Honeywell

Gundrilling Oil Evaluation to Find a Replacement for 50-50

Federal Manufacturing & Technologies

Karl Arnold

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Final Report

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K. F. Arnold, Project Leader

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Abstract

In 2006 the gundrilling oil used at Honeywell FM&T (Federal Manufacturing and Technology) was known as 50-50. This name was selected because the oil is a mixture of two machining oils, Milpro 634 and Pennex N47. Unfortunately, Honeywell FM&T was notified that one component, Pennex N47, would be discontinued by the manufacturer. At this point the Honeywell FM&T team decided to select a single oil to eliminate mixing and procurement of two products. In addition, the team also wanted to select new oil with lower viscosity than the 50-50 mixture. Lower (than 50-50) viscosity oil was recommended by Nagel the manufacturer of the new TBT gundrilling machines. To this end Honeywell FM&T evaluated seven cutting oils in order to select a substitute that would achieve acceptable gundrilling results. This work resulted in the selection of Castrol Ilocut 334 based on cutting performance and human factors. The Castrol oil can easily achieve up to 8 holes per drill at a feed rate 30% greater than that achieved by the 50-50 oil. Once design agency approval is received, this oil will be installed as the drilling oil for all FM&T stems. This oil will also be used for other reservoir machining operations where appropriate.

Summary

In mid 2006 Honeywell FM&T discovered that the supplier of half of the 50-50 drilling oil mixture had discontinued the product, Pennex N47. The 50-50 oil has been in use for reservoir gundrilling activities since the early 2000's. Given the criticality of the quality of the stem bores that were to be pinch welded, Honeywell FM&T undertook a project to select a new cutting oil to replace the existing 50-50 oil. The approach was to first get approval for a transition plan from LANL and SNL/CA. The Gundrilling Oil Transition Plan is contained in Appendix A of this document. Based on the approved transition plan, Honeywell FM&T evaluated and tested 7 drilling oils. As a result of this activity Honeywell FM&T selected oil that performs at least as well as the 50-50 oil in cutting tests. The new oil also has a lower viscosity which is known to improve removal of chips from the cutting area. Chip removal is critical for gundrilling.

This activity was a detailed experiment involving development of baseline gundrilling wear for 50-50 oil on all three pertinent stainless steel alloys, 304L, 316 and 21-6-9. This baseline data was utilized to compare the results of drilling tests on the four oils selected for this testing. This experiment allowed Honeywell FM&T to select the cutting oil best suited for gundrilling 0.0625 inch diameter stem bores in the three key stainless steel alloys.

After the oil was selected based on drilling performance, Honeywell FM&T then selected the feed rate for the new oil on the Nagel TBT[1] twin spindle gundrills installed in Honeywell department. Validation was carried out at 0.8 in/min (inches per minute), a 60% increase over the rate currently used in WR production, 0.5 in/min. For validation the team drilled 21-6-9 and 304L bar stock for five holes per drill. This aggressive rate was selected to push out the envelope of drilling rate to the point where the team could select a lower rate for WR production and be confident of consistently drilling 5 holes per drill without drill breakage. As a result of

[1] The TBT Tiefbohrtechnik twin spindle gundrill is manufactured by Nagel Precision Inc. and is known as the TBT gundrill. The TBT gundrilling machines were installed in another department.

this activity a feed of 0.65 in/min was selected to conservatively reduce the risk of drill breakage when drilling WR production components.

After validation and selection of the drilling rate, test stems for the pinch weld evaluation were manufactured. Results of the pinch weld activity at SRNL are described in References 1 and 2.

Discussion

Background

This report covers the activities undertaken to provide replacement oil for the recently discontinued 50-50 mixture that has been in use at Honeywell FM&T to gundrill reservoirs since the early 2000's. The switch to the 50-50 oil was made with great deliberation and much study. In the early 2000's the gundrilling oil was changed from the Regal 32 to the 50-50 oil currently in use. A diagram of a gundrill (tool) is included in Figure 1.

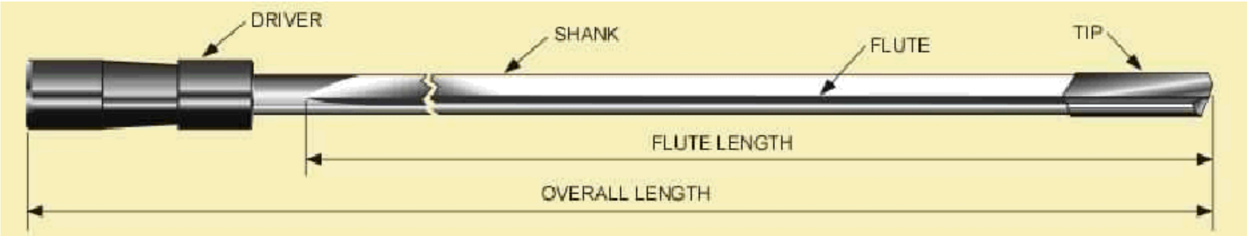

Figure 1. Diagram of an example gundrill. [2]

The 50-50 oil had been in use at Honeywell FM&T for gundrilling and general machining since the 70's. The 50-50 oil was so named because it is a mixture of two commercially available machining oils blended by Honeywell FM&T. One component of the 50-50 mixture, Milpro 634 contained chlorine, while the other component, Pennex N47, contained sulfur. Sulfur and chlorine are extreme pressure (EP) additives that improve the chip formation characteristics of the work piece material. Honeywell FM&T procured two new TBT twin spindle gundrills, manufactured by Nagel Precision Inc. and installed them in department. The old Eldorado gundrills, that had been used previously, were removed.

The stem is a critical component of the Gas Transfer System (GTS). The stem bore surface morphology must be adequate to provide an acceptable pinch weld. The pinch weld is the last barrier to leakage of tritium after filling and during the service life of the GTS components. Unlike other GTS welds, the pinch weld cannot be proof tested. Consequently there is great concern in the Nuclear Weapons Complex (NWC) with the quality of the stem bore and what effect variations in stem bore processing may have on the subsequent pinch weld.

The activities described in this report were described by the Gundrill Oil Transition Plan. This test plan was utilized to gain agreement from the design agencies on the activities that were desired to show the newly selected oil would not adversely impact the pinch welding process. This plan is contained in Appendix A.

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[2] The drill represented here is slightly different than the Honeywell FM&T drill, which is solid carbide while this pictorial represents a steel shank with a carbide tip.

Scope and Purpose

This work supports all gundrilling activities for GTS manufacturing at Honeywell FM&T. Gundrilling is required for virtually all GTS final assemblies.

The goal of this project was to select the replacement for the 50-50 oil currently in use for gundrilling. The approach was to drill representative bar stock and forgings to determine the performance of a selected group of oils on the gundrilling process. The initial group of seven oils was reduced by applying tests for human factors and physical properties (target chemistry [EP's], target viscosity and material compatibility factors).

Activity

This study has eight major activities. First, develop baseline drill wear for the three stainless alloys for the 50-50 drilling oil at the current WR drilling rates. Second, provide test stems drilled with 50-50 oil at current WR drilling rates to SRNL to develop an appropriate pinch welding schedule for 21-6-9 and 316 alloys. Third, select a group of cutting oils that are generally recommended for gundrilling operations. Fourth, evaluate the initial group of oils for human factors. Fifth, perform process material evaluation to determine material compatibility of oils that passed the human factor test. Sixth, perform tool life testing on the department gundrill to determine the best oil. Seventh, validate test results from the department gundrill on the department TBT gundrill while increasing the drilling rate and then section units for surface topography. Eight, produce test stems of three stainless alloys, drilled with the newly selected oil, for pinch weld evaluation at SRNL.

Develop Baseline Tool Life Data for 50-50 Oil

A baseline drill life experiment was developed to evaluate the drill wear performance of the 50-50 oil on forgings (21-6-9 & 304L) at the current production drilling rates of 0.5 in/min and 11000 rpm (revolutions per minute). This experiment was required for us to select oil that performed at least as well as the 50-50 oil in terms of drill wear while drilling multiple holes per drill. Drill life testing was performed on a 2 axis gundrill in Honeywell FM&T's department. The 2 axis drill was selected in order to minimize the number of forgings that would be required to evaluate drill life. The 2 axis drill can drill up to 9 holes per forging (as shown in Figure 5) as opposed to the one hole per forging on the department TBT gundrills. However, the department drill does not have a counter rotating spindle and the drill speed is limited to a maximum of 10,000 rpm. The department gundrill is the machine on which all previous oil evaluation and drill life tests were performed. Oil performance was determined by drill wear rate.

Develop Baseline Pinch Weld Schedule for 50-50 Drilled Stems at SRNL

In addition to drilling evaluation, Honeywell FM&T customers (LANL & SNL/CA) requested units of each work piece material (304L, 316, & 21-6-9) for pinch welding at SRNL. This was to verify that the new oil does not create any unusual problems with the pinch weld. In order to perform the pinch weld study at SRNL a baseline pinch weld schedule had to be established for 21-6-9 and 316 alloys. A baseline had been developed for the 304L alloy as a result of the Stem Team Activities in an earlier project. As a result of this assignment, Honeywell FM&T built and delivered 24 test stems drilled with the 50-50 oil to develop baseline pinch welds at SRNL for 21-6-9 and 316 alloys. The test stem definition is contained in Figure 2. The baseline pinch weld stems were manufactured from 21-6-9 forgings and 316 stainless steel bar stock and drilled with the 50-50 oil at the current WR production rates of 11000 rpm speed and 0.5 in/min feed on the department TBT gundrill. The pinch weld development requirements are described in Appendix B, SRNL-MST-2007-00066 Fill Stem Manufacturing Changes and Pinch Weld Qualifications. The work to develop the baseline weld schedules at SRNL is documented in Fill Stem Manufacturing Changes and Pinch Weld Qualifications, Report number WSRC-STI-2008-000098 (Ref. 1).

