DESIGN AND OPERATION OF THE HYDRAULIC PISTON CORER

HOLE 479

HOLE 480

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

This report was prepared by the Deep Sea Drilling Project, University of California, San Diego as an account of work sponsored by the United States Government's National Science Foundation. Neither the University nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.
The two cores shown on the cover are from Leg 64, The Guymas Basin. Both cores recovered Quaternary sediments, and despite the great difference in degree of disturbance, the shipboard party concluded that the upper 152 m is duplicated in the two holes. The following is an excerpt from the shipboard core descriptions:

**Site 479, Core 12**  
**Cored Interval:** 98 to 107.5 m sub-bottom  
**100% recovery**

"Uniform, moderate olive brown (5Y 4/4) muddy diatomaceous ooze, and rare streaks of lighter pale olive (10Y 6/2). Any bedding has been totally disturbed. No evidence of varves, sand or H₂S gas."

**Site 480, Core 20**  
**Cored Interval:** 95 to 99.5 m sub-bottom  
**99% recovery**

"Moderate olive brown (5Y 4/4) muddy diatomaceous ooze and pale olive (10Y 6/2) diatomaceous ooze laminae occur together as varve-like couplets on a mm-scale. A gray sand layer occurs with a discordant, sharp contact against the varves, but shows no grading. Unconformities and some cross-bedding observed in the varved section."

Core 12, Site 479 was taken using conventional rotary drilling technique. Core 20, Site 480 was taken using the Hydraulic Piston Corer (HPC-15).

(Excerpt from JOIDES Journal Vol. V, No. 2, June 1979)
INTRODUCTION

This Deep Sea Drilling Project Technical Report No. 12 includes a paper on the design and operation of the Hydraulic Piston Corer authored by M.A. Storms, Wil Nugent and D. H. Cameron. Design analyses and detail drawings are included in an appendix.

The Hydraulic Piston Corer was developed at the Deep Sea Drilling Project in response to a scientific requirement for undisturbed core of the upper un lithified section of the seafloor. Conventional coring practice severely disturbed the soft oozes and clays. The new tool recovered complete and undisturbed cores greatly improving stratigraphic resolution. The device also extended by an order of magnitude, the depth capability of piston coring. Conventional piston and gravity corers were limited to approximately 30 meters of penetration. The hydraulic piston corer, through its repeatable process, has penetrated sediments in excess of 300 meters below the seafloor.

Operational tests of the 4.5 m Hydraulic Piston Corer conducted on Leg 64 (December 1978-January 1979), obtained an almost totally undisturbed and complete section from a 152 meter hole along the Guaymas slope in the central Gulf of California. The Hydraulic Piston Corer fully penetrated sediments with shear strengths of 1200 grams per square centimeter recovering in excess of 80% on most cores. Penetration decreased with increasing sediment stiffness. The maximum shear strength of recovered sediment was 3185 grams per square centimeter.

Beginning with Leg 80 (May 1981-July 1981), an improved coring system, referred to as the Variable Length Hydraulic Piston Corer (VLHPC), was utilized. The VLHPC is capable of recovering cores up to 9.5 m in length. Recovery has averaged more than 93% with some holes achieving 100%. In addition, an absolute core orientation system was added and a capability to measure heat flow in situ.

Piston coring operations are conducted with the wireline remaining attached to the barrel. This saves the time required to pump down the core barrel and makes for a more efficient coring system.

The VLHPC recovers core in a standard butyrate core liner. The core bit used is a special 11.5" O.D. roller cone core bit with a 3.62" core throat. Coring must be discontinued when the sediments become too indurated. The VLHPC system is not designed for drilling and coring in hard rock.

A coring system is under development which will be capable of continuing the penetration on to basement. This coring system, called the Extended Core Barrel (XCB), will be compatible with the VLHPC bottom hole assembly. Thus, the XCB will continue coring from that point at which VLHPC coring operations are halted without necessitating a trip of the drill string.
ACKNOWLEDGEMENTS

The Hydraulic Piston Corer (HPC) was designed and developed by Mr. M. A. Storms of the Deep Sea Drilling Project's development engineering group. The HPC proved to be a highly successful adaptation of rotary coring capability to the taking of high quality piston cores. The concept of a high-speed hydraulic ram/corer powered by rig pump pressure has extended the reach of high quality piston cores from 30 to 300 meters below the seafloor of the deep ocean. This capability is contributing to improved understanding of the earth's past climate and to geologic processes reaching back some 15,000,000 years. Mr. Wil Nugent contributed to the system through mathematical analysis and design. Mr. D. Cameron assisted with fabrication and sea trials of the HPC. Mr. S. T. Serocki, Chief Development Engineer, provided general direction of the work. Overall supervision was by Mr. F. C. MacTernan, Deputy Project Manager.

M. N. A. Peterson
Principal Investigator
and Project Manager
IPOD/DSDP/SIO


<table>
<thead>
<tr>
<th>CONTENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>I HYDRAULIC PISTON CORING - A NEW ERA IN OCEAN RESEARCH</td>
</tr>
<tr>
<td>M. A. Storms, W. Nugent, D. Cameron</td>
</tr>
<tr>
<td>II HYDRAULIC PISTON CORER - LEG 64 OPERATIONAL REPORT</td>
</tr>
<tr>
<td>D. Cameron</td>
</tr>
<tr>
<td>III APPENDIX A - HYDRAULIC PISTON CORER ANALYSIS</td>
</tr>
<tr>
<td>W. Nugent</td>
</tr>
<tr>
<td>APPENDIX B - HYDRAULIC PISTON CORER ORIFICE ANALYSIS</td>
</tr>
<tr>
<td>W. Nugent</td>
</tr>
<tr>
<td>APPENDIX C - HYDRAULIC PISTON CORER STRUCTURAL ANALYSIS</td>
</tr>
<tr>
<td>W. Nugent</td>
</tr>
<tr>
<td>APPENDIX D - HYDRAULIC PISTON CORER THREADED CONNECTION ANALYSIS</td>
</tr>
<tr>
<td>W. Nugent</td>
</tr>
<tr>
<td>APPENDIX E - HYDRAULIC PISTON CORER RETRIEVAL FORCE ALLEVIATION</td>
</tr>
<tr>
<td>W. Nugent</td>
</tr>
<tr>
<td>APPENDIX F - HYDRAULIC PISTON CORER LANDING IMPACT</td>
</tr>
<tr>
<td>IV VARIABLE LENGTH HYDRAULIC PISTON CORER PARTS LIST AND ASSEMBLY DRAWINGS</td>
</tr>
</tbody>
</table>
HYDRAULIC PISTON CORING

LIST OF FIGURES

1. Hydraulic Piston Corer.......................................................... 11
2. Hydraulic Piston Corer Performance Curve.............................. 12
3. Scale Model Load Test.......................................................... 13
4. Stress vs Corer Length......................................................... 14
5. Hydraulic Piston Corer Operational Sequences....................... 15
6. DSDP Hydraulic Piston Corer Test........................................... 16
7. Comparison Photos (Rotary vs HPC)........................................ 17
8. Prediction for 9.5 m Hydraulic Piston Corer......................... 18
9. Extended Core Barrel........................................................... 19
10. HPC/XCB Compatibility......................................................... 20

LIST OF TABLES

I Specifications for Clay Products............................................ 21
II HPC Statistical Data (Legs 64-79).......................................... 22
III VLHPC Statistical Data (Legs 80-93)...................................... 23
HYDRAULIC PISTON CORING
A NEW ERA IN OCEAN RESEARCH

by

M. A. Storms
Wil Nugent
D. H. Cameron

ABSTRACT

In December of 1978, the Deep Sea Drilling Project, International Phase of Ocean Drilling, deployed the first hydraulically actuated piston corer. This coring system utilized a hydraulic piston principle. Fluid was pumped through the drill pipe, activating a piston driven core barrel which was ejected into the sediment at the rate of approximately 20 feet per second. This extremely high penetration rate effectively decoupled the core barrel from the heave induced vertical motion of the drill string. On completion of each coring operation, the core barrel assembly was retrieved by wireline. The core bit was then "washed" down to the next coring point where the piston coring procedure was repeated. Operational tests conducted in 865 meter water depth during Leg 64 obtained an almost totally undisturbed and complete section from a 152-meter hole along the Guaymas slope in the central Gulf of California. Variations in climate, productivity and circulation for more than 250,000 years were recorded. This paper describes the analysis, design, testing and field operation of the hydraulic Piston Coring System.

Deep Sea Drilling Project

The Deep Sea Drilling Project (DSDP) began coring in August of 1968. Funding and direction was given by the National Science Foundation's (NSF) Ocean Sediment Coring Program. Their mandate was to increase man's knowledge of the earth's development through an ambitious ocean sediment coring program. The Prime Contract for the Project was executed in 1966 between NSF and the University of California (UC) Board of Regents. Scripps Institution of Oceanography, an integral part of the UC system, was to be responsible for management of the Project. Global Marine Inc. (GMI), through a subcontract with Scripps, was to provide the drilling vessel and crew.

Major oceanographic institutions of the United States were called upon to support the proposed drilling program by contributing to the planning of the scientific objectives. The resultant organization became known as "Joint Oceanographic Institutions for Deep Earth Sampling (JOIDES). These institutions for Deep Earth Sampling (JOIDES)". These institutions continue to provide scientific guidance for the drilling effort.

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 was increasing. 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 Project in 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 Program 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 drillship 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° latitude; as far south as 77° 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, 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.

SCIENTIFIC OBJECTIVES

The development of the Hydraulic Piston Corer (HPC) was in response to a basic need in the science community to recover high quality cores, particularly in soft sediments. The upper 200 meters of the sedimentary column were highly disturbed during the rotary drilling process. Atoms at detailed disciplines such as paleoceanography, paleoclimatology, magnetostratigraphy and high resolution stratigraphy were all but impossible. It was apparent that some means to overcome the limitations of rotary drilling in unlithified sediments was required. Piston cores historically have provided a means to distinguish events recorded in sediments as little as one thousand years apart; events that are homogenized by rotary drilling. Oceanographic vessels were routinely taking piston cores of mudline sediments. These "conventional" piston coring systems, however, were limited to just a few tens of meters of the surface material, lacking the capability for any significant penetration.

At the request of the science community, the Deep Sea Drilling Project undertook the development of a wireline retrievable piston coring system. This new coring system was to make use of all the advantages of a "conventional" piston coring system yet be compatible with the GLOMAR CHALLENGER'S coring operation and have the capability to penetrate up to 200 meters below the
PROTOTYPE DESIGN

In responding to the scientific mandate for a CHALLENGER piston corer, a set of design and operational criteria were compiled which would govern the development of this new coring system. The corer was to be operated hydraulically; the driving force for the coring system would be the circulating pumps aboard the GLOMAR CHALLENGER. These pumps would be used to pressure the drill string. When released, the energy would drive the core barrel into the sediment at a high rate of speed (Figure 1). Actuation pressure was limited to the 2800 psi operating pressure of the circulating system. The tool was required to be wireline retrievable through 5" drill pipe with a nominal 4.12 inch inside diameter. Scientific preference dictated the nominal 2.43 inch (6.20 cm) core size.

Several areas of concern were investigated including potential column and bending loads imposed upon the core barrel itself; what lateral support could be expected from the formation and what penetration rate would have to be achieved to effectively decouple vessel motion from the tool during the coring operation.

It was recognized that occasionally the coring instrument would be ejected at a high velocity into sediment with little or no resistance. For this reason a dampening system had to be incorporated at the end of the stroke, to lower impact forces.

The Hydraulic Piston Corer design criteria was based on using equipment and techniques already developed, and proven successful, in deep sea drilling operations aboard the GLOMAR CHALLENGER. In addition, a review of advanced conventional piston coring operations was conducted with particular emphasis on sediment stiffness and shear strengths encountered in these tests. The information on subsurface foundation material densities and shear strengths compiled in DSDP Technical Report No. 9, dated September 9, 1976, was included in this review.

The design objectives were:

* Assess the friction coefficient of the subsurface material(s) entrained in the Hydraulic Piston Core (HPC) tool, at various penetration velocities, consistent with shipboard pumping capacity.
* Develop mechanization schemes in support of the HPC design.
* Prepare a hydraulic analysis, determine orifice sizes, and flow conditions compatible with the pumping system.
* Establish structural guidelines to ensure safety, repeatability of performance, and fabrication capability using immediately available materials.
* Implement safeguards such as snubbing to reduce end stroke impact.
* Develop procedures for assembly and handling of the HPC compatible with rig floor operations.

ANALYTICAL ANALYSIS

Frictional resistance to coring was recognized to result from sediment shear, internal drag resistance of material being entrained in the corer tube, choking or overspilling at the leading edge of the tool, and external friction. Efforts were directed to the development of a single constant which could be used to characterize the total resistance. The shipboard rig pump pressure and available annulus area provided the force on the core barrel column. The displacement volume of the rig pump provided the core barrel penetration rate. A discharge orifice controlled the discharge rate of the seawater from the lower chamber, and established the maximum achievable corer barrel penetration rate.

An input force is applied by pressure on the piston. The frictional resistance consisted of mechanical sliding friction and the frictional resistance or drag due to the rate at which the hydraulic piston corer penetrated into the sediment.

The sediment was characterized as an emulsified substance rather than a slurry containing particles of discrete size suspended in a fluid. These sediments could be ooze and/or un lithified bases with shear strengths ranging from 100 to 300 grams per square centimeter. The particle grain size was small, less than 0.5 mm average diameter and greater than 50% seawater saturated.

These conditions were recognized to be outside the bounds of discrete particles, and not absolutely fluidic. The substance was similar to a dough which flows as a homogeneous mass, distinct from a turbulent fluid.

It was essential that the corer penetration velocity be controlled. Too fast a penetration rate could cause structural damage to the corer itself or induce core disturbance such as liquifaction. Too slow a penetration rate would fail to decouple the corer from the drill pipe motion, again inducing excessive core disturbance.

With these restraints in mind a velocity requirement was selected in the range of 20 feet per second and decaying not below ten feet per second during the entire coring operation.

The analysis was based on 2000 psi pump pressure and greater than 350 gallons per minute pump delivery capability to the bottom of the drill string. No allowance for compressibility of fluid was taken into account. Since the pump pressure acting on the annulus produces the coring force, the pump displacement (flow rate) produces the corer velocity. The discharge orifice, required for venting seawater from the lower chamber, was used to control the velocity of the corer. For analytical purposes it was assumed that the upper and lower chamber volumes were approximately equal. The effective pressure which discharges fluid through the orifice then becomes the net pressure, or the force on the annulus less the sediment resistance.
Other pressure losses which may occur at the discharge orifice were not considered in the analysis.

The discharge orifice is important in controlling the rate of corer penetration. For a given pressure and penetration resistance, presuming that sufficient fluid flow is available to maintain the pressure, the corer tube will travel at a velocity dependent upon the volume rate of discharge through the orifice.

The characteristics of flow through an orifice are well defined, but the behavior of the sediment when producing resistance to the force on the corer piston requires some definition, particularly for variations in sediment compaction, geology, and the depth of penetration desired.

Although the various sediment types behave neither as a fluid nor as a series of discrete particles, it was recognized that they do have a common characteristic during coring, that is the frictional or drag resistance, which is dependent upon the equation \( \tau = \mu \frac{dv}{dx} \) from which the viscosity (\( \mu \)) of a homogenous substance may be derived when the shear stress is known.

It was assumed that the sediment was "fractured" at an infinite number of diametrically opposite locations along the circumference of the corer during penetration. Knowledge of the sediment shear strength and density allowed an estimate for a friction coefficient (\( f \)). Viscous flow conditions were assumed and the characteristic drag expression \( D = \frac{1}{2} \rho v^2 f X \) (area), where \( v \) = penetration velocity and \( \rho \) = the mass density of the sediment, were used to define the drag resistance for each successive foot of core barrel penetration. This analytical approach connected the behavior of the material to be cores with the energy available to operate the hydraulic piston corer and the desired rate of penetration.

The drag term represented the sediment resistance to coring, and was a function of velocity. In this approach a theoretical velocity exists prior to establishing equilibrium between the driving force and the resisting force. When penetration resistance equals the force available the piston corer stops (Figure 2). Using these elementary approaches, the performance characteristics of the HPC have to date been predictable within reasonable limits.

A Fortran program was compiled which provided HPC operating forces and computed the working stress level at the critical sections of the piston corer column. This program enabled input changes to sediment shear strength, hydraulic pressure and/or shear pin release, effective piston area, side hole support, and penetration velocity to simulate actual operational conditions.

The computer generated output showed good correlation with the results from coring operations in sediment with shear strengths up to 1200 g/cm\(^2\) (2457 lb/ft\(^2\)). Experience in operation confirmed that the hydraulic piston corer performed well in water depths of 3500 m (11,483 ft), and in sediment shear strengths of 2,513 g/cm\(^2\) (5,146 lb/ft\(^2\)) the piston velocity was reduced to zero. Total stroke indication was not observed, although 3.26 m (10.7 ft) of core was retrieved.
Operational results relating shear strength, hydraulic pressure and the length of core recovered, were used to develop an empirical coefficient; which accounted for the observed increase in resistance to coring, with increase in depth of penetration. These sample data were included in an analysis, which yielded the mean values for shear strength, length of core recovered, and applied pressure during coring.

Figure 2 is a data plot predicting the performance of 4.4 meter coring tool used on Leg 68. A sediment drag coefficient was developed using an expression for a uniform two-dimensional flow, which applies the effects of sediment shear strength and mass density.

STRUCTURAL COLUMN

Deflection of the HPC column, resulting from penetration on sloping faces, or offline impact against rock formation, was included as a constraint and analyzed.

This analytical procedure enabled the stresses to be calculated at critical sections, i.e. thread undercuts, etc., along the corer barrel by predicting the deflection and calculating the bending moment.

Additional analysis and scale model tests were conducted to determine the behavior of the upper shaft and the piston rod, for various lengths of HPC configuration. The corer barrel is unsupported when extended beyond the drill bit, but the upper shaft and the piston rod are constrained against deflection with the drill collar assembly. A moment distribution analysis and a static load test on a scale model (Figure 3) showed good correlation.

The result indicated that the maximum rig pump pressure could be applied on the HPC piston configuration, and that precautions should be taken in instances where hole drift angle or excessive side loads could be encountered. A preliminary computer program was compiled, to generate parametric data relating stress and coring length, to various differential side forces applied midway between the cutting shoe, and the drill bit support on the core barrel. Figure 4 presents the results, which indicate the potential to core into 1200 g/cm sediment and retrieve 30 ft (9.5 m) cores, using core barrels fabricated of 4130 CD steel.

OPERATION

The Hydraulic Piston Corer consists of two basic assemblies. An inner assembly which remains stationary during activation of the tool and an outer assembly, which scopes down along the inner assembly during tool operation (Figure 5).

When the tool is in the closed position (ready to run), shear pins secure the outer assembly to the inner assembly.

The tool is lowered down the drill pipe on the wireline until the top sub lands in a special head sub located in the bottom hole assembly. Circulation is then initiated. As the drill string begins to pressurize, the seals around the top sub effect a seal in the head sub. Pressurized water is
directed through the top sub and shaft, and out the lower end of the inner seal sub into the annulus between the inner and outer seal subs.

The pressure increases until the pins shear; then the outer seal sub (attached to the outer assembly) is forced down and away from the inner seal sub (attached to the stationary shaft and piston rod). As the outer body penetrates the mud, the piston head remains stationary, causing the fluid above to be vented to the annulus. At the end of its stroke the inner seal sub, which seals along the outer body, uncovers a set of control orifices drilled through the vent sub body wall. The pressurized fluid can then vent through the orifices to relieve the pressure in the drill string and give the rig floor an indication that the corer has fully stroked. The core barrel is then retrieved, the core bit is washed down to the next coring point, and the sequence begins again.

SHORE BASED TESTING

Prior to field deployment a comprehensive shore based performance test was conducted. The objectives of this test were to verify the mechanical actuation, operation, and structural integrity of the hydraulic piston corer. Variables included sediment shear strength, flow rate, and shear pressure, i.e. that pressure at which the barrel releases and begins to move into the sediment.

Energy for the test system was supplied by a BJ Pacemaker "Duplex" cementing unit. This unit could supply the minimum flow rate of 350 gpm at 2000 psi required for the test.

Four different mixes of clay products were purchased to provide several variations in stiffness for the test. Table I shows the physical properties and compositions of the products used. For ease of handling, the clay was put into standard "Burke" fiber tubes normally used for pouring concrete columns. The tubes used were 12.0" inside diameter by .225" wall (regular) and were 15' in length. To support the Burke tubes during handling, a hanger system was fabricated using 16" casing. This "holder" allowed easy insertion and retrieval of the clay filled tubes into and out of the test hole. The test hole was 46-feet deep and lined with 24-inch diameter casing. The piston corer itself was handled with the aid of a 3-ton electric chain hoist located directly over the hole.

An instrumentation system was developed to determine the average penetration velocity of the tool. A pressure transducer was put in line from the BJ Pacemaker pump to the test assembly. Input from the transducer was fed as an analog signal into an 8-channel multiplexed data acquisition system connected to an IBM 1130 computer. Figure 6 shows a typical pressure vs time curve obtained during a full sequence of tool operation. From this curve the shoot off point and end of stroke venting can be taken. Knowing the distance traveled and elapsed time, an average penetration velocity was determined. Test data collected with the instrumentation system compared favorably with the previously calculated theoretical data.
OPERATIONAL SEA TRIALS

Sea Trials were conducted on the Hydraulic Piston Corer in December 1978 and January 1979, during Leg 64. The new tool was run a total of 52 times on three sites in the Guaymas Basin of the Gulf of California.

At Site 480 (water depth 657 m), 32 cores were taken to a subbottom depth of 152 meters with an average of over 80% recovery (well over 90%, if two low recovery cores are excluded). Finely laminated sedimentary sections ranging from soft mud to very firm diatomaceous ooze were recovered virtually undisturbed. The singular success of the HPC on this site is underlined when compared to the poor quality of cores recovered in the upper 100 m through rotary coring at Site 479, only 6.8 km to the southwest (Figure 7). Only two cores had little or no recovery. On several of the lower depth runs the core liners returned cracked or partially collapsed. This is believed to have been caused by pull-out suction created when retrieving the HPC from increasingly stiff sediments. The recovery was still good and undisturbed except for the short lengths of liner collapse.

The supply of shear pins was depleted after the numerous runs at Site 480, so for the 16 runs at Site 481 (water depth 2016 m) new pins were fabricated from 3/16" brass brazing rod. Sixty four per cent of the 52.25 m sedimentary column cored was recovered, although six cores, including the last two, recovered over 90 per cent. The intermittently low and high recovery may have been due either to possible wide variations in the shear strength of the new pins, or in the sediment type (e.g., sandy layers.) The latter seems probable since two of the low recovery intervals were recored with the same results. The sediments recovered were, again, undisturbed. The core liners did not collapse or crack on any of these runs.

Throughout the tests, routine maintenance on the HPC consisted of replacing seals as needed and complete breakdown and redressing between sites. The internal seals could not be inspected routinely but were still operable when replaced between sites. The external top sub packing was lost or damaged quite frequently during the earlier runs, but lasted much longer (10 runs) when the retrieval rate was slowed from 300 meters/min to 100 meters/min. Being one-way seals, they tended to flare out and grab at each tool joint if the HPC was retrieved too quickly.

As the rig crew became familiar with handling the HPC, the turnaround time on deck was trimmed to 20 minutes when using a single lower core barrel section. It would have been even faster had they been able to alternate between two lower sections, but one was lost on Site 477A. The time between cores still was only slightly longer than for standard coring operations.

TECHNICAL IMPROVEMENTS

The objective of developing a capability to recover 9.5 m undisturbed cores through the 13 cm (5-inch) drill pipe was not abandoned. An assemblage of components were designed with the purpose of configuring 9.5 m, 8 m, 6.5 m, 5 m, and 3.5 m hydraulic piston corer units by rearrangement of common elements adapted to a single seal-sub within the drill pipe. This unit, designated as the Variable Length Hydraulic Piston Corer (VLPHC), enables coring to be accomplished over a wide range of sediment formations to the limit
of the shipboard rig pumping capacity (Figure 8). To date there has been exceptional success with VLHPC operations. After the initial runs, the drill crew handled the entire operation. The VLHPC does not require extensive redressing between runs, and the turnaround time on deck takes about five minutes. The features of this simplistic design approach have been projected into future designs to develop extended coring capability into stiffer formations.

The available force in deep ocean hydraulic piston coring decreases slightly as the corer barrel extends. In the computer program, the resisting force produced by corer penetration is a function of velocity. When the plot of the product of velocity and effective drag coefficient intersects the curve produced as a function of rig pressure and piston area, the corer stroke is assumed to be arrested. The results from operations have validated the analytic procedure within the range of present usage.

ABSOLUTE CORE ORIENTATION

The ability to recover undisturbed soft cores without rotating led quite naturally to a request from the scientific community to develop a means of preserving the downhole azimuthal orientation of the cores. This has been achieved by "piggybacking" a Kuster single-shot survey instrument onto the VLHPC. The Kuster tool is actually incorporated into the sinker bar string which latches onto the VLHPC Top Sub. The Kuster unit essentially consists of a transparent compass and reference line overlaying a film disc, a battery operated delay timer, a magnetic sensor, and a light source. An orientation line on the core liner is aligned with the reference line within the Kuster unit. When the VLHPC is landed in the drill string, the Kuster tool is positioned within a special non-magnetic drill collar. The sensor detects the change in the magnetic field and activates the delay timer which, in turn, activates the light source to take a picture of the compass and reference line. The film is later developed to reveal the angle between magnetic north and the reference line.

OPERATIONAL PERFORMANCE

The original version of the Hydraulic Piston Corer (HPC) was successfully operated aboard the D/V GLOMAR CHALLENGER from December 1978 until May 1981. Its successful performance immediately led to the development of its successor, the Variable Length Hydraulic Piston Corer (VLHPC). This highly improved version has now been deployed in the field for over a year with impressive scientific results. Statistical data for both versions of the HPC can be found in Tables II and III. The application of this new coring technology to the field of earth sciences has unquestionably been a success. Expansion to areas such as geotechnical research and engineering may have even wider reaching ramifications.

Efforts are now underway to develop a coring system which can take over when the HPC system has reached its limitations. This "extended" core barrel (XCB) shown in Figure 9, will be designed to drill down to and into basement, without requiring a pipe trip or change of the HPC bottom hole assembly. The compatibility of these two coring systems is shown in Figure 10.
SCIENTIFIC REWARDS

The Deep Sea Drilling Project (DSDP) Hydraulic Piston Corer (HPC) was developed in response to a major scientific need to recover undisturbed cores from the deep ocean. The technical success of the HPC quite naturally led to an improved successor known as the Variable Length Hydraulic Piston Corer (VLHPC). Hydraulic Piston Coring has been in operation aboard the GLOMAR CHALLENGER for over four years. The scientific rewards are too numerous to mention. DSDP expeditions centering around the use of the hydraulic piston corer have proven to be major successes. The routine recovery of complete geological sections with little or no disturbance has given rise to many new disciplines within the field of marine geology. These new or expanded fields of study are enabling earth scientists to make quantum leaps in their understanding of the earth and its oceans. The potential of this new technology and its contribution to the advancement of earth science research will probably not be fully determined for many years to come.
Figure 1
HYDRAULIC PISTON CORER
CONCEPT

OVER SHOT
TOP SUB
OUTER BODY CAP
SHEAR PIN
SHAFT
OUTER BODY
INNER SEAL SUB
OUTER SEAL SUB
PISTON ROD
INNER CORE BARREL
CORE LINER
PISTON HEAD
CORE CATCHER
CATCHER SUB
CORE

35.7 FT
OVER SHOT
TOP SUB
OUTER BODY CAP
SHEAR PIN
SHAFT
OUTER BODY
INNER SEAL SUB
OUTER SEAL SUB
PISTON ROD
INNER CORE BARREL
CORE LINER
PISTON HEAD
CORE CATCHER
CATCHER SUB
CORE

14.6 FT STROKE

50.3 FT
Figure 2
HPC PERFORMANCE CURVE

FORCE-LBS X 10^-3

CORER PISTON VELOCITY
AVAILABLE FORCE ON THE CORER PISTON
SEDIMENT RESISTANCE TO CORING
CORER PISTON STOPPED

CORING DEPTH FT.

10
9
8
7
6
5
4
3
2
1
0

VELOCITY F.P.S.

