NEW DESIGN API MODIFIED SUCKER ROD CONNECTION AND METHODS AND SYSTEMS FOR PRECISE CONNECTION MAKE-UP - [2005 UPDATE]

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ABSTRACT

At the 50th Annual Southwestern Short Course, a paper was presented titled "New Design API Modified Sucker Rod Connection and Methods and Systems for Precise Sucker Rod Connection Makeup". This paper is an information update of continuing development and field applications of the four-part API Modified connection system in PCP and beam pumping wells. The paper also includes a study of in plant single end coupling make ups on the three part standard API couplings employing the "Precision Coupling Makeup System" where volumes of used inspected number one class sucker rods of all sizes and grades were returned to field service. The study also contains an analysis of the mechanical and economical benefits of receiving the rods at the rig site with the couplings properly made up on one end and performing a single end make up with the rod tongs at the work over rig, as opposed to the standard practice of the "floating coupling" or double end make up.

INTRODUCTION

After concluding the 3 ½ years of basic research and development and extensive laboratory testing as described and presented at the 50th annual "Southwestern Short Course" in the above named paper it was time to field test the design as developed up to that point. It is clearly understood that no matter how much work is done, funds expended, or time consumed, nothing can completely and accurately duplicate the many and varied downhole conditions in laboratory settings. Producers were contacted and requests were made, would it be possible to test the PRO-KC API Modified 4 part connection system, [see Figure 1] in one or more of their wells? More specifically could the well or wells chosen be those with the highest failure rates and most severe load and operating conditions.

FIRST BEAM PUMP TESTS – TWO (2) WELLS – PRO-KC CONNECTION

235 Inspected used number one class 1in. high strength rods and 500 7/8 in. inspected used number one high strength rods, two sets of ponies and a like number of new "T" class couplings were machined to PRO-KC specifications for a large independent oil company to run in two 9000 ft wells on a "new product test basis". The couplings were made up on the rods and ponies to PRO-KC "Precision Neck Stretch" specifications using the PRO-KC sucker rod coupling precision makeup machine and the coupling center torque buttons installed. The rod strings were run in new drills approximately six weeks apart, which were drilled to about 8000 ft. vertically and kicked off to 87 degrees reaching a final drilled footage of approximately 15,000 ft. and cased to 9500 ft. The pumps were set around the radius in the horizontal. The beam pump units were American 1280's with 216 in. strokes at 10 per minute, 2 in. plungers, 42,000+ lbs. peak polish rod loads. Over a period of 5 to 6 months there were no problems, however beyond this time period there were three 7/8 in. pin off failures [see Figure 2] in a short amount of time and both rod strings were pulled and standard API couplings installed. After determining the failure modes, corrective changes were made and the connection design modified. [Note] The deteriorating effects of prior work cycles from a fatigue stand point tend to concentrate in the end areas of the sucker rods where radical cross section variances accelerate this deterioration process. The application of used rods in very high load operating conditions always contains the risk of early fatigue failure. When the work history of a rod string is unknown or confirms it has been worked very hard for log time periods new rods should be run.

FIRST PCP FIELD TEST – PRO-KC CONNECTION

160 inspected used number one class 1in. high strength rods, 1 set of used ponies and new "T" class couplings were machined to PRO-KC specifications for a major oil company to run in a New Mexico 3900 ft. deep well. The couplings were made up on the rods and ponies to PRO-KC "Precision Neck Stretch" specifications using the PRO-KC sucker rod coupling precision makeup machine and coupling center torque buttons installed. This well had been pulled 15 times in a 38 month period for rod connection failures consisting of pins offs at the shoulder radius, pin offs at the stress relief thread scratch off area, and thread shear outs, all failures were sucker rod connection related. The rods with PRO-KC connections were run in this well and performed flawlessly for 13 ½ months enduring the 5 failures listed below:

1. The pin on the top drive hex shaft twisted off.
2. The polish rod pin threads sheared off.
3. Pump locked up and burned the v-belts in half.
4. Split the polish rod coupling wide open.
5. Twisted off the stator to 3 ½ tubing swedge.

