DOWN HOLE SUCKER ROD PUMP BARRELS AND THE PROBLEMS RELATED TO ABRASION

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INTRODUCTION

With today's economic condition, competitive market, and customers world wide clamoring for lower prices, the need to maximize the economic operation of an oilfield has never been greater. This paper is directed toward abrasive wear and increasing pump barrel life.

The first step in increasing the life of a pump barrel is to understand why it wears out. After we grasp the cause of wear we can design or select a product that wears slower. Wear cannot be stopped but only slowed. The user must examine worn out parts, keep records, and have a working knowledge of available materials in order to select a barrel most economic for the task.

The cost you notice most is when you have to pay for another barrel, but the more significant costs are those of pulling, repairing and reinstalling the pumps, and the lost revenue when the oil stops flowing. Those costs tend to get lost in the general aggravation of being in business in the first place.

WHY BARRELS WEAR OUT

The main cause of pump barrel failure is abrasive wear. Abrasive wear is the action of particles of all sizes and shapes, made up of anything in the formation which grind out the barrel. The particles may be soft as talc, or hard as quartz. Their shape may be round, which means that they may roll through the clearance space between plunger and barrel, or sharp, which may mean that they will embed themselves into the metal and act like a file on the mating part until so much clearance is worn that the pump no longer functions. There has to be clearance between the pump plunger and the barrel. This clearance will increase as the pump wears. In conventional machine design, you try to keep particles from getting between piston and bore by making the clearance as small as possible and keeping a sharp edge on the piston. As Fig. 1 shows, only particles smaller than the clearance space can get into it. The larger ones will bounce around a while and either get lost somewhere or get pumped through. Fig. 2 shows what happens when you have a radius on the piston. It forms a funnel which helps guide the particles into the clearance space. To add insult to injury, the plunger rattles around in the barrel as it works, which creates an action very similar to a McCulley Rock Crusher shown in figure 3.

The outer cone, with its liners, is stationary. The inner cone, called a head mantle, is free to rotate on its shaft but is not power driven. It doesn't revolve in operation, but only creeps around as the rocks are worked in the clearance space. The driving mechanism is connected to an eccentric which causes the lower end of the head mantle to gyrate, like a belly-dancer in circular orbit. Obviously, any rock that isn't too big to get started at the top of the gap will be progressively crushed until all the pieces are small enough to come out of the clearance space at the bottom, which is adjustable to make the size rocks you want.

A sucker pump barrel and plunger work in somewhat the same fashion. Perhaps a sharp corner is not practical, because of assembly problems and because of the possibility of the sharp edge digging into the barrel. What can a pump buyer/user do about all this? Principally look for more abrasion-resistant materials.

HARDNESS AND ABRASION RESISTANCE

Many characteristics of parts and materials can be very precisely measured on truly linear scales. An inch at the start of your tape measure is the same length as an inch anywhere along the tape. Neither abrasion-resistance nor hardness can be measured that simply or precisely. The Bureau of Standards once said:

> "The term "Hardness" may be used with reference to the resistance of a material to abrasion, penetration, deformation, cutting, shearing, crushing or reaction to impacts. There is no single measure of hardness, as it is not a single property but is a combination of several properties."

All those different characteristics cannot be measured with one instrument. Readings obtained from several different types of instruments do not come out to a nice, neat, comparable set of numbers.

Close to 200 different wear tests have been devised. All of them rely on doing something to a specimen under very closely-controlled conditions. The test sets up an artificial environment that may or may not represent the real world at the bottom of your well.

You don't need to buy a machine for that kind of testing. You already have a better one--your oil well--if you make careful observations and keep records of what it's doing to your equipment. Fortunately, there is one thing we can say with certainty: The harder the pump barrel is, the slower it will wear. The pump designer's task comes down to finding materials and treatments that are just as hard as it's possible to make , but not so hard that the side effects, like brittleness or cost, rule them out.

It would be nice if there was only one kind of hardness testing machine that would check out everything from soft butter to diamonds and give everything a number on a nice, linear scale. Forget it, look again at what the experts say:

> "The term "hardness" is susceptible to many interpretations and hardness values can be expressed in numerical terms only with reference to the specific testing method."

