DESIGN OF AN AUTOMATIC MARINE CORER

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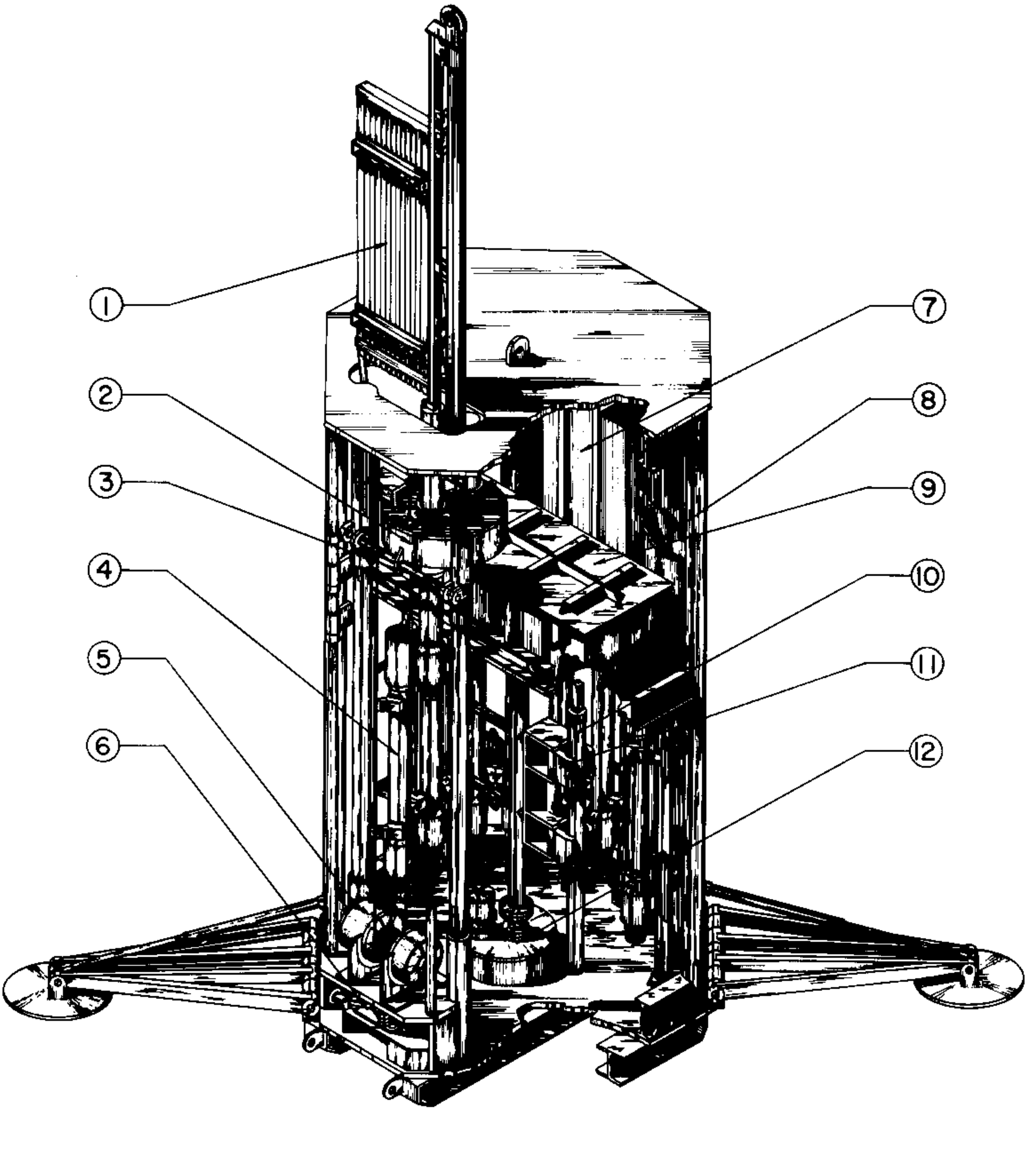
TEXAS A&M UNIVERSITY
AUTOMATIC MARINE CORER



LEGEND

1 - SQUARE ROD MAGAZINE

2 - HYDRAULIC POWER HEAD

3 - POWER HEAD STOP

4 - DRILL PIPE

5 - HYDRAULIC WINCH

6 - DRILL PIPE BREAKERS & SLIPS

7 - AUTOMATIC CONTROLS CONTAINER

8 - COMPRESSED BALANCING GAS

9 - POWER SUPPLY & VALVING CONTAINER

10 - CORE BARREL

11 - PIPE & BARREL HANDLER

12 - INDEX MECHANISM

ABSTRACT

Upon request of several geophysical organizations, a program was initiated at Texas A&M University under the Sea Grant Program to design a selfcontained automatic seafloor setting corer which will: 1) extract up to fifty feet of continuous undisturbed core, 2) operated in depths up to 1,000 feet of water, 3) core in hard as well as soft material, and 4) be as compact as possible to facilitate shipboard handling. This program was partially funded by Oceanonics, Inc., Houston, Texas. The SEACORE 50 will extract a three inch diameter core 49.5 feet long in eleven sections. The unit is octagonal in cross section measuring six feet side to side and is twelve feet in height. When the unit reaches the seafloor, four legs fold down and level the unit on slopes of up to 15^{o}. The unit weighs 10,000 pounds dry, 8,000 pounds in water, and is lowered to the seafloor by a single power-tension cable. An automatic control system is contained in the unit with shipside manual control available at any time. A drill pipe fitted with a ring type core bit is rotated under a considerable thrust load while water is pumped down the center of the drill pipe to wash the cuttings back up the annulus. This water is routed through the double walled bottom joint around the core barrel so that the sample is not washed. A square rod extending from the top of the coring unit restrains the rotation of the core barrel. This square rod also

supports a piston in the core barrel thus affecting "fixed piston" coring. A hydraulic powerhead produces 1,000 ft-lbs of torque and 6,000 pounds of thrust or pull.

ACKNOWLEDGMENTS

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Gratitude is also due to Mr. B. R. Bowen, Bowen and Callender, Inc., Houston, Texas, for his guidance and assistance during the design. Many helpful suggestions were also received from Dr. H. J. Sweet, Mechanical Engineering Department, and from Dr. W. R. Bryant, Oceanography Department, at Texas A&M University.

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CHAPTER I

INTRODUCTION

Despite the many advancements made in oceanographic instrumentation in recent years, the tools and techniques for obtaining good undisturbed material samples of the sea bed in all types of bottom material are still unsatisfactory. Gravity and piston corers are widely used (3, 4, and 6), but cores longer than thirty feet are rare unless the cored sediments are very soft as gravity coring is only effective where the sediment to be sampled can be penetrated by the freefalling tubes.

To circumvent the problem, various coring units have been developed which operate on a vibratory principle (1) whereby eccentric impulses are generated down the barrel causing vibrations that drive the barrel in its downward passage. Although fairly effective in well-sorted sands, these devices will not sample consolidated or semi-consolidated materials, nor are they very effective in coring interstratified deposits consisting of sediments

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The numbers in parentheses indicate references at the end of this proposal.

of varying grain sizes and densities.

There are other coring devices which are lowered to the sea floor and are activated there (1). Some of these exhibit capabilities of up to 200 feet penetration, but without exception, they require the logistic support of divers on the bottom. This makes the cost of a single core prohibitive to many marine interests.

Another accepted technique of obtaining long cores is by rotary drilling (1). This requires a stable platform, necessitating the use of a barge or large vessel and at least a four point anchoring spread (two each on bow and stern). The time consumed in deployment and retrieval of anchors reduces the efficiency and adds to the over-all cost.

Although there are many coring devices in use today, all have important shortcomings (2). The need exists to develop a new coring device which will incorporate the best features of the existing inventory of tools into a single system. A coring device capable to obtaining long cores with a minimum of sample disturbance and without the necessity of a stable platform would be put to immediate use in all disciplines of marine activity, particularly in applications to exploration programs in offshore mining.

The objectives of this research were, therefore, to design an automatic marine coring device with the following capabilities.

It should:

1. be capable of obtaining a three inch diameter core at least fifty feet long in depths of up to 1,000 feet of water. The recovered sample should be at least 90% of the amount drilled.
2. be activated with a power package on the ocean bottom and supplied by a single umbilical control from the surface vessel.
3. be capable of rapid penetration and withdrawal to circumvent anchor spreads.
4. be as compact as possible to facilitate ease of shipboard handling.
5. employ both rotary and push type operations with interchangeable coring bits to handle all types of sediments and must employ the fixed piston method of coring.
6. be self-leveling on slopes of up to 15° so that cores are always taken in the vertical.

The design of the automatic marine coring device proceeded from the penetration and coring tubes which take the core sample, through the inner sections and power equipment, to the square rod magazine utilized on top of the unit. The unit is octagonal in shape with a six foot side to side distance and a height of 12 feet 2 inches.

Standard 6 inch by 3 3/8 inch "I" beams are mounted on the bottom for skids and a single lifting eye for attachment of the power-tension cable is mounted on the top. The square rod magazine will extend 1 foot 5 1/8 inches above the top of the unit in its stored position. Four legs, 5 feet long, are folded against the sides and controlled by hydraulic cylinders. The coring device will weigh approximately 10,000 pounds on land with an in-water weight of 8,000 pounds.

CHAPTER II

PENETRATION AND CORING TUBES

Eleven penetration tubes will be employed in the unit. This includes ten standard tubes (see Drawing Number DP-03) of 4 feet 6 inches in length and the first penetration tube (see Drawing Number DP-02) of 5 feet 6 inches in length with coring bit. Initially, an annulus was to extend through all tubes and eleven different connections to furnish flow for washing cuttings out of the drill hole. This was to have been accomplished by using concentric tubes and special connections, thus leading to very high costs in materials and machining. Instead, ten of the penetration tubes will be made from standard 4 1/2 inch drill pipe with 4 1/2 inch API internal flush threads in tool joints. It was intended that used pipe be employed for this application to reduce cost. This is possible because the used drill pipe still has greater strength characteristics than required for this service. Flow will be effected down the center of these ten tubes. The first penetration tube will be the only one with an annulus around the core barrel. The flow proceeds through this annulus and out the drill bit to wash the cuttings to the outside and away from the core. The first penetration tube is the only one which requires special machining and thus greatly reduces the cost of the drill string.

The first penetration tube was designed to take different styles of bits with 4 inch API internal flush threads. Bit types include cone bits for soft material, "fish-tail" bits for semi-consolidated material, and bits with surfaced hardened teeth for harder material. Both push type operation for soft materials and rotary-push type operations for harder materials were designed into the unit. The core barrel assembly locks into a groove located at the top of the first penetration tube (see Drawing Number DP-01). This allows the core barrel to be carried with the penetration tube during a coring operation and thus slides the core barrel over the core.

The core barrel consists of a PVC (polyvinyl chloride) barrel with a 316 stainless steel cap affixed to the plastic barrel by left-hand threads (see Drawing Number CB-01). The purpose of the left-hand threads is to keep the two pieces together during clockwise rotary operation in coring. The PVC barrel is disposable once the core is obtained. The stainless steel cap is re-usable and interchangeable with other barrels. An "O" ring seal is used between the core barrel and first penetration tube to insure that flow does not wash the sample. The core barrel cap has a spring loaded sliding ball lock for locking it into the first penetration tube (see Drawing Number DP-01). The spring in the cap was designed to give a twenty pound in-service force to keep the balls locked in the groove. The spring specifications are as follows:

FL (Free Length) = 1 1/2 inches

DW (Wire Diameter) = .200 inch

DM (Mean Diameter) = 2.75 inches

Nc (Number of Coils) = 2.5

Squared and Ground Ends

G (Modulus of Rigidity for Stainless Steel Spring Wire) = 10.6×10^6 psi

The spring constant, K, was calculated as follows (5):

$$K = \frac{G\ Dw^4}{8\ Dm^3\ Nc}$$

$$K = \frac{10.6 \times 10^6\ (.200)^4}{8(2.75)^3(2.5)}$$

$$K = 40.6\ \text{lbs/in.}$$

Therefore, the in-service deflection of the spring will be .500 inch to produce 20.3 pounds of force. Also, 30.45 pounds of force is required to deflect the spring an additional .250 inch to release the balls and core barrel from the first penetration tube.

This action is accomplished by a piston held stationary by a square rod which extends to the top of the coring unit. As the core barrel is carried over the sample by the penetration tube, the piston remains stationary (see Figure 1). As the piston reaches the top of the core barrel, it compresses the spring and releases the core barrel from the penetration tube. To keep flow out of the core barrel during a coring operation, the piston has an "O" ring seal between it and the barrel. It also has four one way check valves to allow water to pass through during lowering into the drill hole, but restricting the flow into the barrel during coring.

The piston has four spring loaded balls which fit in a groove in the core barrel cap spacer (see Drawing Number CB-01) to keep the sliding ball lock in the core barrel cap unlocked while lowering into the drill hole. This keeps the spring in the cap deflected the additional .250 inch to keep the force off the ball locks. To unlock the piston from the core barrel cap spacer requires an additional 135 to 160 pounds of push on the piston, depending on the inside diameter of the cap spacer. Four stainless steel Lee Springs No. LC-042C-8, Lee Spring Company, Brooklyn, New York, 11201, are used in the piston. The springs have a free length of 13/16 inch and a spring constant of 60 lbs/inch (see Figure 2). With an in-service deflection of .214 inch, each spring will produce a 12.8 pound force on the ball against the groove in the cap spacer. See Figure No. 2 for force requirement

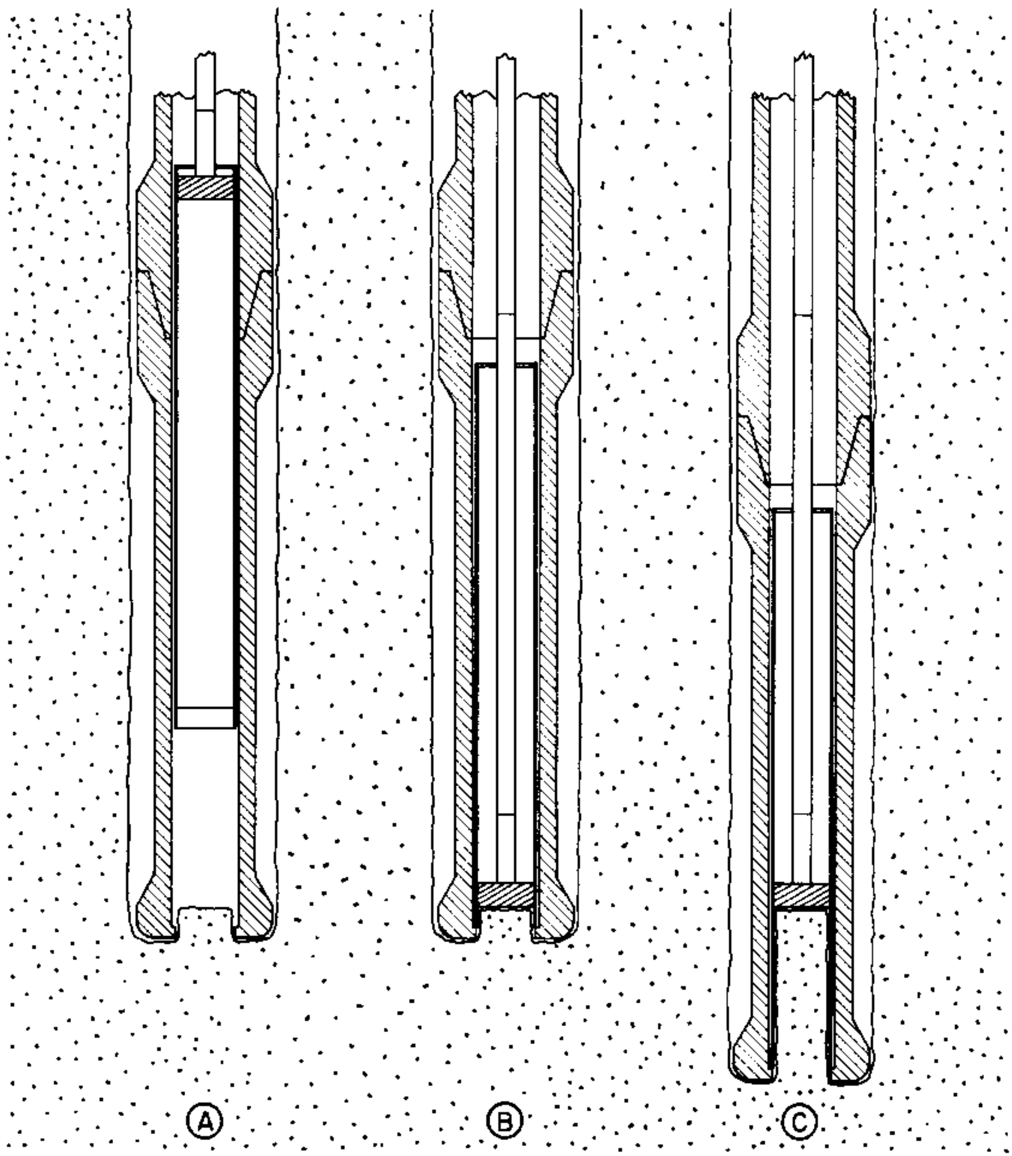
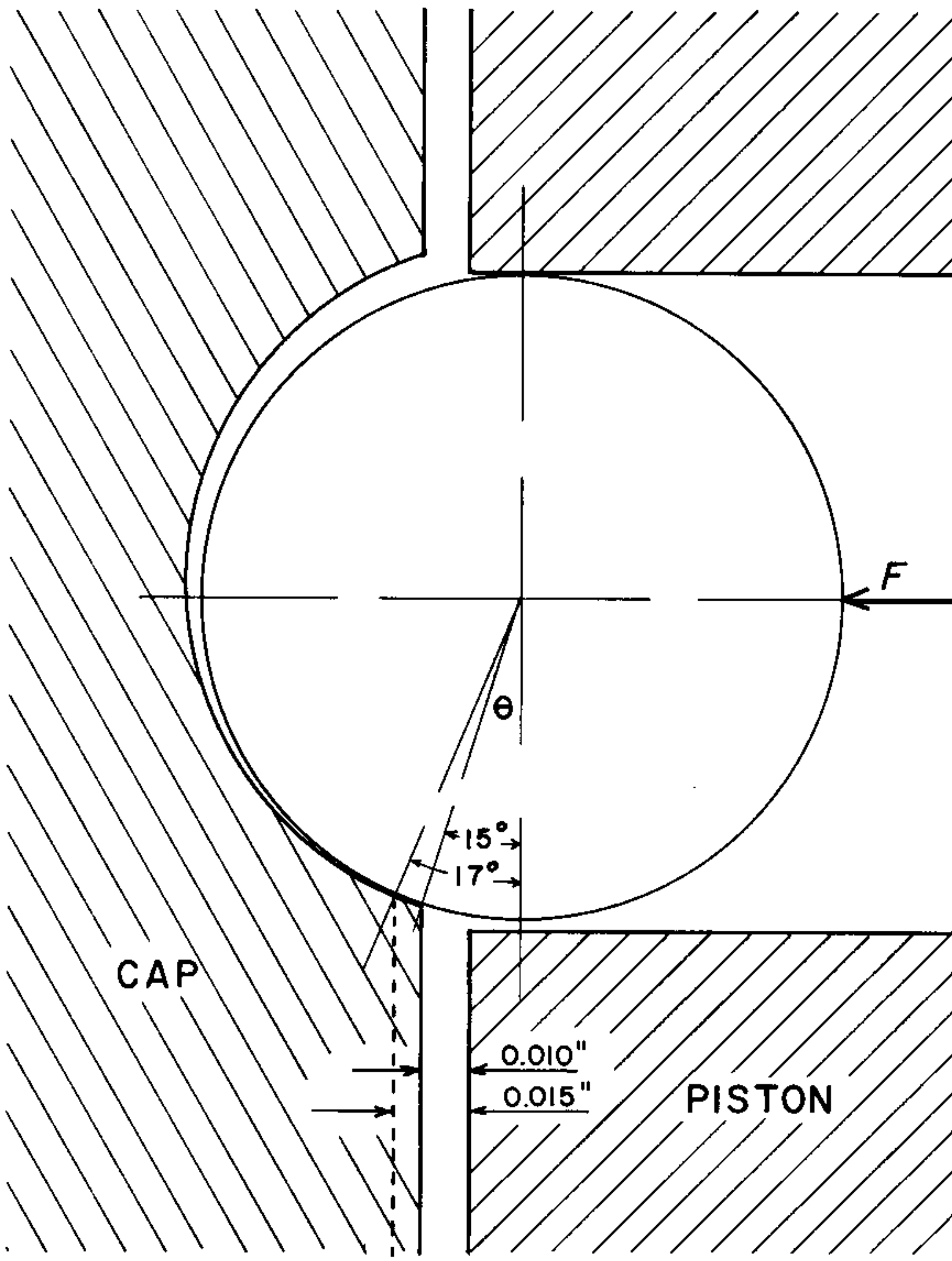


Figure 1. Fixed piston coring.
A: Core barrel being lowered into drill hole by square rod.
B: Piston positioned in bottom of core barrel by square rod.
C: Taking core sample with core barrel being carried over sample and the piston held stationary by the square rod.



