MODIFIED POLISHED ROD WITH SUCKER ROD END – ENSURING STRONGER CONNECTION

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INTRODUCTION

A polished rod is the top and most heavily loaded part of the sucker-rod string, which connects the sucker rod string to the pumping unit. It serves functions to transfer the pumping loads to the surface pumping unit, and to provide a seal against the stuffing box to prevent well fluids from exiting the wellbore into the environment. See Figure 1 for the basic components of a sucker rod pumping system.

The polished rod must be strong enough to carry the full load during the pumping cycle, and typically have diameters larger than the top rod section.

The surface of the polished rod is held to tight tolerances and has a very smooth finish (surface finish of 8 µin to 32 µin) to provide the necessary seal against the stuffing box as well as reduce friction and wear. Usually these are spray metal coated to provide additional hardness and wear resistance. All polished rods are standardized in API Spec 11B and come in various sizes. Standard lengths are between 8-36 ft.

They are solid rods that play a vital role in the operation of a sucker rod pumping system. Having to withstand such high loads and play an important role in the safety of the environment and immediate surrounding area of the pumping unit, the connections to this rod are a key integral aspect. The majority of the failures are not from the rod itself, but occur at the weakest point, the connection to the rod string. Most failures in polished rods are caused by material fatigue due to cyclic loading, usually bending. Bending of the polished rod is unavoidable if the casing head, tubing head, pumping tee, and stuffing box are not on a vertical (5)

Traditionally, the polished rod has pin (male) threaded connections without undercuts on each end. Commonly referred to as a polished rod connection. It is important to note that polished rod threads are different and makeup differently than a sucker rod thread. Polished rod pins do not have the undercut, stress-relieving neck as seen in a sucker rod connection. See below Figure 2 through 5.

There are two different types of couplings used to connect to the sucker rod and polished rod mentioned above. Although they are both box by box connectors, the makeup on a sucker rod connection is different than the makeup on a polished rod connection. Figure 6 shows both types of connections. The polished rod connection on the top, and the sucker rod connection on the bottom.

The Polished Rod Coupling: Polished rod couplings typically have the same box thread size in each end and are used for connecting the polish rod and/or sinker bars with polished rod threads to the sucker rod string (2). The polished rod couplings have a vanish cone angle of 9 degrees in which the taper on the polished rod thread meets up against. This can be seen in Figure 7. A sucker rod coupling cannot be mounted on a polished rod for this reason, as the internal makeup would not allow internal stresses to be achieved for proper pre-tensioning of the threads. However, a polished rod coupling can be used on a sucker rod thread since it will make up properly against the shoulder face.

Sucker Rod Coupling: sucker rod couplings have the same box thread size in each end and are used for connecting sucker rods, and/or pony rods, and/or sinker bars with sucker rod threads. They have a straight thread, the makeup against the sucker rod pin thread shoulder is made up externally against the coupling face. (2) This can be noted in Figure 8.

DIFFERENCES BETWEEN SUCKER ROD AND POLISHED ROD CONNECTION MAKEUP

Recommendations from API contain information pertaining to sucker rod assembly or preloading of sucker rod couplings, also known as make-up. They are based on a circumferential displacement, measured at the shoulder of the sucker rod, while tightening from a hand-tight position.

The sucker rod coupling joint is essentially a bolted joint in tension. The pretension of the threads is necessary to overcome the cyclic stresses that the connection undergoes. The joint should have a preload sufficiently high to prevent separation of the pin and box. (3) See Figure 9.

The make-up of a sucker rod connection covers two primary objectives of preloading the threads:

1. To lock the threaded coupling together so that it will not loosen and eventually uncouple.
2. Improve the fatigue resistance of the threaded connection by reducing the stress in the coupling when subjected to cyclic loading.

The polished rod connection makes up differently than the sucker rod connection. As noted previously, the polished rod threads taper out at 9 degrees and match up with the taper on the coupling. See Figure 10.

The polished rod on most sizes has a small 9-degree surface area to meet up against, which does not create the necessary pretension needed to prevent the thread from backing off or from fatigue stress failure to occur. The makeup forces occur at the tapered 9-degree angle against the polished rod pin thread and box of the coupling. The polished rod coupling does not have as detailed torquing procedures as would a sucker rod connection, and thus there could be large variances in makeup torque on the polished rod connection. Because of the design, the coupling does not have a shoulder designed to face up against and relies on the tapered angle to create enough tension within the connection.