That's just for metals. When you try to include minerals, it gets even more complicated.

HARDNESS TESTING

Around the year 1800, a man by the name of Moh, who was trying to rank the hardness of minerals, reasoned that if mineral "A" scratched mineral "B", "A" was harder. Then he made a shrewd guess and picked the diamond for the hardest specimen and gave it a 10." The softest mineral he could find was talc, so gave it a "1". His scale is shown in Fig. 4. This scale wasn't designed to measure hardness, as we would "inches." It was strictly a method of comparing hardnesses, in terms of "It's Harder," or "It's Softer," thereby helping with the identification of minerals. When you look at Moh's scale, you can easily draw the wrong conclusions. For example, Professor German, of the Norwalk, Conn. State College, "Ranked" Tungsten Carbide on Moh's scale-something old man Moh couldn't do because the stuff hadn't been invented, and placed it at 9.2. That's where we put the left arrow, on Figure 4. Wouldn't that lead you to think that Tungsten Carbide is almost as hard as diamond? Unfortunately, it's nothing of the kind. On Moh's chart there is just about as much difference in hardness between 9 and 10 as there is between 1 and 9. Obviously, that kind of measuring stick won't help us grasp the real relationship in hardness.

In 1929, Vickers, In England, developed "Micro-Hardness" testing. In this country, in 1939, a man named Knoop developed a take-off from the Vickers indentor. A couple more people, Thibault and Nyquist, used it to investigate and rank numerous hard metals and minerals. The system is fairly linear and was blessed by the Bureau of Standards. It was at first intended to cover materials harder than the hardest tool steels. At the same time, others were working on many more approaches to hardness testing, especially of metals.

Like Knoop, most of the equipment they developed relied on pushing some sort of indentor, like a centerpunch, into the surface of the part. The instruments then measured either the size of the impression made, or the depth to which the indentor penetrated.

So what has all this to do with pump barrels? First, abrasive wear is nothing more than making a continuous hardness test, pushing an indentor into the surface of the part and then sliding it. Second, understanding the relative hardnessess and tests allows a comparison of the materials available in the field.

When dealing with barrels made of uniformly hard steel, be it in the soft condition or through-hardened, tests such as Rockwell C are perfectly satisfactory. When testing a material that has been surface treated, such as carburized, nitrided, plated or such, it is much more difficult to evaluate the hardness of the surface, or the rate at which that hardness drops off as wear takes place and exposes the progress- ively softer parent material.

For such determinations, micro-hardness testing, using the Knoop Indentor, is appropriate. With this method, you have a tiny indentor, a small load and you must work with laboratory sectioned and polished specimens under carefully controlled conditions.

It is obvious that using a Rockwell C, or Brinell instrument on surface-treated materials would result in reading the core hardness some distance below the surface--not the surface itself. The thin, hard layer would simply be pushed into the parent stock by the indentor, giving a misleading reading. Figure 5 shows a comparison of the hardness indentations.

Figure 6 shows a photomicrograph of a chrome plated surface showing .006 of chrome. Production barrels usually have only .003 We are working with customers who have determined that wear is very low until the chrome has finally been worn off. They reason that putting on twice as much, which costs little more, will greatly prolong life. Actually, we can put on any amount that is wanted. A hardness bench mark scale was created as shown in Figure 7. In case you're wondering how we were able to connect the two measuring systems and come up with a linear scale, let me say that we used handbook data for each system. We found a number of materials for which the handbooks listed hardnesses under both systems and proportioned the scales to suit these benchmarks. Laboratory tests were made to confirm that we had reasonably linear relationships. Practically speaking, the hardest mineral you have to deal with in an oilwell is quartz.

QUARTZ

Quartz shows up in over 200 varieties and is distributed world- wide in rocks of all geological ages. Insoluble in acids, one of the highest melting points for minerals, as crystals, as amorphous masses and in some brilliant disguises. But always hard, always abrasive, you are pumping it. Yesterday, now and forever--this is the enemy.

