ATTACHMENT I

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REVISION 00
PAGE NO 84

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Savannah River Company

P.O. Box 616
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RTR-2661

August 15, 1989

TO: S. D. Curry

FROM: E. L. Bryant, ELB

LEAD EXPANSION ANCHOR LOAD CAPACITY IN REACTOR BUILDINGS AT THE SAVANNAH RIVER SITE

INTRODUCTION

Walkdowns to determine the seismic adequacy of selected safety systems have been performed for L and K reactors utilizing the Unresolved Safety Issue (USI) A-46 methodology sponsored by the Seismic Qualification Utility Group (SQUG). Actual experience data from earthquakes, test data compiled by the Electric Power Research Institute (EPRI), and other data for certain classes of nuclear plant equipment make up the SQUG data base.

Anchorage is also addressed in the USI A-46 methodology. However, lead expansion anchors are not included. Some safety related equipment in the Savannah River Site (SRS) reactor buildings is supported by lead expansion anchors. Design load capacity was based on the allowable loads listed in SRS Standard B8M which was intended to provided a factor of safety of 4. However, walkdowns have revealed that some lead anchors are not installed per B8M, and therefore the actual load capacity of these anchors may be less than indicated in the B8M. A testing program(SP-2449) was developed and 107 abandoned anchors in K, L, P and R reactor buildings were tested to determine shear and tension load capacities.

SUMMARY

This RTR documents the results of this testing program and provides a method for confirming adequacy of the lead shell type anchor. Test results show that the tension load capacity of lead

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type anchors at failure is below the design failure loads (i.e., four times the B8M). Therefore, the new lower allowable loads listed in Table 1 should be used for lead shell type anchors. If the calculated load on the anchor is greater than the Table 1 load, the anchor still may be adequate providing it is load tested to prove that it is capable of carrying the seismic demand load.

A regression analysis correlation between torque and load has been developed by SRL based on test measurements and can be used for proof load testing those lead type shell expansion anchors that exceeds the new lower allowable (Appendix A). The anchor bolt should be torqued to induce a tension load on the anchor which confirms its capacity to carry its calculated seismic demand load or the B8M design allowable load. This approach may result in a lower factor of safety. The factor of safety of 4 was intended to provide a high level of confidence that the anchor will support the design load. Because the anchors will be load tested to the seismic demand or design allowable load, a lower factor of safety is considered acceptable. Tests also show that the B8M values for shear loads are acceptable .

Table 1

Lead Shell Expansion Anchors

	Load, Lbs				
Anchor Size, inches	3/8	1/2	5/8	3/4	1
Current Tension Allowable Load (B8M)	700	1200	2000	3000	5500
New Recommended Allowable Load Based On Tests *	600	870	970	1280	3160
Proof Torque For B8M Design Allowable, ft-lb	24	37	50	69	

* Applicable only for anchors that have passed the tightness torque per RTR-2582

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CONCLUSIONS

1. The mean measured tension failure load of lead type expansion anchors is less than 4 times B8M.

2. The new lower tension load capacities of lead type expansion anchors that are listed in Table 1 should be used for walkdowns.

3. The tension load on anchors to be seismically qualified should be calculated and shown to be below the Table 1 values.

4. All lead type anchors should be proof loaded if the calculated seismic demand load exceeds the load capacity isted in Table 1 or if B8M allowables are assumed.

5. The torque necessary to induce a tension load on installed anchors should be determined from the correlation given in Figures 8-11 at the 95% confidence level.

6. B8M shear load capacities are adequate.

7. Further use of lead type expansion anchors at SRS should be discontinued.

DISCUSSION

Lead type shell expansion anchors have been used in the reactor buildings to support some safety-related equipment. As part of the seismic upgrade work, the adequacy of these anchors was evaluated using the USI A-46 methodology. This methodology is based on application of actual earthquake experience data, test data compiled by EPRI, and other data and is used to evaluate the seismic adequacy of certain classes of nuclear plant equipment. Anchorage is addressed by SQUG but specific data on lead type expansion anchorage is not available. Allowable loads specified in B8M were originally used during the walkdowns for the purpose of anchorage evaluation. The walkdowns revealed that many of the lead anchors were not installed per B8M and the actual load capacity of lead type expansion anchors was questionable.

A total of 107 lead type anchors covering 5 anchor sizes were load tested to failure in tension and 36 anchors, 3 sizes, were tested to failure in shear per SP 2449. Based on the test results, new lower allowable loads for tension were determined and are listed in Table 2. The shear failure loads exceeded those predicted by B8M and therefore, the B8M values were retained. The lead type expansion anchors exhibited poor load performance in tension as evidenced by a wide variation in failure loads. Because of this poor tension performance, it is concluded that further use of lead type expansion anchors should be discontinued at SRS.

TEST CONDITIONS

Tests were performed under Special Procedure 2449 on abandoned lead type expansion anchors in SRS Reactor Areas. The following conditions were prerequisites to testing:

- Anchor did not pull out or become loose when subjected to a tightness torque of approximately 20% of the installation torque.
- Perpendicularity of the anchor with the wall was less than 5 degrees offset.
- Anchor location was greater than 10 diameters from the next loaded anchor or a concrete edge.

Because of the limited number of available anchors, some anchors closer than 10 diameters to the next abandoned anchor were used. The test was considered acceptable if concrete spalling did not protrude into the area of the adjacent anchor. Also, some expansion anchors were tested if part of the threaded shell was above the concrete surface but all of the lead ring that secures the anchor to the concrete was below the face of the concrete. In this case, a metal spacer was used to provide a gap between the base plate and anchor during the tightness torque.

TEST SETUP

The test setup is shown in Figure 1. A hydraulic ram was used to apply a load to the anchor for tension tests. A stud rod with a

double nut on one end was inserted through the bore of the ram and screwed into the anchor about one diameter. Then the ram was used to apply a load approximately 325 lbs to the anchor. All subsequent loads were applied to the anchor by torquing the nut and measuring the resisting load on the hydraulic ram that is transmitted to the anchor. Both the torque and the load were recorded in step increments until failure.

For shear tests, a special shear plate assembly was made (Figure 1). A bolt was inserted through the shear plate assembly into the anchor. The hydraulic ram was then placed under the shear plate assembly to push the shear plate upward. The resisting pressure at failure was recorded.

RESULTS

Both tension and shear load capacities (Table 2) for lead type expansion anchors were determined. The mean measured tension loads at failure were all below the expected failure loads (i.e., B8M x 4). Therefore, new lower design allowable loads are recommended which includes a factor of safety of 4. A tightness torque was applied to screen out poorly installed anchors during walkdowns and was also applied during these tests. Anchors that failed the tightness torque were not load tested. Thus, the new lower recommended values are applicable to anchors that have been screened (i.e., passed the tightness torque). Additionally, as part of the walkdown effort, calculations should be performed for all lead shell type anchors to show that the seismic demand load is equal or below the new lower recommended loads. If the seismic demand load exceeds the new recommended value, the anchor may still be adequate providing the anchor bolt is torqued to a proof load. The induced proof load will confirm whether the anchor can carry its calculated seismic demand load.

Most pipes at SRS was designed to ANSI Standard B31.1 using B8M anchorage allowables. Pipes design to ANSI B31.1 has proven to be seismically rugged based on earthquake experience data. Therefore, if seismic qualification of SRS piping is accomplished by evaluating the as-built condition against ANSI B31.1 (i.e., no load calculations), then B8M allowables must be assumed, and the anchor bolts must be

proof torqued to induced the B8M design allowable load . In this case, only one torque test (no tightness torque) would be required and calculation of the anchor load would not be necessary.

SQUG methodology permits a factor of safety of 2 for non-shell type anchors but requires a factor of safety of 4 for the shell type anchor. However, this proposed program requires 100% verification of strength of those lead shell type anchors that exceed the new lower recommended loads or if B8M allowables are assumed by performing a torque test. The torque to be applied should be selected based on the lower bound 95% confidence curve (Figures 8-11) and will induce an equivalent mean load on the anchor of approximately1.5 times the seismic demand load. Thus, the SQUG requirement of achieving a 95% confidence level that there are no more than 5% nonconforming anchors is met.

The B8M shear load allowables will be retained because the measured shear load capacities (Table 2) exceeded the B8M failure values. Shear tests of the 3/4" and 1" anchors was not performed because no suitable anchors could be found.

Table 2

Lead Shell Expansion Anchors

	Load, lbs				
Anchor Size, inches	3/8	1/2	5/8	3/4	1
Tension Tests					
Number of Tests	35	34	17	10	9
B8M Design Allowabe Load	700	1200	2000	3000	5500
Failure Load Per B8M	2800	4800	8000	12000	22000
Mean Measured Failure Load	2623	3746	4456	5870	14058
New Recommended Allowable Load	600	880	970	1280	3160
Torque Based On B8M Design Allowable Load, ft-lb	24	37	50	69	
Shear Tests					
Number of Tests	16	12	8	-	-
B8M Allowable	400	800	1400	2000	3500
Failure Load Per B8M	1600	3200	5600	8000	14000
Mean Measured Failure Load	2796	5736	7934	-	-

DATA ANALYSIS

The new lower recommended allowable loads are based on the mean load measured at failure for the sample population tested. The mean (i.e., sample mean) was then statistically adjusted to obtain a true mean load at the 95% confidence interval. The failure load distribution was assumed to be Gaussian. The allowable loads listed in Table 2 provides for a factor of safety of 4.

