INSERT ROCK BITS REDUCE DRILLING COST

BILL GREAVES and ED MOERBE
Security Division, Dresser Industries, Inc.

INTRODUCTION

To gain a better understanding of the significance of insert rock bits in today's drilling, it is important to review the evolutionary process of the entire rock bit development. Modern-day rock bit technology began in 1909 with the introduction of the first rotary cone rock bit. Prior to this time, the use of the rotary drilling process had been limited to soft formations because harder formations were difficult or impossible to drill using the scraping action of the drag bit.

The rotary cone bit, then, enabled the industry to drill much harder formations than previously possible. However, the early designs utilized cones which did not mesh. Consequently, the bit "balled up" readily when drilling soft shale formations.

In 1925, this problem was solved with the introduction of a two-cone bit with intermeshing teeth. As the teeth of one cone passed through the grooves of the opposite cone, accumulated formation was pushed from the grooves of the opposing cone; thus, it was called "self-cleaning." The new cutting structure enabled the drilling industry, for the first time, to make hole through both soft and hard formations with a single bit, markedly reducing overall time on each well.

Until 1932, the basic bearing of rolling cutter bits remained the journal-type. Many attempts were made to effectively lubricate the bearing and extend bit life. However, none were effective, and bearing life remained extremely short until the introduction of anti-friction (roller) bearings in 1932.

TRICONE BIT

The tricone, or three-cutter bit with teeth arranged in rows that intermesh with rows on adjacent cones, was introduced in 1933. This bit was not only smoother running and easier on drill pipe, it could out-drill tl e two-cone anti-friction bit.

The geometry of the three-cone bit permits efficient use of the available space to provide the required strength and durability of its individual parts. Although the individual parts may be made stronger in the two-cone bit, as a whole it is less durable because there are fewer cones and bearings to take the loads and shocks inherent in rock drilling.

A further improvement in tricone bits occurred in 1935 with the introduction of offset cones. For clarity, an offset cone is one in which the apices point to the forward side of the bit axis a slight amount, such as 3/16 inch or more, in the direction of rotation. This construction delivers a shearing or tearing action to the formation as the teeth penetrate bottom.

Early offset tricone bits increased penetration rate more than 30 percent and footage per bit more than 20 percent in salt, red bed, gypsum, anhydrite, and lime formations. Offset cones also substantially increased the usefulness of tricone bits in shale formations that could not be penetrated at a satisfactory rate using the more nearly true-rolling non-offset bits. To this day, the large majority of tricone bits used have some degree of offset.

Until 1948, regular or conventional water courses were used on all bits (Fig. 1A). This system first directs the drilling fluids onto the cutters primarily to clean them, then performs the function of cleaning the hole. Both functions are served only to a limited extent. The disadvantage of this design is a lack of sufficient bottomhole cleaning, which results in bit balling, cone erosion, and comparatively poor performance.

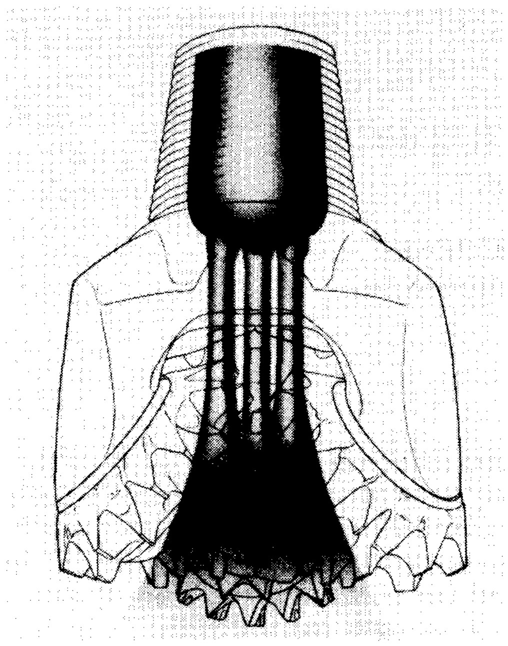

FIG. 1A—REGULAR CIRCULATION

Jet water courses direct the drilling fluid's energy between the bit cones and the bottom of the hole (Fig. 1B). Fluid turbulence is usually sufficient to insure proper cleaning of the cutting structure. Energy level or hydraulic efficiency is controllable and variable at the bit by using bit "nozzles" made of special materials which minimize erosion.

