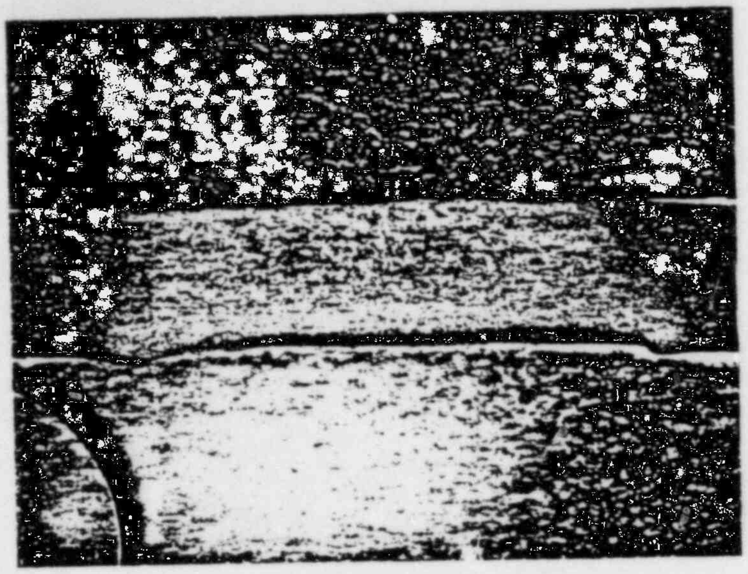
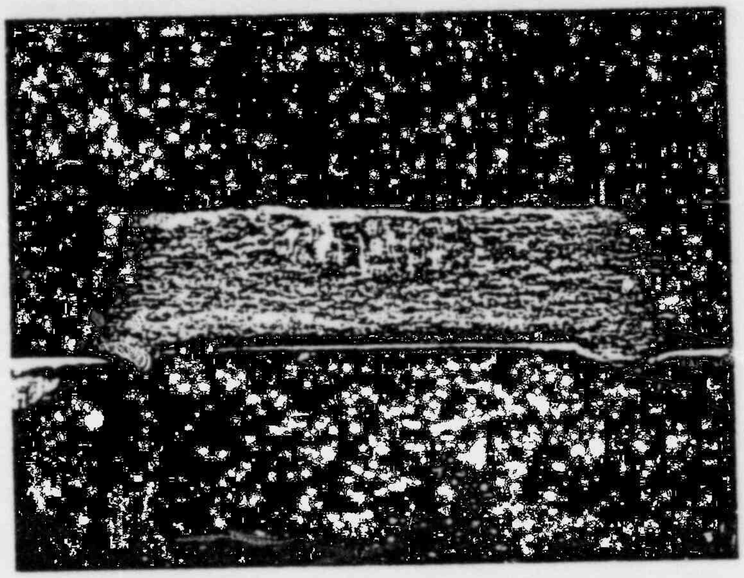
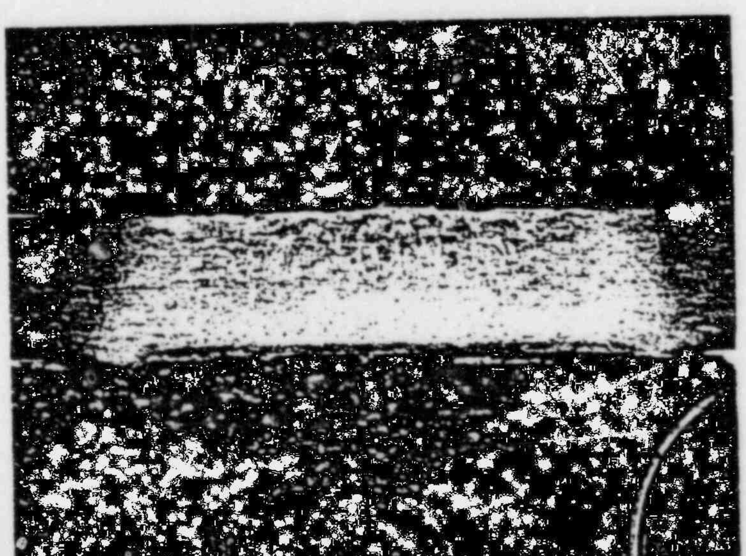


SPOT WELD 1



SPOT WELD 2



SPOT WELD 3

FIGURE 45 - X-sections of Power Strut spot welds.

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APPENDIX 050561 EXHIBIT PS 1A

PACIFIC CALIBRATION SERVICES
133 Lincoln Drive / Sausalito, CA 94965
(415) 332-9160

CERTIFICATE OF VERIFICATION

(No. 0147)

This is to certify that the TINIUS OLSEN UNIVERSAL (MAKE - TYPE) Testing Machine, Serial Number 104356 Located at BECHTEL POWER (COMPANY NAME), SAN FRANCISCO, CAL. (CITY & STATE), MAT. LAB. (DEPT.), has been calibrated by *Pacific Calibration Services* personnel on 12-20-79 (DATE) and verified to be accurate over the following ranges:

MACHINE RANGE	LOADING RANGE	MACHINE RANGE	LOADING RANGE
60.000#	5000-55000#		
10.000#	1000-10.000#		

Method of verification and listed data are in accordance with ASTM Designation E 4, other applicable specifications, or manufacturers recommended procedures. For verification details, refer to the Testing Machine Calibration Data and Report.

PACIFIC CALIBRATION SERVICES

By John Boontoggel
Serv Mgr

050561

EXHIBIT PS 1B

46538

PACIFIC CALIBRATION SERVICES
133 Lincoln Drive / Sausalito, CA 94965
(415) 332-9160

CERTIFICATE OF VERIFICATION

(No. 0120)

This is to certify that the Riehle Universal - (MAKE - TYPE) Testing Machine, Serial Number R-46736 Located at Anamet Labs Inc. (COMPANY NAME) Berkeley Calif. (CITY & STATE), Mat Lab (DEPT.), has been calibrated by *Pacific Calibration Services* personnel on 10-12-79 (DATE) and verified to be accurate over the following ranges:

MACHINE RANGE	LOADING RANGE	MACHINE RANGE	LOADING RANGE
120,000	12000-120000*	6000*	1200-5900*
60,000	6000-59000*		
30,000	5000-30000*		
12,000	1200-11,500*		

Method of verification and listed data are in accordance with ASTM Designation E 4, other applicable specifications, or manufacturers recommended procedures. For verification details, refer to the Testing Machine Calibration Data and Report.

PACIFIC CALIBRATION SERVICES

By John Boonstoppel
Serv. mgr

Recall date
10-12-80
Ea+ 11/13/79

046538 05056 EXHIBIT PSIC JUL 17 80 04731

Bechtel Pwr. Corp
D. GA (B)

2001" 656.617 SR 01179
02066 STARRETT ACC MFG
ITY 25338
ACO
FACTORY P.O. # IC.7892
1-1 3050

☐ OA ☒ NOA Next cal. 10-18-80
☐ FS Reason for service: Periodic check ☒ Repair ☐ Other ☐
☐ OS Condition on arrival: Meets mfgr's specs ☒ Out of specs ☐ Inoperative ☐ Intermittent ☐
Work performed: p.m., clean and adj. to mfgr's specs ☒ Repair W/O Calibration ☐

CALIBRATED PER MIL I-18422 D

Parts Used:

QTY	PART NUMBER	BRIEF DESCRIPTION	QTY	PART NUMBER	BRIEF DESCRIPTION
a			d		
b			e		
c			f		

STANDARD USED	MOD. #	SER. #	CERT. DATE	ACC.
Indicator Checker		1003-336	6-12-80	±10
Ht. Master		1003-238	10-15-79	±10

DATE 7-18-80 I C. Bertr..., certify that the above work was performed and that calibration was in accordance with MIL-C-45662A, and against standards traceable to the National Bureau of Standards. Q (B) C

SIMCO electronics • 382 Martin Ave. • Santa Clara, Calif. 95050

PURCHASE ORDER ☐ REQUIRED ☐ NOT REQUIRED

NO. IC 7892

A MIMINUM HANDLING CHARGE * IS AUTHORIZED WHETHER A PURCHASE ORDER IS ISSUED OR NOT.

*CURRENT RATE SCHEDULE SUPPLIED ON REQUEST.

NOT RESPONSIBLE FOR EQUIPMENT UNCLAIMED OVER 30 DAYS AFTER NOTICE OF WORK COMPLETION.

TIME SAVER AUTHORIZATION (NO WORK WILL BE PERFORMED WITHOUT AUTHORIZATION) LIMIT OF AUTHORIZATION CODES.
1. CALIBRATION AUTHORIZED ONLY.
2. WORK AUTHORIZED NOT TO EXCEED 50% OF VALUE OF INSTRUMENT.
3. ADVISE FIRM FIXED PRICE FOR LABOR ONLY BEFORE PROCEEDING. PARTS WILL BE ESTIMATED IN ADDITION BUT UNDER NO CIRCUMSTANCES FIRM.
4. WORK AUTHORIZED NOT TO EXCEED DOLLAR LIMITATION IN CODE COLUMN.

A D Calig 7/17/80
CUSTOMER AUTHORIZATION TITLE

TH:L-DETACHABLE LINE CORD:M-MANUAL:P-PROBE(NOTE:UNLESS MARKED INDICATED ITEMS ARE NOT WITH INSTRUMENT
**DAMAGE - Note Below:
SPECIAL NOTES:

I have received the instruments listed above, and certify that they have no obvious defects except as noted: A.D. Calig 7/18/80

EXHIBIT PS 1D

LABORATORY CERTIFICATE

046538

Anamet Laboratories, Inc.

