Commonwealth Edison
One First National Plaza, Chicago, Illinois
Address Reply to: Post Office Box 767
Chicago, Illinois 60690

central file

December 7, 1979

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

Subject: Dresden Station Units 2 and 3
Quad-Cities Station Units 1 and 2
Zion Station Units 1 and 2
LaSalle County Station Units 1 and 2
Byron Station Units 1 and 2
Braidwood Station Units 1 and 2
Response to IE Bulletin 79-02,
Revision 2
NRC Docket Nos. 50-237/249/254/265/
295/304/373/374/454/455/456/457

Reference (a): James G. Keppler letter to C. Reed
dated November 8, 1979

Dear Mr. Keppler:

Reference (a) requested a response to additional questions and clarifications as stated in Revision 2 to IE Bulletin 79-02 concerning the use of concrete expansion anchors. The enclosure to this letter contains our response to the revised sections of Item 2 and the additional Items 5 and 6 for Dresden 2 and 3, Quad-Cities 1 and 2, Zion 1 and 2, LaSalle 1 and 2, Byron 1 and 2, and Braidwood 1 and 2.

Please address any questions you may have concerning this matter to this office.

Very truly yours,

Robert F. Janecek
for D. L. Peoples
Director of Nuclear Licensing

RFJ:mae
enclosure

cc: Director, Division of Reactor
Operations Inspection

DEC 20 1979

KB

8001170044 A02

ENCLOSURE

RESPONSE TO REVISION 2 TO IE BULLETIN 79-02

DRESDEN STATION UNITS 2 AND 3
QUAD-CITIES STATION UNITS 1 AND 2
ZION STATION UNITS 1 AND 2
LASALLE COUNTY STATION UNITS 1 AND 2
BYRON STATION UNITS 1 AND 2
BRAIDWOOD STATION UNITS 1 AND 2

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 cannot 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: Concrete expansion anchor baseplate assemblies for Dresden, Units 2 and 3; Quad Cities, Units 1 and 2; Zion, Units 1 and 2; LaSalle County, Units 1 and 2; and Byron/Braidwood, Units 1 and 2, have been designed for a minimum factor of safety equal to 4.0 against manufacturer's recommended ultimate loads for the following piping load combinations:

1) Normal
2) Upset

A minimum factor of safety equal to 2.0 against manufacturer's recommended ultimate loads has been used for the following piping load combinations:

1) Emergency

2) Faulted

It is emphasized these are minimum factors of safety, and in many instances, factors of safety equal to 4.0 or more have been realized under the emergency/faulted conditions due to the relatively light loads supported by the anchors and the use of standardized plate assemblies with high load carrying capacity compared to the applied loads.

It is Commonwealth Edison Company's opinion that factors of safety equal to 2.0 and 4.0 are justified for the emergency/faulted and normal/upset load conditions respectively for the following reasons:

1) Factors of safety are consistent with the philosophy of and the structural acceptance criteria specified in Sections 3.8.3 and 3.8.4 of the Nuclear Regulatory Commission's Standard Review Plans.

2) The factors of safety are consistent with the philosophy of ASME Section III to which safety related piping systems are designed.

3) Test data available today indicates that concrete expansion anchors will perform satisfactorily at load levels equal to one-fourth and one-half their ultimate loads under dynamic conditions.

4) Concrete expansion anchor ultimate loads vary directly with the square root of the concrete strength. Concrete expansion anchors thereby achieve higher ultimate loads than recommended by manufacturers when the in-place concrete strength versus the nominal design strength is considered.

5) Test data has indicated that an elliptical interaction best defines the relationship for concrete expansion anchors under combined tension and shear. The expansion anchored baseplate assemblies for Dresden, Units 2 and 3; Quad Cities, Units 1 and 2; Zion, Units 1 and 2; LaSalle County, Units 1 and 2; and Byron/Braidwood, Units 1 and 2, have been designed using a conservative straight line interaction based upon shear friction concepts. The straight line interaction provides substantial safety margins when compared to the actual elliptical interaction.

