PROCEDURE FOR ESTABLISHING ACCEPTANCE

CRITERIA FOR CONCRETE ANCHOR INSTALLATIONS

DIABLO CANYON POWER PLANT

EMVKELL

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PURPOSE

This procedure will develop inspection criteria that can be used to evaluate concrete anchor installations in the field.

SCOPE

This procedure will determine minimum acceptance criteria for misinstalled concrete anchors for the following conditions in nominal 3,000 psi design concrete: (1) wedge plugs not driven fully, (2) field modified anchors, (3) angular misalignment, and (4) effects of overembedment on shear strength.

This procedure will test 1/2", 5/8", 3/4" and 7/8" concrete anchors (flush shell type) manufactured by both the Phillips Drill Company, Inc. and the Hilti Corporation.

TEST PROCEDURE

A. TEST FIXTURE

The test fixture consists of a base, support structure, hydraulic cylinder with a hollow ram, pressure gauge, hand operated hydraulic pump, hydraulic hose and threaded rods of required sizes to fit anchors. (See Figure 1)

Also, a dial indicator with a magnetic base and various accessories to measure anchor movement will be used.

B. CALIBRATION OF TEST FIXTURE

1. Assemble the hydraulic cylinder, hand pump, pressure hose and calibrated pressure gauge.

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2. Using the concrete compression tester in the concrete testing lab, determine the load applied by the cylinder at various pressure readings as read on the pressure gauge. Record data on Data Sheet No. 1, "Hydraulic Cylinder Force."

NOTE: Make ten calibration runs. At each pressure plateau, record the hydraulic pressure and applied force. Average the ten readings at each pressure plateau and plot the average value on Figure 2.

3. Using the data from Data Sheet 1, develop a curve for Figure 2, "Cylinder Force vs. Hydraulic Pressure."

C. GENERAL TEST INSTRUCTIONS

1. Install anchor of type and size required for testing.

2. Position test fixture over embedded anchor and connect to anchor with threaded rod of required size.

3. Position dial indicator to detect anchor movement. The dial indicator should contact the shoulder of the anchor if possible. Use the dial indicator accessories, (i.e. magnetic base and extension rods) as required to assure that equipment deflection and rod stretch is not affecting the dial indicator.

4. Increase hydraulic pressure until the dial indicator detects movement of the anchor. Record hydraulic pressure on applicable data sheet at which movement is detected.

5. Continue increasing hydraulic pressure until one of the following conditions exist:

   a. the anchor has slipped five percent of the minimum embedment depth,

   b. the concrete cracks, or

   c. the anchor breaks.

   Record on applicable data sheet.

6. Vent hydraulic pressure and remove test apparatus.

7. Using Figure 2, "Cylinder Force vs. Hydraulic Pressure," determine load applied to anchor at which anchor movement is detected. Record the force on the applicable data sheet.

D. TESTING TO DETERMINE ACCEPTANCE CRITERIA

1.0 Unmodified Hilti Anchors

1.1 Plug Depth Before Driving

a. For each size of Hilti anchors, select ten at random.

b. Insert the expansion plug (by hand) as far as possible. Tap the plug lightly to assure it is seated on it's taper.

c. Measure and record the distance from the threaded end shoulder to the top of the plug on Data Sheet No. 2 for ten anchors.

d. From the data obtained, determine the average dimension that the plug can be inserted for each size of Hilti anchors and record on Data Sheet No. 2.

1.2 Minimum Depth of Expansion Plug to Meet Design Load

a. Drill holes in 3,000 psi concrete of the required diameter for each size of Hilti anchors to depths at which the anchors will be flush with the surface of the concrete.

b. Install anchor and drive the expansion plug 1/8". Record on Data Sheet No. 3.
NOTE: The depth of the expansion plug is determined by subtracting the average dimension for each size of Hilti anchor (obtained in Section 1.1) from the distance of the plug to the anchor threaded end shoulder after driving.

c. Perform pull test on anchor and record data at which anchor movement (or failure) is detected on Data Sheet 3. Record the pressure for both initial movement of the anchor and when the anchor has been displaced five percent of minimum embedment.
NOTE: The following are minimum acceptable values for anchor strengths, both for PHILLIPS and HILTI anchors. They are 10% greater than Table A values for 3,000 psi concrete in PG&E Engineering Standard No. 054162, Revision 2.

