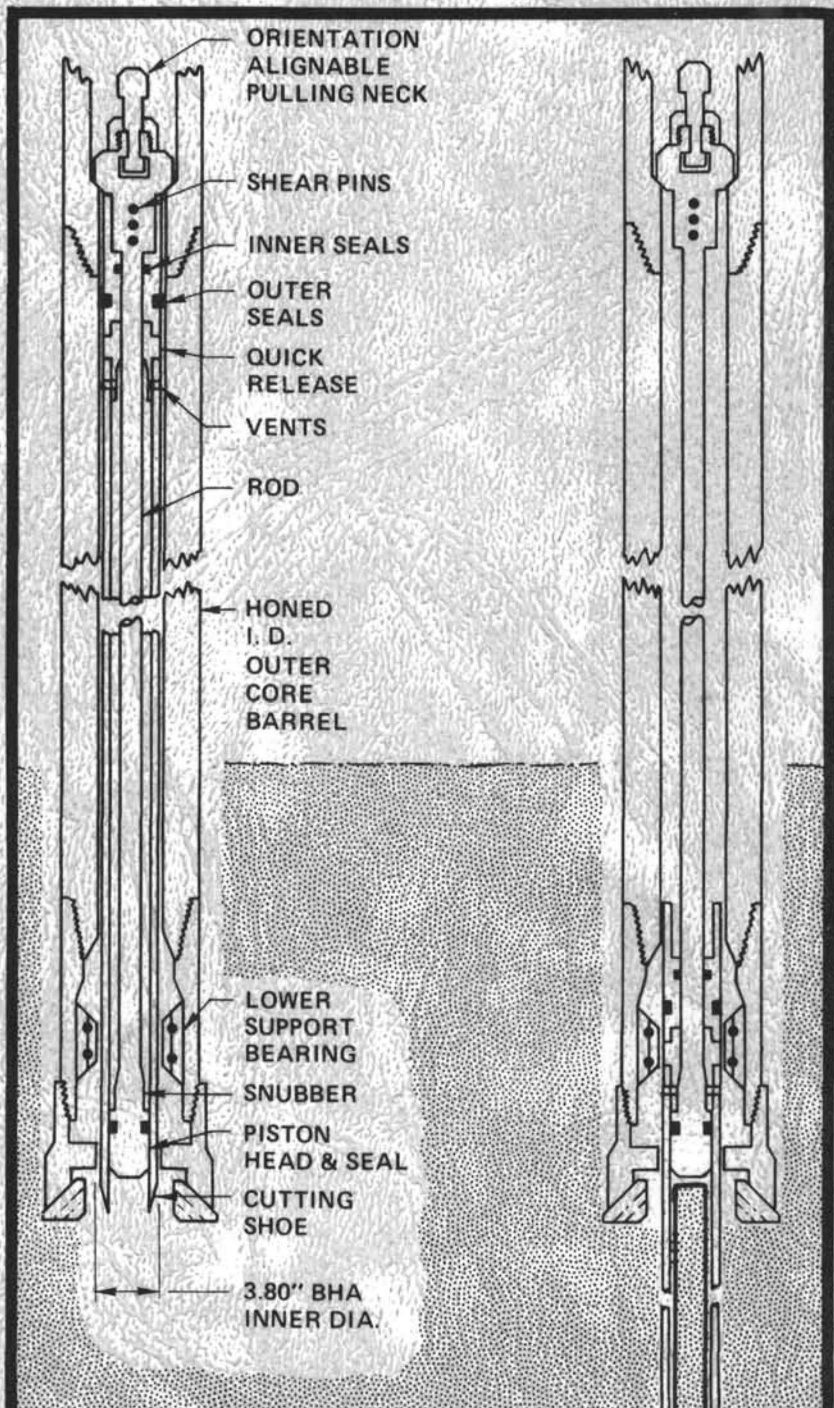
INTERNATIONAL PHASE OF OCEAN DRILLING (IPOD)
DEEP SEA DRILLING PROJECT®
DEVELOPMENT ENGINEERING
TECHNICAL REPORT NO. 21

DESIGN AND OPERATION OF AN ADVANCED HYDRAULIC PISTON CORER



SCRIPPS INSTITUTION OF OCEANOGRAPHY
UNIVERSITY OF CALIFORNIA AT SAN DIEGO
CONTRACT NSF C-482
PRIME CONTRACTOR: THE REGENTS, UNIVERSITY OF CALIFORNIA

The Cover Illustration

A simplified version of the Advanced Piston Corer (APC) in action is depicted. At left, the corer has been landed in the bottomhole assembly so that the outer seals are activated against the bore of the Outer Core Barrel. At the right, the core has been taken by pressuring up to shear the pins and drive the scoping section of tool into the sediment.

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Design and Operation of An Advanced Hydraulic Piston Corer

Prepared for the
National Science Foundation
National Ocean Sediment Coring Program
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by the

University of California
Scripps Institution of Oceanography
Prime Contractor for the Project

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INTRODUCTION

DEEP SEA DRILLING PROJECT

The Deep Sea Drilling Project (DSDP) began coring in August, 1968, under the auspices of the National Science Foundations's (NSF) Ocean Sediment Coring Program to increase man's knowledge of the earth's development through the exploration of the ocean floor. The prime contract for the Project was executed in 1966 between NSF and the Board of Regents of the University of California (UC). Scripps Institution of Oceanography in La Jolla, California, which is part of the UC system, is responsible for the management and operation of the Project. Global Marine, Inc. (GMI) of Los Angeles, owner, designer, and builder of the GLOMAR CHALLENGER, subcontracted with Scripps to provide the drilling vessel for the drilling and coring program.

To plan the scientific objectives of the program, major oceanography institutions in the United States (including Woods Hole Oceanographic Institution, Lamont-Doherty Geological Observatory of Columbia University, Rosenstiel School of Marine Sciences of the University of Miami, the University of Washington and Scripps), joined in an agreement to mutually support such a program of deep ocean drilling. This association is called the Joint Oceanographic Institutions for Deep Earth Sampling (JOIDES) and provides scientific guidance for the Deep Sea Drilling Project. The group was later enlarged to include nine American institutions.

INTERNATIONAL PHASE OF OCEAN DRILLING

Prompted by the vast scientific and technical successes of the first seven years, the Project increased the scope of the coring program to include even deeper penetrations into the ocean floor. International interest in the Project increased. Several foreign scientific institutions, excited by past scientific results and confident of future successes, were interested in becoming members of JOIDES. These institutions were willing to contribute financially to the Projection exchange for a greater role in the scientific planning. In 1975, the " International Phase of Ocean Drilling ", known as IPOD, was born. IPOD was an initial three year Deep Crustal coring Porgram supported both scientifically and financially by the governments of France, Germany, Japan, England, and Russia.

D/V GLOMAR CHALLENGER

The GLOMAR CHALLENGER, with its unique coring procedures, has long been recognized as a major technical achievement in its own right. The 10,500 metric ton drill ship utilizes an advanced on board computer and dual bow and stern thrusters to dynamically position itself. The CHALLENGER has operated as far north as 76 degrees latitude; as far south as 77 degrees latitude and has the capability to maintain its station in 30-knot winds and 7-10 foot seas. Similar to conventional drillships, the vessel incorporates a 43-meter derrick amidship with a hookload capacity of 450 metric tons and can deploy a 7000 m drill string. The CHALLENGER utilizes an automatic pipe racker capable of handling 7,300 meters of 5-inch S-135 drill pipe, and is equipped with a drill pipe heave compensation system.

Most coring operations are conducted in very deep water and all sites are carefully screened to ensure that there is no possibility of encountering gas or hydrocarbons. For these reasons no riser or blow prevention equipment is used. Circulation while coring is provided by two National 1600 mud pumps and consists of seawater without return circulation. Core barrels are retrieved by wireline utilizing a coring winch equipped with up to 7900 m of 6 x 16 wire rope. Well equipped shipboard scientific laboratories are utilized to conduct comprehensive core analyses.

ABSTRACT/TECHNICAL REPORT NO. 21

This Deep Sea Drilling Project Technical Report documents the history, incentives, development and testing of the Advanced Piston Corer (APC) - the third generation in the wireline retrievable, piston coring technology in DSDP. Description and operational guidelines of the latest design iteration, APC Mod. II, are included. Operational sea trials of the Mod. I version are summarized. Appendices are included with related reports, design calculations and machine drawings.

The hydraulic piston corer technology developed by the DSDP engineering staff was successful from the first sea trials of the first 15-ft prototype model. Soon thereafter the Variable Length Hydraulic Piston Corer (VLHPC) was introduced and quickly revolutionized the science of coring in soft marine sediments. The VLHPC could take cores up to 9.5 meters in length but in doing so required a total tool length of nearly 100 feet in the extended condition when retrieved. The APC was developed to achieve equivalent length and quality piston cores using a tool only 60-plus feet long in the retrieved condition and about half as mechanically complex as the VLHPC. By employing the inside of the outer core barrel as a seal surface the hydraulic working area and available coring force were increased by 76% over the VLHPC.

The APC was designed for greater tolerance to overpull tensile loads when extracting the tool from sticky formations as well as more control of selected coring force and velocity. Sea trials of the prototype version were successfully completed during Legs 94, 95, and 96. Design modifications pointed up by the sea trials were incorporated into the current Mod. II version.

ACKNOWLEDGEMENTS

The Advanced Piston Corer was originally conceived by Mr. Michael Storms and Mr. David Huey, DSDP Development Engineers. The idea was to achieve a significant simplification over the VLHPC developed by Mr. Storms and others. Mr. Huey was the APC project engineer, acted as Cruise Operations Manager during Leg 95 sea trials of the tool and prepared this report. Mr. Donald Cameron and Mr. Glen Foss were the Cruise Operations Managers during Legs 94 and 96, respectively, and oversaw sea trial testing during those cruises. The Development Engineering Department of DSDP was under the direction of Mr. Stanley Serocki.

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I. BACKGROUND

The Deep Sea Drilling Project's two original piston corers - the HPC-15 and Variable Length Hydraulic Piston Corer (VLHPC) - were phenomenal successes in making possible an entirely new realm of wireline coring in non-indurated sediments from below the ocean floor. The VLHPC represented a quantum advance in design over the prototype HPC-15 with its variable length capability (from 3.5 to 9.5 m cores), but optimization of the concept came in jumps and spurts over a period of several years because the immediate success of the tool led to a demand for a high usage rate with little or no time allotted for field engineering experimentation or shipboard analyses.

One of the features added in the VLHPC was a Quick Disconnect mechanism in the middle of the assembly which allowed the long tool to be readily separated into two (approximately 30-ft long) sections to facilitate handling on deck during routine core removal. The Quick Disconnect experienced a series of failures when overstressed during the process of pulling the extended corer out of sticky sediments. The design of the Quick Disconnect led to an unavoidable weak link in the overall tool design in spite of attempts to optimize tensile "pull-out" load carrying capability.

During a design analysis to devise alternate means of carrying the problematic pull-out loads the concept was suggested of a corer which traveled down the inside of the Outer Core Barrel (the lowest drill collar) and landed at the Support Bearing located just above the core bit. Fig. 1 illustrates this initial concept. Such a tool would not telescope out as the HPC-15 and VLHPC did and thus would not need to be over 60-ft. long in order to take a 30-ft. core. Thus, no Quick Disconnect weak link would be used. This tool concept involved abandoning many of the principal functional components proven in the VLHPC design. The entire upper working section of the VLHPC, for example, would have to be discarded. In its place would have to be components to serve the same purposes, i.e. achieve an initial landing point in the bottomhole assembly (BHA) relative to the core bit, achieve an initial hydraulic seal, store hydraulic energy and release it suddenly for the coring action, and land again at the bottom of the stroke.

It was not immediately obvious if the initial seal and consequent build-up and release of hydraulic energy would be sufficient to power the tool. If not, a dynamic seal might be required to continue imparting driving thrust to the corer until the end of the stroke. It was, also, not clear if the internal piston used in the VLHPC could be deleted. If the piston was later determined to be necessary, the question was how exactly it could be incorporated in the shorter - concept tool.

Each of these questions and many others raised doubts about the feasibility of the concept, but the potential advantages of a hydraulic piston corer about half as long, complex and expensive as the VLHPC made the concept well worth pursuing.

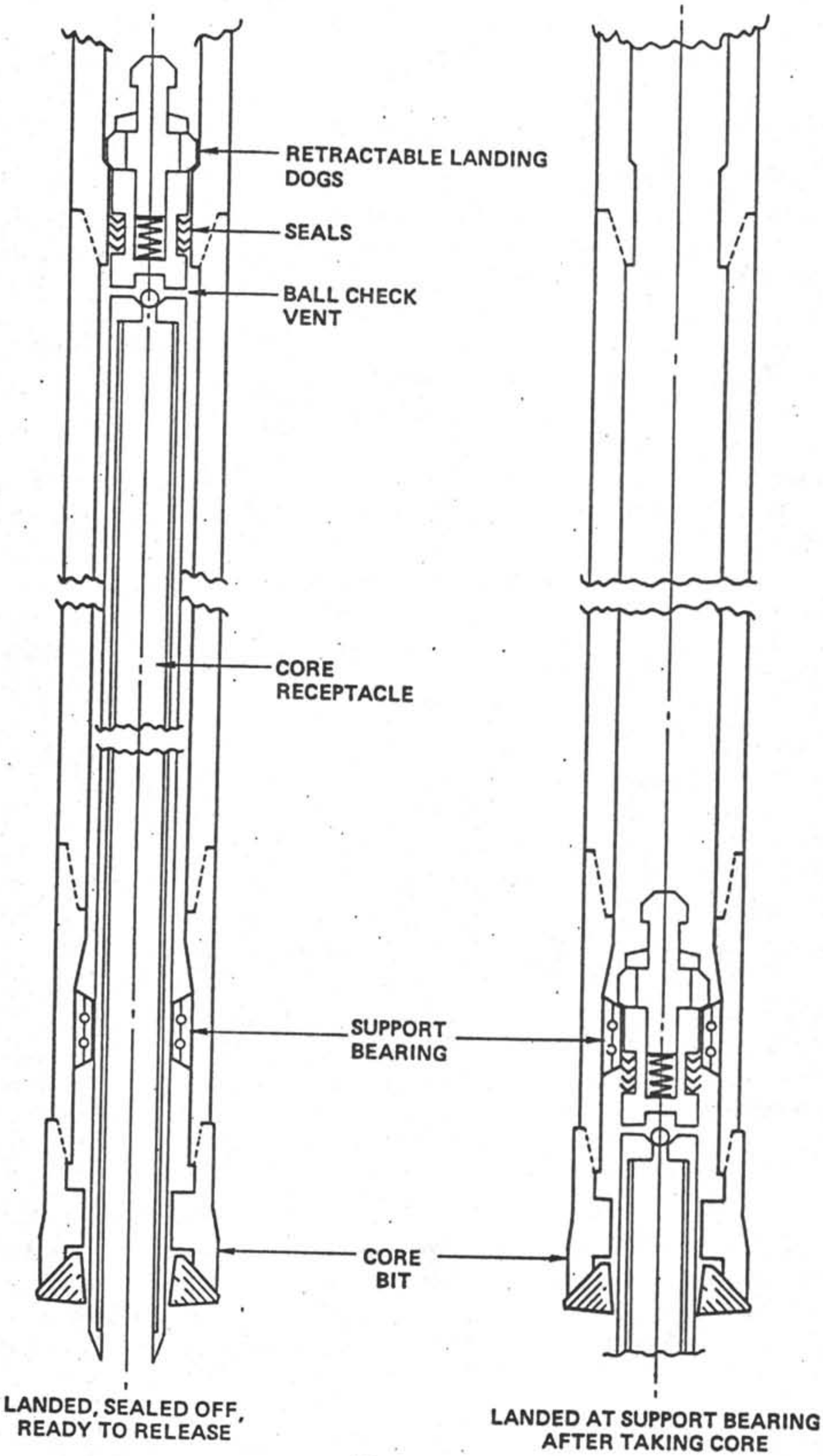


FIG. 1.

Initial concept of a non-telescoping hydraulic piston corer which would travel down the Outer Core Barrel.

At the same time the DSDP Development Engineering Dept. was busy evaluating the potential of an hypothetical Air Chamber Piston Corer (ACPC). It had been established that one of the secrets of success of the VLHPC had been the utilization of stored energy in the form of compressed sea water in the drill string. However, the potential pV energy available in a collapsible atmospheric chamber at great depths was far greater than the maximum stored energy produced hydraulically from the ship's mud pumps and could be much more efficiently converted to mechanical thrust. A piston corer operated by the atmospheric chamber principle would offer coring forces up to three times greater than the VLHPC limit.

Since the best overall piston corer was sought, a comparative analysis of the three competing concepts (VLHPC, APC, ACPC) was performed. Fig. 2 is a graphical comparison of coring forces possible with each of the concepts. The VLHPC and APC offered variable coring forces dependent upon the pressure built up before the shear pins were overcome and the stored energy was released. The force to drive the ACPC, on the other hand, would be dependent on hydrostatic pressure, a function only of depth of operation. Fig. 2 shows how this factor could work for or against the choice of the ACPC as an optimum coring tool. The ability to be able to select the coring force of any piston corer, regardless of operation depth, was thought to be a significant advantage, however.

Another meaningful comparison was utilization of total available stored energy for each of the candidate systems. In all three cases, available stored energy would be a function of operation depth. The Air Chamber tool stored potential energy in the form $E = pV$. With working volume, V, constant the energy available would be strictly a function of hydrostatic pressure, p, or depth. All of the available energy would be converted to useful energy when the corer "fired" since the working volume would decrease to essentially zero. The VLHPC and APC tools would also store energy before "firing" by means of a very small but significant quantity of compressed sea water within the drill string as well as the slight elastic expansion of the drill string elements themselves. The magnitude of this stored energy would be a function of the length of the drill string, or the depth of operation. Unlike the ACPC, all of the potential energy would not be effectively used by the VLHPC or APC. In both tools the expanding sea water would drive the telescoping portion of the corer but total effective expansion would be limited to the working volume within the tools. When the working volumes reached their physical limits any excess compressed water would expand out the bottom of the pipe without doing any useful work. Fig. 3 is a graphical presentation of this information for several different operating depths.

It can be seen from Figures 2 and 3 that both the APC and ACPC offered real advantages over the VLHPC while retaining the best features of hydraulic piston coring in general. The Air Chamber tool offered the greatest possible coring force, up to 49,000 lbs. thrust, as well as the most efficient utilization of stored energy and the greatest potential stored energy. Its prime drawback in these comparisons was depth-sensitivity. The APC did not approach the ACPC in efficiency or power potential at great depths but significantly surpassed the VLHPC in all categories and was not depth-sensitive.

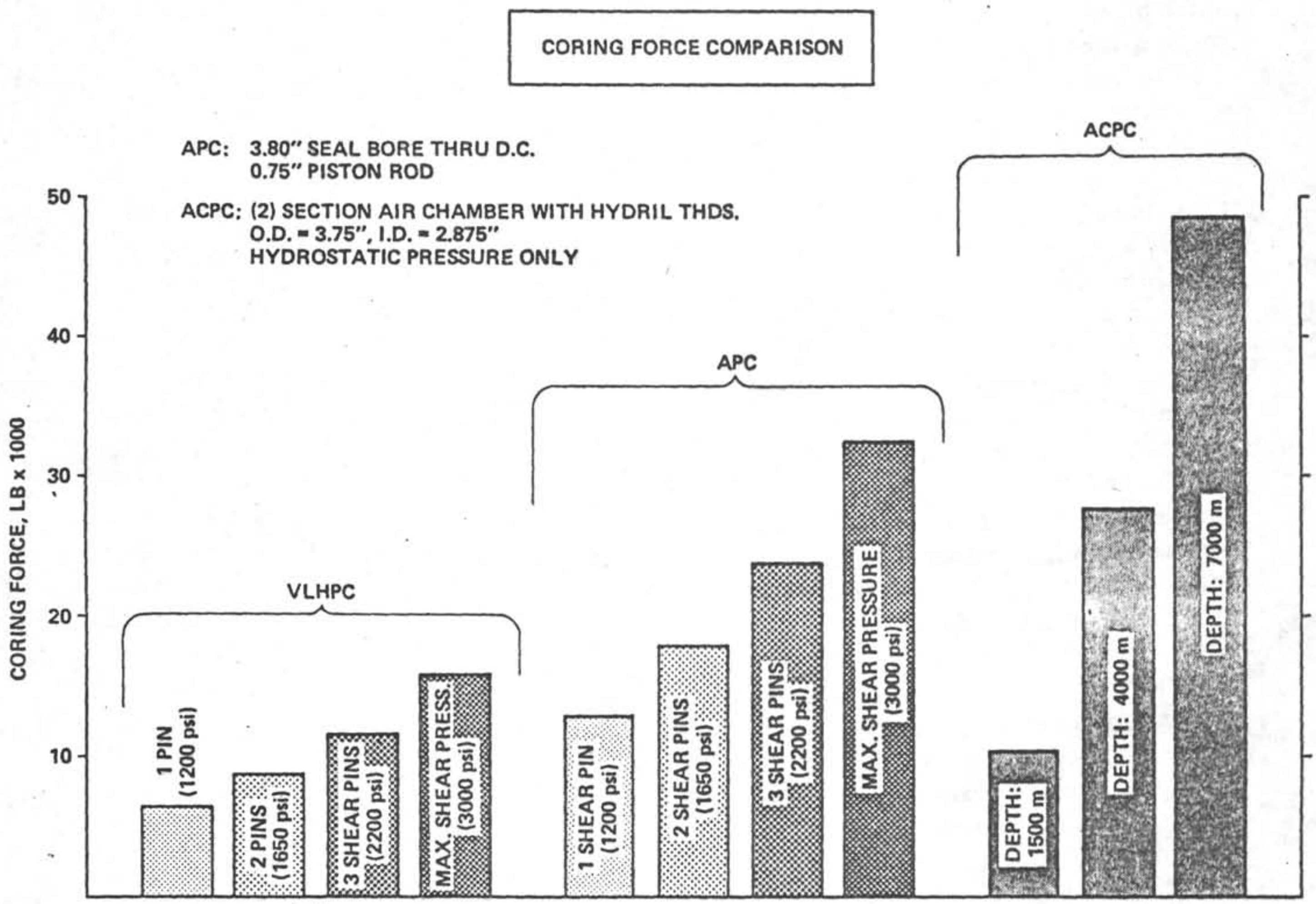


FIG. 2.

Potential Coring Force Comparison for candidate piston corer concepts (VLHPC = Variable Length Hydraulic Piston Corer, APC = Advanced Piston Corer, ACPC = Air Chamber Piston Corer)

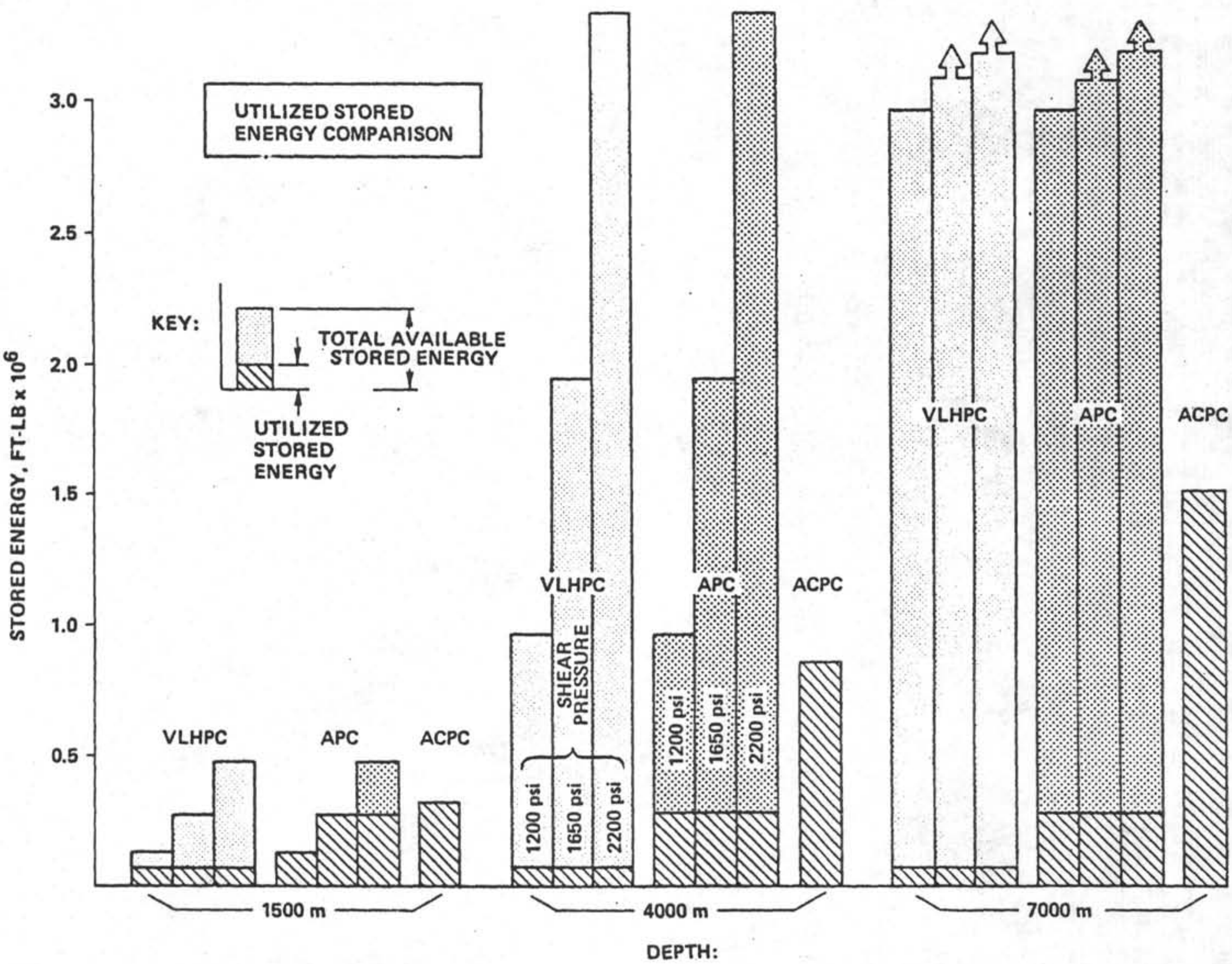


FIG. 3.

Stored Energy Comparison for candidate piston corer concepts.
(VLHPC = Varible Length Hydraulic Piston Corer,
APC = Advanced Piston Corer, ACPC = Air Chamber Piston Corer)

In Table 1 the force and energy comparisons are listed along with other advantage/disadvantage decision factors. The decision made from this tabulation was to proceed with a full commitment to develop a new hydraulic piston corer based on the APC concept. This decision was made on the basis of potential improvements over the existing VLHPC in cost, mechanical complexity and ease of on-deck handling (the latter being quite a significant factor in rough weather for reasons of time saved and personnel safety). The extra force available with the ACPC was not considered enough advantage to offset the high costs and unknown technological difficulties. It is ironic that the original thought which prompted the APC concept -- elimination of a tension-vulnerable Quick Disconnect mechanism -- was not even one of the ultimate factors in choosing to develop the tool.

TABLE 1
ADVANCED PISTON CORING SYSTEM
ADVANTAGE/DISADVANTAGE MATRIX

	VLHPC	APC	ACPC
Max. Length For Rig Floor Handling • Collapsed • Scoped Out	 ~ 60' ~ 62'	 ~ 32' ~ 32'	 ~ 60' ~ 62'
Mech. Complexity	-	1/2 of VLHPC	20% More
Reliability	Proven	Same as VLHPC	No Core if Main Seals Fail
Coring Force	15.8 k lb_f max.	32.7 k lb_f max.	Varies with Depth
Stored Energy Used	Low	4 x VLHPC	Very High ? 10.3k - 48.8 k ft-lb_f
Estim. Cost Per Tool	$20,000	≃ $9,000	≃ $25,000
Development Cost	-	≃ $20,000	≃ $35,000
Use With Heave Comp?	No	Yes	No
Primary Disadvantage	• Long, Hard to Handle • Low Coring Force & Energy Utization • Excessive Complexity	• Probably Requires Seal Bore Thru D.C.	• Long, Hard to Handle • Expensive • Unproven Seals
Primary Advantages	• Track Record • Excellent Cores	• Low Cost, Complexity Easy To Handle • Heave Comp. In Adds To HF/PW Work • Improved Force	• Max. Coring Force at Deep Sites • Leads To Future Technology

II. ENGINEERING DEVELOPMENT

A. PROTOTYPE DESIGN

1. Feasibility Study

The first step in development of the APC after making the decision to proceed was to initiate a technical feasibility analysis to assess the following questions:

a) Determine if the concept was viable in the form sketched in Fig. 1 where the main seals were essentially static and sealed only to build up the initial "shoot off" energy. In this scenario the entire tool would travel down the Outer Core Barrel and extend into the sediment,

b) Determine if, atlernatively, a dynamic seal would be necessary to maintain a driving thrust over the entire stroke,

c) Analyze the feasibility of venting the trapped sea water above the incoming core material and determine the net effect of such required venting on corer performance.

To accomplish this first step the John E. Halkyard Co., private engineering consultants, was engaged to perform a formal Feasibility Analysis. Their report appears in Appendix A The approach in the Halkyard Study was to first generate an approximate expression for penetration resistance of a piston corer working in "medium clay". This was done by modeling the cored material as a viscous, non-newtonian fluid and using fluid dynamic relationships to relate coring resistance, sediment shear strength and velocity of the corer. The tentative mathematical model established was compared to actual shore-test results of the prototype HPC-15 to establish a generalized penetration resistance factor to be used for corer concept comparison. The Halkyard Study then went on to calculate performance curves (penetration depth vs. time) for the APC concepts. Also, the problem of back pressure generated by fluid venting paths was integrated into the analysis.

The conclusions of the analysis were that,

a) a dynamic seal providing coring force for the entire stroke of the tool was necessary to achieve full (or maximum possible) penetration in firm sediments; a simple "shoot off" system did not effectively utilize the stored energy available;

b) a very advantageous by - product of using a continuous seal in the Outer Core Barrel was a large increase in piston working area as compared to the working surface of the VLHPC (approximately 76% increase) which would yield higher coring thrust at any given operating pressure;

c) a piston head fixed in place by a rod assembly was recommended following analysis of back pressures exerted on the cored material; the piston head/ rod arrangement used in the VLHPC would have to be incorporated into the APC design;

d) specific, incremental performance analyses of any design to determine probable penetration vs. velocity was not only possible but essential; a relatively simple computer program should be used to predict performance and enable design parameters to be varied and evaluated.

2. Prototype Design Goals

Following the encouraging results of the Feasibility Analysis, a design phase was begun with establishment of the following goals:

a) Determine a means of producing a Drill Collar (Outer Core Barrel) 30-ft long, 8-1/4" O.D., with a honed, close-tolerance, step free seal bore;

b) Select an appropriate release mechanism to hold the scoping portion of the tool while running down the drill string, store the built-up hydraulic energy, and then release it suddenly to propel the tool into the sediment (the shears pins used with the VLHPC had experienced some shortcomings of pre-shearing and irregular shoot-off pressures);

c) Layout the tool components to determine if a quick release means of shortening the tool on deck would be required for ease of core removal or rig floor handling; if so, determine whether an inner barrel component or Piston Rod disconnect be better;

d) Design the overall system to safely accomodate pull-out loads up to 100,000 lbs. for extracting the extended core barrel from sticky sediment;

e) Determine the optimum means of connection to the tool for a (paleomagnetic) orientation tool;

f) Ensure that the tool was capable of operating in a BHA which could also accept an Extended Core Barrel (XCB).

3. Seal Bore Outer Core Barrel (Drill Collar)

The success of the APC concept with its dynamic outer seals depended to a great degree on the ability to produce a drill collar with a controlled inner diameter to act as the seal surface. Standard drill collars produced for the oil industry do not have seal surface quality requirements and the fabrication technology necessary is not common.

Two designs for the Outer Core Barrel were considered: one piece construction with a honed bore, and two piece, using a finished I.D. liner in a conventional drill collar. The liner technique was questionable in the details of how to fix the liner rigidly in place and how to prevent crevice corrosion between the liner and drill collar body. The liner plan was eventually abandoned when the single piece collar proved feasible, both technically and economically.

Corrosion resistant alloys for the drill collar were considered briefly since pitting or severe scale corrosion on the seal surface would render the part useless. The technology to produce, procure and fabricate drill collars in lengths exceeding thirty feet in materials such as Type 316 stainless or Monel was either non-existant or very expensive (up to 4 times the cost alloy steel). Alloy steel was selected.

The Outer Core Barrels ultimately specified were produced by Chance Collar Co. of Pearland, Texas using some recently developed fabrication techniques. The inside diameter was made by trepanning from one end only to produce a stepless rough bore. The outside, 8-1/4" diameter was then turned to be concentric with the bore. Finally, the inside diameter was honed over the full length to produce an RMS 32-63 finish with a diameter tolerance of + 0.040" - 0.000". The Outer Core Barrels were made of fully heat treated, AISI 4145H alloy steel and had 6-5/8 FH threaded connections on the ends. To preserve the upper threaded, box connection a Landing/Saver Sub was included in the overall BHA plan. This sub was designed to be semi-permanently attached to the top of the Outer Core Barrel so that the box thread connection on the drill collar itself would not be made and broken with every usage. The Sub also provided a landing shoulder for the tool that could more easily be re-machined when worn. The problem of corrosion of the seal surfaces was designated as a maintenance priority, especially during periods of storage after deployment in sea water.

4. Compatibility with the Extended Core Barrel (XCB)

Second and third generation development of the XCB coring tool system was concurrent with the APC development. Because these two tools were seen as the probable coring systems of the future, serious consideration was given to maintaining compatibility between them in the design of the APC. Prior to the advent of the XCB, rotary coring could not follow piston coring without a pipe round trip to change the BHA and core bit.

The XCB was initially made compatible with the longer, VLHPC by including a special Seal/Latch/Landing Sleeve which was installed in the BHA, where both tools landed, the VLHPC sealed off and the XCB latched down. The APC was a shorter tool, intentionally, than the XCB and landed at a point in the BHA lower than the latch sleeve required to hold down the XCB. Several critical dimensions for both tool systems were established to insure full compatibility in a common BHA (refer to Fig. 4):

1) the APC seal bore = 3.800/3.840" dia.;

2) The APC landing shoulder = 4.000/4.005" dia.; this was the maximum drift diameter of the drill pipe;

3) maximum O.D. for any XCB component which was to be located within the 3.8" APC Outer Core Barrel bore = 3-1/2" dia.; this was necessary to avoid excessively high pressure drops within the flow annulus around the XCB asembly through which the sea water was pumped to the bit jets; the XCB would land at the APC Landing/Saver Sub;

4) XCB Latch Sleeve I.D. = 4-1/8" dia.; a special, dead-bolt type latch was designed for the XCB.

5. Designing for Pullout Loads

One of the major problems encountered in using the VLHPC was the high tension loads imposed on the various components of the tool assembly when pulling the core barrel free from high traction formations. A combination of wall friction and suction tended to hold the barrels firmly in certain types of sediment, requiring pullout loads at times exceeding 100,000 lbs. The VLHPC had not been originally designed with this problem in mind and component overload failures at loads as low as 30,000 lbs. had been experienced all too frequently. Attempts to beef up the weak links were only partially successful largely due to the restrictions imposed on retrofit designing.

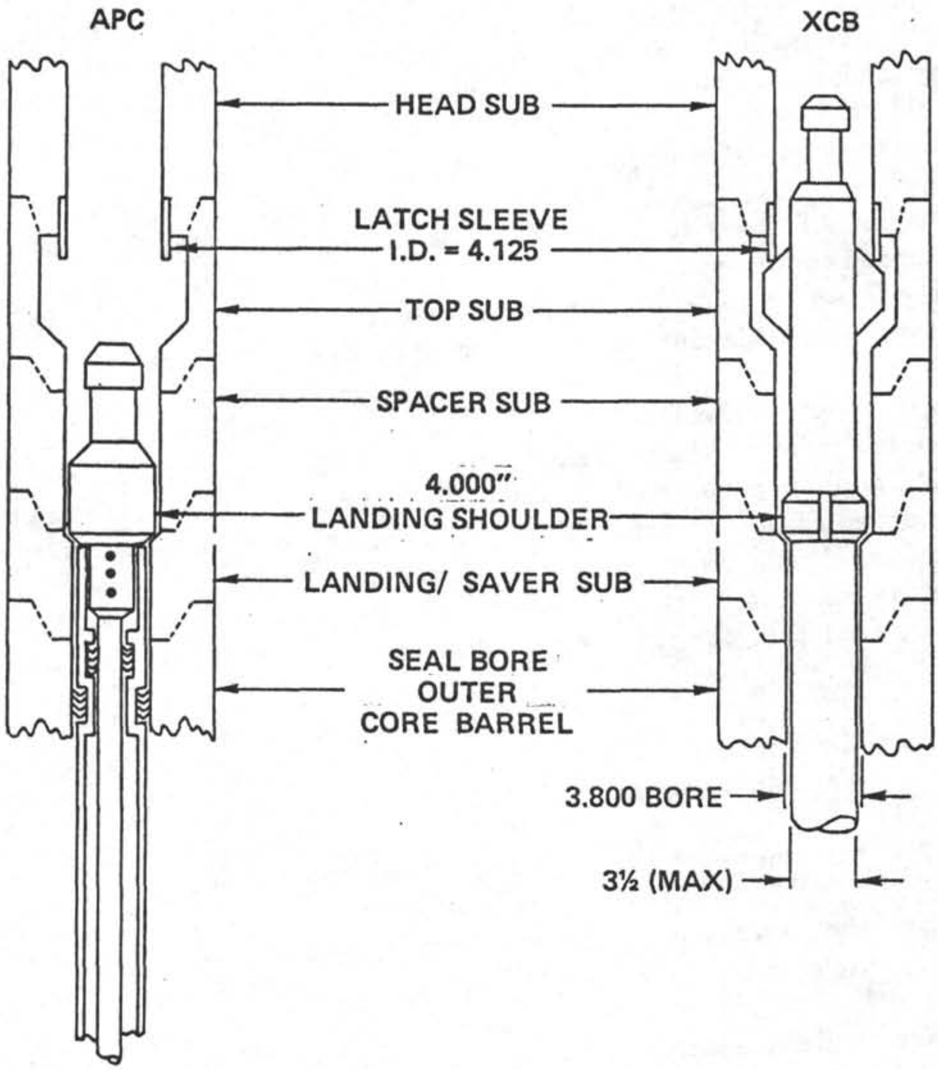


FIG. 4.

Bottomhole Assembly Layout for compatibility between the XCB and APC.

In the early design stages of the APC this problem was not only expected to be significant but, if anything, to be more severe as a result of the 76% greater driving force that would be available (as compared to the VLHPC). A balanced design was sought so that all natural weak links in the system could be sized to tolerate an equal tensile load. The layout of the APC called for pullout to be accomplished by pulling the drill string with the drawworks until the core barrel was free as indicated by absence of overpull. The limit of overpull was arbitrarily selected to be 100,000 lbs. for two reasons. First, for long drill strings 100,000 lbs. overpull was the safe limit designed into the drill string deployment plan to avoid overloading the uppermost pipe joints. Second, overpulls in excess of 100,000 lbs. were not considered safe for the traveling block, power sub or rig floor personnel even when short drill strings would have eliminated the pipe overstress problem. Any inadvertent, sudden release of overpull tension at loads over 100,000 lbs. would cause a highly undesireable rebound of the above-deck rig hardware with the potential of equipment damage or injury to personnel.

Thus the APC was to be operationally limited to 100,000 lbs. overpull with all loaded components to be designed to tolerate that load level plus as much safety factor as could practically be included. Fig. 5 is a schematic illustration of the APC layout showing critically loaded components.

Initial layout of the tool assembly had dictated that an inner barrel Quick Release similar to that developed for the VLHPC would best suit the on-deck handling problems. A piston Rod Assembly Quick Disconnect was abandoned since it would overly weaken the Rod or require an excessive Rod diameter. In the right half of Fig. 5 the core barrel has been extended to take the core and is ready for extraction by raising the entire drill string. It can be seen that the three most vulverable components to the tensile load would be

1) the threaded Piston Rod connections (since a 33-ft single piece Rod was impractical),

2) the inner barrel Quick Release mechanism and,

3) the several Inner Barrel threaded connections below the Quick Release.

The Quick Release mechanism employed with the VLHPC carried tension loads on two rectangular "lugs" engaged in windows (J-slots). Past failures of these parts revealed that bearing stress overload of these lugs was the initial step in ultimate failure. By increasing the total area of the load carrying surface of the lugs the load limit of the mechanism could be correspondingly increased. For the APC maximum lug surface area was achieved within the geometric limits imposed and a third lug was added to the two used on the VLHPC. This brought the minimum tensile failure load up to a calculated

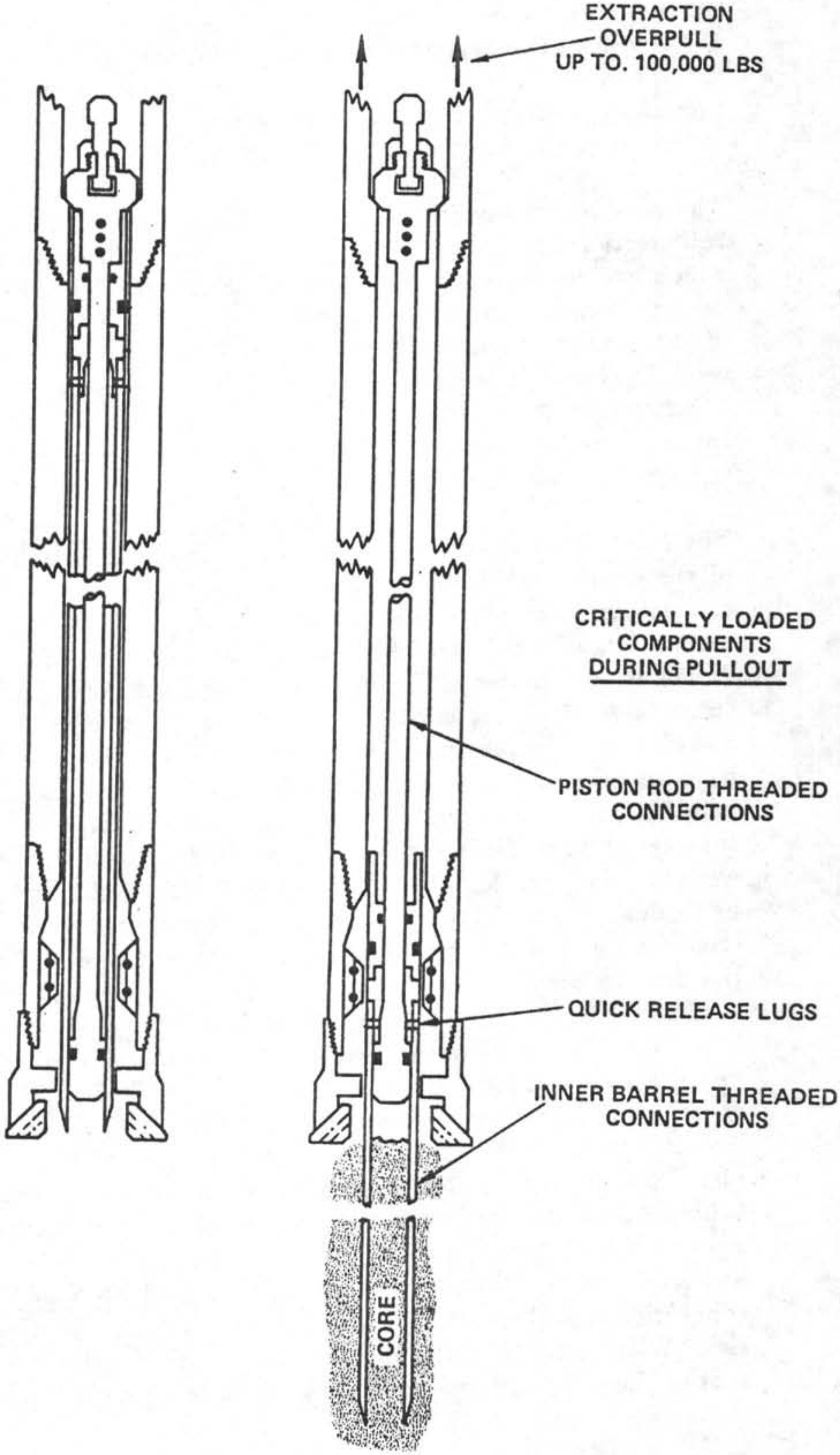


FIG. 5.

ADVANCED PISTON CORER SCHEMATIC.
At left, landed in the BHA.
At right, hydraulically " shot off " into the sediment.
Critically loaded components during extraction overpulls are indicated.

139,500 lbs. The asymetrical design (two lugs on one side, one on the other) also aided in assuring correct assembly of the Quick Release halves for proper paleomagnetic core orientation each time the core barrel was redressed and reassembled.

The core barrel assembly below the Quick Release was made up of several tube sections, 3-1/2" O.D. x 2-7/8" I.D. A tapered, Stub Acme thread form, which had been standardized for all DSDP core barrels for many years, was used to connect the various sections. During high pullout situations several of these connections would be required to carry the full tensile load. The weak links were the pin connections which were rated in various analyses at 133,200 to 159,600 lbs. yield strength. No changes to the standard DSDP Inner Barrel Thread was expected to be necessary to match the required strength for 100,000 lb. overpulls.

The most sensitive design problem in achieving a complete assembly capable of sustaining high pullout loads was the selection of Piston Rod threaded connections. The process required an iterative procedure involving the interaction of four variables: details of the type and size of threads, rod diameter, rod material (limited by commercial availability), and heat-treat strength level of the chosen material (to balance yield strength, toughness and ductility). The initial tool layout showed that the Piston Rod would have to be about 33-ft long overall. For ease of fabrication, shipping and handling the Rod assembly was to be made of three, eleven foot sections - thus two intermediate connections would be required. Since the inner seals were to travel the length of the Piston Rod assembly the connections had to be flush on the O.D. Minimum acceptable rod diameter was sought since the cross-sectional area of the rod sacrificed " working area " and reduced potential driving force.

With these restrictions in mind a rod connection design was established using a rod of 1-5/8" diameter, 15-5PH stainless steel. The rod material could be readily heat treated to Condition H1025 which would develop a yield strength of 165,000 psi and a Charpy V-notch impact strength of 35 ft-lbs. The ideal box-and-pin-balanced connection would have been 1-3/16"- 8 Stub Acme but this was reduced to a 1-1/8"- 8 Stub Acme to make room for an Anti-Spiral Groove which would run the length of the Rod Assembly and had to cross the threaded connections. Fig. 6 shows a cross-section of the connection and illustrates how the Anti-Spiral Groove affects the connection size. With the groove installed in this connection the weak spot became the root of the pin which was calculated to have a yield strength of 139,000 lbs.

6. Piston Rod Tensile Tests & Failure Analysis

During sea trials of the prototype APC on Leg 94 a Piston Rod failed in tension during a series of high overpull situations. The actual load at failure was read at the rig floor to be 40,000 lbs., although on the two previous

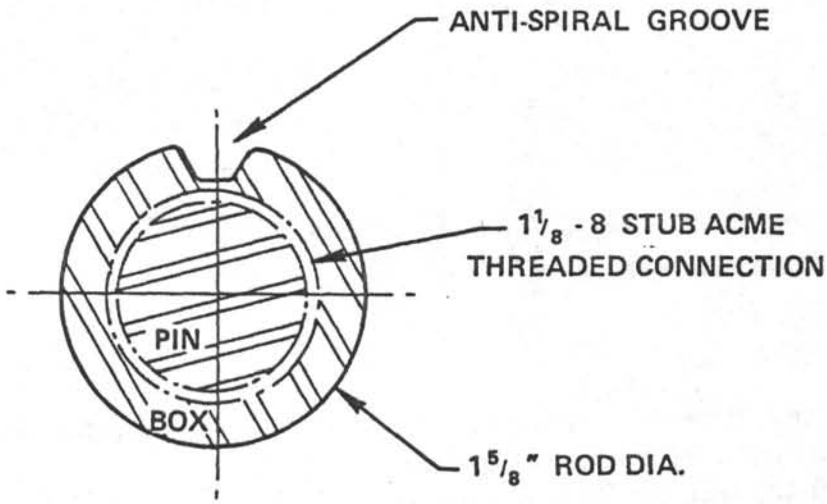


FIG. 6.

CROSS-SECTION OF PISTON ROD THREADED CONNECTION
WITH ANTI-SPIRAL GROOVE.

cores overpulls of 100,000 and 20,000 lbs. had been recorded. The location of the failure was at the last thread of the pin of an intermediate Rod connection.

Further investigation of the failure was indicated because the load at failure was supposed to have been well within safe tension load design limits. To verify theoretical strength calculations a set of full size samples were made of Piston Rod and Std. Inner Barrel Threaded connections. These were pulled to failure on a large tensile test machine with the following results:

Sample Piston Rod Connections -

Measured Ultimate Tensile Strength

#1	179,500 lbs.	All failures at
#2	174,500 lbs.	shoulder fillet of pin.
#3	179,500 lbs.	

Sample Inner Barrel Connections -

Measured Ultimate Tensile Strength

#1	204,500 lbs.	Box failure
#2	201,000 lbs.	Box failure
#3	203,000 lbs.	Pin failure
#4	206,000 lbs.	Pin failure

The test results demonstrated that the theoretical calculations of connection strengths for both Rods and Inner Barrels had been about 27% conservative for the case of simple tensile overload - believed to be the only mechanism of failure possible in high pullout load situations. This suggested that a very different failure mode must have prevailed in the case of the Leg 94 Rod failure. This was augmented by inspection of both the field and lab failed pieces - a distinct difference could readily be seen in the character of the failure surfaces. After verifying that the field rod had been made of the correct specified material and heat treated properly the remaining portion of the pin connection was sent to Battelle Petroleum Technology Center for a formal failure analysis. Their letter-report appears in Appendix B and concludes that failure of the Piston Rod was due to pure torsional overload - not axial tensile overload. Since no torque of any kind is applied to the Piston Rod (or core barrel) during routine deployment the overload was assumed to have been caused during initial assembly of the Rod. It is possible that severe thread galling in the Rod connection may have occured forcing the assemblers to use considerably more than the specified 400 ft-lbs make-up torque in order to shoulder the connection (15-5 PH stainless steel has a high tendency to gall). If this did, indeed, occur a partial torsion failure at the last thread would have resulted and ultimately complete failure would have occurred during pullout of a stuck barrel.

7. Release Mechanism - Shear Pins

One of the shortcomings of the VLHPC design was erratic behavior of the shear pins. This was attributed to a variety of causes, the most significant being a tendency to pre-shear the pin or pins as the core barrel traveled down the drill string. Additional premature damage would occur if the tool landed with any impact, although operational procedures called for this to be avoided as much as possible. In an attempt to achieve real improvement with the new APC the shear pin design was analyzed. Alternate release mechanisms were considered but eventually abandoned on the basis of being unnecessarily experimental. Also, the APC would enjoy a natural advantage in the strength of the shear pins to be used versus the weight of the portion of the tool acting to cause pre-shear.

When the tool is being run into the hole on the sandline the shear pins hold the scoping and stationary halves of the assembly together. Each time the protrusions on the Piston Corer contact a tool joint or Bumper Sub shoulder the impact is transmitted to the shear pins. In many cases using the VLHPC the cumulative damage had been enough to partially (or even totally) preshear the pins. Thus the hydraulic energy was not stored and suddenly released as designed and the tool was not able to take a proper core. The impact damage to the pins is a function of, 1) the weight of the scoping portion of the assembly which is being held and, 2) the shear strength of the pins. With the APC the weight of the scoping components would be about half that of the VLHPC assembly. In addition, the shear strength of the pins used in the APC would have to be 76% greater for a given "shoot-off" pressure to account for the greater hydraulic working area between the inner and outer seals. In combination, these two factors would make the APC shear pins considerably less susceptible to premature damage than the VLHPC pins. Under these conditions it was thought that conventional shear pin technology would provide adequate service until proven otherwise in operations at sea.

The shear pins selected were 1/4" diameter, 17-4 PH stainless steel, heat treated to condition H1150-M. Lab tests were performed to determine the actual loads required to shear one, two and three pins with the following average results for five, room temperature tests of each combination:

No. of pins	Ave. Load, lb.	Equiv. APC shoot-off pressure, psi
1	9,835	1060
2	18,869	2063
3	28,421	3067

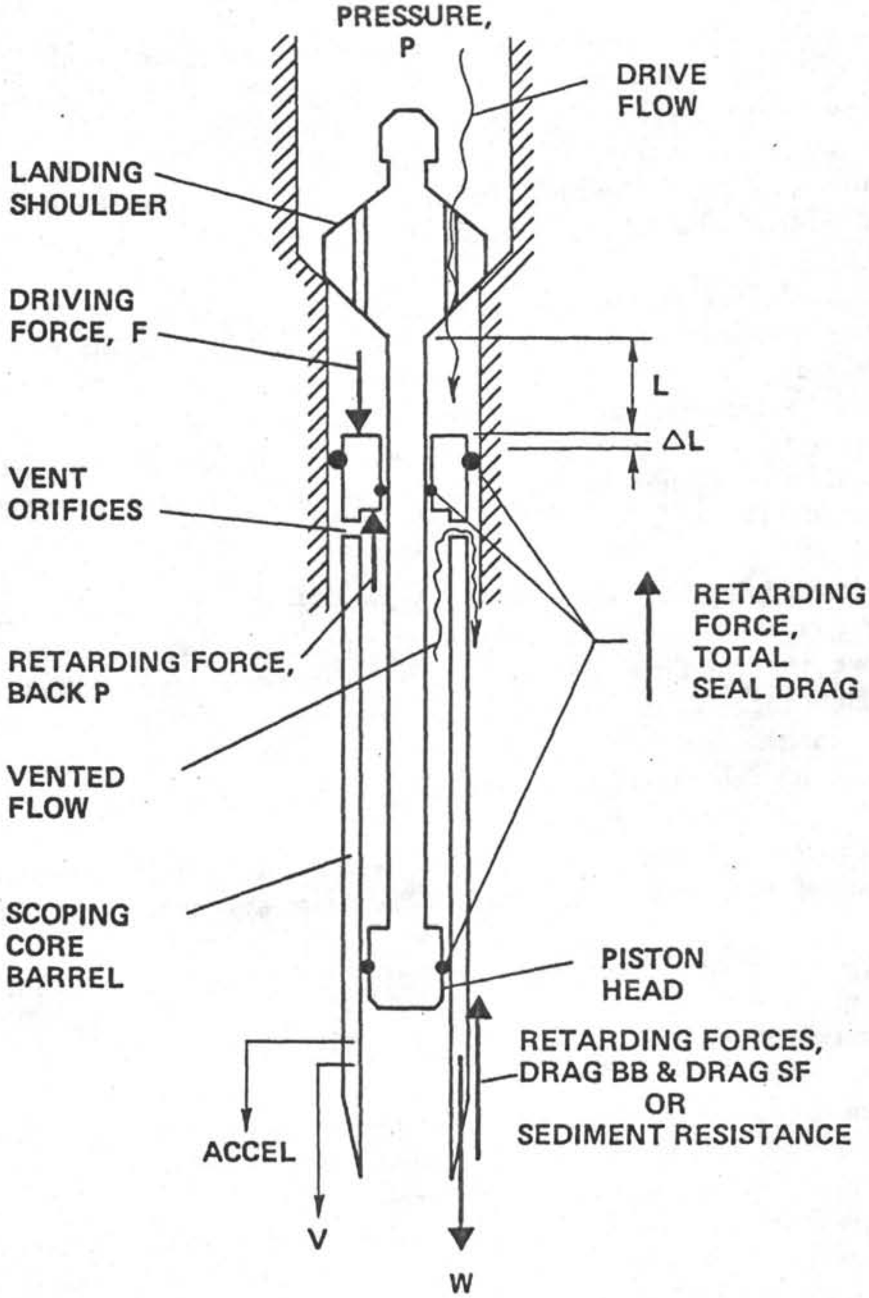
It was desired to achieve a maximum shoot-off pressure for three pins of 2800 psi. This was safely within the approximate 3000 psi relief valve limit of the rig pump system yet still effectively utilized the available hydraulic energy. The lab tests indicatd that three pins averaged in excess of 3000 psi but this fact was tempered with much at-sea operational experience which indicated that in-service shoot-off pressures were regularily 5-10% less than lab test results. As a further safety factor for prototype sea trials a quantity of 1/4" diameter mild steel (1018) shear pins were made available to be used as "half strength" pins in case maximum rig pressure was not sufficient to shear three pins. (These "half strength" pins proved popular and were later incorporated as a regular part of APC operations.) Results of prototype sea trials showed that rig pressures to shear the pins closely approximated lab tests and that pre-shear while running the tool down hole was minimal or non-existent.

8. Piston Corer Performance Analysis

Early testing and use of the HPC-15 and VLHPC had led to the conclusion that piston coring could produce remarkably undisturbed cores in soft sediments without the use of a Heave Compensator, if the coring action could be made to take place fast enough to effectively decouple the corer motion from the heave motions of the ship and drill string. Common spectrums of ocean waves which produce heave of the drillship have periods on the order of 5 to 17 seconds or more. The lower end of the drill string follows a different oscillation pattern but with similar periods. To decouple from these motions the piston corer had to complete its 9.5 m stroke in about two seconds. This was the design goal for the APC.

Two significant questions arose in connection with this goal. First, could the stored hydraulic energy which was released when the shear pins failed effect the acceleration of the core barrel to complete the full stroke in two seconds or less? Second, what would the end-of-stroke velocity be and could the mechanism withstand the impact when the traveling mass came to a sudden stop? The problem was considered more acute with the APC concept due to the significantly increased driving force over the VLHPC.

To assist in analyzing the perfomance of the tool a computer program was written based on the model which appears in Fig. 7. In the figure, the hydraulic pressures and significant forces acting on the core barrel are denoted. The hydraulic pressure, P, is built up until the shear pins fail and release the core barrel. The volume of compressed water in the total drill string in most cases far exceeds the volume required to totally stroke the tool, thus the pressure, P, is assumed constant from an "infinite" reservoir above the Landing Shoulder. The pressure which reaches the seals on the scoping portion and drives the tool is not constant, however. The actual driving pressue is $P - \Delta P$, where the pressure drop, ΔP, is a function of the geometry of the Landing Shoulder and its fluid passages and a function of the velocity of the scoping section of the tool. The driving force, F, is derived by multiplying the working area between the inner and outer seals by the pressure felt at the top of the scoping section at any given point in



$$\Sigma F = ma$$

$$F + W - \text{BACK P} - \text{SEAL DRAG} - \text{DRAG BB} - \text{DRAG SF} = \frac{W}{g}\,\text{ACCEL}$$

FIG. 7.

Schematic model of APC used for computer program showing forces which determine velocity and performance.

the stroke. The acceleration of the tool at any given point in the stroke is derived from $\Sigma F = ma$, where the summation of the forces is the driving forces minus the retarding forces. The driving forces are F plus the weight of the traveling section, W. The retarding forces are seal drag, sediment or water drag resistance and the force resulting from the back pressure of the vented fluid above the Piston Head.

The seal drag relationship is a complicated function of seal type, surface area, pressure, etc. and can only be determined empirically. It is known, however, that for seals of the type and size of interest here, the total drag could be expected to be on the order of hundreds of pounds whereas the driving forces are one or two orders of magnitude greater. No great error was then introduced by simply assuming total seal drag to be equal to a constant 300 lbs.

In determining the potential for impact damage at the end of the stroke the worst case is that of an inadvertent water core (where the tool is fired off above the mudline and no sediment is penetrated). In this case, the decelerating potential of sediment drag would be nil. The retarding drag force for this condition can be calculated by application of conventional fluid mechanics relationships. Appendix D contains the derivation for the function which defines skin friction and bluff body drag of the corer in sea water as a function of velocity. (The derivations for the other force relationships, velocities, accelerations and impact loads also appear in Appendix D.)

The force caused by the back pressure of the vented fluid is a function of the size of the orifices, the fixed geometry of the core barrel and BHA, and the velocity of the corer at any given instant as it strokes out.

When all of these driving and retarding forces are combined by vector addition the result is a net driving force at any given instant in time. Applying $F = ma$ yields an instantaneous acceleration at that point. If this acceleration is then assumed constant for a short interval, ΔL, of travel of the scoping section a velocity at the end of the interval can be calculated directly from

$$V_1 = \sqrt{V_0^2 + 2a\Delta L}.$$

Using the new velocity to re-evaluate each of the driving and retarding forces the process can be repeated for a series of short intervals until the entire stroke is evaluated. It is then possible to examine maximum coring velocities, velocity at the end of the stroke, elapsed time for a full stroke and so on.

The flowchart for Fortran and Basic computer programs is shown in Fig. 8. Using a computer to make these repetive calculations allows the stroke intervals to be made very small - 0.05 ft. was commonly used. The program was employed first as a design tool to "see" the effects of changing the size and shape of the vent orifices, flow passages in the Landing Shoulder and so on. The design of the overall tool was, thus, optimized to meet the design goals.

Early application of the computer program demonstrated that the end-of-stroke velocity would be excessively high if no provisions were made to decelerate the core barrel near the end of its stroke. Using less pressure to shear the pins or reducing the vent orifice or Landing Shoulder flow passage sizes could reduce end-of-stroke velocity but, also, handicapped the useful coring power of the entire stroke. It was deemed better to utilize the available force as efficiently as possible throughout the majority of the stroke and then include a snubbing device to brake the core barrel and bring the end-of-stroke velocity to within safe limits. The stroking portion of the tool would be stopped (and pulled out) by an upset shoulder on the Piston Rod. Impact analysis of the Rod connections determined a safe impact velocity to be 15 ft/sec or less. Therefore, a Snubber was designed to achieve this additional design goal.

One part of the Snubber was an upset at the lower 18 inches of the Piston Rod assembly. When the vent orifices encountered the Snubber upset the primary (large) vent orifices would be closed leaving only four, very small orifices for venting the sea water above the Piston Head. This would result in a sudden increase of back pressure in the vented fluid and a corresponding sudden increase in retarding (or braking) force on the core barrel. Again, the computer program was used as a design tool to optimize the length of the Snubber and the size of the reduced vent orifices. Back pressure above the Piston Head was limited by design to 3000 psi during the high pressure snubbing action to avoid overpowering the Piston Head seals.

Fig. 9 is an example of the hundreds of outputs of the computer program used during the design phase. The stroke length increment used was 0.05 ft. although only results at selected stroke intervals were printed out for brevity. The total elapsed time at the end can be seen to be 1.79 sec - well within the two second goal. Final velocity is 12.7 ft/sec - within the 15 ft/sec limit. Maximum back pressure force is 5026 lb. which corresponds to an acceptable maximum pressure against the Piston Head seals of less than 1000 psi.

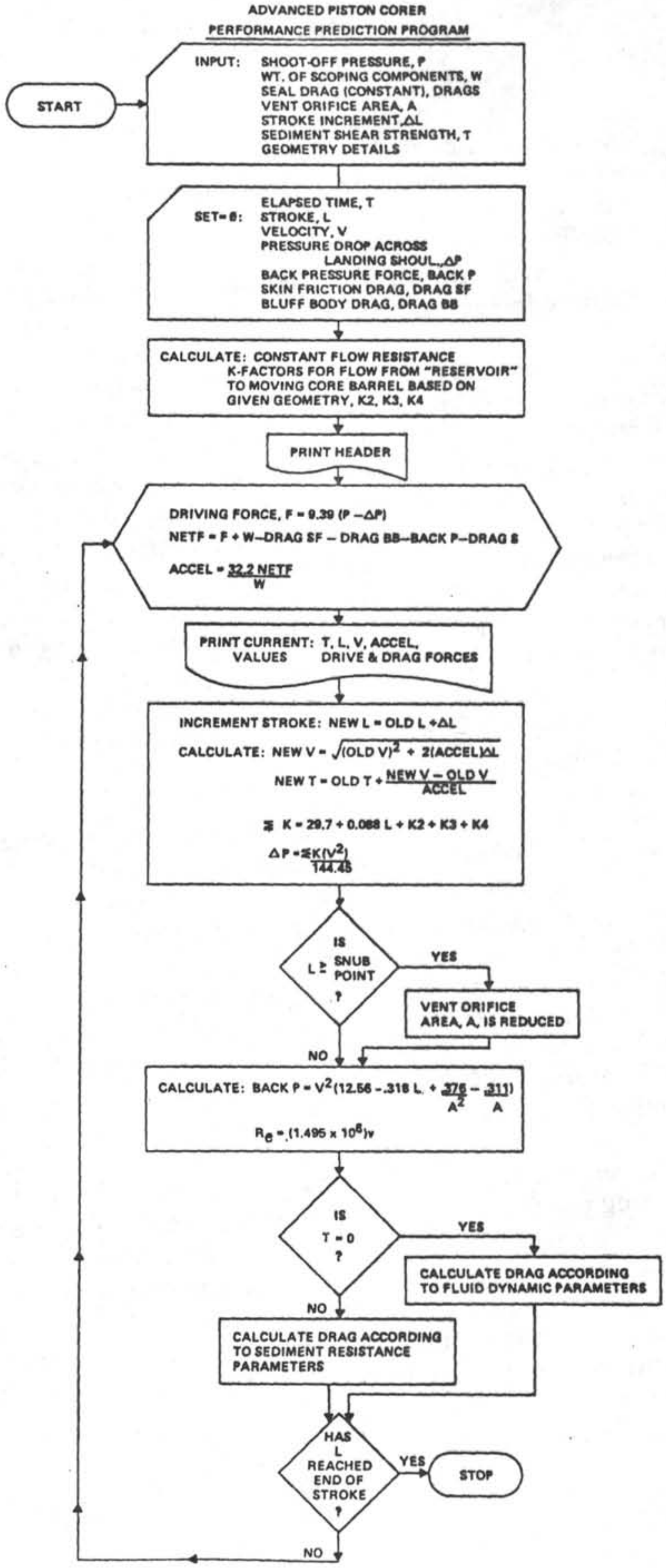


FIG. 8.

ADVANCED PISTON CORER PERFORMANCE PREDICTION PROGRAM

Z= 0.0000000E+00

1000/2/0

PRESSURE= 1000.000 (PSI)
VENT AREA= 2.060000 (SQ.IN.) SNUBBED VENT AREA= 0.1100000 (SQ.IN.)
SNUB POINT IN STROKE= 28.75000 (FT)
WEIGHT= 490.0000 (LBF) SHEAR STRENGTH= 0.0000000E+00(GM/SQ.CM.)
SEAL DRAG= 300.0000 (LBF)
N1= 2.000000 ALWAYS-OPEN BYPASS HOLES AT D1= 0.5000000
N2= 2.000000 PLUGABLE BYPASS HOLES AT D2= 0.4375000

STROKE (FT)	VELOCITY (FT/SEC)	ACCEL (FT/S/S)	DRIVEF (LBF)	DRAGSF (LBF)	DRAGBB (LBF)	BACKP (LBF)	NETF (LBF)	ELAPSED TIME (SEC)
0.0	0.0	623.5	9390.0	0.0	0.0	0.0	9583.0	0.00
0.2	13.4	230.0	3582.1	13.4	1.1	658.0	3499.7	0.03
0.4	15.7	84.3	2024.8	18.0	1.4	853.3	1282.1	0.04
0.6	16.4	31.1	1279.1	19.7	1.6	975.3	472.5	0.05
0.8	16.7	11.6	1010.5	20.4	1.6	1001.7	176.8	0.06
1.0	16.8	4.5	928.9	20.7	1.7	1007.8	63.7	0.08
1.2	16.8	1.6	862.5	21.0	1.7	1005.8	24.1	0.09
1.4	16.8	0.8	847.1	21.1	1.7	1001.6	12.8	0.10
1.6	16.8	0.6	838.2	21.2	1.7	995.6	8.7	0.11
1.8	16.9	0.5	831.5	21.3	1.7	991.3	7.2	0.13
2.0	16.9	0.4	825.7	21.5	1.7	985.9	6.6	0.14
2.5	16.9	0.4	812.1	21.8	1.7	972.3	6.4	0.17
3.0	16.9	0.4	798.7	22.0	1.7	958.6	6.4	0.20
3.5	16.9	0.4	785.3	22.3	1.7	944.9	6.4	0.23
4.0	16.9	0.4	771.8	22.6	1.7	931.1	6.4	0.26
4.5	16.9	0.4	758.3	22.9	1.7	917.3	6.4	0.29
5.0	16.9	0.4	746.1	23.2	1.7	904.9	6.4	0.31
7.0	17.0	0.4	691.6	24.3	1.7	849.1	6.5	0.43
9.0	17.0	0.4	636.5	25.5	1.7	792.6	6.6	0.55
11.0	17.1	0.4	580.7	26.7	1.7	735.5	6.7	0.67
13.0	17.1	0.4	524.2	27.9	1.7	677.7	6.7	0.78
15.0	17.2	0.4	467.0	29.2	1.7	619.2	6.8	0.90
17.0	17.2	0.5	409.1	30.4	1.7	560.0	6.9	1.02
19.0	17.3	0.5	349.0	31.7	1.8	493.6	7.0	1.13
21.0	17.3	0.5	289.7	33.0	1.8	437.9	7.1	1.25
23.0	17.4	0.5	229.6	34.3	1.8	376.4	7.2	1.37
25.0	17.5	0.5	168.8	35.6	1.8	314.2	7.3	1.48
26.0	17.5	0.5	138.1	36.2	1.8	282.8	7.3	1.54
27.0	17.5	0.5	107.2	36.9	1.8	251.2	7.3	1.59
28.0	17.5	0.5	76.1	37.5	1.8	219.4	7.4	1.65
29.0	13.2	-48.3	4125.1	22.5	1.8	5205.9	-734.3	1.71
30.0	12.7	0.1	4491.9	21.3	1.8	4657.5	2.2	1.79

P= 1000.000 A= 2.060000 ASNUB= 0.1100000 SNUBPT= 28.75000
N1= 2.000000 D1= 0.5000000 N2= 2.000000 D2= 0.4375000
TAU= 0.0000000E+00
$

FIG. 9.

SAMPLE OUTPUT OF " APC PERFORMANCE " COMPUTER PROGRAM.

The performance predictions generated by the computer program showed that the Snubber system could safely brake the moving corer when shoot-off pressures up to 2000 psi were used. However, for water core situations fired off at pressures from 2000 to 3000 psi the end-of-stroke velocity would be excessive despite any reasonable Snubber action. The computer runs also demonstrated that performance was quite sensitive to the flow passage area through and around the Landing Shoulder. Manipulation of the flow orifice sizes could be used to easily control maximum (and, thus, final) velocity of the core barrel. A flow system was, therefore, added to the Landing Shoulder which included threaded ports which could be closed with large set screws. These Speed Control Set Screws provided for a vernier-type maximum speed control for the purpose of controlling both end-of-stroke impact and actual penetration velocity. Previous experience with the VLHPC system suggested that relationships exist between optimum coring velocity and lack of core disturbance for different sediment types. Although the only flexibility of coring velocity offered with the VLHPC was shoot-off pressure (as established by the number of shear pins used) the differences in core disturbance were at times evident when different coring speeds were tried. The APC system provides a much more sophisticated approach to the speed control question which, with adequate at-sea experimentation, offers the capability of significant improvement in the control of core quality.

The final problem evaluated via the computer performance program was the effect of sediment drag resistance on corer performance. In the past, piston corer penetration capability had been loosely assumed to be a function of sediment shear strength, but no formal functional relationship was ever developed theoretically and/or verified empirically. A new approach was attempted based on assuming that the sediment in contact with the walls of the core barrel was "fluidized" to the extent that it could be treated analytically as a viscous fluid undergoing laminar flow and subject to fluid mechanics principles. Fig. 10 shows how the "fluidized disturbance layer" was assumed to exist during the one to two seconds of corer penetration.

The functional relationship which was developed was entered into the computer performance program and used to evaluate performance at various sediment shear strengths and shoot-off pressures. The results indicated that the drag resistance relationship was not accurate since shear strengths on the order of 100,000 gm/sq. cm had to be used to significantly model corer response in moderately resistant sediments. The math model was quite useful, however, in demonstrating how sediment drag resistance generally related to shoot-off pressure and velocity even though actual magnitudes were clearly erroneous.

The following is a summary of the analytical approach (the full details appear in Appendix D).

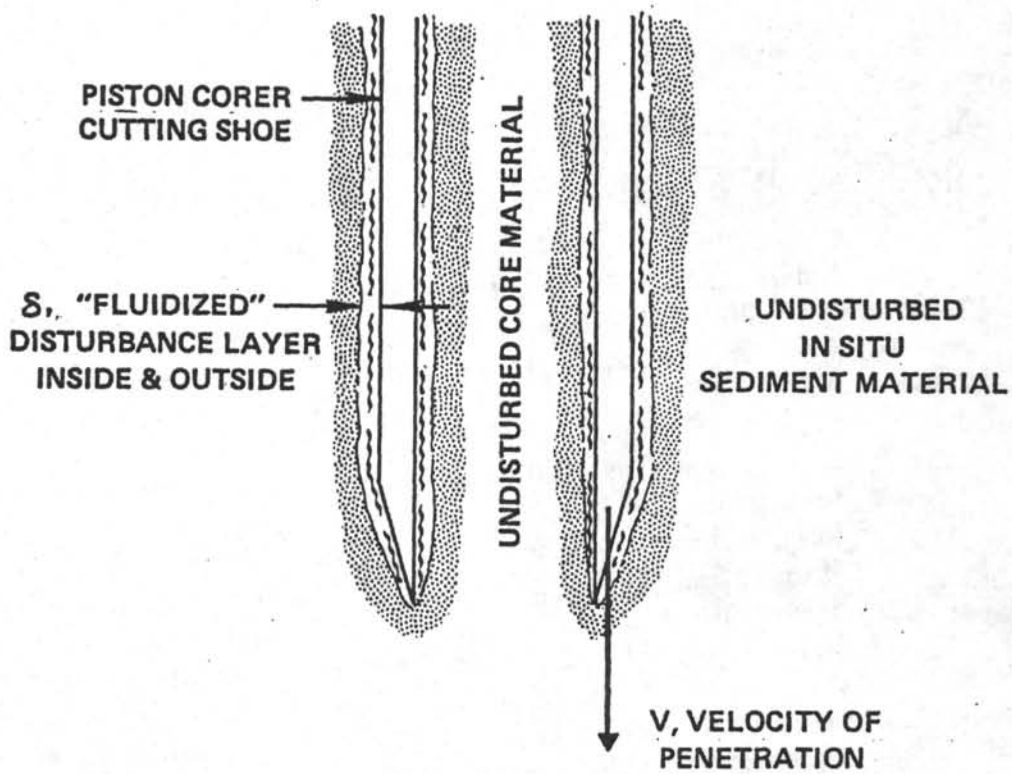


FIG. 10.
" Disturbance Layer " model for evaluation
of sediment drag resistance.

Assume the existence of a fluidized disturbance layer as described above and in Fig. 10. Also, assume that the only known physical properties of the sediment are shear strength, τ and density, ρ. Thus a relationship describing coring resistance (drag) must be developed which is a function of τ and ρ plus variables resulting from the core barrel dimensions but independent of the cored material. If conditions within the fluidized disturbance layer simulate laminar flow of a viscous fluid, skin friction can be derived from the drag equation,

$$Drag = c_{Df} \frac{\rho V^2 A}{2 g_c}$$

where ρ = density of the fluidized material (assumed)
V = velocity of penetration
A = affected surface area

The friction drag coeffient, c_{Df}, can be determined using the Blasius equation for laminar flow in a boundary layer over a flat plate with adjustments made for the shape and size of the cylindrical core barrel. An approximation of "fluid" viscosity, μ, is required for use in calculating the Reynolds number needed in the Blasius equations. The definition of μ is a function of τ for a Newtonian fluid and therefore can be calculated. (It is highly doubtful that the theoretical "fluidized" layer behaves as a Newtonian fluid and this may be the source of significant inaccuracy in this derivation. It does, however, represent some form of approximation and is not the sole parameter of interest.)

Besides skin friction drag, the other major source of penetration resistance results from actual compressive displacement of sediment to make room for the walls of the core barrel as it penetrates. A theoretical compressive strength related to the shear strength is thus used and is multiplied by the frontal area of the core barrel to achieve the compressive displacement factor.

A total sediment drag relationship can then be derived which is a function of shear strength and density of the sediment plus length, velocity and cross-sectional dimensions of the core barrel.

9. Seal Selection

The APC design, which called for fully dynamic outer seals acting against the Outer Core Barrel, necessitated a comprehensive evaluation to determine the best seals to be used. A variety of options were suggested by seal manufacturers and distributors, from which two candidates were chosen, both of which had been proven on the VLHPC. The two were: single Type B, molythane Polypaks and conventional molythane V-packings in a triple stack separated by metal V-spacers.

The APC seal glands for the prototype assemblies were set up to accept either type of seal if appropriate shim washers and assembly order was employed. Sea trials demonstrated that either type of seal system would function for both inner and outer seals. The Polypaks, however, proved to be excessively vulnerable to damage by snagging when the tool was removed from the BHA. The V-packings, which were initially questionable as dynamic seals, especially when retracted thru the tight bores in reverse, proved to be wholly adequate although they were observed to wear considerably faster than the static version used on the VLHPC - which had been expected.

10. Orientation Baseline Alignment

Paleomagnetic core orientation of piston core samples requires knowing the relative angle between the fixed point of attachment of the Kuster (or other) Orientation tool and a reference line on the core liner. Since this angle varies randomly from one tool assembly to the next, a rotating swivel must be included which enables rotation for baseline alignment and then can be locked. The system used on the VLHPC was always cumbersome due mainly to the fact that the two points which required alignment were approximately 38-ft apart. A special telescopic sighting system was needed to perform the alignment operation and accuracy was never guaranteed.

The shorter design of the APC led to a reduction of the distance between the Pulling Neck (the attachment point for any orientation measuring device) and the Liner reference screw to about 5 feet. This meant that the VLHPC telescopic alignment system could be abandoned. In addition, the bulky VLHPC Swivel was discarded in favor of a Split Bushing which allowed the Pulling Neck to be rotated for alignment then locked securely in place.

11. Anti-Spiral System

A recurring complaint by paleomagnetic investigators using VLHPC cores for their research was a lack of assurance that the cores entered the core liners without twisting, or conversely, that the core barrels did not rotate (spiral) into the sediment while cutting the cores. In fact, some specific data on orientation baseline drift within single cores suggested that this was actually happening, at least in sporadic cases.

For the APC design, a mechanical Anti-Spiral system was devised which would constrain the scoping portion of the core barrel from rotating. The system was composed of a key-in-groove. The groove was milled into the

Piston Rod assembly of one of the two prototype APC's after all three Rod sections were assembled. This guaranteed proper groove alignment down the length of the Rod Assembly. The Anti-Spiral Key was mounted in a position in the scoping section of the tool between the seals and the Quick Release.

The traveling key - stationary groove arrangement was chosen rather than putting a ridge on the Piston Rod because the inner seals were required to seal on the Rod assembly. Conventional seals could be used on a grooved rod but not an asymmetric rod with a sharp protrusion. The groove in the Rod under the inner seals did provide an undesireable leak path but this was mitigated by two factors. First, the groove did not have to extend far enough up the Rod to include the area occupied by the seals during static pressure build up prior to shearing the pins. Thus, the leakage via the groove would only begin after the core barrel had scoped out about eleven inches. Examination of Fig. 9, the sample computer program output, shows that the majority of the acceleration (~90%) occurs in the first foot of travel. Also, the leakage into the groove was partially blocked by the traveling Anti-Spiral key which would provide a further pressure drop and, consequently, recover some of the lost hydraulic force.

12. Bypass Grooves

At the end of the stroke the main outer seals were positioned to break out of the seal bore in the Outer Core Barrel. This would allow the pressure behind the corer to be vented to ambient and provide positive full stroke indication at the rig floor. Upon retrieval the corer would be lifted by the sandline and the outer seals would immediately re-enter the bore of the Outer Core Barrel. It would then be necessary to displace the water column inside the pipe until the main seal exited the top of the sealed bore at the Landing/Saver Sub. Although a manometer effect would prevent the problem of trying to "lift the ocean" with the sandline, the Baker Float Valve and various other fluid restrictions in the BHA would add an unnecessary burden to the sandline load.

To prevent this situation a set of bypass grooves were located strategically in the lower Piston Rod section so that the inner seals were effectively bypassed when the core barrel was at the end of its stroke. The Anti-Spiral Groove also extended into the bypass zone so that the combination of it and the two bypass grooves provided adequate flow area.

13. Breakaway Piston Head

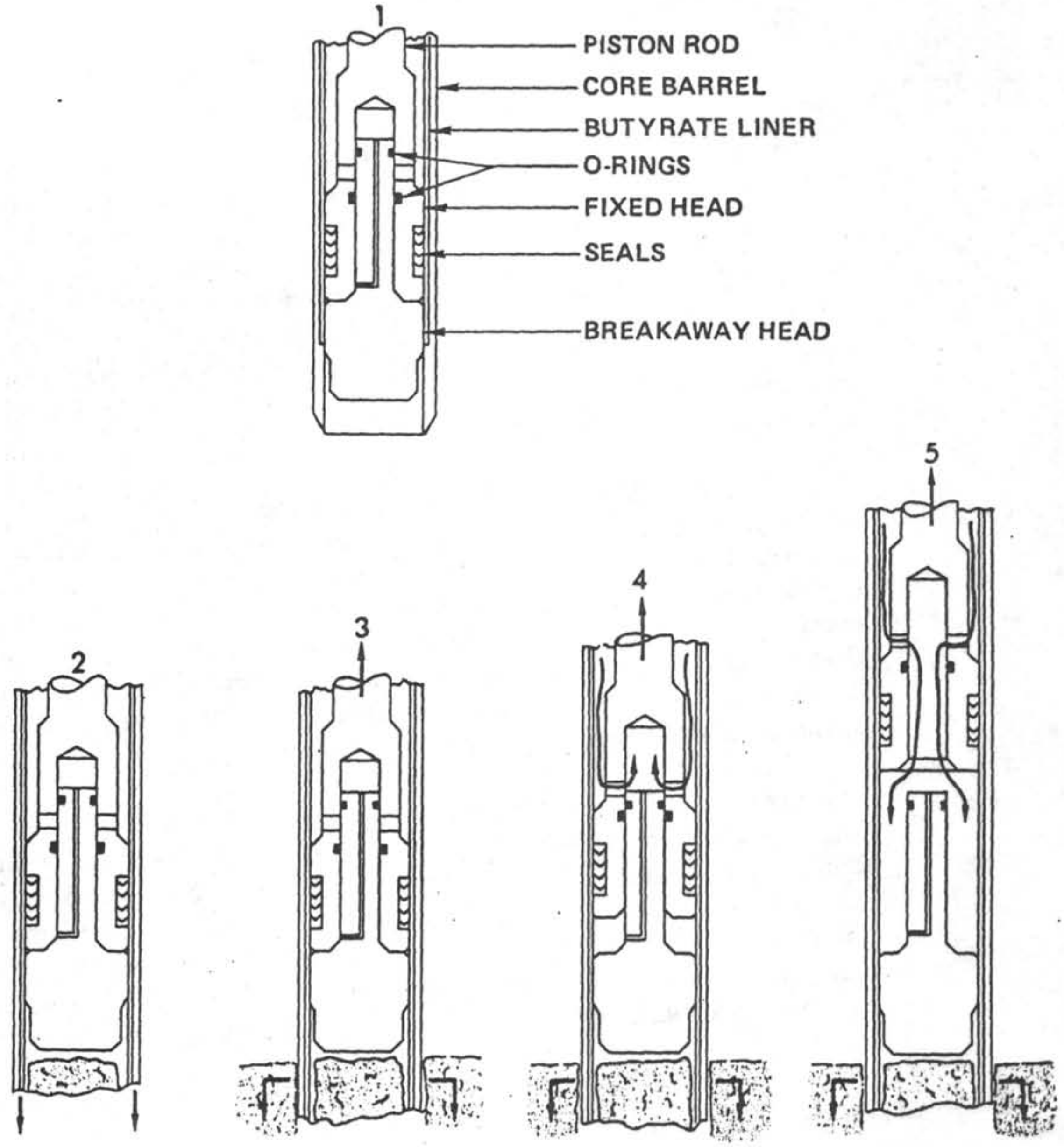
Unlike the VLHPC which could be assembled in various lengths, the APC was designed to be operated in only one 9.5 m version. Thus the problems associated with incomplete strokes in stiff sediments had to be handled by some other technique. When the corer encounters enough sediment resistance to come to a halt before completing the full stroke several problems arise. The pressure trapped above the unvented main seals is released at the rig floor and the drill string is raised to pull the corer out of the formation in the normal fashion. The Piston Rod must pull the Piston Head to the top of the core barrel, however, before the upset on the Rod Assembly can begin to put a strain on the embedded core barrel. When the Piston Head is thus stroked up the unstroked section, a zone of low pressure is created above the core. The result is either severe flow-in disturbance of the core, implosion of the Liner wall, or both.

To avoid such undersireable effects a Breakaway Piston Head was designed specifically for use with the APC. Figure 11 depicts the action of the device. The principle of operation is that the assembled halves remain fixed together during the time that the core barrel is cutting the core. Then during the extraction process the low pressure zone beneath the Piston Head causes the Breakaway portion to release and remain on top of the core. This opens a flow path around the Piston Head seals so that the pressure above the core in the Liner can remain equalized - preventing flow in or Liner implosion.

The Breakaway Piston Head was tested along with the APC on Legs 95 and 96. Results were inconclusive. The Breakaway Head was almost always found to be broken away even on complete-stroke cores. Several cases of successful operation were noted but eventually use of the Piston Head was abandoned when it seemed that the Breakaway section was releasing prematurely and getting stuck at the bottom of the Liner. Further design modifications and experimentation will be needed to perfect the Breakaway Piston Head.

14. Compatibility with Heave Compensator

Theoretically the speed at which a high pressure, hydraulic piston corer takes a 9.5 meter core decouples the coring motion from the heave motions of the drillship. In practice, however, numerous cores in soft sediments taken with the VLHPC system were observed to have unexplained disturbed sections in the middle of the core with undisturbed sections both above and below. This suggested that undesireable heave motion effects could be affecting piston corer performance and core quality. A logical solution would have been to perform piston coring operations while using the Heave Compensator, thus mitigating heave motions in the BHA and the piston corer itself. The VLHPC was not compatible with the Heave Compensator, however. The Heave Compensator functioned to hold the drill pipe approximately motionless with respect to the sea floor despite continous heave motions of the drillship. The sandline attached to the Pulling Neck of the VLHPC during the coring process was not attached to the Heave Compensator as it passed through the Traveling Block, Power Sub and other load-carrying components in the derrick. Thus, the drill pipe was activated to move independently of the sandline which moved with (and was attached to)



1. Piston head as assembled prior to shooting corer.
2. Pins shear and corer shoots into sediment. Breakaway head remains in place. Seals prevent flow-by, thus protecting core from compression force.
3. After partial stroke core barrel is restrained by sediment, retrieval is initiated by pulling on piston rod.
4. As piston rod is lifted, suction below piston head pulls breakaway section away from fixed section.
5. After breakaway head has fully released flow of water above piston head can bypass seals preventing implosion of liner and flow-in disturbance of cored material.

FIG. 11.

Breakaway Piston Head schematic showing operation sequence.

the ship. The resulting mismatch of motion would have caused the VLHPC to lift off its landing point in the BHA in synchronization with heave motions during the time when the system was being pressured up to shear the pins. In addition, the Line Wiper which packed off around the sandline to achieve a top end seal during pressure-up would be required to pack off against a continuously moving line - resulting in rapid wear of the wiper seals. The piston coring operation was thus incompatible with heave compensation unless sandline/wireline compensation was also included synchronized to the drill pipe motions - a sophistication significantly beyond the capabilities of the Heave Compensator used on the Glomar Challenger.

One means of overcoming the problem of no sandline heave compensation would be to eliminate the sandline from the picture either by pumping (or free-falling) the piston cores to the BHA without the line attached or by delivering the tool to the BHA via the sandline and then removing the line by jarring off. Removal of the sandline would effectively double the rig time consumed by sandline trips which was already the dominating time factor in piston coring operations. Running the piston corer to the bit without a line attached was not practical because random impacts en route and the severe landing impact have been proven to partially or completely pre-shear the shear pins of the VLHPC.

Two new approaches to these problems were initiated in the prototype design of the APC. A mechanical device to keep the impact loads from the shear pins was contemplated which would allow the APC to be free-falled to the bit without damage to the pins. A preliminary Shear Pin Protection Device is shown in Fig. 12 which was evaluated during the prototype design phase. The impact loads would be carried on the latch ball (or balls) while the tool was running in the hole. After landing the small piston would be actuated by the pressure being built up and the latch ball(s) would release so that the shear pins would come into play as normal. Frictional analysis suggested that the latch ball would be undesireably sensitive to locking in place even after the small piston had moved. The complexity of a design which would guarantee that friction lock-up could not occur was deemed too much of a problem to be handled during early prototype design and was postponed until sea trials could provide more data abut the need for shear pin protection.

