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MATERIALS TECHNOLOGY

Title: Biaxial Creep Specimen Fabrication

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Abstract: This report documents the results of the weld development and abbreviated weld qualification efforts performed by Pacific Northwest National Laboratory (PNNL) for refractory metal and superalloy biaxial creep specimens. Biaxial creep specimens were to be assembled, electron beam welded, laser-seal welded, and pressurized at PNNL for both in-pile (JOYO reactor, O-arai, Japan) and out-of-pile creep testing. The objective of this test campaign was to evaluate the creep behavior of primary cladding and structural alloys under consideration for the Prometheus space reactor. PNNL successfully developed electron beam weld parameters for six of these materials prior to the termination of the Naval Reactors program effort to deliver a space reactor for Project Prometheus. These materials were FS-85, ASTAR-811C, T-111, Alloy 617, Haynes 230, and Nimonic PE16. Early termination of the NR space program precluded the development of laser welding parameters for post-pressurization seal weldments.

Introduction: For the operating temperatures under consideration for the Prometheus reactor, thermal and irradiation creep were key properties of interest. However, very limited data was available on the effects of irradiation on thermal creep and the extent of irradiation creep in the alloys of interest. As a result, efforts were underway to conduct irradiated biaxial creep testing in the JOYO test reactor (O-arai, Japan). Out-of-pile testing was also planned at JOYO test temperatures and exposure times to separate thermal creep effects from irradiation-induced creep effects.

The Naval Reactors Prime Contracting Team (NRPCT) planned a biaxial creep specimen fabrication and inspection campaign at Pacific Northwest National Laboratory (PNNL) in Hanford, Washington. Specimens were to be fabricated of several materials including the refractory metal alloys FS-85 (Nb-27Ta-10W-1Zr), ASTAR-811C (Ta-8W-1Re-0.7Hf-0.025C), Ta-10W, T-111 (Ta-8W-2Hf), Mo-47.5Re, and Mo-44.5Re, and the nickel-base superalloys Haynes 230 (Ni-22Cr-5Co-14W-3Fe-2Mo-0.4Si-0.3Al-0.5Mn-0.1C-0.015B), Alloy 617 (Ni-22Cr-12.5Co-9Mo-3Fe-1Si-1Mn-0.6Ti-0.1Al-0.006B), Nimonic PE16 (Ni-33Fe-18Cr-4Mo-1.2Ti-1.2Al-0.3Si-0.2Mn-0.1C), and Hastelloy X (Ni-22Cr-18Fe-9Mo-1.5Co-1Si-1Mn-0.6W-0.1C-0.01B). The first JOYO test campaign (JOYO-1) was to include FS-85, ASTAR-811C, Mo-47.5Re, Alloy 617, Haynes 230, and Nimonic PE16. At the time of the restructuring of the Prometheus program, electron beam and laser seal weld development were nearly complete for FS-85, ASTAR-811C, Alloy 617, Haynes 230, and Nimonic PE16. Processing of tube and endcap components for biaxial creep specimens by the NRPCT for the remaining alloys was not complete and further efforts were discontinued.

Over the past 30 years, PNNL welding facilities had been used for fabrication of specimens similar to those planned for this campaign. As a result, PNNL personnel had acquired considerable expertise in welding refractory metal alloys and superalloys. Several years ago, the facility was shut down and equipment and personnel were dispersed over several distinct organizations located on the Hanford site. Just prior to the initiation of the Prometheus project, the welding equipment was moved to a central location under the cognizance of PNNL. Following this move, it was necessary to return the welding equipment to operational status and to contract experienced personnel prior to initiation of the biaxial creep specimen fabrication campaign. As a result, the NRPCT contract with PNNL was divided into three separate phases. Phase 1 included upgrading the equipment and fabricating the fixtures necessary to re-establish operation of the welding equipment, as well as developing plans and procedures for subsequent phases. Phase 2 included weld development and qualification for each material, as well as the placement of subcontracts with other Hanford organizations to ensure that key personnel and facilities would be available for consultation, helium leak testing, and radiographic inspections. Phase 3 involved the fabrication and inspection of the production specimens that would be used for in-pile and out-of-pile testing.

Experimental: The NRPCT planned to fabricate the tube and endcap components for biaxial creep specimens and send them as matched sets to PNNL for weld development, weld qualification, final fabrication, and inspection. Each set would consist of a 1.25" long x 0.25" diameter x 0.025" wall thickness tube and two fitted endcaps as shown in drawing 5D15996 (Figures 1 and 2). One endcap (designated 'top') from each set would have an approximately 0.005"-0.008" diameter through-hole on a small protruding nub in the center of the cap. This hole would be used for pressurization of the specimens with helium. The processing of these components is described in detail in a separate document (Reference 1). PNNL was instructed to electron beam (EB) weld two matched endcaps to each tube utilizing a unique rotating fixture (Figure 3) designed by PNNL to allow them to weld two endcaps to each of 24 tube specimens for every weld box pump-down. After EB welding, the specimens were to be transported to a separate facility for pressurization and laser-seal welding of the fill hole on the top endcap. Recommended pressures for JOYO biaxial creep specimens are discussed in a separate document (Reference 2). Following laser-seal welding, the specimens were to undergo several inspections to ensure suitability for testing. A photograph of an un-welded specimen component set and a specimen that has been both EB and laser-seal welded is shown in Figure 4.

The NRPCT was to provide ten specimen sets (tube and two fitted endcaps) of each material for weld development and six specimen sets of each material for weld qualification. Weld development efforts were to include the optimization of EB and laser weld parameters. Each specimen was to undergo visual inspection followed by destructive evaluation to determine if the EB weld was centered on the endcap-to-tube interface and to confirm proper weld penetration for both EB and laser-seal welds. Based on these evaluations, adjustments to the weld parameters were to be made as needed.

Following weld development and optimization efforts, weld qualification was to involve EB welding, pressurization, and laser-seal welding of six specimens for each material, keeping all parameters constant for each of the six specimens. Each qualification specimen was to undergo visual inspection, radiography, a one-hour proof-test at temperature, helium leak testing, and destructive evaluation. A flow chart of the weld qualification process is shown in Figure 5. A material is successfully qualified if each of the six specimens passes all non-destructive evaluations and if the destructive evaluations reveal that proper weld penetration and placement was achieved for each specimen. PNNL was required to submit the weld qualification results to the NRPCT for formal approval.

Following NRPCT approval of weld development and qualification results, welding and pressurization of production specimens was to begin. The production specimen fabrication flow chart is shown in Figure 6. Inspection steps and special precautions are described below.

<u>Inspections</u>

The NRPCT planned several inspection steps to ensure that production biaxial creep specimens would be acceptable for in-pile and out-of-pile testing. The inspection steps for all specimens would include visual inspection, radiography, a one-hour proof-test at temperature, weight measurements, and helium leak testing. Destructive evaluations would also be performed on a limited number of specimens. Each inspection step is described below:

1. Visual inspections were to be performed by a PNNL quality engineer after EB welding. The goal of this inspection would be to determine whether the concavity of the EB weld at the endcap-to-tube interface was acceptable and to detect any other weld defects. Some concavity is expected due to the presence of a radiography groove in each endcap (discussed below in Step 2), which would be filled with weld material. The NRPCT specified a maximum concavity limit of 0.009" for each material based on a stress analysis of the weakest material, Haynes 230 (Attachment A).
2. Radiography was to be performed on each specimen to determine that sufficient weld penetration was achieved, and to ensure that the EB weld was centered on the interface between the endcap and tube. Because the EB welds are relatively small, the radiographic procedure was to be aided by the presence of a radiography groove. A small groove had been machined in each endcap as seen in Figure 2. During EB welding, this groove should fill completely with weld material. Radiography is used to determine if the groove has been successfully filled. Six images are taken of each specimen, with the specimens rotated 30° between each image. In each radiography image that is taken, un-welded specimens are included for comparison. This work was planned to be performed at COGEMA Engineering Corporation in Richland, WA.
3. A one-hour proof-test of the pressurized specimen was planned as an additional inspection step. This heat-treat was to be performed in vacuum at the same temperature that each specimen would experience during in-pile or out-of-pile testing to screen for major defects in the tube wall or weldments. If a failure occurred and helium leaked from the specimens, this could be detected by the weight measurements described below in Step 4.
4. Weight measurements of the specimens were to be taken at three different points during the inspection process: pre-pressurization, post-pressurization, and post-proof-test. A balance accurate to ±0.00001 grams

was to be used so that changes in weight due to helium loss could be detected. Measurements were to be taken before and after the one-hour proof-test to detect any weight change that would indicate a helium leak. The results of the weight measurements were to be reported to the NRPCT for evaluation.

5. Helium leak testing is another inspection step that was to be performed by COGEMA Engineering Corporation. The NRPCT had required that the helium leak rate not exceed 1 x 10^{-8} std cc/sec. However, after a meeting with COGEMA, it was learned that their equipment can detect helium leak rates of 1 x 10^{-11} std cc/sec. Any leak that was detected by COGEMA was to be reported to the NRPCT and any specimen with a detectable leak rate would have been considered unacceptable.
6. Destructive evaluations were to be performed to determine whether or not proper weld penetration had been achieved. For production biaxial creep specimens, one randomly selected specimen would have been destructively evaluated from each EB weld batch of 24 specimens of the same material. Both EB and laser-seal welds were to be evaluated. Photomicrographs were to be provided to the NRPCT in the final report.

Laser Measurements

To determine the creep properties of each material, diameter measurements were to be taken before and after in-pile or out-of-pile testing. The pre-test measurements were to be taken at PNNL using a laser micrometer measurement system provided by the NRPCT (Figure 7). The laser micrometer measurement system was made by BETA LaserMike (Dayton, OH) and included a Model 162-100 Single Axis Scanner, a Model 2020 Processor, a computer for data acquisition, and fixturing to hold the biaxial creep specimens during measurements. The fixtures for the refractory metal alloy specimens were made of molybdenum-TZM, while the fixtures for the superalloy specimens were made of standard tool steel.

Due to time constraints, dimensional measurements would have been taken only on production specimens. These measurements would have been taken at three separate points during the fabrication process: pre-pressurization, post-pressurization, and post-proof-test. Before measurements on production specimens were to be made, a series of standards was to be measured to determine if any correction would need to be made to the laser micrometer system. The standards were Class XX (0.00002" tolerance) gage pins from Meyer Gage (South Windsor, CT) and included a 0.250" pin (the nominal diameter of the creep specimens), as well as a series of gage pins that were incrementally (0.001") larger up to 0.260" and incrementally (0.001") smaller down to 0.248". After the initial series of standards were to have been measured, the 0.2500" gage pin was to be measured after every ten production specimens had been measured to ensure that the system remained accurate. Measurements for both gage pins and production specimens were to be taken at five evenly spaced axial locations (center – 0.4", center – 0.2", center, center + 0.2", center + 0.4"). At each axial location, there was to be a minimum of 180 measurements taken at 1° intervals. For each measurement, time, room temperature, fixture temperature, and humidity were to be recorded. All measurements were to be provided to the NRPCT in the final report, unless abnormalities were observed. In this case, the data would have been transmitted immediately to the NRPCT from PNNL.

Special Precautions for Refractory Metal Alloys

The welding of refractory metal alloys requires special precautions to ensure that contamination does not occur from weld fixtures or from the atmosphere within the welding rigs. The precautions include:

1. Refractory metal alloys and non-refractory metal alloys should not be welded in the same load. This precaution will prevent contamination of the refractory metal alloys with lower melting point elements that vaporize during welding and redeposit on cooler surfaces.
2. All fixtures in direct contact with the refractory metal alloys should be fabricated from a refractory metal or alloy. PNNL fabricated molybdenum "spuds" in order to hold the refractory metal alloy specimens in place during EB welding. This kept the refractory metal alloy specimens out of contact with the 24-specimen rotating fixture, which was fabricated from non-refractory metals.
3. The EB weld chamber should be evacuated to a minimum of 5×10^{-5} torr prior to welding. This will minimize contamination of the welds with trace levels of oxygen or nitrogen. Once the weld chamber has been evacuated, the vacuum pump should be turned off so that the leak rate can be measured. This will ensure that a small system leak is not present.
4. Laser-seal welding is performed in a high-purity helium environment. For this campaign, the NRPCT required a minimum helium purity level of 99.999%. The NRPCT also required that the weld chamber be evacuated and backfilled at least twice with helium prior to initiating laser-seal welding.

Heat treatments of refractory metal alloys also require special precautions to avoid contamination. These precautions include:

1. Refractory metal alloys should only be heat-treated in furnaces that employ heating elements constructed from refractory metals or refractory metal alloys.
2. Vacuum annealing over a short time period (1 hr or less) should be conducted in an atmosphere of 5×10^{-5} or better to prevent contamination from oxygen and nitrogen. Longer vacuum anneals of niobium and tantalum alloys require an even lower vacuum level to minimize oxygen and nitrogen contamination. The leak rate of the evacuated furnace should be determined prior to heating the furnace.
3. The individual refractory metal alloy specimens should be wrapped in refractory metal foil during the heat treatment to further prevent contamination.
4. Refractory metal alloys should not be heat-treated in the same furnace load as conventional nickel-base or iron-base alloys. It is also preferred that furnaces used for heat treatments of refractory metal alloys be used exclusively for refractory metal alloys if possible. If this is not possible, the furnace should be baked out prior to annealing any refractory metal alloy specimens in order to remove any low melting point constituents that may have vaporized and deposited on the furnace walls during previous heat

treatments of non-refractory alloys. This bake-out should be a minimum of two hours at a temperature that is 50 – 100 K higher than the highest heat treatment temperature.

Special Precautions for Superalloys

1. The Nimonic PE16 alloy should undergo a stress-relief heat treatment following EB welding. The treatment should be 2 hours at 800 °C followed by a forced cooling to 250 °C or below, and then 16 hours at 700 °C followed by a forced cooling to 250 °C or below. The heat treatment shall be in vacuum and the forced cooling should be achieved with inert gas and fan cool or equivalent to prevent any oxide formation on the specimens.
2. The superalloy specimens should be welded in a vacuum environment according to typical commercial practices in order to prevent oxygen and nitrogen contamination.

Special Precautions for both Refractory Metal Alloys and Superalloys

1. The small fill-hole in the top endcap that is used for biaxial creep specimen pressurization should be formed by drilling. Electro-discharge machining (EDM) should not be used to machine the hole because there is no way to remove the recast layer that is formed in the hole during the EDM process. This contamination would make it impossible to perform an acceptable laser weld to seal the hole.

Closeout Actions

At the time of the cancellation of NRPCT participation in Project Prometheus, EB and laser weld developments of FS-85, ASTAR-811C, Mo-47.5Re, Alloy 617, Haynes 230, and Nimonic PE16 were nearly complete. Weld qualification and production specimen fabrication had not yet been initiated. The NRPCT directed PNNL to close-out the biaxial creep specimen fabrication work by finishing weld development efforts that were in progress, and performing a limited weld demonstration using six specimens of each of the six alloys mentioned above. The weld demonstration was performed in lieu of weld qualification and included a demonstration of the EB and laser-seal welding parameters. The specimens were not pressurized prior to laser welding. The limited inspections on these specimens included visual, radiography, and metallography. There was no formal quality assurance oversight or documentation during the demonstration effort. The demonstration effort included completion of Data Sheets, Welding Procedure Sheets, and a Welding Procedure Record. The results of the weld demonstration are documented in a final report from PNNL (Attachment B). No production biaxial creep specimens were made.

Results and Discussion:

1. PNNL learned during the abbreviated weld demonstration program that the existing COGEMA facility for radiography would not be acceptable for specimens fabricated from the tantalum and niobium alloys. The current high frequency, 160 kV, x-ray system at the COGEMA facility does not provide enough power to achieve the necessary resolution for evaluation of the dense tantalum and niobium alloys. There is not enough shielding at

the current facility to increase the power of the source. COGEMA had previously performed radiography of tantalum and niobium alloys at a different location that had a 450 kV source and a lead-lined room for shielding. This facility is currently unused. However, PNNL has indicated that if radiography of tantalum and niobium production specimens had been required, access to the previous COGEMA location would have been feasible with proper administrative approvals by PNNL and COGEMA Engineering.

2. The initial specimen sets sent to PNNL by the NRPCT for weld development did not have acceptable dimensions. The endcaps and tubes were excessively rounded so that fit-up was not ideal. The machining vendor met the NRPCT drawing requirements for sharpness (0.005" max. radius), but PNNL required a more stringent sharpness requirement of a maximum 0.002" radius on the fit-up surfaces of the tubes and endcaps. The roundness of the specimens that had been sent to PNNL would result in too much weld concavity after EB welding. In order to solve the problem of specimen roundness, PNNL sharpened the tubes of specimens that had already been sent, and the NRPCT had the tubes and endcaps that had not yet been sent to PNNL sharpened to a 0.002" maximum radius.
3. During endcap fabrication by the NRPCT, it was learned that the chosen machining vendor for all materials except Haynes 230 [Vangura (Clairton, PA)] was not able to meet the drawing specifications for the radiography groove. The groove that Vangura machined was not as deep as specified by the NRPCT, and was also rounded instead of square. PNNL determined that they could still use this groove to evaluate EB weld penetration, but the weld process and inspection requirements would have to be changed. PNNL felt that they would need the groove to be completely filled with weld material, instead of the original plan of determining whether or not the corner of the square groove was eliminated during welding. The Haynes 230 endcaps were machined to the original specification.
4. The EB weld concavity requirement originally specified in this contract was a maximum of 0.003". This number was based on previous PNNL work with specimens having a significantly smaller wall thickness (0.008"). After preliminary weld development indicated that the 0.003-inch value may not be achievable, it was agreed that this requirement should be re-evaluated for the thicker (0.025") specimens being tested in this program. The NRPCT (Kundrat) performed a stress analysis on the weakest material, Haynes 230, using the highest intended pressurization level. Estimated stresses were calculated as a function of depth of concavity. The results documented in Attachment A indicated that the maximum concavity requirement could be increased significantly above the 0.003" original requirement. The NRPCT agreed on a new concavity limit of 0.009", which would still result in stress levels in the weldment being significantly smaller than the stresses in the bulk of the specimen. None of the EB-welded specimens had concavities in excess of 0.009".
5. Electron beam weld parameters were established for each of the six materials welded by PNNL. The weld parameters were formulated during weld development and confirmed during each six-specimen weld demonstration. Examples of typical EB weld metallography for tantalum-base and nickel-base alloys are seen in Figures 8 and 9, respectively. The

weld parameters used during the weld demonstration resulted in successful, acceptable EB welds for each material. These weld parameters are listed in Table 1 and are documented in Attachment B. The EB weld parameters developed in this campaign would be directly applicable to any future program using specimens of similar alloys and geometries, provided that a high power density EB welding machine and 24-specimen fixture were used.

6. PNNL reported minor difficulty in achieving a balance between adequate penetration and a relatively smooth weld surface finish for the FS-85 specimens. The weld parameters used caused excessive undercut at the weld edges on the outer surface, which could have jeopardized the integrity of the specimen. As a result, PNNL used a second, cosmetic EB weld pass using a less-focused beam. This second pass eliminated the undercut and provided a smooth, uniform weld-bead. An example of this can be seen in the photomicrograph in Figure 10, where the deeper penetration weld represents the first EB weld pass and the shallower penetration represents the second, cosmetic EB weld pass. The use of a cosmetic pass is acceptable for niobium and tantalum alloys due to the high weldability of these alloys. However, this method would not be acceptable for most molybdenum alloys due to the increased ductile-brittle transition temperature (DBTT) of welded metal which could result in cracking in the weld and base metal. A possible exception would be molybdenum alloys with high rhenium content.
7. Laser weld parameters were developed for each of the six materials. These parameters are listed in Table 2 and documented in Attachment B. However, the laser weld demonstration for each material was deemed unsuccessful since at least one specimen from each set of six was determined to be unacceptable. Specimens were rejected due to cracking (Figure 11), an undersized weld (Figure 12), or an incomplete weld (Figure 13). Undersized welds are considered to be those welds that were smaller than the wall thickness of the tube section. ASTAR-811C and FS-85 laser welds were rejected in metallographic examination due to undersized welds. The laser welds on T-111 and FS-85 specimens were rejected due to incomplete sealing. The laser welds for Haynes 230, Alloy 617, and Nimonic PE16 were rejected due to cracking. Unusual weld shapes were also seen during laser-seal welding. In past laser-seal weld campaigns on biaxial creep specimens at PNNL, the laser weld typically resulted in a convex bead at the protruding pressurization hole. Laser welding of the NRPCT specimens resulted in a variety of shapes from convex to flat (Figures 14 and 15). The shape of the weld does not necessarily cause the weld to be rejected, but the inconsistency suggests that there are problems with either the weld parameters or prior processing of the specimens. PNNL discussed two possible causes for the laser weld inconsistencies. One cause may have been inadequate cleaning of the endcap pressurization holes. Many as-machined endcaps had tight fit-ups to tubes and as a result, these endcaps were not pickled as much as others. Machining residue and/or surface oxides may have been present inside the pressurization holes and this could have changed the surface energy, resulting in reduced flow characteristics of the metal. Another possible cause for the problems could have been oversized pressurization holes. Many of the holes appeared to have been drilled to the extreme

upper end of the dimensional tolerance and also appeared to have been drilled off-center. The large size of the holes could have caused much of the laser energy to pass through the hole, thus reducing the energy input and causing undersized and incomplete welds. Cracking in the superalloy specimens could have been due to high shrinkage stresses as a result of the excessive power required to melt the surrounding metal of the oversize fill hole. In the future, further development would need to be performed to develop acceptable laser weld parameters for all six alloys.

Conclusions: PNNL successfully developed electron beam weld parameters for FS-85, ASTAR-811C, T-111, Alloy 617, Haynes 230, and Nimonic PE16 materials prior to the termination of the Naval Reactors program effort to deliver a space reactor for Project Prometheus. Early termination of the NR space program precluded the development of laser welding parameters for post-pressurization seal weldments.

Significance to the NR Program: The production biaxial creep specimens that were to be fabricated at PNNL would have been used to evaluate the irradiated and un-irradiated creep properties of candidate Prometheus space reactor cladding and structural materials. The technology that was developed during this specimen fabrication campaign could potentially be applied to future NR program biaxial creep studies.

Future Action: Due to the termination of the NR program effort to deliver a space reactor for the Prometheus Project, no production biaxial creep specimens will be fabricated for this test campaign. The unused specimen components, including tubes and endcaps, will be retained at Bettis for potential future use. The laser micrometer that was purchased for this program was shipped to the NASA-Marshall Space Flight Center (Huntsville, AL).

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References:

1. R. F. Luther and M. E. Petrichek, B-MT(SRME)-51, "Basic Processing Methods of T-111, Ta-10W, FS-85, Mo-47.5Re, and ASTAR-811C Sample Production," to be issued.
2. E. V. Mader and T. Angeliu, B-MT(SRME)-39, "Recommended Stress and Strain Levels for Biaxial Creep Specimens in the JOYO-1 Test Matrix," dated November 18, 2005.

Attachments:

A. Concavity Analysis
B. "Biaxial Creep Specimen Electron Beam and Laser Seal Welding Demonstration Report," PNNL-15537, dated December, 2005.
C. "Radiograph Examination Procedure," COGEMA-SVRT-PRC-006 Rev. 2, dated November 14, 2003.
D. "Qualification Test Plan for Biaxial Creep Specimen Electron Beam and Laser Seal Welding", SRM-PLAN-005, dated August, 2005.
E. "Manufacturing and Quality Plan for Fabrication of Biaxial Creep Specimens," SRM-PLAN-004 dated August, 2005.

Table 1. EB Weld Parameters

Material	Voltage (kV)	Beam Current (ma)	Beam Focus from Work Surface (in.)	Weld Speed (sec/rev)	Weld Time Set Cycle (sec.)
Haynes 230	100	1.7	0	1	2
Alloy 617	100	1.7	0	1	2
Nimonic PE16	100	1.7	0	1	2
FS-85	110	4.5	Over 30	2	3.5
ASTAR-811C	100	4.5	0	2	3.5
T-111	100	4.5	0	2	3.5

Table 2. Laser Weld Parameters

Material	Aperture	Attenuator	Monitor Volts	Focus Lens (in.)	Voltage (Volts)	Spot Size (in.)
Haynes 230	100	0	85-87	6	2.5	0.747
Alloy 617	100	0	85-87	6	2.5	0.747
Nimonic PE16	100	0	85-87	6	2.5	0.747
FS-85	100	0	194-197	6	3.6	0.747
ASTAR-811C	100	0	194-197	6	3.6	0.747
T-111	100	0	194-197	6	3.6	0.747

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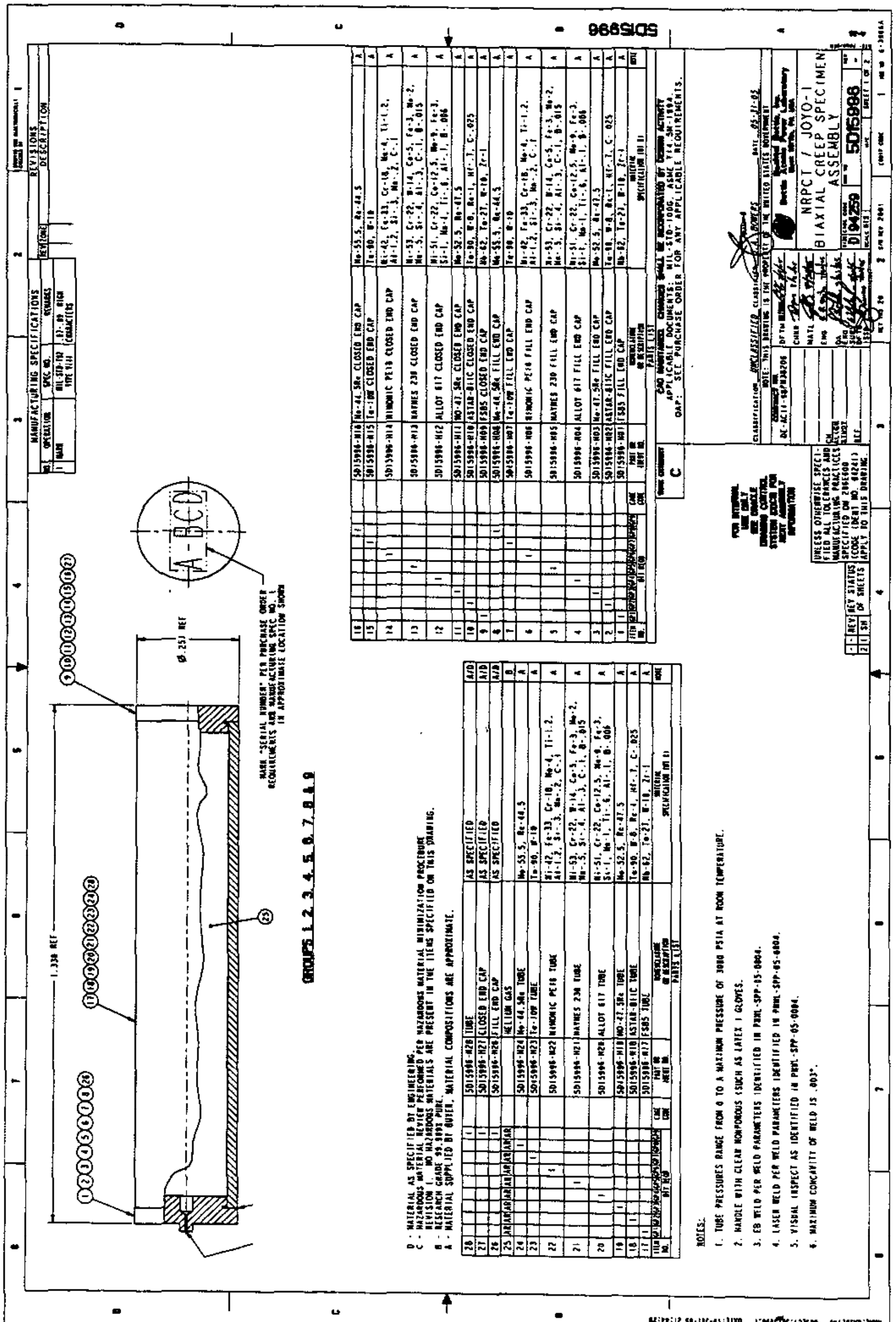


Figure 1. Biaxial Creep Specimen Assembly Drawing (1 of 2)

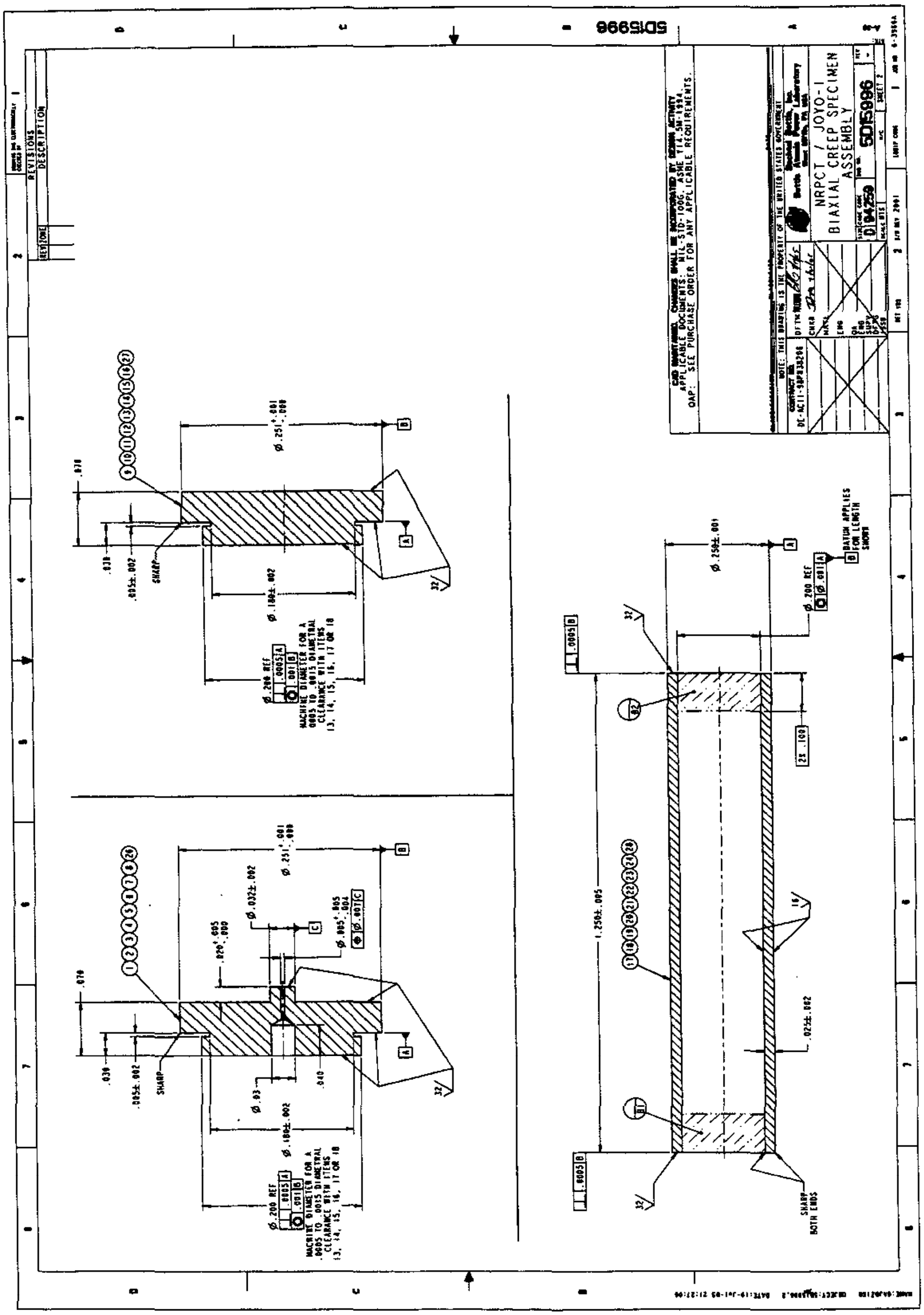


Figure 2. Biaxial Creep Specimen Assembly Drawing (2 of 2)

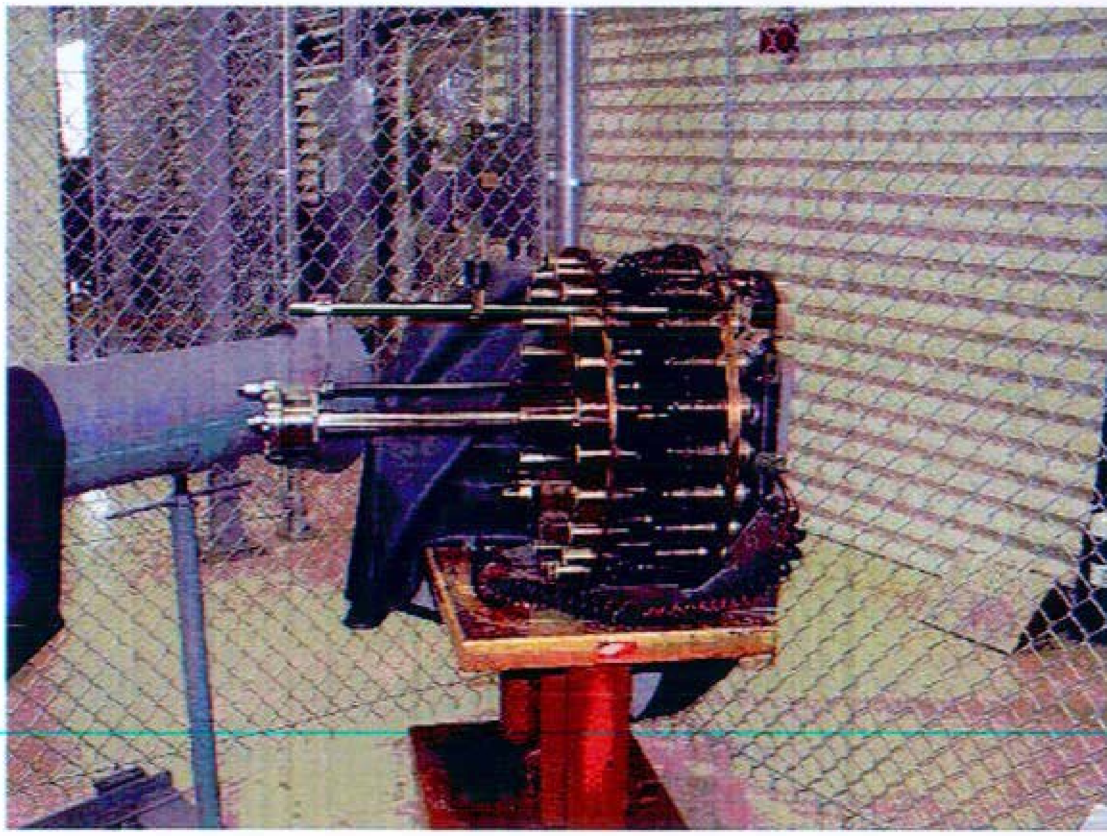


Figure 3. Twenty-four specimen, rotating EB welding fixture

Figure 4. Example of an un-welded specimen component set (top) and a specimen that has been EB and laser-seal welded (bottom). For both specimens, the top endcap is on the left of the tube and the bottom endcap is on the right.