Anchor Size	Min. Acceptable Force
1/2"	965 lbs.
5/8"	1,650 lbs.
3/4"	2,585 lbs.
7/8"	3,685 lbs.

d. Compare pull-out force at initial anchor movement with the minimum acceptable values. If the minimum acceptable force is not met, rerun the test with the anchor expansion plug driven deeper. Increase plug depths in 1/8" increments. Use a new anchor, expansion plug and hole for each test.

e. If the minimum pull-out force is exceeded, run four more anchor pull tests with the plug driven the same minimum amount. Record data on Data Sheet No. 3.

NOTE: Five consecutive pull tests at a selected expansion plug depth must pass the minimum acceptable pull-out force before this plug depth can be established as a minimum field inspection criterion. If, during testing, any anchor fails at the selected plug depth, this depth is not satisfactory and the next deeper increment must be tested.

f. Determine the minimum expansion plug depth for 1/2", 5/8" and 3/4" HILTI Anchors and record findings on Data Sheet No. 3.

g. After once having determined the minimum plug depth to meet design load for each size of anchor, drive the expansion plug deeper in 1/8" increments and perform a pull test at each deeper increment until 300% design load is reached. Record information on Data Sheet No. 3.

h. For each anchor size, drive the expansion plug fully one time and test per above. Record findings on Data Sheet No. 3.

2.0 <u>Unmodified Phillips Anchors</u>

2.1 Plug Depth Before Driving

NOTE: Use Phillips test gauge as shown in Figure 3 for each size of Phillips anchors for measurements.

a. Select ten Phillips anchors. Insert the expansion plugs (by hand) as far as possible. Tap the plug lightly to assure that it is seated on it's taper.

b. Insert test gauge in each selected anchor and measure from the top of the expansion plug to the shoulder of the test gauge. Record the information on Data Sheet No. 2.

NOTE: It is extremely important that the test gauge be inserted as far as possible when obtaining measurements to assure that the test gauge is at the end of the threaded section.

d. Compare pull-out force at initial anchor movement with the minimum acceptable values. If the minimum acceptable force is not met, rerun the test with the anchor expansion plug driven deeper. Increase plug depths in 1/8" increments. Use a new anchor, expansion plug and hole for each test.

e. If the minimum pull-out force is exceeded, run four more anchor pull tests with the plug driven the same minimum amount. Record data on Data Sheet No. 3.
NOTE: Five consecutive pull tests at a selected expansion plug depth must pass the minimum acceptable pull-out force before this plug depth can be established as a minimum field inspection criterion. If, during testing, any anchor fails at the selected plug depth, this depth is not satisfactory and the next deeper increment must be tested.

f. Determine the minimum expansion plug depth for 1/2", 5/8" and 3/4" HILTI Anchors and record findings on Data Sheet No. 3.

g. After once having determined the minimum plug depth to meet design load for each size of anchor, drive the expansion plug deeper in 1/8" increments and perform a pull test at each deeper increment until 300% design load is reached. Record information on Data Sheet No. 3.

h. For each anchor size, drive the expansion plug fully one time and test per above. Record findings on Data Sheet No. 3.

2.0 Unmodified Phillips Anchors

2.1 Plug Depth Before Driving
NOTE: Use Phillips test gauge as shown in Figure 3 for each size of Phillips anchors for measurements.

a. Select ten Phillips anchors. Insert the expansion plugs (by hand) as far as possible. Tap the plug lightly to assure that it is seated on it's taper.

b. Insert test gauge in each selected anchor and measure from the top of the expansion plug to the shoulder of the test gauge. Record the information on Data Sheet No. 2.
NOTE: It is extremely important that the test gauge be inserted as far as possible when obtaining measurements to assure that the test gauge is at the end of the threaded section.

c. From the data obtained above, determine the average dimension that the plug can be inserted for each size of Phillips anchors and record on Data Sheet No. 2.

