THE VALUE OF STABILIZATION

Any evaluation of diamond drilling usually involves consideration of some erratic or disappointing bit runs. Certain basic questions can be asked regarding the vast majority of these particular runs:

WHY do diamond bits often exhibit uneven diamond wear and burning, even in softer formations?

WHY won't higher weights on a diamond bit make the bit drill faster?

WHY do diamond bits sometimes have to ream when following rock bits of the same size?

WHY do diamond bits drill good with stabilization in some instances, and poorly in others?

These questions are so fundamental that most people in the drilling industry have heard them time and again and assume that most of the answers are simply not known or that each example is unique and not applicable to the other.

To develop the answers to this list of WHY'S, we should review the fundamental mechanics involving diamond drilling for clues to the possible causes of disappointing bit runs.

In very basic language, a diamond bit drills in the following manner:

A. The convex, concave, contoured bit is pressed against the formation to engage the diamond surfaces against the rock.

B. Fluid is circulated through predetermined routes in the bit face to cool the diamonds and remove the cuttings.

C. The bit is rotated, and weight constantly applied to maintain diamond penetration.

Important factors which influence diamond bit performance exclusive of rock qualities are:

A. Assuring that the bit face is constantly sealed against the formation so that the pressure differential developed by the fluid is not disrupted, and irregular fluid flow results.

B. Maintaining concentric rotation of the bit face with the centerline of the drill string member above it.

C. Maintaining constant fluid supply across each diamond so heat and cuttings can be removed from the diamond area as they are developed.

D. Initiating drilling with a diamond bit that has not been damaged while getting to bottom.

When these qualifications are met, diamond bit performance is generally satisfactory to the operator. When any of these factors is missing, the possibility of poor performance increases considerably. When several are eliminated, it is a virtual certainty that an unsatisfactory run will result.

An often overlooked fact is that all of the above factors can be influenced to a tremendous extent by two common existing influences:

1. The shape of the hole -- By this we mean the actual configuration of the hole wall.

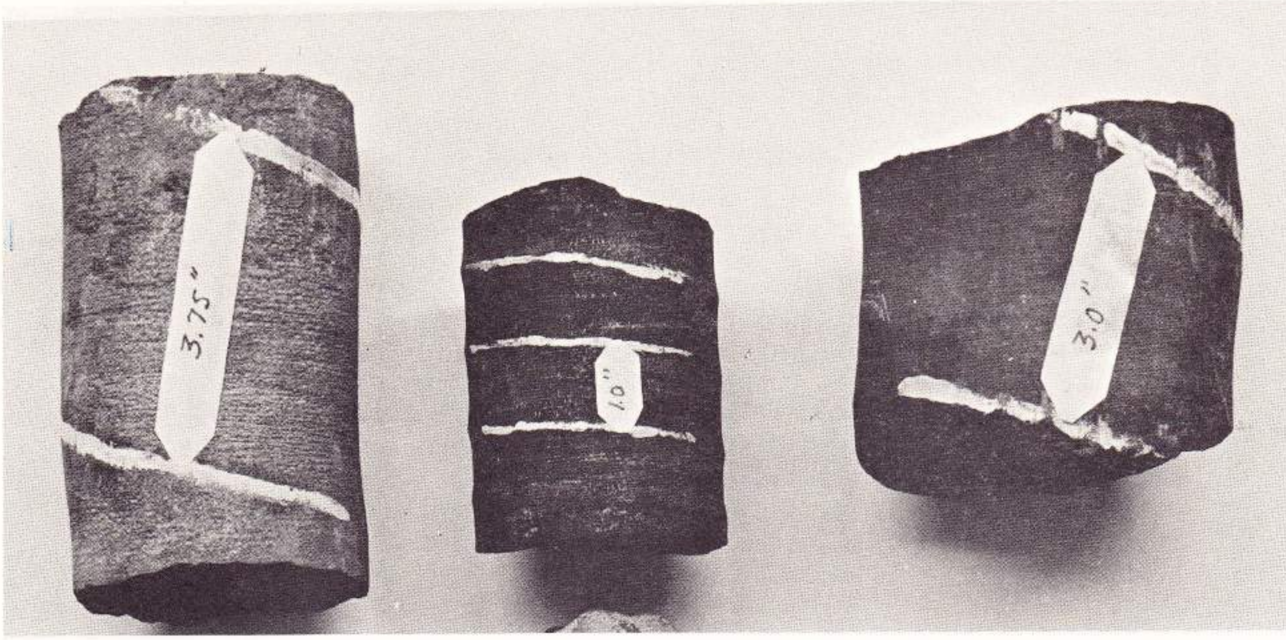
2. The nature of the drill string above the bit.

