RECENT DEVELOPMENTS IN TOOLS FOR LINER MOVEMENT DURING CEMENTATION

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ABSTRACT

Many papers have emphasized the problems of obtaining efficient mud displacement by cement, causing channels, annular gas flow and other problems. Mud displacement in liner cementing is more diff-cult than in full-string cementing because of several factors. Some suggestions for obtaining better results in liner cementing through the use of newly-developed rotation equipment are presented in this paper. Tools designed for these types of jobs are shown and recommended procedures given.

INTRODUCTION

Many cementing techniques have been described in various papers to improve the displacement of mud by cement. The purpose of successful cementing is to displace all of the drilling fluid with cement in the annular space.

As early as 1940, Jones and Berdine[1] performed studies of factors influencing bond between cement and formation in which the pipe was reciprocated and/or rotated during placement. While their studies were directed toward improved bonding through removal of mud filter cake from the formation wall with mechanical scratchers, the paper was a pioneer in the field of casing cementing. In 1948 Howard and Clark[2] made a detailed study of problem wells and concluded that turbulent flow increased the efficiency of mud displacement by cement. Pipe movement was noted in their paper to be an essential part of successful cementing. McLean, Manry and Whitaker[3] in 1967, performed extensive cementing studies and concluded pipe movement is very important in mud displacement, particularly where mud and cement are close to the same weight. They concluded that rotation was preferred over reciprocation when the casing is off center. The authors claimed pipe rotation appeared to exert a drag force on the cement and pull it around to displace the mud and was especially effective in very eccentric annulus. They stated that reciprocation of casing was not effective in a very eccentric annulus; but they conceded their experiments did not provide for lateral movement of the casing during reciprocation as might take place in actual well conditions. Graham[4], in his paper on rheology balanced cementing in 1972, emphasized the importance of moving the pipe throughout displacement. Clark and Carter[5] concluded from their laboratory investigation in 1973 that pipe movement, either rotation or reciprocation, is a major driving force for mud removal. Haut and Crook[6], in 1979, gave a paper based on experimental investigation to determine the relative importance of other displacement factors, neglecting pipe movement, in the mud removal process. This latter paper is interesting in that it strongly implies pipe movement, where possible, is important.

The above papers were given from data obtained in laboratory investigations. One of the early papers based on actual field experience was that of Teplitz and Hassebrock[7] in 1946. They were allowed by their sponsors to perform numerous field tests using procedures advocated by Jones and Berdine[1] in wells on the Texas Gulf Coast, in South Louisiana and West Texas. They reciprocated casing with scratchers on the cementing jobs and the results were dramatic. They virtually eliminated the need for squeezing due to channeling, which had been a major problem.

LINER CEMENTING

Most operators, however, do not move liners during cementing. Probably less than 10% of liner jobs involve movement during cementing. If there is such universal approval of casing movement during cementing, why then do only a relatively small percentage of operators move liners? There are several reasons.

Sometimes the liner-to-hole clearance is very close--closer than in full string cementing jobs--and the liner is long and heavy. For example: a 7,000 ft. long 7-3/4 in. O.D. 46.1 lb./ft. liner is to be cemented in an 8-1/2 in. I.D. hole from 12,000 ft. to 19,000 ft. T.D. in 12 ppg mud. The drill string is a tapered string consisting of 8,000 ft. of 4-1/2 in. 16.6 lb./ft. Grade E drill pipe and 4,000 ft. of 4-1/2 in. 20 lb./ft. Grade X-95 drill pipe. The total buoyed weight of the drill string and liner would be 439,110 lbs. The minimum tensile strength of the drill pipe at 90% of new is 470,000 lbs. To reciprocate such a liner would be dangerous since hole drag would probably exceed the tensile rating of the drill string. Rotation probably would not be possible due to high torque caused by such close tolerance between the liner and the hole. Heavy long liners in close hole tolerance or crooked hole situations probably cannot be moved during cementation unless a special high tensile drill string is available.