The second approach involved the possibility of free-falling the APC assembly without shear pin protection. Although the magnitude of the impact g-loads in free falling tools had never been measured directly it was considered possible that the APC shear pins might survive the trip to the bit. The APC shear pins were designed to shear at a load level 76% greater than those of the VLHPC. In addition, the scoping portion of the APC tool which formed the mass which acted against the pins at impact was 41% lighter than the VLHPC. Thus, the APC shear pins would be able to withstand a landing impact three times greater than the VLHPC. A free - fall

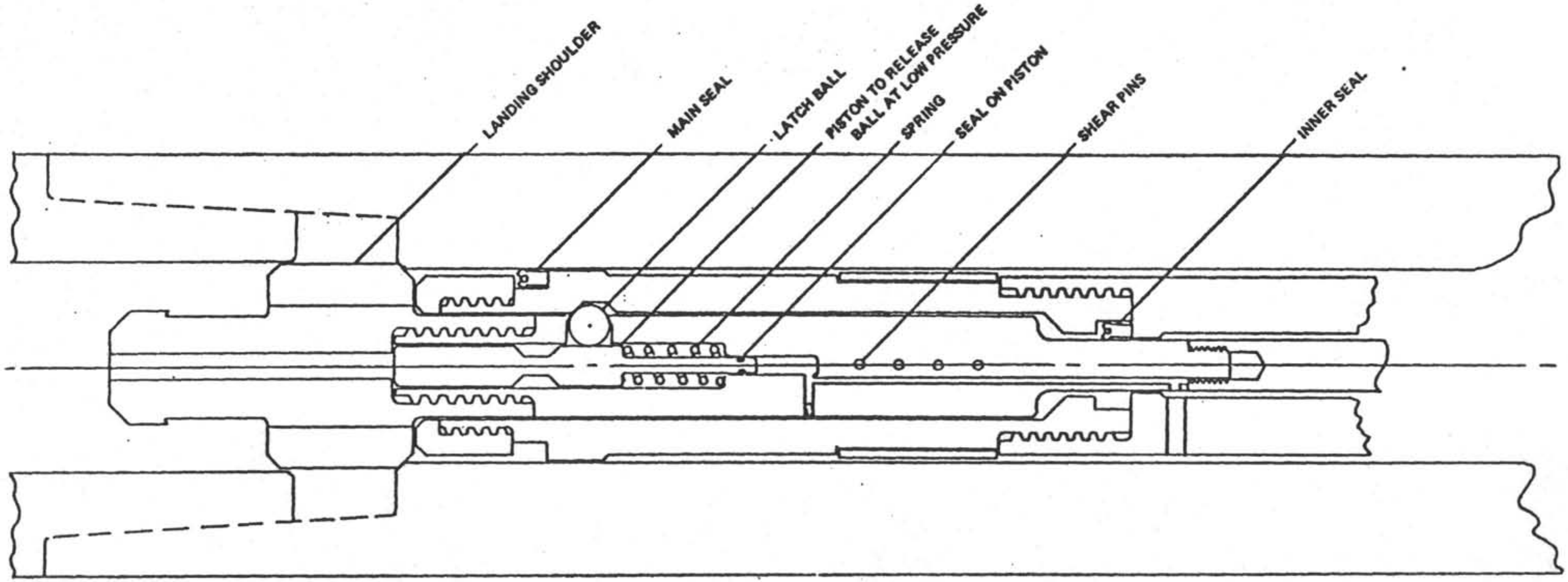


FIG. 12.

PISTON CORER SHEAR PIN PROTECTION CONCEPT.

Never built.

test of the APC was conducted during Leg 95, at Site 612. The APC was assembled with two, 17-4PH shear pins and all speed control holes plugged. (This is the maximum number of shear pins safe to use if a water core is considered possible.) The length of pipe was 2070 meters. The tool was pumped down the pipe using 50 strokes of the mud pumps during the first five minutes and cut back to 25 strokes near the end of the time expected for the tool to reach the BHA. This would have resulted in a relative velocity of the sea water within the pipe of about 9.8 ft/sec slowing to about 4.9 ft/sec after five minutes. A pressure kick at seven minutes indicated that the tool had probably landed which would have meant that the tool traveled the 2070 meters to the bit at an average velocity of 16.1 ft/sec. Exact time and velocity at landing was not known. When the tool was retrieved the two shear pins were cleanly sheared. The calculated impact load required to shear the two pins was 18,760 lb. which would require an impact deceleration of 39.5 g's. It was thus concluded that compatibility between APC operations and heave compensation (without sandline compensation) could only be accomplished if the shear pins could be protected from the landing impacts inherent in free-falling the tool to the bit.

B. MOD. II DESIGN/IMPROVEMENTS

1. Mod. II Design / Improvements

The APC prototype assemblies were tested at sea during Legs 94, 95, & 96. Results were generally very favorable but certain minor problems, typical of prototype designs, were noted. (A full synopsis of prototype operations is included in Section IV of this report.) Following Leg 96 the list of identified problems were evaluated and a Mod. II re-design was undertaken. The specific difficulties and re-design goals were as follows:

a. Shear pin stubs - When the shear pins were double sheared during routine operation of the prototype APC each pin was separated into three pieces, one long section and two end stubs. The stubs had a persistent tendency to then fall into the annular cavity between the Piston Rod and the Outer Shear Pin Sub. These stray stubs would ultimately prevent complete reassembly of the tool when brought back on deck, requiring that they be fished out with a magnet. Mod. II goal - elimination of this problem.

b. Piston Rod Connections - The torsion overload failure of one of the Rod assemblies focused attention on the connection design. The natural galling tendency of 15-5PH stainless steel called for lubrication of the connections during assembly but this, in turn, would necessitate a mechanical thread lock device to forestall inadvertent back-off of the connections downhole. At the same time, a means of positive alignment between Rod sections was required for the Anti-Spiral groove which ran across all three Rod sections.

c. Outer Seal Replacement - Field testing demonstrated that the dynamic outer seals of the APC were subject to enough wear in routine usage to require regular renewal. The outer seals would last for up to ten deployments but could be worn out on a single core especially when working in sandy formations. The prototype design required a difficult sequence of disassembly steps to change the outer seals. Also, the carefully established internal alignment required to match up the inner and outer holes for the shear pins was disturbed at every seal change. Mod. II goal - Re-design so that seals could be quickly changed with the tool in a vertical position. Elimination of inadequate Piston Rod Jam Nut plus a means to easily re-align shear pin holes.

d. Final Seal Selection - The prototype APC's had been fitted with convertible seal glands to accommodate either separated V-packing or single Polypaks. Field tests indicated that the V-packing was preferable for outer seals and double Polypaks would be best for the inner seals.

e. Inner Seal Bypass - Small bypass grooves had been included on the prototype Piston Rod to prevent a complete seal when the tool reentered the seal bore of the outer core barrel during retrieval. Although this bypass area did prevent a complete seal it did not allow enough overall flow to prevent a noticeable increase in drag on the sandline during the entire sandline trip time. Mod. II goal - Provide at least as much end-of-stroke, bypass flow area as the VLHPC to reduce sandline drag.

f. Minor Improvements - Some difficulties in rig floor handling pointed out the need for an additional location to attach a core barrel handling clamp in the vicinity of the Pulling Neck. Minor design improvements which could be made to the Quick Release assembly and the Vent Sub were also identified.

2. Redesign Analysis And Changes

In concert with general changes being made to the entire DSDP coring tool inventory, the Mod. II APC was designed with a core receptacle capable of taking a full 9.8 meter long core. The need to lengthen the capacity beyond the previous standard of 9.5 meters was brought about by the general increase in length of the individual joints of new S-135 drill pipe purchased for the use on the Challenger. Joints raging in length from 9.5 to slightly over 9.7 meters were common in the newest pipe and, therefore, required coring tool capacities to match.

Sea trials of two APC assemblies - one with and one without the Anti-Spiral system - demonstrated that the Anti-Spiral groove and key were functional and caused no operational problems. The Anti-Spiral option was, thus, included as a standard feature in the Mod. II design. The Key was still installed as a separate, removeable piece, so that damaged keys could be easily replaced and the tool could be operated with the key removed if necessary to avoid other, unforeseen, problems.

An optional Breakaway Piston Head had also been introduced with the prototype APC's to accommodate short cores and incomplete strokes. Test results were not entirely favorable so the Breakaway Head was shelved for later development and a standard, fixed Piston Head was adapted for use with the Mod. II design.

a. Upper Scoping Section Mod. II Design

The problems involving the shear pin stubs, outer seal replacement and interval alignment to line up shear pin holes called for changing the entire upper scoping section of the tool above the Quick Release. The potential for shear pin stubs to become trapped between the Outer Shear Pin Sub and the Rod was eliminated by reducing the annular gap to 3/16" so that a 1/4" dia. x 5/8" long stub could not enter. This diameter reduction also eliminated the possibility of using the Jam Nut to align the Piston Rod but it had not been particularily successful in sea trials. A roll pin was introduced instead to lock the Upper Piston Rod section to the Upper Piston Rod section to the Inner Shear Pin Sub in an orientation that was repeatable on each reassembly - required since this connection was part of the overall paleomagnetic baseline alignment and would have to be broken whenever the seals were replaced. To allow the Inner and Outer Shear Pin Subs to align with the Rod locked in place while an Anti-Spiral key prevented rotation of the scoping assembly, a swiveling Outer Shear Pin Sub was introduced. This addition to the original design would allow the rig floor operators to align the shear pin holes by hand each time and eliminated the need for a touchy internal alignment procedure.

The Anti-Spiral key was moved from the bottom of the Outer Seal Sub to the top of the Male Quick Release and the Vent Sub was shortened to be assembled to a Lower Liner Seal Sub. This step was a cost reduction measure for the Vent Sub plus guaranteed interchangeability between Upper tool assembly sections and Lower scoping sections. Since a single Upper section is alternated between two Lower sections in normal operations, full interchangeability is mandatory. The problem is maintaining baseline orientation alignment from the Pulling Neck on the upper section to the Liner Retaining Screw on the Lower section. The Mod. II system establishes a proper alignment at fabrication which would not be not disturbed by interchanging parts.

b. Piston Rod Assembly Mod. II Design

The most significant problem encoutered during sea trials was failure of a Piston Rod under moderate tensile load. Although the failure load was less than the calculated safe limit the failure analysis which followed established that the problem had been torsional overload brought about by inability to deal with the natural galling tendency of 15-5PH stainless steel during assembly while, at the same time, assuring proper make-up of the Rod sections and alignment of the Anti-Spiral Groove from one section to the next.

A new connection design was introduced which used roll pins to lock Rod sections together after hand-tight assembly. This would assure Groove alignment, prevent back-off of the connections and allow proper thread lubricants to be used to eliminate the galling problem. The weakest point in the prototype connection was strengthened by eliminating the threading tool runout under cut at the base of the pin. In its place a tapered runout was specified using a 9° vanish-cone as used on API Sucker Rod connections. A step-by-step fabrication sequence using special thread gages was established to locate the Anti-Spiral Groove in each Rod section relative to the thread orientation so that Rod sections would be interchangeable with sections made singly later while still maintaining proper alignment for the Anti-Spiral Groove. This also eliminated the costly necessity of cutting the Groove only after assembling of a given three Rod sections.

In the Lower Rod section the small Bypass Slots were replaced by flats on three sides of the Rod to provide for about three times the bypass flow area to reduce the sandline drag during retrieval.

III. ADVANCED PISTON CORER - MOD. II

A. General Description

The Advanced Piston Corer (Mod. II) utilizes the technology of past DSDP Hydraulic Piston Corers while incorporating a simplified seal system which results in a Piston Corer capable of 76% greater coring force (up to 28,000 lbf) but about half as mechanically complex as the older VLHPC. The main difference is the use of a dynamic seal acting between the scoping piston corer and a special honed-bore outer core barrel. The inside diameter of the outer core barrel is 3.800-inches minimum which constitutes the tightest restriction in the BHA.

The lower core-taking section of the APC is essentially the same as the VLHPC. The butyrate liners, core catchers and catcher subs are identical. The nonscoping section of the APC incorporates an adjustable-flow-by Landing Shoulder Sub where Speed Control Sets Screws can be added or removed to control coring velocity. Adjustment for base-line alignment of the magnetic orientation system is reduced to one function of the pulling neck.

The Mod. II version of the APC has incorporated several improvements resulting from the sea trials of the prototype. A more convenient method for changing outer seals has been arranged. Piston Rod connections have been re-designed to lock and align using roll pins so that Baker-lock and/or high torque makeup are not required. The Jam Nut used for shear pin alignment has been deleted. End-of-stroke bypass grooves have been enlarged to reduce drag on the sandline during retrieval. The tool now is capable of taking a full 9.8 meter long core.

The Anti-Spiral system tested out successfully in the prototype and has been added as a permanent feature in the Mod. II version. The system prevents rotation of the scoping section of the corer relative to the piston rod. An Anti-spiral key located in the Male Quick Release tracks down a special groove cut in each of the Piston Rod sections. The grooves are located in the Rod sections during fabrication in such a way that Rod sections are fully interchangeable with other similar parts even if fabricated separately. When assembled and locked, a full set of Piston Rod sections (Upper, Center and Lower) will automatically have a fully aligned Anti-spiral groove running the full required length.

1. Outer Barrel (BHA) Components

Several Bottom hole assembly components have been developed specifically for use with the APC. The following BHA arrangement is mandatory, (bottom to top):

XCB/APC Core Bit (with 3.8" min. core guide I.D.)
Long Bit Sub (OL1029)
Seal Bore Outer Core Barrel - 3.8 inch I.D. (OL1044)
Landing/Saver Sub (OL1021)

NOTE: The possible maximum coring thrust of the tool (28,000 lbf) must be counteracted by an equal mass in the BHA. At the moment this thrust is developed the Bumper Subs cannot close since the internal pressure tends to hold them rigidly open. Thus, to avoid subjecting a hydraulically locked-open Bumper Sub to static compression loads (plus potential shock loads) it is necessary to place at least six full drill collars between the Landing/Saver Sub and the lowest Bumper Sub. Whether or not to do this must be determined on a case-by-case basis. If only piston coring is to be done, there is no harm to operating with so much weight below the first Bumper Sub. However, if XCB coring is planned to follow after APC refusal, the lack of a Bumper Sub lower in the BHA may hamper proper weight-on-bit control by the Driller.

It is assumed that the BHA will normally be set up to accommodate both the APC and the XCB interchangeably. Check the XCB Manual for the proper outer barrel components above the APC Landing/Saver Sub to make the BHA compatible to both tools. Always check spacing of coring tools on the rig floor as the BHA is being run the first time.

2. Care and Handling of the Seal Bore Outer Core Barrel

The APC-special Outer Core Barrel and the Landing/Saver Sub that goes with it have honed, seal surface I.D.'s. The quality of these surfaces is critical to the successful operation of the APC. Thus, these components require care and handling beyond the normal for drill collars.

Unused Landing/Saver and Outer Core Barrels should be stored with the inside bores greased to prevent corrosion. Thread protectors should be kept on both ends at all times in storage.

After each site the Landing/Saver Sub and Drill Collar assembly in use should be swabbed with oil or light grease to inhibit corrosion on the inner surface. Between sites they should be stored horizontally on the casing rack filled with fresh water and closed at both ends with sealed thread protectors. The inner surfaces should be inspected before use to determine whether they are in good enough condition to sustain a working seal.

B. ORIENTATION ALIGNMENT PROCEDURE

1. Purpose

To achieve baseline alignment between the double reference line on the core liners and the notch in the pulling neck used to key the paleo-magnetic orientation tools.

2. Procedure

The tool should be fully assembled from the Pulling Neck (OP4801) to the Vent Sub (OP4829) including the Quick Release Assembly. At least the Upper Piston Rod must be in place. The scoping and non-scoping sections should be scoped together.

a) Lay the assembled tool horizontally so that the Liner Orientation Set Screw (OP4361) in the Vent Sub is facing up. This screw marks the double reference lines on the core liner inside the assembly.

b) Turn the Pulling Neck until its notch aligns with the Set Screw in the Vent Sub. Use a string, rope, straight-edge or line-of-sight to achieve proper orientation. (See Photo G) The Pulling Neck should be pushed in as far as possible.

c) While holding the Pulling Neck to prevent it from inadavertently rotating, tighten the Pulling Neck Lock Nut (OP4704) to lock the Pulling Neck.

This Orientation Alignment should remain valid so long as Vent Subs are used which are Baker-locked to matched Female Quick Releases when they were originally fabricated. If a new Vent Sub or Female Quick Release has been added another Liner Orientation Set Screw hole must be added to the Vent Sub as described in the Vent Sub drawing before the above procedure is performed.

C. ASSEMBLY INSTRUCTIONS

Order of Assembly

Non-Scoping Components:

Step 1. Pulling Neck/Landing Shoulder
Step 2. Upper Rod Components
Step 4. Lower Rod Components & Piston Head
(standard or breakaway)

Scoping Components:

Step 3. Above Quick Release
Step 5. Below Quick Release

Step 1. Pulling Neck/Landing Shoulder Assembly

a) Slip the Pulling Neck Lock Nut (OP4704) and the Split Bushing (OP4803) onto the Pullng Neck (OP4801). Split Bushing goes narrow end down.

b) Insert this group into the Landing Shoulder Sub (OP4805).

c) Complete the assembly by adding to the threaded end of the Pulling Neck the following: one Support Washer (OP4712), a 3/4-10 UNC Stainless Nut (OD7231), a Stop Washer (OP4713), and a Retaining Ring #5100-62 (OD7180). (See Assembly Photo A)

d) Do not fully tighten the Lock Nut yet. That is done during the Orientation Alignment procedure.

e) Pack the cavity inside the Landing Sub with Aqua Lube using just enough to cover the 3/4" Nut and Retaining Ring.

Step 2. Upper Rod Components

a) Screw the Inner Shear Pin Sub (OP4809) into the completed Landing Shoulder Assembly. Lock with a 1/2-13 UNC x 1/2 Set Screw.

b) Screw the Upper Piston Rod (OP4817) into the Inner Shear Pin Sub. Wrench flats are provided. Always use anti-sieze compound or grease on Rod Conections to prevent galling the threads. Do not use pipe dope or any zinc-bearing compound. Important: the Piston Rod is screwed in until it shoulders internally then backed off just enough to allow a Roll pin, 3/16 x 1-3/4 (OD7142) to be inserted through the slots in the Inner Shear Pin Sub and the matching hole in the Rod. This locates the Anti-spiral groove on the Rod in a position that can be re-established accurately at any time.

Step 3. Scoping Components - Above Quick Release

These components may be assembled to each other first and then installed on the Upper Rod Section, or, each piece may be slipped over the Upper Rod Section individually and fitted together. Take care not to dislodge the inner seals when assembling the Inner Seal Sub on the Piston Rod.

a) Install the Inner Seals into the Inner Seal Sub (OP4815) by inserting two Polypaks #37501625-625B, lips facing up, into the internal seal gland. (See Photo B)

b) Slip the Shear Pin Sleeve (OP4811) over the Outer Shear Pin Sub (OP4807).

c) Clamp the two halves of the Split Swivel Sub (OP4813) over the notched end of the Outer Shear Pin Sub and hold together while screwing it into the top of the Inner Seal Sub. This step should capture the Sleeve, Outer Shear Pin Sub and inner seals. The Sleeve and Outer Shear Pin Sub should be free to rotate. Lock the Split Swivel Sub in place with a 1/2-13 UNC x 1/2 Set Screw.

d) Grease and install an O-ring #2-331 (OD2331) in the groove of the Outer Seal Sub (OP4821).

e) Install the outer seals onto the Outer Seal Sub by installing the Outer Seal Female Adaptor (OP4730), a V-Packing #37503000VP, an Inner Seal V-Spacer (OP4729), another V-Packing, another V-Spacer, a third V-Packing and the Outer Seal Male Adaptor (OP4728). (See Photos C & D)

f) Mate the Outer Seal Sub to the Inner Seal Sub and lock with a 1/2-13 UNC x 1/2 Set Screw.

g) Insert the Anti-Spiral Key (OP4823) in the slot provided in the top end of the Male Quick Release (OP4825). Lock in place with one Roll Pin, 1/8 x 5/8 (OD7111). (See Photo E)

h) Assemble two Quick Release Dogs (OP4753) into the grooves of the Male Quick Release and screw on the Knurled Quick Release Nut (OP4752) so that it captures the Dogs.

i) Attach the Male Quick Release to the Outer Seal Sub. The Anti-Spiral Key engages in the groove in the Piston rod. The connection must be made up by screwing the assembly above the Quick Release onto the Male Quick Release while holding it stationary on the Rod.

j) Slide the Vent Snubber (OP4756) over the Rod with the vent holes down. (See Photo F)

Step 4. Lower Rod Components

a) Attach a Center Piston Rod section (OP4818) to the Upper Rod Section. Attach a Lower Piston Rod section (OP4819) to the Center Rod. Always use anti-sieze compound or grease on the Rod connections to prevent galling the threads. Do not use pipe dope or zinc-bearing compounds. Be sure to carefully remove any wrench marks or burrs on the Piston Rod sections after assembly. Lock both connections with Roll Pins, 3/16 x 1-3/8 (OD7140). The Anti-Spiral groove should now be aligned from one Rod section to the next.

b) Attach the Piston Rod Snubber (OP4766) to the Lower Piston Rod using a Roll Pin, 3/16 x 1-3/8 (OD7140) in the connection. Use anti-sieze compound or thread lubricant on the Rod Thread.

c) Attach the Piston Rod Extension (OP4769) to the bottom of the Piston Rod Snubber. Lock in place with a Roll Pin, 3/16 x 1-3/8.

Step 5. Scoping Components - Below Quick Release

This is the section which is routinely laid down for core removal and refitting with clean liner sections. Initial assembly is described below.

a) The Vent Sub (OP4829) and Female Quick Release (OP4827) should be assembled with Baker Lock when received and a tapped hole should be located in the Vent Sub as specified on the Vent Sub drawing.

b) Attach a Liner Seal Sub (OP4360) to the Vent Sub. Grease and install two O-rings #2-232 into the Seal Sub.

c) Attach a 12-1/8 inch Inner Barrel Sub (OP3231) below the Liner Seal Sub.

d) Assemble two 15-ft. Inner Barrels (OP3210) to the Inner Barrel Sub.

e) Attach a second Liner Seal Sub (OP4360) to the bottom of the last Inner Barrel. Grease and install two O-rings #2-232 into the Seal Sub.

f) Install a plastic liner and cut off flush with the pin of the Lower Liner Seal Sub. Cap the liner bottom with a short-style Plastic Tube Support (OP4382).

g) Attach a standard Catcher Sub or Heat Flow Catcher Sub with the selected core catchers.

The lower Scoping Components can now be hung off in the Piston Corer working stands by using a clamp below the Female Quick Release. The rod and Upper Scoping Components are assembled by spudding the Piston Head into the Female Quick Release and scoping the Rod Assembly into the Lower Scoping Components. Just before mating the Male and Female Quick Release sections, fit the Vent Snubber into the Female Quick Release (Photo F). Finally, assembly the two Quick Release sections and turn the knurled Quick Release Nut down to engage the Dogs.

D. TYPICAL OPERATION INSTRUCTIONS AND TECHNICAL GUIDLINES

Operation of the APC is very similar to the VLHPC. The rig floor practices that are described below are recommendations for simplicity, speed and efficiency.

1. Initial Set-Up

a) Assemble one lower scoping section (below the Quick Release) fully dressed with a liner. Hang it off in the working stand with a handling clamp located on the Vent Sub just below the Female Quick Release.

b) Assemble the second lower scoping section without a liner to be used as a protector for the exposed Piston Rod when the non-scoping assembly is picked up for the first time.

c) When the non-scoping assembly (with the upper scoping assembly above the Quick Release) is safely in the vertical position hand it off in the HPC working stand by a clamp on the Vent Sub.

d) The non-scoping assembly can now be separated from the undressed lower section and spudded into the fully dressed, lower scoping assembly as is normally done in routine coring operations.

2. Routine Operation

a) Assume a redressed, clean lower scoping section (from the Female Quick Release to the Catcher Sub) is hanging off in the working stand by a lifting clamp attached at the Vent Sub just below the Female Quick Release.

b) Assume that a complete APC with a core has been returned to the rig floor and is hanging in the pipe by the sinker bar/overshot assembly.

c) Hang off the tool in the pipe at the elevator by a lifting clamp located at the Landing Shoulder Sub, then release the overshot.

d) Withdraw the scoped out tool with a tugger line until it is clear of the pipe and lower it into a second shuck in the working stand. Hang it off at a clamp located on the Vent Sub just below the Female Quick Release. Leave the tugger line attached.

e) Break the Quick Release and lift the upper scoping and Rod sections using the tugger until the Piston Head is clear.

f) Swing the Piston Head and Rod assembly over and spud the Head into the redressed lower tool section in the adjacent shuck of the working stand. Scope the tool together. Before the Male Quick Release is made up, the Vent Snubber must be guided into the Female Quick Release. (When the tool is separated, the Piston Head pulls the Vent Snubber out.) Make up the Quick Release and completely stroke the tool together.

g) Use the Shear Pin Tool to remove the stubs of the old shear pins, using the magnet as needed. Insert the Shear Pin Tool into one shear pin hole to align the Outer Shear Pin Sub while inserting the desired Shear Pins. The pins are held in place by partially rotating the Shear Pin Sleeve after removing the Shear Pin Tool.

h) Lift the completely assembled and redressed tool out of the working stand and stab it into the drill pipe. Hand it off on the handling clamp attached to the tugger while the overshot and sinker bar assembly is attached for running in the hole, then remove the handling clamp.

While the fresh tool is being run in the hole, the lower section containing the core can be lifted with a tugger line and laid out for core removal and redressing.

i) Break off the Catcher Sub and the Liner Seal Sub to access the plastic core liner. Remove the liner and core.

j) Wash out the empty barrel thoroughly and insert a new liner. Liners (for piston coring only) should be prepared in advance by using jigs to locate the Orientation Set Screw hole and bevel the outer edge so that it does not dislodge the O-rings in the Liner Seal Sub(s) while being inserted in the core barrel. Take care to feel for the O-rings while inserting the Liner.

k) Rotate the Liner inside the core barrel until the hole marking the double reference line on the Liner appears below the Orientation Set screw hole in the Vent Sub. Install the Set Screw.

l) Check the O-rings in the Liner Seal Sub and make it up, over the Liner, to the bottom core barrel.

m) Cut off the excess plastic liner flush with the end of the Liner Seal Sub. Add a short Plastic Tube Support (OP4382) to the end of the Liner.

n) Insert the chosen Core Catcher assembly into the Catcher Sub and make up to the Liner Seal Sub.

The redressed lower scoping section is now ready to be lifted with a tugger line and hung off in the working stand.

3. Velocity Control

The APC has been designed to operate at various power levels and coring velocities. These operating parameters must be pre-set on deck prior to deployment of the tool in anticipation of the type of sediment about to be cored. The pre-set variables are controlled by:

Number and type of shear pins used, Number of Speed Control Set Screws removed.

a) Shear Pins

One, two, or three shear pins may be used to vary the amount of maximum thrust developed as the corer " shoots off ". The shear pins used are 1/4" diameter 17-4PH (specially heat treated) or mild steel. Both types are magnetic. The mild steel pins can be identified by the fact that they are shorter and tend to be considerably more rust-prone than the 17-4PH pins. The following approximate rig pressures will be encountered:

17-4PH	Mild Steel
1 Pin - 1000 psi	1 Pin - 550 psi
2 Pins - 2000 psi	2 Pins - 1100 psi
3 Pins - 3000 psi	3 Pins - 1650 psi

Any combination of shear pins may be used, for example, two (2) 17-4PH shear pins and one mild steel pin should provide a shoot-off pressure of about 2500-2600 psi.

b) Speed Control Set Screws

The scoping section of the tool is driven by expansion of compressed sea water in the drill string. To reach the moving portion of the tool, the water must first Flow through the ports in the Landing Shoulder Sub (OP4805). Six ports are provided, two of which are always open. The other four can be left open or plugged with 5/8"-11 UNC stainless set screws.

These are the Speed Control Set Screws, which, when used to plug one or more of the ports in the Landing Shoulder Sub, act like governors controlling the maximum speed which the moving portion of the tool can achieve.

When using two or three 17-4 shear pins (pressure greater than 2000 psi), it is possible for the tool to develop a top speed high enough to severely damage itself when taking a water core or low resistance sediment core.

Optimum performance is achieved by using the greatest number of shear pins and the least speed control set screws possible while remaining within the safe top speed limits.

4. APC Operational Guideline Chart

To help achieve optimum performance, (i.e. greatest penetration depth and minimum core distubance) while protecting the tool from damage, refer to the Operational Guideline Chart (Fig. 13).

The Chart is set up to show which combinations of 17-4PH shear pins and open speed control holes can be used safely when sediment resistance to penetration is very low. Also, some indications of safe combinations are given for medium and high resistance sediments, although these will remain somewhat vague until field experience provides adequate performance data . Using the charts, the tool should by operated in the A Zone as much as possible. The B squares are safe but do not adequately utilize the coring force potential of the tool. The C Zone is marginal and the D Zone is where mechanical damage to the corer is definitely possible caused by excessive speed and a sudden stop at the end of the stroke.

Prototype sea trials indicated that the Chart was adequate to prevent damage to the tool when followed. It may prove to be significantly conservative after enough testing at sea.

5. High Pullout Loads

The APC has been designed to safely tolerate overpulls up to 100,000 lbs (with about a 70% safety factor). If 100,000 lbs. is not enough to pull the tool free of the sediment, higher overpulls only risk separating the tool either at an Inner Barrel Thread, a Piston Rod Connection or at the Quick Release.

It is recommended that the highest overpull allowed be limited to 100,000 lbs. Beyond this point, wash carefully over the extended barrel for a meter or

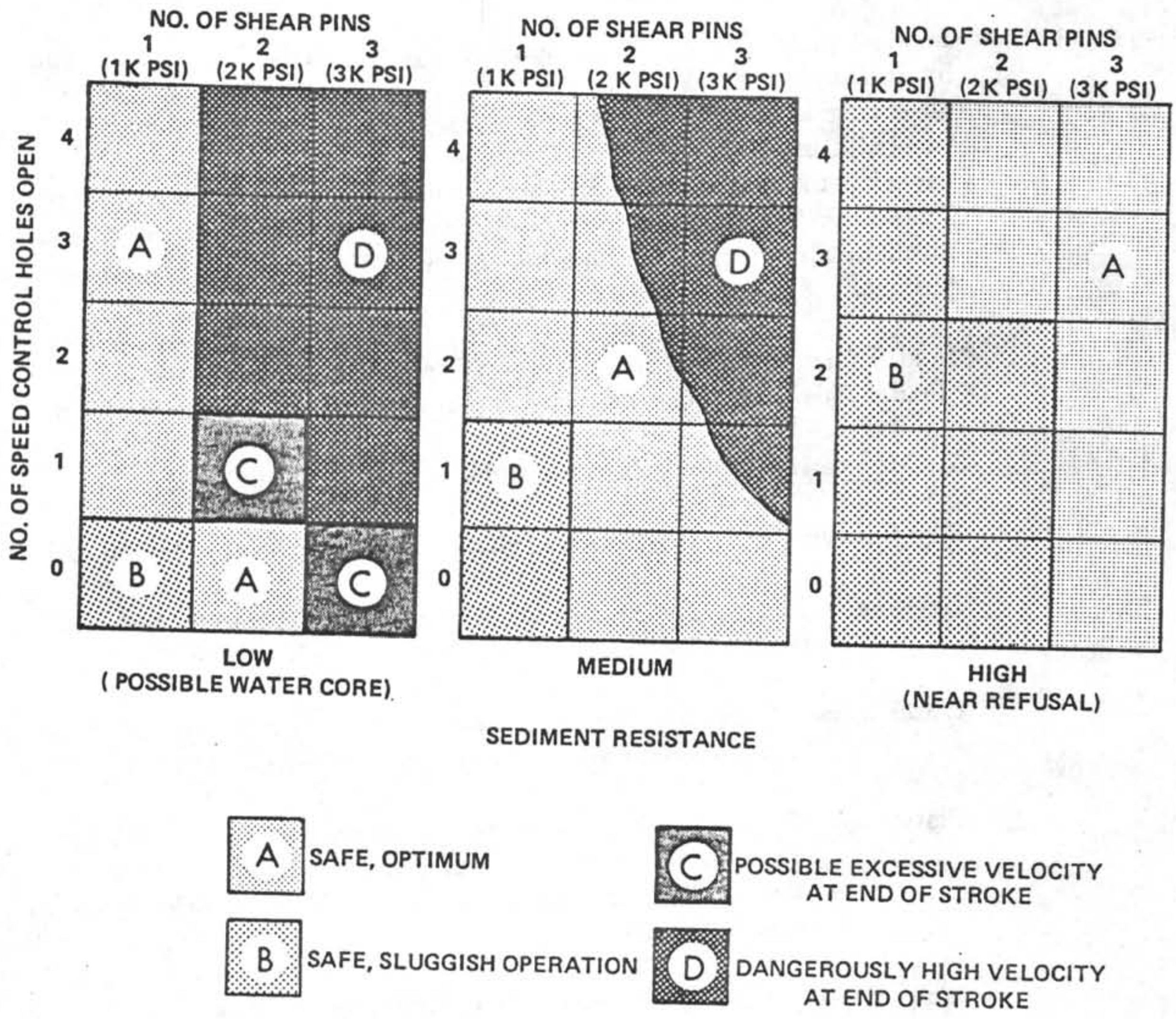


FIG. 13.

APC OPERATIONAL GUIDELINES.

two and then attempt pulling free again up to 100,000 lbs. Repeat this process until the tool comes loose or is completely washed over. This type of washover process may result in bit gouges on the extended Inner Barrel or Core Catcher Sub.

6. Partial Stroke

In most piston-corable formations the onset of APC refusal will be preceeded by incomplete stroking of the tool. This is detectable at the rig floor by observing a distinct difference in the pressure bleed-off characteristics after the build up of pressure to fail the shear pins. The APC does not have the capacity to be assembled in shorter lengths (as the previous VLHPC did). Therefore, flow-in disturbance will probably occur when the piston head is mechanically stroked through the unstroked portion of the core liner during pullout.

In stiff formations the tool can be safely operated with no seals on the Piston Head. This may help to reduce flow-in disturbance after partial strokes.

7. Monitoring Wear & Deterioration

The following critical wear areas should be inspected at every opportunity:

Landing Surfaces - The underside of the Landing Shoulder Sub and the 45° lead-in taper of the Landing/Saver Sub.

Outer Core Barrel and Landing/Saver Sub - The honed I.D.'s should be inspected regularly for corrosion build-up and pitting.

Piston Rod Snubber - The upper (60°), conical surface is the internal landing shoulder for the scoping portion of the tool at the end of the stroke. Damage will result here if coring velocity is too high (especially after water cores).

Inner Barrel Threads, Piston Rod threaded connections, and Quick Release Lugs - High pullout leads may overstress any or all of these.

8. Checking & Changing Seals

a. Piston Head Seals - The seals should be inspected after each core while reassembling the APC. The tool will function well even if these seals are in poor condition or removed entirely but core quality may suffer, especially in soft formations.

The seals are changed by backing off the Seal Retainer (OP4345), removing the Lock Pin (OP4383) and then removing the Piston Head Body.

b. Inner (Polypak) Seals - The inner Polypaks cannot be routinely observed but should last the longest of any of the seals on the tool. They should be removed whenever the tool is redressed between sites or put into storage. This will reduce corrosion in the seal gland when the tool is not in service.

c. Outer (V-packing) Seals - The outer seals can be visually inspected after every core and should be changed whenever their appearance indicates the possibility of not achieving a tight seal downhole.

To change Outer Seals:

1) Hang the scoping section off on a clamp located on the Vent Sub just below the Female Quick Release.

2) Scope the Piston Rod into the lower section and make up the Quick Release.

3) Continue scoping the Piston Rod down until the wrench flats on the Upper Rod section approach the top of the Outer Shear Pin Sub.

4) At this point insert the Hang Off Tool (OP4834) into the hole in the Male Quick Release just above the knurled Nut and engage the matching hole in the Piston Rod.

   The Piston Rod will be supported by the Hang Off Tool while changing the Outer Seals.

5) Remove the 3/16" Roll Pin and back off the Inner Shear Pin Sub from the Upper Piston Rod.

6) Remove the Set Screw and break the scoping section just above the Outer Seals to gain access to the seal gland.

7) After installing new seals reassemble each of the components in reverse order. When re-assembling the Inner Shear Pin Sub, screw it all the way onto the Upper Piston Rod until it shoulders internally and back off just enough to allow a new 3/16" x 1-3/4" Roll Pin to be inserted. This step assures that orientation alignment has been re-established as before.

E. PARTS LIST

ADVANCED PISTON CORER - MOD. II

P/N	DESCRIPTION	NO. REQ'D.
OP4800	Advanced Piston Corer Assy. - Mod. II	--
OP4704	Pulling Neck Lock Nut	1
OP4710	Speed Control Set Screw, 5/8-11 UNC x 5/8 SS	0-4
OP4712	Support Washer	1
OP4713	Stop Washer	1
OP4721	Shear Pin, 1/4 dia x 3-7/32, 17-4PH	1-3
OP4725	Shear Pin, 1/4 dia x 3-1/8, Mild Steel	1-3
OP4728	Outer Seal Male Adaptor	1
OP4729	Outer Seal V-Spacer	2
OP4730	Outer Seal Female Adaptor	1
OP4752	Quick Release Nut	1
OP4753	Quick Release Dog	2
OP4756	Vent Snubber	1
OP4766	Piston Rod Snubber	1
OP4769	Piston Rod Extension (Std. Hd.)	1
OP4801	Pulling Neck	1
OP4803	Split Bushing	1
OP4805	Landing Shoulder Sub	1
OP4807	Outer Shear Pin Sub	1
OP4809	Inner Shear Pin Sub	1
OP4811	Shear Pin Sleeve	1
OP4813	Split Swivel Sub	1
OP4815	Inner Seal Sub	1
OP4817	Upper Piston Rod	1
OP4818	Center Piston Rod	1
OP4819	Lower Piston Rod	1
OP4821	Outer Seal Sub	1
OP4823	Anti-Spiral Key	1
OP4825	Male Quick Release	1
OP4827	Female Quick Release	1
OP4829	Vent Sub	1
OP4834	Hang Off Tool	---
OP4836	Shear Pin Tool	---
OP3210	Inner Core Barrel, 3-1/2 x 2.87 x 14' 9-1/2"	2
OP3231	Inner Barrel Sub, 12-1/8"	1
OP3400	Core Liner, Butyrate, 2.817 x 32' -6"	1
OP4345	Piston Seal Retainer	1
OP4360	Liner Seal Sub	2

P/N	DESCRIPTION	NO. REQ'D.
OP4361	Core Liner Retainer Screw	1
OP4362	Slim Nose Catcher Sub (Alt.)	1
OP4376	Catcher Sub	1
OP4377	Heat Flow Core Catcher - Body (Alt.)	1
OP4378	Heat Flow Core Catcher - Cone (Alt.)	1
OP4381	Piston Head Body	1
OP4382	Plastic Tube Support	1
OP4383	Lock Pin, Piston Head	1
OP4390	Male V-packing Adaptor (Piston Hd.)	1
OP4391	Female V-packing Adaptor (Piston Hd.)	1
OP4392	V-Spacer (Piston Hd.)	2

Fasteners & Seals

OD2232	O-ring #2-232, Buna-N, 70D.	4
OD2331	O-ring #2-331, Buna-N, 70D.	1
OD3150	Polypak, Molythane, #37501625-625B	2
OD4200	V-packing, Molythane, #31202000VP	3
OD4300	V-packing, Molythane, #37503000VP	3
OD6555	Set Screw, Socket, 1/2-13 UNC x 1/2, Stainless	4
OD7111	Roll Pin, 1/8 x 5/8, Stainless	1
OD7140	Roll Pin, 3/16 x 1-3/8, Stainless	4
OD7142	Roll Pin, 3/16 x 1-3/4, Stainless	1
OD7180	Snap Ring, #5100-62	1
OD7231	Hex Nut, Stainless, 3/4-10 UNC	1

Core Catcher Alternatives

OR7010	Core Catcher, Complete, Dog Type "10"	1-2
OR7020	Core Catcher, Complete, Dog Type "8"	1-2
OR7100	Core Catcher, Complete, Flapper Type	1

Outer Barrel Components

OL1021	Landing/Saver Sub	1
OL1029	Long Bit Sub	1
OL1044	Seal Bore Outer Core Barrel	1

IV. OPERATIONAL SYNOPSIS - SEA TRIALS

The prototype assemblies of the Advanced Piston corer were first introduced to the Glomar Challenger on Leg 94 in June 1983. The two prototypes sent for the initial sea trials were not identical. Several design options were included for evaluation including convertible seals glands capable of accepting either Polypak or separated, V-packing seals, two Piston Rod assemblies (with and without the Anti-Spiral Groove), and two different Piston Heads (conventional-fixed and new, Breakaway version.)

Table 2 capsulizes the results of all prototype deployments during Legs 94, 95 and 96. The general performance of the tool was good from the outset. Core quality and functional characteristics were as good or better than the VLHPC. Assembly, maintenance and on-deck handling were considerably better.

A. LEG 94 RESULTS

The Piston Rod assembly with the Anti-Spiral Groove was used for twelve cores at the first site. The tool functioned as designed but the Anti-Spiral Rod was retired when it allowed shear pin stubs to work their way down the groove and became trapped in the inner seals. The ungrooved Rod assembly was then used successfully for twenty five cores in two different holes until a connection in the Rod assembly failed during a retrieval overpull. The cause of failure was later traced to over-torque during assembly of the ungrooved Rod. (The failure analysis is described in detail in Section II). Shortly thereafter, the bottomhole assembly section containing the sole Seal Bore Outer Core Barrel required for APC work was lost in an unrelated accident involving the failure of a Bumper Sub connection. Further APC usage was thus delayed pending delivery of another set of BHA components during the next port call.

The APC tools were highly successful during these first thirty-seven core attempts. minor problems with shear pins and handling sequences were identified to be improved in the re-design for Mod. II. The Polypak seals were determined to be unacceptable for application as Outer Seals.

B. LEG 95 RESULTS

The Outer Barrel components lost were replaced along with a set of APC parts to replace those lost when the Rod connection parted during Leg 94. The APC was used to take only seven cores at Site 612; the remainder of Leg 95 was spent without the need to do any piston coring. Recovery and core qualilty were good. Additional minor shortcomings were identified including the lack of ease of changing outer seals and problems with locking and alignment of the Piston Rod intermediate and upper most connections.

C. LEG 96 RESULTS

An extra set of Outer Barrel Components were provided so that Leg 96 began with duplicate BHA for APC work since piston coring was to be the primay work load. The APC was used at 9 holes taking 122 cores before two mishaps resulted in the loss of both sets of APC bottom hole assembly components - thereby abruptly terminating the sea trials of the APC.

The total usage during Legs 94, 95 and 96 was adequate to thoroughly establish the viability of the APC concept. The rig floor and operations personnel were unanimous in their opinion that only a few design changes were required and that, with them, the APC would effectively obsolete the VLHPC coring system. Leg 96 usage was in the Mississippi Fan area of the Gulf of Mexico where loose sand was common in the upper sediments - an especially difficult material to piston core successfully. Additional problems requiring design improvements identified during the leg were high sandline drag during retrieval and the need to change outer seals as often as once per core in sand-rich zones. The Breakaway Piston Head was used extensively for about the first half of the APC deployments of Leg 96. It was not, ultimately, deemed ready for full operational acceptance and the final APC runs used the Standard (fixed) Piston Head.

Numerous water cores were inadvertently taken during Leg 96 operations while verifying the location of the mudline at several holes. The lack of mechanical damage from these water cores helped verify the operational guideline limitations. High retrieval overpulls, often in excess of 90,000 lbs., were experienced numerous times on Leg 96. No damage to the Rods, Quick Releases or Inner Barrel Threads was observed.

Excerpts of the Cruise Operations Managers' Reports for Legs 94, 95 and 96, discussing the results of APC testing, are included in Appendix E.

TABLE 2
ADVANCED PISTON CORER
PROTOTYPE SEA TRIAL DEPLOYMENT SUMMARY

LEG	SITE	No. of cores attempted	Meters Cored	Meters Recovered	Type of Sediment	Water Depth (meters)	Remarks
94	606	18	165.75	154.15	Spongey nanno ooze.	3022	Anti-spiral rod retired after core #12H
	606A	19	178.40	156.30	Nanno ooze.	3024	Piston Rod parted at 40k overpull on Core #20H
95	612	7	52.10	48.85	Firm Glauconite clay	1414	Core quality good. Anti-spiral Rod assy misaligned.
96	614	5	37.00	37.10	Alternating sand, mud and clay.	3314	Loose sand terminated piston coring.
	614A	11	78.30	55.88	"	3314	Began coring at 37m BSF
	615	20	126.80	103.64	"	3284	APC used intermittently with XCB as needed.
	615A	15	55.40	46.92	"	3286	Spot cored to recover clay-rid intervals.
	616	14	117.60	94.91	Clay & silt	2999	Refusal defined by 95k overpull on Core #18H after XCB was used. Stuck BHA severed.
	616A	5	48.00	24.2	"	2999	Attempted oriented core with new Gyro tool.
	616B	22	143.30	113.04	"	2999	Stroke incomplete below 95m BSF
	617	21	130.10	113.08	Clay & silty mud	2478	Routine operation
	617A	9	83.50	56.99	"	2478	BHA lost-off hole.
TOTALS	12 holes	166 cores	1216.25 meters	1005.06 meters (82.6%)			

APPENDIX A
INITIAL FEASIBILITY STUDY REPORT

JOHN E. HALKYARD & COMPANY

Consultants in Engineering and Business Development
Specializing in Mechanical Systems, Hydraulics and Ocean Engineering

FEASIBILITY ANALYSIS

OF

PISTON CORE BARREL CONCEPTUAL DESIGN

FOR

DEEP SEA DRILLING PROJECT, A-031

UNIVERSITY OF CALIFORNIA, SAN DIEGO

LA JOLLA, CALIFORNIA 92037

By: O. R. Heine
P. M. Riede

Date: May, 1982

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CONCLUSIONS AND RECOMMENDATIONS

This analysis indicates the feasibility of designing a piston core barrel provided the Top Sub Body seals are effective throughout the stroke. For the case of using this seal only to shoot off the tool, insufficient stored energy is available to get adequate penetration of the seabottom.

Based on this analysis, it is recommended that primary attention should be placed on the "full length seal" concept (a). In addition, it is recommended that serious consideration be given to including a piston inside the core tube, particularly if samples of low soil shear strength are to be obtained.

We recommend that future efforts include the following:

1. Review a design configuration of the "full length seal".
   This should result in a full-scale layout drawing of the complete hydraulic piston corer including all pertinent dimensions.
2. Hydraulic and stress analyses to establish the practicability of the design.
3. Prepare detailed fabrication drawings as required for the manufacture of a prototype unit.
4. Prepare a test plan to allow for verification of the performance of the new corer design.

SUMMARY

The results of this approximate effort indicate that it will be advisable to utilize concept (a) as defined in the Statement of Work "Full Length Seal" in favor over concept (b) "Shoot off Tool".

The force balance equation, applying the hydraulic driving forces and hydraulic plus viscous resisting forces acting on the corer, while neglecting secondary terms such as sliding friction and inertial forces, over the full stroke of 30 feet, show that it will be possible to drive the corer into medium clay in about 1.5 to 2.5 seconds with concept (a) relying only on the release of a part of the stored energy and letting the applied pressure thus decay from say 2800 or 2000 psi to about 715 psi at the stored pressurized fluid volume in the pipe string expands during the driving of the tool (see Figure 7).

In contrast, because a flow path is opened to the outside as soon as the piston leaves the seal area (orifice #3) and the stored fluid volume under the initial pressure exhausts quickly (in less than .5 sec. the pressure would drop to 715 psi or so), the stored energy can only effect the initial acceleration of the corer to a peak value of about 16 to 24 ft/sec. but cannot continue to drive the tool.

This initial velocity reached after say 25 feet stroke diminishes rapidly as the pressure generated inside the corer due to headlosses caused by the fluid displaced through restricting orifices tends to decelerate the corer. Because of the distance between the pressure release location and the pump located on the drill ship (1500 m in this example) the pump can only respond to the fall-off in pressure after the pressure change is noticeable at the surface, which is 1.1 seconds later, the time needed for a signal to propagate at the velocity of sound through the 1500 m long pipe string.

Questionable

Flow in system never stops, so time of pump response is not directly related to pressure at lower end of string.

Thus, at best, 1.1 seconds later the pump can pick up where the initial energy release has leveled off, say at 715 psi, and 1 foot of stroke. Since the leakage through the head orifice #3 continues, the system pressure cannot increase beyond a certain level. Again applying the force balance equation, it is estimated that the 30-foot stroke can consequently be completed in about 8 seconds by flow provided by the pump at the maximum rate of 600 GPM.

For heavier clay having say three times the viscous shear resistance of medium clay this process would require significantly more time and may not allow full penetration of 30 feet.

CONCLUSION

While the "shoot-off tool" concept (b) could conceivably work in moderate strength soils, it is questionable whether it would work in heavier or higher strength soils without further performing more detailed analytical effort and subsequent experimental tests.

On the other hand, "the continuous seal" concept (a) should function as well or even better than the present corer inasmuch as more force is initially available due to the larger cross sectional area of the piston compared with the existing one.

STATEMENT OF WORK
PISTON CORE BARREL FEASIBILITY ANALYSIS
APRIL 27, 1982

Based on a verbal description of the desired new coring tool and the conceptual sketch (Fig. 3) enclosed, the following work items should be accomplished:

1. Review the problem description and tool concept with DSDP engineers and acquire the necessary background and support information including dimensional, test and operational data of current HPC and BHA components.

2. Outline and report essential requirements for the tool to function according to the principles envisioned.

3. Analyze hydraulic and mechanical feasibility of two proposed concepts.

    a) One using Top Sub Body seals throughout the stroke.

    b) One using those seals only to shoot off the tool.

4. Analyze hydraulic and mechanical feasibility of check valve or other devices to enable proper venting of the water in the Core Liner when the tool fires.

5. Assess overall feasibility of conceptual design based on above analyses and make recommendations for future efforts both orally and in a summary report with documented concept designs and calculations.

LIST OF REFERENCES.
(USED IN THIS FEASIBILITY ANALYSIS)

(1) "THEORETICAL SOILS MECHANICS", KARL TERZAGHI
JOHN WILEY & SONS, INC., NEW YORK.

(2) "PCA SOIL PRIMER"
PORTLAND CEMENT ASSOCIATION.

(3) "ONE DIMENSIONAL TWO PHASE FLOW", GRAHAM WALLIS
MC GRAW-HILL BOOK CO.

(4) "FLUID MECHANICS", DODGE & THOMPSON
MC GRAW-HILL BOOK CO.

(5) "HANDBOOK OF OCEAN AND UNDERWATER ENGINEERING"
MYERS, HOLM & MC ALLISTER, MC GRAW-HILL BOOK CO.

(6) DRAWINGS & TEST DATA SUPPLIED BY DEEP SEA DRILLING PROJECT:
(a) DSDP STD. WIRELINE CORE BARREL ASS'Y, R-OP 3000 REV. 0
(b) VARIABLE LENGTH HYDRAULIC PISTON CORER ASSEMBLY, R-OP 4300
(c) STATEMENT OF WORK, APRIL 27, 1982
(d) SKETCH OF CONCEPT (b) (FIG.3)
(e) ILLUSTRATION OF STD. HYDRAULIC PISTON CORER (VLHPC) (FIG.-1-)
(f) D.S.D.P HYDRAULIC PISTON CORER TEST RUN 4 (FIG.-2)
(g) VERBAL INF. SUPPLIED BY DAVE HUEY ON 5/12/82:
- RANGE OF CORER PENETRATION VELOCITY EXPECTED = 10 ÷ 20 FT/SEC
- NO. SHEAR PINS VS. APPLIED PRESSURE: 2/1800 ÷ 2000 PSI, 3/2300 ÷ 2500 PSI
- WORKING DEPTH RANGE: 1500 ÷ 7000 m
- PUMP FLOW @ 2000 PSI: 350 ÷ ~~600~~ 480 GPM (MAX.), 8.13 GALLONS/STROKE
- EXPECTED RANGE OF SOIL SHEAR STRENGTH: 1200 ÷ 3000 g/cm^2

ESTIMATED CORING RESISTANCE.

CONSIDER : 1. SOIL (CLAY) MAY BE TREATED AS "NON-NEWTONIAN" VISCOUS FLUID (BINGHAM PLASTIC) PER. (REF.-1-)

2. SPECIFIC GRAVITY OF CLAY IS 2g/cm³ (REF.-2-)

3. EXTERNAL CORING RESISTANCE IS TREATED AS ADDITIONAL INTERNAL FRICTION LOSS.

SHEARING RESISTANCE OF SOIL : (REF.-1.)

?

$$S = C + \sigma \, tg \, \phi = \underline{1000 \; g/cm^2} \quad \text{(GIVEN)}$$

C = COHESIVE SHEAR RESISTANCE $\cong 1000 \; lb/ft^2$ (REF. 2) FOR MEDIUM CLAY $\cong$ 466 g/cm^2

σ = NORMAL STRESS (g/cm^2) IN SOIL.

ϕ = ANGLE OF SHEARING RESISTANCE (ϕ = 20° MAX. FOR CLAY)

THUS APPROXIMATELY 50 % OF THE SHEARING RESISTANCE IS "COHESIVE" IN THIS ASSUMPTION. ?

$$\text{LET} \quad C = \tau_W \quad \text{(SHEAR STRESS @ CORER I.D. WALL)}$$
$$= \tau_w$$

THE EFFECTIVE VISCOSITY IS FOR NON-NEWTONIAN FLUIDS APPROXIMATELY (SEE REF. 3) GIVEN WITH :

$$\mu_{EFF.} = \frac{\tau_W}{8 \, V_m} D$$

MAY 1982
O.R.H.

WHERE: V_w = VELOCITY NEAR PIPE WALL (cm/sec)

D = I.D. OF CORER = 2.617 IN = 6.647 cm

LET: V_w = 1.0 cm/sec, THEN:

$$\mu_{EFF.} = \frac{488}{8 \times 1.0} 6.647 \cong \underline{405 \text{ POISE}}$$

LET: V_W = .5 cm/sec, THEN:

μ_{EFF} = 810 POISE

AT V_W = .25 cm/sec, μ_{EFF} = 1620 POISE

COMPARE THIS WITH TEST RESULTS:

FROM D.S.O.P. HYDRAULIC PISTON CORER TEST RUN 4

P_{MAX} = 1500 PSI

@ STROKE = 15 FT

AVG. VELOCITY = 10 FT/SEC = 304.8 cm/sec

Check for approp. μ_{EFF}

FOR LAMINAR FLOW IN PIPE: (REF. -4-)

$$h_1 - h_2 = \frac{128 Q \nu l}{\pi d^4 g}$$

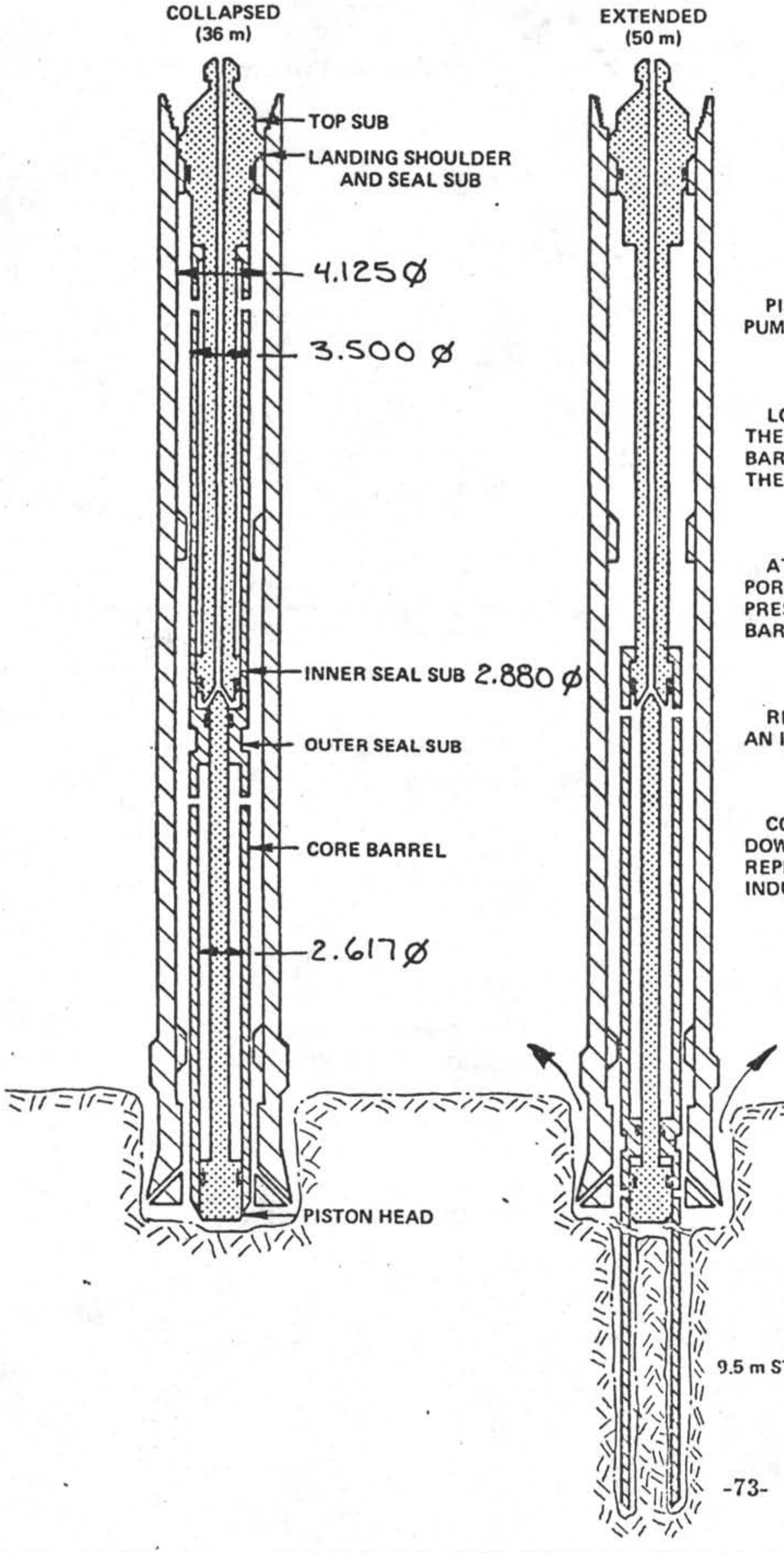
Hagen-Poiseuille Law see pg 20 of Craft

↑ head loss due to flow Q over length of pipe, l

FIG-1

DEEP SEA DRILLING PROJECT

HYDRAULIC PISTON CORER (VLHPC)



OPERATIONAL SEQUENCES

1

PISTON CORER IS SEATED AND SEA WATER IS PUMPED AT 350 GPM to INITIATE ACTION.

2

LOCKING PINS SHEAR AT A MAX. 2800 PSI. THE OUTER SEAL SUB THEN DRIVES THE CORE BARREL INTO THE FORMATION AS FLUID ABOVE THE PISTON HEAD IS VENTED.

3

AT THE END OF THE STROKE DAMPENING PORTS ARE UNCOVERED WHICH VENT THE PRESSURE FLUID AND DECELERATE THE CORE BARREL.

4

RIG FLOOR SEES DROP IN PUMP PRESSURE AS AN INDICATION CORER HAS FULLY STROKED.

5

CORE BARREL IS RETRIEVED. BIT IS WASHED DOWN TO NEXT CORING POINT. PROCESS IS REPEATED UNTIL FORMATION BECOMES TOO INDURATED.

CONSEQUENTLY : $$\nu = \frac{(h_1 - h_2)\pi d^4 g}{128\ Q\ \ell}$$ (KINEMATIC VISCOSITY = $\frac{\mu}{\rho}$)

WHERE:

$(h_1 - h_2)$ = HEAD LOSS OF FLUID (CM OF FLUID)

Q = FLOW (cm^3/sec)

g = 981 cm/sec^2

ℓ = 15 FT = 457.2 cm

THUS : $$Q = (6.647^{cm})^2 \frac{\pi}{4} \times 304.8^{cm/sec} = \underline{10,577\ cm^3/sec}$$ {fluidized core mat'l. into corer

$$(h_1 - h_2) = 1500_{psi} \frac{\frac{\pi}{4}(2.88^2 - 1.25^2)}{\frac{\pi}{4}(2.617)^2} ? = \underline{1474\ PSI}$$ ← ? why this ratio

= $\underline{51,839\ cm}$ LIQUID (CLAY)

$$\nu_e \cong \frac{51,839\ \pi\ (6.647)^4\ 981}{128\ (10,577)\ 457.2} = \underline{504\ cm^2}/sec$$

$$\mu_e \cong \nu\rho \cong 504 \times 2 = \underline{1008\ \text{POISE}}\ \left(\frac{g}{cm\,sec}\right)$$

ESTIMATED EFFECTIVE VISCOSITY OF CLAY @ 1000 g/cm² SHEAR STRENGTH.

THE REYNOLDS NO. IS APPROX. :

$$\sim Re \cong \frac{\rho V D}{\mu} \cong \frac{2.0\ (304.8)\ 6.647}{1008} \cong \underline{4.0}\ \frac{\frac{g}{cm^3}\ \frac{cm}{sec}\ cm}{\frac{g}{cm\text{-}sec}}$$?

INDICATION OF LAMINAR FLOW, THUS APPLICATION OF VISCOUS FLOW EQUATION IS ESSENTIAL.

U.S.D.P. HYDRAULIC PISTON CORER TEST RUN 4

CHAN 2 MAX= -93 MIN= -2664 MEAN= -956.15 DATA 1-1024 SCALE X 7.0

PRESSURE TRANSDUCER DATA CLAY BATCH B3

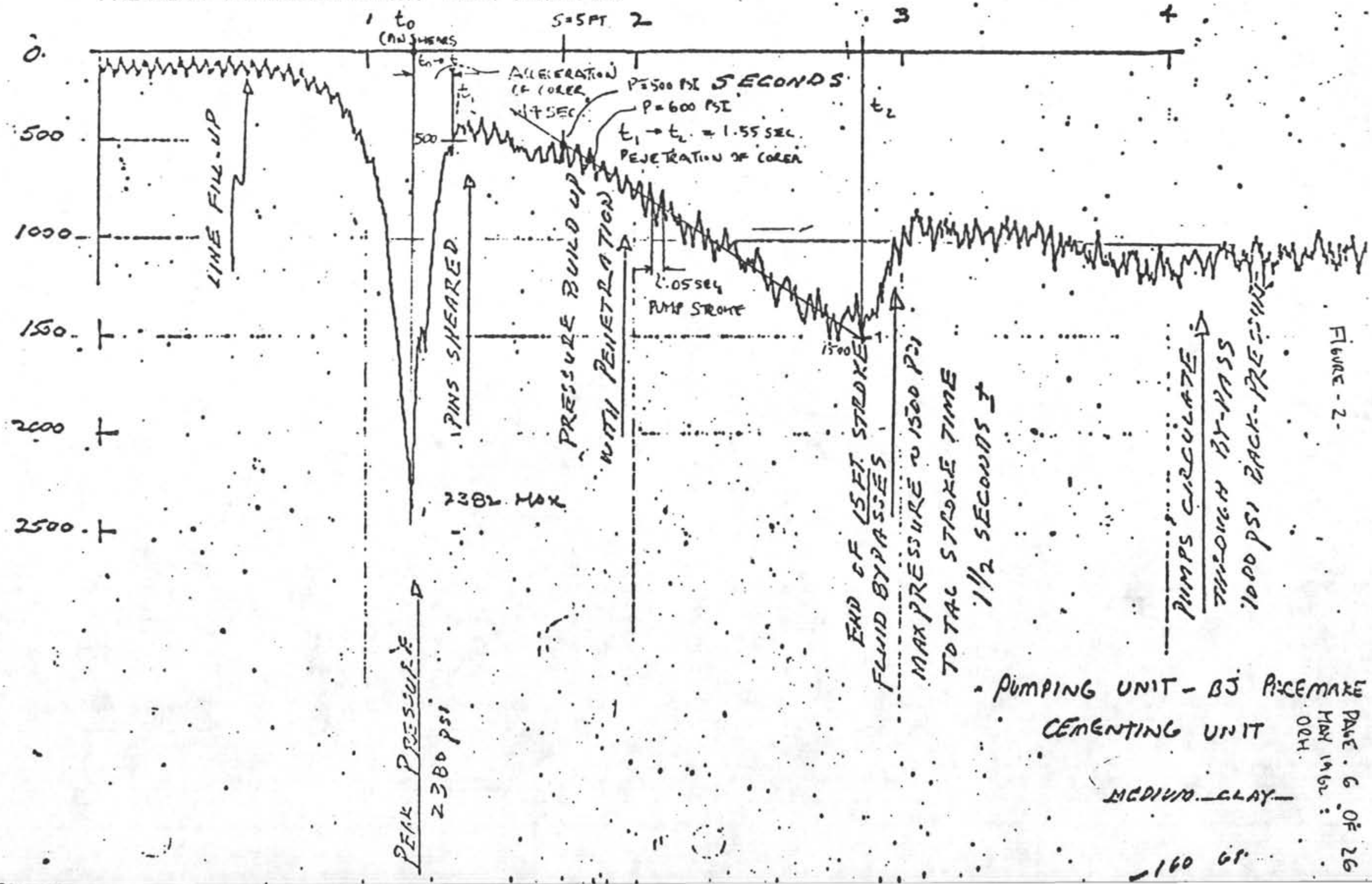


FIGURE - 2 -

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MAY 1982
ORH

MAY 1982
ORH.

THE HYDRAULIC PISTON CORER TEST DATA (RUN 4) INDICATES THAT BOTH THE PRESSURE RISE AND CORING PENETRATION VELOCITY WERE CONSTANT DURING AT LEAST THE LAST 2/3 OF THE 15 FT. STROKE.

THUS FOR MEDIUM CLAY ONE CAN EXPECT THE RESISTANCE OF PENETRATION TO BE APPROXIMATELY:

$$P_R \cong \overset{\text{Pressure}}{1500} \overset{\text{Area}}{\left(2.88^2 - 1.25^2\right)\frac{\pi}{4}} \Big/ \overset{ft}{15} \times \overset{ft/sec}{10} \cong \underline{53 \text{ LB / FT - FT/SEC}}$$

THE MAXIMUM PENETRATION LOAD WAS AT THE END OF THE STROKE:

$$F_{P\,MAX} \cong P_R\,(150) \cong \underline{7{,}950 \text{ LB}}$$

THE PRESSURE AFTER 5' STROKE SHOULD HAVE BEEN THEN:

$$P = \frac{53\,(5 \times 10)}{\frac{\pi}{4}\left(2.88^2 - 1.25^2\right)} \cong \underline{500 \text{ PSI}}$$

$P_R = f(x, V)$

$P_R = f(\mu, l, V^2)$

VS APPROX. 520 PSI INDICATED, WHICH IS IN GOOD AGREEMENT!

THE TEST DATA (FIG.-2, REF. 6F) CONFIRM THE PRESUMPTION THAT CLAY TYPE SOIL IN A SATURATED STATE BEHAVES MORE OR LESS LIKE A VISCOUS FLUID WHEN SUBJECTED TO RAPID PENETRATION SUCH AS PILE DRIVING OR CORING, AS PROPOSED BY TERZAGHI (REF.-1). THE PENETRATION RESISTANCE "P_R" IS CONSEQUENTLY CONSIDERED TO BE SIMPLY A FUNCTION OF THE PENETRATION DEPTH AND THE VELOCITY OF PENETRATION AND IN THIS CASE IS ASSUMED TO BE A CONSTANT FOR MEDIUM STRENGTH CLAY AT P_R = 53 LB/FT - FT/SEC. THIS CONSTANT IS USED THROUGHOUT THE FOLLOWING ANALYSIS. ??

INITIAL ACCELERATION OF CORER UPON RELEASE: (NEW DESIGN)

ASSUME: APPLIED PRESSURE, P_A = 2000 PSI

3.80

DIAMETER OF PISTON, D_P = 3.50 IN (GIVEN)

TRAVEL DISTANCE, S = 2.0 IN

WEIGHT OF CORER, W_C = 450 LB (GIVEN)

WEIGHT OF WATER, W_W = 77 LB (EST'D)

VOL. OF WATER IN CORER, V_W = 1.20 FT^3

$$M_{C\,EFFECTIVE} = \frac{W_C + W_W}{g} = \frac{527}{32.17} = \underline{16.38 \text{ SLUGS}}$$

$$F_{AVAILABLE} = P_A D_P^2 \frac{\pi}{4} = 2000(3.5)^2 \frac{\pi}{4} = \underline{19,242 \text{ LB}}$$

Neglects piston rod

$$\text{ACCELERATION},\ a = \frac{F_A}{M_C} = \frac{19,242}{16.38} = \underline{1175 \text{ FT/SEC}^2}$$

VELOCITY @ 2.0 IN TRAVEL, $V_{MAX} = a t$

$$\text{TIME},\ t = \sqrt{\frac{2S}{a}} = \sqrt{\frac{2(3)}{12(1175)}} = \underline{.021 \text{ SEC}}$$

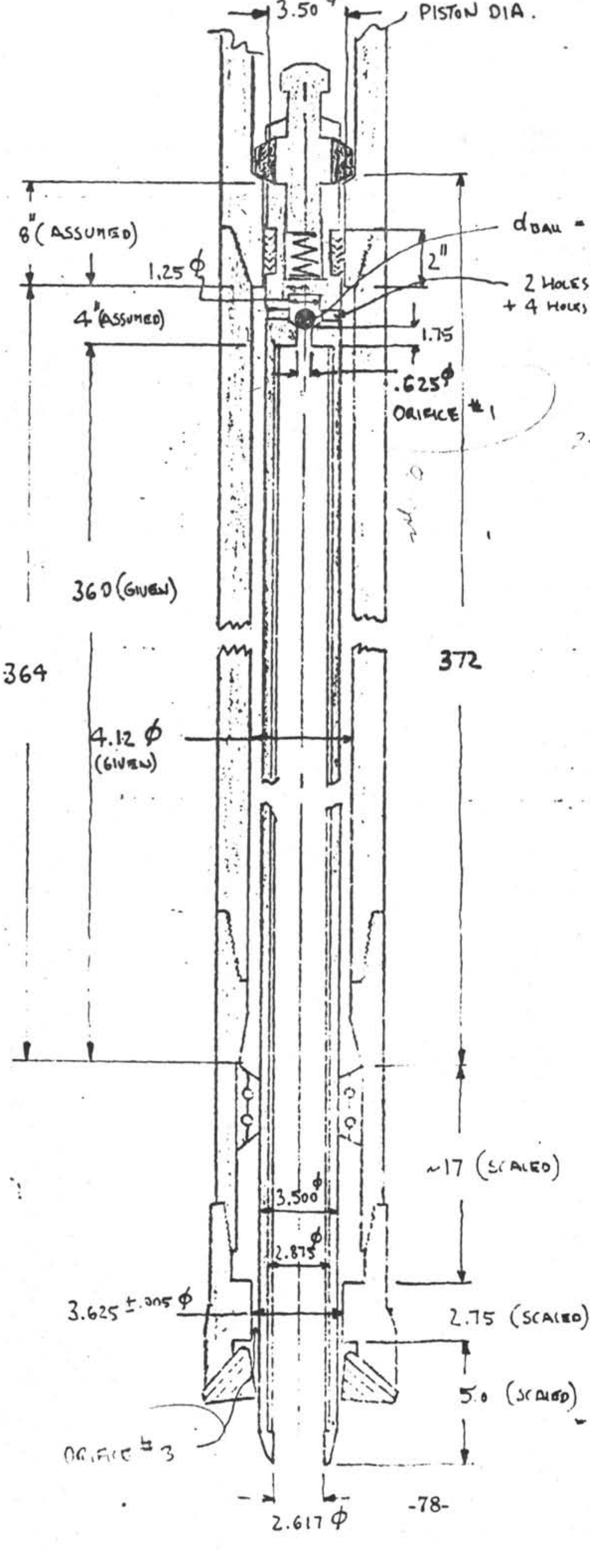
$$V_{MAX} = 1175(.021) = \underline{24 \text{ FT/SEC}}$$

FLOW @ 24 FT/SEC VELOCITY: (inside core liner)

$$Q = (2.617)^2 \frac{\pi}{4} (24)\, 12 = \underline{1550 \text{ IN}^3/\text{SEC}} \cong \underline{402 \text{ GPM}}$$

out thru check valve

FIGURE -3-


3.50 φ
PISTON DIA.
8" (ASSUMED)
1.25 φ
4" (ASSUMED)
d_{BALL} = .875"
2"
2 HOLES @ .687 φ
+ 4 HOLES @ .438 φ
ORIFICE #2
1.75
.625 φ
ORIFICE #1
360 (GIVEN)
364
372
4.12 φ
(GIVEN)
~17 (SCALED)
3.500 φ
2.875 φ
3.625 ± .005 φ
2.75 (SCALED)
5.0 (SCALED)
ORIFICE #3
2.617 φ

PRESSURE DROP DUE TO ORIFICE DISCHARGE: (REF. - 4)

$$LOSS = \left(\frac{1}{C_v^2} - 1\right)\frac{V^2}{2g}$$

Wrong! $Loss = \left(\frac{1}{C_v} - 1\right)^2 \frac{V^2}{2g}$

Ref: Streeter "Fluid Mech." pg. 214

LET: VELOCITY COEFFICIENT, $C_V = .90$

DISCHARGE COEFFICIENT, $C = .61$

$V = Q/A$

not, $V = \frac{Q}{AC_d}$

ORIFICE # 1 :

$$V_1 = \frac{1550}{(.623)^2 \frac{\pi}{4} (.61)} = \underline{8282 \text{ IN/SEC.}}$$

$$LOSS = \left(\frac{1}{(.9)^2} - 1\right)\frac{8282^2}{2(386)} = 20,841 \text{ IN} = \underline{1737 \text{ FT}}$$

$$\Delta p_1 \text{ (IN PSI)} = \frac{1737 \times 64.15}{144} = \underline{774 \text{ PSI}}$$

ORIFICE # 2 :

$$\bar{V}_2 = \frac{1550}{\left[2(.687^2)\frac{\pi}{4} + 4(.438^2)\frac{\pi}{4}\right].61} = \underline{1891 \text{ IN/SEC}} \text{ (AVERAGE)}$$

$$LOSS = \left(\frac{1}{(.9)^2} - 1\right)\frac{1891^2}{2(386)} = 1087 \text{ IN} = \underline{90.5 \text{ FT}}$$

$$\Delta p_2 \text{ (IN PSI)} = \frac{90.5 \times 64.15}{144} = \underline{40 \text{ PSI}}$$

ORIFICE # 3 :

$$V_3 = \frac{1550}{\frac{\pi}{4}(3.625^2 - 3.50^2).61} = \underline{3633 \text{ IN/SEC}}$$

$$LOSS = \left(\frac{1}{.9^2} - 1\right)\frac{3633^2}{2(386)} = 4{,}010 \text{ IN} = \underline{334 \text{ FT}}$$

$$\Delta p_3 \text{ (IN PSI)} = \frac{334 \times 64.15}{144} = \underline{149 \text{ PSI}}$$

TOTAL PRESSURE RISE INSIDE CORER AT t_1 = .021 SEC FROM INITIATION AFTER 3.0 IN TRAVEL IS :

$$\Delta p_{MAX} = \Delta p_1 + \Delta p_2 + \Delta p_3 = 774 + 40 + 149 = \underline{963 \text{ PSI}}$$

AT THIS POINT THE AVAILABLE DRIVE FORCE IS REDUCED FROM $F_{AVAILABLE(1)}$ = 19,242 LB TO :

$$F_{AVAILABLE(2)} = 19{,}242 - 963(2.617^2)\frac{\pi}{4} \cong \underline{14{,}000 \text{ LB}}$$

AS SOON AS THE PISTON SEAL LEAVES THE LAND (SEAL) AREA, THE 2000 PSI PRESSURE CAUSES AN ADDITIONAL PRESSURE RISE BOTH INSIDE & OUTSIDE THE CORER OF 2000 PSI. AT THIS TIME THE AVAILABLE DRIVE FORCE WILL BE FURTHER REDUCED FROM $F_{AVAILABLE(2)}$ OF 14,000 LB TO :

$$F_{AVAILABLE(3)} = 19{,}242 - (2000 + 963)\,2.617^2\frac{\pi}{4} = \underline{3{,}300 \text{ LB}}$$

ESTIMATED VELOCITY OF PENETRATION VS. STROKE:
(ASSUMING PRESSURE IS MAINTAINED @ 2000 PSI)

$$F_{AVAIL.} = F_{REQ'D}$$

$$F_{AVAIL.} = 19{,}242 - \left[2000 + 963\frac{V^2}{24^2}\right] 2.617^2 \frac{\pi}{4}$$

$$F_{REQ'D} = 53\ PV$$

THUS:

$$19{,}242 - \left[2000 + 963\frac{V^2}{24^2}\right] 2.617^2 \frac{\pi}{4} = 53\ PV$$

THIS REDUCES TO:

$$-V^2 - 5.89\ PV + 943.43 = 0$$

LET:

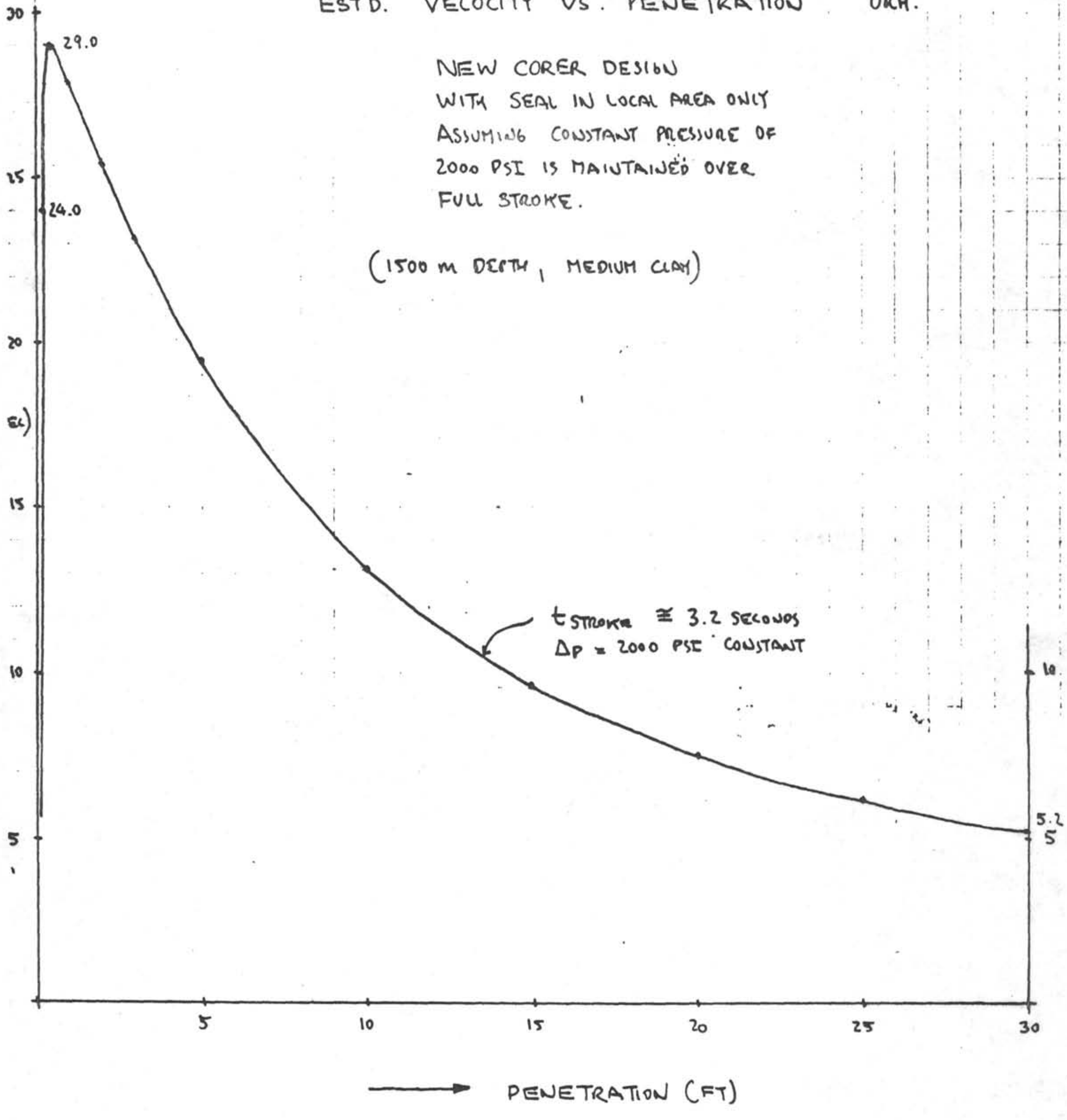
PENETRATION P (FT)	VELOCITY V (FT/SEC)	TIME TO REACH VELOCITY Δt (SEC)
1	27.91	.072
2	25.38	.038
3	13.13	.041
5	19.34	.123
10	13.10	.308
15	9.63	.440
20	7.53	.563
25	6.15	.731
30	5.19	.882

$\Sigma \Delta t \cong$ 3.2 SEC

THIS IS PLOTTED ON THE FOLLOWING PAGE:

FIGURE -4-

EST'D. VELOCITY VS. PENETRATION



STORED ENERGY DUE TO COMPRESSION OF WATER AND EXPANSION OF PIPE IN 1500 m LONG PIPE STRING:

LET:

$\Delta p = 2000$ PSI

$\ell = 1500$ m $= 4{,}921$ FEET

$d_i = 4.125$ IN (I.D. OF PIPE)

$d_o = 8.250$ IN (O.D. OF PIPE)

$t = 2.063$ IN

(Drill collar only — Pipe O.D. = 5.0[illegible], I.D. 4.25, t = 0.375)

$K = 300{,}000$ LB/IN² (BULK MODULUS OF SEAWATER) — Low: K ≈ 320,000 Better estimate

$E = 29.4 \times 10^6$ LB/IN² (YOUNG'S MODULUS OF PIPE)

$$K_{EFF.} \approx \left(\frac{1}{K} + \frac{d_i}{tE}\right)^{-1}$$

("Water hammer" Equ.)

$$= \left(\frac{1}{300{,}000} + \frac{4.125}{2.063 \times 29.4 \times 10^6}\right)^{-1}$$

(320,000; 4.250; 0.375)

$K_{EFF} = \underline{294{,}000}$ LB/IN² (= 284,860 LB/IN²)

Indicates 11% change in effective bulk modulus i.e. spring energy of pipe wall is low compared to compression energy of water. True? NO!

Doubtful assumption: Spring storage ability of pipe wall and water act in parallel, not in series, ∴ $K_{eff} = K + \frac{d_i}{tE} \approx K$, $\approx K$

$$V_0 = 4.125^2 \frac{\pi}{4} (4921 \times 12) = 789{,}173 \text{ IN}^3 = \underline{456.7 \text{ FT}^3}$$

$$\Delta V = -V_0 \frac{\Delta p}{K_{EFF}} = -456.7 \frac{2000 \text{ psi}}{294{,}000} = \underline{-3.11 \text{ FT}^3}$$

(3.2)

$$\Delta \ell = -\ell \frac{\Delta p}{K_{EFF}} = -4921 \frac{2000}{294{,}000} = \underline{-33.5 \text{ FT}}$$

(34.5)

$$\text{STORED ENERGY, } E \approx \frac{\Delta \ell \, P_{MAX}}{2} = \frac{33.5 (4.125)^2 \frac{\pi}{4} \, 2000 \text{ psi}}{2} \approx \underline{448{,}000 \text{ FT LB}}$$

(AT 2,600 PSI E WOULD BE APPROX. 676,000 FT LB)

FLOW THROUGH ORIFICE #3:

(@ 2000 PSI CONSTANT PRESSURE, $t_2 = 3.2$ SEC)

$$Q_{OUT} = CA\sqrt{2g\frac{\Delta P}{W}}\,(t_2) \quad \text{(NEGLECTING VELOCITY OF APPROACH)}$$

$$Q_{OUT} = .61\,\frac{\pi}{4}\left(3.625^2 - 3.5^2\right)\sqrt{2(386)\frac{2000}{69.15/1728}}\;(3.20)$$

$$Q_{OUT} = \underbrace{5.10\ FT^3}_{\text{FLUID LOST}} + \underbrace{\overbrace{3.5^2\,\frac{\pi}{4}\,\frac{360}{1728}}^{2.0}}_{\text{CORE BARREL DISPLACEMENT}} = \underline{7.10\ FT^3}$$

ASSUMING THE PUMP IS CAPABLE OF RESPONDING RAPIDLY AT A MAXIMUM RATE OF 600 GPM = 1.337 FT^3/SEC @ 1600 TO 2000 PSI PRESSURE AFTER t_R SEC. RESPONSE TIME, AND CONSIDERING A FALL-OFF PRESSURE FROM 2000 TO 1600 PSI IS ACCEPTABLE, THE AVAILABLE VOLUME IS OVER $t_1 = 3.2$ SECONDS:

$$\Delta V_1 \text{ @ 1800 PSI} = -456.7\,\frac{1800}{294,000} = \underline{2.80\ FT^3}$$

$$V_{STORED\,(AVAILABLE)} = \Delta V - \Delta V_1 = 3.11 - 2.80 = \underline{.31\ FT^3} \text{ (STORED ENERGY)}$$

$$V_{(FROM\ CORER)} = \frac{\left(2.617^2\,\frac{\pi}{4}\right)360}{1728} = \underline{1.12\ FT^3}$$

$$V_{PUMP} = \frac{600}{60}\left(\frac{231}{1728}\right)(3.2 - 1.1) = \underline{2.81\ FT^3}$$

$$\Sigma V_{AVAIL} = \underline{4.24\ FT^3}$$

BASED ON AN ESTIMATED PUMP RESPONSE TIME $t_R = \frac{4,921}{4,608} = \underline{1.1\ SEC}$, THE TIME REQ'D FOR A PRESSURE SIGNAL TO TRAVEL 1500 m IN THE PIPE.

THIS IS OBVIOUSLY MARGINAL AS $Q_{OUT} > \Sigma V_{AVAIL.}$, BUT COULD CONCEIVABLY WORK WITH A SOMEWHAT HIGHER SYSTEM PRESSURE.

THE LEAKAGE RATE THROUGH ORIFICE #3 IS : (AS A FUNCTION OF PRESSURE)

$$Q_{OUT} = .036\sqrt{P} \quad (FT^3/SEC) \text{ FOR } P\ (PSI)$$

ALSO : $Q_{PUMP} = 1.337\ FT^3/SEC$ MAX.

DISPLACEMENT OF BARREL IS : $Q_{BARREL} = \frac{2.0\ FT^3}{30\ FT} = .067\ FT^3/FT\text{-STROKE}$

AND : DISPLACEMENT OF CORER IS : $Q_{CORER} = \frac{1.12\ FT^3}{30} = .037\ FT^3/FT\ STROKE$

NET DISPLACEMENT OF BARREL − CORER $= .030\ FT^3/FT$ OF STROKE

ASSUME PISTON IS TRIGGERED AT 2000 PSI AND STORED COMPRESSED FLUID VOLUME IS RELEASED SO THAT $V_{AV.} = 2.0\ FT^3$.

PRESSURE THEN FALLS OFF TO :

$$P_2 = \frac{3.11 - 2.0}{456.7}\ 294{,}000 \cong 715\ PSI$$

THE ESTIMATED TIME FOR THE FALL OFF FROM $P_1 = 2000$ PSI TO $P_2 = 715$ PSI IS THEN :

$$t \cong \left[\frac{\frac{456.7}{294{,}000}}{.036} - .030\right]\left(\sqrt{2000} - \sqrt{715}\right) = .24\ SEC$$

t − ASSUMED .5 SEC

LET $\bar{V} = 1\ FT/SEC$, $S = \bar{V}t = .5\ FT$

$$t \cong \left(\frac{\frac{456.7}{294{,}000}}{.036} - .015\right)\left(\sqrt{2000} - \sqrt{715}\right) \cong .50\ SEC\ (OK)$$

AT THIS TIME THE STORED ENERGY IS EXHAUSTED!

AFTER 1.1 SEC. THE PUMP BEGINS TO RESPOND AND HOPEFULLY THE PRESSURE IS STILL 715 PSI.