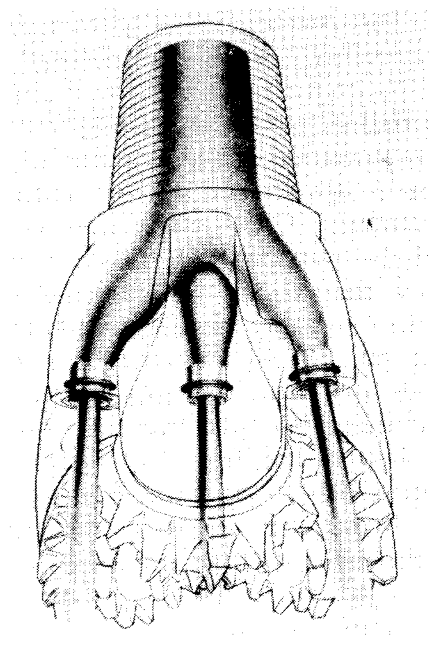

FIG. 1B JET CIRCULATION

Jets were used in rock bits beginning in 1949, and early field tests indicated penetration rates could be increased more than 50 percent. A typical early comparison from tests conducted in California is shown in Fig. 2. In this case, the penetration rate was increased from 16.0 to 26.9 ft/hr, saving approximately 165 rotating hours.

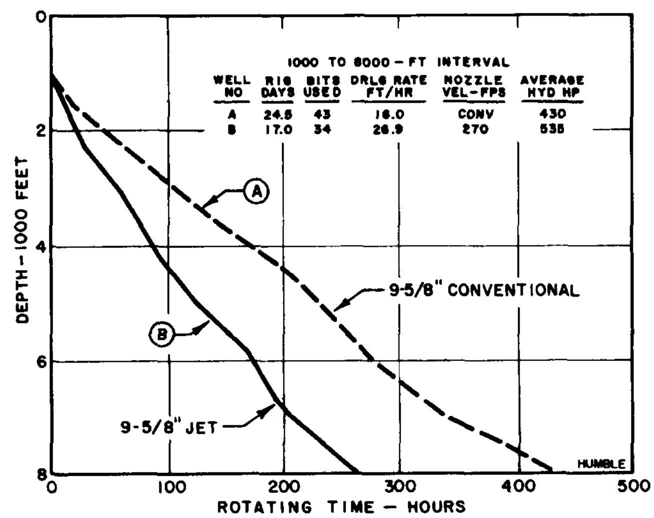

FIG. 2—EFFECT OF JET BITS ON DRILLING PERFORMANCE

TUNGSTEN CARBIDE INSERT BITS

The hard abrasive formations encountered at one-mile depths in the Permian Basin of West Texas created a major drilling problem. Bit records were filled with typical runs of 5 to 10 feet in 4 or 5 rotating hours. Conventional steel-tooth bits were inadequate for the drilling environment encountered.

It became obvious that some material other than steel was needed to provide stronger teeth with greater wear resistance. Although sintered tungsten carbide is high in the hardness scale, materials used in the early 1950's would break when shaped in the conventional steel tooth.

Based upon the concept that a blunt or rounded "cutting edge" would provide maximum resistance to breakage, tungsten carbide "teeth" were shaped like bullets and press-fitted into cones. This cutting structure, characterized by the short, closely spaced tungsten carbide inserts proved durable and the "Chert Bit" performed its task well (Fig. 3). Typically, the 5 to 10 ft runs were increased to 50 to 100 ft runs, and the 4 or 5 hour rotating times increased to 25-40 hours. As often as not, the bit life was terminated by bearing failure, while the cutting structure remained in "new" condition.