Probably 60% of unsatisfactory oilfield diamond bit runs can be attributed to one or both of the above being ill suited for the use of a diamond bit.

1. THE SHAPE OF THE HOLE -- In earlier days of diamond coring, it was not uncommon to retreive a core that had a spiral configuration. As these cores accumulated, a few characteristics of the spirals became evident:

A. The majority of the cores exhibited a left-hand spiral, and resembled a coarse thread in appearance.

B. The distances between the spirals reduced in harder formations.



SPIRAL CORES

The cores illustrated above reflect a mirror image of the hole wall as it was cored. The pitch (or distance between spiral ridges) represents the distance cut in the time interval necessary for that portion of the core barrel making wall contact to make one complete revolution.

The distance between spirals increases in softer drilling situations where penetration rates are higher (example on far left), and decreases in harder rock where slower penetration rates prevail (example in middle).

C. The actual diameter of the core was not necessarily undersize.

Reconstruction of the mechanics necessary to produce the above characteristics suggested that as the barrel was being rotated to the right, and weight applied, a buckle developed in the barrel. When the buckle became great enough to make contact with the hole wall, the right hand rotation of that tube causes the barrel to "walk" the hole wall in a left-hand direction. This action results in the core barrel being constantly tilted, and a left-hand spiral superimposed on the core. The core itself will not necessarily be undersize; in fact, it should be full size when measured diagonally with the pitch of the spirals.

When the mechanics producing a spiral core were finally isolated, two fundamental approaches resulted in its virtual elimination:

