Central file

Iowa Electric Light and Power Company

December 10, 1979
LDR-79-342

LARRY D. ROOT
ASSISTANT VICE PRESIDENT
NUCLEAR GENERATION

Mr. James G. Keppler, Director
Office of Inspection and Enforcement
Region III
U.S. Nuclear Regulatory Commission
799 Roosevelt Road
Glen Ellyn, IL 60137

Dear Mr. Keppler:

The enclosure to this letter is our response to IE Bulletin No. 79-02, Revision 2. This submittal supersedes our previous responses to the bulletin which were dated July 11, 1979 and October 11, 1979. The enclosure includes our response to Items 8.a,b, and c of IE Inspection Report No. 50-331/79-18.

If there are any questions, please feel free to contact us.

Very truly yours,

Larry D. Root

Larry D. Root
Assistant Vice President
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U.S. Nuclear Regulatory Commission
Office of Inspection and Enforcement
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Washington, D.C. 20555

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Enclosure

A Report On

PIPE SUPPORT BASE PLATE DESIGNS

USING CONCRETE EXPANSION ANCHOR BOLTS

(In Response to: NRC IE Bulletin No. 79-02, Rev. 2, dated November 8, 1979)

I. Introduction

This report is in response to NRC IE Bulletin 79-02, Rev. 2 dated November 8, 1979, requiring all licensees and permit holders for nuclear power plants to review the design and installation procedures for concrete expansion anchor bolts used in pipe support base plates in systems defined as Seismic Category I by the NRC Regulatory Guide 1.29, "Seismic Design Classification" Revision 1, dated August, 1973 or by the applicable SAR. It is also intended to provide information to allow resolution of certain unresolved items from IE Inspection Report No. 50-331/79-18 dated September 13, 1979.

In accordance with the intent of the Bulletin 79-02, the following types of supports have been considered in the present review.

a. Pipe Anchors (Seismic Category I)

b. Pipe Supports (Seismic Category I)

Adequacy of supports in these categories which used structural steel members attached directly to the concrete by expansion anchor bolts were also verified in accordance with the intent of the Bulletin.

The design and installation of the expansion anchor bolts on the Duane Arnold Energy Center were governed by the following documents:

a. Technical Specification 7884-M-119 for Pipe Hangers, Supports and Restraints

b. Manufacturers Standardization Society MSS-SP-58, Pipe Hangers and Valves

c. American Society for Testing Materials Standards

II. Response to Action Items

1. Verify that pipe support base plate flexibility was accounted for in the calculation of anchor bolt loads. In lieu of supporting analysis justifying the assumption of rigidity, the base plates should be considered flexible if the unstiffened distance between the member welded to the plate and the edge of the base plate is greater than twice the thickness of the plate. It is recognized that this criterion is conservative. Less conservative acceptance criteria must be justified and the justification submitted as part

of the response to the Bulletin. If the base plate is determined to be flexible, then recalculate the bolt loads using an appropriate analysis. If possible, this is to be done prior to testing of anchor bolts. These calculated bolt loads are referred to hereafter as the bolt design loads. A description of the analytical model used to verify that pipe support base plate flexibility is accounted for in the calculation of anchor bolt loads is to be submitted with your response to the Bulletin.

RESPONSE: All pipe anchor and support base plates using expansion anchor/bolts were (re) analyzed to account for plate flexibility, bolt stiffness, shear-tension interaction, minimum edge distance and proper bolt spacing. Depending on the complexity of the individual base plate configuration one of the following methods of analysis was used to determine the bolt forces:

(i) A quasi analytical method, developed by Bechtel was used for base plates with eight bolts or less. A review of the typical base plates used in supporting the subject piping systems indicate that the majority of them were anchored either by 4, 6 or 8 bolts. The plate thickness usually varied from 3/8" to 2" and are not generally stiffened. For these types of base plates an analytical formulation has been developed which treats the plates as a beam on multiple spring supports subjected to moments and forces in three orthogonal directions. Based on analytical considerations as well as on the results of a number of representative finite element analyses of base plates (using the "ANSYS" Code), certain empirical factors were introduced in the simplified beam model to account for (a) the effect of concrete foundation and (b) the two way action of load transfer in a plate. These factors essentially provided a way for introducing the interaction effect of such parametric variables as plate dimensions, attachment sizes, bolt spacings and stiffnesses on the distribution of external loads to the bolts.

