DIAMOND CORING
and
DIAMOND DRILLING

Drilling & Service INC.

DALLAS, TEXAS

SW Short

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FOREWORD

Drilling & Service was the first company to successfully diamond core an oil well. That was way back in 1945, but since that time TRUCO BRAND diamond coring and drilling equipment (manufactured, sold and serviced by Drilling & Service, Inc. of Dallas, Texas) has become a standard in the industry.

Continuous research in diamond selection, diamond arrangement, bit hydraulics, etc., has made the use of TRUCO diamond products economical in areas where diamond use has not been thought to be practical. To keep pace with the increasing use of TRUCO products in the oil industry, we have prepared this small booklet entitled **Diamond Coring and Diamond Drilling.**

It is our hope that this booklet will, in some way, help you to get more hole, and more core recovery for your money.

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INTRODUCTION

DIAMOND COST.

One of the first things a person sees when he purchases a diamond bit is the original price. What he usually doesn't see is the diamond salvage credit received in his accounting department. Many bits salvage out better than 40 per cent, so the bit cost is really not as high as it appears.

Bit cost is important but it is only one factor to be considered in determining whether a bit run is economical. Some of the direct costs to be considered are: the rig operating cost, the trip time saved, and the number of rock bits replaced. Among the intangibles (but all of which add up in the profit and loss sheet) are: possible lost circulation due to pressure surges when making trips, stuck pipe and increased mud bills due to lost circulation, well kicking due to swabbing when pulling bits, reduction in the number of necessary drill collars and even the reduction in drilling line costs. Another factor that would easily offset the cost of diamond equipment is that properly stabilized diamond bits usually provide a larger effective hole diameter in which to run your liner or casing.

The value received from a diamond bit is what is important and not the original cost of the bit. TRUCO diamond drill bits are specialized drilling tools, proven by field experience, and worthy of an economic analysis. This analysis may be made easily and quickly by the use of the following well known formula:

$$\text{Cost Per Foot} = \frac{\left(\begin{matrix}\text{Operating Cost}\\ \text{Per Hour}\end{matrix}\right)\left(\begin{matrix}\text{Trip Hours} +\\ \text{Rotating Hours}\end{matrix}\right) + \begin{matrix}\text{Net Bit}\\ \text{Cost}\end{matrix}}{\text{Bit Footage}}$$

DIAMOND CORING AND DIAMOND DRILLING

1. CLEAN HOLE:

The importance of a clean hole is recognized and stressed for every method of coring. It is even more important when diamond coring, to insure maximum core recovery and prevent possible damage to the diamond bit. Diamonds are particularly vulnerable to loose junk iron. Therefore, every precaution should be exercised to insure a clean hole before diamond coring is started and to keep it clean during the operation. Normally, it is not difficult to keep a hole clean during the rock bit drilling period, and if the following suggestions are observed the coring point will be reached with a clean hole, eliminating the cost of extra trips to clean the hole:

A. If the rock bit cones are lost, fish out the cones and all the bearings at that time; otherwise, the bearings will become embedded in the walls or stored in cavities. They may then fall to bottom during coring, damaging the diamond bit and core barrel or reducing core recovery.

B. Keep tong dies securely keyed in place.

C. Keep a wiper on the pipe when going in or coming out of the hole. An old wiper may be used when going in the hole.

D. Use a junk basket sub or a similar tool with the last two or three rock bits. This procedure has proven very effective in insuring a clean hole ready for diamonds; however, if there is doubt whether or not the hole is clean, it may be advisable to use a magnetic tool or whatever method meets the operator's preference.

2. DRILL COLLARS.

It is a good drilling practice to use sufficient drill collars to exceed the weight applied to the bit in order to hold the drill pipe in tension. The same practice is desirable in diamond coring and diamond drilling, particularly for diamond drilling and for the first core when rat-holing ahead in open hole, because the drill collars are the only top stabilization. Under these conditions, use the drill collars that were in use with the rock bits for the first core. After the core barrel has been buried, if the rat hole

to be continued is too small for the regular drill collars, they may be replaced with drill collars of a suitable diameter or eliminated entirely at the discretion of the operator. When a full hole diamond bit is being used, regular sized drill collars should be used.

When rat hole coring in open hole and reaming after each core, which always keeps the top of the core barrel and drill collars in the open hole, use the regular string of drill collars.

Drill pipe in compression, when used for drilling weight, "snakes" about in the hole and often induces vibrations not conducive to peak performance by the diamond equipment. However, the use of drill collars is not always feasible and their use should be influenced by: (1) the hole conditions, (2) size of hole, (3) the related hazards involved. Simply remember that drill collars are a definite aid to diamond coring and use them when possible.

3. CORE BARREL STABILIZERS.

Theoretically, a diamond bit will perform best when the core barrel is perfectly stabilized in the center of the hole. Such stabilization requires a series of stabilizers built on the core barrel, spaced about eight feet apart, with an outside diameter of about .010" less than the bit diameter. But there is a serious objection to a perfectly stabilized core barrel because it increases the hazard of sticking it. This objection needs no further amplification and for this reason only one stabilizer with ribs about 12 inches long is recommended to be run directly above the bit. This stabilizer should be closely watched and when it wears to about 1/16" under the bit diameter, it should be replaced or rebuilt to .015" under the bit diameter and the ribs ground in a lathe concentric with the bore. Otherwise, the bit may be damaged and/or a wavy core cut, which will wedge in the inner barrel, reducing the core recovery or the length of the core runs, thereby causing extra rig trips. Also an undersize stabilizer will often allow the bit to walk around, cutting an undersize core too small for the core catcher to sieze. Further, when the bit is allowed to walk around, the bit footage will be reduced.

When core barrels of more than one section are connected with a center sub, the sub is usually equipped with protective ribs to control the wear by the walls of the hole. These ribs have the appearance of a stabilizer; however, they are well under the hole diameter and do not stabilize the core barrel. When these ribs wear down to the body of the sub they should be replaced or rebuilt to prevent wear and subsequent failure of the sub or core barrel. Core barrels without center subs are often equipped with bands of hard metal near the center joint to prevent wear.

In areas of difficult coring problems, due to the nature of the formation to be cored or the bit and core barrel size relationship, it might be helpful to increase the diameter of the protective ribs and let them act as a stabilizer.

4. SELECTING BIT SIZE AND REAMING:

A diamond bit will not always follow a rock bit of the same size unless the hole drilled by the rock bit was fast and easy drilling, leaving a straight full gauge hole. Reaming a rock bit cut hole can be a slow, costly and dangerous operation. The OD of the diamond bit can be damaged and worn, and would greatly reduce the diamond bit life. Selecting the diamond bit of an OD size that will not require reaming of the rock bit cut hole is most important. Reaming should be eliminated when at all possible.

The amount of gauge loss by the rock bits may be the most common measure of the necessary diamond bit OD reduction under rock bit size to avoid reaming. However, the loss in effective hole size or drift diameter may be the most prevalent problem. This loss in effective hole size is a common result from the rock bit drilling a spiral or helix shaped hole due to the action of the unstable drill collar string. Subsequent rock bits, by the design of their cutting cones, can roll through these spirals, whereas the diamond bit with its solid OD gauge section must ream such sections. In cases of the stabilized core bits the possibility of having to ream is greater due to the increased OD area and increased length of the OD area in contact with the hole wall.

The drift diameter or effective hole diameter of a bore hole cut with rock bits is influenced by the following factors:

1. Relation of drill collar OD and bit size.
2. Number, size and location of drill collar stabilizers.
3. Weight applied to the bit.
4. Rotary speed.
5. Penetration rate.

Any increase in stabilization of the bottom hole assembly will increase the drift diameter of the hole drilled. A hole drilled with near perfect stabilization of the bottom hole assembly will have a drift diameter that approaches the rock bit size, and a diamond bit of a similar size could be run. As the stabilization of the bottom hole assembly is reduced the drift diameter of the hole drilled is reduced.

In rock bit drilled holes, drilled with moderate stabilization of the bottom hole assembly the diamond bit diameter may safely come within 1/16" of the rock bit size. In holes drilled with no stabilization of the drill collar string, and with a difference of 1" to 1½" between rock bit size and drill collar OD, the diameter of the diamond bit may have to be ⅛" under rock bit size to prevent reaming of the rock bit cut hole.

In extreme cases where the rock bits have lost gauge and the hole was drilled with poor stabilization of the bottom hole assembly it may be necessary to reduce the diamond bit diameter ¼" or more below rock bit size in order to prevent reaming.

Reaming a rock bit hole is a slow and costly operation because the diamond bit must be fed at a constant slow rate; if it is not, and the bit is dropped into tight places, it will bind. The diamonds on the outside of the bit often shear for this reason, causing the bit to lose its gauge and cut an undergauge hole. This necessitates reaming with the next bit. Also, dropping a diamond bit in a tight undergauge hole is inviting a stuck drill string and perhaps a costly fishing job.

In some of the harder formations, a diamond bit, under continuous use, will often lose a few thousandths of an inch of the OD gauge before the bit is worn out. This means following bits will have to ream to bottom. Such costly reaming may be avoided by estimating the minimum number of bits that will be required to do the job and alternating them, i.e., change bits for each core. Usually this procedure will insure a full gauge hole and if additional bits are needed above the first estimate, they have a chance of going to bottom without reaming. Also, when reaming or tough formations are anticipated, the diamond bit may be set with an increased diamond concentration on the OD in order to insure as full gauge hole as possible for subsequent bits.

When full hole diamond coring, it is often more economical to rock bit drill the soft intermediate sections. Under these conditions, it is common practice to alternate a diamond bit with a rock bit 1/16" to ⅛" larger in diameter, i.e., after diamond coring or drilling a 1/16" to ⅛" larger rock bit can be run through the diamond cut hole to rock bit drill to the next diamond coring point. The diamond bit should then go back to bottom through the rock bit hole with little effort to resume diamond coring or drilling.

5. WEIGHT ON BIT, ROTARY SPEED VS CIRCULATION RATE:

It is impossible to predetermine the most efficient combination of weight and rotary RPM to use in different formations. Many factors influence the best combination of weight and RPM required. The action of a diamond bit, when properly employed, is similar to that of a "drag" bit. The mechanical factors of "making hole" deal with weight and repetition of moving the cutting elements over the formation being drilled. Therefore, for diamond bits to drill, sufficient weight must be applied to cause the cutting points of the diamonds to penetrate the formation. The degree of penetration depends on: (1) the hardness and characteristics of the formation, (2) size and shape of the diamond point and, (3) the applied unit weight. Weight causes the penetration and the rotation gives movement to the diamonds which removes the formation.