ASSUMING NEXT THAT THE PUMP CONTINUOUSLY DELIVERES THE MAXIMUM FLOW OF 600 GPM @ 715 PSI THE FORCE BALANCE BECOMES:

$$F_{AVAILABLE} = 6679 - \left[715 + 963 \frac{V^2}{24^2}\right] 2.617^2 \frac{\pi}{4} = F_{REQ'D} = 53\ PV$$

REARING TO: $-V^2 - 5.89\ PV + 337.4 = 0$

LET:

PENETRATION P (FT)	VELOCITY V (FT/SEC)	TIME TO REACH VELOCITY Δt (SEC)
1	15.66	.064
2	13.40	.069
3	11.55	.080
5	8.82	.196
10	5.26	.710
15	3.67	1.120
20	2.60	1.586
25	2.26	1.976
30	1.69	2.41

$$\Sigma \Delta t = 8.2\ SEC$$

THIS IS PLOTTED ON THE FOLLOWING PAGE, FIG. -5-

FIGURE -5-

EST'D VELOCITY VS. PENETRATION

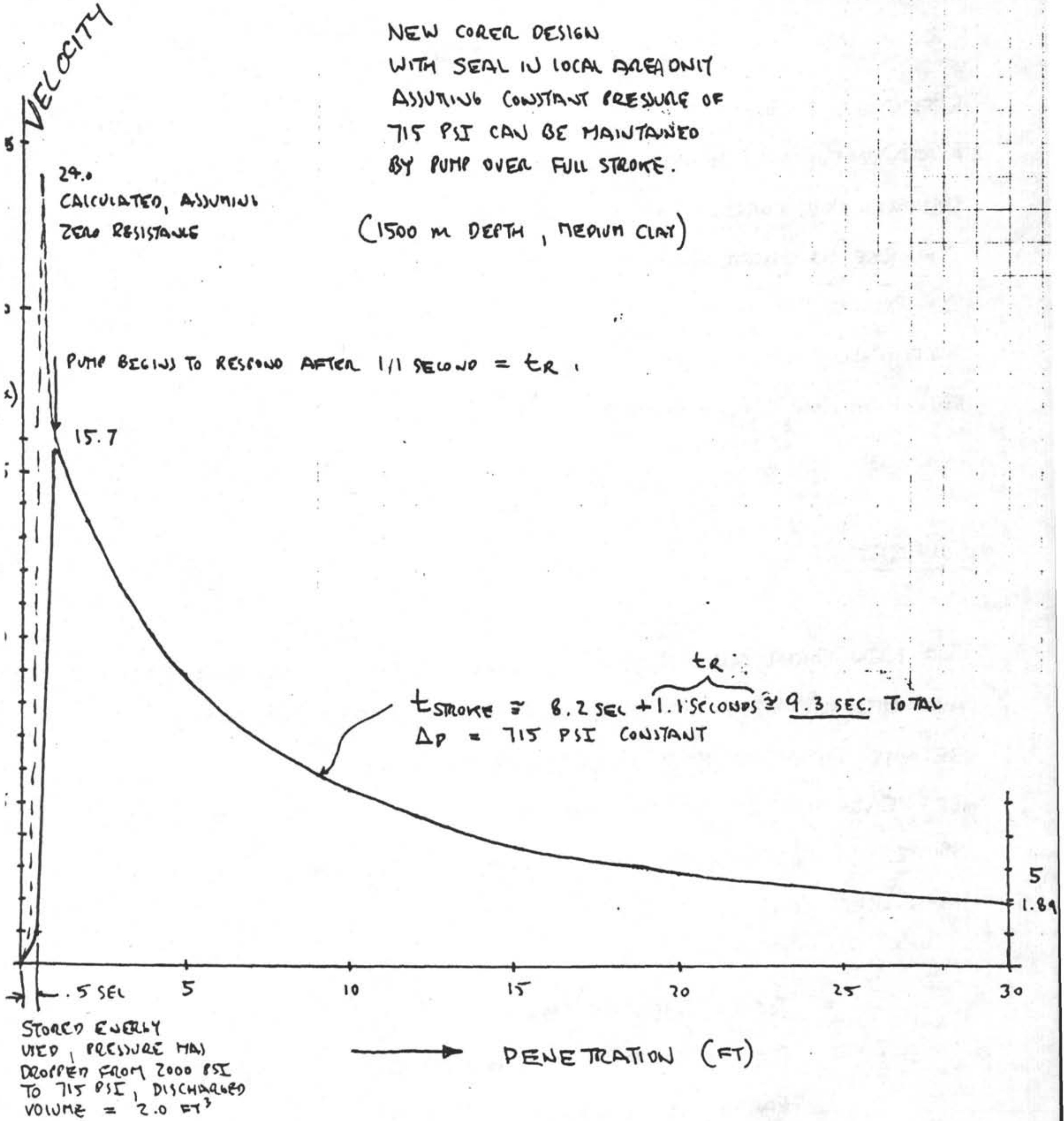


TABLE OF COMPARISON

		? OLD DESIGN * (VLHPC)	? NEW CONCEPT SHOOT OFF
EFFECTIVE PISTON AREA	(IN^2)	5.29	4.24 (after seal is broken)
AVAILABLE FORCE @ 2000 PSI	(LBS)	10,600	8,500
DISPLACED CORE BARREL VOLUME	(IN^3)	1,579	1,936
ΔP RISE IN BARREL @ 2000 PSI	(PSI)	171	2,963
ΔP PRESSURE RISE ON TOP OF CORE	(PSI)	—	2,963
EST'D PRESS. FALL-OFF @ 1500 m & 2000 PSI	(PSI)	—	200 +
EST'D FLUSH FLOW @ HEAD @ 2000 PSI	(FT^3)	.91	5.1 +

SUMMARY

THE NEW CORER CONCEPT WILL ONLY MARGINALLY WORK AT 1500 m DEPTH, AND MEDIUM (CLAY) SOIL IF SEALS ARE ONLY USED TO SHOOT OF THE TOOL, BECAUSE THE FLUID ESCAPING THROUGH THE HEAD ORIFICE (#3) CANNOT BE REPLENISHED BY THE PUMP FAST ENOUGH. TO ASSURE ONE CONTINUOUS 30 FT STROKE. IN ADDITION, THE FOLLOWING DISADVANTAGES ARE INHERENT WITH THIS CONCEPT COMPARED TO THE "BASE DESIGN":

- TOP OF THE CORE WOULD BE SUBJECTED TO HIGH PRESSURE WATER INTERFACE WHICH COULD CAUSE PARTIAL FLUIDIZATION IN THIS AREA.

* USING SEALS ONLY TO SHOOT OFF TOOL @ 2000 PSI CONSTANT PRESSURE.

IN ADDITION, THE CORE WOULD BE AXIALLY COMPRESSED BY THIS PRESSURE UP TO 3000 PSI (ORE MORE)

- THE FLUID PRESSURE ACTING ON THE CORE DURING THE INITIAL INSERTION WILL MOST LIKELY FLUSH AWAY A PART OF THIS AREA SO THAT THE USEFUL LENGTH OF THE CORE SAMPLE WILL BE DECREASED BY SOME AMOUNT.

- THE FLUID FLOW ESCAPING THROUGH ORIFICE #3 OF 5.1 + FT^3 WOULD WASH OUT A SIZEABLE VOLUME OF SOIL IN THE INTERFACE AREA, WHICH MAY OR MAY NOT AFFECT THE CORE SAMPLE.

THESE DISADVANTAGES INHERENT WITH THE "SHOOT OFF" PRINCIPLE/ CONFIGURATION OF THE NEW CONCEPT MAY BE SUCCESSFULLY OVERCOME BY:

1. USING THE TOP SUB BODY SEALS THROUGHOUT THE STROKE, WHICH WOULD DECREASE THE POTENTIAL Δp RISE IN THE CORE BARREL FROM ~ 3000 PSI TO AROUND 800 PSI WITH CORRESPONDING DECREASE IN FLUID OUTFLOW FROM 5.1 + FT^3 TO ABOUT 2.6 FT^3 WHICH WOULD THEN EASILY BE MADE UP BY THE PUMP SO THAT PENETRATION IN ONE SINGLE STROKE CAN BE ACCOMPLISHED.

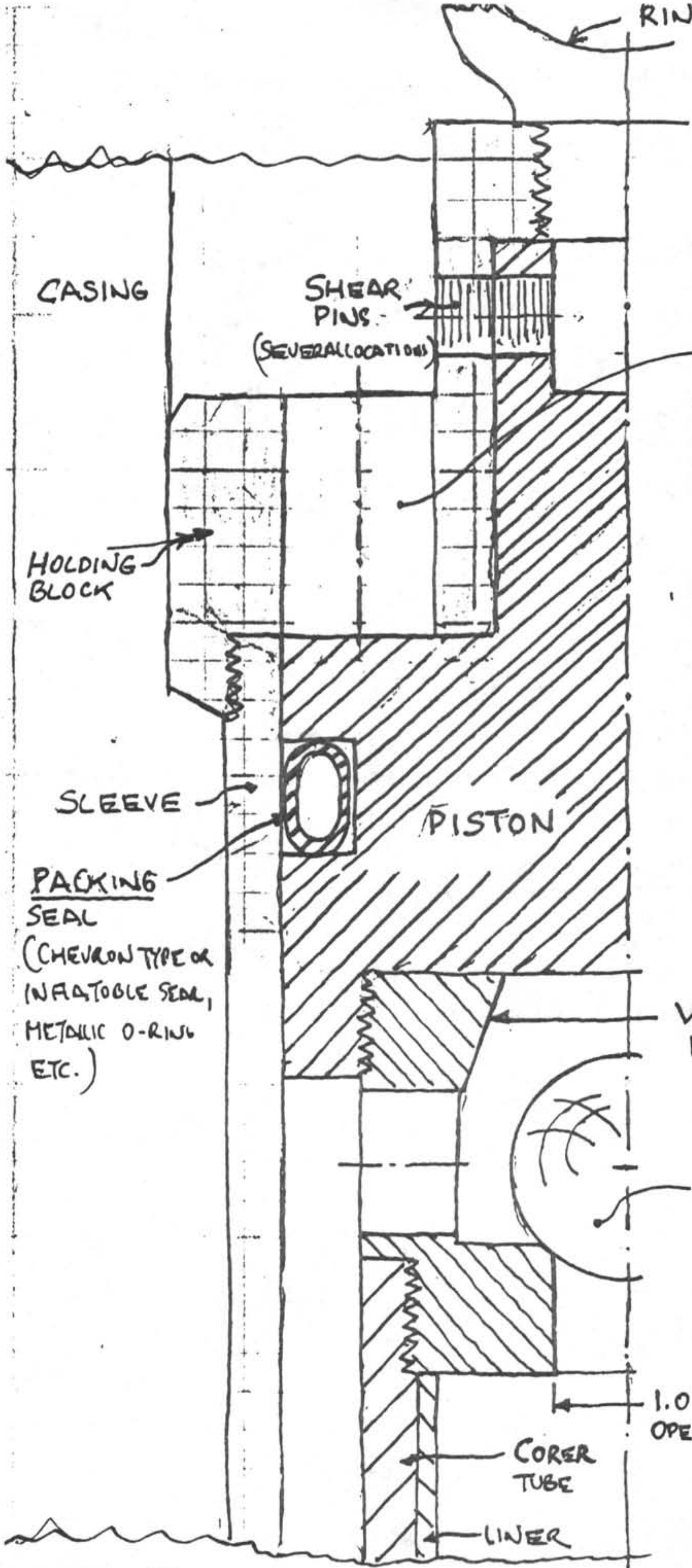
2. ENLARGING ORIFICE AREAS #1 & #3 SO THAT THE COMBINED PRESSURE DROP IN THESE AREAS WOULD BE REDUCED

TO ABOUT 400 PSI WITH FURTHER REDUCTION IN OUTFLOW THROUGH ORIFICE #3 TO ABOUT 1.9 FT^3 OVER THE 3.2 SECONDS IT TAKES TO ACHIEVE A 30 FT. STROKE.

3. IF THE CORE CAN BE SUBJECTED TO AN AXIAL LOAD BUT MUST BE ISOLATED FROM THE FLUID, A FLOATING PISTON COULD BE INTRODUCED AS A SOLID BARIER TO SLIDE WITHIN THE CORE LINER.

4. IF THE CORE SAMPLE MUST NOT BE SUBJECTED TO ANY PRESSURE DIFFERENTIAL IN AXIAL DIRECTION DURING CORING OPERATION, A PISTON/ROD ASSEMBLY MAY BE INCORPORATED IN THE DESIGN WHICH WOULD PENETRATE THROUGH THE CORER SUB.

A FEASIBLE MECHANICAL ARRANGEMENT CAPABLE OF ACHIEVING ALL OF THE ABOVE IS SHOWN ON THE FOLLOWING PAGE (FIG. 6) OF THIS EVALUATIVE REPORT.



SUBJECT Top Portion of Corer DATE May 1982 BY PMR

FIGURE -6-

THE SCENARIO FOR OPERATION WITH A FULL STROKE PISTON SEAL ARRANGEMENT WILL BE QUITE DIFFERENT FROM THE "SHOOT OFF" CONCEPT.

IN THIS CASE THE STORED ENERGY WOULD BE AVAILABLE FOR THE FULL STROKING OF THE CORER SINCE NO FLUID FROM THIS SOURCE WOULD BE EXHAUSTED THROUGH ORIFICE #3. SINCE THE DISPLACEMENT VOLUME OF THE BARREL IS 2.0 FT^3 @ 3.5 IN PISTON DIA. AND 30 FT STROKE AND THE TOTAL VOLUME OF THE STORED FLUID IN THE 1500 M LONG STRING IS $\Delta V = 3.11\ FT^3$ THE PRESSURE WOULD DROP FROM 2000 PSI TO:

$$P_2 = \frac{3.11 - 2.0}{456.7}\ 294{,}000 = \underline{715\ PSI}$$

FROM THE START TO THE END OF THE 30 FT. STROKE. THEN:

$$F_{AVAIL} = \left(2000 - \frac{2000-715}{30}\right)3.5^2\frac{\pi}{4} - 400\left(2.617^2\right)\frac{\pi}{4}\frac{V^2}{24^2} = 53\ PV$$

REDUCING TO: $-V^2 - 14.19\ PV + 5151.34 - 110.3\ P = 0$

P	V	Δt	P	V	Δt	P	V	Δt
.25	69.63	.007	5.0	41.07	.023	20.0	10.02	.223
.50	67.93	.004	7.5	31.36	.069	22.5	8.15	.275
1.0	64.26	.008	10.0	24.35	.090	25.0	6.62	.339
2.0	57.45	.016	12.5	19.19	.115	27.5	5.35	.418
3.0	51.33	.018	15.0	15.37	.145	30.0	4.29	.519
4.0	45.69	.021	17.5	12.36	.181			

$\Sigma \Delta t$ = 2.5 SEC.

SIMILARLY, ASSUMING A HIGHER PRESSURE OF $P_1 = 2800$ PSI :

$$-V^2 - 14.19\,PV + 7211.89 - 111.6\,P = 0$$

P	V	Δt
.25	83.0	.006
.50	81.12	.003
1.0	77.47	.006
2.0	70.60	.014
3.0	64.33	.015
4.0	58.13	.016
5.0	53.48	.018
7.5	42.74	.052
10.0	34.55	.065
12.5	28.28	.080
15.0	23.44	.097
17.5	19.63	.116
20.0	16.58	.138
22.5	14.10	.163
25.0	12.05	.191
27.5	10.34	.223
30.0	8.89	.260

$\Sigma\,\Delta t \approx 1.5$ SEC.

AS INDICATED ON FIG-7, THIS WORKS QUITE WELL IN MEDIUM CLAY. ACTUALLY, THE PUMP WOULD START TO RESPOND AFTER ± 1.1 SEC AND THE RESULTS MAY ACTUALLY BE BETTER.

FOR CLAY 3 X AS VISCOUS THE TIME REQ'D FOR STROKING WOULD INCREASE.

THE RESULTS ARE PLOTTED ON THE FOLLOWING PAGE, FIG. -7-

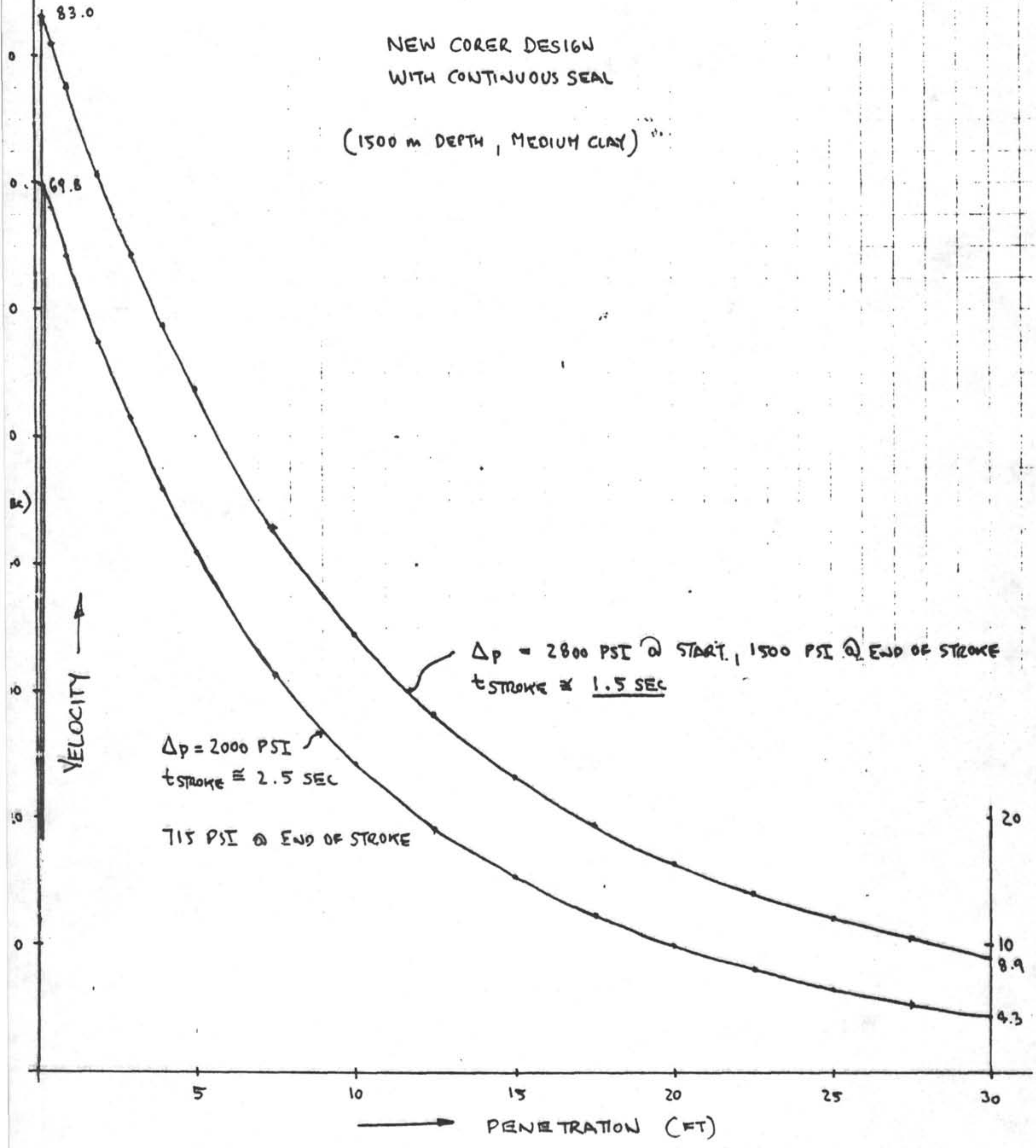
FIGURE -7-

PAGE 25 OF 26
MAY 1962
ORH.

EST'D. VELOCITY VS. PENETRATION

NEW CORER DESIGN
WITH CONTINUOUS SEAL

(1500 m DEPTH, MEDIUM CLAY)



CONCLUSION.

THE "CONTINUOUS SEAL" CORER CONCEPT SHOULD FUNCTION AS WELL OR BETTER THAN THE PRESENT CORER IN AS MUCH AS MORE FORCE IS INITIALLY AVAILABLE DUE TO THE LARGER CROSS SECTIONAL AREA OF THE DRIVING PISTON COMPARED WITH THE EXISTING UNIT.

THE "SHOOT OFF" TYPE CORER CONCEPT MAY WORK REASONABLY WELL IN VERY LIGHT SOILS BUT MAY NOT BE ABLE TO PENETRATE THE HEAVIER (OR MORE VISCOUS) CLAYS AND WOULD CAUSE SEVERE EROSION OF THE SOIL SAMPLE NEAR THE TOP OF THE CORER.

JOHN E. HALKYARD & COMPANY

Consultants in Engineering and Business Development
Specializing in Mechanical Systems, Hydraulics and Ocean Engineering

May 27, 1982

Mr. Dave Huey
Deep Sea Drilling Project, A-031
University of California
Scripps Institution of Oceanography
La Jolla, California 92037

Dear Dave:

We are submitting herewith our report, "Feasibility Analysis of Vented Core Barrel Conceptual Design" performed as per your Statement of Work dated April 27, 1982. Please note from the report that our analysis is favorable for continuation of work on concept (a), using the Top Sub Body seals throughout the stroke.

Specifically we recommend the tasks outlined in our recommendations which would be carried out in sequence.

Accordingly, we propose that recommendations #1 through #4 be performed as separate tasks. We estimate that Task #1 would be of the same magnitude as the one we have just completed, both in cost and time requirements.

Decisions as to the performance and costs of Tasks #2 through #4 could be made upon completion of Task #1.

We found work on the project to be very interesting and look forward to assisting you in the performance of other specific tasks.

Sincerely yours,

John E. Halkyard

John E. Halkyard
President

JEH/vdw

Enclosure

2949 Epaulette St., San Diego, California 92123, (714) 277-2949, TWX 910-322-1356

APPENDIX B
PISTON ROD FAILURE REPORT

Battelle
Petroleum Technology Center
1100 Rankin Road
Houston, Texas 77073
(713) 821-9330
Telex 24-5454

January 25, 1984

David P. Huey
Deep Sea Drilling Project
Scripps Institute of Oceanography
U. of Ca-San Diego,
LaJolla, Ca., 92093

Dear Mr. Huey,

Presented herein is Battelle's report on the project to analyze the failure of a 15-5PH stainless steel piston rod on a core-sampler, and recommend measures to prevent recurrance.

SUMMARY

The rod failed by simple overstress in pure torsion. Such a failure might recur if galling of the threads forces those assembling the tool to over-torque the rod in order to bottom out the threads. The rod material was as hard and tough as expected, and failed in an entirely ductile manner; 15-5PH is a good choice for this application. Measures to prevent recurrence should include the application of either copper plating or commercial oilfield tubing-connection lubricants during make-up. If electrolytic copper plating is used, the rods should be "baked" at 375-400 F for 4 hours to prevent the possibility of hydrogen embrittlement.

INTRODUCTION

The Deep Sea Drilling Project staff designed an Advanced Piston Corer (APC) for sediment sampling during DSDP's oceanographic studies. This core sampler is withdrawn with three 11-foot long sections of ~~1.52~~ 1⅝ inch diameter 15-5 PH stainless steel rod (HI025 condition) threaded together at 1-1/8-8 Stub Acme threaded connections. During field trials the piston rod failed after three core-samples had been withdrawn, one at 100,000 lbs tensile load, one at 20,000 lbs load, and the last at 40,000 lbs load.

This failure occurred well below the expected minimum tensile strength of the pin, which was calculated as 139,000 pounds. Full-scale laboratory tests of box-and-pin connections failed at an average of 177,800 lbs. The failed rod was sent to Battelle Petroleum Technology Center for analysis.

EXPERIMENTAL PROCEDURE AND RESULTS

The failure was located near the root of the pin in the intermediate connector. The fracture surface was relatively flat along its outer edge, with a rougher, grey, textured appearance in the center. By contrast, the laboratory full-scale fractures showed a distinct cup-and-cone formation typical of tensile overload failures, with the rough grey appearance covering the entire fracture surface.

Examination of the field fracture under the scanning electron microscope showed that the flat, smooth zone around the outer edge of the fracture consisted of elongated shear dimples, while the rough grey zone in the center showed the more equiaxed dimples indicative of tensile overload.

A section was taken through the failed rod and polished for metallographic examination. The structure was normal for 15-5PH (H1025) stainless steel, consisting entirely of quenched and tempered martensite. The fracture profile was nondescript, with no evidence of stress-corrosion cracking or hydrogen embrittlement. Micro-hardness measurements averaged 427 KHN_{500g} near the fracture surface. This is equivalent to approximately Rockwell C 39. Significant plastic flow was observed on the threads, indicating that they had been overstressed during make-up.

DISCUSSION

The shiny, flat appearance of the fracture, its orientation, and the shear dimples observed around its outer edge are all indicative of a ductile overload failure in pure torsion. Since the final fracture was by ductile rupture in tension, the rod was apparently stressed past yield in torsion before the tensile loads of core-sampling were applied.

The core sampler is not subjected to torsional loads in service. Applied loads are purely tensile, and any unexpected additional torsion in service (from, for example, sticking of the rod in its tube) would produce a mixed-mode fracture rather than pure torsional overload.

Therefore the only known source of pure torsional stress is the make-up torque.

The specified make-up torque of the rod is 400 ft-lbs. This would produce a calculated shear stress of 24,000 psi. Even allowing for a stress concentration factor of 2.6 at the thread, the resulting stress should have been well below the estimated 107ksi torsional yield strength of the material.

Even relatively hard stainless steels such as 15-5PH (H1025) are prone to galling during machining and assembly. If the threads on the rod had galled during make-up before the pin bottomed out in the box, the connection might have been overtorqued in an attempt to free the threads and run the connection together completely.

To prevent galling, the threads must either have a significant hardness difference (greater than ten Rockwell C points) between the contact surfaces, or they must be lubricated with anti-seize compounds. The "Baker-Lok" thread locking compound was thought to provide some lubrication, but it might not be adequate at high contact stresses.

The most common way to achieve a large hardness difference between surfaces without sacrificing strength in the rod body is by plating either the box or the pin (but not both) with a soft material such as copper, silver or tin. This is an effective anti-galling measure. If the plating is electrolytic, the plated zone should be baked at 400 degrees for approximately four (4) hours to drive off hydrogen absorbed by the steel in the plating process.

There are a number of commercial anti-seize compounds used to make up tubing and casing conections in the oil patch. Provided they are zinc-free, any of these compounds should be useful in preventing galling of the rod threads. Anti-seize compounds specifically made for drill pipe connections should not be used, since these can release hydrogen in long-term static applications.

CONCLUSIONS

1) The rod failed bv simple overstress in pure torsion.
2) The rod material met the strength and toughness required in the specifications.
3) The only known source of torsional stress occurs during assembly, and operates only if the rod is torqued well beyond the specified 400 ft-lbs with the threads either bottomed out or frozen by galling.
4) Galling of the threads is suspected based on damage observed on metallographic examination.
5) Recurrence can be prevented by careful monitoring of applied torque during make-up, and by either plating one set of threads or applying oil-field tubing connection anti-seize compounds to the threads before make-up.

We enjoyed working with DSDP again. If there are any questions on this report, please call or write. Thank you for calling Battelle.

Best regards,

Dale R. McIntyre

Dale McIntyre

DRM/pjm

APPENDIX C
PISTON CORER PERFORMANCE COMPUTER PROGRAM

```
      PROGRAM APC
*     ......THIS PROGRAM PREDICTS THE PERFORMANCE OF THE ADVANCED
*     PISTON CORER.  WHEN FORMATION CORING RESISTANCE IS ZERO
*     IT PREDICTS WATER CORE PERFORMANCE. GIVEN A SHEAR
*     VALUE FOR A SEDIMENT, PERFORMANCE IS CALCULATED WHICH
*     WILL REPERSENT A POSSIBLE BEHAVIOR FOR AN IDEALIZED
*     SEDIMENT HAVING THAT SHEAR STRENGTH. (THESE VALUES
*     SHOULD BE INTERPRETED WITH CAUTION.)
*
*     THE PROGRAM CALCULATES INSTANTANEOUS VALUES FOR VELOCITY,
*     ACCELERATION, ELAPSED TIME, DRIVING FORCE AGAINST THE
*     MAIN SEALS, RETARDING FORCES INCLUDING BACK PRESSURE FORCE
*     OF THE VENTED FLUID, SKIN FRICTION DRAG AND BLUFF BODY
*     DRAG, AND NET DRIVING FORCE ACTING TO ACCELERATE THE
*     SCOPING SECTION OF THE TOOL.
*
*     THESE VARIABLES ARE EVALUATED OVER SHORT INTERVALS OF
*     STROKE OVER WHICH ACCELERATION IS ASSUMED CONSTANT.
*     VALUES ARE TABULATED AT SELECTED POINTS ALONG THE STROKE.
*
*     SEAL DRAG IS TAKEN AS A CONSTANT SUM (STATIC & DYNAMIC)
*     FOR ALL SEALS.
*
*     DRIVING PRESSURE IS INITIALLY INPUT AT THE ANTICIPATED
*     SHOOT-OFF PRESSURE FOR THE NUMBER OF SHEAR PINS USED.
*     AS THE TOOL STROKES, DRIVING PRESSURE DECREASES AS THE
*     DRIVING FLUID TAKES A PRESSURE DROP ACROSS THE PULLING
*     NECK/LANDING SHOULDER ENROUTE TO THE MAIN SEALS.
*     -------------------------------------------------------
*
*
        IMPLICIT LOGICAL(A-Z)

        REAL PRESS,  !(P)PRESSURE (PSI)
     :       AREA ,  !(A)VENT ORICICE TOTAL AREA (SQ. IN.)
     :       AREA1, !      "             "              "
     :       LINCR , !(L INCR)INCREMENTAL STROKE DISTANCE (FT)
     :       DRAGS,  !(F S)SEAL DRAG FORCE(LBF)
     :       DRAGSF, !(F SFD) SKIN FRICTION DRAG(LBF)
     :       WEIGHT, !(W) WEIGHT OF SCOPING COMPONENTS(LBS)
     :       DRAGBB, !(F BBD) BLUFF BODY DRAG(LBF)
     :       BACKP , !(F B)BACKPRESSURE FORCE OF VENTED FLUID(LBF)
     :       STROKE, !(L)LENGTH OF STROKE(FT)
     :       VEL    , !(V)VELOCITY (FT PER SEC)
     :       VNEW  , ! UPDATED VEL (FT PER SEC)
     :       DRIVEF, !(F P)DRIVE FORCE ON MAIN SEALS(LBF)
     :       NETF  , ! NET ACCELERATING FORCE (LBF)
     :       ACCEL,  !(A)ACCELERATION (FT PER SECOND SQUARED)
     :       TIME,   !ELAPSED TIME OF STROKE (SEC)
     :       COUNT,  !CONTROL VARIABLE FOR PRINTING
     :       REYNO, !REYNOLDS NUMBER
     :       SNUBPT, !POINT IN STROKE WHERE SNUBBER ENGAGES (FT)
     :       ASNUB, !REDUCED VENT ORIFICE AREA FOR SNUBBING
     :       SUMK, !SUM OF LOSS COEFFICIENTS
     :       DELP !PRESSURE DROP ACROSS LANDING SHOULDER
         REAL      A3,  !FLOW AREA PAST LANDING SHOULDER (SQ.IN.)
     :       A4, !FLOW AREA FROM LANDING SHOULDER TO D.C. (SQ.IN.)
     :       N1,  !NUMBER OF ALWAYS-OPEN BYPASS HOLES
     :       N2,  !NUMBER OF PLUGABLE BYPASS HOLES
```

```
     :        B,  !LANDING SHOULDER FLUTE ROOT DIMEM.(IN.)
     :        D1,  !DIA. OF N1 ALWAYS-OPEN BYPASS HOLES
     :        D2,  !DIA. OF N2 PLUGABLE BYPASS HOLES
     :        K2,     !PRESSURE LOSS COEFFICIENTS FOR FLOW
 *                    PAST LANDING SHOULDER
     :        K3,   !    "          "               "
     :        K4,    !    "          "               "
     :        Z,    !SEDIMENT SHEAR STRENGTH(GM/SQ.CM.)
     :        TAU,  !SHEAR STRENGTH(PSI)
     :        DEL,  !DISTURBANCE LAYER THICKNESS(FT)
     :        RHO   !SEDIMENT DENSITY(LBM/CU.FT.)


      PARAMETER (LINCR =.05)
      PRINT*
      PRINT*, 'INPUT SHOOT-OFF PRESSURE (PSI)' !PROMP ENG. FOR DATA
       READ*, PRESS
      PRINT*,'PRESS=',PRESS !ECHO CHECK CORRECTNESS OF INPUT

      PRINT*
      PRINT*, 'INPUT VENT ORIFICE AREA (SQ.IN.)'
      READ*,  AREA
      PRINT*, 'AREA=',AREA




      PRINT*
      PRINT*,'INPUT POINT IN STROKE WHERE SNUBBER ENGAGES (FT)'
      READ*, SNUBPT
      PRINT*, 'SNUBPT=' ,SNUBPT


      PRINT*
      PRINT*,'INPUT REDUCED VENT ORIFICE AREA FOR SNUBBING
     :(SQ.IN.)'
      READ*, ASNUB
      PRINT*, 'ASNUB=', ASNUB


*23456789
      PRINT*
*     PRINT*,'INPUT B - FLUTE DIMENSION (1.30 TO 1.88)'
*     READ*, B
*     PRINT*,'B=',B
      PRINT*,'INPUT N1, NUMBER OF ALWAYS-OPEN BYPASS HOLES'
      READ*, N1
      PRINT*,'N1=', N1
      PRINT*
      PRINT*,'INPUT D1, DIA. OF ALWAYS-OPEN BYPASS HOLES (IN.)'
      READ*, D1
      PRINT*,'D1=',D1
      PRINT*
      PRINT*,'INPUT N2, NUMBER OF PLUGABLE BYPASS HOLES LEFT OPEN'
      READ*,N2
      PRINT*,'N2=',N2
      PRINT*
      PRINT*,'INPUT D2, DIA. OF N2 PLUGABLE BYPASS HOLES (IN.)'
```

4

```
      READ*, D2
      PRINT*,'D2=',D2
      PRINT*
      PRINT*,'INPUT SEDIMENT SHEAR STRENGTH (GM/SQ.CM.)
     :     --IF WATER CORE,INPUT ZERO'
      READ*, Z
      PRINT*,'Z=',Z
*     ....INITIZILATION....
      DATA DRAGSF,DRAGBB,BACKP,STROKE,VEL,COUNT,TIME,DELP/
     :       0   , 0   , 0   , 0   ,0  , 0   , 0  , 0  /
*           ...CALCULATE CONSTANTS...
*     A4= 5.563 - 3*B + 1.5706*D**2   FOR FLUTED L.S. WITH HOLES
      A3= 0.7854*(N1*D1**2 + N2*D2**2)
      K2= 0.55*(1-A3/7.21)*((7.21/A3)**2)
      K3= (7.21/A3-1)*(10.82/A3-1)*1.7
*     K4= ((A3/A4-1)*(2.5*A3/A4-1)+((1-A3/5.93)**2))*
*    :         ((9.57/A3)**2)  FOR FLUTED L.S. WITH HOLES
      K4= ((1-A3/6.55)**2)*((9.39/A3)**2)
      AREA1= AREA
      TAU=.014223 * Z !SHEAR STRENGTH (PSI)
      DEL= .1/12       !DISTURBANCE LAYER THICKNESS (FT)
      RHO=  120        !SEDIMENT DENSITY (LBM/CU.FT.)
      DRAGS= 300 !TOTAL APPROX. SEAL DRAG CONSTANT (LBF)
      WEIGHT= 490 !WT. OF SCOPING COMPONENTS (LBF)

*     ...PRINT HEADER...
      PRINT*
      PRINT*
      PRINT*
      PRINT*

      PRINT*,'PRESSURE=',PRESS,'(PSI)'
      PRINT*,'VENT AREA=',AREA,'(SQ.IN.)','  SNUBBED VENT
     :AREA=',ASNUB,'(SQ.IN.)'
      PRINT*,'SNUB POINT IN STROKE=',SNUBPT,'(FT)'
      PRINT*,'WEIGHT=',WEIGHT,'(LBF)','  SHEAR STRENGTH=',Z,
     :'(GM/SQ.CM.)'
      PRINT*,'SEAL DRAG=',DRAGS,'(LBF)'
      PRINT*,'N1=',N1,'ALWAYS-OPEN BYPASS HOLES AT D1=',D1
      PRINT*,'N2=',N2,'PLUGABLE BYPASS HOLES AT D2=',D2
      PRINT*
      PRINT '(4(T6,A,T14,A,T25,A,T36,A,T46,A,T56,A,T66,A,
     :T76,A,T86,A/))',
     :'STROKE','VELOCITY',' ACCEL','DRIVEF','DRAGSF','DRAGBB',
     :'BACKP','NETF','ELAPSED TIME',
     :' (FT) ','(FT/SEC)','(FT/S/S)',' (LBF)','(LBF)','(LBF)'
     :,' (LBF)','(LBF)','(SEC)',
     :'------','--------',' -----','------','------','-----',
     :'----','-----','------'

*234567
      PRINT*
      DO WHILE (STROKE .LE. 30.25)


*
```

```
      DRIVEF= 9.39*(PRESS-DELP)

      NETF=DRIVEF+WEIGHT-DRAGSF-DRAGBB-BACKP-DRAGS

      ACCEL=32.2*NETF/WEIGHT

     IF(STROKE .EQ. 0) THEN
       COUNT = COUNT+.2
       GO TO 100

      ELSEIF ( (STROKE .GE. COUNT) .AND. (STROKE .LE. 2)) THEN
       COUNT =COUNT+.2
       GOTO 100

      ELSEIF ((STROKE .GE. COUNT) .AND. (STROKE .LE. 5)) THEN

       COUNT=COUNT+.5
       GOTO 100

      ELSEIF((STROKE .GE. COUNT) .AND. (STROKE .LE. 25))THEN
       COUNT=COUNT+2
       GOTO 100

       ELSEIF((STROKE .GE. COUNT) .AND. (STROKE .LE. 31))THEN
        COUNT=COUNT+1
        GOTO 100

      ELSEIF(STROKE .GE. 31) THEN
       GO TO 100

      ELSE

       GOTO 199

     ENDIF

 100  PRINT '(T2,F8.1,T12,F8.1,T22,F8.1,T32,F8.1,T42,F8.1,
     :     T52,F8.1,T62,F8.1,T72,F8.1,T87,F5.2)',
     :     STROKE,VEL,ACCEL,DRIVEF,DRAGSF,DRAGBB,BACKP,NETF,TIME

      IF (DELP .EQ. PRESS) THEN
        PRINT*,'DEL P = SHOOT-OFF PRESSURE'
      ENDIF
*23456789
 199  STROKE= STROKE+LINCR  !NEW L=OLD L +LINCR
      VNEW=(SQRT(VEL**2+2*ACCEL*LINCR))

*2345678
      TIME=TIME+(VNEW-VEL)/ACCEL

      VEL=VNEW

        SUMK=29.70+0.038*STROKE+K2+K3+K4

        DELP=(SUMK*VEL**2)/144.45
        IF (DELP .GT. PRESS) THEN
          DELP = PRESS
        ENDIF
```

```
      IF(STROKE .GE. SNUBPT) THEN
       AREA= ASNUB
      ENDIF
      BACKP=VEL**2*(3.749-.106*STROKE+.376/AREA**2-.311/AREA)
      REYNO=((1.495   E6)*VEL)
*234567
      IF(TAU .EQ. 0) THEN
        DRAGSF=(VEL**2*(12.56+.318*STROKE))/((LOG10(REYNO))**2.58)
       DRAGBB=.005913*VEL**2
      ELSE
        DRAGSF=(1.323 * ((154.56*TAU*DEL/RHO)**0.5)*.0249*RHO
     :                    *VEL*STROKE)+3.54*TAU
      ENDIF
      END DO
      PRINT*,'P=',PRESS,'A=',AREA1,'ASNUB=',ASNUB,'
     :  SNUBPT=',SNUBPT,'N1=',N1,' D1=',D1,' N2=',N2,' D2=',D2,
     :'   TAU=',Z
      END
```

```
1:REM ... A.P.C. Performance Program ************
10:REM ...LI=Incremental Stroke Distance (Ft.)
15:LI=.05
20:REM ...A=Vent Orifice Total Area (Sq.In.)
25:A=2.06
30:REM ...W=Weight of Scoping Components (Lbs.)
35:W=490
40:REM ...SN=Snub pt, Point in Stroke Where Snubber Engages (Ft.)
45:SN=28.75
50:REM ...A2=Reduced Vent Orifice Area for Snubbing (Sq.In.)
55:A2=.11
60:REM ...N1=No.of Always-open Bypass Holes
65:N1=2
70:REM ...D1=Dia. of Always-open Bypass Holes (In.)
75:D1=.4375
80:REM ...D2=Dia. of Pluggale Bypass Holes (In.)
85:D2=.4375
90:REM ...DEL=Disturbance Layer Thickness (Ft.)
95:DEL=.1/12
100:REM ...RHO=Sediment Density (LBm/Cu.Ft.)
105:RHO=120
110:REM ...SE=Total Approx. Seal Drag Constant (LBf)
115:SE=300
200:INPUT "SHOOT-OFF PRESSURE (PSI)=";P
210:INPUT "#of PLUGGABLE HOLES OPEN=";N2
220:INPUT "SedimentShearStr(G/SqCm)=";Z
230:A3=PI /4*(N1*D1^2+N2*D2^2)
250:K2=.55*(1-A3/7.21)*((7.21/A3)^2)
260:K3=(7.21/A3-1)*(10.82/A3-1)*1.7
270:K4=((1-A3/6.55)^2)*((9.39/A3)^2)
280:A1=A
290:TAU=.014223*Z
300:SF=0:BB=0:FB=0:L=0:V=0:T=0:DP=0
310:REM ...PRINT HEADER
320:LF 3:LPRINT "P=";USING "#####";P;"PSI";" N2=";USING "##";N2
330:LPRINT "   Z=";USING "##.##^";Z
340:LPRINT "-------------------"
500:IF L>30.25THEN 950
510:FP=9.39*(P-DP):NETF=FP+W-SF-BB-FB-SE:ACC=32.2*NETF/W
520:IF L>1.0AND L<27THEN 800
530:IF L>=27THEN 560
540:IF INT (5*L)<>(5*L)THEN 800
550:GOTO 700
560:IF L<>INT (L)THEN 800
700:LPRINT "L=";USING "###.#";L;"    T=";USING "##.##";T
705:LPRINT "    V=";USING "###.#";V
710:LPRINT "    ACC=";USING "#####.#";ACC
720:LPRINT "    FP=";USING "######.#";FP
730:LPRINT "    FB=";USING "######.#";FB
740:LPRINT "  NETF=";USING "######.#";NETF:LF 1
750:IF DP<>PTHEN 800
755:LPRINT "DP>P.......":LF 1
800:L=L+LI
805:WAIT 0:PRINT "L=";USING "###.##";L
810:V2=SQR (V^2+2*ACC*LI):T=T+(V2-V)/ACC:V=V2:KSUM=29.7+.088*L+K2+K3+K4
820:DP=(KSUM*V^2)/144.45:IF DP<P THEN 825
822:DP=P
825:IF L<SNTHEN 840
830:A=A2
840:FB=V^2*(3.749-.106*L+.376/A^2-.311/A):RE=1.495E6*V:IF TAU<>0THEN 860
850:SF=(V^2*(12.56+.318*L))/((LOG (RE))^2.58):BB=.005913*V^2:GOTO 500
860:SF=(1.328*((154.56*TAU*DEL/RHO)^.5)*.0249*RHO*V*L)+8.54*TAU:GOTO 500
950:END
```

"APC Performance" BASIC Routine for PC-2 Computer

APPENDIX D
DESIGN CALCULATIONS

TENSION (PULLOUT) LIMIT : BEEFED UP

Limiting factors :
1. Quick Release Strength
2. Inner Barrel Thds. (those that are loaded during pullout.)
3. Piston Rod & connections

(1) QUICK RELEASE

Existing VLHPC Quick Releases fail now at ~ 100,000 lb. tension or less. Failure begins as a bearing load (surface) failure.

This failure mode is directly proportional to contact area between the lugs and the Cap Sub Windows.

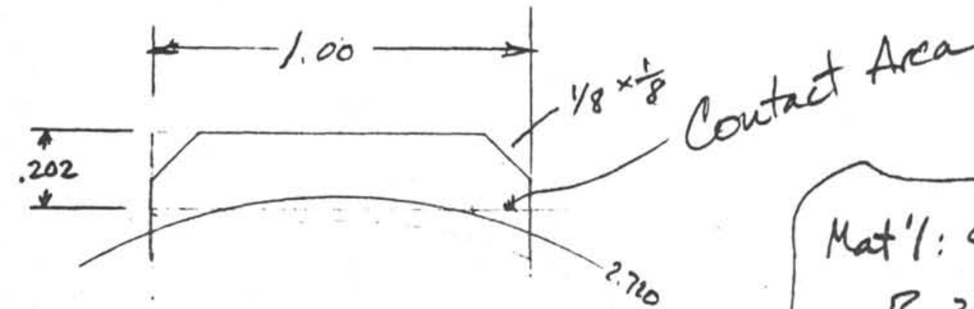
∴ An increase in Lug/Window contact area should bring about a corresponding (proportional) increase in tensil load capacity. (With no change in material.) or hardness

WN 60

2

Present Q.R. Lug/Window Contact Area: } OP 4339-3 / OP 4338-5

2x



Contact Area $= .202(1) - (.125)^2$ 2.5%

$= 0.186\ in^2$ /per Lug

Mat'l: 4130/4142
R_C 34-36
Y.S. = 142-152 ksi
UTS = 155-168 ksi

Total Contact Area (2) Lugs = $0.372\ in^2$

For Y.S. (compression) = 150 ksi

Bearing stress failure of the Lugs should begin at 150,000 psi ($.372\ in^2$) = 55,800 lb. overpull

Ultimate failure may not occur until 168,000 (.372) = 62,500 lb.

* This fits in with experiences of Q.R. failures. Total load at failure would be harder to determine because of wedging action required to separate parts after (during) lug failure.

APC: Q.R. LUG/WINDOW CONTACT AREA

3 lugs @ $0.31 in^2/lug = 0.93 in^2$

Y.S. limit of load = 150,000 (.93)

= 139,500 lb.

(4130/4142 R_c 34-36)

APC – Q.R. min. failure strength

② INNER BARREL

Min. strength at root of first pin thread

3½" STD. INN. BBL THD. [3½" O.D. × 2⅞ I.D.]

Hycalog rates max. tension @ Y.S. = ? = 133,196 lbs.

3½" INNER BBL THREAD

Cross-sectional area at weak point $= \frac{\pi}{4}(3.156^2 - 2.875^2)$

$= 1.33 \text{ in}^2$

Y.S. (4130 C.D.) = 87,000 psi ?

Tensile Strength = 87,000 (1.33) = 115,710 lb.

Less than new Q.R. strength

Box Min. area $= \frac{\pi}{4}(3.5^2 - 3.216^2) = 1.50 \text{ in}^2$

(Yes → C.D.
No → H.T.) ?

3

4N/.62
4

$3\frac{3}{4}$" INNER BBL THD. × $3\frac{1}{8}$ I.D.

$E - 2L = 3.546 - 2(.07) = 3.406$

Pin, min area = $\frac{\pi}{4}(3.406^2 - 3.125^2)$

$= 1.44 \text{ in}^2$

Y.S. = ?

Tensile Strength = $87{,}000(1.44) = 125{,}280$ lb.

For 2x s.f. over Q.R. T.S. req'd = $2(139{,}500) = 278{,}000$

$3\frac{3}{4}$" I.B. requires I.D. thus

$\frac{\pi}{4}(3.406^2 - I.D.^2)\,87{,}000 = 278{,}000$

$3.4\alpha^2 - \frac{278{,}000(4)}{81{,}000\pi} = ID^2$

$I.D. = \sqrt{3.406^2 - \frac{278(4)}{87\pi}}$

I.D. = 2.744"

? Can all I.B. thds. loaded in tension during overpull use $3\frac{3}{4}$" O.D. × $2\frac{3}{4}$" I.D. ? → NO

Std. Inner Barrel Stock → Mill Run

$3\frac{1}{2} \times 2\frac{7}{8}$

Heat Treated to Y.S. = 120,000 psi (~Rc 35)

From Kilsby Order 1981

Static strength of Pin Thd = $1.33(120{,}000) = 159{,}600$ lb.

HEAT TREATED $3\frac{1}{2} \times 2\frac{7}{8}$ 4130 TUBING

15% Greater than now Q.R. strength

5

(3) Piston Rod (& Connections) Strength

Piston Hd. Shear Pin

.375 DIA. @ H1150, YS = 125,000 psi (Min)

Loaded area (double shear) = $2\frac{\pi}{4}(.375)^2 = 0.22$ in²

Strength = 125,000(.22) = 27,500 lb.

Do not carry pullout load on Piston Hd. Use rod upset!!!

Piston Rod w/ Threaded Mid-Connection

$1\frac{1}{2}$" O.D. Rod w/ $1\frac{1}{8}$"-7 UNC

Male Tensile Area = 0.748 in²

Mat'l.: Nitronic 32 or 60 Y.S. = 65,000 psi (annealed)

Max. Pullout Load = 48,620 lb.

Rod w/o Threaded Connection
Body

$1\frac{1}{2}$" O.D. ~~Area~~ = 1.767 in²

Mat'l. Nitronic 32 or 60 Y.S. = 65,000 psi (annealed)

Max. Pull = 114,855 lb.

Rod Connection w/ $1\frac{1}{2}$-6 UNC Thds.

$A_t = 1.405$ @ YS = 65,000

@ YS < 100k

Max. Pull = 91,325 lbs.

5

FAILURE SCENARIOS — DURING OVERPULLS

6
Calc. failure loads

WORST : ROD FAILURE

loss of everything below rod

MID. : Q.R. FAILURE

Loss of entire scoping ass'y below Q.R. female — 140,000

BEST : INNER BARREL THD. FAILURE

loss of scoping ass'y below failed connection & junking of remainder of failed connection (pin) — 160,000 lb

---

To get Rod strength to 150,000 lb (min.)

Assume: $1\frac{3}{8}"$ – 8 stub Acme Thd at Piston Rod lower upset to $1\frac{7}{8}"$ dia.

Min. Cross-Area = 1.193 in² (Female)?

At Strength = 150,000 lb

$$\text{Min. Y.S. req'd} = \frac{150{,}000 \text{ lb.}}{1.193 \text{ in}^2} = 126{,}000 \text{ psi}$$

Mat.l? 17-4 PH? 431 SS? (NO)

Elgiloy? MP35N

Assume Rod must be joined by Thd. Conn.

Use Mat'l = 15-5 PH (H1025)
Y.S. = 165,000 psi CVN = 35 ft-lbs.

~10 ft Length (max) Sections

Worst Case: $1\frac{1}{2}$" Rod Dia. −8 pitch Stud Acme Thd.

Try $1\frac{1}{8}$"−8 | Min. Minor Dia. of Screw #6 | #8 Max. Maj. Dia. of Nut

$D = 1.125$
$p = .125$
$K = 1.050$

#5 1.030 | #7 1.145
#6 1.013 Dia | #8 1.162

$A_1 =$ ~~0.806~~ 0.845 in^2 | $A_2 =$ ~~0.707~~ 0.758 in^2
$S =$ | $S =$

Try 1"−8

$D = 1.000$
$p = .125$
$k = .925$

#5 .905 | #7 1.020
#6 .888 | #8 1.037

$A_1 =$ ~~0.619~~ 0.655 in^2 | $A_2 =$ ~~0.923~~ 0.968
$S =$ | $S =$

Weak Point

6

Compare $1\frac{1}{8}$"−8 ~~Values from~~ Machinery's Hdbk.

$E = 1.088$
#3 = 1.079
#4 = 1.062 ✓
#6 = 1.013

$$\text{Stress Area } A_1 \text{ (Male)} = \pi\left(\frac{E_s + K_s}{4}\right)^2$$

(#4, #6)

9 E = 1.088
#10 1.105
8 1.162

$$= \pi\left(\frac{1.062 + 1.013}{4}\right)^2$$

$$= 0.845 \text{ in}^2 \text{ Male}$$

#12 $K + .05p = D - .6p + .0$..
$= D - .55p$
#12 1.056

$$\text{Stress Area } A_2 \text{ (Female)} = \frac{\pi}{4}(O.D.)^2 - \pi\left(\frac{\#8 + \#10}{4}\right)^2$$

$$= \frac{\pi}{4}(1.5)^2 - \pi\left(\frac{1.162 + 1.105}{4}\right)^2 = 0.758 \text{ Female}$$

1"-8

Male Area ⇒ $E = D - .3P$
$= 1.0 - .3(.125)$
$= 0.963$

Female Area ⇒ $E = 0.963$
#10 = .980

#3 = 0.955
#4 = 0.938

Male Area $= \pi\left(\frac{.938 + .888}{4}\right)^2$
$= 0.655$

Female Area $= \frac{\pi}{4}(1.5)^2 - \pi\left(\frac{1.037 + .98}{4}\right)^2$
$= 0.968$

Worst Case Weak Pt.

$1\frac{1}{2}$" Dia. Rod Connected by $1\frac{1}{8}$"-8 Stub Acme Thds.

Min. Tensile Stress Area occurs at Female = 0.758 in²

For S = 150,000 lb.

Y.S. Reqd = $\frac{150,000}{.758}$ = 198,000 psi

with 15-5PH, Y.S. = 165,000 psi Min. strength = 125,000 psi

Try $1\frac{5}{8}$" dia. Rod

Strength of Connection w/ $1\frac{5}{8}$" Dia. Rod? or $1\frac{3}{4}$" Dia.

Try $1\frac{1}{4}$"-8 Stub Acme

D = 1.250, p = 0.125, E = 1.213, K = 1.175

#3	1.204	#7	1.270
#4	1.187	#8	1.287
#5	1.155	#9	1.213
#6	1.138	#10	1.230

Male Stress Area $= \pi\left(\frac{1.187 + 1.138}{4}\right)^2 = 1.061 \text{ in}^2$

Female Stress Area ($1\frac{5}{8}$" Rod) $= \frac{\pi}{4}(1.625)^2 - \pi\left(\frac{1.287 + 1.230}{4}\right)^2$

$= 0.830 \text{ in}^2$

Female Stress Area ($1\frac{3}{4}$" Rod) $= 1.161 \text{ in}^2$

Try $1\frac{1}{8}$"-8 Stub Acme

D = 1.125, p = .125, E = 1.088, K = 1.050

#3	1.080	#7	1.145
#4	1.063	#8	1.162
#5	1.030	#9	1.088
#6	1.013	#10	1.105

Male Stress Area $= \pi\left(\frac{1.063 + 1.013}{4}\right)^2$

$= 0.846 \text{ in}^2$

Female Stress Area $= \frac{\pi}{4}(O.D.)^2 - \pi\left(\frac{1.162 + 1.10}{4}\right)$

O.D.	$1\frac{1}{2}$"	$1\frac{5}{8}$"	$1\frac{3}{4}$"
Stress Area (in2)	.758	1.065	1.396

Male Stress Area (in²)	Female Stress Area (in²)	Rod Dia	Stub Acme Thd.
0.655	0.980	1½"	1"-8
0.846	0.758		$1\frac{1}{8}$"-8
		(=1.162)	$1\frac{3}{16}$"-8
			$1\frac{1}{4}$"-8
0.846 @YS=165k S=139.6k	1.065 w/Align Groove 0.987 @YS=165k S=163k	1⅝"	1⅛"-8
1.061	0.830		$1\frac{1}{4}$"-8
0.952 @YS=165k S=157k	0.951 w/Align Groove 0.873 @YS=165k S=144k	1⅝	$1\frac{3}{16}$"-8

Use this size to make room for Anti-Spiral Groove, so that Max. Major Dia. of Female (=1.162) does not break into groove.

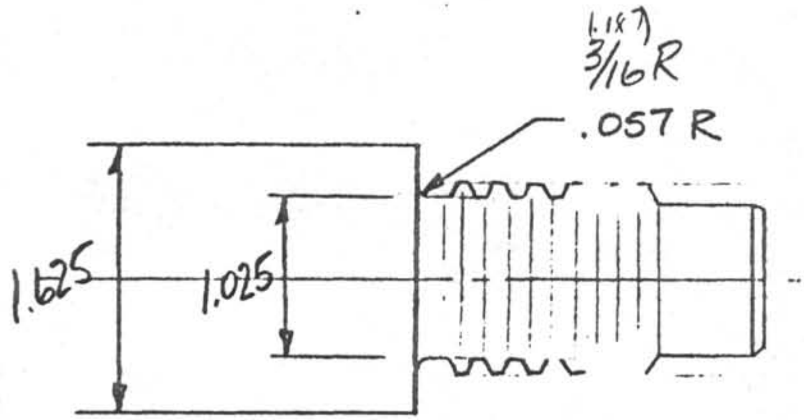
TENSILE STRESS AREAS FOR PISTON ROD THREADED CONNECTION POSSIBILITIES

Static Tensile Strengths - No stress Concentration factors included.

APC: PISTON ROD CONNECTION STRENGTH

Calculations done after:

1. Unexpectedly low level tensile failure of pin thread at Site 606A
2. Observation of machine shop techniques to produce threaded specimens.



$1\frac{1}{8}$-8 STUB ACME PIN CONNECTION

Mat'l. : 15-5 PH Cond. : H1025

Y.S. = 165,000 psi (or more)

Static Tensile Strength

Rod : $S = \frac{\pi}{4}(1.625)^2(165{,}000) =$ 342 k lbs.

Pin root : $S = \frac{\pi}{4}(1.025)^2(165k) =$ 136,150 lbs. (1.005) (130890)

Stress concentration

Ref: Peterson "Stress Conc. Factors" Fig. 72, pg. 96

D = 1.625
d = 1.025 (1.005)
r = .057 (.187)

$D/d = 1.58$ (1.62) $r/d = \frac{.057}{1.025} = .056$ (.187 / 1.005 = .186) $K_t = 2.22$ (1.62) (1.60)

Applicable only for cyclic or shock loading.
Q? Does shock or flucuating load occur during pullo...

(w/ Str Conc.) Net S = 61,890 lbf 84,040 lbf

(Ref: Shigley pg. 303)

Pre-Load

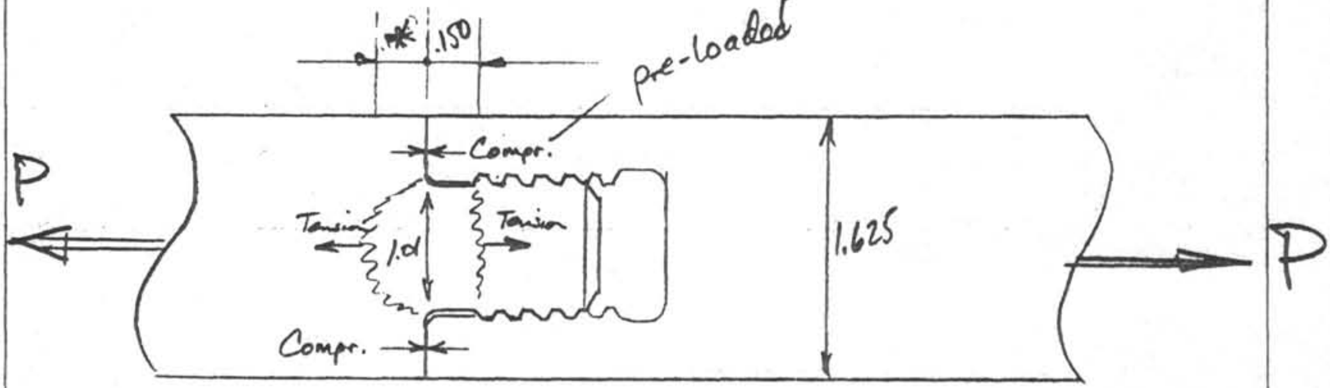
$k_b = \frac{AE}{l}$ $A = \frac{\pi}{4}(1.125)^2 = 0.994 \, in^2$

$E = 28.5 \times 10^6$ psi

$l = 0.150$ (root below last thread)

$$k_b = \frac{.994 \, in^2 (28.5 \times 10^6 \, lb/in^2)}{0.15} = 1.9 \times 10^8 \frac{lbf}{in}$$

$k_m \equiv$ compression stiffness of shoulders of pin and box at pre-load



$$\text{Compression area} = \frac{\pi}{4}(1.625^2 - 1.01^2)$$

$$A_m = 1.273 \, in^2$$

$k_m = \frac{AE}{l}$ Use $l = .150 + {}^{\sim}.3^{*} = .45$ in

$$k_m = \frac{1.273 \, in^2 (28.5 \times 10^6 \frac{lb}{in^2})}{.45 \, in} = 8 \times 10^7 \frac{lbf}{in}$$

$$F_i = \frac{T}{0.2d} = \frac{500 \, ft\text{-}lbf}{0.2(1.025 \, in)}\left(12 \tfrac{in}{ft}\right) = 29,268 \text{ lbf}$$

80

@ $P = 100{,}000\ lb_f$

$$F_b = \frac{k_b P}{k_b + k_m} + F_i$$

$$= \frac{1.9\times10^8 \frac{lb_f}{in}\left(100{,}000\ lb_f\right)}{\left(1.9\times10^8 \frac{lb_f}{in}\right) + \left(8\times10^7 \frac{lb_f}{in}\right)} + 29{,}268$$

$$= 70{,}370 + 29{,}268$$

$$= 99{,}638\ lb_f$$

$$\delta_m = \frac{F_i l}{A_m E} = \frac{29{,}268\ lb\ (.45)\ in}{1.273\ in^2\ (28.5\times10^6)\frac{lb}{in^2}} = 0.00036\ in.$$

$$F_m = k_m \delta_m = .00036\ (8\times10^7) = \underline{28{,}800\ lb.}$$

not applicabl[e] shoulder separat[es] before look[...] overpu[...]

H 1025

$$J = \frac{\pi d^4}{32} = \frac{\pi (1.025)^4}{32} = 0.1084 \text{ in}^4$$

τ_{max} = 107.7 ksi
y.str. 114.2 ksi } 0.2% Torsional Yield strength for H1025
(actual was was closer to H 925) τ_{max} = 114-123 ksi

$$\tau = \frac{Tr}{J} \qquad T = \frac{\tau J}{r}$$

$$\tau = \frac{T d/2}{\frac{\pi d^4}{32}} = \frac{16T}{\pi d^3}$$

$$T = \frac{\tau \pi d^3}{16}$$

$$T = \frac{107{,}700 \frac{lb}{in^2} (0.1084 \text{ in}^4)}{1.025/2 \text{ in} \quad (12 \text{ in/ft})}$$

Min. Danger torque
T = 1898 ft-lb. w/o STRESS CONCENTRATION

Using 3 ft. wrench
Max force = 632 lb.

TORSIONAL STRENGTH OF PISTON ROD CONNECTIONS — 1⅛-8 STUB ACME
: SIGNIFICANT DURING MAKE-UP IF THREADS GALL, BIND OR JAM

Stress Concentration

Petersson Fig. 79a

Assume D = dia @ crest of thd = 1.125
d = fillet dia. = 1.025

$r \cong 0.015$ in $\qquad D/d \cong 1.1$

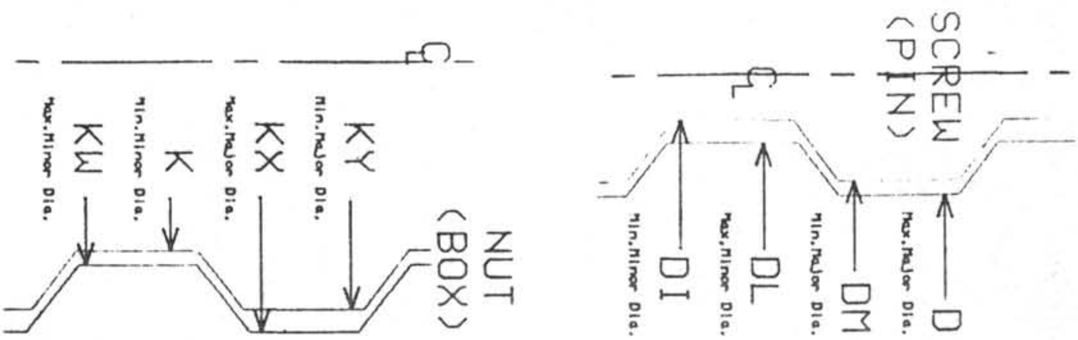
$r/d \cong 0.015$

$K_{ts} \cong 1.6 - 1.9$

Fig. 54 $D/d = 1.1$ $\frac{r}{d} = .015$ $K_{ts} \cong 2.6$
Fig. 55 $d/D = 0.9$ $K_{ts} \cong 2.5$
Fig. 57 $(\alpha = 29°)$ $(K_{ts} \cong 2.5)$

THUS, USING MIN. TORSIONAL YIELD STR. AND A STRESS CONCENTRATION FACTOR OF $K_{ts} = 2.5$ AT THE UPSET BETWEEN PIN NECK DIA. & FIRST THD., 252 LB. FORCE ON A 3-FT. WRENCH WOULD CAUSE TORSIONAL FAILURE.

APC ROD CONNECTIONS



1.125 - 8 THD/IN

D=	1.1250 IN.
DM=	1.1187
DL=	1.0300
DI=	1.0130
KY=	1.1450
KX=	1.1619
K=	1.0500
KW=	1.0562

INTERMEDIATE ROD CONNECTIONS

STRESSED AREAS

Pin Tensile Area (at Thd.)= 0.845
Box Tensile Area (at Thd.)= 1.065

MINIMUM AREAS (Approx.)
At Root of Pin = 0.793
At Box Thd.Relief = 1.004
(Box O.D. = 1.625)
Thd.Shear Area Per Inch of Engagement = 1.6989 SQ.IN.

MACHINING DIMEN.s

Thd. Ht.=	0.0375
Pitch Dia=	1.0875
Crest=	0.0528
Root(Nut)=	0.0476
Wire Dia.=	0.0645
OverWireDia=	1.168

1.250 - 8 THD/IN

D=	1.2500 IN.
DM=	1.2437
DL=	1.1550
DI=	1.1376
KY=	1.2700
KX=	1.2873
K=	1.1750
KW=	1.1812

MOD.II TOP ROD CONNECTION

STRESSED AREAS

Pin Tensile Area (at Thd.)= 1.060
Box Tensile Area (at Thd.)= 1.897

MINIMUM AREAS (Approx.)
At Root of Pin = 1.002
At Box Thd.Relief = 1.829
(Box O.D. = 2.000)
Thd.Shear Area Per Inch of Engagement = ~~1.6989~~ SQ.IN.
1.8938

MACHINING DIMEN.s

Thd. Ht.=	0.0375
Pitch Dia=	1.2125
Crest=	0.0528
Root(Nut)=	0.0476
Wire Dia.=	0.0645
OverWireDia=	1.293

1.375 - 8 THD/IN

D=	1.3750 IN.
DM=	1.3687
DL=	1.2800
DI=	1.2623
KY=	1.3950
KX=	1.4126
K=	1.3000
KW=	1.3062

BOTTOM CONNECTION AT SNUBBER

STRESSED AREAS

Pin Tensile Area (at Thd.)= 1.299
Box Tensile Area (at Thd.)= 1.637

MINIMUM AREAS (Approx.)
At Root of Pin = 1.235
At Box Thd.Relief = 1.563
(Box O.D. = 2.000)
Thd.Shear Area Per Inch of Engagement = ~~1.6989~~ SQ.IN.
2.0877

MACHINING DIMEN.s

Thd. Ht.=	0.0375
Pitch Dia=	1.3375
Crest=	0.0528
Root(Nut)=	0.0476
Wire Dia.=	0.0645
OverWireDia=	1.418

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CONNECTION STRENGTHS OF ROD SECTIONS

TOP OF UPPER SECTION — $1\frac{3}{8}$"-8 STUB ACME

15-5PH ROD (MALE) H1025 CONN. TO. 4340, Rc 32 (FEMALE)

YS = 165 ksi

UTS = 170 ksi

UTS = 145 ksi

From Mach. Hdbk. pg. 1150 ?v thds?

Shear area of rod thd., $A_S = \pi n L_e K_{n\,max}\left[\frac{1}{2n} + .57735(E_{S\,min} - K_n\right.$

Shear area of Inner Shear Pin Sub thd., $A_n = \pi n L_e D_{S\,min}\left[\frac{1}{2n} + .57735(D_{S\,min} - E_{n\,max})\right]$

$n = 8 \qquad L_e = $ unknown (TBD)

#4 $E_{S\,min} \Rightarrow E = 1.3375 \quad \#3 = 1.3281$ #4 $E_{S\,min} = 1.3104$

#12 $K_{n\,max} \Rightarrow K = 1.300$ #12 $= 1.3063 = K_{n\,max}$

#2 $D_{S\,min} \Rightarrow D = 1.375$ #2 $= D_{S\,min} = 1.3688$

#10 $E_{n\,max} \Rightarrow E = 1.3375$ #10 $E_{n\,max} = 1.3552$

$$A_S = \pi(8)L_e(1.3063)\left[\frac{1}{16} + .57735(1.3104 - 1.3063)\right]$$

$$A_S = 2.130\,L_e$$

$$A_n = \pi(8)L_e(1.3688)\left[\frac{1}{16} + .57735(1.3688 - 1.3552)\right]$$

$$A_n = 2.420\,L_e$$

$$J = \frac{A_s (170\ ksi)}{A_n (145\ ksi)} = \frac{2.130\ Le\ (170)}{2.420\ Le\ (145)} = 1.032$$

Req'd Length of Engagement to prevent stripping of Internal Thd (in shear pin sub)

$$Q = J L_e$$

$$L_e = \frac{2 A_t}{\pi K_{n\,max} \left[\frac{1}{2} + .57735 n (E_{s\,min} - K_{n\,max}) \right]}$$

A_t (tensile Area of rod) $= \pi \left(\frac{\#4 + \#6}{4} \right)^2$

#6 => #5 = 1.300 − .02 = 1.28 #6 = 1.262

$$A_t = \pi \left(\frac{1.3104 + 1.262}{4} \right)^2 = 1.300\ in^2$$

$$L_e = \frac{2(1.3)}{\pi (1.3063) \left[.5 + .57735 (8) (1.3104 - 1.3063) \right]}$$

$L_e = 1.221$

Q = 1.26 in. REQ'D. LENGTH OF ENGAGEMENT OF PISTON ROD IN SHEAR PIN SUB

SHEAR PINS

Pressure Working Area $= \frac{\pi}{4}(3.8^2 - 1.625^2)$

$A = 9.267 \text{ in}^2$

Max. load at 3000 psi

$L = 3000\,(9.267) = 27{,}802 \text{ lbf}$

Using 17-4 PH shear Pins,

	Double shear shear strength
@ Condition H900	= 122.4 - 127.4 ksi
H925	114.5 - 119.1
H1025	103.8 - 104.6
H1100	98.0 - 100.2
H1150M	88.5 - 90.1
Condition A (Solu. treated)	98.7 - 100.5

(Above from Armco Product Data Sheet S-6c)

Available from Jorgensen

Condition A or H1150-M, Ground

Diameters 1/8" (.125), 3/16" (.187), 7/32" (.219), 1/4" (.250), 9/32" (.281), 5/16" (.312), 11/32" (.344), 3/8" (.375), 13/32" (.406)

7/16 (.4
15/32 (.4

3 pins in double shear ⇒ 6 areas

Total Shear area $A = 6\left(\frac{\pi}{4}\right)d^2 = 1.5\pi d^2$

Choices of pin sizes @ F = 27,802 lbf {Shoot-off Pressure 3000 psi}

	Condition	Shear Str. (S) (ksi)	$A = \frac{F}{S}$ (in²)	$d = \sqrt{A/1.5\pi}$ (in)	Closest size avail
✓	A	98.7/100.5	.282/.277	.244/.242	1/4 (.250)
	H900	122.4/127.4	.227/.218	.220/.218	7/32 (.219)
	H925	114.5/119.1	.243/.233	.227/.223	" N.G.
	H1025	103.8/104.6	.268/.266	.238/.237	" N.G.
	H1100	98.0/100.2	.284/.277	.245/.243	1/4 (.250)
✓	H1150-M	88.5/90.1 (89.3)	.314/.309	.258/.256	1/4 (.250)

Using 1/4" Ground Rounds

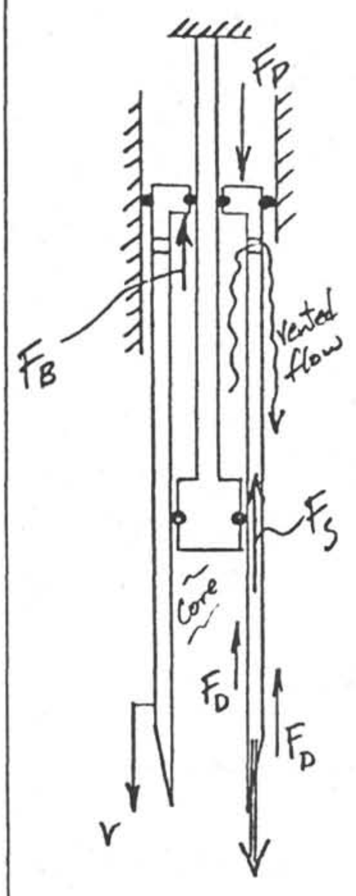
# Shear pins	A =	Ave. Shear Load (lbf) Cond. A	Ave. Shear Load (lbf) Cond. H1150-M	Ave. (psi) Shoot-off Pressure A	Ave. (psi) Shoot-off Pressure H1150-M
3	0.295 in²	29,382	26,343	3170	2843
2	0.196 in²	19,522	17,503	2106	1889
1	0.098 in²	9761	8751	1053	944

USE 1/4" Dia
17-4 PH
Ground Rounds
Condition H1150-M

APC

DECELLERATION CALCULATIONS

Design for protection of mechanical parts from damage caused by excessive impact velocity at end of stroke during water core.



During water core,

terminal velocity is reached, (accel = 0) when dynamic equilibrium is achieved.

$$F_P + W = F_B + F_S + F_D$$

Driving forces — Retarding forces

Driving force, $F_P \equiv$ Force due to pumped water pressure

$$\text{Max. } F_P = 3000 \frac{\text{lb}}{\text{in}^2} \left(\frac{\pi}{4}\right)(3.8^2 - 1.5^2)\text{ in}^2$$
$$= 28{,}722 \text{ lb}_f \text{ @ } 3000 \text{ psi} = P$$

$1\frac{1}{2}$" Rod dia.

$$F_P = \text{Area}\,(P - \Delta P) = 9.39\,(P - \Delta P)$$

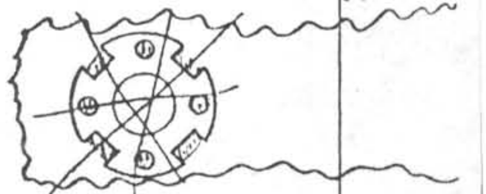
$$\left\{ \text{Area} = \frac{\pi}{4}(\text{Bore}^2 - \text{rod dia}^2) = \frac{\pi}{4}(3.82^2 - 1.625^2) = 9.39 \text{ in}^2 \right\}$$

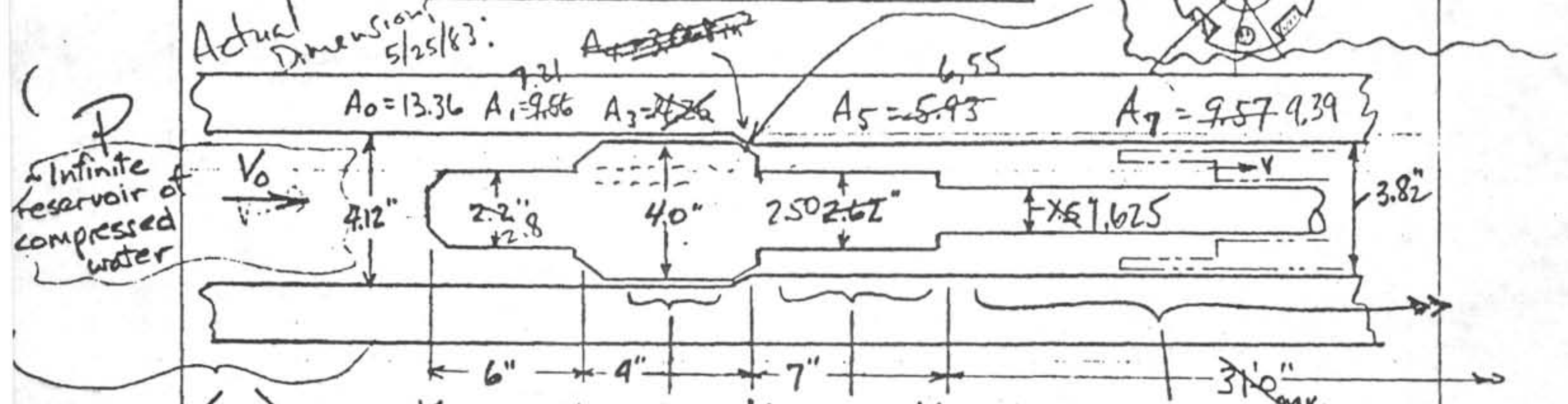
F_p acting on main seals is probably <u>not constant</u> at high stroke velocities.

<u>Req'd</u>: A relationship of pressure drop across pulling neck, landing shoulder and along DC/piston rod annulus as a function of stroke velocity. This function determines how F_p is attenuated during water cores. ($F_p = (P - \Delta P)$

$F_p = f(P - \Delta P)$

<u>Model of flow restrictions</u>





<u>K-factors</u>, Resistance Coefficients

K_0: Accounts for nebulus resistance of pipe wall friction and discontinuities above APC itself. Water to drive scoping portion of tool must flow from compressed "stored" water in pipe string. Pressure far up the string may be assumed to stay constant but a ΔP will occur prior to the flow reaching K_1 location.

K_1, K_2: Sudden contraction loss coefficients

K_3, K_5, K_7: Annulus friction coefficient

K_4, K_6: Sudden enlargement coeff.

K_4: "Orifice" coeff.

K_1: Sudden contraction

Assume break into annular flow acts as a sudden contraction from A_0 to A_1 (plus 5%)

(from Crane # 410, pg. A-26)

$$\{V_0\}\ K_1 = \frac{0.5\,(1-\beta^2)\sqrt{\sin \theta/2}}{\beta^4}$$

Let $\theta = 180°$

$\beta^2 = \frac{A_1}{A_0}$

$$A_0 = \frac{\pi}{4}(4.125)^2 = 13.36\ in^2$$

$$A_1 = \frac{\pi}{4}(4.125^2 - \overset{2.8}{\cancel{2.2}}{}^2) = \cancel{9.56}\ in^2\ \ 7.21\ in^2$$

$$\beta^2 = A_1/A_0 = \cancel{0.716}\ \ 0.540$$

$$K_1 = \frac{0.5(1-\overset{.540}{\cancel{.716}})(1)}{(\underset{.540}{\cancel{.716}})^2} = \cancel{0.277}\ \ 0.789$$

Add 15% to account for fact that annular flow with large surface area rather than concentric pipes occurs here.

$$K_1 = 1.05(\overset{.789}{\cancel{.277}}) = \cancel{0.29}\ \ \{\text{acting on } V_0\}$$

0.829

K_2, K_3, K_4 : Dependent on geometry of flow paths thru landing shoulder — varies with open hole sizes, pluggable hole sizes and number of holes left open.

K_5 : Annular flow

(from Raymond Paper)

$$K_5 = 0.48 \frac{L(ft)}{D(in)} \text{ for straight pipe}$$

$D = 4R_H$ R_H = hydraulic radius

(from Crane #410) R_H for annular openings can be taken as approx. ½ passage width

Therefore take R_H at A_5 to be

$$\frac{1}{2}\left(\frac{3.82 - \overset{2.5}{\cancel{2.62}}}{2}\right)^{\text{pass. width}} = \overset{.330}{\cancel{0.295}}" = R_H$$

$$D = 4R_H = \overset{1.320}{\cancel{1.18}} \text{ in}$$

then $K_5 = 0.48 \dfrac{7}{(12)(\overset{}{\cancel{1.18}}\,1.320)} = \underline{\underline{\overset{0.212}{\cancel{0.237}}}}$ {acting on V_5}

K_6 : Sudden enlargement A_5 to A_7

$$K_5 = \frac{(1-\beta^2)^2}{\beta^4} \qquad \beta^2 = \frac{A_5}{A_7}$$

$$A_5 = \frac{\pi}{4}(3.82^2 - \overset{2.5}{\cancel{2.62}}{}^2) = \overset{6.55}{\cancel{5.95}}$$

$$A_7 = \frac{\pi}{4}(3.82^2 - \underset{1.625}{\cancel{1.5}}{}^2) = \underset{9.39}{\cancel{9.57}} \text{ in}^2$$

$$\beta^2 = \frac{5.95}{9.57} = \underset{.698}{\cancel{.621}}$$

$$K_6 = \frac{(1-\overset{.698}{\cancel{.621}})^2}{\underset{.698}{(.621)^2}} = \overset{0.187}{\cancel{0.37}} + 5\% \text{ (for annular surf. area effect)}$$

$$= \underline{\underline{\overset{0.196}{\cancel{0.39}}}} \text{ \{acting on } V_7\}$$

45

K_7: Annular straight pipe flow

$K_7 = f(\ell)$

$= 0.48 \frac{\ell, ft}{D, in}$ $\quad D = 4R_H = 4 \frac{\text{cross area}}{\text{wetted perim.}}$

$= \frac{(4)\frac{\pi}{4}(3.82^2 - 1.625^2)}{\pi(3.82 + 1.625)}$ (3.8 and 1.5 struck out, corrected to 3.82 and 1.625)

$K_7 = \frac{0.48}{5.445} \ell (ft.)$ (2.3 struck out) $\quad = 5.445$ in. (2.3 struck out)

$K_7 = .088\, \ell (ft.)$ (0.209 struck out) $\{on\ V_7\}$

$K_0 = 0.48 \frac{L (ft)}{D (in)}$ Use 2000 ft. = L as average affected length of pipe where flow from "storage" must pass Velocity is variable from $V = 0$ to V_0, Ave = $V_0/2$

$K_0 = 0.48 \frac{2000}{4.125} = 232$ $\{\text{acting on } \frac{V_0}{2}\}$

$\Delta p = \frac{K_0 \rho V^2}{2g_c} = \frac{\rho}{2g_c} K_0 \frac{V_0^2}{4} \rightarrow \frac{K_0}{4} \{\text{action } V_0\}$

$\{V_0\}$ $K_0 = 58$ $\{\text{acting on } V_0\}$ ✓

ΔP across stationary portions of the tool as moving section scopes

$$\Delta P = \Sigma K_i \frac{\rho Q_c^2}{2g_c A_i^2}$$ $Q_c \equiv$ flow from compressed "storage"

$K_1 =$ ~~0.29~~ .829 coeff. to $V_0 = Q_c/A_0$

$K_2; K_3, K_4$ — Calculated separately

$K_5 =$ ~~0.24~~ 0.212 coeff. to $V_5 = Q_c/A_5$

$K_6 =$ ~~0.39~~ 0.196 " " $V_7 =$ } Q_c/A_7

$K_7 =$ ~~0.21~~ .088 ℓ (ft.) " " $V_7 =$ } Q_c/A_7

$K_0 \cong 58$ " " $V_0 = Q_c/A_0$

To simplify, adjust all K's to act as coefficients to V_7

$$K_i' = K_i \left(\frac{A_7}{A_i}\right)^2 \quad \{\text{all acting on } V_7 = Q_c/A_7\}$$

$K_1' = .829 \left(\frac{9.39}{13.36}\right)^2 = 0.41$

$K_5' = .212 \left(\frac{9.39}{6.55}\right)^2 = 0.44$

$K_6' = .196$

$K_7' = 0.088\ell$

$K_0' = 58 \left(\frac{9.39}{13.36}\right)^2 = 28.65$

$\Sigma K = 29.7 + 0.088\ell + K_2 + K_3 + K_4$ acting on V_7

$$\Delta P = \Sigma K \frac{\rho Q_c^2}{2 g_c A_7^2}$$

where

$A_7 \equiv$ annular area between DC bore and piston rod

$Q_c \equiv$ flow from compressed water "storage"

$$Q_c = V_7 A_7, \quad \frac{Q_c}{A_7} = V$$

$$\rho = 64.2 \ lb_m/ft^3, \quad g_c = 32.2 \ \frac{lb_m\text{-}ft}{lb_f\text{-}sec^2}$$

$$\Delta P = \Sigma K \frac{64.2}{2(32.2)144} V^2$$

$$\boxed{\Delta P = \Sigma K \frac{V^2}{144.45}}$$

19

Weights, Core bbl sections = 332 lb.

QR, seal sub, shear pin sub

$\approx \frac{\pi}{4}(3.25^2 - 1.5^2)48(.283) = 88$ lb.

Catchers, shoe, lower liner seal sub, spacer sub

$\approx \frac{\pi}{4}(3.5^2 - 2.5^2)40(.283) = 53$

473

Use

TOTAL $W = 475$ lb.

Retarding forces: $F_B \equiv$ back pressure force of venting water above piston; a function velocity, V

$F_S \equiv$ force caused by seal drag of cylinder seal, rod seal & piston head seal, a function of velocity, V

$F_D \equiv$ force caused by water drag resistance of corer into still sea water; a function of velocity, V.

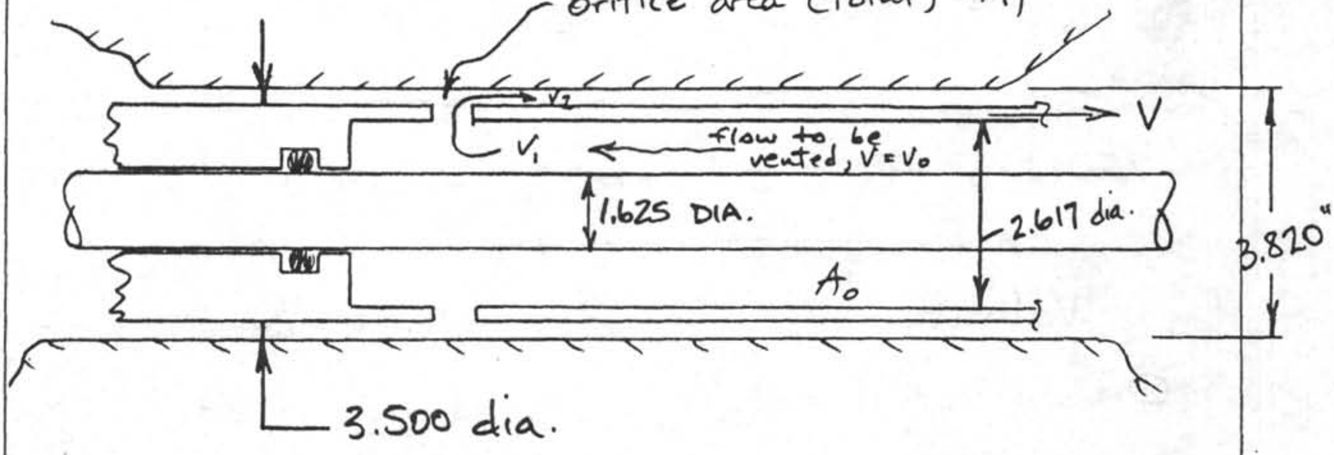
Iterative solution req'd.

e.g., Try $V_{term.}$ based on 30 ft. stroke in 1.5 sec.

$$V_{ave} \cong V_{term} = \frac{30\text{ ft}}{1.5\text{ sec}} = 20\text{ ft/sec}$$

F_B

Simple Vent Model:



Model as sudden contraction / sudden enlargement

K_1 (sudden contraction), K_2 (sudden enlargement)

+ 1.3 (for 180° turn in flow direction)

$$K_1 = 0.5\left(\frac{A_0}{A_1}\right)^2\left(1-\frac{A_1}{A_0}\right)$$

from Raymond paper

$$A_0 = \frac{\pi}{4}(2.617^2 - 1.625^2) = 3.31 \text{ in}^2$$

$$K_1 = 0.5\left(\frac{3.31}{A_1}\right)^2\left(1-\frac{A_1}{3.31}\right)$$

$$= \frac{5.46}{A_1^2} - \frac{1.65}{A_1} \quad \{\text{on } V_0 = V\} \quad + 1.3$$

$$K_2 = \left(1-\frac{A_1}{A_2}\right)^2 = \left(1-\frac{A_1}{1.84}\right)^2 = \left(1-\frac{2A_1}{1.84}+\frac{A_1^2}{3.386}\right)$$

$$\{V_1\}\ K_2 = 1-\frac{A_1}{.92}+\frac{A_1^2}{3.386}$$

, Adjust to V_0, multiply by $\left(\frac{A_0}{A_1}\right)^2$

$$K_2 = \left(1-\frac{A}{.92}+\frac{A^2}{3.386}\right)\left(\frac{3.31}{A_1}\right)^2$$

Adjusted to $V_0 = V$

$$K_2 = \left(1 - \frac{A}{.92} + \frac{A^2}{3.386}\right)\frac{10.96}{A^2}$$

$$K_2 = \frac{10.96}{A^2} - \frac{11.91}{A} + 3.237$$

VENTED FLOW OUT ANNULUS TO BIT THROAT

Velocity, V_2, in annulus between corer O.D. & drill collar I.D. is <u>not</u> equal to $\frac{Q}{A_2}$ since one wall (corer) is moving.

Use relative velocity $V_2' = 1.96\,V$ between vented flow and corer.

$$\left(\begin{array}{ll} Q_V = AV & \underline{\text{Annulus}}\cdot\ V_2 = Q/A_2 \\ \quad = 3.61\,V_0 & \quad = \frac{3.61}{1.84}V \\ & \quad = 1.96\ \text{ft/sec} \end{array} \right)$$

$$Re_{D_h} = \frac{\rho V D_h}{\mu g_c} = \frac{64.2\,(100)(3.82-3.5)}{4\times10^{-5}\,(32.2)\,12} = 1.33\times10^5$$

$$\varepsilon = 150\times10^{-6}\ \text{ft}$$
$$D_h = .0267\ \text{ft}$$

$$K' \propto \left(\frac{V_2}{V}\right)^2 K = (1.96)^2 K = 3.84K$$

$$K_{ann} = \frac{fL}{D_h} = \frac{0.032}{0.0267}(31-\ell)$$

$$= (37.15 - 1.2\ell)\,3.84$$

$$K_{ann} = 142.6 - 4.608\,\ell$$

At Bit Throat $K = 1.5$ (previously calculated) on V_{throat}

Adjusted to V

$$K' = 1.5 \left(\frac{3.31}{1}\right)^2 = 16.43$$

ΣK

$$K_1 = \frac{5.46}{A_1^2} - \frac{1.65}{A_1} + 1.3$$

$$K_2 = \frac{10.96}{A_1^2} - \frac{11.91}{A_1} + 3.237$$

$$K_{ann} = 142.6 - 4.608\,\ell$$

$$K_{throat} = 16.43$$

$$\underset{\{on\ V\}}{\Sigma K} = 163.6 - 4.608\,\ell + \underbrace{\frac{16.42}{A_1^2} - \frac{13.56}{A_1}}_{\text{not very significant}}$$

31
"

$$F_B = \Delta P(A_o) = \frac{3.31\, \Sigma K \rho V^2}{2 g_c\, (144)}$$

$$= \frac{3.31\,(64.2)}{2(32.2)\,144}\, \Sigma K\, V^2$$

$$= \frac{V^2}{43.64}\left(163.6 - 4.608\,\ell + \frac{16.42}{A^2} - \frac{13.56}{A}\right)$$

$$F_B = V^2\left(3.749 - 0.106\,\ell + \frac{.376}{A^2} - \frac{.311}{A}\right)$$

F_S

Seal drag is significant for all three seals. Piston Head seal is pressurized (by ever-increasing F_B)

Take S.W.A.G. ~~total~~ F_S (dynamic) as 60 + 145 + 100 = 305 @ 2000 psi

Say F_S = 300 lb_f at any pressure

(Static or dynamic)

* This estimate is close enuf since the magnitude is only 5-10% of the other significant variables involved.