A computer program for the analytical technique described above has been implemented for determining the bolt loads for routine applications. The program requires plate dimensions, number of bolts, bolt size, bolt spacing, bolt stiffness, the applied forces and the allowable bolt shear and tension loads as inputs.

The results from a number of case studies indicate excellent correlation between the results of the present formulation and those by the finite element method (using the "ANSYS" Code). The quasi analytical method generally gives the bolt loads greater than the finite element method (FEM).

(ii) For special cases where the design of the support did not lend itself to the foregoing method, the finite element method using the "ANSYS" code and/or other standard engineering analytical techniques with conservative assumptions were employed in the analysis.

(iii) Other cases were solved using an approach based on the strength design method given in the ACI 318-77 code.

Although the effect of plate flexibility has been explicitly considered in the formulation described above, the impact of prying action on the anchor bolts was determined not to be critical for the following reasons:

a. Where the anchorage system capacity is governed by the concrete shear cone, the prying action would result in an application of an external compressive load in the cone and would not therefore affect the anchorage capacity.

b. Where the bolt pull out determines the anchorage capacity, the additional load carried by the bolt due to the prying action will be self-limiting since the bolt stiffness decreases with increasing load. At higher loads the bolt expansion will be such that the corners of the base plate will lift off and the prying action will be relieved. This phenomena has been found to occur when the bolt stiffness in the finite element analysis was varied from a high to a low value, to correspond typically to the initial stiffness and that beyond the allowable design load.

2. Verify that the concrete expansion anchor bolts have the following minimum factor of safety between the bolt design load and the bolt ultimate capacity determined from static load tests (e.g. anchor bolt manufacturer's which simulate the actual conditions of installation (i.e., type of concrete and its strength properties):

a. Four - For wedge and sleeve type anchor bolts.
b. Five - For shell type anchor bolts.

The bolt ultimate capacity should account for the effects of shear-tension interaction, minimum edge distance and proper bolt spacing.

If the minimum factor of safety of four for wedge type anchor bolts and five for shell type anchors can not be shown then justification must be provided. The Bulletin factors of safety were intended for the maximum support load including the SSE. The NRC has not yet been provided adequate justification that lower factors of safety are acceptable on a long term basis. Lower factors of safety are allowed on an interim basis by the provisions of Supplement No. 1 to IE Bulletin No. 79-02. The use of reduced factors of safety in the factored load approach of ACI 349-76 has not yet been accepted by the NRC.

RESPONSE: In the current design review, factors of safety (i.e., ratio of manufacturer's specified anchor bolt ultimate capacity to bolt design load) of four for wedge type and five for shell type anchor bolts were used for maximum support load cases including the Safe Shutdown Earthquake (SSE).

The allowable loads for a given bolt are determined based on the concrete edge distance and bolt spacing.

The shear-tension interaction in the anchor bolts has been accounted for in the following manner:

In most cases the total applied tension and shear is considered to be carried by the bolts in accordance with the following interaction formula.

$$\left(\frac{T}{T_A}\right)^2 + \left(\frac{S}{S_A}\right)^2 \leq 1.0$$

Where T and S are the calculated tensile and shear forces and T_A and S_A are the respective allowable values for the specified anchors.

In isolated cases where the applied shear force is less than the frictional force developed in the shear plane between the steel and the concrete surface for balancing the imposed loads, no additional provisions are considered for shear.

In cases where the calculated safety factor for the existing anchor bolt was found to be less than the minimum the support was modified and the anchor bolt was replaced with a bolt which equals or exceeds the required minimum.

589 out of 647 large pipe supports using concrete expansion bolts have been reviewed. To date, 93 have been identified to have no tension loads for all loading cases and need no testing. 161 are spring hangers and have no seismic function. They will be inspected for gross failures and no testing will be performed. 335 supports have been analyzed against the design condition to confirm ~~that the~~ bolt design load and the safety factor between the design load and the specified manufacturer's bolt ultimate capacity has been calculated to meet Bulletin requirements. Analysis of the remaining 58 supports continues.

3. Describe the design requirements if applicable for anchor bolts to withstand cyclic loads (e.g., seismic loads and high cycle operating loads).

RESPONSE: In the original design of the piping systems deadweight, thermal stresses, seismic loads, and dynamic loads were considered in the generation of the pipe support design loads. To the extent that these loads include cyclic considerations, these effects would be included in the design of the hangers, base plates and anchorages.