ANALYTICAL
CHEMICAL
METALLURGICAL

2037-7th STREET · BERKELEY CALIFORNIA 94710 · 841-5771

HIGH TEMPERATURE
APPLIED RESEARCH
PHYSICAL TESTING

December 18, 1979

BLN: 1279-5
M&QS Log #JCG 1279-34
Job #631/-/0002
P.O. #OS1-8-00096

LABORATORY NUMBER: 1279.195

SAMPLE: Calibration of Dial Indicator Gage

MARK: Dial Hand Gage (1 Inch) S/N 3
Mitutoyo No. 2416

DATE SUBMITTED: December 18, 1979

REPORT TO: Bechtel National, Inc.
P.O. Box 3965
San Francisco, California 94119
Attn: Mr. R. T. Dillon

R E P O R T

True Length	Measured Length
0.0000"	0.0000"
0.1600"	0.1600"
0.2500"	0.2496"
0.5000"	0.4995"
0.7500"	0.7500"
1.0000"	0.9996"

Used Jo blocks and End standards, calibrated by Ultralab on 4/24/79, traceable to NBS 232.12/216449, 25 May 1977, and NBS 213.12/218345, 11 April 1978, NBS 213.12/216449, 25 May 1977.

Respectfully submitted,

ANAMET LABORATORIES, INC.