What do we have that is harder and more wear-resistant than quartz? I'm going to take the Rockwell C scale, from 10 to 70, and expand it so we can look at our options in greater detail.

BORE SURFACE HARDNESS

Figure 8 shows the principal bench-mark, quartz, the enemy, and the hardnesses of the bores of a number of commercially available pump barrels. The hardnesses reported were taken by our laboratory, confirmed by an independent laboratory, and are believed by our metallurgists to be consistent with the materials and treatments involved.

Keep in mind your enemy-quartz-pegged by a triangle, at Rockwell "C" 64, the text book number for quartz. The crystal specimen we checked was actually several points harder.

Material (1) is hard chrome, as applied by Scot Industries. It has hardness, throughout the layer, ranging from 70 to 72 Rockwell C. Chrome can be applied to soft or heat treated material, or on material selected for reasons of corrosion resistance. The outstanding hardness of chrome, relative to quartz, is clearly seen.

Material (6) is a carburized and hardened SAE 1020. It was found to be 63 to 64 Rockwell C. There was no decarburization of the surface.

Material (4) is a tube treated by a proprietary method. We understand that a thin coating of a hard nickel alloy is deposited, by a non-electrical method. Twenty to thirty percent of the volume of the coating consists of very hard silicon carbide particles. These have a hardness of Vickers 2,500--way above the Rockwell C range. The nickel alloy matrix is said to be Rockwell C 60 to 65. Because the layer is so thin--.001 to .0015, the indentor sees a combination of matrix and particles, which can be read as a composite reading, claimed to be typically Rockwell C 72 to 75. On the sample tested we found the layer thickness to be Rockwell C .001 and the matrix hardness to be Rockwell C 60 to 65. However, on so thin a layer it is very difficult to obtain meaningful readings. We believe that treatments such as this cannot be fairly evaluated on any basis other than field tests.

Material (8) is a carburized and hardened SAE 1020, found to have a hardness of 57 to 58 Rockwell C. Decarburization of the surface was very slight.

Material (7) is a bore quenched SAE 1040 material which showed 55 to 57 Rockwell C, .005 under the decarburized surface. The honed surface was 51 Rockwell C.

Material (3) is nitrided SAE 4130, coming in at 55 to 57 Rockwell C.

Material (5) is a bore-quenched SAE 1035. The 49 to 50 Rockwell C readings were obtained .005" into the surface, to get under the decarburized skin.

Material (9) is untreated 1020-1026 tubing.

We also investigated chrome plated stainless steel barrels, but did not chart them for the obvious reason that chrome is chrome--it is equally hard no matter what you put it on.

SUMMARY

1. The life of a pump barrel is determined by its abrasion resistance.

2. For all practical purposes, abrasion resistance is a function of hardness. The harder the surface, the longer it will last.

3. The cost of a barrel is only one part of a complex equation. To arrive at the cost per barrel of oil pumped, you need to know your cost of replacing the pump and the lost revenues while that is going on. We can't make that calculation for you because your well, and your costs under your way of operating determines those costs.

4. Our message is that you need to make those calcuations and then consider the alternatives.

We like purchasing agents. We respect them, but their decisions are only as good as the data they get from their operating people-and that's why the foremen, the superintendents, the engineers and the others who make it all come true out in the fields have to make the observations, keep the records, check the results and communicate.

Nothing is as reliable as the results actually being obtained out in the field.