The safety factors used for concrete expansion anchors, installed on supports for safety related piping systems, were not increased for loads which are cyclic in nature. The use of the same safety factor for cyclic and static loads is based on the FFTF Tests. The test results indicate:

1. The expansion anchors successfully withstood two million cycles of long term fatigue loading at a maximum intensity of 0.20 of the static ultimate capacity. When the maximum load intensity was steadily increased beyond the aforementioned value and cycled for 2,000 times at each load step, the observed failure load was about the same as the static ultimate capacity.

2. The dynamic load capacity of the expansion anchors, under simulated seismic loading, was about the same as their corresponding static ultimate capacities.

4. Verify from existing QC documentation that design requirements have been met for each anchor bolt in the following areas:

(a) Cyclic loads have been considered (e.g. anchor bolt preload is equal to or greater than bolt design load). In the case of the shell type, assure that it is not in contact with the back of the support plate prior to preload testing.

(b) Specified design size and type is correctly installed (e.g. proper embedment depth).

If sufficient documentation does not exist, then initiate a testing program that will assure that minimum design requirements have been met with respect to sub-items (a) and (b) above. A sampling technique is acceptable. One acceptable technique is to randomly select and test one anchor bolt in each base plate (i.e. some supports may have more than one base plate). The test should provide verification of sub-items (a) and (b) above. If the test fails, all other bolts on that base plate should be similarly tested. In any event, the test program should assure that each Seismic Category I system will perform its intended function.

RESPONSE: A testing program has been initiated at the DAEC. The intent of the program is to inspect and test 100% of the concrete expansion bolts in Seismic Category I piping systems.

Each anchor is inspected to verify adequate thread engagement, anchor size, spacing, and distance to a concrete edge. Shell type anchors are inspected to verify that the shell is not in contact with the baseplate during testing. Anchors in grouted base plates are inspected to verify that leveling nuts, if used, will not interfere with testing.

Because sufficient documentation does not exist to verify which manufacturer's type of concrete expansion bolt was installed at the DAEC, the test values for the program were based on the manufacturer's type of bolt with the lowest ultimate capacity.

Each anchor is tested to twice the allowable values for the lowest capacity anchors based on the torque/tension relationship shown in Attachment A. For the higher capacity anchors this torque/tension resulted in a value somewhat less than twice design using this relationship. It is believed that the torque/tension relationship is conservative relative to applying enough tension. A future test program will verify this by site specific testing.

If the anchor passes the testing and inspection described above it is preloaded to a value that will ensure a preload equal to or greater than the minimum design allowable anchor load for the type of anchors used at DAEC. If the anchor does not pass the testing and inspection described above, it is replaced with a wedge type anchor installed in accordance with the manufacturer's recommendations. The wedge type replacement anchors are also preloaded to a value greater than the bolt design load.

For piping systems less than 2-1/2" in diameter, the design for seismic loads for the DAEC utilized the rigid range method of analysis. This is a chart analysis method that yields results which can be shown to be highly conservative. For these small pipe systems, a program is being developed to demonstrate system operability. As necessary, sufficient inspection is being included. The program should begin on or before January 7, 1980.

5. Determine the extent that expansion anchor bolts were used in concrete block (masonry) walls to attach piping supports in Seismic Category I systems (or safety related systems as defined by Revision 1 of IE Bulletin No. 79-02). If expansion anchor bolts were used in concrete block walls:

   a. Provide a list of the systems involved, with the number of supports, type of anchor bolt, line size, and whether these supports are accessible during normal plant operation.

   b. Describe in detail any design consideration used to account for this type of installation.

   c. Provide a detailed evaluation of the capability of the supports, including the anchor bolts, and block wall to meet the design loads. The evaluation must describe how the allowable loads on anchor bolts in concrete block walls were determined and also what analytical method was used to determine the integrity of the block walls under the imposed loads. Also describe the acceptance criteria, including the numerical values, used to perform this evaluation. Review the deficiencies identified in the Information Notice on the pipe supports and walls at Trojan to determine if a similar situation exists at your facility with regard to supports using anchor bolts in concrete block walls.

   d. Describe the results of testing of anchor bolts in concrete block walls and your plans and schedule for any further action.

RESPONSE: In all cases where expansion anchor bolts were found to support Seismic Category 1 piping systems in block walls they have been removed and replaced by thru-bolted installations. Out of approximately 1600 large pipe supports 9 of these cases have been found to date.

The integrity of the block walls under design loads was verified by checking worst case loading for sample walls.