The mechanical factors of weight and rotary speed are directly related to the drilling rate. And, the provided hydraulic factors affect the drilling rate in direct relation to the efficiency with which these mechanical factors are applied. Hydraulically speaking, the "jet principal" as applied to the diamond bit is the only efficient means of keeping the diamonds clean and cool so that new formation may be cut with each rotation, thus, increasing the effectiveness and efficiency of the mechanical factors. Therefore, the "jet action" to be effective on a diamond bit, requires sufficient fluid velocity across its face to satisfactorily clean and cool the diamond points. The ideal fluid velocity is known, and usually other factors that may dictate a necessary change in this ideal velocity are also known. Therefore, for best performance, a diamond bit must be designed to meet the hole conditions and with waterways that will give proper fluid distribution at the ideal

velocity, based on the fluid available to the bit. The available fluid may be limited by the capacity of the pump or pumps on the rig or by the fluid capacity of the diamond core barrel in use.

6. FLUID CAPACITY OF DIAMOND CORE BARRELS:

Circulation through a diamond core barrel is in the annulus between the ID of the outer tube and OD of the inner tube. When the circulation rate is sufficient to result in a fluid velocity in excess of twenty-five feet per second in this annulus, the fluid friction developed between the tubes tends to cause the inner tube to rotate with the outer tube, causing frequent core wedging and loss of core.

FLUID CAPACITY CHART
TRUCO CORE BARRELS

Core Barrel No.	Outer Tube	OD Outer Tube Cross Sectional Area Sq. In.	Core Size	Annulus Area Sq. In.	Fluid Capacity GPM
3	3"	3.522	1¼"	1.14	90
3½	3½"	3.1294	2⅛"	1.58	125
4	4"	2.945	2 11/16"	1.95	150
4½-50	4½"	5.584	2⅜"	2.65	210
5	5"	7.069	2¾"	2.95	230
5 11/16**	5 11/16"	7.68	3½"	3.53	275
5 11/16TJ**	5 11/16"	7.68	2¾"	4.35	450*
5¾CDT-40	5¾"	13.40	2¾"	2.94	230
6⅞CDT-40	6⅞"	18.46	3½"	4.48	350
6⅞	6⅞"	11.155	4⅜"	4.31	340
6⅞TJ	6⅞"	11.155	3½"	8.95	700*
7⅝	7⅝"	11.192	4⅞"	8.50	660
4¼WL	4¼"	8.247	1¼"	3.54	275
4½WL	4½"	8.835	1¼"	4.66	350
5¾WL	5¾"	13.401	1⅞"	7.65	600
6⅞WL	6⅞"	10.013	1⅞"	23.30	700*

**Formerly called 25-50 and 25-50 T. J.

*Fluid capacity based on average annulus area.
The fluid capacity shown in the above table is based on maximum fluid velocity of twenty-five (25) feet per second in the annulus between the outer and inner tubes.

7. FLUID CAPACITY OF DIAMOND BITS:

A simple rule that can be followed to determine the volume rate that should be circulated through a diamond bit already on hand is shown in the following example:

Measure the waterways in the bit, width and depth, and count the number of waterways. The waterways will not be square but with a rounded bottom, the depth should be measured to the bottom and the waterways assumed to have 90 degree angles.

Example Bit: Total number of waterways 16

Waterway Size 7/32" x ⅛"

Calculations: 16 x 7/32 x ⅛ = 56/128 Sq. In.

To produce a fluid velocity of 164 feet per second across the bit face, requires 4 U.S. gallons per minute per 1/128 square inches of waterway area:

Fluid Capacity: 56 x 4 = 224 GPM

To insure dissipation of the cuttings and prevent burning of the diamond points, the fluid velocity across the diamond bit face must be as high as possible without seriously fluid cutting the matrix. There are three factors which affect fluid erosion of the bit matrix. These factors are:

1. Fluid velocity across the bit
2. Length of time the bit is in operation
3. The abrasiveness of the drilling fluid

The unknown and uncontrollable factor is the abrasiveness of the drilling fluid, although similar mud types tend to have approximately the same abrasive action.

The "gallons per minute per 1/128 square inches of waterway area" is known as the "FLUID FACTOR." The Fluid Factor is varied to compensate for the abrasiveness of the different types of drilling mud. The following table will assist in selection of the "FLUID FACTOR" most suitable for the type mud being used:

MUD TYPE	FLUID FACTOR	VELOCITY FT/SECOND
1. Water Base Mud (2% sand or less)	4	164
2. Lime Base Starch Mud	4.5	184
3. Water Base Mud (0-0 Ge. Strength)	4.5	184
4. Water Base Emulsion Mud (10% Oil)	5.0	205
5. Lime Base Oil Emulsion Mud	5.5	225
6. Water in Oil Emulsion	6.0	246
7. Water (Nothing Added)	6 to 8	328
8. Crude Oil	6 to 8	328
9. Oil Base Mud	6 to 8	328

The preceding hypothetical example shows how to compute the fluid capacity of bits on hand. When ordering a bit, the type mud and available circulation rate should be given and we will custom design the bit for the job.

8. OBTAINING A BALANCE OF THE MECHANICAL AND HYDRAULIC FACTORS:

When going to bottom with a diamond core or drill bit, stop the bit at least two feet off bottom and regulate the pump strokes to deliver the volume rate at the fluid capacity of the diamond bit in use. Lower the bit to bottom without rotating, if possible, so as to pump any junk iron or pieces of formation off bottom. Apply 5-8,000 pounds to make sure the bit is setting on bottom and not in cavings. After this operation, pick up two to three feet off bottom and rotate slowly (40 to 50 RPM) and then lower to bottom and apply weight (5,000 pounds). Then gradually increase the drilling weight until the best penetration rate is obtained.

After the bit is seated and the core is entering the inner barrel, recheck the pump for the desired number of strokes. The pump pressure with this number of strokes should have increased approximately 200 to 275 PSI. This pressure increase is actually the pressure drop across the diamond bit. By increasing the rotary speed gradually until the best penetration rate is obtained, the most efficient combination of weight and rotary speed will be balanced with the fluid energy delivered to the bit.

This second and final pressure, established after the bit has started drilling, is the important pressure that must be kept in mind constantly throughout the operation. If this final pump pressure increases or decreases, it is a definite indication that something abnormal is occuring and the cause should be determined and corrected. Otherwise, the diamond bit may be damaged, core recovery reduced, or costly rig time needlessly consumed.

The following paragraphs will discuss the possible cause of pump pressure changes:

A. Pressure increase or decrease may be due to a change in the pump volume. When the pressure changes, check the pump strokes first.

B. If the pressure increases and the pump volume is correct, it is possible that the bit has failed. As a rule, a ring of diamonds will have been destroyed, which will allow the formation to wear into the matrix, restricting the waterways and causing a pressure increase. If this is the trouble, the pressure will drop when the bit is picked off bottom. And, when set back on bottom the pressure will immediately increase to the reading before being picked up. When these symptoms are definite, pull the bit to save further diamond damage and costly rig time.

C. Pressure increase may be due to a plugged circulatory system from debris in the mud, such as pieces of piston swabs, valve rubber, pipe protectors, soft rope, etc. If this is the trouble the pressure will remain unchanged when the bit is picked off bottom. The coring might be continued if the trouble is definitely established as a plugged circulatory system; but it would be a rather blind and hazardous operation and the best practice is to come out of the hole to correct the trouble.

D. Increasing or decreasing pressure may be due to spotty, unbalanced mud. However, this mud condition is usually known and continued circulation will usually correct the situation. Meantime, with everything else normal, an allowance may be made for the pressure variations to compensate for the mud conditions until corrected.

E. Pressure decrease may be due to a wedged core holding the bit off bottom, such a decrease being accompanied by loss of torque and slow drilling time. This usually occurs when coring the harder fractured formations and it is a waste of time to try to force the bit to cut. Come out of the hole.

F. Fluctuating pump pressures usually occur when coring the softer fractured formations. When the fractures cause the core to wedge, the bit will quickly cut itself free, transferring the drilling weight to the core. At this point, the penetration rate will slow up noticeably until the weight crushes the soft core in the bit area. As the soft crushed core washes out through the small waterways, the pressure will increase 50 PSI or more. As soon as the crushed core washes out through the small waterways, the pressure will return to normal and at the same time the penetration rate will speed up. When the pump pressure fluctuates and drilling time is erratic in a formation that is known to be soft and fractured, the core barrel should be pulled to avoid core loss.

9. MAKING CONNECTIONS:

Stop the rotary table but maintain circulation. Pick the core barrel off bottom slowly, watching the weight indicator closely.

Most cores break off readily; however, in some formations the cores are tough to break. In such a case, pull at least 22,000 to 30,000 pounds above the drill string weight, then set the brake and slowly rock into the core with the rotary until the core breaks.

When the core breaks, pick up at least 20 feet off bottom and then slowly lower back to within 18 inches of bottom, feeling for any core that may have been lost out of the barrel. If the core is felt in the hole it is usually a comparatively simple operation to work over it.

10. PICKING UP LOST CORE:

Feel for the top of the core slowly and when the top of the core takes approximately 500 pounds, agitate with the rotary or slowly rotate. If the formation is not fractured and long cores have been cut the core barrel should readily go over the core. If it does not, this usually indicates that a short piece of core has turned sideways in the hole, necessitating redrilling. When redrilling over a piece of core, use a very light, steady weight or the bit may be damaged. When available, it is advisable to use an old bit of doubtful further footage for lost core pickup.

11. SUMMARY OF CORING INSTRUCTIONS:

A. Let the hole conditions dictate the mud to be used.

B. Be sure the hole is clean.

C. Make trips in the same manner as with rock bits.

D. Regulate the pump to deliver the correct volume constantly.

E. Keep close watch for pressure changes.

F. Find the weight that gives the best penetration rate. Apply the weight smoothly and continuously so that bottom is crowded at all times.

G. Experiment with the rotary speed to find the RPM that gives best results.

H. Keep the stabilizer directly above the bit within 1/16" of the bit diameter.

I. Use drill collars when possible.

J. Do not exceed the fluid capacity of the diamond bit or diamond core barrel for long periods.

K. Keep the outer and inner tubes straight.

INSTRUCTIONS FOR ASSEMBLING AND MAINTAINING TRUCO CORE BARRELS

Diamond Core Barrel care is a continuous job. It starts before the core barrel is ever used and never stops until the core barrel is finally retired. The following suggestions on care of the diamond core barrel are offered to help operators get maximum service from their core barrels at minimum cost.

1. LUBRICATION THREADED JOINTS:

A. The old adage: "cleanliness is next to Godliness" applies aptly to the threaded joints of the diamond core barrel. Make sure both pin and box threads are perfectly clean and well lubricated with a clean lubricant and swab before making up the threaded joints.

2. MAKE UP TORQUE OF THREADED JOINTS:

A. The threaded joints should be "hand tonged" in and out. That is the spinning rope or chain or rotary should never be used to spin the threads in or out.

B. Final torque on make up of the joints is important. Over-torquing will impose excessive stress on the threads. And insufficient torque can permit a joint to rock to cause wear and premature failure.