F = 12.8 Pounds/Spring (Four Reqd.)

For θ = 15°, Load = 190 Pounds

For θ = 17°, Load = 165 Pounds

Figure 2. Ball lock in piston.

calculations for different inside diameters of the cap spacer.

A 9 inch section of 1 1/2 inch 316 stainless steel square rod with a quick-release connection is pinned to each piston (see Drawing Number CB-02). The square rod has the following functions in the coring operations:

1. To lower core barrels into the drill hole.
2. To unlock the piston from the core barrel cap spacer thus locking the core barrel into the first penetration tube and to push the piston to the bottom of the core barrel.
3. To keep the piston stationary during coring which gives the unit the capability of fixed piston coring.
4. To keep the core barrel from rotating during rotary operation; this is accomplished by the square hole in the top of the core barrel cap.
5. To remove the core barrel from the drill hole once it is full of the sampled material.

The 9 inch section of square rod, attached to a piston, has a female connection which mates with the male pin of the standard square rods. The female section has a spring loaded lever which locks the male pin into it. The lever rotates on a 3/16 inch diameter pin and is normally forced in by the spring to keep the connection together. A release mechanism for the square rod connection will be discussed in Chapter V.

The first square rod for connecting into the 9 inch section in the core barrels will be 6 feet 11 1/2 inches long. There will be eleven standard square rods of 4 feet 6 inches in length. This gives a maximum square rod length as follows:

1 - first square rod -	6.958 feet
11 - standard square rods -	49.500
1 - section in core barrel -	.750
	57.208 feet

The 1 1/2 inch square rod of 316 stainless steel weighs 7.65 pounds per foot of length. Therefore the maximum weight of square rod is 437 pounds. The core barrel with sample will weigh approximately 63 pounds, to give a maximum weight on the top square rod connection of 500 pounds. The sections of the connection with the greatest stress are the section of the lever with the 3/16 inch diameter hole drilled through it and the 3/16 inch diameter pin.

Considering a tensile load of 500 pounds on the critical cross-section of the lever (see Figure 3), the maximum stress at that section is 6400 psi. The maximum stress in the 3/16 inch diameter pin is 9080 psi. Therefore, the square rod connection is an extremely strong connection considering that the ultimate strength

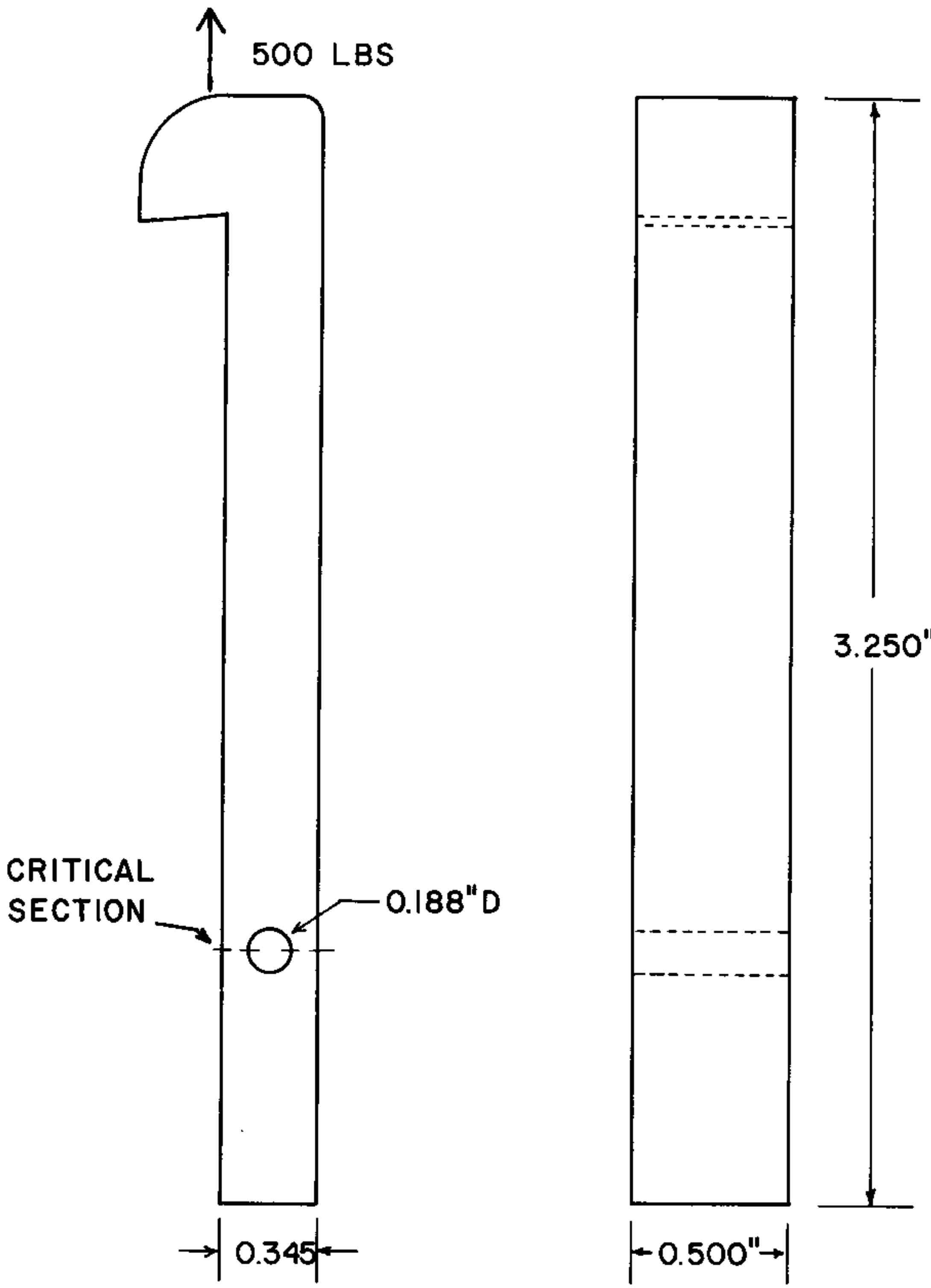


Figure 3. Critical section of square rod connection lever.

of 316 stainless steel is 90,000 psi and its tensile yield strength is 60,000 psi (5).

The spring, which keeps a force on the lever to keep the connection made, is a Lee Spring No. Lc-063G-6, Lee Spring Company, Brooklyn, New York, 11201. It has a wire diameter of .063 inches, free length of 1.250 inches, solid height of .600 inches, and a spring constant of 45 pounds per inch of deflection.

The spring was designed to be deflected .625 inch to release the lever from the male pin. The force required to deflect the spring this amount is 28.1 pounds.

The in-service deflection of the spring is 7/16 inch and therefore the in-service force applied by the spring is 19.7 pounds.

The torsional strength necessary in a connection to keep a core barrel from turning during rotary coring operation is furnished by four 1/4 inch Dowell pins, 5/8 inch long, in the side of the female portion of the connection. The pins mate with a 1/4 inch Keyway slot in the male portion of the connection (see Drawing Number CB-02) keeping the square rod from rotating during coring.

In the bottom three inches of each core barrel is a core catcher (see Drawing Number CB-01). The core catcher is made of spring steel cut into several "leaves". During the downward movement of the core barrel, these "leaves" are forced against the inside of the core barrel. This allows the sample to pass into the barrel during downward movement. Once the piston has released the core barrel from the first penetration tube, the square rod is raised thus picking up the core barrel. This upward movement allows the "leaves" of the core catcher to spring inward cutting off the core at the bottom of the barrel. This secures the core inside the barrel and allows it to be removed from the drill hole and stored.

Once the core has been cut and removed, there is approximately three inches of core remaining in the bottom of the hole. Because of this, the bottom position of the piston is three inches from the bottom of the core barrel. The core barrel cap and piston take an additional three inches of space in the top of the core barrel. Therefore, with a five foot core barrel (including cap), an effective length of 4 feet 6 inches of core sample is obtained per barrel. This corresponds to the 4 feet 6 inches standard penetration tube lengths. The coring unit utilizes eleven core barrels in its operation giving it the capability of taking 49 feet 6 inches of core in 4 feet 6 inch lengths.

If extremely hard material is to be sampled, the coring bit can be adapted to contain core breakers. These core breakers work on the same principle as core catchers except they only break harder cores. The core catcher must still secure them in the barrel for removal from the hole.

CHAPTER III

POWER HEAD

The power head section of the automatic marine corer incorporates the following functions and capabilities. It should:

1. furnish a high torque at stall or low RPM to the drill pipe.
2. supply the thrust load required for the drilling operation and for removal of the drill string after the cores are stored.
3. be reversible for making-up and breaking tool joints.
4. be hydraulically powered.
5. have a shaft sufficiently large enough to allow a 3.5 inch outside diameter and 5 feet long core barrel to be pulled inside it and clear the bottom threads of the drill pipe connection.
6. incorporate a quick release from the drill pipe so as not to be anchored to the penetration tube in case of power failure during coring.
7. have an inlet for water flow down the drill string to wash cuttings out of the drill hole.
8. allow a 1.5 inch square rod to pass through it for positioning and retrieval of the core barrels.

9. produce a maximum speed of 100 RPM of the drill pipe.

After discussions with personnel in the Oceanography Department at Texas A&M University it was decided that the maximum cohesive stress that the coring unit would encounter would vary linearly from 150 to 350 pounds per square foot over a 50 foot drilling depth for a clay-sand material. The average cohesive stress was therefore 250 pounds per square foot. The torque required to break loose a complete drill string if it were stuck in this material over 100% of its 50 foot length would be as follows:

Da - average diameter of drill string = 5 inches

S = cohesive stress

A = area of pipe

Fs = Force required to overcome the cohesive stress

Ts = torque required to produce the force

L - length of drill string = 50 feet

$$A = \frac{Da\ L}{12} \text{ square feet}$$

$$F = SA$$

$$F = \frac{Da\ L\ S}{12}$$

$$F = \frac{(5)\ (5)\ (250)}{12}$$

F = 16,375 pounds

$$T = \frac{F\ (Da)}{12\ (2)}$$

$$T = \frac{16,375\ (5)}{12\ (2)}$$

$$\underline{T = 3,410 \text{ foot-pounds}}$$

After research into a hydraulic motor and pump unit with acceptable gear reducing to produce this amount of torque, it was found to require approximately a 100 horsepower electric motor to drive the hydraulic pump to put out sufficient flow for the hydraulic motor. Since space requirements were very stringent in designing the coring unit, the space required to mount the electric motor and hydraulic pump was unacceptable. The space available to mount a power package unit consisting of an electric motor and two hydraulic pumps (to be discussed in Chapter VII) limited the electric motor to a ten horsepower maximum. Of this ten horsepower, only a portion would be available to power the hydraulic pump for the hydraulic motor on the power head.

A Sundstrand Hydrostatic Transmission System Model 21, Sundstrand Corporation, LaSalle, Illinois, was chosen for the power head (see Figures 4 and 5). The system consists of a variable displacement pump and a constant displacement motor with all controls. The pump requires a four horsepower input to produce sufficient flow for the motor to produce 200 foot-pounds of

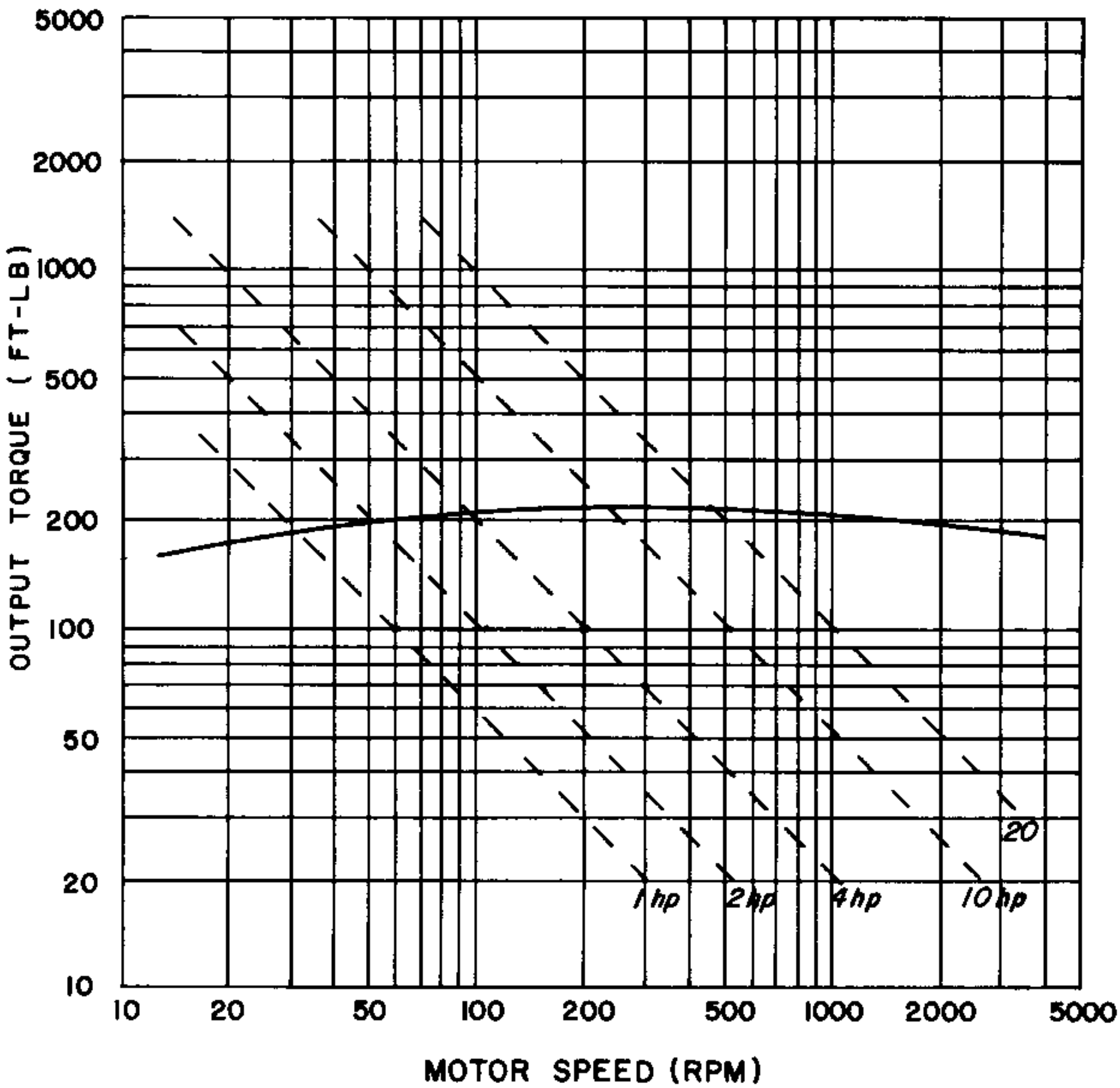


Figure 4. Sundstrand motor torque vs rpm.

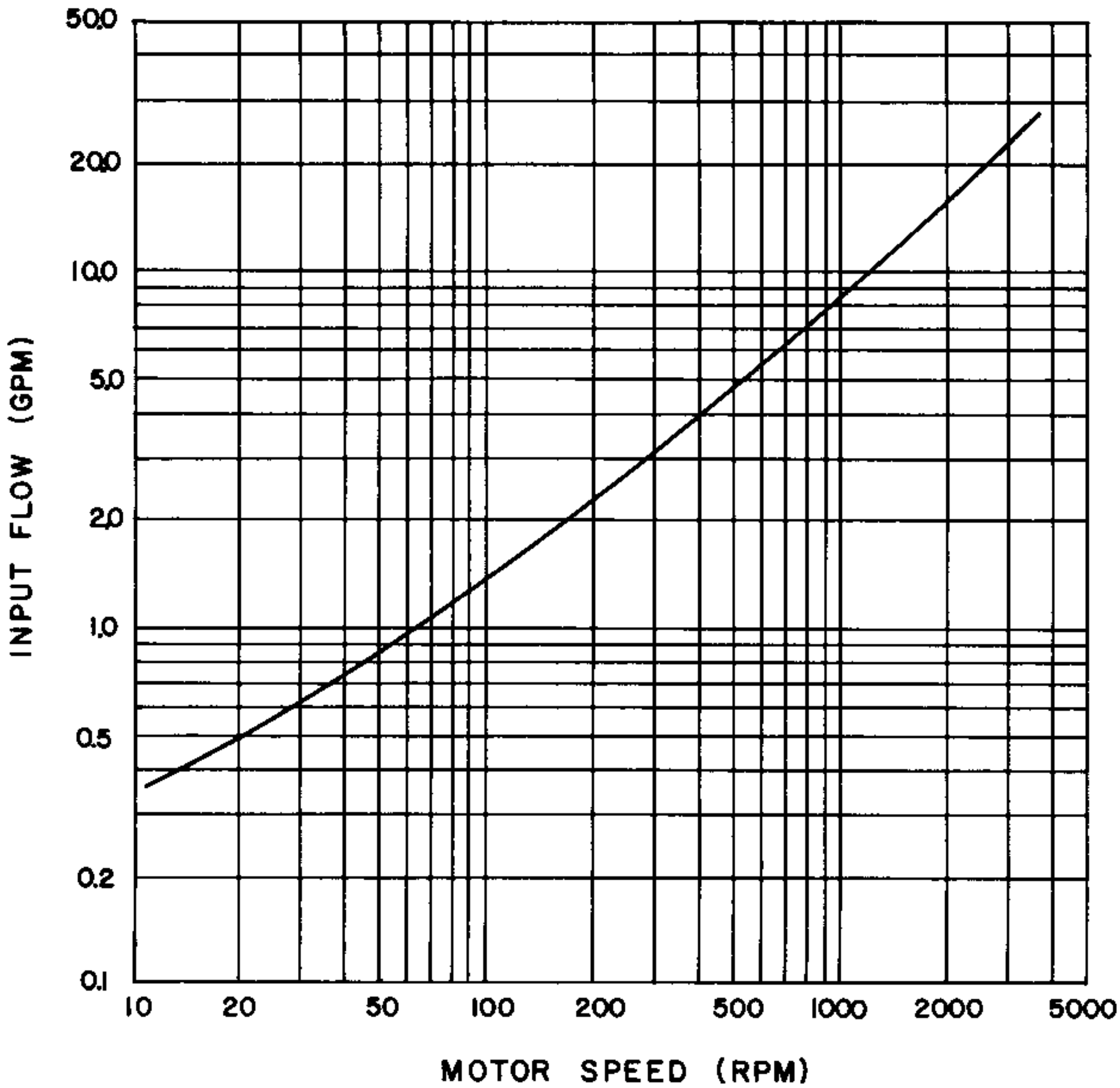


Figure 5. Sundstrand motor input flow vs rpm

torque below 20 RPM and 48 foot-pounds of torque at 500 RPM. With a 5 to 1 gear reduction designed into the power head, 1,000 foot-pounds of torque would be applied to the drill string at stall or a maximum speed of 100 RPM could be obtained at low torque. The 1,000 foot-pounds of torque produced is much less than the 3,410 required to break loose a complete drill string if stuck over 100% of its 50 foot length. This 100% stick condition was considered by personnel in the Oceanography Department to be highly unlikely.