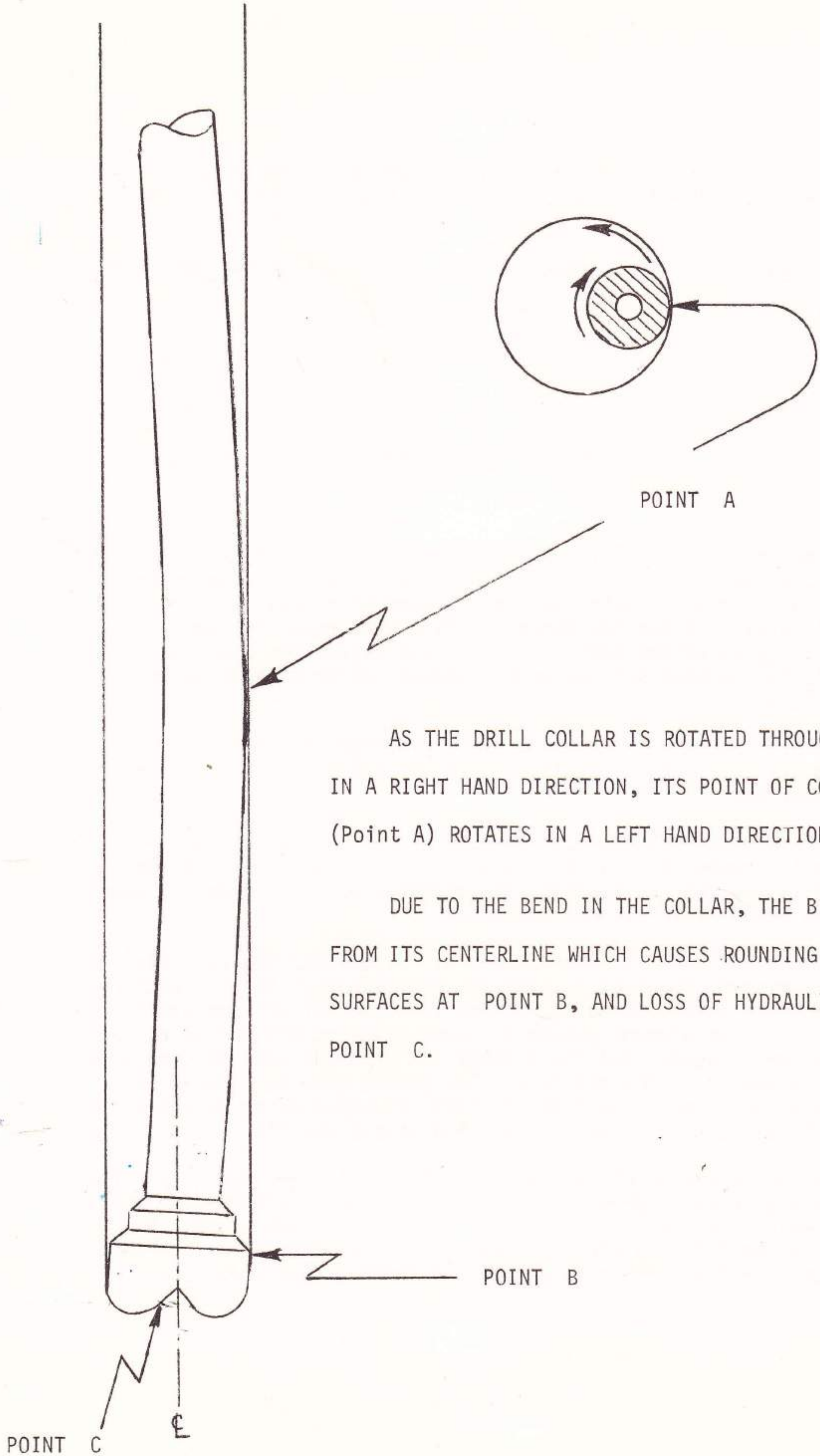
A. Stabilization of the Core Barrel.

B. Developing core barrels with extremely stiff outer walls which resisted bending.

These basic approaches were so successful that spiral cores are very rare today, but the spiral core evidence itself has remained to illustrate a particularly significant fact -- it is the mirror image of the outer portion of the hole wall when drilled with unstabilized assemblies. The extent of the influence these spirals have on hole diameter was defined by Treichler in a published article in a 1959 issue of World Oil when he defined the formula for deriving the effective hole diameter when drilling with an unstabilized assembly. His formula:

$$\text{EFFECTIVE HOLE DIAMETER} = \frac{\text{Bit O.D.} + \text{Drill Collar O.D.}}{2}$$

defines the maximum diameter of continuous length that could be lowered into a hole drilled by an unstabilized assembly. This formula is effective in calculating casing diameters to be run in a hole drilled without stabilization, but it is particularly effective illustrating the problem in running stiff, packed hole diamond assemblies behind unstabilized assemblies.



AS THE DRILL COLLAR IS ROTATED THROUGH A BEND IN A RIGHT HAND DIRECTION, ITS POINT OF CONTACT (Point A) ROTATES IN A LEFT HAND DIRECTION.

DUE TO THE BEND IN THE COLLAR, THE BIT IS TILTED FROM ITS CENTERLINE WHICH CAUSES ROUNDING OF GUAGE SURFACES AT POINT B, AND LOSS OF HYDRAULIC FLOW AT POINT C.

Using current oilfield practices as example, we could use a specific bit size and vary the collar O.D. to achieve effective hole diameters:

BIT O.D.	DRILL COLLAR O.D.	EFFECTIVE HOLE DIAMETER
6 3/4"	4 1/8"	5.437"
6 3/4"	4 1/2"	5.625"
6 3/4"	4 3/4"	5.750"
6 3/4"	6 3/4" - 1/32" Square Collar	6.734"

Following a 6 3/4" Roller Bit drilling any of the four holes with a bit of the same length would not produce problems. A diamond bit of a longer wall contact length (as most diamond bits are) would probably have difficulty with the top three and only size reduction would allow it to go to bottom easily. Stabilized assemblies would only be able to follow hole drilled with a square collar without serious bit size reduction.