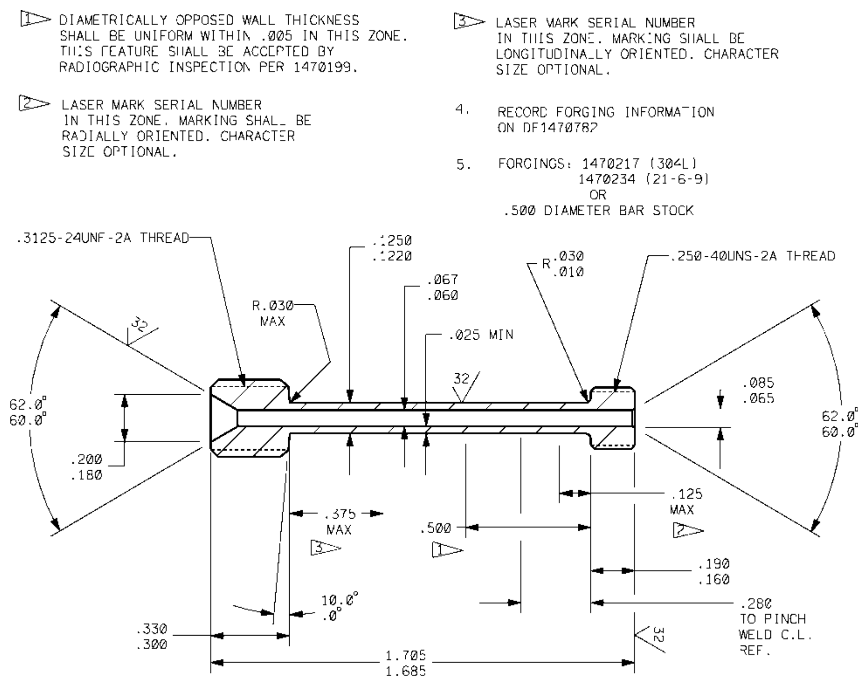

Figure 2. Drawing of test stem to be used for pinch weld evaluation of the new gundrilling oil.

Select Group of Candidate Oils

This activity consisted of reviewing the literature and soliciting the help of the Honeywell FM&T cutting oil expert to select oils that would be potential replacements for the 50-50 oil. The candidate oils should be generally marketed as gundrilling oil. The oils should be from a manufacturer that is believed to be stable and present in the current cutting oil market. The amount of extreme pressure (EP) additives (sulfur and chlorine) should be similar to the existing 50-50. EP additives are present to assist in chip formation and breakage during the gundrilling process. Also, the viscosity should be less than the 50-50 oil to improve removal of chips from the drill during the process and reduce time required to warm up the gundrill for drilling. Seven oils were selected as preliminary candidates for gundrilling at Honeywell FM&T.

Human Factors Testing

Seven oils were evaluated for human factors; smell, color, and consistency. Table 1 lists the seven oils initially selected for screening. This group was then reduced to four candidates based on human factors.

Table 1. Initial oils selected and procured for evaluation

	Manufacturer	Manufacturers Designation
1	Fuchs	Ecocut 482B-Blk
2	Fuchs	Wisura 2315L/CF-Blk
3	Milacron	Milpro 634 with 5% Milplus AS
4	Castrol	Ilocut 334
5	Houghton	Cutmax 206
6	Castrol	Gun drill oil 2190[3]
7	Castrol	Gun drill oil C

Human factor testing was incorporated to involve the machinist and the process engineer who are the individuals who will be working closely with the selected oil to manufacture gundrilled product. Smell and appearance have a significant effect on the desirability of machining oil. As part of this study three machinists and three engineers rated the products based on smell and color.

Process Material Control Evaluation per 1470262

The four oils, listed in Table 2, were selected based on human factors and physical characteristics, and were evaluated for compatibility with reservoir materials per 1470262. Material compatibility testing consisted of a contact test where the oils were put in contact with stainless steel coupons (21-6-9 and 304L) for a period of 10 days. After completion of the 10 day exposure the coupons were inspected for signs of staining or corrosion. The coupons were then cleaned in accordance with the formal reservoir cleaning process per 1470575, using Oakite NST.

After cleaning, the coupons were submitted for cleanliness analysis by X-ray Photoelectron Spectroscopy (XPS) and Ion Chromatography (IC). XPS measures ratios of carbon to iron (C/Fe), silicone to iron (Si/Fe), and chlorine to iron (Cl/Fe). Results of C/Fe are required to be less than 9.6. XPS analysis yields an overall cleanliness based on the fact that organic residue is seen as carbon by the method. The maximum carbon to iron ratio of 9.6 is based on the ethanol cleaning used at Rocky Flats.

After XPS analysis the coupons were checked for ionic contamination by IC extraction. The coupons were extracted with ultra-pure water to measure levels of chloride, fluoride, nitrate, sulfate, and phosphate. Presence of these ionic contaminates in quantities of greater than 0.5 $\mu g/cm^2$ may indicate handling problems (chloride), improper rinsing (sulfate or phosphate), or acid residues (fluoride or nitrate). All four oils passed material compatibility and cleanliness

[3] Castrol 2190 is a second generation of the original White and Bagley oil that was recommended by the previous gundrilling machine's manufacturer (Eldorado) for gundrilling. This oil was previously tested and was not desirable from a human factors standpoint and appeared to be too viscous (thick) for small hole application. This oil was not recommended by the current gundrilling machine manufacturer TBT.

evaluation as required per 1470262 and could be added to the process material list included in that document. However, the final choice was based on drill life, hole quality and pinch welding performance. Compatibility test results are documented in the file clntst30.xls.

Table 2. Oils selected based on human factors and physical characteristics, and submitted for process material control testing.[4]

	Manufacturer	Manufacturers Designation
1	Fuchs	Ecocut 482B-Blk
2	Fuchs	Wisura 2315L/CF-Blk
3	Milacron	Milpro 634 with 5% Milplus AS[5]
4	Castrol	Ilocut 334

Tool Life Testing

The four oils that passed human factors and physical characteristics as well as material control (Table 2) were submitted to tool life testing. Tool life testing utilized forgings of 21-6-9 (1470234-102) and 304L (1470217-102)[6]. In preparation for the drill life tests the forgings (nails) were turned to a 0.50 inch diameter. Drill life testing provided a measure of tool wear over the number of holes drilled with each oil. The wear rate defined which oil was best at minimizing drill wear. Drill life testing results were based on measurements of D-side wear. This is the wear of the drill that has the greatest effect on hole size and bore finish. Drill wear at B-side, C-side, and D-top were also measured. Drill wear locations are illustrated in Figure 3. Based on historical results from years of testing at Honeywell FM&T, the gundrill reaches the end of its useful life when D-side wear approaches 0.005 inches.

[4] These oils were part of clntst30 and the results are recorded in the file clntst30.xls on the authors desktop. Each oil passed the material compatibility and cleanliness testing with no issues.

[5] The 634 product is the chlorinated, low sulfur half of the original 50-50 product. We have added 5% (by volume) of Milplus sulfur additive which is also a Milacron product.

[6] This forging is a larger grain version of the -103 and -104 forgings with the same base number. This forging was used as a representative of the worst case forging for gundrilling.

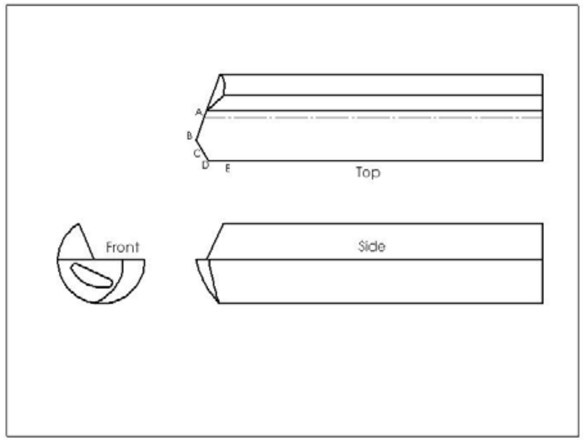

Figure 3. Diagram of wear measurement locations for gundrill wear

Tool life testing was carried out in department on the 2 axis gundrill on "nail" forgings. Feed and speed were normalized at the value used for current 50-50 drilling activities in GTS production. These values were 10,000[7] rpm and 0.5 in/min drill feed. The new oil evaluation required drilling over 132 holes. The 2 axis gundrill was utilized so that a single ½ inch diameter forging could be drilled up to nine times. On the TBT twin spindle gundrill only one hole could be produced per forging. The 2 axis gundrill approach consumed only fifteen forgings while the alternative would have required 132. (See Fig. 4, 5)

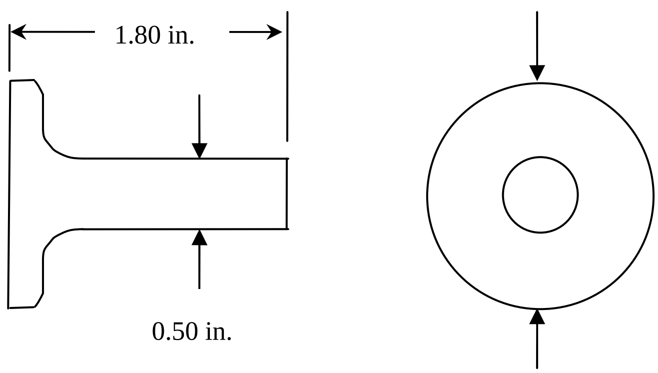

Figure 4. Sketch of nail forging used for drilling tests

[7] The maximum speed for the department 2 axis gundrill at 10,000 rpm is slightly less than the 11,000 rpm utilized in another department. This is why the team was required to perform validation tests on the TBT gundrill in another department. The department drill does not have counter rotation which is why it can drill a single forging 9 times.