Liner movement becomes even more important in cases where there is no centralization or the hole is eccentric. When centralizers, scratchers, or other hardware are used, they must be compatible with the liner setting procedure. They should not interfere with the operation of the liner hanger or impart torque to the liner while going in the hole.

Many liners are ordered with integral flush joint threads to give more room for cement, easier running, and ready availability in special sizes. When flush joint threads are used, many operators do not want to use centralizers for fear the locking rings will slip and cause problems if the centralizers bunch up on one end of the liner. When a liner is not centralized, there is no hope of getting efficient mud displacement by the cement. About the best one can hope for is good bonding at critical spots.

LINER RECIPROCATION

Howell[8], in 1979, wrote of field experience in liner reciprocation while cementing in the Lacassane Refuge Field, Cameron Parish, Louisiana. He stated communication behind production liners was eliminated and that, after obtaining favorable results in Louisiana, liner reciprocation during cementing has since been used in Texas and Oklahoma.

A major reason given against liner movement is the fear of cementing part of the drill string in the hole, if the drill pipe must remain attached to the liner during the operation.

In conventional liner cementing jobs, the drill pipe is usually disconnected from the liner prior to cementing. To reciprocate a liner you have to stay tied-on to the liner until the plugs bump, hang the liner, and then release the drill string and setting tool from the liner. This procedure requires precise performance of the liner hanger and setting tool releasing mechanisms. If either one of these mechanisms fail to perform properly, the results can be very costly. Fig. 1 shows a liner assembly most commonly used for reciprocation.

LINER ROTATION

Hanger equipment has been designed to include ball bearings to facilitate liner rotation. In this type of structure, the hanger is set and the liner weight supported by the bearing. Next, the setting string is released from the liner and a set of spring loaded friction blocks located in a spline sub in a manner which permits the drill pipe to impart rotation to the liner, Fig. 2. In the event of trouble, the drill pipe is ready to be removed from the well without the problem of having to set the hanger or release the setting tool.

Fig. 3 shows the 3 main steps in liner rotation while cementing. Fig. 3(A) shows the liner being carried in the hole just prior to setting the hanger. In Fig. 3(B) the liner setting tool is detached from the liner after the liner hanger is set, and the weight of the liner is suspended on the ball bearing. The drive sub is located in the spline and rotation imparted at the surface while cementing. Fig. 3(C) shows the liner after the plugs bump and the setting string is removed from the well.

It is customary in some areas to impart rotation by power tongs, since the rotary is much too fast and torque is easier to monitor with power tongs. In the Gulf Coast area, some operators use a power swivel especially designed for liner rotation. The swivel has a cement manifold and plug dropping device incorporated in the complete assembly. One thing which must be said is that liner rotation need not be continued if torque is excessive; therefore, a liner rotation cementing job is easily continued as a conventional job--the operator is not committed to finish something which begins to look dangerous.

Even though liner rotation is safer than reciprocation, serious problems occurred resulting in bearing failures. First, the bearings were subjected to great stress and would wear out rapidly. Second, the bearings were open and exposed to erosive well fluids causing freeze-ups. And lastly, a problem with prior art hangers was experienced in some deviated wells because lateral pressure on the bearings would cause the raceways to crack or break.

NEW LINER BEARINGS

Present structures feature a new sealed load bearing consisting of a composite, laminate, fluorocarbon, nylon, resin-bearing material. Fig. 4 shows the new sealed load bearing as it is installed in the liner hanger just above the slip cone. Fig. 5 shows a cross-section of the bearing. It comprises upper and lower race elements separated by the bearing material, usually a resin-bonded Teflon (a registered trademark of Dupont Company). Below the lower race element is a beryllium-copper washer element which provides for additional mobility of the 2 races in the event of a freeze-up.

The load capacity and life expectancy of the sealed friction bearing is dramatically greater than of prior art unsealed ball bearings.[9] Comparative test results depicted in Fig. 6 show that prior art un-sealed ball bearings rotating in drilling mud failed in 3½ hrs. under 100,000 lbs. load at 20 RPM, and in 9½ hrs. under 50,000 lbs. at 20 RPM. The new sealed friction bearing shows no increase in torque under loads of 50,000 lbs. and 70,000 lbs. after 18 hrs. rotation at 20 RPM and 15 RPM, respectively. As illustrated, the improved bearing assemblies are vastly superior in performance to prior art bearings used in liner rotating assemblies.