C. Tonging a joint with the derrick tongs too high above the slips or rotary can easily spring or bend the tubes. Keep the joint and tongs close to the rotary.

D. Outer Tubes: Use derrick tongs and make up joints with approximately the same torque as used on the tool joints in the drill string.

E. Inner Tubes: The cross sectional area of the inner tube threads is small as compared to that of tool joints, therefore, caution should be taken when making up these joints. The final torque on make up of the center inner tube threads should be with the derrick tongs and jerkline, using two raps on the cat head and a series of relatively hard jerks. The inner tube clamp may be placed around the box thread which will prevent "belling" of the box if by accident the final torque on make up is too great.

F. Inner tube head and core catcher sleeve must be made up with the wrenches provided by hitting the handles with a sledge hammer.

3. REPAIRING DIAMOND CORE BARRELS:

During the life of a core barrel it may become necessary to shop it to recut the threads and/or to straighten the tubes. When recutting threads, the correct length relation between the inner and outer tubes must be maintained to insure the correct critical dimension. The following suggestions will insure that the proper tube length relations are maintained:

A. Outer Tubes: When an outer tube is cut off and rethreaded, the exact same amount must be cut off the matching inner tube.

B. Inner Tube: When it is necessary to replace inner tube threads, it is best to cut the damaged end off, rethread and install a threaded repair sub the same length as the portion cut off. 12" inner tube repair subs are normally carried in stock and any other length can be furnished.

4. STABILIZERS:

TRUCO core barrels are equipped with a stabilizer directly above the diamond bit, which is the minimum stabilization recommended for diamond core barrels. The purpose of this stabilizer is to prevent the cutting of a spiral or wavy core which, when excessive will cause core blocking and core loss. The stabilizers are furnished from 0" to .015" under the diamond bit size and when it wears to 1/16" under the bit size it should be rebuilt to the correct diameter or replaced.

A. When rebuilding the stabilizer ribs: build up with tungsten carbide using an acetylene torch. Then grind to size in a lathe to insure the OD of the ribs being concentric with the bore.

The inner tubes are stabilized at only one point with four stabilizer lugs inside of the lower stabilizer sub. These lugs should be kept in repair. The original clearance is 1/16" between the ID of the stabilizer lugs and the OD of the core catcher sleeve.

5. KEEPING THE OUTER AND INNER TUBES STRAIGHT:

The inner tubes are suspended from ball bearings to insure non-rotation. This feature, which is most essential to satisfactory core barrel operation, will be eliminated if either the outer or inner tube becomes bent. Bent tubes will increase the forces acting to cause the inner tube to rotate with the outer tube. To detect bent tubes, hang the assembled core barrel in the derrick, and before installing the diamond bit, swell the fist inside the inner tube and turn it. If the inner tube does not turn freely, indications are that some of the tubes are bent and should be straightened. When assembled, it is often difficult to determine whether it is the inner or outer tube that is bent. When in doubt hang the inner tube in the derrick, assembled to the bearing assembly, and spin by hand. If the inner barrels are bent it will be apparent:

A sure test for tube straightness is to lay them in a set of rollers, roll them on a pipe rack, or take them to a shop.

6. SAFETY JOINT:

The safety joint must be kept clean and well lubricated with both '0" rings in good condition and in place.

7. BEARING ASSEMBLY:

A. Three types of bearing assemblies are available:

1. Standard — 3 bearings enclosed in lubricant.
2. Jar — 6 bearings enclosed in lubricant.
3. Open — flat seat thrust bearing mud lubricated.

B. The enclosed types must be well lubricated at all times. After each trip pump housing full of grease until it comes out freely and clean around the shaft at the grease seal.

1. The standard, three bearing type, has a diaphragm above the bearings to equalize the pressure inside the bearing housing with the hydrostatic pressure in the hole. If grease should come out the small holes above the bearings it is an indication that the diaphragm is ruptured and in need of replacement.

2. The jar type employs a sliding grease seal at the bottom of the assembly to equalize the pressure inside the bearing housing with the hydrostatic pressure in the hole. Otherwise, the maintenance is the same for both types of enclosed bearings.

3. The open bearing assembly requires very little maintenance other than to closely observe its wear and replace parts as needed. The life expectancy of this bearing is somewhat less than the enclosed grease lubricated bearings.

TRUCO CORE BARRELS

Successful coring operations depend greatly on the core barrel performance. Regardless of how perfect the core bit may be, it CANNOT perform effectively unless the core quickly passes into the core barrel, away from the core bit area. To accomplish this, a core barrel should be designed to include the following features:

1. A non-rotating inner tube. If the inner tube rotates, torque will be applied to the core being cut causing fractured cores and wedging. To insure a non-rotating inner tube, the tube must be streamlined inside and outside and suspended on well lubricated anti-fricton bearings.
2. An inner tube having a smooth bore to aid in prevention of core wedging by minimizing core friction.
3. Protection of the core being cut from the circulating fluid. The core should be exposed to the fluid only enough to flush away the cuttings before the core enters the inner tube.
4. A core catcher that will allow the core to pass with a minimum of disturbance. Otherwise, the core will be scrambled and will usually wedge in the inner barrel.
5. Allowance for full fluid circulation.

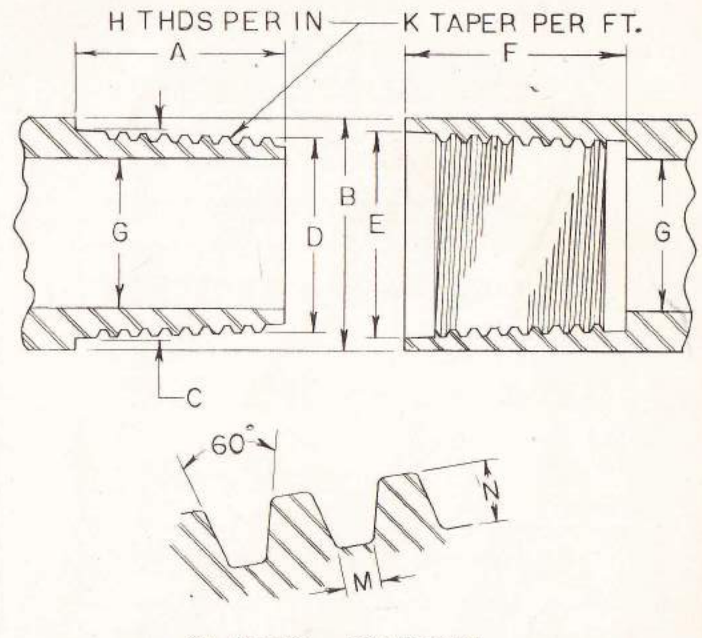
DRILLING & SERVICE, INC. has incorporated all of the above features in their TRUCO core barrels. In addition to these necessary design features the core barrel must be rugged enough to withstand normal oil field use and streamlined enough to give you the maximum hydraulic advantage. The following table was designed to give you a quick reference to the available TRUCO core barrel sizes, their strength and their hydraulic characteristics.

CORE BARREL SPECIFICATIONS

Core Barrel Name or Number	Top Connect.	Outer Tube OD In.	Outer Tube ID In.	Outer Tube Cross Sect. Area In.^{2}	Inner Tube OD In.	Inner Tube ID In.	Annulus Area Outer and Inner In.^{2}	Fluid Capacity GPM*	Core Size In.	Core Bit OD Range	Section Modulus In.^{3}
3½	2⅜ Reg.	3½	2⅞	3.12	2½	2¼	1.58	125	2⅛	3¾ - 4¼	2.29
4	2⅞ Reg.	4	3½	2.94	3⅛	2⅞	1.95	150	2¹¹⁄₁₆	4¼ - 4⁹⁄₁₆	2.64
3-40	2⅜ Reg.	3	2⅛	3.52	1¾	1⅜	1.14	90	1¼	3⅛ - 4¼	2.0
3½-40	2⅜ Reg.	3½	2⅛	6.07	1¾	1⅜	1.14	90	1¼	3⅞ - 4¾	3.65
4½-50	3½ Reg.	4½	3⅝	5.58	3⅛	2½	2.65	210	2⅜	4¾ - 5¾	5.18
5	3½ Reg.	5	4	7.07	3½	2⅞	2.95	230	2¾	5⅜ - 6⅛	7.31
5¹¹⁄₁₆	4½ Reg.	5¹¹⁄₁₆	4¾	7.68	4¼	3⅝	3.53	275	3½	6⅛ - 7¾	8.75
5¹¹⁄₁₆ TJ	4½ Reg.	5¹¹⁄₁₆	4¾	7.68	3½	2⅞	4.35	450	2¾	6⅛ - 7¾	8.75
6⅞	5½ Reg.	6⅞	5¾	11.15	5¼	4½	4.31	340	4⅜	7¼ - 9	16.16
6⅞ TJ	5½ Reg.	6⅞	5¾	11.15	4¼	3⅝	8.95	700	3½	7¼ - 9	16.16
7⅝	5½ Reg.	7⅝	6⅝	11.19	5¾	5	8.50	660	4⅞	8¼ - 10½	18.83
5¾ CDT-40	4½ FH	5¾	4	13.40	3½	2⅞	2.94	230	2¾	6⅛ - 8¾	14.39
6⅞ CDT-40	5½ Reg.	6⅞	4⅞	18.46	4¼	3⅝	4.48	350	3½	7¼ - 9	23.9
4¼ WL	2⅞ IF	4¼	2¾	8.24	1¾	1⅜	3.54	275	1¼	4½ - 5¾	6.88
4½ WL	2⅞ IF	4½	3	8.83	1¾	1⅜	4.66	350	1¼	4¾ - 5¾	7.17
5¾ WL	4½ FH	5¾	4	13.40	2½	2	7.65	600	1⅞	6⅛ - 8¾	14.39
6⅞ WL	5½ Reg.	6⅞	4⅞	18.46	2½	2	13.76	700	1⅞	7¼ - 9	23.9

TJ—Tool Joint
WL—Wire Line
* Based on an annular velocity between the inner and outer tube of 25 feet per second.

TRUCO OUTER BARREL THREADS

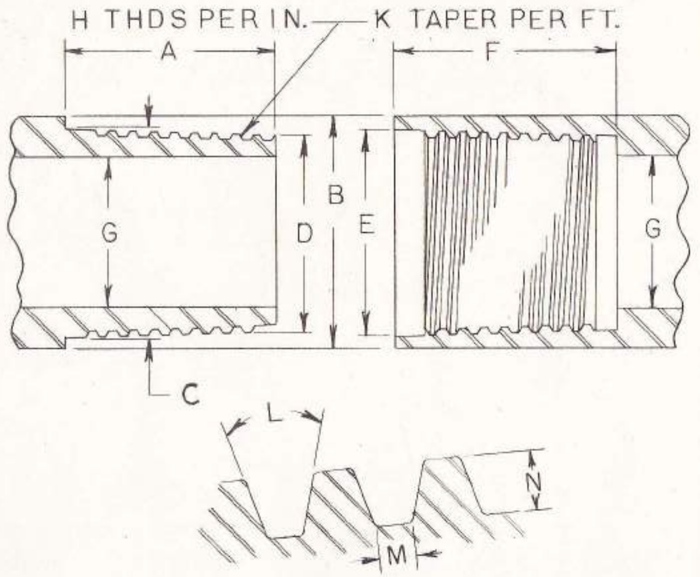


OUTER BARREL

● 25-50 CORE BBL.