BENEFITS OF A SUCKER ROD CONNECTION ON THE POLISHED ROD

Stronger Connection

As mentioned above regarding details in differences in polished rod connection vs. sucker rod connection, the sucker rod coupling can be made up against the shoulder and can be precisely prestressed, to resist displacement, backing off of threads, and fatigue type related failures.

Shock and impact forces with gas or fluid pounding appeared to be the most frequent failure consideration, because these forces excessively stressed the polished rod connection threads as they absorbed the stresses and impact forces on rod (4) The need for a stronger connection is necessary as it is well studied that movement between threaded members tends to destroy the strength of the connection.

The new, improved polished rod integrates a shoulder surface for the coupling to absorb both static and dynamic forces transmitted along the rod string. This can be done from some manufactures of polished rods with a forged upset end on one end of the rod for a stronger connection, see Figure 11, however this process usually comes with higher costs and longer wait times for material. The design of the polished rod using a threaded connection to create a sucker rod end at one end of the polished rod eliminates the need for a forging process, as well as allowing for greater material selection and coating types for the rod.

Materials

Because the sucker rod end is not done via a forging process, simply a left hand, threaded ring that shoulders up against the polished rod OD, followed by a standardized sucker rod thread, material selection is not an issue, and this design can be implemented on any existing polished rod.

A Canadian operator has been field trialing these polished rods using N50 (XM-19) material which is a grade of stainless steel that have excellent strength, ductility, toughness, and corrosion resistance. The design of creating the sucker rod end is not limited to a small amount of material choices.

Ring Design

Not only does the ring provide a purpose for the coupling to face up against and allow for proper pre-tensioning of the connection, it also serves the purpose of minimizing the possibility of the polished rod from ejecting through the stuffing box, due to downhole pressures and/or dynamic forces. Without the ring, when the polish rod breaks (either at the thread or the polished rod), the polished rod can eject up and through the stuffing box creating both environmental hazards and can create a major safety concern. The ring has a larger OD than the Polished rod, so if there was an event where the rod was to break at the polished rod thread, the ring would stop the polish rod from going through the stuffing box.

Better documentation for makeup:

The sucker rod connection has extensive research into proper coupling makeup to occur the appropriate amount of circumferential displacement. The recommended method of reaching proper displacement involves rotating the sucker rod connection to shoulder, then using a torque card from the manufacture. Vertical marks are drawn on the coupling and the rod connection that will be made up. The operator then moves the line the appropriate distance, ensuring proper torque and pretensioning on the coupling is accurate. This ensures the connection is torqued properly and the connection is not over or under torqued.

With the polished rod coupling, there are not as strict standard operating procedures put in place. With not having as well known or studied standards, and without a shoulder to make up against, this can lead to assembly procedures that do not ensure proper connection.

Same thread throughout SR connection

One additional benefit is that with the design of the sucker rod connection on the polished rod, it eliminates the need for the polished rod coupling. Thus, reducing the need for additional inventory, and reducing the likelihood of mistakenly using a sucker rod coupling on a polished rod, which would lead to premature failure, as proper connection makeup would not be achieved.

DESIGN STAGES OF POLISHED ROD WITH SUCKER ROD END

Historical Product Development – Welded Design

Initial design was to machine down one end of the polished rod. From there a ring would slide over the turned down area and then welded to the OD of the polished rod. Once Welded, the weld area would be turned down to match the OD of the polished rod, then a sucker rod connection would be threaded on, facing off some of the initial ring width to allow for a proper connection. See Figure 12.

Although the weld design was successfully tested for strength, there was a lot of machining processes to go into creating the final product, and control over weld consistency can become an issue. To overcome some of the issues of welding, a new threaded design was proposed.

Current Design – Left-Handed Threaded Ring Design

The threaded ring design allows for more efficient manufacturing, quality control, and more consistent connections between the ring and the polished rod body. See Figure 13.

The ring that is threaded onto the one end of the polished rod to serve as a shoulder for the sucker rod coupling to make up against is a left-handed thread. This serves the purpose of eliminating any possibility of the ring backing off when the sucker rod coupling is removed. The ring is made up tight during assembly and the threads have red Loctite applied to ensure continuity of the assembly during storage and handling.