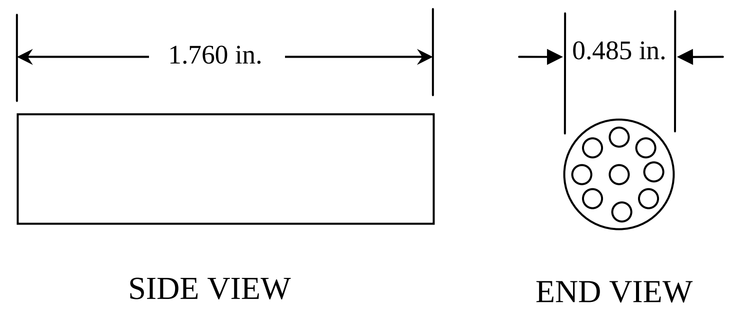

Figure 5. Sketch of nail forging turned to diameter for drill life testing on 2X gundrill. End view shows nine holes that were placed in the work piece.

Figures 6 and 7 are plots of the department tool life data gathered for the four oils including 50-50 wear data as a baseline reference. As a result of the department tool life testing, the Castrol Ilocut 334 was selected to have the best overall drill wear, particularly in the 304L alloy, which tends to be the more difficult to gundrill due to its high modulus of elasticity and resultant gummy cutting and poor chip formation characteristics.

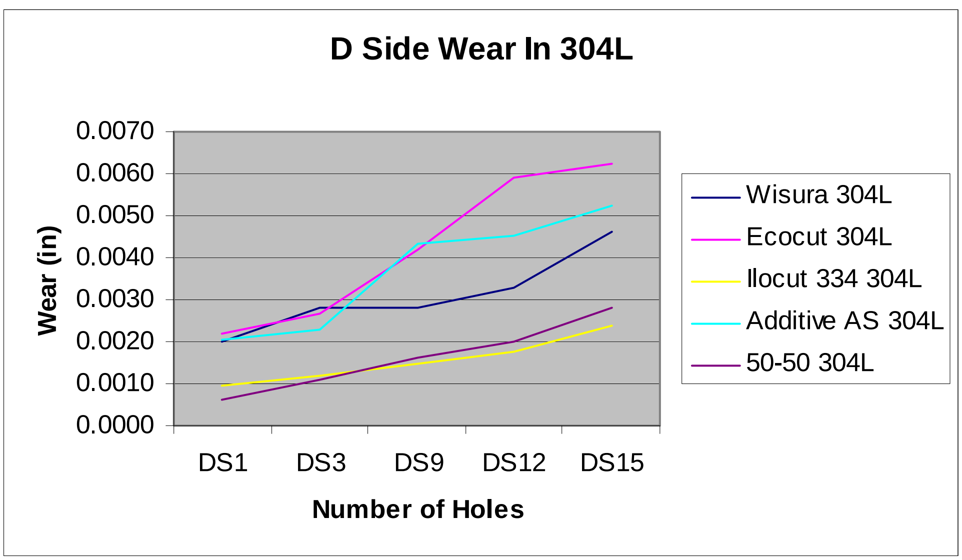

Figure 6. Gundrill D-side wear for 304L stainless steel forgings from 1 – 15 holes per drill.

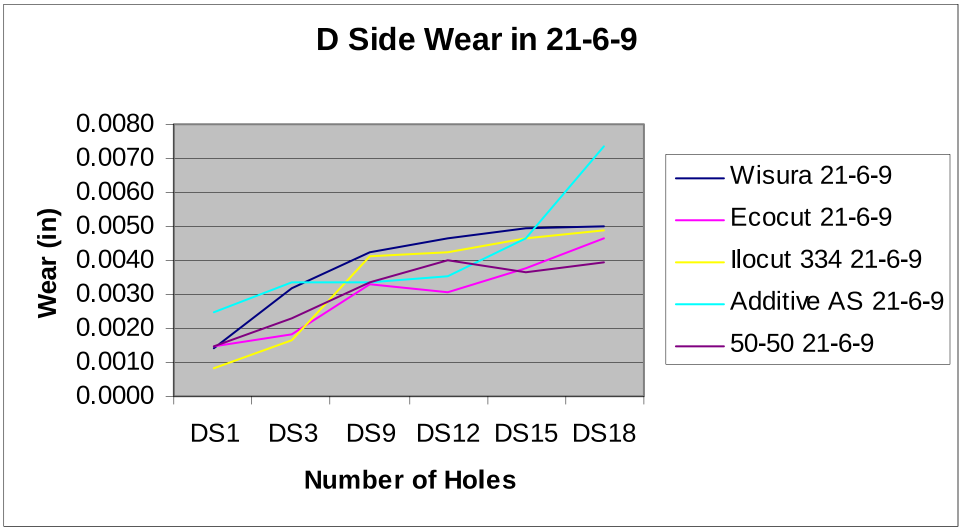

Figure 7. Gundrill D-side wear for 21-6-9 stainless steel forging from 1-18 holes per drill.

Test Validation and Feed Rate Selection for TBT Gundrill

Initial tool life testing was performed at 0.5 in/min and a spindle speed of 10,000 rpm for testing of the 50-50 oil and the four candidate oils. The 0.5 in/min rate was selected to simulate current WR production for a direct comparison. The 10,000 rpm spindle speed was utilized as the maximum available on the department gundrill machine. The WR spindle speed is 11,000 rpm with a counter rotating spindle. In order to determine if the drill life data generated on the department gundrill was applicable to the TBT drilling machines Honeywell FM&T performed the validation experiment. This validation activity would serve two purposes, first to verify that the data generated on the older department gundrill was applicable to the newer TBT drilling machines in another department, and second to help select a feed rate appropriate for the lighter, less viscous, Castrol Ilocut 334 oil for all future WR stem production. To that end a higher feed rate of 0.8 in/min (60% greater than the current WR rate of 0.5 in/min) was selected to determine if the drills were approaching a critical point in drilling rates that might cause catastrophic drill failure. The team's goal is not to increase the feed for the purpose of increased production but to aid in chip formation and breakage. This is a compromise between the ductile and gummy 304L and the harder more abrasive 21-6-9.

Tests on 21-6-9 and 304L bar stock were run for 5 holes per drill at this higher drilling rate. The higher drilling rate was selected as a "worst case scenario" in order to prove the oil and drill combination would drill 5 holes without breakage. The bar stock specimens were drilled in a balanced fashion with Nagel[8] and Drill Master[9] drills. The drills were fabricated to the same drill design that has been used in GTS production since procurement of the TBT drilling machines.

[8] Nagel is the manufacturer of the TBT Honeywell FM&T's current gundrilling machines. The gundrills are made to the same drawing and coated by the same coating vendor.

[9] Drill Masters has been providing gundrills to Honeywell FM&T for years.

Results of this validation process indicated that the TBT machines could easily produce up to 5 holes per drill (either drill manufacturer) on bar stock with D-side wear well below the 0.005 inches level while avoiding drill breakage. D-side wear of over 0.005 has been shown to indicate imminent failure at the WR drilling rates of 0.5 in/min and 10,000 rpm, based on extensive experience with drill wear measurement at Honeywell FM&T. Based on this result, a feed of 0.65 in/min was selected as a conservative speed to consistently produce five holes per drill on all materials forging and bar stock using either drill.

The bar stock units from the validation experiment were sectioned and examined by scanning electron microscope (SEM). These units were used for sectioning due to the lack of other assets available for destructive testing. The spare units for this purpose were sent to SRS for a follow-on pinch weld experiment that was not part of the planned evaluation. The bar stock units also verified the ability of the new oil to remove chips at a high feed rate and prevent drill breakage. These units indicate how the drilled surface appears when drilled at a feed 30% higher than the feed rate selected for reservoir drilling with the new oil. SEM images and energy dispersive spectroscopy (EDS) analysis of the validation holes at the high feed rate are included in Figures 8 through 23. The photographs represent a drill movement along the horizontal axis of the image.

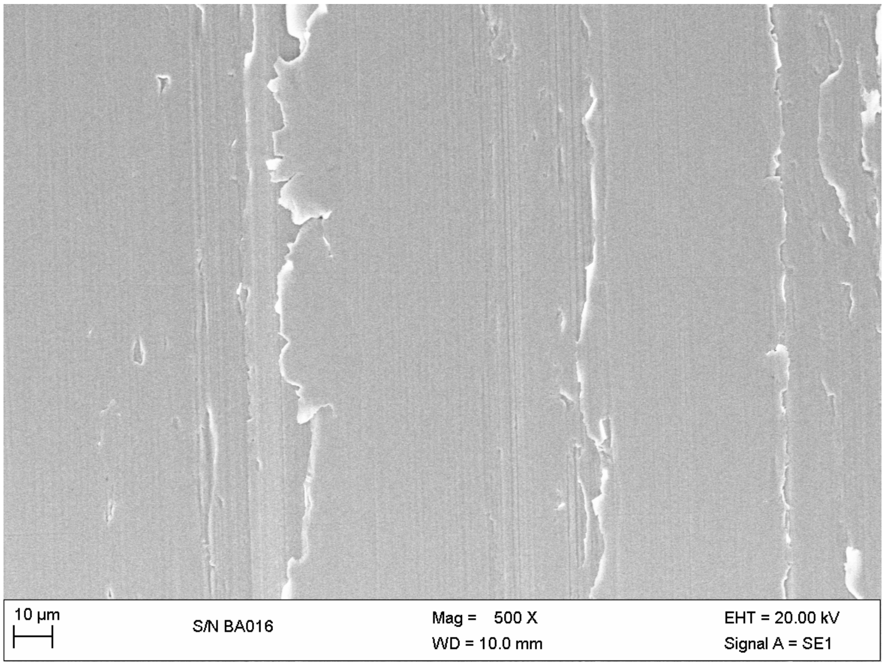

Figure 8. SEM image at 500 X of 304L bar stock (BA016) first hole drilled with Nagle drill at a feed of 0.8in/min.