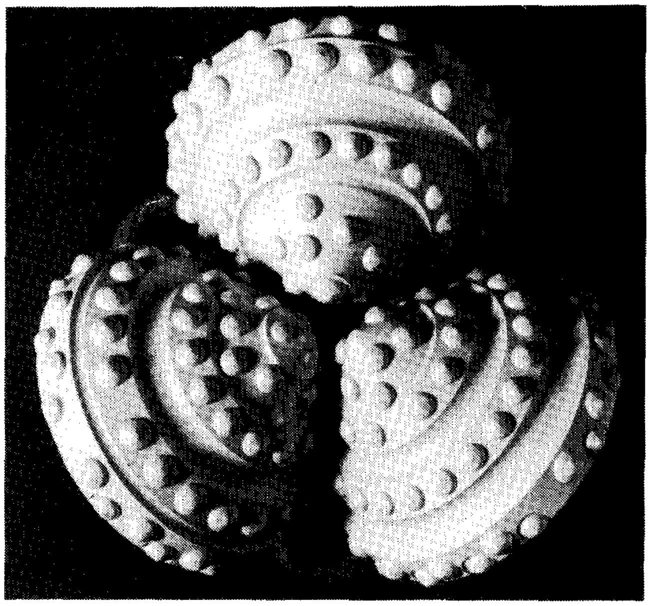

FIG. 3 -HARD FORMATION TUNGSTEN CARBIDE INSERT BIT

SEALED BEARINGS

As drilling became more sophisticated, with higher rotary speeds and heavier weights in deeper holes, more stress was placed on the rock bit bearings. Cutting structures, such as the "Chert Bit", superbly designed and built, were useless once the bearings failed. This imbalance between cutting structure and bearing life was experienced occasionally on steel-tooth bits and became much more frequent with the advent of tungsten carbide cutting elements.

To solve this problem, the first practical sealed bearing rock bit was introduced in 1960. The sealed bearing design incorporated a seal between the cone back-face and the journal arm (Fig. 4). The purpose of the seal was to hold the lubricant in the bearing while preventing the intrusion of drilling fluids into the bearing assembly.

SHAPED AND EXTENDED INSERTS

Although the merits of the use of tungsten carbide in rock bits had long been accepted, it was not until the late 1960's that bit manufacturers obtained sufficient experience with the tungsten carbide material to make it possible to consider this type bit forapplication in virtually all formations -- soft, medium, and hard.