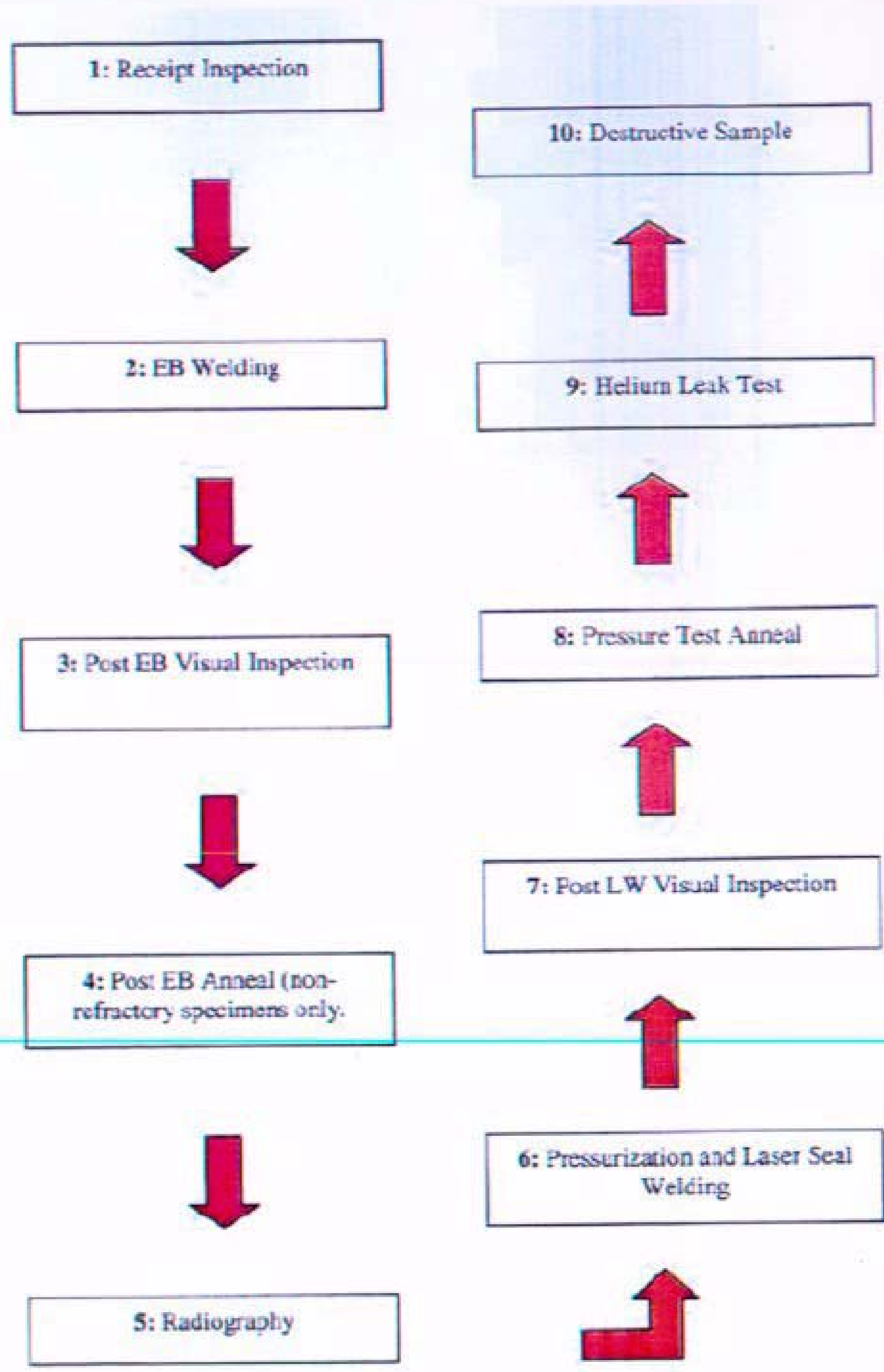


Figure 5. Biaxial Creep Specimen Fabrication Flowchart for Weld Qualification

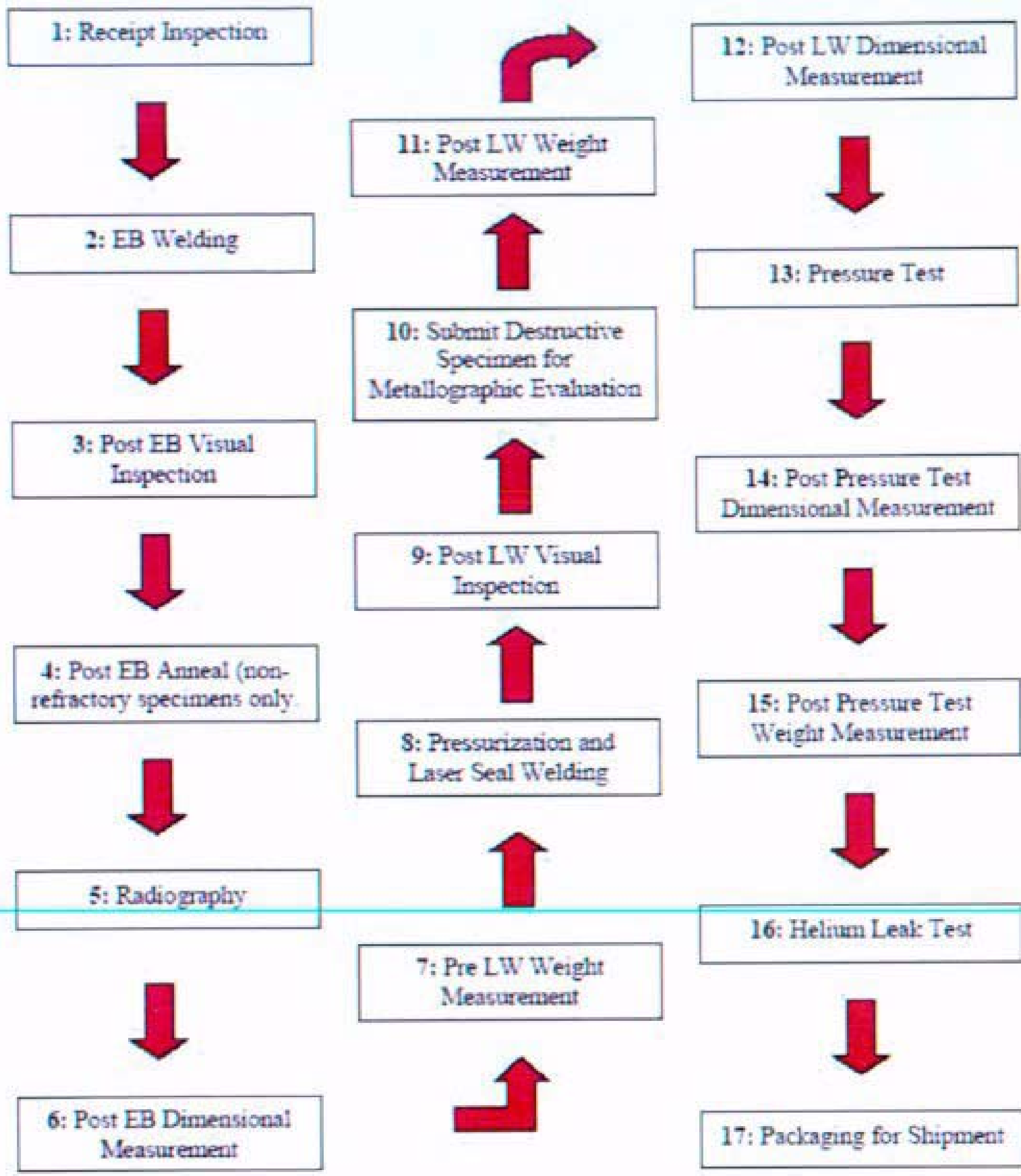


Figure 6. Production Biaxial Creep Specimen Fabrication Flowchart

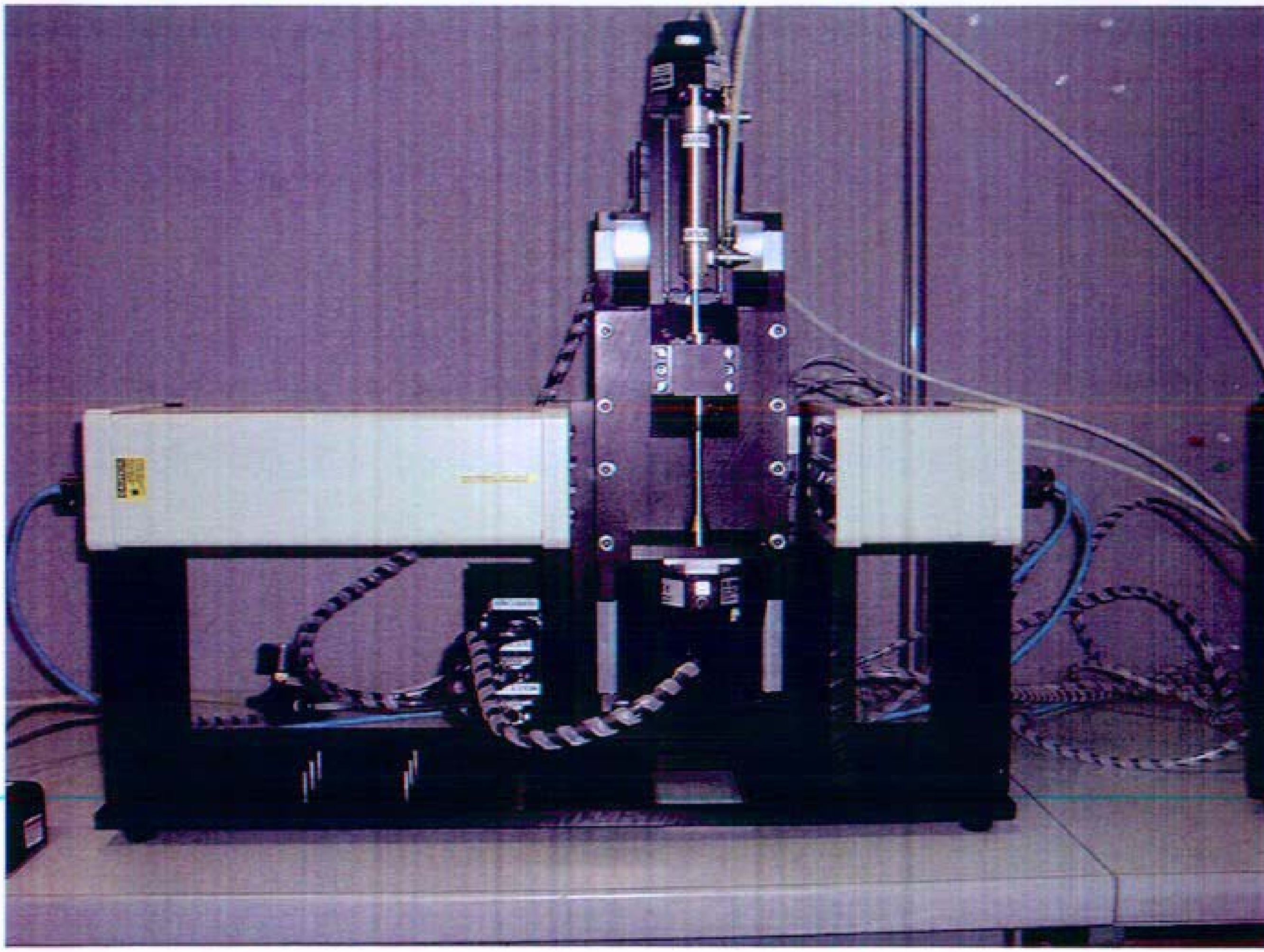


Figure 7. Laser micrometer scanner assembly

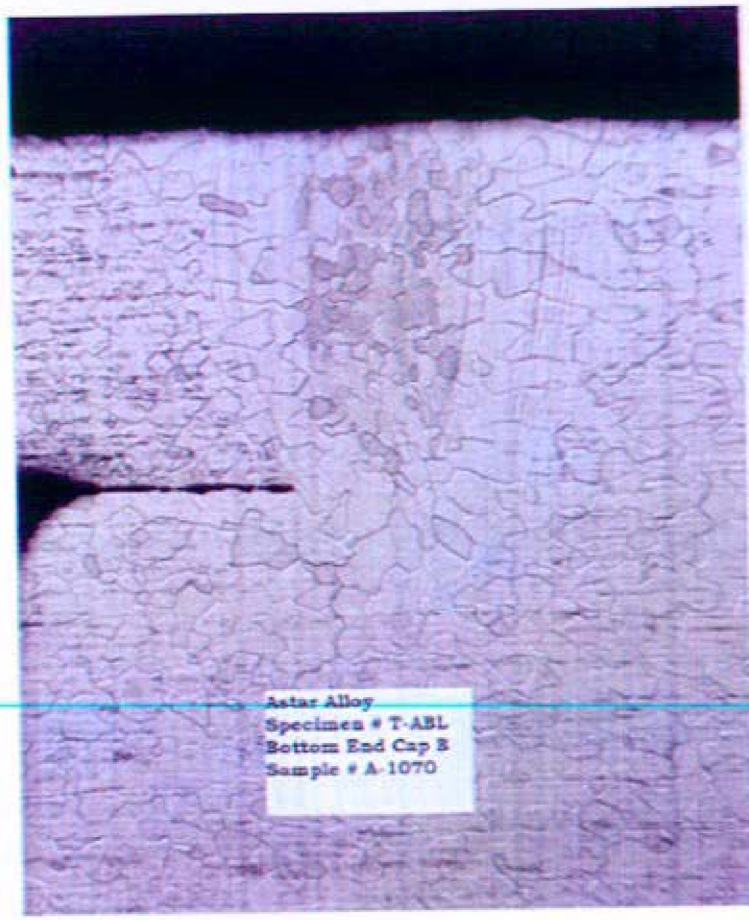


Figure 8. Electron beam weld of ASTAR-811C (60x)

Figure 9. Electron beam weld of Haynes 230 (60x)

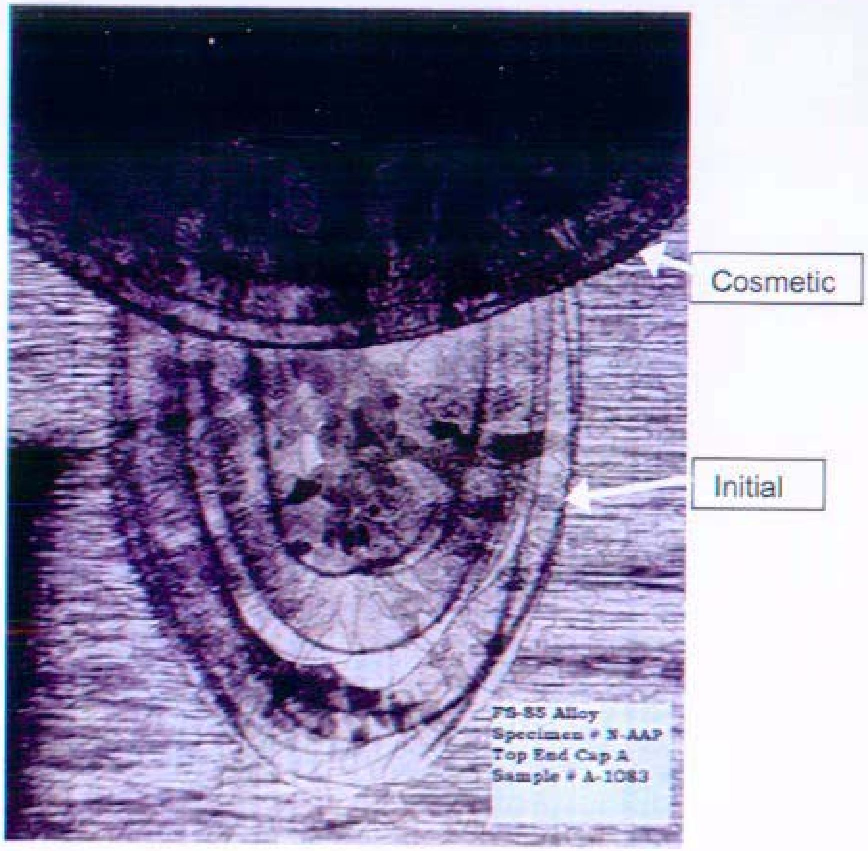


Figure 10. Initial and cosmetic electron beam weld passes of FS-85 (80x)

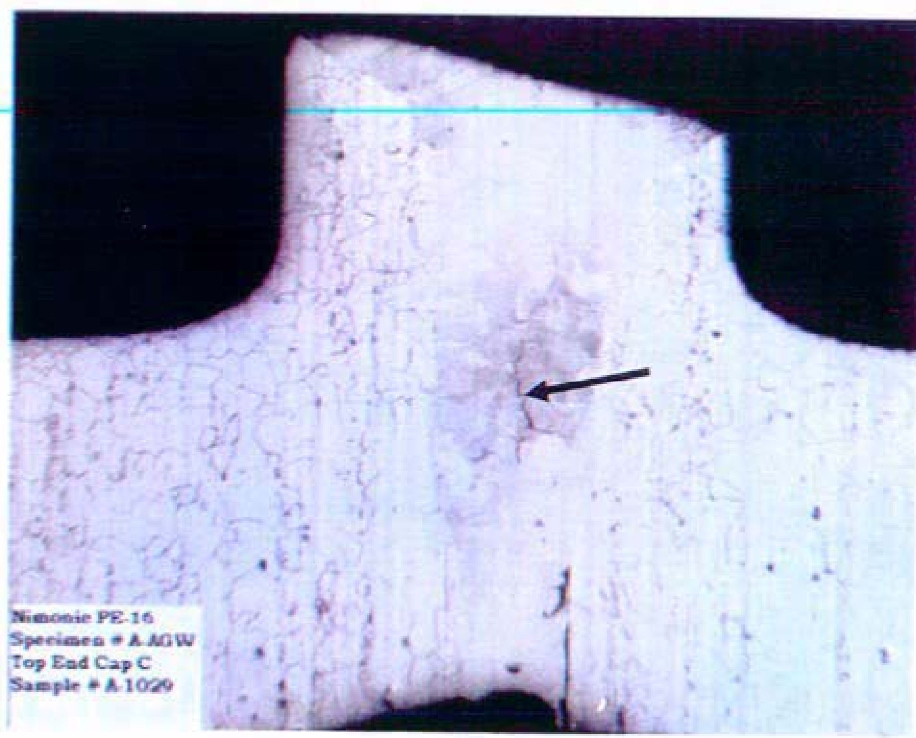


Figure 11. Cracking in Nimonic PE-16 laser weld (70x)

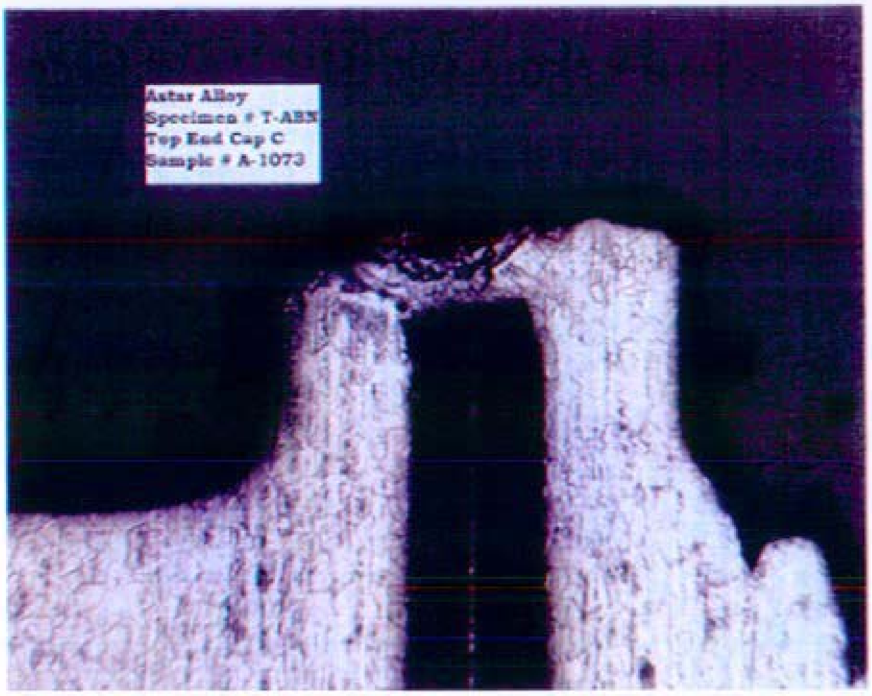


Figure 12. Undersize laser weld in ASTAR-811C (70x)

Figure 13. Incomplete laser weld in T-111 (70x)

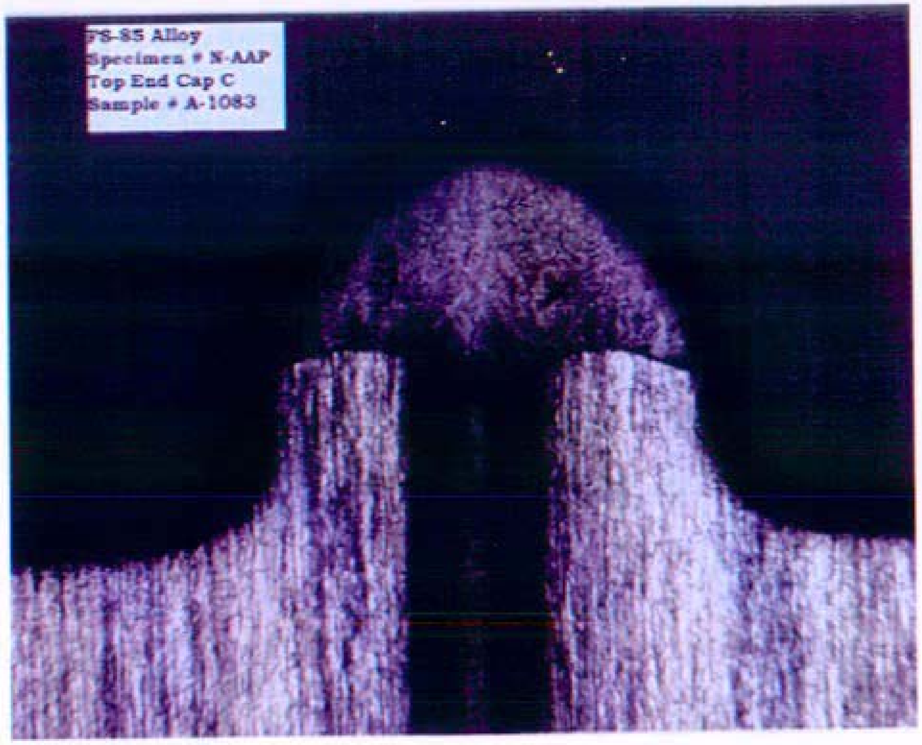


Figure 14. Typical convex laser weld shape in FS-85 (70x)

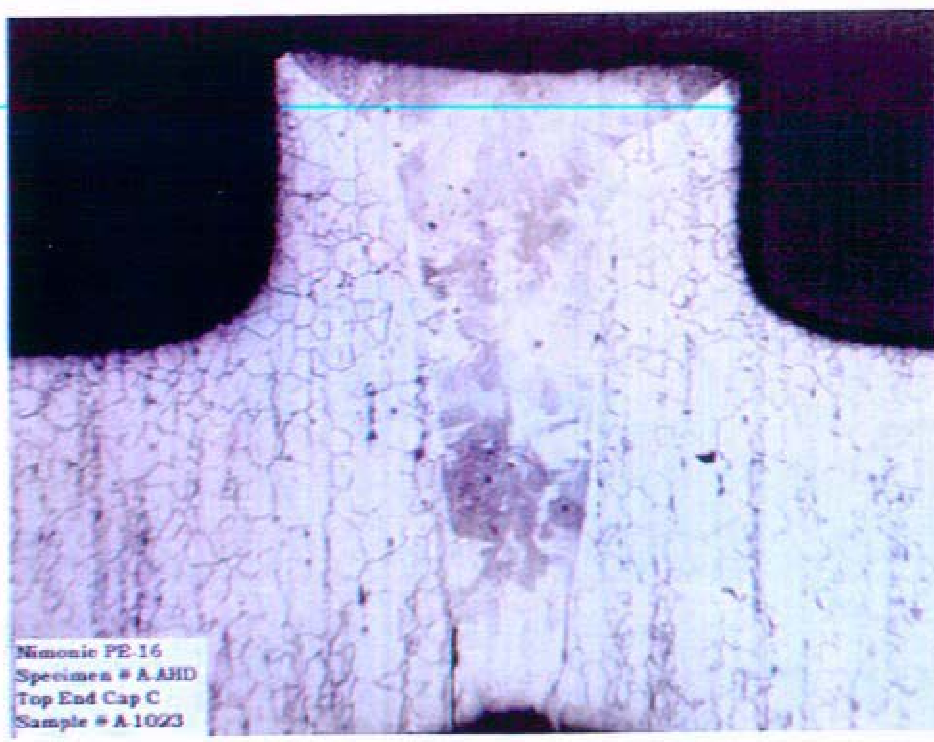


Figure 15. Flat laser weld shape in Nimonic PE-16 (70x)

Attachment A

Concavity Analysis

Table 1. Biaxial Creep Specimen Von Mises Stresses for Increasing Weld Concavity
Stresses in MPa

Position	Reference	3 mil	6 mil	9 mil	12 mil
Weld1	59.6	68.3	79.0	93.6	114.5
Weld2	105.1	104.1	103.8	103.1	102.5
Base	133.9	133.8	133.4	133.1	132.9

Table 2. Biaxial Creep Specimen Radial Displacements for Increasing Weld Concavity
Deflections in inches

Position	Reference	3 mil	6 mil	9 mil	12 mil
Weld1	0.00101	0.00098	0.00096	0.00093	0.00091
Weld2	0.00101	0.00101	0.00101	0.00101	0.00101
Base	0.00104	0.00104	0.00104	0.00104	0.00104

Conditions corresponding to above analyses (bold indicates differences relative to original analysis):

8325 psi internal pressure
1071F uniform temperature
Haynes 230 material of construction
reported stesses: linearized equivalent membrane stresses
weld depression width held constant at **0.020** inches
weld residual stresses assumed to be relieved
axisymmetric model
square notch modeled at interface between cap and wall in backing region (evident in Figure 1)
notch assumed to be partially consumed during weld process; resulting axial gap length reduced to 0.020 inches as measured from cap bottom
fill plug weld assumed to produce flat top
weld concavity considered at upper joint only
wall membrane stresses not reported; no variation from previous analysis

Figure 1. Biaxial Creep Specimen Stress Linearization Cut Lines

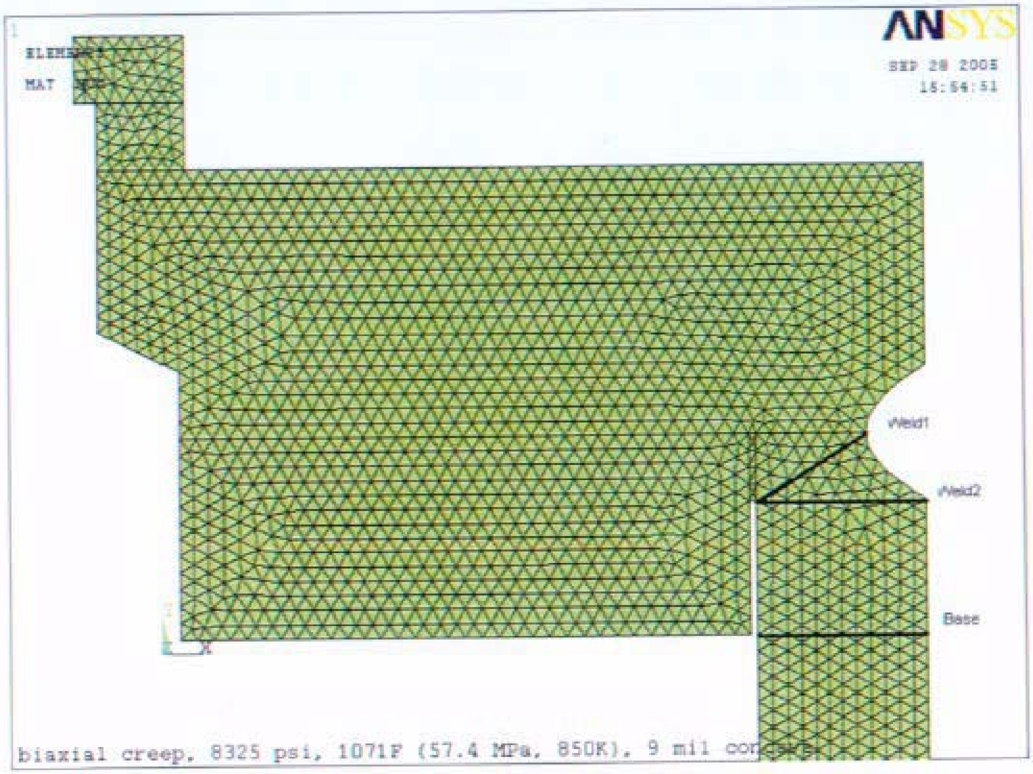


Figure 2. Biaxial Creep Specimen Reference Geometry Von Mises Stresses

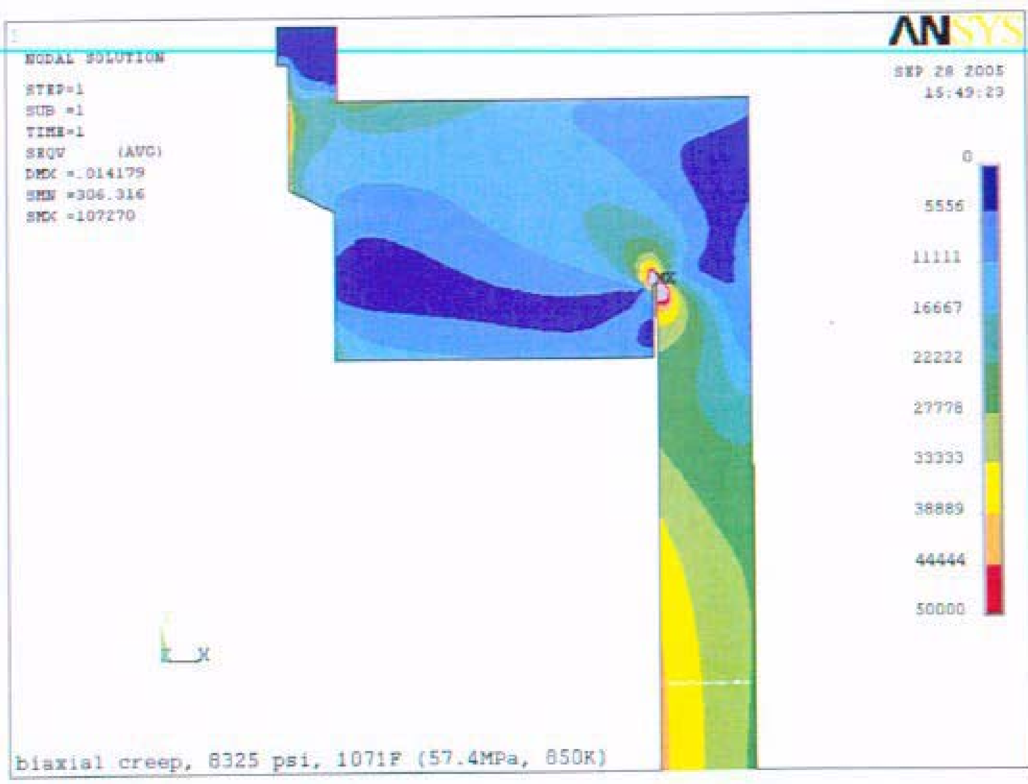
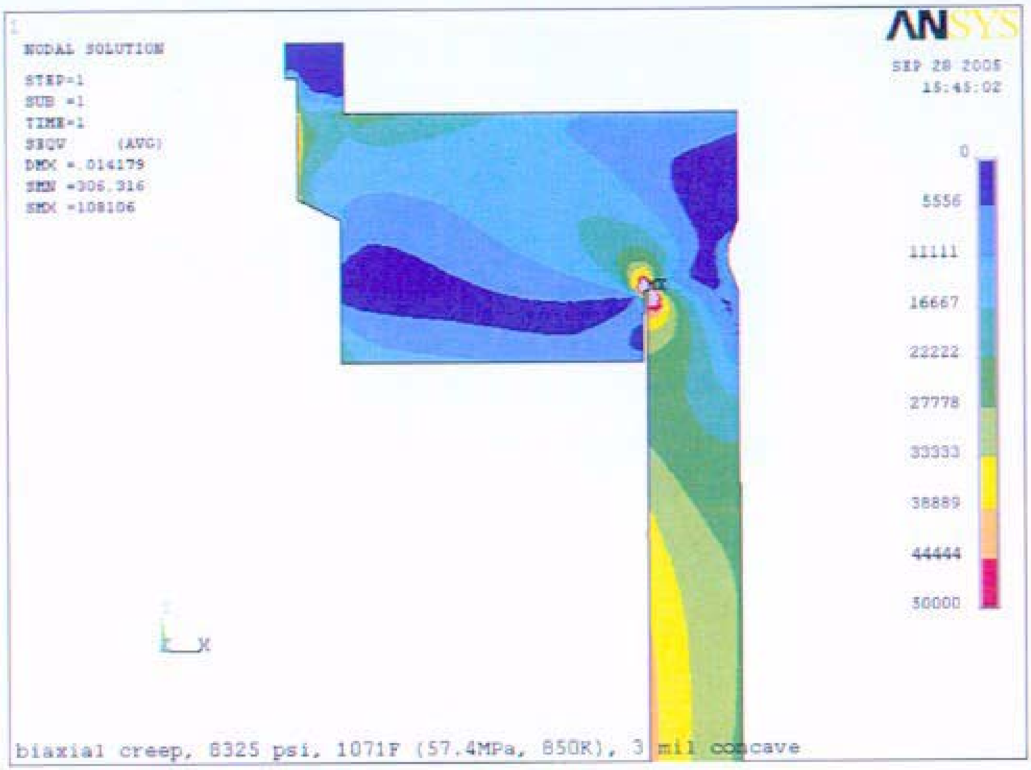