15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0

METERS

15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
Figure 3

SCALE MODEL LOAD TEST

Froude Scaling
Scale Factor $\xi = 11$
Force Full Scale $= \xi^3$ Model Scale
$= 12.5 \times (11)^3$
Axial Force $= 16,037.5$ LB
No Side Force
Figure 4

STRESS VS CORER LENGTH

AXIAL LOAD = 12,800 LB (2878 NEWTONS)
RIG PRESSURE = 3000 PSI (2100 NEWTONS/CM²)
CORER PISTON O. D. = 3.50 INS. (8.89 CM)
CORER PISTON I. D. = 2.875 INS. (7.30 CM)
SEDIMENT SHEAR STRENGTH ≈ 1200 g/cm²
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.
Figure 6

D. S. D. P. HYDRAULIC PISTON CORER TEST

CHAN 2 MAX = -93  MIN = -2664  MEAN = -956.15  DATA 1-1024  SCALE X 7.0
PRESSURE TRANSDUCER DATA  CLAY BATCH 83

SECONDS

POUNDS PER SQUARE INCH

LINE FILL-UP

PINS SHEARED

PRESSURE BUILD UP WITH PENETRATION

MAX PRESSURE 1500 psi

TOTAL STROKE TIME 11/2 SECONDS

END OF 15 FT. STROKE FLUID BYPASSES

PEAK PRESSURE 2380 psi

2382 MAX

2000 psi BACK PRESSURE

PUMPS CIRCULATE THROUGH BY-PASS

PUMPING UNIT – BJ PACEMAKER
CEMENTING UNIT
MEDIUM CLAY
**Figure 7**

**COMPARISON PHOTOS**

**ROTARY CORING VS HYDRAULIC PISTON CORING**

**STANDARD ROTARY CORE**

HOLE: 479 CORED INTERVAL: 90.0–107.5 m

**HYDRAULIC PISTON CORE**

HOLE: 480 CORED INTERVAL: 95–99.5 m
Figure 8
PREDICTION FOR 9.5 m H. P. C.
BASED ON LEG 68 PERFORMANCE
SHEAR PIN RELEASE – 536 Kg/cm²

**MAXIMUM FORCE ON THE PISTON (LB x 10^{-3})**

**EST. FORCE (LESS FRICTION)**

**SEDIMENT RESISTANCE x 10^{-3} LBS.**

**CORER PISTON VELOCITY F. P. S.**

![Graph showing the relationship between coring depth and force](image)
Figure 9

DEEP SEA DRILLING PROJECT
EXTENDED CORE BARREL

Coring Soft Sediment

DOUBLE FINGER LATCH

OUTER BARREL

DISK SPRING PACK
EXPANDED/COMPRESSED

CIRCULATING FLUID

BEARINGS

NON-ROTATING CORE LINER

CIRCULATION JETS

NON-ROTATING CORE-CATCHER

CUTTING SHOE

Coring Hard Formation
DEEP SEA DRILLING PROJECT
BOTTOM HOLE ASSEMBLY COMPATIBILITY
HYDRAULIC PISTON CORER / EXTENDED CORE BARREL

HPC
0–200 m
2.44” (6.20 cm) CORE DIA.
30’ (9.5 m) CORE LENGTH

XCB
200 m BASEMENT
2.37” (6.02 cm) CORE DIA
30’ nom (9.5 m) CORE LENGTH

LANDING SHOULDER
4.00” O. D.

SEAL SLEEVE
3.800” I. D.

LATCH SLEEVE
3.937” I. D.

MAX. O. D.
3.50”

SUPPORT BEARING
3.54” I. D.

CORE BIT
(HPC/XCB)
3.62” x 11 1/4”

LANDING SHOULDER
3.74” O. D.

MAX O. D.
3.50”
# TABLE I

**SPECIFICATIONS FOR CLAY PRODUCTS**

**DSDF PISTON CORE TEST MATERIAL**

<table>
<thead>
<tr>
<th>J. Clay Batch No.</th>
<th>Bentonite</th>
<th>Material in Pounds</th>
<th>Initial Penetrometer Reading (clay only)</th>
<th>Batch Weight lbs</th>
<th>Force (1) Extract</th>
<th>Piston (2) Pressure Required</th>
<th>Hydraulic (3) Horsepower</th>
<th>K/SF Shear Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>FB1</td>
<td>96</td>
<td>384</td>
<td>72</td>
<td>1080</td>
<td>&lt;400</td>
<td>&lt;73</td>
<td>&lt;11</td>
</tr>
<tr>
<td>2</td>
<td>FB2</td>
<td>120</td>
<td>480</td>
<td>68</td>
<td>1166</td>
<td>400</td>
<td>73</td>
<td>11</td>
</tr>
<tr>
<td>3</td>
<td>FB3</td>
<td>144</td>
<td>576</td>
<td>63</td>
<td>1245</td>
<td>1100</td>
<td>200</td>
<td>30</td>
</tr>
<tr>
<td>4</td>
<td>FB4</td>
<td>168</td>
<td>793</td>
<td>57</td>
<td>1435</td>
<td>2200</td>
<td>400</td>
<td>60</td>
</tr>
<tr>
<td>5*</td>
<td>B4</td>
<td>Clay</td>
<td>Soft</td>
<td>--</td>
<td>1250</td>
<td>1200</td>
<td>4.25-4.75</td>
<td>3000</td>
</tr>
<tr>
<td>6*</td>
<td>B3</td>
<td>Clay</td>
<td>Soft</td>
<td>--</td>
<td>1250</td>
<td>1200</td>
<td>4.25-7.75</td>
<td>3000</td>
</tr>
<tr>
<td>7*</td>
<td>B2</td>
<td>Clay</td>
<td>Medium</td>
<td>--</td>
<td>1250</td>
<td>1200</td>
<td>6.15-6.5</td>
<td>8000</td>
</tr>
<tr>
<td>8*</td>
<td>B1</td>
<td>Clay</td>
<td>Stiff</td>
<td>--</td>
<td>1250</td>
<td>1200</td>
<td>9.25-9.75</td>
<td>12000</td>
</tr>
</tbody>
</table>

* Indicates J. Clay Co. product mix

(1) Excludes weight of barrel estimated at approximately 600 lbs; dynamic force during coring likely will exceed steady pull out force; force is 15 ft stroke.
(2) Based on force to extract
(3) Not dynamic, based on 257 GPM (15 ft/sec)

**NOTES:**
- Annular piston cylinder volume per 15 ft stroke = 4.3 gal
- Each batch yields approximately 12 cu ft
<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>64</th>
<th>66</th>
<th>68</th>
<th>69</th>
<th>70</th>
<th>71</th>
<th>72</th>
<th>73</th>
<th>74</th>
<th>75</th>
<th>76</th>
<th>79</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Sites</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>2</td>
<td>4</td>
<td>6</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Number of Holes</td>
<td>3</td>
<td>1</td>
<td>7</td>
<td>1</td>
<td>10</td>
<td>2</td>
<td>5</td>
<td>8</td>
<td>5</td>
<td>4</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Number of Cores</td>
<td>43</td>
<td>11</td>
<td>259</td>
<td>54</td>
<td>85</td>
<td>54</td>
<td>118</td>
<td>203</td>
<td>136</td>
<td>230</td>
<td>50</td>
<td>12</td>
</tr>
<tr>
<td>Total Meters Cored</td>
<td>204</td>
<td>52</td>
<td>1012</td>
<td>227</td>
<td>325</td>
<td>229</td>
<td>488</td>
<td>1778</td>
<td>586</td>
<td>922</td>
<td>244</td>
<td>39</td>
</tr>
<tr>
<td>Total Meters Recovered</td>
<td>155</td>
<td>30</td>
<td>787</td>
<td>175</td>
<td>304</td>
<td>206</td>
<td>413</td>
<td>686</td>
<td>522</td>
<td>816</td>
<td>194</td>
<td>37</td>
</tr>
<tr>
<td>Per Cent Recovery</td>
<td>76</td>
<td>58</td>
<td>78</td>
<td>78</td>
<td>94</td>
<td>90</td>
<td>85</td>
<td>88</td>
<td>89</td>
<td>88</td>
<td>79</td>
<td>94</td>
</tr>
<tr>
<td>Max Penetration Depth</td>
<td>152</td>
<td>71</td>
<td>235</td>
<td>237</td>
<td>40</td>
<td>151</td>
<td>183</td>
<td>194</td>
<td>286</td>
<td>291</td>
<td>168</td>
<td>39</td>
</tr>
<tr>
<td>Max Shear (g/cm²)</td>
<td>1160</td>
<td>1922</td>
<td>3185</td>
<td>1670</td>
<td>319</td>
<td>99</td>
<td>1577</td>
<td>3418</td>
<td>162</td>
<td>2076</td>
<td>635</td>
<td>--</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>List of Holes</th>
<th>477B</th>
<th>492</th>
<th>502</th>
<th>504</th>
<th>506</th>
<th>512</th>
<th>515A</th>
<th>519</th>
<th>525B</th>
<th>530B</th>
<th>533</th>
<th>544B</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>480</td>
<td>502A</td>
<td>506B</td>
<td>514</td>
<td>516</td>
<td>526</td>
<td>532</td>
<td>534A</td>
<td>526A</td>
<td>532A</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>481</td>
<td>502B</td>
<td>506C</td>
<td>516A</td>
<td>520A</td>
<td>526B</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>592C</td>
<td>506D</td>
<td>517</td>
<td>521</td>
<td>526B</td>
<td>533</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>503</td>
<td>507D</td>
<td>518</td>
<td>521A</td>
<td>528</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>503A</td>
<td>507F</td>
<td>522</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>503B</td>
<td>507H</td>
<td>522A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>508</td>
<td></td>
<td>523</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>509</td>
<td></td>
<td>524</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>509B</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**NOTE:** HPC not used on Legs 65, 67, 77, 78,
Shear not measured on Leg 79,
<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>80</th>
<th>81</th>
<th>82</th>
<th>85</th>
<th>86</th>
<th>87</th>
<th>89</th>
<th>90</th>
<th>91</th>
<th>92</th>
<th>93</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Sites</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>4</td>
<td>5</td>
<td>1</td>
<td>1</td>
<td>7</td>
<td>1</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>Number of Holes</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>13</td>
<td>10</td>
<td>3</td>
<td>3</td>
<td>12</td>
<td>3</td>
<td>11</td>
<td>1</td>
</tr>
<tr>
<td>Number of Cores</td>
<td>77</td>
<td>42</td>
<td>16</td>
<td>183</td>
<td>11</td>
<td>49</td>
<td>61</td>
<td>358</td>
<td>7</td>
<td>49</td>
<td>11</td>
</tr>
<tr>
<td>Total Meters Cored</td>
<td>407</td>
<td>217</td>
<td>132</td>
<td>1292</td>
<td>938</td>
<td>258</td>
<td>546</td>
<td>3,546</td>
<td>53</td>
<td>346</td>
<td>91</td>
</tr>
<tr>
<td>Total Meters Recovered</td>
<td>355</td>
<td>216</td>
<td>124</td>
<td>1206</td>
<td>878</td>
<td>174</td>
<td>531</td>
<td>2,812</td>
<td>47</td>
<td>262</td>
<td>90</td>
</tr>
<tr>
<td>Per Cent Recovery</td>
<td>87</td>
<td>100</td>
<td>94</td>
<td>93</td>
<td>93</td>
<td>67</td>
<td>97</td>
<td>79</td>
<td>89</td>
<td>75</td>
<td>99</td>
</tr>
<tr>
<td>Max Penetration Depth</td>
<td>211</td>
<td>193</td>
<td>132</td>
<td>206</td>
<td>176</td>
<td>152</td>
<td>305</td>
<td>315</td>
<td>70</td>
<td>55</td>
<td>91</td>
</tr>
<tr>
<td>Max Shear (g/cm²)</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>700</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>List of Holes</td>
<td>548</td>
<td>552A</td>
<td>558A</td>
<td>571</td>
<td>576</td>
<td>583</td>
<td>586</td>
<td>587</td>
<td>596</td>
<td>597</td>
<td>603C</td>
</tr>
<tr>
<td></td>
<td>549A</td>
<td>553B</td>
<td></td>
<td>572</td>
<td>576A</td>
<td>583A</td>
<td>586A</td>
<td>588</td>
<td>596A</td>
<td>597A</td>
<td></td>
</tr>
<tr>
<td></td>
<td>572A</td>
<td>576B</td>
<td></td>
<td>572B</td>
<td>577</td>
<td>583C</td>
<td>586B</td>
<td>588A</td>
<td>596B</td>
<td>598</td>
<td></td>
</tr>
<tr>
<td></td>
<td>572C</td>
<td>577A</td>
<td></td>
<td>573</td>
<td>577B</td>
<td></td>
<td></td>
<td>589</td>
<td></td>
<td>599</td>
<td></td>
</tr>
<tr>
<td></td>
<td>573A</td>
<td>578</td>
<td></td>
<td>574</td>
<td>579</td>
<td></td>
<td></td>
<td>590</td>
<td></td>
<td>600</td>
<td></td>
</tr>
<tr>
<td></td>
<td>574A</td>
<td>579A</td>
<td></td>
<td>575</td>
<td>580</td>
<td></td>
<td></td>
<td>591</td>
<td></td>
<td>600A</td>
<td></td>
</tr>
<tr>
<td></td>
<td>575A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>591A</td>
<td></td>
<td>601</td>
<td></td>
</tr>
<tr>
<td></td>
<td>575B</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>591B</td>
<td></td>
<td>602A</td>
<td></td>
</tr>
<tr>
<td></td>
<td>575C</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>592</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**NOTE:** VLHPC not used on Legs 83, 84, 88
Shear not measured on HFC cores for Legs 80, 81, 82, 86, 89, 92, 93
ABSTRACT

The Hydraulic Piston Corer (HPC) was brought aboard on the evening of December 22, 1978 during a mid-cruise personnel/equipment transfer. Fourteen hours later it had its first test. It was operated a total of 51 times on three sites at depths ranging from 675 meters to 2100 meters. The tool proved fully operational, recovering a near continuous section totaling 152 meters of beautifully laminated, undisturbed cores on Site 480.

The HPC does not need extensive redressing between runs; the turnaround time on deck is about 20 minutes (when no seals have to be changed), using and redressing the same core barrel. After the initial runs, the drill crew handled the entire operation.

The one recurring problem was the frequent destruction of top sub packing. Some modifications are suggested to facilitate operation and handling of the tool.

SUMMARY OF TESTS

Details of each run can be obtained from the notes following the report. The intent of this section is to summarize the results of the tests and the problems encountered at each site.

The Cameron relief valve was not used in the system. On the first site (477B), the blowout was not used. The Saunders line stripper packing was considered adequate to maintain pressure up to 3000 psi. The wiper packing blowout on Run No. 3 when the system overpressurized. The blowout preventer was used from then on.

Once the tool was landed in the head sub, the normal activation procedure was to:

1) Close the blowout preventer.

2) Start pumping at 40 SPM. After about 30 seconds, the pressure in the drill string would begin to rise, first slowly, then quickly as the HPC seated.

3) When the pressure reached 1500-1700 psi, a slight deflection on the gauge would signal the driller that the pins has sheared and he would shut off the pump.

4) The pressure would then drop as it escaped through the vent holes which are open at the end of the HPC stroke.
Site 477B

Water Depth - 2020 M
Number of Runs - 3
Blowout Preventor - Not Used

At this water depth, the HPC was pumped down on the wireline to approximately 300 meters from the bottom, then lowered the rest of the way with the pumps off.

Run No. 1, the tool seated and activated, but the pressure did not drop afterwards. Later, it was discovered that the piston rod was 10 inches too long, thus at the end of its stroke, the vent holes were not aligned on either side of the outer seal sub and the HPC could not vent. Somewhere along the return trip, the lower core barrel section below the double pin sub backed off and was lost downhole. The threads were not damaged so it is assumed that the connection was not made tight enough.

On Run No. 2, the tool did not seat. Assuming that the lower core barrel from the initial run was still in the pipe, the HPC was retrieved and an unsuccessful fishing attempt was made. Then a regular core barrel, the same length as the HPC, was sent down. It seated so the pipe was thought to be clean.

On the third run, the HPC again did not seat. The pump rate was slowly increased to 60 SPM with gradual pressure rise. Suddenly the tool seated, shot off, and the pressure rose to 3000 psi, at which time the line wiper packing blewout.

The HPC was retrieved and found to have recovered four meters of very soft mud (using the spring leaf catcher). In the catcher was an eight-inch piece of the upper liner support from the missing core barrel. It was neatly sheared in half. When the pipe was pulled, the other half of this piece was found in the outer core barrel. It had been splayed out to the shape of the I.D. of the outer core barrel.

Problems Encountered

1) The top sub ring packing was destroyed or lost on each run. It is suspected that they are destroyed as the tool is pulled back up the pipe, and the lips of the seals snag at the pipe joints (a 1000 pound increase in weight was noted each time a joint was passed until the packing was gone). Each time the HPC was retrieved without pumping and at one half the rate of regular core barrel retrieval.

2) The sectioned piston rod, later found to be ten inches too long, was used for all three runs. After the first run, we replaced the 9-3/4" lower sub with a 15" lower sub to keep the piston head from jamming through the core catchers. But, as stated earlier, this also caused misalignment of the venting holes in the rod.

3) The piston head packing had to be replaced after the second run.
4) After the first run, great care was taken to torque tight the pin sub/core barrel connection. Chain tongs were braced against the standing-off section of drill pipe and a 26" pipe wrench with cheater was used to tighten the connection.

5) After the split locking collar is removed and the cap sub connection is broken, it is still very hard to unscrew the cap sub, since the shaft above the connection cannot be kept straight enough to keep it from binding the cap sub. Therefore, the locking collar was not removed after Run No. 2. Tension was kept on the top sub via the tugger while unscrewing the cap sub.

6) The 3/8" set screw locks are too soft. They frequently jam in their hole, making it necessary to use an easy out to back them out.

Site 480

Water Depth - 765 M  
Number of Runs - 32  
Blowout Preventor - Used

HPC operation on this site was a total success. One hundred fifty two meters of core were drilled with over 90% recovery. The beautifully varved sedimentary sections, ranging from soft mud to very firm diatomaceous ooze, were virtually undisturbed.

Prior to this site, the HPC was totally dismantled and redressed. Both the inner and outer sub seals were worn but still good. They were replaced. There were no damaged parts, but the piston rod was corroded. It was sanded, greased, and stowed away. The outer body was swabbed with solvent and greased on the inside. The HPC was reassembled with the one piece piston rod. The head sub landing surface was filed to smooth the rough edges where the metal had "rolled" slightly.

In an attempt to preserve the top sub packing, the six packing rings were oriented such that they faced each other in sets (i.e., the first ring pointing up; the second pointing down; the third pointing up; etc.). The brass ring was situated between the upper four and lower two packing rings.

To test this configuration, the HPC was run 200 meters down pipe, then retrieved. The lower three packing rings were gone. In order to remove the top connector to change the packing, the eight pins had be sheared (it is impossible to pull them out once they are set). The method used is as follows:

1) Lay down the upper section HPC and unscrew the outer body cap to pull the shaft about a foot out of the outer body.

2) With a sledge and a wedge, force the outer body cap away from the top sub to shear the pins.

3) Slide the outer body cap down the shaft to reveal the set screw locking the top sub to the shaft. The rest is easy.
The packing was replaced in the original configuration and the tool run down the pipe. No pumping was needed in this shallow water.

The first two runs had excellent core recoveries, but the packing was lost each time. On the third run, however, all the packing returned intact. The derrickman had been continually reducing the rate of retrieval, and finally found a slow enough speed to preserve the packing (just under 100 m/min). The packing had to be changed, again, after Runs Nos. 12, 20, and 25.

The piston head "V" packing was changed after Run No. 3. They were replaced with polypaks. The polypaks did not inhibit the tool from scoping together during assembly. This packing had to be changed, again, after Runs Nos. 12, 25, and 27. On Runs Nos. 3, 25, and 27, the core liner had partially collapsed and cracked. This may have caused the damage to the piston head packing.

Runs Nos. 12 and 13, had low recovery. Each of these runs was also characterized by an absence of pressure relief after tool activation. It was suspected that a sandy layer was keeping the HPC from fully extending during actuation. Some sand was recovered on Run No. 13. The driller washed down 4.75 meters in an attempt to get through the sandy section. Also, the inner and outer seals were changed, though after 13 runs, the old ones still looked OK. On the subsequent runs, the recovery increased and the tool actuated normally.

The core liner returned cracked or partially collapsed after Runs Nos. 3, 21, 24, 25, 28 through 32. This may have been caused by the increasing stiffness of the sediment. The recovery was still good. The liners usually collapsed just above the lower liner support. The cracks were longitudinal and usually at the upper end of the liner.

Site 481

Water Depth - 2016 M
Number of Runs - 25
Blowout Preventor - Used

Prior to this site, the HPC was totally dismantled and redressed. The outer sub seals were badly damaged. The "V" packing on the inner seal sub was worn but undamaged. The piston rod was corroded. It was sanded and re-greased. We had run out of shear pins, so we made more out of 3/16" brass brazing rod. They worked very well, shearing at a slightly higher pressure (1700-1900 psi).

On this site, the HPC was pumped down (as it was on Site 477B). The first two runs were water cores. The recovery was good on the next three runs. On the sixth run, the recovery dropped to 1.7 meters; the eighth and ninth runs produced zero recovery. Starting with Run No. 5, the pressure did not drop quickly after the pins sheared. The pressure would build up to 2000 psi, but no deflection registered on the pressure gauge. The driller said there was no evidence of a hard or sandy layer. Suspecting that the inner or outer seals were leaking, the HPC was overhauled. Seals were undamaged.
Runs Nos. 9 and 10, attempted to recore lost intervals from the two previous runs. No recovery on Run No. 9, and 0.2 meters was recovered on Run No. 10. Recovery picked up to 4.57 meters with Run No. 11. On Run No. 12, the HPC came back with pins unsheared. Runs 13 through 16 had good recovery.

The blowout preventer, which had been in use since the beginning of Site 480, was by this time leaking badly (there was no spare packing). This may have had an effect on the driving force behind the HPC as it sheared, thus inhibiting complete extention and proper venting.

The top sub packing had to be changed after Runs Nos. 4 and 14.

CONCLUSIONS

The HPC was an operational and scientific success.

Advantages

1) Good recovery of undisturbed sediments.
2) Relatively fast turnaround time on deck.
3) No major tool damage or breakdowns after extensive use.
4) Entire operation can be handled by rig crew.

Disadvantages

1) The necessity of using a special large diameter drill bit and head sub for HPC coring requires tripping the pipe to change the bottom hole assembly when piston cores are desired.

2) Top sub ring packing lasts from two to ten runs before becoming lost or damaged. The HPC is retrieved at a very slow speed in order to save the packing. In deep water holes this will be time consuming.

3) When making up the double pin sub/cab sub connection (the lower core barrel section is hung off in the pipe, and the upper HPC section is on the tugger line), a rig hand has to ride up on the harness to hold the shaft straight to keep from binding the threads. This is dangerous when the ship is rolling. If the shaft swings out of his grasp, it can swing back and smash him against the drill pipe.

Suggestions

1. Changing shear pins was the most time consuming phase of the turnaround routine. The pins should be made stronger to reduce the number needed. Also, threaded shear pins should be considered. They would eliminate the necessity of lining up the outer body cap with the shear groove to punch out the used stubs. Eliminating the set screw backers would mean less small parts to keep track of during turnaround operation.
2) Several ratchet drive allen keys and a set of easy outs should be purchased. Also need spares for all of the special assembly tools (i.e., handling clamp, special spanner wrench for outer seal sub).

3) Need a reciprocating seal for the top sub.

4) Several spare upper liner supports should be on hand. These damage easily with rough handling on rig floor.

5) Consider machining pin thread at one end of outer body. This would facilitate installation of inner seal sub without damaging seals. An additional double box sub could be used to make the connection.

6) Use the "V" packing only on the inner seal sub. The piston head works fine with polypak packing. Polypaks were tried on the inner seal sub when the "V" packing spares were depleted, but the increased friction makes it very hard to scope the tool together during assembly.

7) Fabricate a special support plate to hang shaft in pipe so the top sub can be removed to change packing without having to lay down the upper section of the HPC. The existing shear pin groove could be used to hang the shaft, or a new groove could be cut about one foot from the top of the shaft.

8) A method should be devised to keep shaft from binding when the double pin sub/cab sub connection is made up or broken when the HPC is hung off in the pipe.

Don Cameron
HYDRAULIC PISTON CORER.

ANALYSIS

CONTENTS

Problem Statement
Work Done
Discussion
Conclusion

Topics

Giant Piston Corer Comparison
Sediment Resistance to Coring
Shore Test Results of H.P.C. penetrating sediment.
H.P.C. coring velocity and resistance to penetration prediction and comparison with operational results.
Development of empirical approaches for H.P.C. performance in varying sediment shear strength and compaction.

Prepared by.  
Wilfred Nugent.
1.0 Problem Statement

During Deep Sea Drilling operations there is a need to take undisturbed core samples from the drilling site. The design of the coring tool 30 ft. long compatible with the drill string, is to be hydraulically actuated by sea water pumped at a pressure of 2500 psi and with a flow rate of 350 gpm; thus pressurizing the drill string and acting on the corer tool piston. Figure 1. presents the details.

1.1 Objectives.

The objectives of the analyses is to:
(a) Predict the velocities, column loads and criteria for the corer tool when penetrating the sub-surface to depths of 100m.
(b) Determine the structural adequacy of the corer tool.
(c) Predict the end of stroke snubbing and recommend devices
(d) Develop shear pin positioning / latching devices.
(e) Predict the load to be reacted by the tension rod.

2.0 Work Done.

1) A review of the Giant Piston Corer (GPC) test conducted by the University of Hawaii.
2) Review of the sub-surface foundation material densities and shear strength. Reference DSDP Technical Report No 9 September 1976
3) Predict friction coefficients for sub-surface materials entrained into the the corer tool at various velocities consistent with the surface pump capacity.
4) Develop mechanization schemes in support of the corer tool design
5) Prepare hydraulic analysis to determine orifice sizes, diametral clearances to ensure an out flow compatible with the pump inflow
6) Analyze and recommend snubbing devices.
7) Conduct structural analysis of critical components.

3.0 Discussion

The GPC tests (University of Hawaii letter) provided velocity, acceleration, and depth of penetration data. With knowledge of the mass of each GPC test, the force developed during corer penetration was calculated. Data from Plates 15 and 19 of DSDP Technical Report no 9 provided soil shear strength, and density values at comparable depths of penetration. An estimate of the sub-surface material viscosity was made, and friction coefficients were developed using the Reynolds Number of a plate simulating the circumference of the pipe. This approach yielded loads and velocities for the hydraulic coring tool which show favourable comparison with the GPC tests.

The resistance (drag) of the material passing through the pipe was calculated by the expression \( R = \frac{1}{2} \rho V^2 f \) per foot penetration. The resistance in terms of \( V^2 \) was used in the equation

\[
V = \frac{C_d a}{\rho g} \left( \frac{2g}{\rho} \right)^{1/2} \left( F - 4F + R \right)^{1/2}
\]

to determine the corer piston velocity as a function of the orifice characteristics.

The procedure yields velocities with reasonable accuracy.
The loads predicted for the hydraulic corer appear to be 12 per cent higher than anticipated when compared to the GFC data.

4.0 Conclusions.

1) Coring operations 0 to 50 feet below the surface are predicted as follows:

<table>
<thead>
<tr>
<th>Depth of Penetration Ft.</th>
<th>Column Stress psi</th>
<th>30 Ft. Column Buckling Stress psi</th>
<th>Deflection 30 Ft. Column ins</th>
<th>Safety Margin</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>1353</td>
<td>2831</td>
<td>1.67</td>
<td>2.08</td>
</tr>
<tr>
<td>20</td>
<td>1739</td>
<td>2831</td>
<td>2.17</td>
<td>1.63</td>
</tr>
<tr>
<td>25</td>
<td>2077</td>
<td>2831</td>
<td>2.55</td>
<td>1.36</td>
</tr>
<tr>
<td>30</td>
<td>2406</td>
<td>2831</td>
<td>3.00</td>
<td>1.17</td>
</tr>
<tr>
<td>*30 at 100m.</td>
<td>2602</td>
<td>2831</td>
<td>3.25</td>
<td>1.08</td>
</tr>
</tbody>
</table>

Taking cores greater than 25 ft. in length with the 3.5 inch diameter barrel is not recommended prior to full scale test. Figure 2 presents a plot of the column stress, corer end load, and penetration velocity versus penetration depth.

2) Coring at 100 m. is accomplished by limiting the surface pump pressure to 1000 psi and 200 gpm.

3) Orifice Characteristics. 2-0.5 inch diameter orifices below the corer piston, Refer to Figure 1. provide fluid flow out from the core chamber at 410 gpm. This added flow compensates for the release of additional fluid stored during pressurization of the drill string. A diametral clearance not less than .028 inches is required to discharge the fluid from the top side of the corer barrel. Refer to Figure 1.

4) Snubbing is provided by a double stack of Bellville washers .19 thickness (a total of 20) to dissipate 2255 ft lbs which results in 40,000 lb/inch² to be reacted by the tension rod.

5) Shear Pin(s) are provided to retain the corer barrel in the lock-shut position during deployment, and to be released under 2000 psi pump pressure. A .37 inch diameter single pin is required. Two pins having 0.213 inch diameter are required as alternatives to one pin. The material 4130 steel HT Ftu 125,000 psi with a yield value 109,000 psi is required.
HYDRAULIC PISTON CORET TOOL

FIGURE 1

RIG PUMP PRESSURE

MIN CLEARANCE 0.028

UPPER CHAMBER

STATIONARY PISTON

CORER BARREL

DISCHARGE ORIFICE

LOWER CHAMBER

CUTTING SHOE
SEDIMENT SHEAR STRESS = 150 PSF
CORER BARREL DIAMETER = 3.50 IN.
PUMP CHARACTERISTICS
PRESSURE  2,000 PSI
FLOW      350 GPM

COLUMN BUCKLING
STRESS ~ 2831 PSI
AT 30 FT

VELOCITY

CORER END LOAD

STRESS

STRESS, LB/IN^2 x 10^-3
Shear Strength versus Penetration for Ocean Sediments

Legend:
- Pelagic Clays
- Hemipelagic & Terrigenous Clays
- Calcareous Ooze
- Diatom Ooze

- McClelland (1966)

Note: Many measurements on disturbed samples.

