# ARE VARIABLES IN THE DESIGN DETAILS OF SUBSURFACE ROD PUMPS CAUSING HIGH LIFTING COSTS AND REDUCED PERFORMANCE?

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## ABSTRACT

There is a generally held opinion among the users of subsurface rod pumps that those pumps built to the specifications of API, Spec 11AX, have the following characteristics:

1. Their design is excellent with little need for improvement.

2. Equal quality can be obtained from various authorized manufacturers by simply specifying dimensions and materials in broad generic terms.

3. The individual design of pump parts has little or no bearing on pump performance.

The author contends that these opinions are erroneous resulting in millions of dollars of unnecessary expense each year for the repair and maintenance of rod pumping equipment. To prove his contention he traces the history of the standardization program considering industry requirements, standardization goals, and the design options left open to the manufacturer/user team. He then discusses design details of some of the rod pump components that can cause major differences in pump performance and run time. In conclusion it is recommended that users consider all these factors to improve pumping system performance and reduce lifting costs.

## HISTORY

The first edition of API Spec 11AX was published in January 1961. It is now in its seventh edition, but there have been no changes in the basic concept of the standard nor in the design of the pumps. During the formulation of this standard in the late 1950's two important factors were involved which affected the pump designs selected and the wide options left to the discretion of the manufacturer for the design and construction of the individual parts.

1. Prior to publishing of this standard interchangeability of parts between manufacturers was seldom possible. If a pump was purchased from one manufacturer, subsequent replacement parts required for that pump, were always a single source purchase. The users insisted that this standard allow interchangeability of all parts manufactured to API specifications. This was the primary charge of the task group assigned to write the standard. The omission of tight specifications involving the design of individual parts was intended to permit and encourage improvement by individual manufacturers.

2. During the period this standard was written the domestic petroleum industry was suffering an economic depression. Most production was restricted by allowable regulations. Depth/volume production requirements from most producing wells was very low. Secondary recovery with its high volume

pumping requirement had not been initiated. This resulted in pump designs that were excellent for low volume pumping, but were not considered the best for the seldom required high volume pumping.

During the first decade after publishing of Spec 11AX the industry continued to be in a depressed economy. The bidding which resulted from interchangeability forced pump costs downward for new pump purchases and also for pump repair costs. Market supply far exceeded demand. This economic pressure forced manufacturers to reduce every possible cost of design, manufacture, marketing, and service. Since Spec 11AX has no requirement of design quality for optimum performance life, and no specifications of metallurgy, process, or hardness, a steady deterioration of pump quality resulted. Some of the competitive cost cutting was good for the industry, but some has been detrimental to pump performance.

In the past decade secondary recovery with its higher volume requirements and deeper wells has greatly increased performance parameter requirements of subsurface pumps. Cost pressures have been reduced. However, manufacturing capability remains ahead of marketing demand. Pump prices have increased with some easing of pressure, but competition remains strong with tough profitability pressure on the manufacturers. There has been very little pressure from users to encourage improvement in product because very few users are aware of the need for product improvement. Several manufacturers have recognized the need for improved pump design, but so few users truly understood the need that the improvements have not been accepted.

## EXAMPLES OF DESIGN DETAILS AFFECTING PERFORMANCE

### API Standard Pumps

The gas anchor connection for all insert pumps is designed for the use of a "Poor Boy" gas anchor. For example, a 25-200 RW Type pump has a 1 1/4" gas anchor connection. The internal cross-sectional area of this gas anchor is 39% of the internal area of the barrel. With the longer and faster strokes being used today a severe inflow restriction frequently results with unnecessarily high pump intake pressure requirements. Inflow restrictions continue through the seating and standing valve assemblies.

The pin plunger specified in all API insert pumps must have flow restrictions because of the wall thickness required for strength in the plunger pin. With viscous fluids and high volume pumping these restrictions within the plunger resist downstroke plunger motion, increasing compressive forces on the lower portion of the rod string.

## METALLURGICAL AND PROCESS CONSIDERATIONS

The most commonly used barrel type is normally called "Hardened and Honed". This is a generic term to lump several types of metal and processes into one group. Several 1000 series carbon steels and 4000 series alloy steels are commonly used. Hardening processes normally used are induction hardening, carburizing, and nitriding. Resulting hardnesses vary from Rockwell C40 to above Rockwell C60. Performance characteristics and manufacturing costs cover a wide range under this "Hardened and Honed" specification. Bidding with this specification will usually result in buying the least expensive "Hardened and Honed" barrel to manufacture, whether it is right for the well or not.