Figure 3. Biaxial Creep Specimen Von Mises Stresses Corresponding to 3 mil and 6 mils of Weld Concavity



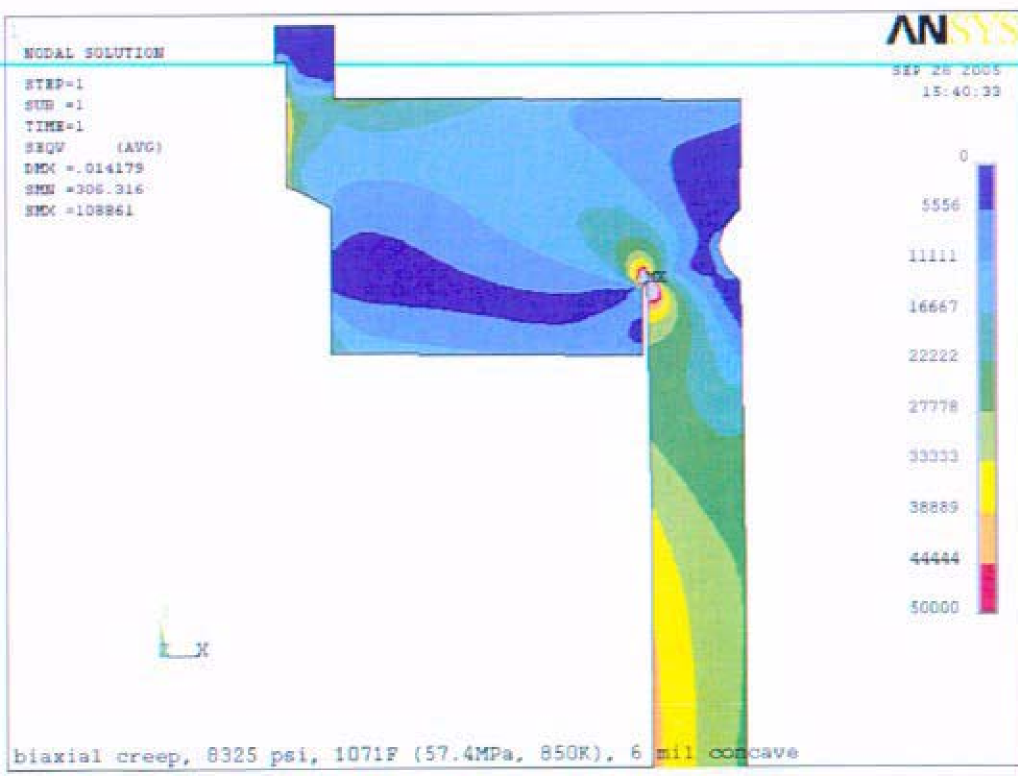
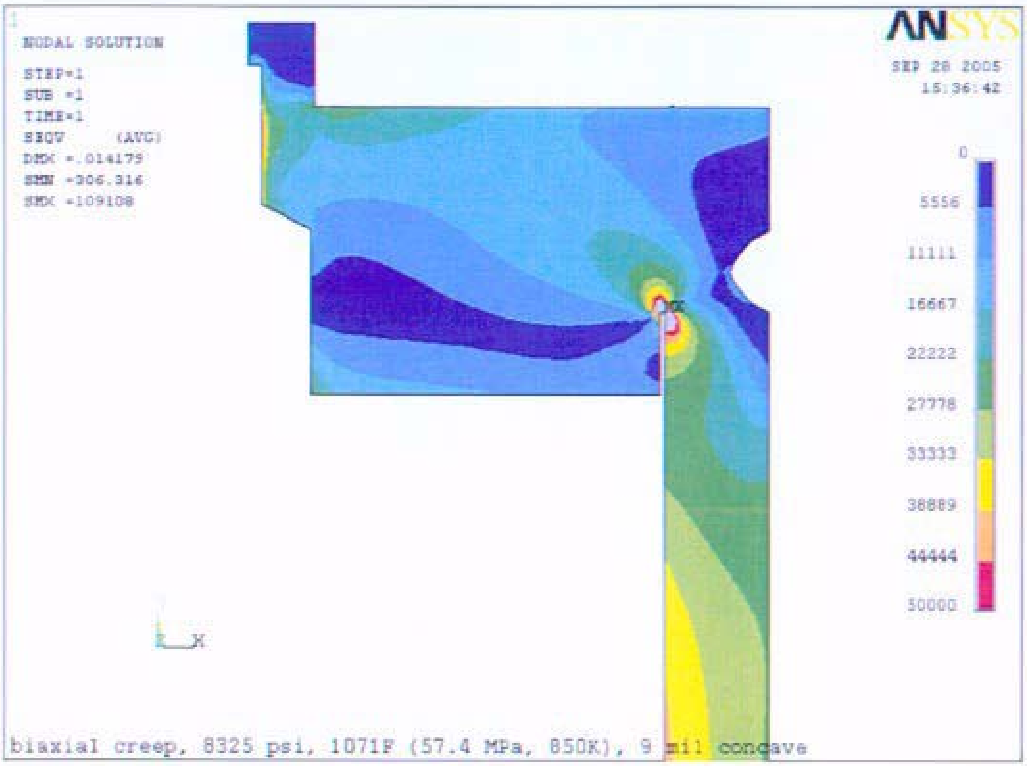
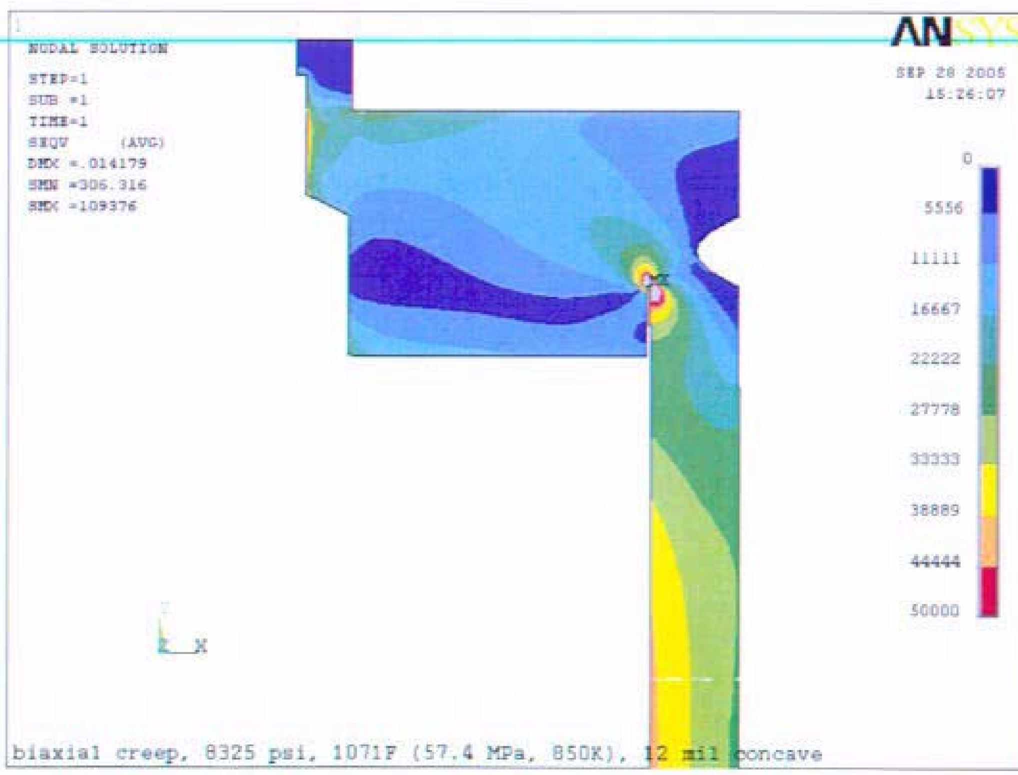


Figure 4. Biaxial Creep Specimen Von Mises Stresses Corresponding to 9 and 12 mils of Weld Concavity





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Attachment B

Biaxial Creep Specimen Electron Beam and Laser Seal Welding Demonstration Report

PNNL-15537

Pacific Northwest
National Laboratory
Operated by Battelle for the
U.S. Department of Energy

December 9, 2005

KAPL Inc.
Attn: Steve Hayden (M/S 111)
P.O. Box 1072
Schenectady, NY 12301

Dear Mr. Hayden:

TRANSMITTAL OF BIAXIAL CREEP SPECIMEN ELECTRON BEAM AND LASER SEAL WELDING DEMONSTRATION TEST REPORT

Enclosed is PNNL-15537 Rev.0, *Biaxial Creep Specimen Electron Beam and Laser Seal Welding Demonstration Test Report.* The NRPCT provided comments to a draft version of this document in the Information-to-Vendor (IV): *Biaxial Creep Specimen Fabrication,* PNNL-SPP-05-0004 Revision 6, dated November 30, 2005. All comments have been incorporated and/or resolved in Rev. 0 of PNNL-15537.

This submittal satisfies the final deliverable defined in Revision 5 of IV PNNL-SPP-05-0004. In addition, PNNL certifies herein that all work was performed as requested in the IV and that the unused parts and metallographic mounts were shipped to Ms. Jessica Bump at Bettis Atomic Power Laboratory on December 8, 2005. A radiological survey of the parts and mounts was completed and a copy of that survey was provided with the hardware.

Once all the PNNL records associated with this work have been submitted to project records the work packages associated with the biaxial creep work will be closed and no further charges will be incurred by the project. It is anticipated that this will be completed by the end of December.

If you have any questions, please contact Dean Paxton at (509) 375-2620.

Sincerely,

MC Stephens for

Chad Painter
Project Manager
Space Reactor Materials Irradiation Testing Project

cc: Jessica Bump, BAPL
Dean Paxton, PNNL
Ken Buxton, PNNL
05-017

902 Battelle Boulevard • P.O. Box 999 • Richland, WA 99352

Telephone (509) 372-4112 ■ Email chad.painter@pnl.gov ■ Fax (509) 372-6421

Space Reactor Materials (SRM) Irradiation Testing Project

Biaxial Creep Specimen Electron Beam and Laser Seal Welding Demonstration Report

PNNL-15537

Revision No. 0

Issue Date: December 2005

Client: Knolls Atomic Power Laboratory

Project No: 48552

Prepared By:	SRM Weld Engineer	12/8/05 Date
Reviewed By:	SRM Biaxial Creep Task Manager	12/7/05 Date
Approved By:	SRM Project Manager	12/7/05 Date
Review By:	SRM Authorized Derivative Classifier	8 Dec 05 Date

1.0 INTRODUCTION

PNNL developed welding parameters for electron beam (EB) welding and laser beam welding processes to support fabrication of biaxial creep specimens intended for irradiation in the JOYO experimental fast reactor in Japan. A plan, *Qualification Test Plan for Biaxial Creep Specimen Electron Beam and Laser Seal Welding* (SRM-PLAN-003 Rev.0), was prepared and issued in July 2005. Based on direction from the Naval Reactors Prime Contractor Team (NRPCT), the qualification plan was modified in September 2005, due to cancellation of Project Prometheus by NASA, to limit the qualification effort to a weld demonstration focused on verifying electron beam and laser seal weld parameters (with no pressure retention). The demonstration includes limited inspections consisting of visual, radiography, and metallography. The demonstration effort was performed with no formal quality assurance oversight or documentation. The modified scope included completion of Data Sheets, Welding Procedure Sheets, and a Welding Procedure Record. This report summarizes the results of the limited weld demonstration effort and reports the weld parameters developed for the various alloys as well as the inspection results.

2.0 DESIGN SPECIFICATIONS AND DRAWINGS

The documents listed below describe the scope of work and technical requirements applicable to the fabrication of biaxial creep pressurized tube specimens.

2.1. KAPL, Inc. Information-to-Vendor, *Biaxial Creep Specimen Fabrication*, PNNL-SPP-05-0004

2.2. RDT Standard, *Welding of Reactor Core Components and Test Assemblies*, RDT (NE) F 6-2T, dated July 1973 and PNNL exceptions to application of standard

2.3. Pacific Northwest National Laboratory, Space Reactor Materials (SRM) Irradiation Testing Project Quality Assurance Plan, SRM-PLAN-002

2.4. Bechtel Bettis Inc. Drawing, *Biaxial Creep Specimen Straight Wall*, SK-DPM1060997

2.5. Bechtel Bettis, Inc. Drawing, Biaxial Creep Specimen Inspection Groove Bottom End Cap, SK-DPM1051705

2.6. Bechtel Bettis, Inc. Drawing, Biaxial Creep Specimen Inspection Groove Top End Cap/Protrusion, SK-DPM3051705

2.7. Bechtel Bettis, Inc. Drawing, NRPCT / JOYO-1 Biaxial Creep Specimen Assembly, 5D15996

3.0 RESULTS OF WELD DEVELOPMENT AND DEMONSTRATION

The following welding processes and inspections were performed on six specimens from each alloy of interest which included Haynes 230, Alloy 617, Nimonic PE16, ASTAR-811C, T-111 and FS-85. The wall of each tube section was drilled through so that when seal-welded the specimen did not retain any pressure. As requested, the Nimonic PE16 specimens were heat treated following electron beam welding, but before radiographic inspection. Each step in the weld demonstration sequence for a single alloy was documented on the *WELDING PROCEDURE DEMONSTRATION RECORD* form along with the individual specimen identification numbers. This demonstration record is included in the data packages which are organized by alloy type and included as Attachments 1-6 to this report.

3.1. Electron Beam Welding Parameters

Electron beam welding was used to attach endcaps onto each end of tube sections. The welding parameters for this demonstration were established based on previous welding experience and confirmed during weld development trials. For the purposes of this welding demonstration, six consecutive specimens were welded with no adjustment of the welding parameters, which are included in the alloy data packages. Based on prior experience with this configuration, the electron beam position in the endcap-tube joint was offset towards the tube by 0.002 in. during welding to facilitate filling of the radiography groove and to manage the heat balance. In addition, the selection of a DC spot size was used to provide the deepest weld penetration with the minimum width. However, a circle beam (5 divisions) was needed to soften the beam to improve the surface condition when welding the FS-85 specimens. The surface condition of this alloy was considerably rougher than the other alloys welded with the DC spot.

Following the initial welding of the six FS-85 specimens, visual inspection revealed excessive undercut which could have jeopardized the integrity of the capsule and caused rejection. The weld engineer directed the welding operator to apply a cosmetic pass to eliminate the undercut and provide a smooth uniform weld bead. Applying a cosmetic weld pass is a common practice to improve weld surface irregularities with the electron beam process. For future welding of FS-85 specimens with similar surface condition, further development could be performed to eliminate the need for a cosmetic pass, if desired.

3.2 Visual Examination of Electron Beam Welds

Weld inspection was performed in accordance with the *Qualification Test Plan for Biaxial Creep Specimen Electron Beam Welding and Laser Beam Welding, Attachment 9: Visual Examination Requirements for Electron Beam and Laser Beam Welding.* The twelve electron beam end closure welds (one top and one bottom) for each alloy type met the specified visual inspection criteria and were considered acceptable. A cosmetic weld pass was applied to the FS-85 closure welds to eliminate excessive undercut that would have been cause for rejection. The modification to the welding parameters was documented in the weld record as a part of the welding procedure specification.

3.3 Heat Treatment of Nimonic PE16 Alloy

Six PE16 specimens were heat treated following electron beam welding. The heat treatment was done in 338 Building, using a Thermal Technology vacuum furnace with molybdenum heating elements. The specimens were cleaned in alcohol and wrapped in molybdenum foil. This foil package was held on a stainless steel support so the specimens would be in the hot zone of the furnace. The following heat treatment was used:

1. Pump down to ~1×10^{-6} torr.
2. Heat to 800°C, hold for 2 hours
3. Backfill with argon to ambient pressure
4. Cool to < 250°C
5. Heat to 700°C, hold for 16 hours.
6. Backfill with argon to ambient pressure
7. Cool to room temperature

The first heating cycle (800°C) was completed on October 21, 2005 and the second heating cycle (700°C) was completed on October 22, 2005. Vacuum was generally in the 10^{-6} torr range, and the highest pressure (1.5×10^{-5} torr) occurred as the temperature reached 800°C. The foil package was clean and free of any evidence of oxidation, and the specimens also appeared to be clean and shiny. No problems were encountered in the heat treatment.

3.4 Radiographic Examination

The nickel-base alloy specimens were radiographed by Cogema Engineering (a subsidiary of Areva) under subcontract to PNNL for inspection services. These specimens were inspected using a high-frequency 160kV Philips x-ray system and were considered acceptable. The documentation of this inspection is included in the data packages for the three nickel-base alloy specimens in attachments 1-3 of the report. Unfortunately, Cogema Engineering was unable to radiograph the refractory alloy specimens. In the past, Cogema staff has radiographed high-density materials, including refractory alloy biaxial creep pressurized tube specimens, but at another Department of Energy facility (306E Building) located in the 300 area on the Hanford Site that included a shielded vault for use of a higher penetrating 450kV x-ray system. This higher power system is not available in the current Cogema Engineering inspection services location due to inadequate shielding. A letter from Cogema Engineering describing the radiography situation is included in each data package for the refractory alloys, which are included as attachments 4-6 of this report. In the event that radiography of Ta and Nb specimens had been required during specimen production, access to the 306E building would have been feasible for a limited time with proper administrative approvals by PNNL and Cogema Engineering.

3.5 Laser Seal Welding Parameters

Laser seal welding was used to close the gas fill hole in the top endcap of each specimen. The parameters for this demonstration were established based on previous welding experience and confirmed during weld development trials. For the purposes of this welding demonstration, six consecutive specimens were welded with no adjustment of the welding parameters, which are documented for each alloy in Attachments 1-6.

3.6 Visual Examination of Laser Seal Welds

Weld inspection was performed in accordance with the *Qualification Test Plan for Biaxial Creep Specimen Electron Beam Welding and Laser Beam Welding, Attachment 9: Visual Examination Requirements for Electron Beam and Laser Beam Welding*. The laser beam vent closure welds for five of the six alloy types met the specified visual inspection criteria and were considered acceptable. The T-111 laser beam vent closure welds were rejected due to incomplete weld. However, for all alloys the weld bead contour and surface condition varied extensively. The normally bright convex bead was present on fewer than half of the welded specimens. This may have been due to inconsistent cleaning of the top end caps. It is critical that the vent hole be free of machining fluids, oxides and general debris. The majority of the vent closure welds appeared flat with a dull textured surface; however, nothing in the appearance of these welds was cause for rejection. The soundness of the weld was determined during metallographic examination.

3.7 Metallographic Examination

The twelve Electron Beam end closure welds (one top and one bottom) for ASTAR-811C, T-111, FS-85, Haynes 230, Alloy 617, and Nimonic PE16 met the specified metallographic examination criteria and were considered acceptable. The specimen numbers in Attachments 1-6 refer to the engraved identification on the endcap for the pressurized tube assembly, whereas the sample numbers were assigned to each metallography sample (top endcap + laser seal weld, bottom endcap) for internal reference at PNNL. As printed in the attachments, the electron beam photomicrographs are at ~60X magnification, except for the FS-85 specimens which are at ~80X magnification. All of the laser seal weld photomicrographs are printed at ~70X magnification. The laser beam vent closure welds on ASTAR-811C and FS-85 were rejected in metallographic examination due to undersize welds as described in Table 1. For this joint configuration, undersize welds were considered to be those welds that were smaller than the wall thickness of the tube section, i.e. the minimum leak path. The laser beam vent closure welds on T-111 and FS-85 alloy specimens were rejected due to incomplete welds that did not

Table 1. Summary of Laser Seal Weld Metallography and Disposition

Alloy	Sample #	Disposition	Rejection Criteria
Nimonic PE16	A-1019	Reject	Cracking
	A-1021	Reject	Cracking
	A-1023	Acceptable	N/A
	A-1025	Acceptable	N/A
	A-1027	Acceptable	N/A
	A-1029	Reject	Cracking
Alloy 617	A-1031	Reject	Cracking
	A-1033	Acceptable	N/A
	A-1035	Reject	Cracking
	A-1037	Reject	Cracking
	A-1039	Acceptable	N/A
	A-1041	Acceptable	N/A
Haynes 230	A-1043	Acceptable	N/A
	A-1045	Acceptable	N/A
	A-1047	Reject	Undersize Weld
	A-1049	Reject	Undersize Weld
	A-1051	Reject	Cracking
	A-1053	Reject	Undersize Weld
T-111	A-1055	Reject	Incomplete Weld
	A-1057	Acceptable	N/A
	A-1059	Acceptable	N/A
	A-1061	Reject	Undersize Weld
	A-1063	Acceptable	N/A
	A-1065	Acceptable	N/A
ASTAR-811C	A-1067	Acceptable	N/A
	A-1069	Acceptable	N/A
	A-1071	Acceptable	N/A
	A-1073	Reject	Undersize Weld
	A-1075	Reject	Undersize Weld
	A-1077	Acceptable	N/A
FS-85	A-1079	Reject	Undersize Weld
	A-1081	Reject	Undersize Weld
	A-1083	Acceptable	N/A
	A-1085	Reject	Undersize Weld
	A-1087	Acceptable	N/A
	A-1089	Reject	Incomplete Weld

close the capsule and left the vent hole open. The laser beam vent closure welds on Haynes 230, Alloy 617, and Nimonic PE16 were rejected due to cracking. Further evaluation could determine whether the observed cracks in the Ni-base alloy laser welds would adversely affect performance.

Inadequate cleaning reduces the flow characteristics of the metal. Contamination of any kind will affect the flow characteristics of metals during welding. Contamination can be located on the metal's surface or within the metal. Oxides that readily form on metals act as a barrier inhibiting the ability of molten weld metal to wet or flow. Some welding processes use flux or alternating current to reduce oxides and scavenge impurities from the molten weld metal. Electron beam and laser beam welding rely on the weld chamber vacuum quality, purity of the base metal, and cleanliness of the surface to control weld quality as flux is not suitable for these processes. Impurities within the metal can produce gases that can affect weld quality generally by the formation of porosity. The rapidity of the laser beam weld cycle makes it particularly sensitive to any contamination.

It was noted during metallographic examination that the vent holes were drilled to the extreme upper end of the dimensional tolerance with many drilled off center. The oversize hole causes much of the laser energy to pass through the hole reducing the weld size. The large weld size in the nickel-base alloys may be responsible for the observed cracks. This is due to the large hole diameter. Excessive power is required to melt the surrounding metal and fill the hole. High shrinkage stresses are developed as the weld metal solidifies resulting in center line cracks.

Drilling of the Laser Vent Hole is critical to the success of the laser welding/closure operation. Based on previous experience with this joint configuration, optimal hole sizes were as close as possible to the nominal 0.005 in. diameter as specified on the drawing. The upper tolerance is provided for the additional metal removed from the cleaning of refractory metals. Additionally, the smaller hole reduces the risk of cracking in both the refractory and nickel base alloys.

3.8 Demonstration Summary

PNNL successfully demonstrated the capability to electron beam weld biaxial creep pressurized tube specimens for the three nickel-base alloys and three refractory alloys. The laser seal welding of the six alloys was less repeatable and would require additional work to be considered fully demonstrated. Improvements in endcap cleanliness and laser welding parameter optimization would be necessary to successfully demonstrate the laser seal welding biaxial creep pressurized tube specimens. In addition, the large vent holes and the off-center position created a threshold condition which may have contributed to the poor weld demonstration results. Dimensional consistency of components is essential to producing acceptable welds.

3.9 Future Capability

The electron beam welding and laser seal welding equipment will be used for other applications at PNNL after the closeout of this contract. However, the infrastructure specific to biaxial creep specimens, such as the fixturing, records, procedures and experience will remain intact at PNNL and available for similar work if the programmatic need should arise. It should be noted that the weld parameters documented in the data packages are specific to the high-power density electron beam welding equipment used to perform this demonstration. The combination of demonstrated equipment, skilled personnel, and established infrastructure at PNNL will be ready and available to conduct similar materials fabrication and welding development work in the future. A summary of the capability and photographs of the welding equipment used to perform this work at PNNL are provided in Attachment 7.

The equipment used to perform these welds as well as the furnace used to heat treat the Nimonic PE16 specimens were calibrated in preparation for a formal qualification and a record of these calibrations is provided in Attachment 8. A list of all equipment, service and supplies purchased to support the work described in NRPCT IV# PNNL-SPP-05-004 is provided in Attachment 9. PNNL recommends that all of the applicable items listed in attachment 8 be dispositioned as "abandon in place" due to the specific nature of the equipment.

Biaxial Creep Specimen Electron Beam and Laser Seal Welding Demonstration Report

PNNL-15537 Rev. 0

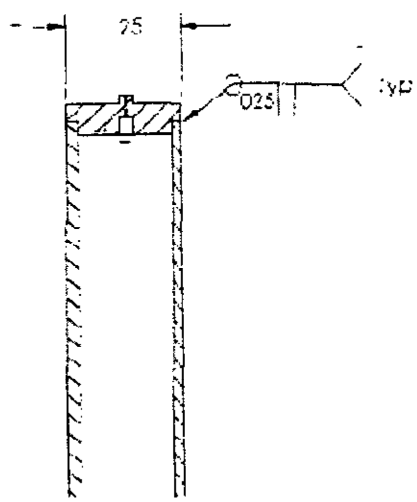
ATTACHMENT I

Weld Demonstration Data Package

for

Nimonic PE16

Test Engineering **Battelle Northwest** **P.O. Box 999** **Richland, WA 99352**	**WELDING PROCEDURE** **Electron Beam Welding Process**



Base Material & Form: **Nimonic Nickel Alloy Tube and Bar**

Filler Material, Form, Size: N/A

Preheat: N/A Postheat: N/A

Weld Position: **1G**

No. of Passes: **1**

"Cosmetic" Pass Used: No

Gun Type. **CLR 32**

Lap-Over (in/deg) 90°

Type Backing: **Intergral**

Machine Make or S/N: **Hamilton Std. EBW S/N 601**

Additional Info.: **Favor tube all by approx .002**

Drawing Number	Joint Assembly Number	Date	Welding Operators
5015996	N/A	19 Oct. 2005	A. Asa Jones

"Penetration Pass"

PROCESS VALUES

Voltage (KV)	100	Deflection	None
Beam Current (ma)	1.70	Type	DC Spot
Beam Focus From Work Surface	0"	Size	Min.
Heat Shield From Work Distance	5 3/8"	Frequency (Hz)	N/A
Weld Speed (sec/rev)	1	Modulation Set	N/A
Weld Speed (in/min)	47	Puddling Set	N/A
Weld Time Set Cycle (Sec.)	2	Vacuum (torr)	10^{-5}
Rise Set	Min.	Beam-to-Joint Offset	N/A
Fall Set	x 1 @ 1	Position Beam at 0°	Favor tube by .002
Rotation Spd Setting	1 sec.		

This procedure is in accordance with: **Bettis IV # PNL-SPP-05-004**	Original Issue: Rev. No. 0 Rev. No. Rev. No.____
Prepared by A. Asa Jones	Procedure No. **Bettis – EB- 100**
Approved by [signature] 11/6/05	

WELDING PROCEDURE DEMONSTRATION RECORD

Procedure No. Bettis - EB- 100	Prepared by: A.A. Jones Date: 11 Oct. 2005
No. of Samples Required 6	Welding Operator Name Asa Jones [signature]
RDT Section 8 Category 4	Welds Made on: 18 Oct. 2005
Sample Identification Nos See Remarks	Welding Equipment ID EBW S/N 601
Component Inspection Report Nos N/A	Welding to Procedure Witnessed by N/A
Material ID and Heat No Nimonic PE-16	PROGRAM Bettis Biaxial Creep Specimens

CHARACTERISTIC	REFERENCED SPECIFICATION	NO. OF SAMPLES REQUIRED	REPORT NO. OR LAB ID NO.	ACC	REJ	TECH. OR INSPECTOR	DATE	REMARKS
Comp. Cleaned	Bettis Procedure # N/A	6				N/A		
Visual (Weld)	NE F6-2t Sec. 6 Para. 6.3.2	6		✓		[signature]	11/26/05	
Helium Leak Test	NE F6-2t Sec. 6 Para. 6.3.6	N/A				N/A		
Radiography	NE F6-2t Sec. 6 Para. 6.3.4	6		✓		[signature]	11-26-05	
Pressure Test	Bettis Procedure # N/A	N/A				N/A		
Metallography	NE F6-2t Sec. 6 Para 6.3.7	6		✓		[signature]	11/16/05	
Dimensional	Drawing requirements	6		✓		[signature]	11/16/05	

Record Data Required For Procedure Qualification Package	Yes	No	Completed
Metallography Report and Mount Nos.	X		✓
Metallography Photos (Information)	X		✓
Radiography Report	X		✓
Helium Leak Rate		X	
Copy of the Procedure	X		✓
Pressure Test Data		X	
Pressure Test Specimens		X	
Tensile Test Data		X	
Tensile Test Specimens		X	

Remarks

Specimen Numbers	Sample #'s Top	Bottom
A-AHB	A-1019	A-1020
A-AHC	A-1021	A-1022
A-AHD	A-1023	A-1024
A-AHF	A-1025	A-1026
A-AHJ	A-1027	A-1028
A-AGW	A-1029	A-1030

Approval:

TA Delucchi [signature] 11/16/05

DM Paxton DM Paxton 11/18/05

TD Hays N/A

Page 1 of __

COGEMA ENGINEERING

NDE CAPSULE RADIOGRAPHIC PROCEDURE AND TEST REPORT

NON DESTRUCTIVE EXAMINATION
2400 STEVENS CENTER - TEL. (509) 376-3597

Job No. 05-3

Requestor (client): A. A. Jones
Company: PNNL
Project/System/Work Package/Traveler No: Bettis Biaxial Creep Specimens

MSIN: P5-22 | Bldg: 240C | Area: N/A

Acceptance Std. / Section / Para / Date: SE PG-2t Sec. 6 Para. 6.3.4 ☐ NA
Dwg. No: Bettis #5015995 ☐ NA
NCR: ☒ NA

PART INFORMATION

Material: Nimonic PE 16
Weld/Material Thickness: 0.025" ☐ NA
Diameter: 0.250" ☐ NA
Schedule: ☒ NA

PRODUCT OR STAGE OF MFG: ☒ As Welded ☐ Weld Surfaced ☐ As Forged ☐ As Cast ☐ As Machined ☐ As Assembled ☐ Other

TYPE WELD: ○ NA ○ GTAW (TIG) ○ GMAW (MIG) ◉ EBW ○ LBW (Laser)

WELD STAGE: ○ Root Pass ◉ Final ○ Repair No.