For loads exceeding the new lower recommended loads, torque tests may be performed to determine anchor adequacy. A least-squares regression analysis correlations between torque and load at the 95% confidence level were tabulated by SRL (Appendix A) and have been plotted on Figures 8-11. The torque to be applied should be selected based on the lower 95% confidence bound curve and will induce an equivalent mean load on the anchor of approximately 1.5 times the seismic demand or the B8M load. Also, the torque to be applied should not be extrapolated beyond the range of the 95% confidence lines.

TENSION TESTS

Tension tests were performed in P,L,K and R reactor buildings for five different sizes of lead shell expansion anchors. These tests were performed in many different locations of the reactor building: 0 level, -20 and -40 clean areas and radiation zones. A total of 107 tension tests were performed (Appendix B). Fewer tests were performed for the 5/8, 3/4 and 1 inch anchors because of the low availability of anchors. Some anchors were load tested without torquing because the anchors were cross threaded. All 1-inch anchors were found at the floor level and contained excessive amounts of rust, therefore the torque to load relationship was not developed.

Tests showed a wide variation in tension load capacities (Figures 2-7) for each anchor size, reactor area, and mode of failure. This wide variation may be expected because the holding capacity of the anchor is largely determined by the correct hole size and compacting of the lead ring between the concrete and the threaded shell. The amount

of force for ensuring adequate compacting of the lead was probably not specified during the original installation. Approximately 7% of the anchors failed due to cone failure of the concrete. Some of the failures (22%) were due to a combination of a concrete failure (i.e., concrete cone did not penetrate to bottom of anchor) and slippage of the anchor out of the hole. Another 22% of the anchors failed because the non-lead portion of the anchor broke. The largest portion (47%) of the anchors failed because of slippage (i.e., the anchor was pulled out of its hole without spalling). About 40% of the slip failures were due to poor installation (i.e., no concrete spalling or significant galling of the lead sleeve was apparent indicating an oversized hole or insufficient packing of the lead sleeve). Nearly all of the 3/4 inch anchors were not installed per B8M. Inspection of the anchors after pullout showed that in most cases only one of the multiple stacked units provided support. A list of the anchors that failed the tightness tests (all turned in hole except1 anchor which was torqued against base plate) or the perpendicularity requirements was not kept but it is estimated that about 10 - 15% of the anchors tested were rejected based on those requirements.

TORQUE TESTS

Data was also collected to determine the correlation between torque and load for the 3/8, 1/2, 5/8, and the 3/4 inch anchors. Regression analysis curve fits (Figures 8-12) were made for each size anchor and show a good correlation between mean torque and load. Also, a good linear correlation between the mean failure load and bolt diameter was determined. The lower bound 95% confidence lines for torque and load are also potted on Figures 8-11 based on SRL analysis. Torque tests should be used to demonstrate anchor installation adequacy for the B8M design allowables or if the seismic demand load is calculated and exceeds the new lower allowables (applicable to K and L areas only). The torques selected from the Figures for load testing the anchor should be based on the 95% confidence lines and will met the SQUG requirement that there are no more than 5% nonconforming anchors.

Wide variation in torque at any specific load was also experienced. Torque values...differ because of perpendicularity of the anchor with the wall. This type of installation would cause the ram to pull the

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anchor out at an angle and would yield an increased torque value. Also, some bolts do not fit tight in the anchor until torqued against the base plate (i.e., thread contact between bolt and anchor is not tight). In some cases this could allow the ram to be mounted with some offset from perpendicularity. Additionally, the concrete wall was visibly not flat in some locations which would allow the ram to pull the anchor at an angle yielding higher torques. All of these variables could result in different torque values for the same load.

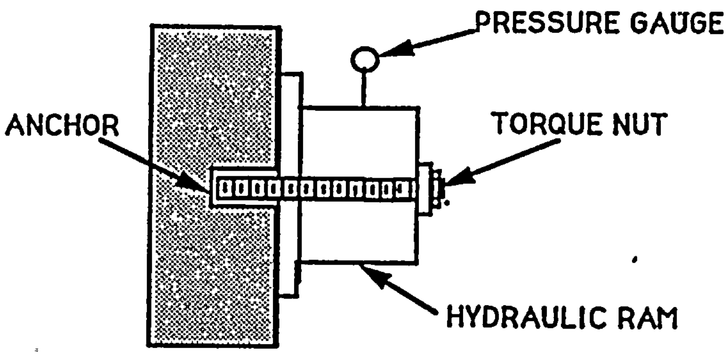
SHEAR TESTS

Shear testing was performed only in R Reactor Area. However, tension tests showed no significant variation in failure load capacities as a function of reactor area (Figure 12). Thus the shear tests are expected to be representative of all reactor areas.

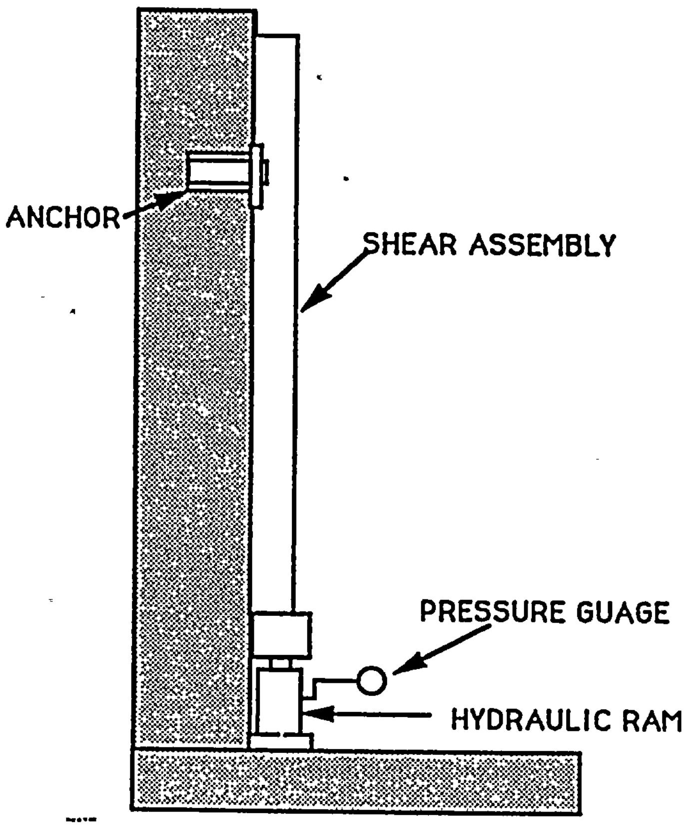
The mean measured shear load was determined for three different size anchors (Figure 13,14) based on the results of 36 different tests. Tests were not performed on the 3/4 and 1 inch anchors because none could be found. The mean measured shear loads at failure were 50 to 74% greater than failure loads indicated in B8M. Only one of the 32 anchors tested failed at a load slightly less than the B8M value times 4 (Figure 14).

FIGURE 1

TENSION GAUGE SETUP



SHEAR GAUGE SETUP



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FAILURE LOAD & MODE
TENSION TEST
3/8" ANCHOR