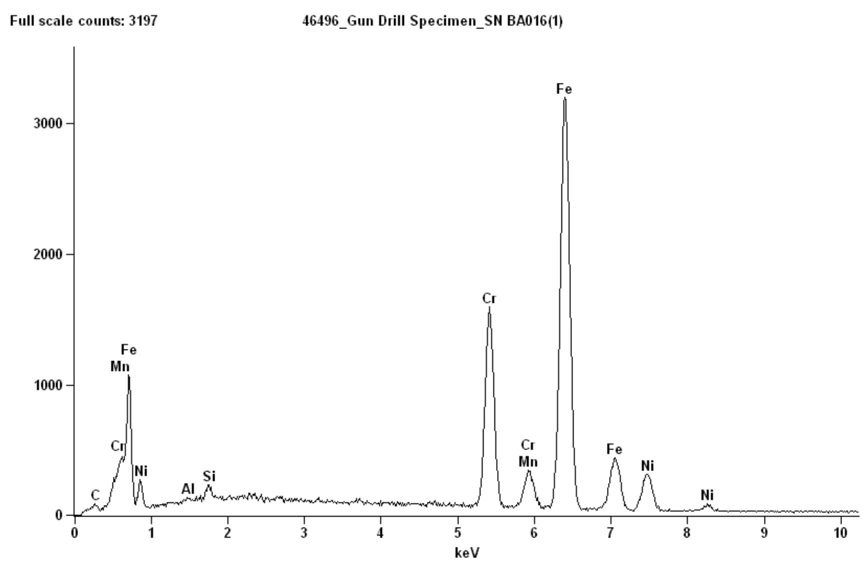

Figure 9. EDS of stem bore created with Nagel drill, 1st hole in 304L stainless steel specimen BA016.

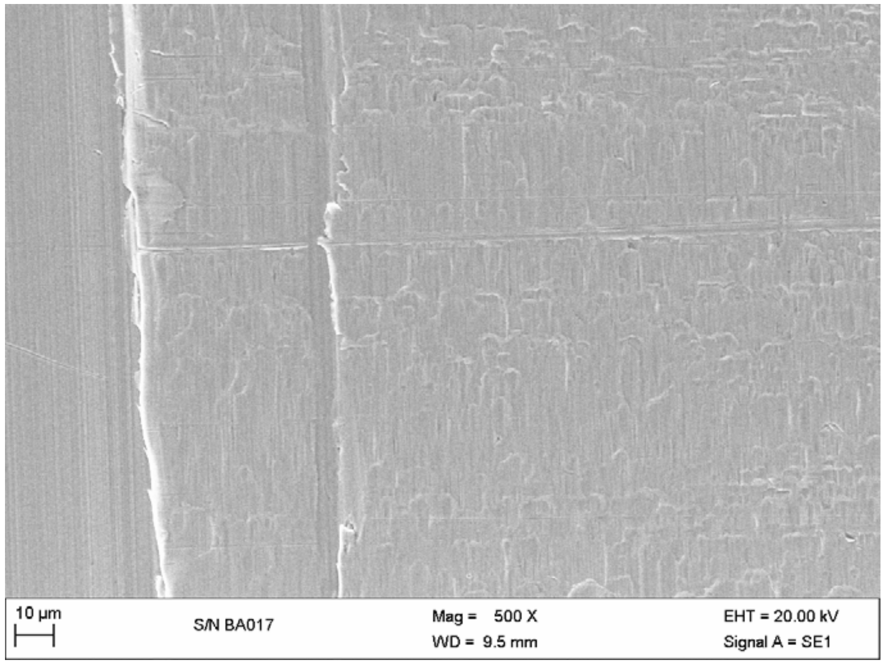

Figure 10. SEM image at 500 X of 304L bar stock (BA017) first hole drilled with Drill Masters drill at a feed of 0.8 in/min.

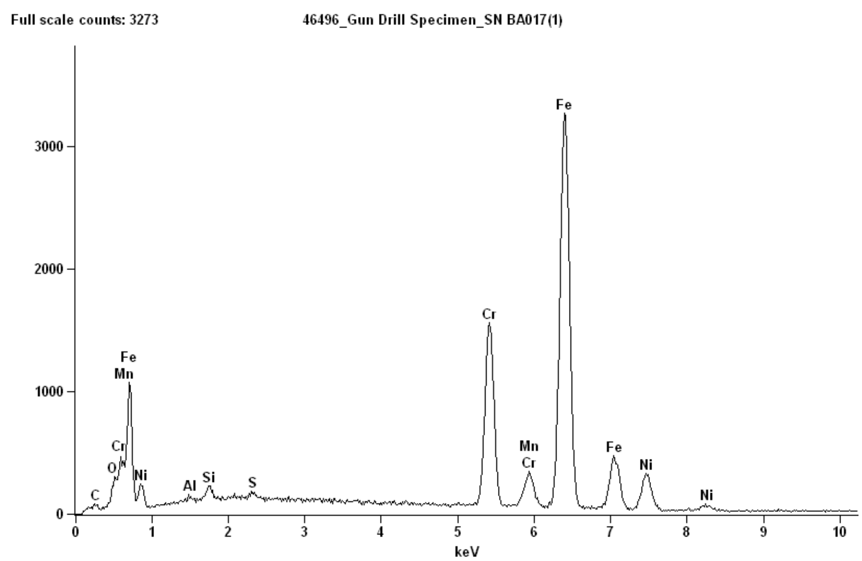

Figure 11. EDS of stem bore created with Drill Masters drill, 1st hole in 304L stainless steel specimen BA017.

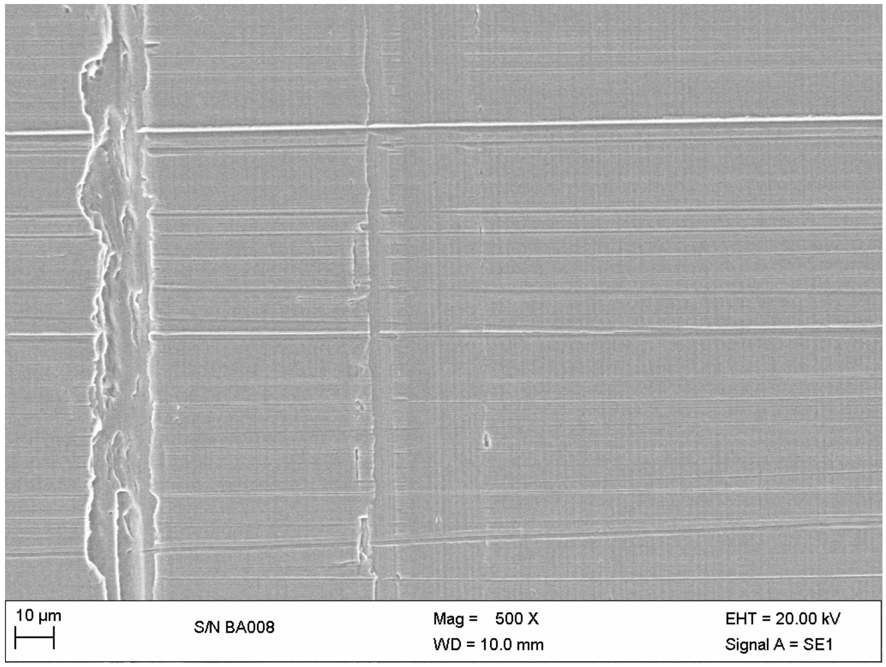

Figure 12. SEM image at 500 X of 304L bar stock (BA008) fifth hole drilled with Nagel drill at a feed of 0.8in/min.

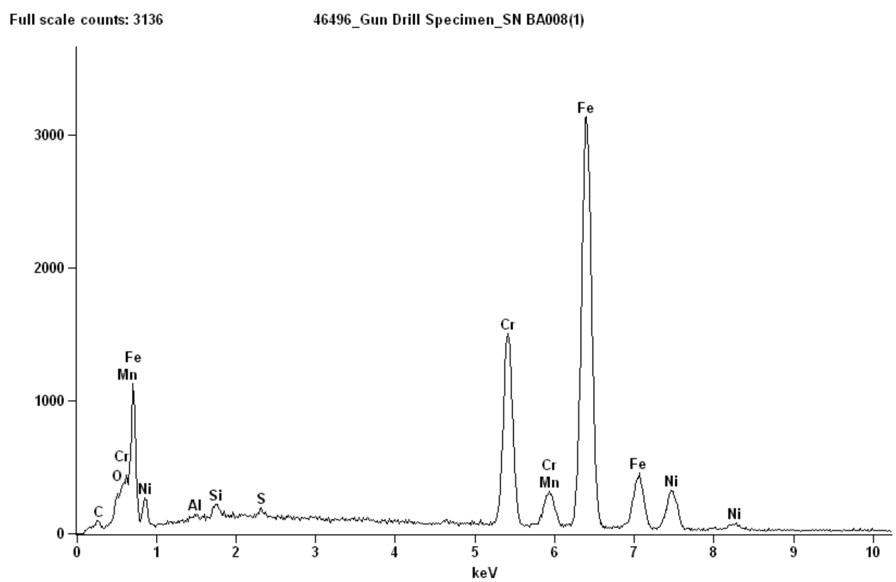

Figure 13. SEM EDS of stem bore created with Nagel drill, 5th hole in 304L stainless specimen BA008