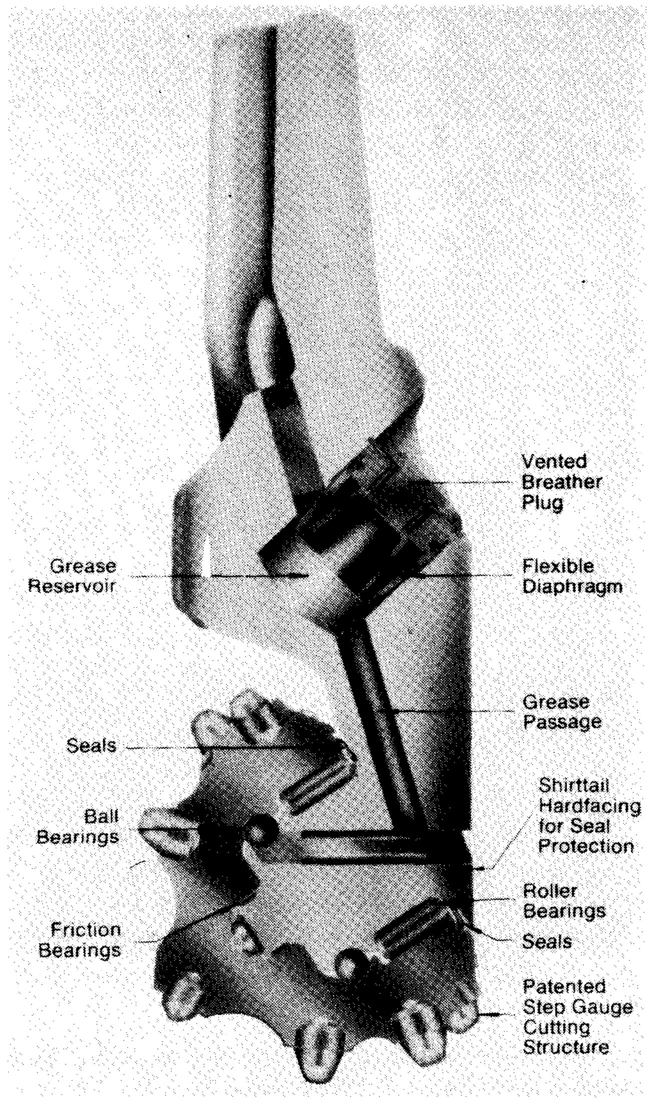

FIG. 4 -CROSS SECTION OF SEALED BEARING ROCK BIT

Much has been learned since the introduction of the initial "Chert Bit" in 1950. The insert extension of this early bit was very small, but adequate, considering formations involved were extremely hard. The insert did not penetrate the formation, but caused rock failure by crushing it.

A major economic impact was made available to the drilling industry in the mid and late 1960's: tungsten carbide technology had developed an insert that could be lengthened and the blunt "button" or rounded cutting edge could be replaced with a chisel or tooth shape (Fig. 5). These features permitted the application of insert bits to medium and soft formations.