A recent example of the above table occurred in the Rocky Mountains where a 8 1/2" bit with 6" drill collars was being drilled with only intermittent use of stabilizers.

To prepare the hole for diamond drilling, a roller bit was run with a roller reamer at near bit to assure that the spirals in the hole were reamed out --- however, the assembly was pulled out of guage and the hole was obviously not reamed out.

A diamond bit with a diamond near bit stabilizer was run after the roller bit and required to ream for over 12 hours before reaching bottom, and was pulled immediately when it would not perform satisfactorily. Examination of the diamond assembly showed both the bit and stabilizer to be worn under guage, and the diamond bit having a well defined groove of 7 5/8" diameter on the bit face. The groove gave no evidence of being caused by rotation on junk; in fact, it appeared to have been made in the absence of normal circulation across the bit.

With the knowledge of the hole conditions, it appears certain that the bit was grooved by progressive reaming of the outermost portions of the remaining spirals in the hole. The groove diameter of 7 5/8" is so close to the 7 1/4" diameter suggested by Treichler's formula that it is significant as a classic example of applied theory correlated with field evidence.

These facts, plus extensive accumulated field data have established that certain basic procedures should be respected when running diamond bits:

1. When downhole programs include drilling with a stabilized diamond assembly, the roller bit assembly preceding it should be stabilized and spaced in the same anticipated manner.

2. A stiff "packed" assembly should never be run following an unstabilized assembly, unless the last bit run in the hole had been run with a similarly spaced assembly and had gone to bottom successfully.

3. When following an unstabilized rock bit in medium to hard drilling situations, diamond bit diameter should be reduced according to area standards to eliminate reaming to bottom.

These procedures are not new, nor do they represent radical departure from certain accepted drilling practices. They simply are reminders of precautions to consider before running any type of diamond bit assembly.

It is also conceded that certain areas will have spirals of such magnitude in pitch that they present no problem in effective hole size, and that these areas may also have hole diameters increase due to fluid washing the hole; however, the vast majority of wells drilled will qualify for these procedures.

A final point on reaming with a diamond bit ---- the diamond bit is designed to operate sealed against bottom developing a pressure differential across the face. When reaming, only the outer portions of the bit are in contact with the formation and no pressure differential is developed across the bit. Diamond surfaces are generally burned quite rapidly under these circumstances, and loss of guage surfaces occurs very quickly. The bit when finally reaching bottom is required to operate with a modified fluid distribution (the O.D. fluid area will be drastically changed due to guage wear), and the outer diameter will likely be eccentric in shape due to uneven guage wear. In addition, diamond failure at that portion of the bit surface initiating into the guage area is likely due to the reaming, and this generally results in progressive failure from the outer surfaces inward.

2. THE NATURE OF THE DRILL STRING ABOVE THE BIT -- "What difference does it make what I screw a diamond bit into -- it's supposed to make hole!"

How many times has a diamond bit gone into the hole with that blessing -- one that assumes the bit will do the digging, and the drill string is simply there to do the rotating. The fact that most diamond bits do a satisfactory job tends to obscure the fact that additional performance could be realized by improving nothing else other than the drill string immediately above the bit.

As an example, examination of the outer surfaces of nearly any diamond bit after being run will reveal a rounding effect on the uppermost guage portions. Closer examination will reveal multiple circular striations in the rounded matrix metal. To achieve this effect, the bit must be experiencing tilting in the hole while rotating, and reflecting the degree of tilting in that worn portion of the guage not containing diamonds. The rounded guage surface is the visible evidence. The obscure evidence is in diamond surfaces broken and burned even though the formation not extremely hard. When the diamond bit is tilted enough to round the guage surfaces, a corresponding tilting of the inner cone area occurs and a loss of fluid control follows. Since the fluid is required not only to remove cuttings, but to also cool the diamonds -- then it is logical that burning of these diamonds opposite the relief side of tilting will take place as the tilting provides a large escape area for fluid. To reduce the tilting effect on the diamond bit, two basic approaches have been found to provide constant improvement:

1. Increasing the stiffness of the drill collar section.

2. Stabilization

Recognizing that stiffness is directly proportional to the drill collar moment of inertia, a comparison of two drill collars commonly run in one specific bit size illustrates the vast difference in stiffness.