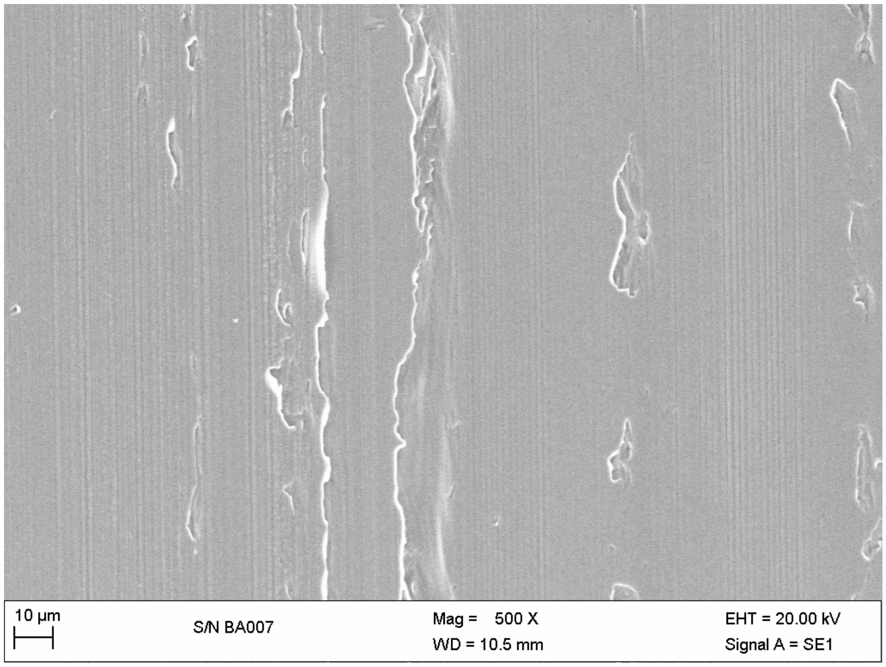

Figure 14. SEM image at 500 X of 304L bar stock (BA007) fifth hole drilled with Drill Masters drill at feed of 0.8 in/min.

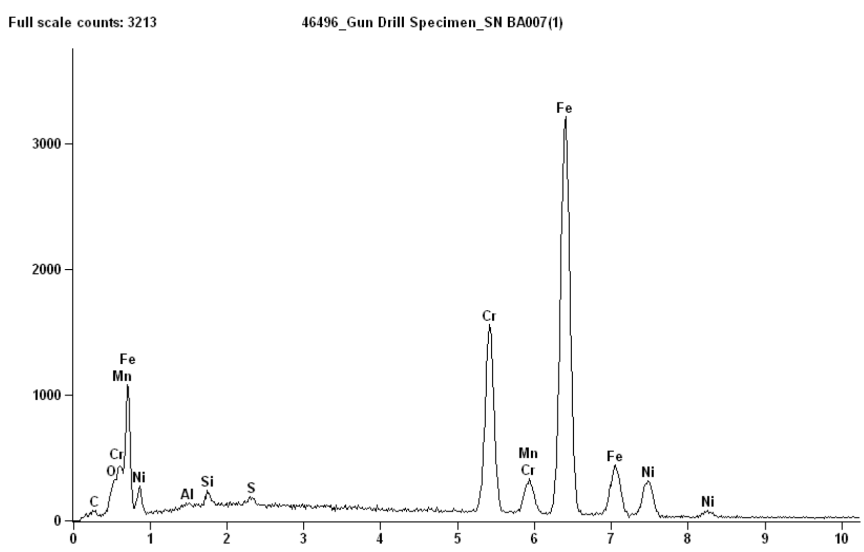

Figure 15. EDS of stem bore created with Drill Masters drill, 5th hole in 304L stainless steel specimen BA007.

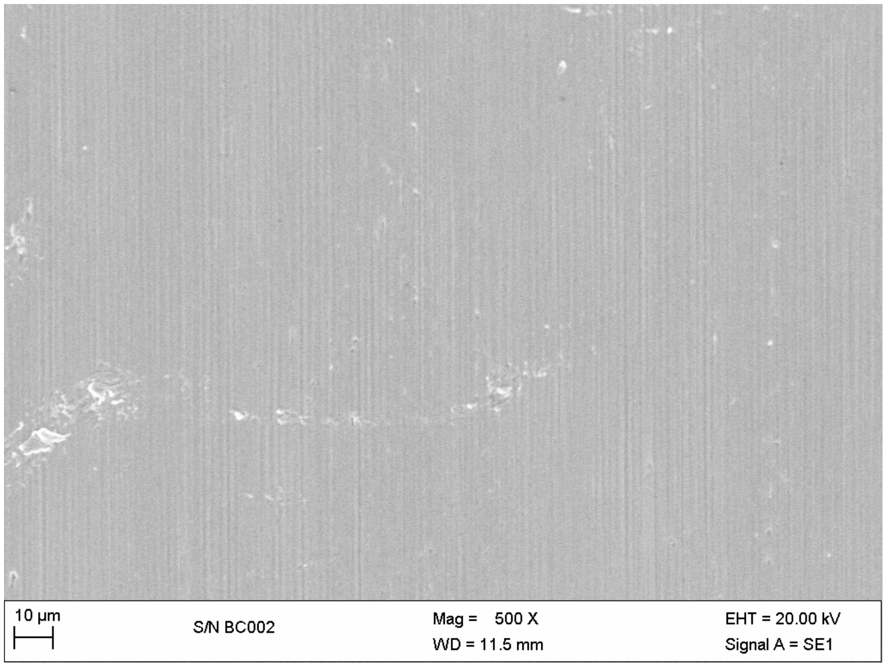

Figure 16. SEM image at 500 X of 21-6-9 bar stock (BC002) first hole drilled with Nagel drill at a feed of 0.8in/min.

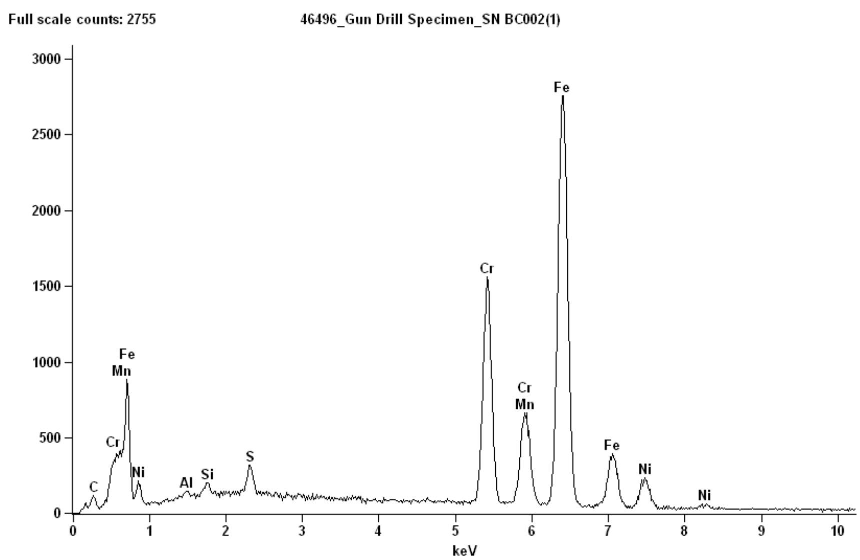

Figure 17. EDS of stem bore created with Nagel drill, 1st hole in 21-6-9 stainless steel specimen BC002.

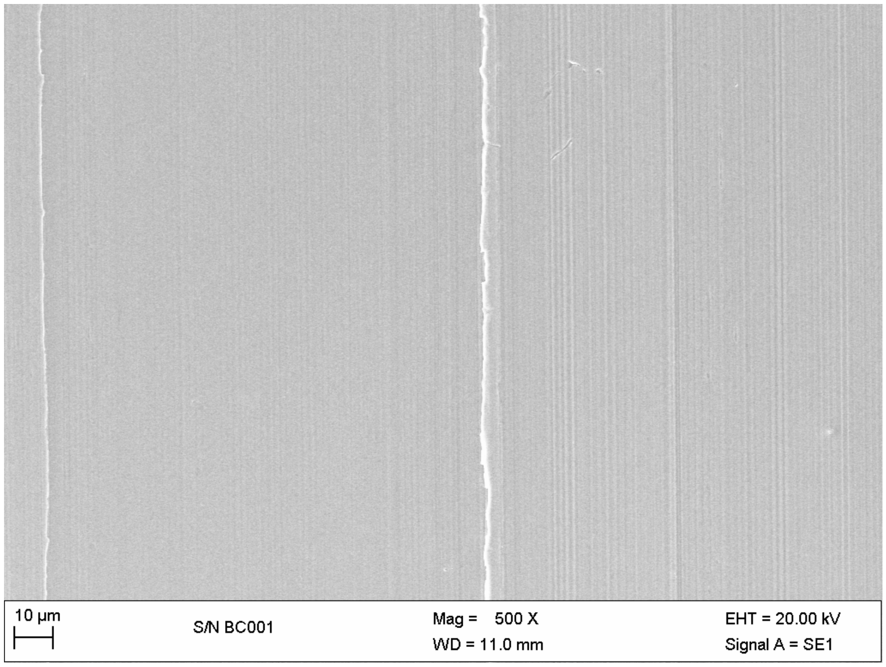

Figure 18. SEM image at 500 X of 21-6-9 bar stock (BC001) first hole drilled with Drill Masters drill at feed of 0.8 in/min.