The Standard Review Plan structural acceptance criteria for normal and severe environmental loading combinations are working load levels and are ultimate load levels for the extreme environmental and abnormal loading combinations. Normal and severe environmental loading combinations correspond to the normal/upset piping load combinations; while the extreme environmental and abnormal loading combinations correspond to the emergency/faulted piping load combinations.

The manufacturers of concrete expansion anchors have traditionally defined allowable working loads to be the ultimate anchor capacity divided by a factor of safety equal to 4.0. Numerous field tests have been conducted by Commonwealth Edison Company to date, substantiating the manufacturer's published ultimate loads. Applying the philosophy of the Standard Review Plans, the allowable concrete expansion anchor loads would be equal to the ultimate load divided by factors of safety equal to 4.0 and 1.0 for the normal/upset and emergency/faulted load combinations, respectively. Therefore, the current Nuclear Regulatory Commission position requiring a factor of safety equal to 4.0 for the emergency and faulted load combinations is not compatible with the Standard Review Plans, nor is it compatible with the design philcsophy with which the structures supporting the expansion anchor plate assemblies have been designed.

Safety related piping systems for Dresden, Units 2 and 3; Quad Cities, Units 1 and 2; Zion, Units 1 and 2; LaSalle County, Units 1 and 2; and Byron/Braidwood, Units 1 and 2, have been designed in accordance with ASME Section III. This code recognizes that stresses in the piping system may approach yield under the emergency/faulted load conditions. Therefore, the 4.0 factor of safety on the supporting system (expansion anchor baseplate assemblies) under the corresponding load combinations is not compatible with the piping system.

A survey of the dynamic test data on concrete expansion anchors indicates:

1) Concrete expansion anchors demonstrate negligible slippage (walking) under dynamic conditions at a load level equivalent to one-fourth the ultimate capacity of the anchor.

2) Noticeable anchor slippage (walking) does not occur in a concrete expansion anchor under dynamic conditions until the load level exceeds 60% of the ultimate capacity of the anchor.

An evaluation of manufacturer's test data and field test data obtained by Commonwealth Edison Company on concrete expansion anchors indicates the capacity of expansion anchors can be conservatively assumed to vary directly with the square root of the concrete compressive strength, f'_c. Certain manufacturers have even recommended that the ultimate capacity varies directly with the concrete strength. The in-place concrete strengths are consistently higher than the nominal design strengths for the following reasons:

1) Concrete exhibits a minimum 10% strength gain after one year and continues to gain strength at a reduced rate beyond one year.

2) Concrete mix proportions have been conservatively established, and concrete cylinder strengths closely monitored. Typical 28 and 90-day concrete cylinder breaks for non-flyash and flyash mixes have average strengths in excess of 20% the nominal design strength.

Concrete expansion anchor ultimate loads have been based upon a nominal concrete strength, f'_c, equal to 3500 psi. Considering these factors, the in-place concrete strength for nominal 3500 psi concrete would be 4600 psi (3500 x 1.2 x 1.1). This strength margin would result in a 15% increase in the ultimate capacity of the concrete expansion anchors which is not accounted for in design. In addition, there are many areas such as the containment buildings and reactor buildings in which the nominal concrete design strength equals 5500 psi. A 44% increase in the ultimate capacity of the anchors would result in this situation.

Tests performed on individual concrete expansion anchors and on concrete expansion anchored baseplate assemblies by the various expansion anchor manufacturers, and more recently by Teledyne-Brown Engineering, indicate that an elliptical interaction best defines expansion anchor capacity under combined tension and shear. The interaction equation would be of the following form:

$$\left(\frac{T}{T_{max}} \right)^{x} + \left(\frac{V}{V_{max}} \right)^{x} \leq 1.0 \qquad (1)$$

where:

- V = Applied shear load.
- T = Applied tension load.
- V_{max} = Maximum pure shear capacity for an individual anchor or assembly.
- T_{max} = Maximum pure tension capacity for an individual anchor or assembly.
- x = Exponent greater than 1.0

This equation can be reduced to:

$$(T)^x + \left(V \frac{T_{max}}{V_{max}} \right)^x \leq (T_{max})^x \qquad (2)$$

The test data indicates that the ratio of T_{max} to V_{max} varies from 0.80 to 1.2.