DRAG, F_D

Skin friction drag

from Handbook of Oc. & Und. Engr. pg. 2-28

$$C_{D_f} = .0025 = \frac{F_D(2)}{\rho V^2 S_{wet}}$$

$$S_{wet} = f(\ell)$$

$$= \text{outside} + \text{inside } f(\ell)$$

$$= \frac{3.5\pi}{12}(30.25) + \frac{2.62\pi}{12}\ell$$

$$S_{wet} = 27.7 + .69\ell \text{ , ft}^2$$

$$\text{Skin drag} = \frac{0.455}{(\log Re_\ell)^{2.58}} \frac{\rho V^2 S_{wet}}{2g_c}$$

$$= \frac{.455(64.2)V^2 (27.7 + .69\ell)}{\left[\log(1.5\times10^6 V)\right]^{2.58} (2)32.2}$$

$$= \frac{.454 V^2 (27.5 + .7\ell)}{\left[\log(1.5\times10^6 V)\right]^{2.58}}$$

$$\text{Skin drag} = \frac{V^2(12.47 + 0.318\ell)}{\left[\log(1.5\times10^6)V\right]^{2.58}}$$

$$\text{Bluff drag} = \frac{0.2\,\rho V^2 A}{2 g_c}$$

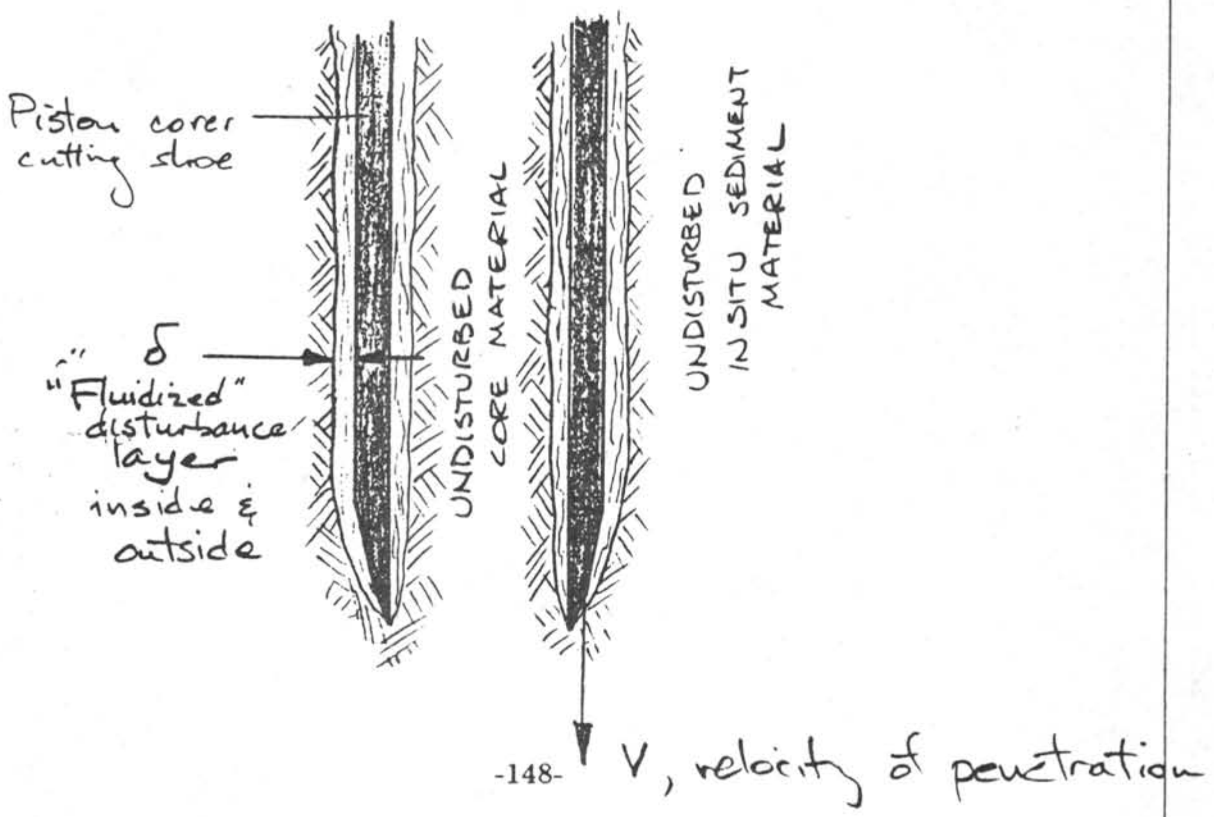
$$= \frac{0.2(64.2)\frac{\pi}{4}(3.5^2 - 2.6^2)V^2}{2(32.2)\,144}$$

$$= \frac{V^2}{168}$$

CORING RESISTANCE RELATIONSHIPS

Assume that the only known property of the cored sediments is shear strength, T. The coring resistance relationship must be a function of varying T plus variables having to do with the corer but independent of the cored material.

Assume that the corer penetrates the sediment material in such a way that disturbance of the insitu material is limited to a "fluidized" disturbance layer of thickness δ on both the inside and outside of the corer.



Further assume that conditions within the disturbance layer simulate ~~laminar~~ flow of a highly viscous fluid. (Reynolds number can later be calculated to check if ~~laminar~~ flow conditions are likely to exist.)

Then frictional resistance to penetration of the corer into the sediment can be approximated by using the skin friction equation,

$$\text{Drag} = C_{Df} \frac{\rho V^2 A}{2g_c}$$

where

ρ = density of "fluidized" material within the disturbance layers

V = velocity of penetration

A = affected surface area

C_{Df}, Friction drag coefficient can be determined by using the Blasius Equ. for laminar boundary layer flow over a flat plate. In this case, the inside or outside surfaces on the corer are treated as a flat plate of length l & width $= \pi d$

$$C_{Df} = \frac{1.328}{\sqrt{Re}}$$

where $Re = \frac{\rho V \ell_{total}}{g_c \mu}$

μ = abs. viscosity

~~ν = kinematic viscosity~~

ℓ_{total} = total length of corer

ρ, "Fluid" density in the disturbance layer should be less than sediment density which may vary between sediments from 143 to 183 lb/ft³

(Ref: DSDP Tech. Report #9)

or 124 lb/ft³ (Ref: Nugent, HPC Anal. Report)

Since this parameter is used to the ½-power in the later derivation, no great error is introduced by assuming it constant. Choose mean density of "fluid layer" $\rho = 120$ lb/ft³ for any value of sediment shear strength, τ.

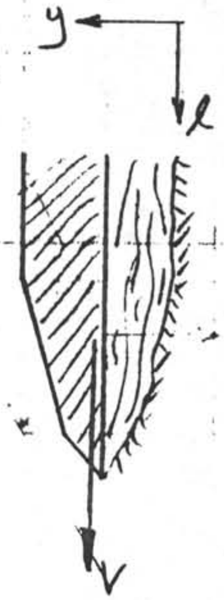
μ, absolute viscosity of the sediment must be derived as a function of τ, which is given.

From the definition of μ

$$\mu = \tau \frac{dy}{dV}$$

This defines a Newtonian fluid which the "fluidized sediment" in the corer disturbance layer probably is <u>not</u>. However, lacking more accurate information pursue this as a rough approximation.

$\frac{dy}{dV}$ is the inverse velocity gradient in the ~~disturbance~~ ~~boundary~~ layer. To find a value certain assumptions are required.



$$dy_{max} = \delta = \text{(by assumption) } 1/10''$$

Then $\frac{dy}{dV} = \frac{0.1''}{V}$ (constant slope)

Therefore $\mu' = \frac{\tau (0.1)''}{V} = \frac{\tau \delta}{V}$ { Defined viscosity for this relationship only, μ'

Arbitrarily select a "typical" "viscosity" to represent "liquified" sediment

$$\mu' = 1 \times 10^{-3} \ \frac{lbf\text{-}sec}{ft}$$
$$= .001$$

← Too low, SAE 10 OIL @ 32°F $\mu > 10^{-2}$

The other source of penetration resistance comes from the actual displacement resistance of the sediment to make way for the volume occupied by the corer wall. This is a function of the frontal area and the compressive strength of the sediment.

Use a compressive strength related to shear strength of $S_c = 2\tau$.

The frontal area to be "compressed aside",

$$A_f = \frac{\pi}{4}(O.D.^2 - \text{core dia}^2)$$
$$= \frac{\pi}{4}(3.5^2 - 2.61^2) = 4.27 \text{ in}^2$$

"Typical Displacement resistance" is then

$$S_c A_f = S_c \ (4.27 \text{in}^2) = 4.27 S_c$$

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Therefore

$$\text{Drag} = C_{D_f} \frac{\rho V^2 A}{2 g_c} + 4.27 S_c$$

where

A = surface area in contact with sediment

$= \ell \left[\pi (\text{O.D.}) + \pi (\text{I.D.}) \right]$

$= \pi \ell \left[\text{O.D.} + \text{I.D.} \right]$

$$\text{Drag} = \frac{1.328}{\sqrt{Re}} \frac{\rho V^2 \pi \ell (\text{O.D.} + \text{I.D.})}{2 g_c} + 4.27 (2\tau)$$

$$= \frac{1.328 \sqrt{\mu' g_c}}{\sqrt{\rho V \ell_{total}}} \frac{\rho V^2 \pi \ell (\text{O.D.} + \text{I.D.})}{2 g_c} + 8.54 \tau$$

$$= \frac{1.328 \sqrt{g_c \tau \delta / V}}{\sqrt{\rho V \ell_{total}}} \frac{\rho V^2 \pi \ell (\text{O.D.} + \text{I.D.})}{2 g_c} + 8.54 \tau$$

$$\underset{(\text{lbf})}{\text{Drag}} = 1.328 \sqrt{\frac{\tau \delta g_c}{\rho \ell_{total}}} \frac{\rho V \pi \ell (\text{O.D.} + \text{I.D.})}{2 g_c} + 8.54 \tau$$

(τ, psi)

DRAG DUE TO SEDIMENT PENETRATION RESISTANCE, $f(\tau, \ell, V)$

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APPENDIX E
EXCERPTS FROM CRUISE OPERATION MANAGER'S REPORTS LEGS 94-96

APPENDIX E
EXCERPTS FROM CRUISE OPERATION MANAGER'S REPORTS LEGS 94-96

ADVANCED PISTON CORER REPORT
LEG 94

The Advanced Piston Corer (APC) was successfully tested on Leg 94. It recovered 37 cores on two holes. The core quality was comparable to that of the VLHPC. All of the special features functioned as designed. The one readily evident feature was the ease of handling afforded by its short (38') length, and its mechanical simplicity. Unfortunately, part of one of the two units was lost down hole apparently due to excessive pull-out forces. Shortly thereafter the lower BHA, including the Seal Bore Drill Collar, was also lost so that no more APC coring could be attempted on this Leg.

ASSEMBLY

Both APC tools were assembled during the 8.1 day transit to site 606. The assembly procedure outlined in the manual was very clear and there were no insurmountable problems. The tool with the anti-spiral groove was the first to be assembled. The rod connections were Baker-locked together. However, when the tool was scoped together it did not close fully, so that the shear pin holes through the Outer and Inner Shear Pin Subs did not align. It was found that the Anti-Spiral Key OP4770 was wedging at the top of the groove in the rod. Both Keys were shortened to the dimensions shown in Fig. 1 to solve the problem.

The second APC was assembled without incident. The lower, scoping section of the second barrel was mated to the upper section of the first tool, and an extra liner lock hole was marked and drilled through the Vent Sub OP4758, so that both scoping sections aligned with the same upper section.

INITIAL TEST - SITE 606

A partial BHA was hung off below the rig floor. It consisted of a bit, bit sub, bit sub spacer, seal core drill collar, landing/saver sub, 3' spacer, top sub, head sub, Monel drill collar, and two stands of 8 1/4" drill collars. The APC with the anti-spiral groove was installed and run down with the BHA. V-packing was used for both the inner and outer seals. One shear pin was used and one flow control screw was left out. Unknown at the time, the APC was inadvertently installed so that the 4" O. D. Top Sub was landed on the Seal Bore Collar instead of on the Landing Saver Sub. The Drilco boreback in the top of the collar allowed enough space for the pin of the Landing Saver Sub to make up fully without contacting the APC Top Sub.

The circulation head was installed onto the BHA, and the system was pressurized. It appeared that the pin sheared at 700 psi, for when the pump was stopped the pressure bled off. Of course it was impossible to retrieve the tool, for the Top Sub was trapped in a space between two 3.8" I.D. sections. The BHA was tripped, and the installation error was discovered; it was also discovered that the pin had not sheared.

The shear pin was changed, and the APC was run back down with the BHA. This time the pin definitely sheared at 1000psi; the event was heard and felt through the pipe. After retrieval the APC would not scope fully closed. It was later found that a shear pin stub from the wall of the Outer Shear Pin Sub had fallen in and was trapped between the jam nut and the inner ledge of that sub. The seals were fine, and the Anti-Spiral Key caused no friction problems. But, as evidenced in this test and in actual coring, the outer seals allow some flow-by.

SITE 606. WATER DEPTH = 3022 METERS

Eighteen APC cores were taken in spongey, adhesive nanno ooze grading from soft to firm. Of the 165.8 meters cored, 154.1 meters were recovered for a 92.9% total recovery. The core quality was excellent. The average time per core was 1.5 hours; this included handling the Kuster orientation tool. The first 12 cores were taken with the grooved piston rod; the last 6 were taken with the grooveless piston rod. V-pack seals were used for both the inner and outer seals.

Following the APC Operational Guidline Chart, two hard (17-4PH) shear pins were used, and no speed control set screws were removed for the first few cores. By core 12 all of the speed control screws were removed, and two pins were still being used. During this time there was no clear indication of shoot-off on any of the cores. The drill string was typically pressurized to 1500-2000 psi to shoot the core.

Beginning on core 13, three shear pins were used (two hard and one soft), with all of the speed control screws removed. Immediately thereafter the shoot-off pressure became very distinct, with a 400-500 psi bleed-off at 2700-2950 psi. This suggests that full stroke may not have been achieved when only two pins were used, though the cores were always nearly full.

The one recurring problem was that the stubs from the sheared pins usually fell out of the wall and onto the internal ledge of the Outer Shear Pin Sub OP4715, to prevent the tool from reclosing fully. These stubs were routinely fished out with a small magnet attached to a length of stiff wire, but more often than not, one stub would find the groove in the rod and fall deeper into the tool and lodge in the inner seals which required almost total disassembly to remove. In addition, during the first ten or so runs through the pipe, much rust also accumulated on the ledge. The shear pin problem was almost completely solved by the following technique: Both ends of the pins were flared with a hammer. Then they were cut in half and inserted through each end of the shear pin holes. The wall-stubs were now held in place, but a few times the center stubs fell out and had to be fished.

The outer V-packing seals normally lasted for 10 runs. The inner seals were replaced only when damaged by shear pin stubs.

SITE 606A

Nineteen APC cores of excellent quality were taken at this site. The groveless piston rod was again used without incident until near the bottom of the hole. An overpull of 100,000 lbs was needed to retrieve core 18. Previously no overpulls higher than 20,000 lbs. were necessary. Less than 20,000 lbs. overpull was needed to retrieve core 19. The piston rod parted at 40,000 lbs. overpull while attempting to retrieve core 20. The break occurred at the base of the pin connection on the Center Piston Rod OP4762 (see attached photos). The Lower Piston Rod, Piston, and the entire scoping section were lost down-hole.

Several hours later, while washing into Hole 607B, the BHA broke off at the mandrel pin connection of the lowest bumper sub. With it went the Seal Bore Drill Collar, the Landing/Saver Sub, and the Bit Sub Spacer. It appears to be only a coincidence that it was lost so soon after the APC failure, but the impact loads and/or the 100,000 lbs. overpull may have been contributing factors. The bumper sub was last magnafluxed at the end of Leg 93.

CONCLUSION

The shorter tool length, ease of handling, and mechanical simplicity make the APC a superior tool to the VLHPC. Obviously either the piston rod will have to be strengthened or the overpull limit will have to be lowered to prevent the failure that occurred on this leg. The inner ledge of the Outer Shear Pin Sub traps pipe corrosion debris and shear pin stubs, but it is not a major problem. A polypak outer seal was tried once, and it was destroyed after one run. The V-packs worked very well, though they have to be changed more often than the static outer seals of the VLHPC. The anti-spiral groove on the one piston rod functioned perfectly; no friction problems were observed either during activation or resetting of the tool. The Break-away Piston Head was not used.

The core liners fractured quite often during APC coring. They were usually not badly damaged - a football shaped crack or partial collapse near the top or the bottom, sometimes a split extending the length of the liner. This is a common problem with the VLHPC also, and is probably due to a break in the atmospheric pressure seal between the o-rings outside the liner. Several times an unbroken o-ring from the Lower Liner Seal Sub was found several meters up inside the core, suggesting that the liner may compress to expose the lower o-rings due to thermal and mechanical contraction during coring.

Don Cameron
Cruise Operations
Leg 94

Advanced Piston Corer (APC)

The APC, the latest generation of the hydraulic piston corer, was used on Leg 95 after successful prototype trials on Leg 94. Results of its usage on this voyage were generally favorable. A few design deficiencies and operating encumberances were noted but the tool could be considered operational. It was used at Site 612 to take seven cores before the sediment became too firm for piston coring.

One of the features, the anti-spiral grooved rod, was abandoned when the alignment of the groove between the rod sections could not be maintained. An ungrooved rod is available to be used for Leg 96 and the grooved assembly remains a viable backup if used without the key which tracks in the groove.

The Seal Bore Drill Collar and Landing/Saver Sub, both of which have honed bores 3.80 inches in diameter, were stored in the casing rack filled with fresh water and sealed by gasketed thread protectors to minimize deterioration of the honed working surfaces.

At the end of Site 612 the APC was picked up and go-deviled to the bit at 25 strokes/min. without the wireline attached to test if this could be done without pre-shearing the shear pins. If successful the APC could be operated without the wireline in the pipe thus making piston coring compatible with the Heave Compensator during bad weather operations where core disturbance is always a problem. The APC had two 17-4 shear pins installed and all four pluggable speed control holes were plugged. The tool was retrieved with the shear pins sheared. All evidence pointed to the pins being sheared at the moment of impact at the landing shoulder. The landing impact was thus calculated to have been greater than 39.5 g's.

Breakaway Piston Head

The new Breakaway Head for the piston coring systems was tested quite successfully at Site 612 with the APC. It is adaptable to either the APC or VLHPC with minor hardware exchanges. The breakaway portion of the head, designed to come off when suction is applied to the top of the core, performed exactly as intended and was found "brokenaway" on top of the core inside the liner after each piston core run.

The assembly was designed to use only Polypak seals which were not satisfactory. A redesign to V-packing seals will be done before future use. Further testing will determine if flow-in disturbance after partial strokes is effectively eliminated by this new device but early indications after Leg 95 testing are positive. Use of the Breakaway Piston Head causes no distinct rig floor problems as long as several head portions are available for redressing with the single upper assembly attached to the Piston Rod.

APC Hole.
614 616 617A
614A 616A
615 616B
615A 617

INTERNATIONAL PHASE OF OCEAN DRILLING
DEEP SEA DRILLING PROJECT
OPERATIONS RESUME
LEG 96

The 96th and final scientific expedition of the Deep Sea Drilling Project concluded 15 1/2 years of continuous worldwide geological coring operations by the drillship GLOMAR CHALLENGER. For the final voyage, the vessel returned "home" to the Gulf of Mexico. The primary focus of study was the sedimentary and biostratigraphic nature of the Mississippi Fan, the huge accumulation of sediment extending across the Gulf from the outlet of the Mississippi River.

Twenty holes were cored at eleven sites on the Mississippi Fan and in the Orca and Pigmy intraslope basins. The scientific goals of the cruise were achieved despite powerful currents that taxed the vessel's positioning system to the limit and unstable hole conditions that frequently threatened to stick the drill string and halt operations. A successful logging program was carried out that produced successful well logs from seven holes.

The voyage commenced on September 26, 1983 at Port Everglades, Florida and terminated on November 8, 1983 at Mobile Alabama. Total length of the leg was 43.1 days, of which 32.3 days were spent on site, 3.5 days in port and 7.3 days in transit. Mechanical breakdown accounted for only 0.5 hour.

Ft. Lauderdale Port Call

Leg 96 had its official beginning at 0654 hours, September 26, 1983 with the first mooring line at Berth Two of Port Everglades in Fort Lauderdale, Florida. Shortly after arrival, it was necessary to shift to Berth One. This was accomplished by 1000 hours, and port call activities then commenced in earnest.

Principal work items included the top overhaul of No. 9 engine, repair of No. 1 gyro compass, U.S. Coast Guard inspection of GLOMAR CHALLENGER, crew change, offloading of cores, on-loading of 1000 sacks of barite and miscellaneous freight and an open house for local visitors. With all scheduled work completed, the vessel departed her berth at 1808 hours, September 29.

Ft. Lauderdale to Site 614

Excellent speed was achieved on the transit to the initial operating area. A nearshore countercurrent of the Gulf Stream combined with a following wind and calm seas to produce a speed of over 11 knots as CHALLENGER rounded the Florida Peninsula and turned west past the Florida Keys. A few hours after leaving the countercurrent, the vessel encountered another current which carried her toward the operating area at speeds increasing to about 13 knots. This unexpectedly strong current hampered maneuvering for the relatively complex preliminary profiling survey. After a 4-1/2 hour survey, a positioning beacon was launched at 1332 hours, October 1, marking arrival at Site 614. The drill site was located about 120 miles west-northwest of the Dry Tortugas Islands and about 150 miles north-northwest of Cuba.

Hole 614 - Lower Mississippi Fan

The approach profile was extended about 15 minutes beyond the beacon drop point before the vessel was turned and the towed seismic gear was retrieved. As the vessel began to approach the beacon to take station, the beacon's acoustic signal weakened abruptly and developed pulse characteristics that were rejected by the positioning system. Using LORAN C navigation, the ship struggled back to the drop coordinates against the strong current and an alternate frequency beacon was dropped at 1510 hours.

Satisfactory positioning was finally achieved at 1645 hours, and the pipe trip began. The current pushed the bottom hole assembly (BHA) so strongly against the moonpool bracing that it was necessary to let the vessel drift momentarily to facilitate setting the upper guide horn into position. The drill string continued to be forced strongly against the pipe restraint and to vibrate violently for the duration of the pipe trip.

The precision depth recorder (PDR) reading placed the seafloor between 3310 and 3320 m below the rig floor. The core bit was positioned at 3314 m for the first attempt with the advanced hydraulic piston corer (APC). The corer stroked to 3323.5 m and was recovered nearly filled with core (9.33 m). One joint of pipe was set back and another core was "shot" from 9.5 m higher to ascertain that no sediment had been missed. It was necessary to interrupt this operation for one hour when the current and wind pushed the vessel about 60 meters off station. The corer was recovered with no trace of sediment, and the water depth was established at 3314.1 m. Two additional mud cores of good quality were taken to 27 m BSF (below seafloor), where soft, loose sand was encountered. Penetration and recovery were reduced to nil, and the same interval was cored three times before a two-meter sand core was recovered. As the corer was being lowered for the next attempt, a sudden drop in sandline weight indicated that the coring assembly had been lost. On recovery of the sandline, it was found that the wireline swivel had come apart, leaving the APC, the sinker bar assembly and the lower portion of the swivel in the pipe. The dimensions of the swivel prohibited recovery from the pipe by wireline fishing. A round trip was therefore necessary to continue operations. In the meantime, however, the dressed corer had settled into position in the outer core barrel. The bit was lowered to the bottom of the hole and the pipe was pressured to actuate the corer before the drill string was recovered.

The corer was recovered from the BHA at the drill floor at 1700 hours, October 2, containing about eight meters of loose sand.

Hole 614A

With the round trip complete, Hole 614A was spudded at 2341 hours, October 2. The bit was "washed" down to 37 m BSF, the total penetration of Hole 614. Another ten meters of loose sand was cored before mud and clay strata were again encountered. APC coring continued through the day in sediments consisting of alternating sand and mud beds, with sand predominating. Core recovery was unexpectedly high, though penetration of the corer, as expected, was limited. This was held to as little as two meters in the cleaner and coarser sands. At about 115 m BSF, the clay became much stiffer and became a factor in both reduced penetration and increased overpull on retrieval. At 131 m BSF, the APC was retired in favor of the extended core barrel (XCB). Two XCB cores were attempted with only a few centimeters recovered each time. At this point, the scientific objectives were considered to be accomplished and coring operations were terminated at a total drill string depth of 3464.4 m. The drill string was recovered and the vessel was under way at 0140 hours, October 4.

Site 614 to Site 615

The next intended drill site lay only about eleven miles to the northeast of Site 614. Because of extensive preliminary profiling, only the 3.5 kHz echosounder was used to supplement LORAN C navigation for final site location. At 0459 hours, a 13.5 kHz acoustic beacon was dropped at the desired location. The approach profile was extended 2.5 miles beyond the drop point before the ship turned to return to the beacon. During this time the beacon's signal was monitored as it fell to the seafloor. The pulse width was noted to be too short for acceptance by the dynamic positioning system (DPS) and the signal rapidly dropped to a low level. More PDR profiling was then done to locate a proper drilling location and a 16 kHz beacon was launched at 0547 hours. As the vessel waited to take station while the second beacon fell through the water column, the original (13.5 kHz) unit began to transmit a strong usable pulse which obliterated the now very weak 16 kHz signal. Optimistically acknowledging that flexibility is a virtue and that one of two is not bad, the GMI staff switched the DPS back to 13.5 kHz and took station on the nearby original beacon.

The pipe trip began at 0700 hours. At 0750 hours, the 13.5 kHz signal degenerated to a completely unusable level. The 16 kHz beacon was now acquired at a distance of 760 m and the DPS was shifted back to that frequency. It soon became apparent that the 16 kHz pulse was too weak to be heard through the thruster noise and frequent loss of acoustics occurred. With beacons transmitting unusable signals on both operating frequencies, it was necessary to abandon the location and to find an alternate drill site out of acoustic range of the two beacons. The BHA was recovered and CHALLENGER got under way profiling at 0900 hours.

A target area was selected about 1.3 km north of the beacons. The towed seismic gear was streamed as less geophysical information was available for the new location. A new 13.5 kHz beacon was launched at 1037 hours, and an additional 1-1/4 hour of surveying was done before the gear was retrieved and final station was taken. The pipe trip commenced at 1245 hours.

Hole 615 - Lower Mississippi Fan

With the PDR depth at 3279 meters, the core bit was positioned at 3275 meters to ensure recovery of the sediment/water interface in the first 9.5 meter APC core. The core barrel was recovered with only traces of sediment in the core catcher, indicating that the very soft material had been washed out during retrieval. A second core was "shot" from two meters deeper and 2.6 meters of core was recovered, establishing water depth at 3283.9 m.

Continuous APC cores found sand beginning at only 19 meters BSF, but good penetration and recovery were realized to about 105 m BSF through alternating sand and mud strata. Performance then dropped sharply, with the APC apparently unable to make significant penetration. At 143 m BSF, the XCB system was deployed. Recovery remained low, but representative cores, averaging about two meters, were obtained to about 210 m BSF. Below this depth only traces of sand and clay were generally recovered. Desperation attempts with the APC were met with full barrels of flow-in sand or very short cores of hard clay. At about 495 m BSF, an abrupt lithology change to carbonate ooze resulted in a return to excellent core recovery with the XCB.

Hole conditions had remained good, considering that the penetrated section consisted of over 60% uncemented sand. Up to five meters of hole fill had been noted between cores, but periodic mud flushes had been fairly effective in cleaning the hole. As the bit (which was not equipped with a float valve) approached 500 meters BSF, back pressure could no longer be controlled and shut in pipe pressures to 400 psi were noted. It was necessary to slug the pipe with weighted mud before core barrels could be dropped against the back flow. Core barrel No. 52 became stuck at the bit and two wireline trips were required to retrieve it. With most of the scientific objectives of the site achieved, coring operations were terminated at 523.2 m BSF for the safety of the drill string.

The lack of core recovery had lent increased importance to the logging program for the delineation of lithologic units. The apparent poor hole conditions made prospects of getting to bottom for open-hole logs look slim. Preparations were therefore made to run a through-pipe formation density/compensated neutron/gamma ray (FDC/CNP/GR) log. The hole was flushed with mud to counteract the back pressure. One stand of pipe was then set back to allow for cumulative hole fill. By the time the logging sheaves had been rigged and the sonde started down the pipe, shut in back pressure had increased from zero to 260 psi and the drill string had become stuck. It was necessary to abort the logging attempt to attempt to free the drill pipe. About 35 minutes of "working" the pipe was required to free it and the through-pipe logging concept was abandoned.

The hole was then filled with 300 barrels of barite weighted mud and the bit was pulled to 3330 meters. The dual induction/long-spaced sonic/gamma ray (DIT/LSS/GR) tool was then assembled. About 2-1/4 hours were spent in tracing an intermittent electrical leak to a connection in the cabling between the winch and recording cabs. The long logging sonde stopped abruptly only a few meters after its lower end had passed through the bit and would go no further. The tool was manipulated with little progress for about one half hour but, just before efforts were abandoned, it broke through into open hole. To the surprise of everyone, the hole was then found to be absolutely clear as the sonde descended to only 17 meters off total depth. A log of excellent quality was then recorded for the length of the hole. The upper portion of the logging sonde had already started into the pipe when the lower portion became firmly stuck at the same spot that had given trouble on the down trip. After over two hours of effort, the tool was finally freed by moving the core bit up and down over the logging tool.

When the first sonde had been recovered, two joints of pipe were added to place the bit below the interval of tight hole. The FDC/CNL/GR tool was then deployed, but the run was aborted when a special spectral gamma ray module malfunctioned. It was replaced by a standard gamma ray cartridge and adapter. This second logging tool also encountered obstructions in the first 20 meters of open hole. It broke into smooth going after much effort, and another good log was recorded from the same depth as the first run.

With logging operations completed, the sheaves were rigged down and the bit was pulled clear of the seafloor in preparation for respudding.

Hole 615A

Hole 615A was spudded at 1317 hours, October 9, in 3285.9 meters of water after the vessel had been offset 19 meters to the northeast. The hole was drilled to collect cores for geotechnical studies at a later date. Since sand was of little interest for this purpose, coring efforts were concentrated on the more clay-rich intervals. Recovery performance of the APC and XCB systems was consistent with that of the first hole as 615A was drilled and spot cored to a total depth of 3494.4 meters. The drill string was recovered, and GLOMAR CHALLENGER departed for the next drill site at 2035 hours, October 10.

Hole 616 - Flank of Middle Mississippi Fan

The new drill site was located about 190 miles southeast of the tip of the Mississippi River delta. The transit was made in 11-1/4 hours, and a beacon was let go at 0745 hours, October 11. After an additional 1-1/2 hours of profiling, the vessel returned to take station on the beacon (which was functioning perfectly).

Following the pipe trip, two unsuccessful attempts were made to capture the sediment/water interface with the APC. Both core barrels were recovered without core and with the breakaway piston head resting at the bottom of the liner. The first barrel stroked to 3000.5 m and bore traces of sediment on the core catcher. The second extended to 2997.5 m and was recovered without a trace. For the third attempt, a fixed piston head was installed, and the bit was positioned at 2995.5 m. The 9.5 meter corer recovered 6.1 meters of core, and water depth was established at 2998.9 m (compared with 2993 m PDR depth).

Good results were obtained with the APC through clay and silt to about 75 m BSF, where recovery dropped to about 50%. The APC was replaced by the XCB system at 104 m BSF, but four consecutive cores produced a total of only 1.36 m. Three APC cores then achieved about one half stroke before a withdrawal overpull of 95,000 pounds again prompted a switch to XCB coring. Three consecutive XCB cores yielded 4.9 m of sand and clay core. With recovery low, the XCB was retrieved on each second pipe joint to 296 m BSF. Continuous XCB cores then gave increasingly good recovery to 371 m in very stiff clay. The XCB was then dropped for the final planned core, and a 40 barrel mud flush was pumped into the pipe to condition the hole for logging.

As the connection was being made for the final core, the drill string abruptly became stuck. This was completely unexpected, as no hole problems had been encountered up to that time. Two hours of working the pipe failed to budge it, and it became evident that the BHA was permanently emplaced. Lack of bumper sub action indicated that the stuck point was more than 50 m above the bit. Because of low core recovery through the lower two thirds of the section, well logs had again become increasingly important for the fulfillment of the site's scientific objectives. The stuck pipe now precluded open-hole logging, but a through-pipe gamma ray log could still be run to delineate the sand/clay boundaries. The logging sheaves were rigged, and a FDC/CNP/GR log was recorded. Surprisingly there was only about four meters of fill and nine meters of open hole was logged below the bit. The natural gamma ray curve was quite readable and was even more useful than had been anticipated.

The severing apparatus was then assembled and run down the pipe. The prima-cord charge successfully parted the string in the lowermost joint of 5-1/2 inch drill pipe. When the logging cable was retrieved, it was found that the line had parted just above the cable head, resulting in the loss of the casing collar locator and the shooting sinker bar assembly.

The drill pipe was then recovered, with the severed joint arriving on deck at 0930 hours, October 14.

Hole 616A

The second borehole was added to the drilling program to obtain an oriented core in a shallow zone of steeply dipping beds and to recore the interval of low recovery at 114-142 m BSF in Hole 616.

Assembling and spacing out the replacement BHA added about four hours to the "down" trip time and Hole 616A was spudded at 1917 hours. The hole was drilled without coring to 34.6 m BSF, where the oriented core was desired.

The special non-spiraling APC assembly and the prototype gyro orientation tool were then deployed. The coring assembly was retrieved after an apparently normal actuation. Disappointment prevailed when the core barrel was found to contain only 39 cm of sediment. The sticky clay had held the core catchers open, allowing the core to fall out during retrieval. The misadventure was compounded when it was found that no orientation data had been recorded. The wiring of the gyro tool had been damaged during final assembly. It was further discovered that a pressure case O-ring seal had failed. The pressure case had flooded and the gyro was damaged beyond repair.

The hole was then drilled to 94 m BSF, where the pipe began torquing. A bentonite mud flush freed the pipe after a delay of one half hour. Continuous coring began at 103.5 m, but operations were again interrupted after two cores when the APC became stuck in the drill pipe as it was lowered for core No. 4H. Two additional wireline trips were made in attempts to dislodge the corer, but each time the overshot pin sheared and no progress was made. The APC was finally knocked to the bottom by pumping a standard inner barrel down the pipe at high speed. Core No. 4H was "shot" and retrieved routinely, and no evidence was found as to the cause of the sticking. The following core attempt produced an incomplete stroke indication and no core was recovered. As this was to be the final core of the hole, no further attempt was made and coring operations were terminated to maintain the operating schedule. The core bit was then pulled clear of the seafloor for respudding.

Hole 616B

The final hole at Site 616 was a planned 200 meter penetration dedicated to geotechnical purposes. Continuous APC cores were taken to about 95 m BSF, where complete stroke of the corer was no longer achieved. Coring then continued in the APC mode with uncored intervals drilled off to maintain the operating pace of one pipe connection per core. At 165 m BSF, the withdrawal overpull following core No. 19H, reached 90,000 pounds. Coring force was reduced somewhat for the remaining four cores by using 2-1/2 shear pins instead of the maximum three. Overpull then remained within operating limits to the total depth of 204.3 m BSF (3203.1 m pipe depth).

Excessive torque was required to rotate the drill string on three occasions during the coring of Hole 616B. In each case, operations were interrupted to flush the hole with bentonite mud and the hole trouble disappeared.

After a routine pipe trip, the vessel got under way for Site 617 at 1445 hours, October 16.

Site 616 to Site 617

The middle fan operating area lay about 105 miles to the west-southwest of Site 616. The approach course was altered slightly to bring the vessel to a turning point just to the northeast of the operating area. A southwesterly profile then crossed the closely spaced proposed Sites MF-7A, MF-6A, and MF-5 in order. A reciprocal line was run back across the latter two sites. Another turn was made and beacons were dropped for Sites MF-6A and MF-5 (617). The transit and survey were made in 15-1/2 hours. The seismic gear was then retrieved and the vessel was positioned on offsets 575 m south and 720 m west of the second beacon.

Hole 617 - Middle Mississippi Fan

At 1334 hours, October 17, the 9.5 meter APC was shot from the PDR depth of 2477 meters. The eight meters of sediment recovered established water depth at 2478.5 m.

Before the second core could be attempted, shifting winds from heavy rain squalls combined with a strong local current to carry the vessel about 120 meters off station. Weather conditions stabilized and positioning became sufficiently steady to resume coring after a delay of 1-1/2 hours.

APC coring then proceeded smoothly through clay and silty mud to a depth of 191.2 m BSF, where the scientific objectives were considered accomplished. The power sub was left in the string to lay out doubles, and the bit was pulled clear of the seafloor at

1227 hours, October 19 to end Hole 617 operations.

Hole 617A

The unexpected absence of sand in Hole 617 led to reconsideration of plans to drill an additional hole at Site MF-7A for geotechnical studies. The known favorable conditions prompted the decision to relocate the middle fan geotechnical hole to Site 617. The vessel was therefore offset 30 meters to the southwest to avoid the Hole 617 disturbed area, and Hole 617A was spudded at 1303 hours.

Continuous APC cores were taken to 74 m BSF without significant problems. Two core attempts at this depth met with no recovery or apparent penetration. The corer was being lowered for a core attempt one joint (9.5 m) deeper, when operations were interrupted by weather.

The wind, which had been almost exactly opposing the strong current, shifted about 30 degrees to the vessel's port quarter and increased in velocity. The ship's thrusters were unable to maintain heading against the resultant turning moment and the vessel broached. It was then quickly carried about 360 meters off station by the current before action could be taken to arrest the excursion.

The rig was brought back over the hole after a 3/4 hour delay, and the APC was run down the pipe. With the BHA not yet fully supported by the hole, damage to the BHA can be expected from a large positioning excursion. Suspicions were confirmed when the APC stopped at the approximate location of the bumper subs, indicating a bent sub. This, of course, meant that no more coring could be done in Hole 617A and that a pipe trip was necessary.

The APC was retrieved and the drill string was recovered. It was found that the mandrel of the upper bumper sub was, indeed, slightly bent. As the next stand of drill collars was brought through the rig floor, it was discovered that the lowermost drill collar and the entire outer core barrel assembly had been lost when bending forces had caused the rotary shouldered connection to fail.

During the pipe trip, it had been determined that positioning could not be maintained within operating limits under the existing current and weather conditions. The only alternative was therefore to move to the Orca and Pigmy Basin operating areas to the west and to hope for improved conditions upon the vessel's return to the middle fan.

Hole 618 - Orca Basin

The 148-mile transit was made in 16 hours. Site 619 was located

APPENDIX F
CURRENT DRAWINGS

E. PARTS LIST

ADVANCED PISTON CORER - MOD. II

P/N	DESCRIPTION	NO. REQ'D.
OP4800	Advanced Piston Corer Assy. - Mod. II	--
OP4704	Pulling Neck Lock Nut	1
OP4710	Speed Control Set Screw, 5/8-11 UNC x 5/8 SS	0-4
OP4712	Support Washer	1
OP4713	Stop Washer	1
OP4721	Shear Pin, 1/4 dia x 3-7/32, 17-4PH	1-3
OP4725	Shear Pin. 1/4 dia x 3-1/8, Mild Steel	1-3
OP4728	Outer Seal Male Adaptor	1
OP4729	Outer Seal V-Spacer	2
OP4730	Outer Seal Female Adaptor	1
OP4752	Quick Release Nut	1
OP4753	Quick Release Dog	2
OP4756	Vent Snubber	1
OP4766	Piston Rod Snubber	1
OP4769	Piston Rod Extension (Std. Hd.)	1
OP4801	Pulling Neck	1
OP4803	Split Bushing	1
OP4805	Landing Shoulder Sub	1
OP4807	Outer Shear Pin Sub	1
OP4809	Inner Shear Pin Sub	1
OP4811	Shear Pin Sleeve	1
OP4813	Split Swivel Sub	1
OP4815	Inner Seal Sub	1
OP4817	Upper Piston Rod	1
OP4818	Center Piston Rod	1
OP4819	Lower Piston Rod	1
OP4821	Outer Seal Sub	1
OP4823	Anti-Spiral Key	1
OP4825	Male Quick Release	1
OP4827	Female Quick Release	1
OP4829	Vent Sub	1
OP4834	Hang Off Tool	---
OP4836	Shear Pin Tool	---
OP3210	Inner Core Barrel, 3-1/2 x 2.87 x 14' 9-1/2"	2
OP3231	Inner Barrel Sub, 12-1/8"	1
OP3400	Core Liner, Butyrate, 2.817 x 32' -6"	1
OP4345	Piston Seal Retainer	1
OP4360	Liner Seal Sub	2

P/N	DESCRIPTION	NO. REQ'D.
OP4361	Core Liner Retainer Screw	1
OP4362	Slim Nose Catcher Sub (Alt.)	1
OP4376	Catcher Sub	1
OP4377	Heat Flow Core Catcher - Body (Alt.)	1
OP4378	Heat Flow Core Catcher - Cone (Alt.)	1
OP4381	Piston Head Body	1
OP4382	Plastic Tube Support	1
OP4383	Lock Pin. Piston Head	1
OP4390	Male V-packing Adaptor (Piston Hd.)	1
OP4391	Female V-packing Adaptor (Piston Hd.)	1
OP4392	V-Spacer (Piston Hd.)	2

Fasteners & Seals

OD2232	O-ring #2-232, Buna-N, 70D.	4
OD2331	O-ring #2-331, Buna-N, 70D.	1
OD3150	Polypak, Molythane, #37501625-625B	2
OD4200	V-packing, Molythane, #31202000VP	3
OD4300	V-packing, Molythane, #37503000VP	3
OD6555	Set Screw, Socket, 1/2-13 UNC x 1/2, Stainless	4
OD7111	Roll Pin, 1/8 x 5/8, Stainless	1
OD7140	Roll Pin, 3/16 x 1-3/8, Stainless	4
OD7142	Roll Pin, 3/16 x 1-3/4, Stainless	1
OD7180	Snap Ring, #5100-62	1
OD7231	Hex Nut, Stainless, 3/4-10 UNC	1

Core Catcher Alternatives

OR7010	Core Catcher, Complete, Dog Type "10"	1-2
OR7020	Core Catcher, Complete, Dog Type "8"	1-2
OR7100	Core Catcher, Complete, Flapper Type	1

Outer Barrel Components

OL1021	Landing/Saver Sub	1
OL1029	Long Bit Sub	1
OL1044	Seal Bore Outer Core Barrel	1

REVISIONS				
…RIPTION	DATE	BY	CH.	APR.

LIST OF MATERIALS

DWG SIZE	PART NO.	DESCRIPTION	NO. REQ'D.
A	OP 4704	PULLING NECK LOCK NUT	1
	OP4710	SPEED CONTROL SET SC, 5/8-11UNC x 5/8 SS	0-4
A	OP4712	SUPPORT WASHER	1
A	OP4713	WASHER	1
A	OP4721	SHEAR PIN, 1/4 DIA x 3 7/32, 17-4 PH	1-3
	OP4725	SHEAR PIN, 1/4 DIA x 3 1/8, MILD STEEL	1-3
A	OP4728	OUTER SEAL MALE ADAPTOR	1
A	OP4729	" " V-SPACER	2
A	OP4730	" " FEMALE ADAPTOR	1
B	OP 4752	QUICK RELEASE NUT	1
A	OP4753	" " DOG	2
B	OP4756	VENT SNUBBER	1
B	OP4766	PISTON ROD SNUBBER	1
B	OP4769	" " EXTENSION (STD. HD.)	1
B	OP4801	PULLING NECK	1
A	OP4803	SPLIT BUSHING	1
C	OP4805	LANDING SHOULDER SUB	1
C	OP4807	OUTER SHEAR PIN SUB	1
C	OP4809	INNER " " "	1
B	OP4811	SHEAR PIN SLEEVE	1
C	OP4813	SPLIT SWIVEL SUB	1
B	OP 4815	INNER SEAL SUB	1
B	OP 4817	UPPER PISTON ROD	1
B	OP 4818	CENTER " "	1
B	OP 4819	LOWER " "	1
C	OP 4821	OUTER SEAL SUB	1
A	OP 4823	ANTI SPIRAL KEY	1
R	OP4825	MALE QUICK RELEASE	1
R	OP4827	FEMALE " "	1
C	OP4829	VENT SUB	1
A	OP4834	HANG OFF TOOL	—
B	OP4836	SHEAR PIN TOOL	—
C	OP4816	PISTON ROD THREADED CONNECTION DETAIL	1
B	OP 3210	INNER CORE BARREL, 3 1/2 x 2.87 x 14'-9 1/2"	2
B	OP 3231	INNER BARREL SUB, 12 1/8	1
A	OP 3400	CORE LINER, BUTYRATE, 2.817 x 32'-6"	1
A	OP 4345	PISTON SEAL RETAINER	1

LIST OF MATERIALS

DWG SIZE	PART NO.	DESCRIPTION	NO. REQ'D.
B	OP 4360	(LOWER) LINER SEAL SUB	2
A	OP 4361	CORE LINER RETAINER SCREW	1
C	OP 4362	SLIM NOSE CATCHER SUB (ALT)	1
B	OP 4376	CATCHER SUB	1
B	OP 4377	HEAT FLOW CORE CATCHER - BODY (ALT.)	1
C	OP 4378	" " " " - CONE (ALT.)	1
B	OP 4381	PISTON HEAD BODY	1
A	OP 4382	PLASTIC TUBE SUPPORT	1
A	OP 4383	LOCK PIN, PISTON HEAD	1
A	OP 4390	MALE V-PACKING ADAPTOR (PISTON HEAD)	1
A	OP4391	FEMALE " " "	1
A	OP4392	V-SPACER " "	2
N	OD2232	O-RING #2-232, BUNA-N, 70 D.	4
N	OD2331	" #2-331, " "	1
N	OD3150	POLYPAK, MOLYTHANE, #37501625-625B	2
N	OD4200	V-PACKING " #31202000 VP	3
N	OD4300	" " #37503000 VP	3
N	OD6555	SET SCREW, SOC, 1/2-13UNC x 1/2 S.S	4
N	OD7111	ROLL PIN, 1/8 x 5/8, STAINLESS	1
N	OD 7140	" ", 3/16 x 1 3/8 "	4
N	OD 7142	" ", 3/16 x 1 3/4 "	1
N	OD 7180	SNAP RING, #5100-62	1
N	OD 7231	HEX NUT, STAINLESS, 3/4-10 UNC	1
A	OR 7010	CORE CATCHER, COMPLETE, DOG TYPE "10"	1-2
A	OR 7020	" " " " " "8"	1-2
B	OR 7100	" " " FLAPPER TYPE	1
B	OL 1021	LANDING / SAVER SUB	1
C	OL 1029	LONG BIT SUB	1
C	OL 1044	SEAL BORE OUTER CORE BARREL	1
B	OL 1022	LONG TOP SUB	1

TOLERANCES UNLESS NOTED
FRACTIONS ± 1/64
DECIMALS ± .005
ANGLES ± 1/2°
CORNERS 1/64 x 45° or 1/64 R
FINISH

SURFACE TREATMENT —
HEAT TREATMENT —

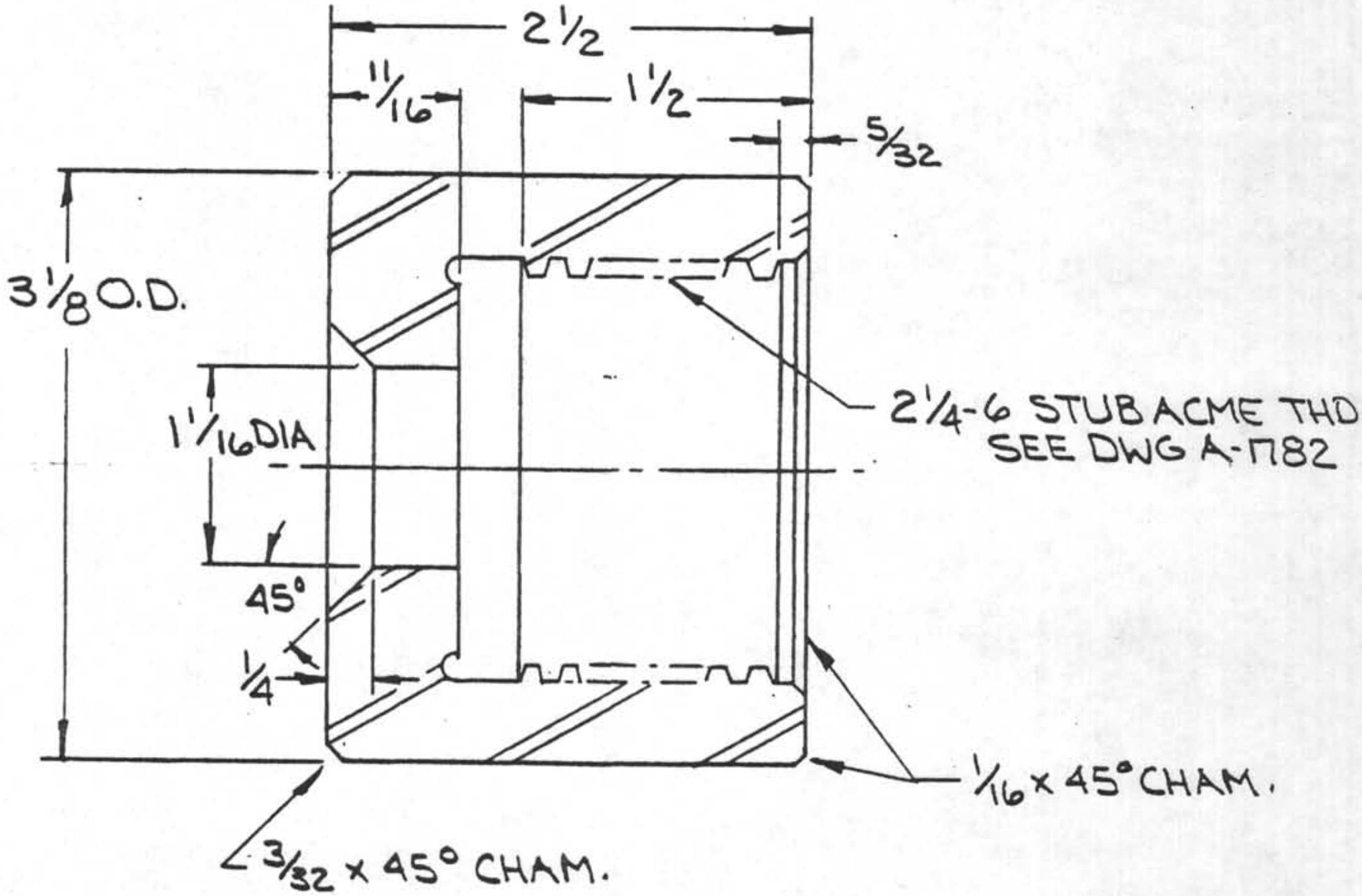
DEEP SEA DRILLING PROJECT
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UNIVERSITY OF CALIFORNIA, SAN DIEGO
LA JOLLA, CALIFORNIA 92093

TITLE ADVANCED PISTON CORER ASSY MOD II

MATERIAL —
PART NO. OP4800
DRAWN BY RK
SIZE R
DWG. NO. R-OP4800

REVISIONS

NO.	DESCRIPTION	DATE	BY	CH.	APR.



DO NOT SCALE

CONCENTRICITY ALL DIAMETERS: TIR .003

TOLERANCES UNLESS NOTED
FRACTIONS ± 1/64
DECIMALS ± .005
ANGLES ± 1/2°
CORNERS 1/64 x 45° or 1/64 R
FINISH 125 ✓

DEEP SEA DRILLING PROJECT
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UNIVERSITY OF CALIFORNIA, SAN DIEGO
LA JOLLA, CALIFORNIA 92093

TITLE: PULLING NECK LOCK NUT ~ A.P.C ~

SURFACE TREATMENT	MATERIAL	DATE	BY	CHECKED	APPROVED
PARKOLUBE	4130/4140	4-29-83	RK	DPH	DPH

HEAT TREATMENT	SCALE	REQ'D/ASS'Y	PART NO.	DWG. NO.	(REV.)
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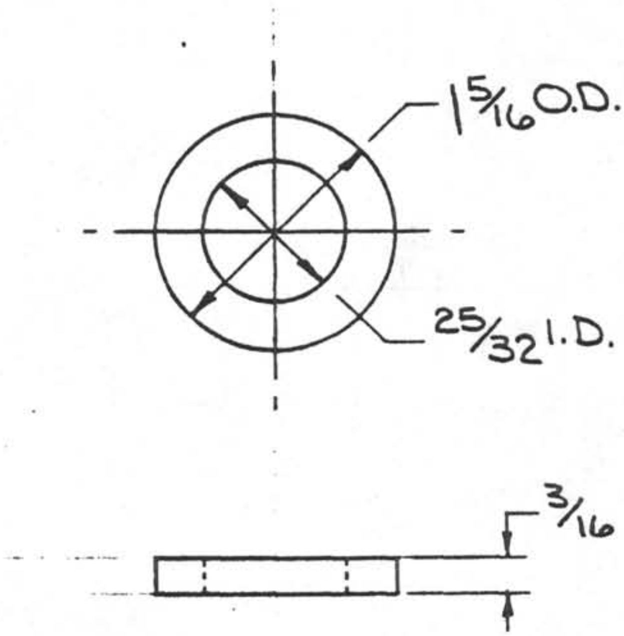
REVISIONS					
NO.	DESCRIPTION	DATE	BY	CH.	APR.



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CONCENTRICITY ALL DIAMETERS: TIR .003

TOLERANCES UNLESS NOTED FRACTIONS ± 1/64 DECIMALS ± .005 ANGLES ± 1/2° CORNERS 1/64 x 45° or 1/64 R FINISH 125	DEEP SEA DRILLING PROJECT SCRIPPS INSTITUTION OF OCEANOGRAPHY UNIVERSITY OF CALIFORNIA, SAN DIEGO LA JOLLA, CALIFORNIA 92093 TITLE SUPPORT WASHER ~ A.P.C. ~					
SURFACE TREATMENT PARKOLUBE	MATERIAL 4130/4140		DATE 4.29.83	BY RK	CHECKED DH	APPROVED DPH
HEAT TREATMENT 28-32 Rc	SCALE 1:1	REQ'D/ASS'Y 1	PART NO. OP4712		DWG. NO. A-OP4712	(REV.)

REVISIONS					
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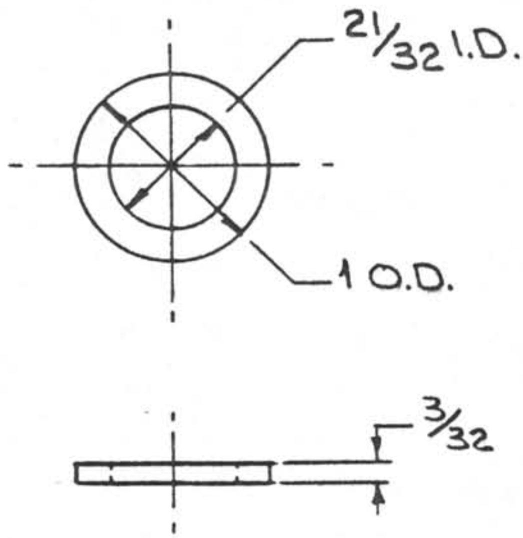

DO NOT SCALE

CONCENTRICITY ALL DIAMETERS: TIR .003

TOLERANCES UNLESS NOTED	DEEP SEA DRILLING PROJECT					
FRACTIONS ± 1/64 DECIMALS ±.005 ANGLES ± 1/2° CORNERS 1/64 x 45° or 1/64 R FINISH 125	SCRIPPS INSTITUTION OF OCEANOGRAPHY UNIVERSITY OF CALIFORNIA, SAN DIEGO LA JOLLA, CALIFORNIA 92093					
	TITLE: STOP WASHER ~A.P.C.~					
SURFACE TREATMENT: PARKOLUBE	MATERIAL: 4130/4140		DATE: 4·29·83	BY: RK	CHECKED: DH	APPROVED: DRH
HEAT TREATMENT: 28-32 Rc	SCALE: 1:1	REQ'D/ASS'Y: 1	PART NO.: OP4713		DWG. NO.: A-OP4713	(REV.)

REVISIONS					
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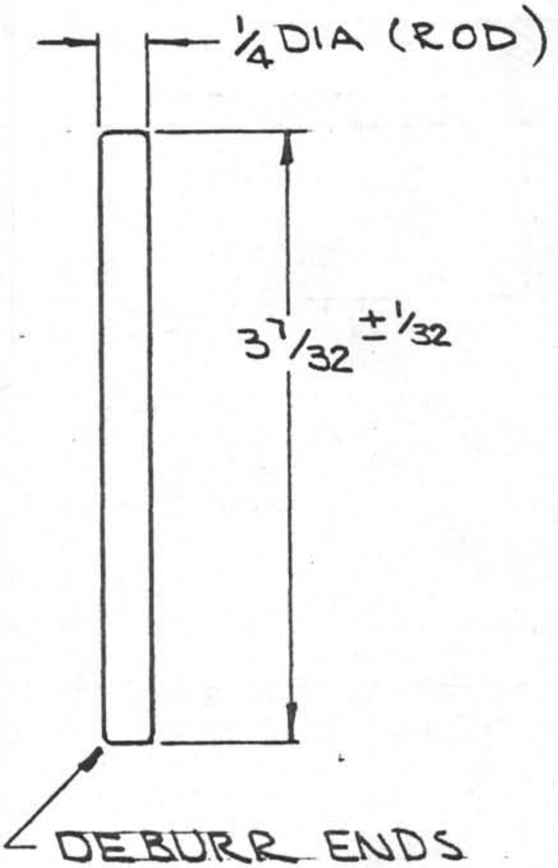


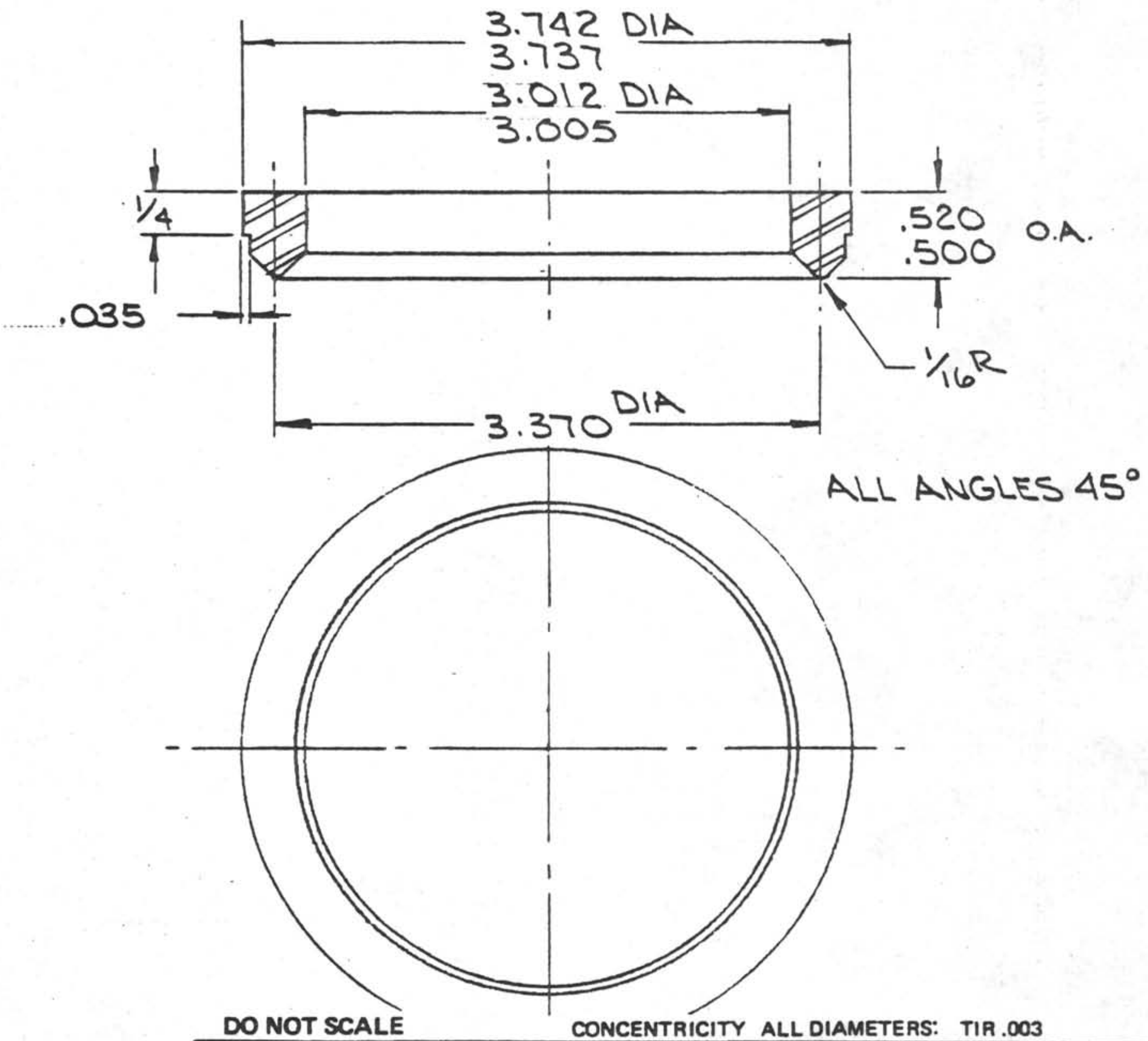
DO NOT SCALE

CONCENTRICITY ALL DIAMETERS: TIR .003

TOLERANCES UNLESS NOTED FRACTIONS ± 1/64 DECIMALS ±.005 ANGLES ± 1/2° CORNERS 1/64 x 45° or 1/64 R FINISH 125	DEEP SEA DRILLING PROJECT SCRIPPS INSTITUTION OF OCEANOGRAPHY UNIVERSITY OF CALIFORNIA, SAN DIEGO LA JOLLA, CALIFORNIA 92093 TITLE SHEAR PINS ~A·PC~				
SURFACE TREATMENT —	MATERIAL 17-4 PH		DATE 6·6·83	BY RK	CHECKED	APPROVED
HEAT TREATMENT COND H1150-M	SCALE 1:1	REQ'D/ASS'Y 1 TO 3	PART NO. OP4721		DWG. NO. A-OP4721	(REV.)

REVISIONS

NO.	DESCRIPTION	DATE	BY	CH.	APR.



DO NOT SCALE

CONCENTRICITY ALL DIAMETERS: TIR .003

TOLERANCES UNLESS NOTED
FRACTIONS ± 1/64
DECIMALS ± .005
ANGLES ± 1/2°
CORNERS 1/64 x 45° or 1/64 R
FINISH 125

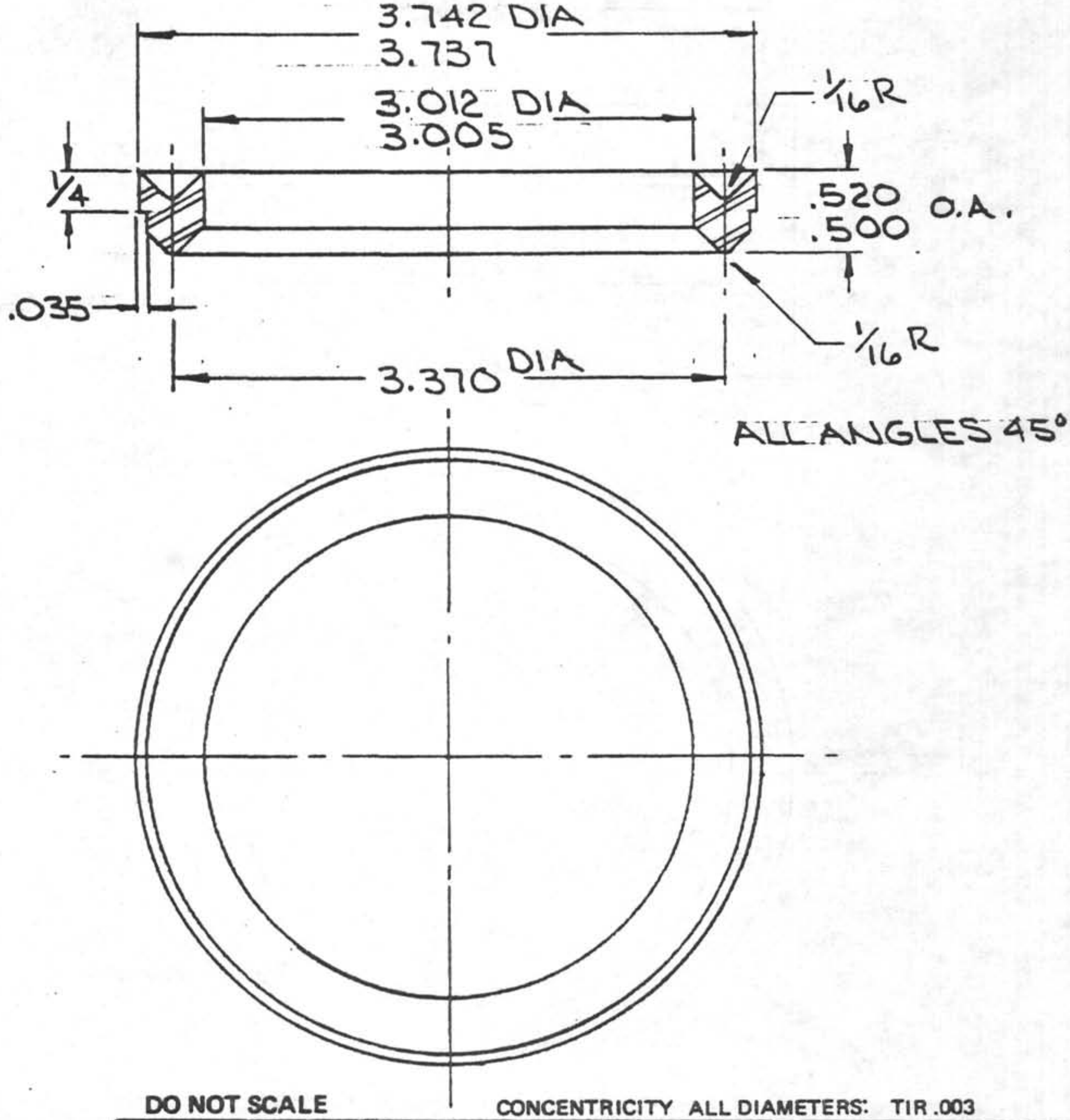
DEEP SEA DRILLING PROJECT
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UNIVERSITY OF CALIFORNIA, SAN DIEGO
LA JOLLA, CALIFORNIA 92093

TITLE: OUTER SEAL MALE ADAPTOR ~A·P·C~

SURFACE TREATMENT	MATERIAL	DATE	BY	CHECKED	APPROVED
—0—	304 S.S.	5·12·83	RK		

HEAT TREATMENT	SCALE	REQ'D/ASS'Y	PART NO.	DWG. NO. (REV.)
ANNEALED	1:1	1	OP4728	A-OP4728

REVISIONS					
NO.	DESCRIPTION	DATE	BY	CH.	APR.



DO NOT SCALE

CONCENTRICITY ALL DIAMETERS: TIR .003

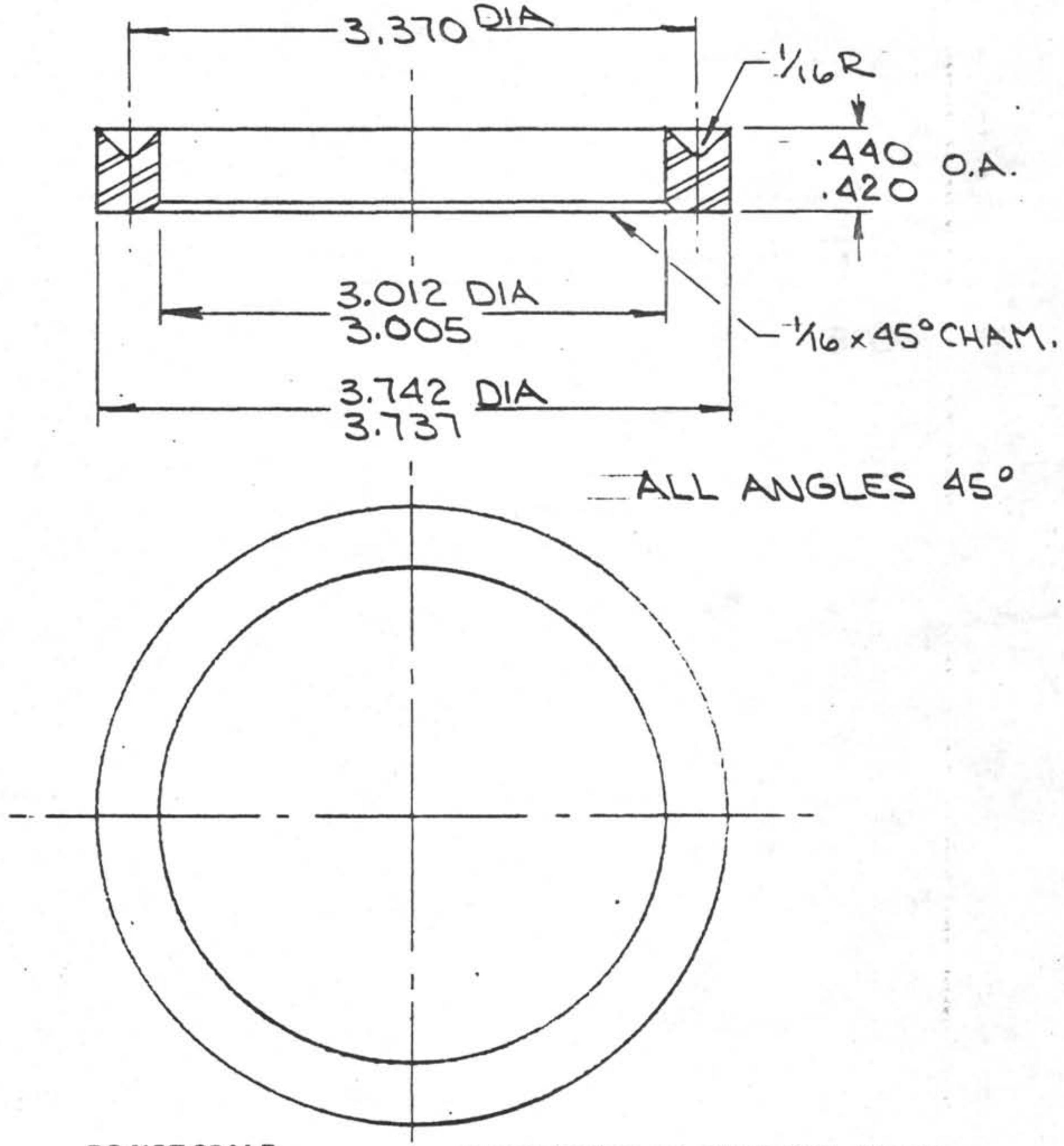
TOLERANCES UNLESS NOTED
FRACTIONS ± 1/64
DECIMALS ± .005
ANGLES ± 1/2°
CORNERS 1/64 x 45° or 1/64 R
FINISH 125

DEEP SEA DRILLING PROJECT
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UNIVERSITY OF CALIFORNIA, SAN DIEGO
LA JOLLA, CALIFORNIA 92093

TITLE: OUTER SEAL V-SPACER ~A·P·C~

SURFACE TREATMENT	MATERIAL		DATE	BY	CHECKED	APPROVED
—	304 S.S.		5.12.83	RK	DH	DRH
HEAT TREATMENT	**SCALE**	**REQ'D/ASS'Y**	**PART NO.**		**DWG. NO.**	**(REV.)**
ANNEALED	1:1	2	OP4729		A-OP4729	

REVISIONS					
NO.	DESCRIPTION	DATE	BY	CH.	APR.

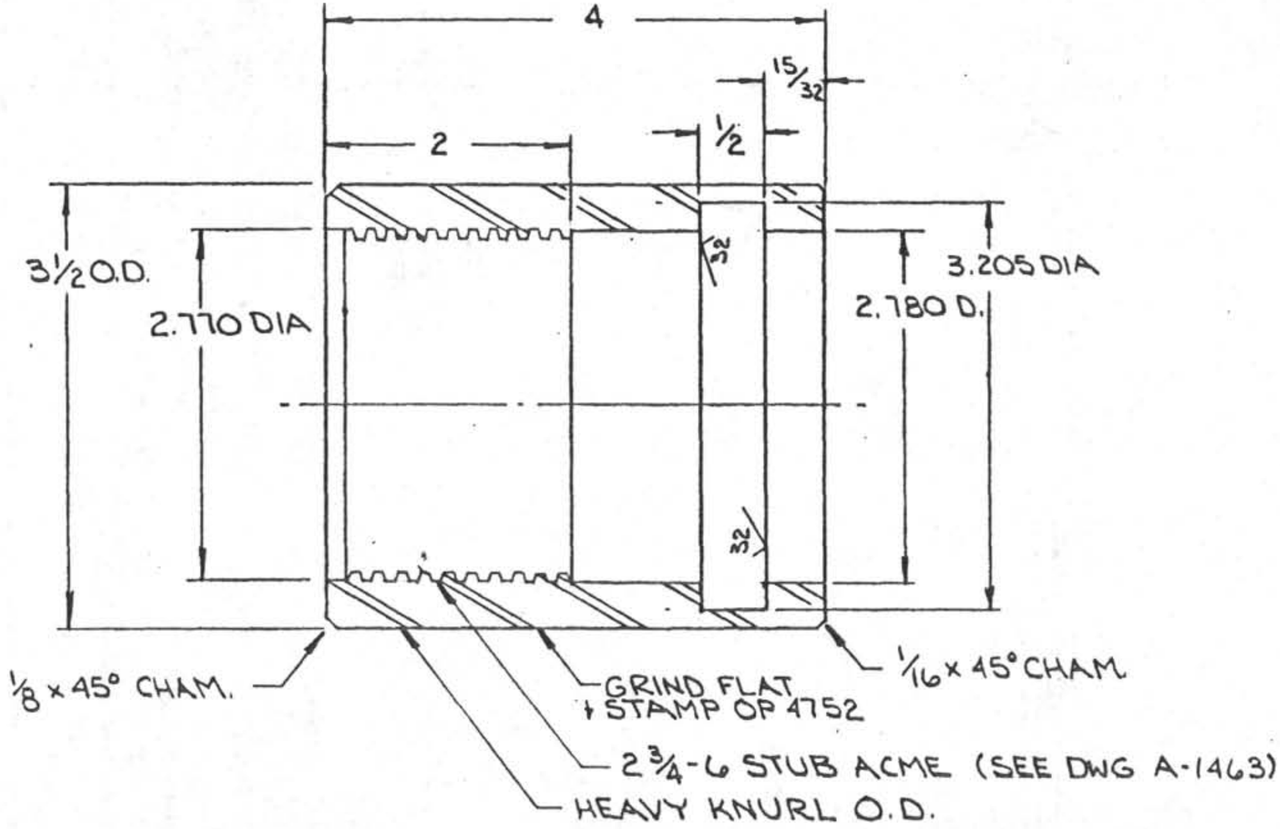


DO NOT SCALE

CONCENTRICITY ALL DIAMETERS: TIR .003

TOLERANCES UNLESS NOTED FRACTIONS ± 1/64 DECIMALS ± .005 ANGLES ± 1/2° CORNERS 1/64 x 45° or 1/64 R FINISH 125 ✓	DEEP SEA DRILLING PROJECT SCRIPPS INSTITUTION OF OCEANOGRAPHY UNIVERSITY OF CALIFORNIA, SAN DIEGO LA JOLLA, CALIFORNIA 92093				
	TITLE OUTER SEAL FEMALE ADAPTOR ~ A·P·C ~				
SURFACE TREATMENT —	MATERIAL 304 S.S.	DATE 5·12·83	BY RK	CHECKED DH	APPROVED DH
HEAT TREATMENT ANNEALED	SCALE 1:1	REQ'D/ASS'Y 1	PART NO. DP 4730	DWG. NO. A-OP4730	(REV.)

REVISIONS					
NO.	DESCRIPTION	DATE	BY	CH.	APR.



NOTE:
BREAK ALL SHARP EDGES
RADIUS ALL INSIDE CORNERS

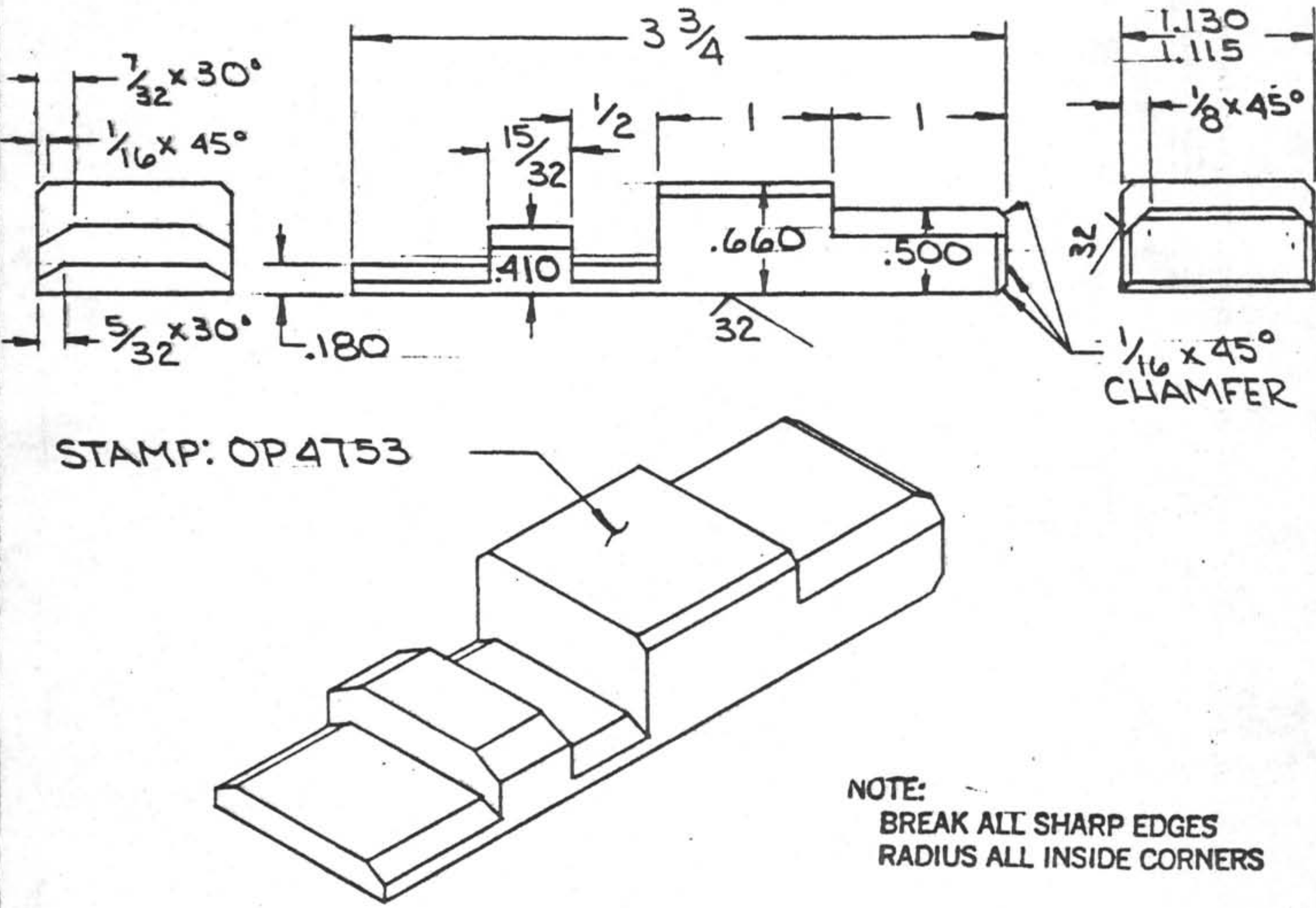
NOTE:
BREAK ALL SHARP EDGES
RADIUS ALL INSIDE CORNERS

DO NOT SCALE

CONCENTRICITY ALL DIAMETERS: TIR .003

TOLERANCES UNLESS NOTED FRACTIONS ± 1/64 DECIMALS ± .005 ANGLES ± 1/2° CORNERS 1/64 × 45° or 1/64 R FINISH 125	DEEP SEA DRILLING PROJECT SCRIPPS INSTITUTION OF OCEANOGRAPHY UNIVERSITY OF CALIFORNIA, SAN DIEGO LA JOLLA, CALIFORNIA 92093				
	TITLE: QUICK RELEASE NUT ~ A.P.C ~				
SURFACE TREATMENT: PARKOLUBE	MATERIAL: 4130	DATE: 4.13.83	BY: RK	CHECKED: DH	APPROVED: DPH
HEAT TREATMENT: Rc 28-32	SCALE: 1:1	REQ'D/ASS'Y: 1	PART NO.: OP 4752	DWG. NO.: B-OP4752	(REV.)

REVISIONS					
NO.	DESCRIPTION	DATE	BY	CH.	APR.



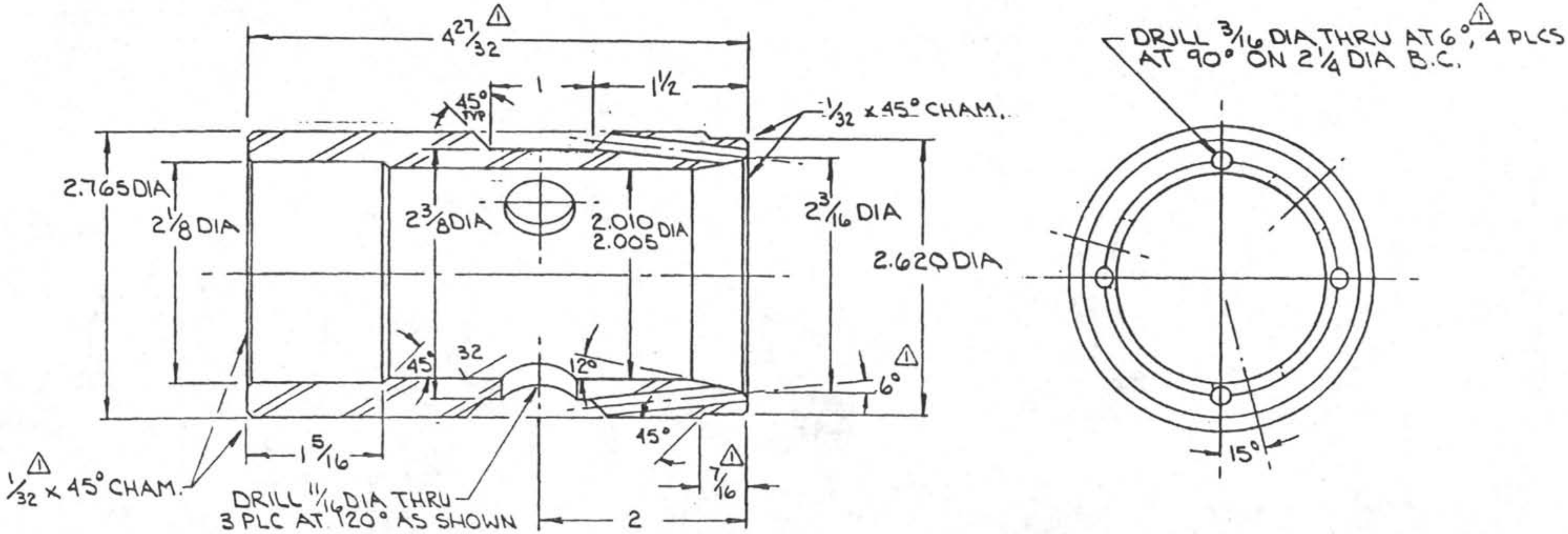
NOTE:
BREAK ALL SHARP EDGES
RADIUS ALL INSIDE CORNERS

DO NOT SCALE

CONCENTRICITY ALL DIAMETERS: TIR .003

TOLERANCES UNLESS NOTED	DEEP SEA DRILLING PROJECT				
FRACTIONS ± 1/64 DECIMALS ± .005 ANGLES ± 1/2° CORNERS 1/64 x 45° or 1/64 R FINISH 125	SCRIPPS INSTITUTION OF OCEANOGRAPHY UNIVERSITY OF CALIFORNIA, SAN DIEGO LA JOLLA, CALIFORNIA 92093				
	TITLE QUICK RELEASE DOGS ~A·P·C~				
SURFACE TREATMENT PARKOLUBE	MATERIAL 4130/4140	DATE 4·13·83	BY RK	CHECKED DH	APPROVED DPH
HEAT TREATMENT Rc 32-34	SCALE 1:1	REQ'D/ASS'Y 2	PART NO. OP 4753	DWG. NO. A-OP 4753	(REV.)