2.2 Minimum Depth of Expansion Plug to Meet Design Load

a. Test Phillips anchors as outlined in Section 2.1 except for the following.

(1) The depth of the expansion plug is the difference from the top of the plug to the shoulder of the test gauge (after driving plug) and the distance determined in 2.1.

(2) Record pull-out data on Data Sheet No. 4 and develop minimum field acceptance criteria for Phillips anchors.

(3) Perform Step 1.2.g for Phillips anchors and record on Data Sheet 4.

(4) Perform Step 1.2.h for each size of Phillips anchors and record on Data Sheet 4.

3.0 Modified Anchors

3.1 HILTI ANCHORS - Establishing a Reference Point for a Modified Anchor

a. Select ten Hilti anchors at random for 1/2", 5/8" and 3/4".

b. Record the distance from the face of the threaded end to the end of the threaded section for each anchor. Record measurements on Data Sheet No. 5.

c. Drill holes of required diameters to the depths noted below.

Anchor Size	Hole Depth
1/2"	1 3/8"
5/8"	1 3/4"
3/4"	2 1/16"

d. Install anchor in the holes and drive the plug until the end of the threaded section is just visible.

e. Perform one pull test on each size anchor with the plugs driven to this depth and record the required information on Data Sheet No. 5.

NOTE: If the anchor fa[illegible]s to meet minimum acceptance criteria at the plug d[illegible]hs in Step 3, reperform this test with the plugs dr[illegible]n deep enough to pass minimum acceptance criteria.

3.2 PHILLIPS ANCHORS - Establishing a Reference Point for a Modified Anchor

NOTE: The distance that the expansion plug is driven can be determined by measuring from the plug to the end of the threaded section. Since this measurement has previously been obtained in Section 2.0, this test on Phillips anchors is not required.

3.3 HILTI ANCHORS - Expansion End Cut Off
(Perform this test for each size of anchor)

a. For each size of anchor, determine the minimum depth that the plug must be driven to meet minimum acceptable design load. Record on Data Sheet No. 15. (See Section 1.? and Data Sheet No. 3 for minimum plug depth)

b. Insert the expansion plug by hand, as far as possible. Tap the plug lightly to assure that it is seated on it's taper.

c. Measure overall length of unmodified anchor and record on Data Sheet No. 15.

d. Measure the distance from the shoulder of the expansion end to the plug. Record on Data Sheet 15.

e. Subtract the minimum distance that the plug must be driven to meet design load (obtained from Data Sheet No. 3) from the distance obtained in Step d. Cut off this amount from the anchor expansion end. Record information on Data Sheet No. 15.

f. Drill a hole in concrete to the required depth so that the modified anchor will be flush or slightly above the surface of the concrete. Record hole depth on Data Sheet No. 15.

g. Insert the anchor and drive the expansion plug fully. Record the distance that the plug was driven.

h. Perform a pull test on the modified anchor and record information on Data Sheet No. 15.

i. Repeat Steps e through h for the same size anchor, except decrease the amount cut off in 1/4" increments until 300% design load is reached.

j. Perform this test for each size of Hilti anchor.

3.4 PHILLIPS ANCHORS - Expansion End Cut Off
(Perform this test for each anchor size)

a. Remove 3/4" from the expansion end of the anchor.

b. Measure the overall length of the modified anchor and record on Data Sheet No. 16.

c. Drill hole depth as required to allow the anchor to be flush with the top surface after fully driving expansion plug. Record hole depth on Data Sheet No. 16.

d. Insert anchor in hole and drive plug fully.

e. Measure the distance that the plug has been driven using the appropriate test gauge. Record on Data Sheet No. 16.

f. Perform a pull test on the anchor and record information on Data Sheet No. 16.

g. Repeat this test, increasing the amount removed from the expansion end in 1/4" increments, until the anchor no longer meets minimum design load.

3.5 HILTI and PHILLIPS ANCHORS - Threaded End Cut Off

a. Obtain one anchor for each size and type.

b. Cut off the threaded end until four full threads remain on each anchor.

c. Perform a pull test on each anchor. The hole depth should be deep enough so that the anchors are flush with the top surface of the concrete after driving their expansion plugs. The plugs should be driven fully for each anchor. Record information on Data Sheet No. 6.
NOTE: The pull test need not be performed to failure. Terminate the test at 300% of the design load.