Figure 3
COMPARISON OF G.P.C TEST NO. 4 UNIV. HAWAII
WITH UNIV CALIFORNIA SCRIPPS INST. HYDRAULIC PISTON COREL
PROPOSED CONFIGURATION

HYDRAULIC PISTON COREL CASE I

<table>
<thead>
<tr>
<th></th>
<th>DIMENSIONS</th>
<th>AREA IN²</th>
<th>AREA FT²</th>
</tr>
</thead>
<tbody>
<tr>
<td>COREZ PISTON ANNULUS</td>
<td>(2.88 ID - 1.12 ROD)</td>
<td>5.5</td>
<td>0.0382</td>
</tr>
<tr>
<td>DRILL COLLAR</td>
<td>4.125</td>
<td>13.364</td>
<td>0.928</td>
</tr>
</tbody>
</table>

VOLUME OF DRILL STRING 18,000 (0.928) 1670.5 FT³

COMPRESSIION OF FRESH WATER .0065 VOL @ 2000 PSI
THEN \( \frac{\Delta V}{V} = 1.0065 \)

COMPRESSED VOLUME IN 18,000 FT STRING = 10.86 FT³
INCREMENTAL COREZ PISTON LOAD (10.86 x 64.3) = 698.3
INCREASED PISTON PRESSURE 698.3/5.5 = 126 PSI
EQUIVALENT WATER COLUMN IN DRILL PIPE = 117 FT³

DATA FROM G.P.C. TEST NO. 4

<table>
<thead>
<tr>
<th>DISPL. DEPTH FT</th>
<th>ACCEL (G)</th>
<th>VELOCITY F.P.S</th>
<th>SHEAR STR. MCCULLOCH AND DATA LB/FT²</th>
<th>( \mu = \gamma (\frac{\Delta V}{V}) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>0.6</td>
<td>18</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>0.8</td>
<td>20</td>
<td>75</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>1.1</td>
<td>22</td>
<td>114</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>1.4</td>
<td>18</td>
<td>152</td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>1.6</td>
<td>16</td>
<td>190</td>
<td></td>
</tr>
</tbody>
</table>

FRICTION ESTIMATE

\[ f = 1.328 \sqrt{\frac{\mu}{\rho V X}} = 1.328 \sqrt{\frac{9.45}{3.85 (18)(112)}} = 0.463 \]

A VALUE OF 18 FEET PER SECOND HAS BEEN USED IN THE ESTIMATE FOR THE AVERAGE PENETRATION VELOCITY.
DYNAMIC PRESSURE (SEDIMENT RESISTANCE TO CORING)
\[ D = \frac{1}{2} \rho V^2 f \text{ P.S.F.} \]
\[ = 1.925 (1463) V^2 = 892 V^2 \text{ P.S.F.} \]

SINCE (DIAM) OF THE PIPE × 12 IN
\[ D = 892 V^2 \text{ (P.S.F.)} = \text{ Resistance Per Foot Length of Penetration} \]

THE FOLLOWING EXPRESSION IS USED TO RELATE THE PENETRATION VELOCITY AND THE RESISTANCE OF THE SEDIMENT TO CORING,

\[ V = \frac{C_L \alpha}{A} \left[ \frac{2g}{s} \right]^{1/2} \left[ \frac{\text{RIG PRESSURE} - \text{DYNAMIC IMPACT PRESSURE}}{A} \right]^{1/2} \]

\[ = \frac{C_L \alpha}{A} \left[ \frac{2g}{s} \right]^{1/2} \left\{ \left[ \frac{F - \mu F}{A} \right]^{1/2} - \left[ D \text{ (P.S.F.)} \right]^{1/2} \right\} \]

WHERE:
\[ V = \text{Piston Velocity FPS (TBD)} \]
\[ A = \text{Piston Annulus Area} = 5.15 \text{ in}^2 = (0.0382 \text{ ft}^2) \]
\[ \sigma = \text{Sea Water Density} = 64.3 \text{ LB/ft}^3 \]
\[ P = \text{Hydraulic Pressure} = 2000 \text{ PSI} (288,000 \text{ P.S.I.}) \]
\[ F = \text{Force on Piston} = 11,000 \text{ lb} (8800 \text{ lb}) \]
\[ \mu = \text{Coefficient of Sliding Friction} = 0.2 \]
\[ \alpha = \text{Sediment Mass Density} = 3.85 \text{ slugs/ft}^2 \]
\[ \alpha = \text{Orifice Area} = 2 \cdot \frac{1}{2} \text{ in}^2 = 0.00273 \text{ ft}^2 \]
\[ C_D = \text{Orifice Discharge Coefficient} = 0.62 \]
\[ Q = \text{Volumetric Discharge} = 0.62 (0.00273) (2 \cdot 12 \text{ in}) = 0.9365 \text{ ft}^3 \]
\[ = 44.83 (0.9365) = 420 \text{ gpm} \]
\[ D = \text{Resistance of the Sediment (Assumed to be Constant for Liquid Sediments in the First Order Analysis)} \]

THEN FOR 5 FEET PENETRATION
\[ V = 0.04426 \left\{ \left[ 230,400 \right]^{1/2} \left[ 15 (892) V^2 \right]^{1/2} \right\} \]
\[ = 21.24 - 0.0935 V \]
\[ = = 21.24 \]
\[ = 1,0935 \]
\[ = 19.42 \text{ FT/SEC} \]
THE COLUMN LOAD ON THE CORER = $5(1.892) V^2$
$= 1682$ LB.

CORING TO 40 FEET PENETRATION

$$V = 0.04426 \left[ \frac{230,400}{40(1.892)} \right]^{1/2}$$
$= 16.8$ FT/SEC

THE COLUMN LOAD ON THE CORER = $10,006$ LB.

FIGURE 4 SHOWS A PLOT OF THE DATA GENERATED BY THE FIRST TRIAL ANALYSIS.

THESE DATA WERE COMPARED WITH THE RESULTS OF THE GIANT PISTON CORER TESTS NO. 4 AND 5.

* ALLOW ADDED MASS AS THE CORE IS TAKEN G.P.C. DATA

<table>
<thead>
<tr>
<th>VELOCITY (F.R.S)</th>
<th>20</th>
<th>22</th>
<th>18</th>
<th>16</th>
</tr>
</thead>
<tbody>
<tr>
<td>PENETRATION (FT)</td>
<td>10</td>
<td>20</td>
<td>30</td>
<td>40</td>
</tr>
<tr>
<td>ACCELERATION (g)</td>
<td>0.8</td>
<td>1.1</td>
<td>1.4</td>
<td>1.6</td>
</tr>
<tr>
<td>TOTAL MASS (LBS)</td>
<td>141</td>
<td>140</td>
<td>152</td>
<td>157</td>
</tr>
<tr>
<td>RESISTANCE (LBS)</td>
<td>3632</td>
<td>5171</td>
<td>6852</td>
<td>8095</td>
</tr>
<tr>
<td>H.P.C. (CASE)</td>
<td>2990</td>
<td>5450</td>
<td>7640</td>
<td>10006</td>
</tr>
</tbody>
</table>

THE RESULTS OF THE H.P.C. FIRST ORDER ANALYSIS COMPARE FAVORABLY WITH THE RESULTS OF THE GIANT PISTON CORER RECORDED TEST CONDITIONS.

FIGURE 5 SHOWS THE RESULT OF A TYPICAL SHORE TEST, WHEN THE H.P.C IN THE OPERATIONAL CONFIGURATION WAS "SHOT" INTO A STIFF CLAY MIX $\approx 0.9$ K/SF. 
FIGURE 4

HYDRAULIC PISTON CORER CASE I

SEDIMENT SHEAR STRENGTH = 152 P.S.F
CORER BARREL DIAMETER = 2.88 INCHES I.D.
ORIFICES 2 - 0.5 INCHES DIAMETER

MAXIMUM AVAILABLE FORCE

CORING VELOCITY

CORING RESISTANCE

CORING RESISTANCE - LBS X 10^-3

CORING VELOCITY F.P.S.

PENETRATION DEPTH FEET
D. S. D. P. HYDRAULIC PISTON CORER TEST

PUMPS CIRCULATE THROUGH BY-PASS
1000 psi BACK-PRESSURE

MAX PRESSURE 1500 psi
TOTAL STROKE TIME 1 1/2 SECONDS
END OF 15 FT. STROKE
FLUID BYPASSES

PRESSURE BUILD UP WITH PENETRATION

PINS SHEARED

PEAK PRESSURE 2380 psi

LINE FILL-UP

POUNDS PER SQUARE INCH

SECONDS
Alternative methods for determining the forces and velocities developed during coring were investigated. One suggestion recommended the use of a friction factor in a Darcy Equation of 0.08 which was extrapolated from test data obtained from evaluating the characteristic of slurry pumped through a continuous loop.

The approach was as follows:

\[
\text{Head loss} = \text{Entrance loss} + \text{Friction loss} \\
\quad h = \left[ 0.5 + f(1/d) \right] \frac{V^2}{2g}
\]

Nomenclature:
- \( h \) = Head loss in feet
- \( f \) = Friction factor
- \( l \) = Length of pipe in feet
- \( d \) = Diameter of pipe in feet
- \( V \) = Velocity of flow (rate of penetration) in feet
- \( Q \) = Flow rate of circulating fluid in gpm.
- \( g \) = Gravitation acceleration in feet/second^2

The flow was assumed to be laminar.

The density of the sediment was taken to be 118 lbs/ft^3

\[
\quad h = \left[ 0.5 + 0.08(30/0.24) \right] \frac{V^2}{64.4}
\]

From previous shore testing the control of the penetration velocity within the limits of 20 ft/second was achieved. Using this value in the above equation, yields a head loss of 65.22 feet.

Expressing pressure as a function of head loss and density, a value of 7696 lbs/ft^2 is obtained.

Let 7696 lbs/ft^2 be the corer barrel internal pressure.

The friction force on the inner wall = \((.753)(30)(7696) = 173,777 \text{ Lbs}\)
which appears unrealistic, in relation to the test results.

This approach was abandoned in favor of expression

\[
\quad V = \frac{Cda}{A^{3/2}} \left( \frac{2g}{p} \right)^{1/2} \left[ \text{Force} - \text{Drag} \right]^{1/2}
\]

Operational data from leg 68 indicated that full cores were not retrieved repeatedly in sediment with shear stress in excess of 3000 g/cm^2. Figure 5 shows the predicted plot of a data sample.

Case I is the mean of ten trials where partial cores were retrieved. Case II represents a condition where 95% of a full core was retrieved. The curves are defined by the law

\[
y = a + b x^n
\]
HYDRAULIC PISTON CORING

ESTIMATE OF CORING RESISTANCE FROM OPERATIONS REPORT.
LEG No 68

CASE I
MEAN VALUE OF DATA FROM CORES No 37 THROUGH No 47
Mean Sediment Shear Strength 2,666.28 g/cm²
Mean Corer Release Pressure 2,103 p.s.i.
Mean Length of Core Recovered 2.3114 meters

CASE II
DATA FROM CORE 29
Sediment Shear Strength 1,170 g/cm²
Corer Release Pressure 1,650 p.s.i.
Length of Core Recovered 4.43 meters

FIGURE 5
HYDRAULIC PISTON CORER ANALYSIS

Derivation of Coring Depth Exponent

Refer to Case I

When \( x = 2 \), \( y = 5600 \) \[ a + b 2^n = 5600 \] (1)

When \( x = 4 \), \( y = 7800 \) \[ a + b 4^n = 7800 \] (2)

When \( x = 8 \), \( y = 9600 \) \[ a + b 8^n = 9600 \] (3)

Subtract (1) from (2)

\[ b 2^n (2^n - 1) = 2200 \]

Subtract (2) from (3)

\[ b 2^n 2^n (2^n - 1) = 1800 \]

\[ 2^n = \frac{1800}{2200} = .81818 \]

\[ n = -.2895 \]

\[ b = \frac{2200}{2^n (2^n - 1)} = -14788 \]

\[ a = 5600 - ( -14788 \cdot 2^{-0.2895}) \]

\[ y = 17700 - 14788 x^{-0.2895} \]

Applying these principles to the ratio of \( x_1, x_2, x_3 \), to \( L \) the length of core retrieved.

When \( x \)

\[
\begin{align*}
2 & \quad 1.225 & \quad a + b 2^n = 1.225 \\
4 & \quad 1.583 & \quad a + b 4^n = 1.583 \\
8 & \quad 3.665 & \quad a + b 8^n = 3.665 \\
\end{align*}
\]

\[ 2^n = -2.982 \cdot .358 = 5.8156 \]

\[ n = 2.539 \]

\[ b = 0.01278 \]

\[ a = 1.225 - 0.01278 \cdot 2^{2.539} \]

\[ y = 1.151 + 0.0128 \cdot 2^{2.539} \]

A program was compiled to calculate the constants and the exponent for a number of cases. During this process a variable for the effect of sediment shear strength was applied.
HYDRAULIC PISTON CORING.

On Leg 68 10,000 feet of drill string was deployed and pressurized to approximately 3,000 p.s.i. which compressed the water column an equivalent 10 cub. ft. The volume of the corer piston barrel is 0.55 cub. ft. The force on the corer piston is assumed to be constant under these conditions. From shore test results the force available for coring is around 8,500 lb. when friction and orifice control are considered.

The resistance to coring (drag) increased with depth as evidenced from the operations report from Leg 68. An exponent was developed as a depth factor using the expression:

\[ y = a + b x^n \]

Where \( x = \) The coring depth ( \( x_1, x_2, \ldots \) etc.)

\[ n = 1.3 + 0.00044 \gamma \]

\[ \gamma = \text{The sediment shear stress in g/cm}^2 \]

\[ a = \text{Constant} = 1.3 \]

\[ b = \text{Constant} = 0.01 \]

This empirical expression was developed by general determination laws connecting a set of tabular values which yielded a regular curve. The slope of the curve at regular intervals was plotted against the predicted value of the Coring Resistance, to give a straight line. A ratio of \( L/(L-x) \) relating the \( x_1, x_2, \ldots \) and the total length of core recovered also yielded a straight line plot, which indicated that \( y = a + bx^n \) might be used to provide a solution.

A program was compiled and the results of the extreme conditions reported from Leg 68 are shown.

<table>
<thead>
<tr>
<th>Sediment</th>
<th>1170 g/cm(^2)</th>
<th>Sediment</th>
<th>2666 g/cm(^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Core</td>
<td>14.9 length 2.</td>
<td>Core</td>
<td>10.864 length 2.</td>
</tr>
</tbody>
</table>

| SOLVE FOR H | 2.1193371744   | SOLVE FOR H | 3.3571188138   |
| SOLVE FOR B | 0.7924478123   | SOLVE FOR B | 2.210545507    |
| SOLVE FOR H | 3.738130435    | SOLVE FOR H | 6.189344139    |
| SOLVE FOR B | 1.902702799    | SOLVE FOR B | 2.629926339    |
| SOLVE FOR H | 0.0206926793   | SOLVE FOR B | 0.0111163780   |
| SOLVE FOR H | 1.232411387    | SOLVE FOR H | 1.29444153     |
| SOLVE FOR H | 1.232411387    | SOLVE FOR H | 1.29444153     |
HYDRAULIC PISTON CORING

Background,

Designs for the Hydraulic Piston Corer (HPC.) were completed in 1978. The performance was predicted on the basis of controlling the penetration velocity between the limits of 20Ft./sec and 10Ft./sec. The available shipboard rig pump pressure and flow were 2500 psi and 350 gpm respectively.

An expression \( V = \frac{C_d a^2}{A^{3/2}} \left( \frac{2g}{f} \right)^{1/2} \) [Piston Force - Sediment Drag] was used as an initial analytical tool.

Laboratory testing in a deep hole with a uniform sediment showed good correlation between the analysis and test. Operation in stiffer sediments indicated that the resistance to penetration increased exponentially with depth. A second "lump" factor in addition to the drag coefficient was developed by evaluating the operational data, as previously discussed.

The drag values were based on an apparent viscosity, applicable for ooze and unlithified sediment, the terms used were:

\[
\mu = \gamma \left( \frac{dx}{dv} \right)
\]

Where \( \gamma \) = Sediment shear strength
\( dx \) = the distance between surfaces
\( dv \) = the velocity change
\( \mu \) = viscosity

Substituting these terms in a friction equation where \( \sigma = \) Sediment density, slug ft^2

\[
f = 1.328 \sqrt{\frac{\mu}{\gamma (\sigma)^{3/2}}}
\]

is obtained

Relating the friction to Hydrodynamic Drag by \( D = \frac{1}{2} \sigma V^2 f S \) where \( S \) is the surface area. A step function analysis was developed which considered each foot of corer penetration and the circumference of the barrel as a unit area. \((3.5\pi)x\) each foot of penetration allows the S term to be neglected numerically.

The drag term can be written \( \frac{1}{2} (\sigma) V^2 + 1.328 (\gamma / V^2 \sigma) \) \( V \)

which reduces to \( D = 0.664 (\gamma \sigma)^{3/2} (V) \)

then \( V = \frac{C_d a^2}{A^{3/2}} \) [Piston Force - 0.664 \( (\gamma \sigma)^{3/2} (V) \) (D) exp] \( V \)

which is solved as a quadratic in the form of \( aV^2 + bV - C = 0 \)

Orifice Parameter
Drag constant
Piston Force

Figures 6 and 7 are analytical solutions which compare with the results obtained during actual coring operations.
NUMERICAL EXAMPLE PREDICTING THE VALUES FOR VELOCITY AND RESISTANCE

CONDITIONS

\[ P = \text{Shipboard Rig Operating Pressure} \quad 2,000 \text{ psi.} \]
\[ A = \text{Annulus Area of the Corer Piston} \quad 5.5" \times \frac{1}{2} \text{ inch} \times \frac{1}{2} \text{ ft}^2 \]
\[ a = \text{Orifice Area} \quad 2\frac{1}{2}\text{-inch diameter} \times \frac{1}{2} \text{ ft}^2 \]
\[ C_d = \text{Orifice Discharge Coefficient} \quad 0.62 \text{ non dimensional} \]
\[ \rho = \text{Sediment Mass Density} \quad 3.65 \text{ slugs/ft}^2 \]
\[ \tau = \text{Sediment Shear Stress} \quad 2,400 \text{ psf.} \]

The Sediment Resistance \[ = 0.664(2400 \times 3.65)^{\frac{1}{2}} (V) = 61.7V \]

Then \[ V = \frac{0.0273(0.62)}{(0.0382)^{3/2}} (11000 - 67.7V)^{\frac{1}{2}} \]
\[ = 0.2265 (11000 - 67.7V)^{\frac{1}{2}} \]
\[ 19.49V^2 = 11000 - 67.7V \]

Solution of the quadratic by completion of the square

\[ 19.49 (V^2 + 3.47V - 564.32) = 0 \]
\[ V^2 + 3.47V + (1.737)^2 = 564.32 + (1.737)^2 \]
\[ V + 1.737 = 23.81 \]

After one foot penetration \[ V = 22.08 \text{ ft/second} \]

The Sediment Resistance to Coring for the first foot depth \[ = 67.7(22.08) \]
\[ = 1494.81 \text{ lbs.} \]

At a Coring Depth of 10 feet \[ n = 1.3 + (0.00044 \times 1200) = 1.828 \]
\[ \text{Exponent } \gamma = 1.3 + (0.01(10) \exp 1.828) = 1.973 \]

The Sediment Resistance to Coring \[ = 67.7 \times 10^{1.973}(V) \]
\[ 19.49 (V^2 + 326V - 564) = 0 \]
\[ V + 163.2 = 164.9 \]

At 10 Feet penetration \[ V = 1.7 \text{ Feet/Second} \]

The Sediment Resistance to Coring \[ = 10,939 \text{ Lbs.} \]

49
HYDRAULIC PISTON CORER  

FIGURE 7

MAXIMUM PRESSURE 3000 PSI
SEDIMENT SHEAR STRENGTH 1200 PSF
CORE BARREL I.D 2.90 INCHES
ORIFICE DIAMETER 0.50 INCHES

- AVAILABLE CORING FORCE LBS
- SEDIMENT DRAG VS VELOCITY
- PENETRATION VELOCITY VS DEPTH

DEPTH - 2 4 6 8 10 12 14 16 18 20 22 24 FT,
VELOCITY - 10 20 30 40 FT/SEC.
HYDRAULIC PISTON CORER

ORIFICE ANALYSIS

CONTENTS

Problem Statement
Work Done
Discussion
Conclusions

Topics

Orifice Sizing to control the H.P.C. penetration rate during coring. This control feature enables the recovery of high quality undisturbed cores to be retrieved.

An arrangement of Vent Orifices provides an efficient method for regulating the end of stroke velocity of the H.P.C, and effects a method of snubbing with reduced impact forces.

A data plot shows the decay in velocity vs the H.P.C. travel (snubbing stroke).

Prepared by: Wilfred Nugent.
HYDRAULIC PISTON CORER ORIFICE ANALYSIS

PROBLEM STATEMENT

Velocity control was a prime design factor in the development of the Hydraulic Piston Corer. A method for regulating the rate of penetration of H.P.C. into a variety of sub-surface foundation materials was essential.

The procedure should be accomplished at the assembly or redress of the H.P.C. on the drill deck.

Protection against impact damage as the H.P.C. is scoped out to the full extended length should be provided.

OBJECTIVES.

Modification of the H.P.C. consistent with operation requirements, shear pin release, and related configuration build-up, should be accomplished in the sea state environment, from the drill deck.

WORK DONE.

The velocity control is accomplished by discharging the fluid through an orifice in the Lower Chamber.

The Expression: \[ v = \left( \frac{C_{da}}{A^{3/2}} \right) \left( \frac{2g}{P} \right)^{\frac{1}{2}} \left[ \text{Force} - \text{Drag} \right]^{\frac{1}{2}} \]

is derived from \[ v = C_{da} \sqrt{\frac{2gP}{C}} \]

The piston Force is the product of the pressure and the area. The Drag is a function of the dynamic impact pressure when penetrating the sediment.

The snubbing orifices function to reduce the rate of displacement of the H.P.C. barrel at the end of the end of the stroke, thus alleviating the impact forces.

DISCUSSION

The results of the orifice analysis indicate that the H.P.C. can be equipped with a range of velocity control orifices for both sediment penetration control, and end stroke impact avoidance.
HYDRAULIC PISTON CORER ORIFICE REVIEW.

1. CONTROL ORIFICES IN THE UPPER CHAMBER BETWEEN THE OUTER BODY & THE UPPER SHAFT.

2. THE ORIFICES FUNCTION THROUGHOUT THE ACTUATION THAT IS, THE COMBINED DISCHARGE RATE CONTROLS THE RATE OF PENETRATION. THEREFORE THE ORIFICES ARE SIZED TO PERFORM THAT FUNCTION.


4. THE CONTROL OCCURS AT THE END OF THE STROKE. THE SNUBBING ORIFICES HAVE CAPABILITY TO REDUCE THE VELOCITY TO 15 FT/SECOND FROM 46 FT/SECOND WITHIN 6 INCHES OF STROKE.

5. THE RESULTS OF THE ANALYSIS ARE SUMMARIZED IN FIG. 2.

6. ESTIMATE THAT IMPACT FORCE CAN BE CONTROLLED OVER THE LAST 0.5 INCH OF STROKE.

   \[ KE = \frac{12 \times 400}{2} = 2400 \text{ FT LB} \]

   \[ \text{FORCE} = 60,000 \text{ LB.} \]
INSTALLATION OF ORIFICES IN ITEM 28 OUTER BODY.

REFERING TO THE INITIAL DESIGN REVIEW A CLEARANCE OF 0.08 WAS SUGGESTED TO PREVENT FLOW RESTRICTION IN THE UPPER CHAMBER FROM AFFECTING THE CORING VELOCITY. THE MAXIMUM CORING VELOCITY WAS ESTABLISHED AT 20 FT/SEC. THE RATE OF DISCHARGE OF FLUID IS THAT DISCHARGED FROM THE LOWER CHAMBER.

OUTER BODY I.D. = 2.875
ROD DIAM = 1.25
AREA = 5.265 IN\(^2\)
VOLUME DISCHARGED = 1263 IN\(^3\)/SEC
DISCHARGE PRESSURE IN UPPER CHAMBER RESULTING FROM DISCHARGING 1263 IN\(^3\)/SEC IS: (FOR CONCENTRIC CYLINDERS)

\[
P = \frac{q I r C_p}{\alpha c^2 (2.25 \times 10^5)}
\]

\[
= \frac{1263 \times (6) \times (2) \times (102)}{2.625 \times (0.56)^3 \times (2.25 \times 10^5)}
\]

\[
= 149 \text{ P.S.I.}
\]

VENT HOLES & SHAFT CLEARANCE ARE SUFFICIENT TO DISCHARGE THE UPPER BARREL.

\(q = \text{FLOW IN}^3/\text{SEC}\)
\(c^3 = (D-d)^3\)
\(Y = \text{VISCOITY CENTSTOKES}\)
\(C_p = \text{SPECIFIC GRAVITY}\)
SNUBBING ORIFICE ANALYSIS

CONDITION: TAKING A CORE IN SEA WATER.
PRESSURE = 3,000 P.S.I.
PISTON AREA (ANNUUS) = 5.261N² (0.03656 ft²)
CONTROL ORIFICE = 2 x 5/8 = 0.447
Cd ORIFICE = 0.62
SLURRY MASS DENSITY \( \gamma \) = 3.6 SLUGS/FT²
SLURRY SHEAR STRENGTH \( \gamma \) = 100 LB/FT²

THEN RESISTANCE TO CORING = 0.644 \( \sqrt{100 \times 3.6} \) V
SAY = 15 V.

\[ V = \frac{13779 \left[ 15,780 - 15V \right]}{7 \left[ V^2 + 2.14V - 2253 \right]} = 0 \]

\[ V^2 + 2.14V + (1.07)^2 = 2254.9 \]

\[ V + 1.07 = 47.48 \]

\[ V = 46.41 \]

USE 46 FT/SEC AS THE CRITICAL VELOCITY FOR SNUBBING.

\( \Phi = \text{FLOW IN THE CORER BARREL} = 46 \times 0.03656 \times 1.682 \text{ FT}^3/\text{SEC} \]

CONSIDER VENTING THE FLOW FROM ABOVE THE PISTON TO REDUCE THE VOLUME OF FLOW IN THE CORE BARREL.
SNUBBING ORIFICE ANALYSIS

PRESSURE

PISTON VELOCITY $P_o$ = 3,000 PSI = 432,000 PSF

PISTON ANNULUS AREA $A_\pi$ = 46 FT/SEC

VENT ORIFICE AREA $A_o$ = 0.03656 FT$^2$

DISCHARGE COEFFICIENT $C_d$ = 0.00767 FT$^2$

FLOW RATE IN BARREL $Q_v$ = 0.005 FT$^2$

INITIAL VELOCITY 46 FT/SEC

$q_0 = 46 (0.03656) = 1.682$ FT$^3$/SEC.

$q_v = \text{ESTIMATE FOR FLOW THROUGH A 3/8 INCH DIA ORIFICE}
= 0.005 \sqrt{432 \times 10^4} = 0.3286$ FT$^3$/SEC

$u = \text{VELOCITY THROUGH ORIFICE} = 0.3286 / 0.005 = 657$ FT/SEC.

WHEN THE FIRST VENT IS EXPOSED BELOW THE STATIONARY PISTON

$q_1 = 1.682 - 0.3286 = 1.353$ FT$^3$/SEC

$v_1 = 1.353 / 0.03656 = 37$, FT/SEC

SOLVE FOR $P_1$

$37 = 0.068 \left[ P - 555 \right]^{1/2}$

$299,082 = P_1 = 2,077$ PSI

WHEN SECOND VENT IS EXPOSED

$C_d a = 0.001$

$q_2 = 0.001 \sqrt{299,082} = 1.547$ FT$^3$/SEC

$v_2 = 1.682 - (0.3286 + 1.547) / 0.03657
= 22.06$ FT/SEC
SNUBBING ORIFICE ANALYSIS

SOLVE FOR $P_2$

$$22 = 0.136 \left[ P - 330 \right]^{1/2}$$

$$26497 = P = 184 \text{ P.S.I}$$

WHEN THIRD HOLE IS EXPOSED.

$$C_{d a} = 0.0015$$

$$Q_3 = 0.0015 \sqrt{26497} = 0.2442 \text{ FT}^3/\text{SEC}$$

$$V_3 = 1.686 - \left( 0.3286 + 0.547 + 2.442 \right) / 0.03656$$

$$= 15.37 \text{ FT/SEC}$$

SOLVE FOR $P_3$

$$15.37 = 0.213 \left[ P - 15(15.37) \right]^{1/2}$$

$$5391 = P_3 = 37.43 \text{ P.S.I}$$

FINAL VENT 4-0.5IN DIA HOLES EXPOSED

$$C_{d a} = 0.0074$$

$$Q_4 = 0.0074 \sqrt{5391} = 1.5433$$

$$V_4 = 1.686 - \left( 0.3286 + 0.547 + 2.442 + 1.5433 \right) / 0.03656$$

$$= 0.517 \text{ FT/SEC}$$
SNABBING CHARACTERISTICS

CONDITIONS: 3000 PSI RIG PRESSURE
CURVE A HPC SHOT OUT IN WATERY SEDIMENT
CURVE B CORING IN 400 PSF SEDIMENT WITH 15 FT H.P.C.

CHART NO.2

![Chart diagram showing velocity vs. snubbing stroke for two curves A and B.](chart.png)
HYDRAULIC PISTON CORER
STRUCTURAL ANALYSIS

CONTENTS

Problem Statement
Work Done
Discussion
Conclusion

Topics

Beam-Column Analysis of the Drill Collar and extended H.P.C. Corer Barrel.

Flexural Model Test. A unit load applied on a scale model to demonstrate the deflection characteristics of the H.P.C.

Froude Scaling Techniques applied to predict the magnitude of the full scale H.P.C. structural loads and stresses.

A Moment Distribution Analysis for the scoped-out H.P.C 9 M column.

A parametric analysis for varying distributed transverse loads Shows H.P.C. barrel length vs stress due to axial and transverse load application.

Prepared by: Wilfred Nugent.
HYDRAULIC PISTON CORER STRUCTURAL ANALYSIS.

Problem Statement
Requirements for coring into increasingly stiff sediment introduced the possibility of slant angle penetration, or other related conditions which could produce side load effects in addition to column loading. The increase in stresses on both the H.P.C. components and the drill collar were considered critical.

Objective
The objective of the analysis was to:
- Predict the ability to recover long cores in stiffer sediment.
- Preclude the possibility of yielding the H.P.C. core barrel thus preventing the retrieval of the H.P.C. through the drill pipe.
- Providing guidelines for safe operation.