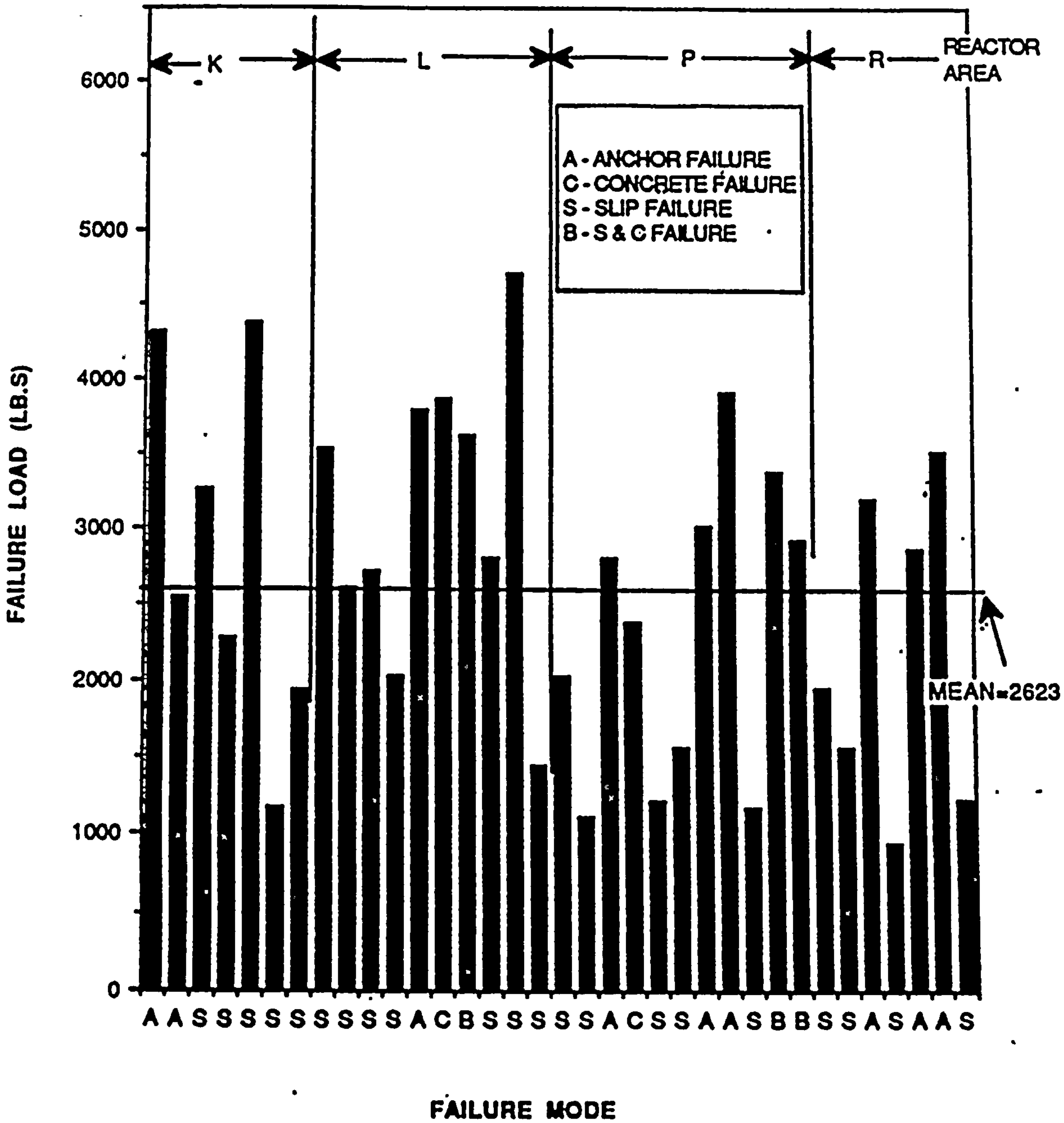

FIGURE 2

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FAILURE LOAD & MODE
TENSION TESTS
1/2" ANCHOR

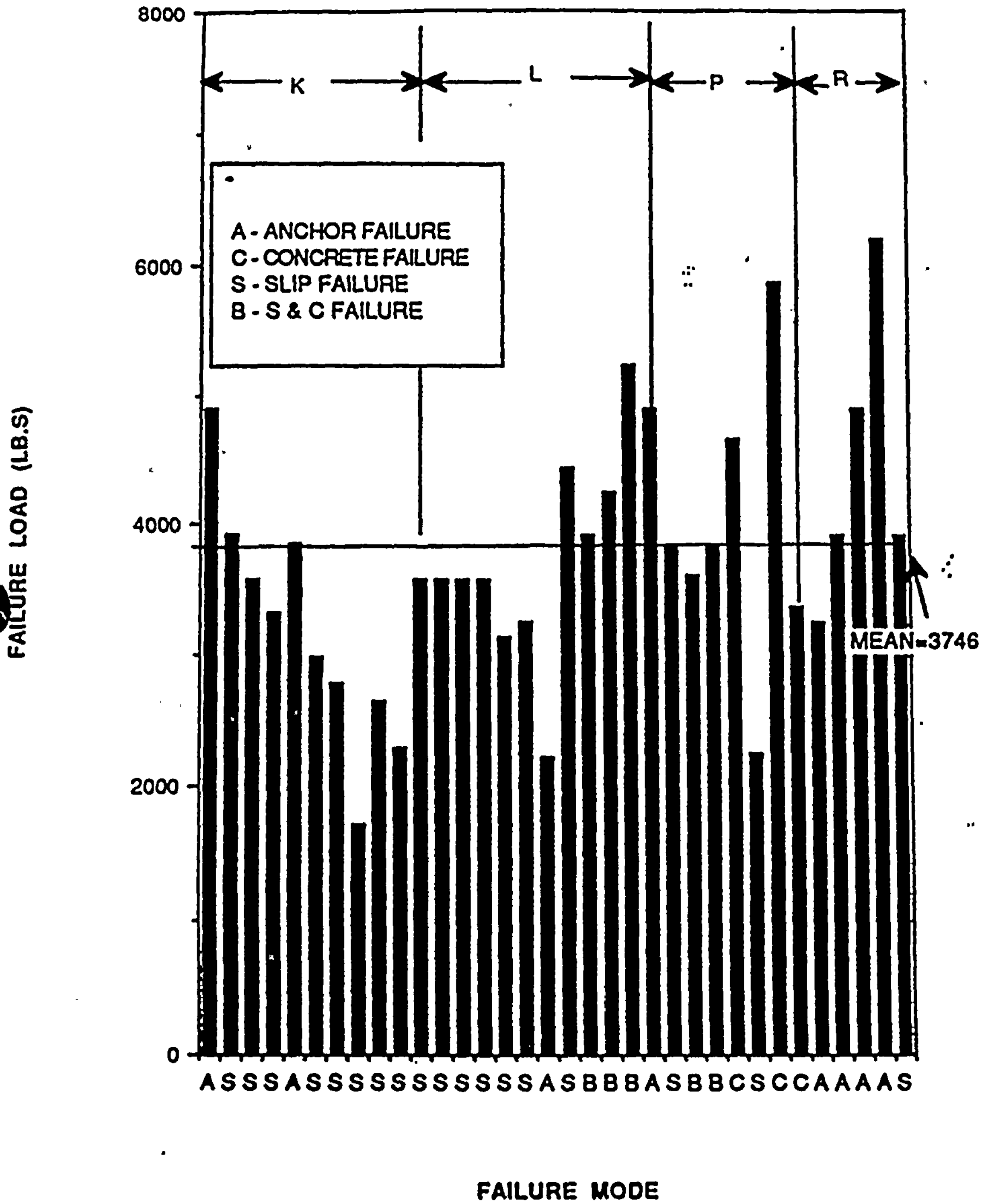

FIGURE 3

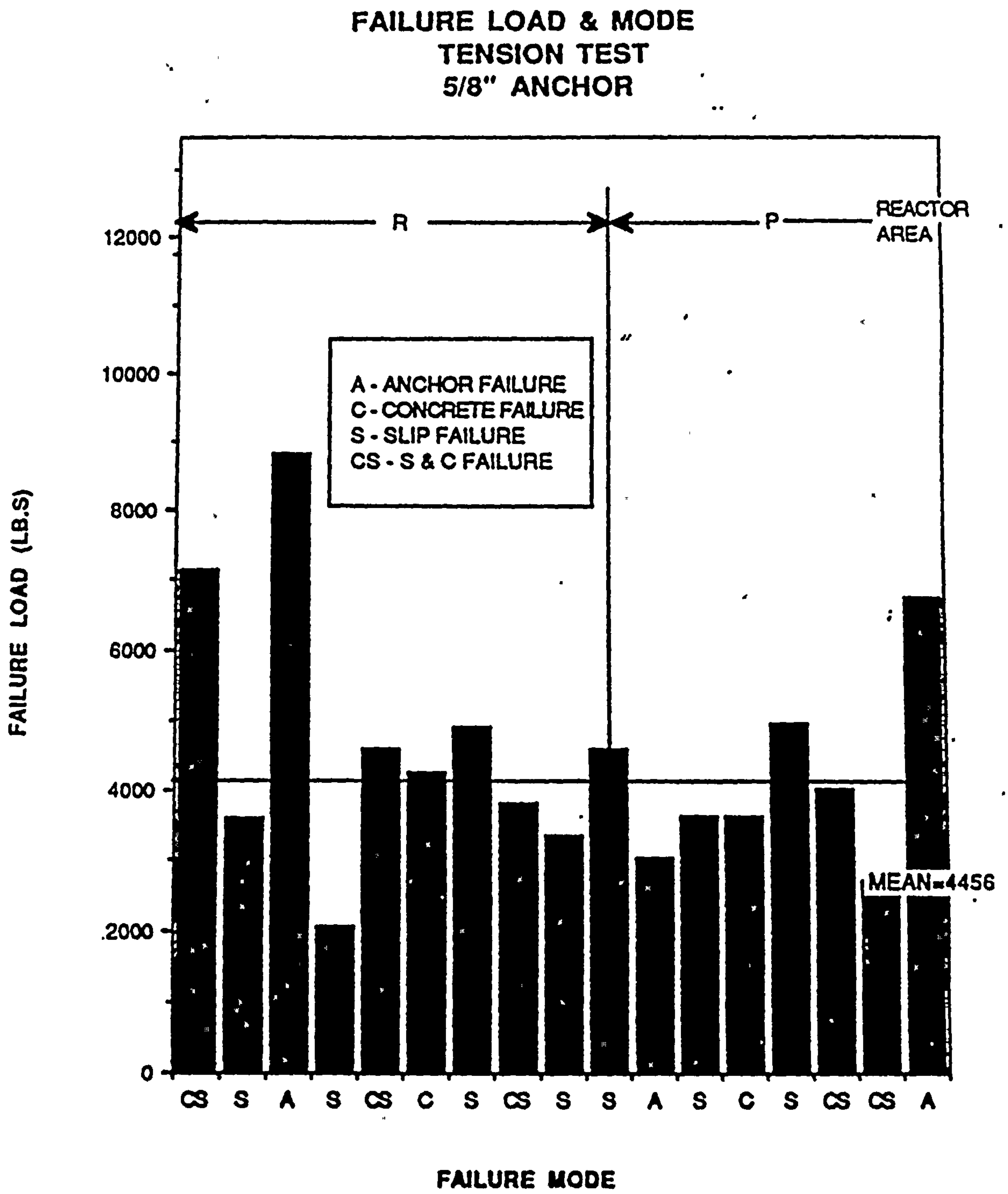
FAILURE LOAD & MODE
TENSION TEST
5/8" ANCHOR
R
P
REACTOR AREA
A - ANCHOR FAILURE
C - CONCRETE FAILURE
S - SLIP FAILURE
CS - S & C FAILURE
MEAN=4456
FAILURE LOAD (LB.S)
0
2000
4000
6000
8000
10000
12000
CS S A S CS C S CS S S A S C S CS CS A
FAILURE MODE