PROCEDURE NO. ☐ NA
☒ SVRT PRC-006 Rev 3
Appendix D Rev. 3
☐ Special Tech. No.

AREA TO BE INSPECTED
☒ Full Inspection; 100% of Area Requested
☐ Other

	Single Wall	Double Wall	
Radiographed			☒ NA
Interpreted			

○ Tangential ○ NA
◉ Edge Enhancement (Tangential)
○ Shape Correction
○ 1/2 Shape Correction

DENSITY REQUIREMENTS
○ 1.3 to 4.0 ○ 2.0 to 4.0
○ 1.4 to 2.0 ○ 2.2 to 3.0
◉ 1.8 to 4.0 ○ NA

DENSITOMETER LINEARITY CALIBRATION

Range	.30	3.0	3.9
Step Wedge	.4	3.0	4.01
Actual	.41	3.02	4.00

SEE REVERSE SIDE FOR BASIC SKETCH

EQUIPMENT MFG.
☒ X-Ray Mfg/Type S/N:
☐ Isotope Phillips 160 01005

EXPOSURE INFORMATION
KV: 160
MA/Ci: 4.0
Time: 2.0

Ug = Fd/D — See procedure for equation definitions
F: .4mm
d: 0.25"
D: 34.0"
Ug: 0.0001"

Beam Filter and Thickness: ☒ Copper ☐ NA 0.010"

Film
Film Mfg: ☒ Fuji
Film Type: IX25
Film Load: ☐ Single ☒ Double ☐ .005" EF.005"
Screens: ☐ NA 0.005"

Penetrameter
Type: ☒ ASME ☐ SS ☐ FS ☒ SL
Size: #5
Hole: ○ 1T ◉ 2T ○ 4T
Shim Mat'l. and Thickness: ☐ Steel Inconel .100, .55

Codes
X, A - Acceptable; X, R - Reject; C - Crack; I - Inclusion; IF - Incomplete Fusion; IP - Incomplete Penetration; HI - Heavy Metal Inclusion; P - Porosity; S - Shrink; U - Undercut; WT - Weld Thickness; GTR - Gas Tag Rupture

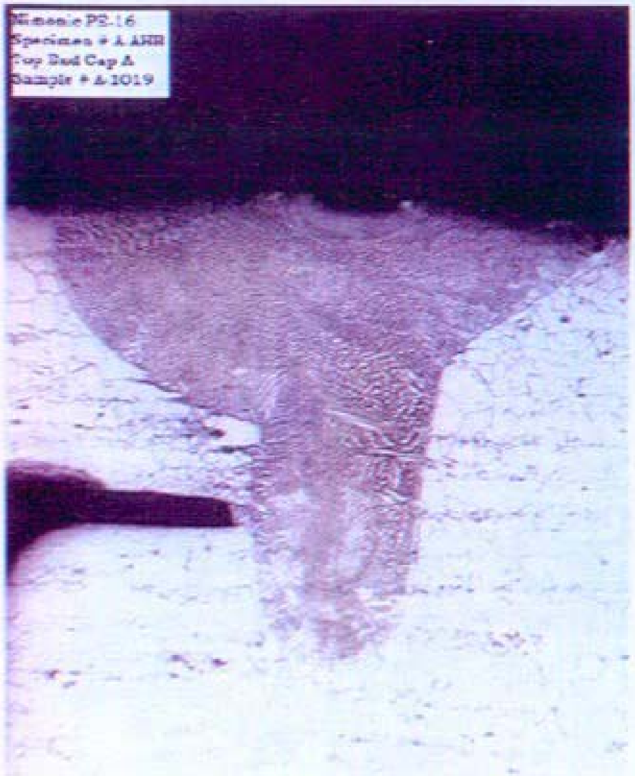
Weld No., Part No. or Serial No.	0	30	60	90	120	150					Acc.	Rej.	No Ind. Noted	Comments
A-AGW	A	A	A	A	A	A					X			
A-AHB	A	A	A	A	A	A					X			
A-AHC	A	A	A	A	A	A					X			
A-AHD	A	A	A	A	A	A					X			
A-AHF	A	A	A	A	A	A					X			
A-AHJ	A	A	A	A	A	A					X			

(Header above degree columns: List Degrees of Rotation Used)

Film Records Transfer
☐ N/A PNNL [signature] Tech 6 [illegible date]
Company / Signature / Title / Date

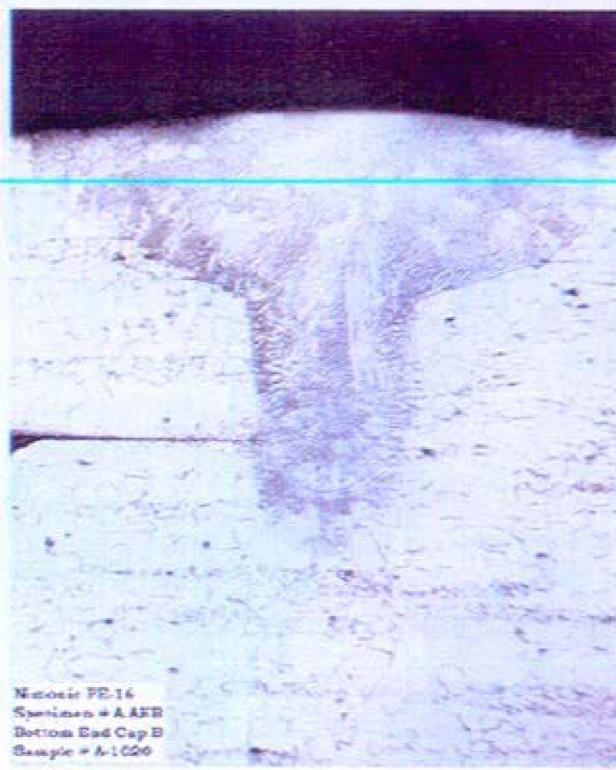
Technician	RT Level	Interpreted by	RT Level	Reviewed by
M. I. Casto [signature]	II	J. K. Kaye [signature]	III	[signature]
J. K. Kaye [signature]	III			
Date of Examination: 10/26/05		Date: 10/26/05		Date: [illegible]

A-6002-564 (8/04)


Nimonic PE-16
Specimen # A-AHB
Top End Cap A
Sample # A-1019


Nimonic PE-16
Specimen # A-AHB
Top End Cap B
Sample # A-1019


Nimonic PE-16
Specimen # A-AHB
Bottom End Cap A
Sample # A-1020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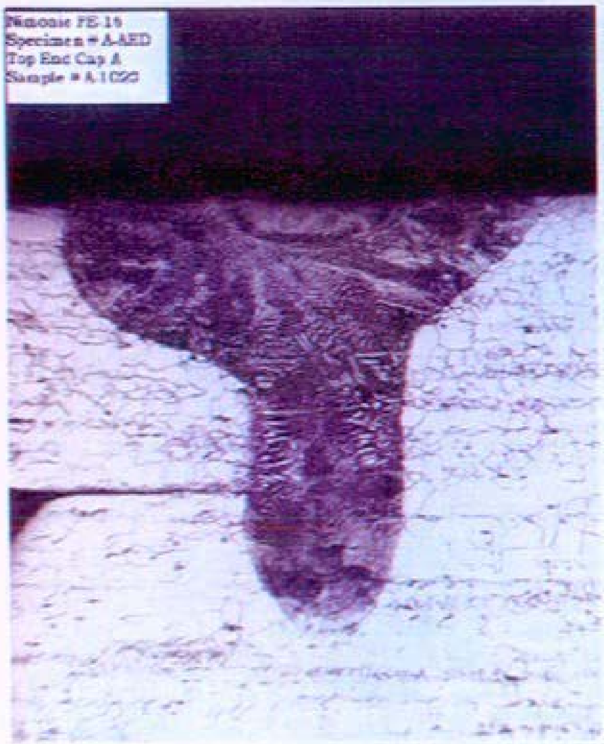
Specimen # A-AHB
Bottom End Cap B
Sample # A-1020


Nimonic PE-16
Specimen # A-AHC
Bottom End Cap A
Sample # A-1022


Nimonic PE-16
Specimen # A-AHC
Bottom End Cap B
Sample # A-1022


Nimonic PE-16
Specimen # A-AHC
Top End Cap B
Sample # A-1021


Nimonic PE-16
Specimen # A-AHC
Top End Cap A
Sample # A-1021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Specimen # A-AED
Top End Cap A
Sample # A-1023


Nimonic PE-16
Specimen # A-AED
Top End Cap B
Sample # A-1023


Nimonic PE-16
Specimen # A-AED
Bottom End Cap A
Sample # A-1024


Nimonic PE-16
Specimen # A-AED
Bottom End Cap B
Sample # A-1024


Nimonic PE-16
Specimen # A-AHF
Top End Cap A
Sample # A-1025


Nimonic PE-16
Specimen # A-AHF
Top End Cap B
Sample # A-1025


Nimonic PE-16
Specimen # A-AHF
Bottom End Cap A
Sample # A-1026


Nimonic PE-16
Specimen # A-AHF
Bottom End Cap B
Sample # A-1026


Nimonic PE-16
Specimen # A-AHJ
Top End Cap A
Sample # A1027

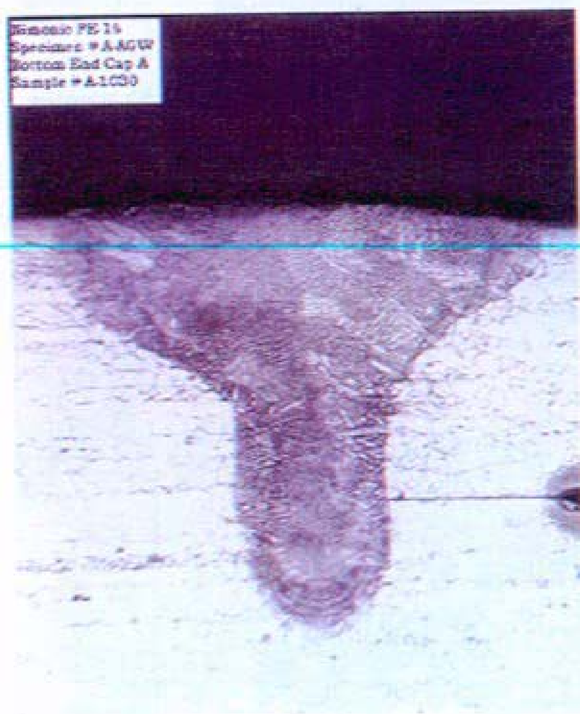

Nimonic PE-16
Specimen # A-AHJ
Top End Cap B
Sample # A1027


Nimonic PE-16
Specimen # A-AHJ
Bottom End Cap A
Sample # A1028


Nimonic PE 16
Specimen # A-AHJ
Bottom End Cap B
Sample # A1028

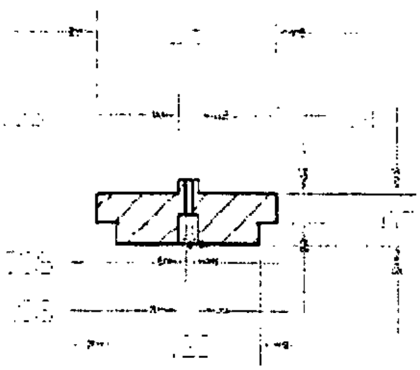

Nimonic PE 16
Specimen # A AGW
Top End Cap A
Sample # A 1029


Nimonic PE 16
Specimen # A AGW
Top End Cap B
Sample # A 1029


Nimonic PE 16
Specimen # A AGW
Bottom End Cap A
Sample # A 1030


Nimonic PE 16
Specimen # A AGW
Bottom End Cap B
Sample # A 1030

TEST ENGINEERING BATTELLE NORTHWEST P.O. BOX 999 RICHLAND, WA 99352	WELDING PROCEDURE LASER WELDING PROCESS



MATERIAL:	Nimonic Alloy (nickel based)
THICKNESS:	0.03
PRE-CLEANING:	Yes
COVER GLASS:	Quartz
MACHINE MAKE:	Korad
MACHINE MODEL:	KWD
ADDITIONAL INFO	Evacuate and back fill with

UHP helium three times prior to welding.

DRAWING NUMBER	JOINT ASSEMBLY NO.	DATE	WELDING OPERATOR
5015996	N/A	11 Oct. 2005	Asa Jones

SEE WELDING PROCEDURE DESCRIPTION Bettis IV # PNNL-SPP-05-004 FOR QUALITY REQUIREMENTS.

PROCESS VALUES

ROD TYPE & I.D. NO.	Nd:YAG	VOLTAGE	2.5
APERTURE	100	SPOT SIZE	0.747
ATTENUATOR	0	JOULES / PULSE	N/A
MONITOR VOLTS	85-87	ATMOSPHERE	Helium
SCALE FACTOR	N/A	PRESSURE	0-3000 PSIG
FOCUS LENS	6"	PULSE WIDTH	Position # 3
NO. OF PULSES	1 or more		

PREPARED BY:		
Asa Jones	ORIGNAL ISSUE	11 Oct. 2005
	REV. NO.	
	REV. NO	
	REV. NO.	

APPROVED FOR TEST ENGINEERING	PROCEDURE NO.
N/A due to rejection	Bettis - Laser - 202

5/05

WELDING PROCEDURE DEMONSTRATION RECORD

Procedure No. Bettis - Laser- 200	Prepared by: A.A. Jones Date: 11 Oct. 2005
No. of Samples Required 6	Welding Operator Name Asa Jones
RDT Section 8 Category 4	Welds Made on: 20 Oct. 2005 [signature]
Sample Identification Nos See Remarks	Welding Equipment ID Korad KWD
Component Inspection Report Nos N/A	Welding to Procedure Witnessed by N/A
Material ID and Heat No Nimonic PE-16	PROGRAM Bettis Biaxial Creep Specimens

CHARACTERISTIC	REFERENCED SPECIFICATION	NO. OF SAMPLES REQUIRED	REPORT NO. OR LAB ID NO.	ACC	REJ	TECH. OR INSPECTOR	DATE	REMARKS
Comp. Cleaned	Bettis Procedure # N/A	6				N/A		
Visual (Weld)	NE F6-2t Sec. 6 Para. 6.3.2	6		✓		[signature]	10/20/05	
Helium Leak Test	NE F6-2t Sec. 6 Para. 6.3.6	N/A				N/A		
Radiography	NE F6-2t Sec. 6 Para. 6.3.4	N/A				N/A		
Pressure Test	Bettis Procedure # N/A	N/A				N/A		
Metallography	NE F6-2t Sec. 6 Para 6.3.7	6			✓	[signature]	[illegible]	
Dimensional	Drawing requirements	6			✓	[signature]	[illegible]	

Record Data Required For Procedure Qualification Package	Yes	No	Completed
Metallography Report and Mount Nos.	X		✓
Metallography Photos (Information)	X		✓
Radiography Report		X	
Helium Leak Rate		X	
Copy of the Procedure	X		✓
Pressure Test Data		X	
Pressure Test Specimens		X	
Tensile Test Data		X	
Tensile Test Specimens		X	

Remarks

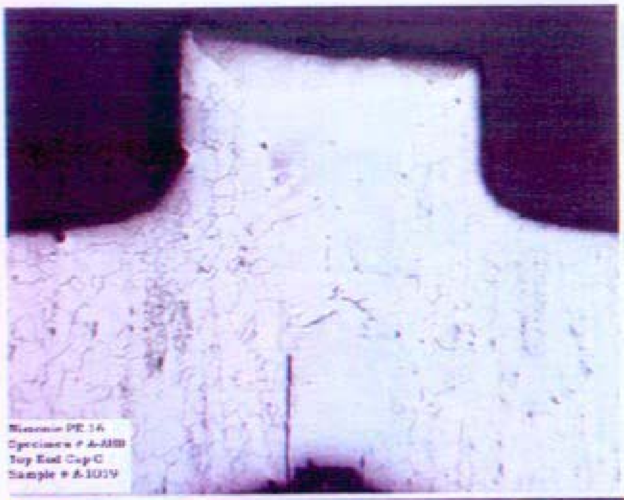
Specimen Numbers	Sample #'s
A-AHB	A-1091
A-AHC	A-1092
A-AHD	A-1093
A-AHF	A-1094
A-AHJ	A-1095
A-AGW	A-1096

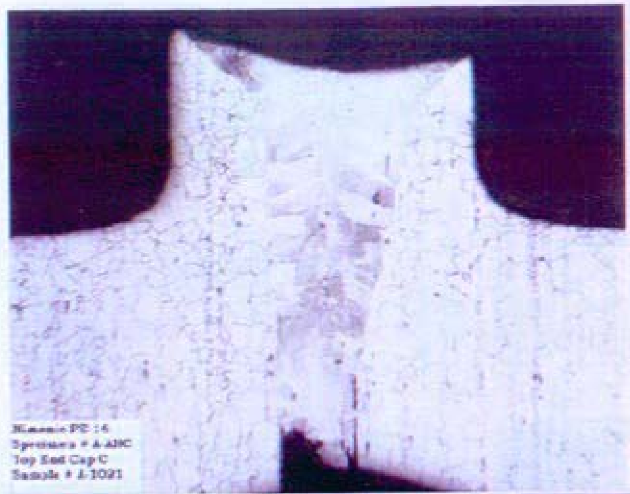
Approval:

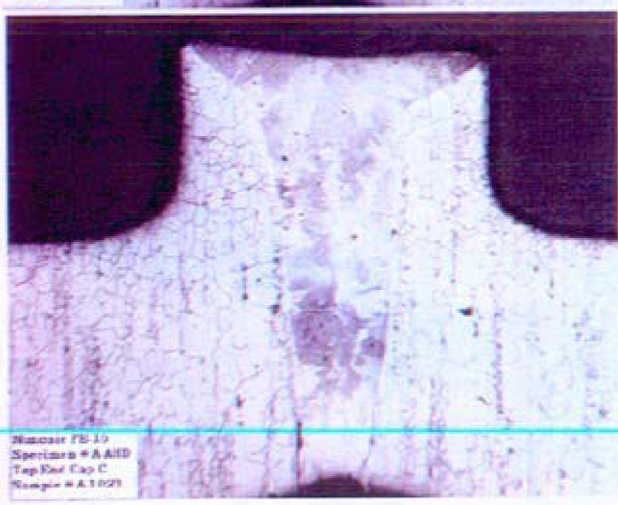
TA Delucchi N/A due to rejection

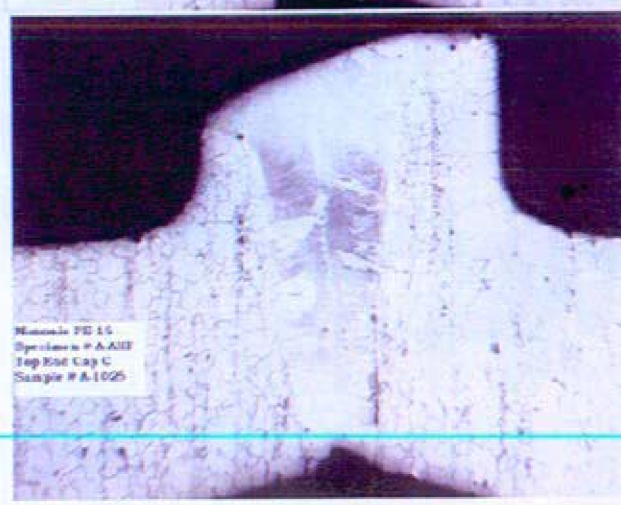
DM Paxton N/A due to rejection

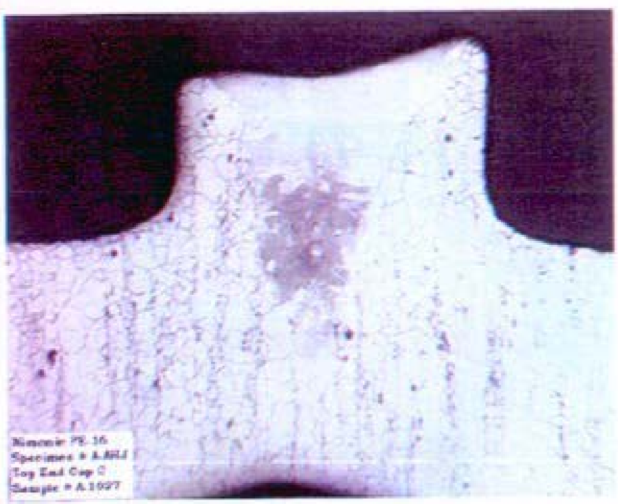
TD Hays N/A

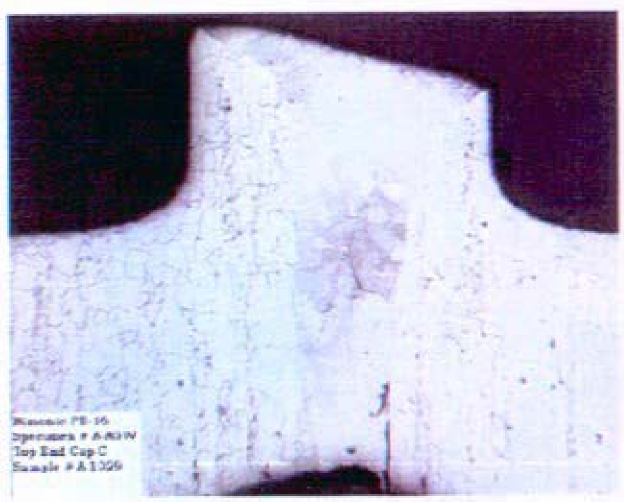

Top End Cap C


Top End Cap C


Top End Cap C


Top End Cap C


Top End Cap C


Top End Cap C

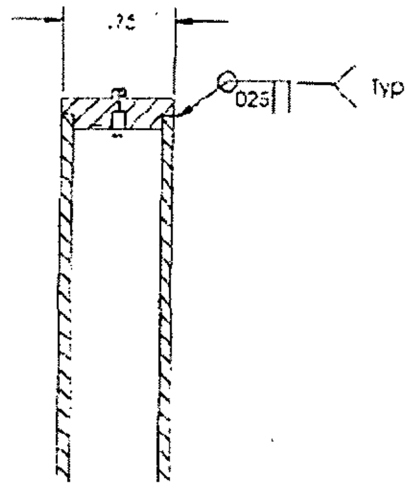
ATTACHMENT 2

Weld Demonstration Data Package

for

Alloy 617

Test Engineering Battelle Northwest P.O. Box 999 Richland, WA 99352	WELDING PROCEDURE Electron Beam Welding Process



Base Material & Form: **Alloy 617**
Tube and Bar

Filler Material, Form, Size: N/A

Preheat: N/A Postheat: N/A

Weld Position: 1G

No. of Passes: 1

"Cosmetic" Pass Used: **No**

Gun Type: **CLR 32**

Lap-Over (in/deg) **90°**

Type Backing: **Intergral**

Machine Make or S/N: **Hamilton Std. EBW S/N 601**

Additional Info.: **Favor tube all by approx .002**

Drawing Number	Joint Assembly Number	Date	Welding Operators
5015996	N/A	19 Oct. 2005	A. Asa Jones

"Penetration Pass"

PROCESS VALUES

Voltage (KV)	100	Deflection	None
Beam Current (ma)	1.70	Type	DC Spot
Beam Focus From Work Surface	0"	Size	Min.
Heat Shield From Work Distance	5 3/8"	Frequency (Hz)	N/A
Weld Speed (sec/rev)	1	Modulation Set	N/A
Weld Speed (in/min)	47	Puddling Set	N/A
Weld Time Set Cycle (Sec.)	2	Vacuum (torr)	10^{-4}
Rise Set	Min.	Beam-to-Joint Offset	N/A
Fall Set	x 1 @ 1	Position Beam at or	Favor tube by .002
Rotation Spd Setting	1 sec.		

This procedure is in accordance with:	Original Issue:
Bettis IV # PNNL-SPP-.5-004	Rev. No. 0 Rev. No. ____ Rev. No. ____
Prepared by A. Asa Jones	Procedure No. **Bettis – EB- 101**
Approved by [illegible signature] [illegible]	

WELDING PROCEDURE DEMONSTRATION RECORD

Procedure No. Bettis - EB- 101	Prepared by: A.A. Jones Date: 11 Oct. 2005
No. of Samples Required 6	Welding Operator Name Asa Jones
RDT Section 8 Category 4	Welds Made on: 19 Oct. 2005
Sample Identification Nos See Remarks	Welding Equipment ID EBW S/N 601
Component Inspection Report Nos N/A	Welding to Procedure Witnessed by N/A
Material ID and Heat No ALLOY 617	PROGRAM Bettis Biaxial Creep Specimens

CHARACTERISTIC	REFERENCED SPECIFICATION	NO. OF SAMPLES REQUIRED	REPORT NO. OR LAB ID NO.	ACC	REJ	TECH. OR INSPECTOR	DATE	REMARKS
Comp. Cleaned	Bettis Procedure # N/A	6				N/A		
Visual (Weld)	NE F6-2t Sec. 6 Para. 6.3.2	6		✓		[signature]	10/…/05	
Helium Leak Test	NE F6-2t Sec. 6 Para. 6.3.6	N/A				N/A		
Radiography	NE F6-2t Sec. 6 Para. 6.3.4	6		✓		[signature]	11-27-05	
Pressure Test	Bettis Procedure # N/A	N/A				N/A		
Metallography	NE F6-2t Sec. 6 Para 6.3.7	6		✓		[signature]	11/…/05	
Dimensional	Drawing requirements	6		✓		[signature]	11/…/05	

Record Data Required For Procedure Qualification Package	Yes	No	Completed
Metallography Report and Mount Nos.	X		✓
Metallography Photos (Information)	X		✓
Radiography Report	X		✓
Helium Leak Rate		X	
Copy of the Procedure	X		✓
Pressure Test Data		X	
Pressure Test Specimens		X	
Tensile Test Data		X	
Tensile Test Specimens		X	

Remarks

Sample #'s

Specimen Numbers	Top	Bottom
A-AAC	A-1031	A-1032
A-AAF	A-1033	A-1034
A-AAG	A-1035	A-1036
A-AAH	A-1037	A-1038
A-AAI	A-1039	A-1040
A-AAJ	A-1041	A-1042

Approval:

TA Delucchi [signature] 11/15/05

DM Paxton [signature] 11/18/05

TD Hays N/A

Page 1 of 1

NDE CAPSULE RADIOGRAPHIC PROCEDURE AND TEST REPORT

COGEMA ENGINEERING

NON DESTRUCTIVE EXAMINATION
2400 STEVENS CENTER - TEL. (509) 375-3367

Job No: 01-3

Requestor (client)	Company	Project/System/Work Package/Traveler No.
P A Jones	PNNL	Bettis Biaxial Creep Specimens

MSIN	Bldg	Area
K8-22	2400	N/A

Acceptance Std / Section / Para / Date	Dwg No	NCR
NE F6-2t Sec. 6 Para. 6.3.4	Bettis 45D15996	☒ NA

PART INFORMATION

Material	Alloy 617	
Wall/Material Thickness	0.025"	☐ NA
Diameter	0.250"	☐ NA
Schedule		☒ NA

PRODUCT OR STAGE OR MFG.: ☒ As Welded; ☐ Weld Surfaced; ☐ As Forged; ☐ As Cast; ☐ As Machined; ☐ As Assembled; ☐ Other

TYPE WELD: ○ NA; ○ GTAW (TIG); ○ GMAW (MIG); ◉ EBW; ○ LBW (Laser)

WELD STAGE: ○ Root Pass; ◉ Final; ○ Repair No.

PROCEDURE NO ☐ NA
☒ SVRT-PRO-006 Rev. 3
Appendix D Rev. 3
☐ Special Tech. No.