Work Done
A Beam-Column analysis was made to determine the combined bending characteristics of the H.P.C. and the Drill Collar. Particular attention was given to the location where the H.P.C. barrel exited the Drill Collar.

The Upper Shaft of the H.P.C. and the stationary piston were analyzed for similar loading conditions by moment distribution methods.

Scale models of equivalent dimensions were tested with axial and transverse loads applied. The reaction at the supports and contact points were observed and measured.

A Froude Scaling technique was used to calculate comparative values for full scale conditions.

Discussion
The results of these analyses and tests are presented herein.
A parametric study was made which used the beam-column analysis approach to indicate the penetration depth (H.P.C. corer length) and differential side loading capability within the limits of the corer barrel yield stress.

Conclusions
The analysis and the test show good co relationship considering that the model unit load test produced a 7.5 inch deflection and the analysis developed a 10.5 inch deflection.

The H.P.C. core barrel and stationary upper shaft have sufficient flexural stability to be considered suitable for use in a 9 meter (30 Feet long) coring tool.
9.0 M. H.P.C. SCOPED OUT

368

390

1118

INS.

360
HYDRAULIC PISTON CORER STRUCTURAL ANALYSIS

CORE BARREL ANALYZED AS A BEAM COLUMN

CONDITIONS:
- PISTON EXTENDED 30 FEET
- END LOAD = 12,044 LB.

DIMENSIONS OF CORE BARREL
- 3.50 O.D, 2.875 I.D. ANNULUS AREA 3,1293 in²
- I = 4.005 in⁴, Z = 2.2886 in³, P = 1.1323 in²

DIMENSIONS OF DRILL COLLAR
- 4.75 O.D, 4.12 I.D. ANNULUS AREA 4,357 in²
- I = 10.82 in⁴, Z = 2.473 in³, P = 1.576 in²

\[ I_d = 2.5 I_o \]

\[ M/EI \text{ DIAGRAM} \]

\[ \theta_b = \frac{1}{2} \left( \frac{3WL}{EI_o} \times 0.3L \right) + \left( \frac{12WL}{EI_o} \times 0.7L \right) + \frac{1}{2} \left( \frac{28WL}{EI_o} \times 0.7L \right) \]

\[ a \rightarrow b \]

\[ \delta_b = \frac{1}{EI_o} \left[ \frac{1}{2} (0.2L) (3WL) (0.3L) + \left( \frac{35}{12} (0.12WL) (0.7WL) + \frac{1}{2} (0.77L) (0.28WL) (0.7L) \right) \right] \]

\[ = \frac{1}{EI_o} \left[ 0.009WL^3 + 0.0294WL^3 + 0.07546WL^3 \right] \]

\[ = \frac{113.86WL^3}{EI_o} = \text{DEFLECTION DUE TO W} \]
M = EI \frac{d^2y}{dx^2} \quad \text{AND} \quad M = P(\frac{y_0 - y}{l}) + WX

\text{SO THAT}
\frac{d^2y}{dx^2} = \frac{P}{EI} y_0 - \frac{P}{EI} y + \frac{WX}{EI}

\text{AND USING AS A SOLUTION}
\begin{align*}
y & = A \sin Wx + B \cos Wx + \frac{WX}{P} \frac{y_0}{\text{EI}} \\
\frac{d^2y}{dx^2} & = -W^2 A \sin Wx - W^2 B \cos Wx
\end{align*}
\begin{align*}
&= -W^2(A \sin Wx + B \cos Wx) \quad \text{WHEN } W^2 = \frac{P}{\text{EI}}
\end{align*}

\text{AND WHEN } x = l, y = 0, \text{ THEN } \frac{dy}{dx} = 0^\circ \quad \text{WHEN } x = 0 \quad y = y_0

\therefore 0 = A \sin Wl + B \cos Wl + \frac{Wl}{P} + y_0 \quad \text{AND}
\begin{align*}
0 & = WA \cos Wl - W \sin Wl + \frac{W}{P} \\
y & = 0 - B + y_0; \text{ SO } B = 0
\end{align*}
\text{AND } A = \frac{W}{PW \cos Wl}
\text{ ALSO } A \sin Wl = \left(\frac{W}{PW (\cos Wl)}\right) \sin Wl
\text{THEN } \frac{W}{PW} \tan Wl + \frac{W}{P} + y_0 = 0 \quad \text{OR}
\begin{align*}
y_0 & = \frac{W}{P} \left(\frac{\tan Wl - Wl}{W} \right) \quad \text{NOTE } \frac{P}{\text{EI}} = W^2 \quad \frac{Pl^3}{\text{EI}} = W^2 l^3
\end{align*}
\begin{align*}
\frac{y_0}{\text{EI}} & = \frac{W}{P} \left(\frac{\tan Wl - Wl}{W^2 l^3} \right) \quad \text{EQ. 3.}
\end{align*}
SUBSTITUTING \( \frac{11386 \, W \, l^3}{E \, I} \) IN EQUATION (3) KNOWING \( I = I_0 \)

\[
Y_0 = \frac{11386 \, W \, l^3}{E \, I_0} \left( \frac{\tan U}{U^3} \right) (11386)
\]

LET \( U = \frac{P}{E \, I} \) RADIANS SINCE \( W^2 = \frac{P}{E \, I} \)

THEN

\[
Y_0 = \frac{11386 \, W \, l^3}{E \, I_0} \left( \frac{\tan U - U}{U^3} \right) (11386) = \text{DEFLECTION}
\]

AXIAL AND NORMAL LOAD ACTING

USING 13,000 LB AXIAL LOAD \( U = \sqrt{\frac{13000}{29 \times 10^6 \times 4}} = 0.01586 \) RADIANS

\[
\frac{\tan U - U}{U^3} (11386) = \frac{3.9096 \times 10^{-7}}{(0.01586)^3} (11386) = 0.03752
\]

\[
Y_0 = \frac{11386 \, W \, (118)^3}{29 \times 10^6} (0.03752) = 0.0515 \, W
\]

BENDING MOM. ON HPC DRILL COLLAR
AXIAL LOAD = 13,000 LB
TRANSVERSE LOAD APPLIED AT \( W = 150 \) LB.

\[
B.M. = P \, Y_0 + W \, l = 13,000 \left( \frac{0.0515}{150} \right) 150 + 150(118)
\]

= 268,125 IN-LB.

BENDING MOMENT ON H, P, C PISTON (STEP 'C')
REF: M/EI DIAG. \( \frac{4 \, W \, l}{E} \) MAX B.M. \( \frac{3 \, W \, l}{E} \) B.M AT STEP'C'

B.M. = 268,125 \( \left( \frac{3}{4} \right) \) = 201,094 IN-LB

\[
f_b = \frac{201,094}{4} \times 1.15 = 87,978 \, \text{PSI}.
\]
HYDRAULIC PISTON CORER (H.P.C)

SCALE MODEL TEST
TO DETERMINE THE FLEXURAL CHARACTERISTICS
OF THE H.P.C.

SCALING CONDITIONS

FULL SCALE H.P.C. BARREL           MODEL BARREL
O.D. 3.5 IN  SECTION MODULUS       O.D. 0.191 IN. SOLID
I.D. 2.7 IN  I = 4.75 in\(^4\)          I = 6.52 \times 10^{-5} \text{in}^4
WALL 0.4 IN

\[
\left(\frac{1}{8}\right)^5 = \text{MOMENT OF INERTIA SCALE} = 1 : 9.5 \text{ (F.S.)}
\]

FULL SCALE UPPER SHAFT           MODEL UPPER SHAFT
O.D. 2.63 IN  I = 1.70          O.D. 0.081 IN. SOLID
I.D. 1.88 IN

\[
\left(\frac{1}{8}\right)^5 = \text{MOMENT OF INERTIA SCALE} = 1 : 15
\]

HYDRAULIC PISTON CORER (H.P.C.)
MODEL TEST CONTINUED

Load was applied at point W & the corer assumed a condition of equilibrium.

The reactions at R1, R2, R3 were measured by adding weights until contact at the stops was just relieved. The reaction at R4 was measured with the applied load reacted at R1, R2, and R3.

<table>
<thead>
<tr>
<th>TEST NO</th>
<th>APPLIED LOAD</th>
<th>REACTIONS</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>180 oz</td>
<td>220 oz</td>
<td>R1 110 oz, R2 70 oz, Constant .191 Dia Rod</td>
</tr>
<tr>
<td>2</td>
<td>200 oz</td>
<td>300 oz</td>
<td>R1 1/2 oz, R2 1/2 oz, Constant .081 Dia Rod</td>
</tr>
<tr>
<td>3</td>
<td>160 oz</td>
<td>250 oz</td>
<td>R1 2 oz, R2 2 1/2 oz, Constant .191 Dia Rod</td>
</tr>
<tr>
<td>4</td>
<td>160 oz</td>
<td>27.6 oz</td>
<td>R2 27.6 oz, Constant .191 Dia Rod</td>
</tr>
<tr>
<td>5</td>
<td>160 oz</td>
<td>29 oz</td>
<td>R2 2 1/4 oz, Clamped, Corer Scale Model</td>
</tr>
<tr>
<td>6</td>
<td>310 oz</td>
<td>36 oz</td>
<td>R2 36 oz, R4 11 oz, 0</td>
</tr>
<tr>
<td>7</td>
<td>400 oz</td>
<td>Not Measured</td>
<td>Shaft neutrally stable, deflects against upper or lower stop</td>
</tr>
</tbody>
</table>

This test tends to indicate that the force & moment distributed to the upper shaft is relatively small compared to that existing at the drill bit.
HYDRAULIC PISTON CORER

FROUDE SCALING

FOR THE SECTION OF THE CORE BARREL EXTENDED BEYOND THE DRILL COLLAR

DEFLECTION = \( \delta = \frac{WL^3}{8EI} \)

SO THAT \( \delta_{\text{model}} = \frac{F_M L_M^3}{8E_I M} \) or \( \frac{\delta_M}{L_M} = \frac{F_M L_M^2}{8E_I M} \)

WRITING \( \frac{F_M L_M^2}{8E_I M} = \frac{F_{F.S} L_{F.S}^2}{8E_I F.S.} \) so that \( \frac{\delta_M}{L_M} = \frac{\delta_{F.S.}}{L_{F.S.}} \)

NOW \( \frac{I_M}{I_{F.S.}} = \frac{\text{FORCE}_{\text{MODEL}}}{\text{FORCE}_{F.S.}} \left( \frac{L_{\text{MODEL}}}{L_{F.S.}} \right) \)

SINCE FORCE SCALING = \( \left( \frac{1}{y} \right)^3 \) & \( L_M \) & \( L_{F.S} \) SCALE \( \left( \frac{1}{y} \right)^2 \)

INERTIA SCALING = \( \frac{I_M}{I_{F.S.}} = \left( \frac{1}{y} \right)^3 \left( \frac{1}{y} \right)^2 = \left( \frac{1}{y} \right)^5 \)

THEN

FORCE FULL SCALE

\( F_{F.S.} = \frac{F_M L_M^2 (I_{F.S.})}{I_M (L_{F.S.})^2} = \frac{1 \times 20^2 \times 4}{6.521 \times 10^{-5} (300)^2} = 273 \text{ LB} \)

\( = 10.9 \text{ LB/LIN FT.} \)

DEFLECTION FULL SCALE

\( \delta_{F.S} = \frac{\delta_M L_{F.S}}{L_M} = \frac{\delta_M (150)}{10} = 7.5 \text{ INCHES} \)

CALCULATED BENDING MOMENT (NO AXIAL LOAD)

B.M = 273(150) = 40,008 IN. LBS

APPLIED AXIAL FORCE = 13,000 LB

TOTAL B.M = 13,000 (7.5) + 40,008

\( = 137,500 \text{ IN. LB (NO SECONDARY BENDING)} \)
HYDRAULIC PISTON CORER

BARREL & UPPER SHAFT ANALYSIS

THE MODEL TEST SHOWED THAT FORCE REACTED BY THE UPPER SHAFT WAS RELATIVE SMALL FOR APPLIED TRANSVERSE LOAD.

WHEN AXIAL LOAD WAS APPLIED WITH THE MODEL HELD IN A POSITION AS DEFLECTED BY THE TRANSVERSE LOAD, THE ROD (MODEL BEAM) DEFLECTED AS INDICATED BY FIGURE.

DEFLECTION - (UPPER SHAFT)

\[ \delta F_s = \frac{F M L f_s}{L_m} \]

\[ = \frac{177(300)}{20} = 2.655 \text{ ins.} \]

APPLY 13,000 AXIAL LOAD

\[ B.M = 13,000(2.655) \]

\[ = 34,515 \text{ in. lb.} \]

THE H.P.C. SEAL SUB HOLD DOWN

RIG PRESSURE 3,000 PSI
SEALING AREA 5.5 IN²

HOLD DOWN FORCE = 16,500 LB

UPPER SHAFT - MAX BENDING

2.63 OD, AREA 1.88 I.D. 2.687 IN² 1.75 IN⁴

\[ B.M = 16,500(2.655) = 43,807 \text{ in. lb} \]

\[ f_b = \frac{43,807(1.25)(1.32)}{1.75} \]

\[ = 41,304 \text{ PSI} < 87,000 \text{ PSI YIELD.} \]
UPPER SHAFT ANALYSIS

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td>$1.5^4\text{ in}^2$</td>
<td>$4\text{ in}^4$</td>
<td>$2.19\text{ in}^4$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F.L</td>
<td>0.02</td>
<td>0.013</td>
<td>0.02</td>
<td>0.013</td>
</tr>
<tr>
<td>DIST FACTOR</td>
<td>0</td>
<td>1</td>
<td>0.39</td>
<td>0.61</td>
</tr>
<tr>
<td>CARRY OVER</td>
<td>0</td>
<td>0.61</td>
<td>0</td>
<td>0.61</td>
</tr>
<tr>
<td>FEM (KIPS) + 313.39</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BALANCE JOINT 'B'</td>
<td>-313.39</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CARRY OVER TO 'C'</td>
<td>-191.16</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BALANCE JOINT 'C'</td>
<td>+74.56</td>
<td>+116.61</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CARRY OVER TO 'D'</td>
<td>0</td>
<td>+71.13</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BALANCE JOINT 'D'</td>
<td>68</td>
<td>-31.13</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CARRY OVER TO 'E'</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

MOMENTS: +313.39 -313.39 -116.6 +116.6 +3.81 -3.13

AXIAL LOAD = 13,000 LB.
DISTRIBUTED SIDE FORCE = 1.5 LB/LN INCH
MAX BENDING MOMENT = $P_y + \frac{wL^2}{2} = 313,390$ IN-LB.

DETERMINATION OF CONSTANTS (CORRECTION FOR STIFFNESS FACTOR)
REFERENCE: BRUHN E.F. AIRCRAFT STRUCTURES A, 11, 21, 1952

<table>
<thead>
<tr>
<th>SPAN</th>
<th>$\frac{EI}{P}$</th>
<th>$L/I$</th>
<th>$K_{FACT}$</th>
<th>$K$</th>
<th>DIST FACT</th>
<th>C.G.F.</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-B</td>
<td>3.74</td>
<td>0.011</td>
<td>-</td>
<td>D</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>B-C</td>
<td>1.83</td>
<td>0.022</td>
<td>0.89</td>
<td>0.02</td>
<td>1</td>
<td>0.61</td>
</tr>
<tr>
<td>C-B</td>
<td>1.83</td>
<td>0.022</td>
<td>0.59</td>
<td>0.013</td>
<td>0.39</td>
<td>0</td>
</tr>
<tr>
<td>C-D</td>
<td>1.83</td>
<td>0.022</td>
<td>0.89</td>
<td>0.02</td>
<td>0.61</td>
<td>0.61</td>
</tr>
<tr>
<td>D-C</td>
<td>1.83</td>
<td>0.022</td>
<td>0.59</td>
<td>0.013</td>
<td>0.956</td>
<td>0</td>
</tr>
<tr>
<td>D-E</td>
<td>5</td>
<td>0.0016</td>
<td>0.0006</td>
<td>0.044</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
### Stress vs Corer Length

- **Axial Load** $P = 12,800$ LB
- **Rig Pressure** $= 3,000$ PSI
- **Corer Piston O.D.** $= 3.50$ INCHES
- **Corer Piston I.D.** $= 2.875$ INCHES
- **Section Modulus** $I = 4.005$ IN$^4$

![Diagram showing stress vs corer length with graphs for 5, 10, and 15 lb differential side force.](image-url)
HYDRAULIC PISTON CORER
THREADED CONNECTIONS ANALYSIS

CONTENTS

Problem Statement
Work Done
Discussion
Analysis Summary

Topics

Taper threads in relatively thin section pipe. Methods for reacting coupling forces by shoulder abuttment.

The effects of reduced cross sectional area due to thread relief and pressure seal grooves.

The effects of "snatch" forces during H.P.C. make up and redress. Stopping of the travelling mass when taking inadvertent water cores.

Corrosion alleviation by substituting Nimonic stainless steel.

Prepared by: Wilfred Nugent.
HYDRAULIC PISTON CORER THREAD ANALYSIS

PROBLEM STATEMENT

The connecting thread elements used in the H.P.C. are generally consistent with those used in the drill string. In the H.P.C. function there are additional loads applied to the threads which result from load reversal, impact stop forces and pull-back. The available envelope (diameter of the drill collar and spacing of the components) is a constraining factor.

Lengthening of thread engagement can be accomplished without severe change to the configuration. The critical regions are in the area of thread relief, necessary to achieve shoulder-to-shoulder abutment, and the recesses for the seal rings.

The alleviation of corrosion and the substitution of material to meet that objective was also included.

OBJECTIVES

The object of the analysis was to determine the feasibility of using corrosion resistant metal which may have lower working yield stress capability. The purpose was to investigate potential improvement in service life of the H.P.C., to reduce the time to redress the components between successive coring deployment; to improve the cost effectiveness and life expectancy of the equipment.

Work Done

Nimonic 60 stainless steel was proposed in an effort to combat corrosion and improve operational turn-around for the H.P.C. Particular attention was required in the areas of undercutting and recessing which create "notch sensitivity" especially when impact and load reversal conditions apply. These critical sections were subjected to detail analysis. The end stroke snubbing which involves methods for venting pressure and discharging the flow of fluid through drilled holes in the barrel had significant impact on the analysis.

Discussion

The analysis indicates that Nimonic 60 stainless steel in the mill condition was satisfactory but a reduced margin of safety resulted. The impact design case used showed the inner seal sub to have a negative margin. The condition can be solved by improvement in the snubbing system. A summary of the results of the analysis is included along with recommendations for limiting the applied pull-out force.
<table>
<thead>
<tr>
<th>ITEM</th>
<th>DWG NO</th>
<th>DESCRIPTION</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>31</td>
<td>1084</td>
<td>TOP SUB BODY</td>
<td>CONTROL IMPACT = 70000 LB STRESS ON THREAD CONNECTION TO UPPER SHAFT</td>
</tr>
<tr>
<td></td>
<td></td>
<td>REF PAGE 1</td>
<td>$f_t = 42,169$ PSI MARGIN = 1.3 ON YIELD FOR NITRONIC 60 S.S.</td>
</tr>
<tr>
<td>27</td>
<td>1210</td>
<td>SHAFT</td>
<td>UNDERCUT GROOVE FOR SHEAR PIN.</td>
</tr>
<tr>
<td></td>
<td>1213</td>
<td></td>
<td>2.36 DIA - 1.875 DIA IMPACT FORCE = 70,000 LB</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>43,392 P.S.I. MARGIN 1.29 ON YIELD FOR NITRONIC 60 ST. STL.</td>
</tr>
<tr>
<td>23</td>
<td>1214</td>
<td>INNER SEAL SUB</td>
<td>IMPACT FORCE = 70,000 LB STRESS ON THREAD CONNECT WITH 1210</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>MARGIN 2.7 ON YIELD FOR NITRONIC 60 ST. STL.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>IMPACT 210,000 LB NEG 1.11 MARGIN ON YIELD FOR NITRONIC 60 ST. STL.</td>
</tr>
<tr>
<td>11</td>
<td>1231</td>
<td>DOUBLE PIN SUB</td>
<td>NO CHANGE MARGIN ADEQUATE FOR 4130.</td>
</tr>
<tr>
<td>8?</td>
<td>1212</td>
<td>LOWER OUTER BODY</td>
<td>IMPACT FORCE 210,000 LB.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>$f_t = 158,447$ P.S.I. IMPACT $= 70,000$</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>$f_t = 52,830$</td>
</tr>
<tr>
<td>ITEM</td>
<td>DWG No.</td>
<td>DESCRIPTION</td>
<td>REMARKS</td>
</tr>
<tr>
<td>------</td>
<td>---------</td>
<td>---------------------</td>
<td>----------------------------------------------</td>
</tr>
<tr>
<td>1216</td>
<td>OUTER SEAL SUB</td>
<td></td>
<td>THREAD RELIEF</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>IF IMPACT ≥ 70,000 LB</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>( f_t = 31,715 \text{ P.s.i.} )</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>MINIMUM YIELD FOR NITRonenic</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>STAINLESS STEEL = 1.76</td>
</tr>
<tr>
<td>1219</td>
<td>PISTON ROD</td>
<td></td>
<td>LIMIT PULL OUT FORCE</td>
</tr>
<tr>
<td>1232</td>
<td></td>
<td></td>
<td>NOT TO EXCEED 20,000 LB</td>
</tr>
</tbody>
</table>

THE CRITICAL AREAS ARE THREAD RELIEF & UNDER CUT GROOVES.

THREAD LENGTHS CAN BE INCREASED TO PRODUCE INCREASED MARGIN.

REVIEW OF CONTROL ORIFICES IN UPPER CHAMBER
TOP SUB BODY  

ATTACHMENT TO UPPER SHAFT DWG 1210

AREA OF THREAD IN SHEAR = 2.107π (1.66/125)(.07084)(.80)  
= 4.98 in² (13 THREADS)  
= 3.00 in² (8 THREADS ENGAGED)

PENETRATING LOAD (STATIC) (3000 PSI RIG PRESSURE)

IMPACT STOP FORCE. REF WORK DONE MAY 1978
PISTON VELOCITY ~ 21 FT/SEC
MASS IN MOTION ~ 10 SLUGS
MOMENTUM DISSIPATED UNDER .001 SEC HALF SINE PULSE
ASSUME CONSTANT FORCE,

\[ F_t = m(v_f - v_i) = 210 \text{ Lb Sec} \]

FORCE = 210 / .001 = 210,000 Lb

STRESS ON THREAD = \[ \frac{210,000}{3.00} = 70,000 \text{ PSI} \]  
(8 THREADS)

MAX NO. THREADS ENGAGED
\[ \frac{2.0(\frac{12.42}{125})}{\frac{1.66}{1125}} = 13.28 \]

\[ \frac{13.28}{3} = 42.26 \text{ PSI} \] (3 THREAD)

MARGIN = 1.33 OVER YIELD FOR NITRONIC 60, ST.ST.
ACME - 8 THREAD

ACME 6 THREAD

PENETRATION (STATIC ANALYSIS) 30.00 x 5.5 = 16,500 LB.

8 THREADS ENGAGED $f_t = 5500$ PSI

UNDERCUT FOR SHEAR PIN (2.36 - 1.86) : 1 $= \frac{1.1657in^2}{1.75} = 210,000$ LB

DYNAMIC IMPACT STOP FORCE AT ITEM (2) UPPER SHAFT UNDERCUT $* f_t = 126,720$ LB

DYNAMIC IMPACT STOP FORCE (210,000 LB TAKING WATER CORE)

IF THE MATERIAL IS CHANGED TO NITRONIC 60 ST. STEEL

THE DYNAMIC IMPACT FORCE MAY REQUIRE AN 8 THREAD ACME CONNECTION TO BE LENGTHENED (INCREASE THE THREAD ENGAGEMENT)

TOP SUB BODY TOP SUB CAP DWG - B1084-04 & B1085-05

THREAID CONTACT AREA = 8.43 in$^2$

IMPACT FORCE = 210,000 LB

$\frac{1}{2}f_t = 24,910$ PSI (NOT CRITICAL)

* NOTE: THE UPPER SHAFT WAS FOUND TO BE CRITICAL IN 165 KSI MATERIAL DUE TO REACTING IMPACT STOP FORCES. REDUCING THE YIELD TO 56 KSI AGGRAVATES THE CONDITION. HOWEVER IF BY SNUBBING THE IMPACT OVER SAY 0.003 SECONDS THE IMPACT FORCE TO BE REACTED BECOMES 210 / 0.003 = 70,000 LB AND THE STRESS BECOMES 42,245 PSI AT THE UNDERCUT.

IMPACT STRESS BECOMES LESS CRITICAL.
UPPER SHAFT DWG 1210
LOWER SHAFT DWG 1213

WITH 4 IMPERFECT THREADS
14.88 TOTAL ~ 10 EFFECTIVE THREADS

THREAD AREA = 3.75 IN²
IMPACT FORCE = 210,000
ft = 56,000 PSI

UNDERCUT AREA
IMPACT FORCE = 210,000
ft = 130,177 PSI

LOWER SHAFT MAY SEE SOME RELIEF FROM THE IMPACT, BUT FOR THE SAKE OF UNIFORMITY THE DESIGN WILL BE STANDARDIZED.
INNER SEAL SUB. B.1214-00

THREADED CONNECTION TO UPPER SHAFT
PARTS B1214-00 - B1210-00

THREAD 2½ STUB ACME LENGTH OF ENGAGEMENT
3.75-(.75 + .44 +1.00) = 1.36 WITH 4 DISCONTINUOUS THDS.

EFFECTIVE AREA OF THREAD:
FULL THREADS ENGAGED = 9 (2.1071) x .071 x .80 = 3.323
CORING & PULL OUT FORCE = 5.5 (3000) = 16,500

\[ \sigma_t = \frac{4876}{16500} = 0.2 \text{ (not critical)} \]

IMpACT STOP (ASSUME SNUBBING EFFECTIVE IN .003 SEC)
\[ F_t = \frac{m(v_f^2 - v_i^2)}{21 \times 10} \text{ THEN } \]
\[ F = \frac{210}{.003} = 70000 \text{ LB} \]

\[ \sigma_t = \frac{20691}{70000} = 0.3 \text{ (more probable)} \]

NOTE: THE EFFECT OF SNUBBING "SPREADING THE IMPACT" OVER A LONGER TIME PERIOD REDUCES THE FORCE BUT THE FORCE IS STILL TO BE REACTED BY THE UPPER SHAFT.

INNER SEAL SUB FOR ITEM 18 PIN
O.D. = 1.795 AREA = 1.2935 IN² \( \sigma_t = 54114 \text{ PSI} \)
I.D. = 1.255 NOT CRITICAL THREADS BEAR THE LOAD.

INNER SEAL SUB- ROD CONNECTION

Dwg B1214-00 & B1217-00
PULL OUT CONDITION = .8 (16,500) = 13,200 LB

THREAD AREA = \( \pi \times 1.066 \times (1.125/125) \times 0.07084 \times 0.8 = 1.708 \)

\[ \sigma_t = \frac{7728}{13200} = 0.6 \text{ (not critical)} \]
DOUBLE PIN SUB DWG.B1231-00

ESTIMATE 5 STUB ACME

THREAD AREA ~ \( 3.14 \times (2/12) \times (13) \times (0.3) = 0.31 \text{ in}^2 \)

PENETRATION (STATIC ANALYSIS) = 16,100 LB

\( f_t = 16,01 \text{ psi} \)

NOT CRITICAL

IMPACT FORCE (STOP ON UPPER SHAFT)

LOWER ASSEMBLY IS CONNECTED BY DOUBLE PIN SUB

IMPACT FORCE

\( f_t = 210,000 \text{ LB} \)

\( f_t = 20,388 \text{ psi} \)

NOT CRITICAL FOR MAX IMPACT.

UNDERCUT MIL SLOTS

O.D 3.5

AREA 3.1293

SLOT 0.165

EFFECTIVE AREA 2.96

IMPACT \( f_t = \frac{m(v_f - v_i)}{A} = \frac{210,000 \text{ LB}}{2.96} \)

\( f_t = 70,842 \text{ psi} \)

IF IMPACT IS REDUCED TO

\( f_t = 70,000 \text{ LB} \)

\( f_t = 23,1649 \text{ psi} \)

LOWER OUTER BODY - B1212

SIMILAR CONNECTION TO B1231 DOUBLE PIN

THREAD NOT CRITICAL

UNDERCUT AT THREAD TERMINATION

O.D 3.5

AREA 1.325

IMPACT FORCE = 210,000 LB

\( f_t = 158,447 \text{ psi} \)

IF IMPACT FORCE IS REDUCED TO

\( f_t = 70,000 \text{ LB} \)

\( f_t = 52,830 \text{ psi} \)

THIS SECTION WAS CRITICAL IN 4130 STEEL.
OUTER SEAL SUB R-1216-00

THREADED CONNECTION TO OUTER BODY

3 INCH-8 STUB ACME

<table>
<thead>
<tr>
<th>MAJOR DIA</th>
<th>EFFECTIVE DIA</th>
<th>WIDTH EFFECTIVE</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.00</td>
<td>2.636</td>
<td>0.07084</td>
</tr>
</tbody>
</table>

AREA IN CONTACT = 2.636\pi \cdot \left( \frac{2.00}{125} \right) \cdot (0.07084) \cdot 0.80

= 7.30 in²

IMPACT FORCE = 210,000 LB

\sigma_t = 28,000 PSI \hspace{1cm} \text{NOT CRITICAL}

THREAD RELIEF

D.D. = 2.63

I.D. = 2.020

AREA = 2.20 in²

IMPACT FORCE \ 210,000

\sigma_t = \frac{210,000}{2.20} = 95,455 PSI

IF IMPACT IS REDUCED TO 70,000 LB

\sigma_t = 31,715 PSI

PULL OUT FORCE = 0.8 \times 16,500 = 13,200

\sigma_t = 6000 PSI \hspace{1cm} \text{NOT CRITICAL}

THREADED CONNECTION TO SHOULDER SUB(R0919-01)

2.0 INCH-8 STUB ACME

LENGTH OF THREAD ENGAGEMENT = 1.50 INCHES

AREA = 4.5 in²

IMPACT FORCE \ 210,000 ; \ \sigma_t = 46,667 PSI

MARIN = 1.2 OVER YIELD FOR NITRONIC 60 ST, STEEL.
CENTER PISTON ROD DWG B1219
LOWER PISTON ROD DWG R-1232

THE IMPACT FORCE IS REACTED ABOVE THE PISTON ROD CONNECTIONS.