The PRO-KC connections endured the above events with no failures or visible damage and at the 13½ month mark the string was pulled and the well re-completed with an ESP in order to move a much higher volume of fluid. The rod string was visibly inspected and junked for severe corrosion damage due to the lack of a proper chemical program. [Note] During each trip out and when the string was laid down 50 % of the pin ends were measured with depth micrometers and confirmed to be at the original machined shoulder to pin end and coupling edge to torque button tolerances and operating well within the elastic range of the material.

SECOND PCP FIELD TEST – PRO-KC CONNECTION

This well was the first opportunity to test the PRO-KC connection system on a new string of rods for the same major oil company as above in New Mexico. This string was run on the same lease with the same problems at the same depth, 3900 ft. as the first PCP test well. In order that some spares and replacement rods could be in inventory, 175 new high strength 1 in. rods were machined to PRO-KC specifications, along with one set of new ponies and a like number of new "T" class slim hole couplings. The couplings were made up on to the rods and ponies to PRO-KC "Precision Neck Stretch" specifications using the PRO-KC precision make up machine and coupling center torque buttons installed. This rod string was installed during the merger of two major oil companies resulting in several movements of persons responsible. After many attempts to obtain a prior failure history it seems the well records have been misplaced and no information has come to light. The pump is 30 ft. long, the rpm and torque that it is running is unknown, however, it has been running continuously for 2 years and 4 months with zero problems.

THIRD BEAM PUMP TEST – PRO-KC CONNECTION

365 inspected used number one class rods of which 115 were 1 in. high strength, 250 were 7/8 in. high strength, 10 - 1½ in. weight bars, and one set of ponies were machined to PRO-KC specifications. 1 in. "T" class slim hole and 7/8 in. full size couplings were machined and made up on the rods and weight bars to PRO-KC "precision neck stretch" using the PRO-KC sucker rod precision make up machine and the coupling center torque buttons installed. 8975 ft. of this material was run into a well for a large independent oil company. The beam pump unit is a 1280, the pump has a 1 3/4in. plunger and 216 in. stroke at 8 strokes per minute, with a peak polish rod load of 42,000+ lbs. This well has been a problem since drilled having to be pulled every 4 to 6 weeks for connection failures. After the PRO-KC connection was run it pumped 153 days or 5.1 months and the polish rod coupling split open and the string was dropped. After picking up the string and replacing the polish rod, the well pumped 56 days and a 7/8in. pin failed 10 rods below the 1in. with the remainder of the string being dropped again. The well pumped 41 days and a 1.0 in. coupling failed at the center area. This was discussed with the person responsible who was not on the site when repairs were made and could not furnish detailed failure information, however ½ of this broken coupling was returned and its failure analyzed. [see Figure 3] It has been agreed by all involved that parting the polish rod coupling and dropping the string has been a contributing factor to the rod connection failures. In November of 2004 a 36 ft. long 1 ½ in. polish rod modified to PRO-KC shouldered specifications was installed. In late December 2004 the rod string parted again but has not been pulled due to the remote mountain location and very bad weather conditions making it impossible to get a work over rig on location. First week January, 2005 the principals involved met and the well performance analyzed bringing to light several problems, the worst of which was the pump off controller which had been allowing an inordinate amount of pump off fluid pounding. Steps have been taken to resolve the problems and at this writing a new rod string as stated above is being prepared with PRO-KC Connections and will be run in this well as soon as weather permits.

FOURTH BEAM PUMP TEST – PRO-KC CONNECTION

100 1 in. – 100 7/8 in. – 100 ¾ in. - 30 ft. long, used number one rods, one set of ponies, and a like number of couplings were machined and prepared to PRO-KC specifications, one 1 ½ in. 30 ft. long polish rod modified to PRO-KC specifications consisting of the addition of a shoulder and a standard 1 in. sucker rod connection. 1 in. "T" class slim hole couplings and 7/8 in. and ¾ in. full size couplings were machined to PRO-KC specifications and were made up on the rods to PRO-KC "Precision Neck Stretch" using the PRO-KC precision make up machine and the coupling center torque buttons installed. This string was run on December 20th. 2004 for a major oil company combine in California.