AREA TO BE INSPECTED
☒ Full Inspection; 100% of Area Requested
☐ Other

	Single Wall	Double Wall	
Radiographed			☒ NA
Interpreted			

○ Tangential ○ NA
◉ Edge Enhancement (Tangential)
○ Shape Correction
○ 1/2 Shape Correction

DENSITY REQUIREMENTS
○ 1.3 to 4.0 ○ 2.0 to 4.0
○ 1.4 to 2.0 ○ 2.2 to 3.0
◉ 1.8 to 4.0 ○ NA

DENSITOMETER LINEARITY CALIBRATION

Range	.30	3.0	3.9
Step Wedge	.4	3.0	4.01
Actual	.41	3.02	4.00

SEE REVERSE SIDE FOR BASIC SKETCH

EQUIPMENT/MFG.
☒ X-Ray Mfg/Type S/N
☐ Isotope Phillips 160 01005

EXPOSURE INFORMATION

KV	160
MA/CI	4.0
Time	2.0

$U_g = \frac{Fd}{D}$ — See procedure for equation definitions

F	.4mm
d	0.25"
D	34.0"
Ug	0.0001"

Beam Filter and Thickness: ☒ Copper ☐ NA 0.010"

Films/Screens

Film Mfg	☒ Fuji
Film Type	IX25
Film Load	☐ Single; ☒ Double; ☐ .005"FF C05"
Screens	☐ NA 0.005"

Penetrameters

Type	☒ ASME ☐ SS ☐ FS ☒ BL
Size	#5
Hole	○ 1T ◉ 2T ○ 4T
Shim Mat'l and Thickness	☐ Steel; Inconel .100, .155

Codes: X, A - Acceptable; X, R - Reject; C - Crack; I - Inclusion; IF - Incomplete Fusion; IP - Incomplete Penetration; HI - Heavy Metal Inclusion; P - Porosity; S - Shrink; U - Undercut; WT - Wall Thickness; GTR - Gas Tag Rupture

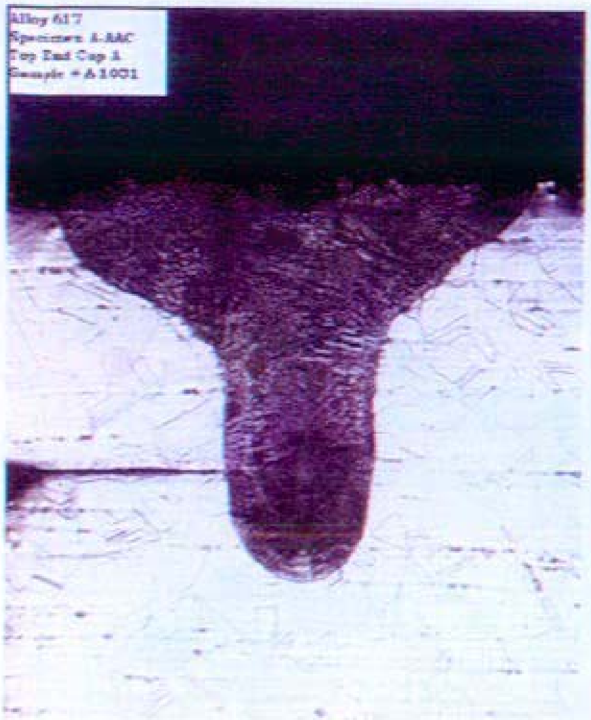
Weld No., Part No., or Serial No.	0	30	60	90	120	150				Acc	Rej	No Ind Noted	Comments
A-AAC	A	A	A	A	A	A				X			
A-AAF	A	A	A	A	A	A				X			
A-AAG	A	A	A	A	A	A				X			
A-AAH	A	A	A	A	A	A				X			
A-AAI	A	A	A	A	A	A				X			
A-AAJ	A	A	A	A	A	A				X			

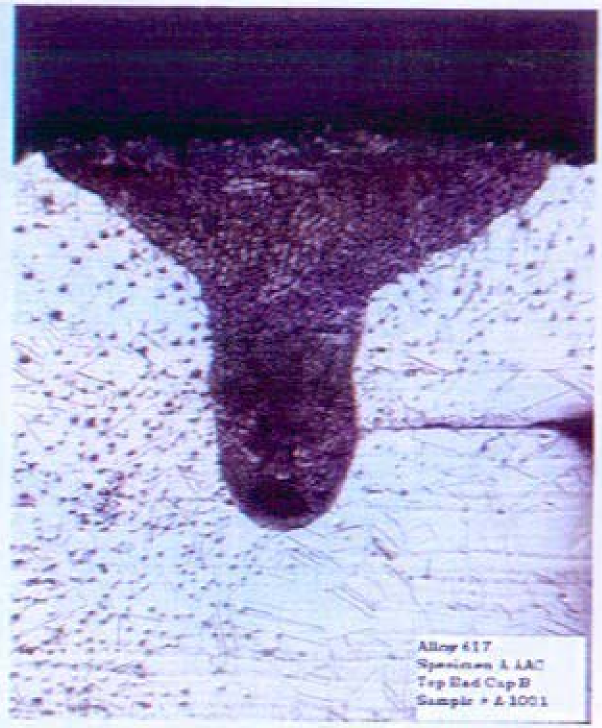
(List Degrees of Rotation Used)

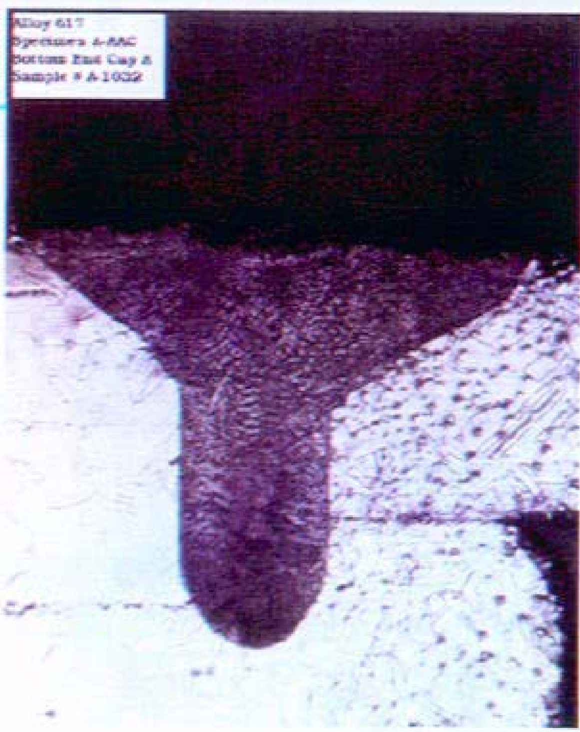
Film Records Transfer ☐ NA
Company: PNNL — Signature: [signature] — Title: Tech 6 — Date: 31 Oct 2005

Technician	RT Level	Interpreted by	RT Level II	Reviewed by
M. L. Castro [signature]	II	J. K. Kovo [signature]	III	[signature]
J. K. Kovo [signature]	III			
Date of Examination: 10/26/05		Date: 10/26/05		Date: 11/28/05

A-6000-664 (05/04)

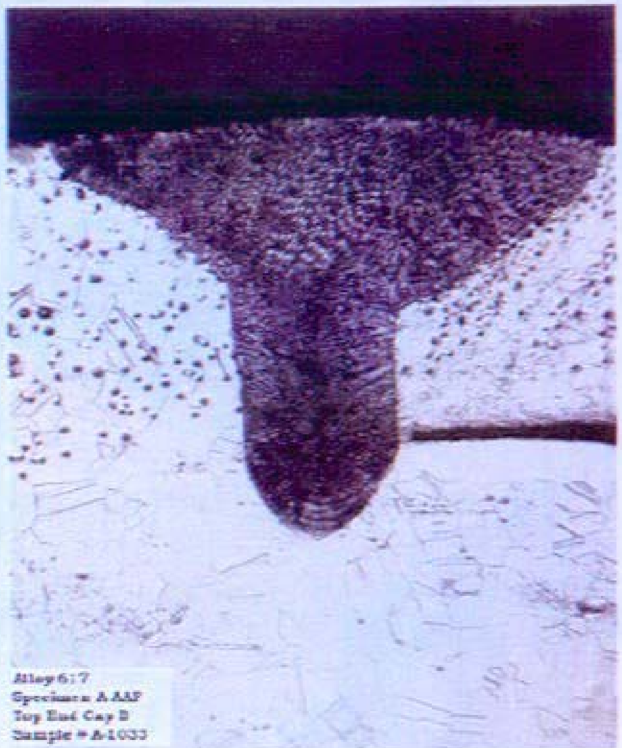

Alloy 617
Specimen A-AAC
Top End Cap A
Sample # A-1001


Alloy 617
Specimen A-AAC
Top End Cap B
Sample # A-1001

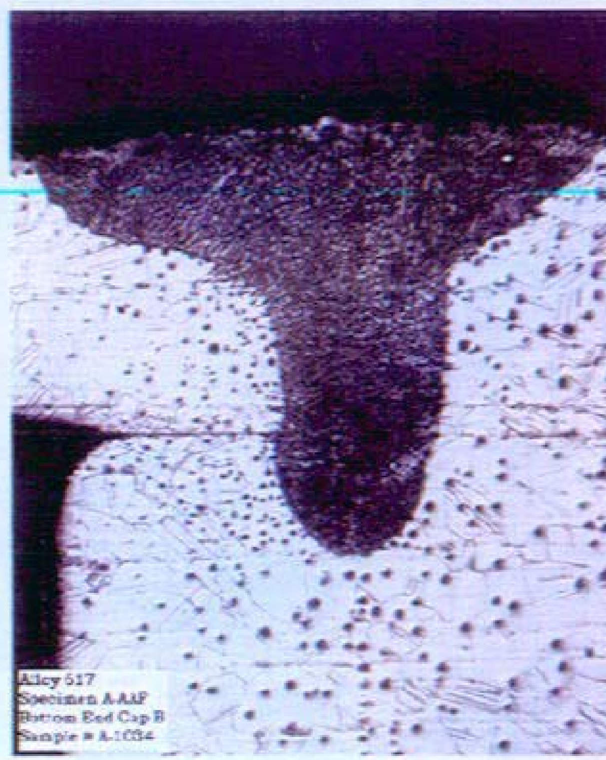

Alloy 617
Specimen A-AAC
Bottom End Cap A
Sample # A-1002


Alloy 617
Specimen A-AAC
Bottom End Cap B
Sample # A-1002


Alloy 617
Specimen A-AAF
Top End Cap A
Sample # A-1033

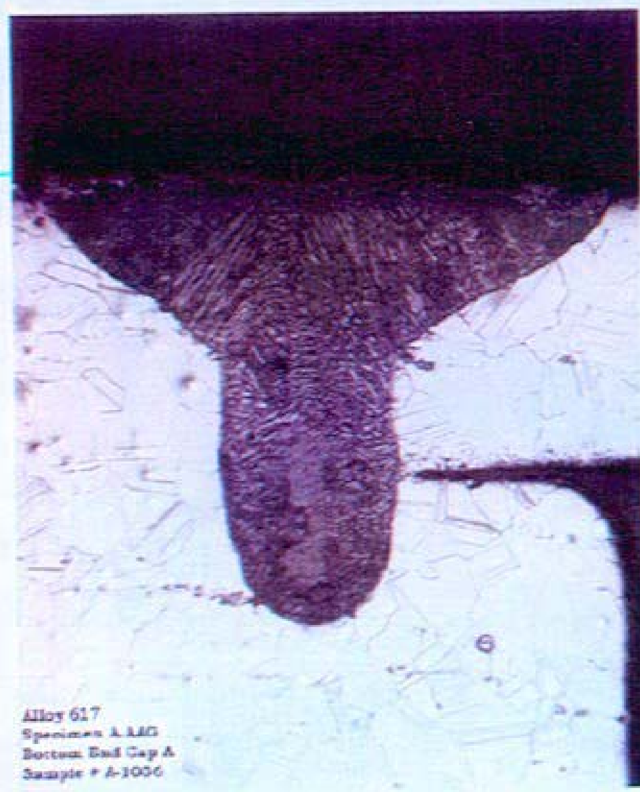

Alloy 617
Specimen A-AAF
Top End Cap B
Sample # A-1033


Alloy 617
Specimen A-AAF
Bottom End Cap A
Sample # A-1034


Alloy 617
Specimen A-AAF
Bottom End Cap B
Sample # A-1034

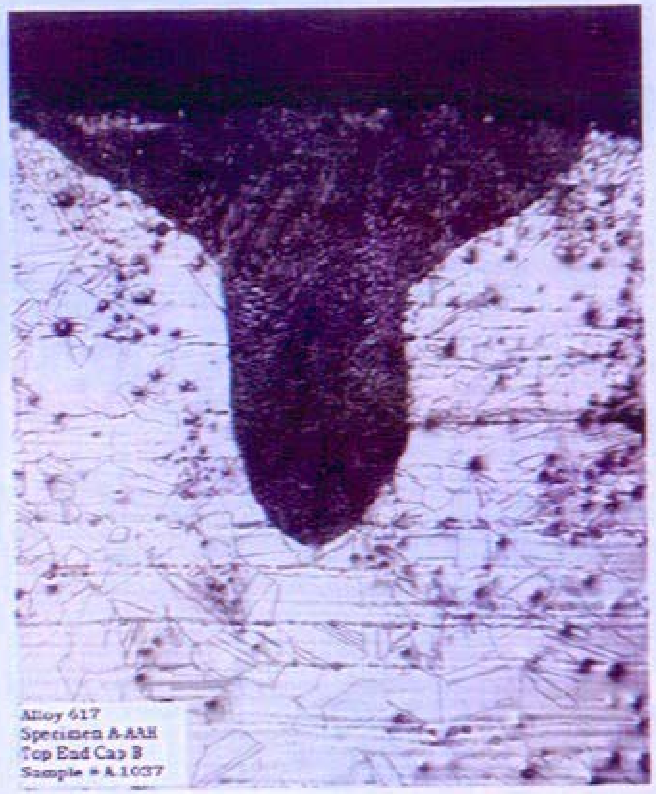

Alloy 617
Specimen A-AAG
Top End Cap A
Sample # A-1035


Alloy 617
Specimen A-AAG
Top End Cap B
Sample # A-1035


Alloy 617
Specimen A-AAG
Bottom End Cap A
Sample # A-1036


Alloy 617
Specimen A-AAG
Bottom End Cap B
Sample # A-1036


Alloy 617
Specimen A-AAH
Top End Cap A
Sample # A-1037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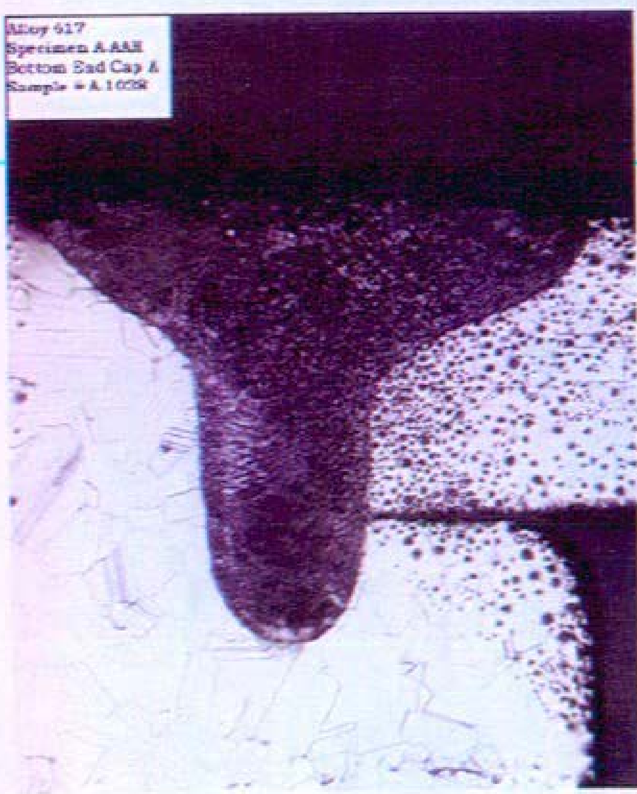
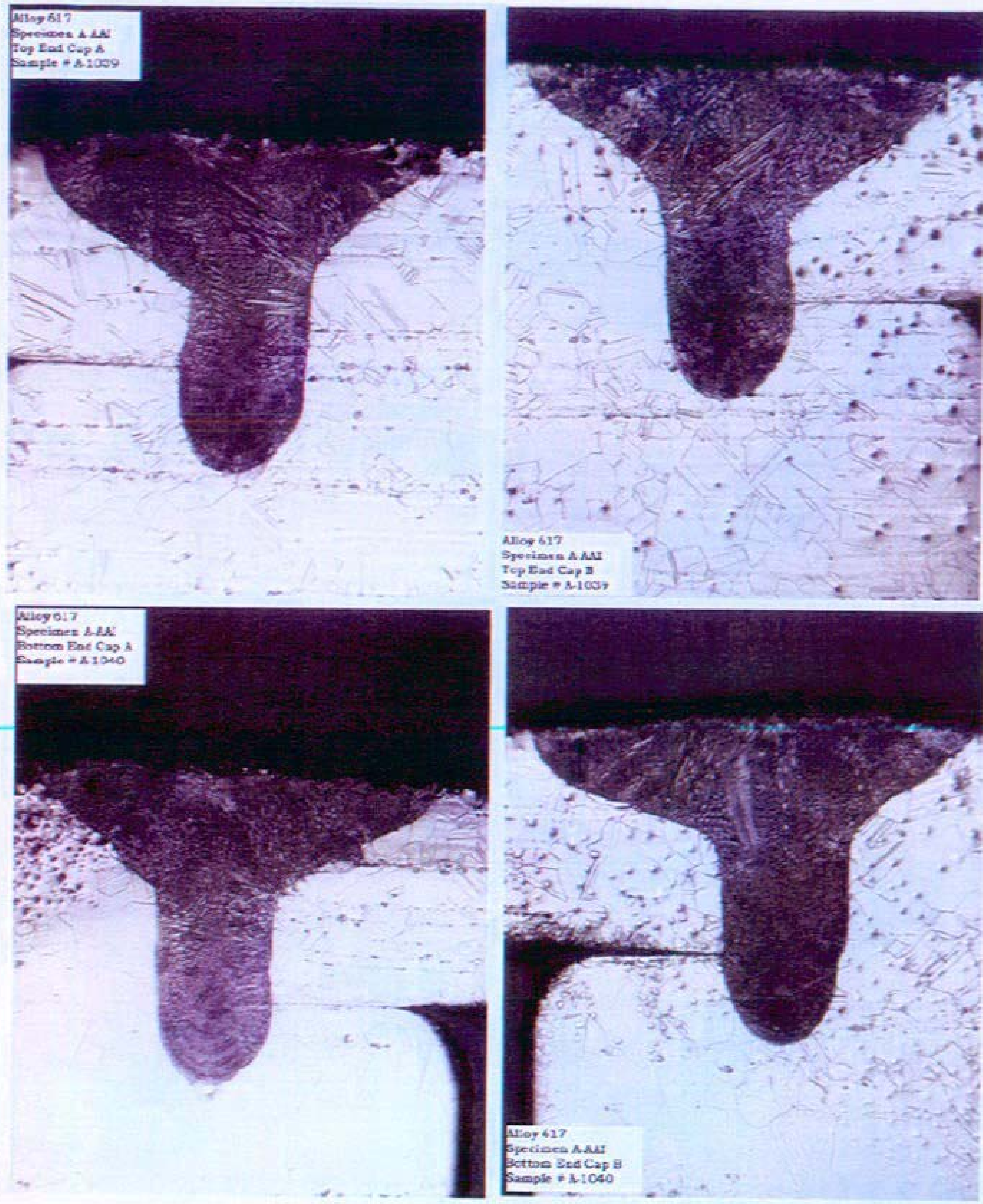
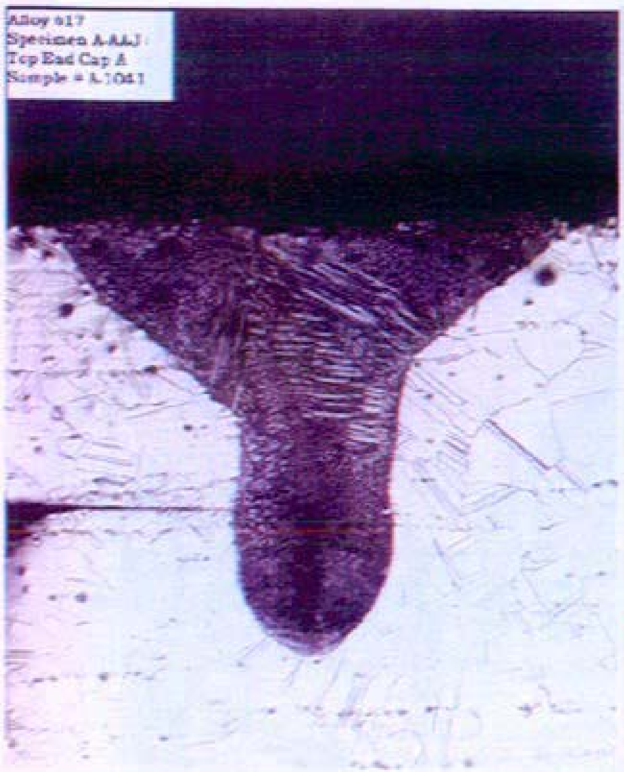
Specimen A-AAH
Top End Cap B
Sample # A 1037


Alloy 617
Specimen A-AAH
Bottom End Cap A
Sample # A 1038


Alloy 617
Specimen A-AAH
Bottom End Cap B
Sample # A 1038


Alloy 617
Specimen A-AAI
Top End Cap A
Sample # A-1039
Alloy 617
Specimen A-AAI
Top End Cap B
Sample # A-1039
Alloy 617
Specimen A-AAI
Bottom End Cap A
Sample # A-1040
Alloy 617
Specimen A-AAI
Bottom End Cap B
Sample # A-1040

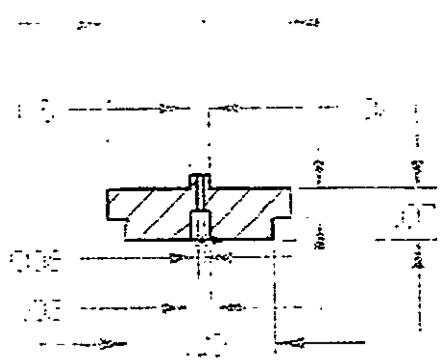

Alloy 617
Specimen A-AAJ
Top End Cap A
Sample # A-1041


Alloy 617
Specimen A-AAJ
Top End Cap B
Sample # A-1041


Alloy 617
Specimen A-AAJ
Bottom End Cap A
Sample # A-1042


Alloy 617
Specimen A-AAJ
Bottom End Cap B
Sample # A-1042

TEST ENGINEERING BATTELLE NORTHWEST P.O. BOX 999 RICHLAND, WA 99352	WELDING PROCEDURE LASER WELDING PROCESS



MATERIAL:	Alloy 617 (nickel based)
THICKNESS:	0.03
PRE-CLEANING:	Yes
COVER GLASS:	Quartz
MACHINE MAKE:	Korad
MACHINE MODEL:	KWD
ADDITIONAL INFO	Evacuate and back fill with UHP helium three times prior to welding.

DRAWING NUMBER	JOINT ASSEMBLY NO.	DATE	WELDING OPERATOR
5015996	N/A	11 Oct. 2005	Asa Jones

SEE WELDING PROCEDURE DESCRIPTION Bettis IV # PNNL-SPP-05-004 FOR QUALITY REQUIREMENTS.

PROCESS VALUES

ROD TYPE & I.D. NO.	Nd:YAG	VOLTAGE	2.5
APERTURE	100	SPOT SIZE	0.747
ATTENUATOR	0	JOULES / PULSE	N/A
MONITOR VOLTS	85-87	ATMOSPHERE	Helium
SCALE FACTOR	N/A	PRESSURE	0-3000 PSIG
FOCUS LENS	6"	PULSE WIDTH	Position # 3
NO. OF PULSES	1 or more		

PREPARED BY: Asa Jones	ORIGNAL ISSUE	11 Oct. 2005
	REV. NO.	
	~~REV. NO.~~	
	REV. NO	

APPROVED FOR TEST ENGINEERING N/A due to rejection	PROCEDURE NO. Bettis - Laser - 201

5/05

WELDING PROCEDURE DEMONSTRATION RECORD

Procedure No. Bettis - Laser- 201	Prepared by: A.A. Jones Date: 11 Oct. 2005
No. of Samples Required 6	Welding Operator Name Asa Jones
RDT Section 8 Category 4	Welds Made on: 20 Oct. 2005
Sample Identification Nos See Remarks	Welding Equipment ID Korad KWD
Component Inspection Report Nos N/A	Welding to Procedure Witnessed by N/A
Material ID and Heat No Alloy 617	PROGRAM Bettis Biaxial Creep Specimens

CHARACTERISTIC	REFERENCED SPECIFICATION	NO. OF SAMPLES REQUIRED	REPORT NO. OR LAB ID NO.	ACC	REJ	TECH. OR INSPECTOR	DATE	REMARKS
Comp. Cleaned	Bettis Procedure # N/A	6				N/A		
Visual (Weld)	NE F6-2t Sec. 6 Para. 6.3.2	6		✓		[signature]	10/20/05	
Helium Leak Test	NE F6-2t Sec. 6 Para. 6.3.6	N/A				N/A		
Radiography	NE F6-2t Sec. 6 Para. 6.3.4	N/A				N/A		
Pressure Test	Bettis Procedure # N/A	N/A				N/A		
Metallography	NE F6-2t Sec. 6 Para 6.3.7	6			✓	[signature]	[illegible]	
Dimensional	Drawing requirements	6		✓		[signature]	11/10/05	

Record Data Required For Procedure Qualification Package	Yes	No	Completed
Metallography Report and Mount Nos.	X		✓
Metallography Photos (Information)	X		✓
Radiography Report		X	
Helium Leak Rate		X	
Copy of the Procedure	X		✓
Pressure Test Data		X	
Pressure Test Specimens		X	
Tensile Test Data		X	
Tensile Test Specimens		X	

Remarks

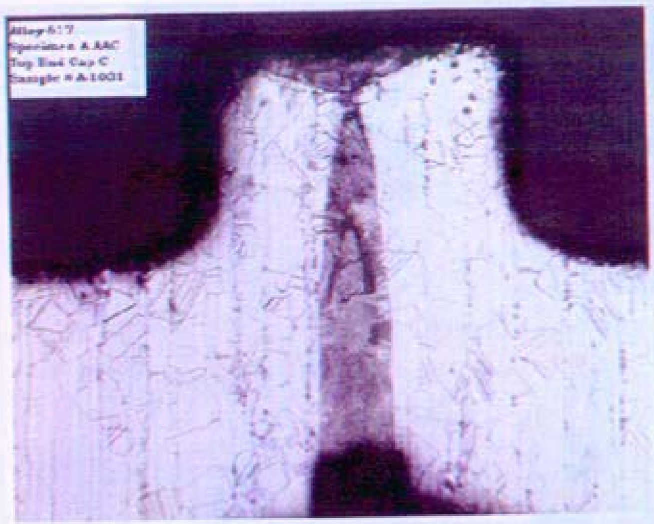
Specimen Numbers	Sample #'s
A-AAC	A-1097
A-AAF	A-1098
A-AAG	A-1099
A-AAH	A-1100
A-AAI	A-1101
A-AAJ	A-1102

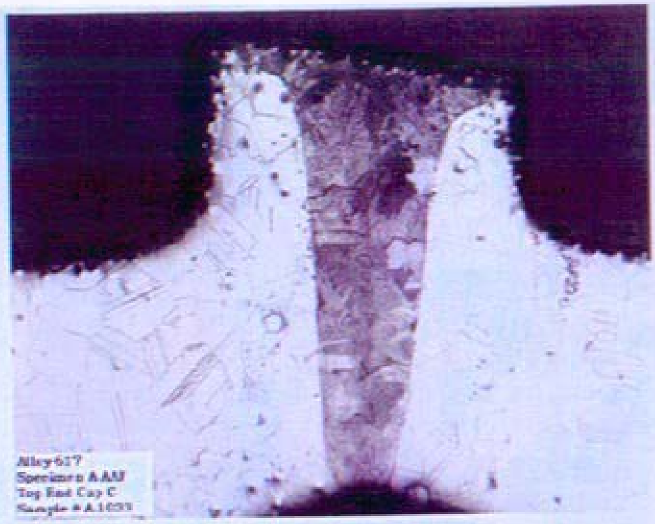
Approval:

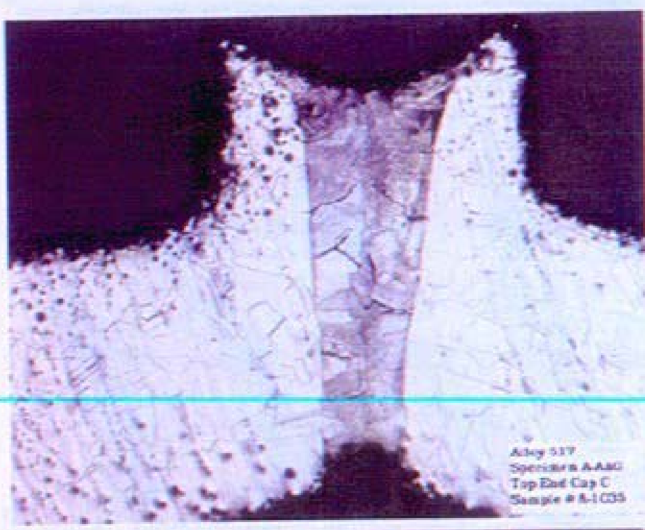
TA Delucchi N/A due to rejection

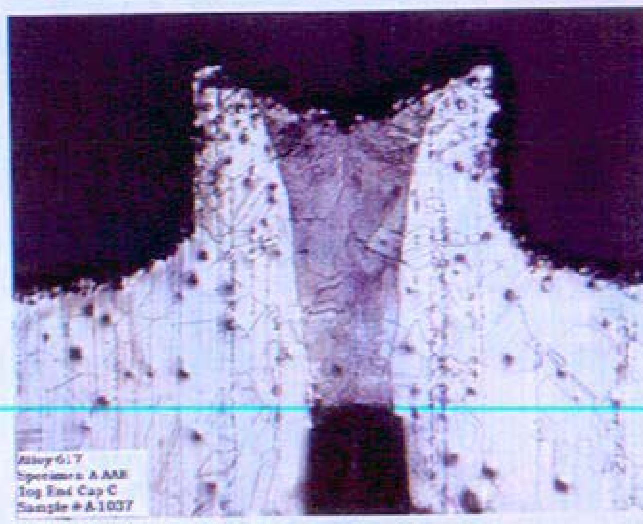
DM Paxton N/A due to rejection

TD Hays N/A

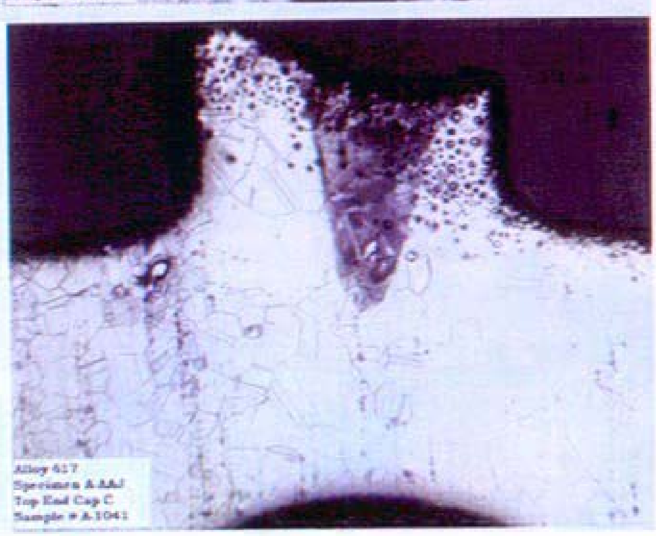

Alloy 617
Specimen A-AAC
Top End Cap C
Sample # A-1031


Alloy 617
Top End Cap C


Specimen A-AAG
Top End Cap C
Sample # A-1035


Alloy 617
Specimen A-AAH
Top End Cap C
Sample # A-1037


Alloy 617
Top End Cap C


Alloy 617
Specimen A-AAJ
Top End Cap C

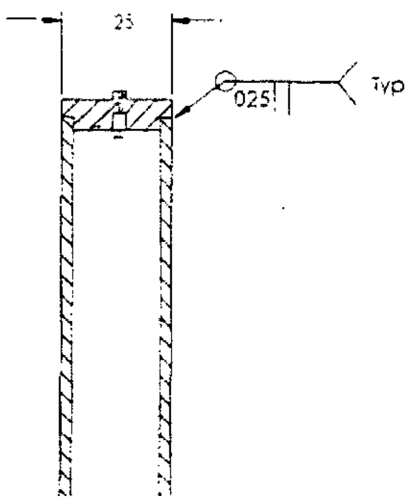
ATTACHMENT 3

Weld Demonstration Data Package

for

Haynes 230

Test Engineering Battelle Northwest P.O. Box 999 Richland, WA 99352	**WELDING PROCEDURE** **Electron Beam Welding Process**



Base Material & Form: **Haynes 230 Alloy Tube and Bar**

Filler Material, Form, Size. **N/A**

Preheat: **N/A** Postheat: **N/A**

Weld Position: **1G**

No. of Passes: **1**

"Cosmetic" Pass Used: **No**

Gun Type: **CLR 32**

Lap-Over (in/deg) **90°**

Type Backing: **Intergral**

Machine Make or S/N: **Hamilton Std. EBW S/N 601**

Additional Info.: **Favor tube all by approx .002**

Drawing Number	Joint Assembly Number	Date	Welding Operators
5015996	N/A	19 Oct. 2005	A. Asa Jones

"Penetration Pass"

PROCESS VALUES

Voltage (KV)	100	Deflection	None
Beam Current (ma)	1.70	Type	DC Spot
Beam Focus From Work Surface	0"	Size	Min.
Heat Shield From Work Distance	5 3/8"	Frequency (Hz)	N/A
Weld Speed (sec/rev)	1	Modulation Set	N/A
Weld Speed (in/min)	47	Puddling Set	N/A
Weld Time Set Cycle (Sec.)	2	Vacuum (torr)	10^{-5}
Rise Set	Min.	Beam-to-Joint Offset	N/A
Fall Set	x 1 @ 1	Position Beam at or	Favor tube by .002
Rotation Spd Setting	1 sec.		