RECOMMENDED ROTATING LINER CEMENTING PROCEDURE

The following is a good liner rotation procedure:

General: An accurate means of measuring the torque of the drill pipe is required. Most operators use the casing tongs with the proper dies to rotate the drill pipe.

(1) Before pulling out of the hole to log, or when on bottom during the clean up trip, determine the torque required to turn the drill pipe and collars with the bit off bottom. This will approximate the torque required to turn the liner with mud in the open hole.

(2) Pull drill collars into the casing and measure torque required to rotate. This will approximate torque when setting string is released from liner and turning free.

(3) Run and hang liner in usual manner. Establish circulation and condition hole as required.

(4) With rotating spline engaged, rotate liner at low RPM (usually 3-10 RPM). Do not exceed _____ ft./lbs. (Use torque from step 1 and add torque rating of weakest joint in liner less a 20% safety factor.) Pick up setting string to disengage spline and observe torque. Set down, engage spline and prepare to cement.

(5) It is not necessary to rotate through the entire job. Rotation should begin when cement turns the shoe. Monitor torque closely. Slow rate of rotation if torque builds; discontinue rotation, if torque approaches limit set in step 4.

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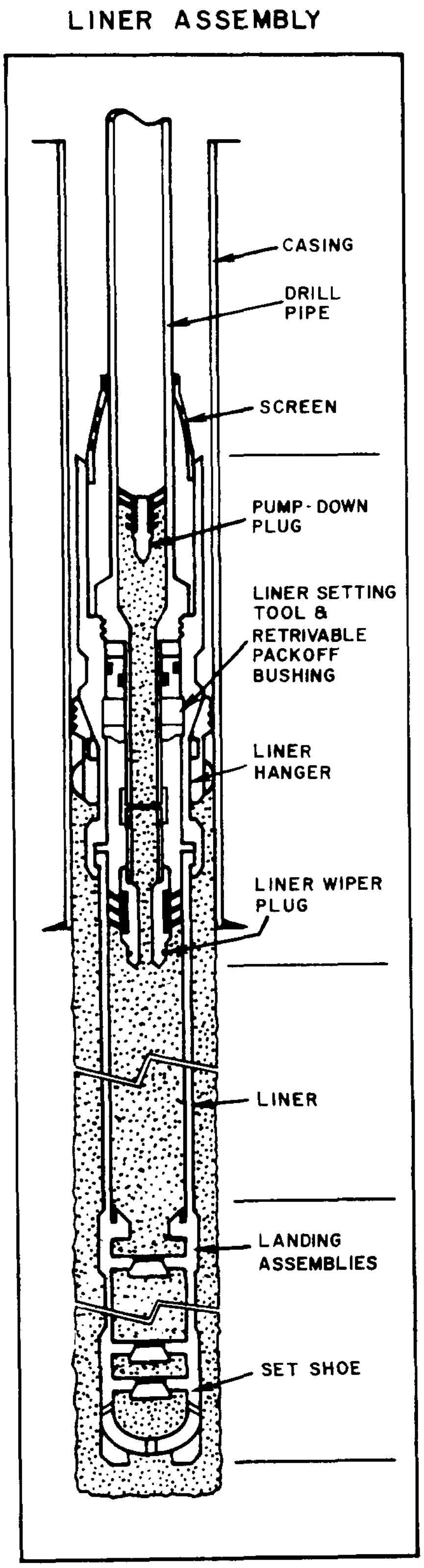