These walls were:

1) The wall with the largest span and high span to thickness ratio:

and;

2) A wall with high imposed loads:

These walls are not relied upon to act as shear walls.

The following load combinations were considered in the review.

1.25(D+L+Ho+E)+1.0 To

D+L+E'+To+Ho+R

Where:

D: Dead Load
L: Live Load
Ho: Piping Thermal
To: Thermal
E: OBE (Operating Basis Earthquake)
E': SSE (Safe Shutdown Earthquake)
R: Pipe Rupture (inside dry well only)

These combinations are consistent with the criteria presented in the FSAR (Chapter 12) for reinforced concrete structures.

Acceptance criteria for the load combinations given above is as follows.

Loads involving E: use Uniform Building Code (denoted as S)

Loads involving E': use 1.5 times Uniform Building Code (denoted as 1.5S)

These acceptance criteria are consistent with those presented in the FSAR. (FSAR question 12.5)

Using these load combinations and acceptance criteria the following critical load case was selected

1.5S = E' + Ho.

The walls were reviewed on a global basis using the following procedure.

a) The spectral accelerations, frequency calculations, and blockwall properties were taken from the original design calculations. These calculations considered the wall to act as a simply-supported beam spanning vertically. Cracking was considered in the frequency calculations.

b) The SSE accelerations were applied as transverse loads to the wall modeled as a plate with the spectral acceleration applied at the center decreasing to the upper floor acceleration at all edges. This resulted in loads in the wall due to its own inertia.

c) The total weight of all large pipe (Seismic Category I and Non-seismic Category I) within six feet of the wall was evaluated. This weight was uniformly distributed on the wall and an increase factor applied for other items such as cable tray and small piping that could be attached to the wall. The lateral loading due to SSE seismic piping responses was evaluated by multiplying the distributed piping load by both the peak of the SSE 1% response spectrum and an additional factor of 1.5 to account for multi-modal piping responses. This load was then reduced by a factor of the square root of 2 to account for phasing differences between the different piping systems.

   The uniformly distributed load described above was applied to the wall modeled as a plate. This resulted in an upper bound for loads in the wall due to SSE piping responses.

d) Piping thermal loads were applied as a uniformly distributed load to the wall modeled as a plate. This resulted in an upper bound for loads in the wall due to piping thermal reactions.

e) The wall loads due to wall inertia, piping inertia, and piping thermal reactions were summed on an absolute basis and checked against the acceptance criteria.

The maximum calculated global loading did not exceed the calculated acceptance criteria for these walls.

Local effects due to a pipe hanger were evaluated for pullout and local shearing. The maximum calculated local loading did not exceed the acceptance criteria allowables for these walls.

6. Determine the extent pipe supports with expansion anchor bolts used structural steel shapes instead of base plates. The systems and lines reviewed must be consistent with the criteria of IE Bulletin No. 79-02, Revision 1. If expansion anchor bolts were used as described above, verify that the anchor bolt and structural steel shapes in these supports were included in the actions performed for the Bulletin. If these supports cannot be verified to have been included in the Bulletin actions:

a. Provide a list of the ystems involved, with the number of supports, type of anchor bolt, l ne size, and whether the supports are accessible during norr 1 plant operation.

b. Provide a detailed evaluation of the adequacy of the anchor bolt design and installation. The evaluation should address the assumed distribution of loads on the anchor bolts. The evaluation can be based on the results of previous anchor bolt testing and/or analysis which substantiates operability of the affected system.

c. Describe your plans and schedule for any further action necessary to assure the affected systems meet Technical Specifications operability requirements in the event of an SSE.

RESPONSE: A significant portion of the pipe supports at the DAEC used structural steel shapes such as channel which were bolted directly to the concrete. In all cases where this design was encountered the entire support was treated in accordance with the criteria for this Bulletin.

7. For those licensees that have had no extended outages to perform the testing of the inaccessible anchor bolts, the testing of anchor bolts in accessible areas is expected to be completed by November 15, 1979. The testing of the inaccessible anchor bolts should be completed by the next extended outage. For those licensees that have completed the anchor bolt testing in inaccessible areas, the testing in accessible areas should continue as rapidly as possible, but no longer than March 1, 1980. The analysis for the Bulletin items covering base plate flexibility and factors of safety should be completed by November 15, 1979. Provide a schedule that details the completion dates for IE Bulletin No. 79-02, Revision 2, items 1, 2, and 4.