REVISIONS					
NO.	DESCRIPTION	DATE	BY	CH.	APR.
1	6° WAS 8°, 4 27/32 WAS 4 13/16, 7/16 W/ 9/32, 1/32 W/ 1/16	5-23-83	RK		



DO NOT SCALE

CONCENTRICITY ALL DIAMETERS: TIR .003

TOLERANCES UNLESS NOTED
FRACTIONS ± 1/64
DECIMALS ± .005
ANGLES ± 1/2°
CORNERS 1/64 x 45° or 1/64 R
FINISH 125

DEEP SEA DRILLING PROJECT
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UNIVERSITY OF CALIFORNIA, SAN DIEGO
LA JOLLA, CALIFORNIA 92093

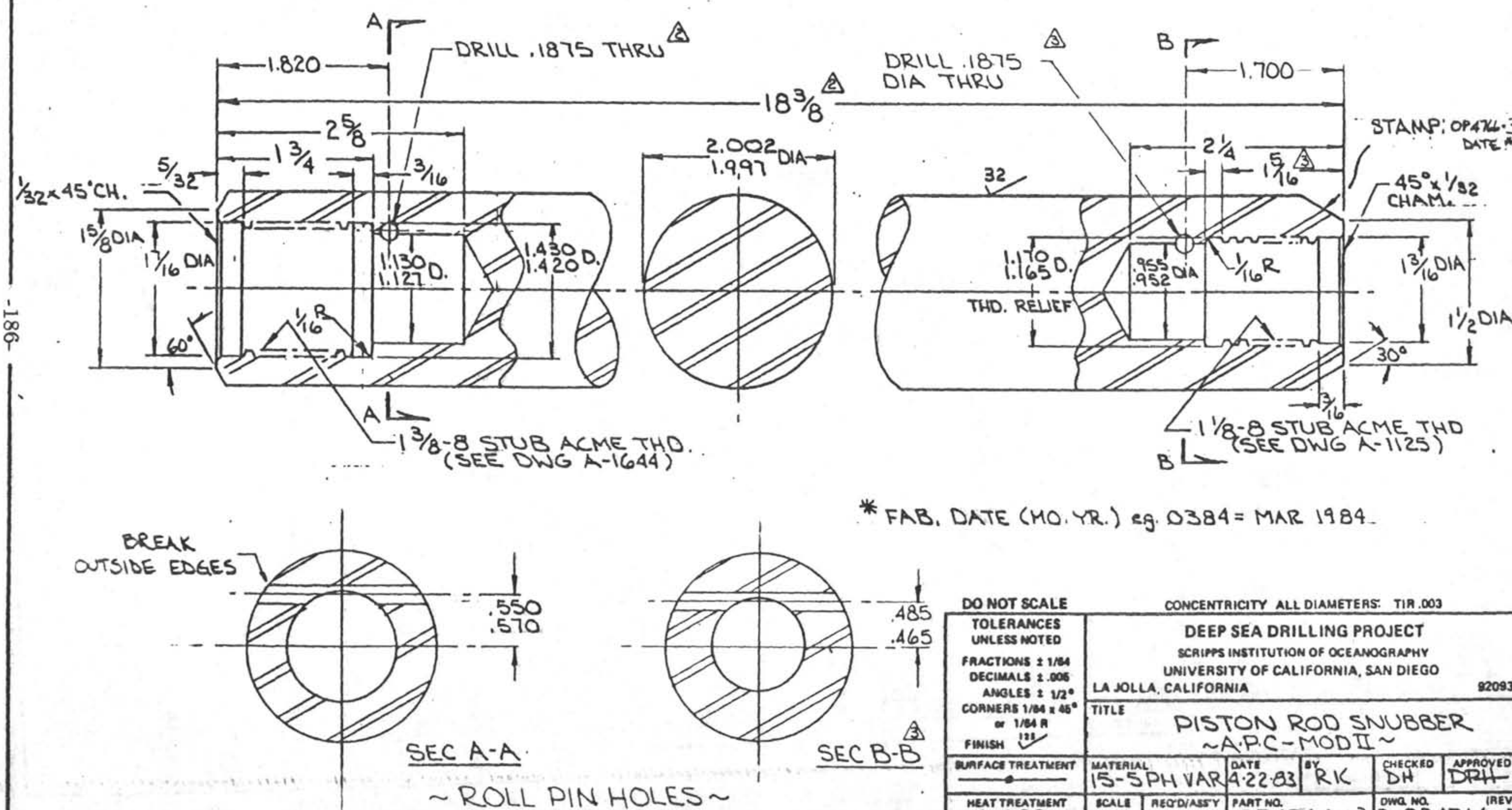
TITLE: VENT SNUBBER ~A.P.C~

SURFACE TREATMENT	MATERIAL	DATE	BY	CHECKED	APPROVED
—	NITRONIC 60	4-19-83	RK	DH	DPH 8/4

HEAT TREATMENT	SCALE	REQ'D/ASS'Y	PART NO.	DWG. NO.	(REV.)
—	1:1	1	OP4756-1	B-OP4756-1	

REVISIONS

NO.	DESCRIPTION	DATE	BY	CH.	APR.
1	1 1/8-8 BOX REVISED, 1 3/8 BOX REVISED	7·26·83	RK	DA	DRH
2	ADDED .1875 HOLE, WAS 17 5/8 LONG	2·16·84	RK	DH	DRH
3	ADDED SECOND .1875 HOLE, 1 5/16 WAS 1 1/16	5·10·84	RK		



DO NOT SCALE

CONCENTRICITY ALL DIAMETERS: TIR .003

TOLERANCES UNLESS NOTED
FRACTIONS ± 1/64
DECIMALS ± .005
ANGLES ± 1/2°
CORNERS 1/64 x 45° or 1/64 R
FINISH 125

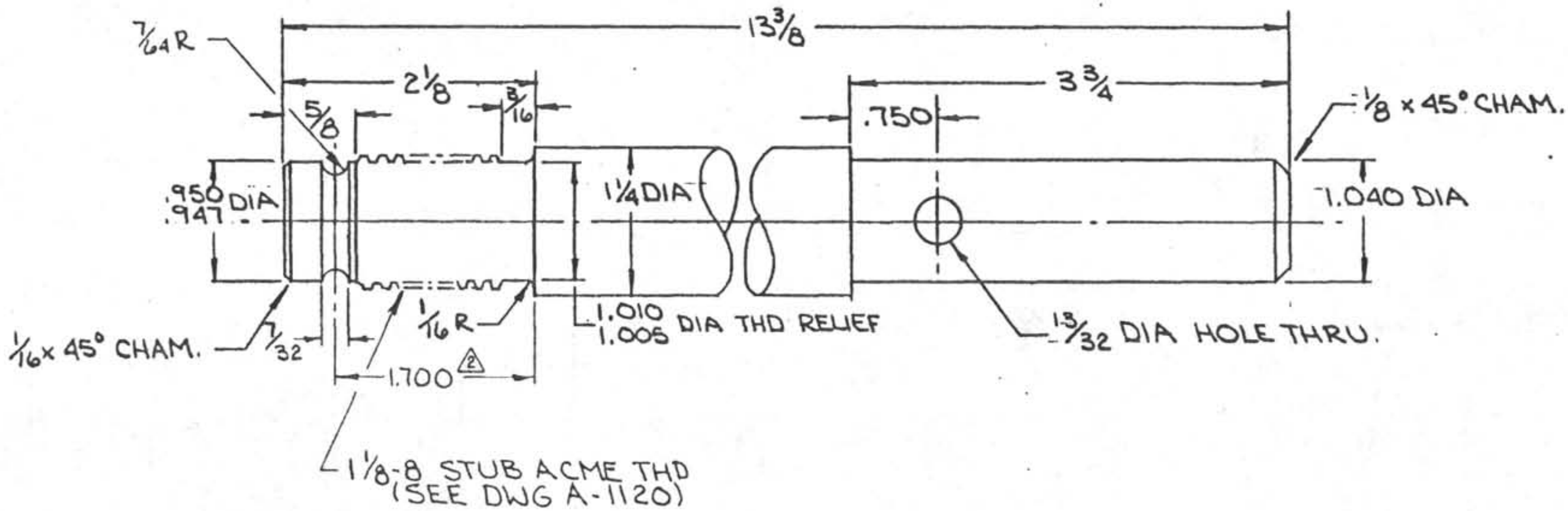
DEEP SEA DRILLING PROJECT
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UNIVERSITY OF CALIFORNIA, SAN DIEGO
LA JOLLA, CALIFORNIA 92093

TITLE: PISTON ROD SNUBBER ~A·P·C–MOD II~

SURFACE TREATMENT	MATERIAL	DATE	BY	CHECKED	APPROVED
—	15-5PH VAR	4·22·83	RK	DH	DRH

HEAT TREATMENT	SCALE	REQ'D/ASS'Y	PART NO.	DWG. NO. (REV)
H1025	1:1		OP4766-3	B-OP4766-3

REVISIONS					
NO.	DESCRIPTION	DATE	BY	CH.	APR.
1	1⅛-8 PIN REVISED	7·25·83	RK	DH	DPH
2	ADDED NOTCH	5·10·84	RK		



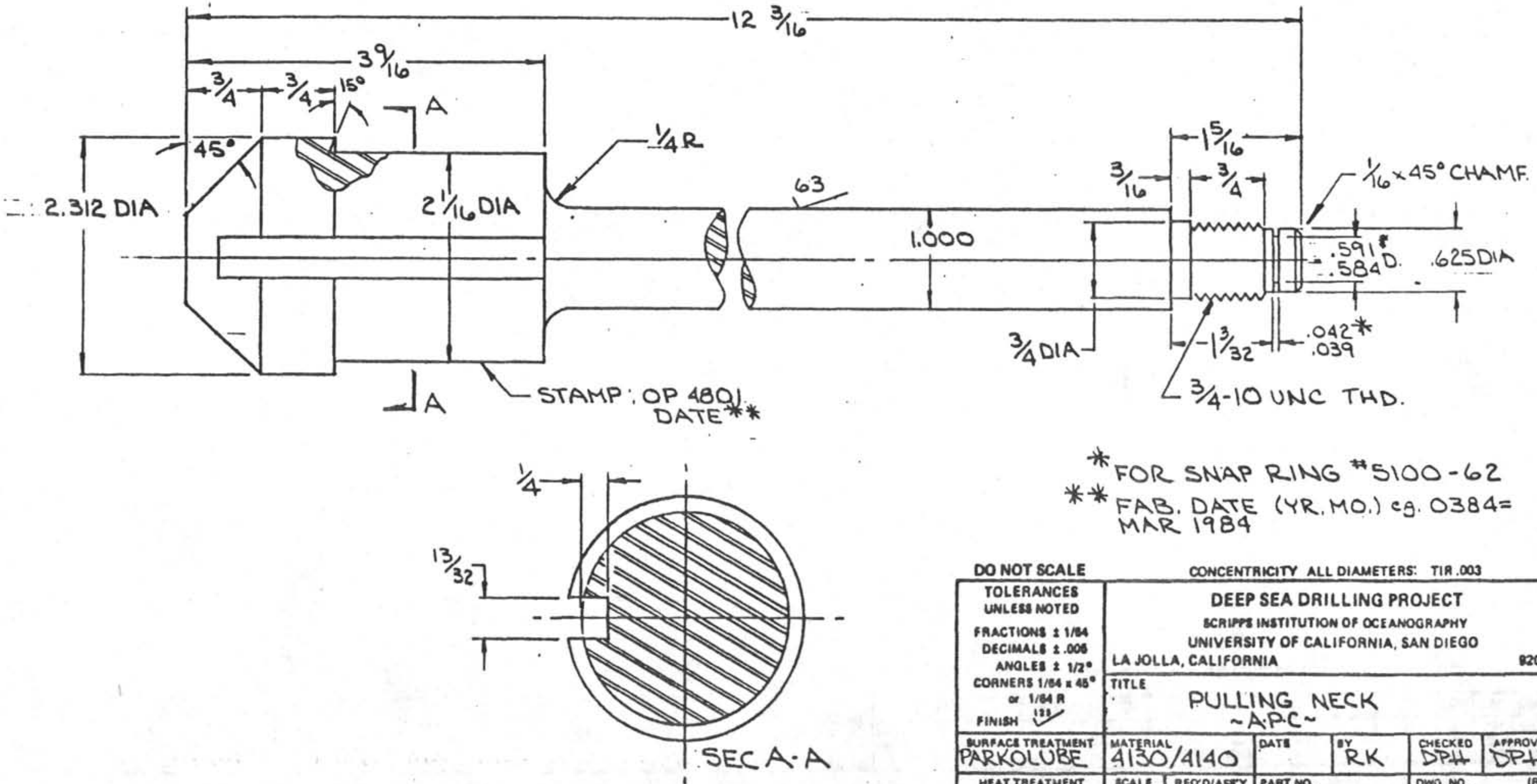
DO NOT SCALE

CONCENTRICITY ALL DIAMETERS: TIR .003

TOLERANCES UNLESS NOTED	DEEP SEA DRILLING PROJECT SCRIPPS INSTITUTION OF OCEANOGRAPHY UNIVERSITY OF CALIFORNIA, SAN DIEGO LA JOLLA, CALIFORNIA 92093
FRACTIONS ± 1/64 DECIMALS ± .005 ANGLES ± 1/2° CORNERS 1/64 × 45° or 1/64 R FINISH 125	TITLE PISTON ROD EXTENSION ·~A.P.C~ FOR VLHPC PISTON HEAD

SURFACE TREATMENT	MATERIAL		DATE	BY	CHECKED	APPROVED
PARKOLUBE	4130		4·21·83	RK	DH	DPH
HEAT TREATMENT	**SCALE**	**REQ'D/ASS'Y**	**PART NO.**		**DWG. NO. (REV.)**	
Rc 30-32.	1:1	1	OP4769-2		B-OP4769-2	

REVISIONS					
NO.	DESCRIPTION	DATE	BY	CH.	APR.



* FOR SNAP RING #5100-62

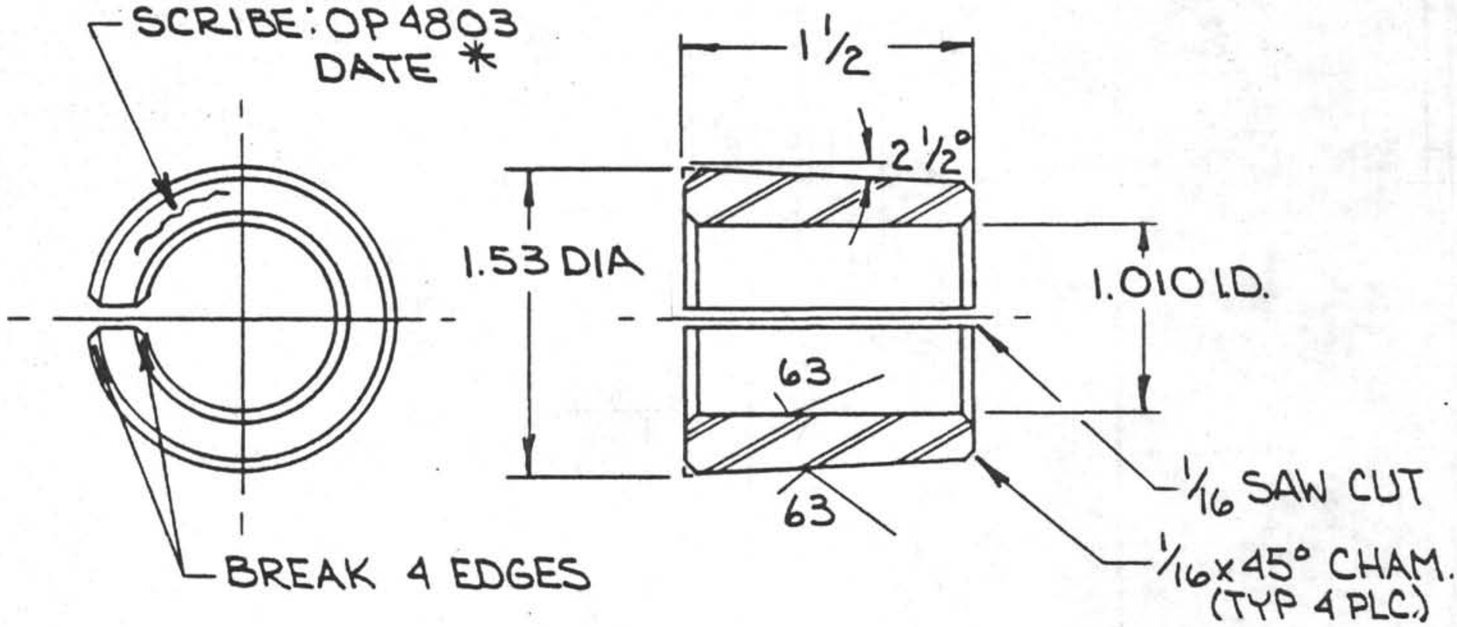
** FAB. DATE (YR. MO.) eg. 0384= MAR 1984

DO NOT SCALE

CONCENTRICITY ALL DIAMETERS: TIR .003

TOLERANCES UNLESS NOTED FRACTIONS ± 1/64 DECIMALS ± .005 ANGLES ± 1/2° CORNERS 1/64 x 45° or 1/64 R FINISH 125	DEEP SEA DRILLING PROJECT SCRIPPS INSTITUTION OF OCEANOGRAPHY UNIVERSITY OF CALIFORNIA, SAN DIEGO LA JOLLA, CALIFORNIA 92093					
	TITLE PULLING NECK ~A.P.C~					
SURFACE TREATMENT PARKOLUBE	MATERIAL 4130/4140		DATE	BY RK	CHECKED DPH	APPROVED DPH
HEAT TREATMENT 30-32 Rc	SCALE 1:1	REQ'D/ASSY 1	PART NO. OP4801		DWG. NO. B-OP4801	(REV.)

REVISIONS					
NO.	DESCRIPTION	DATE	BY	CH.	APR.

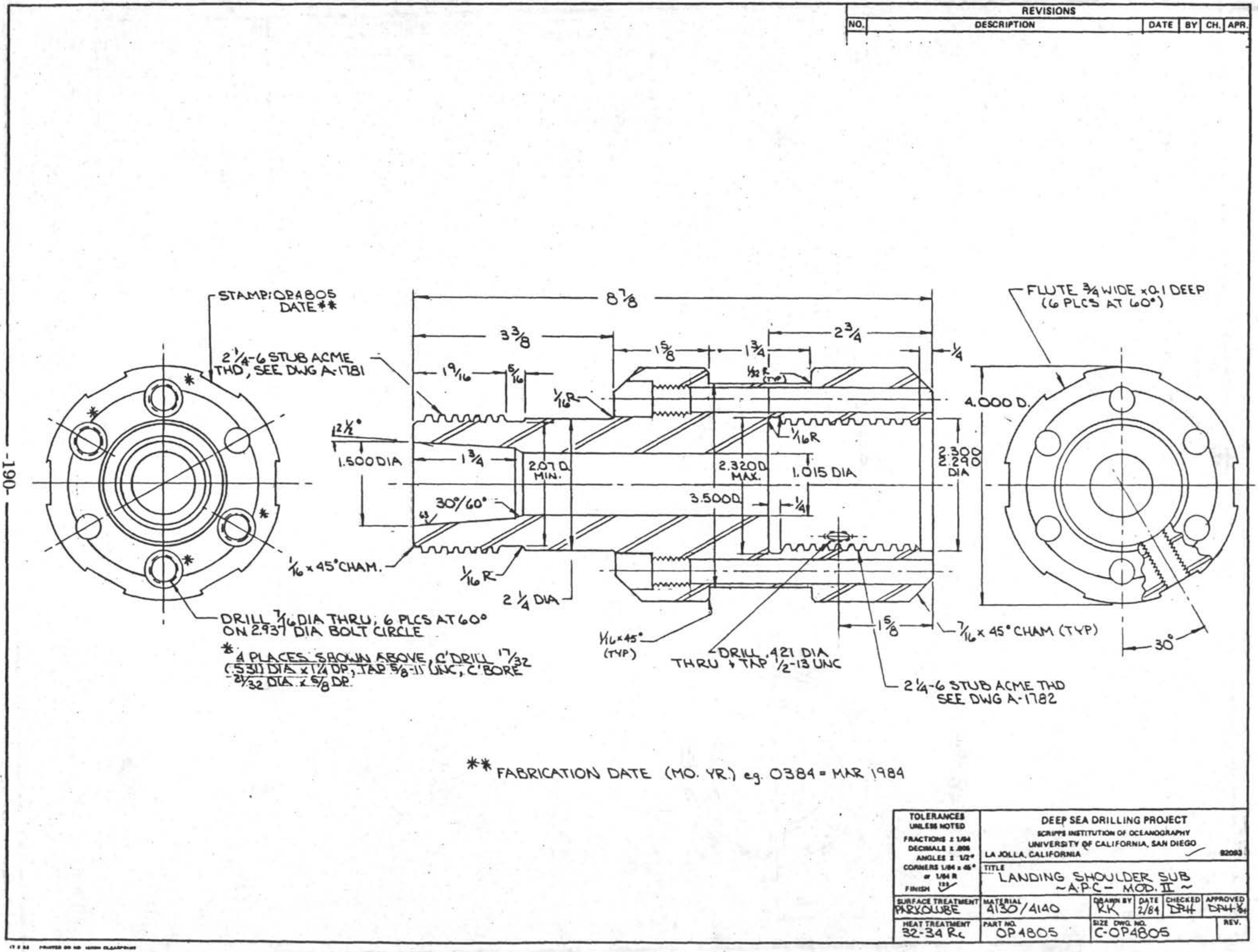


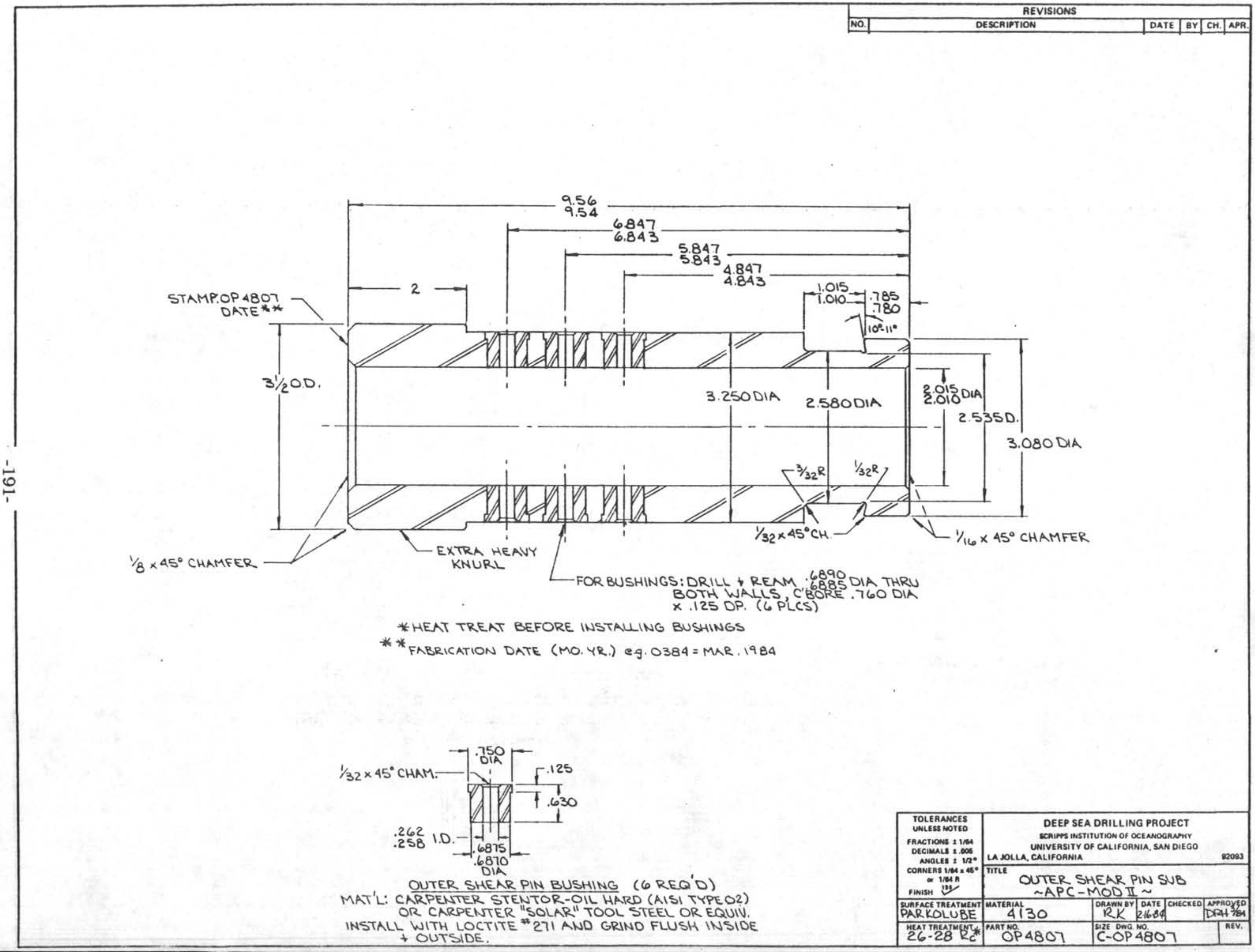
*DATE OF FABRICATION (MO., YR.) e.g. 0384 = MAR 1984

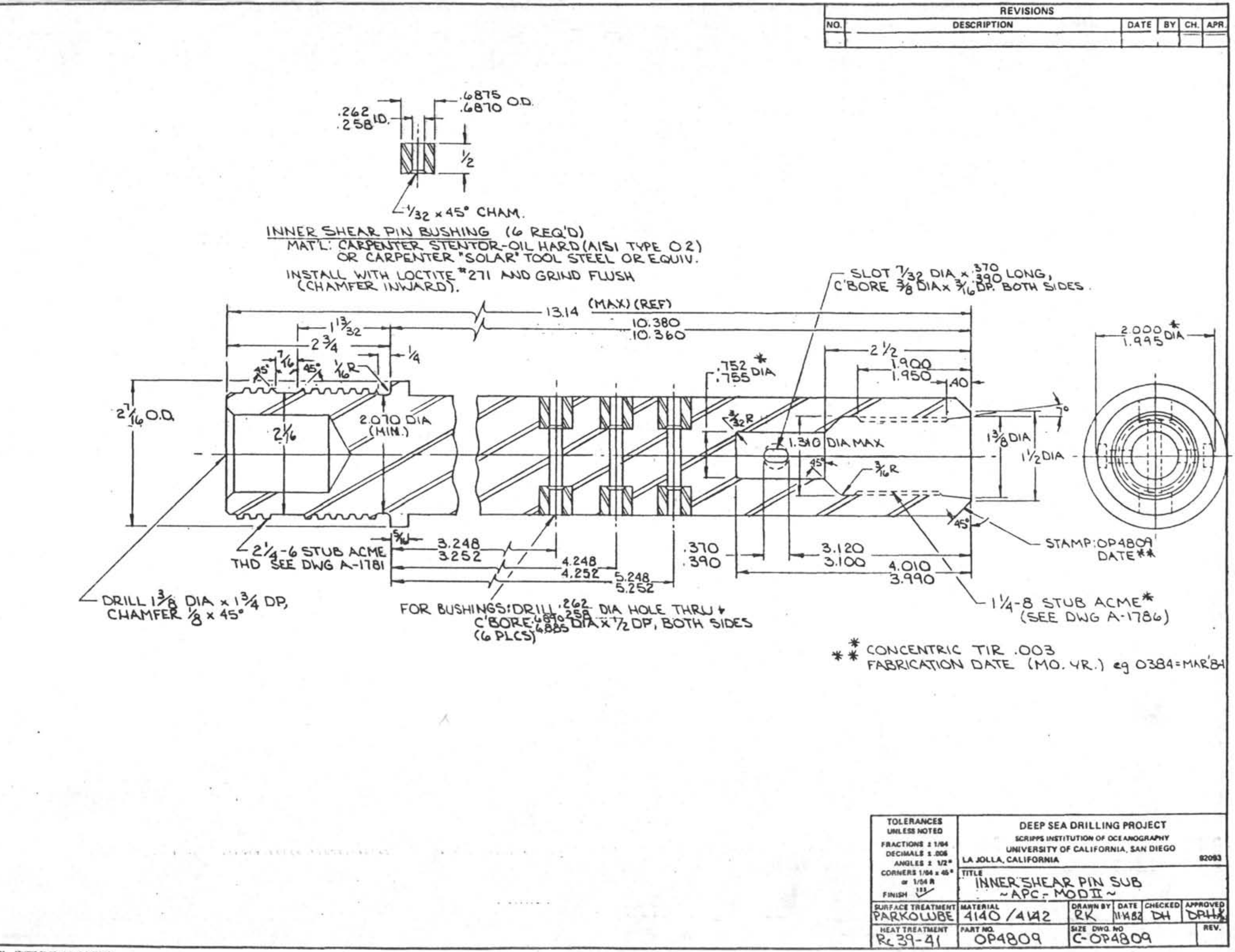
DO NOT SCALE

CONCENTRICITY ALL DIAMETERS: TIR .003

TOLERANCES UNLESS NOTED FRACTIONS ± 1/64 DECIMALS ± .005 ANGLES ± 1/2° CORNERS 1/64 x 45° or 1/64 R FINISH 125	DEEP SEA DRILLING PROJECT SCRIPPS INSTITUTION OF OCEANOGRAPHY UNIVERSITY OF CALIFORNIA, SAN DIEGO LA JOLLA, CALIFORNIA 92093 TITLE SPLIT BUSHING ~ A.P.C - MOD. II ~				
SURFACE TREATMENT PARKOLUBE	MATERIAL 4130/4140	DATE 2.13.84	BY RK	CHECKED DPH	APPROVED DPH 3/84
HEAT TREATMENT 28 - 32 Rc	SCALE 1:1	REQ'D/ASS'Y 1	PART NO. OP 4803	DWG. NO. A-OP4803	(REV.)

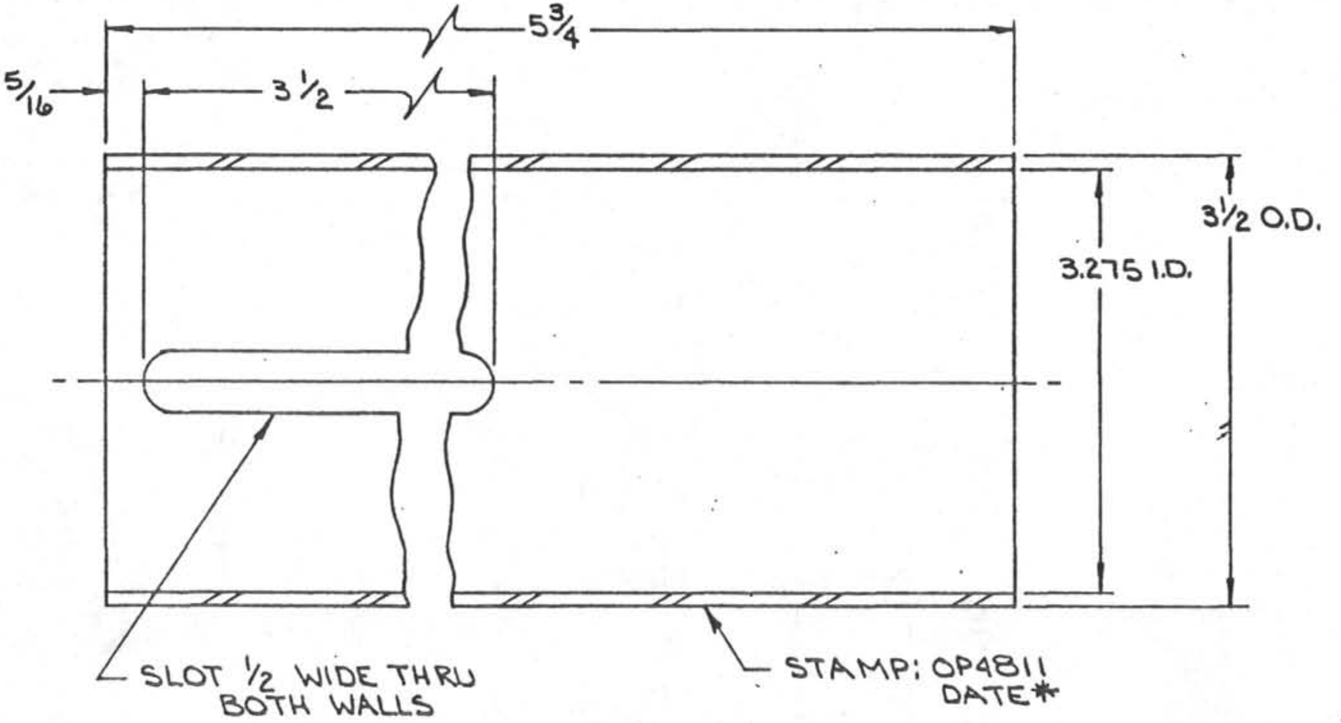

REVISIONS
NO. DESCRIPTION DATE BY CH. APR.
STAMP: OP4805
DATE **
2 1/4-6 STUB ACME THD, SEE DWG A-1781
8 7/8
3 3/8
1 9/16
5/16
1 5/8
1 3/4
2 3/4
1/4
1/32 R (TYP)
1/16 R
FLUTE 3/4 WIDE x 0.1 DEEP (6 PLCS AT 60°)
4.000 D.
12 1/2°
1.500 DIA
1 3/4
2.070 D. MIN.
2.320 D. MAX.
1.015 DIA
2.300 2.290 DIA
3.500 D.
1/4
30°/60°
63
1/16 x 45° CHAM.
1/16 R
2 1/4 DIA
1/16 x 45° (TYP)
DRILL .421 DIA THRU + TAP 1/2-13 UNC
1 5/8
7/16 x 45° CHAM (TYP)
30°
DRILL 7/16 DIA THRU; 6 PLCS AT 60° ON 2.937 DIA BOLT CIRCLE
* 4 PLACES SHOWN ABOVE, C'DRILL 17/32 (.531) DIA x 1/4 DP, TAP 5/8-11 UNC, C'BORE 21/32 DIA x 5/8 DP.
2 1/4-6 STUB ACME THD SEE DWG A-1782
** FABRICATION DATE (MO. YR.) eg. 0384 = MAR 1984
TOLERANCES UNLESS NOTED
FRACTIONS ± 1/64
DECIMALS ± .005
ANGLES ± 1/2°
CORNERS 1/64 x 45° or 1/64 R
FINISH 125
DEEP SEA DRILLING PROJECT
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UNIVERSITY OF CALIFORNIA, SAN DIEGO
LA JOLLA, CALIFORNIA
92093
TITLE
LANDING SHOULDER SUB
~ A.P.C. - MOD. II ~
SURFACE TREATMENT PARKOLUBE
MATERIAL 4130/4140
DRAWN BY KK
DATE 2/84
CHECKED DPH
APPROVED DPH
HEAT TREATMENT 32-34 Rc
PART NO. OP4805
SIZE DWG. NO. C-OP4805
REV.


REVISIONS
NO.
DESCRIPTION
DATE
BY
CH.
APR.
9.56
9.54
6.847
6.843
5.847
5.843
4.847
4.843
2
1.015
1.010
.785
.780
10°-11°
STAMP: OP 4807
DATE**
3½ O.D.
3.250 DIA
2.580 DIA
2.015
2.010 DIA
2.535 D.
3.080 DIA
3/32R
1/32R
1/32 x 45° CH.
1/16 x 45° CHAMFER
1/8 x 45° CHAMFER
EXTRA HEAVY
KNURL
FOR BUSHINGS: DRILL + REAM .6890 .6885 DIA THRU
BOTH WALLS, C'BORE .760 DIA
x .125 DP. (6 PLCS)
*HEAT TREAT BEFORE INSTALLING BUSHINGS
**FABRICATION DATE (MO. YR.) eg. 0384 = MAR. 1984
.750
DIA
1/32 x 45° CHAM.
.125
.630
.262
.258 I.D.
.6875
.6870
DIA
OUTER SHEAR PIN BUSHING (6 REQ'D)
MAT'L: CARPENTER STENTOR-OIL HARD (AISI TYPE O2)
OR CARPENTER "SOLAR" TOOL STEEL OR EQUIV.
INSTALL WITH LOCTITE #271 AND GRIND FLUSH INSIDE
+ OUTSIDE.
TOLERANCES
UNLESS NOTED
FRACTIONS ± 1/64
DECIMALS ± .005
ANGLES ± 1/2°
CORNERS 1/64 x 45° or 1/64 R
FINISH 125
DEEP SEA DRILLING PROJECT
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UNIVERSITY OF CALIFORNIA, SAN DIEGO
LA JOLLA, CALIFORNIA
92093
TITLE
OUTER SHEAR PIN SUB
~APC-MOD II~
SURFACE TREATMENT
PARKOLUBE
MATERIAL
4130
DRAWN BY
RK
DATE
2-16-84
CHECKED
APPROVED
DRH 3/84
HEAT TREATMENT
26-28 Rc*
PART NO.
OP 4807
SIZE DWG. NO.
C-OP 4807
REV.



REVISIONS
NO.
DESCRIPTION
DATE
BY
CH.
APR.
.262
.258 I.D.
.6875
.6870 O.D.
1/2
1/32 × 45° CHAM.
INNER SHEAR PIN BUSHING (6 REQ'D)
MAT'L: CARPENTER STENTOR-OIL HARD (AISI TYPE O2)
OR CARPENTER "SOLAR" TOOL STEEL OR EQUIV.
INSTALL WITH LOCTITE #271 AND GRIND FLUSH
(CHAMFER INWARD).
SLOT 7/32 DIA × .370/.390 LONG,
C'BORE 3/8 DIA × 3/16 DP. BOTH SIDES.
13.14 (MAX) (REF)
10.380
10.360
1 13/32
2 3/4
1/4
7/16
45°
45°
1/16 R
2 7/16 O.D.
2 1/16
2.070 DIA
(MIN.)
.752 *
.755 DIA
3/32 R
1.310 DIA MAX
45°
3/16 R
2 1/2
1.900
1.950
.40
7°
1 3/8 DIA
1 1/2 DIA
45°
2.000 *
1.995 DIA
STAMP: OP4809
DATE **
2 1/4-6 STUB ACME
THD SEE DWG A-1781
5/16
3.248
3.252
4.248
4.252
5.248
5.252
.370
.390
3.120
3.100
4.010
3.990
DRILL 1 3/8 DIA × 1 3/4 DP,
CHAMFER 1/8 × 45°
FOR BUSHINGS: DRILL .262/.258 DIA HOLE THRU &
C'BORE .6890/.6885 DIA × 1/2 DP, BOTH SIDES
(6 PLCS)
1 1/4-8 STUB ACME *
(SEE DWG A-1786)
* CONCENTRIC TIR .003
** FABRICATION DATE (MO. YR.) eg 0384=MAR'84
TOLERANCES
UNLESS NOTED
FRACTIONS ± 1/64
DECIMALS ± .005
ANGLES ± 1/2°
CORNERS 1/64 × 45°
or 1/64 R
FINISH
DEEP SEA DRILLING PROJECT
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UNIVERSITY OF CALIFORNIA, SAN DIEGO
LA JOLLA, CALIFORNIA
92093
TITLE
INNER SHEAR PIN SUB
~APC - MOD II~
SURFACE TREATMENT
PARKOLUBE
MATERIAL
4140 / 4142
DRAWN BY
RK
DATE
11-1-82
CHECKED
DH
APPROVED
DRH
HEAT TREATMENT
Rc 39-41
PART NO.
OP4809
SIZE DWG. NO
C-OP4809
REV.

REVISIONS					
NO.	DESCRIPTION	DATE	BY	CH.	APR.



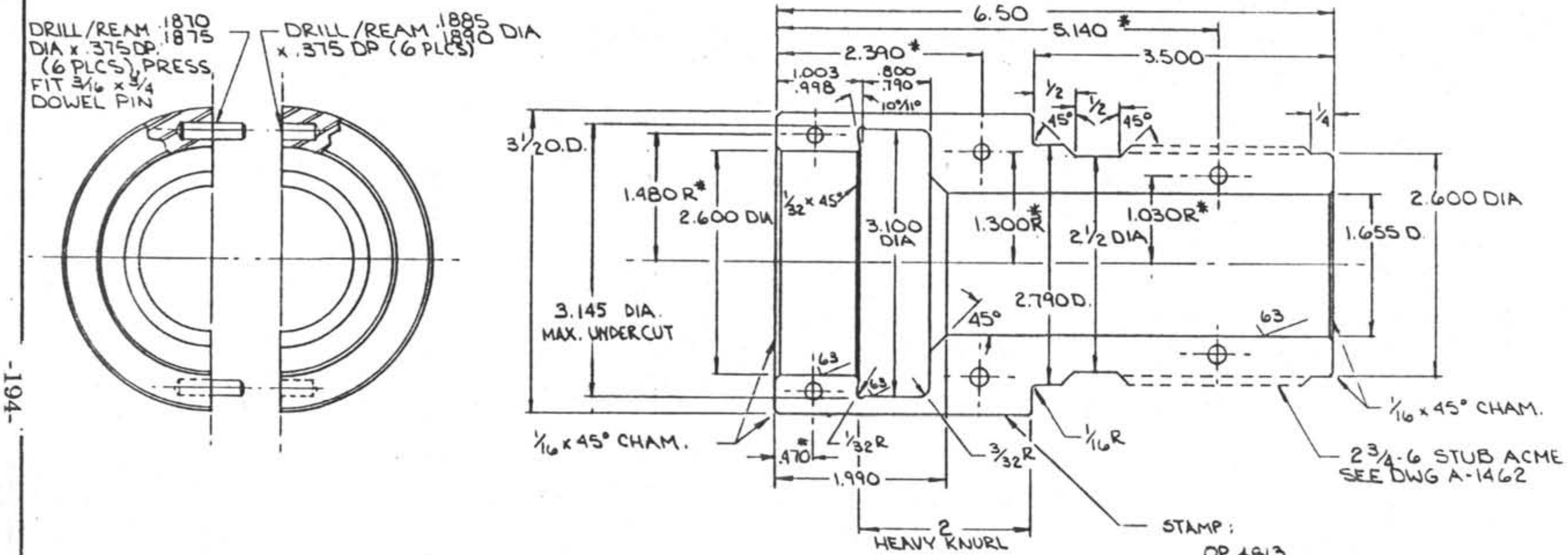
* FAB. DATE (MO. YR.) eg. 0384 = MAR '84

DO NOT SCALE

CONCENTRICITY ALL DIAMETERS: TIR .003

TOLERANCES UNLESS NOTED FRACTIONS ± 1/64 DECIMALS ± .005 ANGLES ± 1/2° CORNERS 1/64 x 45° or 1/64 R FINISH 125	DEEP SEA DRILLING PROJECT SCRIPPS INSTITUTION OF OCEANOGRAPHY UNIVERSITY OF CALIFORNIA, SAN DIEGO LA JOLLA, CALIFORNIA 92093				
	TITLE SHEAR PIN SLEEVE ~A.P.C~ MOD II				
SURFACE TREATMENT PARKOLUBE	MATERIAL 4130/4140	DATE 2.14.84	BY RK	CHECKED DRH	APPROVED DRH
HEAT TREATMENT R_c 28	SCALE 1:1	REQ'D/ASS'Y 1	PART NO. OP4811	DWG. NO. B-OP4811	(REV.)

REVISIONS					
NO.	DESCRIPTION	DATE	BY	CH.	APR.



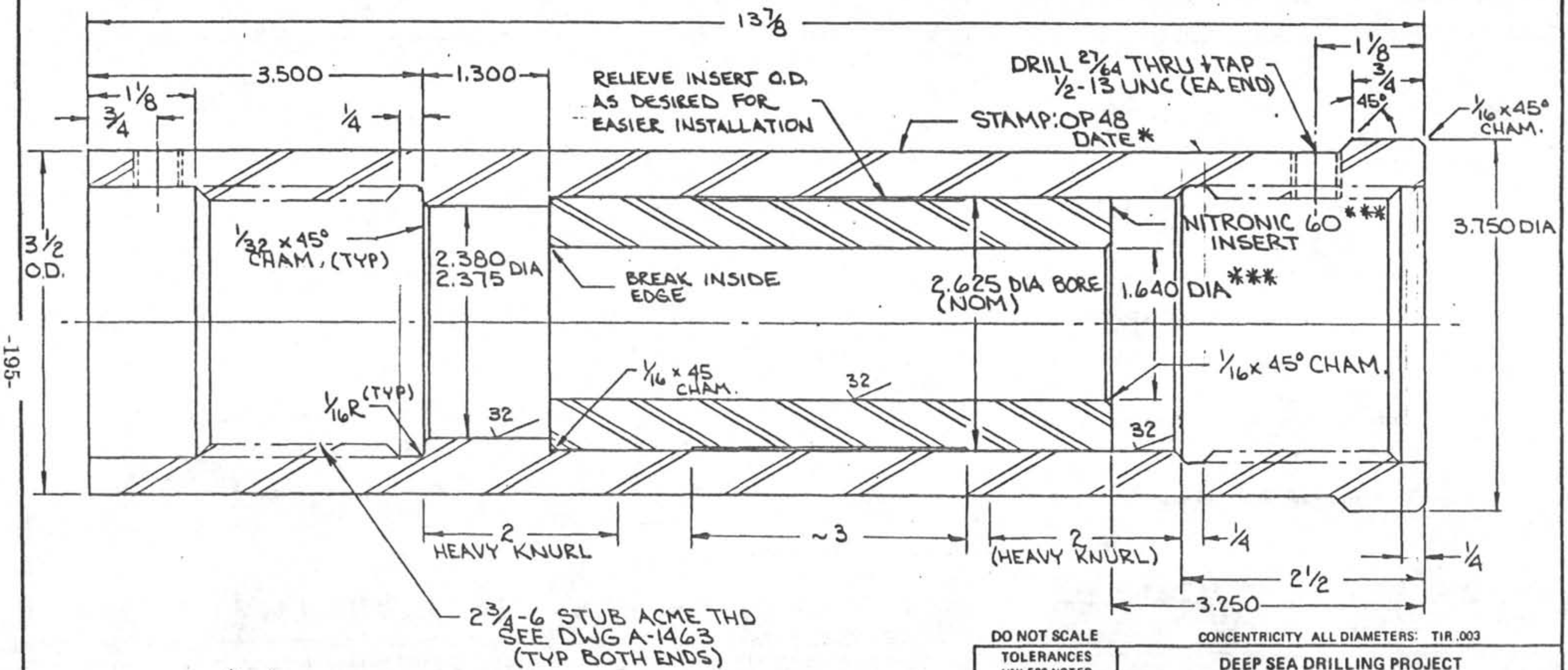
FABRICATION SEQUENCE

1. ROUGH MACHINE 3 3/4 O.D. x 1 3/8 I.D.
2. STRESS RELIEVE
3. SPLIT LENGTHWISE
4. MILL MATING SURFACES FLAT & SQUARE
5. DRILL/REAM DOWEL HOLES AND INSTALL DOWELS
6. ASSEMBLE AND TACK WELD HALVES
7. FINISH MACHINE
8. SPLIT HALVES AND REMOVE WELDS
9. DEBURR ALL THREADS AT SPLIT SURFACE
10. HEAT TREAT.

* BASIC DIMENSION, (TYP 2 PLCS)
** FABRICATION DATE (MO. YR.) eg. 0384 = MAR 84

TOLERANCES UNLESS NOTED	DEEP SEA DRILLING PROJECT SCRIPPS INSTITUTION OF OCEANOGRAPHY UNIVERSITY OF CALIFORNIA, SAN DIEGO LA JOLLA, CALIFORNIA 92093				
FRACTIONS ± 1/64 DECIMALS ± .005 ANGLES ± 1/2° CORNERS 1/64 x 45° or 1/64 R FINISH 125	TITLE SPLIT SWIVEL SUB ~ APC - MOD II ~				
SURFACE TREATMENT PARKOLUBE	MATERIAL 4130	DRAWN BY RK	DATE 2-16-84	CHECKED	APPROVED DRH 3/84
HEAT TREATMENT 28-32 Rc	PART NO. OP4813	SIZE C	DWG. NO. OP4813		REV.

REVISIONS					
NO.	DESCRIPTION	DATE	BY	CH.	APR.



* FABRICATION DATE (MO. YR) eg. 0384 = MAR '84

** NITRONIC 60 INSERT - SHRINK FIT INTO PLACE AND FINAL BORE I.D. AFTER HEAT TREATING ALLOY STEEL BODY. RECOMMENDED INTERFERENCE = .0004 / .0014

*** 1.640 DIA BORE TO BE CONCENTRIC WITH AXES OF BOTH THREADS: TIR .003

DO NOT SCALE

CONCENTRICITY ALL DIAMETERS: TIR .003

TOLERANCES UNLESS NOTED
FRACTIONS ± 1/64
DECIMALS ± .005
ANGLES ± 1/2°
CORNERS 1/64 x 45° or 1/64 R
FINISH 125

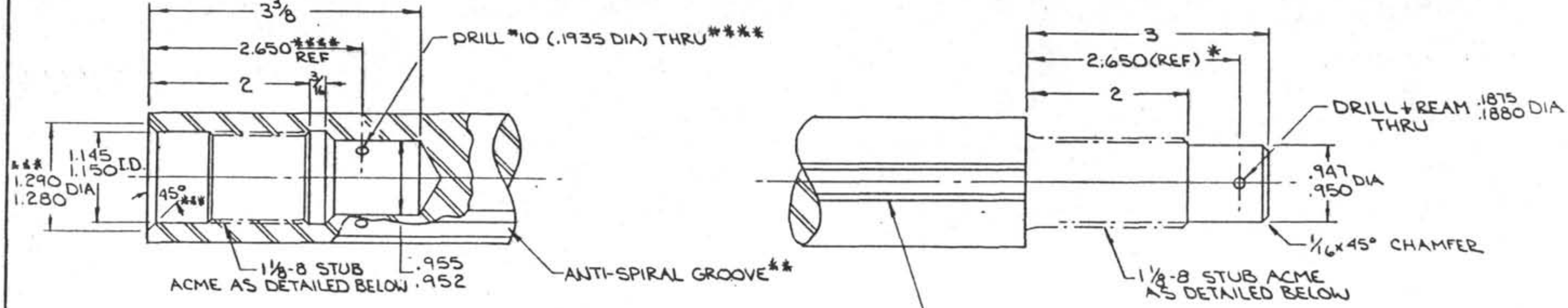
DEEP SEA DRILLING PROJECT
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UNIVERSITY OF CALIFORNIA, SAN DIEGO
LA JOLLA, CALIFORNIA 92093

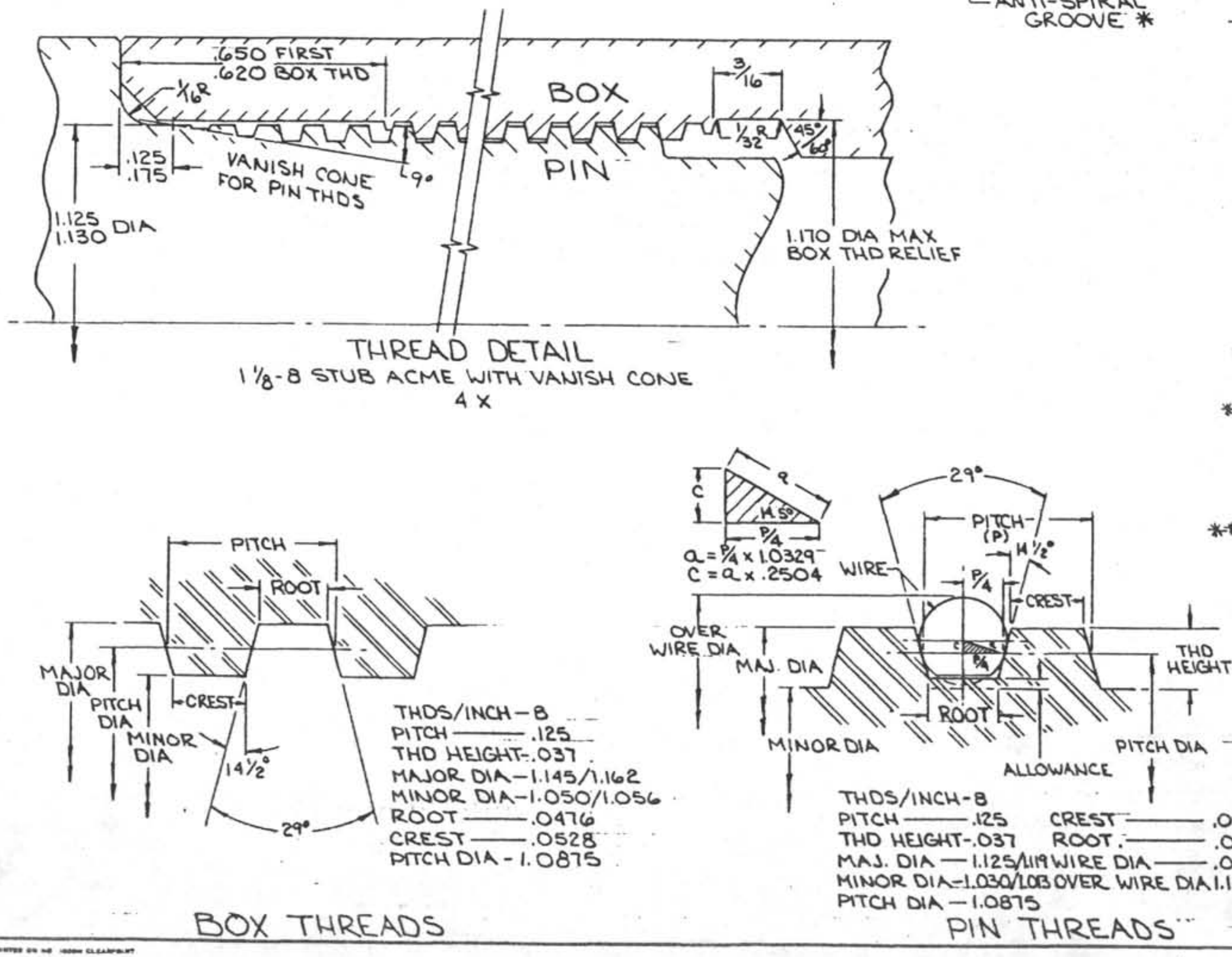
TITLE: INNER SEAL SUB ~A.P.C. - MOD II ~

SURFACE TREATMENT	MATERIAL	DATE	BY	CHECKED	APPROVED
PARKOLUBE	4130/4140 **	2-21-84	RK	DPH	DPH 4/84

HEAT TREATMENT	SCALE	REQ'D/ASS'Y	PART NO.	DWG. NO.	(REV.)
34-36 Rc **	1:1	1	OP4815	B-OP4815	

REVISIONS					
NO.	DESCRIPTION	DATE	BY	CH.	APR.





NOTES:

FOR UPPER PISTON ROD (OP 48 17) PIN ONLY AND CENTER PISTON ROD (OP 48 18) PIN AND BOX

1. 1⅛-8 PIN CONNECTION MUST BE FABRICATED FIRST

*2 LOCATE ANTI-SPIRAL GROOVE AND .1875/.1880 HOLE USING FEMALE THREAD GAGE OD0408 ASSEMBLED SNUGLY HAND-TIGHT.

3. CUT ANTI-SPIRAL GROOVE AS SPECIFIED ON ROD DWG.

FOR CENTER PISTON ROD (OP 4818) BOX

4. FABRICATE 1⅛-8 BOX CONNECTION (EXCEPT FOR ASTERISKED DETAILS)

** 5. LOCATION OF ANTI-SPIRAL GROOVE AT BOX END ALREADY DETERMINED BY STEP 2 ABOVE.

*** 6. ASSEMBLE MALE THREAD GAGE TO BOX SNUGLY HAND TIGHT. CAREFULLY FACE OFF SHOULDER OF BOX UNTIL ANTI-SPIRAL GROOVES IN THREAD GAGE AND ROD SECTION ALIGN. (0.00245" OFF FACE MOVES GROOVE POSITION 0.1" ON CIRCUMFERENCE). FINISH 1.290/1.280 x 45° CHAMFER ON BOX END.

**** 7. LOCATE #10 (.1935) HOLE IN CENTER OF ANTI-SPIRAL GROOVE AT A DISTANCE FROM THE BOX END DETERMINED BY DRILL JIG OD0650

FOR LOWER PISTON ROD (OP 4819) BOX ONLY

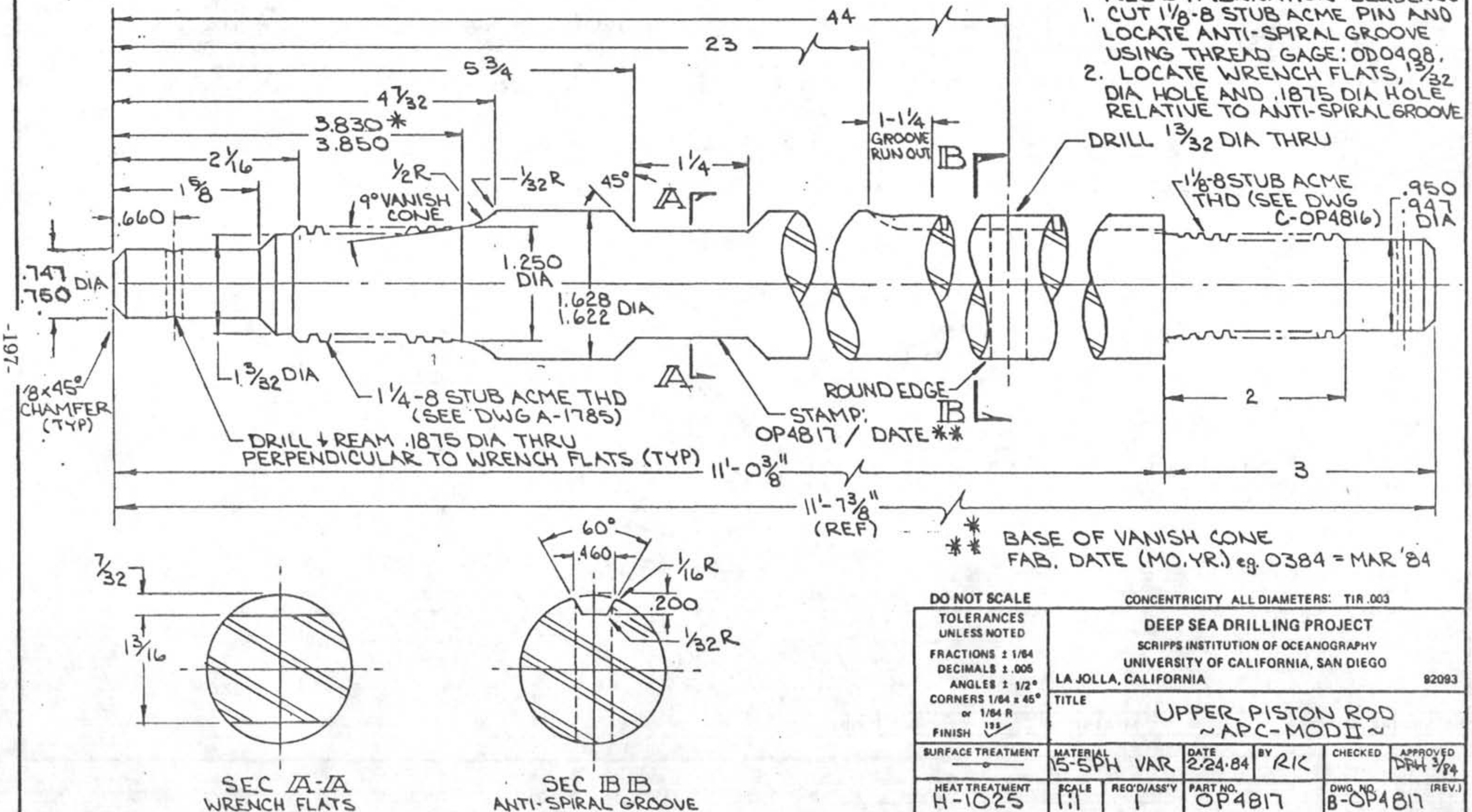
1. CUT 1⅛-8 BOX CONNECTION AND LOCATE ANTI-SPIRAL GROOVE USING SNUG HAND TIGHT MALE THREAD GAGE. NO FACE OFF REQUIRED.

2 LOCATE ROLL PIN HOLE BY STEP 7 ABOVE.

TOLERANCES UNLESS NOTED	DEEP SEA DRILLING PROJECT SCRIPPS INSTITUTION OF OCEANOGRAPHY UNIVERSITY OF CALIFORNIA, SAN DIEGO LA JOLLA, CALIFORNIA 92093			
FRACTIONS ± 1/64 DECIMALS ± .005 ANGLES ± 1/2° CORNERS 1/64 x 45° or 1/64 R FINISH 125	TITLE PISTON ROD THREADED CONNECTION DETAILS-APC-MOD II			
SURFACE TREATMENT —0—	MATERIAL —0—	DRAWN BY RK	DATE 2-29-84	CHECKED / APPROVED DPH 3/84
HEAT TREATMENT —0—	PART NO. OP4816	SIZE C DWG. NO. C-OP 4816		REV.

REVISIONS					
NO.	DESCRIPTION	DATE	BY	CH.	APR.

REQ'D FABRICATION SEQUENCE
1. CUT 1⅛-8 STUB ACME PIN AND LOCATE ANTI-SPIRAL GROOVE USING THREAD GAGE: OD0408.
2. LOCATE WRENCH FLATS, 13/32 DIA HOLE AND .1875 DIA HOLE RELATIVE TO ANTI-SPIRAL GROOVE



* BASE OF VANISH CONE
** FAB. DATE (MO.YR.) eg. 0384 = MAR '84

DO NOT SCALE

CONCENTRICITY ALL DIAMETERS: TIR .003

TOLERANCES UNLESS NOTED
FRACTIONS ± 1/64
DECIMALS ± .005
ANGLES ± 1/2°
CORNERS 1/64 x 45° or 1/64 R
FINISH 125

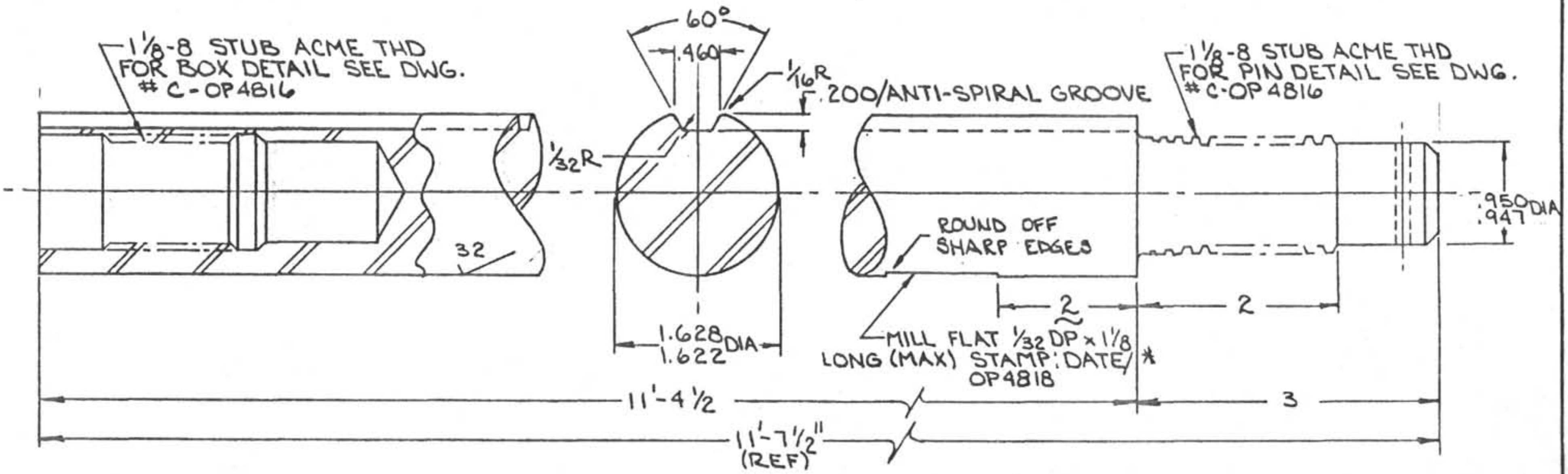
DEEP SEA DRILLING PROJECT
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UNIVERSITY OF CALIFORNIA, SAN DIEGO
LA JOLLA, CALIFORNIA 92093

TITLE: UPPER PISTON ROD ~APC-MOD II~

SURFACE TREATMENT	MATERIAL	DATE	BY	CHECKED	APPROVED
—	15-5PH VAR	2-24-84	RK		DRH 3/84

HEAT TREATMENT	SCALE	REQ'D/ASS'Y	PART NO.	DWG. NO.	(REV.)
H-1025	1:1	1	OP4817	B-OP4817	

REVISIONS					
NO.	DESCRIPTION	DATE	BY	CH.	APR.



REQUIRED FABRICATION SEQUENCE

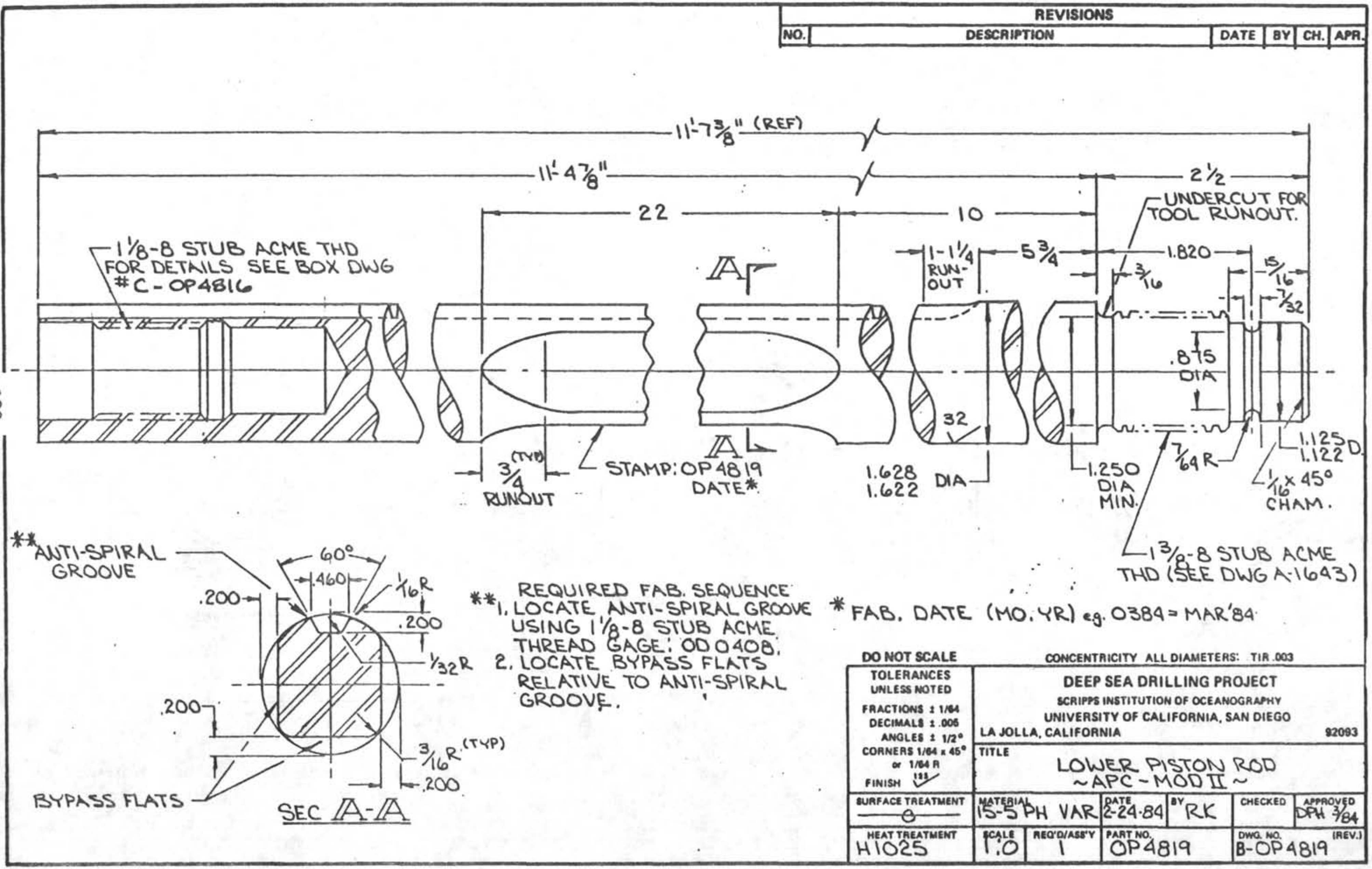
1. CUT PIN CONNECTION.
2. LOCATE ANTI-SPIRAL GROOVE USING 1 1/8-8 STUB ACME THREAD GAGE: OD0408.
3. CUT BOX CONNECTION.
4. LOCATE MILL FLAT FOR STAMPED P/N.

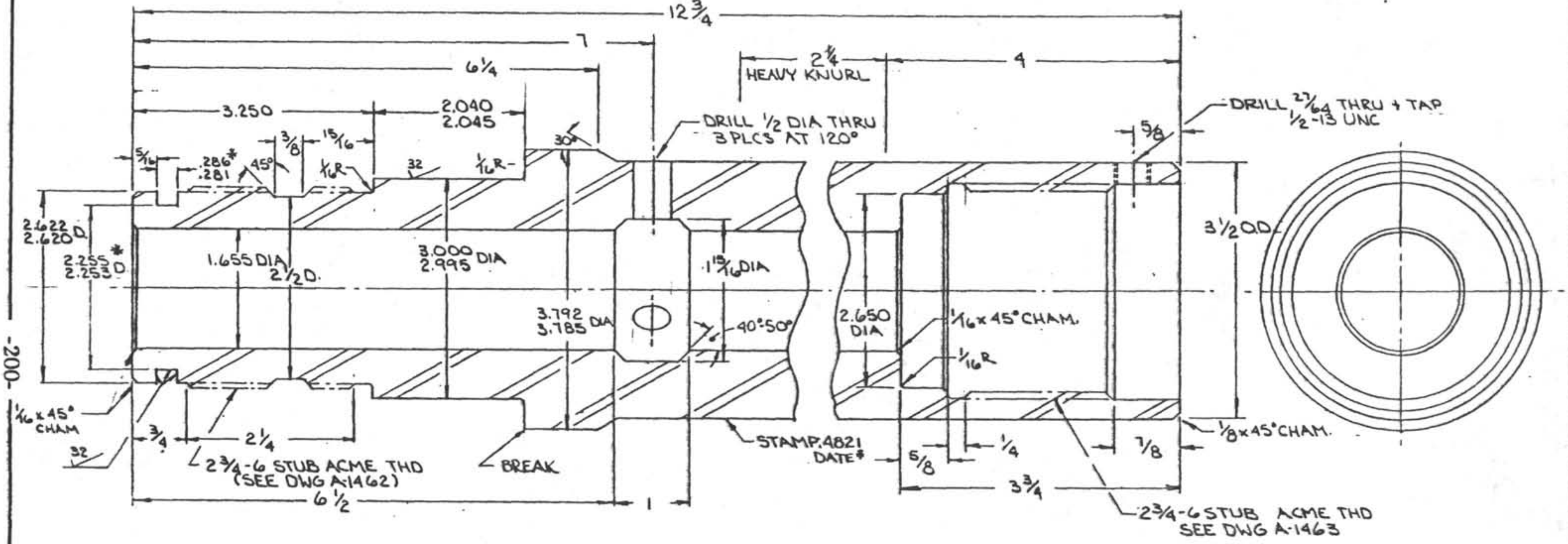
* FABRICATION DATE (MO. YR.) e.g. 0384 = MAR 84

DO NOT SCALE

CONCENTRICITY ALL DIAMETERS: TIR .003

TOLERANCES UNLESS NOTED FRACTIONS ± 1/64 DECIMALS ± .005 ANGLES ± 1/2° CORNERS 1/64 x 45° or 1/64 R FINISH 125	DEEP SEA DRILLING PROJECT SCRIPPS INSTITUTION OF OCEANOGRAPHY UNIVERSITY OF CALIFORNIA, SAN DIEGO LA JOLLA, CALIFORNIA 92093				
	TITLE: CENTER PISTON ROD ~ A.P.C – MOD II ~				
SURFACE TREATMENT: —⊖—	MATERIAL: 15-5PH VAR	DATE: 2-28-84	BY: RK	CHECKED	APPROVED: DPH 3/84
HEAT TREATMENT: H 1025	SCALE: 1:1	REQ'D/ASS'Y: 1	PART NO.: OP4818	DWG. NO. (REV.): B-OP4818	


REVISIONS
NO.
DESCRIPTION
DATE
BY
CH.
APR.
11'-7 3/8" (REF)
11'-4 7/8"
2 1/2
22
10
UNDERCUT FOR TOOL RUNOUT.
1 1/8-8 STUB ACME THD FOR DETAILS SEE BOX DWG #C-OP4816
A
1-1 1/4 RUN-OUT
5 3/4
1.820
3/16
15/16
7/32
.875 DIA
32
3/4 (TYP) RUNOUT
STAMP: OP4819 DATE*
1.628 1.622 DIA
1.250 DIA MIN.
7/64 R
1.125 1.122 D.
1/16 x 45° CHAM.
1 3/8-8 STUB ACME THD (SEE DWG A-1643)
** ANTI-SPIRAL GROOVE
60°
.460
1/16 R
.200
.200
1/32 R
.200
3/16 R (TYP)
.200
BYPASS FLATS
SEC A-A
REQUIRED FAB. SEQUENCE
** 1. LOCATE ANTI-SPIRAL GROOVE USING 1 1/8-8 STUB ACME THREAD GAGE: OD 0408.
2. LOCATE BYPASS FLATS RELATIVE TO ANTI-SPIRAL GROOVE.
* FAB. DATE (MO. YR) eg. 0384 = MAR'84
DO NOT SCALE
CONCENTRICITY ALL DIAMETERS: TIR .003
TOLERANCES UNLESS NOTED
FRACTIONS ± 1/64
DECIMALS ± .005
ANGLES ± 1/2°
CORNERS 1/64 x 45° or 1/64 R
FINISH 125
DEEP SEA DRILLING PROJECT
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UNIVERSITY OF CALIFORNIA, SAN DIEGO
LA JOLLA, CALIFORNIA 92093
TITLE
LOWER PISTON ROD ~APC - MOD II~
SURFACE TREATMENT
MATERIAL 15-5 PH VAR
DATE 2-24-84
BY RK
CHECKED
APPROVED DPH 3/84
HEAT TREATMENT H1025
SCALE 1:0
REQ'D/ASS'Y 1
PART NO. OP4819
DWG. NO. B-OP4819
(REV.)



*FOR O-RING *2-331 (OD 2331)

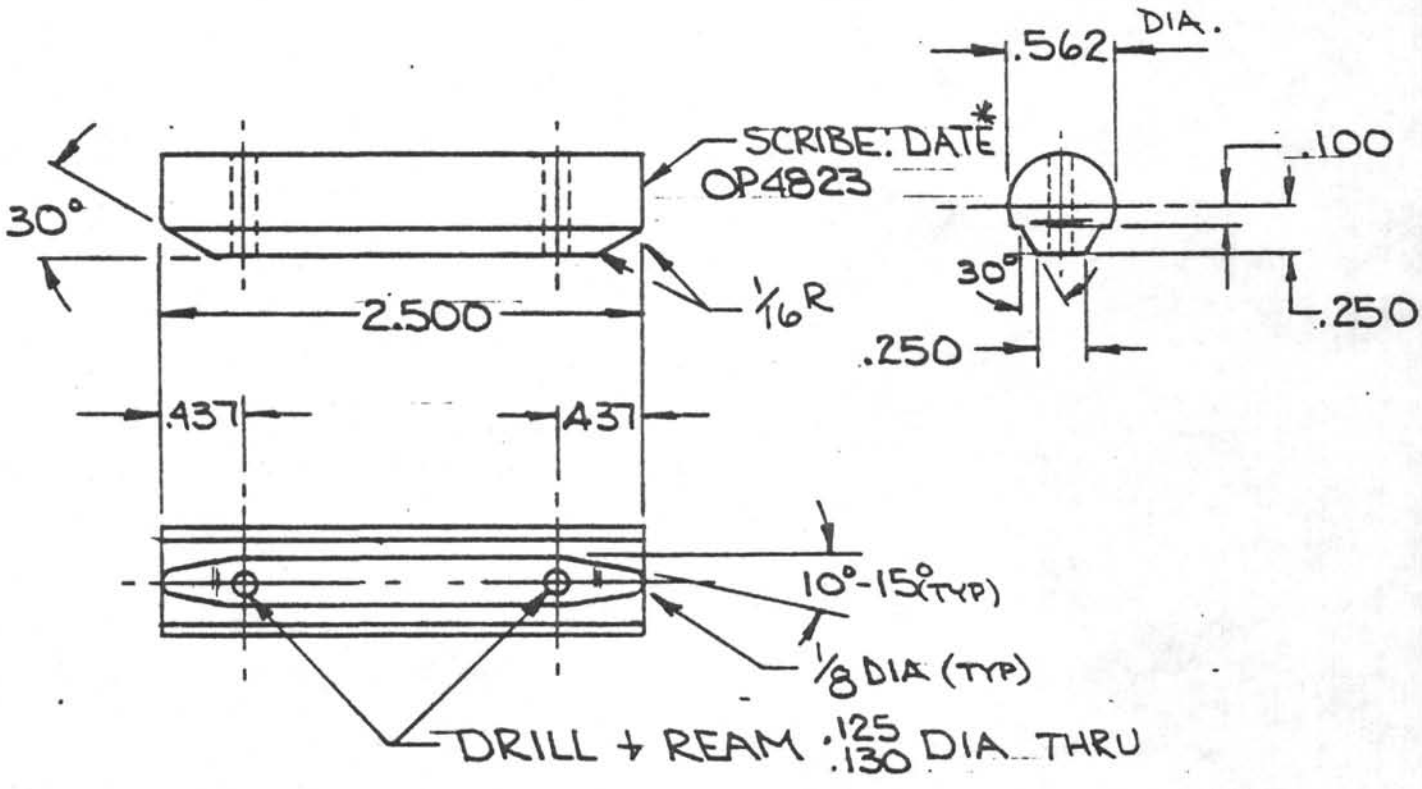
*FABRICATION DATE (MO. YR.) e.g. 0384 = MAR '84

-200-

TOLERANCES UNLESS NOTED	DEEP SEA DRILLING PROJECT SCRIPPS INSTITUTION OF OCEANOGRAPHY UNIVERSITY OF CALIFORNIA, SAN DIEGO LA JOLLA, CALIFORNIA 92093				
FRACTIONS ± 1/64 DECIMALS ± .005 ANGLES ± 1/2° CORNERS 1/64 x 45° or 1/64 R FINISH 125	TITLE: OUTER SEAL SUB ~A.P.C.-MOD II~				
SURFACE TREATMENT: PARKOLUBE	MATERIAL: 4130/4140	DRAWN BY: RK	DATE	CHECKED	APPROVED: DRH 3/84
HEAT TREATMENT: Rc 34-36	PART NO.: OP4821	SIZE DWG. NO.: C-OP4821			REV.

REVISIONS					
NO.	DESCRIPTION	DATE	BY	CH.	APR.

REVISIONS					
NO.	DESCRIPTION	DATE	BY	CH.	APR.

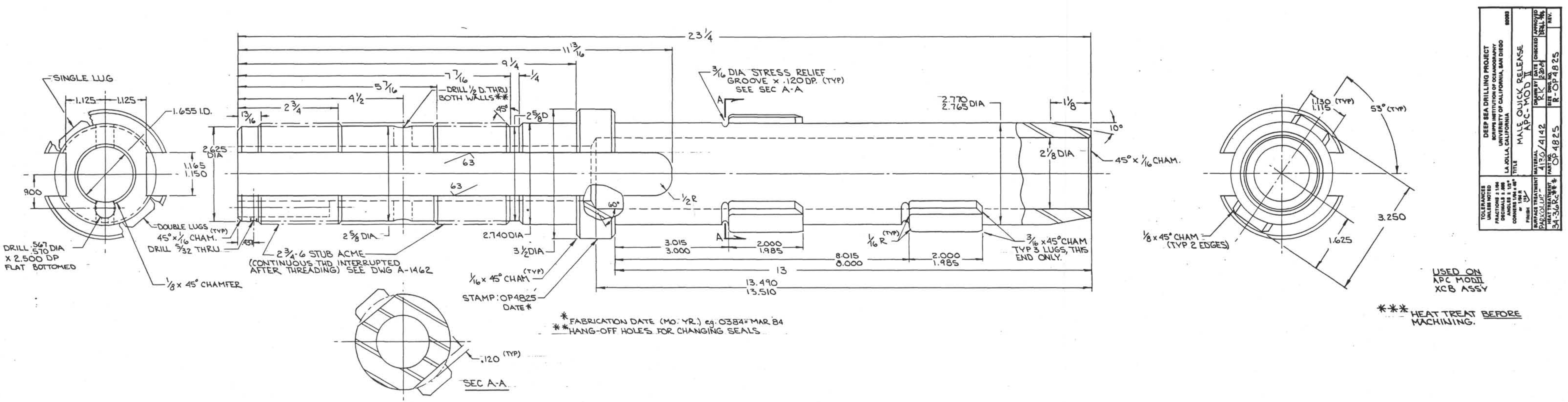


*FAB. DATE (MO. YR) eg. 0384 = MAR'84

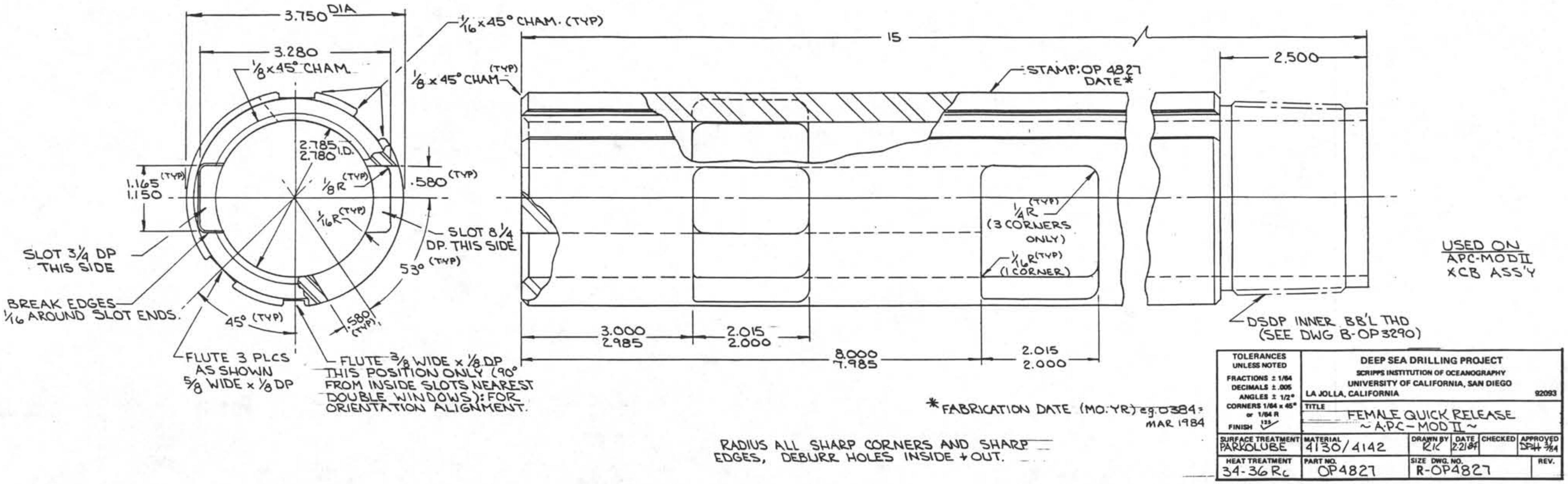
DO NOT SCALE

CONCENTRICITY ALL DIAMETERS: TIR .003

TOLERANCES UNLESS NOTED FRACTIONS ± 1/64 DECIMALS ± .005 ANGLES ± 1/2° CORNERS 1/64 x 45° or 1/64 R FINISH 125	DEEP SEA DRILLING PROJECT SCRIPPS INSTITUTION OF OCEANOGRAPHY UNIVERSITY OF CALIFORNIA, SAN DIEGO LA JOLLA, CALIFORNIA 92093					
	TITLE ANTI-SPIRAL KEY ~APC-MOD II~					
SURFACE TREATMENT	MATERIAL NITRONIC 60		DATE 2.17.84	BY RK	CHECKED DPH	APPROVED DPH
HEAT TREATMENT	SCALE 1:1	REQ'D/ASS'Y 1	PART NO. OP4823		DWG. NO. A-OP4823	(REV.)

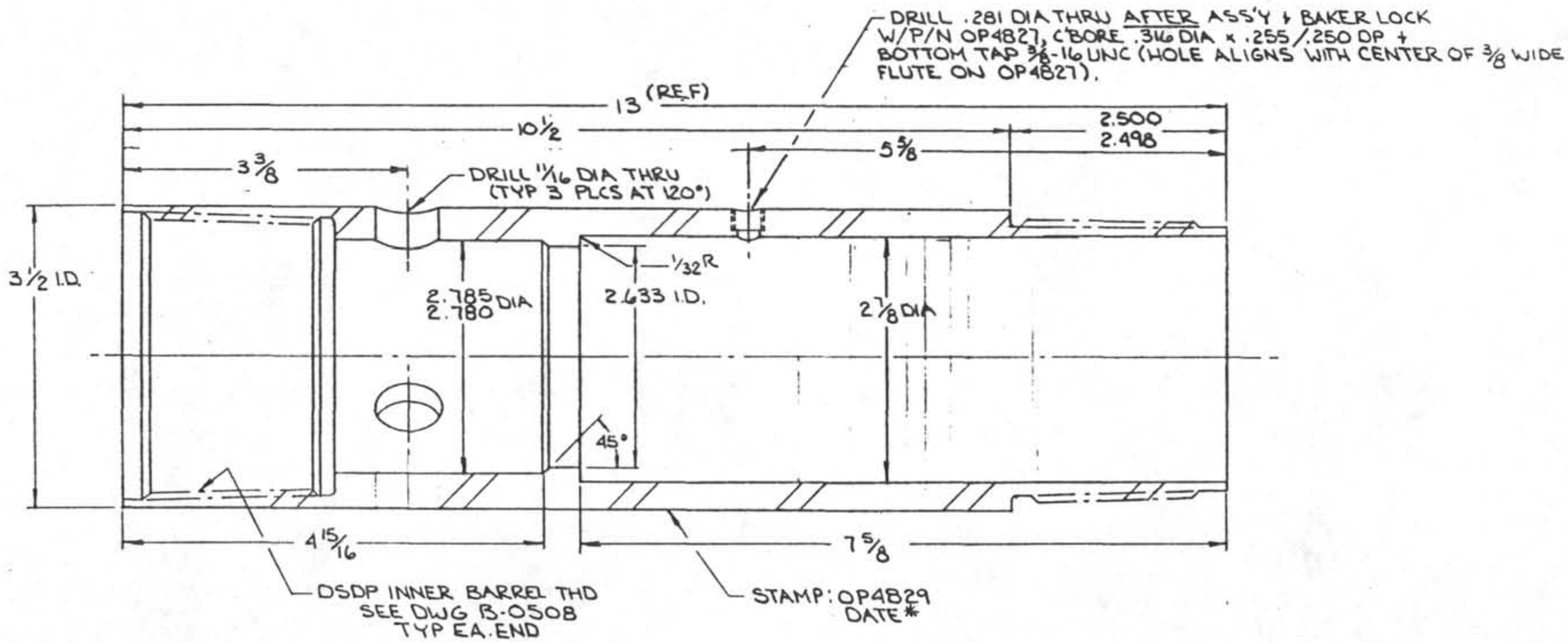


SINGLE LUG
1.125
1.125
1.655 I.D.
2.625 DIA
1.165
1.150
.900
DOUBLE LUGS (TYP)
45° x 1/16 CHAM.
DRILL 5/32 THRU
DRILL .567 .570 DIA
X 2.500 DP
FLAT BOTTOMED
1/8 x 45° CHAMFER
23 1/4
11 13/16
9 1/4
7 7/16
5 7/16
4 1/2
2 3/4
13/16
1/4
DRILL 1/2 D. THRU
BOTH WALLS **
45°
2 5/8 D
63
2 5/8 DIA
2 3/4-6 STUB ACME
(CONTINUOUS THD INTERRUPTED AFTER THREADING) SEE DWG A-1462
2.740 DIA
3 1/2 DIA
1/16 x 45° CHAM (TYP)
STAMP: OP4825 DATE *
60°
1/2 R
3/16 DIA STRESS RELIEF
GROOVE x .120 DP. (TYP)
SEE SEC A-A
A
2.770
2.765 DIA
1 1/8
10°
2 1/8 DIA
45° x 1/16 CHAM.
3.015
3.000
2.000
1.985
8.015
8.000
2.000
1.985
1/16 R (TYP)
3/16 x 45° CHAM
TYP 3 LUGS, THIS END ONLY.
13
13.490
13.510
.120 (TYP)
SEC A-A
* FABRICATION DATE (MO. YR.) eg. 0384 = MAR 84
** HANG-OFF HOLES FOR CHANGING SEALS
1.130
1.115 (TYP)
53° (TYP)
3.250
1.625
1/8 x 45° CHAM
(TYP 2 EDGES)
USED ON
APC MOD II
XCB ASSY
*** HEAT TREAT BEFORE MACHINING.
TOLERANCES UNLESS NOTED
DEEP SEA DRILLING PROJECT
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UNIVERSITY OF CALIFORNIA, SAN DIEGO
LA JOLLA, CALIFORNIA
MALE QUICK RELEASE
APC-MOD II
MATERIAL 4130/4142
PART NO. OP4825
R-OP4825
PARKOLUP
34-36Rc***



3.750 DIA
3.280
1/8 x 45° CHAM.
1/16 x 45° CHAM. (TYP)
1/8 x 45° CHAM (TYP)
2.785
2.780 I.D.
1/8 R (TYP)
.580 (TYP)
1.165 (TYP)
1.150
1/16 R (TYP)
SLOT 8 1/4 DP. THIS SIDE
53° (TYP)
SLOT 3/4 DP THIS SIDE
BREAK EDGES 1/16 AROUND SLOT ENDS.
45° (TYP)
.580 (TYP)
FLUTE 3 PLCS AS SHOWN 5/8 WIDE x 1/8 DP
FLUTE 3/8 WIDE x 1/8 DP THIS POSITION ONLY (90° FROM INSIDE SLOTS NEAREST DOUBLE WINDOWS): FOR ORIENTATION ALIGNMENT.
15
2.500
STAMP: OP 4827 DATE*
1/4 R (TYP) (3 CORNERS ONLY)
1/16 R (TYP) (1 CORNER)
3.000
2.985
2.015
2.000
8.000
7.985
2.015
2.000
DSDP INNER BB'L THD (SEE DWG B-OP3290)
USED ON APC-MOD II XCB ASS'Y
*FABRICATION DATE (MO. YR) eg. 0384 = MAR 1984
RADIUS ALL SHARP CORNERS AND SHARP EDGES, DEBURR HOLES INSIDE + OUT.
TOLERANCES UNLESS NOTED
FRACTIONS ± 1/64
DECIMALS ± .005
ANGLES ± 1/2°
CORNERS 1/64 x 45° or 1/64 R
FINISH 125
DEEP SEA DRILLING PROJECT
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UNIVERSITY OF CALIFORNIA, SAN DIEGO
LA JOLLA, CALIFORNIA 92093
TITLE
FEMALE QUICK RELEASE ~ A.P.C - MOD II ~
SURFACE TREATMENT PARKOLUBE
MATERIAL 4130/4142
DRAWN BY RK
DATE 2-21-84
CHECKED
APPROVED
HEAT TREATMENT 34-36 Rc
PART NO. OP4827
SIZE DWG. NO. R-OP4827
REV.