FIGURE 4

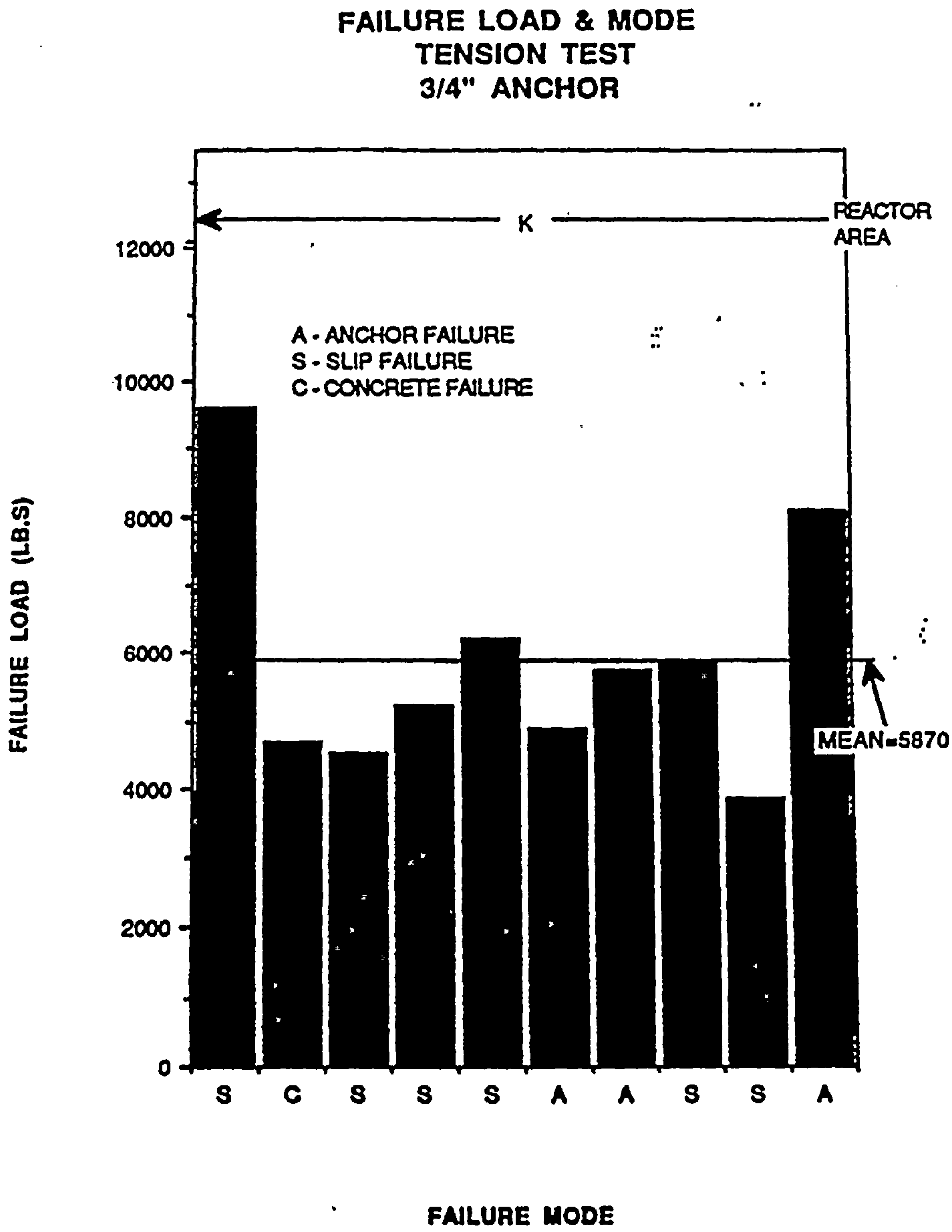
FAILURE LOAD & MODE
TENSION TEST
3/4" ANCHOR
K
REACTOR AREA
A - ANCHOR FAILURE
S - SLIP FAILURE
C - CONCRETE FAILURE
MEAN=5870
FAILURE LOAD (LB.S)
12000
10000
8000
6000
4000
2000
0
S C S S S A A S S A
FAILURE MODE

FIGURE 5

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MEAN FAILURE LOAD
TENSION TEST
3/8, 1/2, 5/8, & 3/4 ANCHORS