The width of the ring ensures a strong shear strength to hold the rod in place if there were to be a break at the coupling/pin thread. Calculations of thread shear strength greatly overcome the strength of the material at around 75,000 lbs. with a built-in factor of safety, thus ensuring the ring will not fail and will be contained at the stuffing box, having benefits for both the environment and safety.

CONCLUSION

Traditional polished rod connections have limitations that can affect the reliability of sucker-rod pumping systems. Analysis of the shortcomings of conventional polished rod connections can be overcome by the implementation of an innovative yet simple design modification in the form of a modified polished rod with a sucker rod end.

The integration of a sucker rod end onto the polished rod not only addresses inherent weaknesses in the conventional connection but also offers a range of substantial benefits. By incorporating a shoulder surface for the coupling to interact with, our design enhances the connection's ability to withstand static and dynamic forces, consequently mitigating the risk of failures attributed to shock and impact forces. The utilization of standardized sucker rod threads eliminates the need for forging processes, allowing for material selection flexibility, and reducing manufacturing costs and lead times.

The left-handed threaded ring design ensures a secure connection while offering ease of assembly and manufacturing. Its incorporation significantly improves the reliability and durability of the connection and prevents the polished rod from ejecting through the stuffing box, thus enhancing operational safety and environmental protection. Additionally, the standardized makeup procedures associated with sucker rod connections provide better documentation and operational consistency, minimizing the likelihood of assembly errors and premature failures.

FIGURES

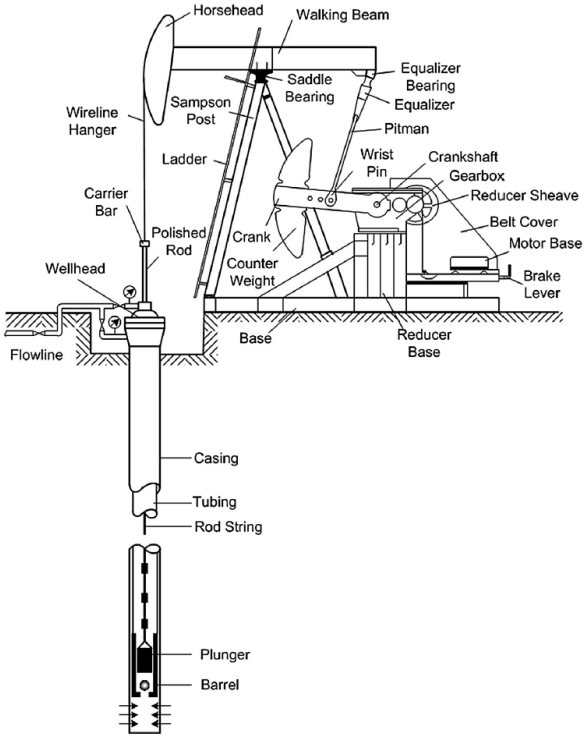


Figure 1 Basic Components of the Sucker Rod Pumping System (5)

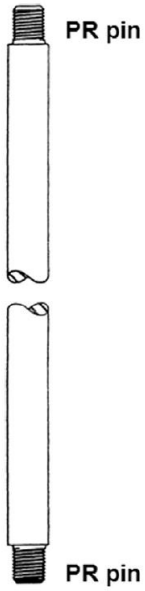


Figure 2 Polished Rod Pin Connection (5)