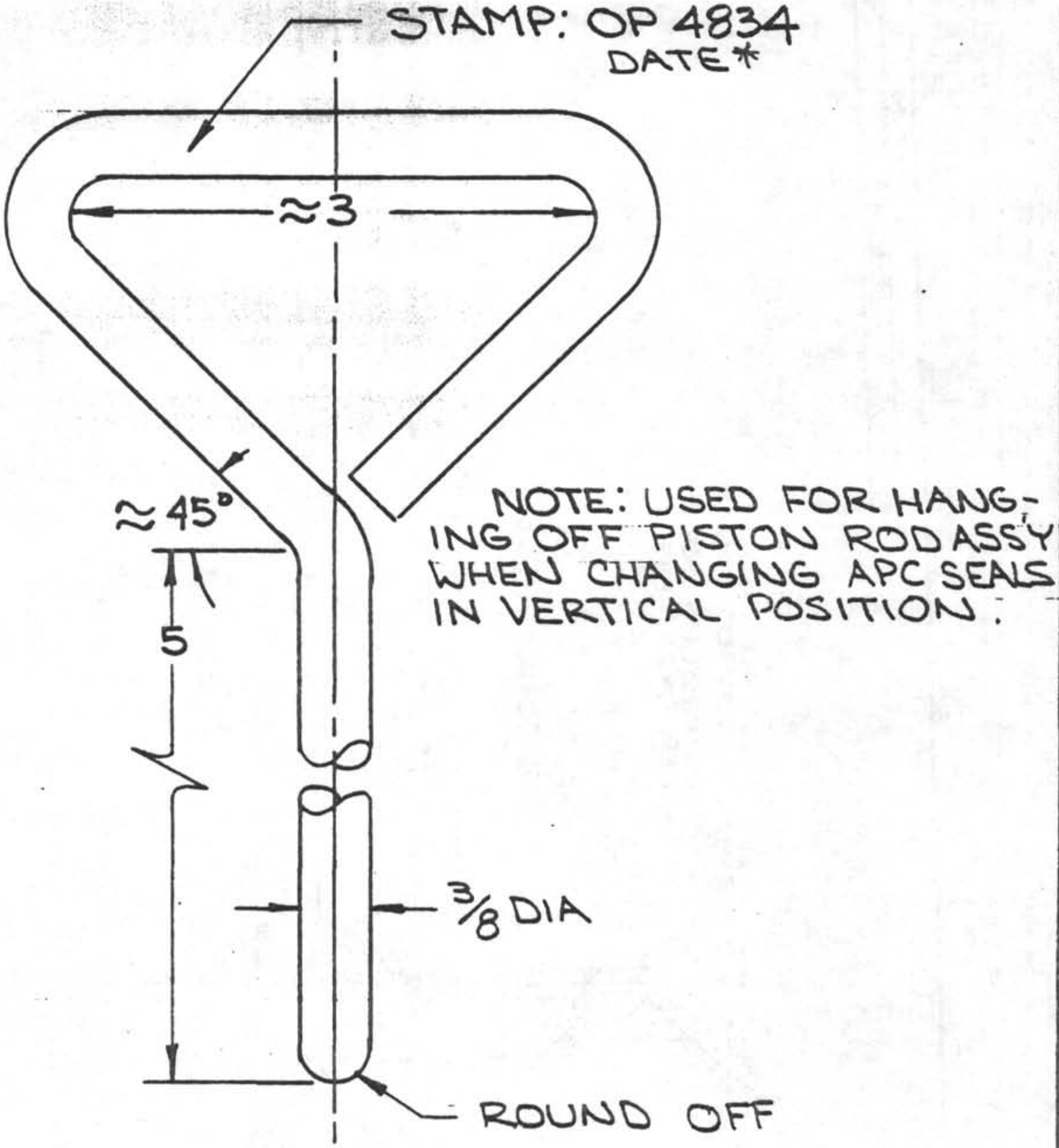
REVISIONS					
NO.	DESCRIPTION	DATE	BY	CH.	APR.



* FABRICATION DATE (MO. YR) eg. 0384 = MAR '84

TOLERANCES UNLESS NOTED FRACTIONS ± 1/64 DECIMALS ± .005 ANGLES ± 1/2° CORNERS 1/64 x 45° or 1/64 R FINISH 125	DEEP SEA DRILLING PROJECT SCRIPPS INSTITUTION OF OCEANOGRAPHY UNIVERSITY OF CALIFORNIA, SAN DIEGO LA JOLLA, CALIFORNIA 92093 TITLE VENT SUB ~APC-MOD II~				
SURFACE TREATMENT PARKOLUBE	MATERIAL 4130/4140	DRAWN BY RK	DATE 2-2-84	CHECKED	APPROVED DPH 3/84
HEAT TREATMENT 34-36 Rc	PART NO. OP4829	SIZE DWG. NO. C-OP4829			REV.

REVISIONS					
NO.	DESCRIPTION	DATE	BY	CH.	APR.



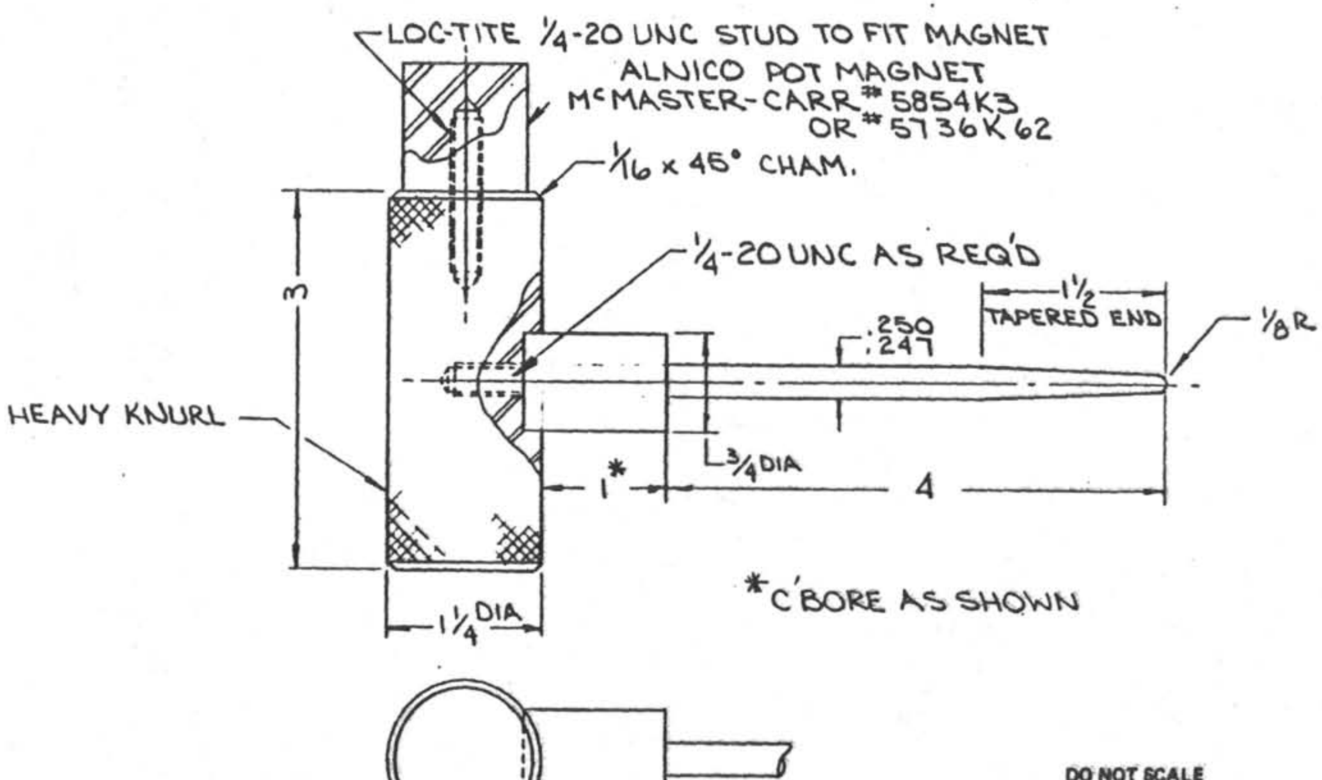
DO NOT SCALE

CONCENTRICITY ALL DIAMETERS: TIR .003

TOLERANCES UNLESS NOTED FRACTIONS ± 1/64 DECIMALS ± .005 ANGLES ± 1/2° CORNERS 1/64 x 45° or 1/64 R FINISH 125	DEEP SEA DRILLING PROJECT SCRIPPS INSTITUTION OF OCEANOGRAPHY UNIVERSITY OF CALIFORNIA, SAN DIEGO LA JOLLA, CALIFORNIA 92093 TITLE: HANG-OFF TOOL APC - MOD. II				
SURFACE TREATMENT	MATERIAL 300 S.S.	DATE 2-21-84	BY RK	CHECKED DPH	APPROVED DPH 3/84
HEAT TREATMENT	SCALE 1:1	REQ'D/ASS'Y 1	PART NO. OP 4834	DWG. NO. A-OP4834 (REV.)	

REVISIONS

NO.	DESCRIPTION	DATE	BY	CH.	APR.

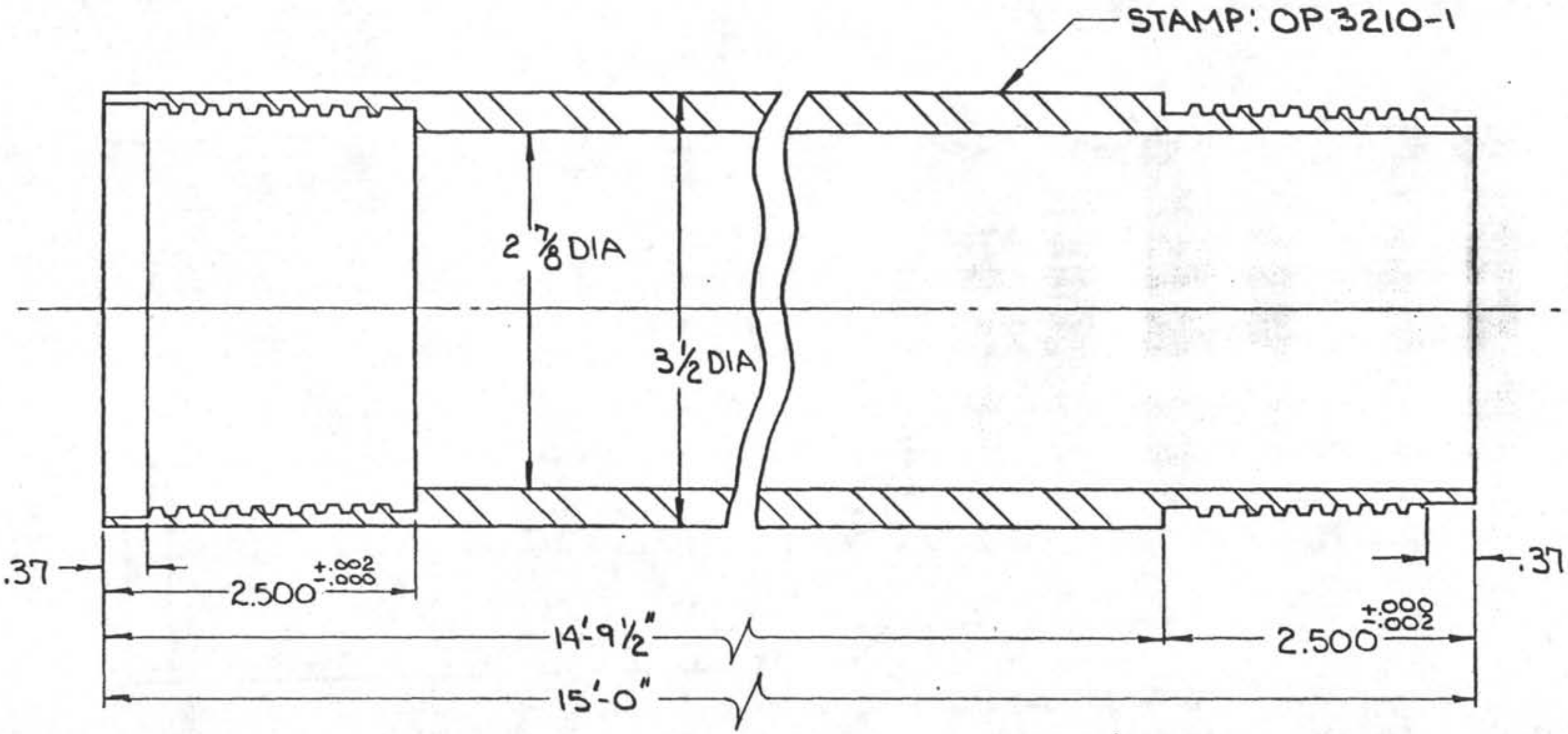


DO NOT SCALE

CONCENTRICITY ALL DIAMETERS: TIR .003

TOLERANCES UNLESS NOTED FRACTIONS ± 1/64 DECIMALS ± .005 ANGLES ± 1/2° CORNERS 1/64 x 45° or 1/64 R FINISH 125	DEEP SEA DRILLING PROJECT SCRIPPS INSTITUTION OF OCEANOGRAPHY UNIVERSITY OF CALIFORNIA, SAN DIEGO LA JOLLA, CALIFORNIA 92093				
	TITLE SHEAR PIN TOOL ~APC - MOD. II ~				
SURFACE TREATMENT —0—	MATERIAL 300 STAINLESS ST	DATE 3-14-84	BY RK	CHECKED	APPROVED DPH 3/84
HEAT TREATMENT —0—	SCALE 1:1	REQ'D/ASS'Y 1	PART NO. OP4836	DWG. NO. B-OP4836	(REV.)

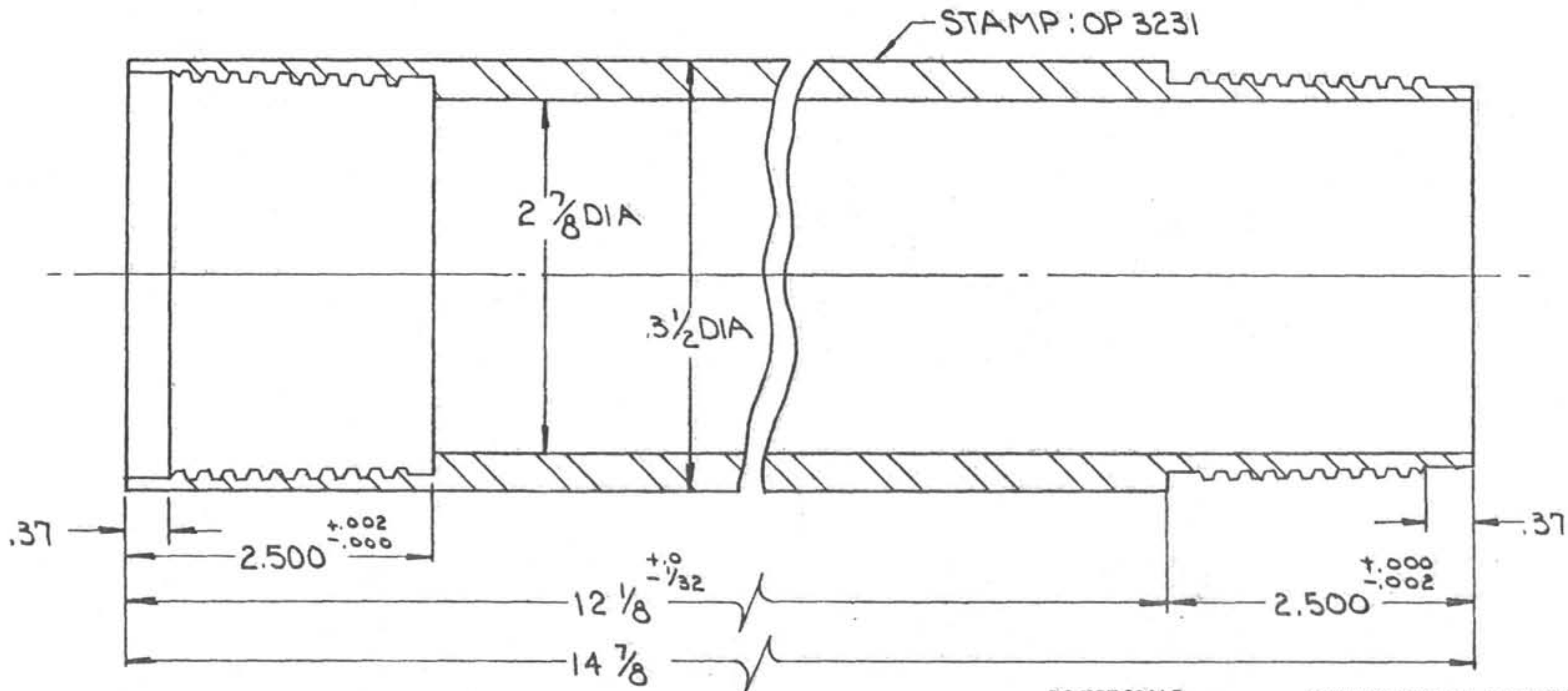
REVISIONS					
NO.	DESCRIPTION	DATE	BY	CH.	APR.
1	DWG NO. WAS B-WL-21	6·4·81	RK	[illegible]	[illegible]



DSDP INNER BARREL THDS
SEE DWG No. B-0508

TOLERANCES UNLESS NOTED	DEEP SEA DRILLING PROJECT. SCRIPPS INSTITUTION OF OCEANOGRAPHY UNIVERSITY OF CALIFORNIA, SAN DIEGO LA JOLLA, CALIFORNIA 92093				
FRACTIONS ± 1/64 DECIMALS ± .005 ANGLES ± 1/2° CORNERS 1/64 x 45° or 1/64 R FINISH 125	TITLE 14'-9 1/2" INNER CORE BB'L				
SURFACE TREATMENT	MATERIAL 4130 C.D.	DRAWN BY RK	DATE 6·4·81	CHECKED	APPROVED
HEAT TREATMENT	PART NO. OP 3210	SIZE DWG. NO. B - OP 3210			REV. 1

REVISIONS					
NO.	DESCRIPTION	DATE	BY	CH.	APR.
1	12 1/8 WAS 12 3/8	3·80	VFL	PT	V



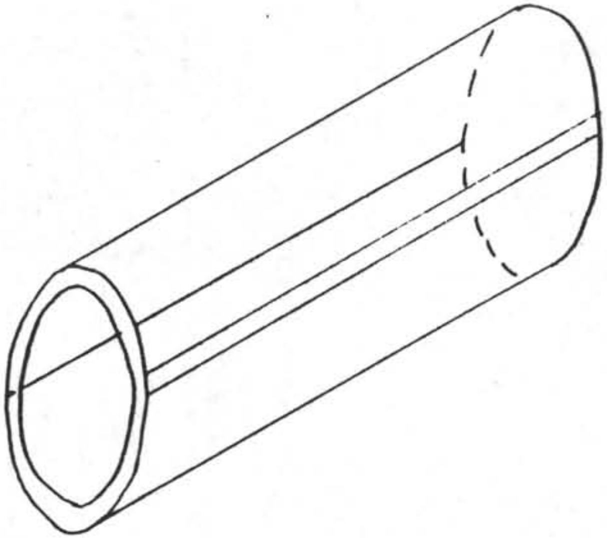
DSDP INNER BARREL THDS
SEE DWG No B-0508

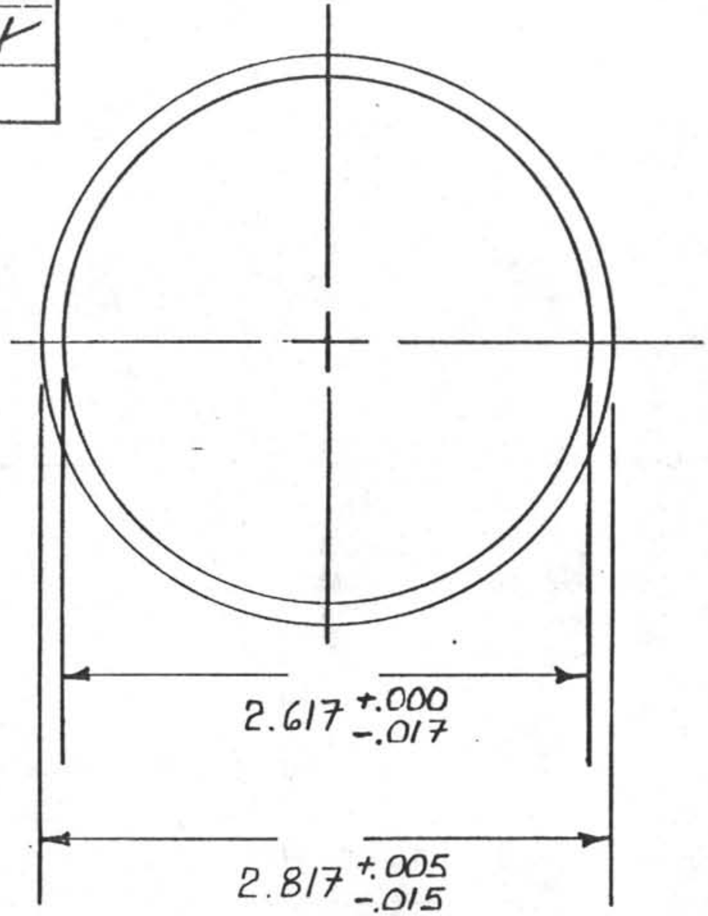
DO NOT SCALE

CONCENTRICITY ALL DIAMETERS: TIR .003

TOLERANCES UNLESS NOTED	DEEP SEA DRILLING PROJECT SCRIPPS INSTITUTION OF OCEANOGRAPHY UNIVERSITY OF CALIFORNIA, SAN DIEGO LA JOLLA, CALIFORNIA 92093				
FRACTIONS ± 1/64 DECIMALS ± .005 ANGLES ± 1/2° CORNERS 1/64 x 45° or 1/64 R FINISH 125	TITLE 12 1/8 IN. INNER BBL SUB ~4 CONE T/O BIT~				
SURFACE TREATMENT —	MATERIAL 4130 C.D.	DATE 4-2-76	BY RK(PT)	CHECKED	APPROVED
HEAT TREATMENT —	SCALE 1:1	REQ'D/ASS'Y	PART NO. OP 3231 - 1	DWG. NO. (REV.) B-OP3231-1	

No.	DESCRIPTION	DATE	BY	APR.
1	H.P.C. NOTE ADDED, 3/4 WAS 2.76	11-27-78	RK	[signature]
2	DELETE H.P.C. NOTE	11-11-80	RK	





MATERIAL: CLEAR BUTYRATE PLASTIC

NOTE: COLOR LINER ON QTR.
ONE DOUBLE - THREE SINGLE
1/16" WIDE LINES
- NO PROTUBERANCE AT CORE LINER SURFACE -

MINIMUM WALL: 0.092"
CONCENTRICITY WITHIN .050"

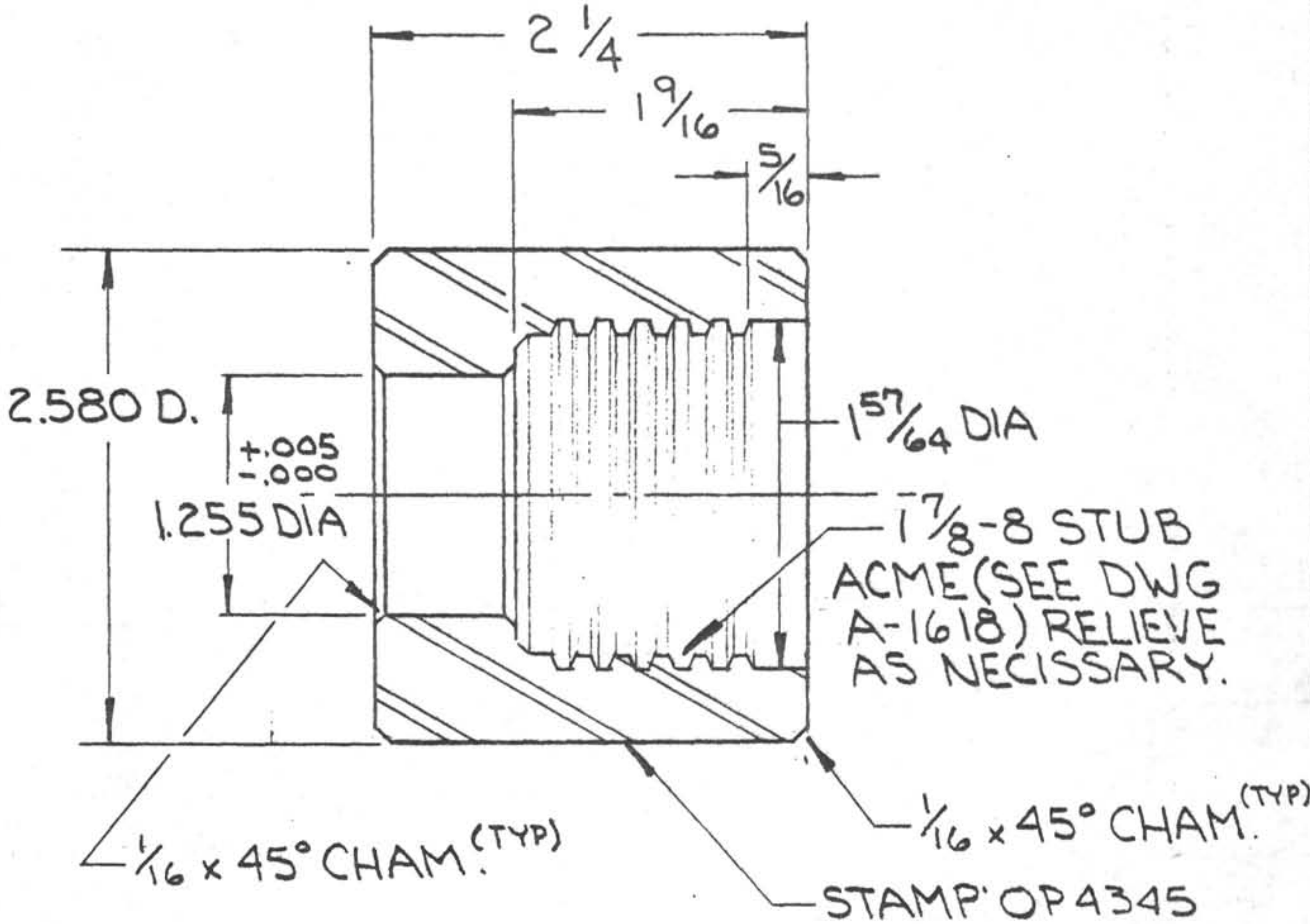
DSDP STANDARD CORE LINER

SCALE: NONE
DATE: 15 OCT. 74
APPROVED BY: [signature] 10/4
DRAWN BY [signature]
REVISED [signature]

SKETCH No. 1 PART No. OP 3400-2

FOR USE IN 3 1/2" INNER C'BBL.
DRAWING NUMBER A-OP3400-2

NO.	REVISIONS DESCRIPTION	DATE	BY	CH.	APR.

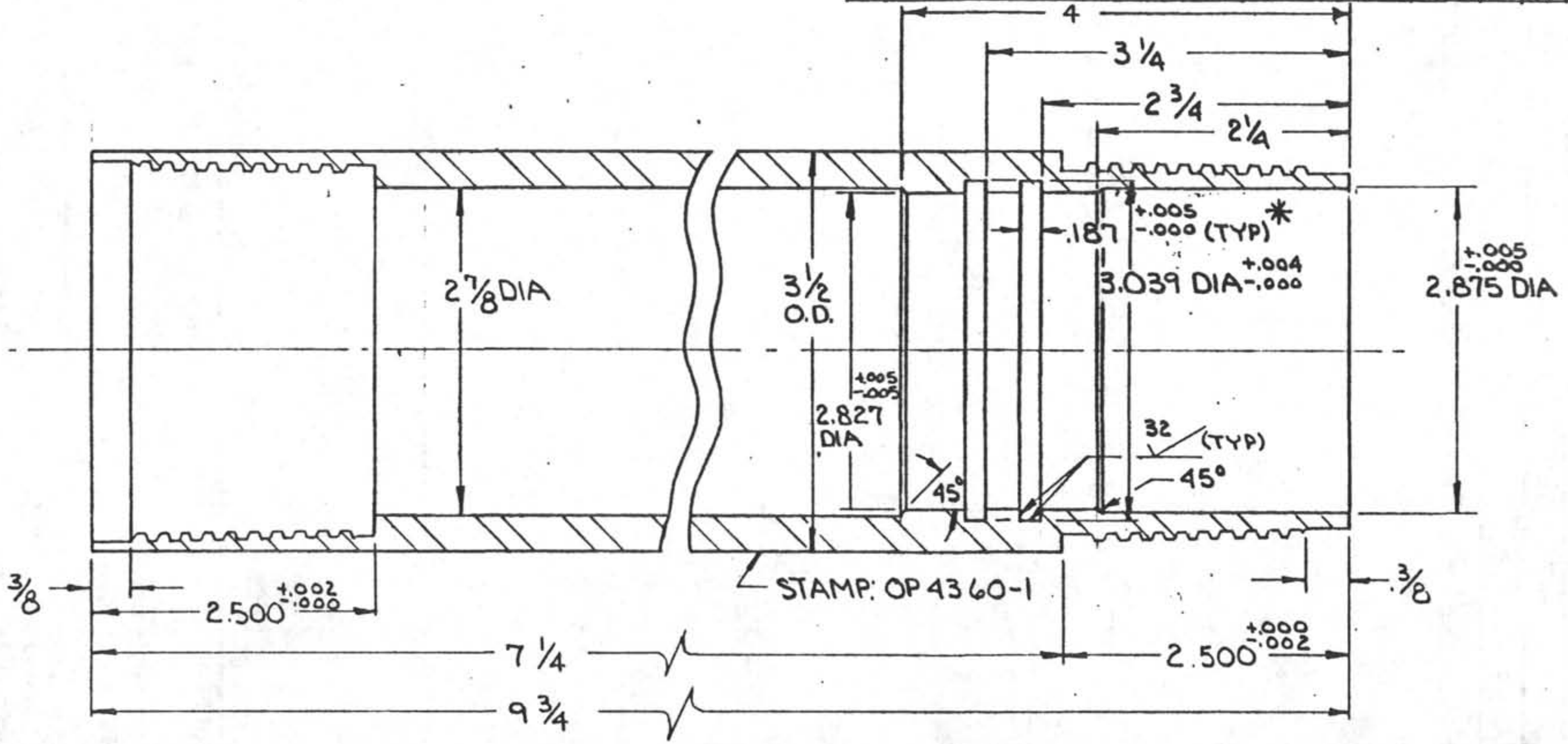


DO NOT SCALE CONCENTRICITY ALL DIAMETERS: TIR .003

TOLERANCES UNLESS NOTED. FRACTIONS ± 1/64 DECIMALS ± .005 ANGLES ± 1/2° CORNERS 1/64 x 45° or 1/64 R FINISH 125	DEEP SEA DRILLING PROJECT SCRIPPS INSTITUTION OF OCEANOGRAPHY UNIVERSITY OF CALIFORNIA, SAN DIEGO LA JOLLA, CALIFORNIA 92093 TITLE PISTON SEAL RETAINER ~VLHPC~			
SURFACE TREATMENT PARKOLUBRITE	MATERIAL 4130 STEEL	DATE 10-8-80	BY RK	CHECKED / APPROVED
HEAT TREATMENT Rc 28-32	SCALE 1:1 / REQ'D/ASS'Y ONE	PART NO. OP 4345		DWG. NO. A-OP4345 (REV.)

REVISIONS

NO.	DESCRIPTION	DATE	BY	CH.	APR.
1	O-RING# 2-232 WAS 2.335 (1 PLC)	12-12-31	RK	[illegible]	[illegible]



* FOR O-RING # 2-232
** DSDP INNER BBL THDS
SEE DWG B-0508

DO NOT SCALE

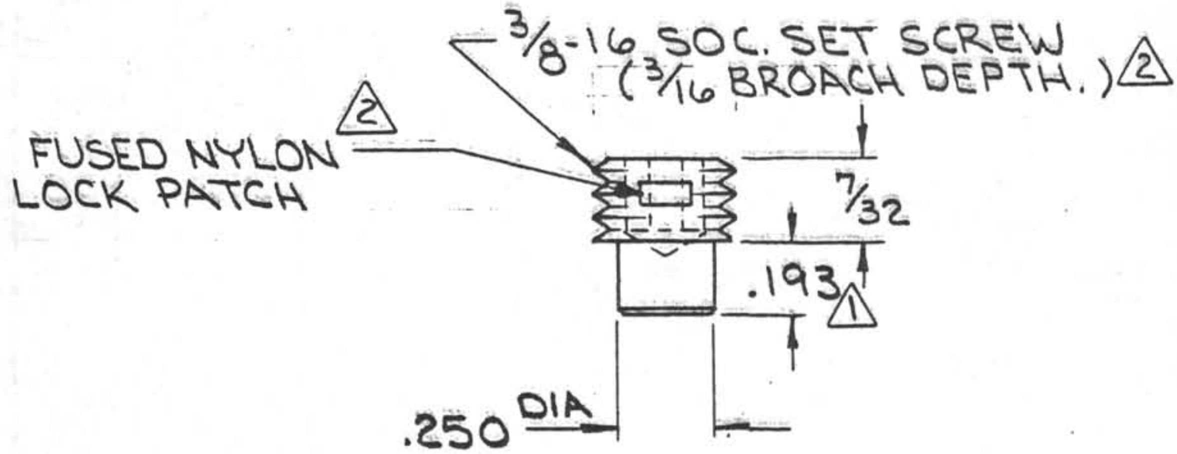
CONCENTRICITY ALL DIAMETERS: TIR .003

TOLERANCES UNLESS NOTED	DEEP SEA DRILLING PROJECT SCRIPPS INSTITUTION OF OCEANOGRAPHY UNIVERSITY OF CALIFORNIA, SAN DIEGO LA JOLLA, CALIFORNIA 92093
FRACTIONS ± 1/64 DECIMALS ± .005 ANGLES ± 1/2° CORNERS 1/64 x 45° or 1/64 R FINISH 125	TITLE LOWER LINER SEAL SUB VL HPC

SURFACE TREATMENT	MATERIAL	DATE	BY	CHECKED	APPROVED
PARKOLUBE	4130 C.D.	11-2-80	RK	[illegible]	[illegible]

HEAT TREATMENT	SCALE	REQ'D/ASS'Y	PART NO.	DWG. NO.	(REV.)
	1:1	1	OP4360-1	B-OP4360-	1

REVISIONS					
NO.	DESCRIPTION	DATE	BY	CH.	APR.
1	.193 WAS .1985	7·12·82	RK		
2	WAS NYLOC SC. ADD. 3/16 BROACH, LOCK PATCH	1·24·83	RK		



DO NOT SCALE

CONCENTRICITY ALL DIAMETERS: TIR .003

TOLERANCES UNLESS NOTED
FRACTIONS ± 1/64
DECIMALS ± .005
ANGLES ± 1/2°
CORNERS 1/64 x 45° or 1/64 R
FINISH 125

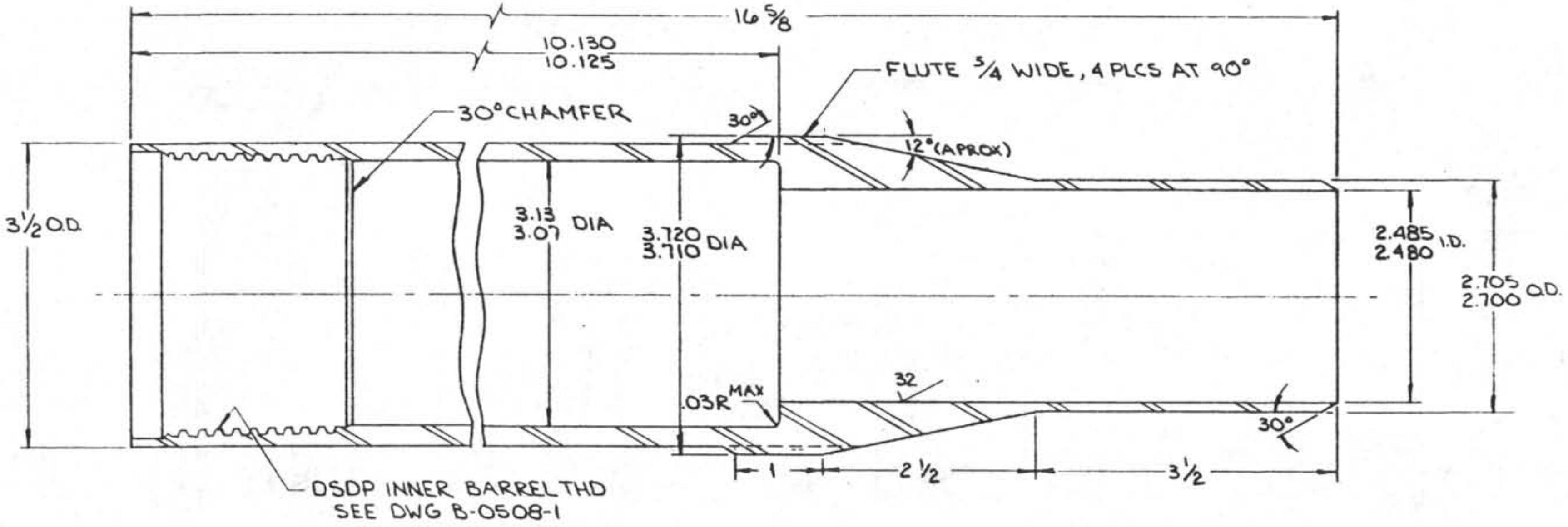
DEEP SEA DRILLING PROJECT
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UNIVERSITY OF CALIFORNIA, SAN DIEGO
LA JOLLA, CALIFORNIA 92093

TITLE: UPPER LINER SEAL SUB RETAINER SCREW ~ VLHPC

SURFACE TREATMENT	MATERIAL	DATE	BY	CHECKED	APPROVED
	ALLOY STEEL	3-12-81	RK		

HEAT TREATMENT	SCALE	REQ'D/ASS'Y	PART NO.	DWG. NO. (REV.)
	2:1	ONE	OP4361-2	A-OP4361-2

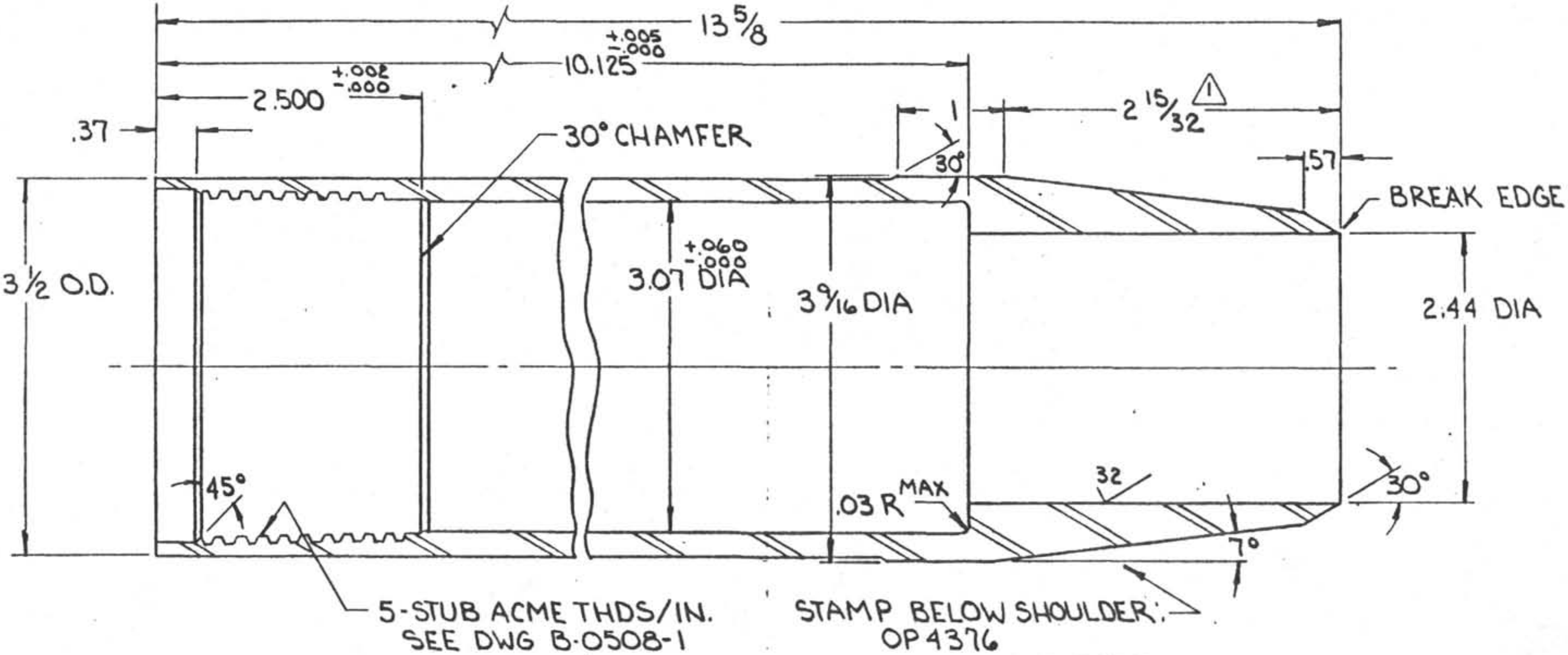
REVISIONS					
NO.	DESCRIPTION	DATE	BY	CH.	APR.



YIELD 167,000 PSI
IZOD 38 FT LBS

TOLERANCES UNLESS NOTED	DEEP SEA DRILLING PROJECT SCRIPPS INSTITUTION OF OCEANOGRAPHY UNIVERSITY OF CALIFORNIA, SAN DIEGO LA JOLLA, CALIFORNIA 92093				
FRACTIONS ± 1/64 DECIMALS ± .005 ANGLES ± 1/2° CORNERS 1/64 x 45° or 1/64 R FINISH 125	TITLE 3.7 SLIM NOSE CATCHER SUB ~VLHPC~				
SURFACE TREATMENT PARKOLUBE	MATERIAL 4140 STEEL	DRAWN BY RK	DATE 10-26-83	CHECKED	APPROVED
HEAT TREATMENT 38-40 Rc	PART NO. OP4362	SIZE DWG NO. C-OP4362 -			REV. 0

REVISIONS					
NO.	DESCRIPTION	DATE	BY	CH.	APR.
1	ADDED 2 15/32	10·15·81	RK	[illegible]	[illegible]



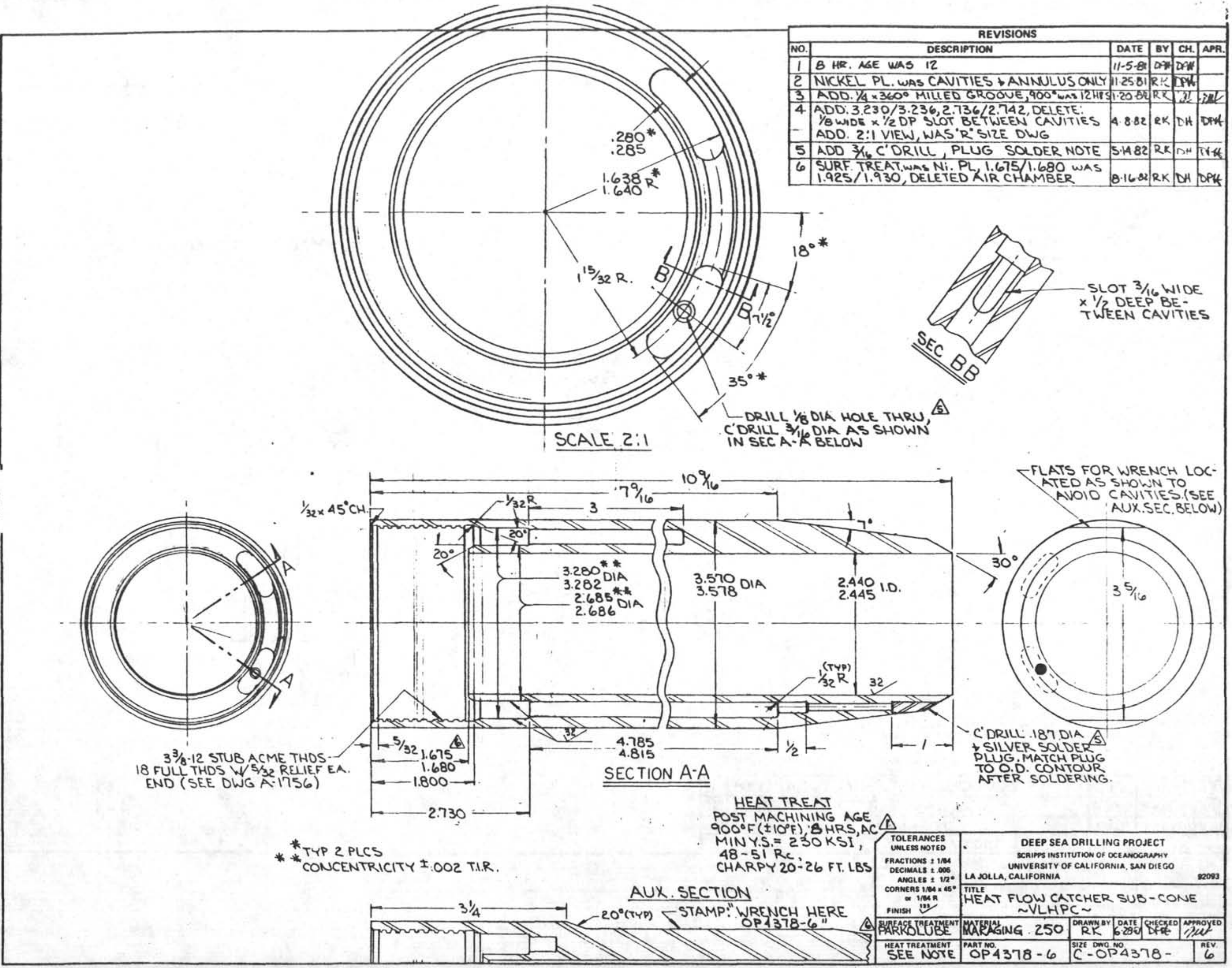
HEAT TREAT 38-40 Rc
YIELD 167,000 PSI
IZOD 38 FT LBS

NOTE:
BREAK ALL SHARP EDGES
RADIUS ALL INSIDE CORNERS

DO NOT SCALE

CONCENTRICITY ALL DIAMETERS: TIR .003

TOLERANCES UNLESS NOTED FRACTIONS ± 1/64 DECIMALS ± .005 ANGLES ± 1/2° CORNERS 1/64 x 45° or 1/64 R FINISH 125	DEEP SEA DRILLING PROJECT SCRIPPS INSTITUTION OF OCEANOGRAPHY UNIVERSITY OF CALIFORNIA, SAN DIEGO LA JOLLA, CALIFORNIA 92093 TITLE CATCHER SUB ~VLHPC~					
SURFACE TREATMENT PARKOLUBE	MATERIAL 4140 STEEL		DATE 11·2·80	BY RK	CHECKED [illegible]	APPROVED [illegible]
HEAT TREATMENT SEE ABOVE	SCALE 1:1	REQ'D/ASS'Y 1	PART NO. OP4376 - 0		DWG. NO. B30P4376 - 1	(REV.)



REVISIONS

NO.	DESCRIPTION	DATE	BY	CH.	APR.
1	8 HR. AGE WAS 12	11-5-81	DPH	DPH	
2	NICKEL PL. WAS CAVITIES & ANNULUS ONLY	11-25-81	RK	DPH	
3	ADD. 1/4 x 360° MILLED GROOVE, 900° WAS 12 HRS	1-20-82	RK	JL	DPH
4	ADD. 3.230/3.236, 2.736/2.742, DELETE: 1/8 WIDE x 1/2 DP SLOT BETWEEN CAVITIES ADD. 2:1 VIEW, WAS 'R' SIZE DWG	4-8-82	RK	DH	DPH
5	ADD 3/16 C'DRILL, PLUG SOLDER NOTE	5-14-82	RK	DH	DPH
6	SURF. TREAT. WAS Ni. PL, 1.675/1.680 WAS 1.925/1.930, DELETED AIR CHAMBER	8-16-82	RK	DH	DPH

HEAT TREAT
POST MACHINING AGE 900°F (±10°F), 8 HRS, AC
MIN Y.S.= 230 KSI,
48-51 Rc.
CHARPY 20-26 FT. LBS

* TYP 2 PLCS
** CONCENTRICITY ±.002 T.I.R.

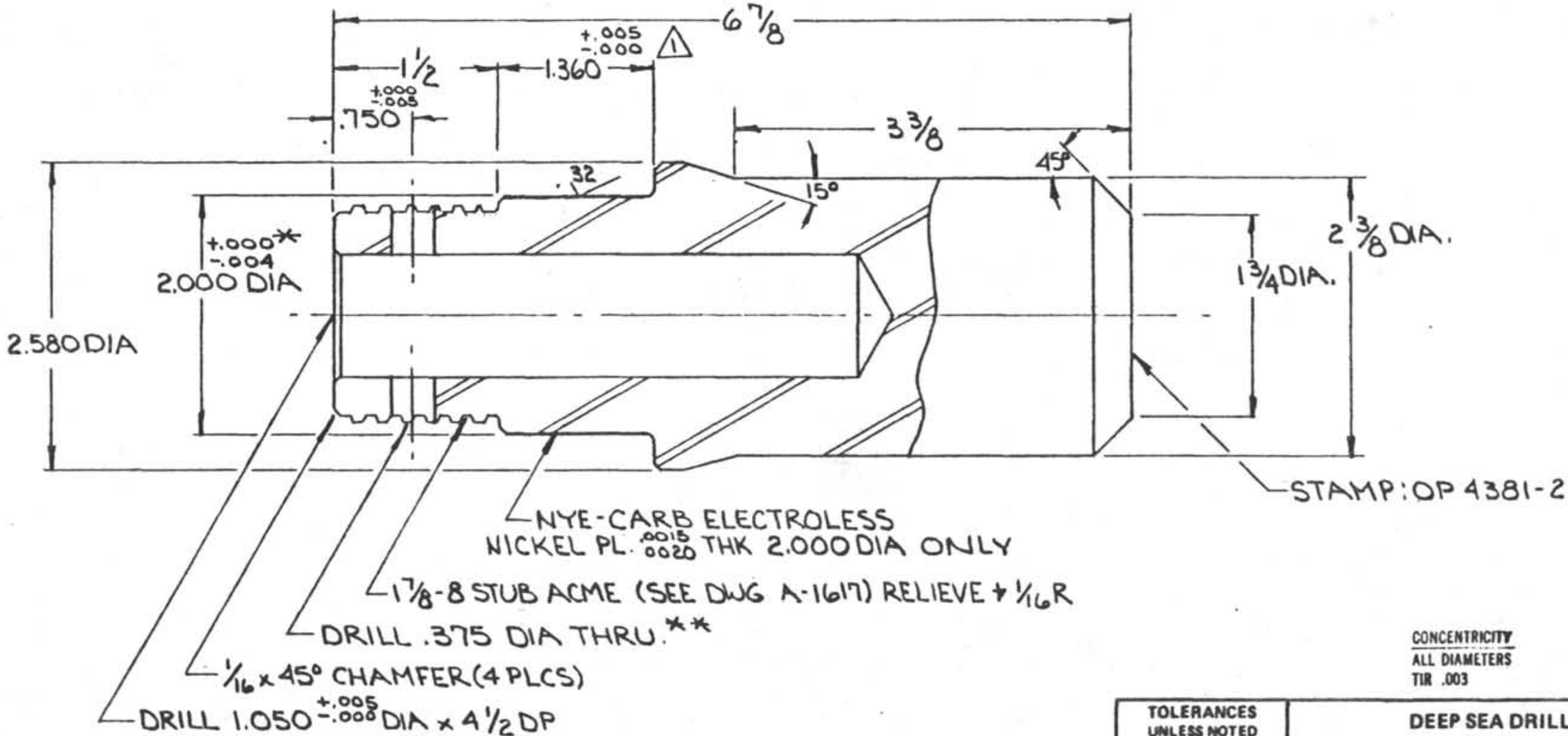
TOLERANCES UNLESS NOTED
FRACTIONS ± 1/64
DECIMALS ± .005
ANGLES ± 1/2°
CORNERS 1/64 x 45° or 1/64 R
FINISH 125

DEEP SEA DRILLING PROJECT
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UNIVERSITY OF CALIFORNIA, SAN DIEGO
LA JOLLA, CALIFORNIA 92093

TITLE: HEAT FLOW CATCHER SUB-CONE ~VLHPC~

SURFACE TREATMENT: PARKOLUBE
MATERIAL: MARAGING 250
DRAWN BY: RK | DATE: 6-28-81 | CHECKED: DPH | APPROVED: DPH
HEAT TREATMENT: SEE NOTE
PART NO.: OP4378-6
SIZE DWG NO.: C-OP4378-
REV.: 6

REVISIONS					
NO.	DESCRIPTION	DATE	BY	CH.	APR.
1	1.360 WAS 1.115, 2½ WAS 4.250	11-20-81	RK		
2	REDRAWN COMBINING OP4385	4-3-81	RK		



CONCENTRICITY
ALL DIAMETERS
TIR .003

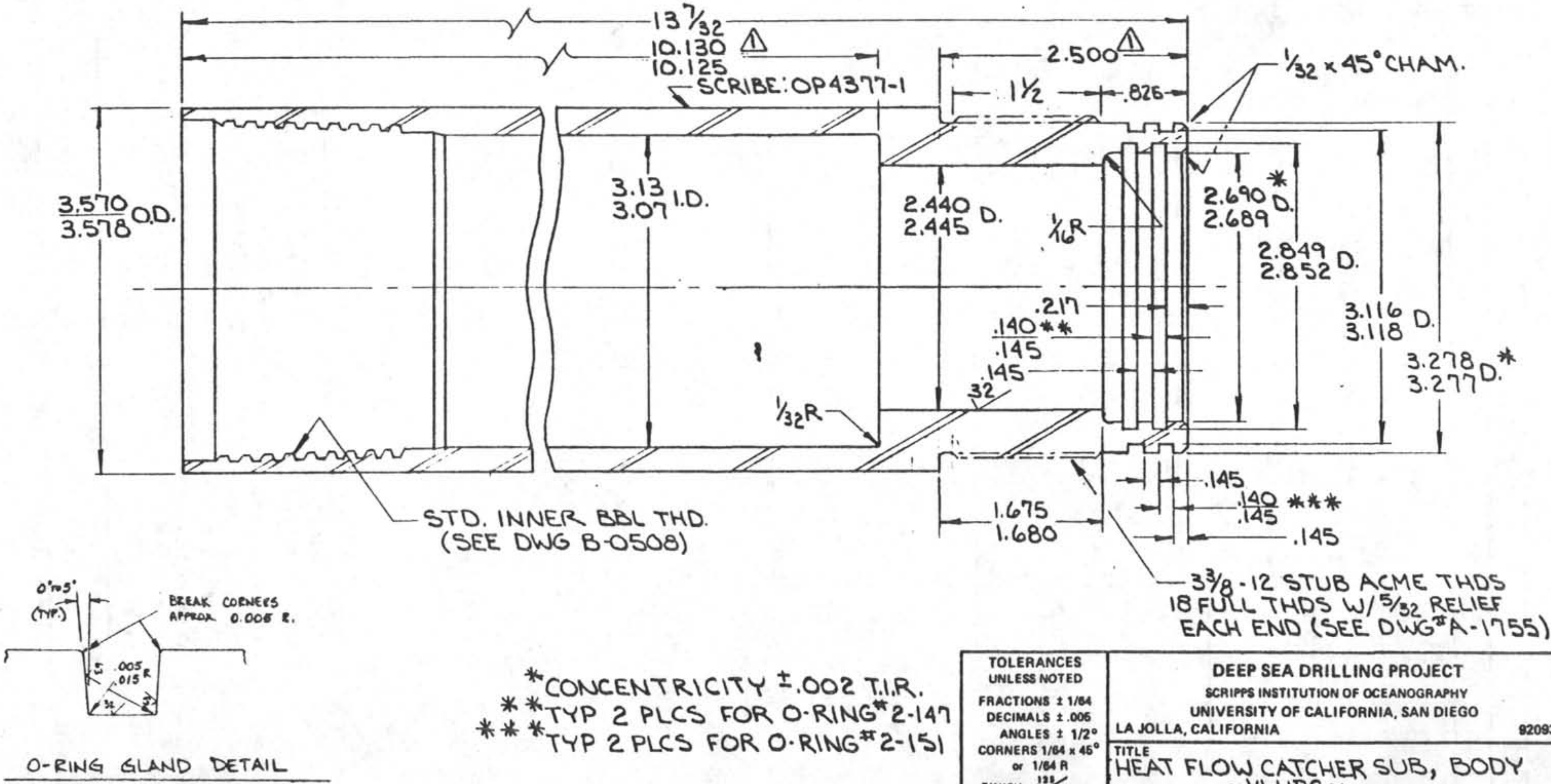
* FOR SEALS OP4179

** DEBURR + CLEAN UP THREADS AFTER DRILLING.

NOTE:
BREAK ALL SHARP EDGES
RADIUS ALL INSIDE CORNERS

TOLERANCES UNLESS NOTED	DEEP SEA DRILLING PROJECT				
FRACTIONS ± 1/64 DECIMALS ± .005 ANGLES ± 1/2° CORNERS 1/64 x 45° or 1/64 R FINISH 125	SCRIPPS INSTITUTION OF OCEANOGRAPHY UNIVERSITY OF CALIFORNIA, SAN DIEGO LA JOLLA, CALIFORNIA 92093 TITLE QUICK RELEASE PISTON HEAD ~ VLHPC ~				
SURFACE TREATMENT PARKOLUBRITE	MATERIAL 4140 STEEL	DRAWN BY RK	DATE 4-3-81	CHECKED	APPROVED
HEAT TREATMENT 36-38 Rc	PART NO. OP4381-2	SIZE DWG. NO. B-OP4381-			REV. 2

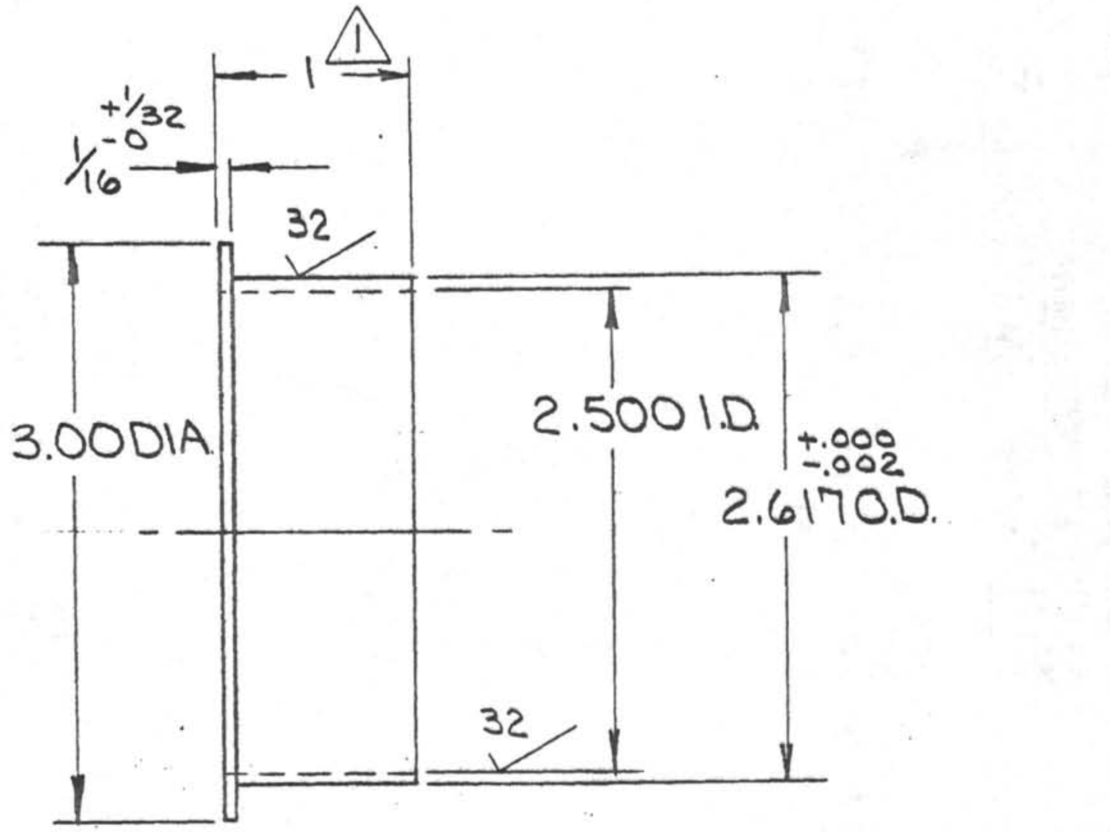
REVISIONS					
NO.	DESCRIPTION	DATE	BY	CH.	APR.
1	2.500 WAS 2.742/2.737, .875 WAS 1.075, DELETED NYLON INSERT HOLE	8-16-82	RK		



*CONCENTRICITY ±.002 T.I.R.
**TYP 2 PLCS FOR O-RING # 2-147
***TYP 2 PLCS FOR O-RING # 2-151

TOLERANCES UNLESS NOTED FRACTIONS ± 1/64 DECIMALS ± .005 ANGLES ± 1/2° CORNERS 1/64 × 45° or 1/64 R FINISH 125	DEEP SEA DRILLING PROJECT SCRIPPS INSTITUTION OF OCEANOGRAPHY UNIVERSITY OF CALIFORNIA, SAN DIEGO LA JOLLA, CALIFORNIA 92093				
	TITLE HEAT FLOW CATCHER SUB, BODY ~VLHPC~				
SURFACE TREATMENT —	MATERIAL NITRONIC 60	DRAWN BY RK	DATE 6-23-81	CHECKED DPH	APPROVED
HEAT TREATMENT —	PART NO. OP4377-1	SIZE DWG. NO. B-OP4377 —			REV. 1

REVISIONS					
NO.	DESCRIPTION	DATE	BY	CH.	APR.
1.	1 WAS 2	4.16.81	RK	MA	MAL



MAT'L:
SHELBY C.R.S. TUBING 3.000 O.D. × .250 WALL

DO NOT SCALE

CONCENTRICITY ALL DIAMETERS: TIR .003

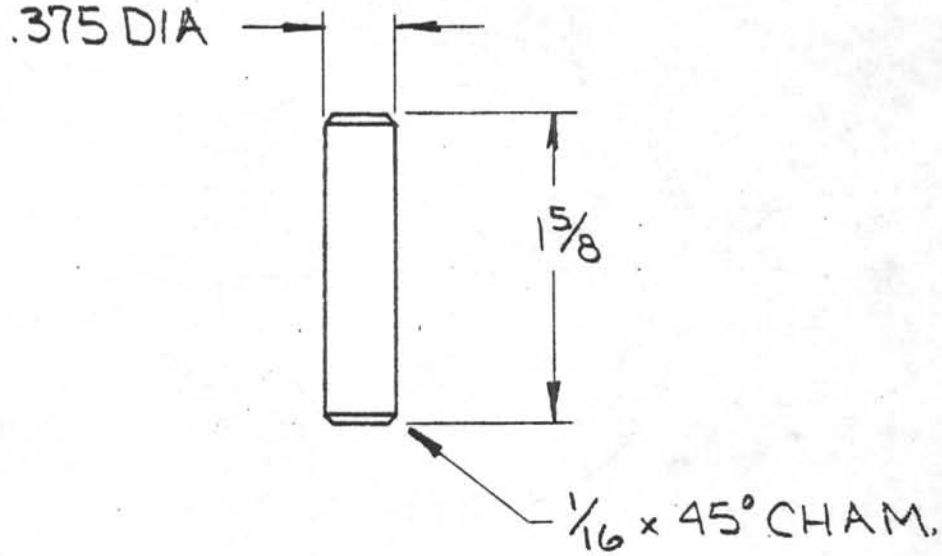
TOLERANCES UNLESS NOTED
FRACTIONS ± 1/64
DECIMALS ± .005
ANGLES ± 1/2°
CORNERS 1/64 x 45° or 1/64 R
FINISH 125

DEEP SEA DRILLING PROJECT
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UNIVERSITY OF CALIFORNIA, SAN DIEGO
LA JOLLA, CALIFORNIA 92093

TITLE: PLASTIC TUBE SUPPORT ~VLHPC~

SURFACE TREATMENT	MATERIAL		DATE	BY	CHECKED	APPROVED
	SEE ABOVE		11.21.80	RK	MAL	MAL
HEAT TREATMENT	SCALE	REQ'D/ASS'Y	PART NO.		DWG. NO. (REV.)	
	1:1	1	OP4382-1		A-OP4382-1	

REVISIONS					
NO.	DESCRIPTION	DATE	BY	CH.	APR.
1	CHANGE MAT'L FROM 304 SS TO 17-4 PH SS, ADD H1150	7-13-81	DC	[signature]	[signature]

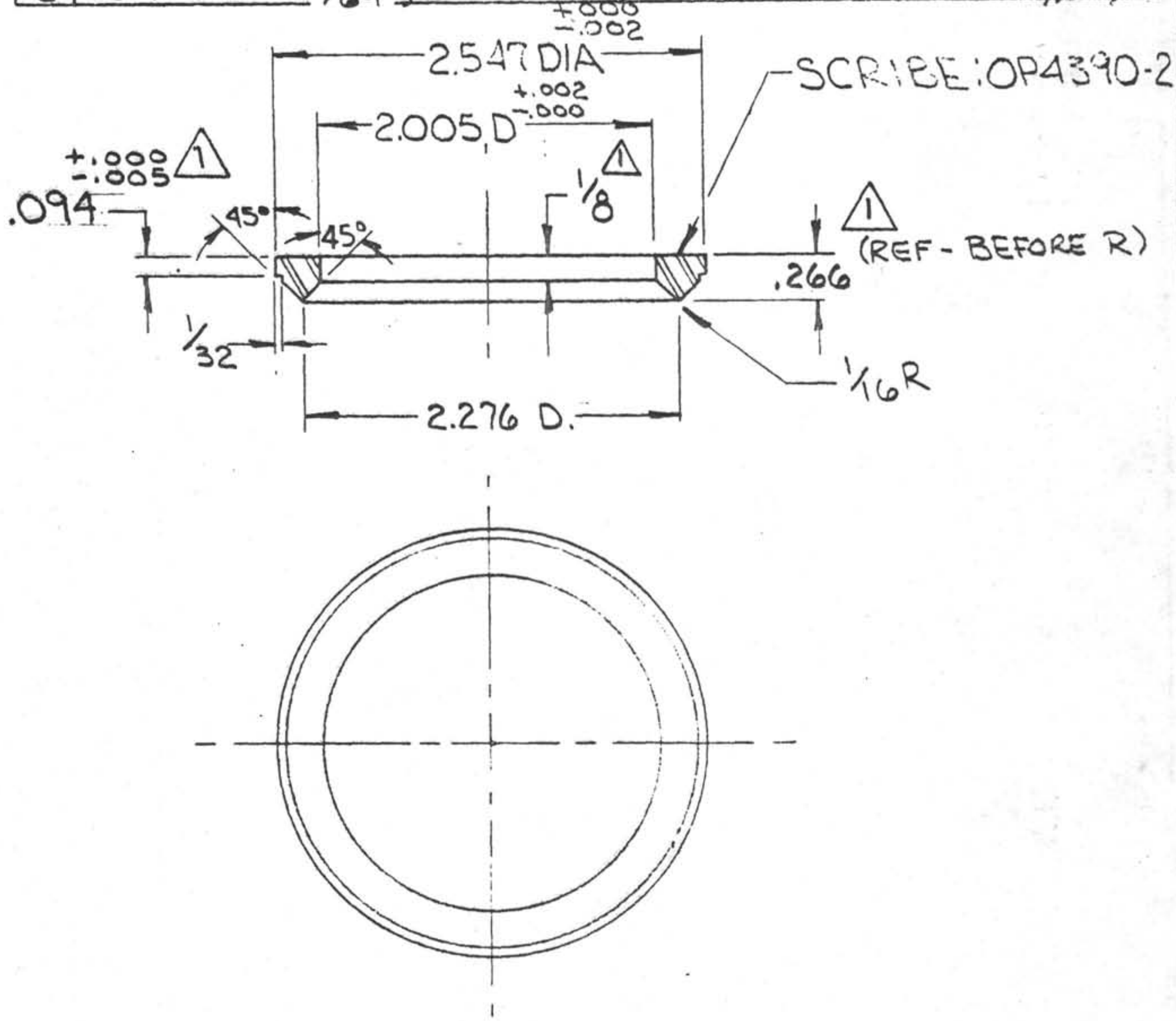


DO NOT SCALE

CONCENTRICITY ALL DIAMETERS: TIR .003

TOLERANCES UNLESS NOTED FRACTIONS ± 1/64 DECIMALS ± .005 ANGLES ± 1/2° CORNERS 1/64 x 45° or 1/64 R FINISH 125	DEEP SEA DRILLING PROJECT SCRIPPS INSTITUTION OF OCEANOGRAPHY UNIVERSITY OF CALIFORNIA, SAN DIEGO LA JOLLA, CALIFORNIA 92093				
	TITLE LOCK PIN - PISTON ~VLHFC~				
SURFACE TREATMENT —	MATERIAL 17-4 PH SS		DATE 10.14.80	BY RK	CHECKED [signature] / APPROVED [signature]
HEAT TREATMENT H1150	SCALE 1:1	REQ'D/ASS'Y ONE	PART NO. OP4383-1		DWG. NO. A-OP4383-1 (REV.)

REVISIONS					
NO.	DESCRIPTION	DATE	BY	CH.	APR.
1	REDUCED THICKNESS	11·21·80	RK		
2	.094 WAS 7/64, 1/8 WAS 9/64, .266 WAS 9/32	1·26·81	RK		



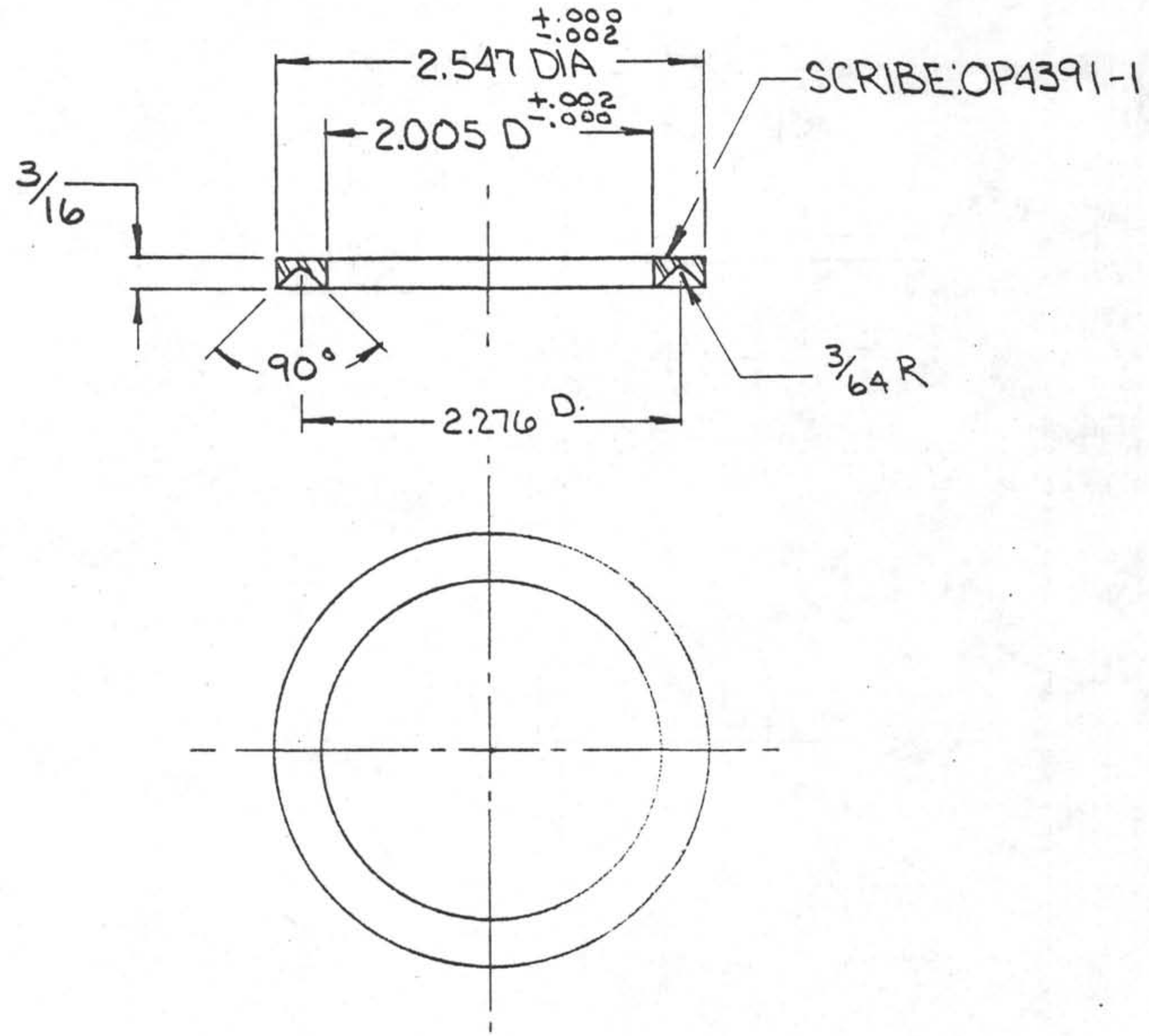
FABRICATE FROM 2 5/8 × 9/16 WALL MECH. TUBING - 304 S.S.

DO NOT SCALE

CONCENTRICITY ALL DIAMETERS: TIR .003

TOLERANCES UNLESS NOTED FRACTIONS ± 1/64 DECIMALS ± .005 ANGLES ± 1/2° CORNERS 1/64 × 45° or 1/64 R FINISH 125	DEEP SEA DRILLING PROJECT SCRIPPS INSTITUTION OF OCEANOGRAPHY UNIVERSITY OF CALIFORNIA, SAN DIEGO LA JOLLA, CALIFORNIA 92093 TITLE MALE V-PACKING ADAPTER (PISTON HEAD) ~ VLHPC ~					
SURFACE TREATMENT	MATERIAL SEE ABOVE		DATE 10·13·80	BY RK	CHECKED	APPROVED
HEAT TREATMENT ANNEALED	SCALE 1:1	REQ'D/ASS'Y 1	PART NO. OP4390-2		DWG. NO. A-OP4390-2	(REV.)

REVISIONS					
NO.	DESCRIPTION	DATE	BY	CH.	APR.
1	REDUCED THICKNESS	11·21·80	RK	[signature]	[signature]



FABRICATE FROM 2 5/8 x 9/16 WALL MECH. TUBING - 304 S.S.

DO NOT SCALE

CONCENTRICITY ALL DIAMETERS: TIR .003

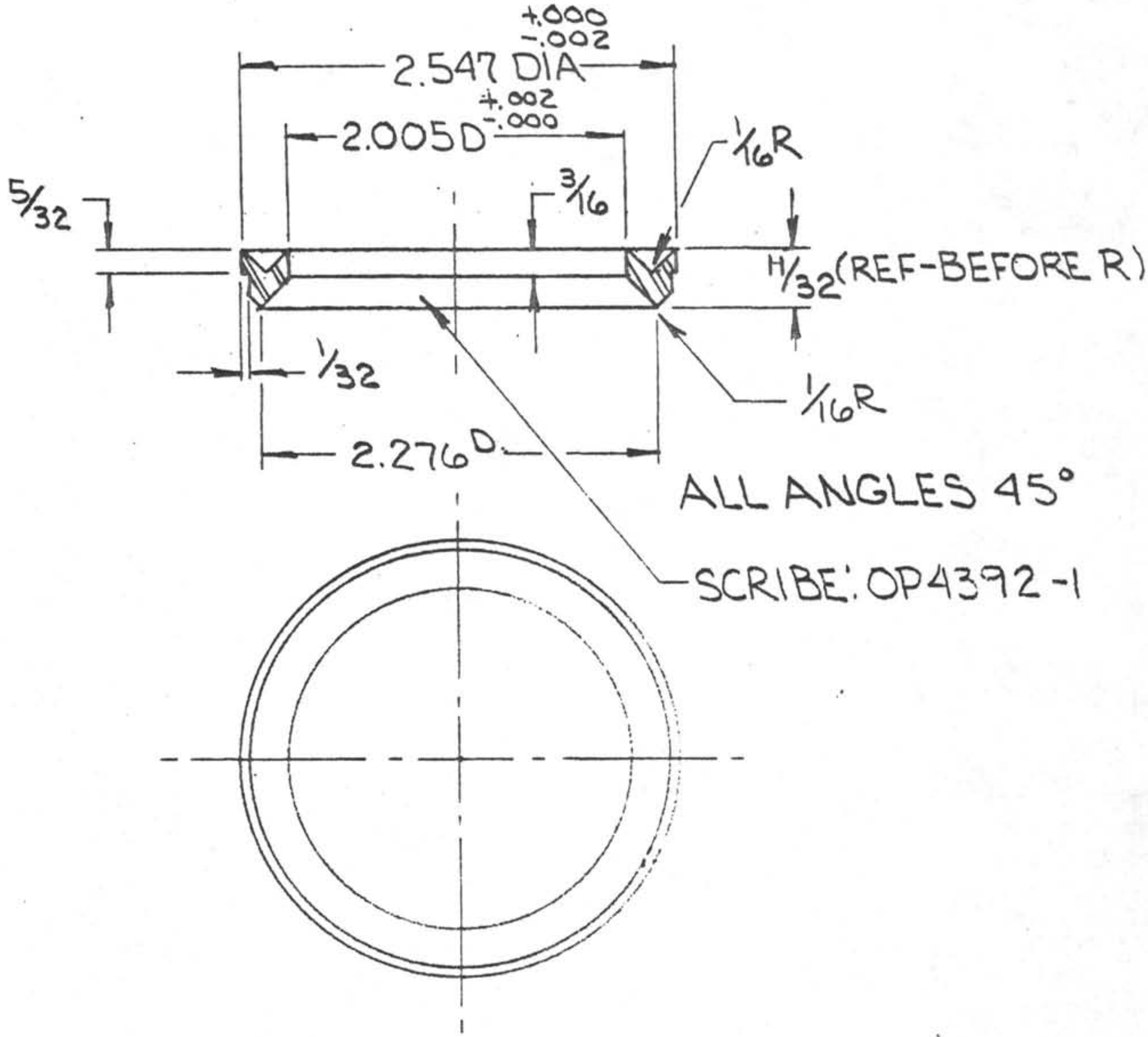
TOLERANCES UNLESS NOTED
FRACTIONS ± 1/64
DECIMALS ± .005
ANGLES ± 1/2°
CORNERS 1/64 x 45° or 1/64 R
FINISH 125

DEEP SEA DRILLING PROJECT
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UNIVERSITY OF CALIFORNIA, SAN DIEGO
LA JOLLA, CALIFORNIA 92093

TITLE: FEMALE ADAPTER ~ PISTON HEAD ~VLHPC~

SURFACE TREATMENT	MATERIAL		DATE	BY	CHECKED	APPROVED
	SEE ABOVE		10·13·80	RK	[signature]	[signature]
HEAT TREATMENT	**SCALE**	**REQ'D/ASS'Y**	**PART NO.**		**DWG. NO.**	**(REV.)**
ANNEALED	1:1	1	OP4391-1		A-OP4391	1

REVISIONS					
NO.	DESCRIPTION	DATE	BY	CH.	APR.
1	REDUCED THICKNESS	11·21·80	RK	[signature]	[signature]



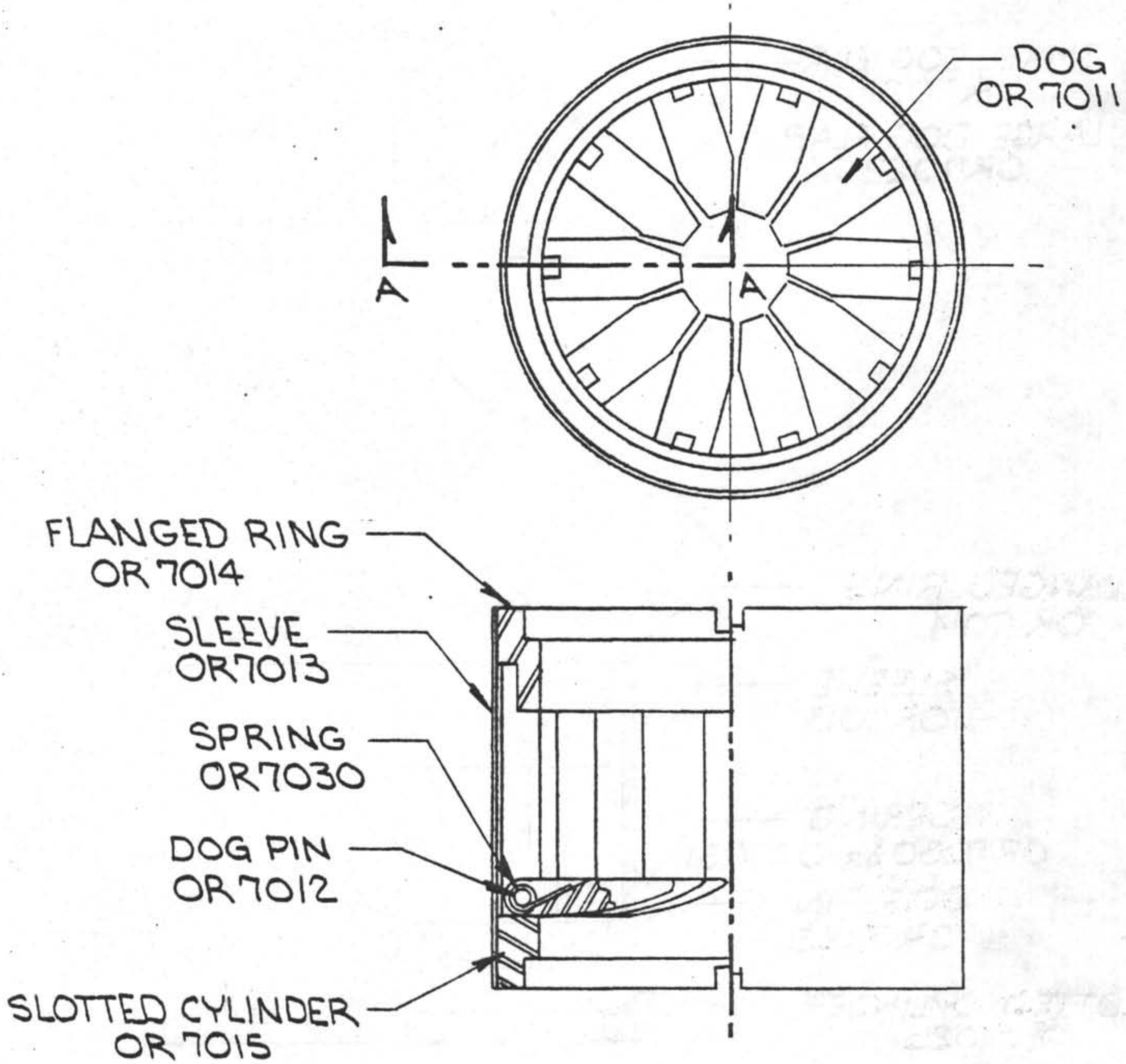
FABRICATE FROM 2 5/8 x 9/16 WALL MECH TUBING - 304S.S.

DO NOT SCALE

CONCENTRICITY ALL DIAMETERS: TIR .003

TOLERANCES UNLESS NOTED	DEEP SEA DRILLING PROJECT				
FRACTIONS ± 1/64 DECIMALS ± .005 ANGLES ± 1/2° CORNERS 1/64 x 45° or 1/64 R FINISH 125	SCRIPPS INSTITUTION OF OCEANOGRAPHY UNIVERSITY OF CALIFORNIA, SAN DIEGO LA JOLLA, CALIFORNIA 92093 TITLE V-SPACER ~ PISTON HEAD ~VLHPC~				
SURFACE TREATMENT	MATERIAL SEE ABOVE	DATE 10·13·80	BY RK	CHECKED [signature]	APPROVED [signature]
HEAT TREATMENT ANNEALED	SCALE 1:1	REQ'D/ASS'Y	PART NO. OP4392-1	DWG. NO. A-OP4392-1	(REV.) 1

REVISIONS					
NO.	DESCRIPTION	DATE	BY	CH.	APR.
5	REDRAWN WAS B-0190	2·9·81	RK	PGT	



DO NOT SCALE

CONCENTRICITY ALL DIAMETERS: TIR .003

TOLERANCES UNLESS NOTED
FRACTIONS ± 1/64
DECIMALS ± .005
ANGLES ± 1/2°
CORNERS 1/64 x 45° or 1/64 R
FINISH 125

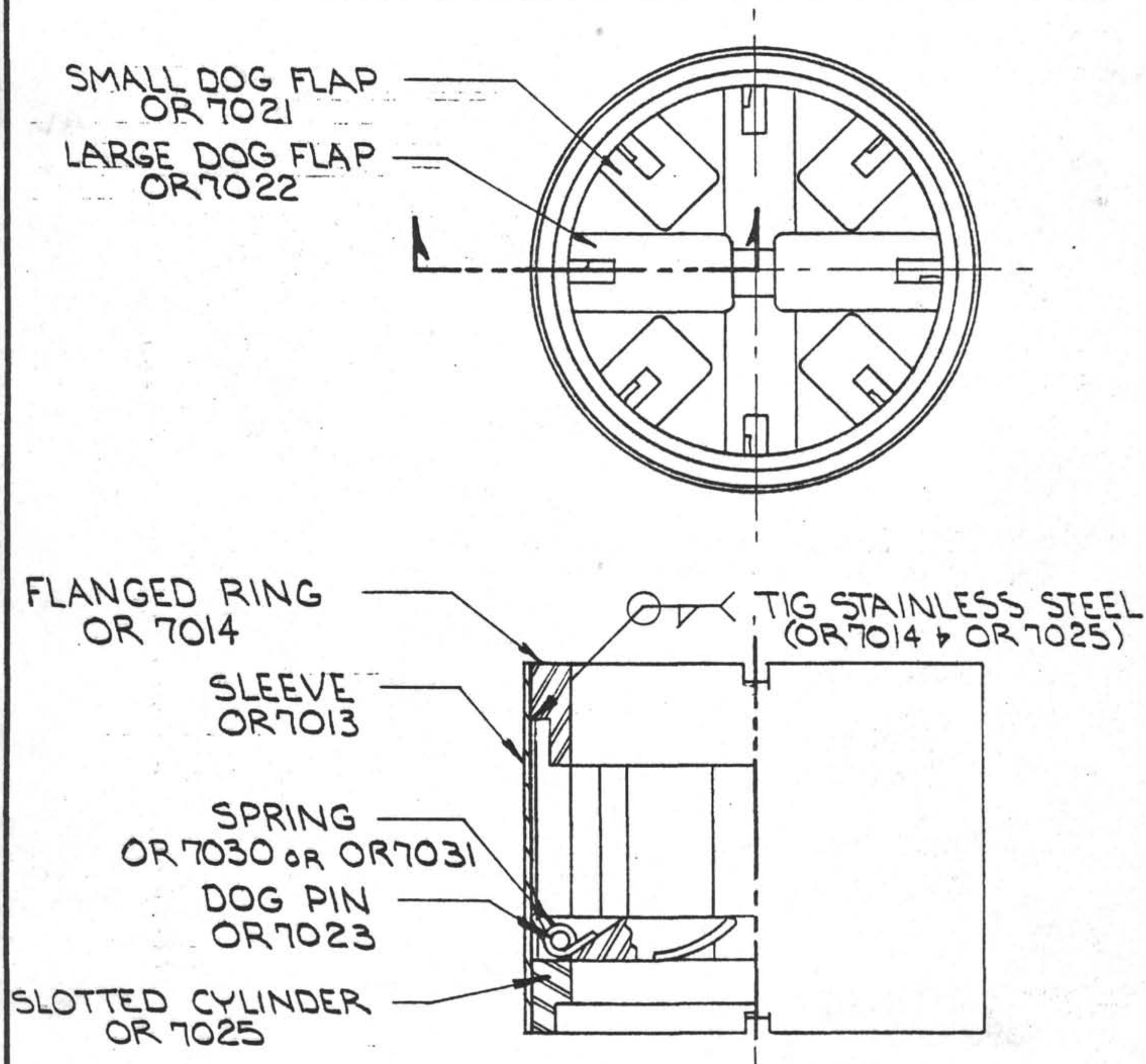
DEEP SEA DRILLING PROJECT
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UNIVERSITY OF CALIFORNIA, SAN DIEGO
LA JOLLA, CALIFORNIA 92093

TITLE: 10 FINGER CORE CATCHER ASSY 3 1/16 x 2 1/2 DIA

SURFACE TREATMENT	MATERIAL	DATE	BY	CHECKED	APPROVED
-		2·9·81	RK	PGT	UBR

HEAT TREATMENT	SCALE	REQ'D/ASS'Y	PART NO.	DWG. NO. (REV.)
	1:1		OR 7010 -5	A-OR7010-5

REVISIONS					
NO.	DESCRIPTION	DATE	BY	CH.	APR.
3	REDRAWN	2.3.81	RK	PGT	UBR



DO NOT SCALE

CONCENTRICITY ALL DIAMETERS: TIR .003

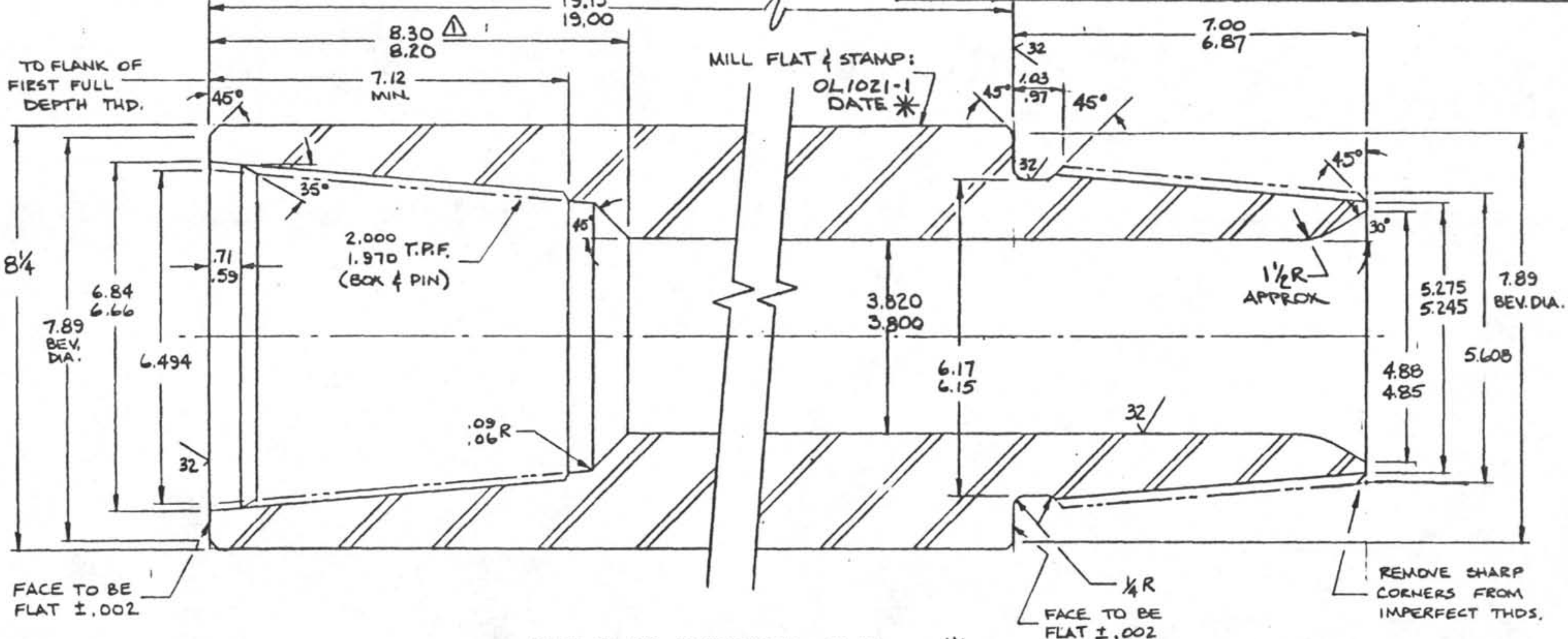
TOLERANCES UNLESS NOTED
FRACTIONS ± 1/64
DECIMALS ± .005
ANGLES ± 1/2°
CORNERS 1/64 x 45° or 1/64 R
FINISH 125

DEEP SEA DRILLING PROJECT
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UNIVERSITY OF CALIFORNIA, SAN DIEGO
LA JOLLA, CALIFORNIA 92093

TITLE
CORE CATCHER ASS'Y
~3 1/16 x 2 1/2 HARD + SOFT FORMATION~

SURFACE TREATMENT	MATERIAL		DATE	BY	CHECKED	APPROVED
—ø—	—ø—		2.3.81	RK	PGT.	
HEAT TREATMENT	SCALE	REQ'D/ASS'Y	PART NO.		DWG. NO. (REV.)	
—ø—	1:1	—ø—	OR7020-3		A-OR7020-3	

REVISIONS					
NO.	DESCRIPTION	DATE	BY	CH.	APR.
1	8.30/8.20 WAS 8.50/8.30	2-13-84	RK		

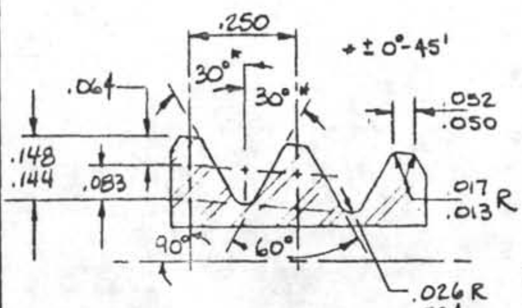


PART TO BE FABRICATED USING HARDENED & GROUND GAGES BEARING A.P.I. MONOGRAM AND CERTIFIED WITHIN PAST 3 YEARS.