RESPONSE: Iowa Electric plans to complete testing and repair of 343 supports out of the 353 in accessible areas prior to the next extended outage beginning in 2/80. The 10 remaining supports in accessible areas as well as 20 inaccessible supports will be tested and/or repaired during the extended outage. Calculations verifying the required minimum factor of safety shall be completed by 2/1/80. The design requirement for bolt preload and proper installatio will be met and verified on QC documentation during the repair and testing of each support.

8. Maintain documentation of any sampling inspection of anchor bolts required by item 4 on site and available for NRC inspection. All holders of operating licenses for power reactor facilities are requested to complete items 5, 6, and 7 within 30 days of the date of issuance of Revision No. 2. Also describe any instances not previously reported, in which you did not meet the revised (R2) sections of items 2 and 4 and, if necessary, your plans and schedule for resolution. Report in writing within 300 days of the date of this revision issuance, to the Director of the appropriate Regional Office, completion of your review. For action not yet complete, a final report is to be submitted upon completion of your action. A copy of your report(s) should be sent to the United States Nuclear Regulatory Commission, Office of Inspection and Enforcement, Division of Reactor Operations Inspection, Washington, D.C. 20555. These reporting requirements do not preclude nor substitute for the applicable requirements to report as set forth in the regulations and license.

RESPONSE: Documentation for the anchor bolt testing and repair program is maintained on site at the DAEC. Items 5, 6, & 7 are addressed as noted in the previous responses for items 5, 6 & 7 in this report.

The calculations for required factors of safety included SSE loads as required in the revised section of item 2, and anchor bolt testing and repair has proceeded in a manner consistent with the provisions of Supplement No. 1 to the Bulletin.

For all tested or repaired anchor bolt installations, the requirement for preload has been met as outlined in item 4 of the Bulletin.

9. All holders of construction permits for power reactor facilities are requested to complete items 5 and 6 for installed pipe supports within 60 days of date of issuance of Revision No. 2. For pipe supports which have not yet been installed, document your action to assure that items 1 through 6 will be satisfied. Maintain documentation of these actions on site available for NRC inspection. Report in writing within 60 days of date of issuance of Revision No. 2, to the Director of the appropriate NRC Regional Office, completion of your review and describe any instances not previously reported, in which you did not meet the revised (R2) sections of items 2 and 4 and, if necessary, your plans and schedule for resolution. A copy of your report should be sent to the United States Nuclear Regulatory Commission, Office of Inspection and Enforcement, Division of Reactor construction Inspection, Washington, D.C. 20555.

RESPONSE: No response required.

ATTACHMENT A

TORQUE-TENSION RELATIONSHIP

THe development of the following torque vs. tension relationship for various anchor bolt diameters is based on the combined friction resistance in the bolt threads and between the bolt head (or nut) and the bearing surface (base plate or washer).

The torque, T_1, due to friction in the threads would be approximately equal to the product of the friction factor μ, the bolt radius r, and the bolt tension P.

$$T_1 = \mu P r$$

THe torque, T_2, due to friction under the bolt head would be approximately equal to the product of the friction factor μ, the bolt tension P, and the mean radius of the loaded area of the bolt head or nut $\bar{r}$

$$T_2 = \mu P \bar{r}$$

The torque T required to turn the nut or bolt under a preload P would be

$$T = T_1 + T_2$$

$$T = \mu P (r + \bar{r})$$

substituting:

$$r = \frac{D}{2}$$

$$\bar{r} = \frac{\bar{D}}{2}$$

$$\bar{D} = \frac{D + 1.5D}{2}$$

$$T = \mu P \left(\frac{D}{2} + \frac{D + 1.5D}{4}\right)$$

$$T = \frac{9}{8} \mu P D \qquad \text{Eq (1)}$$

μ = Friction factor

P = Bolt tension preload (pounds)

D = Bolt diameter (in)

T = Torque (in-pounds)

For torque T expressed in foot-pounds

$$T = \frac{3}{32} \mu P D \qquad \text{Eq (2)}$$

T = Torque (foot-pounds)

Letting $\frac{3}{32} \mu$ equal the bolt friction factor K, the relationship between applied torque and bolt tension is then

$$\frac{T}{P} = K D \qquad \text{Eq (3)}$$

Figure 1 shows a plot of T/P values obtained from a set of tests on Ramset Trubolt wedge anchors (letter to Bechtel Power Corporation from R. J. Mentzinger of Ramset Fastening Systems dated April 5, 1978). The experimental values represent the ratio of the lower limit tension values obtained for preset torque values. T/P values using a range of torque values from the Final Report, Tests on Self Drilling Anchors by E. G. Burdette dated July 1979 are also shown for comparison.