4.0 Angular Misalignment

4.1 15° Misalignment - Plugs at Minimum Depth to Meet Design Load.

a. Perform one pull test for each size and type of anchor. The plugs are to be inserted to the minimum depths that have been determined to meet design load (Sections 1.0 and 2.0). The holes are to be drilled as close to 15° from vertical as possible. The hole depths are to be flush with the surface of the concrete after driving the expansion plugs. Record information on Data Sheet No. 8.

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3.4 PHILLIPS ANCHORS — Expansion End Cut Off
(Perform this test for each anchor size)

a. Remove 3/4" from the expansion end of the anchor.

b. Measure the overall length of the modified anchor and record on Data Sheet No. 16.

c. Drill hole depth as required to allow the anchor to be flush with the top surface after fully driving expansion plug. Record hole depth on Data Sheet No. 16.

d. Insert anchor in hole and drive plug fully.

e. Measure the distance that the plug has been driven using the appropriate test gauge. Record on Data Sheet No. 16.

f. Perform a pull test on the anchor and record information on Data Sheet No. 16.

g. Repeat this test, increasing the amount removed from the expansion end in 1/4" increments, until the anchor no longer meets minimum design load.

3.5 HILTI and PHILLIPS ANCHORS - Threaded End Cut Off

a. Obtain one anchor for each size and type.

b. Cut off the threaded end until four full threads remain on each anchor.

c. Perform a pull test on each anchor. The hole depth should be deep enough so that the anchors are flush with the top surface of the concrete after driving their expansion plugs. The plugs should be driven fully for each anchor. Record information on Data Sheet No. 6.

NOTE: The pull test need not be performed to failure. Terminate the test at 300% of the design load.

4.0 <u>Angular Misalignment</u>

4.1 15° Misalignment - Plugs at Minimum Depth to Meet Design Load.

a. Perform one pull test for each size and type of anchor. The plugs are to be inserted to the minimum depths that have been determined to meet design load (Sections 1.0 and 2.0). The holes are to be drilled as close to 15° from vertical as possible. The hole depths are to be flush with the surface of the concrete after driving the expansion plugs. Record information on Data Sheet No. 8.

4.2 15° Misalignment - Plugs Fully Inserted.

a. Perform one pull test for each size and type of anchor with their holes as close to 15° from vertical as possible. The expansion plugs are to be driven fully and the hole depths are to be deep enough for the tops of the anchors to be flush with the surface of the concrete. Record on Data Sheet No. 7.

5.0 Shear Loading Over Embedded Anchors

5.1 HILTI ANCHORS - Perform Once for Each Size of Anchor.

a. Drill holes of required size in a vertical concrete surface. Hole depths should be sufficiently deep to embed the anchors 1/2" below the surface of the concrete.

NOTE: Drill the holes at the required height above the floor so that the hydraulic cylinder may be placed on the floor and apply a shear force to the anchor bolt.

b. Drive the expansion plugs fully on each anchor to be tested.

c. Insert a bolt of the proper size through the shear load test fixture shown in Figure 4. Tighten the bolt.

d. Position the hydraulic cylinder under the test fixture.

e. Increase the hydraulic pressure until the anchor or the bolt fails, or 300% design load is reached. Record information on Data Sheet No. 9.

6.0 Discussion and Conclusions

6.1 Anchor Uniformity

Data Sheets 2 and 5 indicate that anchors are manufactured with sufficient uniformity to use various reference points on the anchors to measure distances that expansion plugs are driven. Measurements were repeatable within 1/16" and in most cases, 1/32".

6.2 Expansion Plugs - Minimum and Fully Driven Distances

The following table summarizes test results for both (1) fully driven expansion plugs and (2) expansion plugs driven to minimum depths and still meet acceptance criteria. The results are from Data Sheets 3 and 4, including the remarks for each entry. An anchor was considered to have failed when it's total displacement exceeded 0.010".