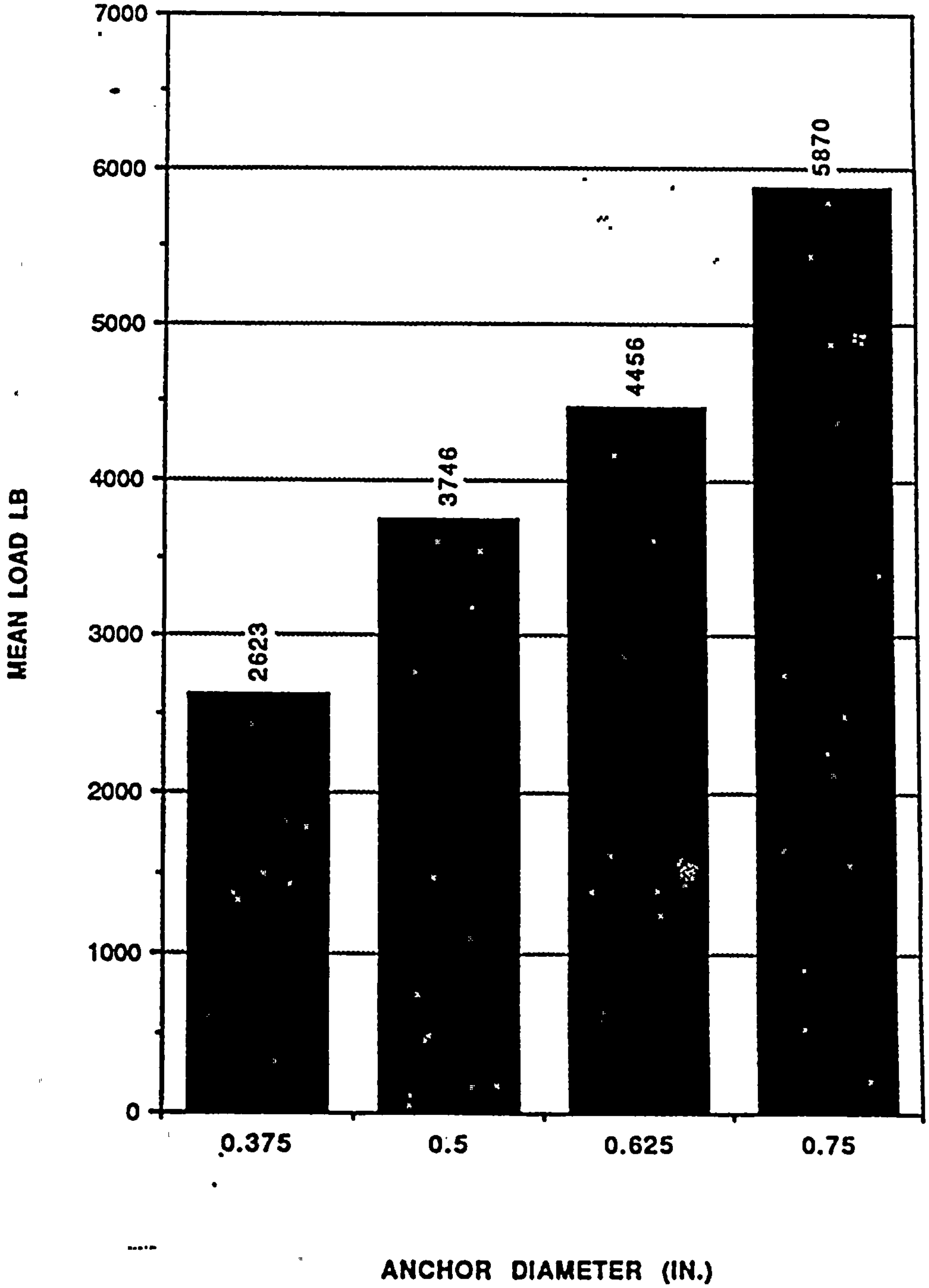

FIGURE 6

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MEAN FAILURE LOAD VS. ANCHOR SIZE
TENSION TEST

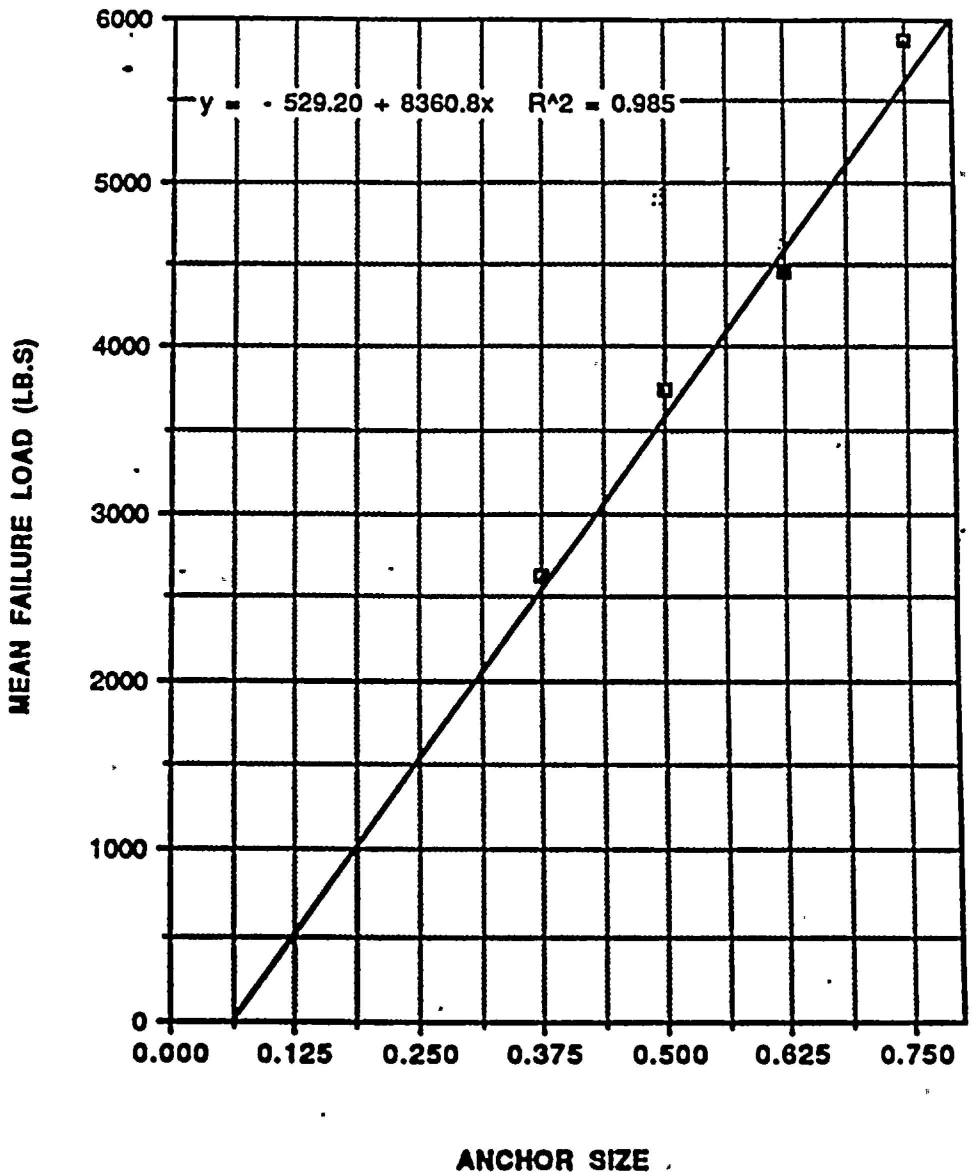

FIGURE 7

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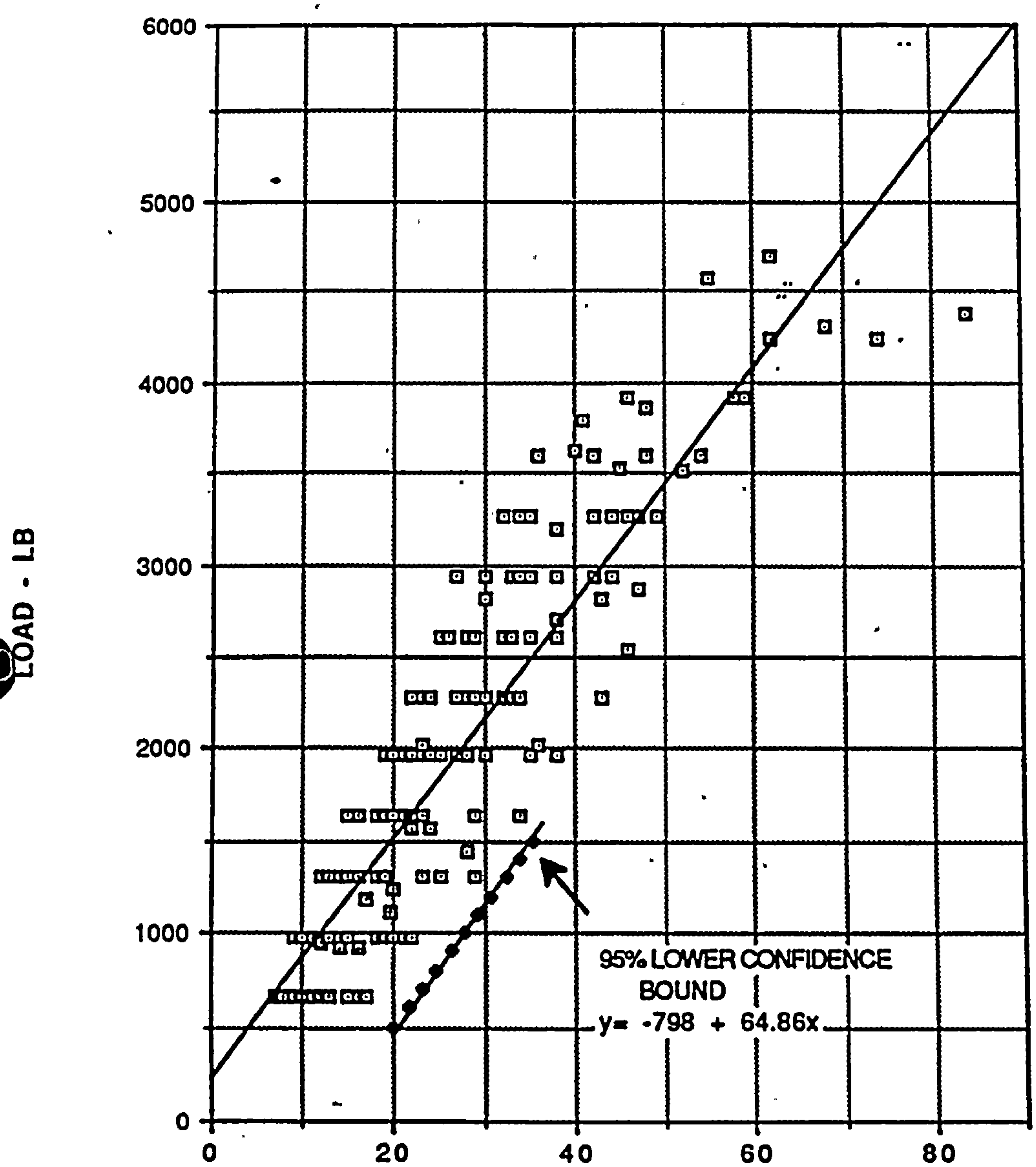
TORQUE VS LOAD
TENSION TEST
3/8" ANCHOR



TORQUE (FT-LB)

FIGURE 8

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TORQUE VS LOAD
TENSION TESTS
1/2" ANCHOR