LIST OF CONNECTION FAILURES

The failures incurred on the PCP test wells are explained in the sections above and no sucker rod connections were involved. The beam pump failures are as listed below:

One (1) – 1 ½ in. polish rod – coupling split axially.
One (1) – 1 in. sucker rod coupling – parted at the coupling center – slight wear and O.D. mechanical damage.
Four (4) – 7/8 in. sucker rod pins – three were typical pin off at the last engaged thread next to the stress relief neck. One (1) was a shoulder radius failure.
Zero (0) – ¾ in. connection failures.
Zero (0) – ¾ in. or 7/8 in. weight bar connection failures.

DISCUSSION OF FAILURES

Polish rod pin ends – three standard API polish rod connections have failed, two on the same PCP unit, the first failure being pin thread shear off and the second failure being a full length axial coupling split. One standard API polish rod connection on a beam pump unit failed, again a full length axial split of the coupling. The API standard polish rod pin end and coupling design is more than sufficient to handle axial and torsion loads within the Goodman diagram but when these design parameters are exceeded as they often are in the present artificial lift environment, failures will occur. The PCP failures appeared to be a simple case of the rod strings being run at near maximum torque and rpm and then subjected to intermittent torque spikes. Since the polish rod pin thread does not have a shoulder, a 9 degree taper, reduced thread height, scratch off area has been designed in. This creates a radial thread taper interference in the 9 degree cone area of the pin and coupling and provides a sufficient friction area to resist further make up advancement and also resist a nominal amount of back torque under normal loads and operating conditions. However, when very high torsion loads combined with torque spikes are encountered, the polish rod pin can be rotated deeper down the thread helix causing the 9 degree taper area on the pin to swell the coupling end until the threads shear or the coupling splits.

The failure mode for beam pump polish rods is exactly the same as PCP pumps, thread shear or axial coupling split, the causes however are unique to the loads and forces created by beam pump reciprocation. Very high loading with the lack of a shoulder combined with the shock and impact of pounding be it fluid, gas, or controller pound must be handled solely within the threaded region of the polish rod pin and coupling end. These loads and forces tend to swage the coupling end outwardly due to the cam effect of the 30 degree flank angles and 9 degree thread scratch off area of the pin resulting in thread shear or coupling split.

Sucker rod connections – four (4) 7/8 in. pin off failures have occurred and three were typical first thread adjacent to the stress relief neck where the cracks initiated in the last scratch thread area and propagated through the cross section. The fourth pin parted in the shoulder to stress relief neck radius and all four pin failures were on beam pump applications where the alternating loads were between 30,600 lbs. and 33,200 lbs. combined with very long strokes, high stroke rates and all the rods involved were used inspected number one class.

PRO-KC PRECISION COUPLING MAKEUP SYSTEM - STANDARD API COUPLINGS [see FIGURE 4]

Approximately 70% of all pin ends inspected have evidence of pin "GAPPING" which is caused by insufficient connection make up. As each sucker rod is made up at ground level, atmospheric pressure is sealed in the connection between each coupling end and pin shoulder. When run in the hole with less than the necessary pin pre-load neck stretch the operating loads will lower the pin shoulder to coupling end contact pressure and fluid will implode into the coupling. "GAPPING" is confirmed when the connections are backed out as the string is pulled out of the well and emit a spitting sound along with the expulsion of a mixture of thread lube and produced fluids. The presence of fluid in connections manifests itself by staining the smooth surface of the pin neck a dark brown or black and indicates the start of the corrosion process. After the sucker rods are inspected and classified, Permian Rod Operations makes up the coupling onto the rods using the "Precision Neck Stretch" method that was developed during the R &D and testing phase of the PRO-KC Connection System. This insures proper pin end pre-stress and coupling end to pin shoulder contact force is established in order that pin shoulder to coupling end "GAPPING" will be eliminated when operating loads are applied. This make up method has been preformed on 40,175 rods over the last 20 months for 18 major and independent oil companies in the Permian Basin with no reported pin failures of any size or grade that have been made up with the "Precision Neck Stretch" method. However, this brought to the forefront problems of proper make up at the rig site. New and inspected used rods are typically delivered to the well site with the couplings boxed separately and a double end make up performed where the coupling is started by hand on the first pin and the second pin stabbed into the coupling. The rod tong is then positioned with the gripping jaws on the top wrench flat and the backup wrench on the bottom wrench flat with the coupling between the two and made up power tight. This method is also known as the floating coupling or double end make up. The problem with the double end make up is that the applied torque is never evenly distributed 50% and 50% to each pin thread and shoulder end, and it is impossible to determine the exact amount of torque in each thread helix or the exact amount of contact force between each pin shoulder and coupling end. When sucker rod strings are pulled, one pin end breaks free and the other remains absolutely tight, confirming that the net input torque into any given connection is very unevenly divided between the two pin end threaded sections and therefore the result is vast differences of pin pre-stress and pin shoulder to coupling end contact force. The investigation to establish a more consistent field end make up continues, however, it has been determined that when rod strings are run in the wells with the coupling made up on the first pin end to the "Precision Neck Stretch" method, many of the problems of the double end make up are reduced in severity or eliminated. The benefits of the single end make up are as follows; reduces by approximately one half the friction of the thread helix load flank intimate contact area and pin shoulder to coupling end contact area. Having the torque generated at the rig by the rod tongs applied to one pin end greatly increases the opportunity to establish some degree of pin pre-stress load and pin shoulder to coupling end contact force that will greatly increase the working life of the sucker rod connections when subjected to the tension, torsion, or reciprocating loads of modern pumping designs.