CORE BBL. NAME OR NO.	A	B	C	D	E	F	G	H	K	M	N
3-40	2,500	3	2,728	2,556	2,738	2,500	2¼	5	¾	.045	.080
3½-40	2,500	3½	3,046	2,736	3,056	2,500	2¼	5	¾	.045	.090
4½-50	2,750	4½	4,228	4,056	4,233	2,750	3⅝	5	¾	.058	.080
5	2,750	5	4,625	4,285	4,635	2,750	4	5	¾	.058	.080
5¹¹⁄₁₆ ●	2,750	5¹¹⁄₁₆	5,385	5,214	5,395	2,750	4¾	5	¾	.058	.080
5¹¹⁄₁₆-TJ	2,750	5¹¹⁄₁₆	5,385	5,214	5,395	2,750	4¾	5	¾	.058	.080
6⅞	2,500	6⅞	6,587	6,431	6,597	2,500	5⅞	5	¾	.058	.080
6⅞-TJ	2,500	6⅞	6,587	6,431	6,597	2,500	5⅞	5	¾	.058	.080
7⅝	2,750	7⅝	7,360	7,188	7,370	2,750	6⅝	5	¾	.058	.080
5¾ CDT-40	4,000	5¾	5,111	4,861	5,131	4,000	4	4	¾	.056	.114
6⅞ CDT-40	4,000	6⅞	6,111	5,861	6,121	4,000	4⅛	4	¾	.056	.111
4¼ WL	4,000	4¼	3,736	3,236	3,746	4,000	2¾	4	¾	.056	.111
4½ WL	4,000	4½	3,986	3,736	3,996	4,000	3	4	¾	.056	.111
5¾ WL	4,000	5¾	5,111	4,611	5,121	4,000	4	4	¾	.056	.111
6⅞ WL	4,000	6⅞	6,111	5,861	6,121	4,000	4⅞	4	¾	.056	.111

TRUCO INNER BARREL THREADS



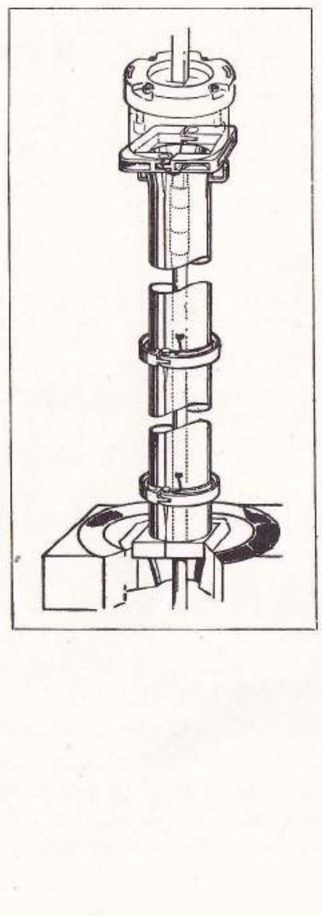
INNER BARREL—AVAILABLE L.H. OR R.H.

● 25-50 CORE BBL.

CORE BBL. NAME OR NO.	A	B	C	D	E	F	G	H	K	L	M	N
3—40	1.375	1 3/4	1.625	1.625	1.635	1.375	1 3/8	10	0	60	.023	.045
3 1/2—40	1.375	1 3/4	1.625	1.625	1.635	1.375	1 3/8	10	0	60	.023	.045
4 1/2—50	2.000	3 1/8	2.935	2.810	2.945	2.000	2 1/2	5	3/4	29	.093	.060
5	2.000	3 1/2	3.310	3.185	3.320	2.000	2 7/8	5	3/4	29	.093	.060
5 11/16 ●	2.000	4 1/4	4.060	3.935	4.070	2.000	3 5/8	5	3/4	29	.093	.060
5 11/16 TJ	1.250	1 3/4	1.500	1.500	1.510	1.250	1 3/8	10	0	60	.023	.090
6 7/8	2.500	5 1/4	5.015	4.859	5.025	2.500	4 1/2	5	3/4	29	.093	.060
6 7/8 TJ	2.750	4 1/2	4.228	4.056	4.233	2.750	3 5/8	5	3/4	60	.058	.080
7 5/8	2.500	5 3/4	5.503	5.537	5.513	2.500	5	5	3/4	29	.093	.060
5 3/4 CDT	2.500	3 1/2	3.286	3.130	3.296	2.500	2 7/8	5	3/8	29	.095	.060
6 7/8 CDT	2.500	4 1/4	4.036	3.958	4.046	2.500	3 5/8	5	3/8	29	.093	.060
4 1/4 W L	1.250	1 3/4	1.500	1.500	1.510	1.250	1 3/8	10	0	60	.023	.090
4 1/2 W L	1.250	1 3/4	1.500	1.500	1.510	1.250	1 3/8	10	0	60	.023	.090
5 3/4 W L	1.500	2 1/2	2.167	2.167	2.172	1.500	2	12	0	60	0	.050
6 7/8 W L	1.500	2 1/2	2.167	2.167	2.172	1.500	2	12	0	60	0	.050

TRUCO'S KELLY EXTENSION DRIVE

PATENT # 3,038,547



The TRUCO KELLY EXTENSION DRIVE is a simple mechanical means of supplying torque to the Kelly bushing, while the bushing is above the rotary table.

The KELLY EXTENSION DRIVE can be used for the following operations:

1. Diamond Coring — Eliminates making connections.
2. Washover — Pulling off of the fish to make connection is eliminated.
3. Spudding in well when the weight of an extra drill collar is required.
4. Drilling back through a key-seat or tight hole.
5. Drilling under pressure — Rotates round pipe in pack off.

The KELLY EXTENSION DRIVE is 20 feet long and weighs 1750 pounds.

PROCEDURE FOR HANDLING KELLY EXTENSION DRIVE

1. Check drill pipe measurements before reaching bottom to determine whether a pup joint will be needed to give a minimum of 50 feet of Kelly and drill pipe above the rotary to avoid making a connection when cutting a 50 foot core.

2. The maximum drill pipe that can be above the rotary is: 16 feet.

3. If a "pup joint" is to be used, add it to the drill string prior to picking up the last regular joint of drill pipe. The "pup joint" will permit washing the hole to bottom; then a "rat hole" connection can be made to add the last joint of pipe between the Kelly and "pup joint" without setting the bit on bottom.

4. INSTALLING KELLY EXTENSION DRIVE:

A. Pull Drive into V-door with cat-line and chain sling with longer chains hooked in the two eyes at top of Drive.

B. Remove all lock pins except the bottom one.

C. Set Drive in vertical position on or near rotary with opening split toward draw-works and remove remaining bottom lock pin.

D. Open drive, pick up with cat-line and place in position around Kelly.

E. Replace all lock pins and lower Kelly bushing into top of Drive, ready to proceed with coring.

F. Core until a minimum of 5' of Kelly is above Kelly bushing. Otherwise, it will make it difficult to raise the Kelly bushing out of the Drive preparatory to laying it down.

5. LAYING THE KELLY EXTENSION DRIVE DOWN:

A. Stop the rotary with lock pins toward the draw works and remove all of them.

B. Hook the two short chains of the chain sling to the Kelly bushing and the two long chains in the eyes on the Drive. The cat-line will then pick up the Kelly bushing and Drive simultaneously.

C. Remove Drive, set on rotary on the driller's side and install bottom lock pin.

D. Pick Drive up with catline and start lower end toward V-door, allowing sufficient slack for Kelly bushing to slide down Kelly into its regular position in the rotary table and unhook chains.

E. Proceed out V-door with Drive.

6. Two catlines on a rig will greatly facilitate laying down the Drive, because one can be used to handle the Kelly bushing while the other is used to handle the Drive independently. Often a second cat-line can be easily installed on some rigs for the purpose.

7. SAFETY PRECAUTIONS:

A. The Kelly Drive is heavy. Therefore, the cat-line must be in good condition. Examine it closely for weak points and it should be $1\frac{1}{2}$" rope.

B. Avoid holding weight of Drive on cat-line for long periods. Plan ahead and handle in minimum of time.

C. If cat-head and line develop excessive heat, cool with water.

D. Close Drive and insert a lock pin before attempting to lay down. Otherwise, it may snap shut with terrific force, endangering the workmen.

E. Keep hands and arms clear of split when installing or removing Drive.

8. RIG REQUIREMENTS FOR HANDLING KELLY EXTENSION DRIVE:

A. Two cat-lines; one of which should be $1\frac{1}{2}$" will easily install and remove the Kelly Extension Drive.

B. When only one cat-line is available, a 20' ladder attached to a V-slot in the Drive, provides access to all the lock ring pins and lifting chains.

TRUCO'S EXPANDABLE DRILL REAMER

PATENT # 3,051,255

The TRUCO Expandable Drill Reamer is a positive, mechanically actuated, expandable drill reamer which may also be used as an under-reamer. The reamer sub and blades comprise an integral part of the drill string, operating immediately above the bit, for the purpose of reaming and/or under-reaming simultaneously with the drilling of the hole; therefore, extra trips and rig time are eliminated when reaming or under-reaming.

Mechanical operation of the tool is very simple; when going in the hole, a Shear Pin arrangement maintains the Reamer Blades in a retracted position by holding the grease enclosed splined mandrel in an "up" position. When the drill bit reaches bottom, weight is applied — usually about 10,000 pounds — the pin shears allowing the mandrel to move downward and in the same motion expand the reamer blades outward (see Fig. 2). As long as weight is on the drill bit, reaming is certain.

For under-reaming below pipe, 18" of open hole is required below the pipe to allow the blades to expand into formation rather than pipe.

When removing the drill string from the hole, the tapered mandrel travels upward to retracted position, allowing the blades to also retract so the reamer can be pulled from the hole.

Expandable drill reamers are available in three sizes shown in the table and may be used with either diamond or rock bits.