Examination of these data indicates that a bolt friction factor K of about 0.04 would be required to ensure obtaining a tension preload value equal to or greater than P.

The following relationship was therefore used to establish test torque values.

$$T = 0.04 P D$$

T = Test torque (ft-pounds)

D = Bolt diameter (inches)

P = Test tension value (pounds)

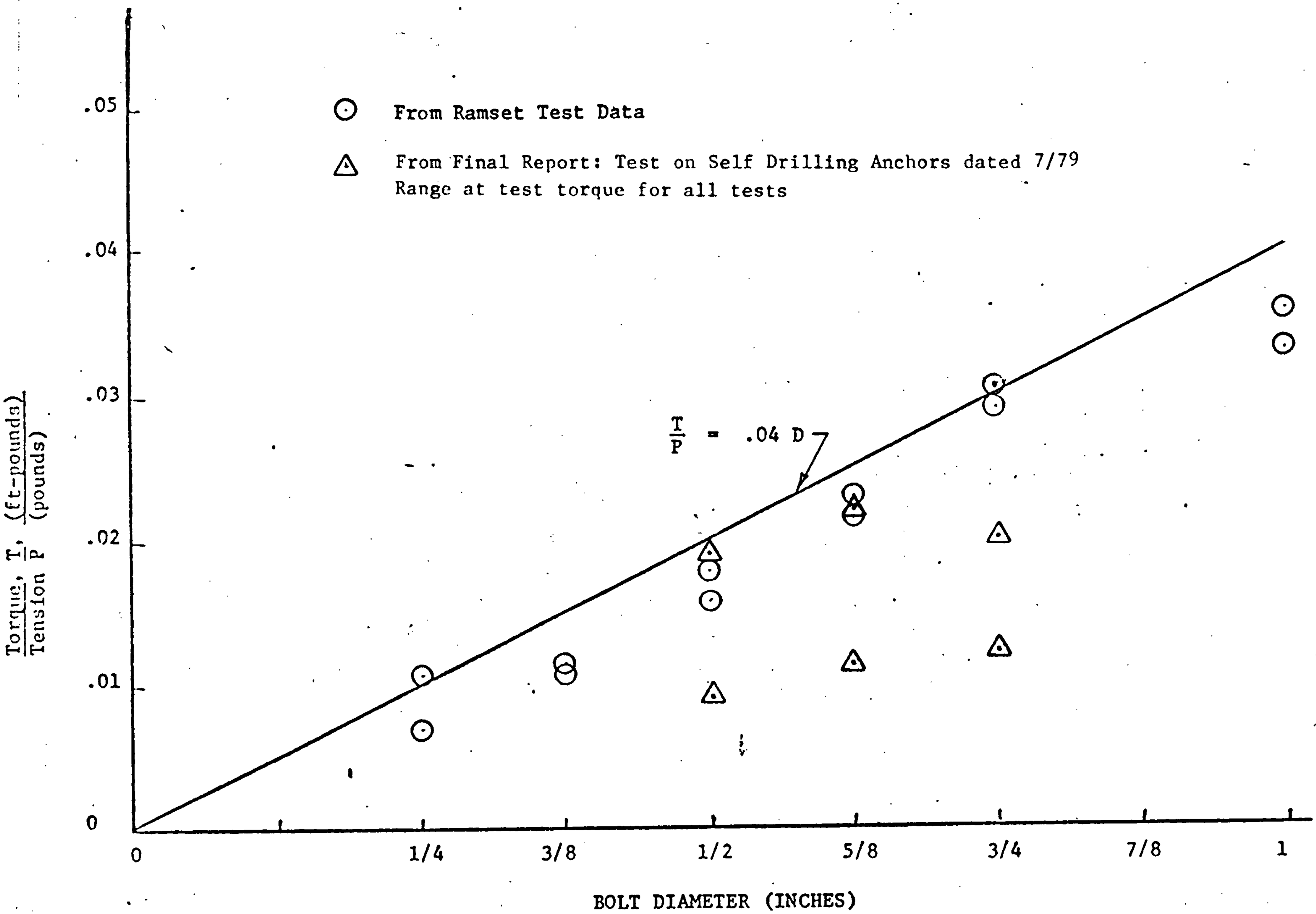

FIGURE 1 BOLT DIAMETER VS. TORQUE-TENSION RATIO