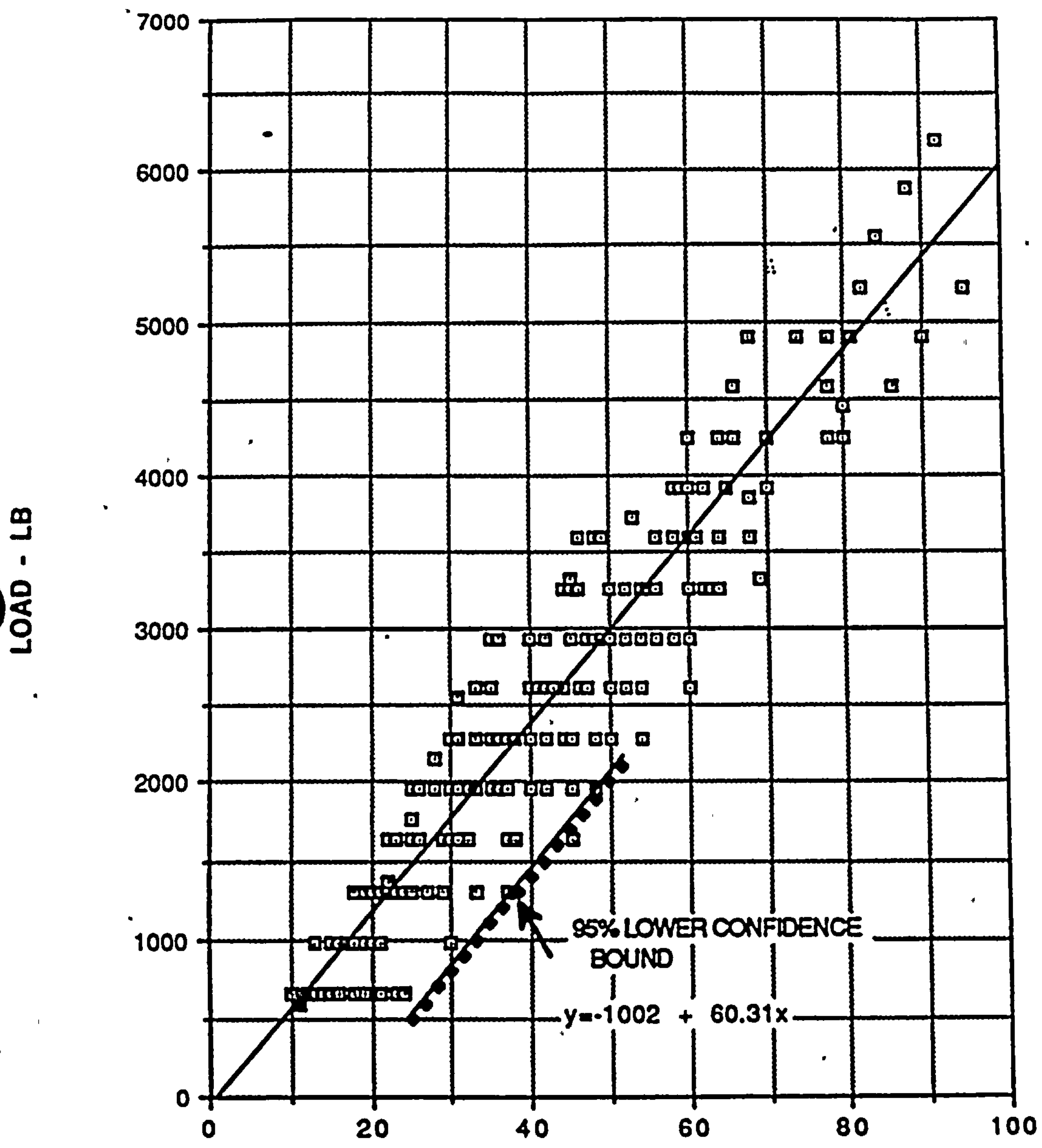

FIGURE 9

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TORQUE VS LOAD
TENSION TEST
5/8" ANCHOR

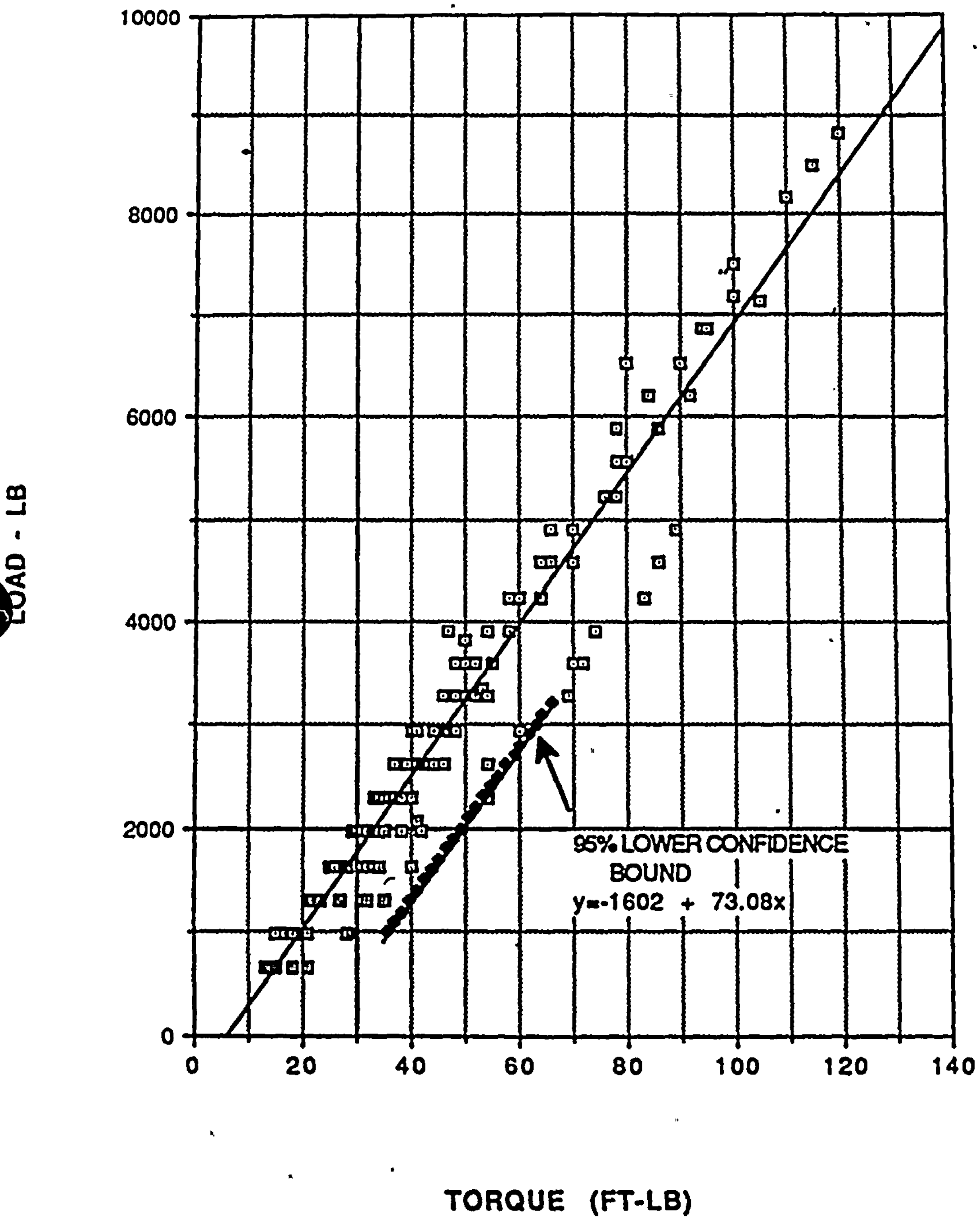

FIGURE 10

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TORQUE VS LOAD
TENSION TEST
3/4" ANCHOR