CONCLUSIONS

First a sincere thank you to the companies and individuals in those companies that enabled testing to take place under real world conditions. The information derived completed the design, care & handling, and running procedures including make up with existing rod tong equipment.

The PRO-KC Connection System combined with the PRO-KC Precision Make Up System have performed to design expectations in the above down hole tests by extending the working life of the sucker rod connections under very severe conditions. However, the tests are considered preliminary as all rod strings but two were used sucker rods with unknown prior work histories and subject to some degree of fatigue cycle deterioration. At this writing the third new string is being machined and prepared with PRO-KC Connections for a beam pump well with several other new strings arranged for and will be run in the near future for both beam and PCP pump applications.

The PRO-KC Precision Make Up System for Standard API sucker rods has been an extremely valuable information gathering tool. The in plant precision neck stretch make up of 40,000+ couplings has allowed the observation of the torque required to accomplish proper linear pin displacement pre-stress and pin shoulder to coupling end contact force for all sizes and grades up to 1in. on the first one half of the connections. These make up samples have created a torque information data base that can be implemented into the rig make up equipment and procedures insuring a more consistent and accurate second side or field end connection make up. The long term economic benefits of a proper single end make up at the rig site are, establishing the proper pin pre-load and shoulder contact force which greatly increases fatigue life of the connection, the elimination of connection gapping and the damage due to corrosive produced fluid intrusion. The immediate economic benefit is the average savings of three hours running time on 7500 ft. rod strings because the couplings are properly made up on the rods which eliminate thread cleaning, application of new thread lube, and handling all the couplings, the rods are picked up, made up, and run in the hole without interruption.

The systems, methods, and procedures described in this paper have created economic benefits where applied, and Permian Rod Operations and this author are dedicated to a continuing effort to increase the level of performance and economic benefits of Standard API and PRO-KC Modified API sucker rod connections to the industry.