Anchor Size and Type	1/2" HILTI	5/8" HILTI	3/4" HILTI	1/2" PHILLIPS	5/8" PHILLIPS	3/4" PHILLIPS	7/8" PHILLIPS
Minimum Acceptable Force Required	965 lbs.	1650 lbs.	2585 lbs.	965 lbs.	1650 lbs.	2585 lbs.	3685 lbs.
Min. Acceptable Plug Driven Distance / % of Fully Driven Plug Distance	3/8" / 63%	3/8" / 55%	1/4" / 29%	3/16" / 50%	1/2" / 76%	1/2" / 84%	1/2" / 73%
Ave. Force Dev. at Min. Plug Driven Dis. / % of Min. Acceptable Force	4010 lb. / 416%	3039 lb. / 184%	3475 lb. / 134%	1606 lb. / 166%	3312 lb. / 201%	6576 lb. / 254%	5692 lb. / 154%
Fully Driven Plug Distance	19/32"	11/16"	7/8"	3/8"	21/32"	19/32"	11/16"
Force Developed For Fully Driven Plug / % of Min. Acceptable Force	4910 lb. / 508%	6140 lb. / 372%	11,000 lb. / 426%	3740 lb. / 388%	2380 lb. / 144%	6750 lb. / 261%	5890 lb. / 160%

Testing was performed in the northwest corner of the Diablo Canyon auxiliary building, elevation 64. Concrete in that area is typical of 3000 psi concrete used throughout the plant.

Anchor slippage was the predominate mode of failure, even for fully driven expansion plugs. Hilti anchors generally held until the applied force was sufficient to cause them to move. Once movement began, it continued quickly to failure. Generally, the force required to maintain a steady displacement was less than the force that initially caused slippage.

Phillips anchors also failed by slipping, however, their mode of slippage was different than Hilti anchors. Once slipping began, and if the applied force was then held constant, the anchors would eventually stop slipping. Increasing the force would reinitiate anchor slipping. Holding the force constant at a larger value would allow the anchor to stabilize again. Further force application would cause the same effect until the point at which the anchor no longer stabilized; it would either slip to failure (especially true for small expansion plug driven distances) or the concrete failed because it's shear cone became too small (especially true for anchors with their expansion plugs driven farther or fully driven).

Some Phillips anchors were tested into the slip range and ultimately to failure. Several tests were performed in which the load was held constant after slipping had begun. After a short time, the anchor displacement stabilized. The load was released and then, slowly reapplied. The anchor was able to withstand the load at which slipping had originally begun without further displacement. The force required to reinitiate slipping was approximately the same as that at which the anchor had previously stabilized. Larger forces would then cause correspondingly larger anchor displacements until the ultimate force was reached causing total failure.

Conclusion - Anchors with their expansion plugs driven at least the distances shown in the above table will develop sufficient strengths to meet minimum acceptable loads.

6.3 Modified Anchors - Threaded End Cut Off

Results obtained from Data Sheet 5 indicate that if Hilti expansion plugs are driven to the point at which the end of the threaded section is just visible, only the 3/4" Hilti anchor will develop sufficient force to meet the acceptance criterion. The expansion plugs for 1/2" and 5/8" Hilti anchors must be driven 3/16" and 3/32" beyond the end of the threaded section, respectively, to meet acceptance criteria. These additional plug depths were required to meet the minimum plug driven distances previously established.

Data Sheet No. 6 contains results of anchors modified by cutting off the threaded end until four full threads remained. Generally, concrete failure, either cracking or shear cone pull-out, occurred during Hilti anchor testing. This can be attributed to the anchors being closer to the surface of the concrete. Phillips anchors exhibited their typical slipping phenomonon during this testing phase; their failure occured with no apparent concrete damage. The effective grip area of Phillips anchors is farther below the concrete surface than that for Hilti anchors, hence the differences in failure modes. The following summarizes results of Data Sheet No. 6:

Forces Developed With Threaded End Cut Off

Anchor Size and Type	Max. Amount Cut Off	Force Dev. at Failure	% of Min. Acceptable Force
1/2" Hilti	1/2"	2860 lb.	296%
5/8" Hilti	25/32"	4710 lb.	285%
3/4" Hilti	1 1/8"	7350 lb.	284%
1/2" Phillips	5/8"	3340 lb.	346%
5/8" Phillips	1/2"	5310 lb.	322%
3/4" Phillips	1 1/8"	7770 lb.	301%
7/8" Phillips	15/16"	11,200 lb.	304%

Conclusion - Anchors with their threaded end cut off to the extent shown above, will meet minimum acceptable loads. However, their expansion plugs must be fully driven and hole depths must be sufficient to allow the anchors to be flush with the concrete surface.