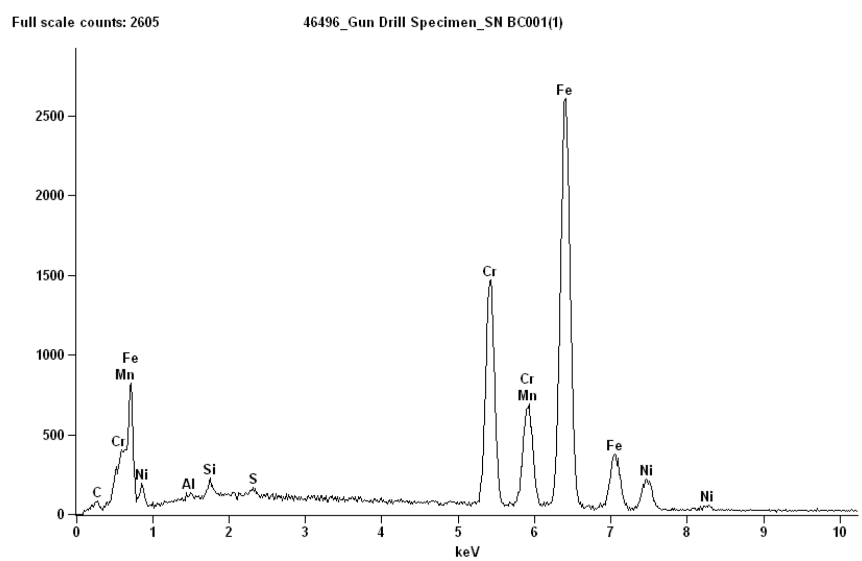

Figure 19. EDS of stem bore created with Drill Masters drill, 1st hole in 21-6-9 stainless steel specimen BC001.

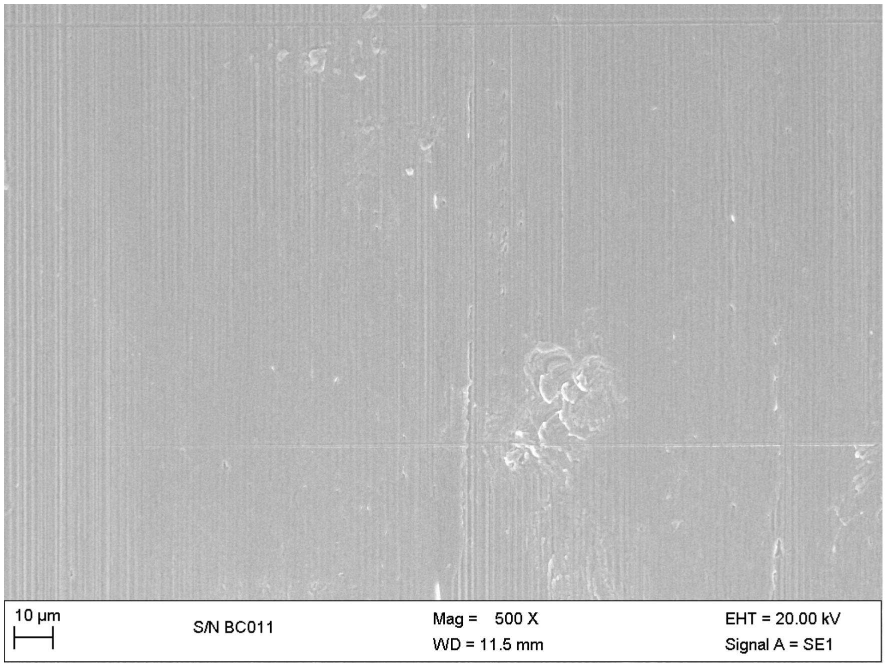

Figure 20. SEM image at 500 X of 21-6-9 bar stock (BC011) fifth hole drilled with Nagel drill at a feed of 0.8 in/min.

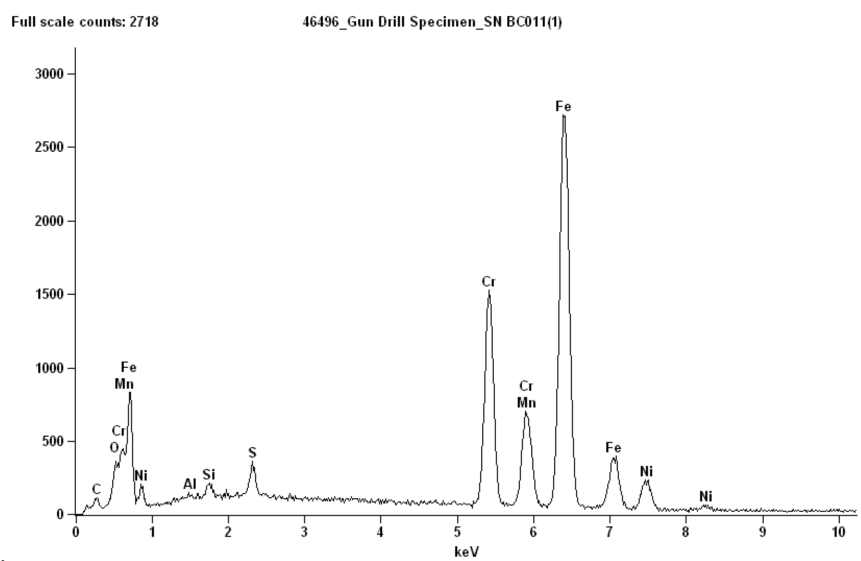

Figure 21. EDS of stem bore created with Nagel drill, 5th hole in 21-6-9 stainless steel specimen BC011.

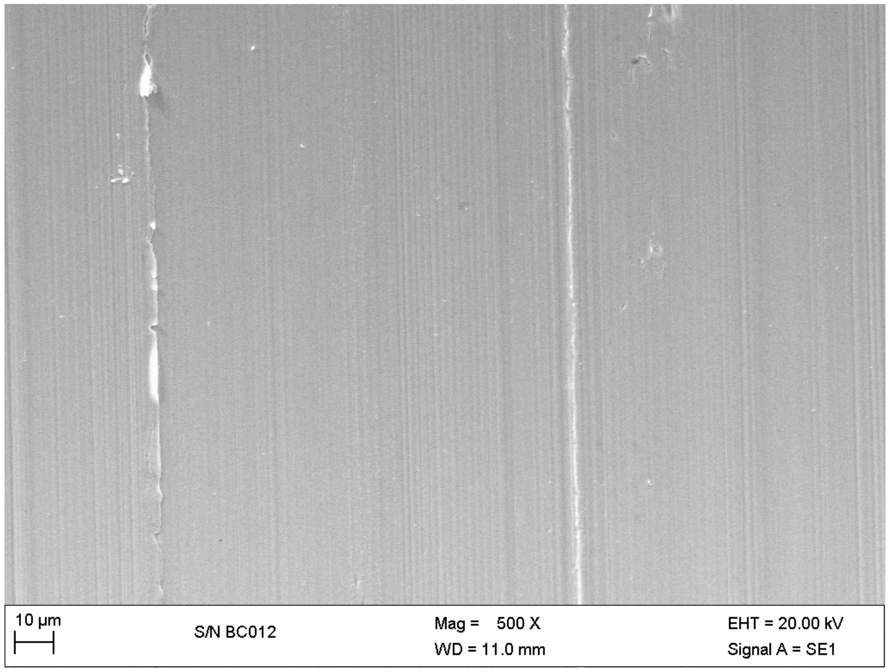

Figure 22. SEM image at 500 X of 21-6-9 bar stock (BC012) fifth hole drilled with Drill Masters drill at feed of 0.8 in/min.

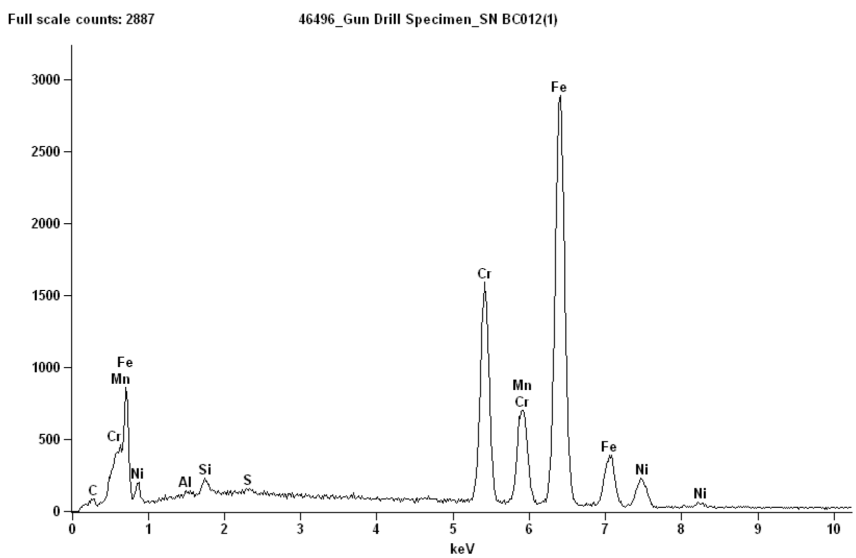

Figure 23. EDS of stem bore created with Drill Masters drill, 5th hole in 21-6-9 stainless steel specimen BC012.

Two historical SEM images of gundrilled holes, produced using 50-50 oil on the TBT drill, have been presented in Figures 24 and 25 as a reference. These images resulted from testing on the TBT gundrill to determine the machine's capability to drill multiple holes per drill on GTS product. Keep in mind that the comparison of surfaces is not quantitative and is generally arbitrary. However, the surface appearance of the holes produced by the Castrol Ilocut 334 at a high feed in bar stock have similar surface appearance to those produced previously by 50-50 at a lower drill feed rate of 0.5 in/min in forgings.