By E. A. Foreman

E. A. Foreman
Manager, Quality Control

3c
jm

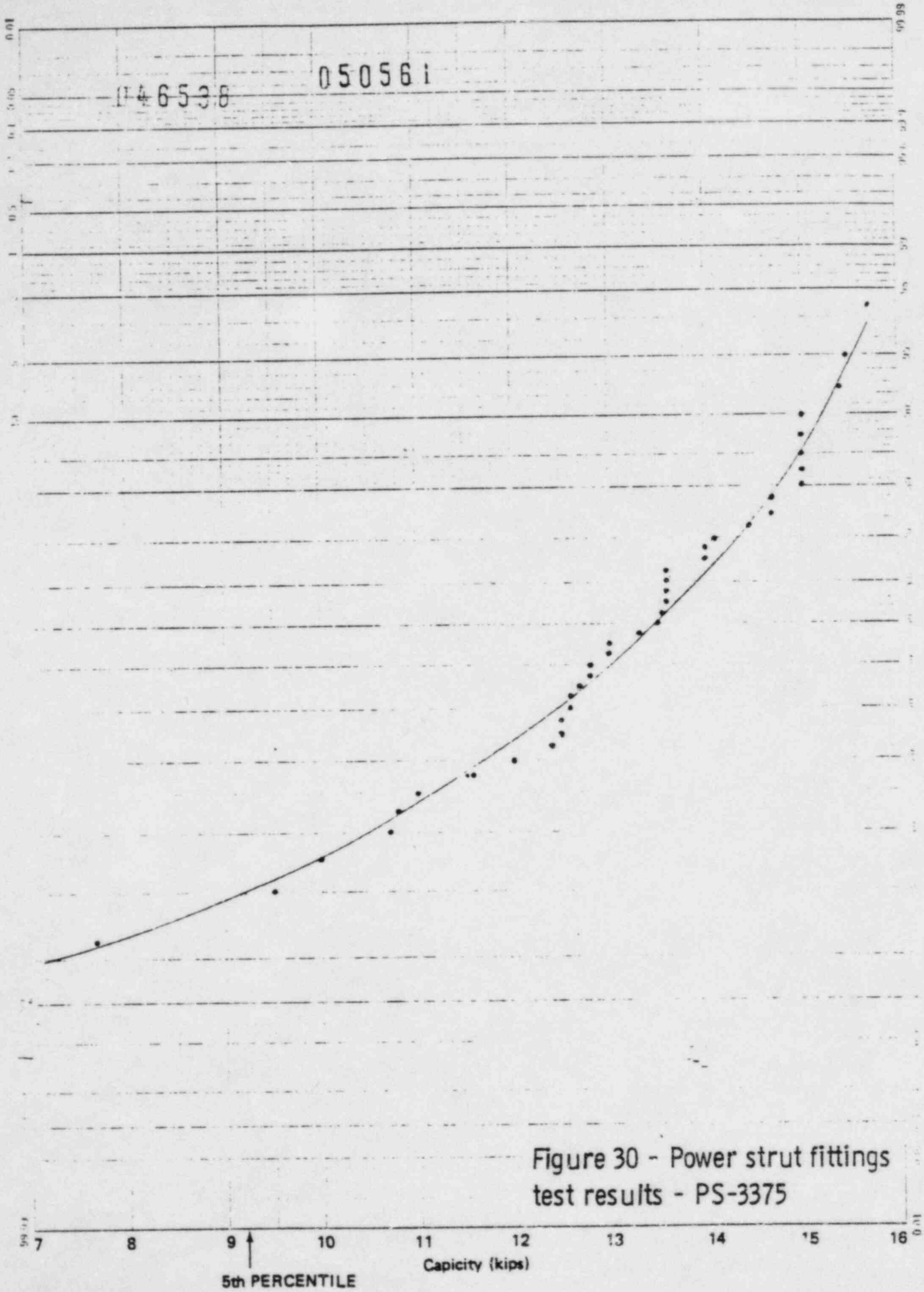

Figure 30 - Power strut fittings test results - PS-3375

050561

046538

TWO WELDS AT A TIME

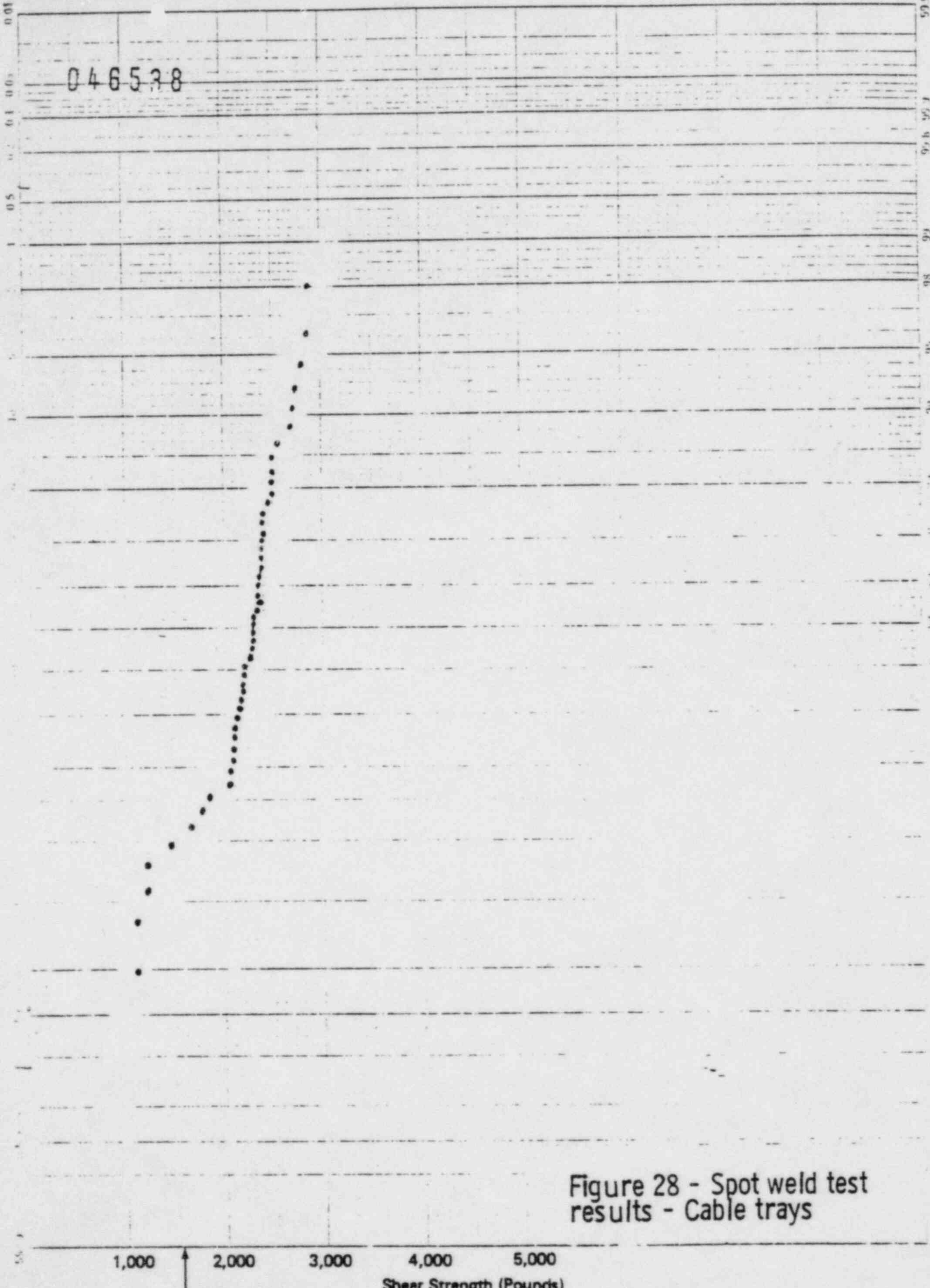

Figure 28 - Spot weld test results - Cable trays

050561

046538

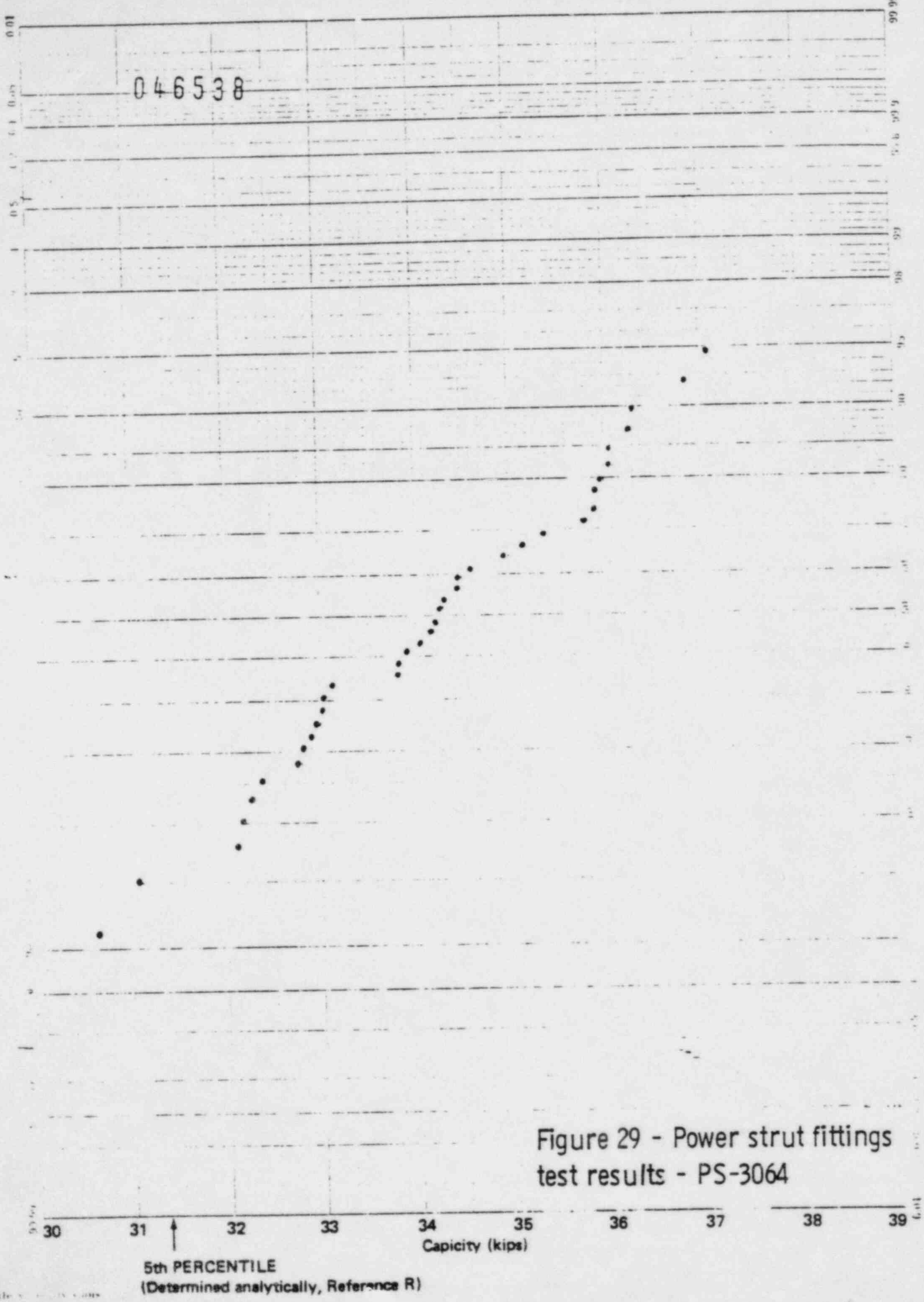

Figure 29 - Power strut fittings test results - PS-3064

050561