DRILL COLLAR O.D.	DRILL COLLAR I.D.	MOMENT OF INERTIA
4 1/8"	2"	13.3 $in.^4$
4 3/4"	2 1/4"	23.2 $in.^4$

The 4 3/4" collar is nearly twice as stiff as the 4 1/8" collar which explains the tendency to have faster diamond bit runs with bits using the largest possible drill collar. It also explains the success of "Heavy-Wall" core barrels in maintaining low cost while increasing performance. When an assembly above a diamond bit can be made more rigid and stiff --- performance increases will nearly always follow.

STABILIZATION

The intent of this paper is to relate the significant contribution that proper stabilization can make to diamond drilling. We have attempted to outline the many symptoms of need for stabilization as well as the limitations imposed on stabilization by the hole conditions.

With these conditions in mind, the function of the stabilizer on a diamond bit should be:

A. To resist bending forces while transferring weight to the bit face.

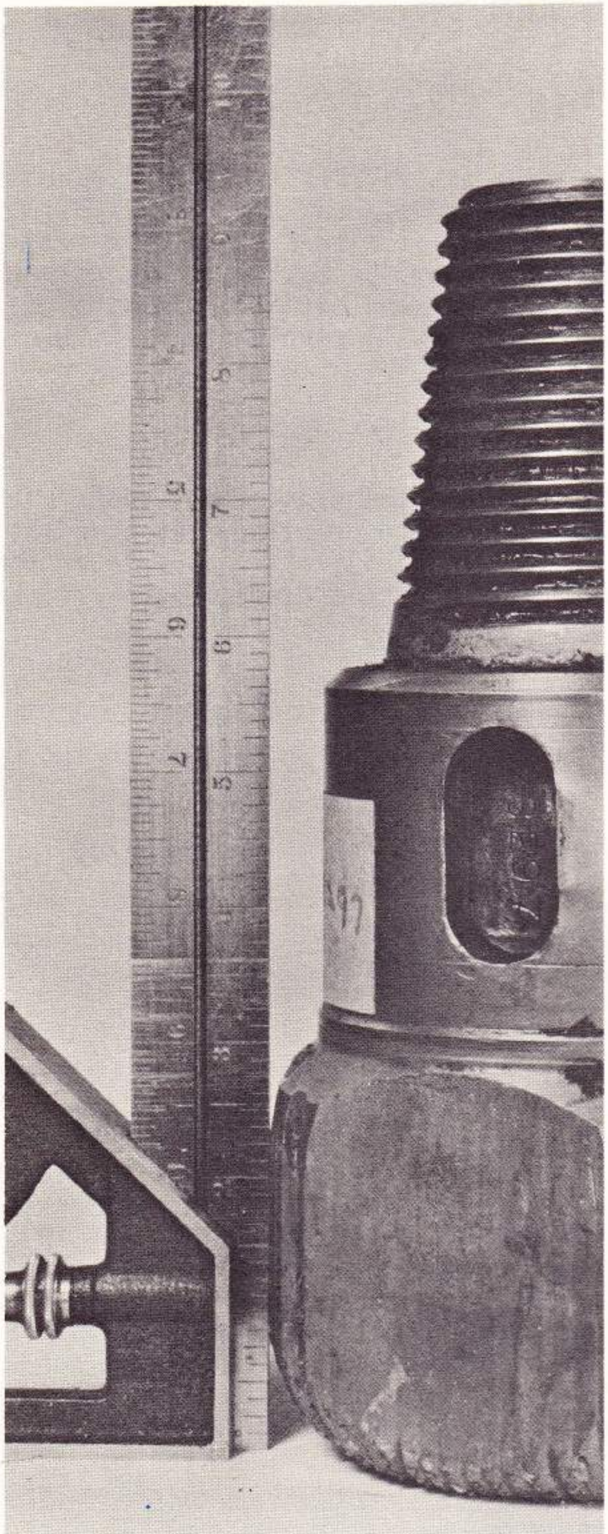
B. To assure that adequate wall contact area is maintained during rotation.