Reamer No.	Threads API Reg.	OD of Body	Maximum Expansion
2⅞	2⅞	4¼	½"
3½	3½	5¼	¾"
4½	4½	7¼	¾"

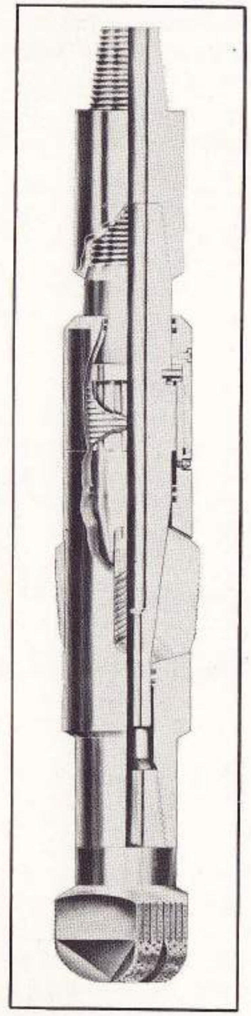


Fig. 1

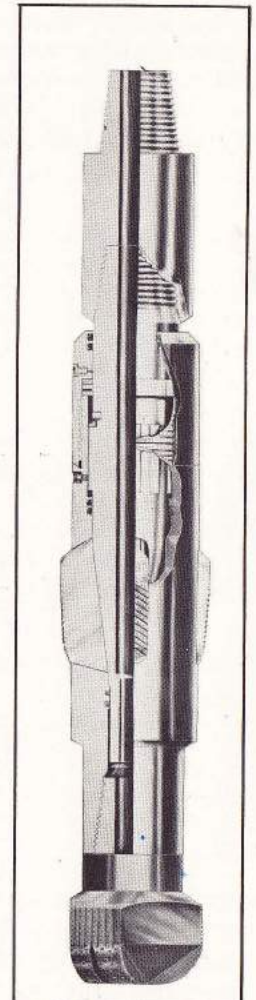


Fig. 2

DIAMOND BIT SPECIFICATIONS

A reprint from API Std. 7, March 1963, Sect. 8

8.1 Diamond Bit Tolerances. Diamond drilling and diamond coring bits shall be subject to the OD tolerances shown in Table, 8.1.

TABLE 8.1

DIAMOND DRILLING AND DIAMOND CORING BIT TOLERANCES

1	2
Nominal Bit Size, OD, inches	OD Tolerance, inches
6¾ and smaller	+0, —0.015
From 6¾ to and including 9	+0, —0.020
Larger than 9	+0, —0.030

8.2 Diamond Drilling Bit Connections. Diamond drilling bits shall be furnished with the size and style pin connection shown in Table 8.2. All connection threads shall be right hand.

TABLE 8.2

DIAMOND DRILLING BIT CONNECTIONS

1	2
Size of Bit, inches	Size and Style of Rotary Connection
3$\frac{11}{16}$ to 4½ incl.	2⅜ REG
4$\frac{9}{16}$ to 5 incl.	2⅞ REG
5$\frac{1}{16}$ to 7⅜ incl.	3½ REG
7$\frac{7}{16}$ to 9½ incl.	4½ REG
9$\frac{9}{16}$ and larger	6⅝ REG

8.3 Diamond Bit Gaging. In field gaging diamond bits the following dimensions and practice are recommended:

a. Gage Specification. "Go" and "No Go" gages should be fabricated as shown in Fig. 8.1 and as described below:

1. "Go" and "No Go" gages should be a ring fabricated from 1 in. steel with an OD equal to nominal bit size plus 1½ in.

2. "Go" gage ID should equal nominal bit size plus 0.002 in. clearance with a tolerance of +0.003, —0.

3. "No Go" gage ID should equal minimum bit size (nominal less maximum negative tolerance) minus 0.002 in. interference with a tolerance of +0, —0.003.

b. Gaging Practice. The "Go" and "No Go" gages should be used as follows:

1. If acceptable, the product bit should enter the "Go" gage (Product not too large).

2. If acceptable, the product bit should not enter the "No Go" gage (Product not too small).

3. Both the "Go" and "No Go" gages should be within 20° F of the same temperature as the bit or corehead for accurate measurement.

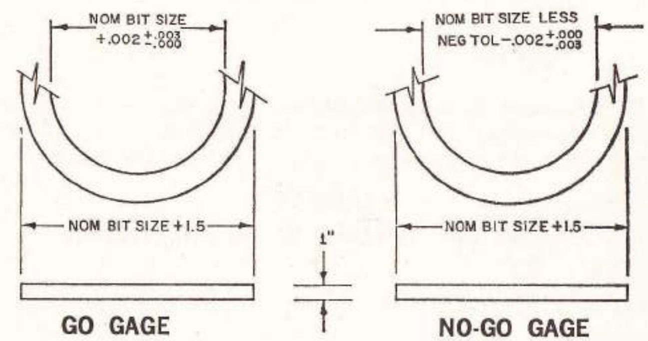


FIG. 8.1

DIAMOND BIT GAGE DIMENSIONS

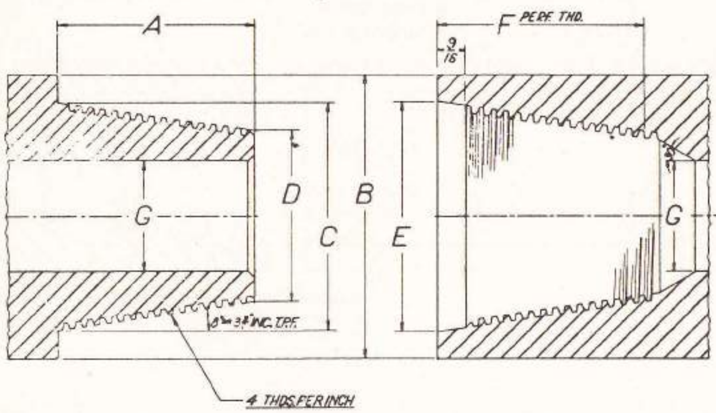
(All Dimensions in Inches)

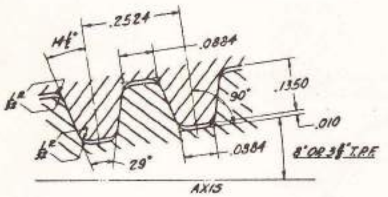
8.4 Marking. Diamond bits shall be die stamped with the manufacturer's name or identification mark, the API monogram, and the size and style of connection.

Example: A bit with 4½ in. regular rotary connection shall be stamped as follows:

A B CO API **4½ REG**

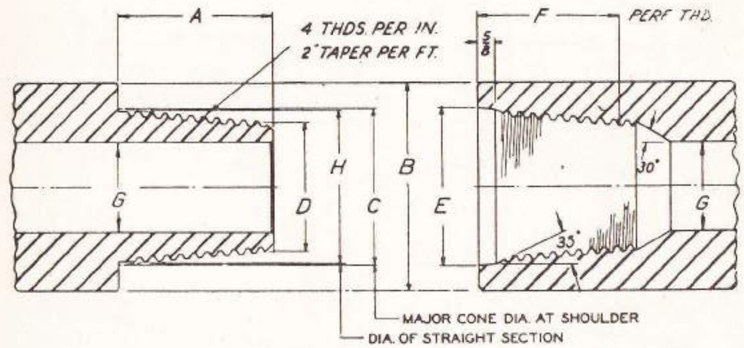
NOTE: The API monogram may be applied by authorized manufacturers only.

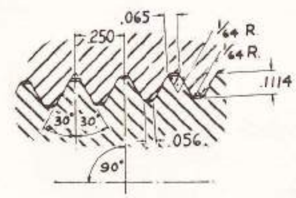




ACME REGULAR

SIZE	A	B	C	D	E	F	G
2 3/8	3	3 1/8	2 19/32	1 3/4	2 5/8	3 1/2	1
2 7/8	3 1/2	3 3/4	2 63/64	2	3 1/64	4	1 1/4
3 1/2	3 1/2	4 1/4	3 17/32	2 17/32	3 9/16	4	1 3/4
4 1/2	4	5 1/2	4 39/64	3 31/64	4 21/32	4 1/2	2 1/2
5 1/2	4 1/2	6 3/4	5 41/64	4 3/8	5 11/16	5	3
6 5/8	5	7 3/4	6 27/64	5 1/64	6 15/32	5 1/2	3 1/2

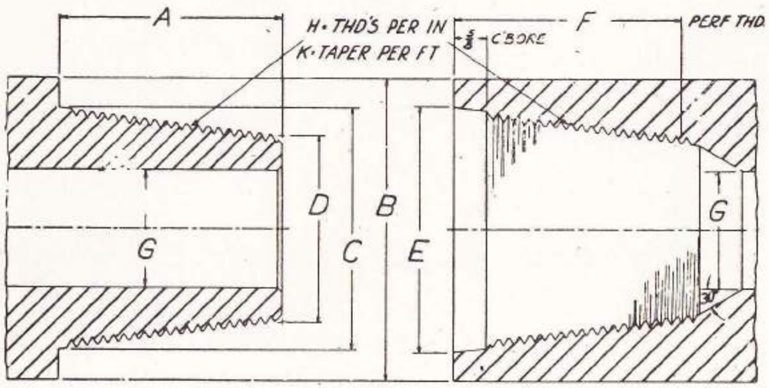


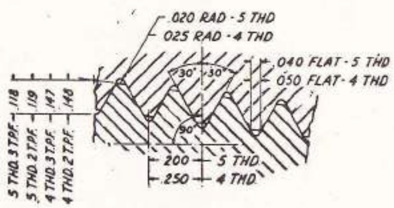


HUGHES XTRA HOLE

SIZE	A	B	C	D	E	F	G	H
① 2 7/8	3 7/8	4 1/4	3 21/64	2 11/16	3 23/64	4 1/2	1 7/8	3 15/64
② 3 1/2	3 3/8	4 3/4	3 13/16	3 1/4	3 7/8	3 15/16	2 7/16	—
③ 4 1/2	4 3/8	6	4 53/64	4 7/64	4 29/32	4 15/16	3 1/4	—
④ 5	4 1/2	6 1/4	5 1/4	4 1/2	5 5/16	4 7/8	3 3/4	—

① THREADED PORTION SAME AS 3 1/2" REED DBL. STREAMLINE.
② " " " " 4 1/2" HUGHES EXT. FLUSH AND 4 1/2" F.H. REED EXT. FLUSH
③ " " " " 4" API-IF AND 5" REED DOUBLE STREAMLINE
④ " " " " 4 1/2" API-IF AND 5 1/2" REED DOUBLE STREAMLINE