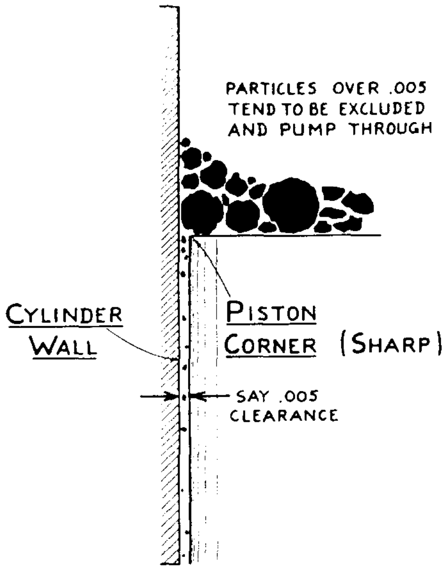

Figure 1 - Conventional machine design

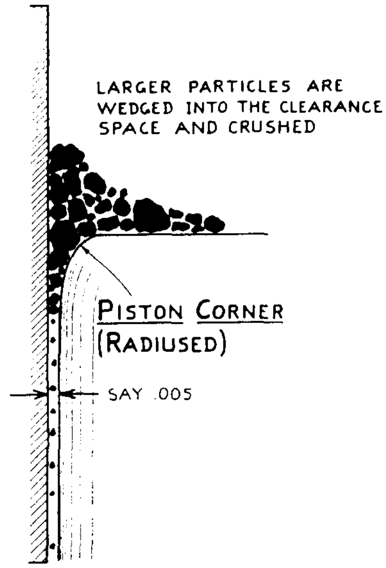

Figure 2- - Effect of radiused piston

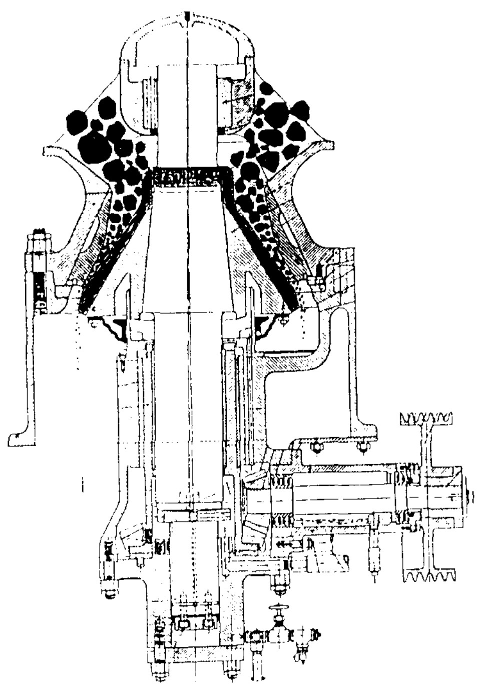

Figure 3 - McCulley rock crusher

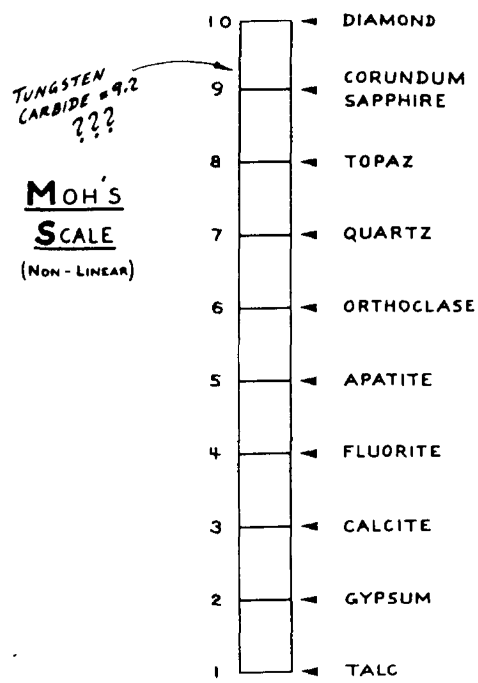

Figure 4 - Moh's scale

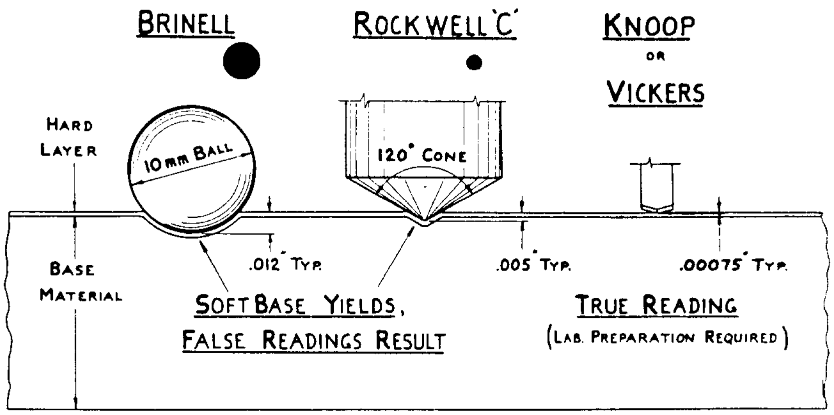