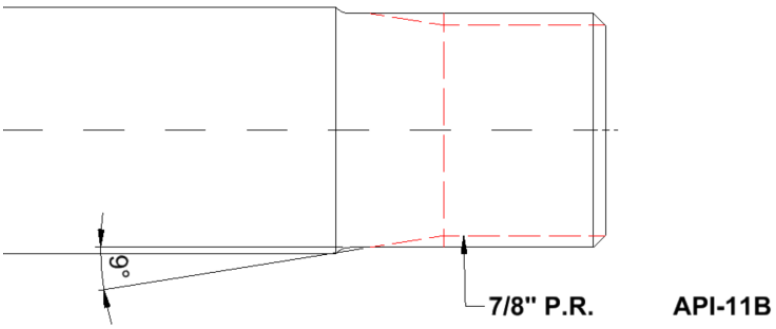
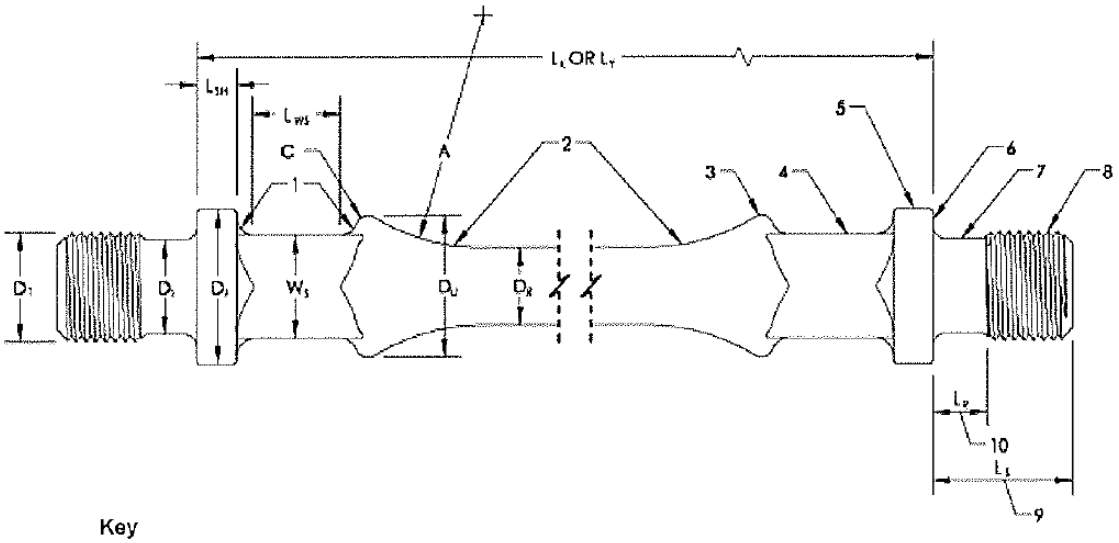


Figure 3 Sketch of Polished Rod Pin Thread



Key

1	Shape of transition optional	6	face
2	sucker rod body	7	stress relief
3	upset bead	8	thread (same each end)
4	wrench square	9	pin length
5	pin shoulder	10	stress relief length

Figure 4 Steel Sucker Rod Illustration (2)

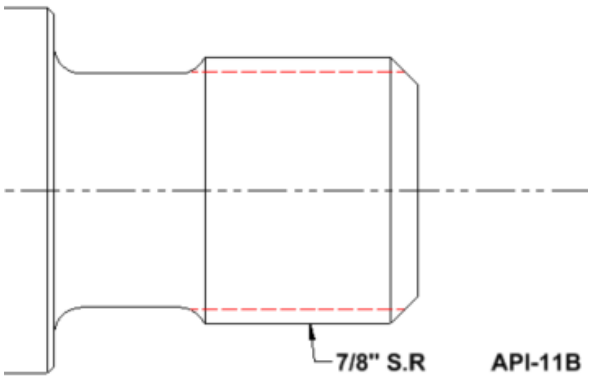


Figure 5 Sketch of Sucker Rod Pin Thread

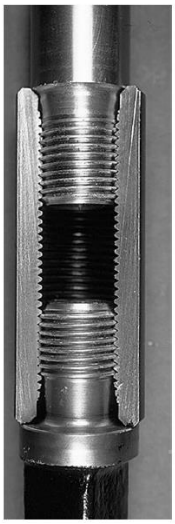


Figure 6 Polished Rod Connection (Top) Sucker Rod Connection (Bottom) (5)

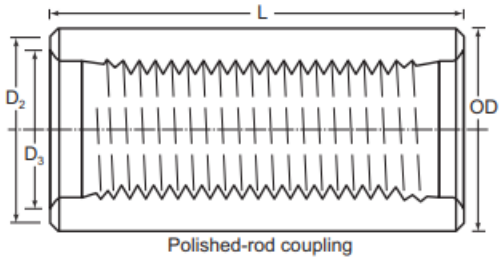


Figure 7 Sketch of Polished Rod Coupling (5)