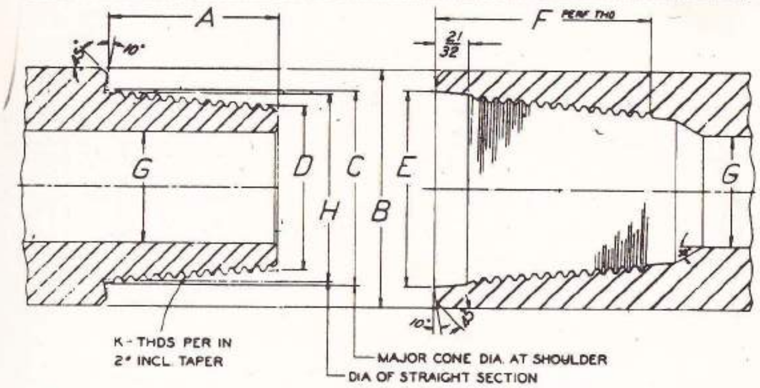


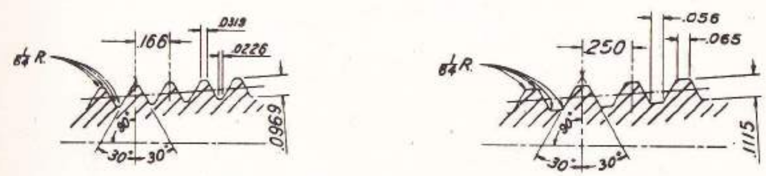


A. P. I. REGULAR

SIZE	A	B	C	D	E	F	G	H	K
2 3/8	3	3 1/8	2 5/8	1 7/8	2 11/16	3 3/8	1	5	3
2 7/8	3 1/2	3 3/4	3	2 1/8	3 1/16	3 7/8	1 1/4	5	3
3 1/2	3 3/4	4 1/4	3 1/2	2 9/16	3 9/16	4 1/8	1 1/2	5	3
4 1/2	4 1/4	* 5 1/2	4 5/8	3 9/16	4 11/16	4 5/8	2 1/4	5	3
5 1/2	4 3/4	6 3/4	5 33/64	4 21/64	5 37/64	5 1/8	2 3/4	4	3
6 5/8	5	7 3/4	6	5 5/32	6 1/16	5 3/8	3 1/2	4	2
7 5/8	5 1/4	8 7/8	7	5 11/16	7 1/16	5 5/8	4	4	3
8 5/8	5 3/8	10	7 61/64	6 33/64	8 1/64	5 3/4	4 3/4	4	3

* 5 3/4 O.D. IS OPTIONAL





6 THD. 2" T.P.F.

4 THD. 2" T.P.F.

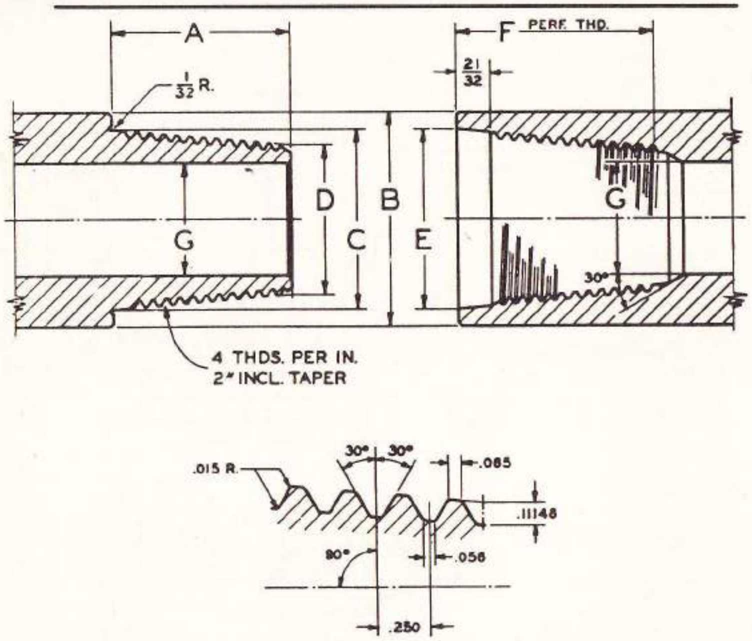
HUGHES EXTERNAL FLUSH

SIZE	A	B	C	D	E	F	G	H	K
③ 2 3/8	2 3/8	2 1/2	2 7/64	1 23/32	* 2 1/16	3 1/4	1	2 1/64	6
2 7/8	2 5/8	3	2 1/2	2 1/16	2 17/32	3	1 1/16	–	6
① 3 1/2	3 1/4	3 5/8	3	2 29/64	3 1/32	4	1 1/2	–	4
① 3 1/2	3 1/4	3 11/16	3	2 29/64	3 1/32	4	1 1/2	–	4
② 4 1/2	3 3/8	4 11/16	3 13/16	3 1/4	3 7/8	4 1/4	2 3/16	–	4
② 4 1/2	3 3/8	4 17/32	3 13/16	3 1/4	3 7/8	4 1/4	2 3/16	–	4

① THREADED PORTIONS ARE SAME AS 3 1/2" F.H REED EXTERNAL FLUSH.
② " " " " " 4 1/2" " " " " &
3 1/2" HUGHES XTRA HOLE.

* STRAIGHT COUNTERBORE

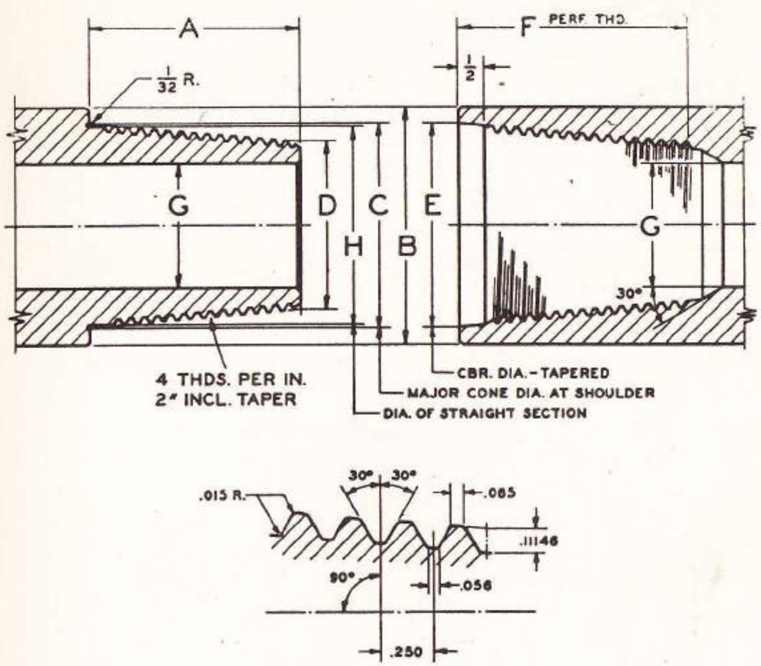
③ SAME AS 2 3/8 HOMCO 'LITTLE INCH'



HUGHES SLIM HOLE

SIZE	A	B	C	D	E	F	G
$2\frac{3}{8}$		$2\frac{7}{8}$	$2\frac{7}{16}$		$2\frac{1}{2}$		$1\frac{1}{4}$
① $2\frac{7}{8}$	$2\frac{7}{8}$	$3\frac{3}{8}$	$2\frac{7}{8}$	$2\frac{25}{64}$	$2\frac{15}{16}$	$3\frac{1}{4}$	$1\frac{3}{4}$
② $3\frac{1}{2}$	$3\frac{3}{8}$	4	$3\frac{25}{64}$	$2\frac{53}{64}$	$3\frac{29}{64}$	$3\frac{3}{4}$	$2\frac{1}{8}$
③ 4	$3\frac{3}{8}$	$4\frac{1}{2}$	$3\frac{13}{16}$	$3\frac{1}{4}$	$3\frac{7}{8}$	$3\frac{3}{4}$	$2\frac{9}{16}$
④ $4\frac{1}{2}$		5	$4\frac{1}{64}$		$4\frac{5}{64}$		$2\frac{11}{16}$

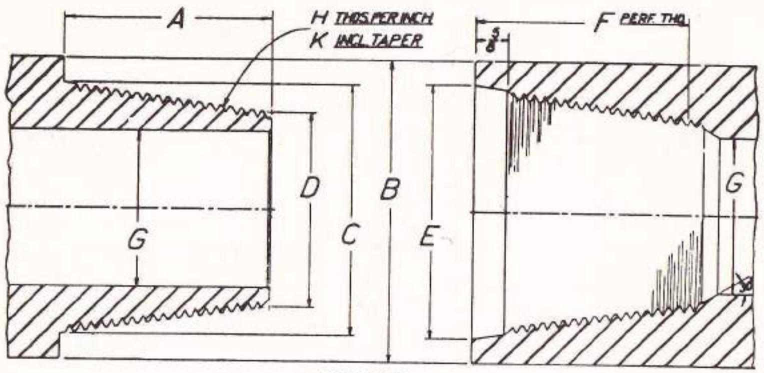
① THREADED PORTION SAME AS 2 3/8" API-IF
② " " " " 2 7/8" API-IF
③ " " " " 3 1/2" HUGHES XTRA HOLE AND 3 1/2" REED SEMI-INTERNAL FLUSH
④ " " " " 3 1/2" API-IF

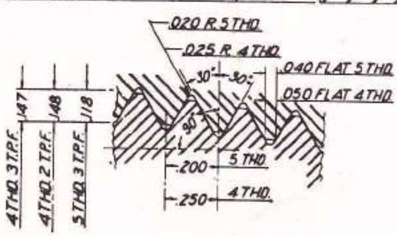


HUGHES DOUBLE STREAMLINE

SIZE	A	B	C	D	E	F	G	H
① $3\frac{1}{2}$	$3\frac{7}{8}$	$3\frac{7}{8}$	$3\frac{21}{64}$	$2\frac{11}{16}$	$3\frac{23}{64}$	$4\frac{1}{4}$	$1\frac{13}{16}$	$3\frac{15}{64}$
② 4	4	$4\frac{1}{2}$	$3\frac{57}{64}$	$3\frac{7}{32}$	$3\frac{59}{64}$	$4\frac{3}{8}$	$2\frac{3}{8}$	$3\frac{51}{64}$
③ $4\frac{1}{2}$	$4\frac{1}{2}$	5	$4\frac{9}{32}$	$3\frac{17}{32}$	$4\frac{5}{16}$	$4\frac{7}{8}$	$2\frac{11}{16}$	$4\frac{3}{16}$

① THREADED PORTION SAME AS 2 7/8" HUGHES XTRA HOLE AND 3 1/2" REED DOUBLE STREAMLINE
② " " " " 4" REED DOUBLE STREAMLINE
③ " " " " 4 1/2" REED DOUBLE STREAMLINE