Not included so far is the thrust available to help unstick the drill string. For drilling in harder material, 5,000 pounds of thrust should be available to the drill bit. This thrust will be provided with a hydraulic winch with steel cable connections on the housing of the power head (see Drawing Number AMC-01). The winch is a Gearmatic Hydraulic Winch Model 6-35 with a single direction brake, Gearmatic Company, Ltd., North Surrey, British Columbia, Canada (see Figure 6). There will be one wrap of 5/16 inch cable on the drum giving essentially a bare drum for line speed and pull computations. At a pressure of 1,350 psi, the winch will produce 6,000 pounds of pull. This therefore gives the power head the capability of producing 6,000 pounds of thrust to the drill bit and 6,000 pounds of pull to remove drill pipe from the hole. With this amount of pull and torque produced by the power head,

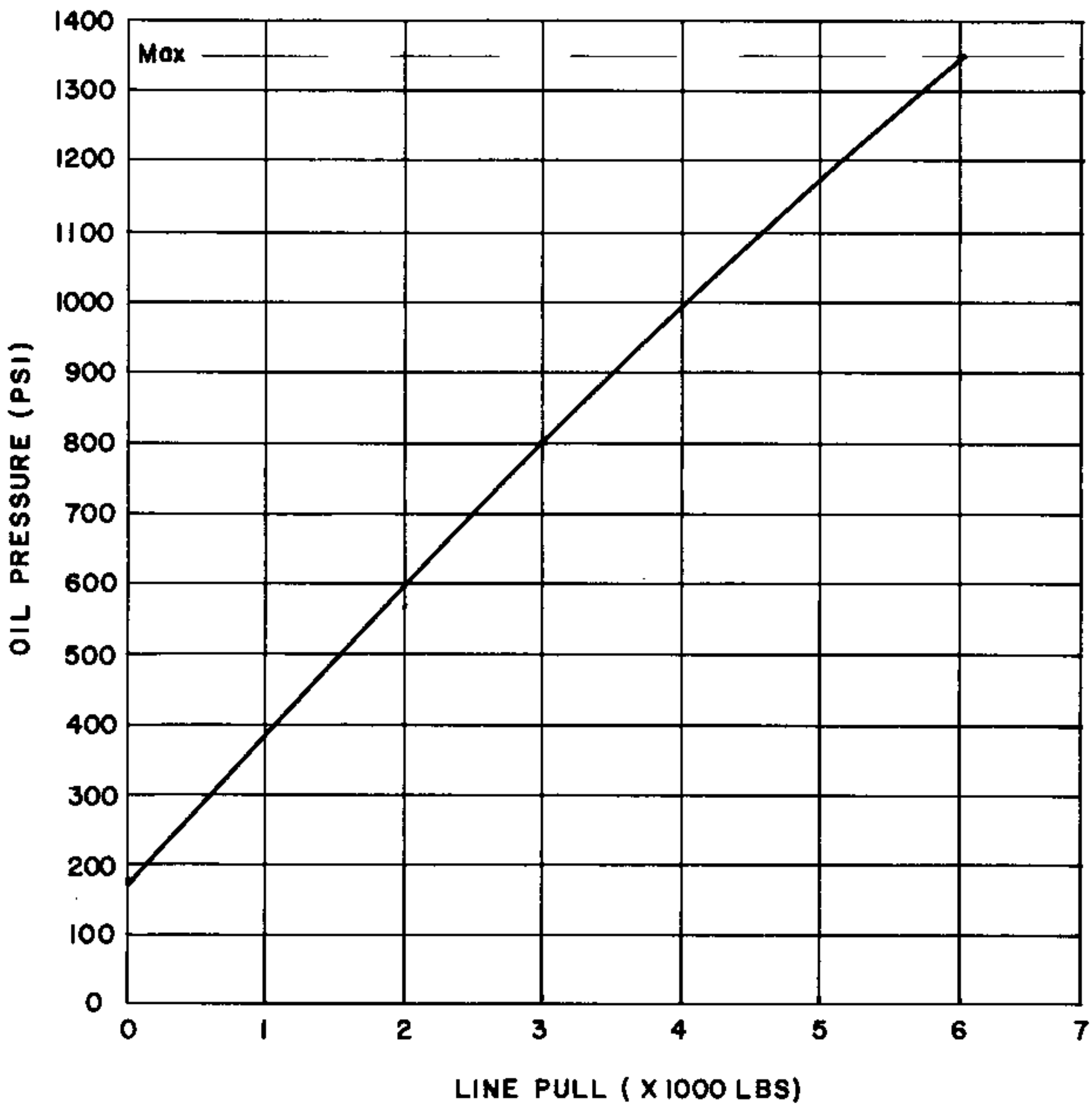


Figure 6. Gearmatic winch load curve (at 5,000 psi).

the likelihood of not being able to retrieve the drill string after coring was considered to be very slight.

The five to one reduction in the power head was accomplished by using a 12 tooth, 3 inch pitch diameter pinion and a 60 tooth, 15 inch pitch diameter gear (see Drawing Number PH-01). The gears were designed to transmit 1,000 foot-pounds of torque at a maximum of 100 RPM using standard design procedures (5). Each gear has a pressure angle of 20° and a face width of 2.5 inches. The tangential load produced by the gears is given as follows:

$$Ft = \frac{33,000\ HP}{\pi\ Dn}$$

D - Diameter of gear = 1.25

n - speed of gear = 100 RPM

$$HP = \frac{T\ n}{63,000}$$

T = torque in inch-pounds

$$HP = \frac{12\ (1,000)(100)}{63,000}$$

HP = 19 horsepower

$$Ft = \frac{33,000\ (19)}{(1.25)(100)}$$

<u>Ft = 1,600 pounds</u>

The radial load produced for 20° pressure angle gears is therefore:

$Fr = Ft \tan 20^{o}$

$Fr = 1,600\ (.364)$

<u>Fr = 582 pounds</u>

The mainshaft bearings for the power head were designed on the assumption that one bearing would carry all the radial load of 582 pounds. The bearings were designed also for a thrust load of 6,000 pounds and a life of 3,000 hours at 100 RPM. Standard design procedures were used (9) and two type TS Timken Tapered Roller Bearings were chosen for the service. Specifications on the bearings are as follows:

Bore - 5 inches

Outside diameter - 7 3/16 inches

Width - 1 5/8 inches

Rated thrust at 500 RPM - 6,700 pounds

Rated radial load at 500 RPM - 11,200 pounds

The pinion shaft bearings were then designed using the procedures set forth in reference 8. The bearings were designed for a radial load of 582 pounds at 500 RPM, a negligible thrust load, a life of 3,000 hours, and on the assumption that one bearing carries all the load. Two Number 3209 New Departure ball bearings with a 1 3/4 inch bore were chosen for the service.

The case and cover for the power head were designed using standard job shop techniques. They are to be made of mild steel plate and welded together using current ASME standards (see Drawing Number PH-01). The only strength requirement for the case was being able to withstand the 6,000 pounds of thrust placed on the drill string. The case will be filled with a light gear oil and pressurized with nitrogen through a demand regulator to maintain a five psi pressure differential between the inside and outside of the case. Sufficient "pop" valves will be installed to prevent rupture of the case when raising the unit to the surface.

Two sleeves, 20 inches long, 4.5 inches outside diameter, and 3.5 inches inside diameter, are attached to the case with 1 inch steel plate. These sleeves slide on two 11 feet 5 1/2 inch long guides which are fixed into tubes welded to the top and bottom plates of the coring unit. The tubes are made of 3 inch schedule eighty, standard steel pipe with a 3.500 inch outside diameter and a .300 inch wall thickness. If the guides were considered to have pinned ends with the maximum load occurring at the center of their 11 feet 5 1/2 inch length, then the maximum normal shear stress in each guide would be 13,200 psi and the maximum deflection would be 0.198 inch (7).

Four stop positions of the power head are used in the coring operation (see Drawing Number AMC-01). They are numbered from the bottom to the top of the coring unit as follows:

1. Stop No. 1 - Storage and bottom position of the power head for making and breaking drill string connections.
2. Stop No. 2 - An intermediate stop used for making and breaking the bottom connection when placing and removing standard drill pipe sections; also used for setting the core barrel and piston in preparation for taking a core sample.
3. Stop No. 3 - An intermediate stop used for making and breaking the top connection when placing and removing drill pipe sections.
4. Stop No. 4 - Top stop for the power head, insures that the lower sub of the power head is clear when drill pipe sections and core barrels are handled.

Stop numbers 1 and 4 are accomplished by the sleeve attached to the power head shouldering against the tubes to which the power head guides are fixed. They are the lowest and highest positions of the power head. Stop numbers 2 and 3, located 16 1/2 and 4 inches respectfully below stop number 4, are accomplished by using two 1 inch bore, 3 3/4 inch stroke hydraulic cylinders attached to the side of the power head case. The rod of these cylinders is attached to a 1.500 inch diameter pin which slides through two "dog ear" plates, two inches apart and one inch thick with 1.500 inch diameter holes, welded to the power head sleeves. The sliding stop sleeves are located on power head stop guides at an angle of 25° and a distance of 6 3/4 inches from the power head guides. The power head stop guides, which extend from the middle plate to top plate of the coring unit, are made of schedule 80, 316 stainless steel, pipe with an outside diameter of 2.375 inch. The stop sleeves are made of 316 stainless steel schedule 80 pipe with an outside diameter of 3.500 inches. Two dowel pins, positioned in the sliding sleeves, fit in a slot on the stop guides to keep the sleeves from rotating out of position. Welded to the stop sleeves are pieces of 1 inch plate, 2 1/2 by 4 inches. These slide between the "dog ears" welded to the power head sleeves. Three 3 inch lengths of 3 inch pipe are welded to each stop guide to keep the sliding stop sleeves in the correct position. With the power head stop cylinders stroked in, the pieces of 1 inch plate slide through the slots between the "dog ears" on the power head sleeves allowing the power head to move past the stops. With the cylinders stroked out, the 1 inch plates on the sliding stop sleeves strike the 1.500 inch diameter pin in the "dog ears" and stop the power head at the appropriate position. The sliding stop sleeves allow the power head to be stopped at the same desired position on upward or downward movement.

A quick release mechanism is incorporated into the lower shaft-sub of the power head (see Drawing Number PH-02) so that, in the event of an emergency, the unit may be released from the drill string and returned to the ocean surface. Two hydraulic cylinders (3/4 inch bore with 1 3/4 inch stroke) are attached to the bottom of the power head case to keep a circular plate forced downward. This allows a retainer spring to hold a sliding ball retainer in position in the connection to the lower shaft-sub. The two hydraulic cylinders were designed with a pressure sensing, timed switch. Once hydraulic power is lost, the switch will open the valve to the cylinders after 30 minutes has elapsed thus releasing the pressure on the cylinders. In the event of pressure failure to the two hydraulic cylinders, two fabricated spring loaded cylinders will retract the circular plate, thereby lifting the steel ball retainer. The balls will then be released from a groove in the lower shaft-sub and separation will occur from the drill string. The required drilling torque is transmitted through the quick release mechanism by interlocking teeth machined on the mating sub ends. Machined on the bottom of the lower sub is 3 inches of 4 1/2 inch API internal flush threads for mating with the box end of the drill pipe sections. The thrust is transmitted through the balls locked in the groove of the lower shaft-sub.

The springs in the spring-loaded cylinders were designed using standard procedures (5) to maintain a constant upward force of 80 pounds on the hydraulic cylinders. The ball retainer spring was designed, using the same procedures, to maintain a force of 20 pounds downward on the retainer. In the event of hydraulic failure, the upward force will be four times greater than the downward force, thereby insuring that the unit be released from the drill string. The specifications for the springs are as follows:

A. Retainer Spring - one

1. Material ASTM A313 stainless
2. Wire diameter - .250 inch
3. Number of active coils - 6
4. Free length - 7 1/2 inches
5. Mean diameter - 5.500 inches
6. Spring constant - 5 pounds per inch
7. Solid height - 2 inches
8. Squared and ground ends

B. Release Springs - two

1. Material ASTM A313 stainless
2. Wire diameter - .125 inch
3. Number of active coils - 16

4. Free length - 9 inches

5. Mean diameter - 1.750 inches

6. Spring constant - 5 pounds per inch

7. Solid height - 2.250 inches

8. Squared and ground ends

The upper part of the power head is made of 5 inch standard steel pipe and has a 1 1/2 inch nipple welded to it. Attached to the nipple is an electrically driven water pump which will produce approximately 20 gallons per minute of flow at 200 psi pressure down the drill line for washing cuttings out of the drill hole. In the top of the upper sleeve of the power head is a 3 inch outside diameter by 3 inch long nylon bushing with a 1.500 inch square hole in it. The bushing seals around the 1.500 inch square rod which passes through it. The leakage between the bushing and square rod was considered insignificant when compared to the total flow required down the drill line.

Also attached to the top of the upper sleeve of the power head is a 1/2 inch bore by 4 inch stroke hydraulic cylinder used for clamping the square rod extending out of the power head. The cylinder is pinned to a lever arm which rotates a shaft with right and left hand "jackscrew" threads. Two jaws are threaded on the shaft. A counterclockwise rotation of the shaft will cause the jaws to be moved toward each other thus clamping the square rod.

The inside diameter of the lower shaft-sub of the power head is 3.750 inches and that of the upper part is 5.0 inches. The over-all length of the power head is 5 feet 4 1/4 inches thus allowing a 5 foot section of core barrel to be pulled inside by the square rod.

CHAPTER IV

TUBE STORAGE AND LEGS

The initial design of the storage compartments for the penetrations tubes (drill pipe) and core barrels was to have consisted of two separate spring-loaded magazines which would have moved the tubes into position in preparation for coring. The physical size of the magazines was too large to be contained in a compact unit and still be moved to give clearance for the power head movement which was initially to be located in the center of the unit. A hydraulically operated magazine was considered but the stroke required for hydraulic cylinders made the cylinders too long for containment within the unit.

The center line of the drill string and power head was therefore moved 23 inches off center of the coring unit and the drill pipe stored around the inside of the unit. All core barrels were to be stored in front of the corresponding drill pipes in the order to be utilized. A core barrel would be placed in the drill line and then pulled inside the power head. Then the stored drill pipe behind the core barrel just removed would be placed in the line and a sample cored. The full core barrel would be removed and stored in the position that the drill pipe had occupied. Once the complete coring operation was finished, the drill pipes would then be stored in front of the core barrels. This interchange of storage positions would have necessitated the design of a clip mechanism to be strong enough to hold the heavier drill pipe sections but not so strong as to crush the core barrel when securing them. The design was also further complicated by the fact that the core barrels had an outside diameter of 3.500 inches and that of the drill pipes is 4.500 inches. For these reasons the core barrels are stored behind the drill pipes and off-set so that the first core barrel to be utilized is stored alone in a compartment. This gave twelve storage compartments with the last compartment containing only the last section of drill pipe to be used. The drill pipes are stored on the same 23 inch radius as that of the drill string location from the center of the unit.

There are eleven storage compartments for the drill pipe with 22 1/2° angles between the centers of each compartment. Each drill pipe is held in place by two pairs of spring loaded chocks. The core barrels are stored directly behind the drill pipe on a 29 inch radius (see Drawing Number AMC-02). The space between the spring-loaded chocks is wide enough to allow a 3.500 inch outside diameter core barrel to pass through for storing in two clip retainers made of spring steel.

The first storage compartment is located at an angle of 45° fron the drill string center line and has only the first core barrel stored in it. Subsequent storage compartments are at angles of 22 1/2° with a drill pipe and core barrel stored in them. The last storage compartment contains only the eleventh drill pipe section. In the coring operation, the first core barrel is placed in the drill line, connected to the square rod, and pulled inside the power head. It must, therefore, be stored alone to be removed from its compartment. The first penetration tube (first drill pipe section with drill bit) is then placed in the drill line to be made-up to the power head, have the core barrel set into it, and core the first sample. This leaves the second storage position with only a core barrel stored in it, clear for removal, and ready to be utilized in taking the second core sample after the first core barrel, full of core, has been removed from the drill hole and is stored in its original position.

Main supports for the storage compartments were designed using 1 1/2 inch schedule 80 steel pipe, 6 feet long, extending from the bottom plate to the middle plate of the coring unit and on a 31 inch radius from the center of the unit. Two sections of 1/2 inch steel plate 3 1/2 inches by 5 inches long are welded to each main support. The steel plates extend toward the center of the coring unit and are supported on the ends with 1 inch schedule 80 steel pipe at a 24 1/2 inch radius from the center of the unit. These plates form the compartments for storage fo the tubes. Welded to the end of each 1/2 inch steel plate are sections of 1/4 inch steel plate to form retainers for the spring loaded chocks which keep the drill pipes in their storage positions (see Drawing Number HD-01). The chocks are made of a 3 inch by 3 inch section of steel with a radius milled on one face conforming to the outside radius of the drill pipes. Since there are ten standard drill pipe sections with an outside diameter of 4 1/2 inches and only the first drill pipe section with a diameter of 4 3/4 inches, all chocks were designed with a 2 1/4 inch radius milled on a face. The difference in radii of the first drill pipe and chocks securing it was not considered significant enough to design separate chocks for only one section of pipe since the chocks will secure this section of pipe also.

Two stainless steel Lee Springs, number LC-125M-3, are used to force the chocks against the pipe. The springs have an outside diameter of 1.095 inches, a free length of 2 1/4 inches, a wire diameter of .125 inch, and a spring constant of 69 pounds per inch. The springs were designed to have an in-service deflection of .85 inch giving a force of 58.5 pounds per spring. With two springs a force of 117 pounds will be applied to the drill pipes at four different points since two pairs of chocks are used to secure each section of pipe. The spring steel clip retainers for storing the core barrels are bolted to a section of 1/2 inch plate. The plate is hinged and pinned to the main supports of the storage compartments. Once the plates are unpinned they swing open to allow easy access to the core barrels.

In their storage positions, (see Drawing Number AMC-01), the core barrels and first drill string rest on 1/2 inch plate which is 5 inches above the bottom plate. The 4 feet 6 inch standard sections of pipe rest on sections of 1/2 inch plate welded to the 1 inch steel pipe supports. These plates are 11 inches above the bottom plate. The clearance between the drill pipes and square rod sections in the core barrels and the middle plate of the coring unit is 1 inch. This gives a height of 6 feet 2 1/2 inches to the top of the middle plate. It is an additional 5 feet 5 1/2 inches to the top of the top plate of the coring unit to give an 11 feet 8 inches overall height.

The three main plates of the coring unit are to be octagonal in shape with a 6 foot side to side distance. The main supports for the unit will consist of sections of used 4 1/2 inch standard drill pipe which will be left over from the fabrication of the ten standard drill pipe sections discussed in Chapter II. Eight of these sections will be utilized and will extend over the entire height of the unit.

The self-leveling legs for the coring unit are attached to four sides of the bottom plate (see Drawing Number AMC-02). They were designed using 4 inch by 1 5/8 inch standard steel channel welded to sections of schedule 80, 3 1/2 inch, standard steel pipe. Alternating sections of like pipe are welded to the bottom plate and to standard 8 inch by 4 inch "I" beams. The sections of 3 1/2 inch pipe are hinged together with a 33 inch length of 3 1/4 inch outside diameter steel tubing with .375 inch wall thickness. The center of this hinge is located 2 inches outside and 1/2 inch up from the bottom plate. The legs are five feet long with a 2 inch diameter pin in the end for mounting a 24 inch diameter pad and the rod end of a hydraulic cylinder. Four hydraulic cylinders with a 4 inch bore were used for raising and lowering of the legs. They are automatically controlled to level the unit on slopes of up to 15°. The cylinders are clevis mounted on 2 inch diameter pins with a solid height from pin to pin of 3 feet 8 inches and a stroke of 2 feet 5 inches. The clevis end of the cylinder is mounted 17 inches above the bottom plate and 2 1/4 inches in from the side of the plate. The leg is stored in the up position with the cylinder stroked in. The 2 foot 5 inch stroke of the cylinder will move the leg through an angle of 125^{o} allowing the legs to extend three feet below the unit.

The legs were designed to carry a vertical load of 2,000 pounds each using standard procedures and theory (5, 7, and 10). The maximum forces on the legs were found to occur when the legs were in their most extended position. These forces were a compressive force of 10,460 pounds on the cylinder and a tensile force of 9,080 pounds on the leg. The 4 inch bore cylinder will produce 12,560 pounds of force at 1,000 psi pressure. A 2 1/8 inch diameter rod was used in the cylinder. The rod was checked for buckling for a 6 foot length and the critical force was found to be 57,000 pounds. Thus the design of the cylinder was sufficient for the service intended.

A 24 inch diameter pad made of one inch steel plate is pinned to the end of each leg. The pads are used for stabilization of the unit on the bottom. Triangular shaped 1/2 inch plates are welded to the bottom of the pads to penetrate into the ocean floor. These pads and the 1/2 inch plates keep the unit stable during rotary operation in coring. Two extension retainer springs are connected to each pad and leg. These springs aid in keeping the pads in their stored positions when the legs are in their raised positions.