FIGURE 1

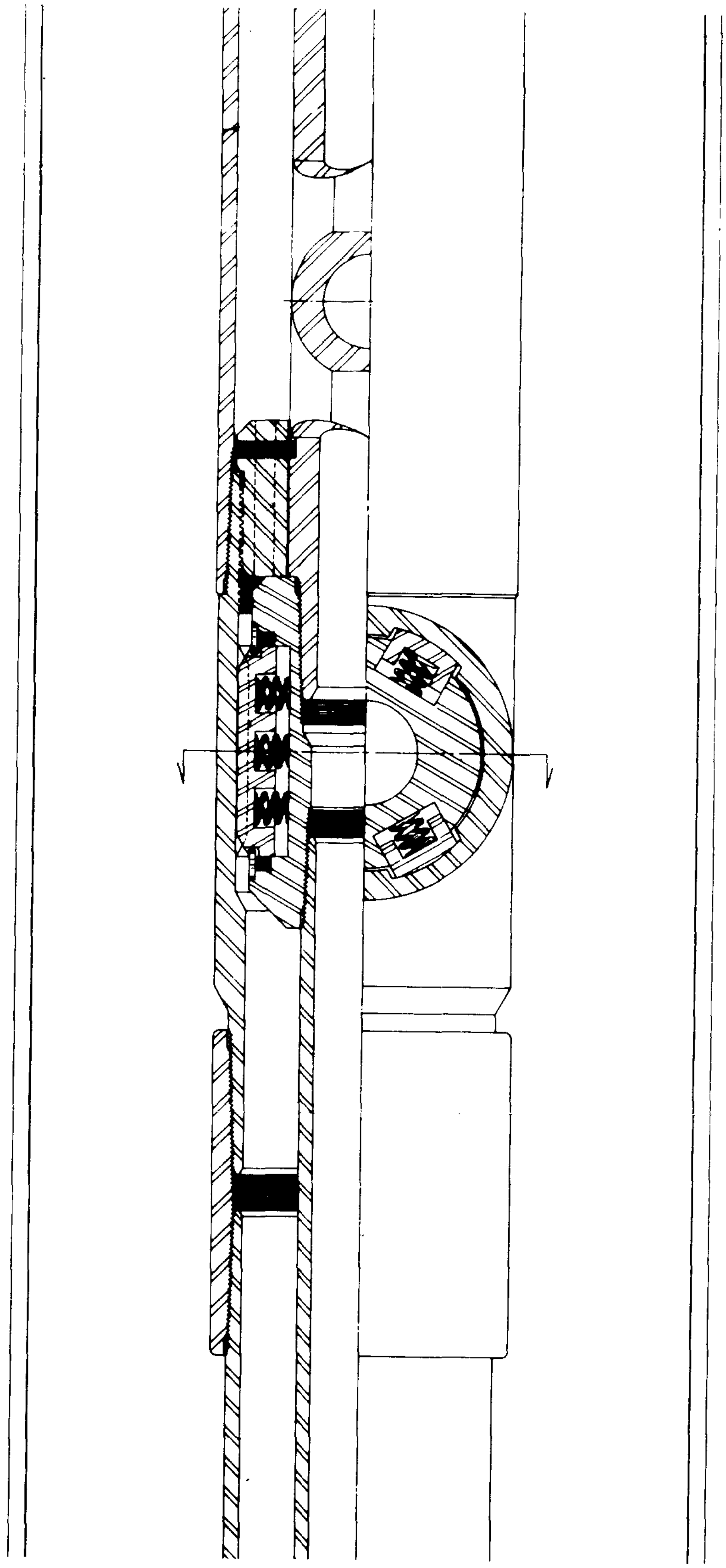