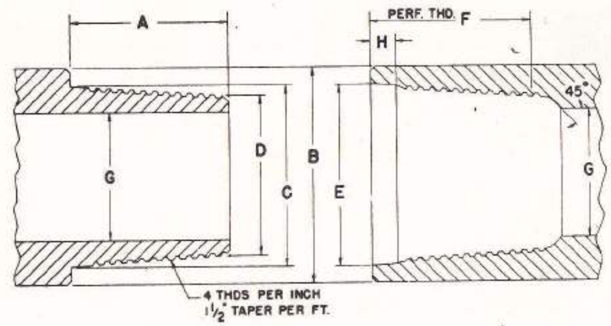
A. P. I. FULL HOLE

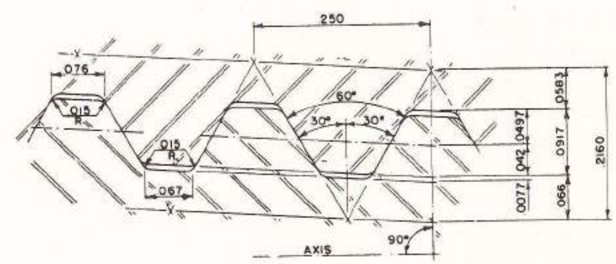
SIZE	A	B	C	D	E	F	G	H	K
* 2 7/8	3 1/2	4 1/4	3 5/8	2 3/4	3 11/16	3 7/8	2 1/8	5	3
3 1/2	3 3/4	4 5/8	4	3 1/16	4 1/16	4 1/8	2 7/16	5	3
* 4 ②	4 1/2	5 1/4	4 9/32	3 17/32	4 11/32	4 7/8	2 13/16	† 4	2
4 1/2	4	5 3/4	4 51/64	3 51/64	4 55/64	4 3/8	3 5/32	5	3
5 1/2	5	7	5 53/64	5	5 57/64	5 3/8	4	4	2
6 5/8	5	8	6 3/4	5 59/64	6 13/16	5 3/8	5	4	2

* NOT A.P.I. STANDARD   † THREAD FORM SAME AS API-IF JOINT

② THREADED PORTION SAME AS 4 1/2" REED DOUBLE STREAMLINE

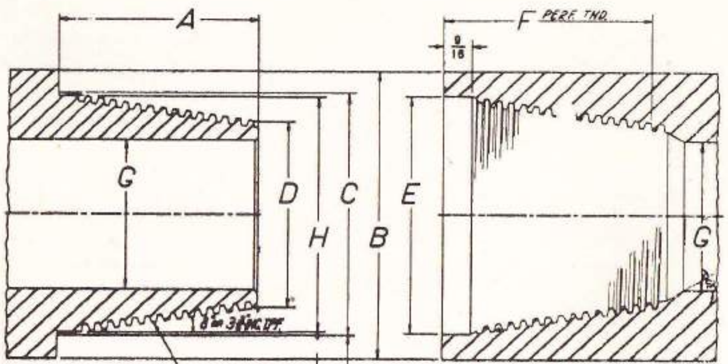
AMERICAN IRON OPEN HOLE

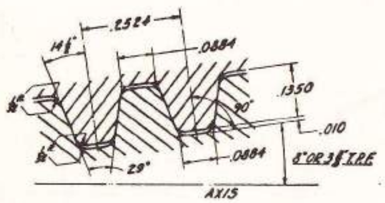




SIZE	A	B	C	D	E	F	G	H	FT. LBS. TORQUE *
DRILL PIPE TOOL JOINTS									
2 7/8	2 7/8	3 7/8	3 9/64	2 25/32	3 3/16	2 7/8	2 5/32	3/8	3000-4000
4	4	5 1/2	4 37/64	4 5/64	4 41/64	4	3 1/4	5/8	8500-11,500
TUBING TOOL JOINTS									
2 3/8	2 3/8	3 1/16	2 3/4	2 29/64	2 25/32	2 1/2	2	3/8	1700-1800
2 7/8	2 1/2	3 11/16	3 9/64	2 27/32	3 3/16	2 1/2	2 27/64	3/8	1800-2000
3 1/2	3 1/4	4 1/2	3 57/64	3 31/64	3 61/64	3 1/4	2 29/32	5/8	5000-7000

* RECOMMENDED MAKE UP TORQUE IN FOOT POUNDS

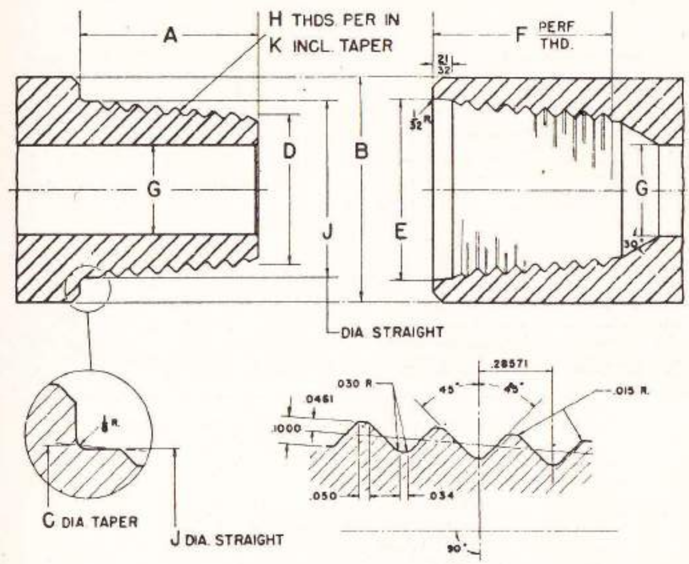




ACME STREAMLINE AND ACME FULL HOLE

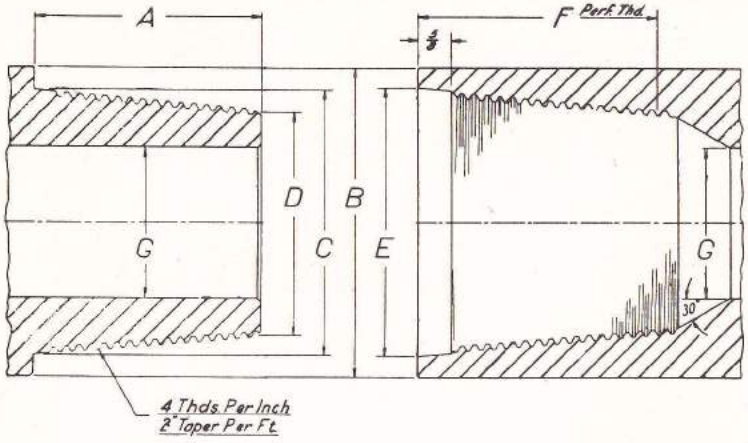
SIZE	A	B	C	D	E	F	G	H
2 3/8	3	3 3/8	2 7/8	2 1/32	*2 3/4	3 1/2	1 7/16	2 47/64
2 7/8	3 1/2	4	3 29/64	2 15/32	*3 21/64	4	1 9/16	3 5/16
3 1/2	3 3/8	4 5/8	4	3 3/64	*3 7/8	3 7/8	2 7/16	3 35/64
4 1/2	4	5 3/4	4 55/64	3 47/64	4 7/8	4 1/2	3	4 23/32
5 1/2	4 1/2	7	5 31/32	4 45/64	5 63/64	5	4	—

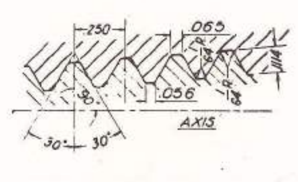
* STRAIGHT COUNTERBORE



HUGHES H-90

SIZE	A	B	C	D	E	F	G	H	J	K
3 1/2	3 7/8	5-5 1/8-5 1/4 5 3/8 5 1/2	4 1/8	3 31/64	4 3/16	4 7/16	2 3/8 2 1/4 2	3 1/2	3 15/16	2
4	4 1/8	5 1/2-5 5/8-5 3/4 5 7/8 6	4 1/2	3 13/16	4 9/16	4 11/16	2 7/8 2 5/8 2 3/8	3 1/2	4 5/16	2
4 1/2	4 3/8	6-6 1/8-6 1/4 6 3/8 6 1/2	4 53/64	4 7/64	4 57/64	4 15/16	3 2 3/4 2 1/2	3 1/2	4 41/64	2
5	4 5/8	6 1/2 6 5/8 6 3/4 6 7/8-7	5 7/64	4 21/64	5 11/64	5 3/16	2 7/8 2 3/4 2 1/2 2 1/4	3 1/2	4 59/64	2
5 1/2	4 5/8	6 3/4-6 7/8-7-7 1/8 7 1/4 7 3/8	5 3/8	4 39/64	5 7/16	5 3/16	3 1/4 3 2 1/2	3 1/2	5 3/16	2
6 5/8	4 7/8	7 1/2-7 5/8-7 3/4-7 7/8-8 8 1/8 8 1/4	6	5 3/16	6 1/16	5 11/16	3 1/2 3 1/4 3	3 1/2	5 13/16	2

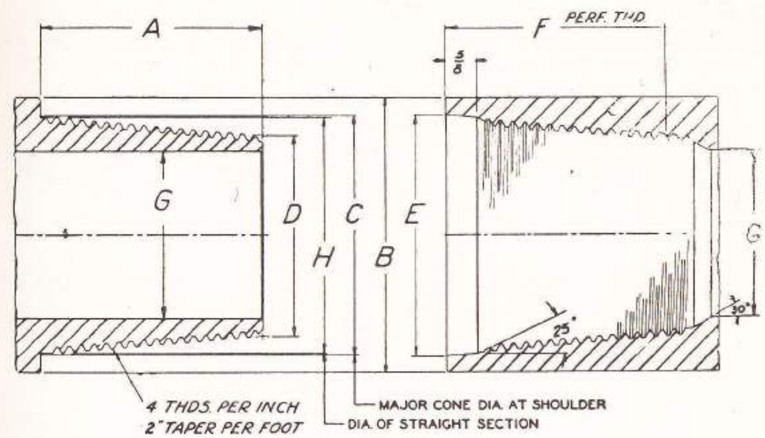


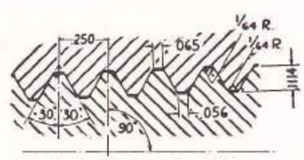


A. P. I. INTERNAL FLUSH

SIZE	A	B	C	D	E	F	G
2 3/8	3	3 3/8	2 7/8	2 3/8	2 15/16	3 3/8	1 3/4
2 7/8	3 1/2	4 1/8	3 25/64	2 13/16	3 29/64	3 7/8	2 1/8
3 1/2	4	4 3/4	4 1/64	3 11/32	4 5/64	4 3/8	2 11/16
① 4	4 1/2	5 3/4	4 53/64	4 5/64	4 57/64	4 7/8	3 1/4
② 4 1/2	4 1/2	6 1/8	5 1/4	4 1/2	5 5/16	4 7/8	3 3/4
5 1/2	5	7 3/8	6 25/64	5 1/2	6 29/64	5 3/8	4 13/16
6 5/8	5	8 1/2	7 29/64	6 5/8	7 33/64	5 3/8	5 29/32

① THREADED PORTION SAME AS 4 1/2" HUGHES XTRA HOLE & 5" DBL. STREAMLINE.
② " " " " 5 1/2" REED DOUBLE STREAMLINE.