As shown in Fig. 6, insert bits reduced the overall

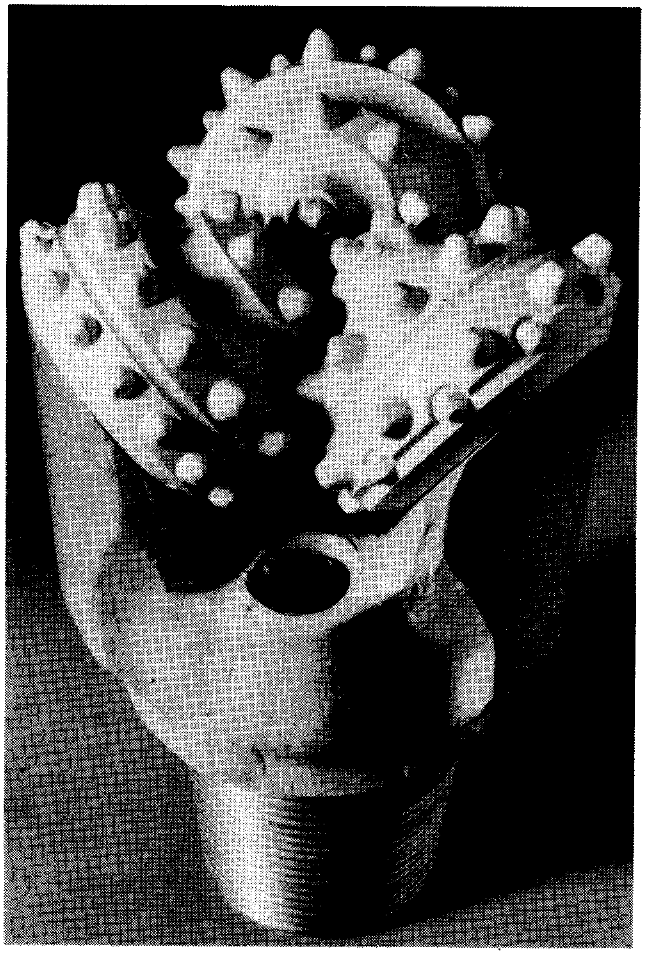

FIG. 5 –SOFT FORMATION TUNGSTEN CARBIDE INSERT BIT

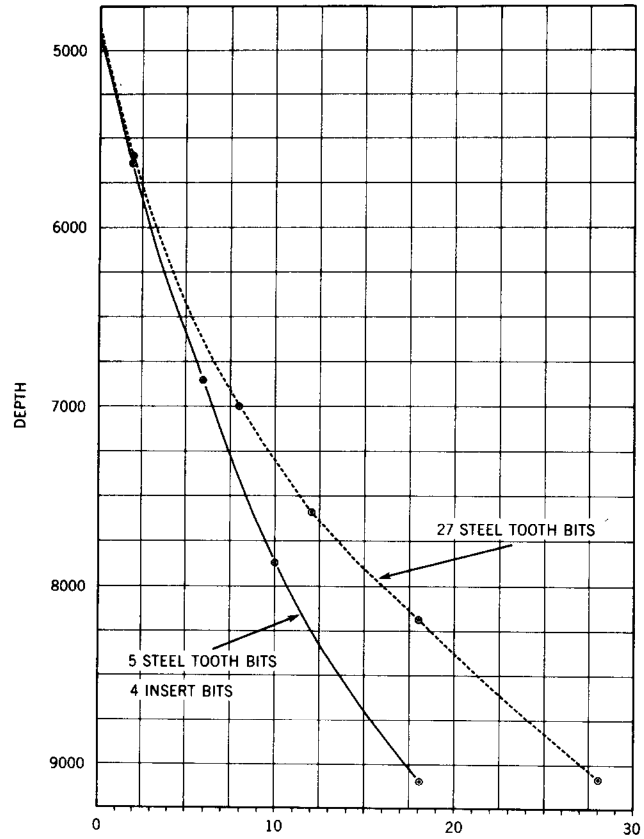

FIG. 6 –EFFECT OF INSERT BITS ON DRILLING PERFORMANCE CHAVES COUNTY, NEW MEXICO

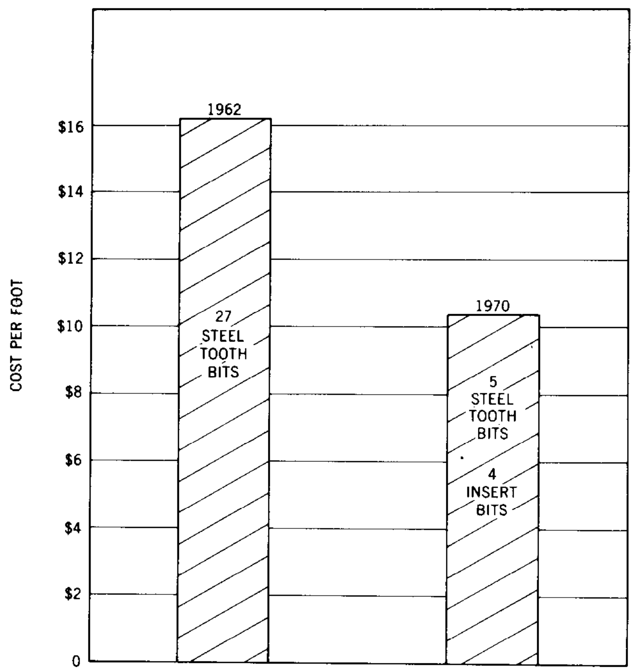

FIG. 7 –EFFECT OF INSERT BITS ON COST/FT CHAVES COUNTY, NEW MEXICO

drilling time by 10 days in an interval from 5000-9000 ft in Chaves County, New Mexico. This was accomplished primarily by reducing the number of bits from 27 steel-tooth bits to six sealed-bearing steel tooth and three sealed-bearing insert rock bits (Fig. 7).

JOURNAL BEARING

The most recent development in rock bit technology is the re-introduction of the journal or friction bearing. Discarded in the 1920's in favor of the roller or anti-friction bearing because of an inability to maintain a lubricated bearing, the journal bearing has found renewed application (Fig. 8).

A journal bearing system has a distinct mechanical advantage over the current roller bearing arrangement: it presents a larger contact