The design of expansion anchored baseplate assemblies for Dresden, Units 2 and 3; Quad Cities, Units 1 and 2; Zion, Units 1 and 2; LaSalle County, Units 1 and 2; and Byron/ Braidwood, Units 1 and 2, have been designed using a straight line interaction based upon the shear friction concepts using a coefficient of friction μ equal to 0.7. The resulting interaction curve is:

$$T + 1.4 V \leq T_{max}$$

It can be seen by inspection that the straight line interaction curve will result in smaller allowable loads than the elliptical interaction for all circumstances in which the ratio of T_{max} to U_{max} is less than 1.4. Attached are several typical ultimate shear tension interaction curves comparing the elliptical interaction determined by test with the straight line interaction used in design.

In August, 1978, Appendix B to ACI 349 was published in the ACI Journal. Beginning in 1979, ultimate concrete expansion anchor loads for LaSalle County, Units 1 and 2, and Byron/Braidwood, Units 1 and 2, were established in accordance with the proposed requirements of ACI 349, Appendix B. This criteria assures a ductile behavior of the individual anchor and precludes a non-ductile tensile failure of the concrete. This criteria yields factors of safety compatible with those used prior to 1979.

Commonwealth Edison Company has committed to performing a comprehensive static and dynamic testing program for concrete expansion anchors under the direction of an Independent Testing Laboratory. It is anticipated this testing program will demonstrate the ability of concrete expansion anchors to satisfactorily carry normal/upset and emergency/faulted loads using factors of safety equal to 4.0 and 2.0 against manufacturer's recommended ultimate loads, respectively. The results of this testing program will be available and reported to the Nuclear Regulatory Commission upon completion.

5. Determine the extent that expansion anchor bolts were used in concrete block (masonry) walls to attach piping supports in Seismic Category 1 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.

Response: Safety related piping systems have not been attached to concrete masonry walls. The field survey of concrete expansion anchors conducted to date at the operating plants, Dresden, Units 2 and 3; Quad Cities, Units 1 and 2; and Zion, Units 1 and 2, has substantiated that safety related piping systems have not been attached to concrete masonry walls. The present criteria for units under construction, LaSalle County, Units 1 and 2, and Byron/Braidwood, Units 1 and 2, do not permit safety related piping systems to be attached to concrete masonry walls.

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

Response: The use of concrete expansion anchors in concrete masonry walls at Dresden, Units 2 and 3; Quad Cities, Units 1 and 2; Zion, Units 1 and 2; LaSalle County, Units 1 and 2; Byron/Braidwood, Units 1 and 2, has been restricted to solid and grouted concrete masonry walls, and to the attachment of small loads, typically less than 500 pounds. Items falling under this category, for example, are electrical junction boxes and conduit. Heavier loads have not been permitted to be attached to concrete masonry walls, nor have concrete expansion anchors been used in hollow concrete masonry walls.

All concrete masonry walls have been designed for a concentrated live load of 180 pounds applied on one-foot wide horizontal beam strips, spanning the length of the wall over its entire height. The 180 pound concentrated live load has been placed on the beam strips to envelope the maximum resultant moment and shear. Items actually attached to concrete masonry walls are verified by field survey, and a final load check is conducted to assure the adequacy of the walls to carry the applied loads.

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.

Response: The allowable design loads for expansion anchors in concrete masonry walls have been determined by static tests conducted at various units currently under construction. The anchors in these tests were installed in solid concrete masonry units and in the masonry mortar joints. The ultimate loads for concrete expansion anchors installed in concrete masonry walls have, thereby, been established as approximately one-half of the corresponding allowables in plain concrete.

The following concrete masonry units were used at Dresden, Units 2 and 3; Quad Cities, Units 1 and 2; and Zion, Units 1 and 2:

1) Solid concrete masonry

a) Masonry units - ASTM C145, Type N-I blocks, having a minimum net compressive strength equal to 1800 psi.

b) Mortar - ASTM C270, Type N, having a minimum compressive strength equal to 750 psi at 28 days.