This procedure is in accordance with:	Original Issue:
Bettis IV # PNNL-SPP-05-004	Rev. No. 0 Rev. No. ___ Rev. No. ___
Prepared by A. Asa Jones	Procedure No.
Approved by [signature] 11/10/05	**Bettis - EB - 102**

WELDING PROCEDURE DEMONSTRATION RECORD

Procedure No. Bettis - EB- 102	Prepared by: A.A. Jones Date: 11 Oct. 2005
No. of Samples Required 6	Welding Operator Name Asa Jones
RDT Section 8 Category 4	Welds Made on: 19 Oct. 2005
Sample Identification Nos See Remarks	Welding Equipment ID EBW S/N 601
Component Inspection Report Nos N/A	Welding to Procedure Witnessed by N/A
Material ID and Heat No Haynes 230 Alloy	PROGRAM Bettis Biaxial Creep Specimens

CHARACTERISTIC	REFERENCED SPECIFICATION	NO. OF SAMPLES REQUIRED	REPORT NO. OR LAB ID NO.	ACC	REJ	TECH. OR INSPECTOR	DATE	REMARKS
Comp. Cleaned	Bettis Procedure # N/A	6				N/A		
Visual (Weld)	NE F6-2t Sec. 6 Para. 6.3.2	6		✓		[signature]	10/19/05	
Helium Leak Test	NE F6-2t Sec. 6 Para. 6.3.6	N/A				N/A		
Radiography	NE F6-2t Sec. 6 Para. 6.3.4	6		✓		[signature]	10-27-05	
Pressure Test	Bettis Procedure # N/A	N/A				N/A		
Metallography	NE F6-2t Sec. 6 Para 6.3.7	6		✓		[signature]	11/1/05	
Dimensional	Drawing requirements	6		✓		[signature]	11/1/05	

Record Data Required For Procedure Qualification Package	Yes	No	Completed
Metallography Report and Mount Nos.	X		✓
Metallography Photos (Information)	X		✓
Radiography Report	X		✓
Helium Leak Rate		X	
Copy of the Procedure	X		✓
Pressure Test Data		X	
Pressure Test Specimens		X	
Tensile Test Data		X	
Tensile Test Specimens		X	

Remarks

Specimen Numbers	Sample #'s Top	Bottom
A-ADJ	A-1043	A-1044
A-ADK	A-1045	A-1046
A-ADL	A-1047	A-1048
A-ADM	A-1049	A-1050
A-ADN	A-1051	A-1052
A-ADO	A-1053	A-1054

Approval:

TA Delucchi [signature] 11/1/05

DM Paxton DM Paxton 11/18/05

TD Hays N/A

Page 1 of 1

NDE CAPSULE RADIOGRAPHIC PROCEDURE AND TEST REPORT

COGEMA ENGINEERING
NON DESTRUCTIVE EXAMINATION
2460 STEVENS CENTER - TEL (509) 375-3567

Job No: JA-3

Requestor (client)	Company	Project System/Work Package/Traveler No
A.A. Jones	PNNL	Bettis Biaxial Creep Specimens

MSIN	Bldg.	Area
K5-22	2400	N/A

Acceptance Std	Section	Para	Date	Dwg No	NCR
NE F6-1t Sec 6 Para. 6.3.4			☐ NA	Bettis #5015996 ☐ NA	☒ NA

PART INFORMATION

Material	Haynes 230 Alloy	
Wall/Material Thickness	0.025"	☐ NA
Diameter	0.250"	☐ NA
Schedule		☒ NA

PROCEDURE NO ☐ NA
☒ SVRT-PRC-006 Rev 3
Appendix D Rev. 3
☐ Special Tech. No

AREA TO BE INSPECTED
☒ Full inspection, 100% of Area Requested
☐ Other

EQUIPMENT/MFG
☒ X-Ray — Mfg/Type: Phillips 160 — S.N.: 01065
☐ Isotope

EXPOSURE INFORMATION

KV	160
MA/CI	4.0
Time	2.0

Ug = Fd / D — See procedure for equation definitions

F	.4mm
d	0.25"
D	34.0"
Ug	0.0001"

PRODUCT OR STAGE OR MFG.
☒ As Welded
☐ Weld Surfaces
☐ As Forged
☐ As Cast
☐ As Machined
☐ As Assembled
☐ Other

TYPE WELD
○ NA
○ GTAW (TIG)
○ GMAW (MIG)
◉ EBW
○ LBW (Laser)

WELD STAGE
○ Root Pass
◉ Final
○ Repair No

	Single Wall	Double Wall	
Radiographed			☒ NA
Interpreted			

○ Tangential ○ NA
◉ Edge Enhancement (Tangential)
○ Shape Correction
○ 1/2 Shape Correction

Beam Filter and Thickness: ☒ Copper ☐ NA 0.010"

Film Parameters
Film Mfg: ☒ Fuji
Film Type: IX25
Film Load: ☐ Single ☒ Double ☐ .005"FF.005"
Screens: ☐ NA 0.005"

Penetrameter
Type: ☒ ASME ☐ SS ☐ FS ☒ SL
Size: #5
Hole: ○ 1T ◉ 2T ○ 4T
Shim Mat'l and Thickness: ☐ Steel — Inconel .100, .155

Codes

K A - Acceptable	H - Heavy Metal Inclusion		
K R - Reject	P - Porosity		
C - Crack	S - Shrink		
I - Inclusion	U - Undercut		
IF - Incomplete Fusion	WT - Weld Thickness		
IF - Incomplete Penetration	GTR - Gas Tag Rupture		

DENSITY REQUIREMENTS
○ 1.3 to 4.0 ○ 2.3 to 4.0
○ 1.4 to 2.0 ○ 2.2 to 3.0
◉ 1.8 to 4.0 ○ NA

DENSITOMETER LINEARITY CALIBRATION

Range	.30	3.0	3.9
Step Wedge	.4	3.0	4.01
Actual	.41	3.02	4.03

SEE REVERSE SIDE FOR BASIC SKETCH

Weld No., Part No., or Serial No.	0	30	60	90	120	150					Acc	Rej	No. Ind. Noted	Comments
A-ADJ	A	A	A	A	A	A					X			
A-ADK	A	A	A	A	A	A					X			
A-ADL	A	A	A	A	A	A					X			
A-ADM	A	A	A	A	A	A					X			
A-ADN	A	A	A	A	A	A					X			
A-ADO	A	A	A	A	A	A					X			

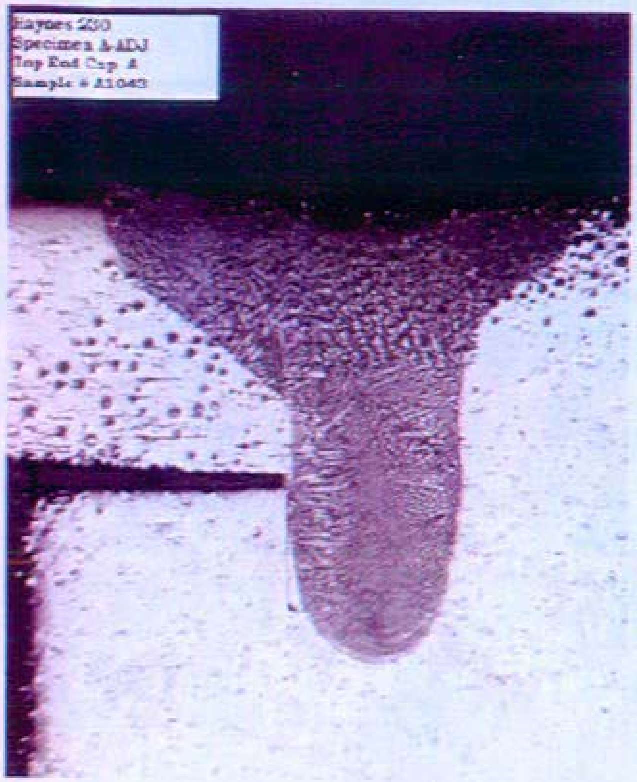
(List Degrees of Rotation Used)

Film Records Transfer
☐ N.A. PNNL (Company) — [signature] (Signature) — Tech 6 (Title) — 31 Oct 2005 (Date)

Technician	RT Level	Interpreted by	RT Level	Reviewed by
M. L. Casto [signature]	II	J. R. Reve [signature]	III	[signature]
J. R. Reve [signature]	III			

Date of Examination: 10/25/05 — Date: 10/26/05 — Date: 11/3/05

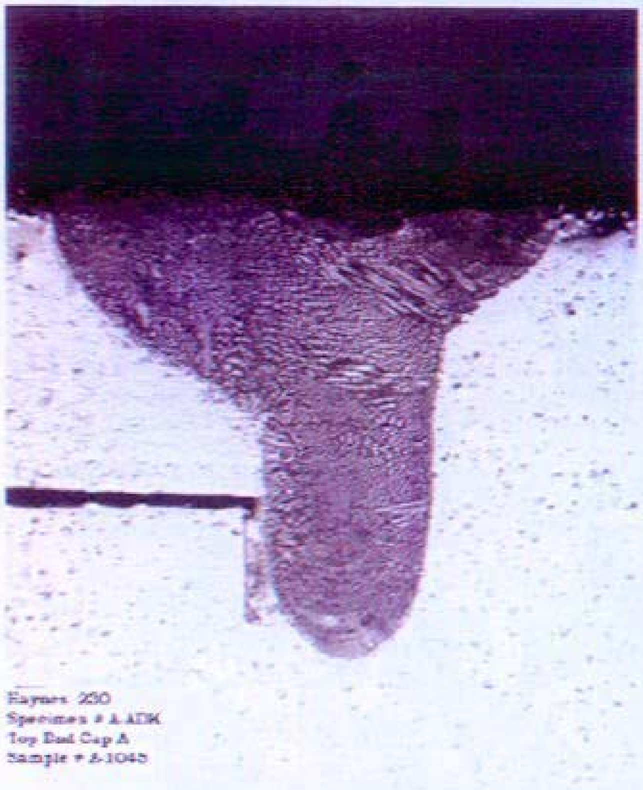
A-6002-664 (08/04)


Haynes 230
Specimen A-ADJ
Top End Cap A
Sample # A1043


Haynes 230
Specimen A-ADJ
Top End Cap B
Sample # A1044


Haynes 230
Specimen # A-ADJ
Bottom End Cap B
Sample # A-1044


Haynes 230
Specimen A-ADJ
Bottom End Cap A
Sample # A-1044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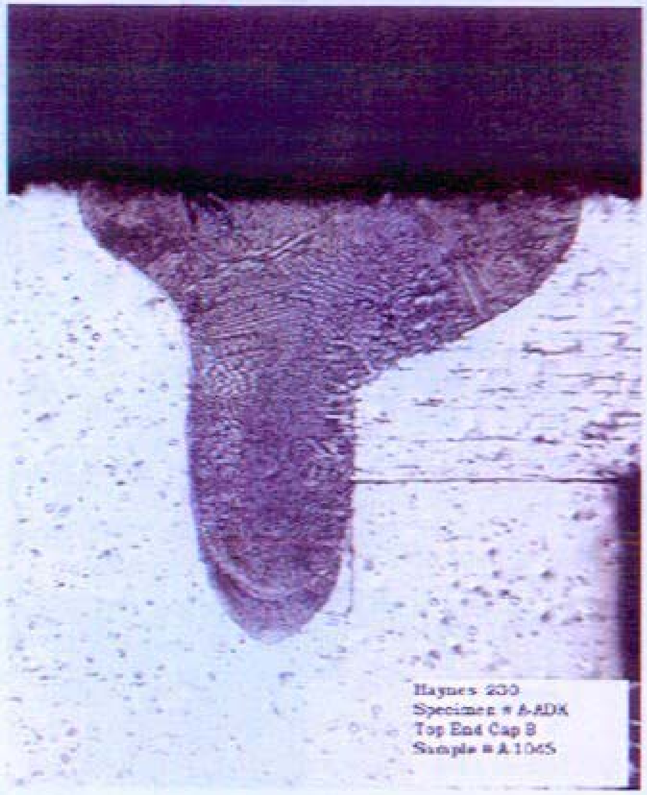
Specimen # A-ADK
Top End Cap A
Sample # A-1045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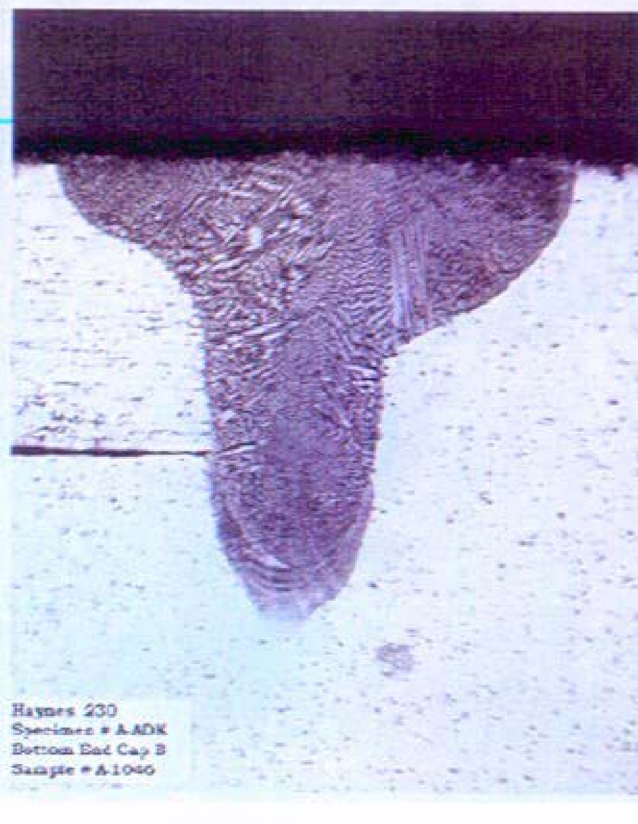
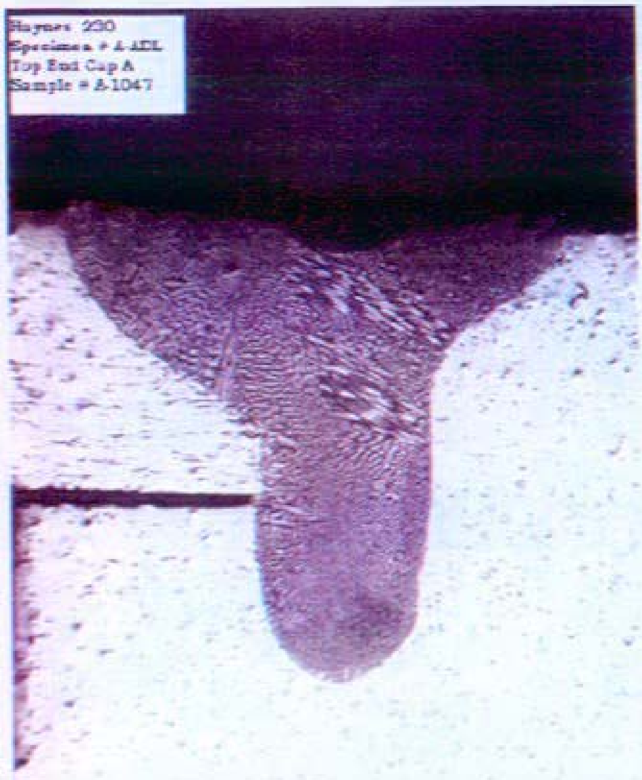
Specimen # A-ADK
Top End Cap B
Sample # A-1065

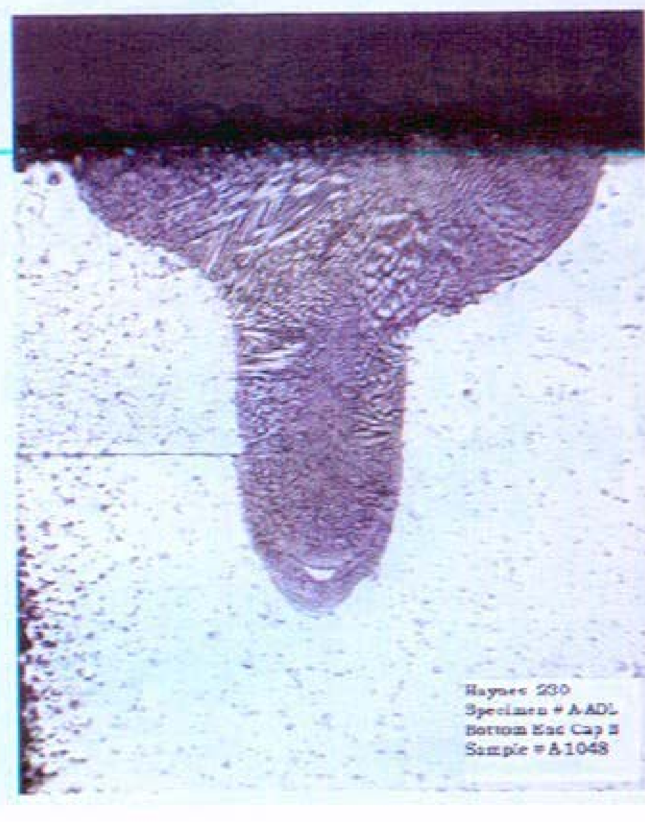

Haynes 230
Specimen # A-ADK
Bottom End Cap A
Sample # A-1046


Haynes 230
Specimen # A-ADK
Bottom End Cap B
Sample # A-1040


Haynes 230
Specimen # A-ADL
Top End Cap A
Sample # A-1047


Haynes 230
Specimen # A-ADL
Top End Cap B
Sample # A-1047


Haynes 230
Specimen # A-ADL
Bottom End Cap A
Sample # A-1048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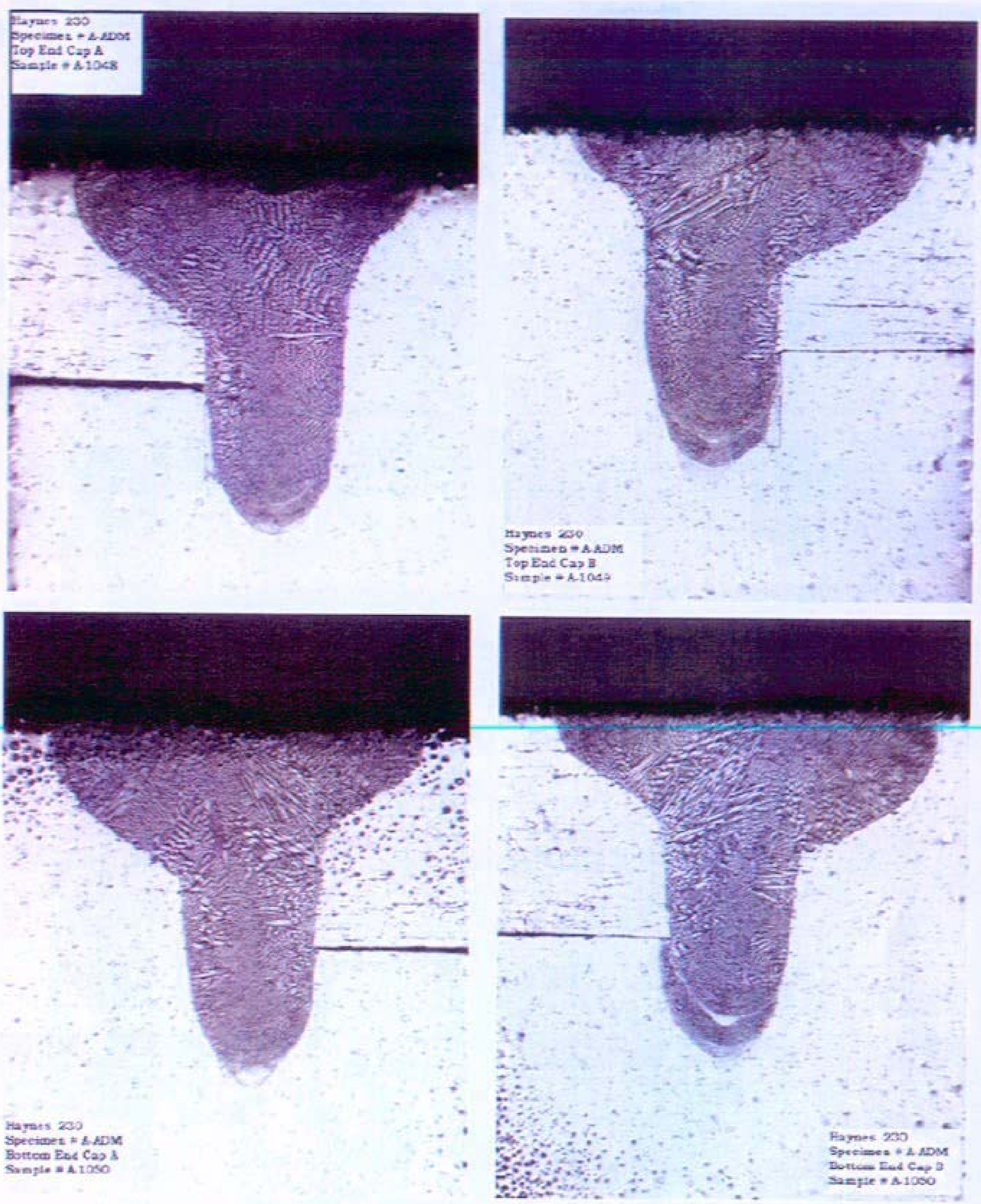
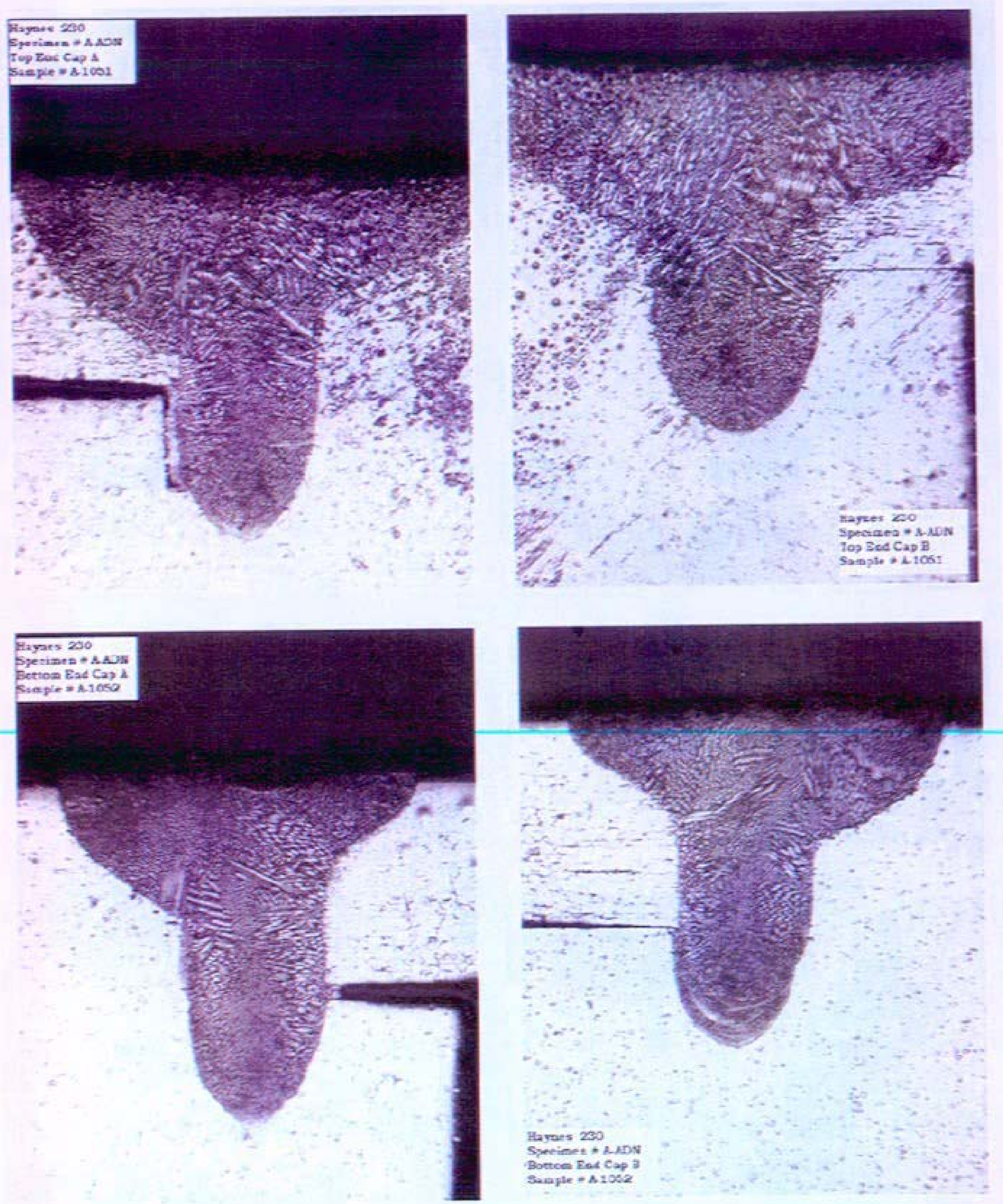
Specimen # A-ADL
Bottom End Cap B
Sample # A-1048


Haynes 230
Specimen # A-ADM
Top End Cap A
Sample # A-1048
Haynes 230
Specimen # A-ADM
Top End Cap B
Sample # A-1049
Haynes 230
Specimen # A-ADM
Bottom End Cap A
Sample # A-1050
Haynes 230
Specimen # A-ADM
Bottom End Cap B
Sample # A-1050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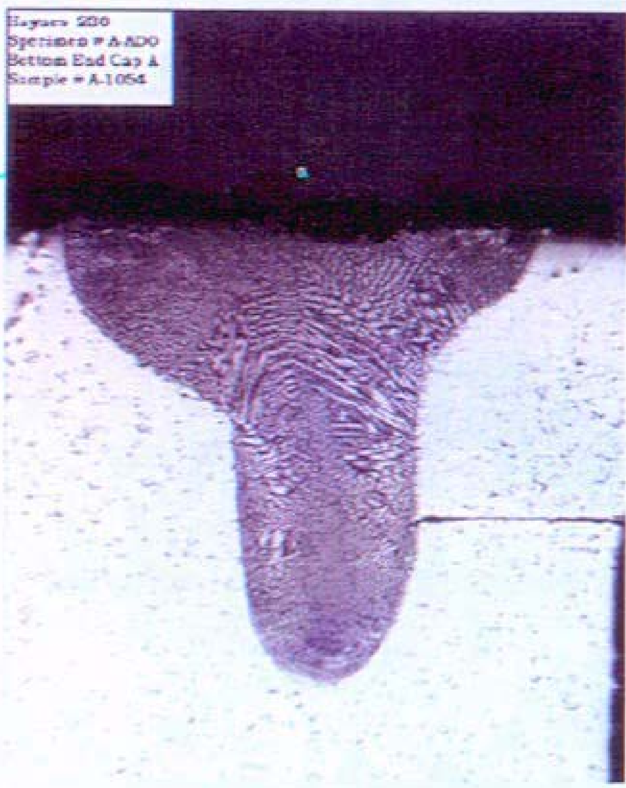
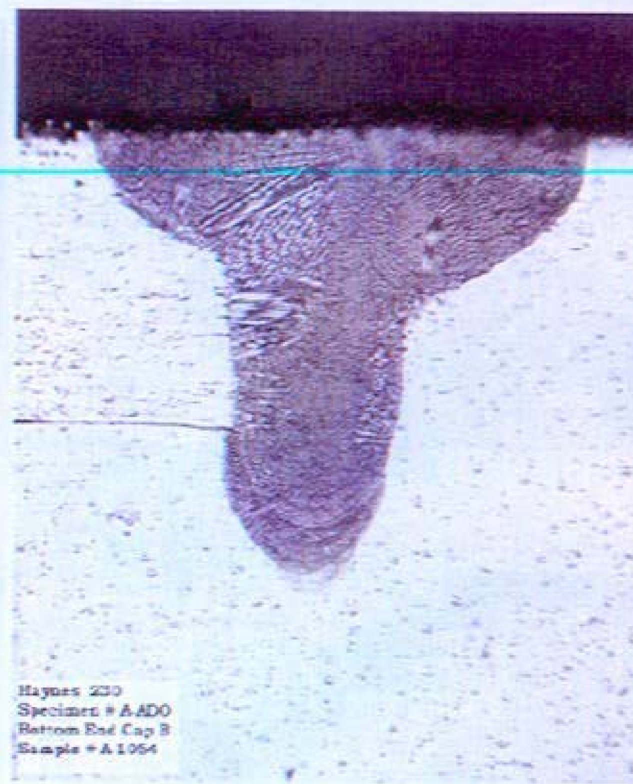
Specimen # A-ADN
Top End Cap A
Sample # A-1051
Haynes 230
Specimen # A-ADN
Top End Cap B
Sample # A-1051
Haynes 230
Specimen # A-ADN
Bottom End Cap A
Sample # A-1052
Haynes 230
Specimen # A-ADN
Bottom End Cap B
Sample # A-1052

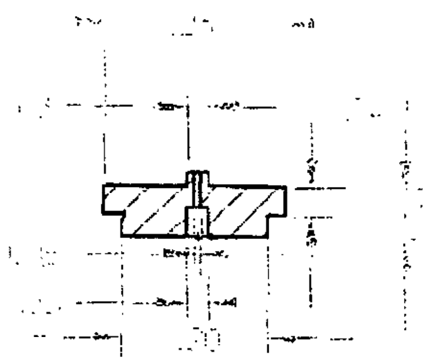

Haynes 230
Specimen # A-ADO
Top End Cap A
Sample # A-1053


Haynes 230
Specimen # A-ADO
Top End Cap B
Sample # A-1053


Haynes 230
Specimen # A-ADO
Bottom End Cap A
Sample # A-1054


Haynes 230
Specimen # A-ADO
Bottom End Cap B
Sample # A-1054

TEST ENGINEERING BATTELLE NORTHWEST P.O. BOX 999 RICHLAND, WA 99352	WELDING PROCEDURE LASER WELDING PROCESS



MATERIAL:	Haynes 230 Alloy (nickel based)
THICKNESS:	0.03
PRE-CLEANING:	Yes
COVER GLASS:	Quartz
MACHINE MAKE:	Korad
MACHINE MODEL:	KWD
ADDITIONAL INFO	Evacuate and back fill with UHP helium three times prior to welding.

DRAWING NUMBER	JOINT ASSEMBLY NO.	DATE	WELDING OPERATOR
5015996	N/A	11 Oct. 2005	Asa Jones

SEE WELDING PROCEDURE DESCRIPTION Bettis IV # PNNL-SPP-05-004 FOR QUALITY REQUIREMENTS.

PROCESS VALUES

ROD TYPE & I.D. NO.	Nd:YAG	VOLTAGE	2.5
APERTURE	100	SPOT SIZE	0.747
ATTENUATOR	0	JOULES / PULSE	N/A
MONITOR VOLTS	85-87	ATMOSPHERE	Helium
SCALE FACTOR	N/A	PRESSURE	0-3000 PSIG
FOCUS LENS	6"	PULSE WIDTH	Position # 3
NO. OF PULSES	1 or more		

Asa Jones

REV. NO.
REV. NO.
REV. NO.