CHAPTER V

TUBE HANDLING DEVICE AND PIPE SLIPS

A handling device was designed for the coring unit to remove core barrels and drill pipes from their storage positions, place them in the drill line in preparation for coring, and store them in their original positions once the coring operation is complete. The device has the following characteristics and capabilities. It:

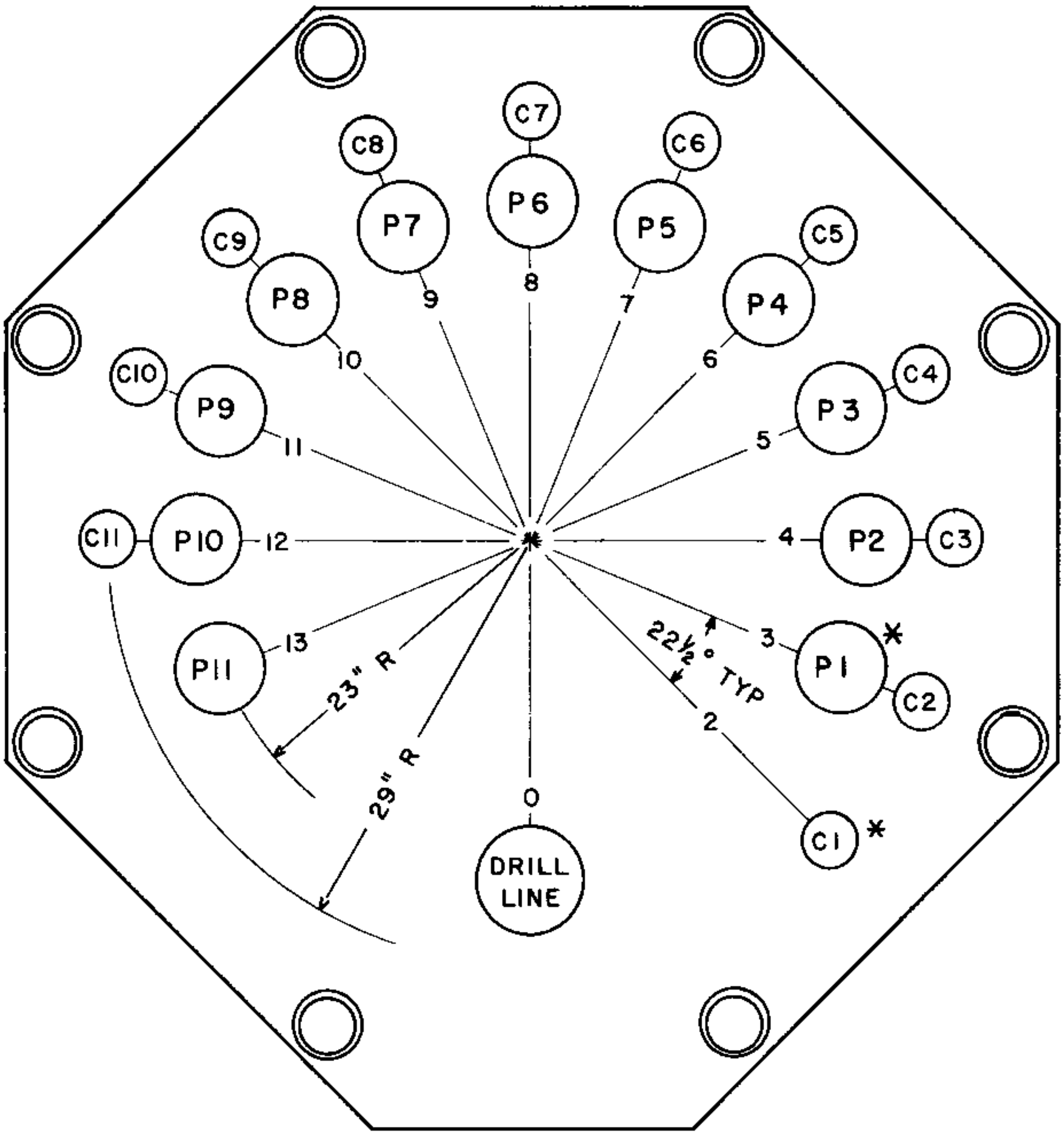
1. is located in the center of the coring unit in the tube storage section and rotates about that point.
2. extends to a core barrel or drill pipe position and clamps either one with the same clamping device.
3. retracts to remove a core barrel or drill pipe from its storage position and indexes them to a position concentric with the drill line.
4. contains a square rod clamp and connection release for handling the square rod section in the core barrel.
5. secures drill pipe sections to make-up and break the connection to the power head.
6. guides the core barrel when it is being pulled inside the power head.

7. indexes to be clear from the power head on its downward stroke.

8. removes core barrels and drill pipes from the drill line after coring and indexes them to be stored in their original positions.

The main section of the handling device is welded to a 3.5 inch outside diameter steel pipe (see Drawing Number AMC-01). The pipe mounts between an indexing mechanism on the bottom plate and a 4-bolt flange bearing mounted on the middle plate of the unit. The bearing takes a 2 7/16 inch diameter shaft which is welded to the pipe. It is indexed by the mechanism in 22 1/2° steps, clockwise or counterclockwise. This gives 16 positions for the handling device. Twelve positions are used for tube storage compartments and one for the drill string center. The remaining three positions were utilized for clearance of the power head during its movement. The positions are numbered starting with the drill line as number "0" and progressing counterclockwise to position number 15 (see Figure 7). The first core barrel is stored alone in position number 2 and the eleventh drill pipe section is stored alone in position number 13.

The indexing of the handling device was accomplished by using a Geneva type indexer. It consists of a 12 inch diameter "gear"



✱ – First Core Barrel & Drill Pipe Storage Positions

Figure 7. Tube storage and handler positions.

with sixteen 1/2 inch slots and is keyed to a shaft which is flanged to the pipe of the handling device. A 1/2 inch pin rotates on a radius of 1.300 inches, engages into a slot on the indexer, and rotates it 22 1/2° for one rotation of the pin (see Drawings Number IM-01, IM-02, and IM-03). The pin is attached to an 8 inch pitch diameter spur gear driven by a hydraulic motor, Torqmotor MAB 08 series, TRW Ross Gear Division, Lafayette, Indiana. Since the indexing device only operates when the power head is not functioning, the same hydraulic pump that furnishes power for the power head can be utilized to operate this motor through adequate throttling and pressure regulating. With 2 gallons per minute of flow at 800 psi pressure, the Torqmotor will produce 602 inch-pounds of torque at 60 revolutions per minute. With the 4 to 1 gear reduction the 1/2 inch pin will rotate at 15 revolutions per minute. The pin has an engagement angle of 120° with the indexer, thereby giving it 240° of dwell movement. During this dwell, a 1 3/4 inch diameter slotted shaft fits a similar radius between the 1/2 inch slots on the indexer to keep it stationary while the pin is not engaged in a slot. Electrical proximity switches are used on the 8 inch diameter spur gear to stop and start the hydraulic motor to control the number of revolutions desired.

The bearings used on the 2 inch and 8 inch spur gears were

New Departure Bearings Number 3L08 with a bore of 1.575 inches, an outside diameter of 2.677 inches, and a width of 1.591 inches. Two such bearings were utilized for each gear. The shaft to which the indexer is keyed utilized two New Departure Bearings Number 3213 with a bore of 2.559 inches, an outside diameter of 4.720 inches, and a width of .906 inch. The case of the mechanism was designed using steel plates and pipe. It is filled with a light gear oil and pressurized with nitrogen through a demand regulator to maintain a 5 psi differential between the inside and outside of the case.

The handling device consists of a 1 inch bore hydraulic cylinder with a 13 3/4 inch stroke (see Drawing Number AMC-01). This cylinder extends the clamps mounted on a one inch steel plate to either the pipe or core barrel storage radius. The one inch plate is attached to two 1 1/2 inch diameter steel rods 18 inches long. The rods are guided in 2 1/2 inch outside diameter, 1 1/2 inch inside diameter steel tubes which are welded and braced to the 3.5 inch outside diameter pipe of the handler. These rods carry the weight of the handler and drill pipe sections. A 1/2 inch bore cylinder, with a 2 1/2 inch stroke, moves a pin into position to stop the extension cylinder on a 7 inch stroke when removing or storing drill pipe sections or placing tubes in the drill line. When the cylinder is not activated, the extension cylinder will stroke 13 inches out to remove or store a core barrel.

The two sets of clamps employed with the handling device were designed to clamp both 3 1/2 inch diameter core barrels and the 4 1/2 inch outside diameter of the drill pipes (see Drawing Number HD-01). The main section of the clamp is 6 inches long with a 2 1/4 inch radius milled on its clamping face which corresponds to the outside radius of the drill pipe sections. Clamping action was accomplished by using a 3/4 inch bore hydraulic cylinder with 1 3/4 inch stroke on each clamp. When the cylinder is stroked in, it engages a linkage system which forces the clamps against the drill pipe. An air ballast is used in the hydraulic lines to these cylinders. When the cylinders are stroked in to a clamp position, the valves are closed to lock the cylinders into place. The air in the ballast will be pressurized to 1,000 psi and for small leakages of fluid, the decrease in pressure against the cylinders will be very small. This locking of the cylinders while handling sections of tube is necessary to insure that the clamps are not released and the tubes dropped in the event of a short power failure. The 3/4 inch bore cylinders produce 331 pounds of pull at 1,000 psi pressure and the linkage system multiplies this force so that opposing forces of 2,500 pounds will be placed on the drill pipe by each set of two clamps. This force is required to secure the drill pipe when making-up and breaking the connection to the power head.

Each clamp set has two opposing spring loaded steel blocks which fit inside the milled face of the clamp. These blocks are utilized when clamping a core barrel since the force produced by the clamp would crush the plastic barrels if they could reach the smaller diameter. Therefore with the clamps engaged, the steel blocks are forced against the core barrel to secure them for handling. Four Lee Springs number LC-067J-7, Lee Spring Company, Brooklyn, New York, are utilized in each block. They have a wire diameter of .067 inches, an outside diameter of .720 inches, a solid height of .606 inches, a free length of 2 inches, and a spring constant of 15.5 pounds per inch. With a .85 inch in-service deflection, the springs will produce a force of 52.7 pounds to force the blocks against the core barrels in each set of clamps. Each block is retained in the clamp face by two 1/4 inch set screws. When clamping drill pipes, the blocks are forced in thereby allowing the main portion of the clamp to contact the pipe.

Attached to the top of the 3.5 inch diameter pipe of the handling device is a square rod clamp and connection release mechanism (Square Rod Clamp and Release Number 1). This mechanism is utilized to secure the square rod extension in the core barrel and release the connection when taking a full core barrel from the drill line. It consists of a 3/4 inch bore hydraulic cylinder with a 12 inch stroke to move a 3/4 inch bore, 1 inch stroke clamping cylinder and a 3/4 inch bore, 1 inch stroke release cylinder into a position concentric with the drill string centerline. The device is guided by a 1 inch diameter steel rod inside a 2 inch outside diameter steel tube. The steel tube is welded to the 3.5 inch diameter pipe (see Drawing Number HD-01). The 3/4 inch bore clamping cylinder is stroked 1 inch out and actuates to an over center linkage system to engage the clamp on the 1 1/2 inch square rod to secure it. Another 3/4 inch bore cylinder is positioned 5 inches below the top of the square rod extension in the core barrel and facing the bottom portion of the lever in the square rod connection. When this cylinder is stroked 1 inch out, the rod of the cylinder contacts the lever, depresses the spring behind it, and rotates the top of the lever out to disengage it from the male pin of the connection. The square rod joint can then be pulled apart thereby breaking the connection. The clamp and release mechanism is only utilized when a core barrel is placed in or ready to be removed from the drill line. Otherwise it remains in its stored position to stay clear when handling drill pipes or core barrels.

During coring, the top of a drill pipe section is drilled down by the power head to a position 4 1/2 inches above the bottom plate. At this point, a set of hydraulic pipe slips clamps the 5 7/8 diameter of the box end of the drill pipe section. Another set of breaking slips clamps to the 5 7/8 diameter sub of the power head and another cylinder rotates these slips to break the joint. The breaking slips were needed because the power head places 1,000 foot-pounds of torque on the joints in make-up and drilling, which would not be sufficient to break the joint. Therefore, a set of breaking slips were designed to produce 1,500 foot-pounds of torque for breaking the joint.

The pipe slips utilize two three inch bore hydraulic cylinders with a two inch stroke. The cylinders oppose each other and move two steel blocks against the drill pipe (see Drawing Number PS-01). Each cylinder will produce 7,068 pounds of force at 1,000 psi pressure to secure the drill pipe and keep it from rotating when breaking the joint. The steel blocks are 4 inches high and 6 inches wide with a 2 15/16 inch radius milled on one face to conform to the outside diameter of the box end of a drill pipe section. Attached to this face are pipe slip inserts with hardened teeth to aid in gripping the drill pipes. A steel block is pinned to the rod of each cylinder and guided on each side by 5 inch long sections of one inch plate welded to the bottom plate.

A set of pipe breaker slips is mounted on a moveable 1/2 inch steel plate. This plate rotates about the drill string center line on a stationary 1/2 inch plate which is mounted 1/2 inch above the pipe slips (see Drawing Number PS-01). A 3 inch bore cylinder with 1 3/4 inch stroke actuates a linkage system to force the clamps against the 5 7/8 outside diameter of the power head sub. The faces of the clamps contacting the sub have a 2 15/16 inch radius milled on them with pipe slip inserts attached to them. The 3 inch bore cylinder produces a force of 7,068 pounds at 1,000 psi pressure. With the force multiplication of the linkage system, the same force will be placed on the sub by the opposing clamps. A 1 1/2 inch bore cylinder with a 6 inch stroke is pinned to the breaking slips mounting plate 11 inches from the drill string center line. This cylinder will produce 1,767 pounds of force at 1,000 psi pressure to produce up to 1,620 foot-pounds of torque on the drill string connection when the breaking slips are engaged. When this cylinder is stroked 6 inches out, it rotates the mounting plate of the breaker slips 30° counterclockwise. This rotates the breaker slips and the sub of the power head while the pipe slips below keep the drill string stationary. The breaker slip clamps are then released and the breaker cylinder retracted and the operation performed again to insure that the connection is sufficiently broken for the power head to rotate the connection apart with its own power.

CHAPTER VI

SQUARE ROD MAGAZINE

The 1 1/2 inch square rods utilized in the coring unit are stored in a separate magazine above the power head. The magazine is attached to two 16 inch long sleeves that slide on the power head guides (see Drawing Number AMC-01). In the coring unit's stored position, the power head is down against the bottom tubes of the guides. The square rod magazine is down with its sleeves shouldered against the sleeves of the power head. Just prior to the coring operation, the power head is raised to its top position carrying with it the square rod magazine. Two square rod magazine locking cylinders, of 1 1/2 inch bore and 4 inch stroke, are utilized to move 1 inch diameter pins through holes in a 1 inch steel plate attached to the square rod magazine sleeves, (see Drawing Number AMC-01). This locks the square rod magazine in the up position and its sleeves form the top stop for the power head (Power Head Stop Number 4). The square rod magazine is in this position, extending 7 feet 3 5/8 inches above the top plate of the unit, during the coring operation.

The magazine is made of angle iron and steel plate. The square rods are stored in the vertical position and are fed to a position concentric with the drill hole in a clip type fashion. The first square rod is 6 feet 11 1/2 inches long not including the 3 3/4 inch long male pin on the bottom. The eleven remaining square rods are 4 feet 6 inches long, which corresponds to the length of the drill pipe sections. A back up square rod is utilized in the magazine to keep the other square rods vertical. Attached to the back up rod are two 3/16 inch cables. The cables run around a pulley and attach to two extension springs. The springs maintain a force on the backup rod to pull the square rods toward the front of the magazine to a position concentric with the drill hole.

A square rod head was designed to move the square rods to connect to the square rod section in the core barrel. It consists of a 4 inch length of square rod with a 3 3/4 inch male pin for connecting to the female connections in the tops of the square rods. This head is stored above the first square rod over the drill hole and is guided by the angle iron of the framework of the magazine. Welded to the head is a section of 3/8 inch steel plate, 4 inches by 4 inches. This plate is welded to a 4 inch length of 2 7/8 inch outside diameter standard steel pipe. This section of pipe is guided by a 2 3/8 inch outside diameter standard steel pipe which is a part of the square rod magazine and extends over its entire length. Attached to the top of this pipe guide is a pulley which a 1/4 inch steel cable passes over and is attached to the top of the 3/8 inch steel plate of the square rod head. Another section of cable is attached to the bottom of the plate and both cables connect to a winch at the bottom of the square rod magazine. The winch is driven by a hydraulic motor, Torqmotor MAB 08, TRW Ross Gear Division, Lafayette, Indiana. The MAB 08 Torqmotor will use 2 gallons per minute of flow at 1500 psi pressure to produce 1, 145 inch-pounds of torque at 38 RPM and a stall torque of 860 inch-pounds. The motor also has a no-load speed of 73 RPM. With a 6 to 1 gear reduction between the motor and the drum of the winch, 6,870 inch-pounds of torque at 6.33 RPM will be available to move the square rod head. The drum of the winch will be 6 inches in diameter. This gives the winch the capability of producing 860 pounds of pull which is sufficient to pull a full core barrel out of the drill hole with all sections of square rods attached. The drum speed of 6.33 RPM will give a square rod line speed of 2 inches per second. The no-load speed of the square rod head will be twice as fast. Since the winch on the square rod magazine is only functioning when the power head is not in use, the hydraulic pump furnishing flow to the power head motor can also supply this motor. The square rod head can, therefore, be moved to connect to a section of square rod and force the rod down to make-up to a section of core barrel, and then be moved up to pull a core barrel inside the power head.

Several stop positions are utilized for the square rod head. To stop the square rod head on its downward or upward movement at an intermediate position, a 1/2 inch bore hydraulic cylinder with a 1 1/2 inch stroke is utilized. The cylinder moves a 3/4 inch diameter pin (see Drawing Number SR-01) into the path of the 3/8 inch plate of the square rod head and stops it in the desired position. There are three intermediate positions at which the square rod head must be stopped and two of these must be on the down stroke as well as the up stroke of the head. This requires the use of five stop cylinders. The stops are numbered from the bottom to the top of the square rod magazine as follows:

A. Stop Number 1 - 4 inches above the top of the unit, the bottom position of the square rod head, utilized to position the piston in the bottom of the core barrel to begin taking a core sample. A 1/2 inch bore, 1 inch stroke cylinder is mounted on the magazine 5 inches below this position to break the square rod connection (Square Rod Release No. 2) when additional lengths of square rods are to be added. The cylinder functions like the release cylinder discussed in Chapter V.

B. Stop Number 2

   1. Down Stroke - 1 foot 4 inches above the top of the unit

utilized to connect the first square rod into a core barrel below the power head so the core barrel can be pulled inside it.

2. Up Stroke - 1 foot 8 1/8 inches above the top of the unit, utilized to stop the first square rod when pulling a full core barrel from the drill hole, this positions the core barrel below the power head to be disconnected from the first square rod by Square Rod Release Number 1 and removed from the drill line by the handling device discussed in Chapter V.

C. Stop Number 3

1. Down Stroke - 4 feet 10 inches above the top of the unit, utilized to make-up to a standard square rod section when adding additional square rods, also utilized to move the core barrel down while connecting the power head to another drill pipe section so the barrel will not interfere with the power head's downward movement.

2. Up Stroke - 5 feet 2 1/4 inches above the top of the unit, utilized to stop the head when pulling square rod out of the drill hole in removing a full core barrel. The Square Rod Release Cylinder Number 2 is used

to break the connection to the lower square rod at the bottom of the magazine. The square rod clamp on the top of the power head (Square Rod Clamp No. 2, discussed in Chapter III) is utilized at this time to secure the square rod below the magazine while storing the section just disconnected.

D. Stop Number 4 - Up stroke only, 5 feet 6 1/4 inches above the top of the unit, is utilized to stop the head when removing square rod sections from the drill line. It stops the square rod in a position ready to be stored in the magazine. A 1/2 inch bore, 1 inch stroke connection release cylinder (Square Rod Release Number 3) is mounted on the magazine 9 inches below this position to break the connection between the head and square rod section.

E. Stop Number 5 - top stop of the square rod head, 7 feet 3 1/4 inches above the top of the unit, is utilized to pull the core barrels inside the power head.

Two 3/4 inch bore, 1 3/4 inch stroke hydraulic cylinders were used to store standard sections of square rod when removing them from the drill line. They are located on the side of the square rod magazine. One is located 1 foot above the top of the unit and the other is 4 feet 6 inches above the unit. The cylinders are attached to sections of steel plate that fit around the edge of the square rod and allow the plate of the square rod head to pass by them (see Drawing Number SR-01). With the cylinders stroked out, a square rod is moved into position to be utilized. When the head is disconnected from a square rod and moved clear, the cylinders are stroked in pulling the square rod back into the storage position. The head can then be moved down on the outside of the sections of plate to connect to the next square rod in the bottom of the magazine. As the next square rod is pulled into the magazine, electrical proximity switches are tripped by the head to stroke the storage cylinders out as the head nears them. The square rod being pulled into the magazine will keep the other square rods in their stored position and this will allow the next square rod to pass inside the plates attached to the cylinders for storage when the head is disconnected. When square rods are being added in the drill line, the square rod head trips additional proximity switches to stroke the storage cylinders in after the head passes the plates. This keeps the stored square rods back until the head has moved back up and is ready to pick up the next square rod.

CHAPTER VII

POWER PACKAGE AND OPERATION SEQUENCE

A power package is mounted on the middle plate of the coring unit. It contains a leak-proof 10 horsepower electric explosion proof motor to run two hydraulic pumps. One pump is a Sundstrand Series 21 variable displacement pump to furnish flow to the Sundstrand hydraulic motor on the power head, the MAB 08 Torqmotor on the indexing mechanism, and the MAB 08 Torqmotor on the square rod control winch. The other pump is a variable displacement type which furnishes flow at 1,350 psi pressure to the Gearmatic winch on the power head and at 1,000 psi pressure to all hydraulic cylinders.

Power is furnished to the electric motor through an insulated power-tension cable which runs to the surface ship. The cable attaches to a lifting eye on top of the coring unit and has a capacity of 25,000 pounds. The cable is then run to the power package compartment and connected to the electric motor.

The power package compartment will be constructed of 1/4 inch steel plate and welded together using current ASME standards, (see Drawing Numbers AMC-01 and AMC-03). The compartment will be filled with a light non-conductive oil and pressurized with nitrogen through a demand regulator to maintain a 5 psi pressure differential between the inside and outside of the compartment during lowering and operation of the unit. Since the pressure on the outside will decrease when raising the unit, sufficient relief valves will be installed in the compartment to maintain the 5 psi differential. This is necessary to keep from rupturing the sides of the case.

All electrically controlled valves and manifolding will be located on the sides of the power package compartment. All hydraulic lines will extend from this manifold to the cylinders and hydraulic motors in the coring unit.