2) Grouted concrete masonry

a) Masonry units - ASTM C90, Type N-I blocks, having a minimum net compressive strength equal to 1800 psi.

b) Mortar - ASTM C270, Type N, having a minimum compressive strength equal to 750 psi at 28 days.

c) Grout - Conforming to ASTM C476.

The following concrete masonry units were used at Byron/ Braidwood, Units 1 and 2; and LaSalle County, Units 1 and 2:

1) Masonry units - ASTM C145, Type N-I blocks, having a minimum net compressive strength equal to 1800 psi.

2) Mortar - ASTM C270, Type M, having a minimum compressive strength equal to 2500 psi at 28 days.

The concrete masonry walls at Dresden, Units 2 and 3; Quad Cities, Units 1 and 2; Zion, Units 1 and 2; LaSalle County, Units 1 and 2; and Byron/Braidwood, Units 1 and 2, have been designed using elastic techniques. The allowable stresses in concrete masonry walls are in accordance with the National Concrete Masonry Association Specifications for Non-Reinforced Cocnrete Masonry. These stresses are:

Allowable Stess	Type M Mortar	Type N Mortar
Shear	34 psi	23 psi
Tension in flexure normal to bed joints	39 psi	27 psi
Tension in flexure parallel to bed joints	78 psi	54 psi

These allowable stresses are upon a factor of safety equal to approximately 3.0 against ultimate stresses.

No overstress has been permitted for OBE load combinations. A 1.6 overstress factor has been permitted for SSE load combinations. This results in a factor of safety equal to approximately 2.0 against ultimate stresses.

Concrete expansion anchor baseplate assemblies in concrete masonry walls have been analyzed using rigid plate theory. Commonwealth Edison Company has previously demonstrated that the rigid plate analysis procedure provides results compatible with a flexible plate analysis at the ultimate loading conditions when the effects of expansion anchor flexibility and baseplate flexibility are properly accounted for.

Commonwealth Edison Company has reviewed the deficiencies identified in IE Bulletin 79-28 concerning the adequacy of concrete masonry walls to support attached items at the Trojan plant, and has determined that a similar situation does not exist at Dresden, Units 2 and 3; Quad Cities, Units 1 and 2; Zion, Units 1 and 2; LaSalle County, Units 1 and 2; and Byron/Braidwood, Units 1 and 2.

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

   Response: Tests have been performed on the capacity of concrete expansion anchors in concrete masonry walls on several plants currently under construction. These static tests have indicated that the ultimate capacity of expansion anchors in solid and grouted concrete masonry walls be more than 50% of their corresponding capacity in plain concrete. Commonwealth Edison Company has committed to participate in a comprehensive static and dynamic test program to substantiate the behavior of expansion anchors in concrete masonry walls. These tests will include:

1) Static load tests on individual anchors.
2) Load relaxation tests on individual anchors.
3) Dynamic tests on individual anchors under the following conditions:
   a) Pipe transient cyclic loads.
   b) OBE and SSE seismic loads.

The test program will encompass the following combination of variables:

1) Expansion anchor types
   a) Wedge type anchors
   b) Self-drilling type anchors
2) Anchor diameters
   a) 3/8"
   b) 1/2"
   c) 5/8"
   d) 3/4"
3) Embedment Depth
   a) 4-1/2 anchor diameters
   b) 8 anchor diameters

4) Embedment material

a) Masonry units - ASTM C145, Type N-I blocks

b) Masonry mortar

1) ASTM C270, Type M

2) ASTM C270, Type N

The results of the static and dynamic test program for concrete expansion anchors in concrete masonry will be available and reported to the Nuclear Regulatory Commission upon completion.