APPROVED FOR TEST ENGINEERING
N/A due to rejection

PROCEDURE NO.
Bettis - Laser - 200

5/05

WELDING PROCEDURE DEMONSTRATION RECORD

Procedure No. Bettis - Laser- 202	Prepared by: A.A. Jones Date: 11 Oct. 2005
No. of Samples Required 6	Welding Operator Name Asa Jones
RDT Section 8 Category 4	Welds Made on: 20 Oct. 2005 [illegible]
Sample Identification Nos See Remarks	Welding Equipment ID Kerad KWD
Component Inspection Report Nos N/A	Welding to Procedure Witnessed by N/A
Material ID and Heat No Haynes 230 Alloy	PROGRAM Bettis Biaxial Creep Specimens

CHARACTERISTIC	REFERENCED SPECIFICATION	NO. OF SAMPLES REQUIRED	REPORT NO. OR LAB ID NO.	ACC	REJ	TECH. OR INSPECTOR	DATE	REMARKS
Comp. Cleaned	Bettis Procedure # N/A	6				N/A		
Visual (Weld)	NE F6-2t Sec. 6 Para. 6.3.2	6		✓		[illegible]	[illegible]	
Helium Leak Test	NE F6-2t Sec. 6 Para. 6.3.6	N/A				N/A		
Radiography	NE F6-2t Sec. 6 Para. 6.3.4	N/A				N/A		
Pressure Test	Bettis Procedure # N/A	N/A				N/A		
Metallography	NE F6-2t Sec. 6 Para 6.3.7	6			✓	[illegible]	[illegible]	
Dimensional	Drawing requirements	6		✓		[illegible]	[illegible]	

Record Data Required For Procedure Qualification Package	Yes	No	Completed
Metallography Report and Mount Nos.	X		✓
Metallography Photos (Information)	X		✓
Radiography Report		X	
Helium Leak Rate		X	
Copy of the Procedure	X		✓
Pressure Test Data		X	
Pressure Test Specimens		X	
Tensile Test Data		X	
Tensile Test Specimens		X	

Remarks

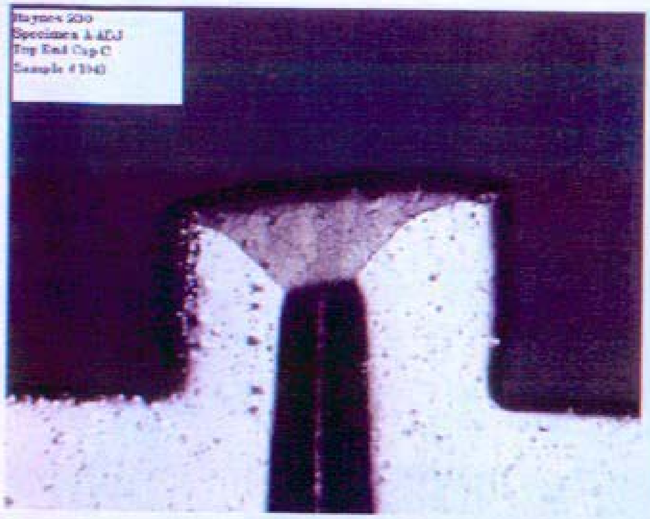
Specimen Numbers	Sample #'s
A-ADJ	A-1103
A-ADK	A-1104
A-ADL	A-1105
A-ADM	A-1106
A-ADN	A-1107
A-ADO	A-1108

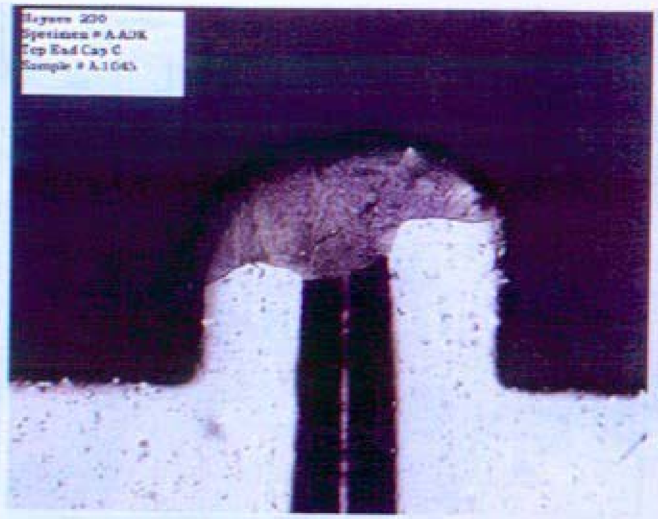
Approval:

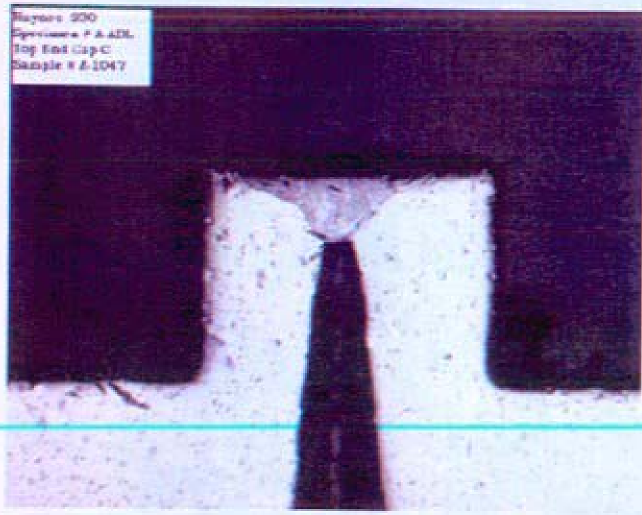
TA Delucchi N/A due to rejection

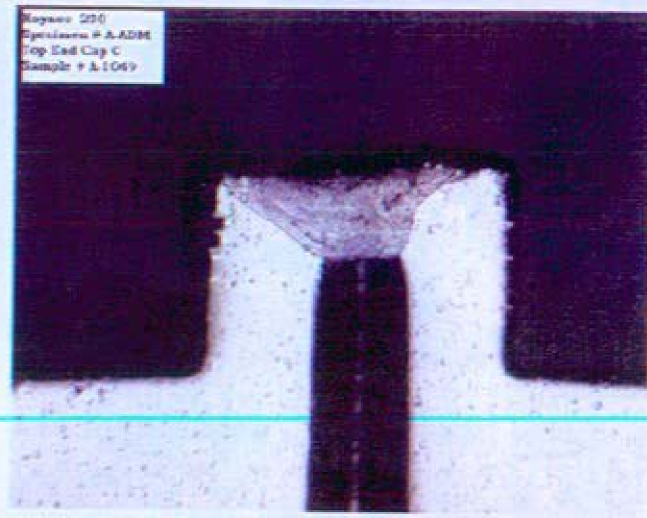
DM Paxton N/A due to rejection

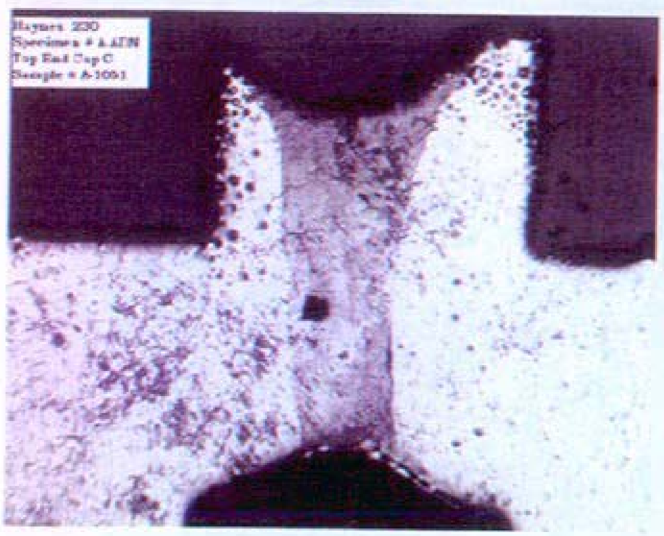
TD Hays N/A

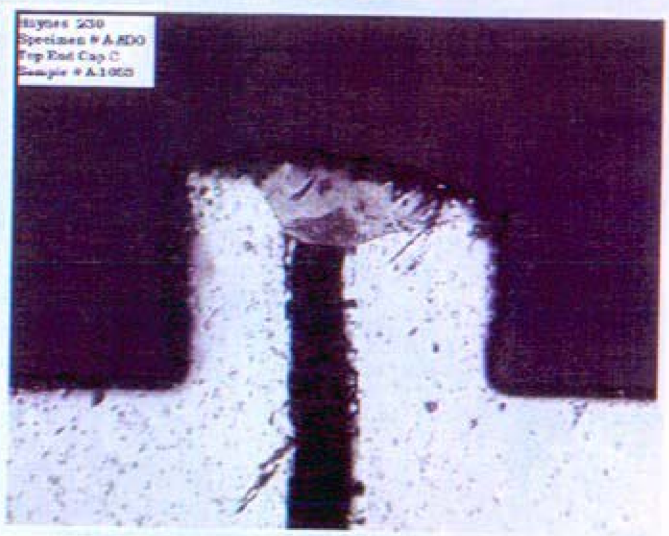

Haynes 230
Top End Cap C


Haynes 230
Top End Cap C


Haynes 230
Top End Cap C


Haynes 230
Top End Cap C


Haynes 230
Top End Cap C


Haynes 230
Top End Cap C

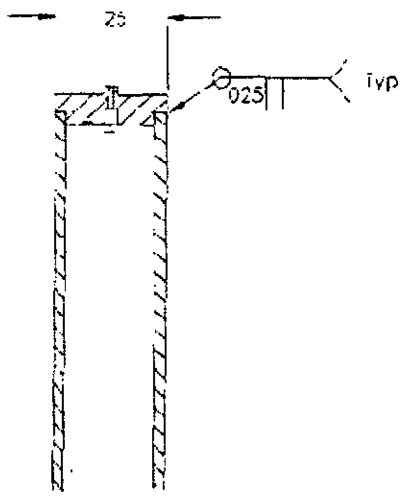
ATTACHMENT 4

Weld Demonstration Data Package

for

T-111

Test Engineering Battelle Northwest P.O. Box 999 Richland, WA 99352	**WELDING PROCEDURE** **Electron Beam Welding Process**



Base Material & Form: **T-111 Alloy (Ta) Tube and Bar**

Filler Material, Form, Size: N/A

Preheat: **N/A** Postheat: **N/A**

Weld Position: **1G**

No. of Passes: 1

"Cosmetic" Pass Used: **No**

Gun Type: **CLR 32**

Lap-Over (in/deg) **90° Min.**

Type Backing: **Intergral**

Machine Make or S/N: **Hamilton Std. EBW S/N 601**

Additional Info.: **Favor tube all by approx .002**

Drawing Number	Joint Assembly Number	Date	Welding Operators
5015996	N/A	19 Oct. 2005	A. Asa Jones

"Penetration Pass"

PROCESS VALUES

Voltage (KV)	100	Deflection	None
Beam Current (ma)	4.5	Type	DC Spot
Beam Focus From Work Surface	0"	Size	Min.
Heat Shield From Work Distance	5 3/8"	Frequency (Hz)	N/A
Weld Speed (sec/rev)	2	Modulation Set	N/A
Weld Speed (in/min)	24	Puddling Set	N/A
Weld Time Set Cycle (Sec.)	3.5	Vacuum (torr)	10^{-5}
Rise Set	Min.	Beam-to-Joint Offset	N/A
Fall Set	x 1 @ 2	Position Beam at or	Favor tube by .002
Rotation Spd Setting	2 sec.		

This procedure is in accordance with:

Bettis IV # PNNL-SPP-05-004

Original Issue:

Rev. No. 0
Rev. No. ____
Rev. No. ____

Prepared by

A. Asa Jones

Approved by

[signature] 11/10/05

Procedure No.

Bettis – EB- 103

WELDING PROCEDURE DEMONSTRATION RECORD

Procedure No. Bettis - EB- 103	Prepared by: A.A. Jones Date: 11 Oct. 2005
No. of Samples Required 6	Welding Operator Name Asa Jones
RDT Section 8 Category 4	Welds Made on:
Sample Identification Nos See Remarks	Welding Equipment ID EBW S/N 601
Component Inspection Report Nos N/A	Welding to Procedure Witnessed by N/A
Material ID and Heat No T-111 Alloy (Ia)	PROGRAM Bettis Biaxial Creep Specimens

CHARACTERISTIC	REFERENCED SPECIFICATION	NO. OF SAMPLES REQUIRED	REPORT NO. OR LAB ID NO.	ACC	REJ	TECH. OR INSPECTOR	DATE	REMARKS
Comp. Cleaned	Bettis Procedure # N/A	6				N/A		
Visual (Weld)	NE F6-2t Sec. 6 Para. 6.3.2	6		✓		[signature]	[date]	
Helium Leak Test	NE F6-2t Sec. 6 Para. 6.3.6	6				N/A		
Radiography	NE F6-2t Sec. 6 Para. 6.3.4	6				See Enclosed		
Pressure Test	Bettis Procedure # N/A	N/A				N/A		
Metallography	NE F6-2t Sec. 6 Para 6.3.7	6		✓		[signature]	11/10/05	
Dimensional	Drawing requirements	6		✓		[signature]	11/10/05	

Record Data Required For Procedure Qualification Package	Yes	No	Completed
Metallography Report and Mount Nos.	X		✓
Metallography Photos (Information)	X		✓
Radiography Report	X		NO
Helium Leak Rate		X	
Copy of the Procedure	X		✓
Pressure Test Data		X	
Pressure Test Specimens	X		NC
Tensile Test Data		X	
Tensile Test Specimens		X	

Remarks

Sample #'s

Specimen Numbers	Top	Bottom
T-AAD	A-1055	A-1056
T-AAF	A-1057	A-1058
T-AAG	A-1059	A-1060
T-AAI	A-1061	A 1062
T-AAN	A-1063	A-1064
T-ABA	A-1065	A-1066

Approval:

TA Delucchi [signature] 11/10/05

DM Paxton DM Paxton 11/10/05

TD Hays N/A

AREVA

COGEMA-05-0162

Mr. Dean Paxton
Battelle
Post Office Box 999, MSIN K2-44
Richland, Washington 99352

November 8, 2005

Dear Mr. Paxton:

CONTRACT NO. 16052 - CONSULTING SERVICES OF DELUCCHI / CASTO

As requested, this letter outlines the success and short-comings of the radiography of the pressurized specimens.

- The nickel-based materials, even though the x-ray grooves in the end caps were not square and undersized in some of the samples, were examined in accordance with the requirements and found to be acceptable.

- The niobium alloy materials may have been properly examined; however, the x-ray grooves were not machined to the proper size. This would have made radiography results inconclusive since the groove in the test exposures of the non-welded samples was very faint in one end cap and non-existent in the other. The 160 kV x-ray system appears to be at its penetration limit for this material at this thickness (wall thickness measured at approximately 0.025") as the inner wall was not resolved to the level it should have been. However, in the opinion of COGEMA, Inc. Level III certified radiographer, this type of pressurized specimen material could have been successfully examined.

- The tantalum materials were not examined because the 160 kV x-ray system does not have the penetration power for this dense material. The wall of neither the tube nor the end cap could be resolved.

When pressurized specimen radiography of high-density materials was performed in the past it was conducted at a Department of Energy (DOE) facility. This DOE facility is now in the process of being demolished. The 160 kV and 450 kV x-ray systems were removed from the building and acquired by COGEMA, Inc. through the non-destructive examination contract. The current COGEMA, Inc. radiography facility features a high-frequency 160 kV Philips x-ray system. The interior of the x-ray vault is approximately 6 feet by 6 feet and about 6 feet in height, which is adequate for most small steel and stainless steel parts up to thickness of about 1.25 inches.

COGEMA-05-0162
Mr. Dean Paxton
Page 2
November 8, 2005

Unfortunately, this cabinet's shielding is not adequate for the more penetrating 450 kV x-ray system that would be required to examine the tantalum type of materials. COGEMA, Inc. has explored the possibility of building a suitable shielded vault to house the 450 kV x-ray system, but currently we have not been able to identify enough business to make construction of a facility economically viable.

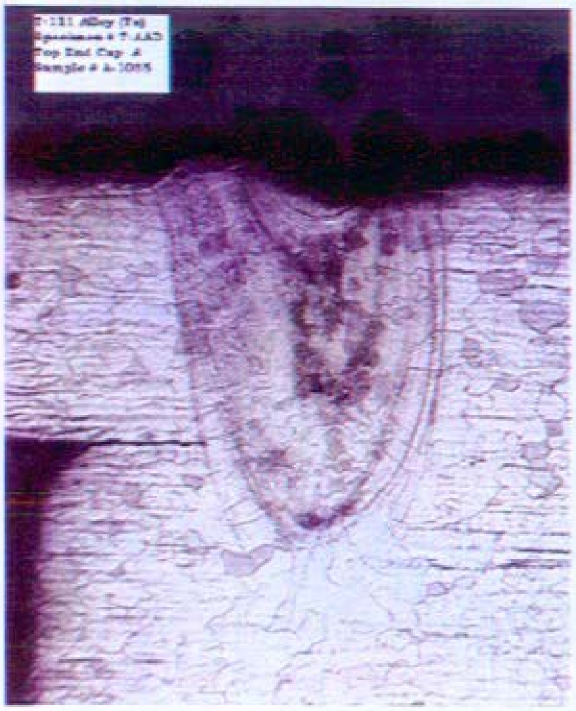
If you have any questions or require additional information, please feel free to contact Mr. John Keve at 375-4003.

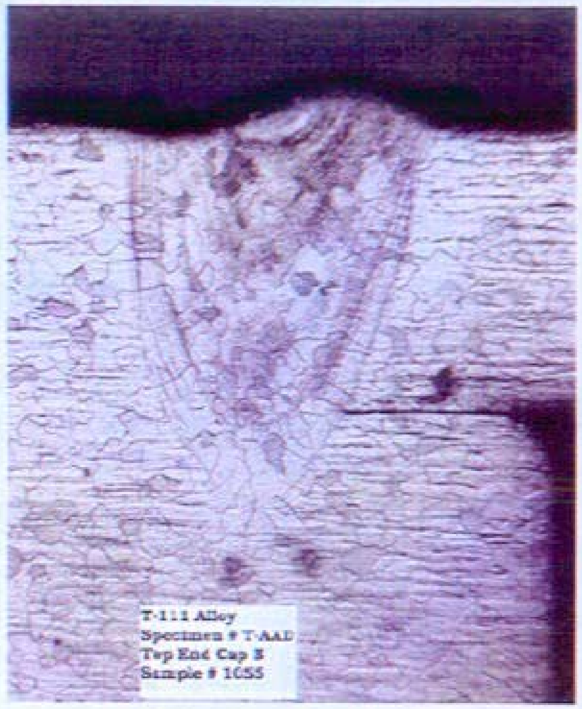
Sincerely,

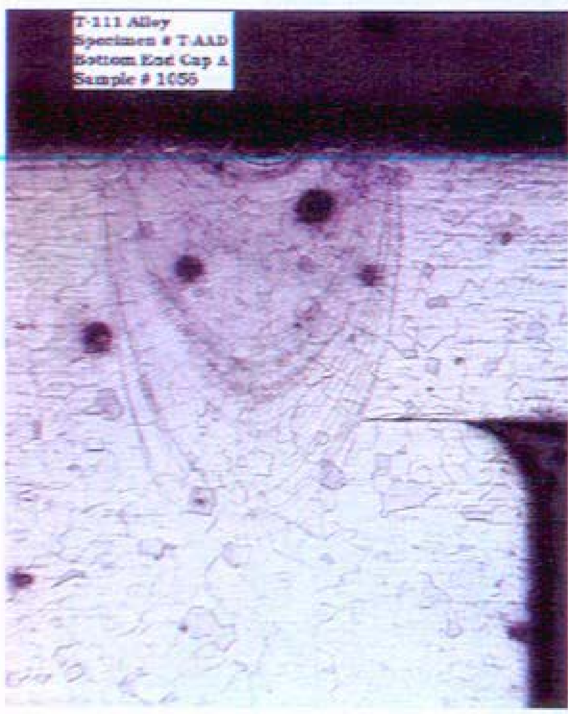
Mark D. Rickenbach
Director, Services
COGEMA, Inc.
Richland Office

CONCURRENCE:

John K. Keve, NDE Level III
COGEMA, Inc.


T-111 Alloy
Top End Cap A

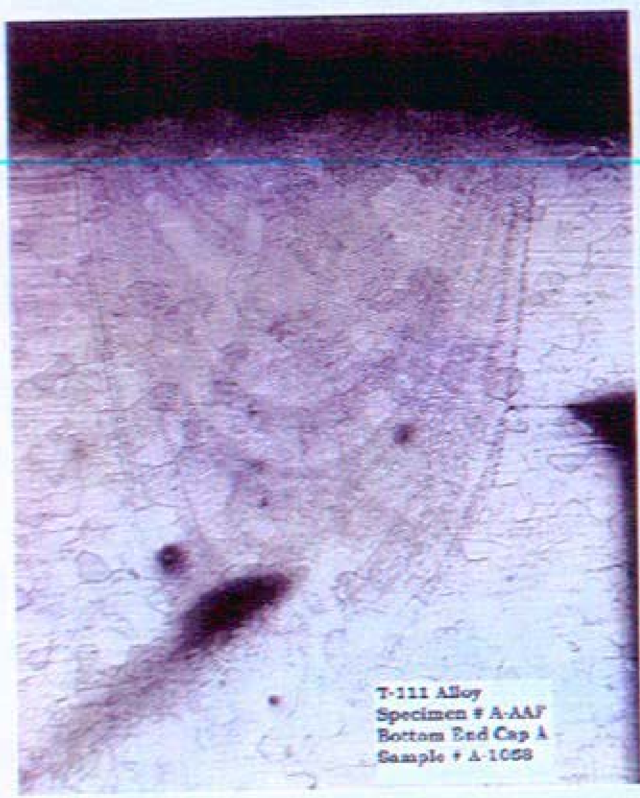

T-111 Alloy
Specimen # T-AAD
Top End Cap B
Sample # 1055


T-111 Alloy
Specimen # T-AAD
Bottom End Cap A
Sample # 1056


T-111 Alloy
Specimen # T-AAD
Bottom End Cap B
Sample # 1056


T-111 Alloy
Specimen # T-AAF
Top End Cap A
Sample # 1057


T-111 Alloy
Specimen # T-AAF
Top End Cap B
Sample # 1057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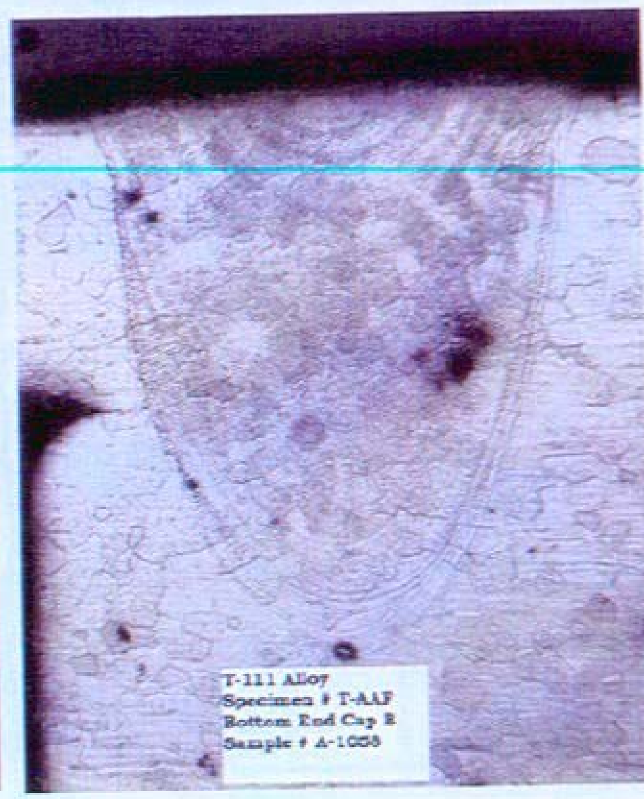
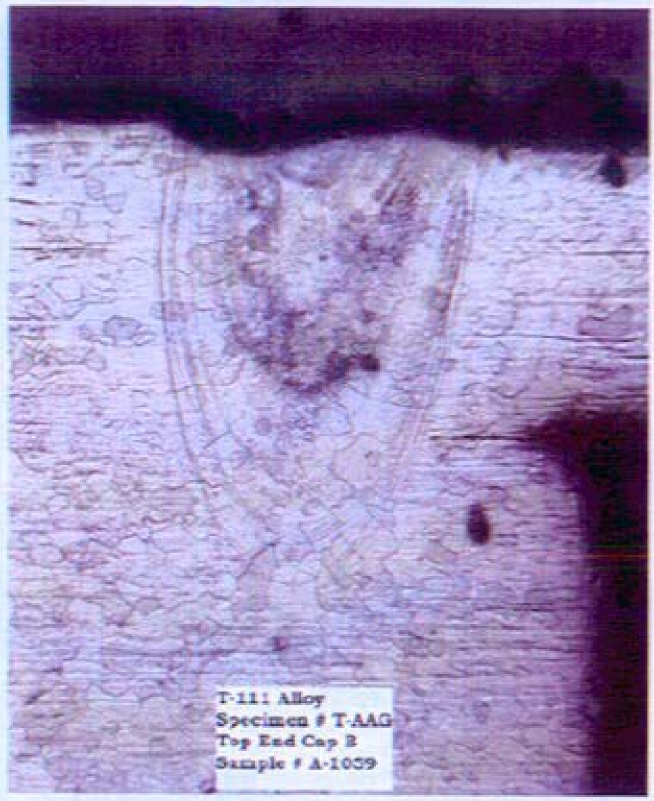
Specimen # A-AAF
Bottom End Cap A
Sample # A-1058


T-111 Alloy
Specimen # T-AAF
Bottom End Cap B
Sample # A-1058


T-111 Alloy
Specimen # T-AAG
Top End Cap A
Sample # A-1059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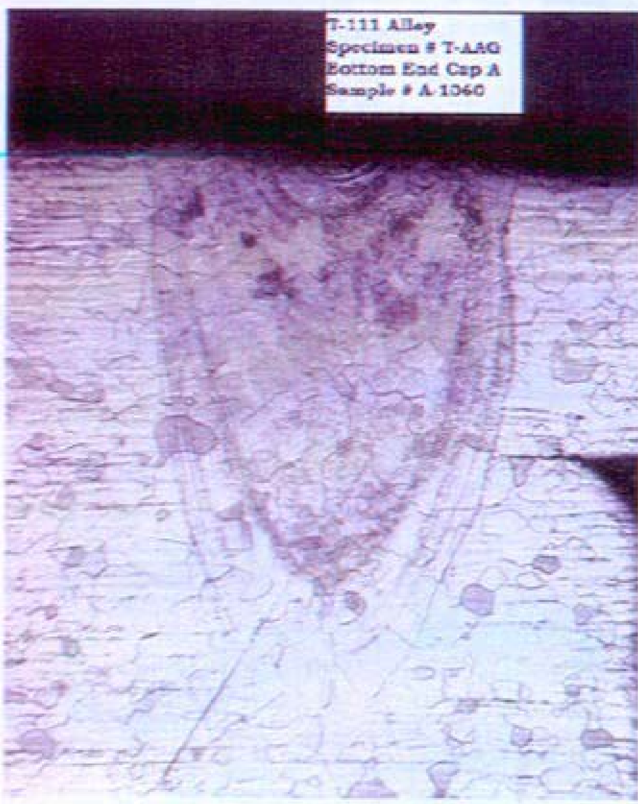
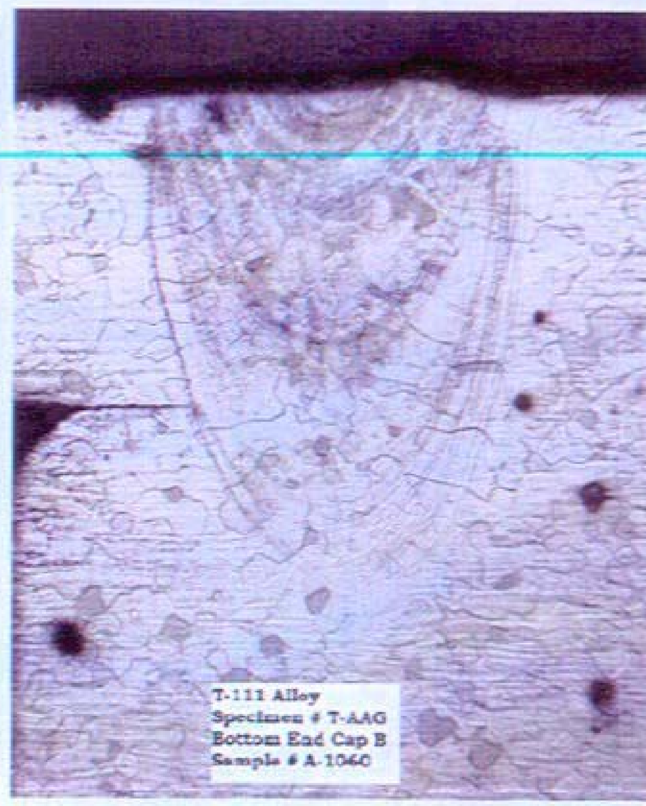
Specimen # T-AAG
Top End Cap B
Sample # A-1059


T-111 Alloy
Specimen # T-AAG
Bottom End Cap A
Sample # A-1060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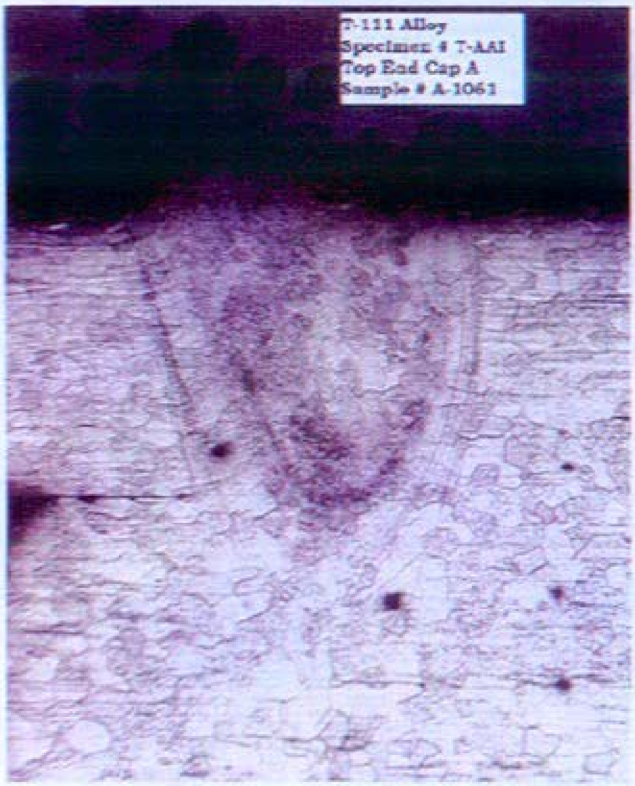
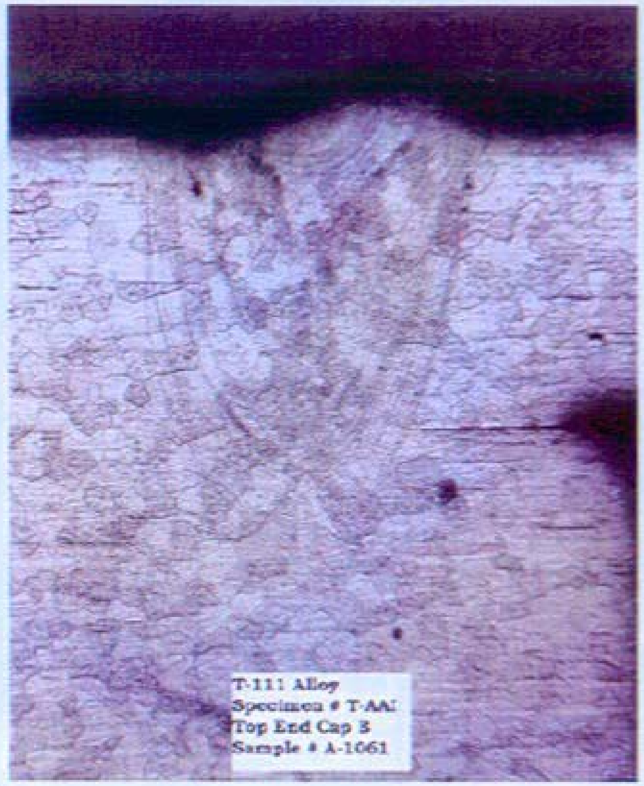
Specimen # T-AAG
Bottom End Cap B
Sample # A-1060


T-111 Alloy
Specimen # T-AAI
Top End Cap A
Sample # A-1061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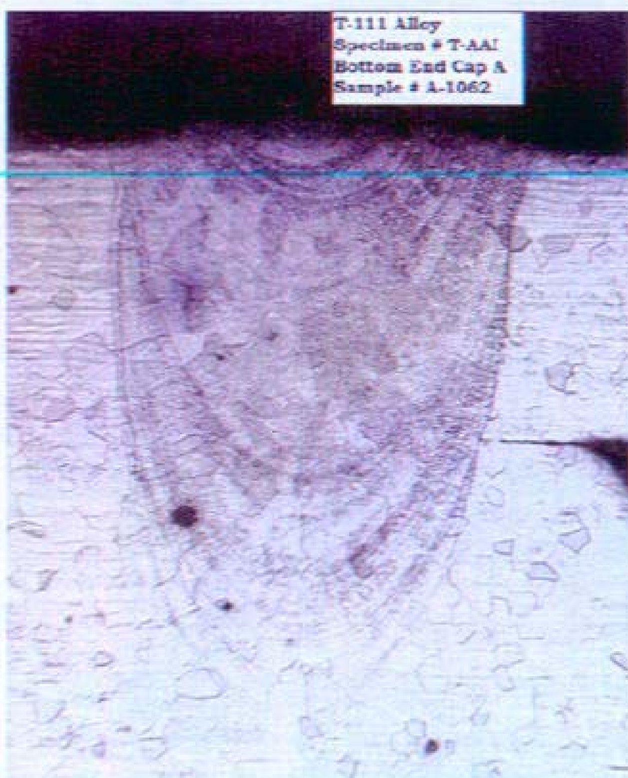
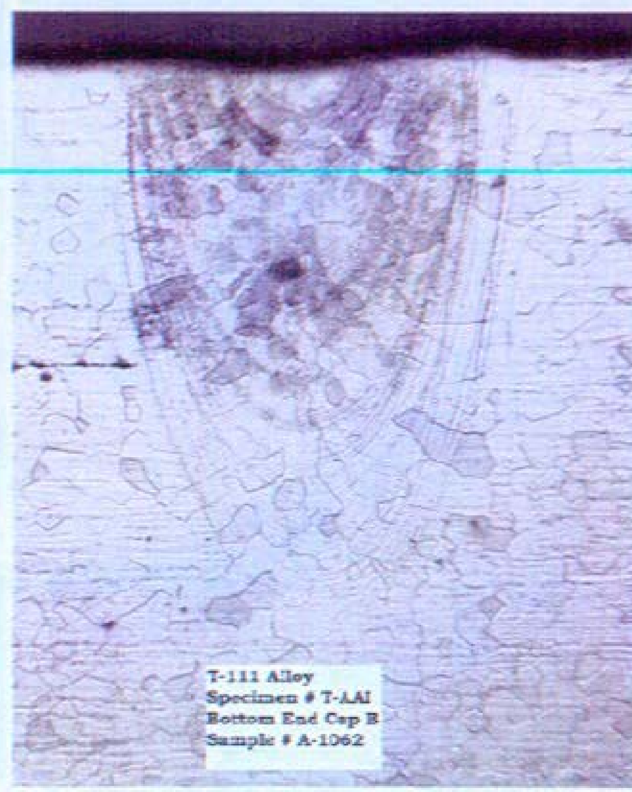
Specimen # T-AAI
Top End Cap B
Sample # A-1061