THE CRITICAL LOADING CONDITIONS APPEAR TO BE PENETRATION & PULL OUT PLUS SNATCH LOADS
PENETRATION - COLUMN LOADING, FULL FIXITY BOTH ENDS
PISTON ROD IN TENSION BY VIRTUE OF SLIDING FRICTION
HENCE ALLOW FRICTION COEFFICIENT = 0.2

PRESSURE MAXIMUM = 3000 P.S.I
PISTON AREA = 5.5 IN²
FORCE = 3300 LB
AREA = 1.2272 IN²

\[ f_t = \frac{16500 \times 1.8 \times 3}{1.2272} = 32,268 \text{ P.S.I} \]

STRESS AT REDUCED SECTION = 89,560 P.S.I

THREADED CONNECTIONS R1232, A1218, & B1219
THREAD 7/8 N.S., COARSE 9 TPI LENGTH 1.12 (8 THREADS ENGAGED)
AREA = 0.42 IN²

\[ f_t = \frac{94,285}{0.42} = 94,285 \text{ P.S.I} \]

LIMIT THE EXTRACTION FORCE NOT EXCEED 20,000 LB.

STRESS ON THREADS \[ f_t = 47,019 \text{ P.S.I} \]
APPENDIX E

HYDRAULIC PISTON CORER
RETRIEVAL FORCE ALLEVIATION

CONTENTS

Problem Statement
Candidate Approaches
Study Matrix
Discussion
Category Grouping.

Topics
Study Matrix a listing and first order evaluation of proposed approaches for the solution.
Sketches for design concepts.
Description of a cursory test and scaling technique.

Prepared by: Wilfred Nugent.
Problem Statement
Hydraulic Piston Coring into increasingly stiffer sediment, produces greater resistance to pull-out. These H.P.C. pull-out forces are approaching the capacity limits of ship-board auxilliary equipment.

The objective of this study is to evaluate methods for the alleviation the holding force of the corer barrel when driven into the sediment.

Candidate Approaches
- Cutting shoe profile (shaping)
- Fluid flow to the shoe tip & annulus.
- Expendable sheath.
- Rotation of the lower barrel.
- Vibration & Jarring of the corer
- Retrievable sheath.
- Coated lower barrel.
- Flexible shoe.

Study Matrix.
The study matrix presents a description, functional analysis, a statement on the available equipment, fabrication factors, test requirements and competitive criteria comparison.

Discussion
Sketches which show the configurations are shown to aid in the selection process of candidate concepts.
There appears to be a possibility of grouping concepts which involve similar design and/or functional approach.

Category Grouping
The shaping of the shoe may be designed to compress or splay the cored hole (sidewall) thus relieving the retention condition.
Items No1 & No 8 may be evaluated on competitive terms.
The expendable and retrievable sheath configurations 3 & 6 and the coated barrel No 7 have similar end approaches.

The Deep Sea Drilling Project has significant advantage over "gravity drop" oceanographic coring tools in that jarring and pull-back can be accomplished by raising the drill pipe.
<table>
<thead>
<tr>
<th>CONCEPT</th>
<th>DESCRIPTION</th>
<th>FUNCTION ANALYSIS</th>
<th>FAB. FACTORS</th>
<th>TEST REQMTS</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cutting Shoe Profile</td>
<td>Shape the external profile of the cutting shoe</td>
<td>Hydrodynamic shaping. Flow testing of models</td>
<td>Machine</td>
<td>Flow Channel</td>
<td>No operation-al risk</td>
</tr>
<tr>
<td>Fluid flow to shoe &amp; tip</td>
<td>Cut spiral flutes Cut flutes axially along core barrel</td>
<td>Break the side of the cored hole. Neg. Press. in pull-back draws in water lub. effect</td>
<td>Machine O.D.</td>
<td>Test in operation</td>
<td>Notches the barrel</td>
</tr>
<tr>
<td>Expendable Sheath</td>
<td>On O.D. of Barrel Instal a sliding element</td>
<td>Provide initial sliding at start of pull-out</td>
<td>No impact</td>
<td>Test in operation</td>
<td>Left in core hole could cause problem</td>
</tr>
<tr>
<td>Rotation of Lower barrel</td>
<td>Unlock a thread connection &amp; allow the barrel to rotate</td>
<td>Rotate the barrel to break the side hole bond</td>
<td>New design</td>
<td>Model test &amp; shore test in sediment</td>
<td>Core barrel must not rotate around core Destoy alignmt. or twist core</td>
</tr>
<tr>
<td>Vibration &amp; Jarring</td>
<td>Use drill deck equipment</td>
<td></td>
<td>Electroplate</td>
<td>Test in operation</td>
<td>No risk involved.</td>
</tr>
<tr>
<td>Coated lower barrel</td>
<td>Hard smooth surface on lower barrel</td>
<td>Provide an inpenetrable surface on the barrel</td>
<td>Flame spay</td>
<td>Test in operation</td>
<td></td>
</tr>
<tr>
<td>Corer barrel O.D. configurations</td>
<td>Refer to sketches 8,9,&amp;10</td>
<td>Enlarge core hole during penetration relax during</td>
<td>New shoe</td>
<td>Test in operation</td>
<td>No risk involved.</td>
</tr>
</tbody>
</table>
ITEM B & 10

EXPANDING "C" RING

ITEM. 11
LATCH DOG.

CIRCULAR SPRING RETAINER
ITEM 9 FLEXIBLE SHOE

ELASTOMER RING FREE POSITION

ELASTOMER RING BULGES OUT PENETRATING

ALTERNATIVE FLEXIBLE BELLows.
A CURSORY TEST WAS RUN TO QUALITATIVELY OBSERVE THE EFFECTS OF PULL BACK FORCE ON FOUR SECTIONS OF TUBES, DRIVEN INTO SATURATED GARDEN CLAY. THE RESULTS ARE TABULATED AS FOLLOWS.

<table>
<thead>
<tr>
<th>DIAMINS.</th>
<th>CIRCUMF</th>
<th>6 INCH LENGTH FORCE</th>
<th>LOAD/IN</th>
<th>12 INCH LENGTH FORCE</th>
<th>LOAD/IN</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/8</td>
<td>1.178</td>
<td>6</td>
<td>.85</td>
<td>12.5</td>
<td>.884</td>
</tr>
<tr>
<td>1.</td>
<td>3.1416</td>
<td>13</td>
<td>.69</td>
<td>25</td>
<td>.663</td>
</tr>
<tr>
<td>1/4</td>
<td>3.927</td>
<td>15.5</td>
<td>.637</td>
<td>33</td>
<td>.70</td>
</tr>
<tr>
<td>1 3/4</td>
<td>5.977</td>
<td>18</td>
<td>.5019</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

THE (FORCE) LOAD PER INCH APPEARS TO DECREASE WITH INCREASE IN DIAMETER. HOWEVER IT SHOULD BE NOTICED THAT THE L/D RATIO IS 32 FOR A 12 INCH LENGTH OF 3/8 DIA TUBE WHEREAS THE L/D REDUCES TO 9.6 FOR A 12 INCH LENGTH OF 1/4 DIA TUBE.

APPLYING FROUDE SCALING FACTORS $\lambda = \frac{L}{L_f}$, $\lambda^2 = \frac{A}{A_f}$, $\lambda^3 = \frac{F}{F_f}$,

$$F_m = \frac{V^2}{L_f} \frac{m}{L_m g^3} \quad \text{and} \quad F_f = \frac{V^2}{L_f} \frac{m}{L_m g^3}$$

Then

$$V_{model} = \frac{V_{full \ scale}}{\sqrt{\lambda}} \quad \text{and} \quad F_{model} = \frac{F_{full \ scale}}{\lambda^3} \quad \text{and} \quad V_{model} = \sqrt{\frac{V_{full \ scale}}{\lambda}}$$

VELOCITY SCALING

PRESSURE SCALING

TOTAL FORCE

$$W = \frac{1}{2} \rho V^2 S f \quad \text{AREA} = \left( \frac{1}{\lambda} \right)^2$$

Then

$$W_{model} = \left( \frac{1}{\lambda} \right)^3 W_{full \ scale} \quad \text{PRESSURE} = \left( \frac{1}{\lambda} \right)$$

THE 3/8 DIA X 12 INCH TUBE MORE CLOSELY CONFORMS TO THE 3.5 INCH X 180 INCH CORER BARREL, & WILL
BE REVIEWED FOR COMPARISON USING FROUDE
SCALING TECHNIQUES.

3/8 DIA TUBE

SCALE FACTOR \( L = 9,334 \)

FORCE VARIES AS THE CUBE OF THE SCALE FACTOR

\[
F_{\text{full scale}} = F_{\text{model}} L^3
\]

\[
= 12.5 (9,334)^3 = 10,165\, \text{LB}
\]

THIS COMPARISON NEGLECTS THE LENGTH FACTOR \( 180/12 = 15 \).

TO COMPENSATE FOR THIS DIFFERENCE USE THE RATIO

OF CIRCUMFERENCE 9,334 AND THE AREA SCALING FACTOR

\( L^2 \), AND THE PULL BACK FORCE PER INCH.

FOR THE 3/8 DIA x 12 INCH TUBE USE 884 LB/INCH

THEN

\[
F_{\text{full scale}} = F_{\text{model}} L^2
\]

\[
= 1.884(9,334)^2 = 771\, \text{LB/INCH}
\]

FOR 15 FEET LENGTH OF 3.5 INCH DIA CORER BARREL

THE PROBABLE PULL BACK FORCE = 13,863, LB.

THERE IS A HIGH PROBABILITY THAT THE PULL BACK FORCE

INCREASES EXPONENTIALLY WITH THE DEPTH OF CORER

PENETRATION.
APPENDIX F

HYDRAULIC PISTON CORER
LANDING IMPACT

CONTENTS

Problem Statement
WorkDone
Discussion
Conclusions

Topics

A H.P.C. instrumented core barrel was to be landed onto a support bearing within the Drill String to a depth of 20,000 feet.
Terminal velocity estimates with varying hydrodynamic drag values
An evaluation of the impact on the instrument package.
Transmissibility of shock.
Testing of the shock mitigation device.

Prepared by: Wilfred Nugent.
Subject: Impact of the Core Barrel on the Support Bearing Mount.

1.0 Problem Statement.
During coring operation an instrumented core barrel is allowed to fall within the drill pipe at its terminal velocity, estimated to be 500 feet per minute.

The purpose of this analysis is to define the impact acceleration and make a prediction as to the shape of the curve.

2.0 Work Done.
A check on the range of the terminal velocity was made, with variation in hydrodynamic drag coefficient.
An estimate of the spring rate for the elements and the characteristics at the impact face was made and used in the solution of a spring mass system.
Damping factors were developed and used intuitively.

Five Cases were examined as follows:
I. Free fall of the mass at 10 ft/sec, no damping.
II. " 18 ft/sec, light damping
III. " 10 ft/sec, more heavily damped
IV. Same as III, but with reduced damping coefficient & spring rate.
V. Same as IV, but with reduced damping coefficient.

An additional analysis evaluates the effect of the impact on the instrument package installed within the core barrel.

3.0 Conclusions.
The conclusions drawn from the work done are:
1) Case I an undamped system does not occur in reality, but serves to indicate the maximum impact condition for the selected case.
2) Case II was developed to examine the effects of increased descent velocity (18 ft/sec.)
3) Cases III, IV, and V, vary mainly by the degree of damping coefficient applied.
4) Case II presents the most severe condition.
5) The instrument package can be protected against exposure to high positive or negative acceleration if the mounting has a spring frequency \( f = \frac{1}{2\pi\sqrt{\frac{k}{m}}} = 83.5 \text{ Hz} \) for a 30 lb instrument.

The data generated is plotted for Cases I, II, III, IV, & V. The plotted data shows the Change in Velocity versus Time and enables the acceleration to be derived as a tangent to points on the curve.
VALUES FOR C AND K,

THE CORE BARREL PACKAGE FALLS AT A TERMINAL VELOCITY ATTAINED WHEN THE STATE OF EQUILIBRIUM IS REACHED BETWEEN THE TOTAL DRAG FORCE ACTING (FRONTAL & SURFACE FRICTION) AND THE WEIGHT. THEN \( W = D \).

IN A FLUID MEDIUM, DRAG IS EXPRESSED AS \( \frac{1}{2} \rho C_D S V^2 \)

THEN \( W = \frac{1}{2} \rho C_D S V^2 \)

AND

\[
V = \left( \frac{W}{\frac{1}{2} \rho C_D S} \right)^{\frac{1}{2}}
\]

FROM THE GEOMETRY OF THE CORE BARREL, A \( C_D \) OF 2 IS USED

THE MASS DENSITY OF SEA WATER \( \sim 2 \)

FRONTAL AREA \( 12 \text{ in}^2 = \frac{1}{2} \text{ ft}^2 \)

\[
\left( \frac{360 \times 12}{2} \right)^{\frac{1}{2}} = 46.47 \text{ ft/sec}
\]

THE VALUE FOR DRAG COEFFICIENT FOR A LONG, SLENDER BODY MOVING WITHIN A CYLINDER IS SIGNIFICANTLY HIGHER THAN THE CHARACTERISTIC CASE OF 2.0 THEREFORE CONSIDER AN INCREASE BY ORDER OF MAGNITUDE, AND WE GET 14.7 FT/SEC SPECIFIED VELOCITY IS 500 FT/MIN. USE 10 FT/SEC

DAMPING CONSTANT ZERO TO ESTABLISH MAXIMUM IMPACT

SPRING RATE

USING 180,000 PSI BEARING STRESS AND .80 OF THE ANNULUS AREA OF THE IMPACT STOP. \( \sim 2.64 \text{ in}^2 \)

ASSUME THE COLUMN DEFLECTS 0.12 (BOWING DURING IMPACT)

DEFLECTION OF CONTACT 0.005
BEARING DEFLECTION 0.005
TOTAL DEFLECTION 0.13 INCHES \( \leq 0.1 \text{ ft} \)

ALLOWABLE SURFACE LOAD = 180,000 \times 2.64 = 475,200 \text{ lb}

SPRING RATE \( \text{LB/ft} \) = 47,520,000

THE PLOT OF THESE DATA POINTS WILL INDICATE A CONTINUING CYCLE WHICH IN REALITY DOES NOT OCCUR.
WRITING THE EQUATION OF MOTION IN TERMS OF THE DISPLACEMENT \( x \), A DAMPING CONSTANT \( c \) AND A SPRING RATE \( k \), THE FOLLOWING EQUATION IS DEVELOPED

\[ c\ddot{x} + kx = -m\dddot{x} \]

OR

\[ \frac{d^2x}{dt^2} + \frac{c}{m} \frac{dx}{dt} + \frac{k}{m} x = 0 \]

EQU (1)

LET \( c/m = 2a \) AND \( k/m = b^2 \)

THEN EQU (1) CAN BE WRITTEN AS

\[ \frac{d^2x}{dt^2} + 2a \frac{dx}{dt} + b^2 x \]

SOLVING THE QUADRATIC USING \( A \theta^{\alpha_t} \):

\[ \alpha^2 + 2a + b^2 = 0 \]

\[ \alpha_1 = -a + \sqrt{a^2 - b^2} \]

\[ \alpha_2 = -a - \sqrt{a^2 - b^2} \]

THEN \( x = Ae^{\alpha_1 t} + Be^{\alpha_2 t} \) IS THE COMPLETE SOLUTION
NUMERICAL ANALYSIS CASE NO 1

MASS OF CORE BARRIL = \frac{360}{32.2} = 11,180 \text{ lb sec}^2 / \text{ft};

ACCELERATION = T, B, D, \approx 600 \text{ g est.}

DESCENT VELOCITY = 10 \text{ ft/sec}

SPRING RATE = 4.75 \times 10^6 \text{ lb/ft.}

DAMPING CONSTANT = 0

FROM PAGE (1) \( x = A e^{\lambda t} + B e^{-\lambda t} \)

\( c/m = \omega = 0, \) \( k/m = b = 4,248,611; \) \( b = 2061 \)

LET D = 2000 FOR NUMERICAL ANALYSIS

\( \alpha = -a \pm \sqrt{a^2 - b^2} \quad \text{WHEN } a = 0 \)

\( b^2 = 4,000,000 \)

THEN

\( x = A e^{(2000i)t} + B e^{(-2000i)t} \)

\( = e^{t}(A e^{2000i} + Be^{-2000i}) \)

AND WHEN C & D ARE CONSTANTS DEPENDING ON THE INITIAL CONDITIONS,

\( x = e^{t}(C \cos 2000t + D \sin 2000t) \)

\( \frac{dx}{dt} = e^{t}(C \cos 2000t + D \sin 2000t) \)

\( + e^{t}(-2000C \sin 2000t + 2000D \cos 2000t) \)

FOR THE INITIAL CONDITIONS \( x = 0, \) \( v = 10, \) & \( t = 0 \)

WHEN \( t = 0, \) \( x = 0, \) THEN \( C = 0 \)

WHEN \( t = 0, \) \( v = 10, \) THEN \( D = 0.005 \)

PUT THESE VALUES IN \( x = e^{t}(C \cos 2000t + D \sin 2000t) \)

\( = e^{t}(0.005 \sin 2000t) \)

\( \frac{dx}{dt} = e^{t}(0.005 \sin 2000t + 10 \cos 2000t) \)

\( \frac{d^2x}{dt^2} = e^{t}(0.005 \sin 2000t + 10 \cos 2000t) \quad \text{SMALL} \)

\( \frac{d^2x}{dt^2} + e^{t}(10 \cos 2000t - 20000 \sin 2000t) \)
VELOCITY VS TIME

CONDITIONS:
CORE BARREL DESCENT VELOCITY ~ 360 LBS
~ 10 FT/SEC

CASE NO. I
\( e^t (0.005 \sin 2000t + 10 \cos 2000t) \)
MAX ACCEL = 634 g

CASE NO. II
\(-300e^{-300t} (0.00769 \sin 1300t) + e^{-300t} (10.051300t) \)
MAX ACCEL = 465 g

CASE NO. IV
\(-500e^{-500t} (0.0083 \sin 1200t) + e^{-500t} (10 \cos 1200t) \)
MAX ACCEL = 341 g

FIGURE 1 WN4 22
CASE II

VELOCITY VS TIME

VELOCITY 18 FEET/SECOND
PERIOD 0.0035 SECONDS
MAXIMUM HALF AMPLITUDE ~ 0.1014 INCHES

\[-200 e^{-200t} (0.01 \sin 1800t) + e^{-200t} (18 \cos 1800t)\]

FIGURE 2
WIN 4-13-77
CASE II

VELOCITY VS TIME

INITIAL VELOCITY 10 F.P.S
PERIOD 0.003 SECONDS

VELOCITY, F.P.S

\[-700 e^{-700t} (0.005 \sin 2000t) + e^{-700t} (10 \cos 1800t)\]

FIGURE 3
W.N 4-16-77
1. DATA PRESENTED ROUGH DRAFT OF REPORT DS.D.P 4.2

GENERAL CONCLUSION OF MEETING

FORCE OF IMPACT ~ 335,000 LB
THEORETICAL G'S ~ 900 G
TRANSMITTED G'S ~ 900 G

2. CORRECTION TO ESTIMATE FOR DETERMINING SPRING CONSTANT

LIMIT THE ALLOWABLE STRESS AT THE FACE OF THE
LANDING SUB & THE BEARING BLOCK TO 120,000 PSI.
THIS PRODUCES (120,000 x 1.35) 162,000 LB END FORCE
THE END FORCE 360 (400/1.35) = 106,666 PSI.

CASE IV

MASS OF CORE BARREL
ACCELERATION = 11.18 LB SEC²/F
T.B.D.

DESCENT VELOCITY = 10 FT/SEC
SPIRING RATE \( \beta \)
DAMPING CONSTANT
KE OF BARREL = \( \frac{1}{2} \) MV²
DISPLACED VOLUME IN LOWER CHAMBER \( \frac{5}{3} \pi \) (6)²/(1728) = 0.033 FT³
PULSE PRESSURE IN LOWER CHAMBER²
ANNULUS AREA
LENGTH OF THE LOWER CHAMBER
FLOW VELOCITY THROUGH THE CONSTRUCTION
FLOW THROUGH CONCENTRIC CYLINDERS \( \Phi = \frac{d(C)^{2}R}{2\pi} \times \frac{1.3 \times 10^{5}}{F \times 3} \) FT³/SEC

EQUIVALENT DISCHARGE AREA \( C_d \alpha = \frac{\Phi}{\sqrt{\frac{2 \pi}{\Phi}}} = \frac{10.68}{130} = 0.082 \)

\[ V = \frac{C_d \alpha \left( \frac{\rho}{F} \right)^{2}}{A^{3/2}} \]

\[ F = \frac{V^2 A^3}{S} \]

DAMPING FORCE ~ 2988 LB \( \beta \)10.5 FT IN .05 SECONDS
THEN DAMPING RATE ~ \( \frac{2988}{10.5} \) \( \alpha \) = 119.52 LB SEC/FT
(119520 LB/10 FT²/SEC \( \alpha \) \( \beta \) \( \alpha \) = 119.52 LB SEC/FT

101
NUMERICAL ANALYSIS CASE IV

\[ x = Ae^{\alpha t} + Be^{-\alpha t}. \]

[Given values and calculations have been made]

\[ \alpha = -\frac{a \pm \sqrt{a^2 - b^2}}{2}, \]
\[ \alpha = -500 \pm 1198.87i. \]

**Then**

\[ x = Ae^{(-500+1200i)t} + Be^{(-500-1200i)t}. \]

\[ = e^{-500t}(Ae^{1200t} + Be^{-1200t}). \]

\[ V = \frac{dx}{dt} = -500e^{-500t}(C \cos 1200t + D \sin 1200t) \]
\[ + e^{-500t}(-1200C \sin 1200t + 1200D \cos 1200t). \]

**INITIAL CONDITIONS**:

\[ x = 0, \quad V = 10, \quad t = 0. \]

**When** \( t = 0 \), \( x = 0 \), AND \( C = 0 \)

**When** \( t = 0 \), \( V = 10 \) THEN \( D = 0.0833 \)

\[ x = e^{-500t}(0.0833 \sin 1200t). \]

\[ \frac{dx}{dt} = -500e^{-500t}(0.0833 \sin 1200t) + e^{-500t}(10 \cos 1200t). \]

\[ \frac{d^2x}{dt^2} = 500e^{-500t}(0.0833 \sin 1200t) - 500e^{-500t}(10 \cos 1200t) \]
\[ - e^{-500t}(-1200 \sin 1200t) + e^{-500t}(-1200 \cos 1200t). \]

**PERIOD**

\[ T = 2\pi \sqrt{\frac{m}{k}} \]
\[ T = 5.22 \times 10^{-3} \text{ seconds}. \]
CODE BARREL ASSEMBLY IMPACT CONDITION

A previous drop test of a cylindrical shaped body with a pointed spike on a flat steel plate produce a 700 g (0.4 millisecond) half sine wave pulse. The shock response of a spring mass system was calculated by the following procedure:

\[ f = \frac{1}{2\pi \sqrt{\frac{k}{m}}} \text{ NAT FREQ} \]

The equation of motion is:

\[ m \left[ \ddot{x} + \dot{u}(t) \right] - k \dot{x} = 0 \]

where \( \ddot{x} \) is the relative acceleration \( \ddot{x} = (x - \ddot{w}) \)
\( \dot{u} \) is the input acceleration \( \dot{u} = \ddot{u}_{\text{max}} \sin \frac{\pi}{T} \) when \( 0 \leq t \leq T \)
\( = 0 \) when \( T \leq t \)

\( T \) is the acceleration pulse width in seconds.

The solution of \( \text{Equation 1} \) is:

\[ \text{Equation 2} \quad \dot{x} = \frac{\ddot{u}}{T^2} \left( \frac{\sin \frac{\pi}{T} \left( T \frac{t}{2} - \frac{T}{2} \right)}{\frac{T}{2}} \right)^2 \]

\[ \text{Equation 3} \quad \dot{x} = \frac{\ddot{u}}{T^2} \left( T \cos \left( \frac{\pi T}{T} \right) \right) \sin \left( \frac{T}{2} - \frac{T}{2} \right) \]

Where \( \ddot{u} \) is the static deflection of the mass assuming a steady load.

\( \ddot{x} \) is maximum when \( t > T \)

\( T \) is \( \frac{1}{\omega} \)

Assumption: Let the instrument package weigh 85 lb.
And the potting compound have a compressive yield = 3,000 psi.
The support area = 1 sq inch and the total deflection be .05 inches for the applied static load of 3,000 lb.

\[ f = \frac{1}{2\pi \sqrt{\frac{72 \times 10^4}{2 \times 6.3}}} = 83.2 \text{ Hz} \]
STATIC LOAD $6000/80 = 75$ GRAVITIES

$$f = 80 \text{ HZ} \quad T = \frac{1}{0.03034} \text{ SECONDS}$$

$$T = 10016 \text{ MILLISEND} \quad \frac{T}{T} = 8.15$$

$$\omega_n = \frac{2\pi}{T}$$

$$\omega_n = \sqrt{\frac{k}{m}} \quad \text{NATURAL FREQUENCY RADS/SEC}$$

**EQUATION 4**

$$\delta_{\text{MAX}} = S_p \cdot 7.37 \cdot \cos \left( \frac{\pi}{7.87} \right) \cdot \sin \left( \frac{2\pi}{T} \left[ t - \frac{T}{2} \right] \right) \bigg|_{T=0}$$

$$\delta_{\text{MAX}} = 0.03463 S_p$$

**LOOK FOR MAXIMUM PRODUCED BY FUNCTIONS OF t**

$$\sin \left( \frac{2\pi}{T} \left[ t - \frac{T}{2} \right] \right) \text{ LET THIS } = 1 \quad \text{ IF}$$

**THEN** \( \sin \left( \frac{\pi}{2} \right) \text{ IS PROBABLY A MAXIMUM} \)

$$\frac{2\pi}{T} \left[ t - \frac{T}{2} \right] = \frac{\pi}{2}$$

**AND** \( t = \frac{\pi}{2} \left( \frac{T}{2\pi} \right) + \frac{T}{2} \)

$$t = 0.00391$$

$$\delta_{\text{MAX}} = 0.0326$$

31.16 < \frac{3}{0.03463} \cdot (900)

31.16 < 35.29
1. **FREQUENCY OF COLUMN AT IMPACT**

\[ f = \frac{1}{2\pi} \sqrt{\frac{E I}{\mu L^4}} \]

**ESTIMATE**

RANGE ~ 200 TO 400 Hz

2. **TRANSVERSE BENDING, FREE-FREE BEAM**

\[ f = \frac{1}{2\pi} \alpha_n \sqrt{\frac{E I}{\mu L^4}} \]

**WHERE**

- \( \alpha_n = 2 = 6.1 \)
- \( \alpha_n = 3 = 13.1 \)
- \( \alpha_n = 5 = 29.8 \)

**SECOND MODE**

\[ \frac{6\pi}{2\pi} (1.6476) \]

\[ = 16 \text{ Hz} \]

**THIRD MODE**

\[ \frac{12\pi}{2\pi} (1.6476) \]

\[ = 34 \text{ Hz} \]

**FIFTH MODE**

\[ \frac{20\pi}{2\pi} (1.6476) \]

\[ = 78 \text{ Hz} \]

3. **ANALYSIS USING ANALOGY OF A WATER COLUMN IN A CLOSED PIPE**

REFERENCE: MECHANICAL VIBRATION DEN HERTOG, P. 431

\[ f = (1 + 2n) \frac{14,200}{L} \]

**SECOND MODE**

\[ \sim 200 \text{ Hz} \]

**THIRD MODE**

\[ \sim 276 \text{ Hz} \]

**FIFTH MODE**

\[ \sim 434 \text{ Hz} \]

4. **IMPACT CONDITIONS**

\[ K'E = 560 \text{ FT LB} ; \text{ DEFLECTION AT CONTACT } \sim 0.01 \text{ FT} \]

**ESTIMATE AREA UNDER CURVE** = KE

**THEN FORCE**

\[ \text{ACCELERATION} \text{ g's} \]

\[ = 112,000 \text{ LB} \]

\[ = 112,000 / 360 = 311g \]

5. **TRANSMISSIBILITY**

\[ K_T = \sqrt{\frac{1 + \left(2 \frac{c}{c_e} \frac{u}{u_n}\right)^2}{\left(1 - \frac{u^2}{u_n^2}\right)^2 + \left(2 \frac{c}{c_e} \frac{u}{u_n}\right)^2}} \]
FROM THE TRANSMISSIBILITY EXPRESSION IT IS SEEN THAT THE TRANSMISSIBILITY IS INFINITE AT RESONANCE.

FROM ANALYSIS AND TEST THE DAMPING RATE IS SMALL THE FREQUENCY RATIO \( \frac{w}{w_n} \) APPEARS TO BE \( \approx 0.95 \) AS A CONSEQUENCE THE CONDITIONS ARE NEAR RESONANCE.

CONSIDER THE DAMPING RATIO \( \frac{c}{c_c} = 0.2 \) \( \frac{w}{w_n} \approx 1.0 \)

\[
K_T = \sqrt{1 + \frac{\left(2(0.2)\right)^2}{\left(2(0.2)\right)^2}} = 2.693
\]

WHEN \( \frac{c}{c_c} = 0.15 \) \( K_T = 3.15 \)
CONCLUSIONS:
1. FROM THIS AND PREVIOUS ANALYSIS IT IS SEEN THAT
THE IMPACT CONDITIONS APPROACH OR EXCEED THE BOUNDARY
CONDITIONS (500g AND 500G PULSE - 3000G 1 MS PULSE) OF
THE ACCELEROMETER.