C. To assure that the bit is sealed against bottom at all times, and that rotation of the bit face is concentric with the threaded connection.

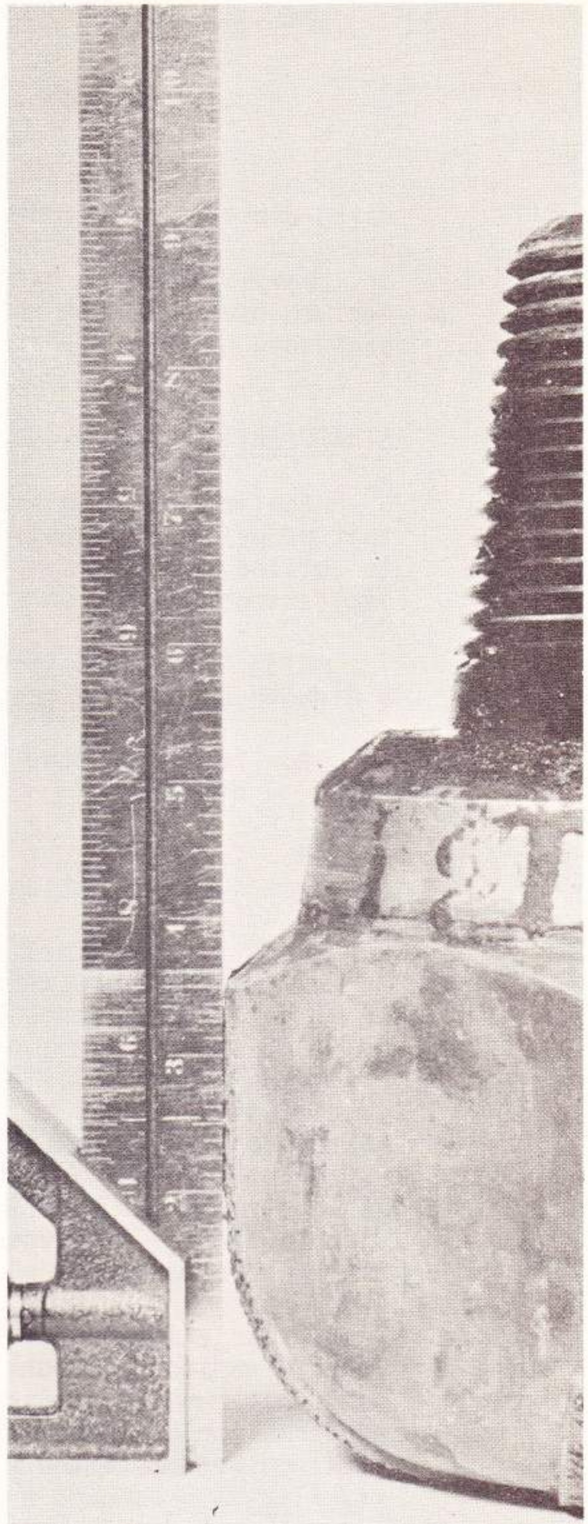
When these conditions are met, the maximum use of fluid hydraulics is possible, as well as assurance that diamond loss will be limited to normal consumption due to formation characteristics. The results of proper stabilization in terms of better hole conditions are difficult to measure in exact terms and values. The results of proper stabilization in terms of increased diamond bit performance can be shown in cases where many diamond bits have been run in a specific area.

As an example of this, we can refer to the state of Mississippi where deep Smackover drilling has recently involved the use of considerable numbers of diamond bits. Bit records involving 10,500 feet of formation diamond drilled were surveyed comparing performance of bits run both with and without stabilization. Diamond bits run with stabilization showed a 36% increase in penetration rate, while also increasing total footage per bit by 8%!