All hydraulic cylinders utilized in the automatic coring unit will be manufactured under the same specifications. Operating pressure for all cylinders will be 1,000 psi with a safe operating pressure for seals and materials of 5,000 psi. The rods for the cylinders will be made of 316 stainless steel because of its corrosive resistance to sea water. Rod wipers will be installed to keep the rods cleaned during service. The bores of the cylinders will be chrome plated to increase their resistance to the sea water. See Table 1 for a list and specifications of all cylinders.

An operation sequence was established during the design of the automatic marine coring device using all hydraulic and electrical

TABLE 1. AUTOMATIC CORING DEVICE HYDRAULIC CYLINDERS.

No.	Function	Bore	Rod Dia.	Stroke	OD	Force @ 1,000 psi Push	Force @ 1,000 psi Pull	Type of Rod End	Type of Mount	Length*	No. Req.
1	Power Head Quick Release	3/4	3/8	1 3/4	1 1/4	442	331	1/4 - 28 NF Female Thd. 1/2 Deep	End Plate	3 13/16	2
2	Leg Control	4	2 1/8	29	5 3/4	12566	9020	2 - 12 NF Male Thd.	Clevis	44	4
3	Square Rod Magazine Locking	1 1/2	5/8	4	2 3/16	1767	1460	3/8 - 24 NF Female Thd. 11/16 Deep	End Plate w/Rod Clevis	8 3/4	2
4	Handling Device Extension	1	11/16	13 3/4	1 1/2	785	414	7/16 - 20 NF Female Thd. 3/4 Deep	End Plate	16	1
5	Handling Device Extension Stop	1/2	1/4	2 1/2	1	196	147	1/4 - 28 NF Male Thd.	Front Plate	4 1/4	1
6	Handling Device Clamps	3/4	3/8	1 3/4	1 1/4	442	331	1/4 - 28 NF Female Thd. 1/2 Deep	End Plate	3 13/16	2
7	Square Rod Clamp No. 1 Extension	3/4	3/8	12	1 1/4	442	331	1/4 - 28 NF Female Thd. 1/2 Deep	End Plate	14 1/16	1
8	Square Rod Release No. 1	1/2	1/4	1	1	196	147	6 - 32 NC Female Thd. 3/8 Deep	Front Plate	2 15/16	1
9	Square Rod Release No. 2	1/2	1/4	1	1	196	147	6 - 32 NC Female Thd. 3/8 Deep	Front Plate	2 15/16	1
10	Square Rod Release No. 3	1/2	1/4	1	1	196	147	6 - 32 NC Female Thd. 3/8 Deep	Front Plate	2 15/16	1
11	Square Rod Clamp No. 1	1/2	1/4	1	1	196	147	1/4 - 28 NF Male Thd.	Front Plate w/Rod Clevis	3 11/16	1
12	Square Rod Clamp No. 2	1/2	1/4	4	1	196	147	1/4 - 28 NF Male Thd.	Clevis	7 3/8	1
13	Square Rod Storage	3/4	3/8	1 3/4	1 1/4	442	331	1/4 - 28 NF Female Thd. 1/2 Deep	End Plate	3 13/16	2
14	Drill Pipe Slips	3	1 7/16	2	4	7068	5445	3/4 - 16 NF Female Thd. 1 5/8 Deep	End Plate	8 1/4	2
15	Drill Pipe Breaker Slips	3	1 7/16	1 3/4	4	7068	5445	3/4 - 16 NF Female Thd. 1 5/8 Deep	End Plate	7	1
16	Drill Pipe Breaker	1 1/2	5/8	6	2 3/16	1767	1460	5/8 - 18 NF Male Thd.	Clevis	12	1
17	Power Head Stop	1	7/16	3 3/4	1 1/2	785	635	5/16 - 24 NF Female 5/8 Deep	End Plate	6 5/16	2
18	Square Rod Stop No. 2 Down	1/2	1/4	1 1/2	1	196	147	1/4 - 28 NF Male Thd.	Front Plate	3 7/8	1
19	Square Rod Stop No. 2 Up	1/2	1/4	1 1/2	1	196	147	1/4 - 28 NF Male Thd.	Front Plate	3 7/8	1
20	Square Rod Stop No. 3 Down	1/2	1/4	1 1/2	1	196	147	1/4 - 28 NF Male Thd.	Front Plate	3 7/8	1
21	Square Rod Stop No. 3 Up	1/2	1/4	1 1/2	1	196	147	1/4 - 28 NF Male Thd.	Front Plate	3 7/8	1
22	Square Rod Stop No. 4 Up	1/2	1/4	1 1/2	1	196	147	1/4 - 28 NF Male Thd.	Front Plate	3 7/8	1

*Lengths are given as solid height length – (pin to pin center on clevis mounts and end to rod connection on plate mounts).

equipment. Many steps are repeated during the process of taking eleven core samples. The steps required were broken down into operation groups, where an operation may require 1 to 15 steps to complete it but is repeated several times in the coring sequence. An example would be the operation of adding standard sections of square rod to position the piston at the bottom of the core barrel. Nine separate steps are required to add one square rod but the steps remain the same for each additional square rod added. When the last core sample is being taken, eleven square rods must be added in the drill hole and, therefore, the operation of adding square rods is repeated eleven times to take this one core sample.

The operations sequence has been broken into 17 separate routines that are combined to make the complete control program. There are 3, 107 discrete steps involved in the operation to take 50 feet of core and the sequence diagram is rather lengthy so it is not included here. It does lend itself, however, to being simply controlled by relays and stepping switches and this control system is near completion.

CHAPTER VIII

CONCLUSIONS AND RECOMMENDATIONS

The design of the automatic marine coring device was the first phase of a project being conducted under the Sea Grant Program at Texas A&M University. The program calls for the design, construction, and testing of such a unit. The design presented comprises a unit which, to date, has not been available to marine mining activities. It meets all requirements set forth in Chapter I. The only limitation to depth of water at which this unit can operate is the number of nitrogen bottles needed to keep the encased equipment pressurized through the entire coring operation.

Similar power equipment and components of the coring unit are used successfully throughout industry. Therefore, presented here is the design and method of application of equipment into a functional unit to perform an underwater coring operation without the need of logistic support from the surface, which until this time was lacking. It is therefore recommended that the construction phase of the project be initiated and that, during this phase, sufficient model building and testing be conducted to reduce as many trouble areas as possible.

LITERATURE CITED

1. Bouma, Arnold H., Methods for the Study of Sedimentary Structures, 1st Edition, John Wiley and Sons, New York, New York, 1969.

2. Burns, R. E., "A Note on Some Possible Misinformation From Cores Obtained by Piston Type Coring Devices," J. Sediment. Petrol., 33, 1963, pp. 950-952.

3. Emery, G. R., and D. E. Broussard, "A Modified Kullenberg Piston Corer," J. Sediment, Petrol., 24, 1954, pp. 207-211.

4. Emery, K. O., and J. Hulsemann, "Shortening of Sediment Cores Collected in Open Barrel Gravity Cores," Sedimentology, 3, 1964, pp. 144-154.

5. Faires, Virgil Moring, Design of Machine Elements, 4th Ed., The MacMillan Company, New York, 1965.

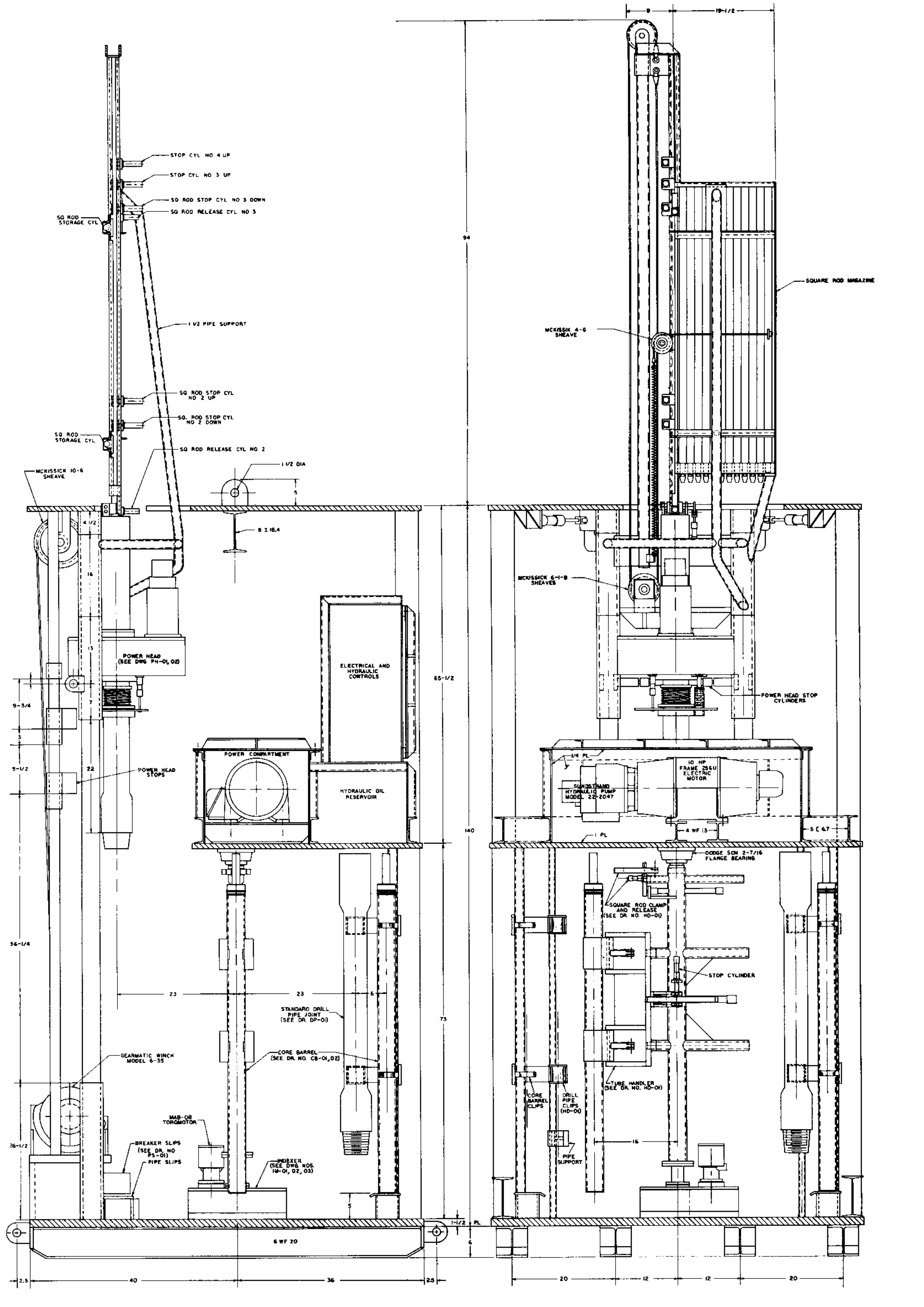
6. Kermabon, A., P. Blavier, V. Cortis, and H. Delauze, "The 'Sphincter' Corer: A Wide Diameter Corer with Water Tight Core Catcher," Marine Geol., 4, 1966, pp. 149-162.

7. Manual of Steel Construction, 6th Ed., American Society of Steel Construction, Inc., 101 Park Avenue, New York 17, New York.

8. New Departure Handbook, Ball Bearing Catalog, Volume 1, 24th Ed., General Motors Division, Briston Conn., 1960.

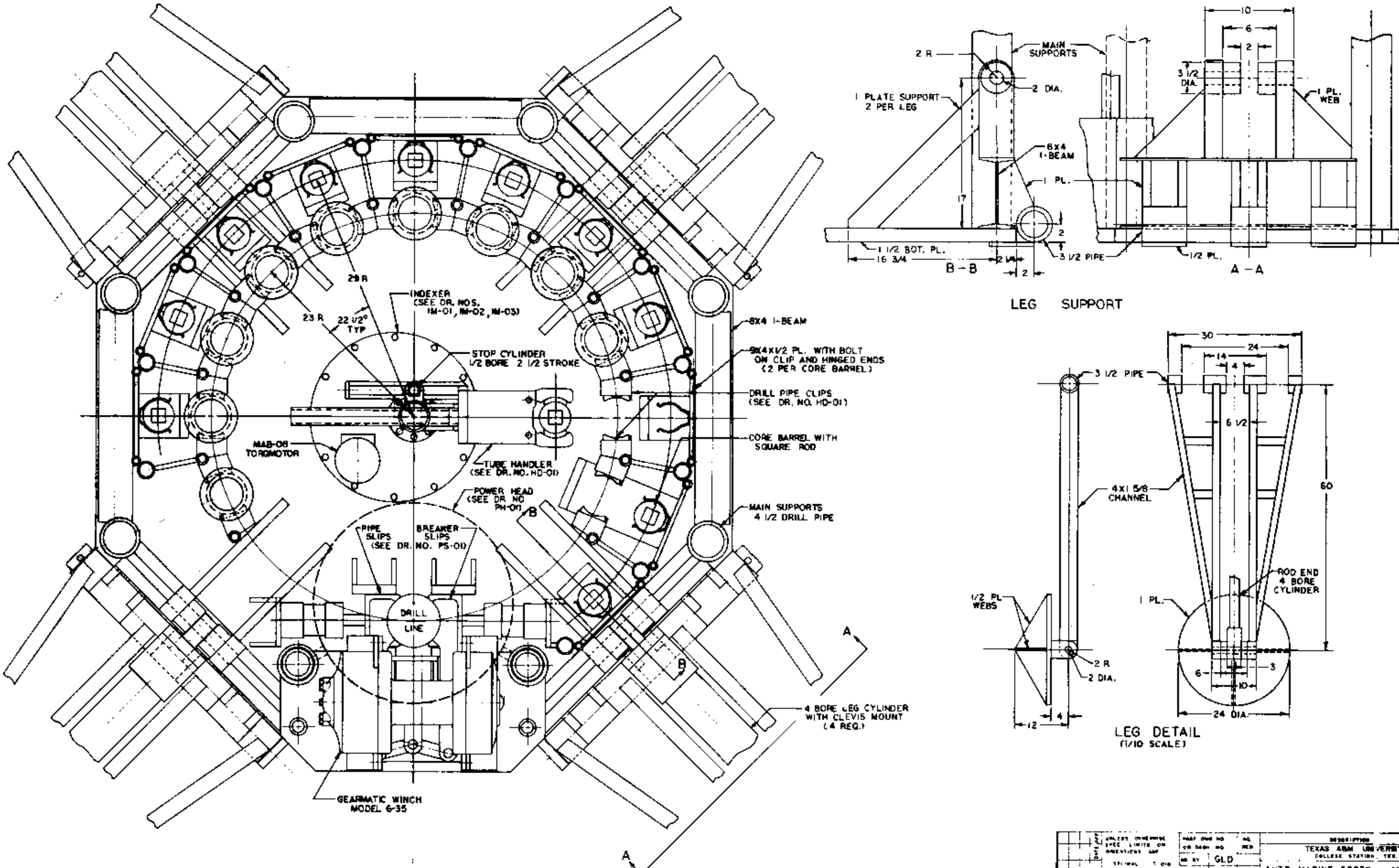
9. The Timken Engineering Journal, Section I, The Timken Roller Bearing Company, Canton 6, Ohio, 1957.

10. Timoshenko, S., Strength of Materials, Third Ed., D. Van Nostrand Co., Inc., Princeton, New Jersey, 1955.



ELEVATION DETAILS

TEXAS A&M UNIVERSITY
COLLEGE STATION, TEX.
AUTO MARINE CORER M E DEPT
HOH
HOH
TITLE
AUTOMATIC MARINE CORER ASSEMBLY
SCALE FIFTH
DATE 7/20/70
AMC-01



TEXAS A&M UNIVERSITY
COLLEGE STATION, TEX.

AUTO MARINE CORER — M E DEPT

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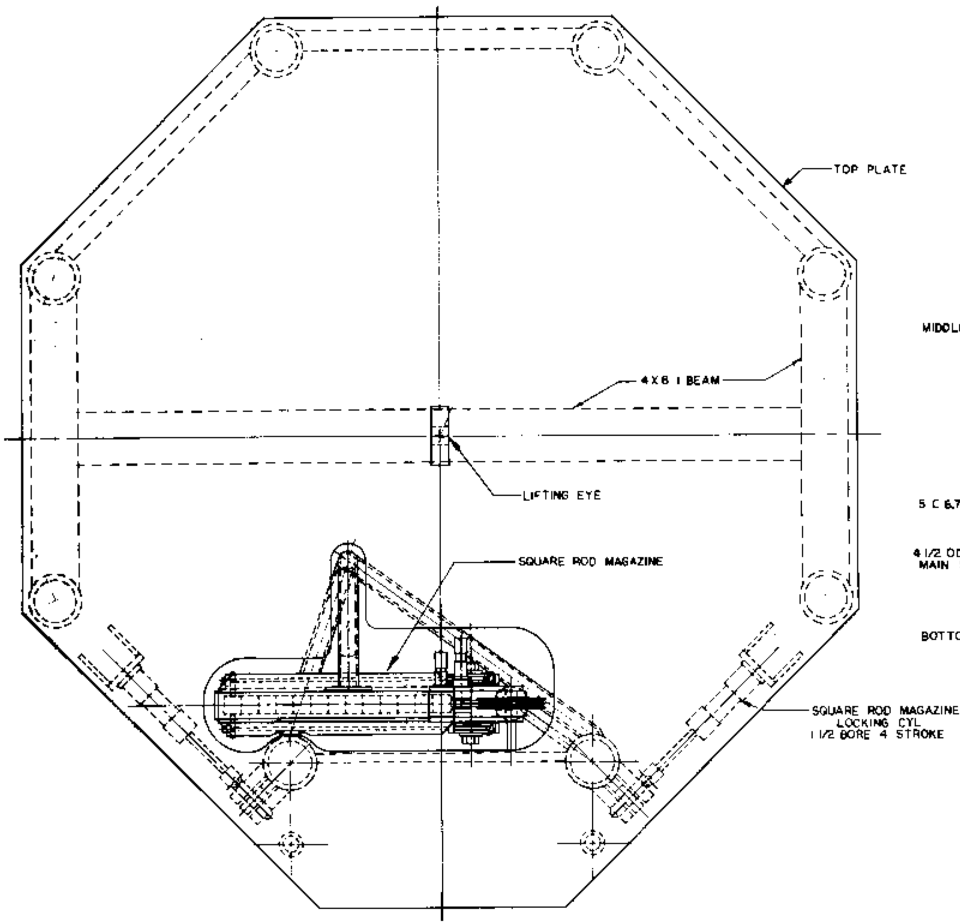
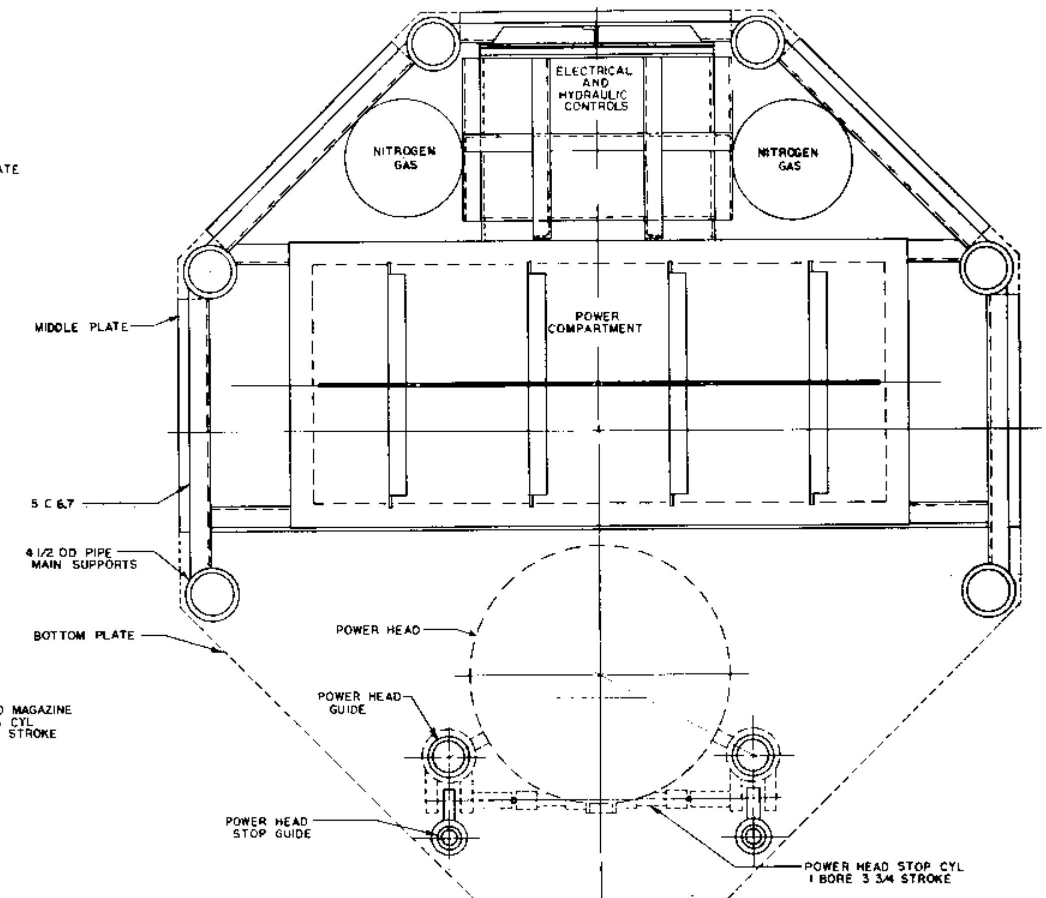
DR. BY: GLD
CHKD: GLD