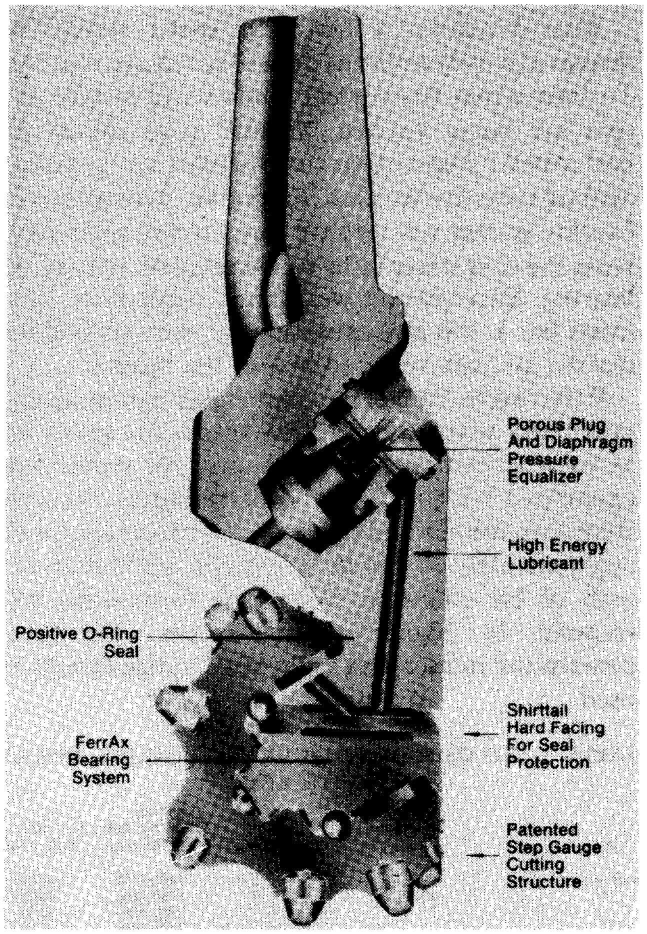

FIG. 8 -CROSS SECTION OF JOURNAL BEARING ROCK BIT

area at the load bearing point. Such a distribution of the load eliminates the chief cause of roller bearing assembly failure -- spalling of the load sector of the bearing journal.

It is not uncommon for a journal bearing insert bit to drill more than 100 hours. The impact of the journal bearing is illustrated in Fig. 9, showing 1966 and 1972 drilling data in Ward County, Texas. In 1966, a typical well required 78 steel tooth and 21 insert bits to drill to 15,000 ft. Total drilling time was approximately 135 days. By contrast, a Ward County well drilled in 1972, to approximately the same depth, utilized nine steel-tooth bits, 10 roller bearing insert bits and 11 journal bearing insert bits. Similarly, the drilling time was reduced to 99 days.

The total cost for each well, at $100 per hour rig cost, was $343,500 for the well drilled in 1966 versus $211,311 for the well drilled in 1972, (Fig. 10), producing a savings of $132,189. Although insert rock bits have contributed significantly to this savings, it must be recognized that improved drilling techniques and proper weight/speed applications also played an important role.