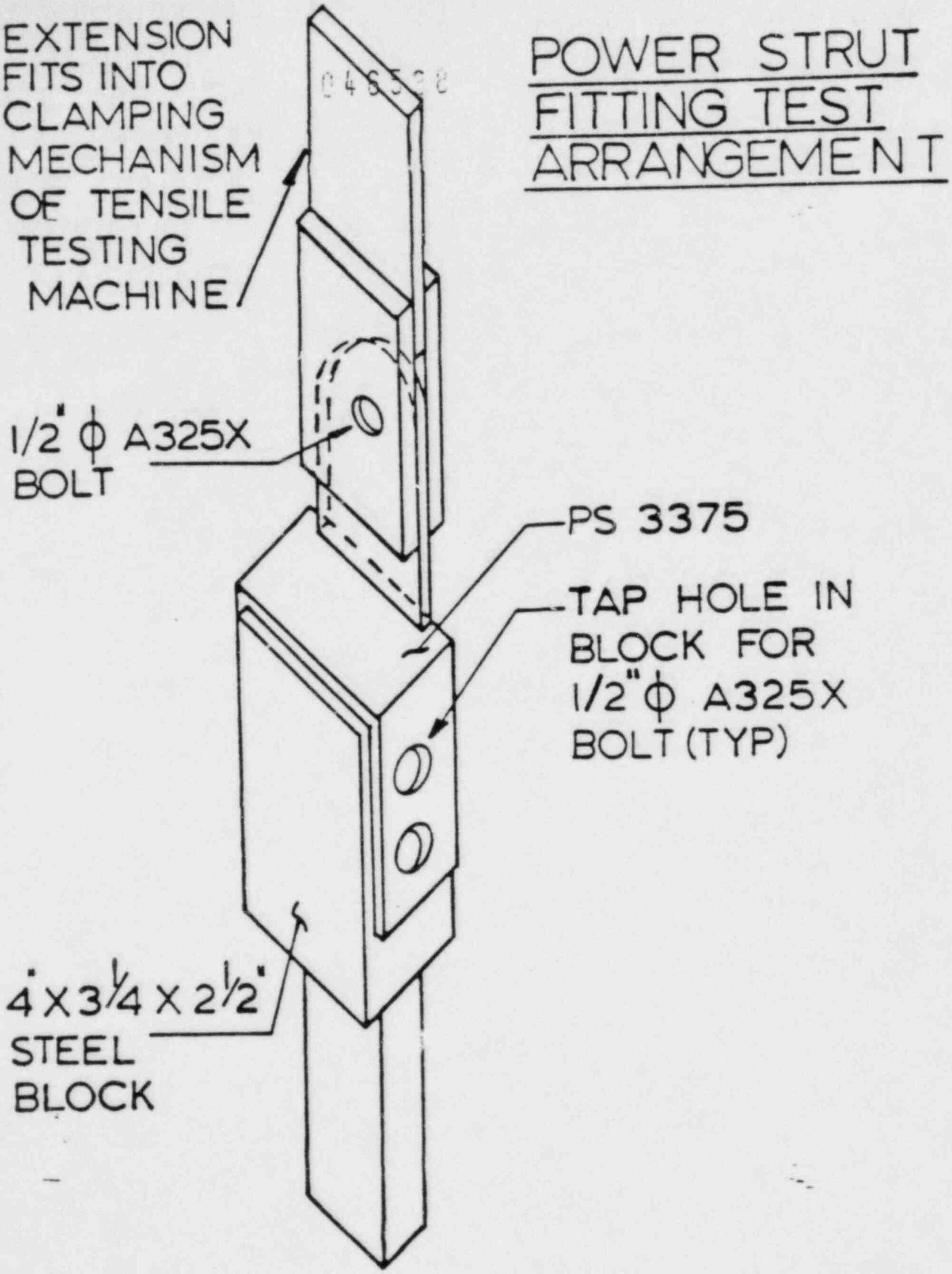

FIGURE 14

POWER STRUT FITTING TEST ARRANGEMENT

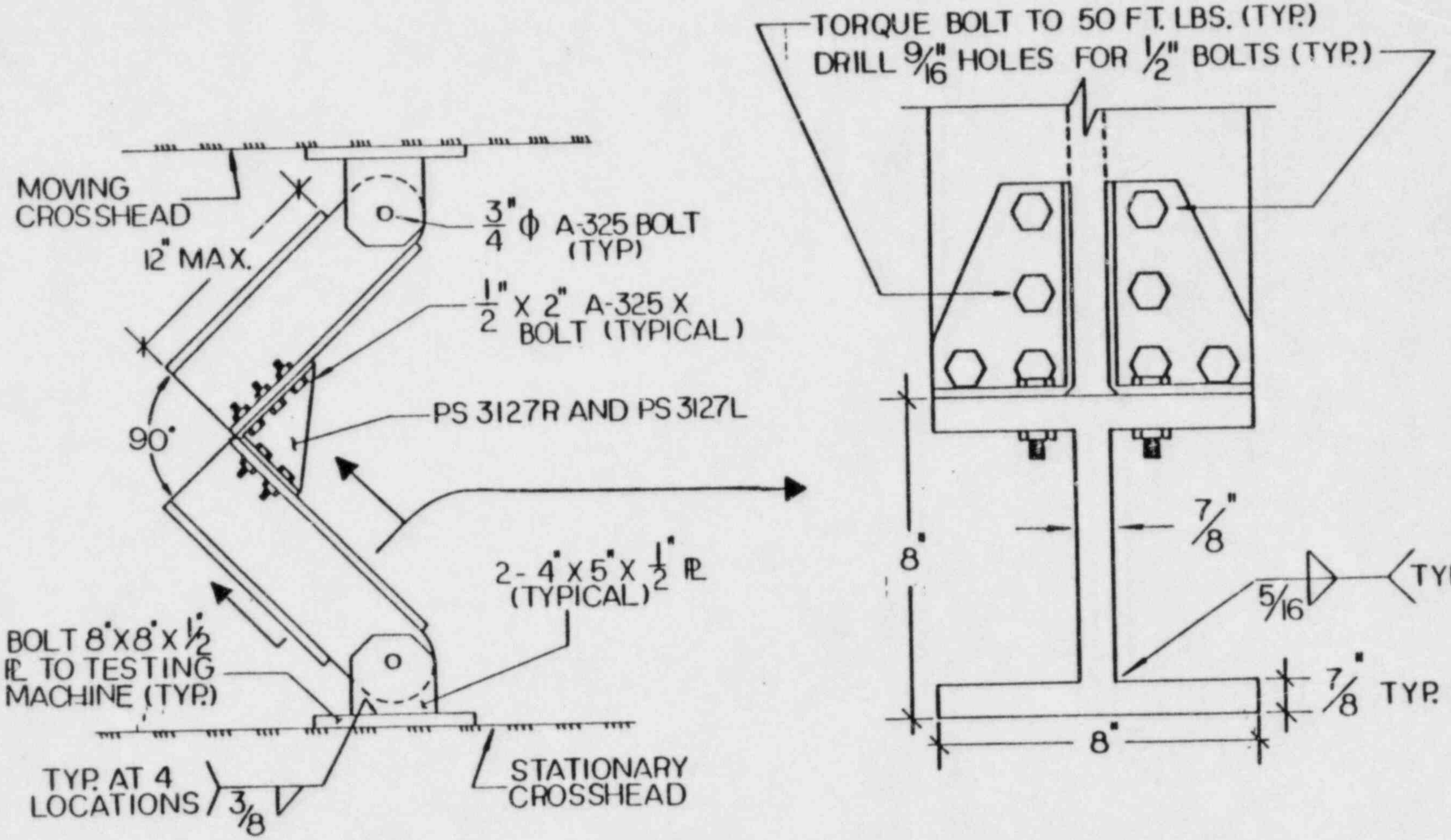

FIGURE 15

0465 38

505561

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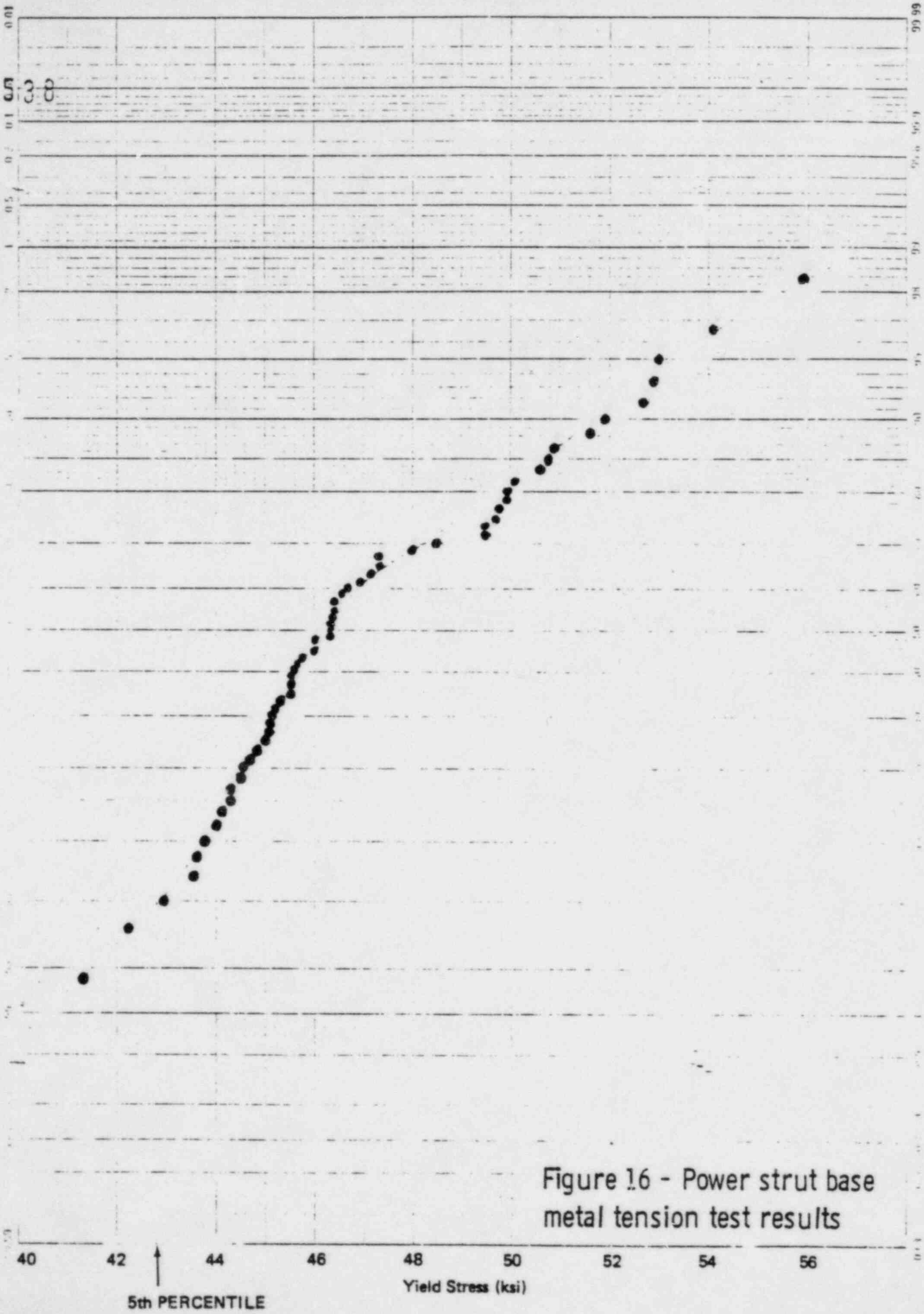

Figure 16 - Power strut base metal tension test results

050561

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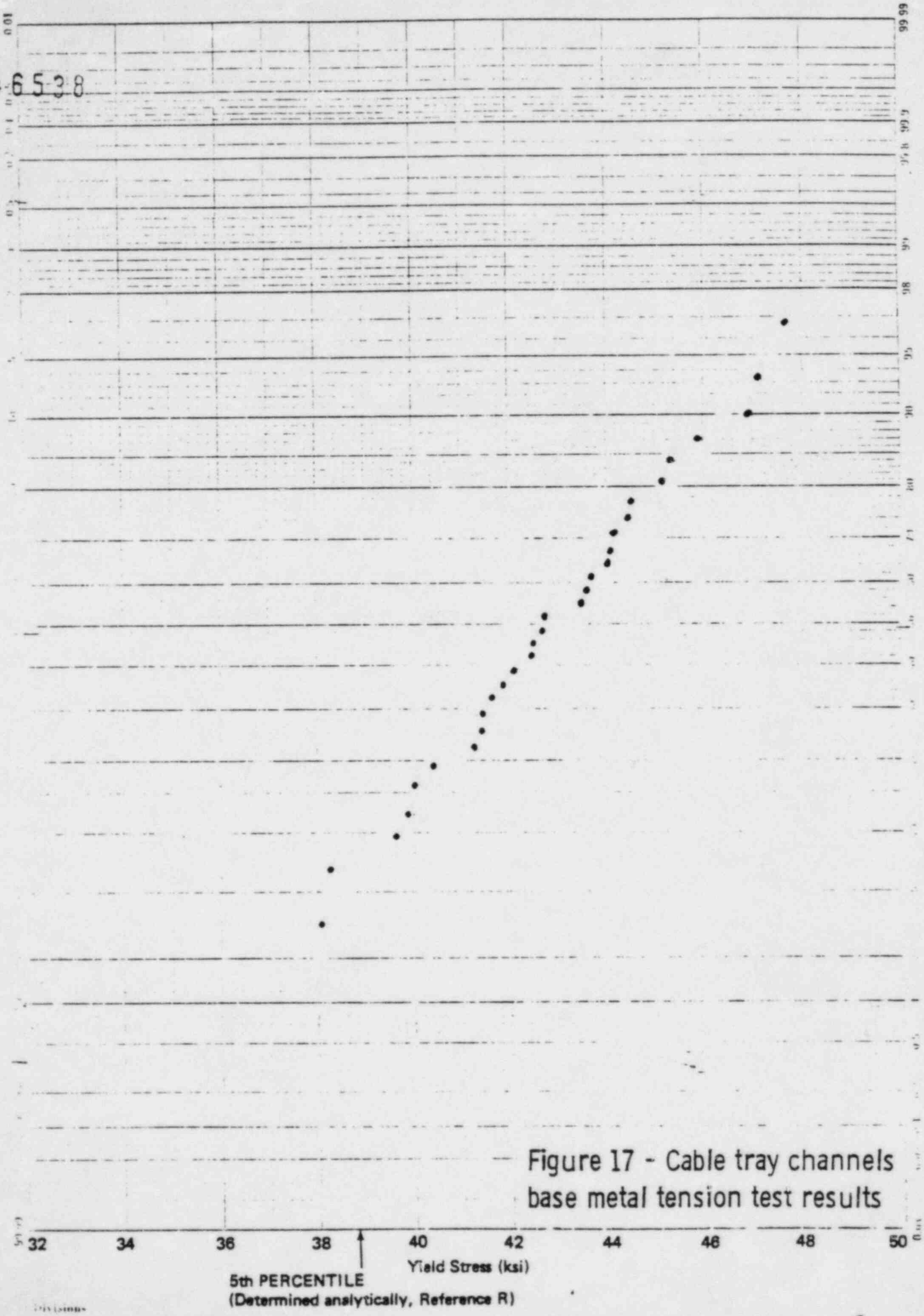