Valves (balls and seats) are normally classified by users as either stainless steel, Stellite or cast cobalt alloy, or carbide. There are at least twenty different combinations of valve material available with at least six of them in the stainless steel class. The stainless steel valves available range in hardness from 40 to

66 on the Rockwell C scale. The user cannot possibly evaluate performance unless he knows the specifics of hardness and metallurgy being evaluated.

Throughout the pump various metals and processes are currently being used that are not definitively being identified by either the manufacturer or user. This leads to frequent misapplication of product.

EXAMPLES OF VARIATIONS IN PARTS DESIGN AFFECTING PERFORMANCE

Figure 1 depicts the drawing specification from Spec 11AX of the V11 - Valve, Ball and Seat. It should be noted that there is no internal diameter specification for the flow passage through the seat. Figure 2 shows the option of a small flow passage (a) and a larger flow passage (b). As the ID of the seat is increased the pressure on the contact area between the ball and seat is increased. This increased pressure improves the seal capability of the valve. However, where the pressure differential across the valve is very high the yield pressure of the valve material could be exceeded with failure resulting. The larger flow passage through the seat reduces flow restrictions. These characteristics should be considered for individual pump applications.

The seat seal configuration is also not specified by this standard. Figures 3, 4, and 5 show some of the current methods of preparing seat seal surfaces. Figure 3 has a single flat chamfer on the seat which is tangential to the ball. This is the least expensive method of manufacture. It has two disadvantages:

- The lap width (Lw) tends to be wider on this flat surface which increases the area of contact between ball and seat. This increased area reduces seal effectiveness.

- If the ball's cage allows lateral movement of the ball it can strike the seat at point (P) causing premature failure of both parts.

Figure 4 has two flat chamfers with their juncture being the point of contact with the ball. When the seat is then lapped, removing the point contact, the resulting lap width (Lw) will be small for good seal effectiveness. However, this seat has a sharp point (P) for damage to occur where lateral ball movement is permitted. Figure 5 has a radial contact with the ball. This is a more difficult manufacturing procedure, but it has the advantage of no sharp edges and a narrow lap width (Lw). This seat also has the advantage that it can be double-lapped to accommodate both the regular pattern and the smaller alternate pattern ball.

Figure 6 depicts the drawing specification from Spec 11AX of the C13 - Cage, Closed, Pin Plunger. It has no internal specifications for the ball containment chamber. No ball guides are specified. Therefore, some inexpensive cages are furnished as shown in the cross section of Figure 7 allowing considerable lateral movement of the ball resulting in excessive valve and cage wear. This cage does have the least possible flow restriction around the ball. In Figure 8 the ball guides are formed by eccentric milling of flow passages between the guides. This type cage gives excellent service with good ball protection especially if the guides are hard lined and ground with a very close tolerance between the ball and the guides. If three ball guides are used instead of four there is an increase in flow passage, but more lateral ball motion is permitted with the same ball-to-guide tolerance. Figure 9 is the cross-sectional view of an insert guided cage. This cage has excellent guide and flow passage characteristics, but has increased fluid seal problems and usually requires the use of the smaller, alternate pattern ball.

Figure 10 depicts a flat cage material surface to stop the upward travel of the ball. When this configuration is used the ball tends to beat out the cage causing relatively frequent cage replacement. Some cages have been furnished with a hard-lined bead of weld material, as shown in Figure 11, to reduce cage wear at this point. However, this bead is of a relatively hard material and its rounded surface causes point contact with the ball. This results in unnecessary ball damage, especially if the pump is operating in a fluid pound condition. When a ball stop is formed in the hollow-cone configuration of Figure 12 the ball stop is changed from point contact to linear (circle) contact. This reduces the stresses on both materials increasing wear life of both parts. This ball stop will eventually beat out, but it will contribute to maximum wear life of the ball.

There are many other important design procedures that should be considered for each pump application. This paper is not an in-depth study of those details, but its purpose is to point out the importance of those details.

## CONCLUSIONS

- The pumps specified in API Spec 11AX are not of the design or quality necessary for today's requirements.

- The users and manufacturers must work as a team to develop and test better pumps.

- These better pumps will initially cost more because they will be manufactured in smaller quantities and cannot be competitively bid.

This improved pump will not be accomplished until a reasonably large group of the users recognize the need and actively solicit the help and assistance of the manufacturers and properly reward them through business. It is a project that could be handled through the API Standardization Committee on Production Equipment, but it would probably take a considerable amount of time. The capability and reliability of the API sucker rod string has been greatly improved in recent years by the team effort of users and manufacturers within the API. This could and should be done for subsurface rod pumps.