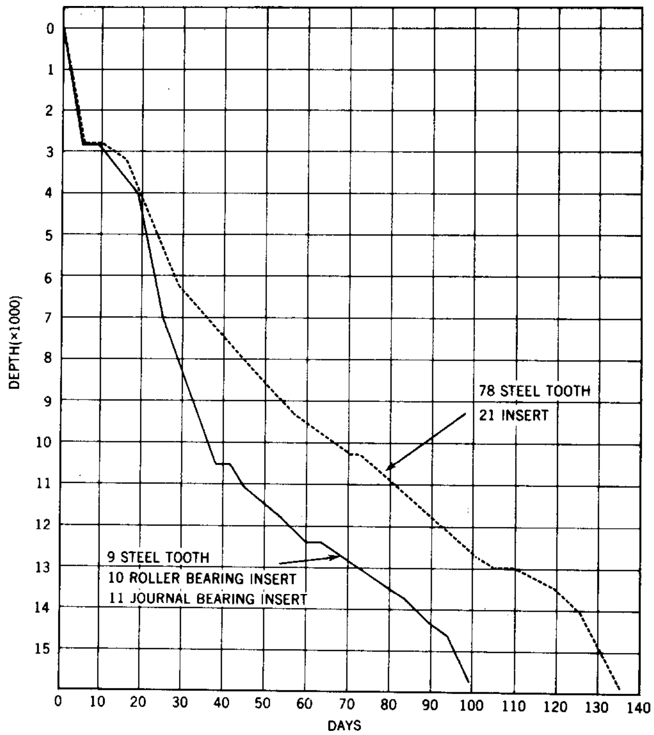

FIG. 9—EFFECT OF JOURNAL BEARING INSERT BITS ON OVERALL DRILLING PERFORMANCE WARD COUNTY, TEXAS

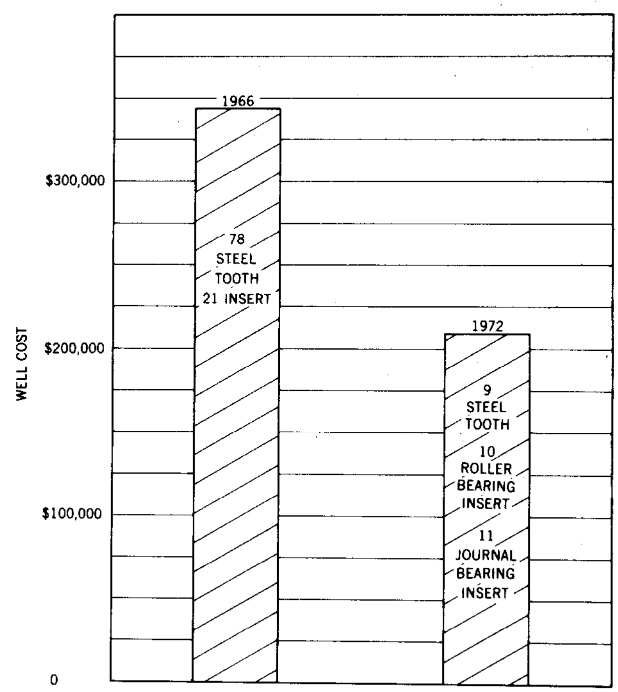

FIG. 10—EFFECT OF JOURNAL BEARING INSERT BITS ON TOTAL COST WARD COUNTY, TEXAS

APPLICATION OF INSERT ROCK BITS

Several improvements to the rock bit have made it an exceptional tool. However, the true value of this product can only be realized with proper application.

Selecting the correct bit for the formations anticipated is the first step in obtaining optimum performance from all types of bits, especially journal bearing bits. This is accomplished by using electric logs, bit records, and any other offset well data which may be available.

Long, homogeneous sections are desirable, although not mandatory, for best economics. For example, if the offset information indicates a sandy shale or clay with a low compressive strength, a 517-type bit would be selected because of its maximum journal offset, long inserts, and greatest cone profile variation.

These design features impart to the cutting structure a certain amount of slippage and gouging action which is needed in soft formations.

On the other extreme, if offset well information suggests a hard, abrasive quartzitic formation, then a bit with numerous short inserts, such as the 837-type, should be selected. Very hard, abrasive formations require closely spaced rows of inserts to minimize uncut bottom and to withstand the heavy loads needed to crush the rock. This bit has no journal offset; it has a minimum amount of cone profile variation, and it also has very good gauge protection.

After the proper bit has been selected, observe caution when running in the hole. Drill out bridges, if necessary, to prevent damage to the bearing assembly and cutting structure. (Wash and rotate to bottom carefully to prevent bit balling, and to clear debris from under the new bit.) If under-gauge hole is to be encountered, ream to bottom carefully to prevent pinching of the bit.

Once on bottom, proper "break-in" procedures should be followed using low weights and rotary speeds. This gives the new bit a chance to establish its own bottomhole pattern from that of the previous bit. Easing the bit into the formation also insures that the seals are well-lubricated. The time required to establish a new pattern depends on the dull condition of the previous bit; however, at least 6-12 in. of new hole should be drilled before increasing weight and rpm.

After break-in, weight and speed should be increased slowly until the desired levels are reached. To insure that the correct amounts of weight and rpm are being applied, drill-off tests should be performed. These tests are helpful in guarding against excessive weights. Premature damage to the bearing system will result if this allows shock loads from the drill string to be transmitted directly to the bearing. Excessive bit weight and subsequent total insert burial will also cause cone erosion around the inserts, and can result in loss of the inserts.

Referring to Table 1, recommended minimum and maximum weights and rotary speeds are given for various formations, bit sizes, and bit types. For example, a 7-7/8 in. 517-type bit drilling a soft sandy shale formation should give good performance with approximately 30,000 lb bit weight, or 3800 lb per inch of bit diameter. Soft shale formations will respond to higher rotary speeds. For best penetration rates, rpm's in the 80-90 range should be used.