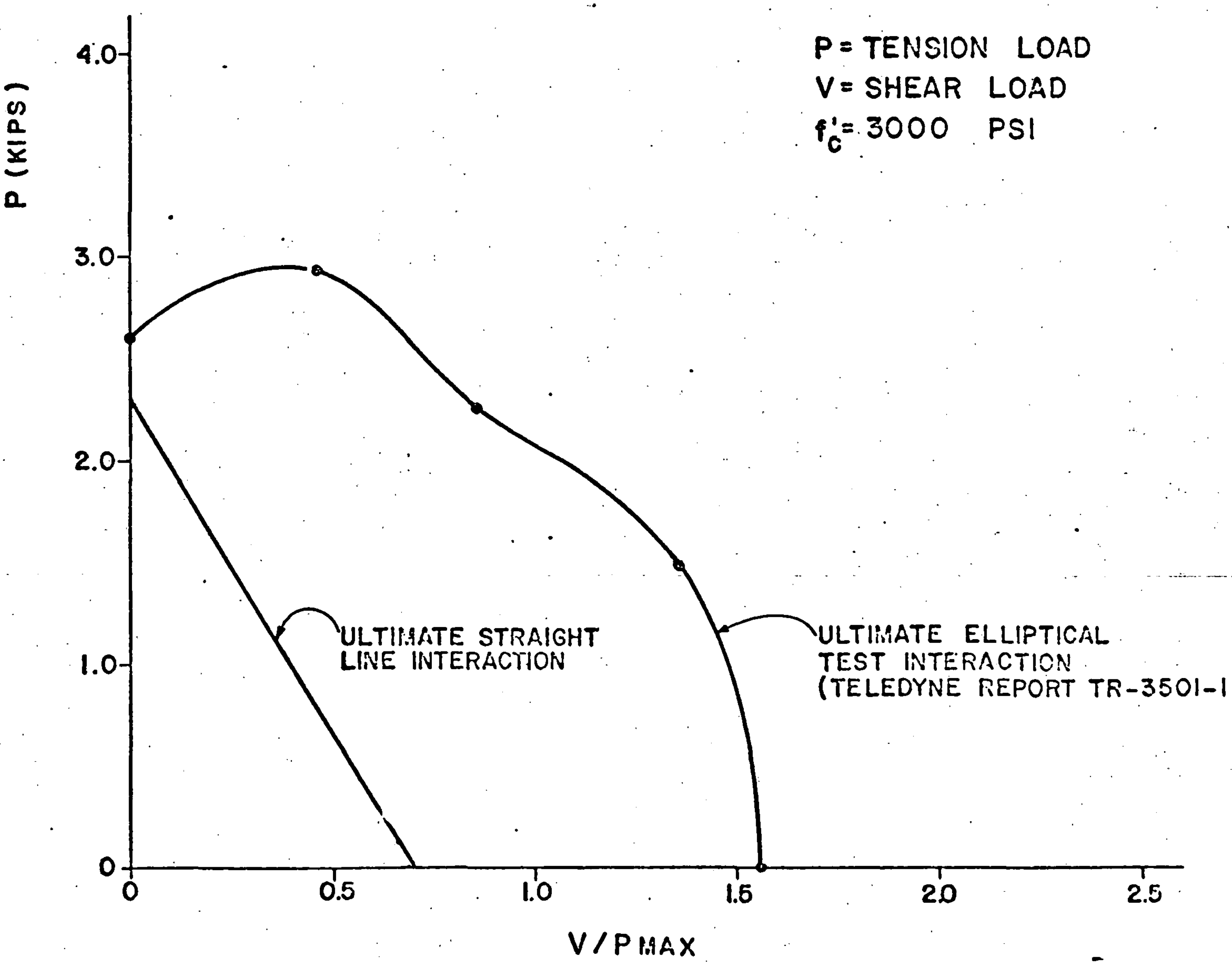
6. Determine the extent that pipe supports with expansion anchor bolts used structural steel shapes instead of base plates. The systems and lines reviewed must be consistent with the criteria of IE Bulletin No. 70-02, Revision 1. If expansion anchor bolts were used as described above, verify that the 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 systems involved, with the number of supports, type of anchor bolt, line size, and whether the supports are accessible during normal plant operation.