SCALE: FIFTH
DATE: 7/20/70
DR. NO. AMC-02



TOP DECK PLAN



POWER COMPARTMENT PLAN

TEXAS A&M UNIVERSITY
COLLEGE STATION, TEX

AUTO MARINE CORER — M E DEPT

POWER COMPARTMENT
AND TOP DECK PLANS

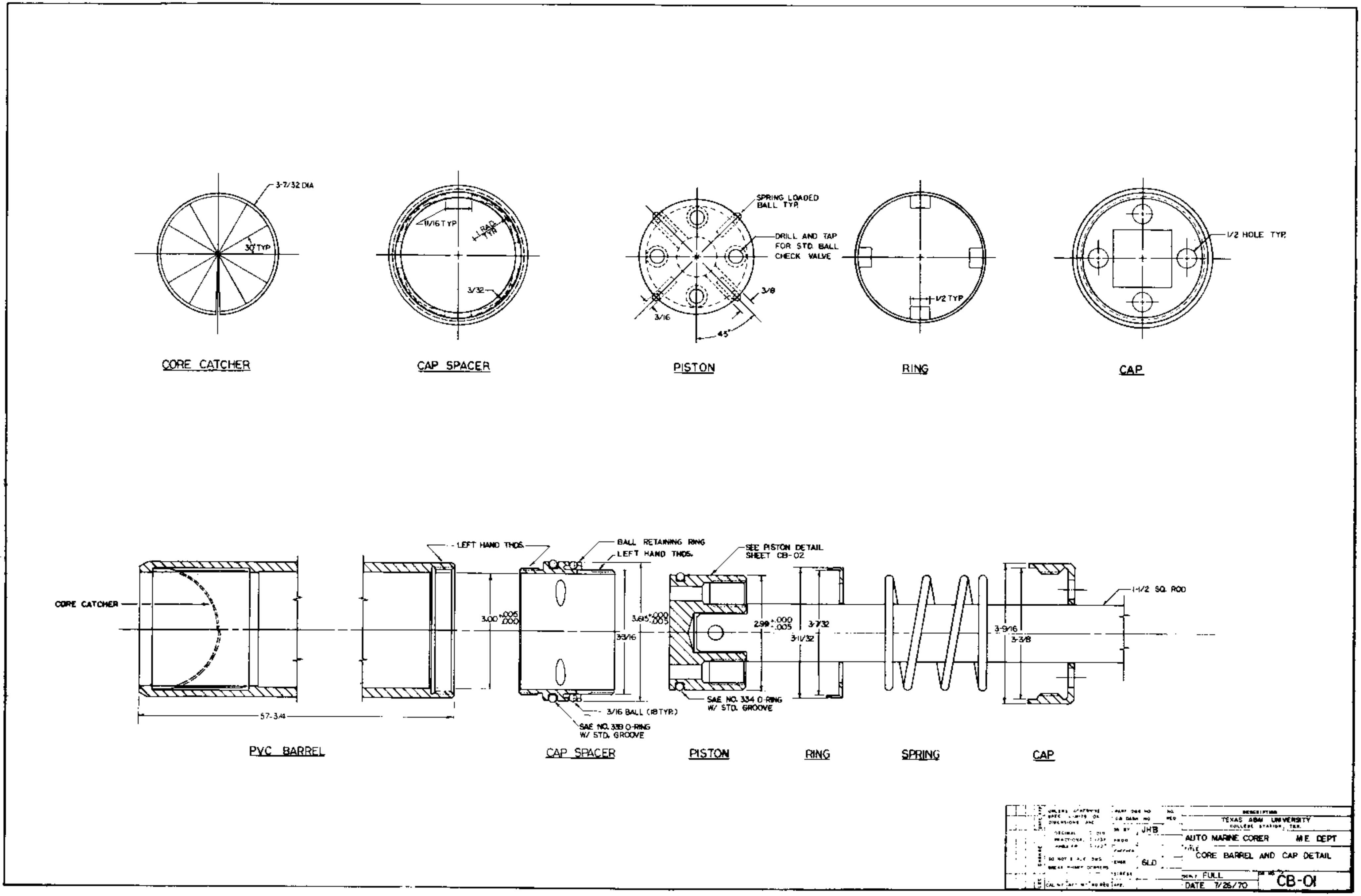
DR BY GLD

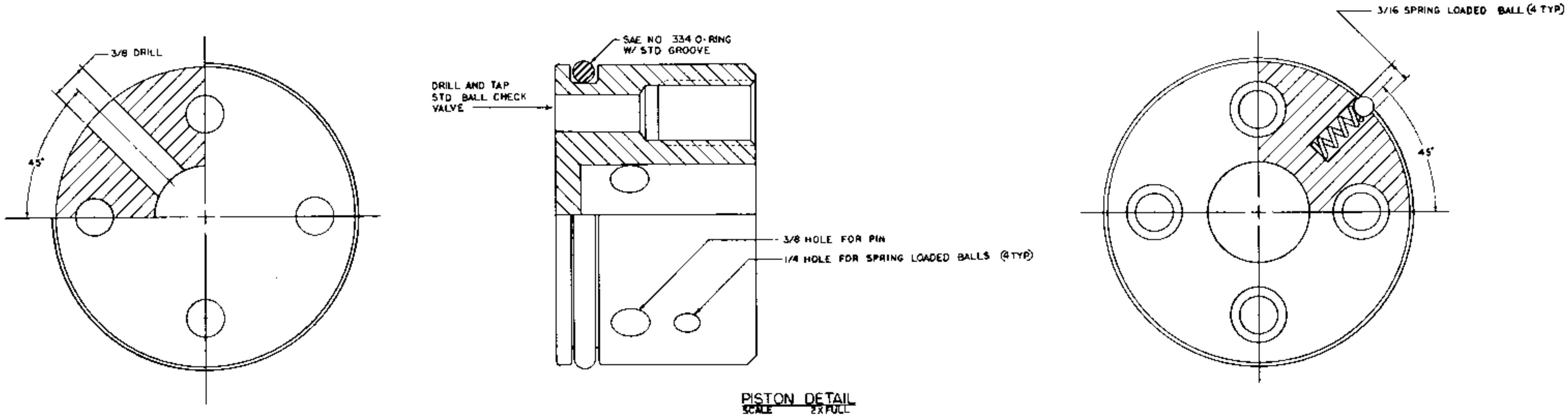
CHECKED GLD

SCALE FIFTH

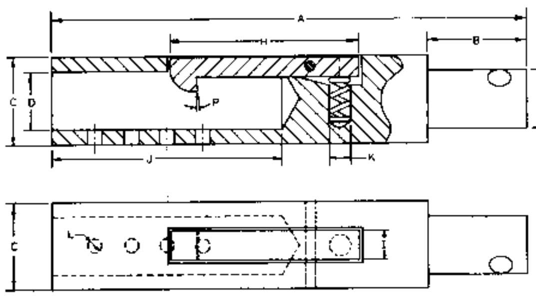
DATE 7/30/70

AMC-03

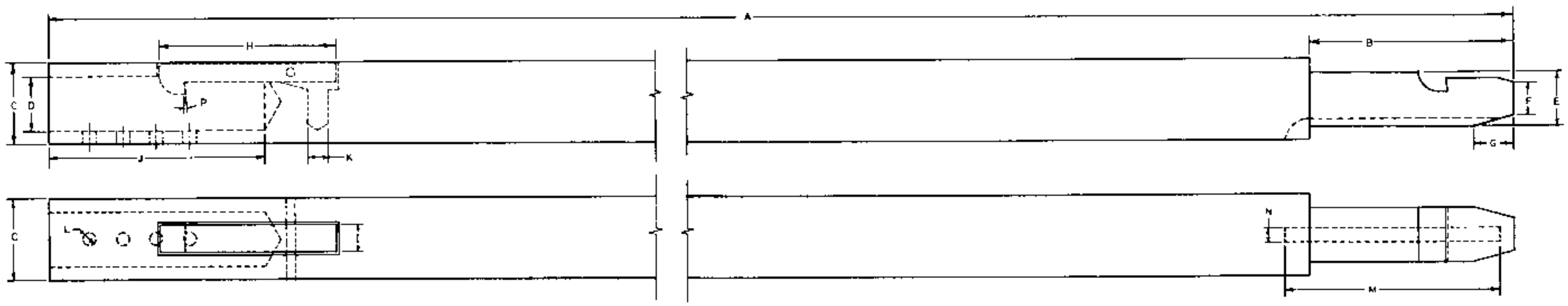

3-7/32 DIA
30° TYP
CORE CATCHER
11/16 TYP
1 RAD TYP
3/32
CAP SPACER
SPRING LOADED BALL TYP.
DRILL AND TAP FOR STD. BALL CHECK VALVE
3/8
3/16
45°
PISTON
1/2 TYP
RING
1/2 HOLE TYP.
CAP
CORE CATCHER
LEFT HAND THDS.
BALL RETAINING RING
LEFT HAND THDS.
SEE PISTON DETAIL SHEET CB-02
1-1/2 SQ. ROD
3.00 +.005 -.000
3.615 +.000 -.005
3-3/16
2.99 +.000 -.005
3-7/32
3-11/32
3-9/16
3-3/8
57-3/4
3/16 BALL (18 TYP.)
SAE NO. 339 O-RING W/ STD. GROOVE
SAE NO. 334 O-RING W/ STD. GROOVE
PVC BARREL
CAP SPACER
PISTON
RING
SPRING
CAP
TEXAS A&M UNIVERSITY
COLLEGE STATION, TEX.
AUTO MARINE CORER
ME DEPT
CORE BARREL AND CAP DETAIL
DR BY JHB
GLD
SCALE FULL
DATE 7/26/70
CB-01



PISTON DETAIL
SCALE 2 X FULL



QUANITY REQ'D	A	B	C	D DIA	E DIA	F	G	H	I	J	K DIA	L DIA	M	N	P
11	8-3/16	1-23/32	1-1/2	1	1	—	—	3-1/4	1/2	4	3/8	1/4	—	—	5°
11	57-3/4	3-3/4	1-1/2	1	1	17/32	3/4	3 1/4	1/2	4	3/8	1/4	3 15/16	1/2	5°
1	83-1/2	3-3/4	1-1/2	1	1	17/32	3/4	3 1/4	1/2	4	3/8	1/4	3 15/16	1/2	5°



SQUARE ROD DETAIL
SCALE FULL

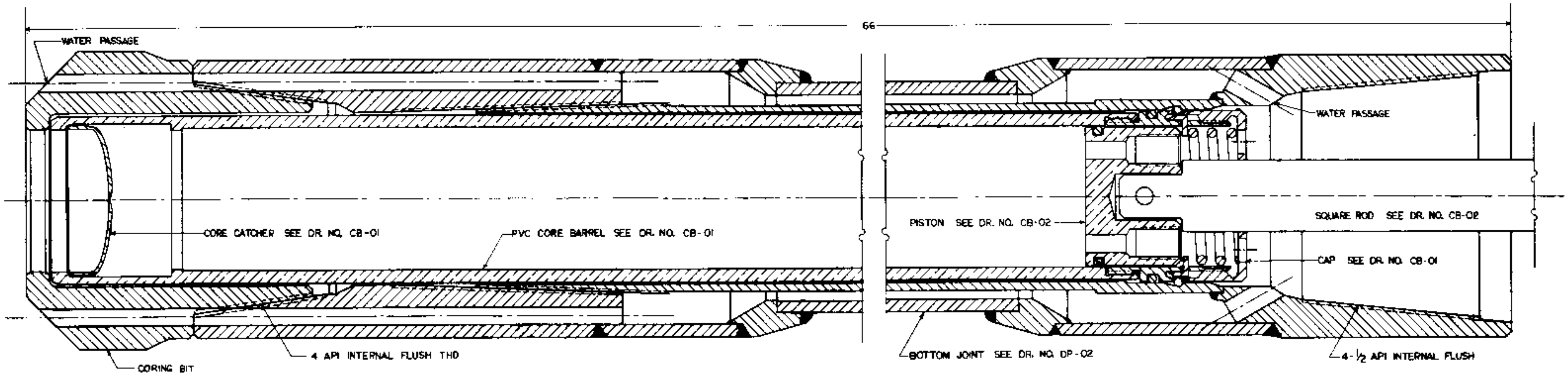
TEXAS A&M UNIVERSITY
COLLEGE STATION, TEX

AUTO MARINE CORER ME DEPT

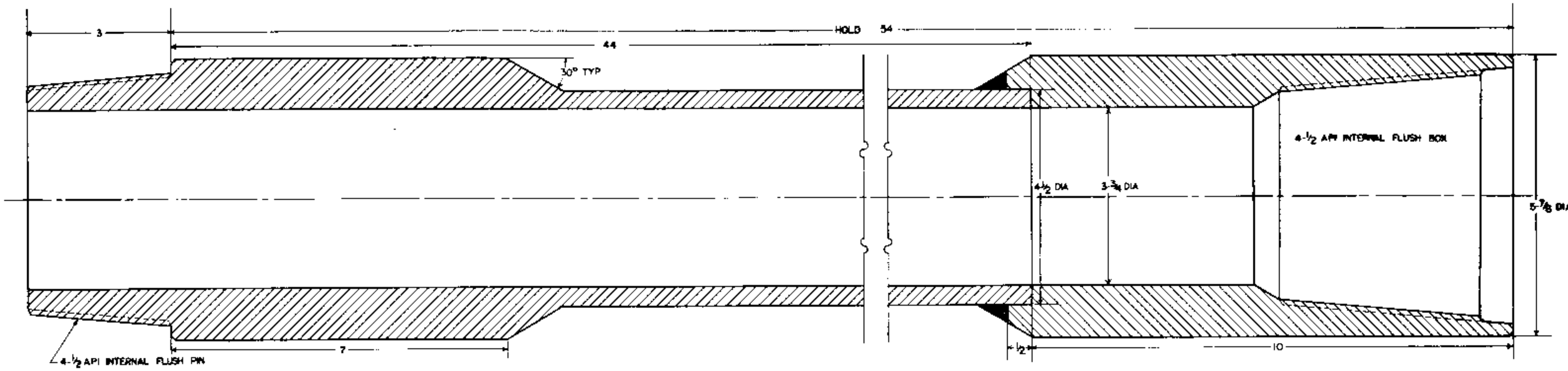
PISTON AND SQUARE ROD DETAIL

JMB
GLD

SCALE AS NOTED
DATE 8/1/70
CB-02

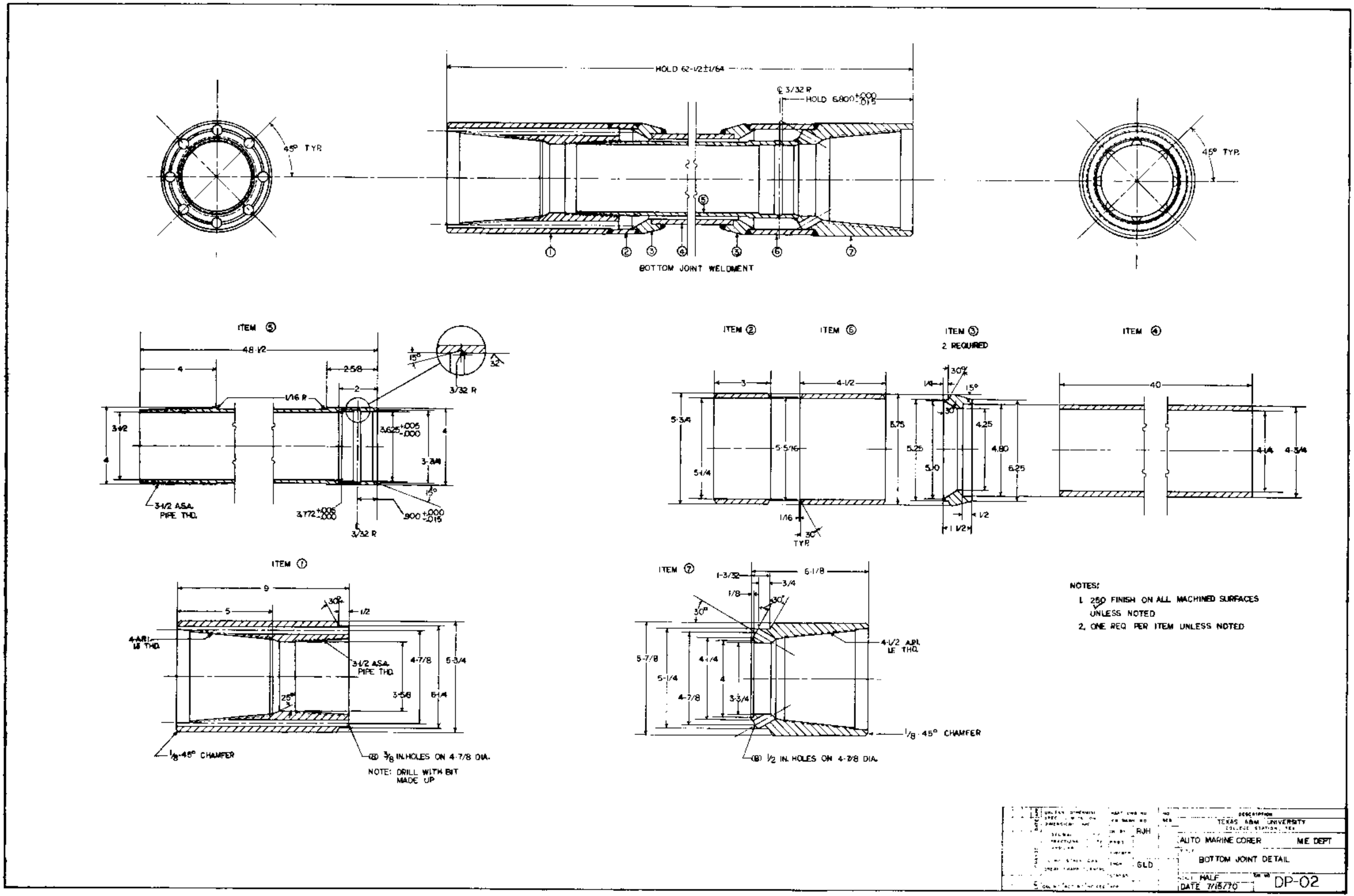


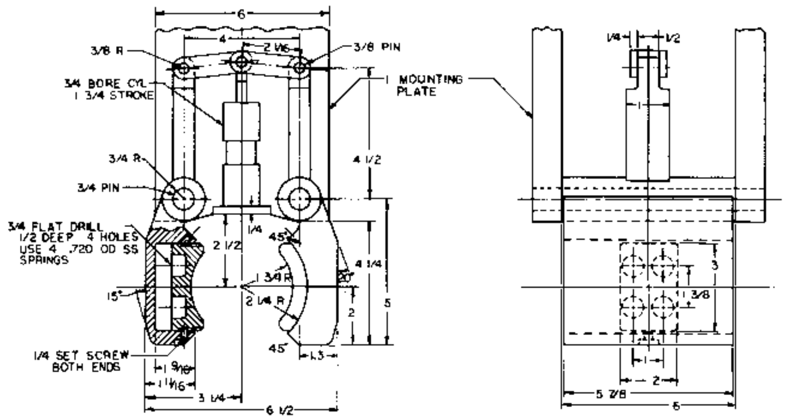
BOTTOM JOINT ASSEMBLY



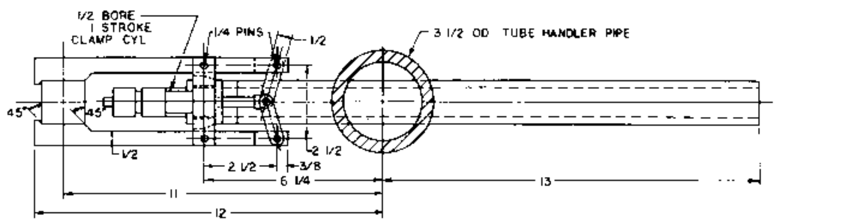
STANDARD JOINT DETAIL

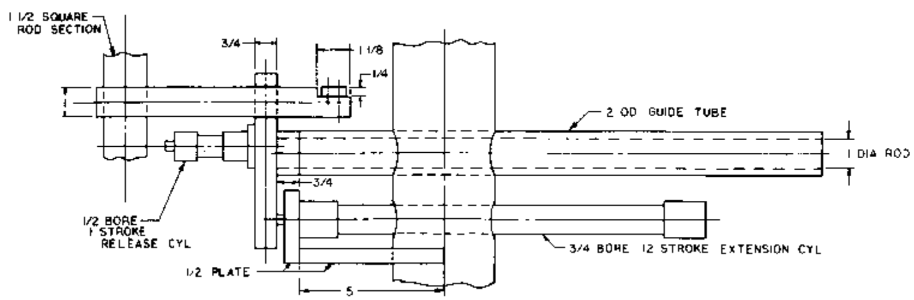
TEXAS A&M UNIVERSITY
COLLEGE STATION, TEX.
AUTO MARINE CORER M E DEPT
TITLE BOTTOM JOINT ASSEMBLY AND STANDARD JOINT DETAIL
DR. BY RJH
GLD
SCALE FULL
30 JULY 70
DR. NO. DP-01