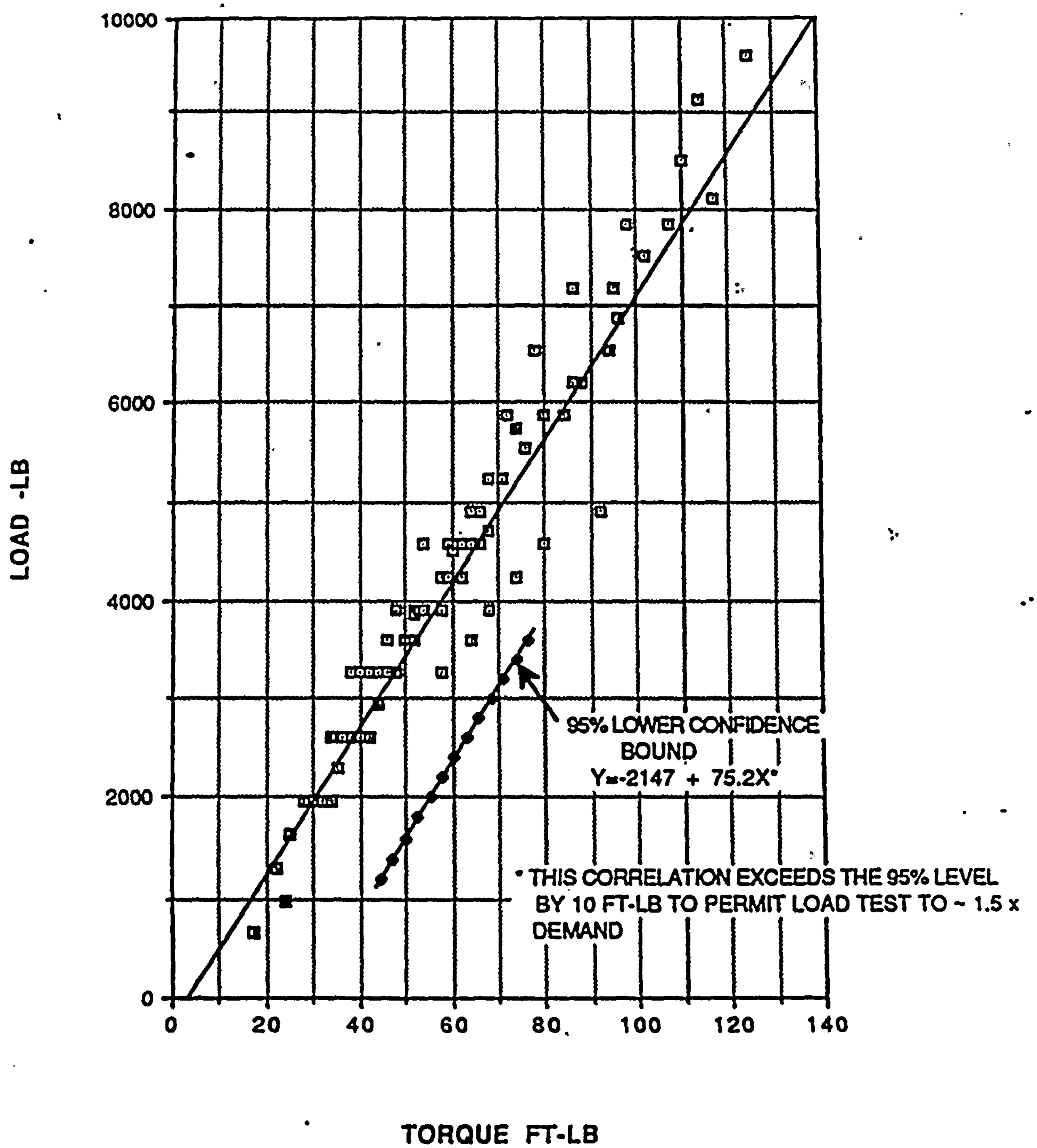

FIGURE 11

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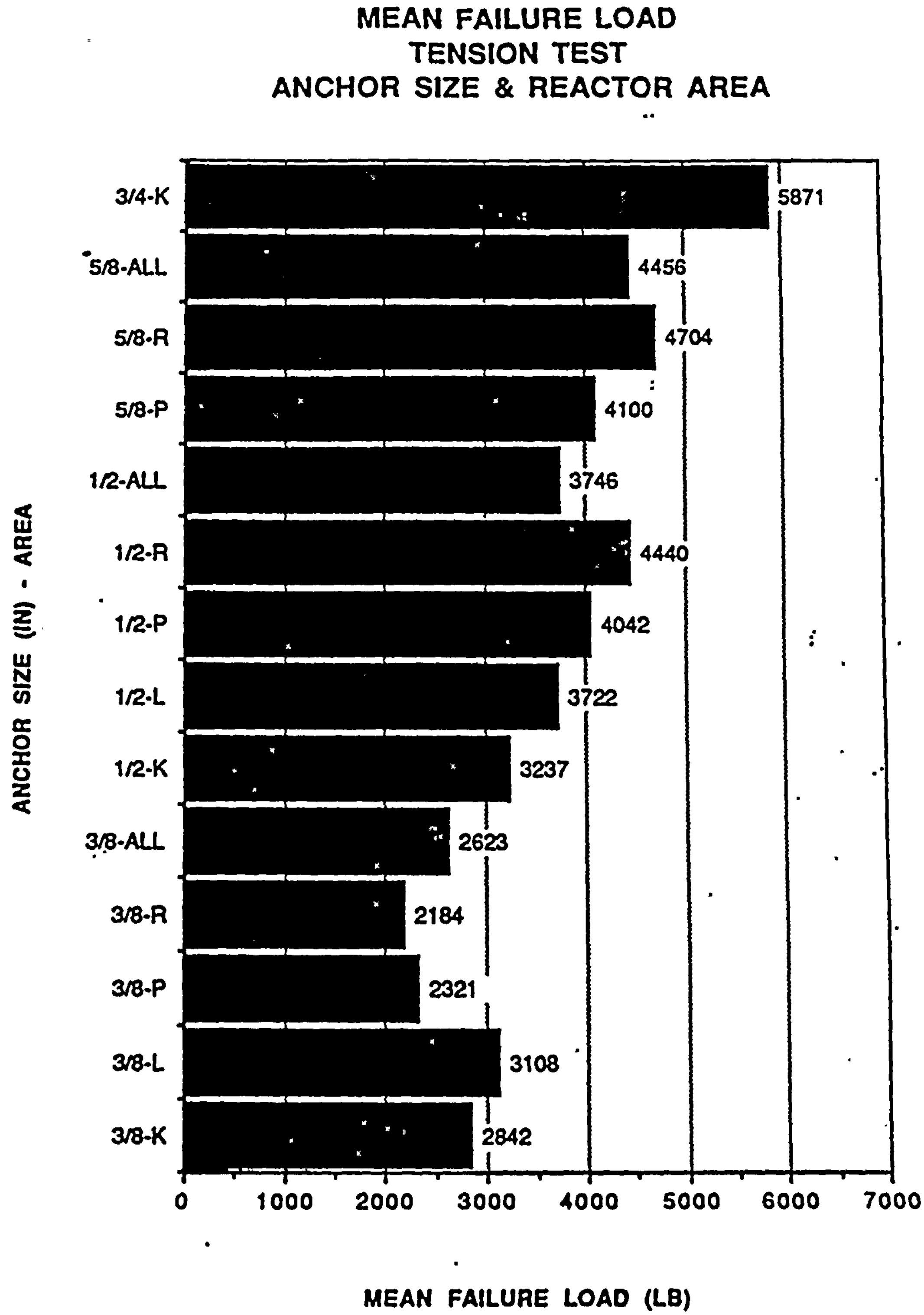

FIGURE 12

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MEAN FAILURE LOAD
SHEAR TEST
3/8, 1/2, & 5/8 ANCHORS