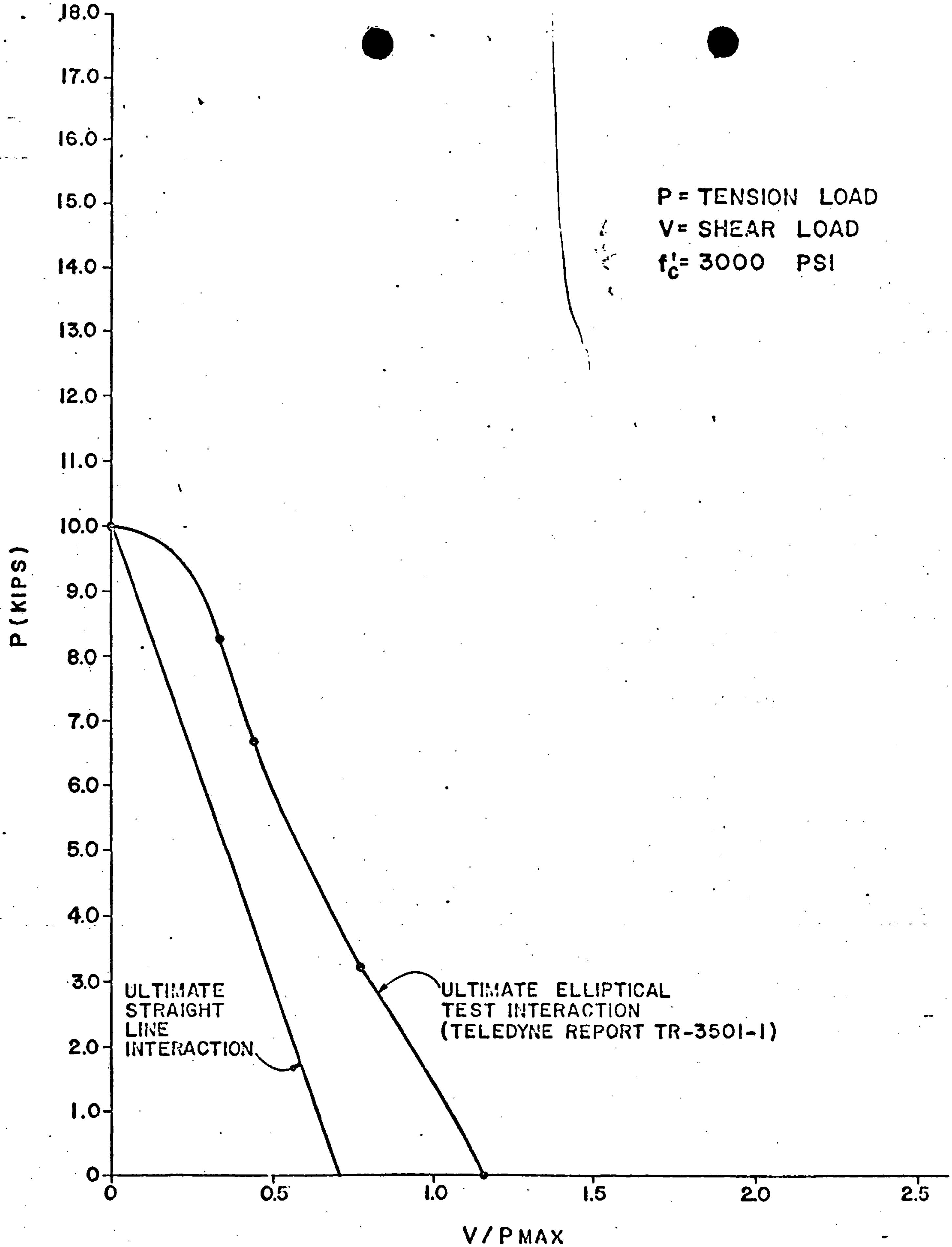
   b. Provide a detailed evaluation of the adequacy of the anchor bolt design and installation. The evaluation should address the assumed distribution of loads on the anchor bolts. The evaluation can be based on the results of previous anchor bolt testing and/or analysis which substantiates operability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