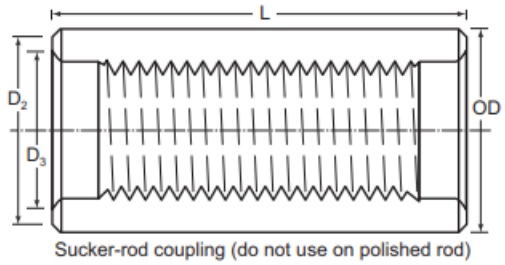


Figure 7 Sketch of Sucker Rod Coupling (5)

Table 1: API Sucker Rod Joint Make-up Recommendations

Rod Size (in)	Pin Shoulder OD (in)	Minimum Circumferential Displacement (in)	Calculated axial displacement or interference (in)
3/4	1.500	7/32	4.64×10^{-3}
7/8	1.625	9/32	5.51×10^{-3}
1	2.000	12/32	5.97×10^{-3}

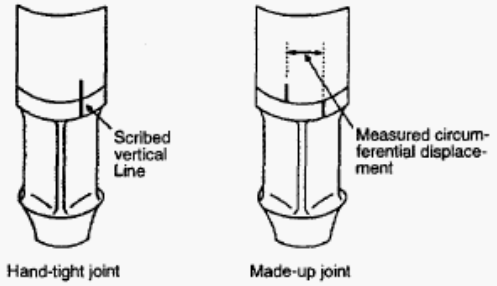


Figure 8 API Sucker Rod Joint Makeup Recommendations – Circumferential Displacement (3)

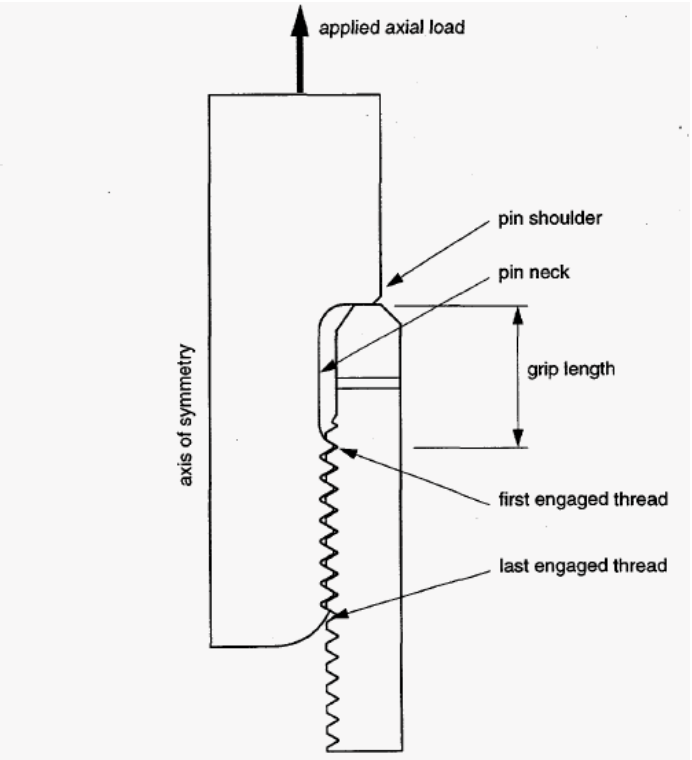
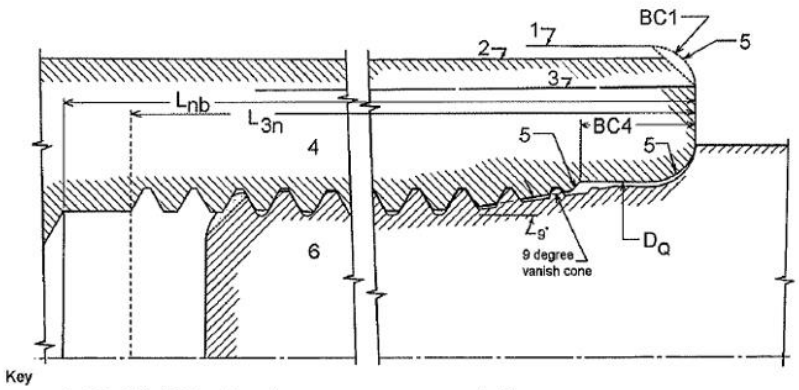


Figure 9 Sucker Rod Pin/Box Connection (3)



Key

1 OD of 1 in. (25.4 mm) coupling
2 OD of 5/8 in. (15.9 mm), 3/4 in. (19.1 mm), 7/8 in. (22.2 mm), and 1 1/8 in. (28.6 mm) coupling
3 OD of slim hole coupling
4 Box
5 Shape optional with manufacturer
6 Pin

NOTE For dimensional purposes only, not intended to show physical make-up.