Figure 17 - Cable tray channels base metal tension test results

050561

046538

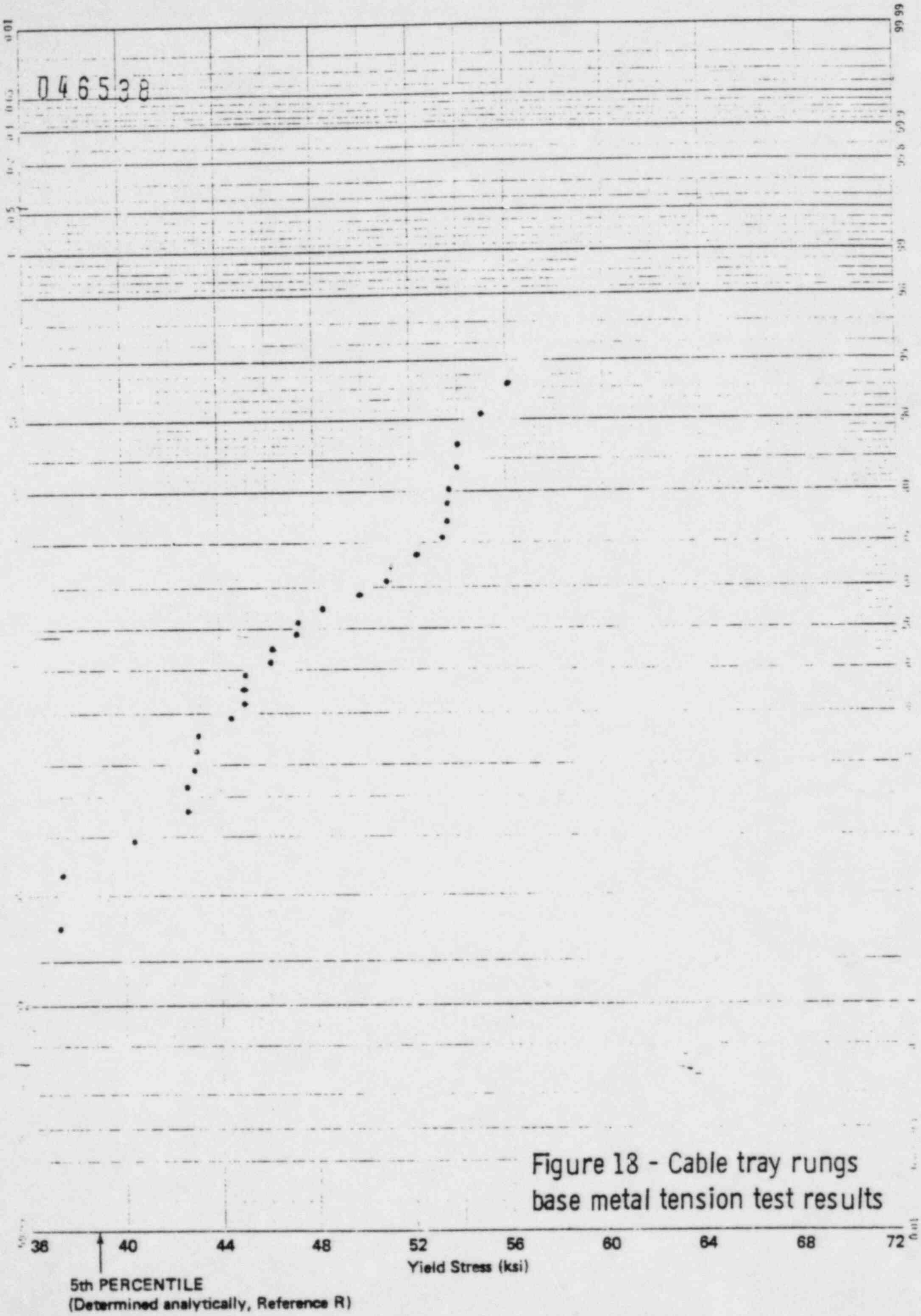

Figure 18 - Cable tray rungs base metal tension test results

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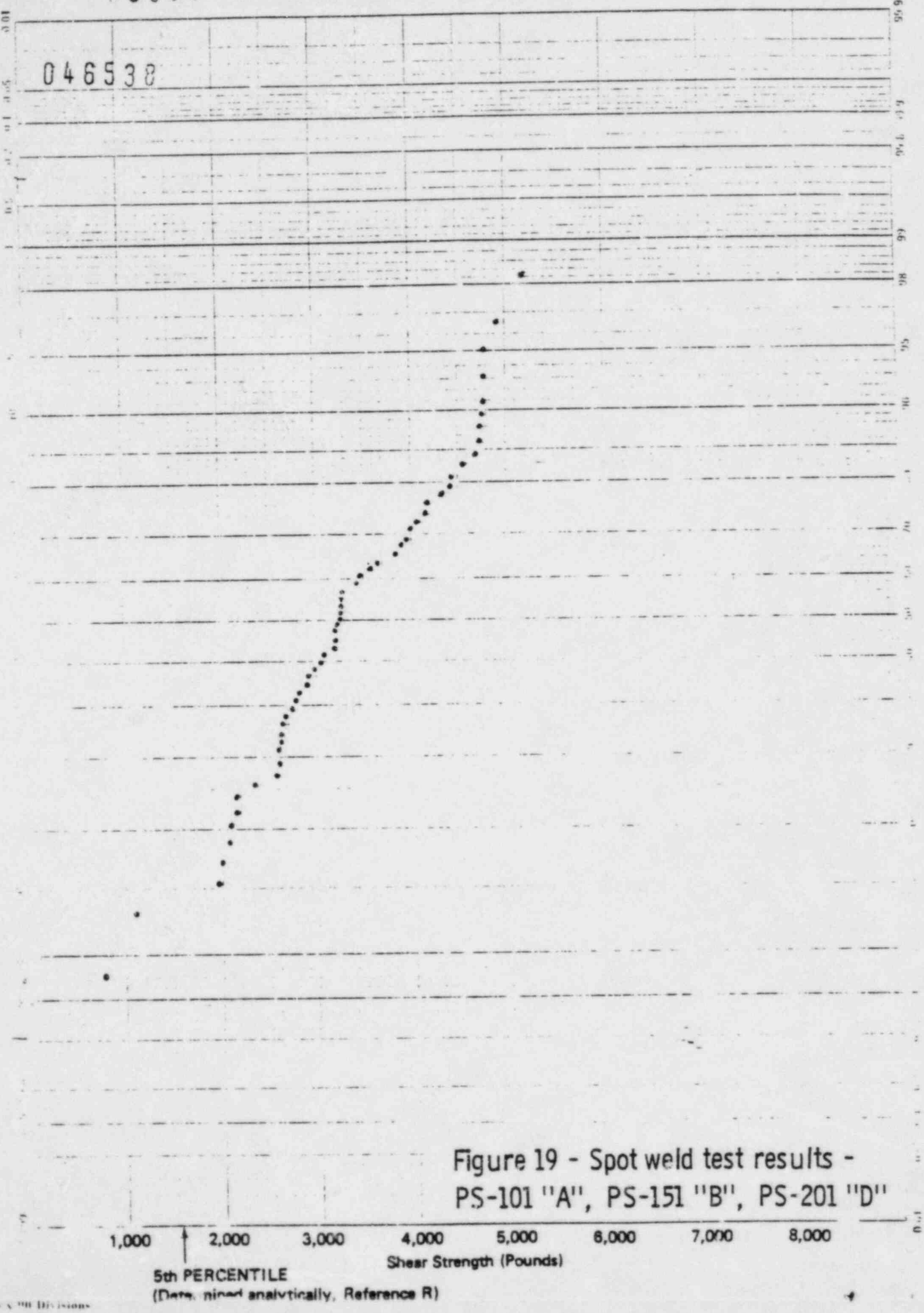

Figure 19 - Spot weld test results - PS-101 "A", PS-151 "B", PS-201 "D"

Probability Scale x 90 Divisions

050561

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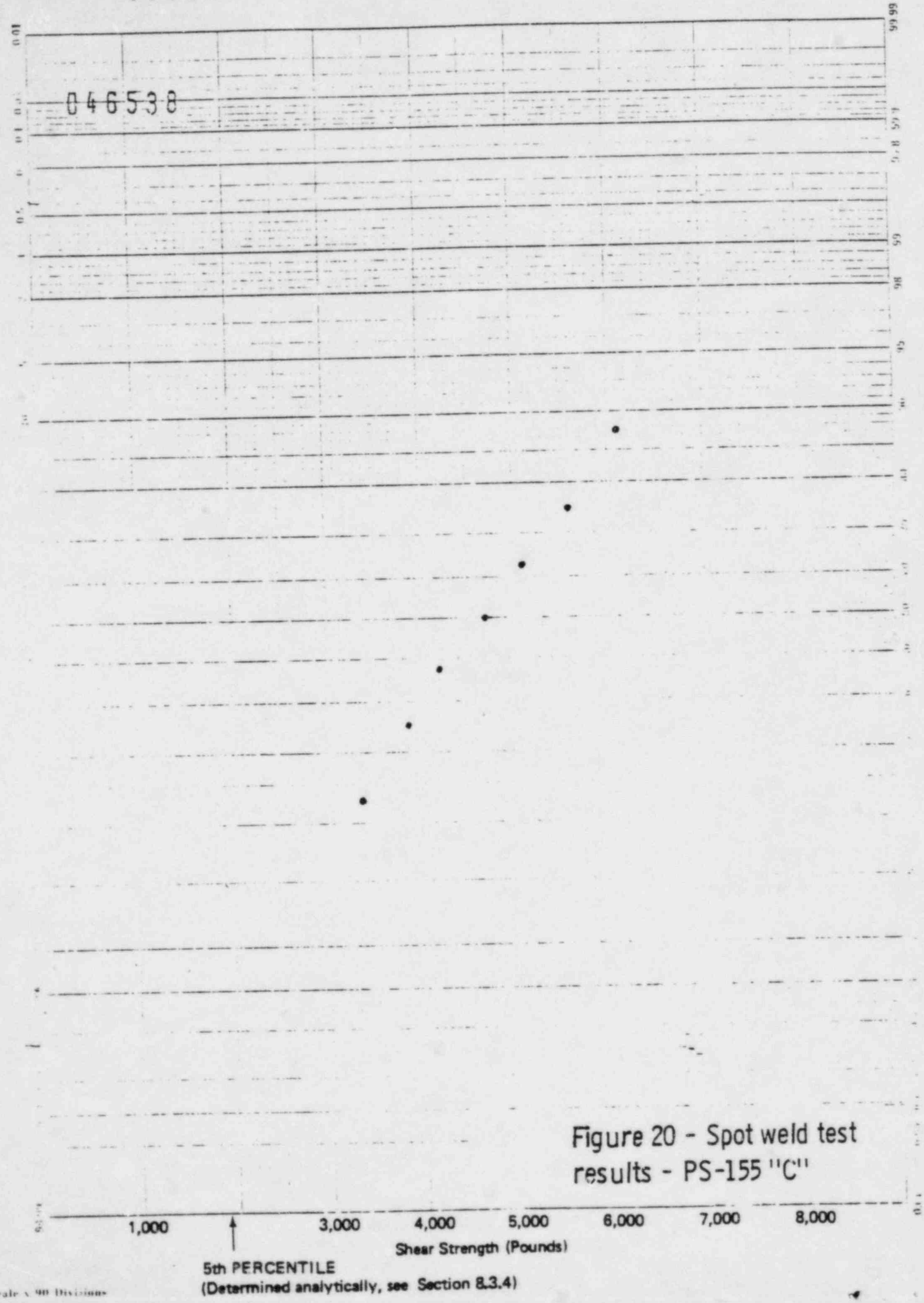