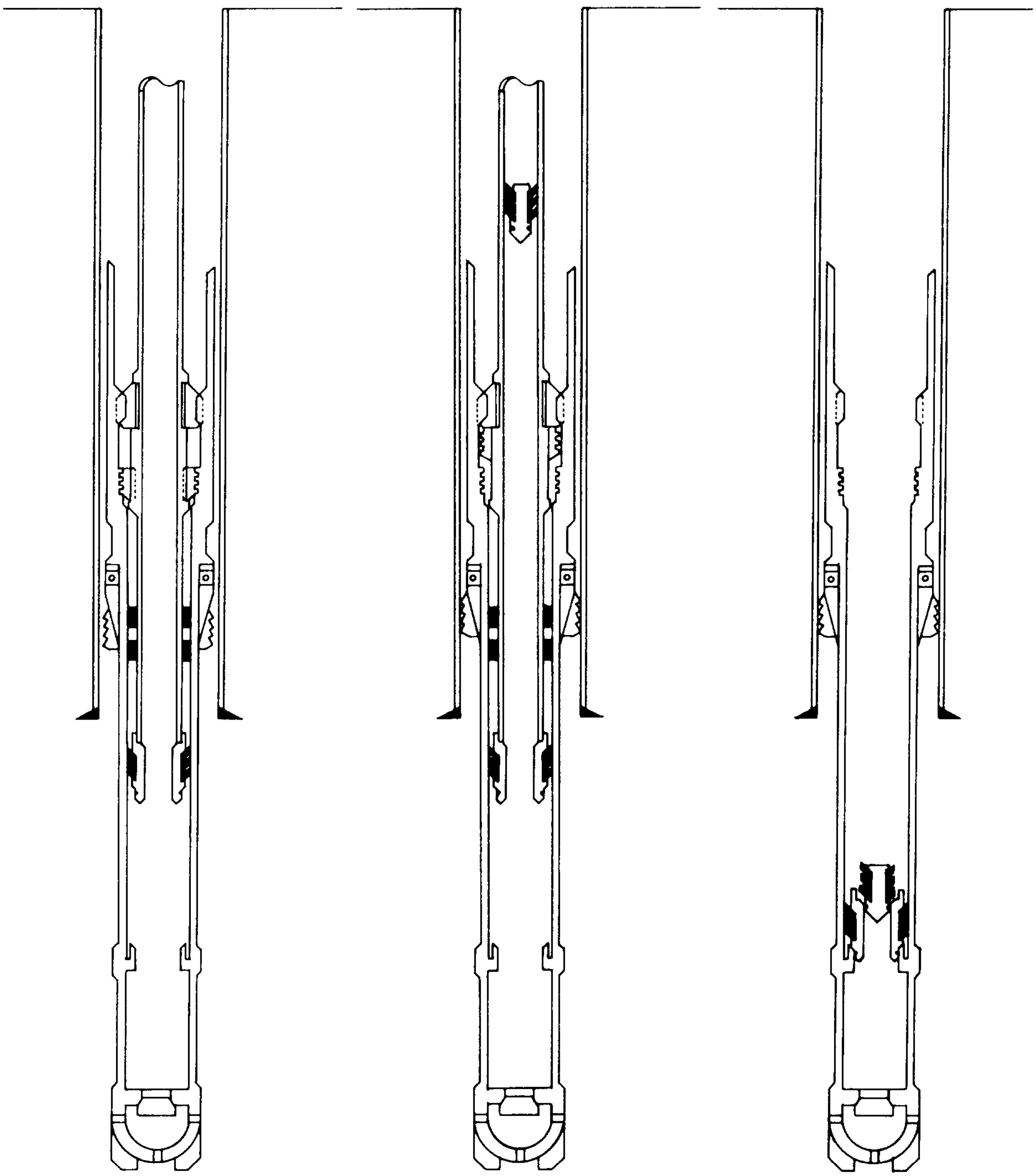
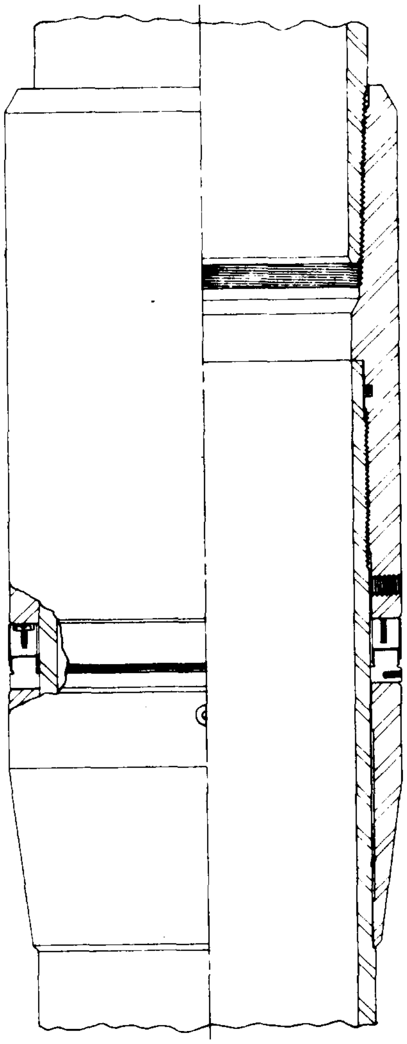