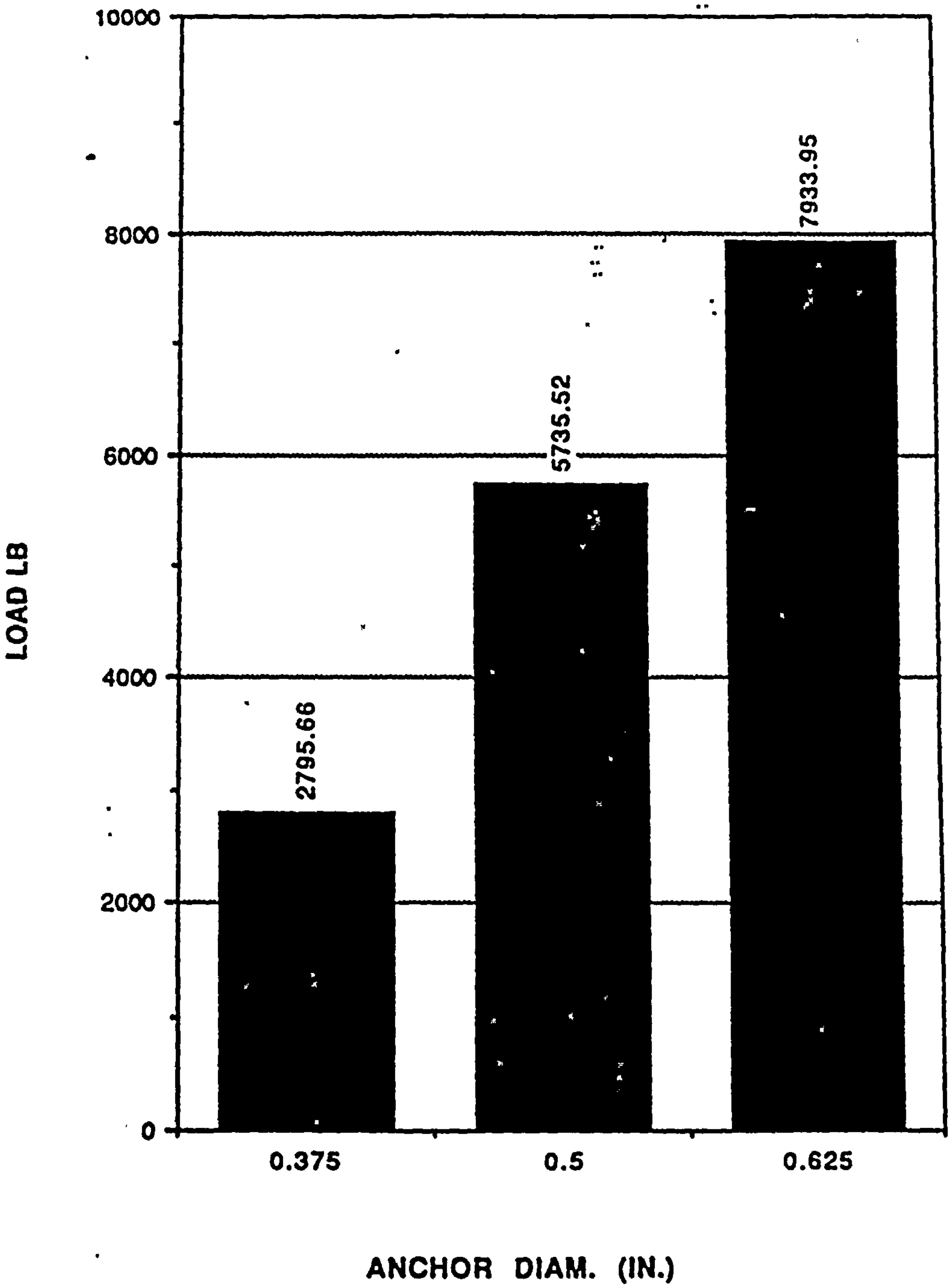

FIGURE 13

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SHEAR FAILURE LOAD

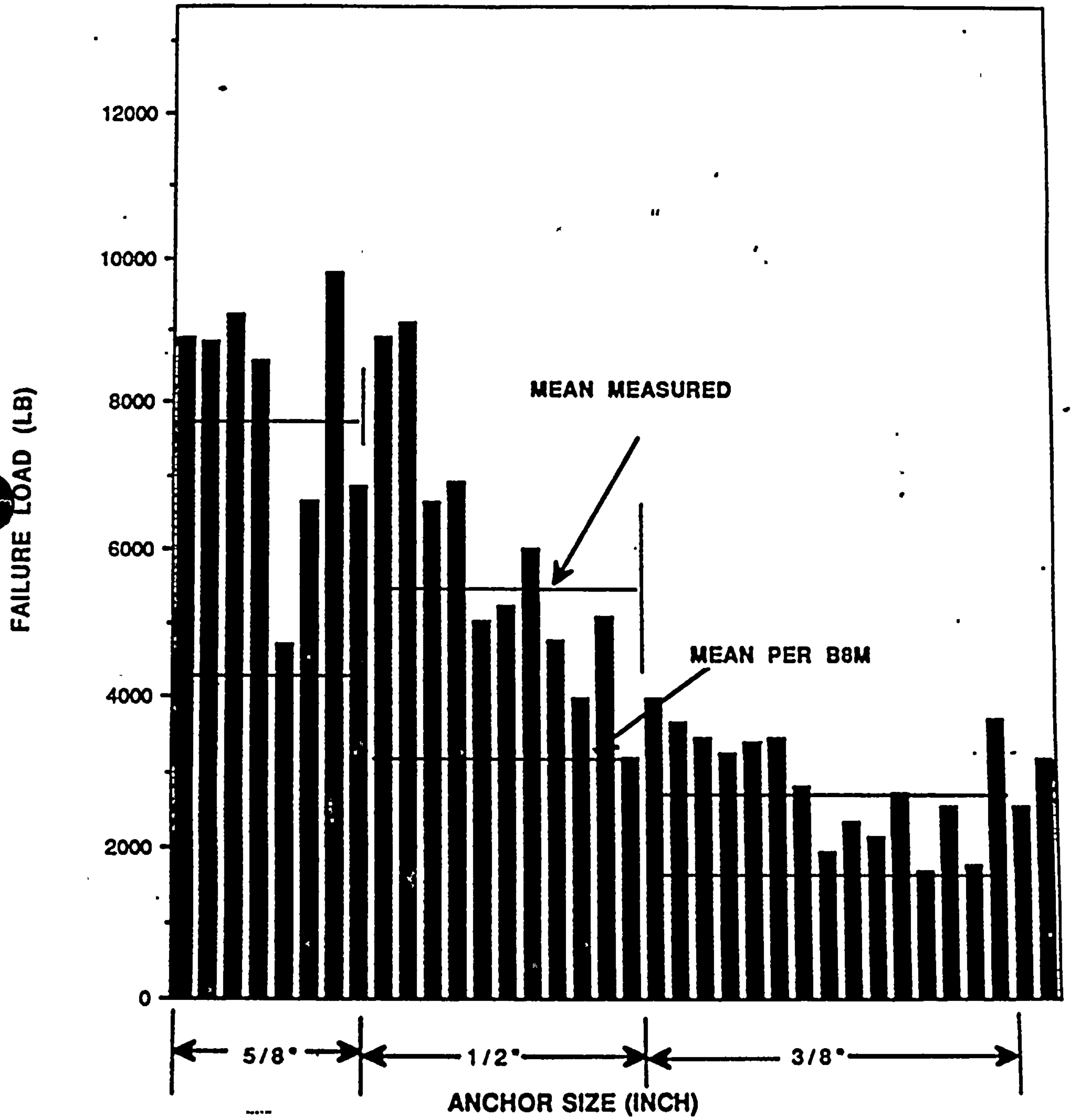
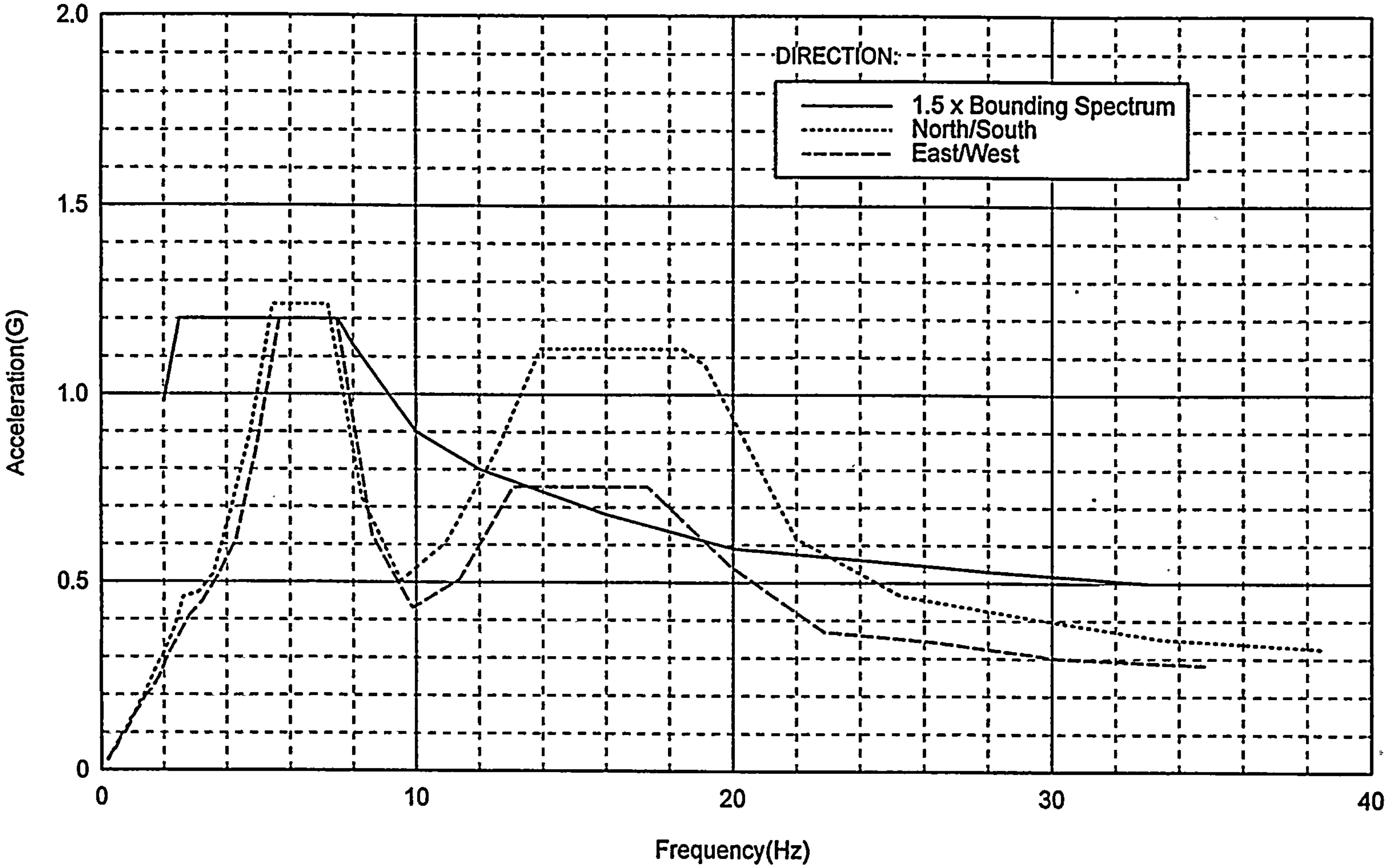


FIGURE 14

Niagara Mohawk Power Corporation
Nine Mile Point Nuclear Station, Unit No. 1
In-Structure Response Spectra
Excitation SSE (NUREG/CR-0098, PGA of 0.13G)

BUILDING: Reactor
ELEVATION: 259'
ROW/COL: LA8
DAMPING: 5%
MODEL NODE: 58



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Nine Mile Point Unit 1 A-46 Bounding Spectrum Vs. SSE Plot