Another example in comparative performances is a deep hole drilled in South Louisiana by a major operator where the 5 3/4" hole was drilled



DIAMOND BIT RUN WITHOUT STABILIZATION



DIAMOND BIT RUN WITH STABILIZATION

THE SIGNIFICANT ROUNDING OF THE GUAGE SURFACE ON THE UNSTABILIZED BIT ILLUSTRATES THE DEGREE OF TILTING THE BIT HAS EXPERIENCED.

with roller and diamond bits to below 18,200 feet. The last of three twistoffs resulted in the bit and collar section being cemented in the hole.

A total of 806 feet of hole was diamond drilled by three Williams bits. The diamond bits exhibited rounded guage surfaces and uneven diamond wear even though minimum weights were run on them. After setting a whipstock, the same section was diamond drilled by another identical Williams bit with a packed hole diamond stabilizer assembly. The section of 924 feet was drilled with one bit; no hole problems occured in the same section where a severe dogleg existed in the original hole --- the bit was pulled with no visible rounding of the guage surfaces. The savings of two trips plus two bits are minor compared to three prior fishing jobs caused by the doglegs in the hole, and yet represent the only real demonstrable savings by stabilization. Twist-offs, or other hazards due to hole conditions cannot be accurately predicted or specifically evaluated in terms of dollars. But, they do represent a common hazard usually eliminated in a smooth bore hole drilled by a well stabilized assembly.

These examples illustrate the effect and influence that proper hydraulics and consistant diamond wear can have on diamond bit performance. The stabilizers do no more than assure that the diamond bit is not tilted while drilling, and that the bit face rotates concentric to the threaded connection -- when this is accomplished, performance is improved and footage increases.

In the same area, diamond bits are run on 15 foot free flow stabilizers, some on square drill collars out to bit O.D., and still others on diamond stabilizers. What type is best, and why do people use such a variety?

The answer is simple -- there is no demonstrable "best" stabilizer for diamond bits, but there are several types that have clear cut superiority over others and this superiority is based on certain features:

1. Hard outer surfaces that are concentric with the threaded connections ---- Many stabilizers feature welded blades with tungsten carbide particles fused into the surface. The outer surfaces are often warped by heat during welding, as well as being irregular in thickness due to the tungsten carbide being applied unevenly. To assure that the outer surfaces are concentric, the most dependable method yet developed involves grinding the stabilizers between centers. This procedure when done correctly, results in accurate, concentric stabilizer surfaces capable of sustaining long rotating hours in medium to soft drilling applications.

2. Accurate outer dimensions ---- API specifications for diamond bits are demanding in that they allow only a small minus tolerance. As an example, a 6 5/8" diamond bit has tolerances of 6.625" +0.000", -0.015". On the other hand, stabilizer tolerances vary from manufacturer to manufacturer since there are no API specifications regarding their tolerances -- while this is assurance enough of widespread variation in size tolerance, it is complicated by the fact that there are not even manufacturers' guidelines governing the most critical aspects of a stabilizer -- its size and concentricity!

   To illustrate the problems this can create, consider the application of a diamond bit with a near bit stabilizer which is oversize by 1/8", and out of true 3/16". The resultant eccentric motion applied to the bit face from the crooked stabilizer would cause the bit to rotate eccentric rather than concentric. The oversize nature of the stabilizer would create excessive torque, and result in the operator running less weight (if he didn't twist off) and therefore realize still another reduction in performance. When the bit was pulled and examined, the diamond bit representative would immediately be called to explain the premature wear and slow penetration rate when he had a well stabilized assembly! This situation is not unique, and occurs time and again, and yet it has a simple solution --- ring guages! Any stabilizer assembly to be run with a diamond bit should be held to the same dimensional demands as the bit, and should be ring guaged before and after each bit run.

   The process of grinding between centers establishes both demands on bladed stabilizers. At the same time it is being ground to the correct diameter, it is being ground concentric.

The majority of oilfield stabilizers considered for use with diamond bits are discussed below with specific comments regarding their uses.

Welded blade "Tantem", and "Free Flow" 15 foot Stabilizers ---- These stabilizers have had considerable success in super packed hole assemblies and have been associated with some outstanding diamond bit runs. They should be API ring guaged, and ground between centers.