KEM PLATE THREADS

DEGREASE EXTERIOR & COAT W/ PRIMER & BLUE TOP COAT

* DATE OF FAB. (MO. YR.) eg. 0384 = MAR '84



THREAD DETAIL

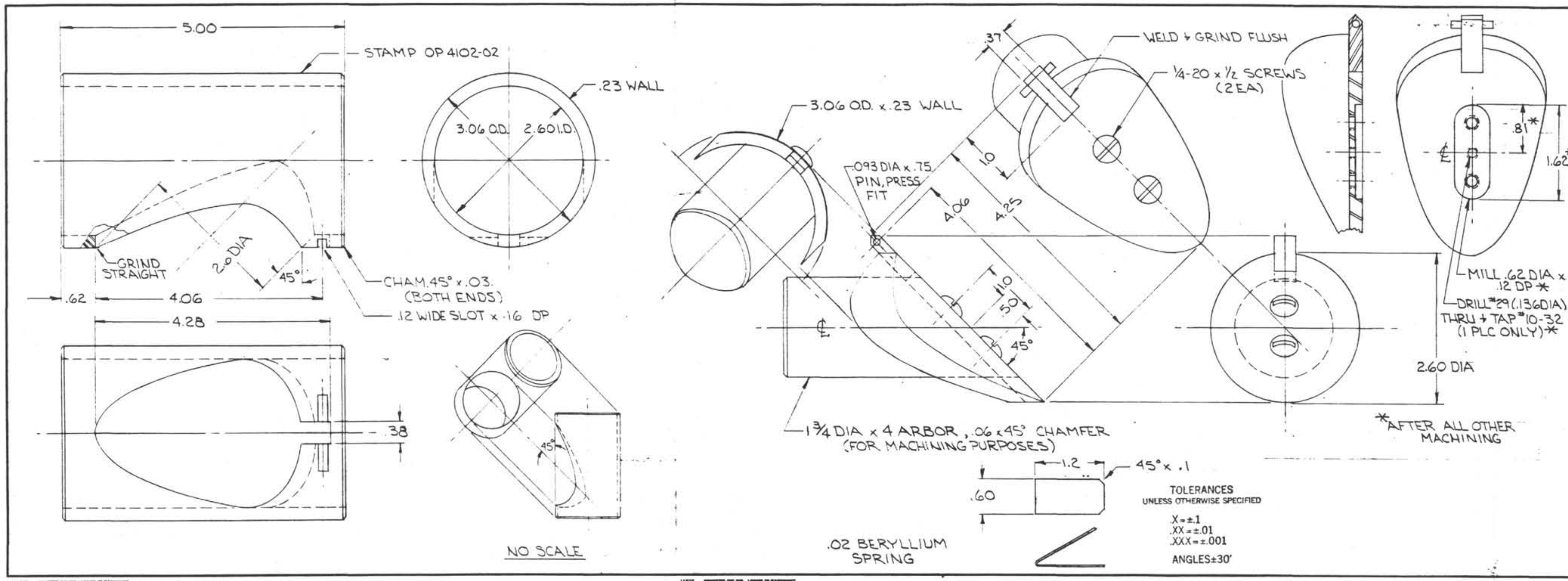
4 T.P.I. 2" TAPER PER FT. PITCH TOLER. ±.0015 PER INCH

DO NOT SCALE

CONCENTRICITY ALL DIAMETERS: TIR .003

TOLERANCES UNLESS NOTED	DEEP SEA DRILLING PROJECT				
FRACTIONS ± 1/64 DECIMALS ± .005 ANGLES ± 1/2° CORNERS 1/64 x 45° or 1/64 R FINISH 125	SCRIPPS INSTITUTION OF OCEANOGRAPHY UNIVERSITY OF CALIFORNIA, SAN DIEGO LA JOLLA, CALIFORNIA 92093				
	TITLE LANDING / SAVER SUB ~ APC ~				
SURFACE TREATMENT SEE NOTES	MATERIAL 4142 / 4145		DATE 3/25/83	BY DH	CHECKED	APPROVED DPH
HEAT TREATMENT 30-34 Rc	SCALE HALF	REQ'D/ASS'Y ONE	PART NO. OL 1021-1		DWG. NO. (REV.) B-OL1021-1

WAS OG 0620



TOLERANCES
UNLESS OTHERWISE SPECIFIED
.X = ±.1
.XX = ±.01
.XXX = ±.001
ANGLES ±30'

REVISIONS					
NO.	DESCRIPTION	DATE	BY	CH.	APR.
1					
2	PARKOLUBE FINISH ADDED	8-21-79	RK		

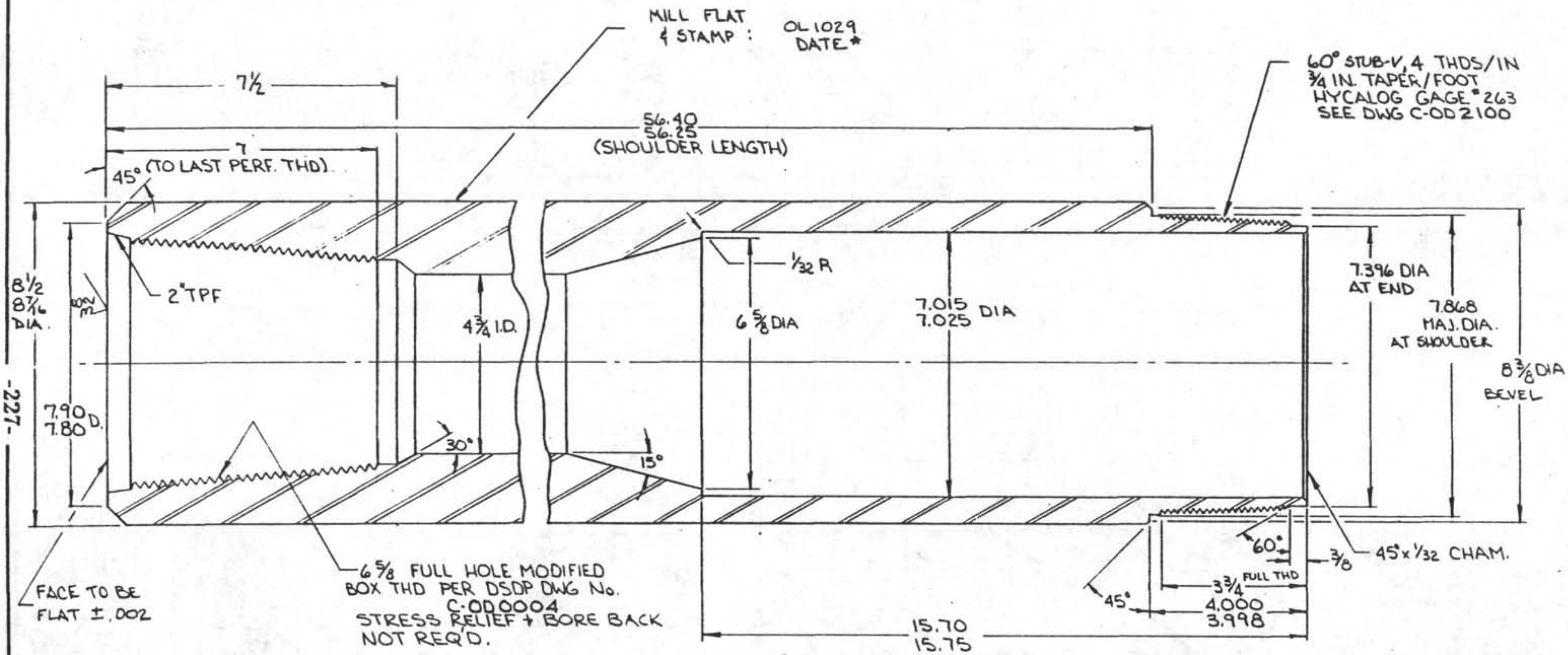
MAT'L:
SHELBY TUBING + CRS
FINISH:
PARKOLUBE ②

NOTE:
BREAK ALL SHARP EDGES
RADIUS ALL INSIDE CORNERS

TOLERANCES
UNLESS OTHERWISE SPECIFIED
.X = ±.1
.XX = ±.01
.XXX = ±.001
ANGLES ±30'

UNIV. OF CALIF. DEEP SEA DRILLING PROJECT		
SCALE: FULL	APPROVED BY:	DRAWN BY RK
DATE: 9-6-78		REVISED
CORE CATCHER - FLAPPER TYPE ~ 15'+9.5M ~ H.P.C. ~		
PART No OR 7100-2		DRAWING NUMBER R-OR 7100-2

REVISIONS					
NO.	DESCRIPTION	DATE	BY	CH.	APR.



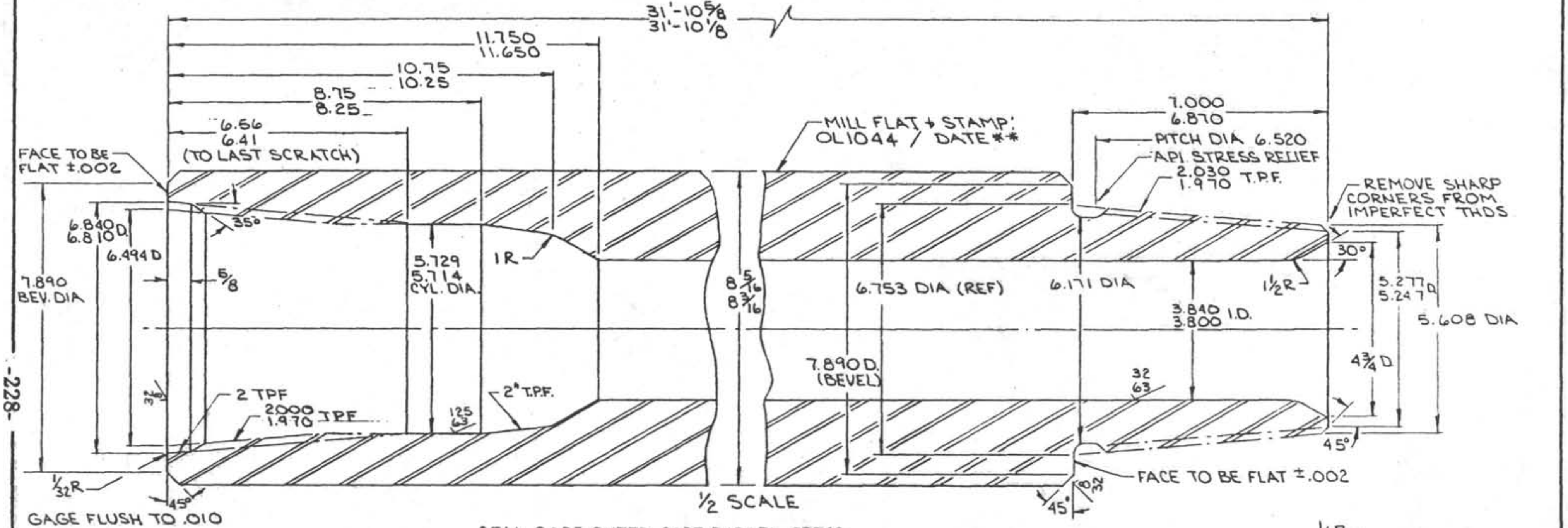
HALF SCALE

NOTE:
1. KEM PLATE THREADS.
2. COAT THDS WITH A PLASTIC DIP.
3. COAT EXTERIOR WITH PRIMER AND ONE COAT OF BLUE EPOXY.

*FABRICATION DATE (MO. YR.) eg. 0384 = MAR 1984

TOLERANCES UNLESS NOTED	DEEP SEA DRILLING PROJECT SCRIPPS INSTITUTION OF OCEANOGRAPHY UNIVERSITY OF CALIFORNIA, SAN DIEGO LA JOLLA, CALIFORNIA 92093				
FRACTIONS ± 1/64 DECIMALS ± .005 ANGLES ± 1/2° CORNERS 1/64 x 45° or 1/64 R FINISH 125	TITLE LONG BIT SUB				
SURFACE TREATMENT SEE NOTE	MATERIAL 4140 STEEL	DRAWN BY RK	DATE 5-21-79	CHECKED	APPROVED DPH
HEAT TREATMENT 30-36 Rc	PART NO. OL 1029	SIZE C	DWG. NO. OL 1029		REV.

REVISIONS					
NO.	DESCRIPTION	DATE	BY	CH.	APR.



SEAL BORE OUTER CORE BARREL SPECS
OL1044

REQ'D IN BOTTOM HOLE ASSEMBLY FOR USE W/ ADVANCED PISTON CORER.

I.D. FINISH: 32-64 rms + NO STEPS.

MAT'L: PREMIUM GRADE AISI 4145H ALLOY ST, FULLY HEAT TREATED OVER ENTIRE LENGTH TO 285-341 BRINNEL HARDNESS.

MIN. YIELD = 120,000 PSI AT 1" BELOW O.D.

GUARANTEED MIN: 40 FT-LBS IZOD IMPACT.

CONNECTIONS: 6 5/8" FULL HOLE MODIFIED BOX UP WITH DRILCO BORE BACK AS SHOWN. 6 5/8" FULL HOLE MODIFIED PIN DOWN (7" LONG) WITH API STRESS RELIEF GROOVE AS SHOWN.

THREADS TO BE HOB CUT AND KEM PLATED.

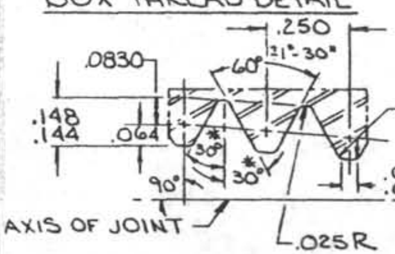
THREADS TO BE FABRICATED UTILIZING HARDEN AND GROUND GAGES BEARING API MONOGRAM AND CERTIFIED WITHIN THE PAST THREE YEARS.

PROVIDE WITH PRESSED STEEL BOX + 7" LONG PIN THREAD PROTECTORS.

O.D. TO BE PRIMED AND TOP COATED

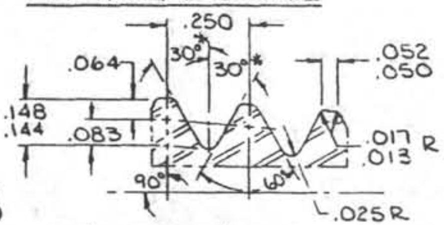
I.D. TO BE WELL OILED FOR CORROSION PROTECTION WHILE IN TRANSIT AND STORAGE.

BOX THREAD DETAIL

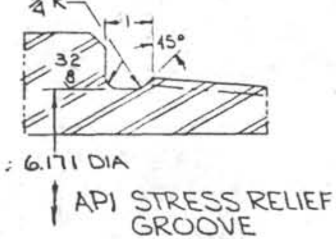


4 TPI - 2" TAPER PER FT
PITCH TOL ±.0015 PER IN
* ±0°-45'

PIN THREAD DETAIL



4 TPI — 2" TAPER PER FT.
PITCH TOL. ±.0015 PER INCH
* ±0°-45'
** FAB. DATE (MO. YR)
e.g. 0348 = MAR 48



TOLERANCES UNLESS NOTED: FRACTIONS ± 1/64, DECIMALS ± .005, ANGLES ± 1/2°, CORNERS 1/64 x 45° or 1/64 R, FINISH 125	DEEP SEA DRILLING PROJECT, SCRIPPS INSTITUTION OF OCEANOGRAPHY, UNIVERSITY OF CALIFORNIA, SAN DIEGO, LA JOLLA, CALIFORNIA 92093				
	TITLE: SEAL BORE OUTER CORE BARREL (APC-MOD II)				
SURFACE TREATMENT: SEE SPECS	MATERIAL: SEE SPECS	DRAWN BY: RK	DATE: 3-5-84	CHECKED	APPROVED: DH 3/84
HEAT TREATMENT: SEE SPECS	PART NO.: OL1044	SIZE DWG NO.: C-OL1044			REV.

APPENDIX G
OLD DRAWINGS

REVISIONS					
NO.	DESCRIPTION	DATE	BY	CH.	APR.
1	UPDATED PART NOS.	10-27-83	RK		

LIST OF MATERIALS

ITEM NO.	PART NO.	SIZE-DWG. NO.	DESCRIPTION	NO. REQ'D.
	OG0620	B-OG0620	LANDING / SAVER SUB	1
	OG0621	B-OG0621	BIT SUB SPACER	1
	OP4702	B-OP4702	PULLING NECK	1
	OP4704	A-OP4704	PULLING NECK LOCK NUT	1
	OP4706	A-OP4706	SPLIT BUSHING	1
	OP4708	C-OP4708	LANDING SUB	1
	OP4710		SPEED CONTROL SET SCREWS	10
	OP4712	A-OP4712	SUPPORT WASHER	1
	OP4714		HEX NUT 3/4-10 UNC S.S.	1
	OP4715	A-OP4715	PISTON ROD JAM NUT	1
	OP4716	C-OP4716	INNER SHEAR PIN SUB	1
	OP4718	B OP4718	OUTER SHEAR PIN SUB	1
	OP4720	B-OP4720	SHEAR PIN SLEEVE	1
	OP4721	-OP4721	SHEAR PINS	1
	OP4722	A-OP4722	ALIGNMENT DOWEL	1
	OP4724	B-OP4724	INNER SEAL SUB	1
	OP4726	C-OP4726	OUTER SEAL SUB	1
	OP4728	A-OP4728	OUTER SEAL MALE ADAPTOR, 3 3/4	1
	OP4729	A-OP4729	" " V-SPACERS, 3 3/4	2
	OP4730	A-OP4730	" " FEMALE ADAPTOR, 3 3/4	1
	OP4732	A-OP4732	INNER SEAL MALE ADAPTOR	1
	OP4733	A-OP4733	" " V-SPACERS	2
	OP4734	A-OP4734	" " FEMALE ADAPTOR	1
	OP4750	R-OP4750	MALE QUICK RELEASE	1
	OP4751	R-OP4751	FEMALE " "	1
	OP4752	B-OP4752	QUICK RELEASE NUT	1
	OP4753	A-OP4753	" " DOGS	2
	OP4756	B OP4756	VENT SNUBBER	1
	OP4758	C-OP4758	VENT SUB	1
	OP4760	B-OP4760	LOWER PISTON ROD (W/O GROOVE)	1
	OP4761	B-OP4761	" " " (W/ GROOVE)	1
	OP4762	B-OP4762	CENTER PISTON ROD (W/O GROOVE)	1
	OP4763	B-OP4763	" " " (W/ GROOVE)	1
	OP4764	B-OP4764	UPPER PISTON ROD (W/O GROOVE)	1
	OP4765	B-OP4765	" " " (W/ GROOVE)	1
	OP4766	B-OP4766	PISTON ROD SNUBBER	1
	OP4768	B-OP4768	PISTON ROD EXTENSION (BREAKAWAY HD)	1

LIST OF MATERIALS

ITEM NO.	PART NO.	SIZE-DWG. NO.	DESCRIPTION	NO. REQ'D.
	OP4769	B-OP4769	PISTON ROD EXTENSION (STD. HEAD)	1
	OP4770	A-OP4770	ANTI-SPIRAL KEY	1
	OP4774	———	3/8-16 x 3/8 SOC. HD. SC.	
	OP4711	———	SNAP RING #5100-62	1
	OP4713	A-OP4713	STOP WASHER	1
	OP4717	A-OP4717	INNER SHEAR PIN BUSHINGS	6
	OP4719	A-OP4719	OUTER SHEAR PIN BUSHINGS	6
	OP4731	A-OP4731	OUTER V-PACK SHIM WASHER	1
	OP4735	A-OP4735	INNER V-PACK SHIM WASHER	1
	OP4725	———	O-RING #2-331	1
	OP4727	———	POLY PAK, MOLYTHANE #37503000-625B	1
	OP4723	———	" " #37501625-625B	1
	OP4737	———	OUTER V-PACK " #37503000 VP	3
	OP4775		1/4-20 x 3/4 SOC. SET SC.	
	OP4776		1/2 x 13 x 1/2 " " "	
	OP4739	———	INNER V-PAC, MOLYTHANE #37501625 VP	3
	OP4740	A-OP4740	LOCK PIN NUT	1
	OP4741	B-OP4741	BREAKAWAY HEAD	1
	OP4742	B-OP4742	PISTON HEAD BODY	1
	OP4743	B-OP4743	" " SEAL RETAINER	1
	OP4744	A-OP4744	SPECIAL LOCK PIN NUT	1
	OP4745	———	O-RING #2-214	
	OP4746	———	" 2-210	
	OP4747	———	" 2-324	
	OP4360	B-OP4360	LOWER LINER SEAL SUB	1
	OP4361	A-OP4361	UPPER LINER SEAL SUB RETAIN. SC.	1
	OP4377	B-OP4377	HEAT FLOW CATCHER SUB BODY	1
	OP4378	C-OP4378	" " " " CONE	1
	OP4382	A-OP4382	PLASTIC TUBE SUPPORT	1
	OP4383	A-OP4383	LOCK PIN - PISTON	1
	OP4112	B-OP4112	FLAPPER - FLAPPER CORE CATCHER	1
	OP4113	B-OP4113	CYLINDER - " " "	1
	OR7020	A-OR7020	CORE CATCHER ASSY	1
	OP3210	B-OP3210	INNER CORE BARREL	
	OP3400	A-OP3400	CORE LINER 2.817" x 32'	
	OL1043	A-OL1043	3.8 I.D. DRILL COLLAR	1
	OP4147	———	O-RING #2-232	

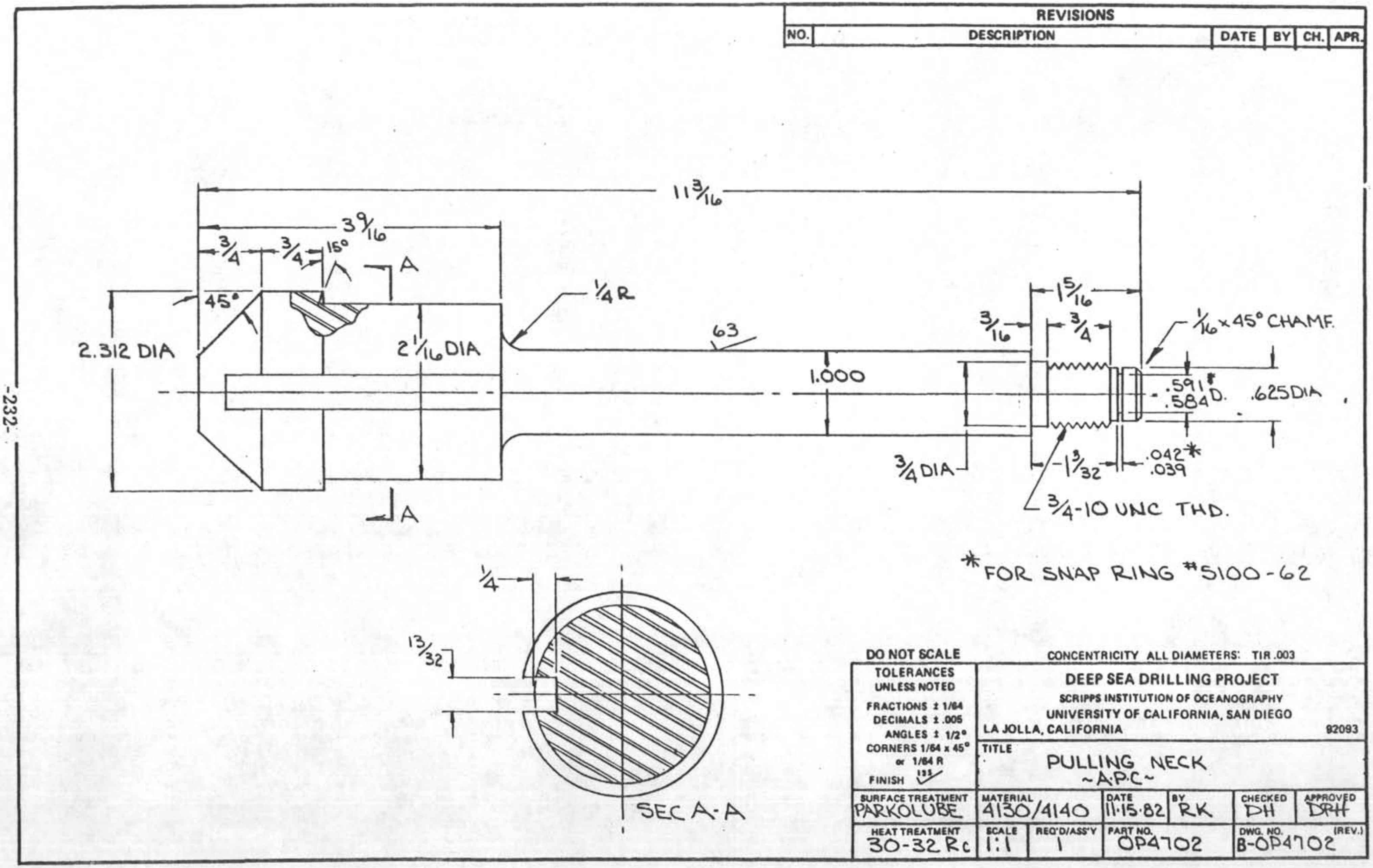
TOLERANCES UNLESS NOTED
FRACTIONS ± 1/64
DECIMALS ± .005
ANGLES ± 1/2°
CORNERS 1/64 x 45° or 1/64 R
FINISH 125

DEEP SEA DRILLING PROJECT
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UNIVERSITY OF CALIFORNIA, SAN DIEGO
LA JOLLA, CALIFORNIA 92093

TITLE: ADVANCED PISTON CORER (APC) ASSEMBLY

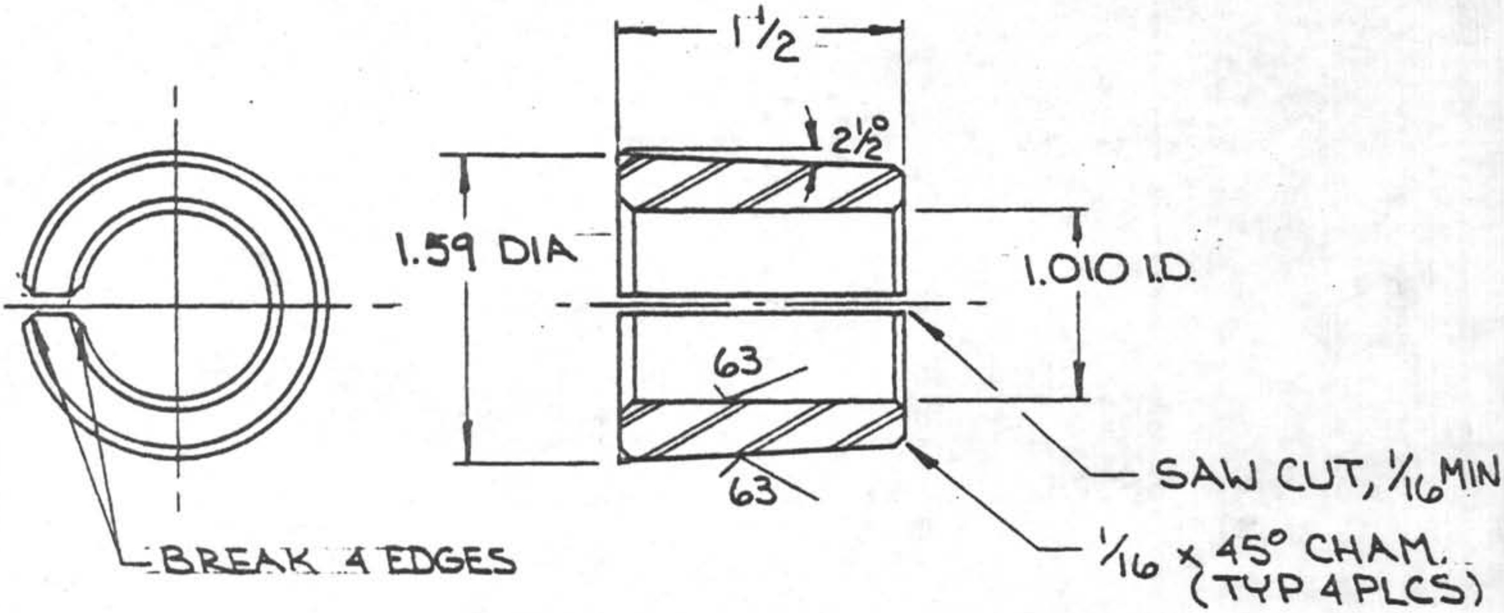
MATERIAL	DRAWN BY	DATE	CHECKED	APPROVED
—	RK	1-24-83	DH	DPH 6/83

SURFACE TREATMENT	HEAT TREATMENT	PART NO.	SIZE	DWG. NO.	REV.
—	—	OP4700-1	R	OP4700	1


REVISIONS
NO.
DESCRIPTION
DATE
BY
CH.
APR.
11 3/16
3 9/16
3/4
3/4
15°
A
45°
1/4 R
2.312 DIA
2 1/16 DIA
63
1.000
1 5/16
3/16
3/4
1/16 × 45° CHAMF.
.591* / .584 D.
.625 DIA
3/4 DIA
1 3/32
.042* / .039
3/4-10 UNC THD.
A
* FOR SNAP RING #5100-62
1/4
13/32
SEC A-A
DO NOT SCALE
CONCENTRICITY ALL DIAMETERS: TIR .003
TOLERANCES UNLESS NOTED
FRACTIONS ± 1/64
DECIMALS ± .005
ANGLES ± 1/2°
CORNERS 1/64 x 45° or 1/64 R
FINISH 125
DEEP SEA DRILLING PROJECT
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UNIVERSITY OF CALIFORNIA, SAN DIEGO
LA JOLLA, CALIFORNIA
92093
TITLE
PULLING NECK
~A.P.C~
SURFACE TREATMENT
PARKOLUBE
MATERIAL
4130/4140
DATE
11.15.82
BY
RK
CHECKED
DH
APPROVED
DRH
HEAT TREATMENT
30-32 Rc
SCALE
1:1
REQ'D/ASS'Y
1
PART NO.
OP4702
DWG. NO.
B-OP4702
(REV.)

REVISIONS

NO.	DESCRIPTION	DATE	BY	CH.	APR.



DO NOT SCALE

CONCENTRICITY ALL DIAMETERS: TIR .003

TOLERANCES UNLESS NOTED

FRACTIONS ± 1/64
DECIMALS ± .005
ANGLES ± 1/2°
CORNERS 1/64 x 45° or 1/64 R
FINISH 125✓

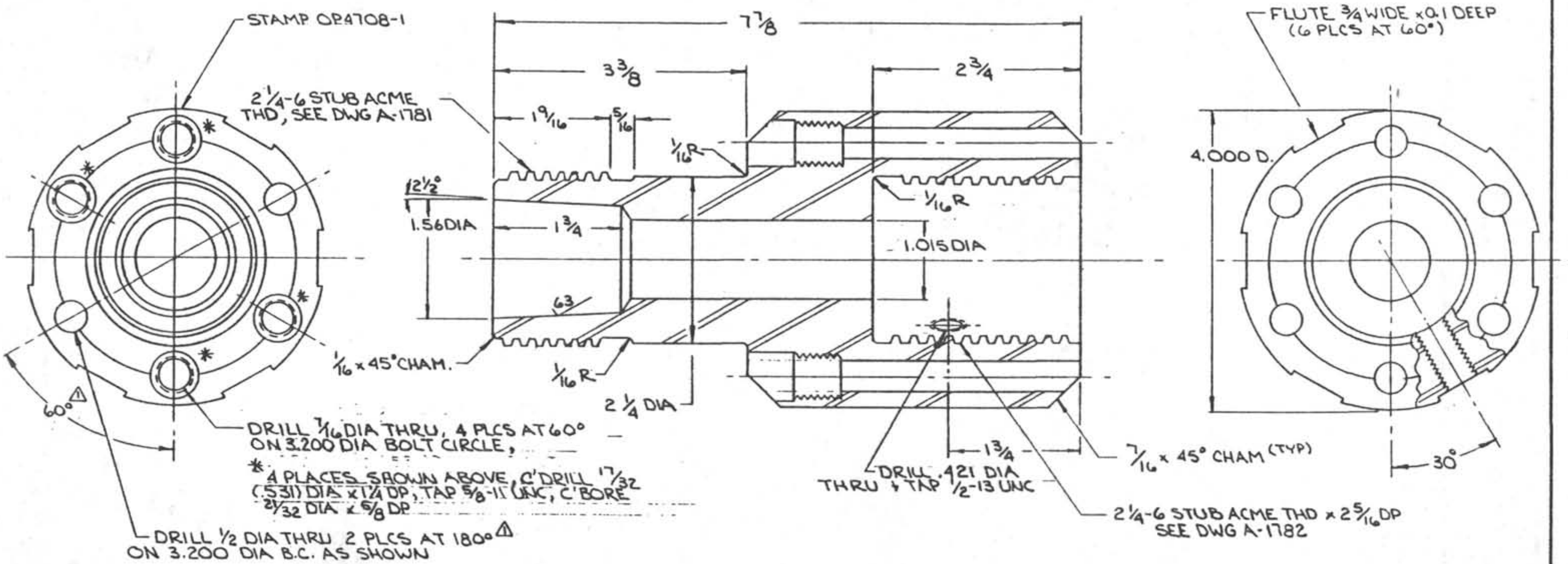
DEEP SEA DRILLING PROJECT
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UNIVERSITY OF CALIFORNIA, SAN DIEGO
LA JOLLA, CALIFORNIA 92093

TITLE: SPLIT BUSHING ~A.P.C~

SURFACE TREATMENT	MATERIAL	DATE	BY	CHECKED	APPROVED
PARKOLUBE	4130/4140	11·15·82	RK	DH	DPH

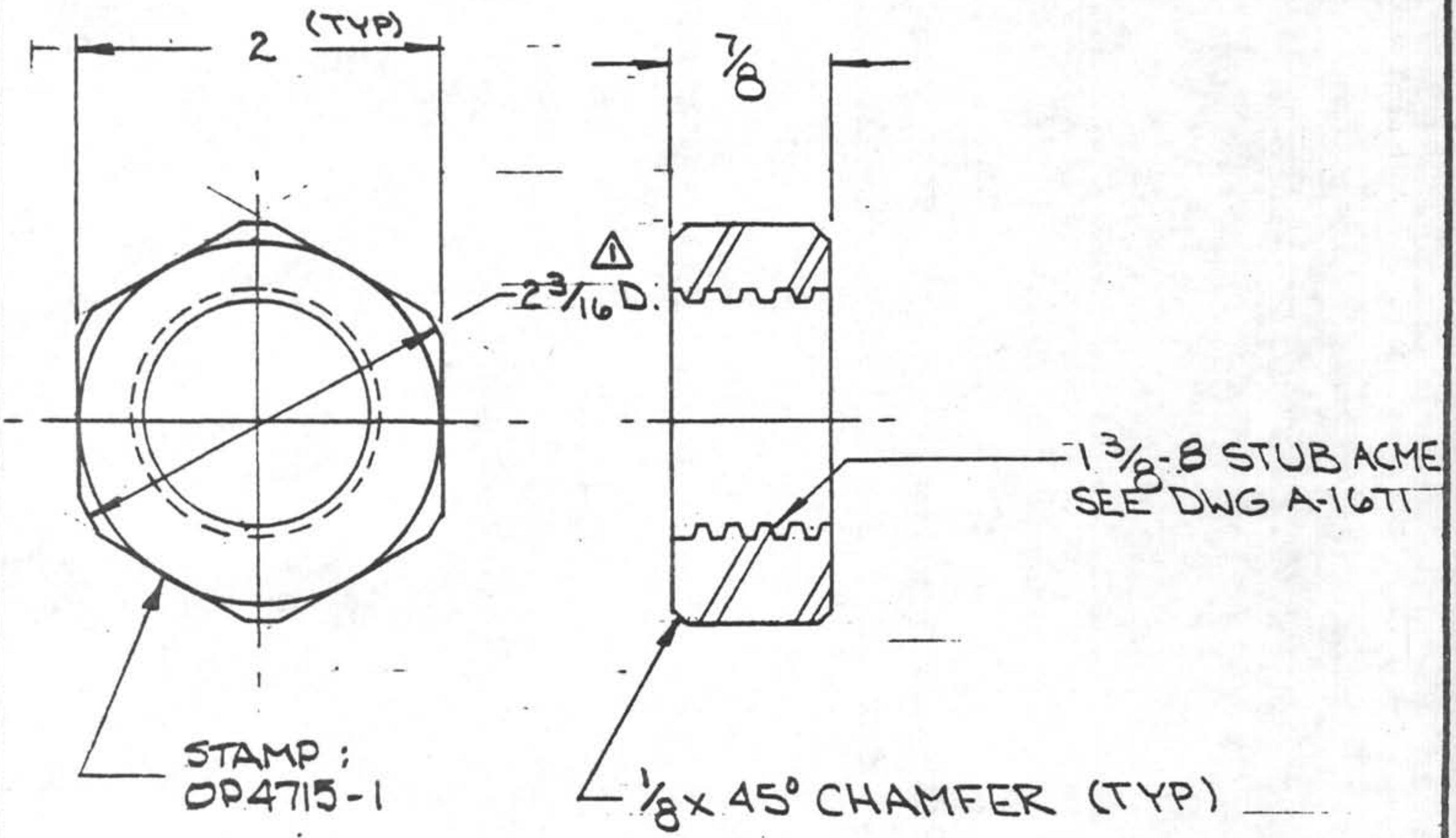
HEAT TREATMENT	SCALE	REQ'D/ASS'Y	PART NO.	DWG. NO.	(REV.)
Rc 28-32	1:1	1	OP4706	A-OP4706	

REVISIONS					
NO.	DESCRIPTION	DATE	BY	CH.	APR.
1	1/2 DIA HOLES WERE 7/16	5-31-83	RK	DH	DH



TOLERANCES UNLESS NOTED FRACTIONS ± 1/64 DECIMALS ± .005 ANGLES ± 1/2° CORNERS 1/64 x 45° or 1/64 R FINISH 125	DEEP SEA DRILLING PROJECT SCRIPPS INSTITUTION OF OCEANOGRAPHY UNIVERSITY OF CALIFORNIA, SAN DIEGO LA JOLLA, CALIFORNIA 92093				
	TITLE LANDING SUB ~A.P.C~				
SURFACE TREATMENT PARKOLUBE	MATERIAL 4130/4140	DRAWN BY RK	DATE 11-1982	CHECKED DH	APPROVED DH
HEAT TREATMENT 32-34 Rc	PART NO. OP4708-1	SIZE DWG. NO. C-OP4708-			REV. 1

REVISIONS					
NO.	DESCRIPTION	DATE	BY	CH.	APR.
1	ADDED 2 3/16 DIA	7·19·83	RK	DH	DRH

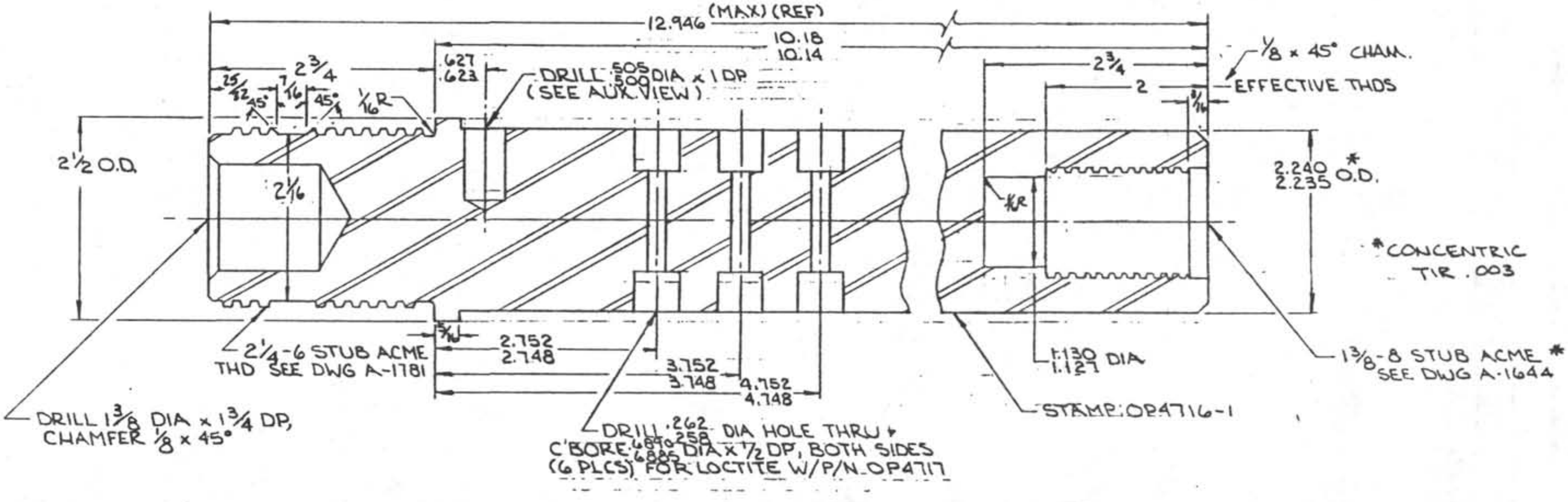


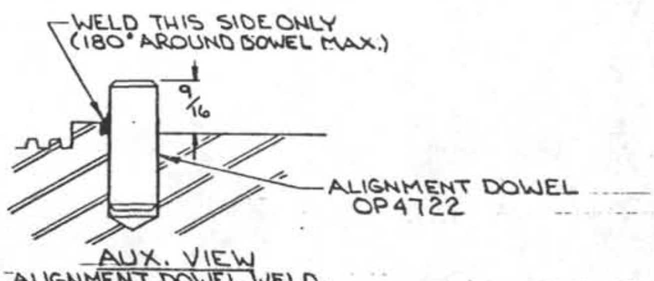
DO NOT SCALE

CONCENTRICITY ALL DIAMETERS: TIR .003

TOLERANCES UNLESS NOTED	DEEP SEA DRILLING PROJECT SCRIPPS INSTITUTION OF OCEANOGRAPHY UNIVERSITY OF CALIFORNIA, SAN DIEGO LA JOLLA, CALIFORNIA 92093				
FRACTIONS ± 1/64 DECIMALS ± .005 ANGLES ± 1/2° CORNERS 1/64 x 45° or 1/64 R FINISH 125	TITLE PISTON ROD JAM NUT ~ A.P.C ~				
SURFACE TREATMENT PARKOLUBE	MATERIAL 4130/4140	DATE 4·14·83	BY RK	CHECKED DRH	APPROVED DRH
HEAT TREATMENT Rc 28-32	SCALE 1:1	REQ'D/ASS'Y 1	PART NO. OP4715-1	DWG. NO. A-OP4715-1	(REV.)

REVISIONS					
NO.	DESCRIPTION	DATE	BY	CH.	APR.
1	2.240/2.235 WAS 2.500/2.495	7.18.83	RK		

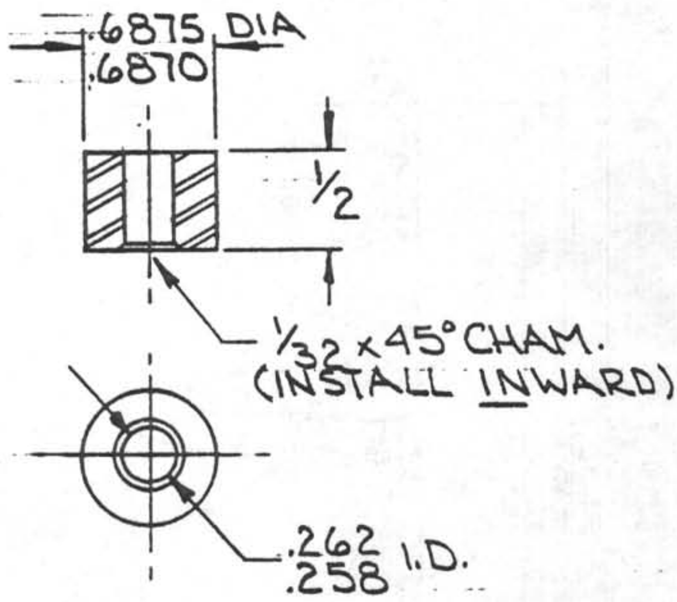




AUX. VIEW
ALIGNMENT DOWEL WELD DETAIL

TOLERANCES UNLESS NOTED: FRACTIONS ± 1/64, DECIMALS ± .005, ANGLES ± 1/2°, CORNERS 1/64 x 45° or 1/64 R, FINISH 125	DEEP SEA DRILLING PROJECT, SCRIPPS INSTITUTION OF OCEANOGRAPHY, UNIVERSITY OF CALIFORNIA, SAN DIEGO, LA JOLLA, CALIFORNIA 92093				
	TITLE: INNER SHEAR PIN SUB ~A.P.C~				
SURFACE TREATMENT: PARKOLUBE	MATERIAL: 4130/4140	DRAWN BY: RK	DATE: 11.16.82	CHECKED: DH	APPROVED: DPH
HEAT TREATMENT: Rc 34-36	PART NO. OP4716-1	SIZE DWG. NO. C-OP4716-			REV. 1

REVISIONS					
NO.	DESCRIPTION	DATE	BY	CH.	APR.



MAT'L: CARPENTER TOOL STEEL (AISI TYPE 02)

H.T. : STENTOR-OIL HARD

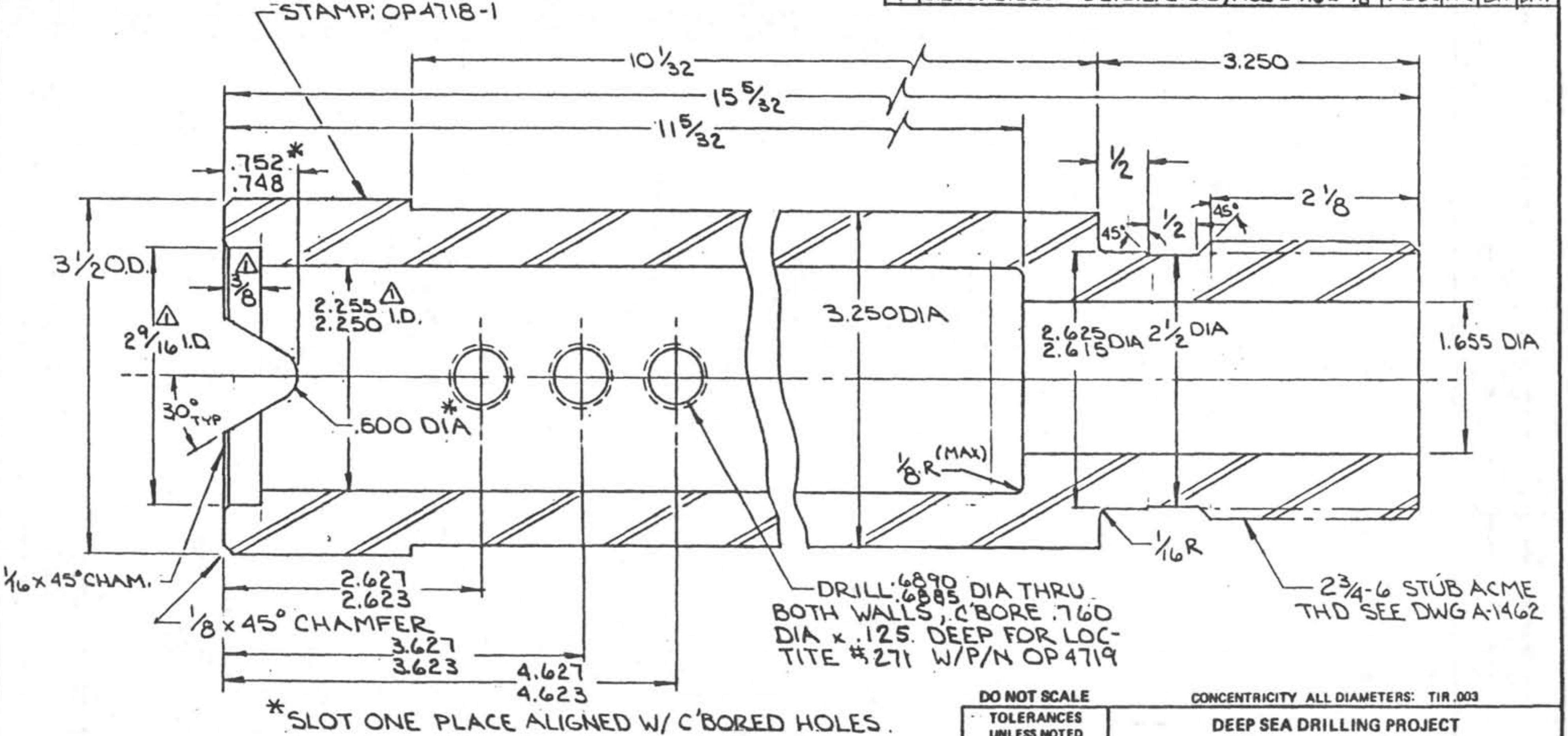
LOCTITE #271 WITH P/N OP4716, GRIND FLUSH
(I.D. CHAMFER INWARD)

DO NOT SCALE

CONCENTRICITY ALL DIAMETERS: TIR .003

TOLERANCES UNLESS NOTED FRACTIONS ± 1/64 DECIMALS ± .005 ANGLES ± 1/2° CORNERS 1/64 x 45° or 1/64 R FINISH 125	DEEP SEA DRILLING PROJECT SCRIPPS INSTITUTION OF OCEANOGRAPHY UNIVERSITY OF CALIFORNIA, SAN DIEGO LA JOLLA, CALIFORNIA 92093 TITLE INNER SHEAR PIN BUSHING ~ A.P.C ~				
SURFACE TREATMENT —0—	MATERIAL SEE ABOVE	DATE 5.16.83	BY RK	CHECKED DH	APPROVED DRH
HEAT TREATMENT SEE ABOVE	SCALE 1:1 / REQ'D/ASS'Y 6	PART NO. OP 4717		DWG. NO. A-OP4717	(REV.)

REVISIONS					
NO.	DESCRIPTION	DATE	BY	CH.	APR.
1	2.255/2.250 WAS 2.515/2.510, ADD 2 9/16 x 3/8	7-18-83	RK	DH	DPH



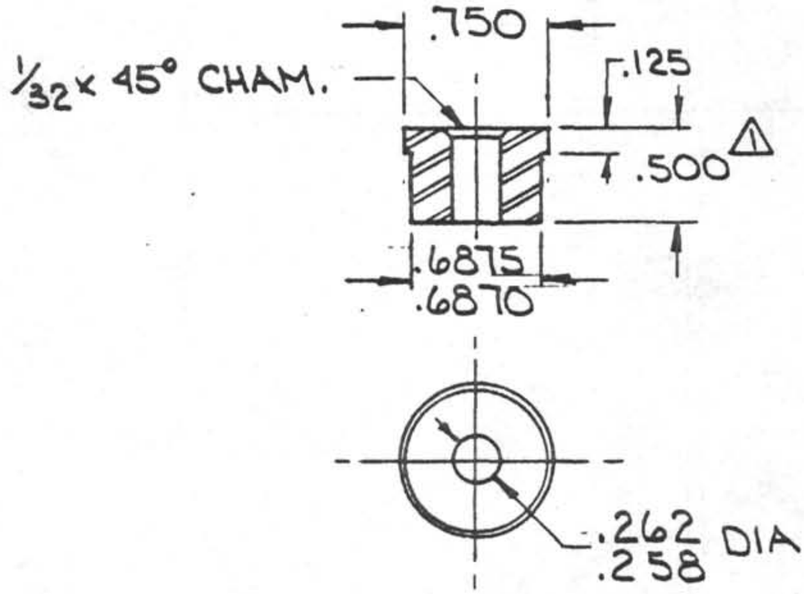
DO NOT SCALE

CONCENTRICITY ALL DIAMETERS: TIR .003

TOLERANCES UNLESS NOTED FRACTIONS ± 1/64 DECIMALS ± .005 ANGLES ± 1/2° CORNERS 1/64 x 45° or 1/64 R FINISH 125	DEEP SEA DRILLING PROJECT SCRIPPS INSTITUTION OF OCEANOGRAPHY UNIVERSITY OF CALIFORNIA, SAN DIEGO LA JOLLA, CALIFORNIA 92093				
	TITLE OUTER SHEAR PIN SUB ~A.P.C~				
SURFACE TREATMENT PARKOLUBE	MATERIAL 4130/4140	DATE 11-13-82	BY RK	CHECKED DH	APPROVED DPH
HEAT TREATMENT Rc 34-36	SCALE 1:1	REQ'D/ASS'Y 1	PART NO. OP4718-1	DWG. NO. (REV.) B-OP4718-1	

REVISIONS

NO.	DESCRIPTION	DATE	BY	CH.	APR.
1	.500 WAS .375, ADDED "SOLAR"	7.18.83	RK	DH	DPH



MAT'L: CARPENTER STENTOR-OIL HARD (AISI TYPE O2) OR CARPENTER "SOLAR" TOOL STEEL.

LOCTITE #271 WITH P/N OP4718-1 GRIND FLUSH

DO NOT SCALE

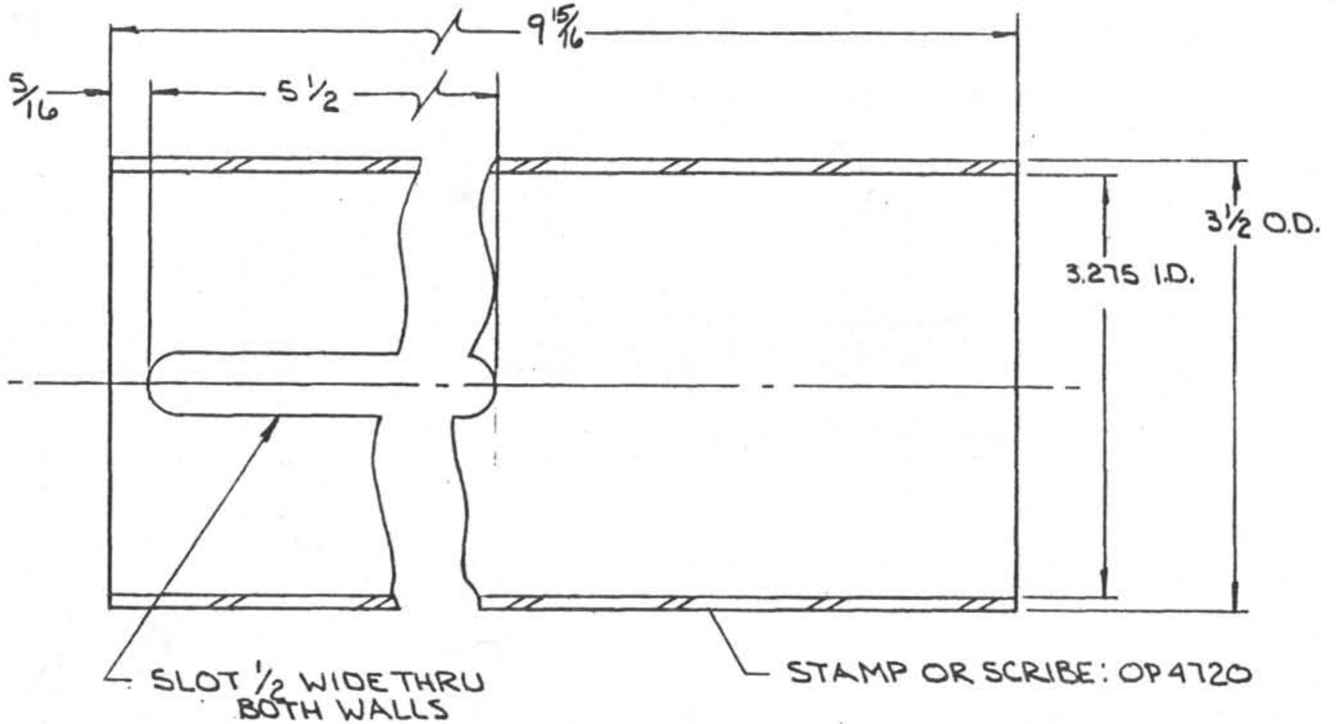
CONCENTRICITY ALL DIAMETERS: TIR .003

TOLERANCES UNLESS NOTED	
FRACTIONS ± 1/64 DECIMALS ± .005 ANGLES ± 1/2° CORNERS 1/64 x 45° or 1/64 R FINISH 125	**DEEP SEA DRILLING PROJECT** SCRIPPS INSTITUTION OF OCEANOGRAPHY UNIVERSITY OF CALIFORNIA, SAN DIEGO LA JOLLA, CALIFORNIA 92093 TITLE: OUTER SHEAR PIN BUSHING ~ A.P.C ~

SURFACE TREATMENT	MATERIAL	DATE	BY	CHECKED	APPROVED
—	SEE ABOVE	5.16.83	RK	DH	DPH

HEAT TREATMENT	SCALE	REQ'D/ASS'Y	PART NO.	DWG. NO. (REV.)
SEE ABOVE	1:1	6	OP4719-1	A-OP4719-1

REVISIONS					
NO.	DESCRIPTION	DATE	BY	CH.	APR.



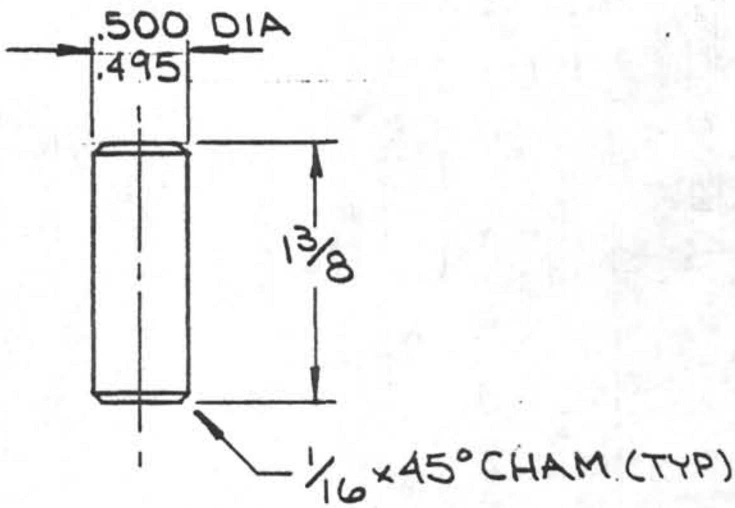
DO NOT SCALE

CONCENTRICITY ALL DIAMETERS: TIR .003

TOLERANCES UNLESS NOTED FRACTIONS ± 1/64 DECIMALS ± .005 ANGLES ± 1/2° CORNERS 1/64 x 45° or 1/64 R FINISH 125	DEEP SEA DRILLING PROJECT SCRIPPS INSTITUTION OF OCEANOGRAPHY UNIVERSITY OF CALIFORNIA, SAN DIEGO LA JOLLA, CALIFORNIA 92093 TITLE SHEAR PIN SLEEVE ~ A.P.C ~						
SURFACE TREATMENT PARKOLUBE	MATERIAL 4130/4140		DATE 1.10.83	BY RK	CHECKED DH	APPROVED DH	
HEAT TREATMENT 30-32 Rc	SCALE 1:1	REQ'D/ASS'Y 1	PART NO. OP4720		DWG. NO. B-OP4720		(REV.)

REVISIONS

NO.	DESCRIPTION	DATE	BY	CH.	APR.

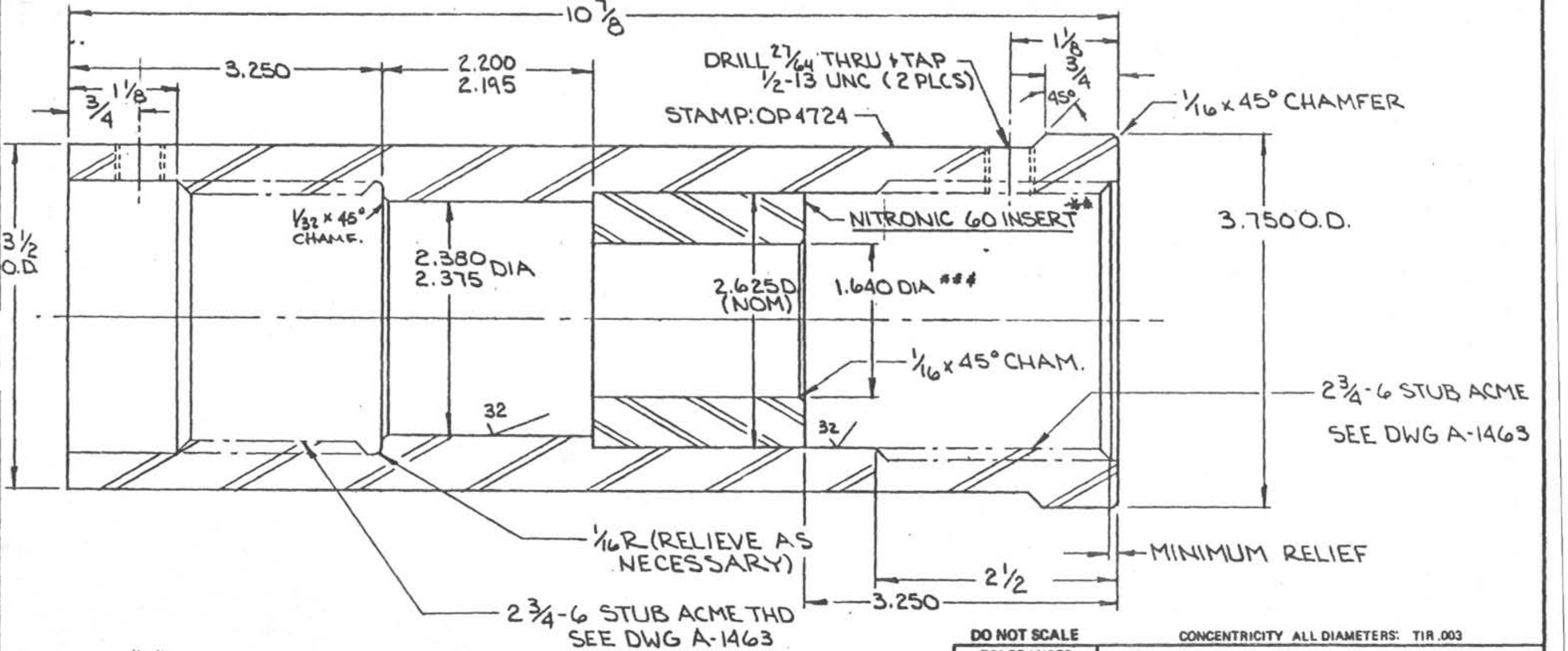


DO NOT SCALE

CONCENTRICITY ALL DIAMETERS: TIR .003

TOLERANCES UNLESS NOTED FRACTIONS ± 1/64 DECIMALS ± .005 ANGLES ± 1/2° CORNERS 1/64 x 45° or 1/64 R FINISH 125	DEEP SEA DRILLING PROJECT SCRIPPS INSTITUTION OF OCEANOGRAPHY UNIVERSITY OF CALIFORNIA, SAN DIEGO LA JOLLA, CALIFORNIA 92093 TITLE: ALIGNMENT DOWEL ~ A·P·C ~				
SURFACE TREATMENT —o—	MATERIAL 4130/4140	DATE 5·16·83	BY RK	CHECKED DH	APPROVED DPH
HEAT TREATMENT 34-36 Rc	SCALE 1:1	REQ'D/ASS'Y 1	PART NO. OP4722	DWG. NO. A-OP4722	(REV.)

REVISIONS					
NO.	DESCRIPTION	DATE	BY	CH.	APR.
1	ADDED NITRONIC 60 INSERT, WAS ALL NITRON.	7·18·83	RK	DH	DPH



** NITRONIC 60 INSERT
SHRINK FIT INTO PLACE AND FINAL BORE I.D. AFTER HEAT TREATING ALLOY STEEL BODY. RECOMMENDED INTERFERENCE = .0004 / .0014

*** 1.640 DIA. BORE TO BE CONCENTRIC WITH AXES OF BOTH THREADS: TIR .003

* EXCEPT INSERT

DO NOT SCALE

CONCENTRICITY ALL DIAMETERS: TIR .003

TOLERANCES UNLESS NOTED
FRACTIONS ± 1/64
DECIMALS ± .005
ANGLES ± 1/2°
CORNERS 1/64 x 45° or 1/64 R
FINISH 125

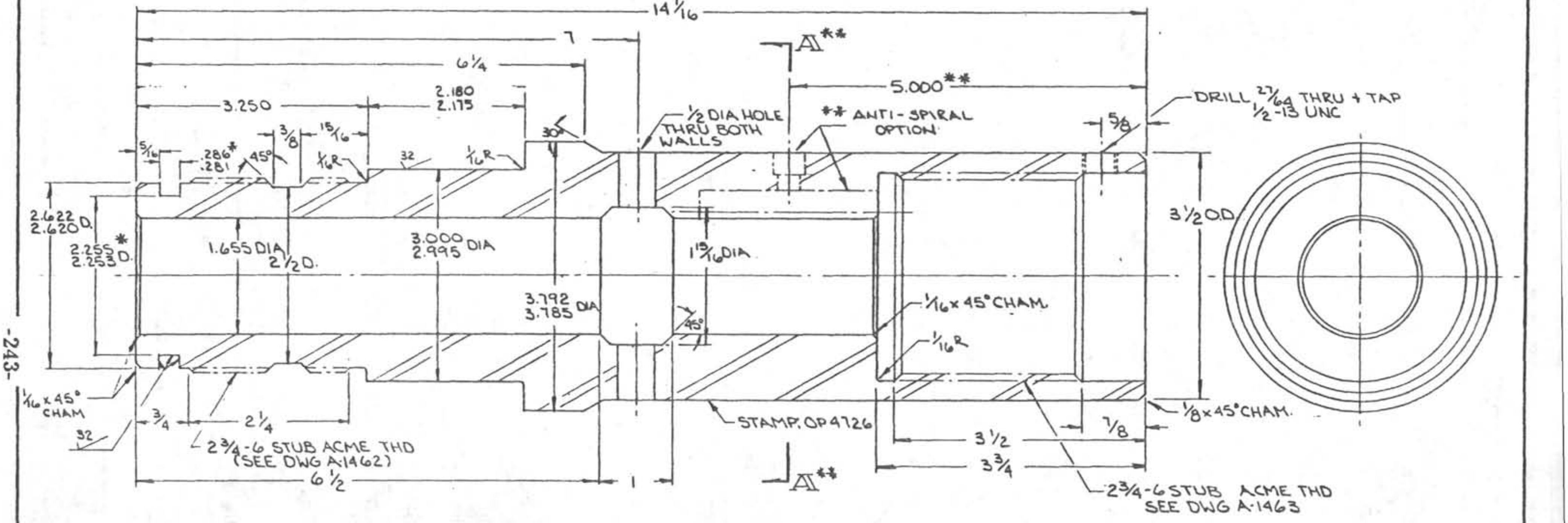
DEEP SEA DRILLING PROJECT
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UNIVERSITY OF CALIFORNIA, SAN DIEGO
LA JOLLA, CALIFORNIA 92093

TITLE: INNER SEAL SUB ~A·P·C~

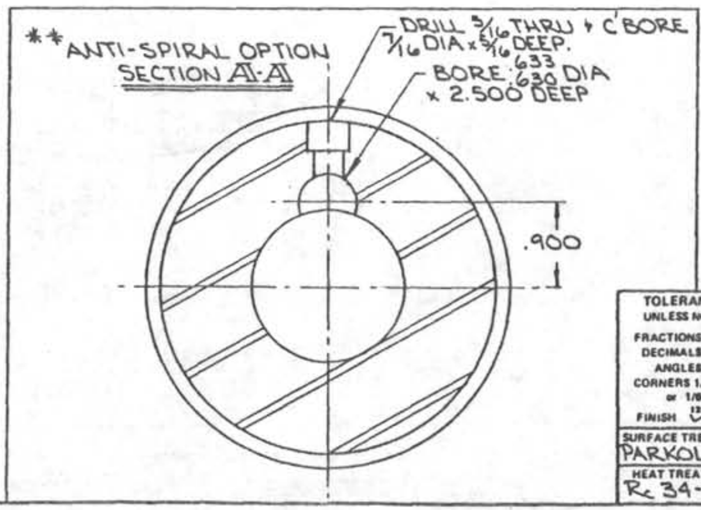
SURFACE TREATMENT	MATERIAL	DATE	BY	CHECKED	APPROVED
PARKOLUBE	4130/4140 *	1·13·82	RK	DPH	DPH

HEAT TREATMENT	SCALE	REQ'D/ASS'Y	PART NO.	DWG. NO. (REV.)
Rc 34-36 *	1:1	1	OP4724-1	B-OP4724-1

REVISIONS					
NO.	DESCRIPTION	DATE	BY	CH.	APR.



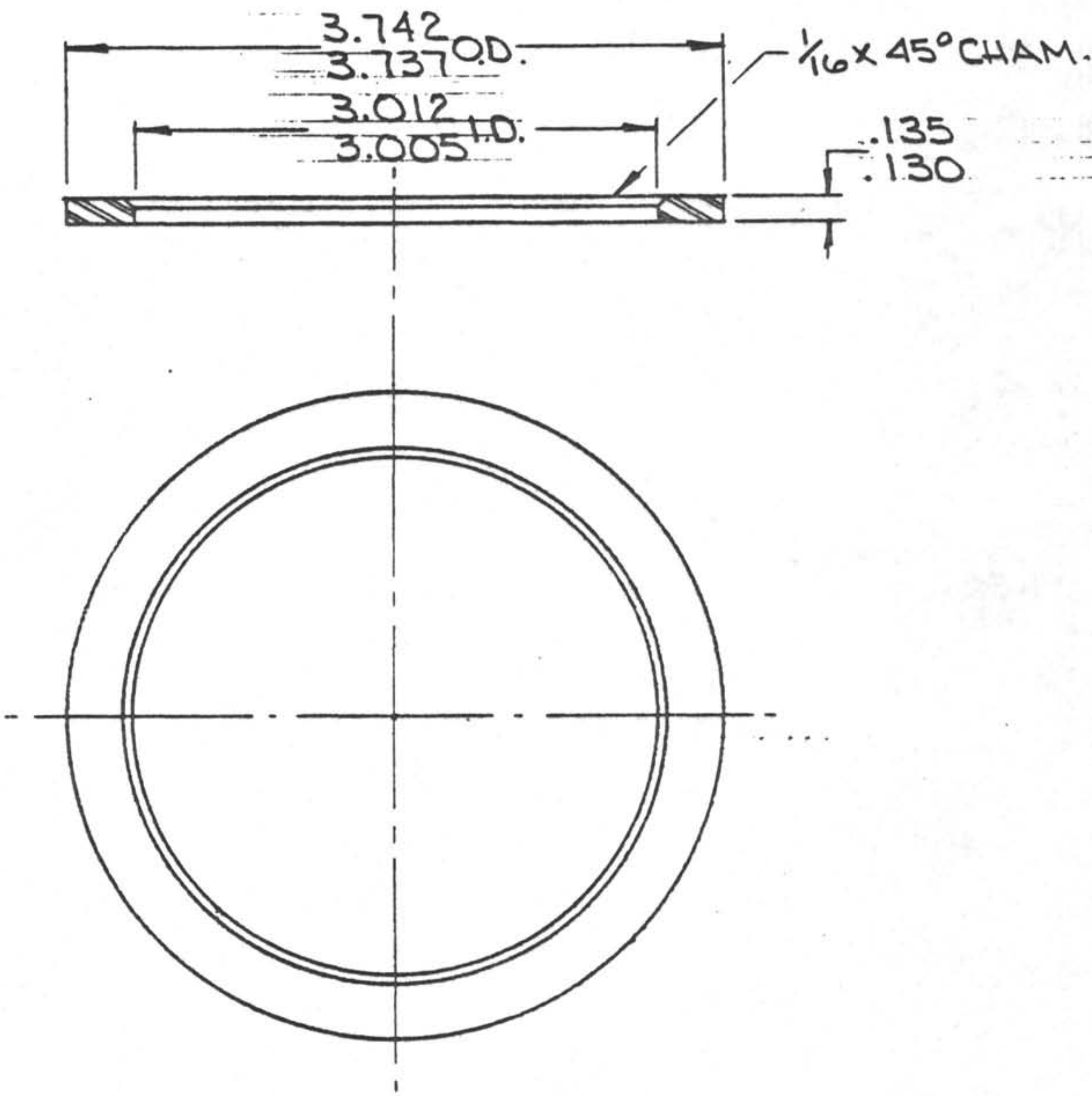
*FOR O-RING #2-331



TOLERANCES UNLESS NOTED	DEEP SEA DRILLING PROJECT SCRIPPS INSTITUTION OF OCEANOGRAPHY UNIVERSITY OF CALIFORNIA, SAN DIEGO LA JOLLA, CALIFORNIA 92093			
FRACTIONS ± 1/64 DECIMALS ± .005 ANGLES ± 1/2° CORNERS 1/64 x 45° or 1/64 R FINISH 125	TITLE OUTER SEAL SUB ~A·P·C~			
SURFACE TREATMENT PARKOLUBE	MATERIAL 4130 / 4140	DRAWN BY RK	DATE 4-15-83	CHECKED DH / APPROVED DRH
HEAT TREATMENT Rc 34-36	PART NO. OP4726	SIZE DWG NO. C-OP4726		REV.

REVISIONS

NO.	DESCRIPTION	DATE	BY	CH.	APR.



DO NOT SCALE

CONCENTRICITY ALL DIAMETERS: TIR .003

DEEP SEA DRILLING PROJECT
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UNIVERSITY OF CALIFORNIA, SAN DIEGO
LA JOLLA, CALIFORNIA 92093

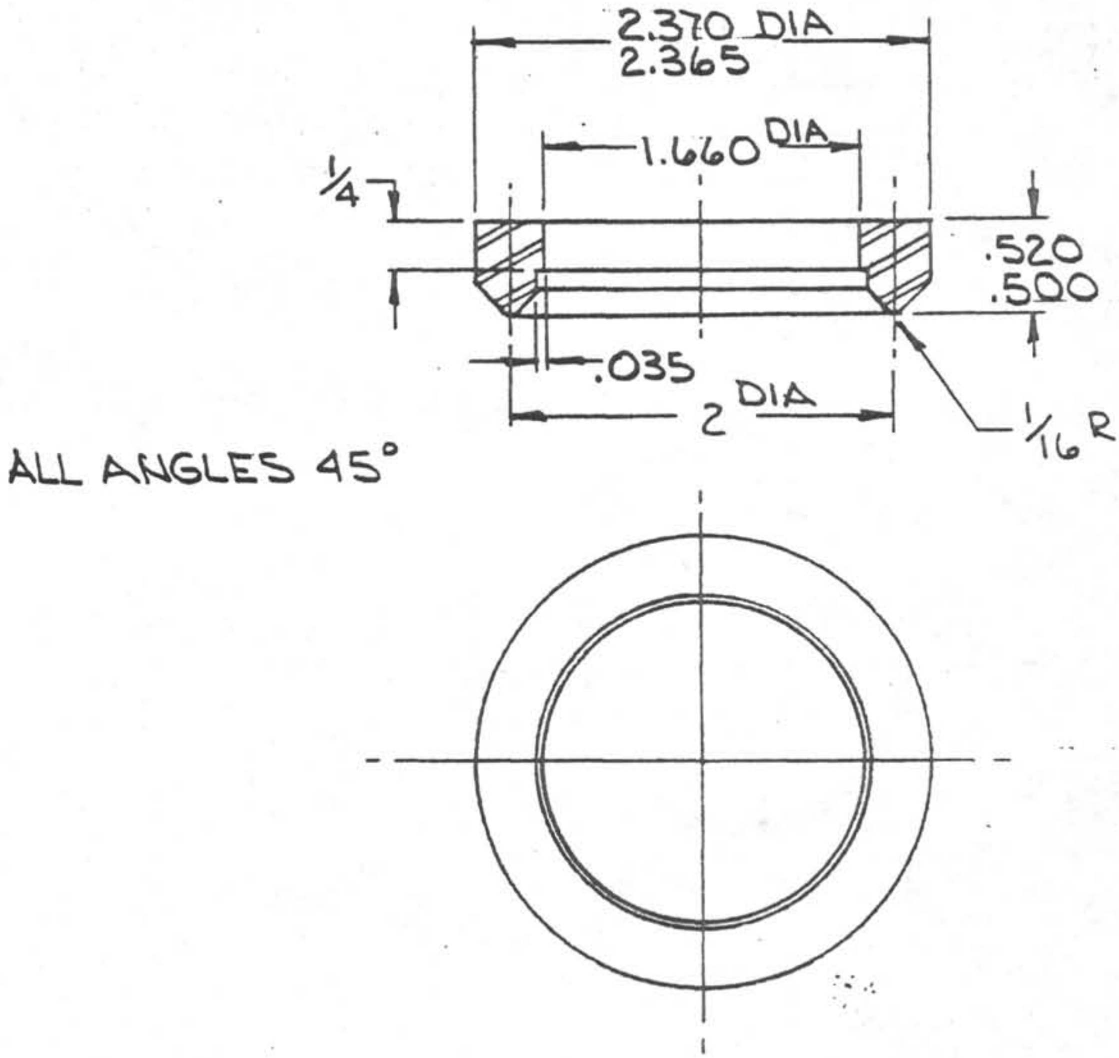
TOLERANCES UNLESS NOTED
FRACTIONS ± 1/64
DECIMALS ± .005
ANGLES ± 1/2°
CORNERS 1/64 x 45° or 1/64 R
FINISH 125 ✓

TITLE: OUTER V-PACKING SHIM WASHER ~ A.P.C ~

SURFACE TREATMENT	MATERIAL	DATE	BY	CHECKED	APPROVED
	304 S.S.	5·23·83	RK	DH	DRH

HEAT TREATMENT	SCALE	REQ'D/ASS'Y	PART NO.	DWG. NO.	(REV.)
ANNEALED	1:1	1	OP4731	A-OP4731	

REVISIONS					
NO.	DESCRIPTION	DATE	BY	CH.	APR.



DO NOT SCALE

CONCENTRICITY ALL DIAMETERS: TIR .003

TOLERANCES UNLESS NOTED

FRACTIONS ± 1/64
DECIMALS ± .005
ANGLES ± 1/2°
CORNERS 1/64 x 45° or 1/64 R
FINISH 125 ✓

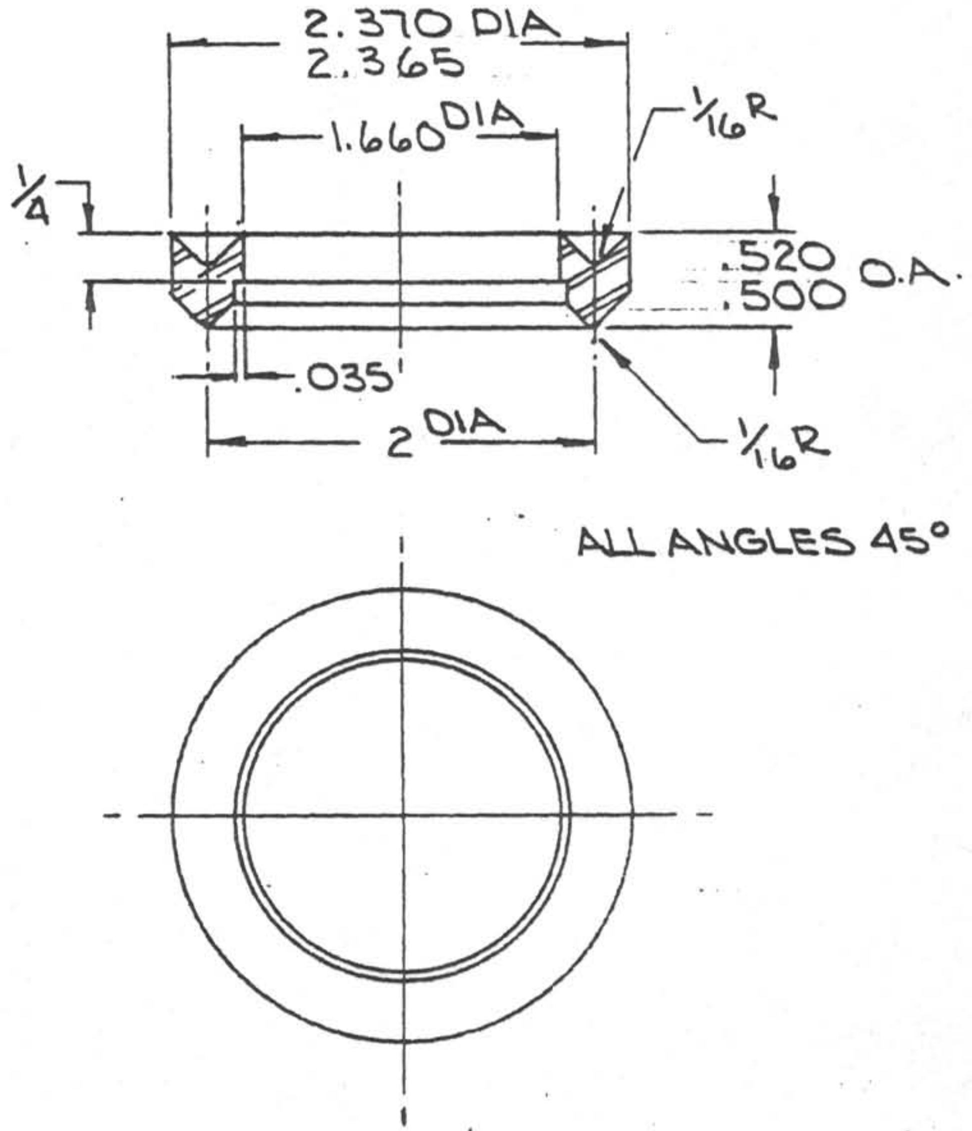
DEEP SEA DRILLING PROJECT
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UNIVERSITY OF CALIFORNIA, SAN DIEGO
LA JOLLA, CALIFORNIA 92093

TITLE: INNER SEAL MALE ADAPTOR ~A.P.C~

SURFACE TREATMENT	MATERIAL	DATE	BY	CHECKED	APPROVED
—	304 S.S.	5.12.83	RK	DH	DH

HEAT TREATMENT	SCALE	REQ'D/ASS'Y	PART NO.	DWG. NO.	(REV.)
ANNEALED	1:1	1	OP4732	A-OP4732	

REVISIONS					
NO.	DESCRIPTION	DATE	BY	CH.	APR.

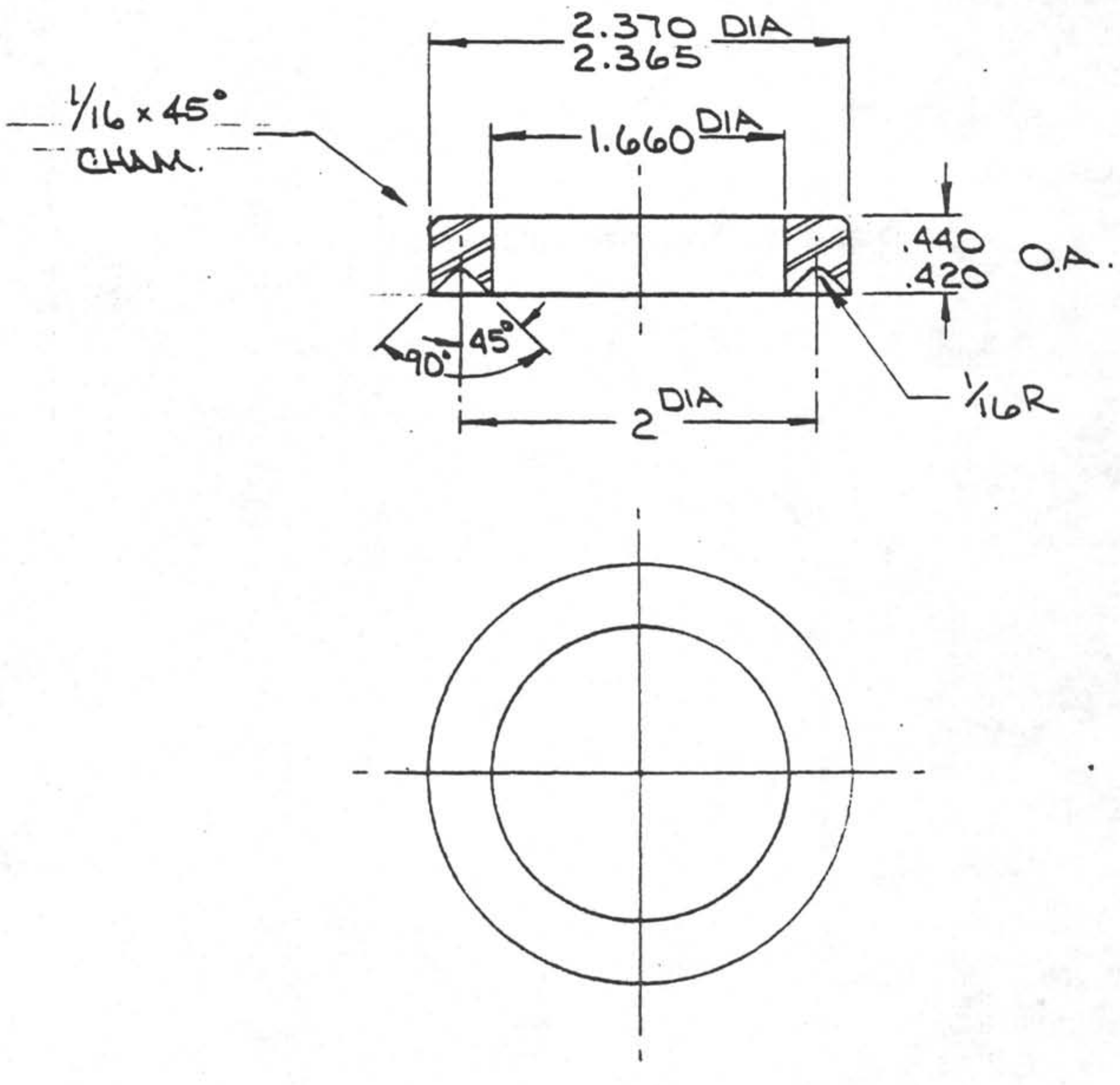


DO NOT SCALE

CONCENTRICITY ALL DIAMETERS: TIR .003

TOLERANCES UNLESS NOTED FRACTIONS ± 1/64 DECIMALS ± .005 ANGLES ± 1/2° CORNERS 1/64 x 45° or 1/64 R FINISH 125	DEEP SEA DRILLING PROJECT SCRIPPS INSTITUTION OF OCEANOGRAPHY UNIVERSITY OF CALIFORNIA, SAN DIEGO LA JOLLA, CALIFORNIA 92093					
	TITLE INNER SEAL V-SPACER ~A.P.C~					
SURFACE TREATMENT	MATERIAL 304 S.S.		DATE 5.12.83	BY RK	CHECKED DRH	APPROVED DRH
HEAT TREATMENT ANNEALED	SCALE 1:1	REQ'D/ASS'Y 2	PART NO. OP4733		DWG. NO. A-OP4733	(REV.)