Figure 20 - Spot weld test results - PS-155 "C"

050561

MODELLED DISTRIBUTION FUNCTIONS

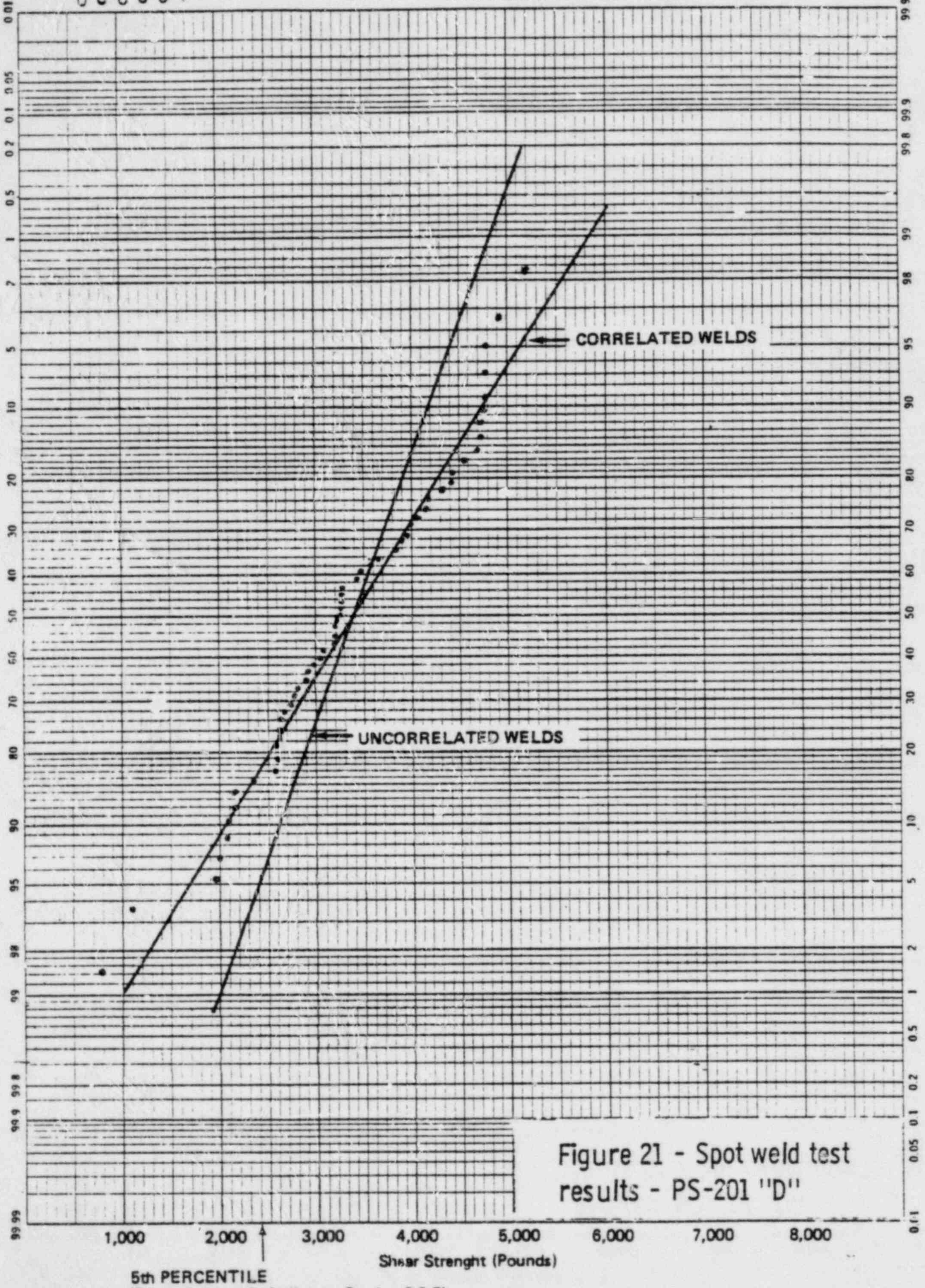

Figure 21 - Spot weld test results - PS-201 "D"

robability Scale x 90 Divisions

050561

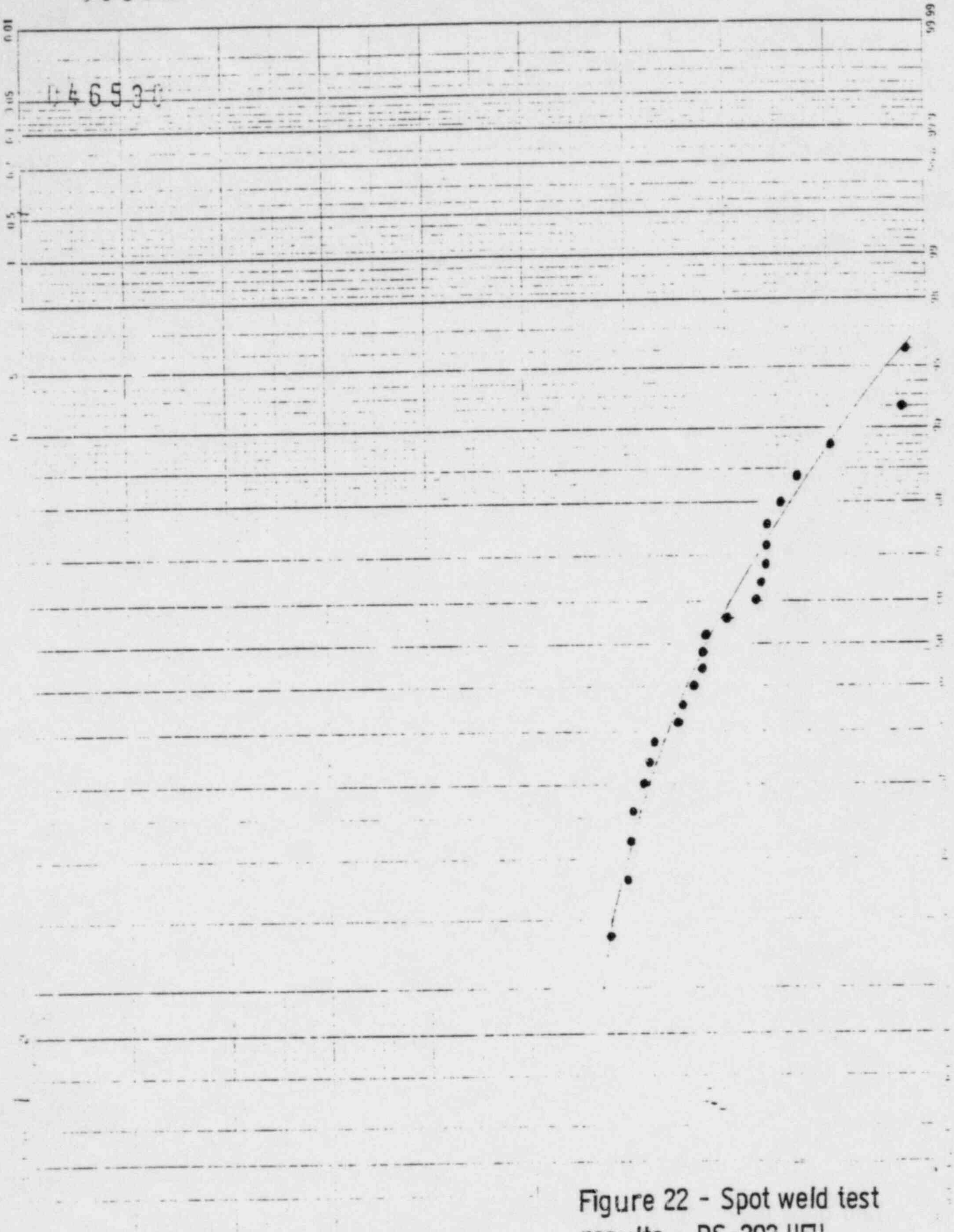

Figure 22 - Spot weld test results - PS-202 "E"