Conventional Welded Blade, and Integral Blade Stabilizers ---- Once again, they must be ground between centers. The spacing and proper number of stabilizers varies with operators, although most now run short drill collars between the near bit stabilizer and the next stabilizer.

Square Drill Collars ---- When dimensional tolerances are accurate, and the collar runs true to the connections, these tools provide very good stabilization for diamond bits. Square collars that are worn, or that have been straightened in the field should never be run in the bottom 30 feet of a drill string with a diamond bit.

Roller Reamers and "Knobby" Stabilizers ---- These stabilizers are usually oversize, which is not a desirable condition. In addition, they have the smallest wall contact area of any stabilizer since it is a point contact area. In hard, well consolidated rock, a roller type stabilizer is sometimes used, but the vast majority of drilling applications with these assemblies have not been satisfactory. It is believed that under stress conditions the rollers tend to "bite" into the hole wall and cause eccentric rotation. By and large, we discourage the use of these type assemblies as stabilizers with diamond bits.

Diamond Stabilizers ---- Diamond impregnated stabilizers cannot be ground between centers. Their accuracy must be established at the time of manufacture. Due to the nature of the blades, they will not warp during welding, and therefore ring guaging is an adequate check of dimensional accuracy. To maintain concentric rotation, the threaded connections should be cut only after the blades have been trued with a dial indicator in the lathe.

What Size? To provide the most effective stabilization, the stabilizers should be the same size as the diamond bit. Running a stabilizer 1/16" under the bit size will not provide functional stabilization near the bit -- it could be tolerated up the hole. This is one of the qualities of diamond stabilizers that should not be overlooked -- they maintain dimensional accuracy for extremely long periods of time.

How Many? The number and spacing of stabilizers varies with areas and operators. A minimum of two stabilizers is suggested with one at near-bit and a string stabilizer spaced close by. In many cases, as many as four to six string stabilizers are run at 30 foot interfals above the first two stabilizers.

SUMMARY -- There are no doubt, exceptions to the broad guidelines included in this reference to the value of stabilization. However, in the vast majority of diamond bit applications these procedures have time and again resulted in overall reduction of drilling costs, and this is the intent of our efforts to accumulate and present this information.

We originally listed four common WHY'S regarding diamond drilling. With the information developed in this presentation, we feel that the answers can now be provided:

WHY do diamond bits often exhibit uneven diamond wear and burning even in softer formations?

ANSWER -- because they are tilted on bottom due to bends in the collar section, and lose the important hydraulic control across the bit face.

WHY won't higher weights on a diamond bit make the bit drill faster?

ANSWER -- As long as a diamond bit is held firmly against the formation and rotated concentric to its centerline, additional weight will make the bit drill faster. When additional weight causes buckling of the drill string and tilting of the bit, performance will fall off.

WHY do diamond bits sometimes have to ream when following rock bits of the same size?

ANSWER -- The longer guage section of a diamond bit interfers with the spiral hole configuration left by the shorter guage section of a roller bit.

WHY do diamond bits drill good with stabilization in some instances and poorly in others?

ANSWER -- When a properly designed stabilized assembly reaches bottom intact, it nearly always results in good performance. If the assembly is oversized, not concentric to connections, or otherwise faulty due to design, it will not perform satisfactorily. In addition, if the assembly suffers loss of guage or grooving of the bit while reaming spirals, it will result in poor performance and high costs.

Diamond bits have a continually increasing application in the oil field. Their use can be made even more profitable by the use of proper planning of drilling assemblies associated with these bits. The savings that can be realized far outweigh the very nominal costs of proper equipment to go with the bit.

Similar bulletins regarding stabilization have been used within Williams Diamond Bits to further advance the Williams personnel in the basic principles of stabilization. At the request of several interested individuals outside of this company, we have expanded the basic bulletin to include more specific information for those who might desire it.

We wish to acknowledge the considerable contribution and influence on this bulletin by Mr. L. W. Short of our company. Without his significant contribution, the bulletin would have been without a great deal of proven fundamentals that he has shared in developing over the years.