TABLE 1—RECOMMENDED JOURNAL BEARING INSERT WEIGHTS, RPM*

Formation	IADC Bit Code (Security Type)	Bit Size	Weight (LB. Per Inch Of Bit Diameter)	RPM (Min. - Max.)
Sandy Shales	517	6-1/2 - 8-3/4	2000-4500	40-90
	(S84F)	9-7/8 - 11	3000-4500	40-80
		12-1/4	3000-5500	40-80
		14-3/4 - 17-1/2	2800-5000	40-70
Med. Soft Shales, Lime	527	6-1/2 - 8-3/4	2200-5000	40-90
	(S86F)	9-7/8 - 11	3500-4500	40-80
		12-1/4	3500-6000	40-80
		14-3/4 - 17-1/2	3000-5200	40-70
Sandy Shales, Dolomites, Hard Shales, Soft Lime	537, 617	6-1/2	2200-5500	40-90
	(S88F) (M84F)	7-7/8 - 9-7/8	3500-6500	40-80
		11 - 12-1/4	3700-7300	40-70
		14-3/4	3200-6200	40-60
		17-1/2	3000-5500	40-60
Med. Hard to Hard Lime & Dolomite, Hard Sandy Shales	627, 637	6-1/2	2200-5500	40-90
	(M89TF) (M89F)	7-7/8 - 9-7/8	3500-8000	40-80
		11 - 12-1/4	3700-7500	40-60
		14-3/4	3200-6500	40-55
		17-1/2	3000-5700	40-55
Chert, Basalt, Granite	727, 747	6-1/2	2200-6000	30-50
	(H88F). (H99F)	7-7/8 - 8-3/4	3500-8000	30-50
		9-7/8 - 11	3800-8100	30-50
		12-1/4	3700-7500	30-45
		14-3/4	3200-6500	30-45
		17-1/2	3000-5700	30-45
Hard, Abrasive Quartzite, Quartzitic Sands Very Hard Granite	837	6-1/2	2200-6000	30-50
	(H100F)	7-7/8 - 8-3/4	3500-8000	30-50
		9-7/8 - 11	3800-8100	30-50
		12-1/4	3700-7500	30-45
		14-3/4	3200-6500	30-45
		17-1/2	3000-5700	30-45

*Note: Specific formations, drill program criteria, or abnormal conditions may require either higher or lower energy levels.

Both good hydraulics and low solids drilling fluids are essential for optimum bit performance. Although the circulating fluid does not in itself cause rock failure, it does aid in keeping the bit clean and is an important factor in maintaining long bearing life and good penetration rates.

It is also important to prevent the bit from gyrating or rotating off-center. Off-center rotation causes abnormal insert wear and heavy cone shell erosion. This type of detrimental wear is usually associated with insufficient penetration rates in soft to medium strength formations. A softer bit type or an increase in the weight and rpm levels usually eliminates this problem. Bottomhole stabilizers will also minimize off-center rotation.

Excessive bouncing in broken, hard formations will result in undue shock loading on the bit and can cause insert breakage and premature bearing failure. Shock absorbers can minimize severe shock loading and can be beneficial in helping to obtain faster penetration rates and to extend bit life.

"Chasing" the pipe on deep wells should be done with care. A long string of pipe can be stretched enough to cause the bit to tag bottom. If the bit strikes the bottom of the hole with sufficient force, the cutting structure and bearing assembly will be severely damaged.

In summary, the proper selection of an insert bit, when coupled with proper application, yields performance figures that represent excellent results, whether measured operationally or economically.

BIBLIOGRAPHY

1. Eckel, J. R. : Effect of Mud Properties on Drilling Rate. *API Drilling and Production Practices*, 1954.
2. Greaves, Bill T. : Bit Selection - The Center of a Good Drilling Program. *Southwestern Petroleum Short Course Proceedings*, April 1975.
3. Jackson, Robert A.: Rock Bit Technology - The Effect on Drilling Costs. *Petr. Soc. of CIM*, June 1975.
4. Moerbe, O.E.: How to Optimize Journal Bearing Bit Performance. *Drill. Mag.*, June 1975.