6.4 Modified Anchors - Expansion End Cut Off

Cutting off the expansion end reduced the anchor's ability to withstand loads. The forces required to cause initial movements of Hilti anchors decreased as more of the expansion ends were removed. However, the reverse is true for Phillips anchors. In all cases, the modified anchors were able to exceed the minimum acceptable test loads. The following summarizes test results contained in Data Sheets 15 and 16:

Expansion End Cut Off

Anchor Size and Type	Max. Amount Cut Off	Force Dev. at Failure	% of Min. Acceptable Force
1/2" Hilti	9/32"	3210 lb.	333%
5/8" Hilti	3/8"	3175 lb.	192%
3/4" Hilti	11/16"	3500 lb.	135%
1/2" Phillips	7/8"	2080 lb.	216%
5/8" Phillips	1"	2980 lb.	181%
3/4" Phillips	1 1/16"	3730 lb.	144%
7/8" Phillips	1 1/2"	9570 lb.	260%

Conclusion - The expansion end of anchors can be cut off to the extent shown above and still maintain sufficient strengths to meet acceptance criteria. However, the expansion plugs must be driven fully and hole depth must be sufficient to allow the anchor to be flush with the concrete surface.

6.5 Angular Misalignment

Anchors installed approximately 15° from vertical were still able to meet minimum acceptance criteria. The following summarizes test results contained in Data Sheet 7 and 8:

	Plugs Fully Driven		Plugs Driven Min. Distance	
Anchor Size and Type	Applied Force	% of Min. Acceptable Load	Applied Force	% of Min. Acceptable Load
1/2" Hilti	3130 lb.	324%	3100 lb.	322%
5/8" Hilti	5725 lb.	347%	1740 lb.	105%
3/4" Hilti	8820 lb.	341%	2670 lb.	103%
1/2" Phillip	2900 lb.	300%	2170 lb.	225%
5/8" Phillip	5725 lb.	347%	2940 lb.	178%
3/4" Phillip	7770 lb.	300%	4120 lb.	135%
7/8" Phillip	11,420 lb.	310%	10,000 lb.	271%

Phillips anchors did not exhibit the previously experienced slip phenomenon when angularily misinstalled. They generally were able to sustain larger loads than equivalent properly installed anchors.

Conclusion - Anchors with expansion plugs driven at least the minimum distances previously established can be misinstalled up to 15° from vertical and still meet minimum acceptance criteria.

6.6 Over Embedment Effects on Shear Strengths

All Hilti anchors easily exceeded 300% minimum acceptable shear strength values. There was no evidence of concrete failure after testing, however, threads on the bolts were slightly flattened. Several bolts were bent approximately two to five degrees.

Minimum acceptable shear strength values are 10% greater than Table A shear values for 3000 psi concrete in PG&E Engineering Standard 054162, Revision 2.

Phillips anchors were not tested because their self drilling feature prevents overembedment. However, the same test results would have been obtained had Phillips anchors been tested.

Conclusion - Over embedding anchors up to 1/2" below the surface of the concrete will not affect the shear strength of the bolted connection.

6.7 Testing in 5000 psi Concrete

Testing was not performed in 5000 psi concrete because design did not take credit for the extra strength developed by

5000 psi concrete. Also, the failure mode predominately encountered was anchor slippage, not concrete failure. In the few cases where concrete failed, stronger concrete should produce more favorable results.

Since testing in 5000 psi concrete was not performed, Data Sheets 10 through 14 have been deleted from the procedure.

APPENDIX

CONTENTS:

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19. Data Sheet 15 - Hilti Anchor-Expansion End Cut Off

20. Data Sheet 16 - Phillips Anchor-Expansion End Cut Off

21. Data Sheet 17 - Instruments Used During Testing

22. References:

a. "Concrete Expansion Anchors for Static and Seismic Loading", Engineering Design Standard 054162, Change 2, 4/17/73.