FIGURE 2



(A) (B) (C)

FIGURE 3



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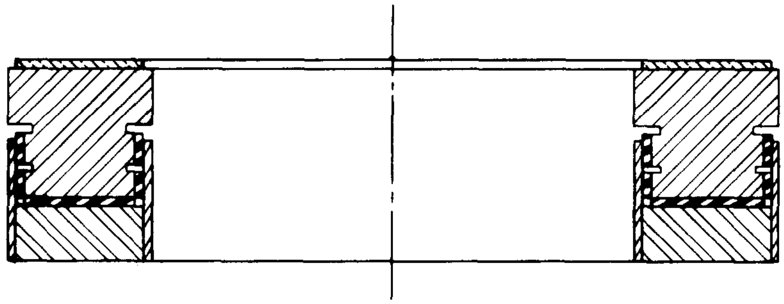

FIGURE 5

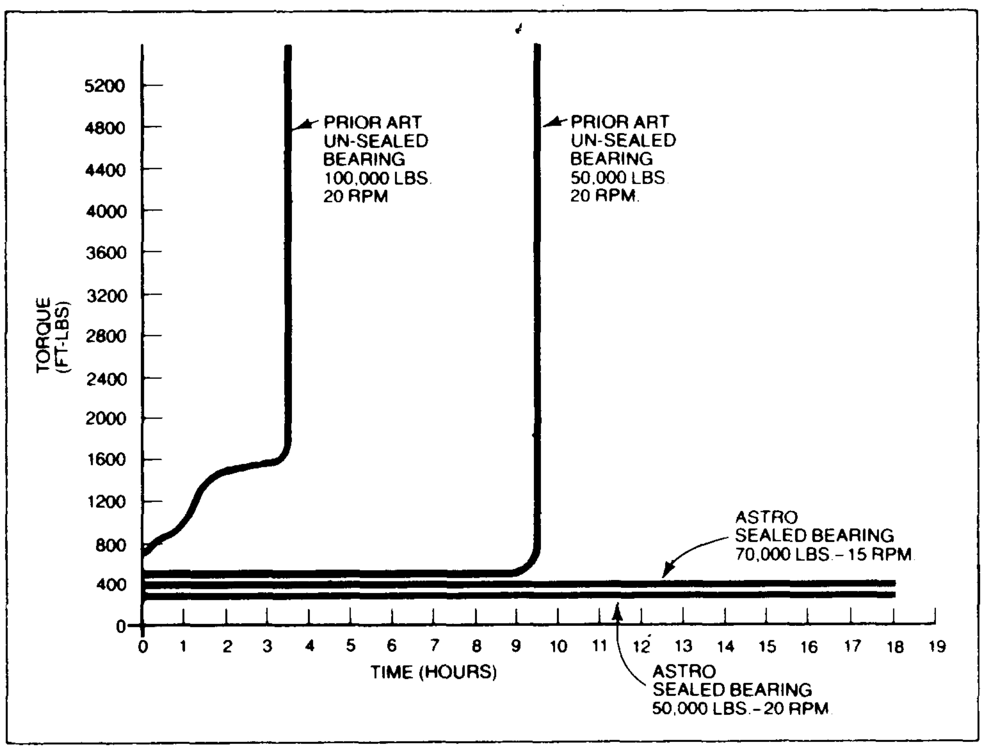

FIGURE 6