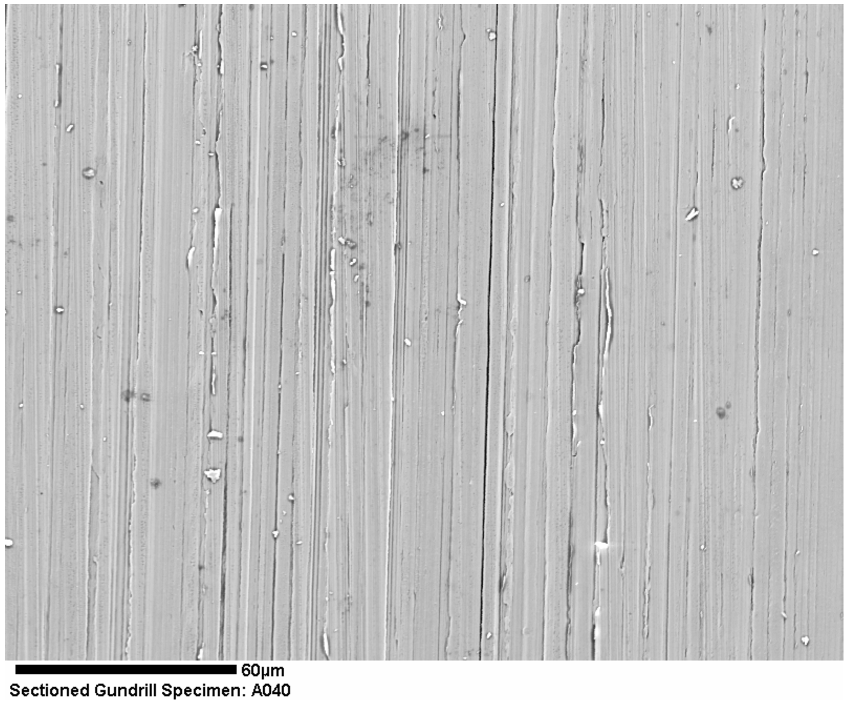

Figure 24. 500X SEM of A040. 304L; The seventh hole drilled at 0.5 in/min, and 11,000 rpm in a 304L forging with 50-50oil.

Figure 24 is a 500x SEM image that shows the surface morphology of the fourth hole by a given drill in a 304L forging with 50-50 oil a feed of 0.5 in/min and 11,000 rpm on the TBT gundrilling machine.

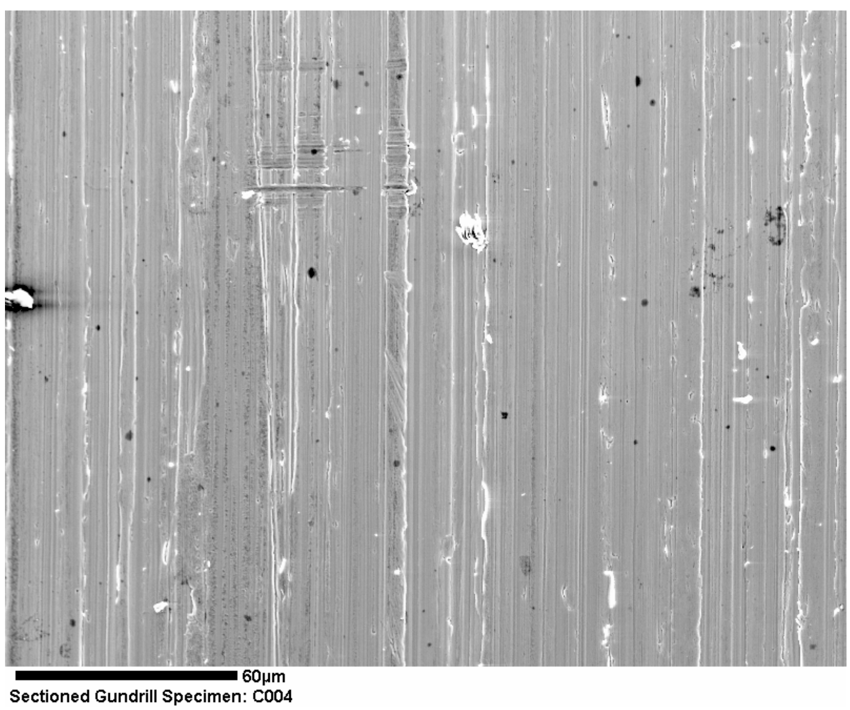

Figure 25. A 500X SEM image of the seventh hole drilled in 21-6-9 forging with 50-50 oil at 0.5 in/min, and 11,000 rpm on TBT gundrill machine in another department.

Figure 25 is a 500x SEM image that shows the surface morphology of the seventh hole by a given drill in a 21-6-9 forging with 50-50 oil, a feed of 0.5 in/min and 11,000 rpm on the TBT gundrill.

These last two images are different from that produced by the Castrol Ilocut 334 oil. Is this grounds for rejection or selection? Not really. Examination at 500x is a pretty tough standard. The bottom line is that the variability in hole appearance is somewhat independent of the specifics of the drilling oil, drilling rate and cutting tool.

Production of PRJ706566-102 Specimens for Pinch Weld Evaluation at SRNL

For this activity the team utilized forgings for the 304L and 21-6-9 alloys and bar stock for the 316 stems. Twelve test stems of each alloy were produced in the configuration in another department using WR manufacturing methods and the Castrol Ilocut 334 oil. Eight holes per drill were produced at a feed rate of 0.65 in/min and 11,000 rpm while drilling the pinch weld specimens. The parts were tracked with a serial number prefix, A, B or C. The A indicates 304L; the B indicates 316 while the C indicates 21-6-9. The serial numbers are marked on the test stem in two locations (flag note 2 & 3) as shown in Figure 2. The specific forging lot number used to create each stem can be identified with the serial number.

The pinch weld specimens were drilled in a balanced fashion with Nagel[10] and Drill Master[11] drills at a feed rate of 0.65 in/min and an rpm of 11000. The drills were fabricated to the same drill design that has been used in GTS production since procurement of the TBT drilling machines. The drills achieved up to eight holes with no problems. Test stems shipped to SRNL represented the 1st, 2nd, 3rd, 4th, 5th, & 7th parts drilled with a given drill[12]. The drill used and the hole count on the drill can be tracked with the test stem serial number.

[10] Nagel is the manufacturer of the TBT Honeywell FM&T's current gundrilling machines. The gundrills are made to the same drawing and coated by the same coating vendor.

[11] Drill Masters has been providing gundrills to Honeywell FM&T for years.

[12] The stems with 8 holes per drill were not provided to SRNL due to one setup error on one of the alloys where the drill was set too deep and hit the part before the spindle started. Not having a part from each alloy with 8 holes per drill, the team stopped at 7 to be consistent. However, two parts with 8 holes per drill were sent to SRS for welding on production tooling.

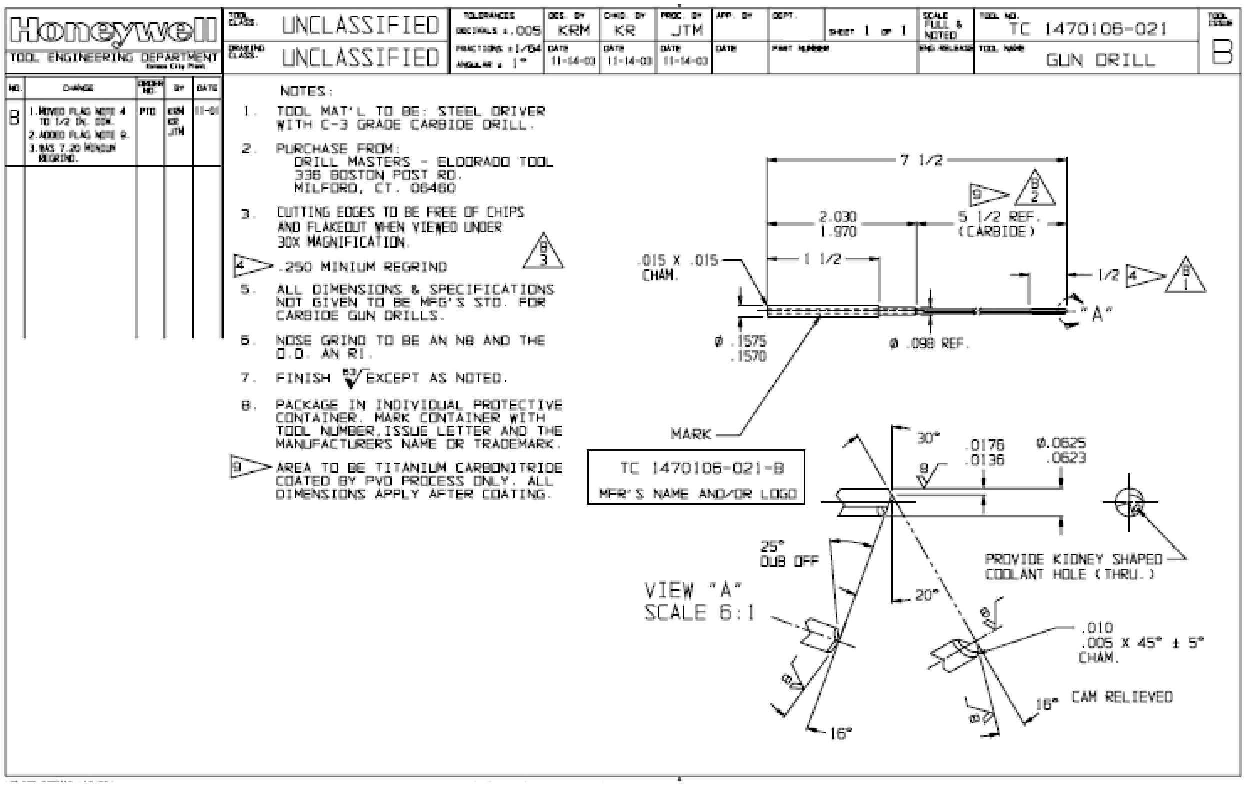

Figure 26. Drawing of gundrill, TC1470106-021B, used in another department for drilling of GTS components.