NOTE 1  
311G AND 4.35 MS HAFESINE PULSE AT IMPACT  
930G AND 1.6 MS  
2400G AND 2.0 MS  
THIS CASE:  
CASE II STUDY  
CASE IV STUDY

THE TRANSMISSIBILITY ~ 3.5 TO 3 COULD PRODUCE ~ 1000G

THE VIBRATION DUE TO FLOW THROUGH DURING DESCENT 200-400Hz
IT IS NOT APPARENT THE THE LOAD FACTOR WOULD BE EXCEED
IN THIS CASE

WITHOUT SPECIAL HANDLING & OR SHOCK & VIBRATION PROTECTION
THERE APPEARS TO BE HIGH RISK DEPLOYING THE INSTRUMENT
PACKAGE (PARTICULARLY THE ACCELEROMETER) IN THIS ENVIRONMENT
VARIABLE LENGTH HYDRAULIC PISTON CORER (VLHPC)

PARTS LIST AND ASSEMBLY DRAWINGS
**VARIABLE LENGTH HYDRAULIC PISTON CORER (VLHPC)**

**PARTS LIST - COMPONENTS**

<table>
<thead>
<tr>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
<th>DRAWING NUMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td>OL 1019</td>
<td>Seal Sleeve</td>
<td>B-1030</td>
</tr>
</tbody>
</table>

**TOP SUB ASSEMBLY**

<table>
<thead>
<tr>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
<th>DRAWING NUMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td>OP 4309</td>
<td>Top Sub Cap</td>
<td>R-OP4309</td>
</tr>
<tr>
<td>OP 4307</td>
<td>Top Sub Body</td>
<td>B-OP4307</td>
</tr>
<tr>
<td>OP 4156</td>
<td>Male Adapter F/Top Sub</td>
<td>A-1264</td>
</tr>
<tr>
<td>OP 4157</td>
<td>Female Adapter F/Top Sub</td>
<td>A-1256</td>
</tr>
<tr>
<td>OP 4155</td>
<td>V-Spacer F/Top Sub</td>
<td>A-1266</td>
</tr>
</tbody>
</table>

**SWIVEL ASSEMBLY**

<table>
<thead>
<tr>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
<th>DRAWING NUMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td>OP 4365</td>
<td>Inner Swivel Body</td>
<td>B-OP4365</td>
</tr>
<tr>
<td>OP 4366</td>
<td>Swivel Retainer</td>
<td>B-OP4366</td>
</tr>
<tr>
<td>OP 4367</td>
<td>Outer Swivel Body</td>
<td>B-OP4367</td>
</tr>
</tbody>
</table>

**SHAFT ASSEMBLY**

<table>
<thead>
<tr>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
<th>DRAWING NUMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td>OP 4329</td>
<td>Bypass Sub (7/32&quot;)</td>
<td>R-OP4329</td>
</tr>
<tr>
<td>OP 4317</td>
<td>Shear Bushing (7/32&quot;) F/Bypass Sub</td>
<td>A-OP4317</td>
</tr>
<tr>
<td>OP 4314</td>
<td>Shaft Connector</td>
<td>B-OP4314</td>
</tr>
<tr>
<td>OP 4320</td>
<td>4.5 m Shaft Link</td>
<td>B-OP4320</td>
</tr>
<tr>
<td>OP 4354</td>
<td>3.0 m Shaft Link</td>
<td>B-OP4354</td>
</tr>
<tr>
<td>OP 4355</td>
<td>Lower Shaft</td>
<td>B-OP4355</td>
</tr>
</tbody>
</table>

**INNER SEAL SUB ASSEMBLY**

<table>
<thead>
<tr>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
<th>DRAWING NUMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td>OP 4150</td>
<td>Inner Seal Sub</td>
<td>B-0927-0</td>
</tr>
<tr>
<td>OP 4151</td>
<td>Inner Seal Retainer</td>
<td>B-0928</td>
</tr>
<tr>
<td>OP 4324</td>
<td>Male Adapter F/Inner Seal Sub</td>
<td>A-OP4323</td>
</tr>
<tr>
<td>OP 4325</td>
<td>Female Adapter F/Inner Seal Sub</td>
<td>A-OP4325</td>
</tr>
<tr>
<td>OP 4326</td>
<td>V-Spacer F/Inner Seal Sub</td>
<td>A-OP4326</td>
</tr>
</tbody>
</table>

**PISTON ROD ASSEMBLY**

<table>
<thead>
<tr>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
<th>DRAWING NUMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td>OP 4364</td>
<td>Upper Piston Rod</td>
<td>B-OP4364</td>
</tr>
<tr>
<td>OP 4371</td>
<td>4.5 m Piston Rod Link</td>
<td>B-OP4371</td>
</tr>
<tr>
<td>OP 4335</td>
<td>3.0 m Piston Rod Link</td>
<td>B-OP4335</td>
</tr>
<tr>
<td>OP 4341</td>
<td>Rod Connector</td>
<td>A-OP4341</td>
</tr>
<tr>
<td>OP 4344</td>
<td>Lower Piston Rod</td>
<td>B-OP4344</td>
</tr>
</tbody>
</table>

**PISTON HEAD ASSEMBLY**

<table>
<thead>
<tr>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
<th>DRAWING NUMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td>OP 4381</td>
<td>Q-R Piston Head</td>
<td>B-OP4381</td>
</tr>
<tr>
<td>OP 4345</td>
<td>Q-R Piston Seal Retainer</td>
<td>A-OP4345</td>
</tr>
<tr>
<td>OP 4383</td>
<td>Lock Pin - Piston</td>
<td>A-OP4383</td>
</tr>
<tr>
<td>OP 4390</td>
<td>Male Adapter F/Piston Head</td>
<td>A-OP4390</td>
</tr>
<tr>
<td>OP 4391</td>
<td>Female Adapter F-Piston Head</td>
<td>A-OP4391</td>
</tr>
<tr>
<td>OP 4392</td>
<td>V-Spacer F/Piston Head</td>
<td>A-OP 4392</td>
</tr>
</tbody>
</table>
### VARIABLE LENGTH HYDRAULIC PISTON CORER (VLHPC)

**PARTS LIST - COMPONENTS**

Continued

<table>
<thead>
<tr>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
<th>DRAWING NUMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td>OP 4312</td>
<td>Sleeve - Outer Body Cap</td>
<td>A-OP4312</td>
</tr>
<tr>
<td>OP 4310</td>
<td>Sleeve Ring - Outer Body Cap</td>
<td>A-OP4310</td>
</tr>
<tr>
<td>OP 4321</td>
<td>Outer Body Cap (7/32)</td>
<td>A-OP4321</td>
</tr>
<tr>
<td>OP 4318</td>
<td>Shear Bushing (7/32) F/Outer Body Cap</td>
<td>A-OP4318</td>
</tr>
<tr>
<td>OP 4357</td>
<td>7/32&quot; Dia. Shear Pin</td>
<td>A-OP4357</td>
</tr>
</tbody>
</table>

**OUTER BODY ASSEMBLY**

<table>
<thead>
<tr>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
<th>DRAWING NUMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td>OP 4313</td>
<td>Outer Body Vent</td>
<td>B-OP4313</td>
</tr>
<tr>
<td>OP 4343</td>
<td>4.5 m Outer Body Link</td>
<td>B-OP4343</td>
</tr>
<tr>
<td>OP 4356</td>
<td>3.0 m Outer Body Link</td>
<td>B-OP4356</td>
</tr>
<tr>
<td>OP 4328</td>
<td>Lower Outer Body</td>
<td>B-OP4328</td>
</tr>
</tbody>
</table>

**OUTER SEAL SUB ASSEMBLY**

<table>
<thead>
<tr>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
<th>DRAWING NUMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td>OP 4160</td>
<td>Outer Seal Sub</td>
<td>C-0921</td>
</tr>
<tr>
<td>OP 4363</td>
<td>Outer Seal Retainer</td>
<td>A-OP4363</td>
</tr>
<tr>
<td>OP 4394</td>
<td>Male Adapter F/Outer Seal Sub</td>
<td>A-OP4394</td>
</tr>
<tr>
<td>OP 4395</td>
<td>Female Adapter F/Outer Seal Sub</td>
<td>A-OP4395</td>
</tr>
<tr>
<td>OP 4396</td>
<td>V-Spacer F/Outer Seal Sub</td>
<td>A-OP4396</td>
</tr>
</tbody>
</table>

**QUICK DISCONNECT ASSEMBLY**

<table>
<thead>
<tr>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
<th>DRAWING NUMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td>OP 3055</td>
<td>Q/R Shoulder Sub</td>
<td>R-OP3055</td>
</tr>
<tr>
<td>OP 4338</td>
<td>Q/R Cap Sub</td>
<td>C-OP4338</td>
</tr>
<tr>
<td>OP 4337</td>
<td>Sleeve - Q/R Shoulder Sub</td>
<td>B-OP4337</td>
</tr>
<tr>
<td>OP 4340</td>
<td>Dogs - Q/R Shoulder Sub</td>
<td>B-OP4340</td>
</tr>
</tbody>
</table>

**INNER BARREL ASSEMBLY**

<table>
<thead>
<tr>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
<th>DRAWING NUMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td>OP 4342</td>
<td>Upper Liner Seal Sub</td>
<td>B-OP4342</td>
</tr>
<tr>
<td>OP 3210</td>
<td>4.5 m Inner Core Barrel</td>
<td>B-WL-21</td>
</tr>
<tr>
<td>OP 4353</td>
<td>3.0 m Inner Core Barrel</td>
<td>B-OP4353</td>
</tr>
<tr>
<td>OP 4360</td>
<td>Lower Liner Seal Sub</td>
<td>B-OP4360</td>
</tr>
<tr>
<td>OP 3400</td>
<td>Core Liner</td>
<td>A-1230</td>
</tr>
<tr>
<td>OP 4382</td>
<td>Plastic Tube Support (VLHPC)</td>
<td>A-OP4382</td>
</tr>
</tbody>
</table>

**CORE CATCHER ASSEMBLY**

<table>
<thead>
<tr>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
<th>DRAWING NUMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td>OP 4376</td>
<td>Catcher Sub</td>
<td>B-OP4376</td>
</tr>
<tr>
<td>OP 4109</td>
<td>Spring, Flapper Core Catcher</td>
<td>A-1290</td>
</tr>
<tr>
<td>OP 4112</td>
<td>Flapper, Flapper Core Catcher</td>
<td>B-1296</td>
</tr>
<tr>
<td>OP 4113</td>
<td>Cylinder, Flapper Core Catcher</td>
<td>B-1297</td>
</tr>
<tr>
<td>OR 7020</td>
<td>Dog (8) Type Core Catcher</td>
<td>A-0191</td>
</tr>
</tbody>
</table>
### VARIABLE LENGTH HYDRAULIC PISTON CORER (VLHPC)

#### PARTS LIST - WIRELINE

<table>
<thead>
<tr>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
<th>DRAWING NUMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td>OP 4347</td>
<td>Single Shot Pressure Case</td>
<td>B-OP4347</td>
</tr>
<tr>
<td>OP 4350</td>
<td>Single Shot Top Plug F/Pressure Case</td>
<td>B-OP4350</td>
</tr>
<tr>
<td>OP 4349</td>
<td>Single Shot Bottom Plug F/Pressure Case</td>
<td>B-OP4349</td>
</tr>
<tr>
<td>OP 4358</td>
<td>Pipe Plug F/Bottom Plug</td>
<td>A-OP4358</td>
</tr>
<tr>
<td>OP 4351</td>
<td>Non-Magnetic Sinker Bar</td>
<td>B-OP4351</td>
</tr>
</tbody>
</table>

### KUSTER SINGLE SHOT ASSEMBLY

<table>
<thead>
<tr>
<th>KUSTER P/N</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>2299-101</td>
<td>0-20 Angle Unit (short)</td>
</tr>
<tr>
<td>4030-105</td>
<td>Battery Case, 5 Cell*</td>
</tr>
<tr>
<td>3600-101</td>
<td>Electronic Timer**</td>
</tr>
<tr>
<td>4100-102</td>
<td>Main Frame, Short</td>
</tr>
<tr>
<td>4104-101</td>
<td>Spacer Tube, Short</td>
</tr>
<tr>
<td>3601-000</td>
<td>E.T. Test Sleeve</td>
</tr>
<tr>
<td>6221-001</td>
<td>Anchor</td>
</tr>
<tr>
<td>6221-002</td>
<td>Plug</td>
</tr>
<tr>
<td>6221-003</td>
<td>Tang</td>
</tr>
<tr>
<td>6221-004</td>
<td>Anchor Screw</td>
</tr>
<tr>
<td>791-049</td>
<td>Set Screw</td>
</tr>
<tr>
<td>6221-001</td>
<td>Nose Spring 6&quot;</td>
</tr>
<tr>
<td>6205-001</td>
<td>0-Ring</td>
</tr>
<tr>
<td>4301-100</td>
<td>Film Disc Loader</td>
</tr>
<tr>
<td>4401-100</td>
<td>Developing Tank</td>
</tr>
<tr>
<td>4600-000</td>
<td>Carrying Case - S.S.</td>
</tr>
<tr>
<td>4602-000</td>
<td>Disco Reader</td>
</tr>
<tr>
<td>4604-000</td>
<td>Orientation Reader</td>
</tr>
<tr>
<td>- - - -</td>
<td>Non-Steel Jacketed Batteries (1.5 V C-size) (Hot Shot Prod. Col.)</td>
</tr>
</tbody>
</table>

*Battery Case, 3-Cell

**Clock, 90 minutes

Flash Unit

<table>
<thead>
<tr>
<th>DRAWING NUMBER</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>B-OP4351</td>
<td>KUSTER P/N</td>
</tr>
<tr>
<td>4030-103</td>
<td>Battery Case, 3-Cell</td>
</tr>
<tr>
<td>3201-101</td>
<td>**Clock, 90 minutes</td>
</tr>
<tr>
<td>4025-101</td>
<td>Flash Unit</td>
</tr>
</tbody>
</table>
## VARIABLE LENGTH HYDRAULIC PISTON CORER (VLHPC)
### PARTS LIST - SET SCREWS, ETC.

<table>
<thead>
<tr>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
<th>DRAWING NUMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td>OP 4302</td>
<td>1/2-13 x 3/4 Socket Set Screw F/Top Sub Cap</td>
<td>A-OP4302</td>
</tr>
<tr>
<td></td>
<td>1/2-13 x 3/4 Socket Set Screw F/Q.R. Sleeve</td>
<td>A-OP4302</td>
</tr>
<tr>
<td>OP 4301</td>
<td>1/2-20 x 3/4 Socket Head Cap Screw F/Overshot Alignment</td>
<td>A-OP4301</td>
</tr>
<tr>
<td>OP 4369</td>
<td>5/8-11 x 1/2 Socket Set Screw F/Outer Swivel Body</td>
<td>A-OP4369</td>
</tr>
<tr>
<td>OP 4361</td>
<td>3/8-16 x 3/8 Socket Set - Half Dog Core Liner Retainer Screw F/Upper Liner Seal Sub</td>
<td>A-OP4361</td>
</tr>
<tr>
<td>OP 4185</td>
<td>3/8-16 x 3/8 Socket Set Screw F/4.5 m Shaft Link</td>
<td>A-1471</td>
</tr>
<tr>
<td></td>
<td>3/8-16 x 3/8 Socket Set Screw F/3.9 m Shaft Link</td>
<td>A-1471</td>
</tr>
<tr>
<td></td>
<td>3/8-16 x 3/8 Socket Set Screw F/Inner Seal Sub</td>
<td>A-1471</td>
</tr>
<tr>
<td></td>
<td>3/8-16 x 3/8 Socket Set Screw F/Lower Outer Body</td>
<td>A-1471</td>
</tr>
<tr>
<td></td>
<td>3/8-16 x 3/8 Socket Set Screw F/Outer Shaft</td>
<td>A-1471</td>
</tr>
<tr>
<td></td>
<td>3/8-16 x 3/8 Socket Set Screw F/Outer Seal Sub</td>
<td>A-1471</td>
</tr>
<tr>
<td></td>
<td>3/8-16 x 3/8 Socket Set Screw F/Swivel Retainer</td>
<td>A-1471</td>
</tr>
</tbody>
</table>

**NOTE:** All set screws are alloy steel with cadmium plating and nyloc locking.
<table>
<thead>
<tr>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
<th>DRAWING NUMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td>OP 4192</td>
<td>Hang Off Plate</td>
<td>B-0942</td>
</tr>
<tr>
<td>OP 4330</td>
<td>Sighting Bar - Baseline Orientation</td>
<td>C-OP4330</td>
</tr>
<tr>
<td>OP 4331</td>
<td>Telescope Frame - Baseline Orientation</td>
<td>C-OP4331</td>
</tr>
<tr>
<td>OP 4332</td>
<td>Sighting Bar Reducer</td>
<td>B-OP4332</td>
</tr>
<tr>
<td>OP 4334</td>
<td>Orientation Hold Down Strap</td>
<td>A-OP4334</td>
</tr>
<tr>
<td>OP 4389</td>
<td>Drill Jig - Core Liner Orientation Lock</td>
<td>A-OP4389</td>
</tr>
<tr>
<td>OP 4327</td>
<td>Quick Release Nose Guard</td>
<td>R-OP4327</td>
</tr>
<tr>
<td>OP 4384</td>
<td>Assembly Bar for Swivel Assembly</td>
<td>A-OP4384</td>
</tr>
<tr>
<td></td>
<td>Face Spanner Wrench F/Outer Seal Retainer Assembly</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Parmelee Wrench (1.25 dia) F/Piston Rod Assembly</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Parmelee Wrench (2.18 dia) F/P Case Assembly</td>
<td></td>
</tr>
<tr>
<td>OP 3615</td>
<td>HPC - Handling Clamp</td>
<td>C-OP3615</td>
</tr>
<tr>
<td></td>
<td>Non-Magnetic Drill Collar</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Magnetic Pickup &amp; Stud Finder (Craftsman 94001)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Spanner Wrench</td>
<td></td>
</tr>
<tr>
<td>OP 4305</td>
<td>Seal Installation Tool-Single Shot Pressure Case</td>
<td>A-OP4305</td>
</tr>
<tr>
<td>OC 1080</td>
<td>XCB Core Bit (10 7/32 x 3 13/16)</td>
<td>D-1694</td>
</tr>
<tr>
<td>OP 4333</td>
<td>Core Orientation Baseline Adjustment</td>
<td>B-OP4333</td>
</tr>
</tbody>
</table>
## VARIABLE LENGTH HYDRAULIC PISTON CORER (VLHPC)
### PARTS LIST - ANCILLARY DRAWINGS

<table>
<thead>
<tr>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
<th>DRAWING NUMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td>OP 4300</td>
<td>Variable Length Hydraulic Piston Corer Assembly</td>
<td>R-OP4300</td>
</tr>
<tr>
<td>OP 4311</td>
<td>VLHPC System Schematic</td>
<td>C-OP4311</td>
</tr>
<tr>
<td>OP 4348</td>
<td>VLHPC Single Shot Assembly</td>
<td>R-OP4348</td>
</tr>
</tbody>
</table>
### VARIABLE LENGTH HYDRAULIC PISTON CORER (VLHPC)

#### PARTS LIST - SEALS, O-RINGS, BACK-UP RINGS

<table>
<thead>
<tr>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
<th>VENDOR NUMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td>OP 4158</td>
<td>Top Sub Seal (3.63 x 2.87)</td>
<td>37502850VP</td>
</tr>
<tr>
<td>OP 4154</td>
<td>Inner Seal Sub Seal (2.87 x 2.25)</td>
<td>31202250VP</td>
</tr>
<tr>
<td>OP 4393</td>
<td>Outer Seal Sub Seal (1.87 x 1.25)</td>
<td>31201250VP</td>
</tr>
<tr>
<td>OP 4179</td>
<td>Piston Head Seal (2.00 x 2.62)</td>
<td>31202000VP</td>
</tr>
<tr>
<td>OP 4148</td>
<td>O-Ring F/Shaft Connectors</td>
<td>2-326</td>
</tr>
<tr>
<td></td>
<td>O-Ring F-Alternate Bypass Sub - 7/32</td>
<td>2-326</td>
</tr>
<tr>
<td></td>
<td>O-Ring F/Inner Seal Sub</td>
<td>2-326</td>
</tr>
<tr>
<td>OP 4165</td>
<td>O-Ring F/Outer Seal Sub</td>
<td>2-231</td>
</tr>
<tr>
<td>OP 4147</td>
<td>O-Ring F/Upper Liner Seal Sub</td>
<td>2-232</td>
</tr>
<tr>
<td></td>
<td>O-Ring F/Lower Liner Seal Sub</td>
<td>2-232</td>
</tr>
<tr>
<td>OP 4306</td>
<td>O-Ring F/Single Shot Bottom Plug</td>
<td>2-324</td>
</tr>
<tr>
<td></td>
<td>O-Ring F/Single Shot Top Plug</td>
<td>2-324</td>
</tr>
<tr>
<td>OP 4385</td>
<td>Parbac F/Single Shot Bottom Plug</td>
<td>8-324</td>
</tr>
<tr>
<td></td>
<td>Parbac F/Single Shot Top Plug</td>
<td>8-324</td>
</tr>
<tr>
<td>OP 4303</td>
<td>Polypac F/Inner Swivel</td>
<td>18702375</td>
</tr>
<tr>
<td>OP 4304</td>
<td>Polypac Alt. F/Single Shot Top &amp; Bottom Plugs</td>
<td>18701375</td>
</tr>
</tbody>
</table>
NOTE! - BREAK ALL SHARP EDGES
RADIUS ALL INSIDE CORNERS

DEEP SEA DRILLING PROJECT
SCRIPPS INSTITUTE OF OCEANOGRAPHY
UNIVERSITY OF CALIFORNIA, SAN DIEGO
LA JOLLA, CALIFORNIA

TOLERANCES
UNLESS NOTED

FRACTIONS 1/16
DECIMALS 0.005
ANGLES 1/2*
CORNERS 1/16 R

NOTE: - BREAK ALL SHARP EDGES
RADIUS ALL INSIDE CORNERS

CONCENTRICITY:
ALL CHAM. (ERS)
TIR .003

45° x 3/16 CHAM. (TYP)

2 3/16 STUB ACME
(SEE Dwg A-1129)

* TYP 6 PLCS AT 60°

STAMP: 4300-3

DEEP SEA DRILLING PROJECT
SCRIPPS INSTITUTE OF OCEANOGRAPHY
UNIVERSITY OF CALIFORNIA, SAN DIEGO
LA JOLLA, CALIFORNIA

TOLERANCES
UNLESS NOTED

FRACTIONS 1/16
DECIMALS 0.005
ANGLES 1/2*
CORNERS 1/16 R

NOTE: - BREAK ALL SHARP EDGES
RADIUS ALL INSIDE CORNERS

CONCENTRICITY:
ALL CHAM. (ERS)
TIR .003

45° x 3/16 CHAM. (TYP)

2 3/16 STUB ACME
(SEE Dwg A-1129)

* TYP 6 PLCS AT 60°

STAMP: 4300-3
<table>
<thead>
<tr>
<th>NO.</th>
<th>DESCRIPTION</th>
<th>DATE</th>
<th>BY</th>
<th>CH.</th>
<th>APR.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>ADD 3.25, 2.125 WAP 2.1/8</td>
<td>4/16</td>
<td>RK</td>
<td></td>
<td>7/18</td>
</tr>
<tr>
<td>2</td>
<td>3.25 MISDIMENSIONED</td>
<td>6/18</td>
<td>RK</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**REVISIONS**

**CONCENTRICITY:**

ALL DIAMETERS TIR .003

NOTE:

- GRIND ALL SHARP EDGES
- RADIUS ALL INSIDE CORNERS

**TOLERANCES UNLESS NOTED:**

- FRACTIONS 1/64
- DECIMALS ± .005
- ANGLES ± 1/2°
- CORNERS 1/64 ± 45° or 1/64 R

**SURFACE TREATMENT:** PARCOLUBRITE

**MATERIAL:** 4130 ST.

**HEAT TREATMENT:** R 32-34

**DRAWN BY:** 7/18 7/18 7/18

**DATE:** 7/18 7/18 7/18

**CHECKED:** 7/18 7/18 7/18

**APPROVED:** 7/18 7/18 7/18

**SIZE DWG NO:** B-OP4307-

**REV:** 2
Revisions

<table>
<thead>
<tr>
<th>No.</th>
<th>Description</th>
<th>Date</th>
<th>By</th>
<th>CH.</th>
<th>Apr.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.348 WAS 7/16, 0.567/27/32, 0.379/15/32</td>
<td>1-26-81</td>
<td>RK</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Description

- 3.617 DIA
- 2.880 DIA
- 1/16 R

Fabricate from 3 5/8 x 7/16 Wall Mechanical Tubing

Deep Sea Drilling Project
Scripps Institution of Oceanography
University of California, San Diego
La Jolla, California

Title
MALE V-PACKING ADAPTER ~ H.P. C ~ (TOP SUB)

Material
304 SS.

Surface Treatment
Annealed

Heat Treatment
Annealed

Part No.
Op4156 - 1

Size
A - 1264

Drawn by
RK

Date
1-10-81

Checked

Approved

Rev.
1
FABRICATE FROM 3 5/8 x 7/16 WALL MECHANICAL TUBING

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 V-PACKING ADAPTER
HPC (TOP SUB)

SURFACE TREATMENT
HEAT TREATMENT

MATERIAL 304 S.S.
PART NO. OP4157

DRAWN BY RK DATE 3-28-71
CHECKED
APPROVED

REV. 122
FABRicate FROM 3\(\frac{5}{8}\) x 7\(\frac{1}{16}\) WALL MECHANICAL TUBING.

TOLERANCES UNLESS NOTED
FRACTIONS ± 1/64
DECIMALS ± .005
ANGLES ± 1/2°
CORNERS 1/64 x 45° or 1/64 R
FINISH \(12\frac{5}{8}\)

DEEP SEA DRILLING PROJECT
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UNIVERSITY OF CALIFORNIA, SAN DIEGO
LA JOLLA, CALIFORNIA

TITLE
MALE- FEMALE V-PACKING ADAPTER ~ HPC ~ (TOP SUB)

MATERIAL
304 SS

PART NO.
OP41SS

SIZE DWG. NO.
A - 1266 -
NO. 1

DESCRIPTION  5/28 U3A

DATE  5/7/81

BY CH.  RK

APR  7/21

REVISIONS

1 .228 WAS .195

2 LOCTITE WAS #431

DATE  4/28/2

BY CH.  RK

APR  2/2

TOLERANCES

DO NOT SCALE

FRACTIONS ± 1/64

DECIMALS ± .005

ANGLES ± 1/2°

CORNERS 1/64 x 45°
or 1/64 R

FINISH  123

MTL: CARPENTER TOOL STEEL

H.T.: STENTOR-OIL HARD

LOCITITE #271 WITH P/N OP4329, GRIND FLUSH
AFTER INSTALLING (I.D. CHAMFER INWARD)

CONCENTRICITY ALL DIAMETERS: TIR .003

DEEP SEA DRILLING PROJECT

SCRIPPS INSTITUTION OF OCEANOGRAPHY

UNIVERSITY OF CALIFORNIA, SAN DIEGO

LA JOLLA, CALIFORNIA

92093

TITLE

BUSHING, SHEAR, 7/32

~ BYPASS SUB ~ VLBPC

SURFACE TREATMENT

SEE DWG

HEAT TREATMENT

SEE DWG

SCALE  1:1

REQU'D/ASS'Y  .6

PART NO. OP4317-2

DWG. NO. A-OP4317-2

REV. 1

DATE  4/23/81

CHECKED  RK

APPROVED
TVP

2.
Z
Nüii:
Z
- "tb£ (o
BREAK ALL SHARP EDGES
ΠΛ:•:U5 ALL
ir;:iöf
OORMFRS
CONCENTRICITY
Mi DIAMETERS
TIR .033
FRACTIONS 1/16
DECIMALS .005
ANGLES 1/16
CORNERS 1/64 x 45°
or 1/64 R
FINISH
SURFACE TREATMENT
HFAT TREATMENT

DEEP SEA DRILLING PROJECT
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UNIVERSITY OF CALIFORNIA, SAN DIEGO
LA JOLLA, CALIFORNIA
92031

SHWAFT CONNECTOR
V.L.H.P.C.