Probability Scale x 90 Divisions

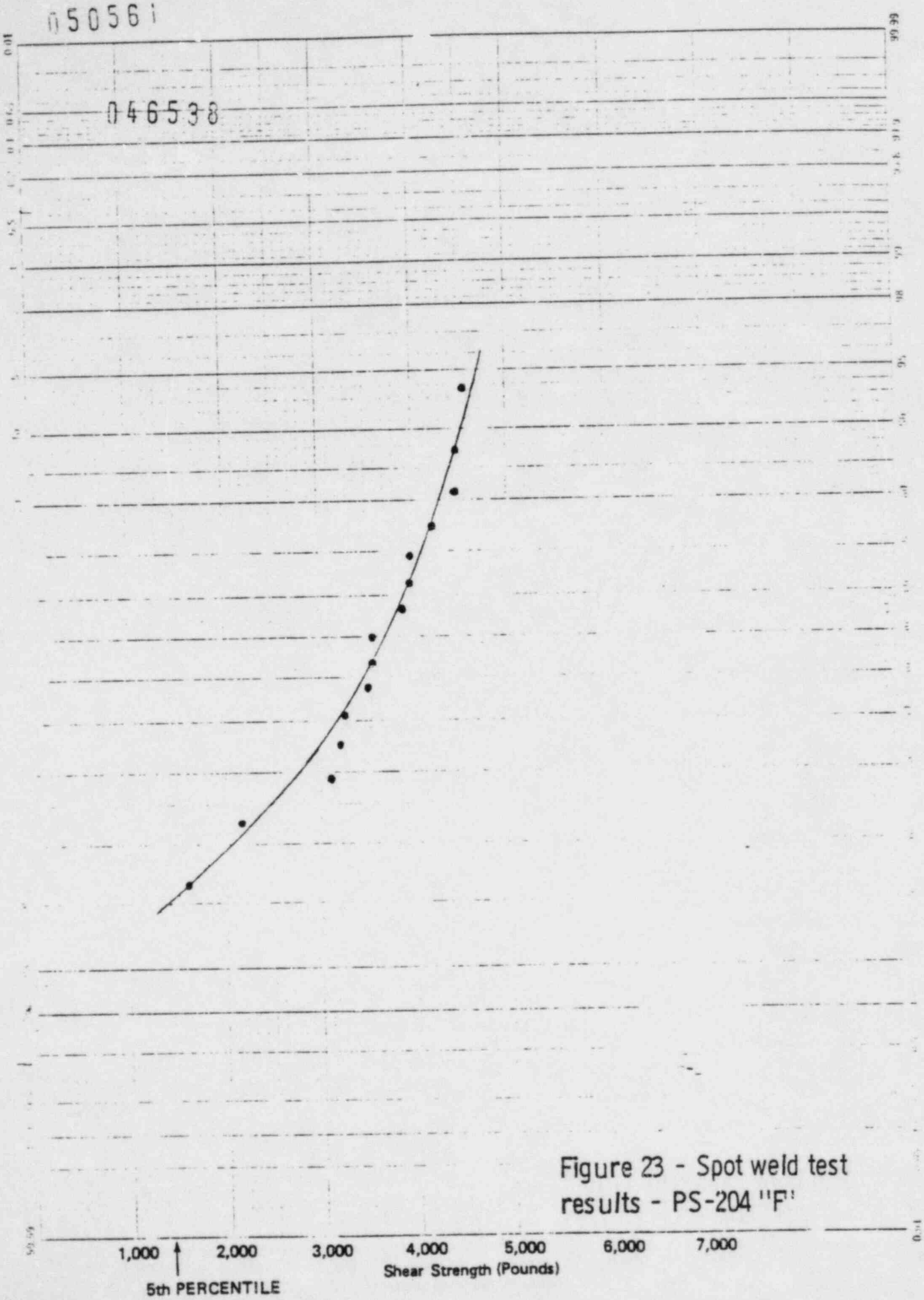

Figure 23 - Spot weld test results - PS-204 "F"

Probability Scale x 90 Divisions

2-083

050561

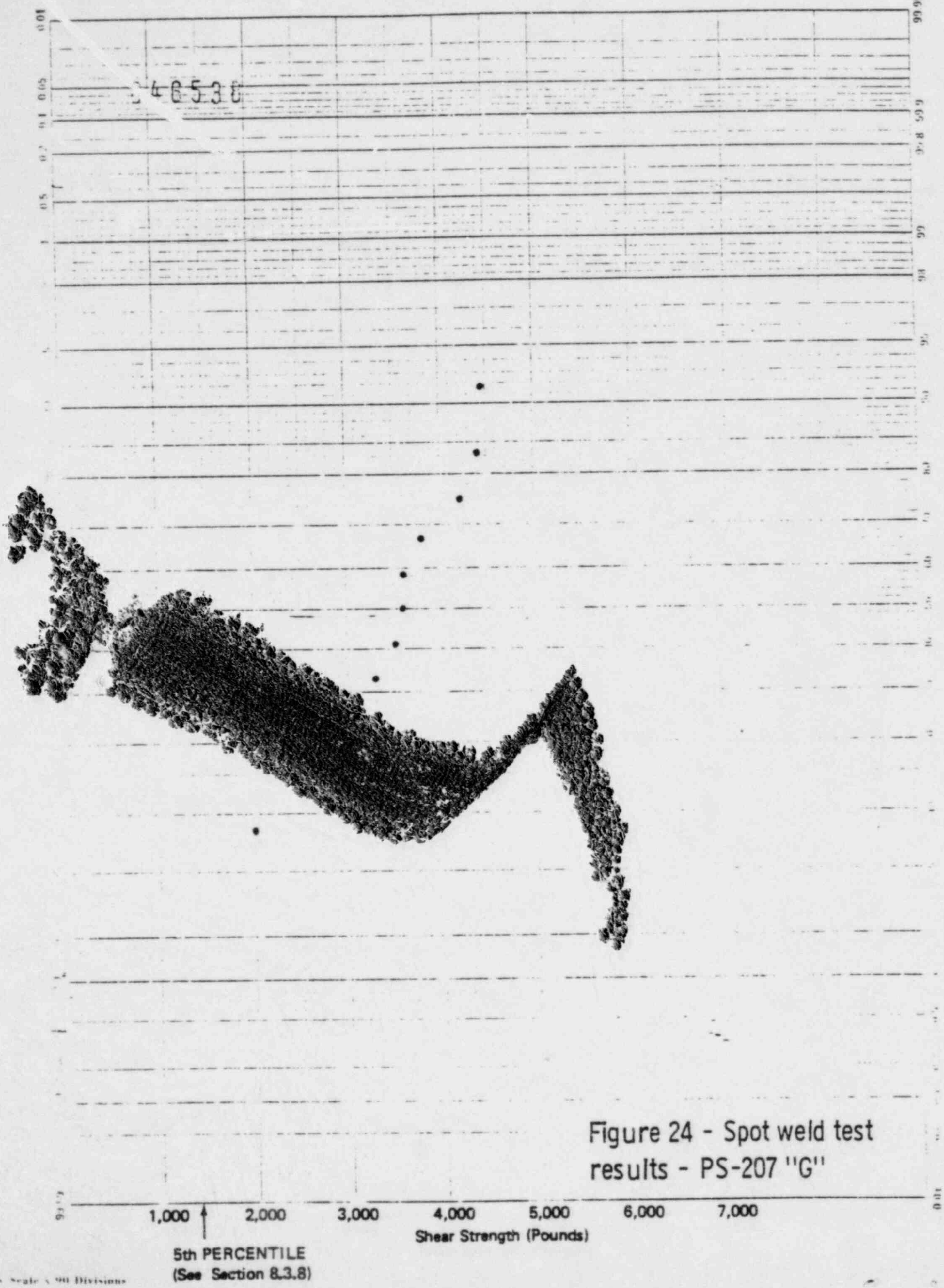

Figure 24 - Spot weld test results - PS-207 "G"