Figure 5 - Comparison of hardness indentors

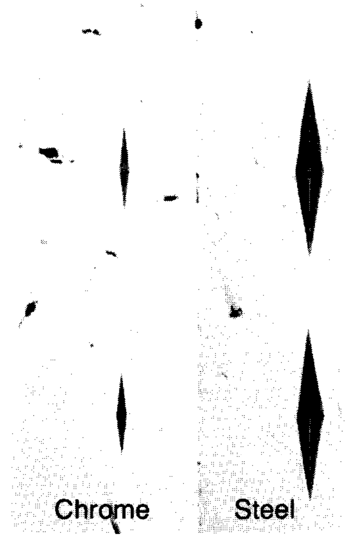

Figure 6 - Knoop indentations in chrome plate and steel substrate

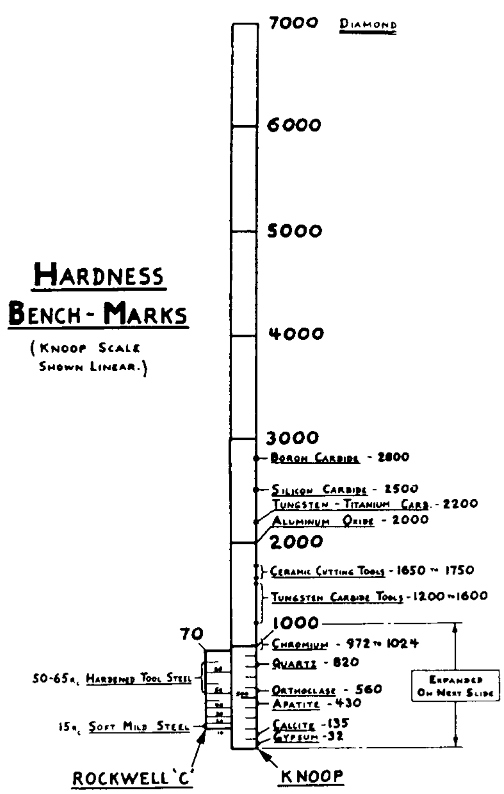

Figure 7 - Hardness bench-marks

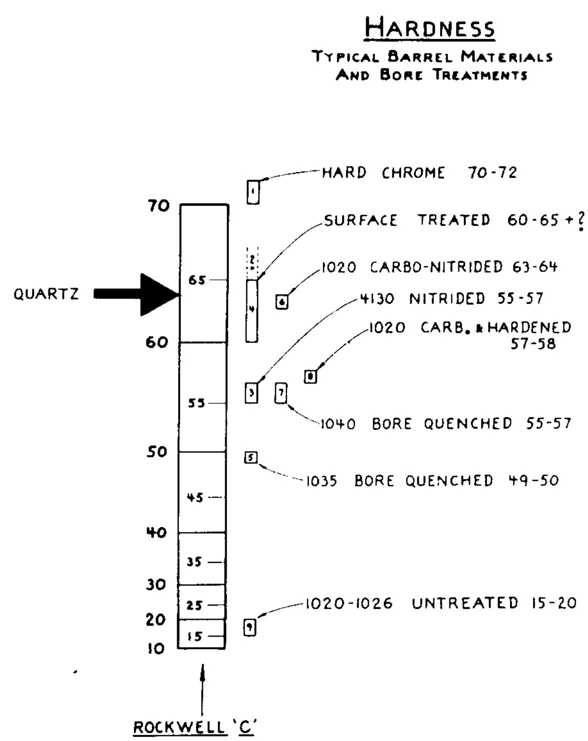

Figure 8 - Barrel surface hardnesses