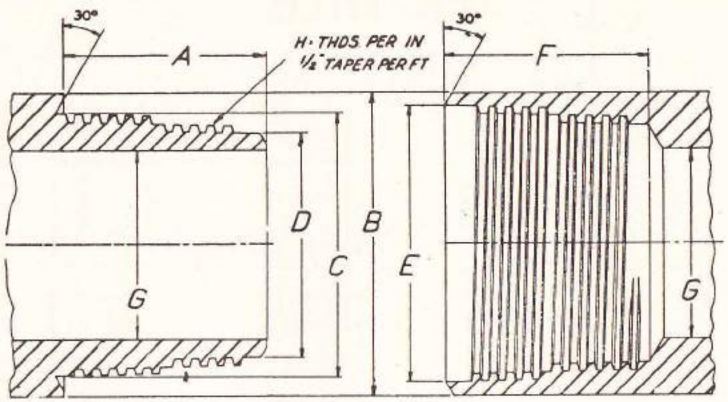




REED DOUBLE STREAMLINE

SIZE	A	B	C	D	E	F	G	H
2 7/8	3 1/2	3 1/4	2 45/64	2 1/8	*2 5/8	3 7/8	1 1/4	2 19/32
① 3 1/2	4	3 7/8	3 21/64	2 21/32	* 3 1/4	4 3/8	1 13/16	3 15/64
4	4	4 1/2	3 57/64	3 7/32	* 3 27/32	4 3/8	2 3/8	3 51/64
4 1/2	4 1/2	5	4 9/32	3 17/32	* 4 1/4	4 7/8	2 11/16	4 13/64
② 5	4 1/2	5 9/16	4 53/64	4 5/64	4 55/64	4 7/8	3 3/8	4 3/4
③ 5 1/2	4 1/2	6 1/8	5 1/4	4 1/2	5 5/16	4 7/8	3 3/4	5 3/16

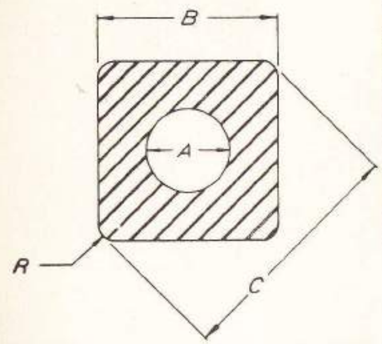
* STRAIGHT COUNTERBORE
① THREADED PORTIONS SAME AS 2 7/8" HUGHES XTRA HOLE.
② " " " " 4" A.P.I.-I.F & 4 1/2" HUGHES XTRA HOLE.
③ " " " " 4 1/2" A.P.I.-I.F.



HYDRIL JOINTS

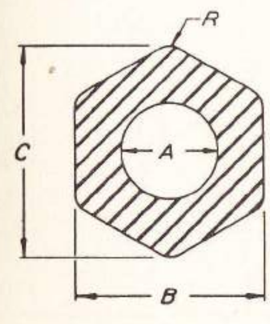
TYPE	SIZE	A	B	C	D	E	F	G	H
I F	2 3/8 · 6.65*	3 15/16	3 3/8	2 13/16	2 21/64	2 13/16	3 59/64	1 3/4	3
	2 7/8 · 10.4*	3 57/64	3 7/8	3 3/16	2 45/64	3 3/16	3 59/64	2 7/64	3
	2 7/8 · 11.8*	3 57/64	3 7/8	3 3/16	2 45/64	3 3/16	3 59/64	2	3
	3 1/2 · 13.3*	3 61/64	4 1/2	3 27/32	3 23/64	3 27/32	3 31/32	2 3/4	3
	3 1/2 · 15.5*	3 61/64	4 1/2	3 27/32	3 23/64	3 27/32	3 31/32	2 9/16	3
	4 1/2 · 16.6*	4	6	5 13/64	4 35/64	5 7/32	4 1/64	3 3/4	3
	4 1/2 · 18.1*	4	6	5 13/64	4 35/64	5 7/32	4 1/64	3 3/4	3
	5 · 20.5*	4 23/32	6 5/8	5 25/32	5 1/64	5 51/64	4 3/4	4 3/16	2
F	2 3/8	2 5/8	2 3/8	1 59/64	1 43/64	1 15/16	2 15/32	1	4
	2 7/8	3 21/32	2 7/8	2 23/64	1 29/32	2 3/8	3 1/2	1 1/16	4
	3 1/2	4 1/16	3 1/2	2 13/16	2 21/64	2 13/16	3 59/64	1 1/2	3
	4 1/2	3 61/64	4 1/2	3 27/32	3 23/64	3 27/32	3 31/32	2 3/16	3
	5	4 5/16	5	4 3/16	3 35/64	4 13/64	4	2 5/16	3
	5 9/16	4 1/4	5 9/16	4 21/32	4 1/64	4 43/64	4 1/32	2 3/4	3
	6 5/8	5 5/16	6 5/8	5 11/16	4 29/32	5 45/64	5 1/8	3 1/2	2
E I U	3 1/2	4 1/4	4 5/8	3 47/64	3 17/64	3 3/4	4	2 7/16	3
	4	4 5/16	5 9/16	4 21/64	4 1/64	4 43/64	4 1/32	3 1/8	3
	4 1/2	4 7/16	5 3/4	4 47/64	4 3/32	4 3/4	4 1/8	3 5/32	3
	5 9/16	5 1/2	7	5 53/64	5 1/16	5 27/32	5 1/8	4	2
	6 5/8	5 1/2	8	6 7/8	6 7/64	6 57/64	5 1/8	5	2

SQUARE KELLYS



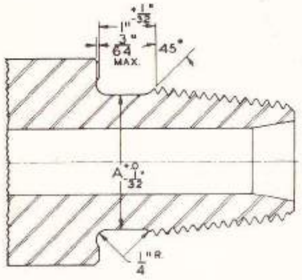
A.P.I. NOM. SIZE	MAX. BORE A	ACROSS FLATS B	ACROSS CORNER C	RADIUS R
2 1/2	1 1/4	2 1/2	3 9/32	5/16
3	1 3/4	3	3 15/16	3/8
3 1/2	2 1/4	3 1/2	4 17/32	1/2
4 1/4	2 3/4	4 1/4	5 9/16	1/2
5 1/4	3 1/4	5 1/4	6 29/32	5/8
6	3 1/2	6	7 7/8	3/4

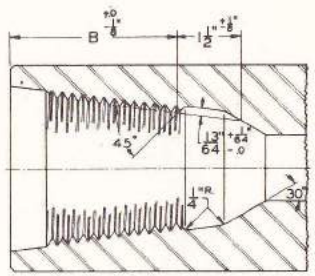
HEXAGON KELLYS



A.P.I. ST'D. SIZE	ALTERNATE	MAX. BORE A	ACROSS FLATS B	ACROSS CORNER C	RADIUS R
3		1 1/2	3	3 3/8	1/4
3 1/2		2 1/4	3 1/2	3 31/32	1/4
	3 1/2	2 1/4	3 3/4	4 1/4	5/16
4 1/4		2 3/4	4 1/4	4 13/16	5/16
	4 1/2	3 1/4	4 27/32	5 1/2	5/16
5 1/4		3 1/2	5 1/4	5 31/32	3/8
	5 9/16	4	5 31/32	6 3/4	3/8
6		4	6	6 13/16	3/8
	6 3/8	4 1/4	6 27/32	7 3/4	1/2

A. P. I. DRILL COLLAR AND JOINT SIZES





COLLAR DIA. MIN. INCHES	BORE INCHES ‡	SIZE AND STYLE OF CONNECTION	A INCHES	B INCHES	LENGTH OVERALL FEET
3 1/2	1 3/4	2 3/8 I.F.	*	*	30
4 1/8	2	2 7/8 I.F.	2 47/64	3 1/8	30
4 3/4	2 1/4	3 1/2 F.H.	3 27/64	3 3/8	30
5 3/4	2 1/4	4 F.H.	3 25/32	4 1/8	30
5 3/4	2 13/16	4 1/2 F.H.	4 13/64	3 5/8	30
6	2 1/4	4 1/2 F.H.	4 13/64	3 5/8	30 and 42
6	2 13/16	4 I.F.	4 21/64	4 1/8	30 and 42
6 1/4	2 1/4	4 I.F.	4 21/64	4 1/8	30 and 42
6 1/4	2 13/16	4 I.F.	4 21/64	4 1/8	30 and 42
6 1/2	2 13/16	4 I.F.	4 21/64	4 1/8	30 and 42
6 1/2	2 1/4	4 I.F.	4 21/64	4 1/8	30 and 42
6 3/4	2 13/16	4 1/2 I.F.	4 3/4	4 1/8	30 and 42
6 3/4	2 1/4	4 I.F.	4 21/64	4 1/8	30 and 42
7	2 13/16	4 1/2 I.F.	4 3/4	4 1/8	30 and 42
7 1/4	2 13/16	5 1/2 REG.	4 53/64	4 3/8	30 and 42
7 3/4	2 13/16	6 5/8 REG.	5 27/64	4 5/8	30 and 42
7 3/4	3	6 5/8 REG.	5 27/64	4 5/8	30 and 42
8	2 13/16	6 5/8 REG.	5 27/64	4 5/8	30 and 42
8	3	6 5/8 REG.	5 27/64	4 5/8	30 and 42

‡ When two bores are given for one O.D., the first bore listed is standard and the second is optional.

* The 2 3/8 I.F. connection is not provided with a stress–relief groove because of insufficient metal.

Duplex Pump Capacity – Gallons Per Stroke – 100% Efficiency

1 Stroke = 1 Complete Round Trip of Each Piston
For Triplex Pumps Multiply Table Values by 1.5

	LINER SIZE												
LENGTH STROKE	4 1/2"	5"	5 1/4"	5 1/2"	5 3/4"	6"	6 1/4"	6 1/2"	6 3/4"	7"	7 1/4"	7 1/2"	7 3/4"
10"	2.41	3.06	3.40	3.78	4.12	4.64	4.98	5.39	5.85	6.31	6.94	7.30	7.93
12"	2.89	3.67	4.20	4.53	5.10	5.46	5.96	6.48	7.02	7.58	8.25	8.59	8.83
14"	3.39	4.28	4.85	5.28	5.85	6.38	6.95	7.57	8.19	8.85	9.63	10.22	10.81
15"	3.61	4.59	5.20	5.67	6.18	6.96	7.47	8.03	8.77	9.46	10.41	10.95	11.89
16"	3.86	4.89	5.56	6.03	6.70	7.28	7.95	8.65	9.36	10.11	11.00	11.69	12.63
18"	4.34	5.50	6.00	6.79	7.36	8.19	8.94	9.72	10.53	11.35	12.20	13.15	14.00
20"	4.82	6.11	6.94	7.55	8.38	9.10	9.93	10.80	11.70	12.60	13.36	14.61	15.40

Use 85% Efficiency When Using Earth Pits
Use 95% Efficiency When Using Steel Pits with Flooded Suction

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