## REFERENCE

1. API Spec 11AX, Seventh Edition, June 1979.

## ACKNOWLEDGEMENTS

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Spec 11AX
V11 - Valve, Ball and Seat

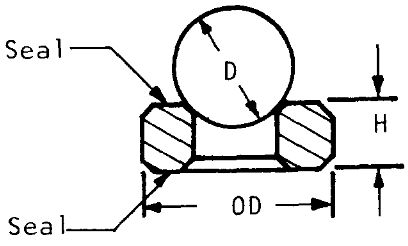


FIGURE 1

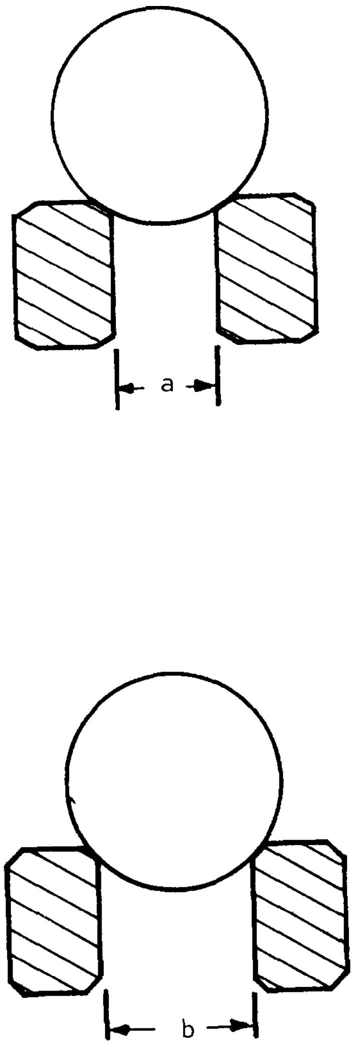


FIGURE 2

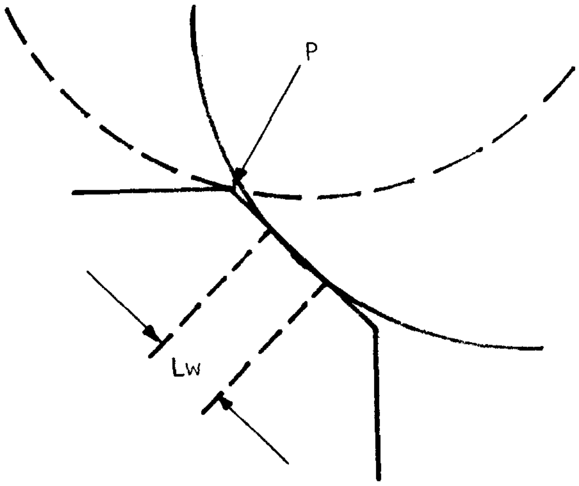


FIGURE 3

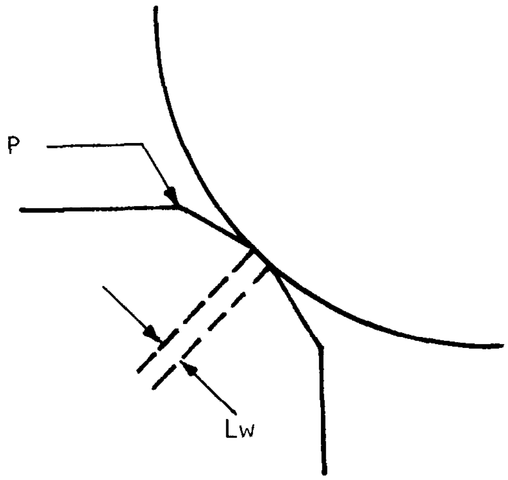


FIGURE 4

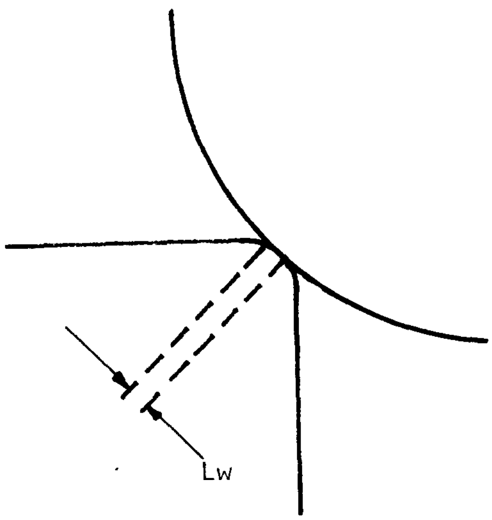


FIGURE 5

Spec 11AX
C13 - Cage, Closed, Pin Plunger

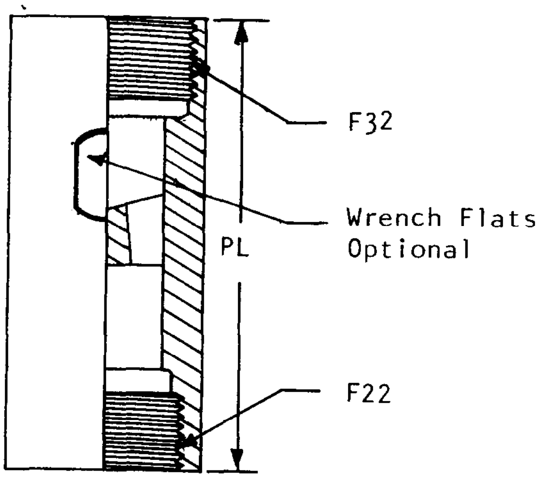


FIGURE 6