NOTE:
BREAK ALL SHARP EDGES
RADIUS ALL INSIDE CORNERS

* TYP BOTH ENDS

* * FOR O-RING * 2-326

TOLERANCES
UNLESS NOTED
FRACTIONS 1/16
DECIMALS .005
ANGLES 1/16
CORNERS 1/64 x 45°
or 1/64 R
FINISH
SURFACE TREATMENT
HFAT TREATMENT

MATERIAL
430 STEEL

HEAT TREATMENT
31-33 Rc

PART NO.
01:4314

SIZE DWG. NO.
B-OP 4314

NO. REQ'D.
3.5 m = 1
5 m = 1
6.5 m = 2
8 m = 2
9.5 m = 2

NO.
DESCRIPTION
REVISIONS
DATE
BY
CH.
APR.
**REVISIONS**

<table>
<thead>
<tr>
<th>NO.</th>
<th>DESCRIPTION</th>
<th>DATE</th>
<th>BY CH.</th>
<th>APR.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>ASSES +0 -1/16 TOL.</td>
<td>4-7-51</td>
<td>4-7-51</td>
<td></td>
</tr>
</tbody>
</table>

**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** U"3

**DO NOT SCALE**

DEEP SEA DRILLING PROJECT
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UNIVERSITY OF CALIFORNIA, SAN DIEGO
LA JOLLA, CALIFORNIA

92093

**TITLE**

4.5m SHAFT LINK
VLHPC~

**MATERIAL**

4130 STEEL

**HEAT TREATMENT**

SCREWED

**SCALE**

1:1

**REV.**

B-OP4320-1

---

**Diagram Description:**

- **Drill:** 5/16 (.312) Dia. thru
- **Tap:** 3/8-16 (Deburr inside & out)
- **2 1/8-8 Stub Acme Thd.**
- **SEE DWG A:1127**
- **2 5/8 Dia.**
- **Mill Flat + Stamp.**
- **OP4320-1**
- **1 87 I.D.**
- **2 80**
- **2 06**
- **1 00**
- **Concentricity All Diameters: TIR.003**

**Notes:**

1. Heat Treat: 34-38Rc, Min Yield: 140,000 PSI
2. Straighten
3. Park. Kolubrite
REVISIONS

<table>
<thead>
<tr>
<th>NO.</th>
<th>DESCRIPTION</th>
<th>DATE</th>
<th>BY</th>
<th>APR</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>ADDED +0 - 1/16 TOL.</td>
<td>4-7-8</td>
<td>RK</td>
<td></td>
</tr>
</tbody>
</table>

DEEP SEA DRILLING PROJECT
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UNIVERSITY OF CALIFORNIA, SAN DIEGO
LA JOLLA, CALIFORNIA 92093

3m SHAFT LINK
~VLHPC~

FORGE:
4443 STEEL
DATE: 11-28-0
SY: 1.1

HEAT TREATMENT: SCALE 1:1
SEE DWG: CPA4354-1

SURFACE TREATMENT: PARKOIL

TOLERANCES UNLESS NOTED
FRACTIONS ± 1/64
DECIMALS ± .005
ANGLES ± 1/2°
CORNERS 1/64 x 45° or 1/64 R
FINISH TO...

NO. REQ'D:

3.5m = 1
5.0m = 0
6.5m = 2
8.0m = 1
9.5m = 0

DO NOT SCALE
CONCENTRICITY ALL DIAMETERS: TIR .003

DECLARATION OF CONSTRUCTION: 92093
**Concentricity:**

**All diameters**

**Typ Both Ends**

**Drill 5/16 (0.312) Dia thru + Tap 3/8-16 (De-Burr, In + Out)**

**Mill Flat + Stamp: OP 4355-1**

**Heat Treat:** 34-38 RC, min yield 140,000 PSI

**Material:**

<table>
<thead>
<tr>
<th>DEEP SEA DRILLING PROJECT</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCRIPPS INSTITUTION OF OCEANOGRAPHY</td>
</tr>
<tr>
<td>UNIVERSITY OF CALIFORNIA, SAN DIEGO</td>
</tr>
<tr>
<td>LA JOLLA, CALIFORNIA</td>
</tr>
</tbody>
</table>

**Title:**

**Lower Shaft**

**V.L.H.P.C**

**Concentricity:**

**All diameters**

**TYP BOTH ENDS**

**Drill 5/16 (0.312) Dia thru + Tap 3/8-16 (De-Burr, In + Out)**

**Mill Flat + Stamp: OP 4355-1**

**Heat Treat:** 34-38 RC, min yield 140,000 PSI
MILL .35 DIA x \( \frac{3}{4} \) LONG SLOT x \( \frac{5}{32} \) DP
(2 PLCS AT 180\(^\circ\)) (BREAK EDGES)

\( 10 \frac{7}{8} \)

\( 3 \frac{3}{4} \) (TUNG PLATE .0003 THK)

\( 32 \)

\( 2.125 \) DIA

\( 2.250 \) DIA

\( 2.863 \) DIA

\( 1 \frac{13}{16} \) DIA

\( 45 \times \frac{1}{32} \)

\( 45 \times \frac{1}{32} \)

\( 32 \)

\( 8 \times 45^\circ \) Cham.

\( 2.750 \)

\( 2.750 \) DP + THD 1\( \frac{1}{8} \) STUB ACME (SEE DWG A-1125)

\( 45^\circ \times \frac{1}{16} \) CHAM.

\( 45^\circ \times \frac{1}{16} \) CHAM.

**FOR O-RING #2-326 1 EA.
FOR MOLYTHANE V-PACKING, 4 EA + M+F.**

HT. 34-38Rc, 7200 45 FT. LBS.
MIN. YIELD 140,000 PSI

DEEP SEA DRILLING PROJECT
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UNIVERSITY OF CALIFORNIA, SAN DIEGO
LA JOLLA, CALIFORNIA 92037

DO NOT SCALE

CONCENTRICITY ALL DIAMETERS: TIR .003
NOTE:
BREAK ALL SHARP EDGES
RADIUS ALL INSIDE CORNERS

CONCENTRICITY:
ALL DIAMETERS
TIR .003

SURFACE TREAT: PARKOLUBRITE
MATL: 4140 STEEL HT: 34-38 Rc

TOLERANCES UNLESS NOTED
FRACTIONS ± 1/64
DECIMALS ± 0.005
ANGLES ± 1/2°
CORNERS 1/64 x 45°
or 1/64 R
FINISH

REVISIONS

<table>
<thead>
<tr>
<th>No.</th>
<th>DESCRIPTION</th>
<th>DATE</th>
<th>BY</th>
<th>APR</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.863 DIA.4±.000, 2.873 CHAM. 0.03 ONE SIDE</td>
<td>12/16</td>
<td>RK</td>
<td>K</td>
</tr>
<tr>
<td>2</td>
<td>ADD 45° CHAM, CONCENTRICITY TOL.</td>
<td>10/7</td>
<td>RK</td>
<td>K</td>
</tr>
<tr>
<td>3</td>
<td>ADDED 7.5M TO TITLE</td>
<td>8/21</td>
<td>RK</td>
<td>K</td>
</tr>
<tr>
<td>4</td>
<td>MATL WAS 4140 34-38 Rc, PARKOLUBRITE</td>
<td>9/16</td>
<td>RK</td>
<td>K</td>
</tr>
</tbody>
</table>

STAMP: HPC OP4151-04

SIGNED: 10/16/57

(UNSIGNED)
CONCENTRICITY ALL DIAMETERS: TIR .003

DEEP SEA DRILLING PROJECT
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UNIVERSITY OF CALIFORNIA, SAN DIEGO
LA JOLLA, CALIFORNIA 92030

TITLE
MALE ADAPTER - INNER SEAL SUB "VLHPC"

MATERIAL
304 SS

DATE
9.19.80

BY
RK

CHECKED
APPROVED

SURFACE TREATMENT
- O

HEAT TREATMENT
ANNEALED

SCALE
1:1

REQU'D/ASS'Y
ONE

PART NO.
OP4324-1

DWG. NO.
A-OP4324-1

REV.
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

TITLE
FEMALE ADAPTER - INNER SEAL SUB〜VLHPC〜

MATERIAL
304 SS

DATE
9.19.80

BY
RK

CHECKED
APPROVED

SURFACE TREATMENT
FINISH

HEAT TREATMENT
ANN.ADEAL

SCALE
1:1

PART NO.
OP4325 - 1

REV.
A:OP4325 - 1
DEEP SEA DRILLING PROJECT
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UNIVERSITY OF CALIFORNIA, SAN DIEGO
LA JOLLA, CALIFORNIA

TITLE
V-SPACER-MALE/FEMALE-
INNER SEAL SUB- V/LHPC

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 1/25

SURFACE TREATMENT
HEAT TREATMENT
ANNEALED

MATERIAL 304 SS
DATE 9-18-80
CHECKED
APPROVED

PART NO. OP4326-1
DWG. NO. A-OP4326-1

92093
NOTE:
BREAK ALL SHARP EDGES
RADIUS ALL INSIDE CORNERS

CONCENTRICITY:
ALL DIAMETERS
TIR .008

TOLERANCES UNLESS NOTED
FRACTIONS 1/64
DECIMALS .005
ANGLES 1/2°
CORNERS 1/64 + 45°
FINISH

MATERIAL
NITRONIC 32

DRAWN BY
DATE
CHECKED
APPROVED

DEEP SEA DRILLING PROJECT
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UNIVERSITY OF CALIFORNIA, SAN DIEGO
LA JOLLA, CALIFORNIA
92032

TITLE
UPPER PISTON ROD
V.L.H.C.

SURFACE TREATMENT
HEAT TREATMENT

PART NO.
B-OP4364-3

SAME AS AQUAMET 18
DO NOT SCALE

CONCENTRICITY ALL DIAMETERS: TIR .008

DEEP SEA DRILLING PROJECT
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UNIVERSITY OF CALIFORNIA, SAN DIEGO
LA JOLLA, CALIFORNIA 92037

TITLE 4.5m PISTON ROD LINK
~VLHPC~

SURFACE TREATMENT MATERIAL
NITRONIC 37

HEAT TREATMENT
1:1 HEAT TREAT: OP4371 - 4

SAME AS AQUAMET 18
REVISIONS

<table>
<thead>
<tr>
<th>NO.</th>
<th>DESCRIPTION</th>
<th>DATE</th>
<th>BY</th>
<th>CH.</th>
<th>APR.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5/8 WAS 3/8 (ERROR)</td>
<td>12/16/85</td>
<td>LK</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>15/16-8 WAS 3/8 Sinker Bar</td>
<td>2/5/81</td>
<td>LK</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Matl WAS 4130, Was Tube, No HT.</td>
<td>3/5/81</td>
<td>LK</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>REVISED NOTE</td>
<td>3/9/81</td>
<td>LK</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

TOLERANCES UNLESS NOTED
FRACTIONS 1/164
DECIMALS 0.005
ANGLES 1/12
CORNERS 1/64 x 45° or 1/64 R
FINISH 15

NO. REQ'D
3.5n=1
5.0n=0
6.5n=2
8.0n=1
9.5n=0

*SAME AS AQUAMET 18
15/16-8 STUB ACME THD
SEE DWG A-1676
(both ends)
(bakerloc in final Assy)

NOTE:
break all sharp edges
radius all inside corners

SAME AS AQUAMET 18

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 15/32

DEEP SEA DRILLING PROJECT
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UNIVERSITY OF CALIFORNIA, SAN DIEGO
LA JOLLA, CALIFORNIA
92093

TITLE
ROD CONNECTER
~VL HFC~

SURFACE TREATMENT
HEAT TREATMENT
MATERIAL NITRONIC 32
PART NO. OP4341-2
SIZE DWG. NO. A-OP4341

DRAWN BY DATE CHECKED APPROVED
RK 6/135 A/C REV. 2

NO. REQ'D.
3.5 m = 1
5.0 m = 1
6.5 m = 2
8.0 m = 2
9.5 m = 2
NO. | DESCRIPTION | DATE | BY | CH. | APR.
--- | --- | --- | --- | --- | ---
1 | 1.360 was 1.115, 2/1 was 4.250 | 11/25/21 | KK | VP | 7
2 | REDRAWN COMBINING OP4385 | 4/1/21 | KK | VP | 7

**DEEP SEA DRILLING PROJECT**
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UNIVERSITY OF CALIFORNIA, SAN DIEGO
LA JOLLA, CALIFORNIA 92037

**TOLERANCES UNLESS NOTED**
FRACTIONS ± 1/64
DECIMALS ± .0005
ANGLES ± 1/6°
CORNERS ± 1/64 x ± 45°
FINISH ± .003

**SURFACE TREATMENT**
PARK / SUBLIM

**HEAT TREATMENT**
26 - 33 Rc

**MATERIAL**
4130 STEEL

**DRAWN BY**
KK

**DATE CHECKED APPROVED**
A-38 S 26/7 1/5

---

**REV.**
B-OP4381-2

---

**NOTE:**
DEBURR + CLEAN UP THREADS AFTER DRILLING.

---

**DESIGN:**
NYE-CARB ELECTROLESS NICKEL PL. 0025 THK 2.000 DIA ONLY

**DRILL .375 DIA THRU.**
1/16 x 45° CHAMFER (4 PLCS)

**DRILL 1.050 ± .005 DIA x 4 1/2 DP**

---

**CONCENTRICITY:**
ALL DIAMETERS TIR .003

---

**DEEP SEA DRILLING PROJECT**
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UNIVERSITY OF CALIFORNIA, SAN DIEGO
LA JOLLA, CALIFORNIA 92037

**TITLE:**
QUICK RELEASE PISTON HEAD

**SIZE DWG NO:**
B-OP4381-2
<table>
<thead>
<tr>
<th>NO.</th>
<th>DESCRIPTION</th>
<th>DATE</th>
<th>BY</th>
<th>CH.</th>
<th>APR.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**REVISIONS**

<table>
<thead>
<tr>
<th>NO.</th>
<th>DESCRIPTION</th>
<th>DATE</th>
<th>BY</th>
<th>CH.</th>
<th>APR.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**DO NOT SCALE**

<table>
<thead>
<tr>
<th>TOLERANCES UNLESS NOTED</th>
<th>CONCENTRICITY ALL DIAMETERS: TIR.003</th>
</tr>
</thead>
<tbody>
<tr>
<td>FRACTIONS ± 1/64</td>
<td>DEEP SEA DRILLING PROJECT</td>
</tr>
<tr>
<td>DECIMALS ± .005</td>
<td>SCRIPPS INSTITUTION OF OCEANOGRAPHY</td>
</tr>
<tr>
<td>ANGLES ± 1/2°</td>
<td>UNIVERSITY OF CALIFORNIA, SAN DIEGO</td>
</tr>
<tr>
<td>CORNERS 1/64 x 45°</td>
<td>LA JOLLA, CALIFORNIA</td>
</tr>
<tr>
<td>or 1/64 R</td>
<td></td>
</tr>
<tr>
<td>FINISH 1/32</td>
<td></td>
</tr>
</tbody>
</table>

**PARKOUBRITE**

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>DATE</th>
<th>CHECKED</th>
<th>APPROVED</th>
</tr>
</thead>
<tbody>
<tr>
<td>4130 STEEL</td>
<td>10-8-80</td>
<td>RK</td>
<td></td>
</tr>
</tbody>
</table>

**HEAT TREATMENT**

<table>
<thead>
<tr>
<th>SCALE</th>
<th>RFG/ASS'Y</th>
<th>PART NO.</th>
<th>DWG. NO.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1:1</td>
<td>ONE</td>
<td>OP4345</td>
<td>A-OP4345</td>
</tr>
</tbody>
</table>
REVISIONS

<table>
<thead>
<tr>
<th>NO.</th>
<th>DESCRIPTION</th>
<th>DATE</th>
<th>BY</th>
<th>CH.</th>
<th>APR.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>CHANGE MAT'L FROM 304 SS TO 17-4 PH SS, ABD HI150</td>
<td>7/13/81</td>
<td>DC</td>
<td>M12</td>
<td>P232</td>
</tr>
</tbody>
</table>

DEEP SEA DRILLING PROJECT
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UNIVERSITY OF CALIFORNIA, SAN DIEGO
LA JOLLA, CALIFORNIA 92093

DO NOT SCALE

TOLERANCES UNLESS NOTED
FRACTIONS ± 1/64
DECIMALS ± .005
ANGLES ± 1/2°
CORNERS 1/64 x 45°
or 1/64 R
FINISH 1/64

CONCENTRICITY ALL DIAMETERS: TIR .003

TITLE
LOCK PIN - PISTON
~YLHPC~

MATERIAL 17-4 PH SS

SCALE 1:1

REO'D/ASS'Y ONE

PART NO. OP4383-1

DWG. NO. A-OP4383-1 (REV.)

1/16 X 45° CHAM.
FABRICATE FROM 2\(\frac{5}{8}\) x 9\(\frac{1}{16}\) WALL MECH. TUBING - 304 S.S.
FABRICATE FROM 2 5/8 x 9 1/6 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

TITLE
FEMALE ADAPTER ~ PISTON HEAD
~ VLHPC ~

DEEP SEA DRILLING PROJECT
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UNIVERSITY OF CALIFORNIA, SAN DIEGO

LA JOLLA, CALIFORNIA

92093
FABRICATE FROM 2 5/8 x 1/16 WALL MECH TUBING - 304 S.S.

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

TITLE
V-SPACER ~ PISTON HEAD
~VLHPC~

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>DATE</th>
<th>BY</th>
<th>CHECKED</th>
<th>APPROVED</th>
</tr>
</thead>
<tbody>
<tr>
<td>SEE ABOVE</td>
<td>10-13-80</td>
<td>RK</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SURFACE TREATMENT</th>
<th>SCALE</th>
<th>PART NO.</th>
<th>RG/ASSY</th>
</tr>
</thead>
<tbody>
<tr>
<td>SEE ABOVE</td>
<td>1:1</td>
<td>OP4392-1</td>
<td></td>
</tr>
</tbody>
</table>

148
**NOTE:**

BREAK ALL SHARP EDGES

RADIUS ALL INSIDE CORNERS
CONCENTRICITY:
ALL DIAMETERS ±0.002

GRIND FLAT AND SCRIBE:
OP4310

NOTE:
BREAK ALL SHARP EDGES
RADIUS ALL INSIDE CORNERS

TOLERANCES UNLESS NOTED
FRACTIONS ± 1/64
DECIMALS ± .005
ANGLES ± 1/2°
CORNERS 1/64 x 45°
or 1/64 R

SURFACE TREATMENT PARCOLUBRITE
HEAT TREATMENT Rc 30-32
MATERIAL 4130 C.D.
PART NO. OP4310

DEEP SEA DRILLING PROJECT
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UNIVERSITY OF CALIFORNIA, SAN DIEGO
LA JOLLA, CALIFORNIA
92031
REVISIONS

NO. DESCRIPTION DATE BY CH. APR.
1 LOCTITE WAS #431 4-12-82 RK 7/14

DRILL 1/2 DIA x 1/2 DEEP HOLE AT 90° TO SHEAR PIN HOLES (ONE SIDE ONLY)

1/8 WIDE x 1/8 DP GROOVE IN LINE WITH SHEAR PIN (ONE SIDE ONLY)

DRILL THRU BOTH WALLS WITH ALIGNMENT JIG

NOTE:
BREAK ALL SHARP EDGES
RADIUS ALL INSIDE CORNERS

H.T. PRIOR TO LOCTITE & FINISH MACHINE

LOCTITE #: 271
N/P N OP 43218

DEEP SEA DRILLING PROJECT
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UNIVERSITY OF CALIFORNIA, SAN DIEGO
LA JOLLA, CALIFORNIA

BODY-OUTER BODY CAP (1/32)
VLHPC

TOLERANCES UNLESS NOTED
FRACTIONS ± 1/64
DECIMALS ± 0.005
ANGLES ± 1/2°
Corners 1/64 x 45°
or 1/64 R

FINISH 135°

SURFACE TREATMENT PARSOLIPRITE

HEAT TREATMENT RC - 36 - 23

MATERIAL 4130 C.D.

PART NO. OP 4321 - 1

SIZE DWG. NO. A - OP 4321 - 1

DRAWN BY DATE CHECKED APPROVED
U I
4-28-82 11/14 11/14

DSDP INNER BB'L
THD (SEE DWG
B-0508)

.562 DIA

1/8 x 45° CHAMFER

SCRIBE: OP 4321 - 1

C'BORE .626 DIA x .081 DEEP TO SLIP FIT OVER SHAFT O.D.'s.

NOTE:
TOLERANCES

FRACTIONS ± 1/64
DECIMALS ± 0.005
ANGLES ± 1/2°
CORNERS 1/64 x 45°
or 1/64 R
FINISH 135°
SURFACE TREATMENT PARSOLIPRITE
HEAT TREATMENT RC - 36 - 23
MATERIAL 4130 C.D.
PART NO. OP 4321 - 1
SIZE DWG. NO. A - OP 4321 - 1
DRAWN BY DATE CHECKED APPROVED
U I
4-28-82 11/14 11/14
REVISIONS

<table>
<thead>
<tr>
<th>NO.</th>
<th>DESCRIPTION</th>
<th>DATE</th>
<th>BY</th>
<th>CM.</th>
<th>APR.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>.228 WAS .195, CHAM. WAS ON INSIDE</td>
<td>5.7.81</td>
<td>RK</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>.087 WAS FROM LOWER SURFACE LOCTITE WAS #431</td>
<td>4.6.82</td>
<td>RK</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**DIMENSIONS**

- .6255 DIA
- .6260
- .087
- .280
- .5620 D

**NOTES**

- MAT'L: CARPENTER TOOL STEEL
- H.T.: STENTOR-OIL HARD
- LOCTITE #271 W/P/N OP4321, GRIND FLUSH AFTER INSTALLATION

**Tolerances**

- DO NOT SCALE
- CONCENTRICITY: ALL DIAMETERS: TIR .003
- FRACTIONS ± 1/64
- DECIMALS ± .005
- ANGLES ± 1/2°
- CORNERS 1/64 x 45° or 1/64 R
- FINISH 13

**Material**

- DEEP SEA DRILLING PROJECT
- SCRIPPS INSTITUTION OF OCEANOGRAPHY
- UNIVERSITY OF CALIFORNIA, SAN DIEGO
- LA JOLLA, CALIFORNIA
- 92093

**Title**

- BUSHING, SHEAR, 7/32 ~OUTER BODY CAP~ VLHPC

**Scale**

- 1:1
- 6

**Part No.**

- OP4318-2

**Drawing No.**

- A-OP4318-2
NO. 1
REVISIONS

<table>
<thead>
<tr>
<th>NO.</th>
<th>DESCRIPTION</th>
<th>DATE</th>
<th>BY</th>
<th>CH. APR.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>WAS: 3/16 DIA</td>
<td>5.781</td>
<td>RX</td>
<td></td>
</tr>
</tbody>
</table>

MAT'\L: 1018 C.R. STEEL, TENSILE 85,000 PSI, YIELD 70,000 PSI

ALT. MAT'\L: 12L14 LEADLOY A, TENSILE 78,000 PSI, YIELD 70,000 PSI

NOTE: PINS ARE IN DOUBLE SHEAR.

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

TITLE 7/32 SHEAR PIN

MATERIAL SEE ABOVE

DATE 4.23.81

BY RK

CHECKED

APPROVED

SURFACE TREATMENT

HEAT TREATMENT

SCALE 1:1

REV. 1

DWG. NO.

REV.

PART NO.

153
NOTE:
- BREAK ALL SHARP EDGES
- RADIUS ALL INSIDE CORNERS

** NYE-CARB ELECTROLESS NICKEL PLATE - .005 THICK (I.D. ONLY) .0020
- THREADS TO BE STOPPED OFF AND NOT PLATED

** 4135 TUBE 3½ x 2½
NOTE: 

- BREAK ALL STAMP EDGES 
- RADIUS ALL INSIDE CORNERS 

DO NOT SCALE 

- TOLERANCES UNLESS NOTED 
- FRACTIONS 1/64 
- DECIMALS ± 0.005 
- ANGLES ± 1/2° 
- CORNERS 1/64 x 45° 
- 1/64 R 
- FINISH [ ] 

DEEP SEA DRILLING PROJECT 
SCRIPPS INSTITUTION OF OCEANOGRAPHY 
UNIVERSITY OF CALIFORNIA, SAN DIEGO 
LA JOLLA, CALIFORNIA 92037 

TITLE: 4.5m OUTER BODY LINK
~ VL.HPC~ 

SURFACE TREATMENT: 
MATERIAL: 4130 C.D. 
HEAT TREATMENT: 
SCALE: 1:1 
REVISIONS 
DESCRIPTION 
DATE 
BY 
CH. 
APR. 
1. ID was . 
2. ADDED + 1/6, -O TOL 

DO NOT SCALE • ONGENTRICITY ALL DIAMETERS — TIR.003 

MILL FLAT + STAMP: OP4343-2 

DSDP INNER BB'L THD (TYP) 
(SEE DWG B-0508) 
TO BE CONCENTRIC W/I.D. TIR .003 

3 1/2 O.D. 

180 
177 1/2 - 6 

MILL .750 DIA 
X 3/16 DP (3 AT 120°) 

HOLE 2.879 
2.881 DIA 
FINISH 32 

* I.D. (ONLY) TO BE NYE-CARB ELECTROLESS NICKEL TREATED TO 2.815 DIA (.005 THK) POLISH 32 

1/6 x 45° CHAM.

1/6 x 45° CHAM.
TOLERANCES UNLESS NOTED

FRACTIONS 1/64
DECIMALS ± .005
ANGLES ± 1/2°
CORNERS 1/64 ± 45°
or 1/64 R

DEPTH 19.37

MILL FLAT + STAMP: OP-1328-2

3½ OD.

HONE 2.8279 DIA
2.881 FINISH 32

3/8 STUD ACME THOS
(MAJ. DIA. 3.020-.000)
(RELIEVE AS NECESSARY)**

3×4 CHAMFER

3.015 DIA

3.000

LOWER OUTER BODY
VL-115C

DEEP SEA DRILLING PROJECT
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UNIVERSITY OF CALIFORNIA, SAN DIEGO
LA JOLLA, CALIFORNIA 92037

NOTE:

DRILL ALL SHARP EDGES

FINISH

TIGHT COAT 

SURFACE TREATMENT

MATERIAL

DRAWN BY

DATE

CHECKED

APPROVED

REVISION

1

2

1 D. FINISH WAS 63
1 3/16 WAS 1.26

3 3/4 IN. 8D4

3 1/2 OD.

2.8279 DIA

0.005

2.881 FINISH

32

3/8 STUD ACME THOS
(MAJ. DIA. 3.020-.000)
(RELIEVE AS NECESSARY)**

3×4 CHAMFER

3.015 DIA

3.000

LOWER OUTER BODY
VL-115C

DEEP SEA DRILLING PROJECT
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UNIVERSITY OF CALIFORNIA, SAN DIEGO
LA JOLLA, CALIFORNIA 92037

NOTE:

DRILL ALL SHARP EDGES

FINISH

TIGHT COAT 

SURFACE TREATMENT

MATERIAL

DRAWN BY

DATE

CHECKED

APPROVED

REVISION

1

2

1 D. FINISH WAS 63
1 3/16 WAS 1.26

3 3/4 IN. 8D4

3 1/2 OD.

2.8279 DIA

0.005

2.881 FINISH

32

3/8 STUD ACME THOS
(MAJ. DIA. 3.020-.000)
(RELIEVE AS NECESSARY)**

3×4 CHAMFER

3.015 DIA

3.000
O RING #2-359 OMITTED, ADD O RING 3 3/8 THD, 3/32 x 2 63 D

1. OMIT O RING ABOVE 2.65 2.415 D

2. 2.65 was .33 WAS .17, .17 WAS .60, .73 WAS .50, ADD .02 x .25 DIA

3. WAS .34 WAS .56.

4. REDRAWN, .59 WAS .87, .51 WAS .31, .17 WAS .150, .2 .64 WAS .2 .64

5. WAS A 'R' DRAWING

6. 2.050 ID WAS 2.000

7. 1.540 WAS 1.115, 1.265 WAS 1.263, 2.85 WAS 2.63

8. 1.650 WAS 1.115 (ERROR)

MILL FLAT + STAMP
H.P.C. OPV6-7

DRILL 5/16 (.312 DIA) THRU Y TAP 3/8-16.

AX FOR DEEP POLYPACK TYPE 0 SEAL

A FOR O RING NO 2-251

BREAK ALL STAMP EDGES RADIUS ALL INSIDE CORNERS

CONCENTRICITY TIR 0.003

MATERIAL (REF) YIELD: 153,000PSI
HIVO STEEL (REF) YIELD: 30,000PSI

TOLERANCES UNLESS NOTED

DEEP SEA DRILLING PROJECT
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UNIVERSITY OF CALIFORNIA, SAN DIEGO
LA JOLLA, CALIFORNIA
03/03

VINTAGE HIVO SIL

DRAWN BY DATE

CHECKED BY DATE

DEPT: EE-200

SPECIFICATIONS

MILL FLAT + STAMP

TAPPING

THD RELIEF

CHAMFER 316 X 45°

AX FOR DEEP POLYPACK TYPE 0 SEAL

MATERIAL (REF) YIELD: 153,000PSI
HIVO STEEL (REF) YIELD: 30,000PSI

TOLERANCES UNLESS NOTED

DEEP SEA DRILLING PROJECT
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UNIVERSITY OF CALIFORNIA, SAN DIEGO
LA JOLLA, CALIFORNIA
03/03

VINTAGE HIVO SIL

DRAWN BY DATE

CHECKED BY DATE

DEPT: EE-200

SPECIFICATIONS

MILL FLAT + STAMP

TAPPING

THD RELIEF

CHAMFER 316 X 45°
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 µ

NOTE:
BREAK ALL SHARP EDGES
RADIUS ALL INSIDE CORNERS

DEEP SEA DRILLING PROJECT
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UNIVERSITY OF CALIFORNIA, SAN DIEGO
LA JOLLA, CALIFORNIA 92033

TITLE
OUTER SEAL RETAINER
~ VL- H-P.C ~

SURFACE TREATMENT
PARKLUBRITE
HEAT TREATMENT
34-38 KC

MATERIAL
4140 STEEL
PART NO.
OP-4363-3

DRAWN BY
DATE
CHECKED
APPROVED

REV.