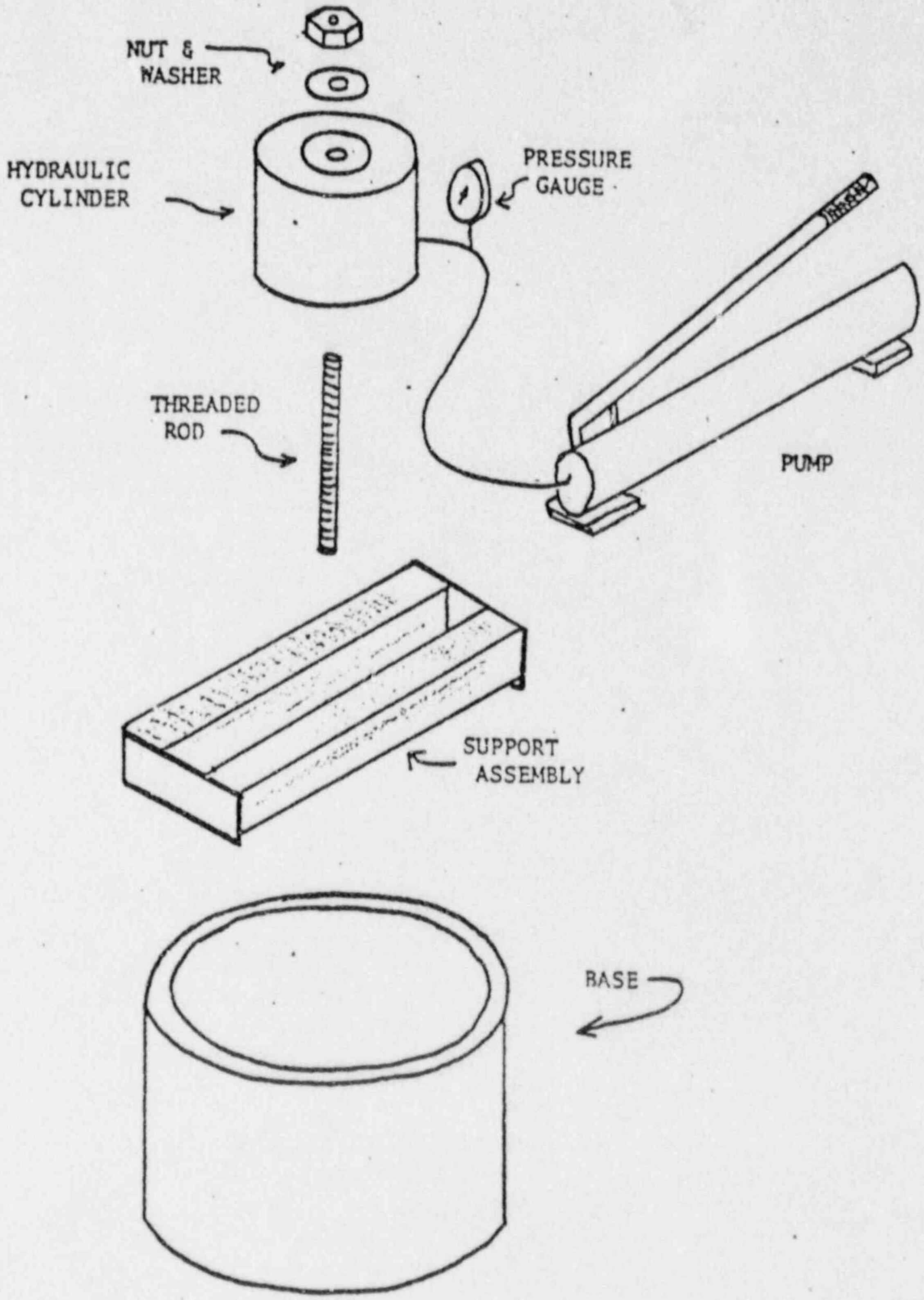

FIGURE 1 - PULL TEST FIXTURE

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