HOLD 62-1/2±1/64
℄ 3/32 R
HOLD 6.800 +.000 -.015
45° TYP.
BOTTOM JOINT WELDMENT
ITEM ⑤
48-1/2
1/16 R
3-1/2 ASA PIPE THD.
3/32 R
ITEM ②
ITEM ⑥
ITEM ③
2 REQUIRED
ITEM ④
ITEM ①
4-API LE THD.
3-1/2 ASA PIPE THD.
1/8-45° CHAMFER
(8) 3/8 IN. HOLES ON 4-7/8 DIA.
NOTE: DRILL WITH BIT MADE UP
ITEM ⑦
4-1/2 API LE THD.
1/8-45° CHAMFER
(8) 1/2 IN. HOLES ON 4-7/8 DIA.
NOTES:
1. 250 FINISH ON ALL MACHINED SURFACES UNLESS NOTED
2. ONE REQ PER ITEM UNLESS NOTED
TEXAS A&M UNIVERSITY
COLLEGE STATION, TEX.
RJH
GLD
AUTO MARINE CORER
ME DEPT
BOTTOM JOINT DETAIL
HALF
DATE 7/15/70
DP-02

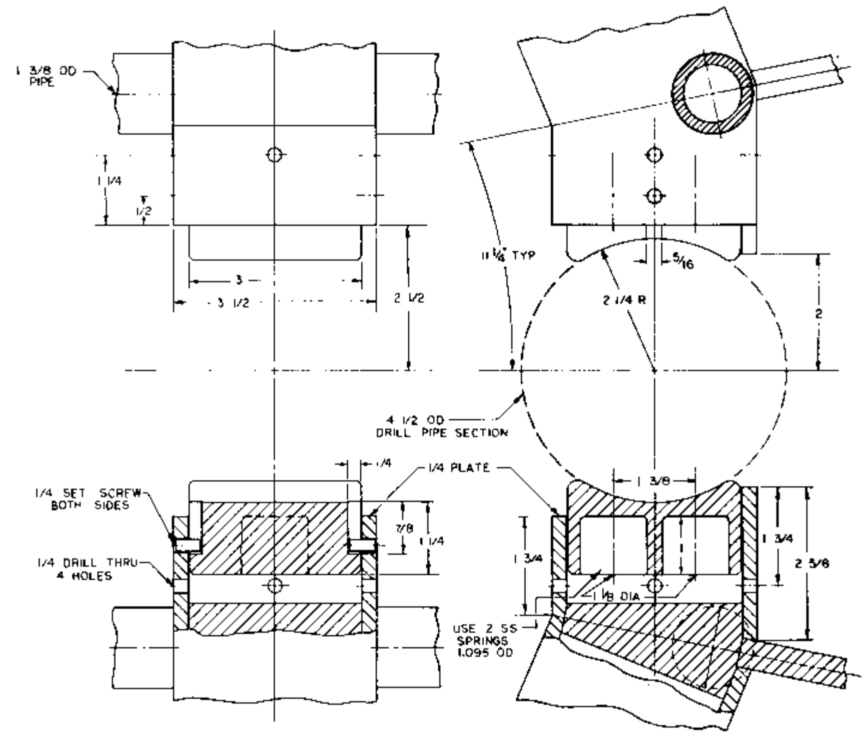


TUBE HANDLER CLAMP
(1/2 SCALE)





SQUARE ROD CLAMP AND CONNECTION RELEASE NO 1
(1/2 SCALE)



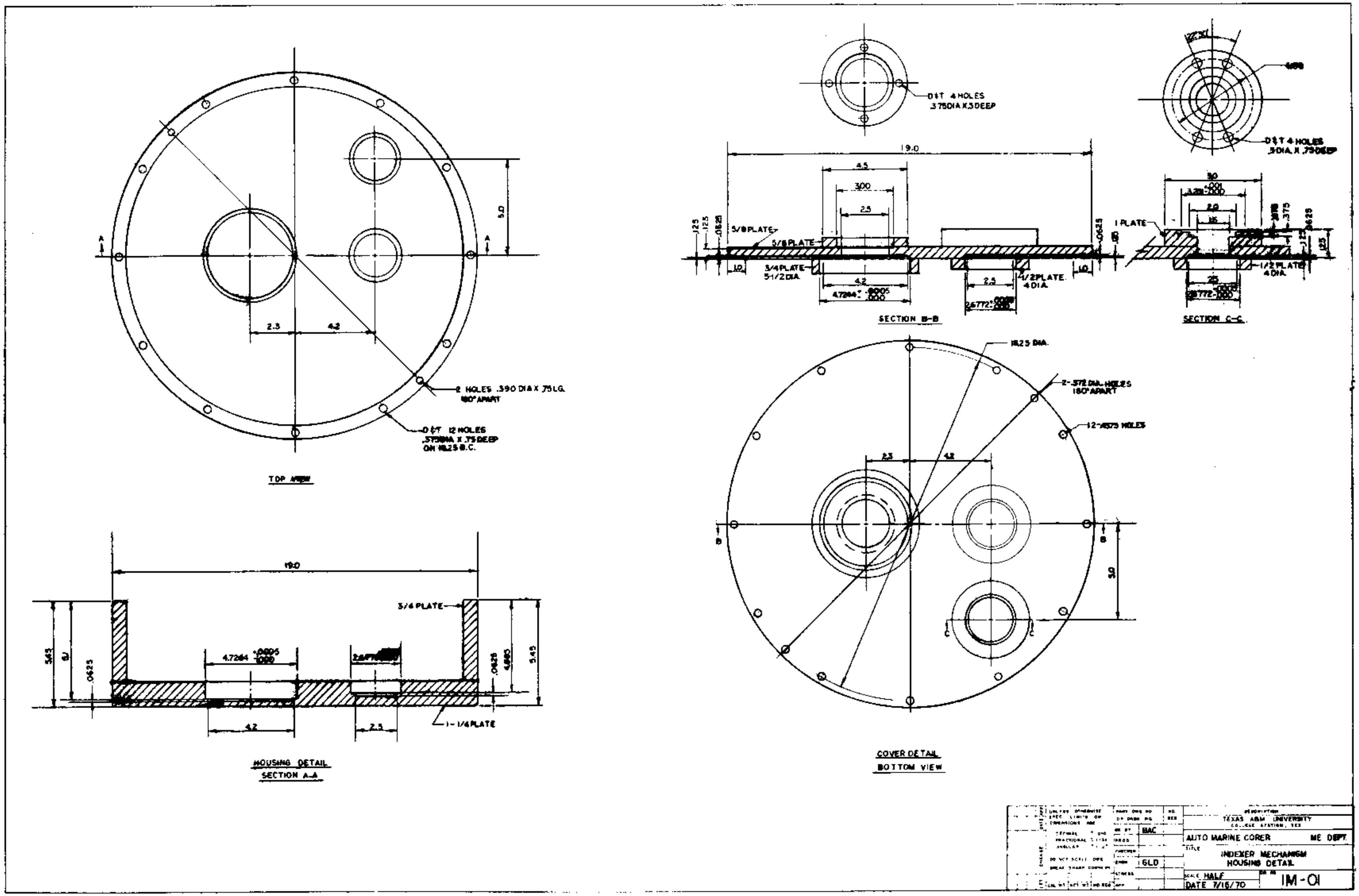
DRILL PIPE STORAGE CLIP
(FULL SCALE)

TEXAS A&M UNIVERSITY

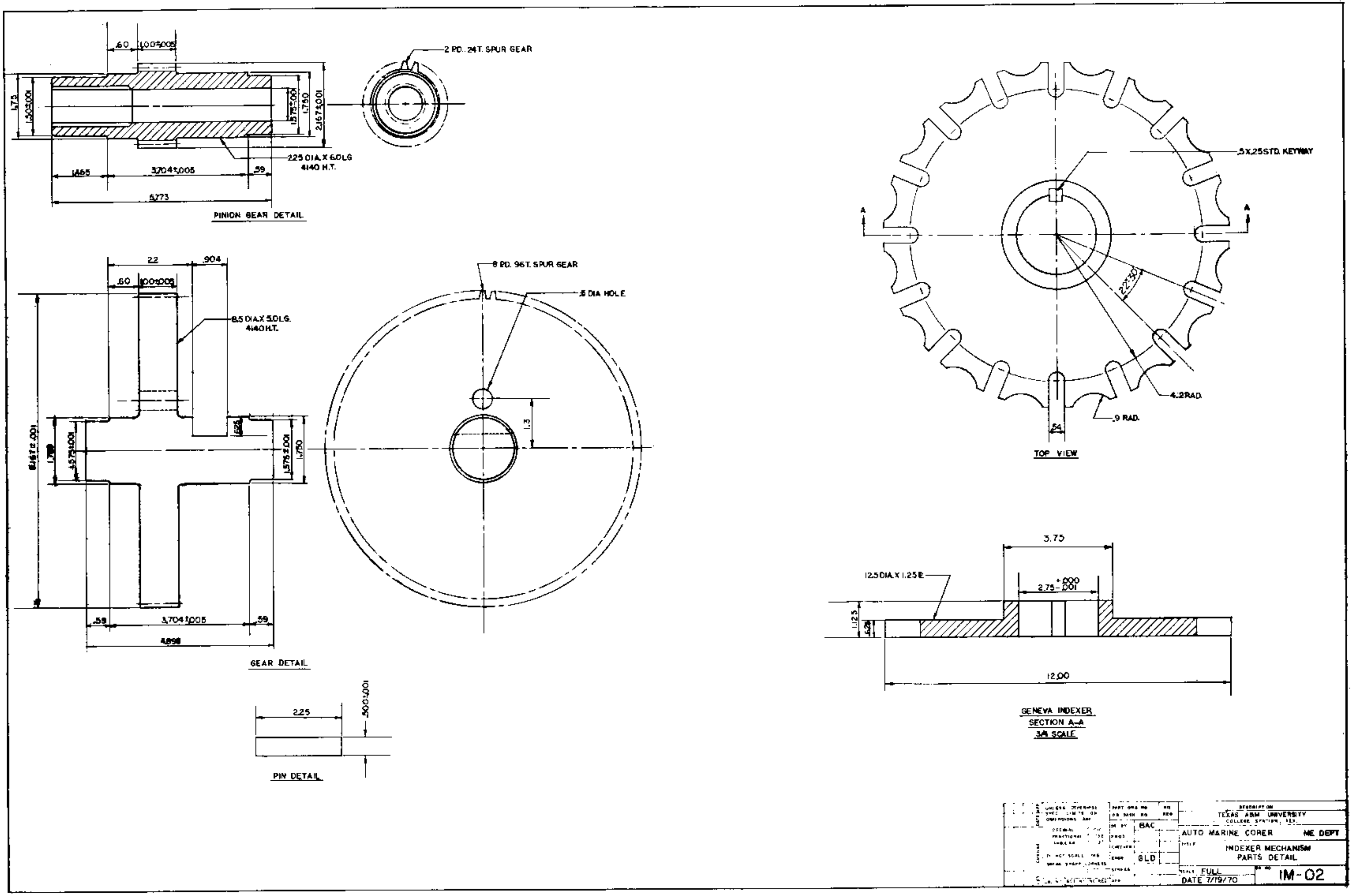
GLD | AUTO MARINE CORER | M E DEPT

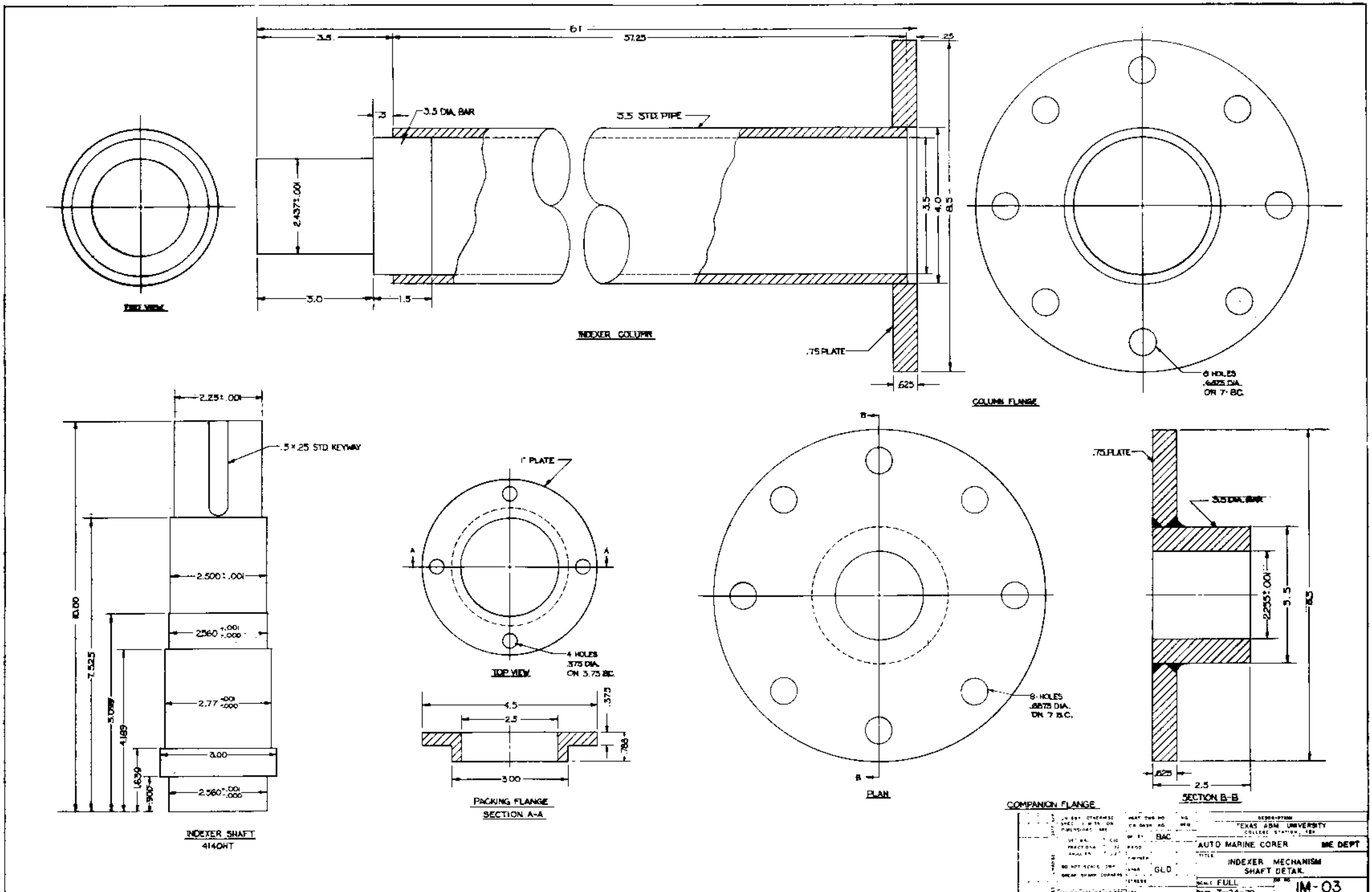
GLD | HANDLING DEVICE CLAMP DETAIL

SCALE AS NOTED | DATE: 7/21/70 | HD-01

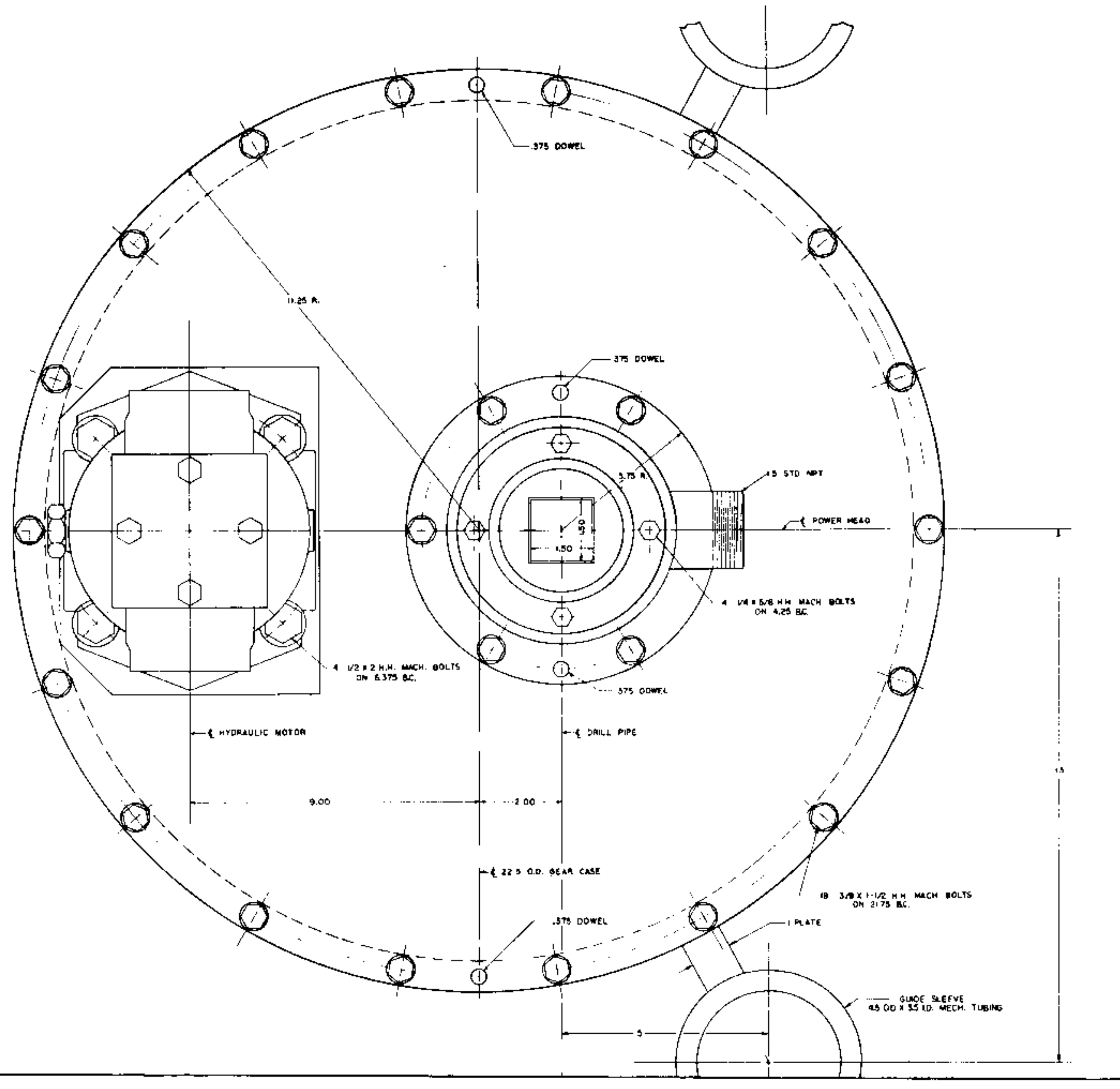


TOP VIEW
2 HOLES .390 DIA X .75 LG. 180° APART
D&T 12 HOLES .375 DIA X .75 DEEP ON 18.25 B.C.
HOUSING DETAIL
SECTION A-A
3/4 PLATE
1-1/4 PLATE
SECTION B-B
5/8 PLATE
3/4 PLATE 5-1/2 DIA
1/2 PLATE 4 DIA
D&T 4 HOLES .375 DIA X .5 DEEP
SECTION C-C
1 PLATE
1/2 PLATE 4 DIA
D&T 4 HOLES .5 DIA X .75 DEEP
COVER DETAIL
BOTTOM VIEW
18.25 DIA.
2-.572 DIA. HOLES 180° APART
12-.4575 HOLES
TEXAS A&M UNIVERSITY
AUTO MARINE CORER
ME DEPT.
INDEXER MECHANISM HOUSING DETAIL
SCALE HALF
DATE 7/15/70
BAC
GLD
IM-01