Probability Scale x 90 Divisions

050561

046538

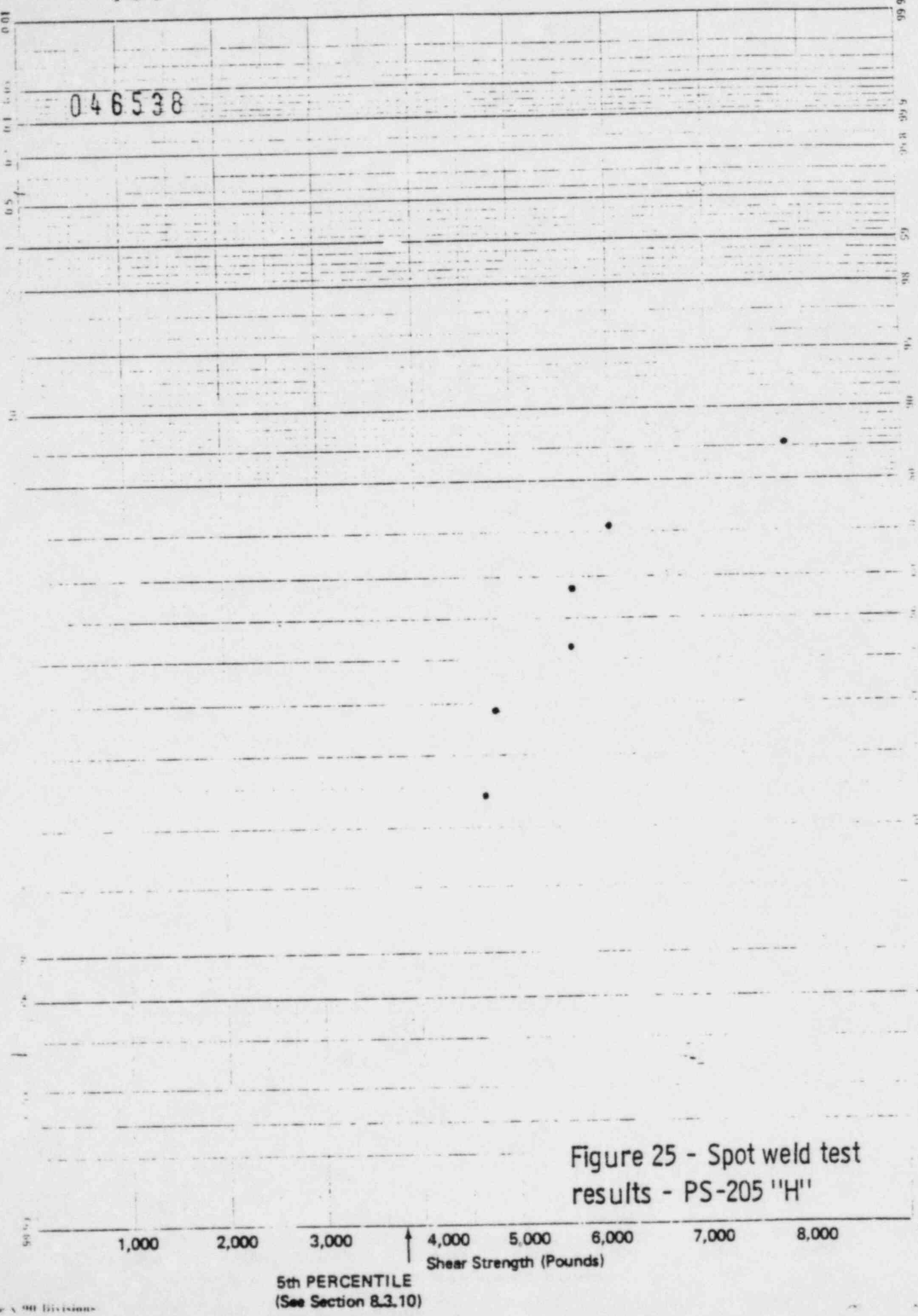

Figure 25 - Spot weld test results - PS-205 "H"

2.083

050561

046538

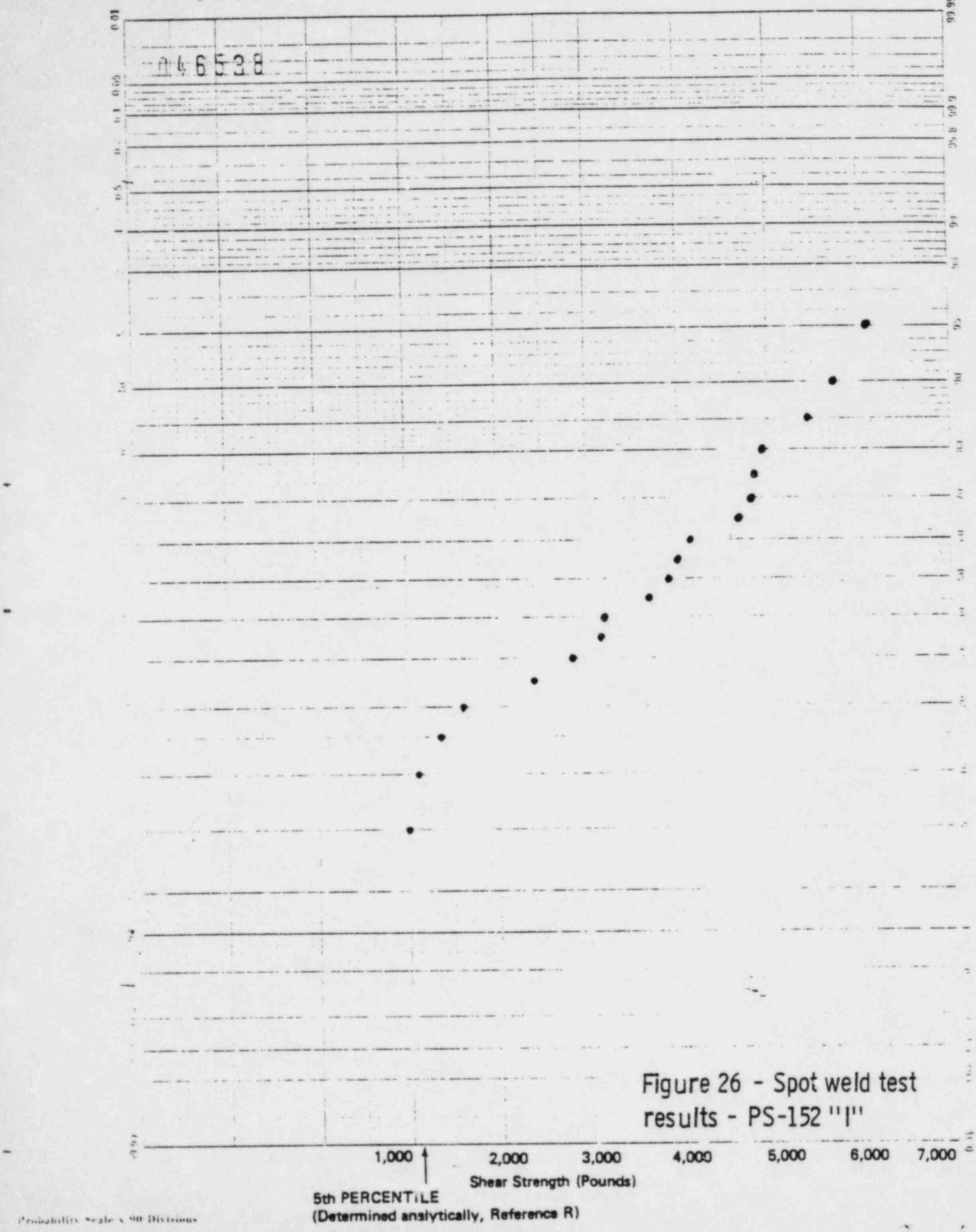

Figure 26 - Spot weld test results - PS-152 "I"

0 5 0 5 6 1

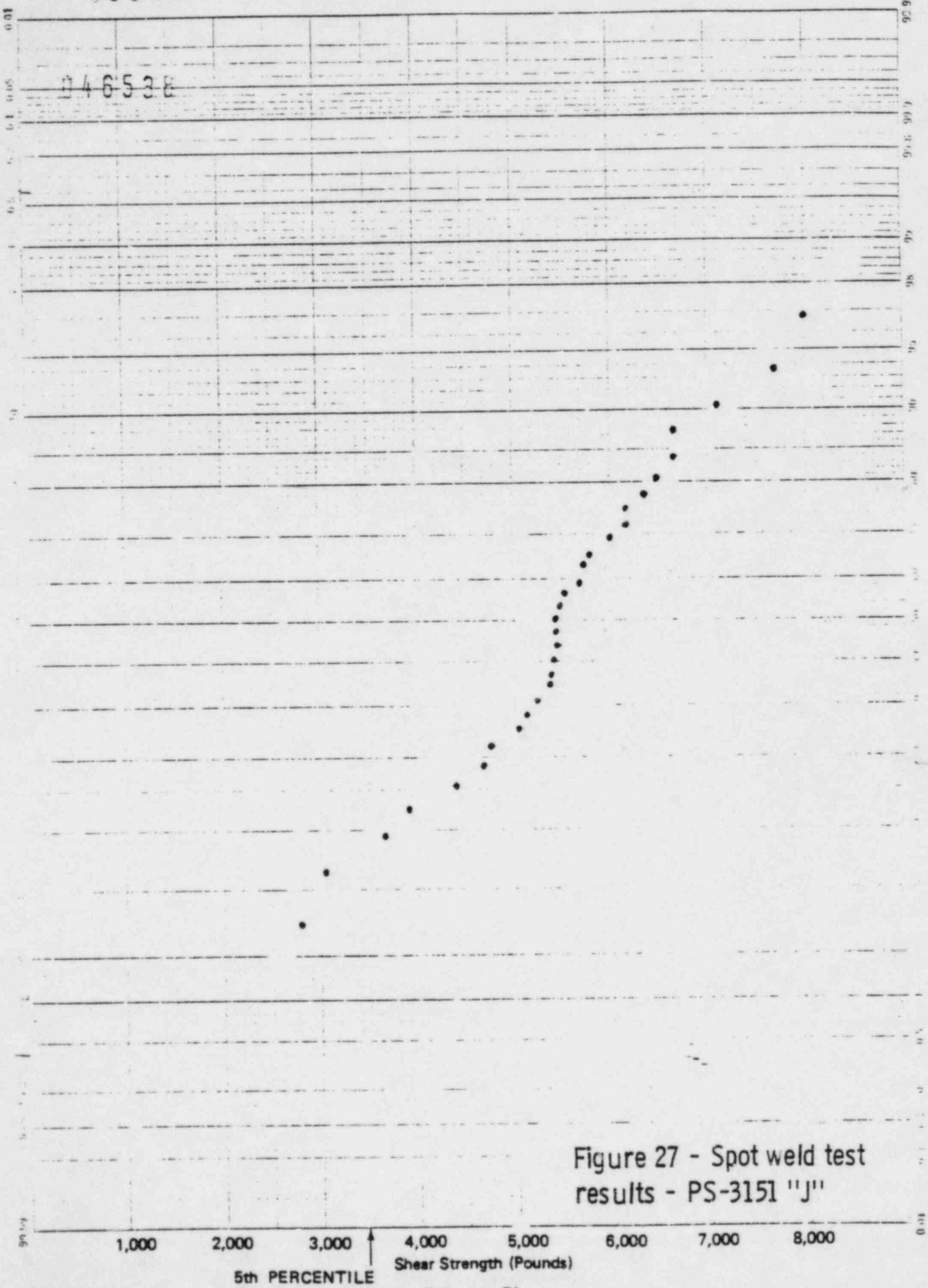

Figure 27 - Spot weld test results - PS-3151 "J"

Probability Scale x 90 Divisions