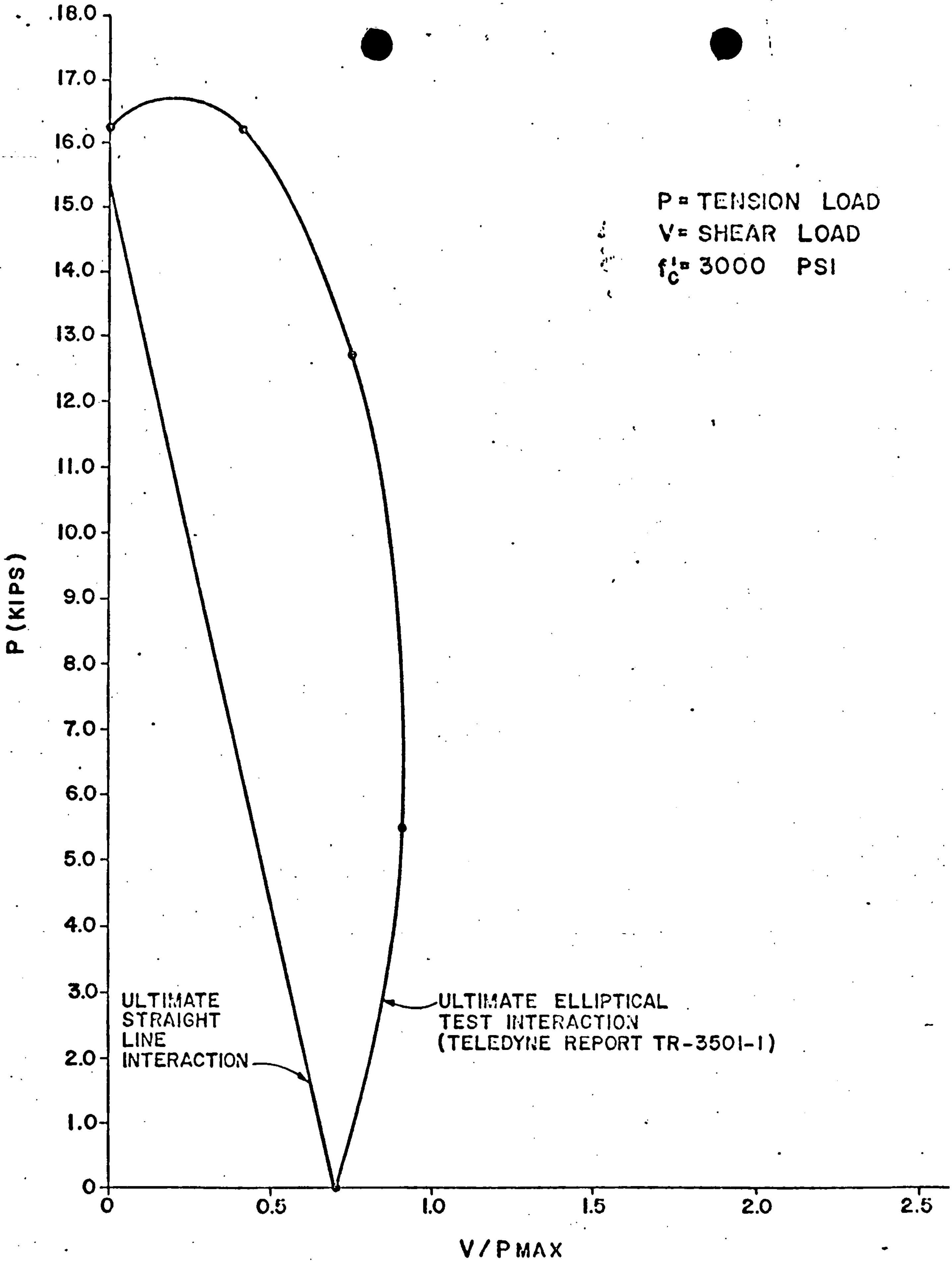
Response: Concrete expansion anchors have been used to attach structural steel shapes to concrete walls to support safety related piping systems. Structural angles have been the predominant steel shape used. These structural shapes have been used to support relatively light loads, less than 1,000 pounds, and have been included in the expansion anchor field verification programs in accordance with the criteria set forth in IE Bulletin 79-02, Revision 1.