Figure 10 Polished Rod Coupling Illustration (2)

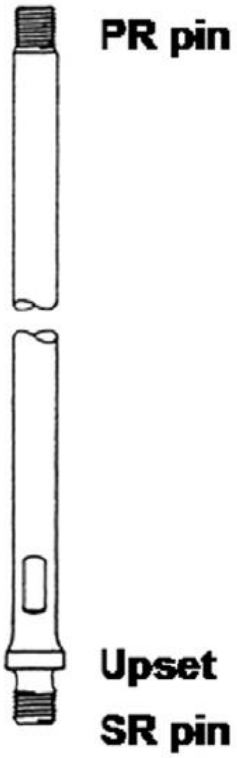


Figure 11 Polished Rod with Forged Upset Sucker Rod Pin End (5)

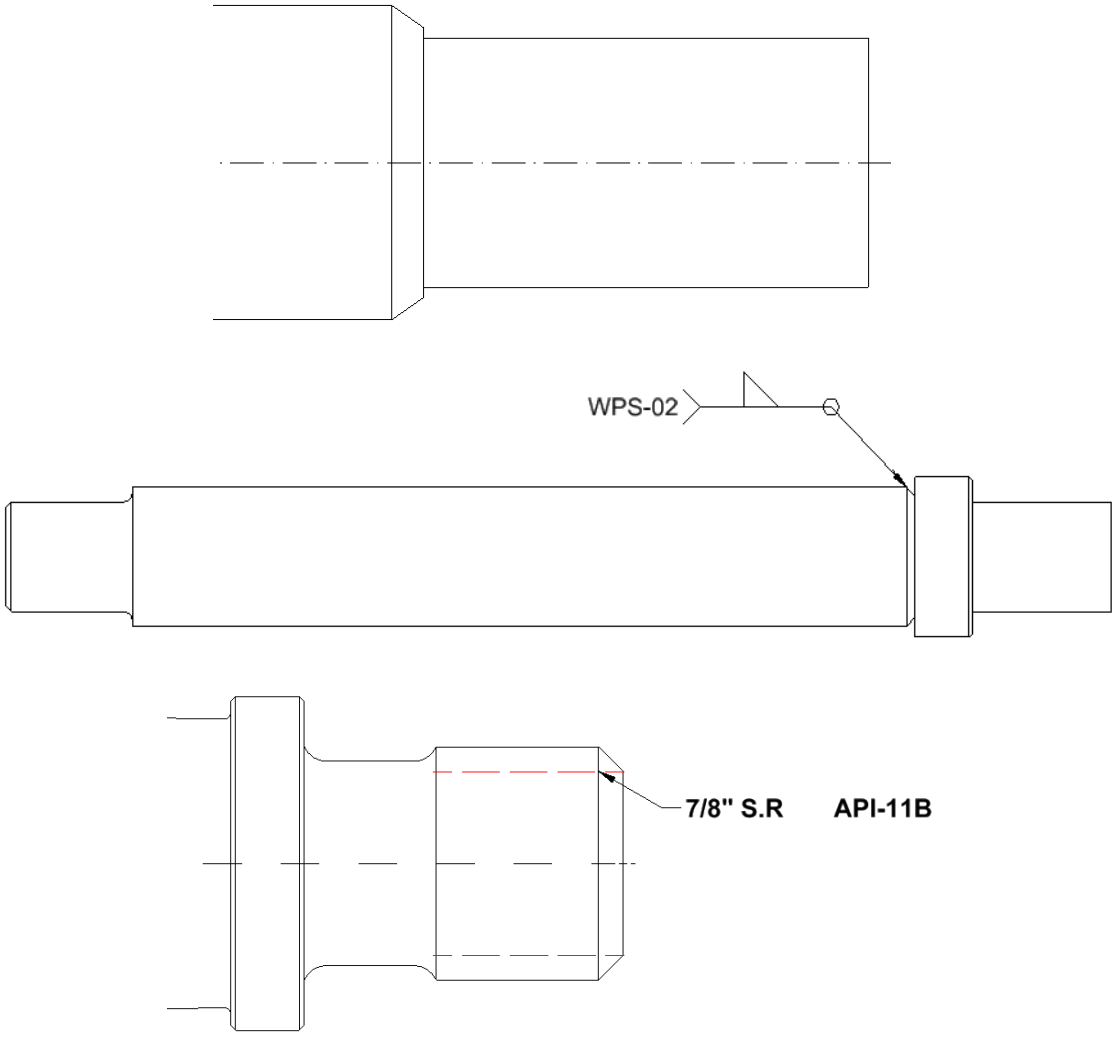


Figure 12 Design of Welded Sucker Rod End on Polished Rod

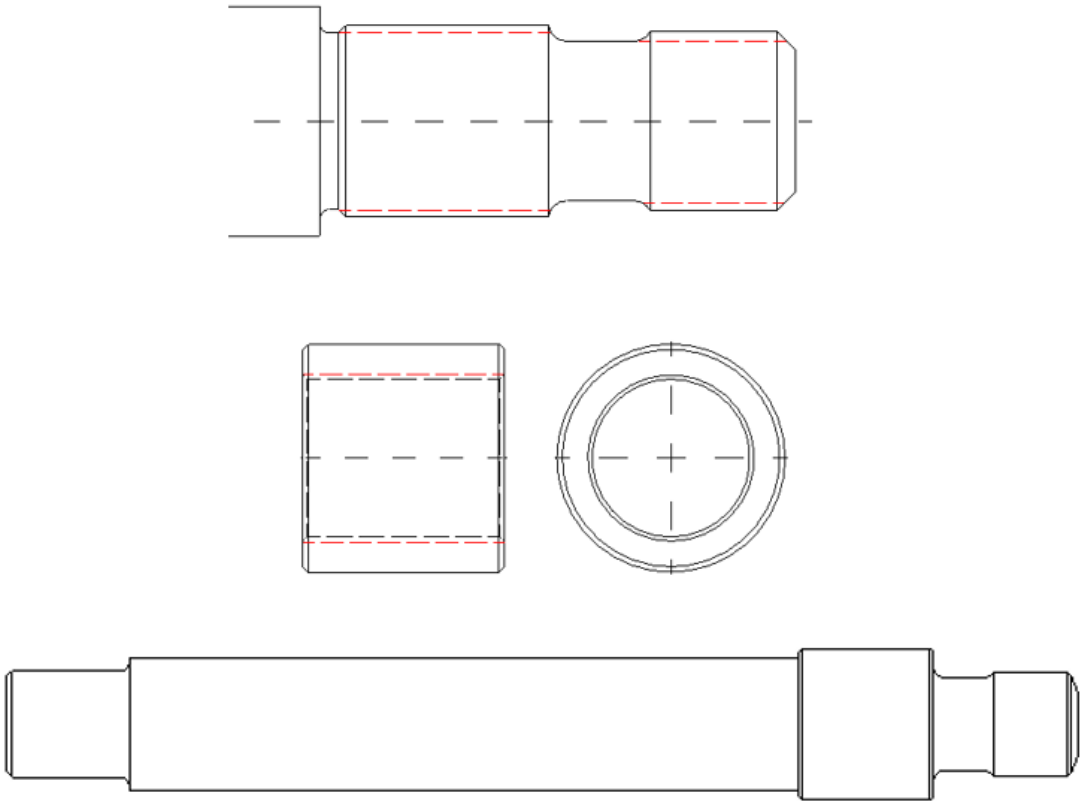


Figure 13 Design of LH Threaded Ring Sucker Rod End on Polished Rod

REFERENCES

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2. API 11B, 27th Edition, “Specification for Sucker Rods, Polished Rods and liners, Couplings, Sinker Bars, Polished Rod Clamps, Stuffing Boxes, and Pumping Tees”.

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4. Jul 12, 2006 (no date) Connectable rod system for driving downhole pumps for oil field installations, Justia. Available at: https://patents.justia.com/patent/7596847 (Accessed: 25 March 2024).

5. Takacs, G. (2015) ‘Introduction to sucker-rod pumping’, Sucker-Rod Pumping Handbook, pp. 1–12. doi:10.1016/b978-0-12-417204-3.00001-7.