REVISIONS					
NO.	DESCRIPTION	DATE	BY	CH.	APR.

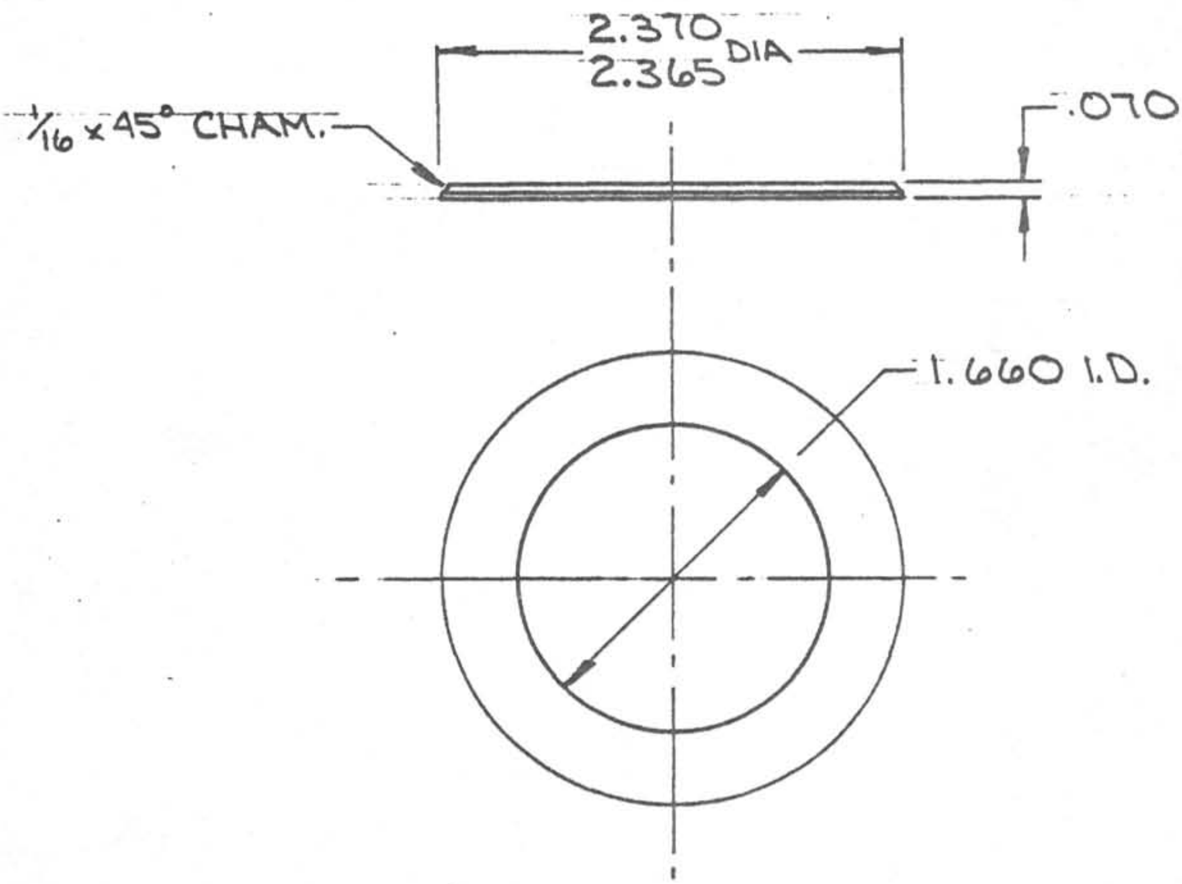


DO NOT SCALE

CONCENTRICITY ALL DIAMETERS: TIR .003

TOLERANCES UNLESS NOTED	DEEP SEA DRILLING PROJECT SCRIPPS INSTITUTION OF OCEANOGRAPHY UNIVERSITY OF CALIFORNIA, SAN DIEGO LA JOLLA, CALIFORNIA 92093				
FRACTIONS ± 1/64 DECIMALS ± .005 ANGLES ± 1/2° CORNERS 1/64 × 45° or 1/64 R FINISH 125	TITLE INNER SEAL FEMALE ADAPTOR ~ A.P.C ~				
SURFACE TREATMENT ——	MATERIAL 304 S.S	DATE 5.12.83	BY RK	CHECKED DH	APPROVED DPH
HEAT TREATMENT ANNEALED	SCALE 1:1	REQ'D/ASS'Y 1	PART NO. OP4734	DWG. NO. A-OP4734	(REV.)

REVISIONS					
NO.	DESCRIPTION	DATE	BY	CH.	APR.

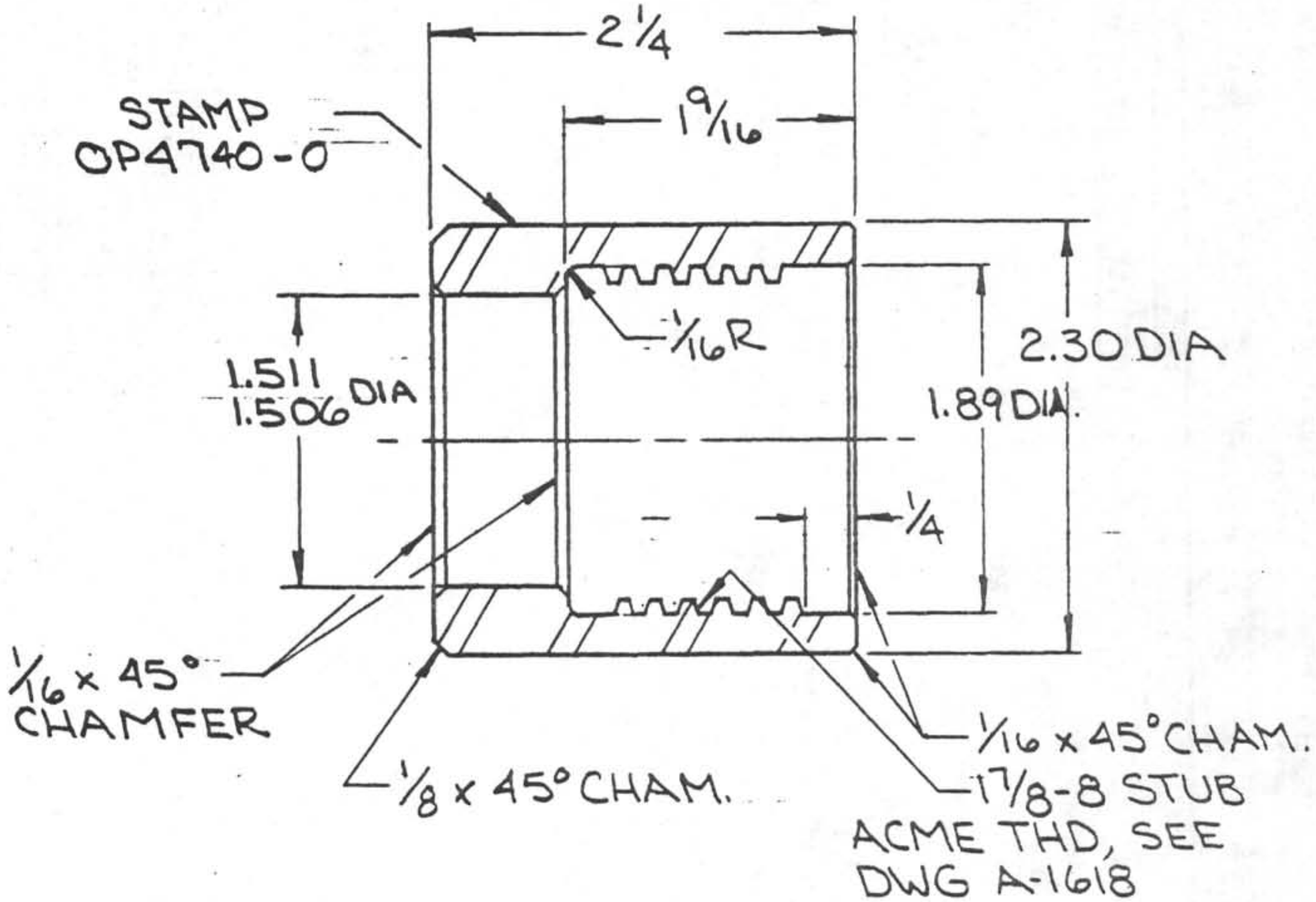


DO NOT SCALE

CONCENTRICITY ALL DIAMETERS: TIR .003

TOLERANCES UNLESS NOTED FRACTIONS ± 1/64 DECIMALS ± .005 ANGLES ± 1/2° CORNERS 1/64 x 45° or 1/64 R FINISH 125	DEEP SEA DRILLING PROJECT SCRIPPS INSTITUTION OF OCEANOGRAPHY UNIVERSITY OF CALIFORNIA, SAN DIEGO LA JOLLA, CALIFORNIA 92093 TITLE INNER V-PACK SHIM WASHER ~ A.P.C ~				
SURFACE TREATMENT —o—	MATERIAL 304 S.S.	DATE 5.19.83	BY RK	CHECKED DPH	APPROVED DPH
HEAT TREATMENT ANNEALED	SCALE 1:1	REQ'D/ASS'Y 1	PART NO. OP4735	DWG. NO. (REV.) A-OP4735	

REVISIONS					
NO.	DESCRIPTION	DATE	BY	CH.	APR.



DO NOT SCALE

CONCENTRICITY ALL DIAMETERS: TIR .003

TOLERANCES UNLESS NOTED
FRACTIONS ± 1/64
DECIMALS ± .005
ANGLES ± 1/2°
CORNERS 1/64 x 45° or 1/64 R
FINISH 125

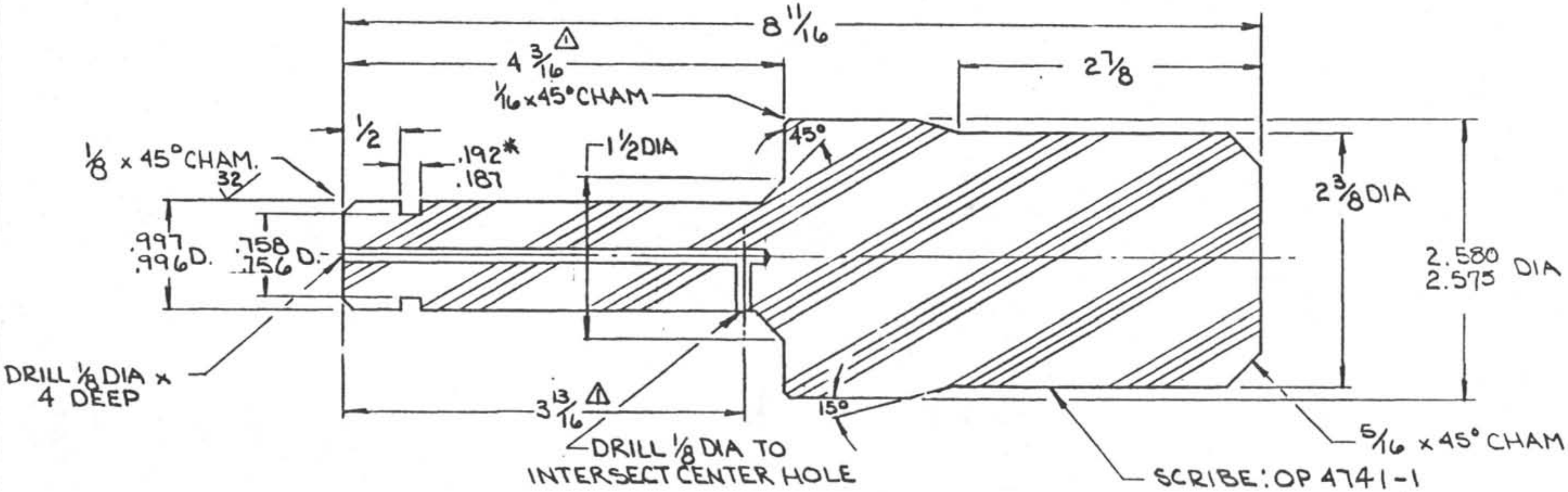
DEEP SEA DRILLING PROJECT
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UNIVERSITY OF CALIFORNIA, SAN DIEGO
LA JOLLA, CALIFORNIA 92093

TITLE: LOCK PIN NUT ~ A.D.C ~

SURFACE TREATMENT	MATERIAL	DATE	BY	CHECKED	APPROVED
PARKOLUBE	4130	11.9.82	RK	DRH	DRH

HEAT TREATMENT	SCALE	REQ'D/ASS'Y	PART NO.	DWG. NO. (REV.)
28-32 Rc	1:1	1	OP4740	A-OP4740

REVISIONS					
NO.	DESCRIPTION	DATE	BY	CH.	APR.
1	4 3/16 WAS 3 3/8, 3 13/16 WAS 3	8-30-83	RK		



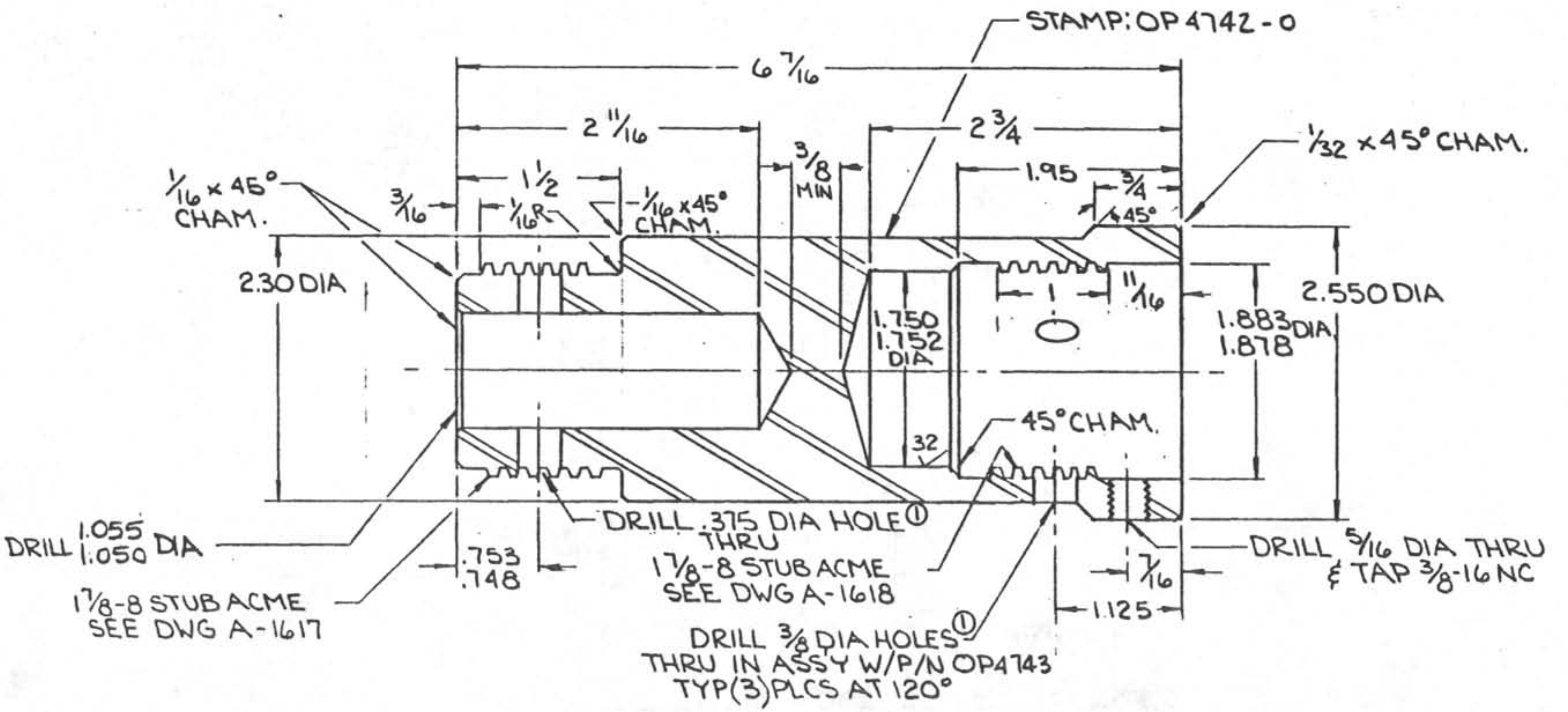
* FOR O-RING # 2-210

DO NOT SCALE

CONCENTRICITY ALL DIAMETERS: TIR .003

TOLERANCES UNLESS NOTED	DEEP SEA DRILLING PROJECT SCRIPPS INSTITUTION OF OCEANOGRAPHY UNIVERSITY OF CALIFORNIA, SAN DIEGO LA JOLLA, CALIFORNIA 92093				
FRACTIONS ± 1/64 DECIMALS ± .005 ANGLES ± 1/2° CORNERS 1/64 x 45° or 1/64 R FINISH 125	TITLE BREAKAWAY HEAD ~ A·P·C ~				
SURFACE TREATMENT —o—	MATERIAL DELRIN AF	DATE 11-9-82	BY RK	CHECKED DPH	APPROVED DPH
HEAT TREATMENT —o—	SCALE	REQ'D/ASS'Y	PART NO. OP4741-1	DWG. NO. (REV.) B-OP4741-1	

REVISIONS					
NO.	DESCRIPTION	DATE	BY	CH.	APR.



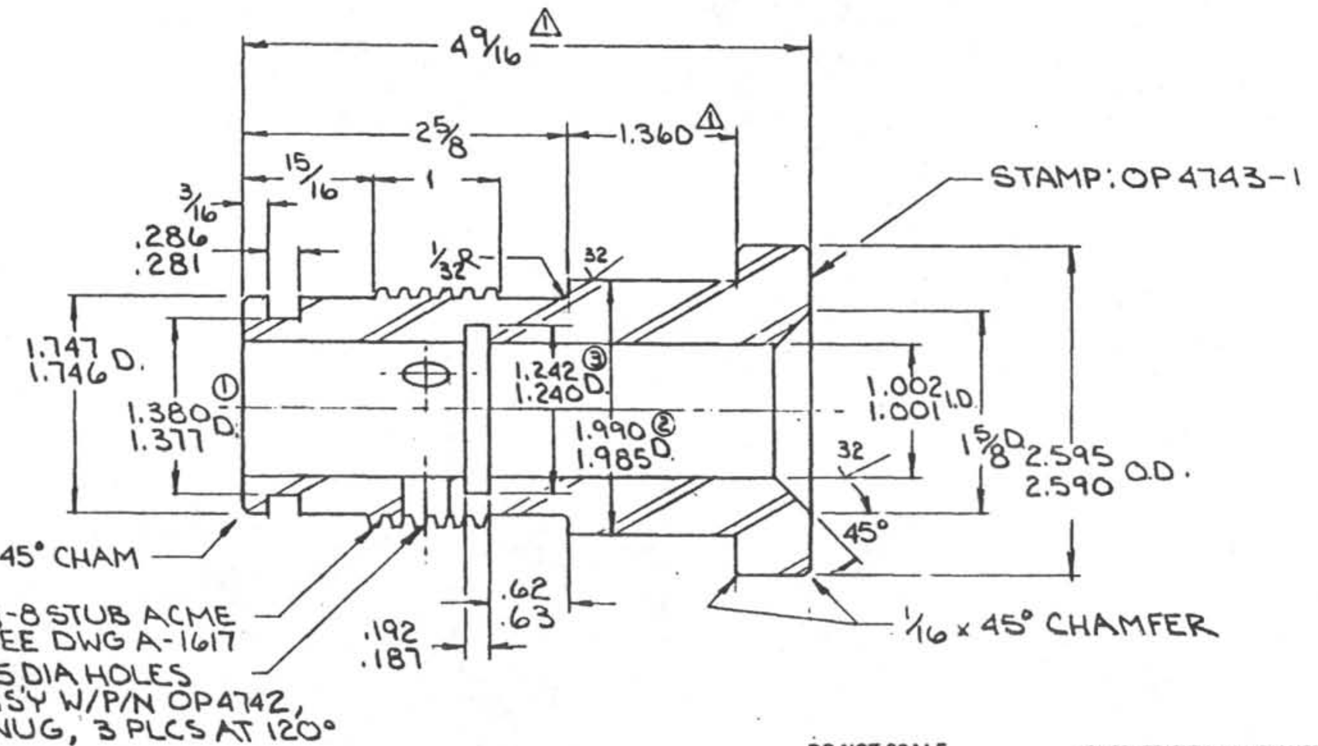
① DEBURR + CLEAN UP THDS. AFTER DRILLING.

DO NOT SCALE

CONCENTRICITY ALL DIAMETERS: TIR .003

TOLERANCES UNLESS NOTED	DEEP SEA DRILLING PROJECT SCRIPPS INSTITUTION OF OCEANOGRAPHY UNIVERSITY OF CALIFORNIA, SAN DIEGO LA JOLLA, CALIFORNIA 92093					
FRACTIONS ± 1/64 DECIMALS ± .005 ANGLES ± 1/2° CORNERS 1/64 × 45° or 1/64 R FINISH 125	TITLE PISTON HEAD BODY ~A·P·C~					
SURFACE TREATMENT PARKOLUBE	MATERIAL 4140		DATE 11·9·82	BY RK	CHECKED DPH	APPROVED DPH
HEAT TREATMENT 28-32 Rc	SCALE 1:1	REQ'D/ASS'Y 1	PART NO. OP4742		DWG. NO. B-OP4742	(REV.)

REVISIONS					
NO.	DESCRIPTION	DATE	BY	CH.	APR.
1	4 9/16 w/ 3 3/8, 1.360 w/.550, V-PACK w/ POLY PACK	8.30.88	RK		



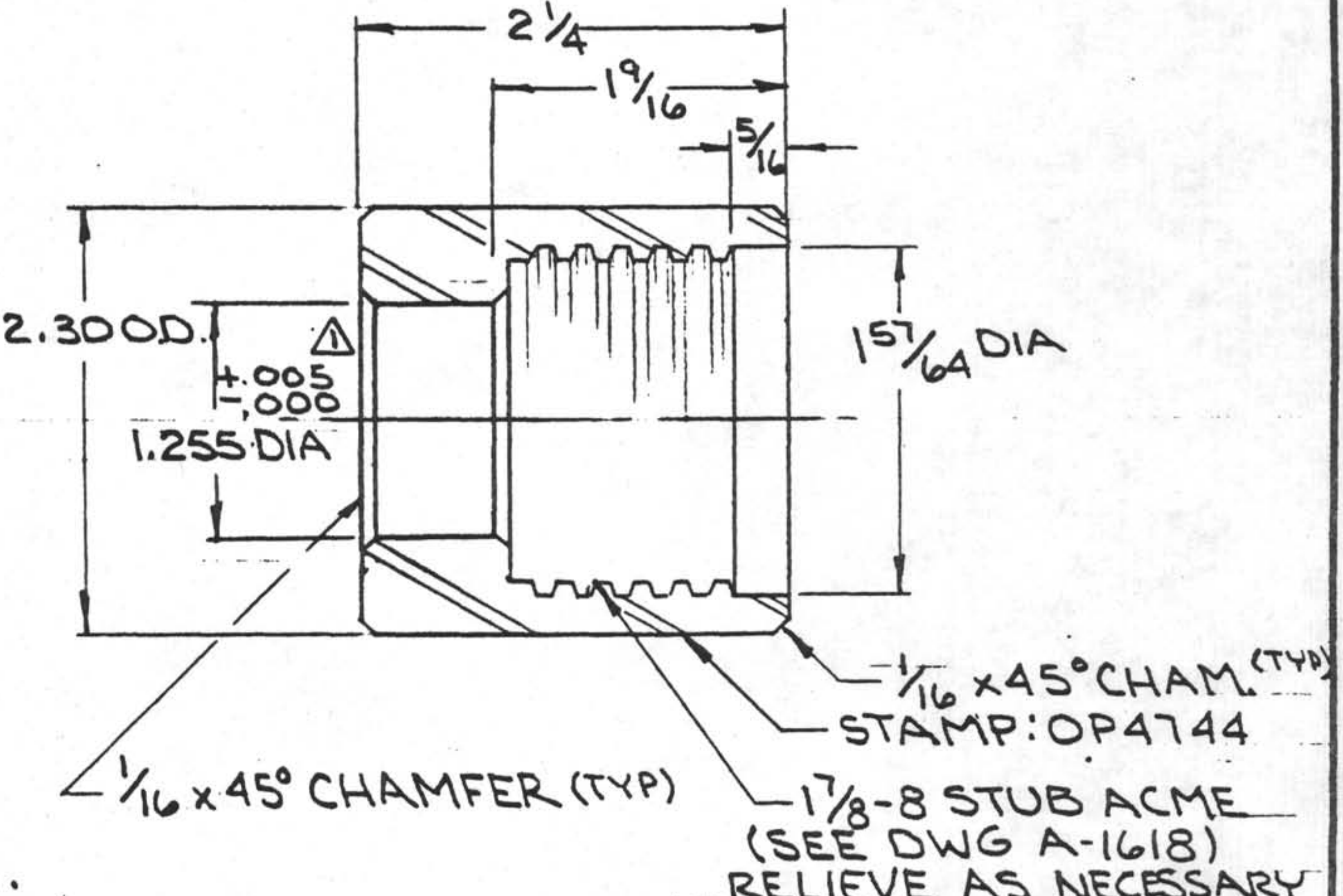
① FOR O-RING # 2-324
② FOR MOLYTHANE V-PACKING 2 × 2.62 (# 31202000) ⚠
③ FOR O-RING # 2-214

DO NOT SCALE

CONCENTRICITY ALL DIAMETERS: TIR .003

TOLERANCES UNLESS NOTED FRACTIONS ± 1/64 DECIMALS ± .005 ANGLES ± 1/2° CORNERS 1/64 x 45° or 1/64 R FINISH 125	DEEP SEA DRILLING PROJECT SCRIPPS INSTITUTION OF OCEANOGRAPHY UNIVERSITY OF CALIFORNIA, SAN DIEGO LA JOLLA, CALIFORNIA 92093 TITLE PISTON HEAD SEAL RETAINER ~ A.P.C ~				
SURFACE TREATMENT PARKOLUBE	MATERIAL 4140	DATE 11.9.82	BY RK	CHECKED DPH	APPROVED DPH
HEAT TREATMENT 28-32 Rc	SCALE 1:1	REQ'D/ASS'Y 1	PART NO. OP4743-1	DWG. NO. (REV.) B-OP4743-1	

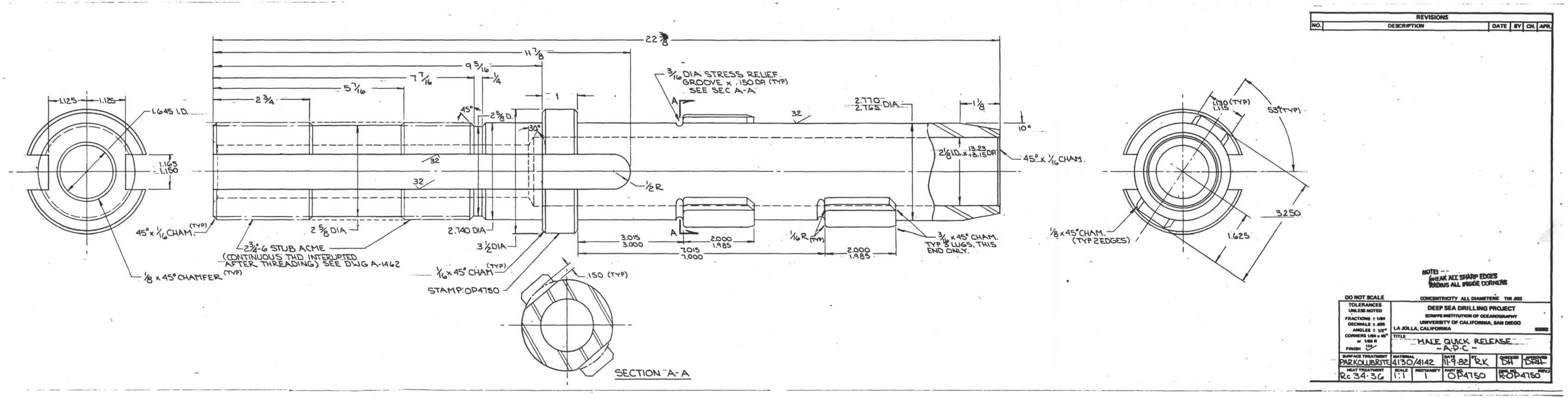
REVISIONS					
NO.	DESCRIPTION	DATE	BY	CH.	APR.



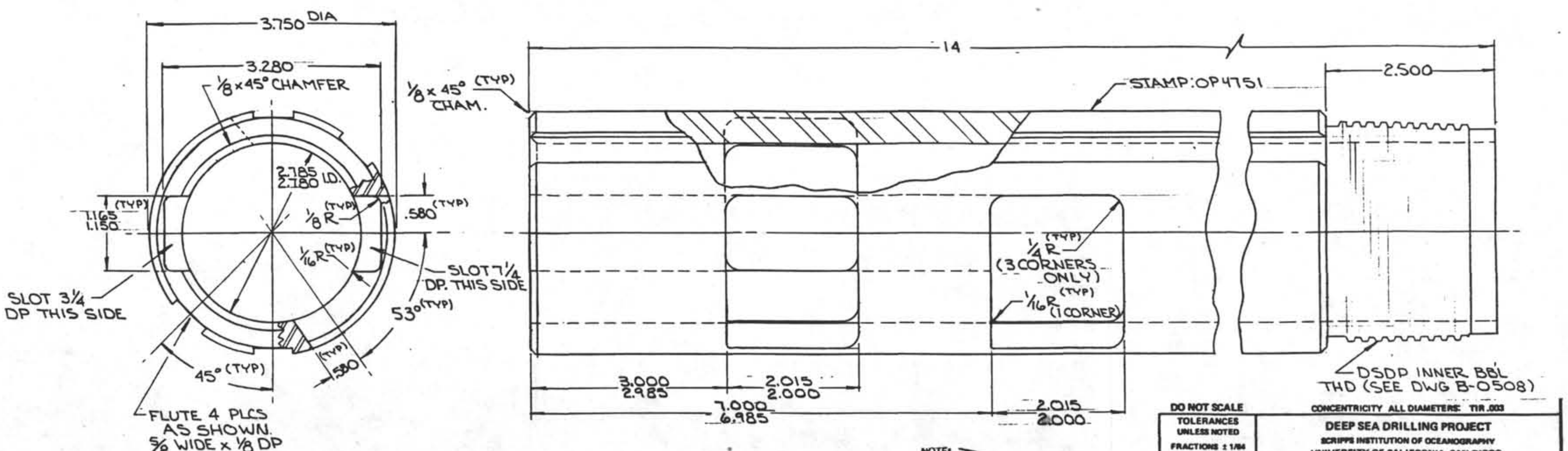
NOTE:
THIS PART REQUIRED TO ADAPT BREAKAWAY PISTON HEAD ASS'Y. (APC) TO VLHPC. IF DESIRED IT CAN BE MADE FROM EXISTING VLHPC PART #OP4345 BY REDUCING O.D.

DO NOT SCALE — CONCENTRICITY ALL DIAMETERS: TIR .003

TOLERANCES UNLESS NOTED FRACTIONS ± 1/64 DECIMALS ± .005 ANGLES ± 1/2° CORNERS 1/64 x 45° or 1/64 R FINISH 125	DEEP SEA DRILLING PROJECT SCRIPPS INSTITUTION OF OCEANOGRAPHY UNIVERSITY OF CALIFORNIA, SAN DIEGO LA JOLLA, CALIFORNIA 92093 TITLE: SPECIAL LOCK PIN NUT ~APC~				
SURFACE TREATMENT: PARKOLUBE	MATERIAL: 4130 STEEL	DATE: 11.12.82	BY: RK	CHECKED: DPH	APPROVED: DPH
HEAT TREATMENT: Rc 28-32	SCALE: 1:1	REQ'D/ASS'Y: 1	PART NO. OP4744	DWG. NO. A-OP4744	(REV.)


REVISIONS
NO.
DESCRIPTION
DATE
BY
CH.
APR.
22 3/8
11 7/8
9 5/16
7 7/16
5 7/16
2 3/4
1/4
1
3/16 DIA STRESS RELIEF GROOVE x .150 DP. (TYP) SEE SEC A-A
2.770
2.765 DIA
1 1/8
10°
1.125
1.125
1.645 I.D.
1.165
1.150
45°
2 5/8 D.
30°
32
2 1/8 I.D. x 13.23 / 13.15 DP.
45° x 1/16 CHAM.
1/2 R
45° x 1/16 CHAM. (TYP)
2 5/8 DIA
2.740 DIA
3 1/2 DIA
2 3/4-6 STUB ACME (CONTINUOUS THD INTERUPTED AFTER THREADING) SEE DWG A-1462
1/8 x 45° CHAMFER (TYP)
1/16 x 45° CHAM (TYP)
STAMP: OP4750
.150 (TYP)
3.015
3.000
2.000
1.985
7.015
7.000
1/16 R (TYP)
3/16 x 45° CHAM. TYP 3 LUGS, THIS END ONLY.
1.130
1.115 (TYP)
53° (TYP)
3.250
1.625
1/8 x 45° CHAM. (TYP 2 EDGES)
SECTION A-A
NOTE: BREAK ALL SHARP EDGES RADIUS ALL INSIDE CORNERS
DO NOT SCALE
CONCENTRICITY ALL DIAMETERS TIR .003
TOLERANCES UNLESS NOTED
FRACTIONS ± 1/64
DECIMALS ± .005
ANGLES ± 1/2°
CORNERS 1/64 x 45° or 1/64 R
FINISH 125
DEEP SEA DRILLING PROJECT
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UNIVERSITY OF CALIFORNIA, SAN DIEGO
LA JOLLA, CALIFORNIA
TITLE MALE QUICK RELEASE ~A.P.C~
SURFACE TREATMENT PARKOLUBRITE
MATERIAL 4130/4142
DATE 11-9-82
BY RK
CHECKED DH
APPROVED DRH
HEAT TREATMENT Rc 34-36
SCALE 1:1
REQ'D/ASSY 1
PART NO. OP4750
DWG. NO. R-OP4750 (REV.)

REVISIONS					
NO.	DESCRIPTION	DATE	BY	CH.	APR.
1	4 FLUTES WAS 6 FLUTES	6-7-83	RK	DH	DRH



NOTE: BREAK ALL SHARP EDGES RADIUS ALL INSIDE CORNERS

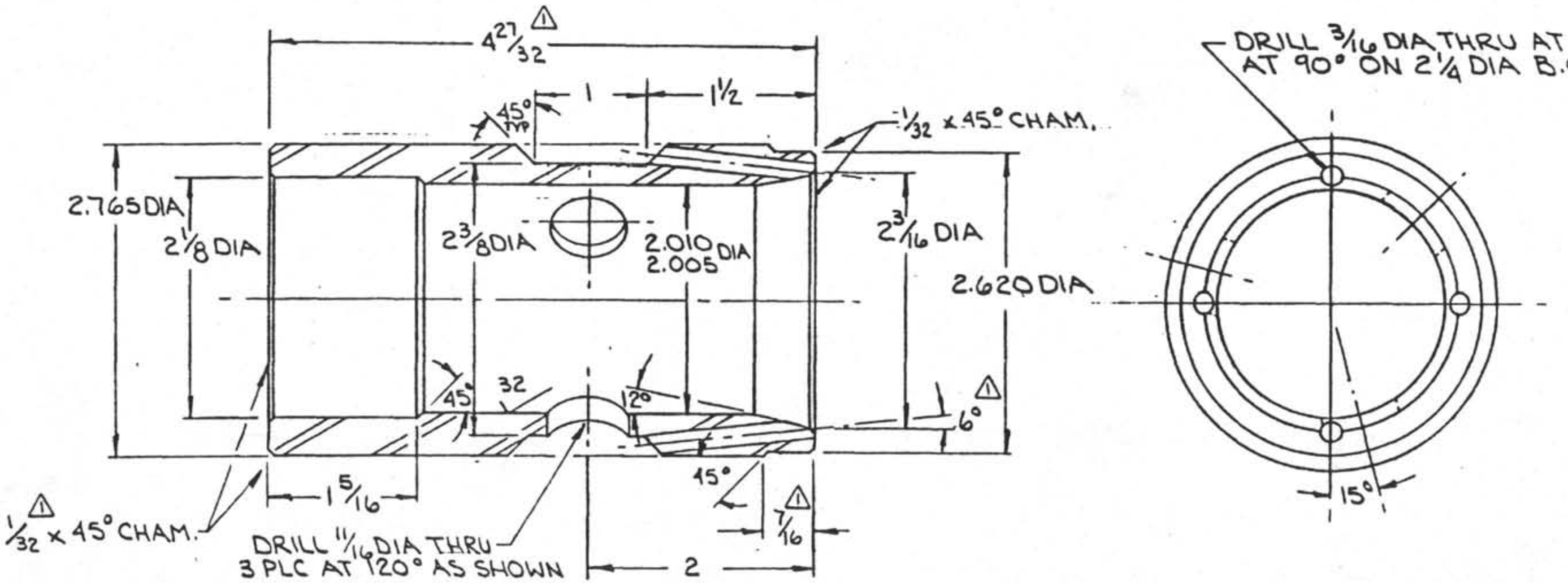
RADIUS ALL SHARP CORNERS AND SHARP EDGES, DEBURR HOLES INSIDE + OUT.

DO NOT SCALE

CONCENTRICITY ALL DIAMETERS: TIR .003

TOLERANCES UNLESS NOTED FRACTIONS ± 1/64 DECIMALS ± .005 ANGLES ± 1/2° CORNERS 1/64 x 45° or 1/64 R FINISH 125	DEEP SEA DRILLING PROJECT SCRIPPS INSTITUTION OF OCEANOGRAPHY UNIVERSITY OF CALIFORNIA, SAN DIEGO LA JOLLA, CALIFORNIA 92093 TITLE FEMALE QUICK RELEASE ~A.P.C~					
SURFACE TREATMENT PARKOLUBE	MATERIAL 4130/4142		DATE 11-9-82	BY RK	CHECKED DH	APPROVED DRH
HEAT TREATMENT 34-36 Rc	SCALE 1:1	REQ'D/ASS'Y 1	PART NO. OP4751-1		DWG. NO. (REV.) R OP4751-1	

REVISIONS					
NO.	DESCRIPTION	DATE	BY	CH.	APR.
1	6° WAS 8°, 4 27/32 WAS 4 13/16, 7/16 W/ 9/32, 1/32 W/ 1/16	5.23.83	RK		



DO NOT SCALE

CONCENTRICITY ALL DIAMETERS: TIR .003

TOLERANCES UNLESS NOTED
FRACTIONS ± 1/64
DECIMALS ± .005
ANGLES ± 1/2°
CORNERS 1/64 x 45° or 1/64 R
FINISH 125

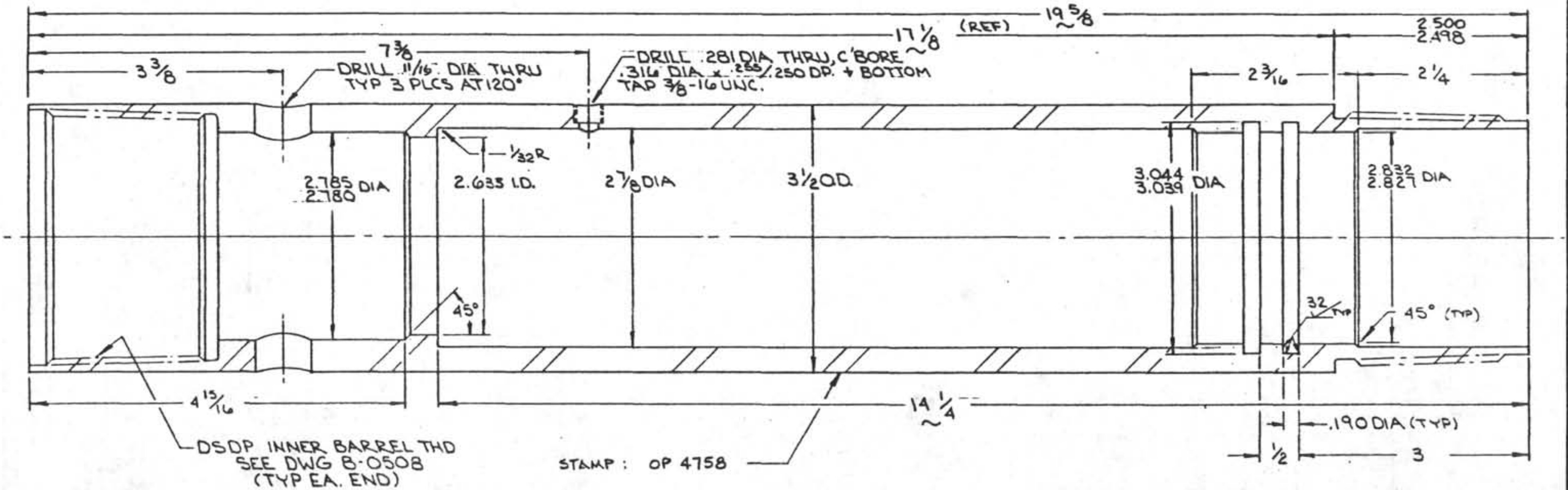
DEEP SEA DRILLING PROJECT
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UNIVERSITY OF CALIFORNIA, SAN DIEGO
LA JOLLA, CALIFORNIA 92093

TITLE VENT SNUBBER ~ A.P.C ~

SURFACE TREATMENT	MATERIAL	DATE	BY	CHECKED	APPROVED
—	NITRONIC 60	4.19.83	RK	DH	DPH 1/84

HEAT TREATMENT	SCALE	REQ'D/ASS'Y	PART NO.	DWG. NO. (REV.)
—	1:1	1	OP4756-1	B-OP4756-1

REVISIONS					
NO.	DESCRIPTION	DATE	BY	CH.	APR.



*FOR O-RING #2-232

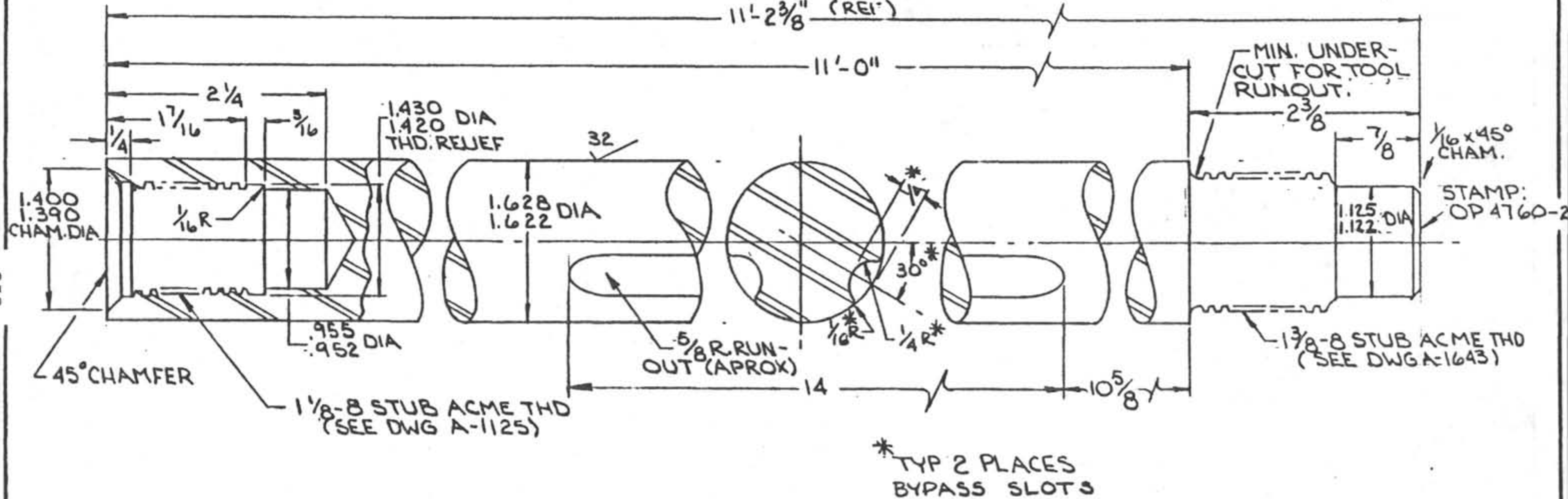
TOLERANCES UNLESS NOTED
FRACTIONS ± 1/64
DECIMALS ± .005
ANGLES ± 1/2°
CORNERS 1/64 x 45° or 1/64 R
FINISH 125

DEEP SEA DRILLING PROJECT
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UNIVERSITY OF CALIFORNIA, SAN DIEGO
LA JOLLA, CALIFORNIA 92093

TITLE: VENT SUB ~A.P.C~

SURFACE TREATMENT	MATERIAL	DRAWN BY	DATE	CHECKED	APPROVED
PARKOLUBE	4130 / 4140	RK	4-1983	DH	DPH
HEAT TREATMENT	PART NO.	SIZE DWG. NO.			REV.
34-36 Rc	OP4758	C-OP4758			

REVISIONS					
NO.	DESCRIPTION	DATE	BY	CH.	APR.
1	LENGTHS WERE 8'-4 3/8" + 8'-2"	4·29·83	RK	DH	DPH
2	1⅛-8 BOX REVISED	7·25·83	RK	DH	DPH



DO NOT SCALE

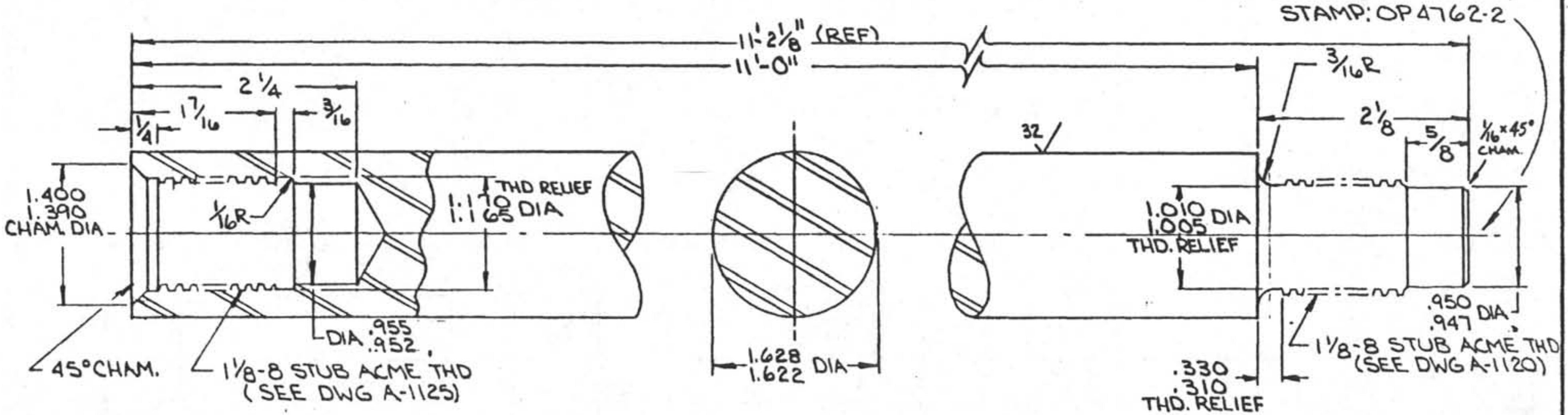
CONCENTRICITY ALL DIAMETERS: TIR .003

TOLERANCES UNLESS NOTED	DEEP SEA DRILLING PROJECT
FRACTIONS ± 1/64 DECIMALS ± .005 ANGLES ± 1/2° CORNERS 1/64 x 45° or 1/64 R FINISH 125	SCRIPPS INSTITUTION OF OCEANOGRAPHY UNIVERSITY OF CALIFORNIA, SAN DIEGO LA JOLLA, CALIFORNIA 92093 TITLE: LOWER PISTON ROD ~A·P·C~

SURFACE TREATMENT	MATERIAL	DATE	BY	CHECKED	APPROVED
— o —	15-5 PH VAR	4·21·83	RK	DH	DPH

HEAT TREATMENT	SCALE	REQ'D/ASS'Y	PART NO.	DWG. NO. (REV.)
H1025	1:1	1	OP4760-2	B-OP4760-2

REVISIONS					
NO.	DESCRIPTION	DATE	BY	CH.	APR.
1	LENGTHS WERE 8'-4" + 8'-2'	4·29·83	RK		
2	REVISED PIN + BOX	7·25·83	RK	DH	DPH



DO NOT SCALE

CONCENTRICITY ALL DIAMETERS: TIR .003

TOLERANCES UNLESS NOTED
FRACTIONS ± 1/64
DECIMALS ± .005
ANGLES ± 1/2°
CORNERS 1/64 x 45° or 1/64 R
FINISH 125 ✓

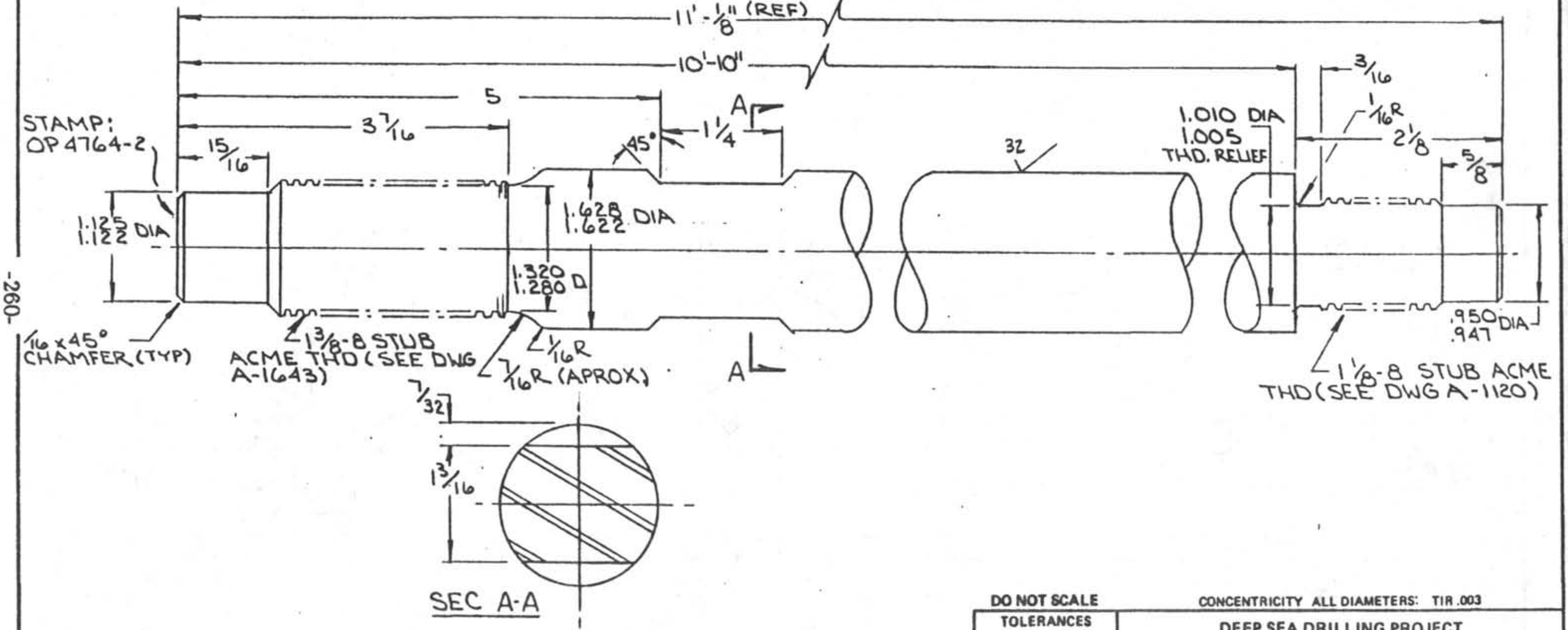
DEEP SEA DRILLING PROJECT
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UNIVERSITY OF CALIFORNIA, SAN DIEGO
LA JOLLA, CALIFORNIA 92093

TITLE: CENTER PISTON ROD ~A.P.C~

SURFACE TREATMENT	MATERIAL	DATE	BY	CHECKED	APPROVED
—	15-5 PH VAR	4·21·83	RK	DH	DPH

HEAT TREATMENT	SCALE	REQ'D/ASS'Y	PART NO.	DWG. NO. (REV.)
H 1025	1:1	1	OP4762-2	B-OP4762-2

REVISIONS					
NO.	DESCRIPTION	DATE	BY	CH.	APR.
1	LENGTHS WERE 8'-6" + 8'-4"	4·29·83	RK	DH	DRH
2	1 1/8-8 PIN REVISED	7·25·83	RK	DH	DRH

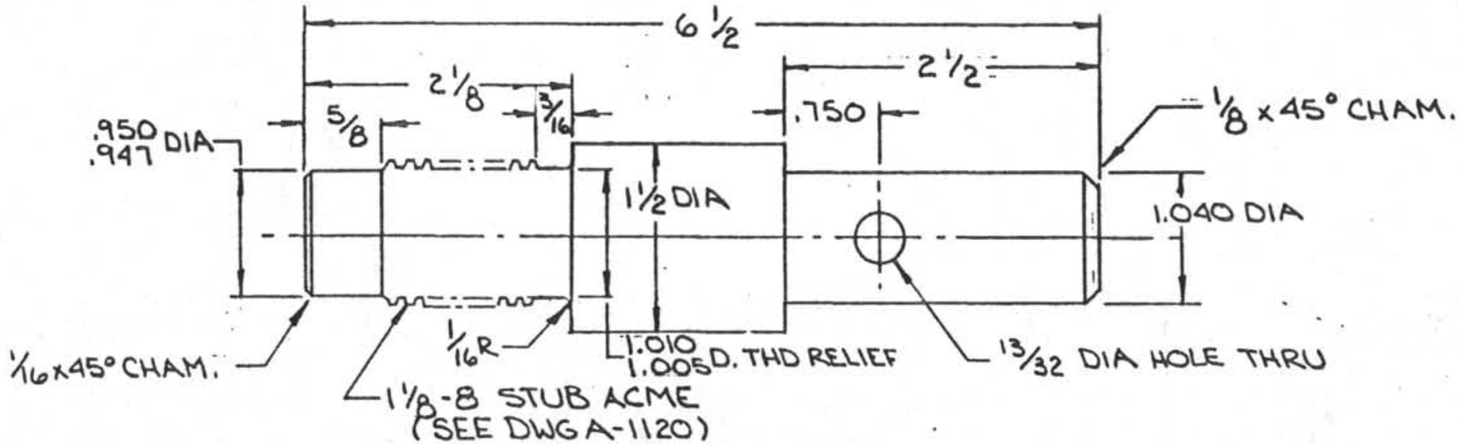


DO NOT SCALE

CONCENTRICITY ALL DIAMETERS: TIR .003

TOLERANCES UNLESS NOTED FRACTIONS ± 1/64 DECIMALS ± .005 ANGLES ± 1/2° CORNERS 1/64 x 45° or 1/64 R FINISH 125	DEEP SEA DRILLING PROJECT SCRIPPS INSTITUTION OF OCEANOGRAPHY UNIVERSITY OF CALIFORNIA, SAN DIEGO LA JOLLA, CALIFORNIA 92093 TITLE: UPPER PISTON ROD ~A.P.C~				
SURFACE TREATMENT	MATERIAL 15-5 PH VAR	DATE 4·20·83	BY RK	CHECKED DH	APPROVED DRH
HEAT TREATMENT H 1025	SCALE 1:1	REQ'D/ASS'Y 1	PART NO. OP4764-2	DWG. NO. B-OP4764-2	(REV.)

REVISIONS					
NO.	DESCRIPTION	DATE	BY	CH.	APR.
1	1⅛-8 PIN REVISED	7·25·83	RK	DH	DRH



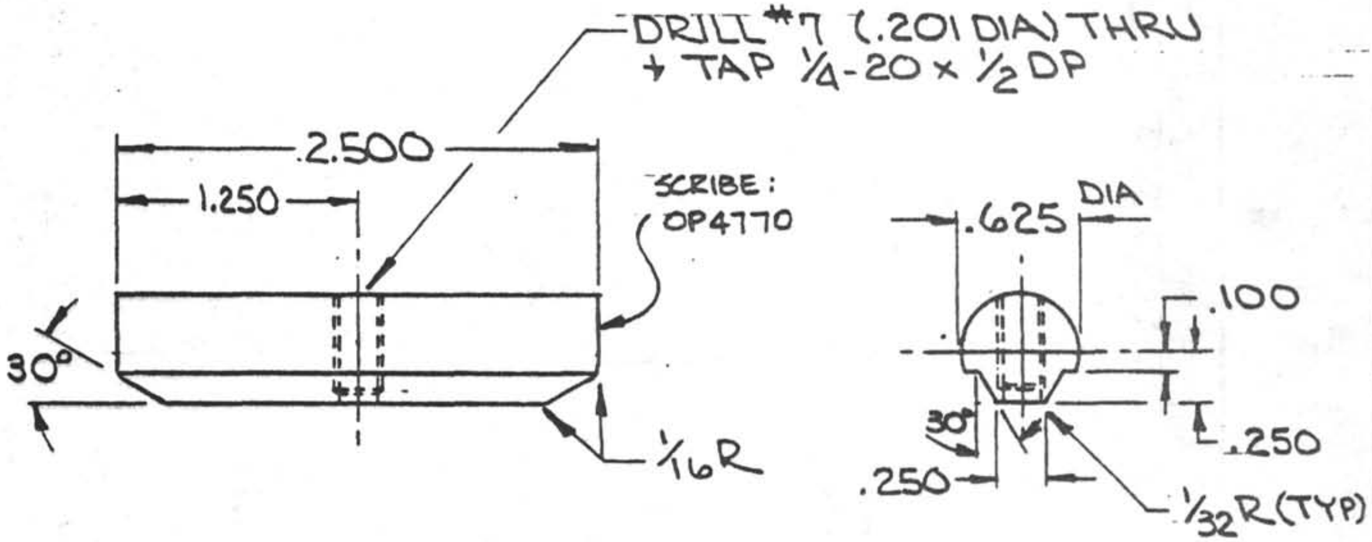
STAMP: OP 4768-1

DO NOT SCALE

CONCENTRICITY ALL DIAMETERS: TIR .003

TOLERANCES UNLESS NOTED FRACTIONS ± 1/64 DECIMALS ± .005 ANGLES ± 1/2° CORNERS 1/64 x 45° or 1/64 R FINISH 125	DEEP SEA DRILLING PROJECT SCRIPPS INSTITUTION OF OCEANOGRAPHY UNIVERSITY OF CALIFORNIA, SAN DIEGO LA JOLLA, CALIFORNIA 92093					
	TITLE PISTON ROD EXTENSION - BREAKAWAY PISTON HEAD ~A.P.C~					
SURFACE TREATMENT PARKOLUBE	MATERIAL 4130		DATE 4·22·83	BY RK	CHECKED DH	APPROVED DRH
HEAT TREATMENT 30-32 Rc	SCALE 1:1	REQ'D/ASS'Y 1	PART NO. OP4768-1		DWG. NO. (REV.) B-OP4768-1	

REVISIONS					
NO.	DESCRIPTION	DATE	BY	CH.	APR.

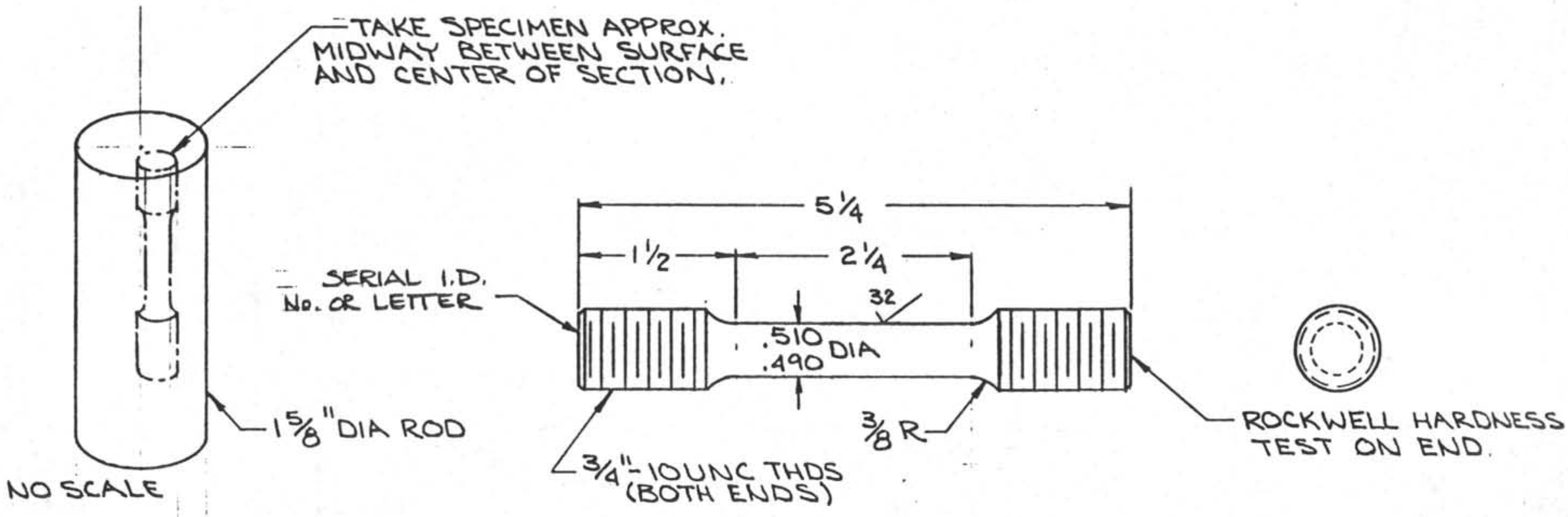


DO NOT SCALE

CONCENTRICITY ALL DIAMETERS: TIR .003

TOLERANCES UNLESS NOTED FRACTIONS ± 1/64 DECIMALS ± .005 ANGLES ± 1/2° CORNERS 1/64 x 45° or 1/64 R FINISH 125	DEEP SEA DRILLING PROJECT SCRIPPS INSTITUTION OF OCEANOGRAPHY UNIVERSITY OF CALIFORNIA, SAN DIEGO LA JOLLA, CALIFORNIA 92093				
	TITLE ANTI-SPIRAL KEY ~ A.P.C ~				
SURFACE TREATMENT —	MATERIAL NITRONIC 60	DATE 4·25·83	BY RK	CHECKED DH	APPROVED DPH
HEAT TREATMENT —	SCALE 1:1	REQ'D/ASS'Y 1	PART NO. OP4770	DWG. NO. A-OP4770	(REV.)

REVISIONS					
NO.	DESCRIPTION	DATE	BY	CH.	APR.



NOTE:
MEASURE & RECORD DIAMETER (±.001) AT BOTH ENDS AND CENTER OF GAGE SECTION AND HARDNESS FOR EA. SPECIMEN.

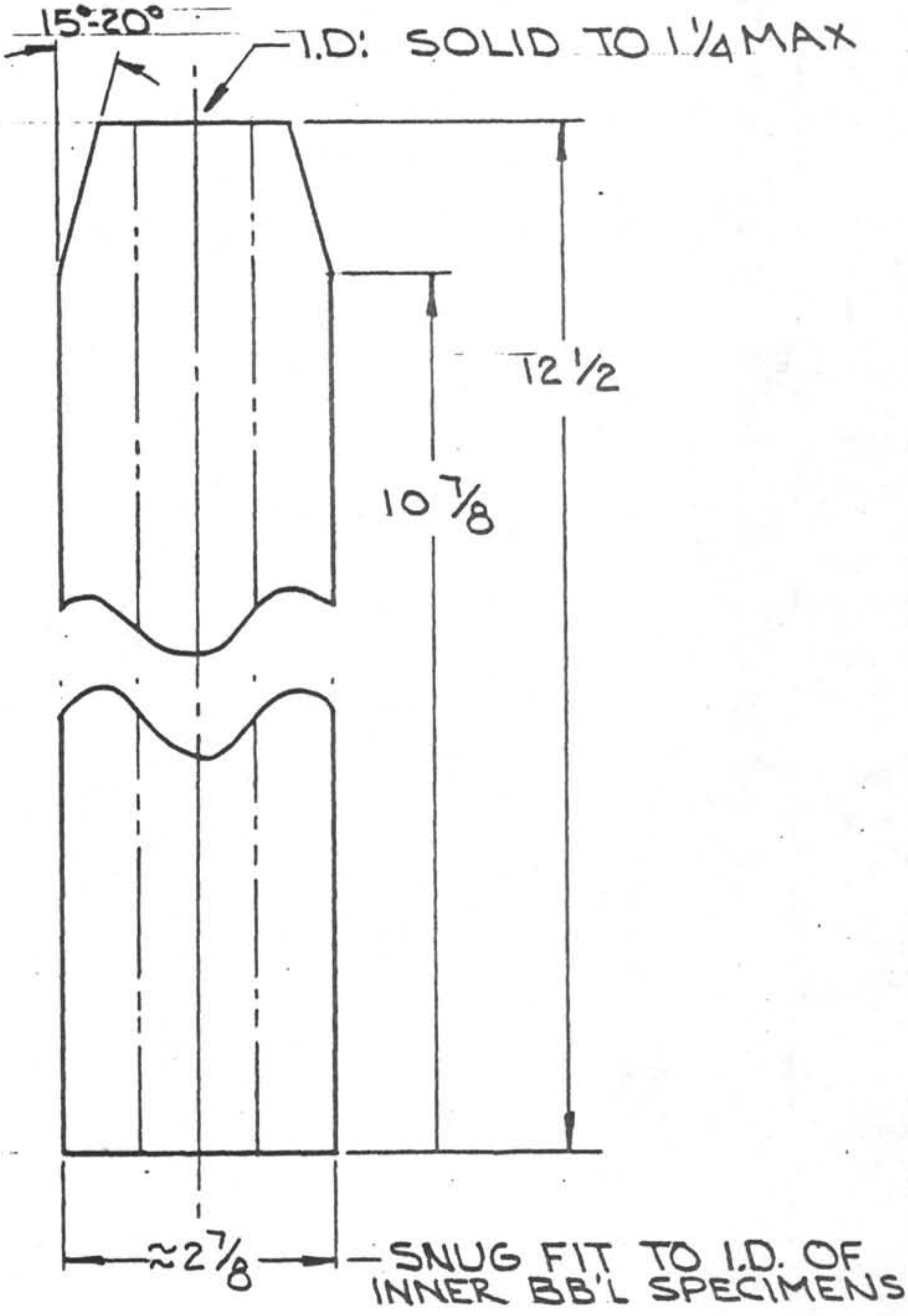
REFERENCE:
ASTM A370, FIG 7, SPECIMEN TYPE 1

DO NOT SCALE

CONCENTRICITY ALL DIAMETERS: TIR .003

TOLERANCES UNLESS NOTED FRACTIONS ± 1/64 DECIMALS ± .005 ANGLES ± 1/2° CORNERS 1/64 x 45° or 1/64 R FINISH 125	DEEP SEA DRILLING PROJECT SCRIPPS INSTITUTION OF OCEANOGRAPHY UNIVERSITY OF CALIFORNIA, SAN DIEGO LA JOLLA, CALIFORNIA 92093					
	TITLE PISTON ROD TENSILE TEST SPECIMEN - A.P.C.					
SURFACE TREATMENT —	MATERIAL 15-5 PH		DATE 8·10·83	BY RK	CHECKED DH	APPROVED DDH
HEAT TREATMENT —	SCALE 1:1	REQ'D/ASS'Y 3	PART NO. OP4794		DWG. NO. B-OP4794	(REV.)

REVISIONS					
NO.	DESCRIPTION	DATE	BY	CH.	APR.



DO NOT SCALE

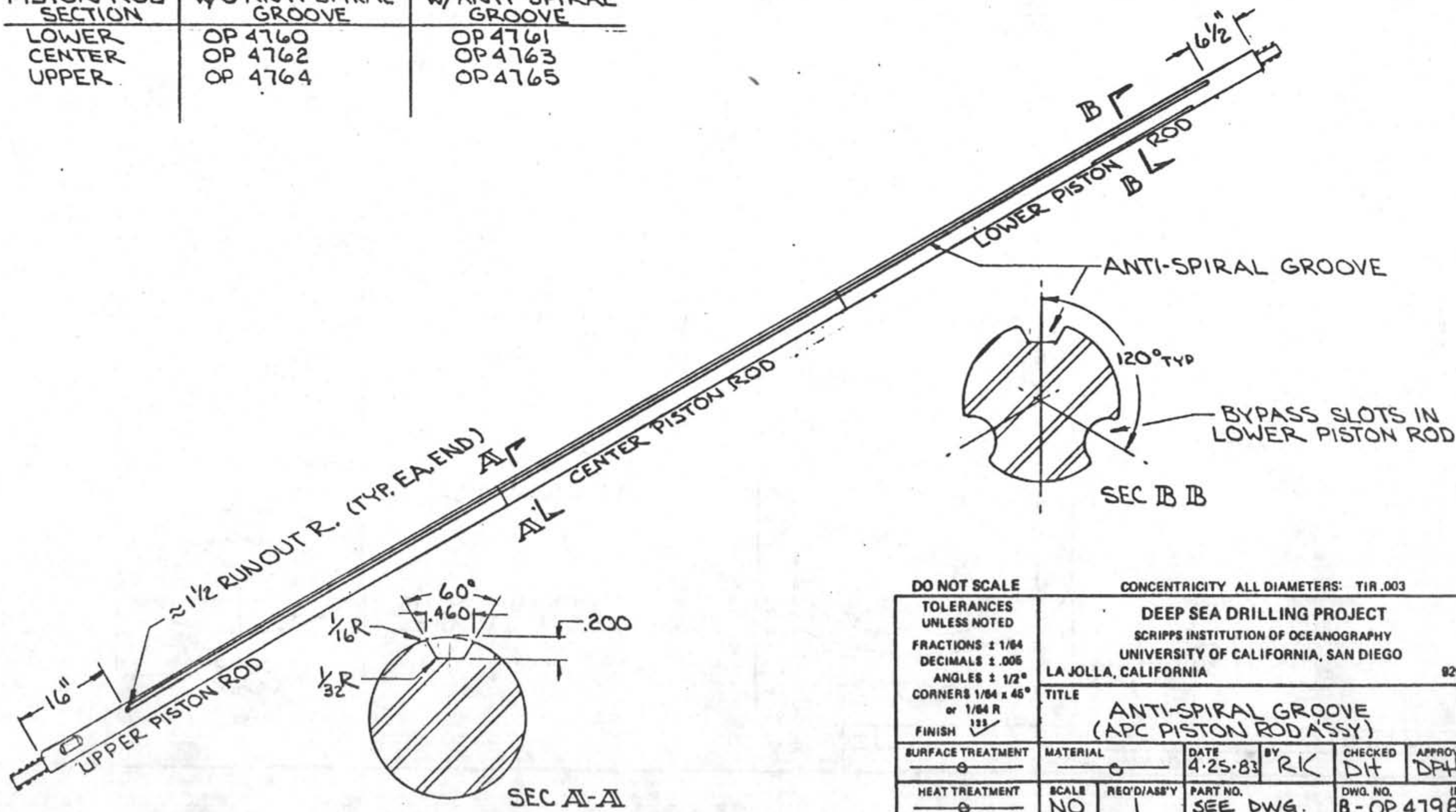
CONCENTRICITY ALL DIAMETERS: TIR .003

TOLERANCES UNLESS NOTED FRACTIONS ± 1/64 DECIMALS ± .005 ANGLES ± 1/2° CORNERS 1/64 x 45° or 1/64 R FINISH 125	DEEP SEA DRILLING PROJECT SCRIPPS INSTITUTION OF OCEANOGRAPHY UNIVERSITY OF CALIFORNIA, SAN DIEGO LA JOLLA, CALIFORNIA 92093				
	TITLE PLUG FOR INNER BARREL TENSILE TEST				
SURFACE TREATMENT —	MATERIAL MILD STEEL		DATE 7·14·83	BY RK	CHECKED DH / APPROVED DPH
HEAT TREATMENT —	SCALE 1/2	REQ'D/ASS'Y 1	PART NO. OP 4795		DWG. NO. A-OP4795 (REV.)

REVISIONS					
NO.	DESCRIPTION	DATE	BY	CH.	APR.
1	WAS WITH 2 CENTER ROD SECTIONS	4.29.88	RK		

1. ASSEMBLE ONE UPPER ROD SECTION, TWO CENTER ROD SECTIONS AND ONE LOWER ROD SECTIONS WITH THREADS MADE UP FIRMLY.
2. CUT ANTI-SPIRAL GROOVE AS SHOWN IN ASSEMBLY.
3. PART NUMBERS AS FOLLOWS:

PISTON ROD SECTION	W/O ANTI-SPIRAL GROOVE	W/ANTI-SPIRAL GROOVE
LOWER	OP 4760	OP 4761
CENTER	OP 4762	OP 4763
UPPER	OP 4764	OP 4765

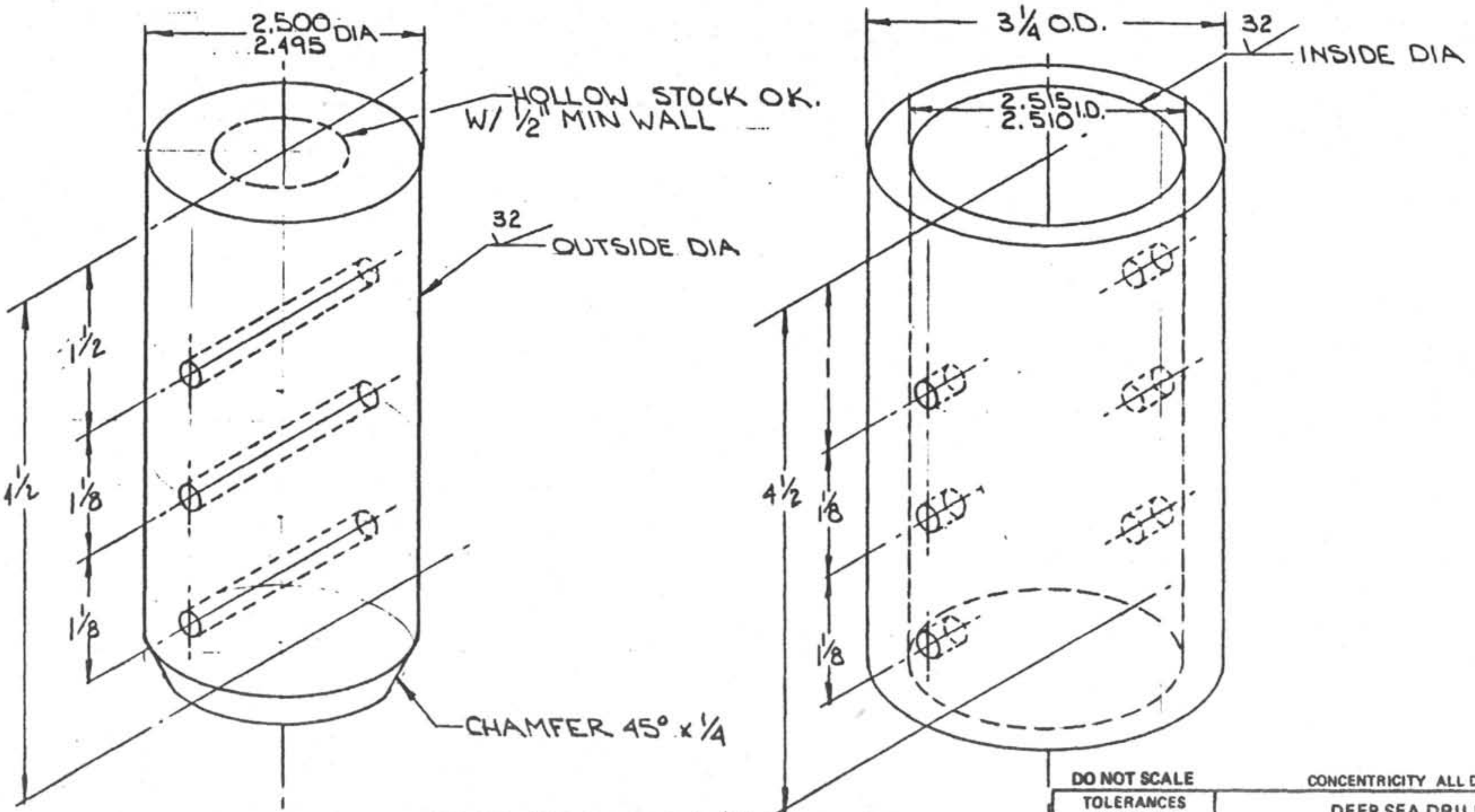


DO NOT SCALE

CONCENTRICITY ALL DIAMETERS: TIR .003

TOLERANCES UNLESS NOTED	DEEP SEA DRILLING PROJECT SCRIPPS INSTITUTION OF OCEANOGRAPHY UNIVERSITY OF CALIFORNIA, SAN DIEGO LA JOLLA, CALIFORNIA 92093				
FRACTIONS ± 1/64 DECIMALS ± .005 ANGLES ± 1/2° CORNERS 1/64 x 45° or 1/64 R FINISH 125	TITLE: ANTI-SPIRAL GROOVE (APC PISTON ROD A'SSY)				
SURFACE TREATMENT: —	MATERIAL: —	DATE: 4·25·83	BY: RK	CHECKED: DH	APPROVED: DPH
HEAT TREATMENT: —	SCALE: NO	REQ'D/ASS'Y: 1	PART NO.: SEE DWG.	DWG. NO.: B-OP 4798-1	(REV.)

REVISIONS					
NO.	DESCRIPTION	DATE	BY	CH.	APR.



DRILL ALL HOLES 'F' (.257 DIA) THRU DO NOT CHAMFER.
MATCH DRILL BOTH PARTS FOR HOLE ALIGNMENT.

MAT'L + HEAT TREAT:
ANY APPROPRIATE TOOL STEEL (OR ALLOY) HARDENED TO Rc 45 OR GREATER.

DO NOT SCALE

CONCENTRICITY ALL DIAMETERS: TIR .003

TOLERANCES UNLESS NOTED
FRACTIONS ± 1/64
DECIMALS ± .005
ANGLES ± 1/2°
CORNERS 1/64 x 45° or 1/64 R
FINISH 125

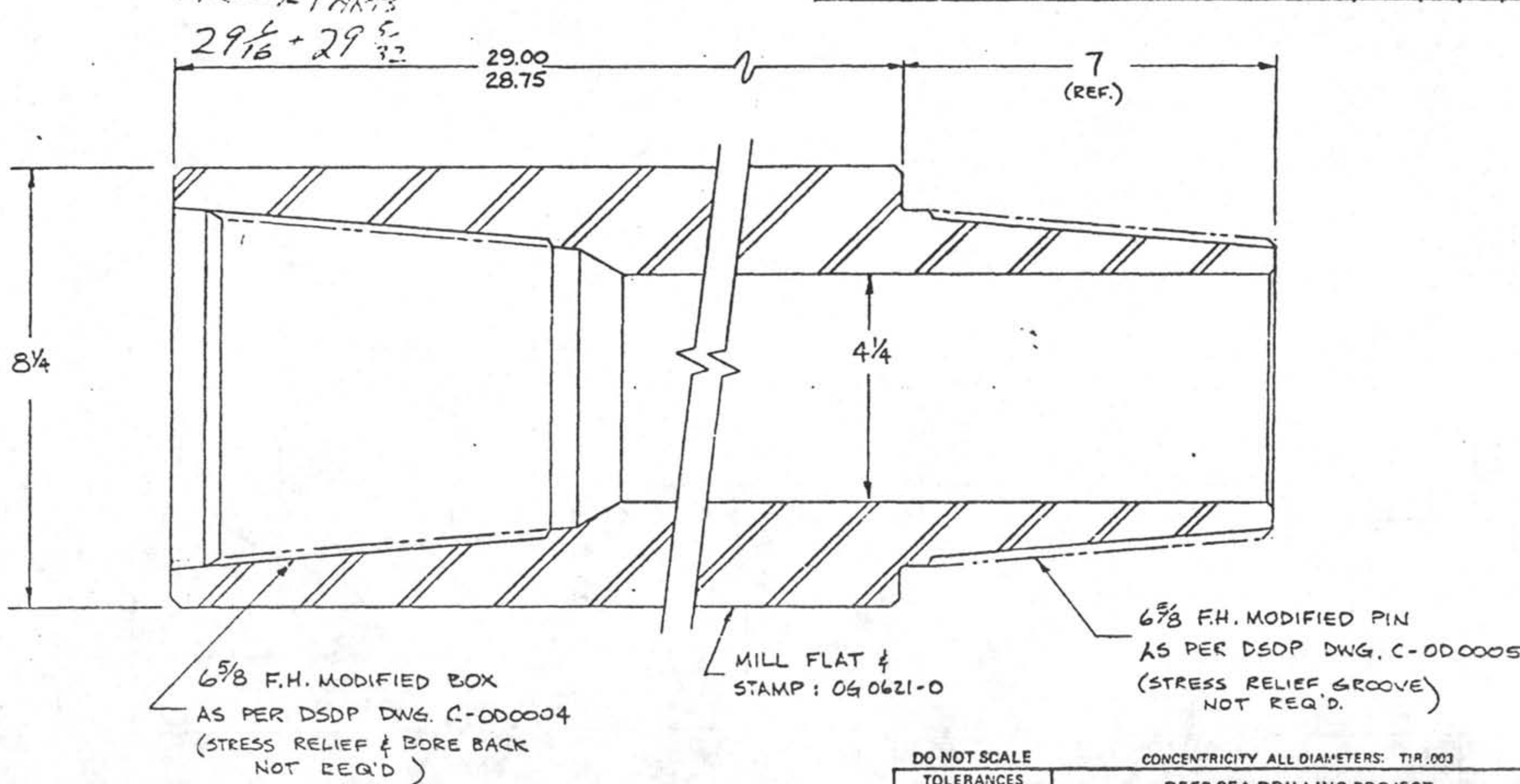
DEEP SEA DRILLING PROJECT
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UNIVERSITY OF CALIFORNIA, SAN DIEGO
LA JOLLA, CALIFORNIA 92093

TITLE: SHEAR PIN TEST JIG ~A.P.C~

SURFACE TREATMENT	MATERIAL	DATE	BY	CHECKED	APPROVED
—	SEE NOTE	4.13.83	RK	DH	DRH

HEAT TREATMENT	SCALE	REQ'D/ASS'Y	PART NO.	DWG. NO.	(REV.)
SEE NOTE	1:1	1	OP4799	B-OP4799	

REVISIONS					
NO.	DESCRIPTION	DATE	BY	CH.	APR.



KEM PLATE THREADS

DEGREASE EXTERIOR & COAT
W/PRIMER & BLUE TOP COAT PER

DO NOT SCALE

CONCENTRICITY ALL DIAMETERS: TIR .003

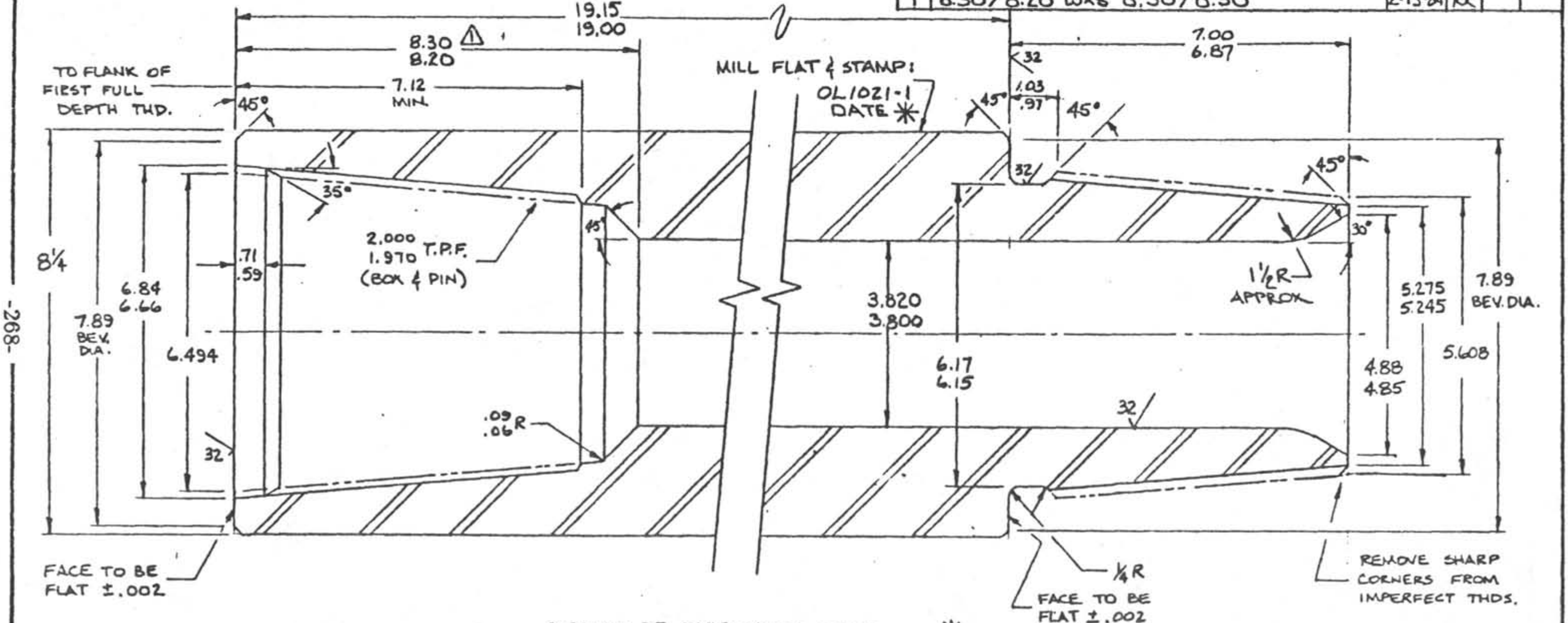
TOLERANCES UNLESS NOTED
FRACTIONS ± 1/64
DECIMALS ± .005
ANGLES ± 1/2°
CORNERS 1/64 x 45° or 1/64 R
FINISH 125

DEEP SEA DRILLING PROJECT
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UNIVERSITY OF CALIFORNIA, SAN DIEGO
LA JOLLA, CALIFORNIA 92093

TITLE BIT SUB SPACER
~ APC ~

SURFACE TREATMENT	MATERIAL		DATE	BY	CHECKED	APPROVED
SEE NOTE	4140/4145		3/25/83	DH		DH
HEAT TREATMENT	SCALE	REQ'D/ASS'Y	PART NO.		DWG. NO. (REV.)	
30-34 Rc	HALF	ONE	OG 0621		B-OG 0621	

REVISIONS					
NO.	DESCRIPTION	DATE	BY	CH.	APR.
1	8.30/8.20 WAS 8.50/8.30	2-13-84	RK		



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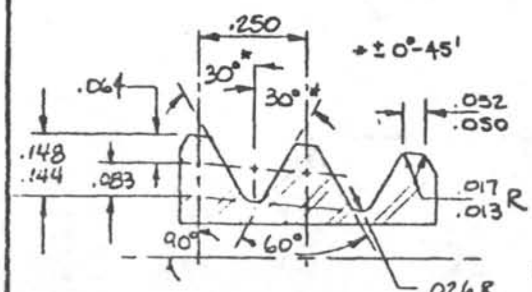

THREAD DETAIL

PART TO BE FABRICATED USING HARDENED & GROUND GAGES BEARING A.P.I. MONOGRAM AND CERTIFIED WITHIN PAST 3 YEARS.

KEM PLATE THREADS

DEGREASE EXTERIOR & COAT W/ PRIMER & BLUE TOP COAT

* DATE OF FAB. (MO. YR.) eg. 0384 = MAR '84

4 T.P.I. 2" TAPER PER FT. PITCH TOLER. ±.0015 PER INCH

DO NOT SCALE

CONCENTRICITY ALL DIAMETERS: TIR .003

TOLERANCES UNLESS NOTED
FRACTIONS ± 1/64
DECIMALS ± .005
ANGLES ± 1/2°
CORNERS 1/64 x 45° or 1/64 R
FINISH 125

DEEP SEA DRILLING PROJECT
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UNIVERSITY OF CALIFORNIA, SAN DIEGO
LA JOLLA, CALIFORNIA 92093

TITLE: LANDING / SAVER SUB ~ APC ~

SURFACE TREATMENT	MATERIAL	DATE	BY	CHECKED	APPROVED
SEE NOTES	4142/4145	3/25/83	DH		DPH

HEAT TREATMENT	SCALE	REQ'D/ASS'Y	PART NO.	DWG. NO. (REV.)
30-34 Rc	HALF	ONE	OL 1021-1	B-OL1021-1

WAS OG0620

SEAL BORE DRILL COLLAR
SPECIFACATIONS
OL 1043

Required in Hole Assembly for use with Advanced Piston Corer (APC)

Size: 8¼ ± 1/16" O.D. x 3.800 I.D. x 31' -2 ± ½" long, shoulder-to-shoulder

I.D. Finish: 32-64 rms & no steps

Material: Premium grade AISI 4145H Alloy Steel, fully heat treated over entire length to 285-341 brinnel hardness.

Minimum Yield = 120,000 psi at 1" below O.D.

Guaranteed minimum 40 ft-lbs Izod Impact Test

Connections: 6 5/8" Full Hole Box Up per DSDP Drwg. #C-OD-0004

6 5/8 Full Hole Modified Pin Down (7' long) per DSDP Drwg. #C-OD-0005

Threads to be Hob Cut and Kemplated. Box to have Drillco Bore Back. Pin to have API Stress Relief Groove and 30° I.D. chamfer x 0.8" deep

Provide with pressed steel box and pin thread protecters.