159
### REVISIONS

<table>
<thead>
<tr>
<th>NO.</th>
<th>DESCRIPTION</th>
<th>DATE</th>
<th>BY</th>
<th>CH.</th>
<th>APR.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>.055 WAS 9/64, .196 WAS 9/32, 1.347/1.285/2.581</td>
<td>12K</td>
<td>F71</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Diagram:**
- Concentricity: All diameters ± TIR .003
- Tolerances
  - 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 Adapter - Outer Seal Sub

**Specifications:**
- Material: 304 S.S.
- Heat Treatment: Annealed
- Scale: 1:1
- Date: 10-17-80
- By: RK
- Checked
- Approved

**Drawing Number:** A-OP4394-1
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 ±

SURFACE TREATMENT

MATERIAL
HEAT TREATMENT

304 S.S.
ANNEALED

DEEP SEA DRILLING PROJECT
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UNIVERSITY OF CALIFORNIA, SAN DIEGO
LA JOLLA, CALIFORNIA

TITLE
FEMALE ADAPTER-OUTER SEAL SUB
~VLHPC~

92093

DATE
10/17/80

TIGHTEN

BY
RK

CHECKED

APPROVED

PART NO.
OP4395-2

DWG. NO.
A-OP4395-2

INCH
DO NOT SCALE

TOLERANCES UNLESS NOTED
FRACTIONS ± 1/64
DECIMALS ±.005
ANGLES ± 1/2°
CORNERS 1/64 x 45°
or 1/64 R
FINISH 15^3

SCREWS IN DRILLING PROJECT
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UNIVERSITY OF CALIFORNIA, SAN DIEGO
LA JOLLA, CALIFORNIA

CONCENTRICITY ALL DIAMETERS TIR .003

V-SPACER - MALE - FEMALE - VLHPC - OUTER SEAL SUB

MATERIAL 304 SS
DATE 10.07.83
BY RK
CHECKED
APPROVED

SCALE 1:1
REQ'D/ASS'Y
PART NO. OP4396
DWG. NO. A-OP4396-0

V-SPACER - MALE - FEMALE - VLHPC - OUTER SEAL SUB

CONCENTRICITY ALL DIAMETERS TIR .003

DO NOT SCALE

TOLERANCES UNLESS NOTED
FRACTIONS ± 1/64
DECIMALS ±.005
ANGLES ± 1/2°
CORNERS 1/64 x 45°
or 1/64 R
FINISH 15^3

SCREWS IN DRILLING PROJECT
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UNIVERSITY OF CALIFORNIA, SAN DIEGO
LA JOLLA, CALIFORNIA

CONCENTRICITY ALL DIAMETERS TIR .003

V-SPACER - MALE - FEMALE - VLHPC - OUTER SEAL SUB

MATERIAL 304 SS
DATE 10.07.83
BY RK
CHECKED
APPROVED

SCALE 1:1
REQ'D/ASS'Y
PART NO. OP4396
DWG. NO. A-OP4396-0


**DEEP SEA DRILLING PROJECT**

**M.F.C. UNIVERSITY OF CALIFORNIA, SAN DIEGO**

**ANGUS I, LA JOLLA, CALIFORNIA 92038**

---

**REVISIONS**

<table>
<thead>
<tr>
<th>NO</th>
<th>DESCRIPTION</th>
<th>DATE</th>
<th>BY</th>
<th>CH</th>
<th>APB</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>ADD 1/2 x 1/2 Groove</td>
<td>4-28-61</td>
<td>K.R.</td>
<td>W.</td>
<td>K.V.</td>
</tr>
<tr>
<td>2</td>
<td>ADD DEBURR &amp; RADIUS NOTES, 2.720/1.0 RLOZAIN</td>
<td>4-28-61</td>
<td>K.R.</td>
<td>W.</td>
<td>K.V.</td>
</tr>
<tr>
<td>3</td>
<td>ADD WELD DIAGRAM, MFG PROC., R5 WELD 28-32, 4180 WELD 4740</td>
<td>4-28-61</td>
<td>K.R.</td>
<td>W.</td>
<td>K.V.</td>
</tr>
<tr>
<td>4</td>
<td>DELETE WELDING MFG. FROM 1 PC.</td>
<td>4-28-61</td>
<td>K.R.</td>
<td>W.</td>
<td>K.V.</td>
</tr>
<tr>
<td>5</td>
<td>ADD MFG. WS 1/8 GAGES</td>
<td>4-28-61</td>
<td>K.R.</td>
<td>W.</td>
<td>K.V.</td>
</tr>
</tbody>
</table>

---

**TYP. 2 PC'S AT 180°**

RADIUS ALL SHARP CORNERS AND SHARP EDGES, DEBURR HOLES INSIDE AND OUT.

1/2 R x 1/2 Ø x 11 L GROOVE CUT IN ASSY. WITH OP 4338 TP 4342. ALIGN W/ E OF DOG GROOVE OF OP 4338.

DRILL 1/4 Dia Thru (2 PC's AT 180°) DEBURR INSIDE

1/4 Dia Thru + TAP 1/4 HT (4 AT 10°, 45° FROM 681 HOLES)

DEBURR INSIDE AFTER TAPPING

DRILL 1/8 Dia Thru

DEBURR INSIDE AFTER TAPPING

1/8 x 45° CHAMFER

D50P INNER, B81, THD SAE DUG B-0508 BAKERLOK W/P/N OP 4342

STAMP: OP 4338-5

---

**TOLERANCES**

UNITS: INCHES

FRACTIONS: 1/64

DECIMALS: 1/100

ANGLES: ± 10°

CORNERS 90°± 1/4°

1/16" T

**DEEP SEA DRILLING PROJECT**

**Scripps Institution of Oceanography**

**UNIVERSITY OF CALIFORNIA, SAN DIEGO**

**LA JOLLA, CALIFORNIA**

92038
REVISIONS

<table>
<thead>
<tr>
<th>NO.</th>
<th>DESCRIPTION</th>
<th>DATE</th>
<th>BY CH. APR.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>ADD TOL: +.025</td>
<td>4/16/82</td>
<td>P.K.</td>
</tr>
<tr>
<td>2</td>
<td>DELETED 1/2-13 HOLE</td>
<td>7/12/82</td>
<td>R.K.</td>
</tr>
<tr>
<td>3</td>
<td>2.765+/- was 2.750</td>
<td>2/16/82</td>
<td>R.K.</td>
</tr>
</tbody>
</table>

NOTE:
- BREAK ALL SHARP EDGES
- RADIUS ALL INSIDE CORNERS
- CONCENTRICITY ALL DIAMETERS TIR .0005

TOLERANCES
- UNLESS NOTED
- FRACTIONS ±1/64
- DECIMALS ±.005
- ANGLES ±1/2
- CORNERS 1/64 x 45° or 1/64 R

SURFACE TREATMENT
- PARCOLUBRITE

HEAT TREATMENT
- RC 28-32

DEEP SEA DRILLING PROJECT
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UNIVERSITY OF CALIFORNIA, SAN DIEGO
LA JOLLA, CALIFORNIA

SLEEVE-QUICK RELEASE SHOCKER SOCKET ~ V.L.: HPC ~

*HEAT TREAT BEFORE MACHINING.*
NOTE:
BREAK ALL SHARP EDGES
RADIUS ALL INSIDE CORNERS

HEAT TREAT/HARDFACE:
1. PRE-HEAT TO 600°F
2. ARC WELD STOODY 1/4 x 1/16 THK. & GRIND (32)
3. PRE-HEAT TO 1575°F AND OIL QUENCH.
4. DRAW AT 1200°F FOR CORE HARDNESS OF 28-30 Rc (271-361 BRINELL).

APPLY STOODY 1/8 HARD FACING AND GRIND BACK TO DESIGNATED DIMENSION

REVISIONS

<table>
<thead>
<tr>
<th>NO.</th>
<th>DESCRIPTION</th>
<th>DATE</th>
<th>BY</th>
<th>CH.</th>
<th>APR.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>REDESIGNED</td>
<td>04/14/93</td>
<td>RR</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>2</td>
<td>ADDED STOODY &amp; ASSOC. NOTES</td>
<td>54/81</td>
<td>RR</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>3</td>
<td>.525 was 1.615 R</td>
<td>6/19/81</td>
<td>RR</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>4</td>
<td>ADDED H.T. SPEC</td>
<td>2/17/82</td>
<td>RR</td>
<td>10</td>
<td>10</td>
</tr>
</tbody>
</table>

TOLERANCES
UNLESS NOTED

FRACTIONS 1/64
DECIMALS .005
ANGLES 1/12°
CORNERS 1/64 x 45°
FINISH 1/64 R

SURFACE TREATMENT
VAROLUBRITE

HEAT TREATMENT
H.P. H.T. STOCK

SEE NOTE

PART NO. 40-4
SIZE 4WD NO. B - OP 4340

DEEP SEA DRILLING PROJECT
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UNIVERSITY OF CALIFORNIA, SAN DIEGO
LA JOLLA, CALIFORNIA

9203
TOLERANCES UNLESS NOTED
FRACTIONS 2/164
DECIMALS 0.005
ANGLES 1/2°
CORNERS 1/64 x 45°
FINISH U

DEEP SEA DRILLING PROJECT
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UNIVERSITY OF CALIFORNIA, SAN DIEGO
LA JOLLA, CALIFORNIA

TITLE 14' 9 1/2" INNER CORE BB/L

MATERIAL 4130 C.D.

DRAWN BY R.K.
CHECKED
APPROVED

HEAT TREATMENT PART NO.

SIZE DWG. REV.

DSDP INNER BARREL THDS
SEE DWG NO. B-0508
NOTE: 
- BREAK ALL SHARP EDGES
- RADIUS ALL INSIDE CORNERS

DSDP INNER BBL THD (TYP) 
(SEE DWG # B-0508)

MILL FLAT + STAMP: OP4353

DO NOT SCALE
TOLERANCES UNLESS NOTED
FRACTIONS: 1/64
DECIMALS: 0.005
ANGLES: 1/2°
CORNERS 1/64 x 45°
FINISH: UV

CONCENTRICITY ALL DIAMETERS: TIR .003

DEEP SEA DRILLING PROJECT
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UNIVERSITY OF CALIFORNIA, SAN DIEGO
LA JOLLA, CALIFORNIA

3 M INNER BBL - VLHPC -

Material: 4130 C.D.
Date: Oct 18
Cheked: 7/1
Approved: 7/1

Scale: 1/16

169
FOR O-RING #2-232
**DSDP INNER BBL THDS
SEE DWG B-0508

4.003 DIA

2.827 DIA

3.039 DIA ± 0.000

2.875 DIA

3/8

2.500

7 1/4

9 3/4

3/8

3 1/4

2 3/4

2 1/4

0.005 (TYP)*

-0.000

0.004

+0.005

1/64 » 45°

32° (TYP)

45°

1/16

STAMP: OP 4360-1

DEEP SEA DRILLING PROJECT
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UNIVERSITY OF CALIFORNIA, SAN DIEGO
LA JOLLA, CALIFORNIA

97093

DO NOT SCALE

CONCENTRICITY ALL DIAMETERS: TIR .003

DEEP SEA DRILLING PROJECT
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UNIVERSITY OF CALIFORNIA, SAN DIEGO
LA JOLLA, CALIFORNIA

97093

LOWER LINER SEAL SUB
VL HPC

MATERIAL
4130 C.D.

DATE 11/2/83

QUALITY C.

FINISH V

PART NO. OPA 4360-1
MATERIAL: CLEAR BUTYRATE PLASTIC

NOTE: COLOR LINTER ON OUT.
ONE DOUBLE - THREE SINGLE
1/16" WIDE LINES
-NO PROTRUBERANCE AT
CORE LINER SURFACE-

MINIMUM WALL: 0.092"
CONCENTRICITY WITHIN .050"
MAT'L: SHELBY C.R.S. TUBING 3.000 O.D. x .250 WALL

DO NOT SCALE

TOLERANCES UNLESS NOTED
FRACTIONS ± 1/64
DECIMALS ± .005
ANGLES ± 1/2°
CORNERS 1/64 x 45°
or 1/64 R
FINISH ✓

CONCENTRICITY ALL DIAMETERS: TIR .003

DEEP SEA DRILLING PROJECT
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UNIVERSITY OF CALIFORNIA, SAN DIEGO
LA JOLLA, CALIFORNIA
92093

TITLE PLASTIC TUBE SUPPORT ~VLHFC~

MATERIAL SEE ABOVE
DATE 11-21-82
BY RK
CHECKED
APPROVED

SURFACE TREATMENT

HEAT TREATMENT
SCALE REQ'D/ASS'Y

PART NO. OP4382-1

Dwg. No. A-OP4382-1
REVISIONS

<table>
<thead>
<tr>
<th>NO.</th>
<th>DESCRIPTION</th>
<th>DATE</th>
<th>BY</th>
<th>CH.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>ADDED 2.5/32</td>
<td>2/19/32</td>
<td>RK</td>
<td>2/19/32</td>
</tr>
</tbody>
</table>

DEEP SEA DRILLING PROJECT
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UNIVERSITY OF CALIFORNIA, SAN DIEGO
LA JOLLA, CALIFORNIA

SCALE 1/1

HEAT TREAT 38-40 Rc
YIELD 167,000 PSI
IZOD 38 FT LBS

DO NOT SCALE
TOLERANCES
UNLESS NOTED
FRACTIONS ±1/64
DECIMALS ±.005
ANGLES ±1/2°
CORNERS 1/64 x 45°
or 1/64 R
FINISH 0.32

CONCENTRICITY ALL DIAMETERS TIR .003

5-STUB ACME THDS/IN.
SEE DWG B-0508-1

30° CHAMFER
3.0 T DIA
3.32 DIA

STAMP BELOW SHOULDER:
OP 43 76

BREAK EDGE

2.44 DIA

3.75 O.D.

30°

MAX 0.03 R

45°

57

2.500

13 5/8

10.125


HEAT TREAT 38-40 Rc
YIELD 167,000 PSI
IZOD 38 FT LBS

TITLE CATCHER SUB
~VLHPC~

MATERIAL 4140 STEEL

PART NO. OPA376-0

CHECKED 2/23/32
APPROVED 3/12/32
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
SPRING, FLAPPER C'CATCHER
H.P.C 15'

MATERIAL .05 BERYLLIUM
PART NO. OP 4107

DRAWN BY KK DATE 12/77
CHECKED APPROVED

SIZE
DWG. NO. A - 12 10 -
TOLERANCES UNLESS NOTED

DEEP SEA DRILLING PROJECT
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UNIVERSITY OF CALIFORNIA, SAN DIEGO
LA JOLLA, CALIFORNIA

FRACTIONS $\frac{1}{64}$
DECIMALS .005
ANGLES 1° 1/2'
CORNERS 1/8" or 1/64 R

SURFACE TREATMENT PAR KO LUBS
HEAT TREATMENT 360 LC

STEP 1

- 3.06 OD x .23 WALL
- $\frac{1}{4}$-20 x $\frac{1}{2}$ SC (2)
- TAPER PINTO 1.53 R
- 20 DIA

- 1$\frac{3}{4}$ DIA x 4 ARBOR, $\frac{1}{6}$ x 45° CHAMFER (FOR MACHINING PURPOSES)

STEP 2
CONCENTRICITY ALL DIAMETERS', TIR .003 TOLERANCES UNLESS NOTED FRACTIONS ± 1/64 - DECIMALS ± .005 ANGLES ± 1/2° CORNERS 1/64 x 45° or 1/54 R

FINISH

SUN FACET TREATMENT

HF. FACT TREATMENT

S20S3 CT014

MATERIAL

SCALE REQ'D/Ash.

DATE

PART NO.

CH. CKED

APPROVED

DWG. NO.

REVISIONS

NO.

REDRAWN

DESCRIPTION

DATE BY CH. APR.
REVISIONS

<table>
<thead>
<tr>
<th>NO.</th>
<th>DESCRIPTION</th>
<th>DATE</th>
<th>BY</th>
<th>CH.</th>
<th>APR.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>REVISED (PRE REV. 963)</td>
<td>1-20-81</td>
<td>RK</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>.100 was .190, .281/190.00/2 1/2, .464/1.380</td>
<td>2-6-81</td>
<td>RK</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>.3/4= A4, .850 was .100, ADD. 1.400 x .380</td>
<td>2-5-81</td>
<td>RK</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>.815 was .850, 3/11, 3/16 was .281, .350</td>
<td>4-17-81</td>
<td>RK</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

CONCENTRICITY
ALL DIAMETERS: TIR .003

TOLERANCES
UNLESS NOTED
FRACTIONS ± 1/64
DECIMALS ± .005
ANGLES ± 1/2°
CORNERS 1/64 x 45°
FINISH 13/4

SURFACE TREATMENT

MILL FLAT + STAMP:
OP4350-4

* FOR O-RING # 2-324
AND PARBAK 8-324

DO NOT SCALE

CONCENTRICITY ALL DIAMETERS: TIR.003

DEEP SEA DRILLING PROJECT
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UNIVERSITY OF CALIFORNIA, SAN DIEGO
LA JOLLA, CALIFORNIA

TITLE
SINGLE SHOT TOP PLUG
VLHPC

MATERIAL
K500 MONEL

DATE
1-12-81

REVIEWED
RK

CHECKED

APPROVED

SCALE
1:1

RECV/ASMT

PART NO.
OP4350-4

DRAW NO.
BOOP4350-4

(REV)
<table>
<thead>
<tr>
<th>NO.</th>
<th>DESCRIPTION</th>
<th>DATE</th>
<th>BY</th>
<th>CH.</th>
<th>APR.</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>REVISIONS</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>NO.</th>
<th>DESCRIPTION</th>
<th>DATE</th>
<th>BY</th>
<th>CH.</th>
<th>APR.</th>
</tr>
</thead>
</table>

**NOTE:**
After installation top of plug may require machining to avoid interference with P/N No. OP4350. Baker loc in place.

---

**DEEP SEA DRILLING PROJECT**  
**SCRIPPS INSTITUTION OF OCEANOGRAPHY**  
**UNIVERSITY OF CALIFORNIA, SAN DIEGO**  
**LA JOLLA, CALIFORNIA**  

**TITLE:** Pipe Plug - Single Shot Bottom Plug ~ VL-HPC ~

**SURFACE TREATMENT:**
- NITRONIC 60

**HEAT TREATMENT:**
- SCALE: 1.1
- REO'D/ASS'Y: 1

**DATA:**
- PART NO.: OP4358
- DWG. NO.: A-OP4358-C

---

**TOLERANCES**
- UNLESS NOTED
- FRACTIONS ± 1/64
- DECIMALS ± .005
- ANGLES ± 1/2°
- CORNERS 1/64 x 45° or 1/64 R

**FINISH:**
- 125
NOTE:
COLD DRAWN AGE HARDENED
<table>
<thead>
<tr>
<th>REVISIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO.</td>
</tr>
<tr>
<td>---</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>1/2-13 x 3/4 SOCKET SET SCREW</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAT'L: ALLOY STEEL</td>
</tr>
<tr>
<td>FEATURES: NYLOC, CUP POINT</td>
</tr>
<tr>
<td>FINISH: CAD. PLATE</td>
</tr>
</tbody>
</table>

USED ON:
- TOP SUB CAP - OP4300
- QUICK RELEASE SLEEVE - OP4337

---

**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

**MATERIAL**
- GCAL, 1 NICKEL PLATED

**PART NO.**
- 0P4302

**DATE**
- 4-16-81

**CHECKED**
- RK

**APPROVED**
- HEV

**DRAWN**
- OP4302-0
REVISIONS

<table>
<thead>
<tr>
<th>NO.</th>
<th>DESCRIPTION</th>
<th>DATE</th>
<th>BY</th>
<th>CH.</th>
<th>APR.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>RE-DRAWN</td>
<td>3-5-81</td>
<td>RK</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>2</td>
<td>3/64 WAS 3/8 DIA</td>
<td>3-19-81</td>
<td>RK</td>
<td></td>
<td>Y</td>
</tr>
<tr>
<td>3</td>
<td>ADDED 45° CHAMFER</td>
<td>9-24-81</td>
<td>RK</td>
<td></td>
<td>Y</td>
</tr>
</tbody>
</table>

DO NOT SCALE

CONCENTRICITY ALL DIAMETERS: TIR .003

DEEP SEA DRILLING PROJECT
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UNIVERSITY OF CALIFORNIA, SAN DIEGO
LA JOLLA, CALIFORNIA

DO NOT SCALE

TOLERANCES UNLESS NOTED
FRACTIONS ± 1/64
DECIMALS ± .005
ANGLES ± 1/2°
CORNERS 1/64 x 45°
or 1/64 R
FINISH 1/32

SURFACE TREATMENT
MATERIAL ALLOY STEEL
DATE 3-5-81
BY. RK
CHECKED
APPROVED

HEAT TREATMENT
SCALE 1:1
REQ'D ASSY. ONE
PART NO. OP4301-3
DWG. NO. A-OP4301-3

NOTE:
Baker-Loc w/ Pulling Tool Cylinder OT 3010

1/32 x 45° CH.

1/2 - 20 x 3/4 SOC. SET SC. (CUP POINT)

17/32

3/4

25/64 DIA

CHAMFER 1/16 x 45°
<table>
<thead>
<tr>
<th>NO.</th>
<th>DESCRIPTION</th>
<th>DATE</th>
<th>BY</th>
<th>CH.</th>
<th>APR</th>
</tr>
</thead>
</table>

**DO NOT SCALE**

- **TOLERANCES** UNLESS NOTED
  - FRACTIONS ± 1/64
  - DECIMALS ± .005
  - ANGLES ± 1/2°
  - CORNERS 1/64 x 45° or 1/64 R
  - FINISH 125

**SURFACE TREATMENT**
- CAD. PLATE

**HEAT TREATMENT**
- 0

**CONCENTRICITY ALL DIAMETERS:** TIR .003

**DEEP SEA DRILLING PROJECT**
**SCRIPPS INSTITUTION OF OCEANOGRAPHY**
**UNIVERSITY OF CALIFORNIA, SAN DIEGO**
**LA JOLLA, CALIFORNIA**

<table>
<thead>
<tr>
<th>TITLE</th>
<th>MATERIAL</th>
<th>DATE</th>
<th>BY</th>
<th>CHECKED</th>
<th>APPROVED</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/2-13 x 3/4 SOC SET SCREW-OUTER SWIVEL BODY ~ VLHPC ~</td>
<td>ALLOY ST.</td>
<td>4-16-81</td>
<td>RK</td>
<td>1st</td>
<td>1st</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SCALE</th>
<th>REO'D/ASS'Y</th>
<th>PART NO.</th>
<th>DWG. NO.</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>OP4369-0</td>
<td>OP4369-0</td>
</tr>
<tr>
<td>No.</td>
<td>Description</td>
<td>Date</td>
<td>By</td>
</tr>
<tr>
<td>-----</td>
<td>---------------------------------</td>
<td>--------</td>
<td>-------</td>
</tr>
<tr>
<td>1</td>
<td>.193 Ws. .1985</td>
<td>7-12-82</td>
<td>RK</td>
</tr>
<tr>
<td>2</td>
<td>was NYLOC SC. ADD. 3/16 BROACH, LOCK PATCH</td>
<td>1-24-83</td>
<td>RK</td>
</tr>
</tbody>
</table>

**REVISIONS**

**TOLERANCES**
- UNLESS NOTED
  - FRACTIONS ± 1/64
  - DECIMALS ± .005
  - ANGLES ± 1/2°
  - CORNERS 1/64 x 45° or 1/64 R

**FINISH**
- 125

**SURFACE TREATMENT**

**HEAT TREATMENT**

**CONCENTRICITY ALL DIAMETERS:** TIR .003

**DEEP SEA DRILLING PROJECT**
SCHIPPS INSTITUTION OF OCEANOGRAPHY
UNIVERSITY OF CALIFORNIA, SAN DIEGO
LA JOLLA, CALIFORNIA

**TITLE**
UPPER LINER SEAL SUB RETAINER SCREW ~ V LHPC

**MATERIAL**
ALLOY STEEL

**DATE:** 3-12-81
**BY:** RK

**CHECKED:**

**APPROVED:**

**SCALE:** 2:1
**REO/DIA:** ONE
**PART NO.:** 0P4361-2
**REV.:** A-0P4361-2

**NOTE:** DO NOT SCALE
3/8-16 x 3/8 SOCK SET SCREW

MAT'L: ALLOY STEEL
FEATURES: NYLOC, CUP POINT
FINISH: CAD, PLATE

USED ON: (VLHPC) BYPASS SUB OP4309
4.5m SHAFT LINK OP4320
INNER SEAL SUB OP4323
LOWER OUTER BODY OP4328
3.0m SHAFT LINK OP4354
LOWER SHAFT OP4355
OUTER BODY SEAL OP4362
SWIVEL RETAINER OP4366
SINGLE SHOT PRESS, CASE OP4347

DO NOT SCALE

CONCENTRICITY ALL DIAMETERS: TIR .003

DEEP SEA DRILLING PROJECT
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UNIVERSITY OF CALIFORNIA, SAN DIEGO
LA JOLLA, CALIFORNIA

SURFACE TREATMENT
CAD, PLATE
HEAT TREATMENT

MATERIAL
ALLOY STEEL

DATE
4-16-81

CHECKED

APPROVED

A-1724-0

REV.

REV.

DWG. NO.

OP4185-0

PART NO.

REQ'D/ASSY
BREAK ALL SHARP EDGES
RADIUS ALL INSIDE CORNERS

TOLERANCES
UNLESS OTHERWISE SPECIFIED
X ± .1
XX ± .01
XXX ± .001
ANGLES ± 30°

NOTE:
BREAK ALL SHARP EDGES
RADIUS ALL INSIDE CORNERS

FINISH: PARKOLUBRITE
MAT'L:
COLD ROLLED STEEL

UNIV. OF CALIF
DEEP SEA DRILLING PROJ.

HANG OFF PLATE - HPC-.15

PART NO. OP4/92

DRAWING NUMBER
B-0942-03

(WAS 25-0347-00)
DRILL 1/8 DIAM THRU (2)

1/32 x 1/32 GROOVE

SCRIBE 5° x 10° LINES +
STAMP NO. AS SHOWN

SLOT + BRAZE

5/8 LONG x 1/4 + 7/16 DIA

1/4-20 x 7/16 BOLT + WASH. (5.5)

DEEP SEA DRILLING PROJECT
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UNIVERSITY OF CALIFORNIA, SAN DIEGO
LA JOULLA, CALIFORNIA

TOLERANCES
UNLESS NOTED
FRACTIONS 1/16
DECIMALS ± 0.001
 ANGLES ± 1°
CORNERS EMA ± 1/16

FINISH

MATERIAL BRASS
DRAWN DATE CHECKED APPROVED

SLIT TREATMENT 0
PART NO. C-OP4330

V. R. V.

C-OP4330
DRILL 3/8 (1.69 DIA) THRU (4 PLCS)

BRAZE (SIDES ONLY)

BRAZE (SIDES ONLY)

DRILL 3/4 DIA THRU (2)

1/4 DIA × 3/4 PIN (AS SHOWN)

1/4 × 1/4 GROOVE

1/4-20×1/4 BOLT
+ WASHERS S.S.

WELD

TELESCOPE FRAME, FRAME LINE ORIENTATION ~ VMLPC ~

DEEP SEA DRILLING PROJECT
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UNIVERSITY OF CALIFORNIA, SAN DIEGO
LA JOLLA, CALIFORNIA

TOLERANCES
UNLESS NOTED
FRACTIONS : 1/16
DECIMALS : .001
ANGLES : 1/2°
CORNERS 15° × 45°
1/16
1/32
1/64

SURFACE TREATMENT
MATERIAL
HEAT TREATMENT

DATE: 3/14/74
DRAWN BY: J.D.C.
CHECKED: K.K.
APPROVED: 3/14/74
\[ \text{Drill} 7 \text{ (201 Dia. Thru + Tap \( \frac{1}{4} - 20 \) (2)} \]

\[ \frac{1}{32} \times \frac{1}{32} \text{ Groove} \]

\[ \frac{1}{32} \times \frac{1}{32} \text{ Groove (Typ)} \]

\[ 2\frac{1}{32} \]

\[ 13\frac{32}{32} R \]

**Tolerances**

- **Fractions**: ±1/64
- **Decimals**: ±.005
- **Angles**: ±1/16°
- **Corners**: 1/64 x 45° or 1/64 R

**Surface Treatment**

- **Finish**: "Y" or "Y/1 R" or "Y/1 R" or "Y/1 R" or "Y/1 R"

**Deep Sea Drilling Project**

- **Sighting Bar Reducer**

**Material**: Brass or Alum

**Drawing by**: KIC

**Checked**: BXLNU

**Approved**: Meer
REVISIONS

<table>
<thead>
<tr>
<th>NO.</th>
<th>DESCRIPTION</th>
<th>DATE</th>
<th>BY CH.</th>
<th>APR</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2&quot; WAS TO OUTSIDE</td>
<td>4-16-81</td>
<td>RK</td>
<td></td>
</tr>
</tbody>
</table>

DO NOT SCALE

CONCENTRICITY ALL DIAMETERS: TIR .003

DEEP SEA DRILLING PROJECT
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UNIVERSITY OF CALIFORNIA, SAN DIEGO
LA JOLLA, CALIFORNIA

LA JOLLA, CALIFORNIA

TITLE

DRILL JIG - CORE LINER

SURFACE TREATMENT
PARKOLUB.

HEAT TREATMENT
38-42 Rc.

MATERIAL
4140 C.D.

SCALE
1:1

REV. A-OP4389-1

DOC. NO.
DO NOT SCALE

CONCENTRICITY ALL DIAMETERS: TIR .003

TOLERANCES UNLESS NOTED
FRAC TIONS ± 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: ASSY BAR FOR SWIVEL ASSEMBLY ~VL HPC~

SURFACE TREATMENT: PARKOLUBE
HEAT TREATMENT

MATERIAL: C.R. STEEL
SCALE: 1:1
REO'D/ASS'Y: 1
PART NO.: OP4384-1

DATE: 4-14-81
CHECKED:
APPROVED:

DWG. NO.: A-OP4384-1 (REV.)

REVISIONS

NO. DESCRIPTION DATE BY CH. APR.
1 15/16 WAS 1 1/8 5-12-81 RK 722
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

TITLE
SEAL INSTALLATION TOOL- PRESS: CASE
~ VLI HPC ~

MATERIAL BRASS

DATE 5-19-81

BY RK

CHECKED

APPROVED

Dwg. No.

PART NO.

SCALE 1:1

197
SCHEMATIC OF REQD. COMPONENTS FOR 9.5, 8.0, 6.5, 5.0 AND 3.5 meter H.P.C. SYSTEMS