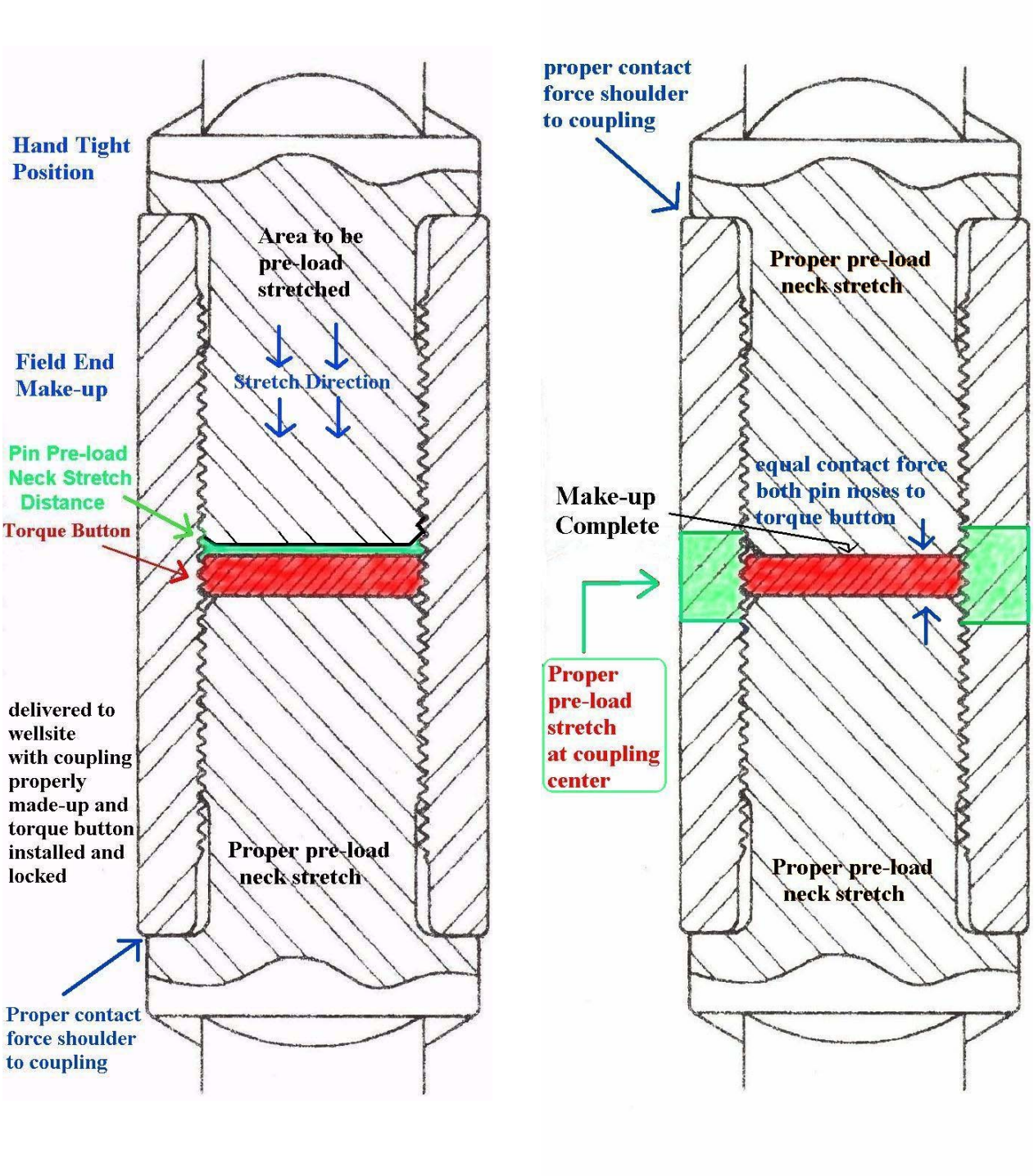

Hand Tight Position
Area to be pre-load stretched
Stretch Direction
Field End Make-up
Pin Pre-load Neck Stretch Distance
Torque Button
delivered to wellsite with coupling properly made-up and torque button installed and locked
Proper pre-load neck stretch
Proper contact force shoulder to coupling
proper contact force shoulder to coupling
Proper pre-load neck stretch
equal contact force both pin noses to torque button
Make-up Complete
Proper pre-load stretch at coupling center
Proper pre-load neck stretch