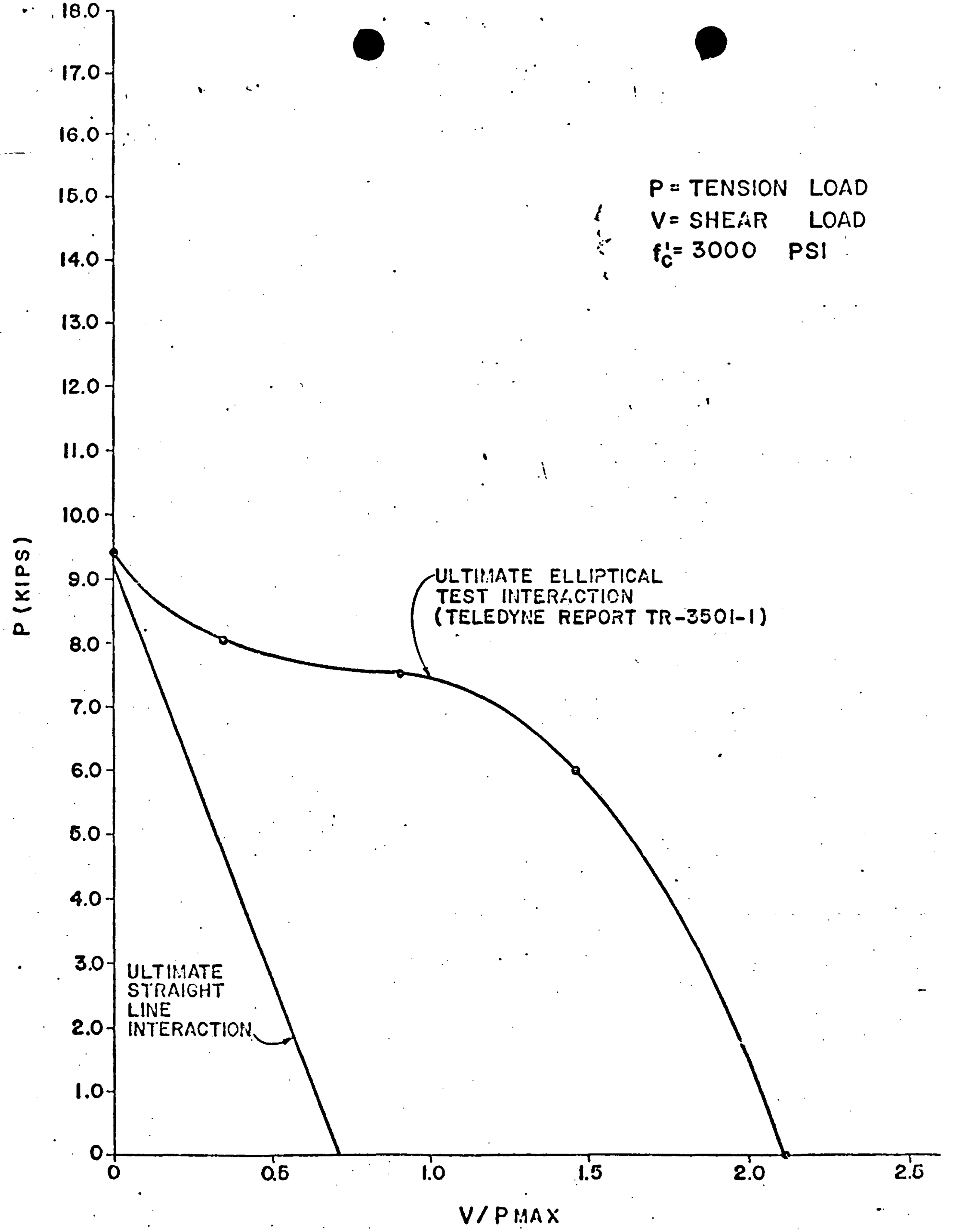
SHEAR TENSION INTERACTION FOR
3/8" Φ HILTI KWIK - BOLT
WEDGE ANCHOR (4.5 EMBDMENT)



SHEAR TENSION INTERACTION FOR
5/8" φ PHILLIPS SELF-DRILLING ANCHOR



SHEAR TENSION INTERACTION FOR
7/8" ϕ PHILLIPS SELF-DRILLING ANCHOR



SHEAR TENSION INTERACTION FOR
3/4" φ HILTI KWIK - BOLT
WEDGE ANCHOR (4.5 EMBDMENT)