Pinch weld test results are published in a technical report, Pinch Weld Testing To Support Change in Manufacturing Oil at the KCP, Report number WSRC-STI-2008-00041 (Ref. 2). In addition to this Honeywell FM&T was asked to provide stems for welding on SRS production tooling. At the time of the request Honeywell FM&T had three specimens of each of the stainless steels that were to be used for evaluation of surface appearance and morphology. These stems were diverted to the unplanned SRS welding evaluation requested by LANL. This work is not complete at the time of this documents release.

Accomplishments

Applied a systematic approach to testing and selection of the next generation gundrilling oil for manufacturing stem bores.

Developed a baseline of the performance of the 50-50 oil relative to tool wear when drilling forgings. This data will provide a yardstick to measure the relative performance of any new oil against the standard in use at Honeywell FM&T since the 70's.

Implemented a human factors experiment to select the oil that is most attractive to the machinist and engineer within the context of a group of oils that have appropriate extreme pressure additives and drilling capability.

Conducted a drilling experiment with four oils and multiple holes per drill with drill wear as the output. This drill experiment allowed us to select the best oil from the group of 4 products while comparing drilling performance to the existing 50-50 oil.

Validated the WR drilling process at a feed of 0.65 inches per minute and the use of two independent drill manufacturers drills (made to the same drawing). Up to 8 holes were produced per drill with no drill breakage due to drill wear over the 45 stems produced.

Saved over 148 forgings at an approximate cost of $100 each and reduced gundrill setup time by 88% by using the department 2 axis gundrill for preliminary drill wear. Cost of specimen preparation was also reduced by 88%.

Conclusions

The Castrol Ilocut 334 is a good gundrilling oil and produces parts equivalent to the existing 50-50 oil and was tested to be compatible with reservoir materials per 1470262.

The lower viscosity of the Castrol Ilocut 334 oil aids in chip breakage and removal, reducing the incidence of drill breakage when compared to the 50-50 oil. To date all drilling experiments have had no drill failures caused by drill wear or chip packing. The only drill failure that occurred was due to a setup error, the drill hit the part before the spindle was turning.

Future Work

Obtain approval for changing oil from 50-50 to Castrol Ilocut 334 and implement at FM&T.

Appendix A: Gundrilling Oil Transition Test Plan

Gundrilling Oil Transition Test Plan

1. Identify oils. Identified approximately ten potential oils.
2. Evaluate candidates based on vendor history and location. This evaluation cut the list by three based on availability in the USA.
3. Evaluate seven oils for human factors and physical characteristics.
4. Write appropriate Process Hazard Analysis (PHA) and Job Hazard Analysis (JHA) paper as well as obtain MSDS's and set up materials as samples in the Maintenance Repair Order (MRO) system as appropriate given the fact that several of these materials will not be incorporated into the procurement system.
5. Smell them and look at them. Check product data sheets for sulfur, chlorine and phosphorous and viscosity. Target values similar to the 50-50 product and factor in TBT (Nagle TBT –is the twin spindle gundrill manufacturer) recommendations of low viscosity to aid chip removal.
6. Run baseline drill life experiment for current 50-50 oil using forgings (304L: 1470217-102, & 21-6-9: 1470234-102) on department 2 axis gundrill. The two axis gundrill allows us to drill six to nine holes per forging. Holes were drilled at the current WR feed rate of 0.50 inches/minute. The drills were used until wear reached 0.005 inches flank wear or they broke. We recorded drill wear and charted as a baseline for comparison to the performance of the new oils.
7. Selected four oils to move into to the drilling experimentation phase.
8. Set up four candidate oils in FM&T stores system (Write 317 for oil(s) selected).
9. Submit samples of oils, selected for drilling test, for testing per 1470262 in parallel with drilling experiment. The four oils tested are, Fuchs Wisura, Fuchs Ecocut, Castrol Ilocut and Millacron Milpro 634 and 5% Milplus AS (per clntst30.xls). All four oils met requirements for cleanliness.
10. Procure enough oil for the drill life experiment to be run in department. The drill life experiment will determine the number of holes that can be drilled with each oil in both 304L and 21-6-9 forgings (304L: 1470217-103, & 21-6-9: 1470234-102). Drill life experiment will utilize forgings drilling up to nine holes per forging using the WR feed rate (0.50 inches/minute). D-side wear will be measured and charted for comparison to results of the 50-50 oil drill life experiment (item six).
11. Castrol 334 was selected based on tool wear results. The results will then be validated on the TBT gundrill drill in another department using drills from two manufacturers to drill 304L and 21-6-9 bar stock. The feed rate will also be increased to a value 60% higher than the rate used for tool life testing (the WR rate 0.5 inches/minute). The validation activity will target five holes per drill. In this experiment, drill run-out will be measured. D-side wear on the gundrill after holes 1, 2, 4 and 5. Validation will push the drills and the oils capability to determine if more than 5 holes can be drilled at a high rate of feed

without breaking drills. Hole quality will be evaluated by bore scope inspection. Parts with holes drilled at specific intervals (I.e. first middle and end holes) will be sectioned and examined with SEM photographs and SEM EDS and possibly XPS.

12. The Castrol 334 will then be used to drill the pinch weld validation stems on the TBT with equivalent drills from two different manufacturers. The feed rate used for the final drill test (0.65 inch/minute) is 30% higher than current WR 50-50 rate (0.50 in/min). We will drill forgings for the 304L and 21-6-9 (1470217-104, 1470234-102 respectively) and nuclear grade bar stock for the 316 (9852415-00-800). The bar stock was selected to match the material used for SNL/CA stems. The test stems will be manufactured, cleaned, and inspected utilizing a WR-like process to yield parts in the PRJ706566-102 test stem configuration developed for pinch weld testing by the stem team. This activity will target up to 8 holes per drill. In the pinch weld validation experiment the following will be measured: drill run-out and wear at A top, B top, C top, D top, D-side and E top on the gundrill at 1, 3, 5, 7 or 8 holes. For each material drill five parts with two different new drills (one in front one in rear).
13. Send 12 stems of each material 304L, 316 and 21-6-9 in PRJ706566-102 configuration to SRNL for pinch weld validation.
14. Write report on gundrilling activity and associated pinch welding tests.
15. Get DA approval to implement new oil.
16. Write FCO to place new oil on Honeywell FM&T Reservoir Process Materials List 1470262.
17. Provide report title and draft for insertion into LANL IER. Provide report title and draft to SNL/CA and SNL/NM for development of REN as required.
18. FCO process material control list to add new oil to reservoir products list
19. Begin procurement of new oil
20. Pump out machines and put in new oil

Appendix B: Fill Stem Manufacturing Changes and Pinch Weld Qualifications

SRNL-MST-2007-00066

Fill Stem Manufacturing Changes and Pinch Weld Qualifications

To:

Based on previous discussions from the Stem Team the following protocol is recommended to ensure that manufacturing changes that are not expected to result in the need for a full qualification in the tritium facility. In order to accomplish this task with the fewest reasonable number of stems, the following plan is tendered:

1. Determine weld conditions on the SRNL prototypic welder for 316 stainless steel fill stems that produce class 1 and 2 bonds. Test stems of the PRJ706566-102 will be used. The stems will be machined with 50/50 cutting oil

    A. Preliminary conditions for 316 based on email dated 3-6-07 from B. West

        3/16” electrode, 1250 lbs +/- 50 lbs, current from 3300-3700 A for WR weld conditions

        Weld in 2 atm of Nitrogen or deuterium

        Weld one stem each at 3300 A and 3500A and 3700A

        Proof test at 40ksi

        X-ray for closure length, extrusion, and geometry

        Transverse metallographic examination

    B. Based on these conditions either increase or decrease current (voltage) range for welds, weld a new set to if range is changed.

        Weld three 50/50 test stems at the low and high conditions, with current at low and force at high and current at high with force low, to ensure suitable weld parameters

2. Determine weld conditions on the SRNL prototypic welder for 21-6-9 stainless steel fill stems that produce class 1 and 2 bonds.

    A. Preliminary conditions for 21-6-9 based on email dated 3-6-07 from B. West

        3/16” electrode, 1500 lbs, current from 3750 to 4150 A for WR weld conditions (this simulates M conditions).

        Weld one stem each at 3750 A, 3950A, and 4150A

        Weld in 2 atmospheres of Nitrogen or deuterium

        Proof test at 60 KSI

X-ray for closure length, extrusion, and geometry

Transverse metallographic examination

B. Based on these conditions either increase or decrease current (voltage) range for welds.

Weld three 50/50 test stems at the low and high conditions, with current at low and force at high and current at high with force low, to ensure suitable weld parameters

3. Use current range established during fill stem project for 304L (3500-3900) A.

Based on these conditions weld three 50/50 test stems at the low and high conditions, with current at low and force at high and current at high with force low, to ensure suitable weld parameters

Using these conditions, weld a total of ten stems of each material manufactured using modified, i.e., changed cutting oil, process. Weld four stems at "cold" condition, three at midpoint (nominal) condition, and three at "hot" condition, varying force opposite of current. Use standard suite of non-destructive and destructive tests to ensure acceptable quality.

Upon successful completion of these tasks, issue report(s) detailing the work that was completed and circulate to stakeholders. Include recommendation indicating approval of process for WR components.

The Tritium Facility will weld qualification stems as part of their normal quality assurance program for equipment validation prior to loading reservoirs. A full re-qualification of the process will not be required.

Test stems needed:

Type	Quantity	Cutting Fluid	Purpose
21-6-9	6	50/50	Weld window tuning
21-6-9	6	50/50	Low and high validation
21-6-9	12	New	Process verification (and 2 contingency)
316	6	50/50	Weld window tuning
316	6	50/50	Low and high validation
316	12	New	Process verification (and 2 contingency)
304L	6	50/50	Low and high validation
304L	12	New	Process verification (and 2 contingency)