Figure 1

Figure 2

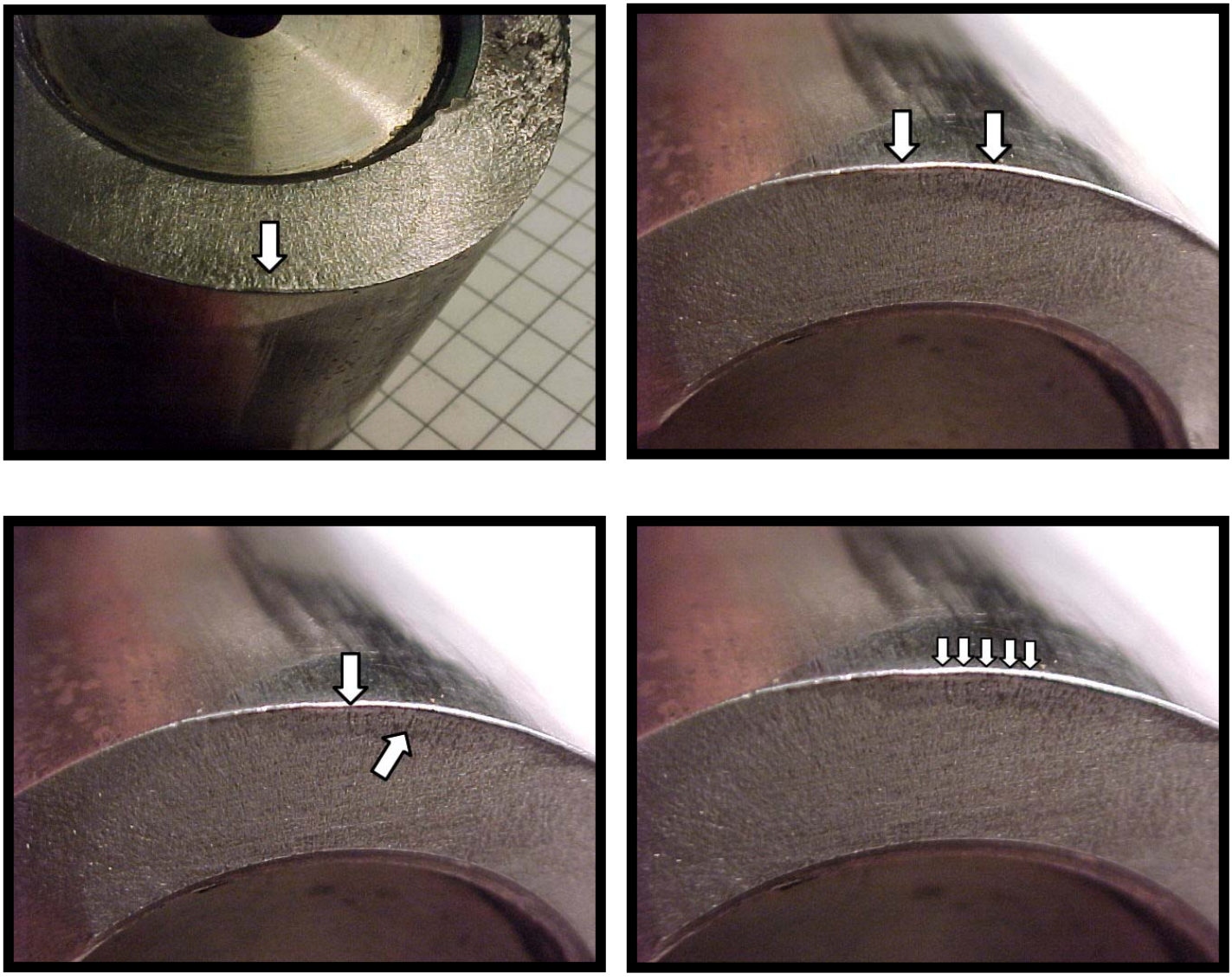
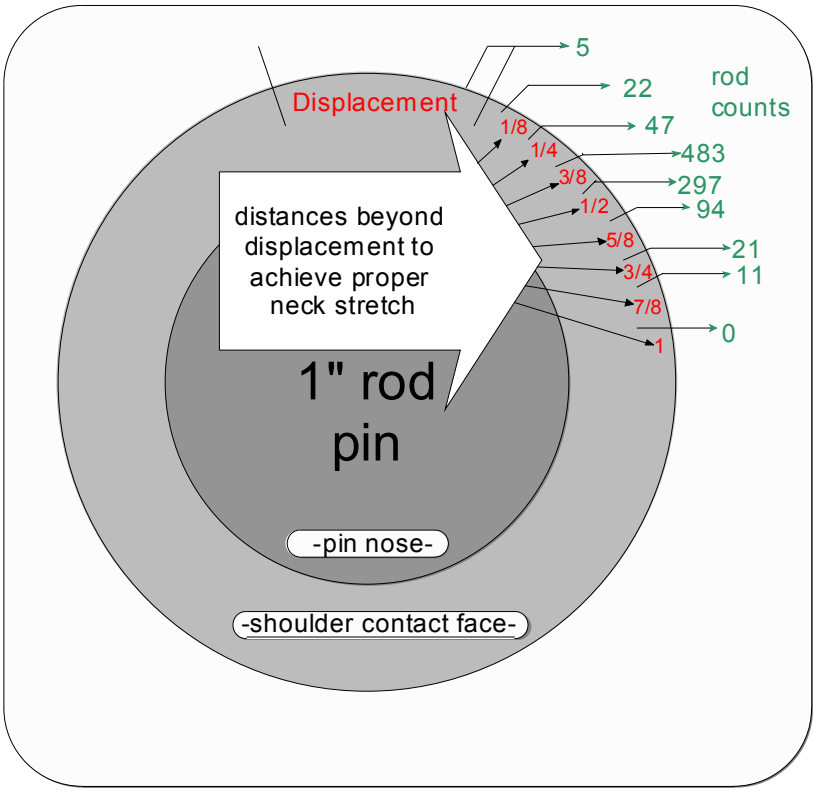