Cage Cross-section, Ball Area
(Unguided)

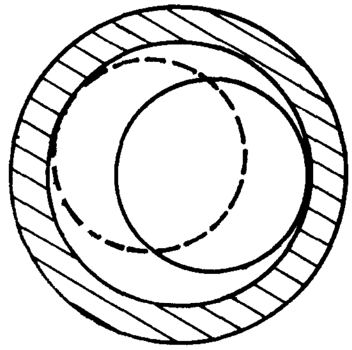

FIGURE 7

Cage Cross-section, Ball Area
(Guided)

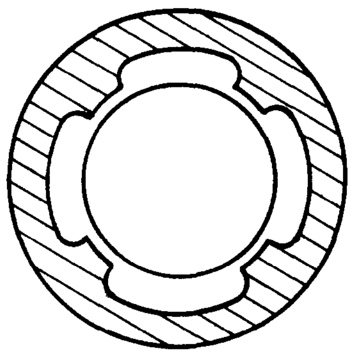

FIGURE 8

Cage Cross-section, Ball Area
(Insert Guided)

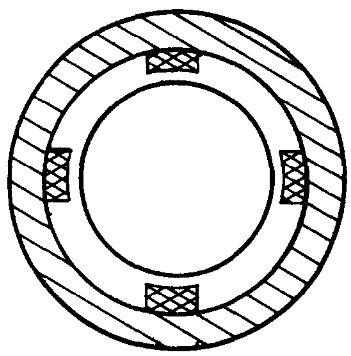

FIGURE 9

Cage with Flat Ball Stop

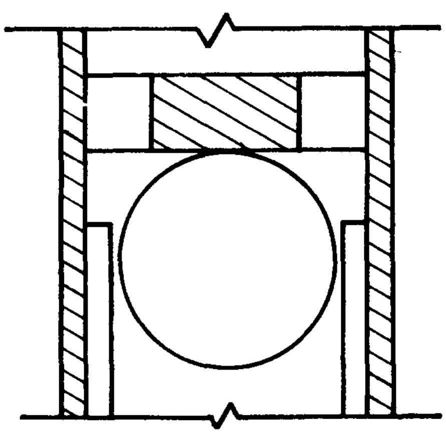

FIGURE 10

Cage with Hard Bead Ball Stop

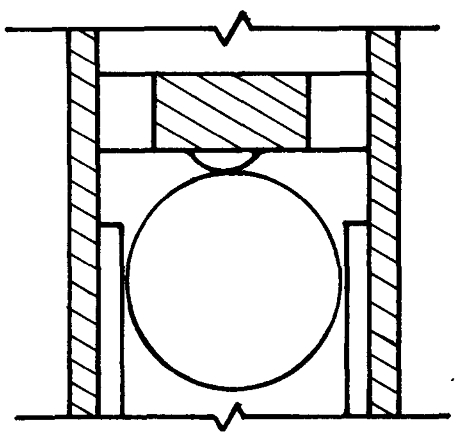

FIGURE 11

Cage with Hollow Cone Ball Stop

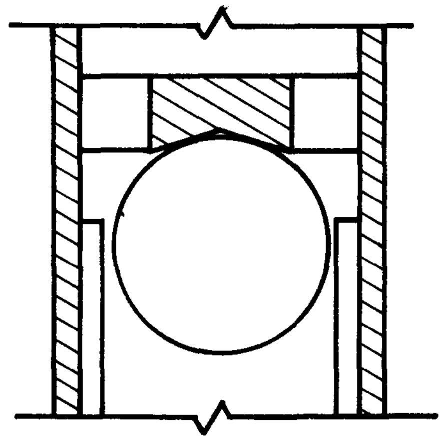

FIGURE 12