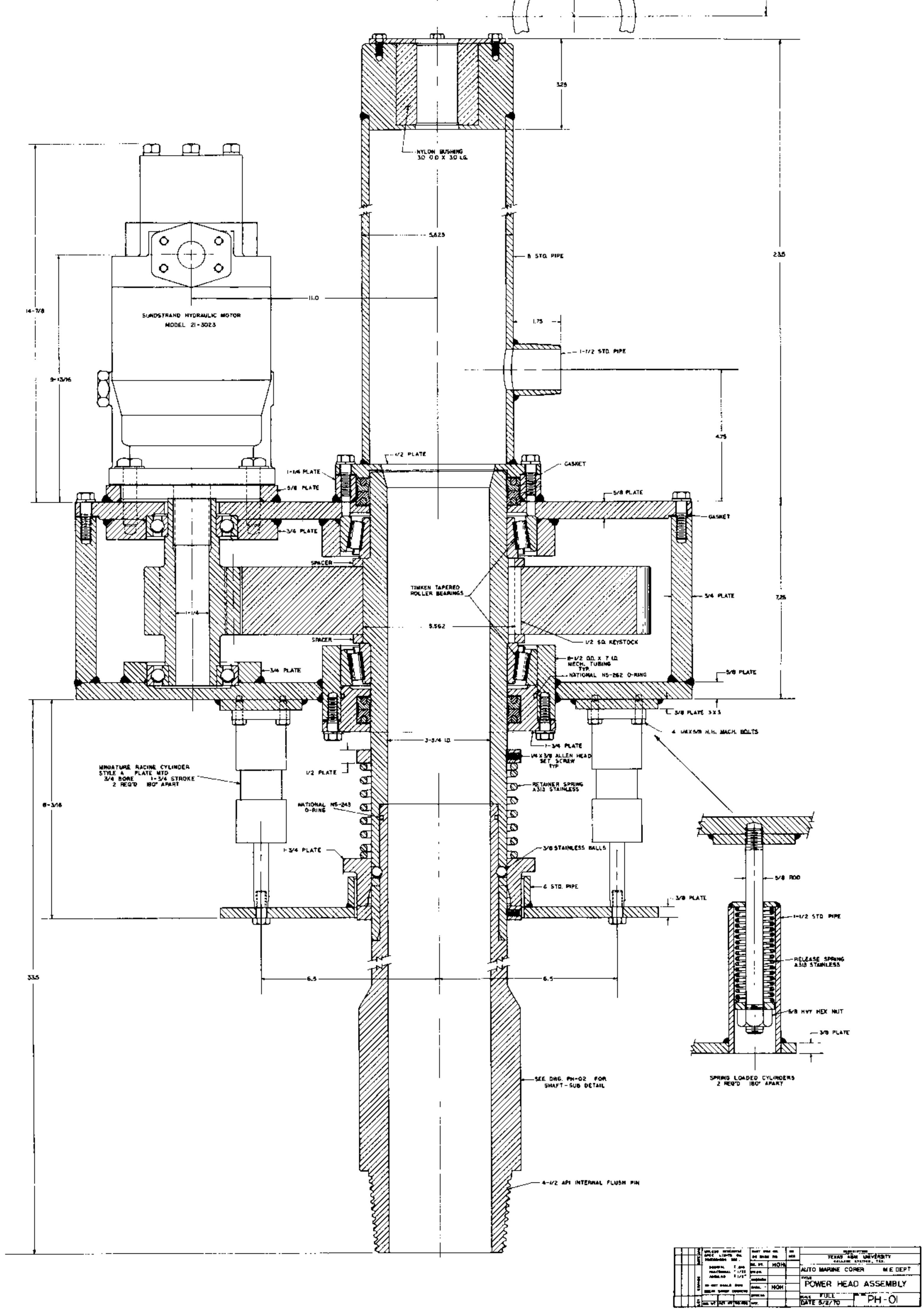

PINION GEAR DETAIL
2 P.D. 24 T. SPUR GEAR
2.25 DIA. X 6.0 LG
4140 H.T.
.60
1.00±.005
1.73
1.503±.001
1.575±.001
1.750
2.167±.001
1.465
3.704±.005
.59
5.773
GEAR DETAIL
8 P.D. 96 T. SPUR GEAR
.5 DIA HOLE
8.5 DIA X 5.0 LG.
4140 H.T.
2.2
.904
.60
1.00±.005
.625
8.167±.001
1.750
4.575±.001
1.575±.001
1.750
1.3
.59
3.704±.005
.59
4.898
PIN DETAIL
2.25
.500±.001
.5 X .25 STD. KEYWAY
22°30'
4.2 RAD.
.9 RAD.
.54
TOP VIEW
A
A
3.75
12.5 DIA. X 1.25 R.
2.75 +.000 -.001
1.125
.625
12.00
GENEVA INDEXER
SECTION A-A
3/4 SCALE
TEXAS A&M UNIVERSITY
AUTO MARINE CORER
ME DEPT
INDEXER MECHANISM
PARTS DETAIL
BAC
GLD
SCALE FULL
DATE 7/19/70
IM-02

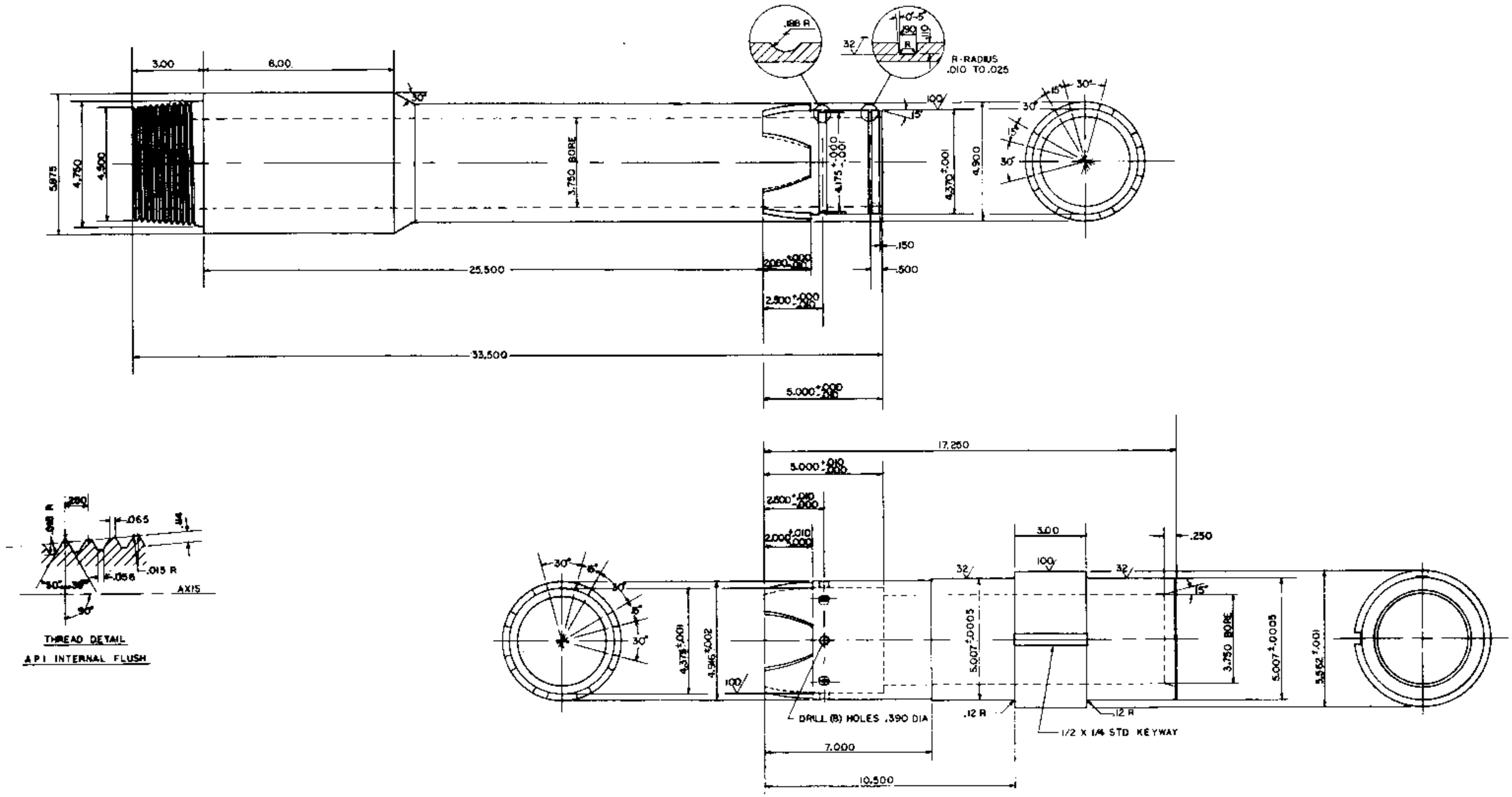


INDEXER COLUMN
TWO VIEW
61
3.5
57.25
.25
3.5 DIA. BAR
3.5 STD. PIPE
2.437±.001
3.0
1.5
3.5
4.0
8.5
.75 PLATE
.625
COLUMN FLANGE
6 HOLES .6875 DIA. ON 7" BC
INDEXER SHAFT
4140HT
2.25±.001
.5 × .25 STD KEYWAY
2.500±.001
2.560 +.001 -.000
2.77 +.001 -.000
3.00
10.00
7.525
5.099
4.189
1.639
.900
1" PLATE
TOP VIEW
4 HOLES .375 DIA. ON 3.75 BC
PACKING FLANGE
SECTION A-A
4.5
2.5
3.00
.375
.788
PLAN
8 HOLES .6875 DIA. ON 7 B.C.
COMPANION FLANGE
.75 PLATE
3.5 DIA. BAR
2.255±.001
5.5
8.5
.625
2.5
SECTION B-B
TEXAS A&M UNIVERSITY
AUTO MARINE CORER
ME DEPT
BAC
GLD
INDEXER MECHANISM SHAFT DETAIL
SCALE FULL
DATE 7-24-70
IM-03



.375 DOWEL
11.25 R.
.375 DOWEL
3.75 R.
1.5 STD NPT
℄ POWER HEAD
1.50
1.50
4 1/4 x 5/8 H.H. MACH. BOLTS
ON 4.25 B.C.
4 1/2 x 2 H.H. MACH. BOLTS
ON 6.375 B.C.
.375 DOWEL
℄ HYDRAULIC MOTOR
℄ DRILL PIPE
9.00
2.00
℄ 22.5 O.D. GEAR CASE
18 3/8 X 1-1/2 H.H. MACH. BOLTS
ON 21.75 B.C.
.375 DOWEL
1 PLATE
GUIDE SLEEVE
4.5 OD x 3.5 I.D. MECH. TUBING
5


3.25
NYLON BUSHING 3.0 O.D X 3.0 LG.
5.625
5 STD. PIPE
23.5
11.0
14-7/8
SUNDSTRAND HYDRAULIC MOTOR
MODEL 21-3023
9-13/16
1.75
1-1/2 STD. PIPE
4.75
1/2 PLATE
1-1/4 PLATE
GASKET
5/8 PLATE
5/8 PLATE
GASKET
3/4 PLATE
SPACER
TIMKEN TAPERED ROLLER BEARINGS
3/4 PLATE
7.25
1-1/4
5.562
1/2 SQ. KEYSTOCK
SPACER
8-1/2 OD. X 7 I.D. MECH. TUBING TYP
NATIONAL NS-262 O-RING
3/4 PLATE
5/8 PLATE
3/8 PLATE 3 X 3
4 1/4X5/8 H.H. MACH. BOLTS
3-3/4 I.D.
1-3/4 PLATE
1/4 X 3/8 ALLEN HEAD SET SCREW TYP
MINIATURE RACINE CYLINDER
STYLE 4 PLATE MTD
3/4 BORE 1-3/4 STROKE
2 REQ'D 180° APART
1/2 PLATE
RETAINER SPRING A313 STAINLESS
8-3/16
NATIONAL NS-243 O-RING
3/8 STAINLESS BALLS
1-3/4 PLATE
6 STD. PIPE
3/8 PLATE
5/8 ROD
1-1/2 STD. PIPE
33.5
6.5
6.5
RELEASE SPRING A313 STAINLESS
5/8 HVY HEX NUT
3/8 PLATE
SPRING LOADED CYLINDERS
2 REQ'D 180° APART
SEE DWG. PH-02 FOR SHAFT-SUB DETAIL
4-1/2 API INTERNAL FLUSH PIN
TEXAS A&M UNIVERSITY
HOH
HOH
AUTO MARINE CORER
M E DEPT
POWER HEAD ASSEMBLY
FULL
DATE 5/2/70
PH-01



MATERIAL: 4140 HT

TEXAS A&M UNIVERSITY
COLLEGE STATION, TEX.

AUTO MARINE CORER — M E DEPT

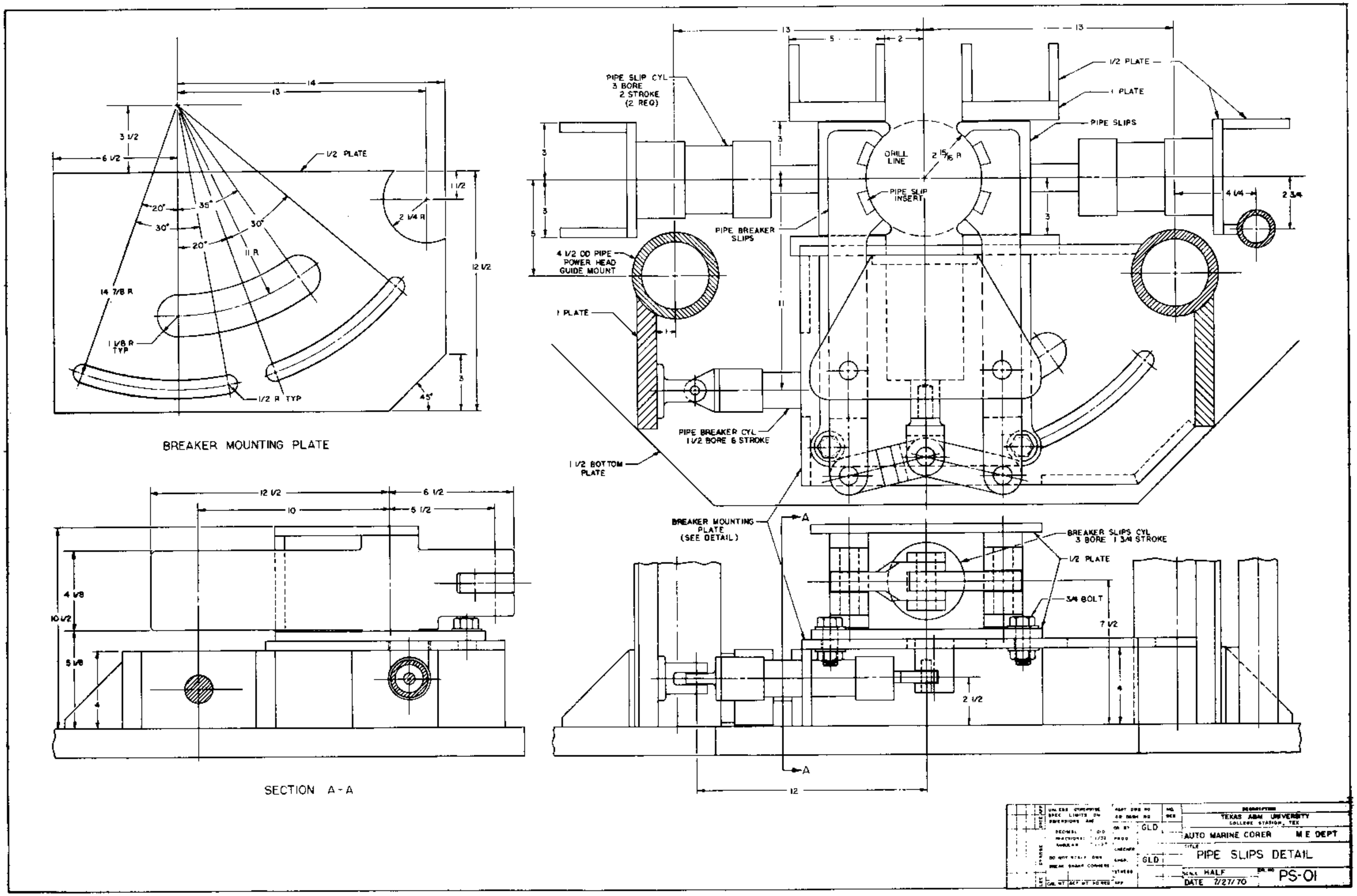
POWER HEAD SHAFT-SUB DETAIL

DRAWN BY: HOH — CHECKED: HOH

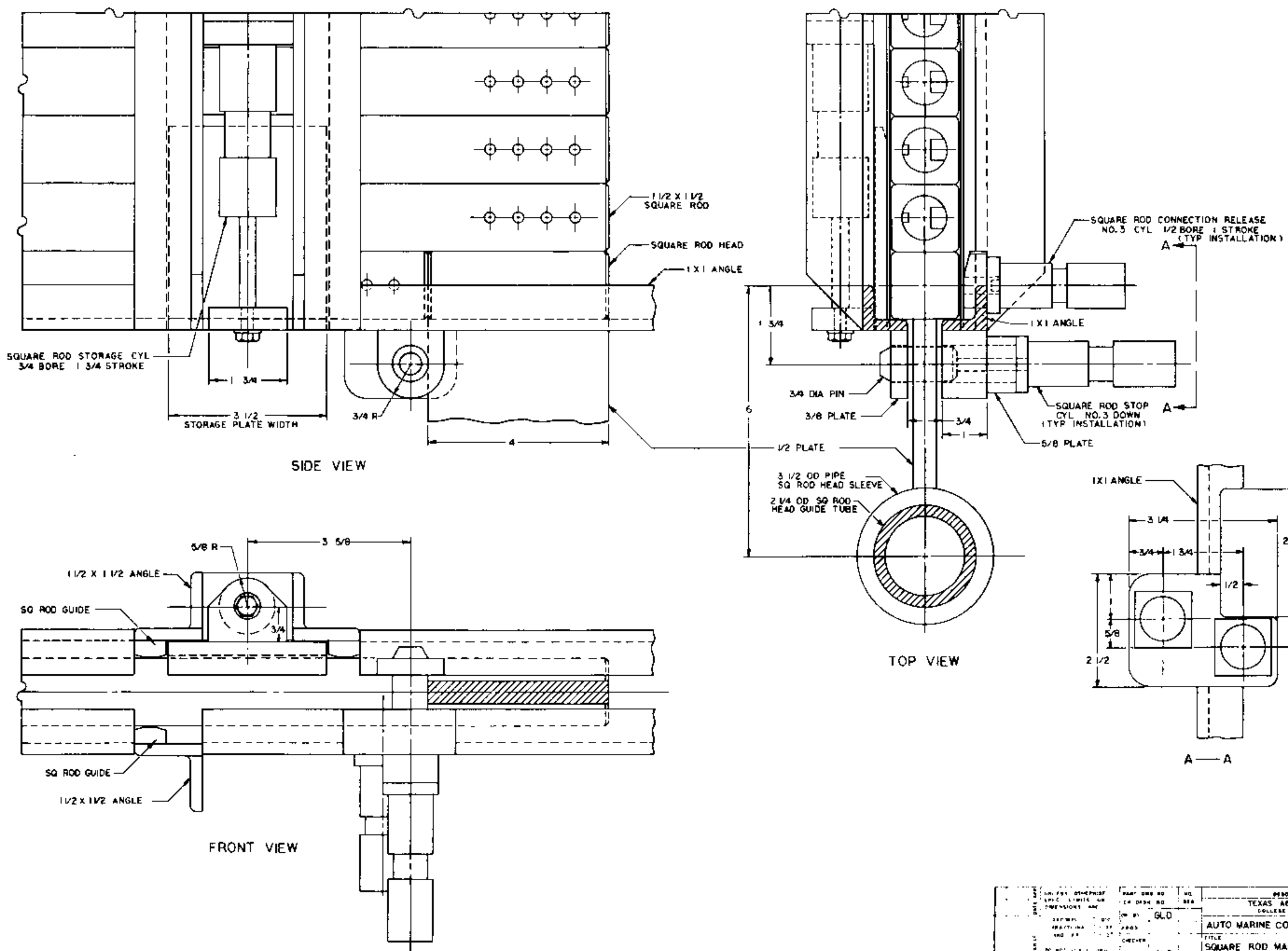
SCALE: HALF

DATE: 5/15/70

PH-02



BREAKER MOUNTING PLATE
1/2 PLATE
14 7/8 R
1 1/8 R TYP
1/2 R TYP
2 1/4 R
11 R
45°
SECTION A-A
PIPE SLIP CYL 3 BORE 2 STROKE (2 REQ)
PIPE BREAKER SLIPS
4 1/2 OD PIPE POWER HEAD GUIDE MOUNT
1 PLATE
PIPE BREAKER CYL 1 1/2 BORE 6 STROKE
1 1/2 BOTTOM PLATE
DRILL LINE
PIPE SLIP INSERT
2 15/16 R
PIPE SLIPS
BREAKER MOUNTING PLATE (SEE DETAIL)
BREAKER SLIPS CYL 3 BORE 1 3/4 STROKE
3/4 BOLT
TEXAS A&M UNIVERSITY
COLLEGE STATION, TEX
AUTO MARINE CORER
M E DEPT
PIPE SLIPS DETAIL
SCALE HALF
DATE 7/27/70
PS-01
GLD



TEXAS A&M UNIVERSITY, COLLEGE STATION, TEX
AUTO MARINE CORER — M E DEPT
TITLE: SQUARE ROD MAGAZINE DETAILS
DR BY: GLD — ENGR: GLD
SCALE: FULL — DATE: 7/25/70 — SR-01