Figure 3


Displacement
rod counts
5
22
47
483
297
94
21
11
0
1/8
1/4
3/8
1/2
5/8
3/4
7/8
1
distances beyond displacement to achieve proper neck stretch
1" rod pin
-pin nose-
-shoulder contact face-

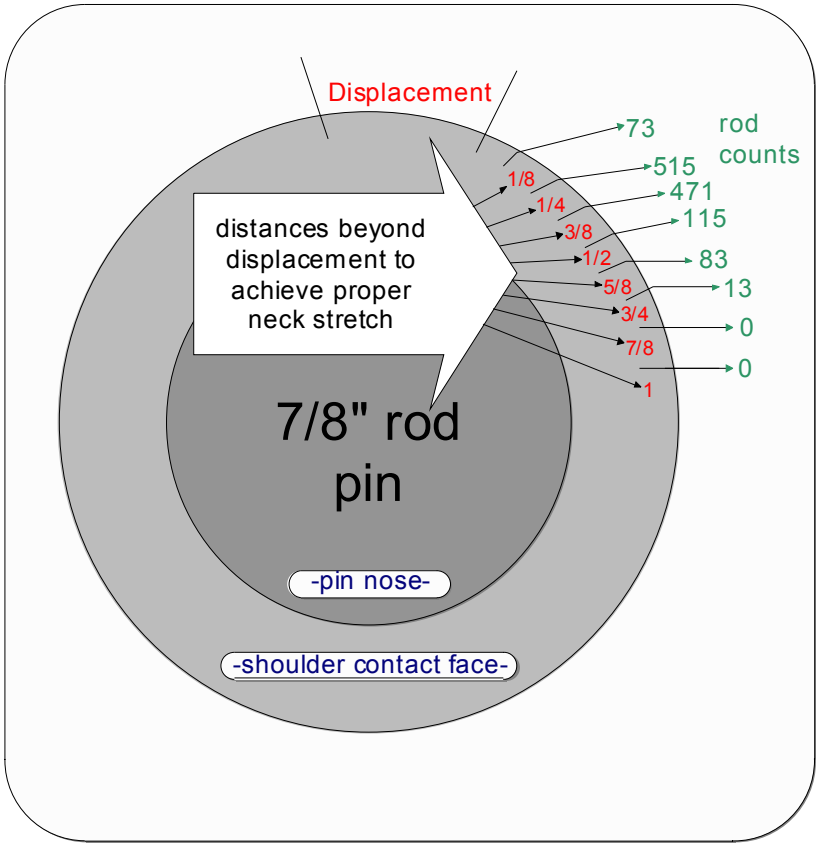

Displacement
rod counts
73
515
471
115
83
13
0
0
1/8
1/4
3/8
1/2
5/8
3/4
7/8
1
distances beyond displacement to achieve proper neck stretch
7/8" rod pin
-pin nose-
-shoulder contact face-

Figure 4