T-111 Alloy
Specimen # T-AAI
Bottom End Cap A
Sample # A-1062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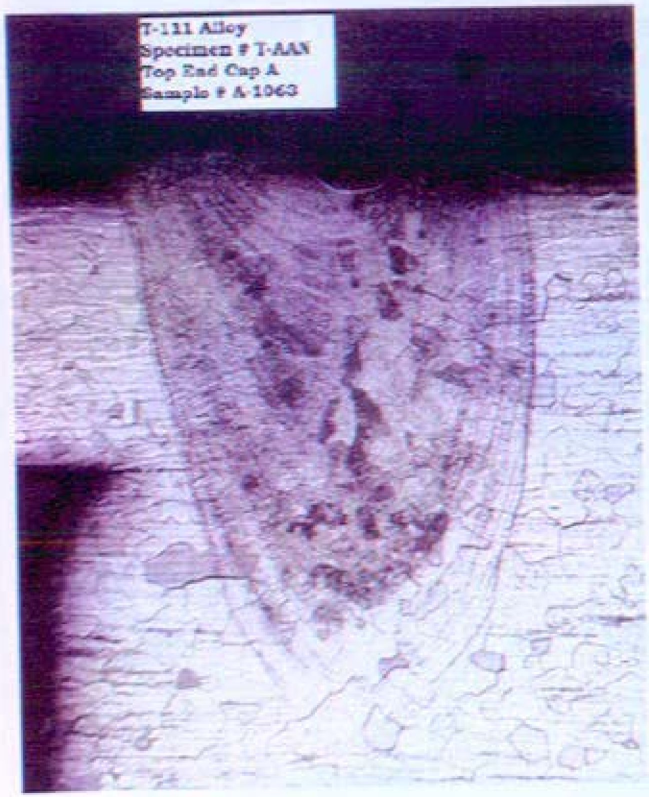
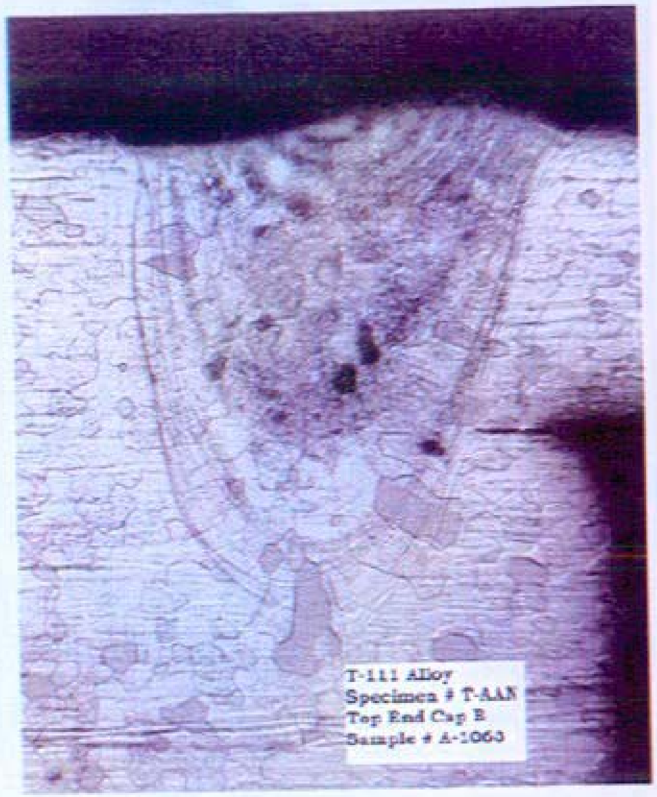
Specimen # T-AAI
Bottom End Cap B
Sample # A-1062


T-111 Alloy
Specimen # T-AAN
Top End Cap A
Sample # A-1063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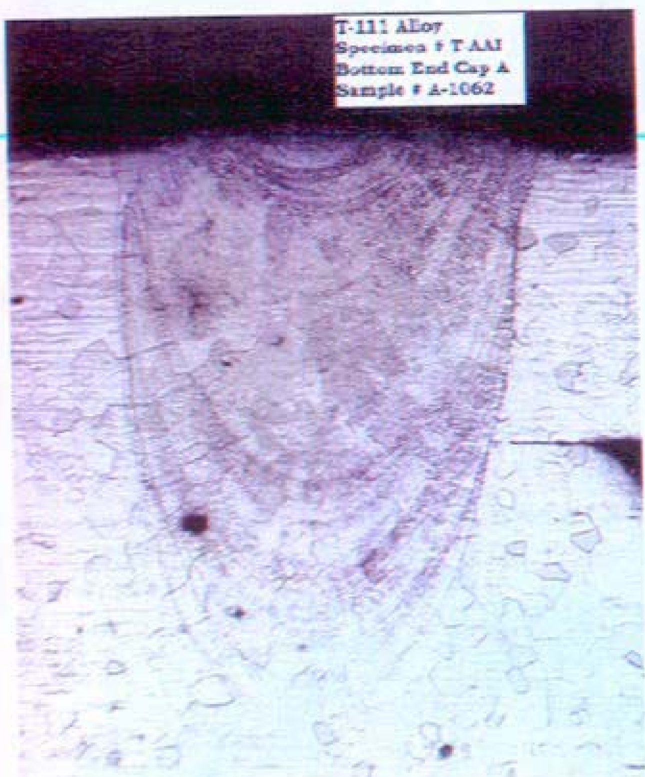
Specimen # T-AAN
Top End Cap B
Sample # A-1063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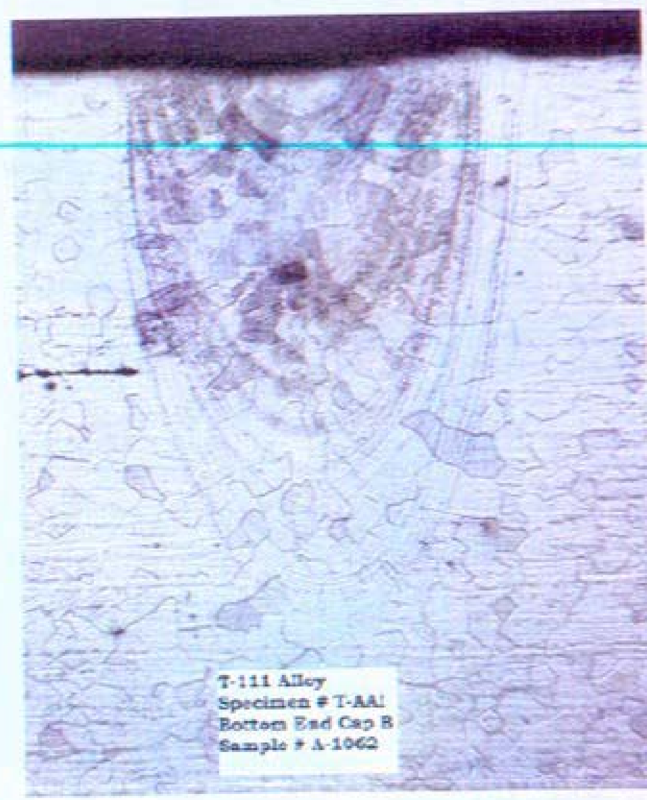
Specimen # T-AAI
Bottom End Cap A
Sample # A-1062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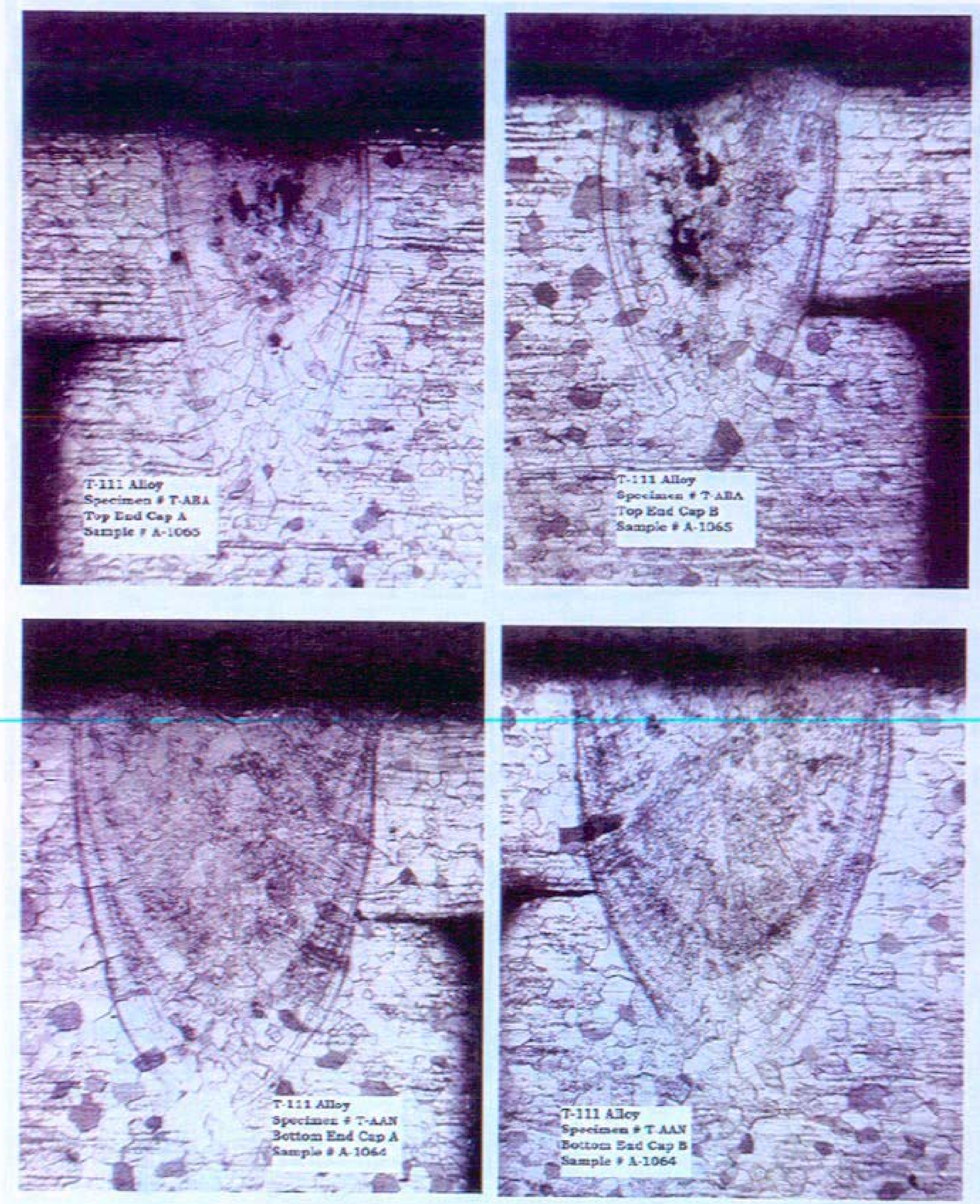
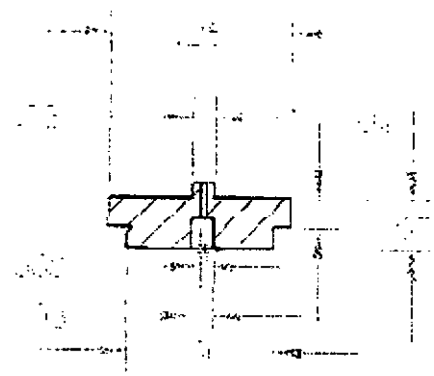
Specimen # T-AAI
Bottom End Cap B
Sample # A-1062


T-111 Alloy
Specimen # T-ABA
Top End Cap A
Sample # A-1065
T-111 Alloy
Specimen # T-ABA
Top End Cap B
Sample # A-1065
T-111 Alloy
Specimen # T-AAN
Bottom End Cap A
Sample # A-1064
T-111 Alloy
Specimen # T-AAN
Bottom End Cap B
Sample # A-1064

TEST ENGINEERING BATTELLE NORTHWEST P.O. BOX 999 RICHLAND, WA 99352	WELDING PROCEDURE LASER WELDING PROCESS



MATERIAL:	T-111 Alloy (Ta)
THICKNESS:	0.03
PRE-CLEANING.	Yes
COVER GLASS	Quartz
MACHINE MAKE:	Korad
MACHINE MODEL.	KWD
ADDITIONAL INFO	Evacuate and back fill with UHP helium three times prior to welding.

DRAWING NUMBER	JOINT ASSEMBLY NO.	DATE	WELDING OPERATOR
5015996	N/A	11 Oct. 2005	Asa Jones

SEE WELDING PROCEDURE DESCRIPTION Bettis IV # PNNL-SPP-05-004 FOR QUALITY REQUIREMENTS.

PROCESS VALUES

ROD TYPE & I.D. NO.	Nd:YAG	VOLTAGE	3.6
APERTURE	100	SPOT SIZE	0.747
ATTENUATOR	0	JOULES / PULSE	N/A
MONITOR VOLTS	194-197	ATMOSPHERE	Helium
SCALE FACTOR	N/A	PRESSURE	0-3000 PSIG
FOCUS LENS	6"	PULSE WIDTH	Position # 3
NO. OF PULSES	1 or more		

PREPARED BY:		
Asa Jones	ORIGNAL ISSUE	11 Oct. 2005
	REV. NO.	
	REV. NO.	
	REV. NO.	

APPROVED FOR TEST ENGINEERING

N/A due to rejection

PROCEDURE NO

Bettis - Laser - 203

5/05

WELDING PROCEDURE DEMONSTRATION RECORD

Procedure No. Bettis - Laser- 203	Prepared by: A.A. Jones Date: 11 Oct. 2005
No. of Samples Required 6	Welding Operator Name Asa Jones
RDT Section 8 Category 4	Welds Made on:
Sample Identification Nos See Remarks	Welding Equipment ID EBW S/N 601
Component Inspection Report Nos N/A	Welding to Procedure Witnessed by N/A
Material ID and Heat No T-111 Alloy (Ta)	PROGRAM Bettis Biaxial Creep Specimens

CHARACTERISTIC	REFERENCED SPECIFICATION	NO. OF SAMPLES REQUIRED	REPORT NO. OR LAB ID NO.	ACC	REJ	TECH. OR INSPECTOR	DATE	REMARKS
Comp. Cleaned	Bettis Procedure # N/A	6				N/A		
Visual (Weld)	NE F6-2t Sec. 6 Para. 6.3.2	6			✓	[signature]	[illegible]	
Helium Leak Test	NE F6-2t Sec. 6 Para. 6.3.6	N/A				N/A		
Radiography	NE F6-2t Sec. 6 Para. 6.3.4	N/A				N/A		
Pressure Test	Bettis Procedure # N/A	N/A				N/A		
Metallography	NE F6-2t Sec. 6 Para 6.3.7	6			✓	[signature]	[illegible]	
Dimensional	Drawing requirements	6			✓	[signature]	[illegible]	[illegible]

Record Data Required For Procedure Qualification Package	Yes	No	Completed
Metallography Report and Mount Nos.	X		✓
Metallography Photos (Information)	X		✓
Radiography Report		X	
Helium Leak Rate		X	
Copy of the Procedure	X		✓
Pressure Test Data		X	
Pressure Test Specimens		X	
Tensile Test Data		X	
Tensile Test Specimens		X	

Remarks

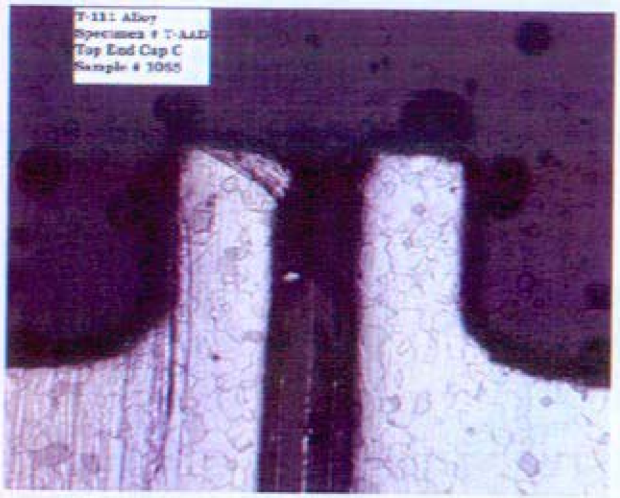
Specimen Numbers	Sample #'s
T-AAD	A-1109
T-AAF	A-1110
T-AAG	A-1111
T-AAI	A-1112
T-AAN	A-1113
T-ABA	A-1114

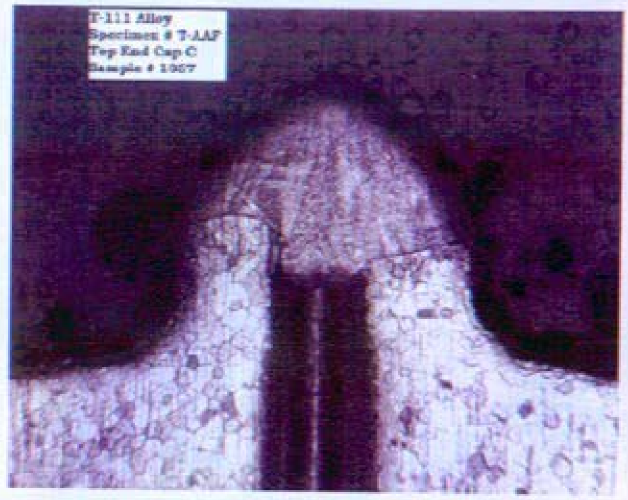
Approval:

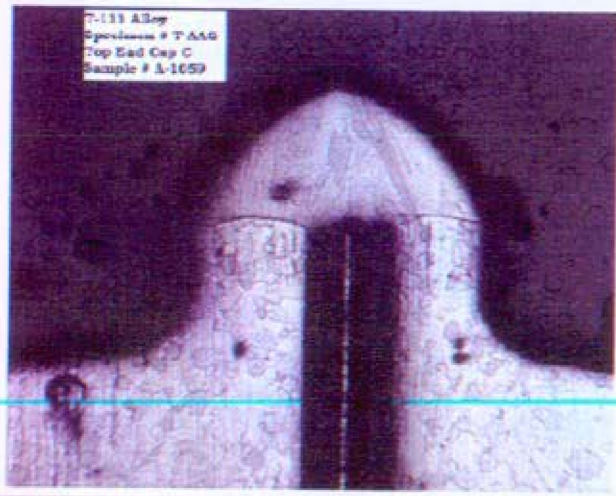
TA Delucchi N/A due to rejection

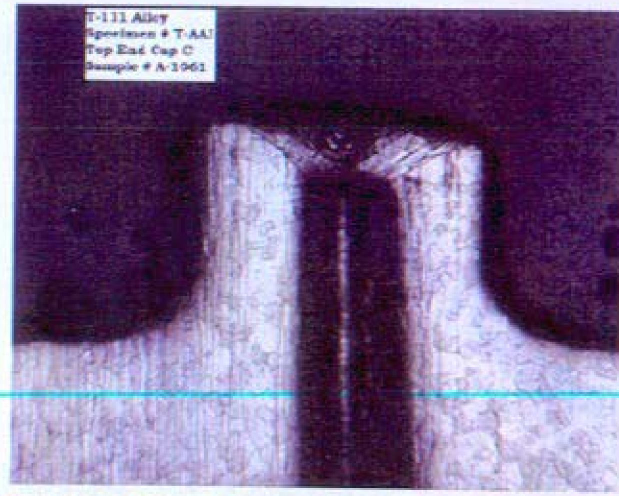
DM Paxton N/A due to rejection

TD Hays N/A


T-111 Alloy
Specimen # T-AAD
Top End Cap C
Sample # 1055


T-111 Alloy
Specimen # T-AAF
Top End Cap C
Sample # 1057


T-111 Alloy
Specimen # T-AAG
Top End Cap C
Sample # A-1059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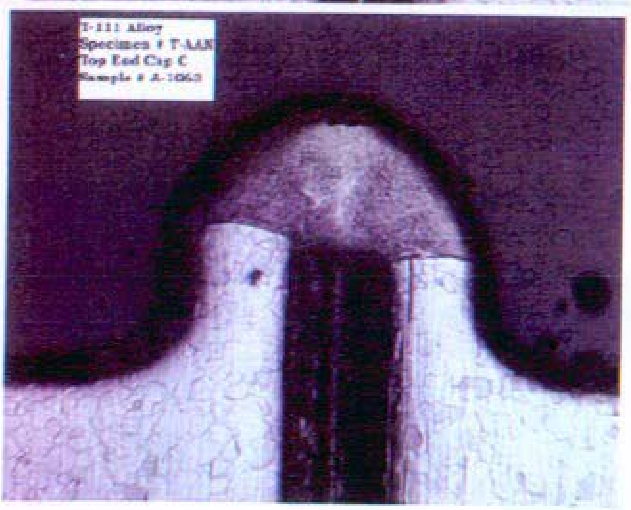
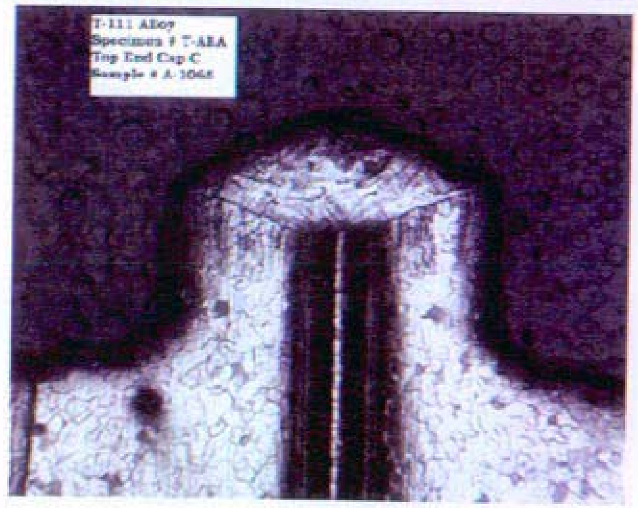
Specimen # T-AAJ
Top End Cap C
Sample # A-1061


T-111 Alloy
Specimen # T-AAN
Top End Cap C
Sample # A-1063


T-111 Alloy
Specimen # T-ABA
Top End Cap C
Sample # A-1065

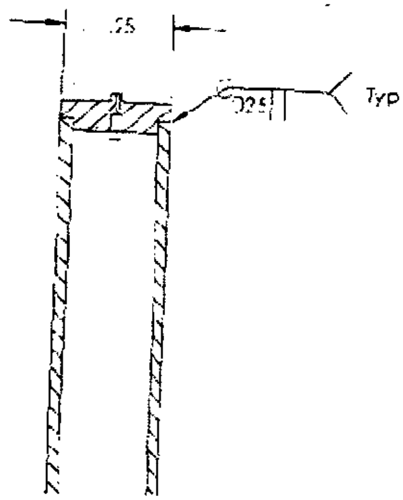
ATTACHMENT 5

Weld Demonstration Data Package

for

ASTAR811C

Test Engineering Battelle Northwest P.O. Box 999 Richland, WA 99352	WELDING PROCEDURE Electron Beam Welding Process



Base Material & Form: **Astar Alloy (Ta) Tube and Bar**

Filler Material, Form, Size: N/A

Preheat: **N/A** Postheat: **N/A**

Weld Position: **1G**

No. of Passes: 1

"Cosmetic" Pass Used: **No**

Gun Type: **CLR 32**

Lap-Over (in/deg) **90° Min.**

Type Backing: **Intergral**

Machine Make or S/N: **Hamilton Std. EBW S/N 601**

Additional Info.: **Favor tube all by approx .002**

Drawing Number	Joint Assembly Number	Date	Welding Operators
5015996	N/A	19 Oct. 2005	A. Asa Jones

"Penetration Pass"

PROCESS VALUES

Voltage (KV)	100	Deflection	None
Beam Current (ma)	4.5	Type	DC Spot
Beam Focus From Work Surface	0"	Size	Min.
Heat Shield From Work Distance	5 3/8"	Frequency (Hz)	N/A
Weld Speed (sec/rev)	2	Modulation Set	N/A
Weld Speed (in/min)	24	Puddling Set	N/A
Weld Time Set Cycle (Sec.)	3.5	Vacuum (torr)	10^{-5}
Rise Set	Min.	Beam-to-Joint Offset	N/A
Fall Set	x 1 @ 2	Position Beam at or	Favor tube by .002
Rotation Spd Setting	2 sec.		

This procedure is in accordance with:	Original Issue:
Bettis IV # PNNL -SPP-05-004	Rev. No. 0 Rev. No. Rev. No.

Prepared by A. Asa Jones	Procedure No.
Approved by [signature] 11/10/05	**Bettis – EB- 104**

WELDING PROCEDURE DEMONSTRATION RECORD

Procedure No. Bettis - EB- 104	Prepared by: A.A. Jones Date: 11 Oct. 2005
No. of Samples Required 6	Welding Operator Name Asa Jones
RDT Section 8 Category 4	Welds Made on: 19 Oct. 2005
Sample Identification Nos See Remarks	Welding Equipment ID EBW S/N 601
Component Inspection Report Nos N/A	Welding to Procedure Witnessed by N/A
Material ID and Heat No Astar Alloy (Ta)	PROGRAM Bettis Biaxial Creep Specimens

CHARACTERISTIC	REFERENCED SPECIFICATION	NO. OF SAMPLES REQUIRED	REPORT NO. OR LAB ID NO.	ACC	REJ	TECH. OR INSPECTOR	DATE	REMARKS
Comp. Cleaned	Bettis Procedure # N/A	6				N/A		
Visual (Weld)	NE F6-2t Sec. 6 Para. 6.3.2	6		✓		[signature]	11/10/05	
Helium Leak Test	NE F6-2t Sec. 6 Para. 6.3.6	N/A				N/A		
Radiography	NE F6-2t Sec. 6 Para. 6.3.4	6				See enclosed		
Pressure Test	Bettis Procedure # N/A	N/A				N/A		
Metallography	NE F6-2t Sec. 6 Para 6.3.7	6		✓		[signature]	11/10/05	
Dimensional	Drawing requirements	6		✓		[signature]	11/10/05	

Record Data Required For Procedure Qualification Package	Yes	No	Completed
Metallography Report and Mount Nos.	X		✓
Metallography Photos (Information)	X		✓
Radiography Report	X		No
Helium Leak Rate		X	
Copy of the Procedure	X		✓
Pressure Test Data		X	
Pressure Test Specimens		X	
Tensile Test Data		X	
Tensile Test Specimens		X	

Remarks

Sample #'s

Specimen Numbers	Top	Bottom
T-ABK	A-1067	A-1068
T-ABL	A-1069	A-1070
T-ABM	A-1071	A-1072
T-ABN	A-1073	A-1074
T-ABO	A-1075	A-1076
T-ABP	A-1077	A-1078

Approval:

TA Delucchi [signature] 11/10/05

DM Paxton DM Paxton 11/18/05

TD Hays N/A

AREVA

COGEMA-05-0162

Mr. Dean Paxton
Battelle
Post Office Box 999, MSIN K2-44
Richland, Washington 99352

November 8, 2005

Dear Mr. Paxton:

CONTRACT NO. 16052 - CONSULTING SERVICES OF DELUCCHI / CASTO

As requested, this letter outlines the success and short-comings of the radiography of the pressurized specimens.

- The nickel-based materials, even though the x-ray grooves in the end caps were not square and undersized in some of the samples, were examined in accordance with the requirements and found to be acceptable.
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When pressurized specimen radiography of high-density materials was performed in the past it was conducted at a Department of Energy (DOE) facility. This DOE facility is now in the process of being demolished. The 160 kV and 450 kV x-ray systems were removed from the building and acquired by COGEMA, Inc. through the non-destructive examination contract. The current COGEMA, Inc. radiography facility features a high-frequency 160 kV Philips x-ray system. The interior of the x-ray vault is approximately 6 feet by 6 feet and about 6 feet in height, which is adequate for most small steel and stainless steel parts up to thickness of about 1.25 inches

COGEMA, INC.

Unfortunately, this cabinet's shielding is not adequate for the more penetrating 450 kV x-ray system that would be required to examine the tantalum type of materials. COGEMA, Inc. has explored the possibility of building a suitable shielded vault to house the 450 kV x-ray system, but currently we have not been able to identify enough business to make construction of a facility economically viable.

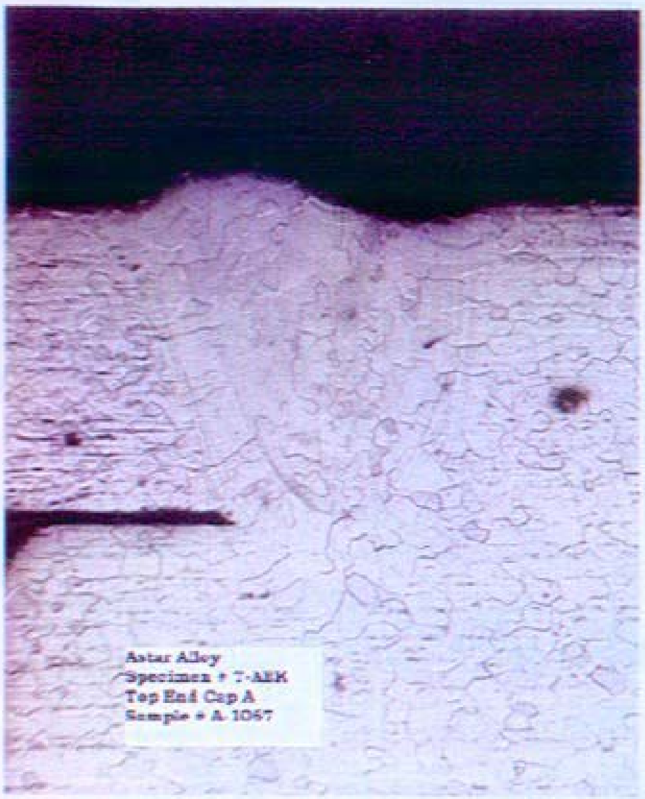
If you have any questions or require additional information, please feel free to contact Mr. John Keve at 375-4003.

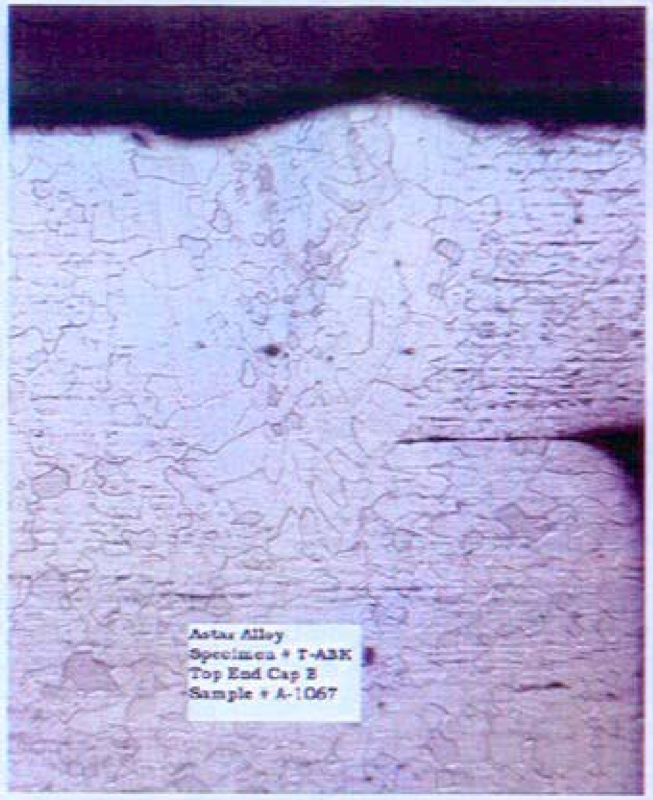
Sincerely,

Mark D. Rickenbach
Director, Services
COGEMA, Inc.
Richland Office

CONCURRENCE:

John K. Keve, NDE Level III
COGEMA, Inc.


Astar Alloy
Specimen # T-ABK
Top End Cap A
Sample # A-1067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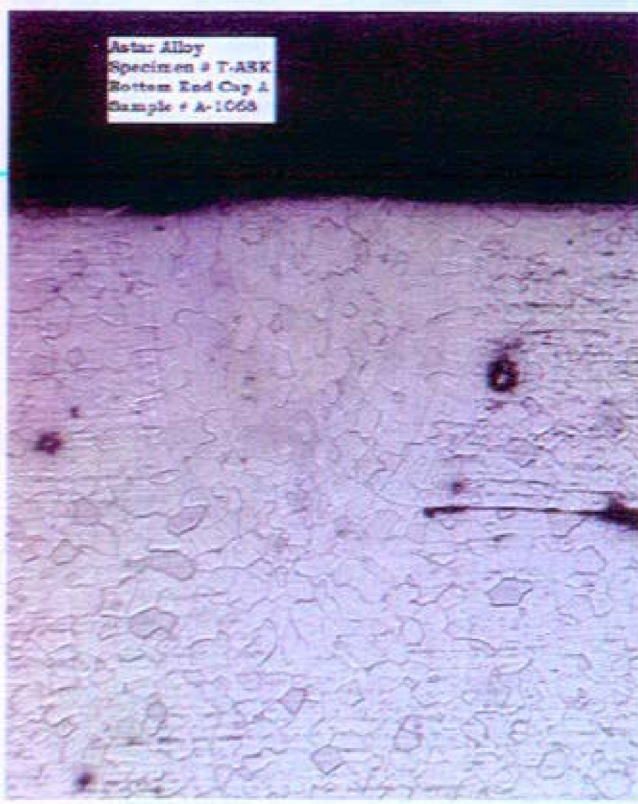
Specimen # T-ABK
Top End Cap B
Sample # A-1067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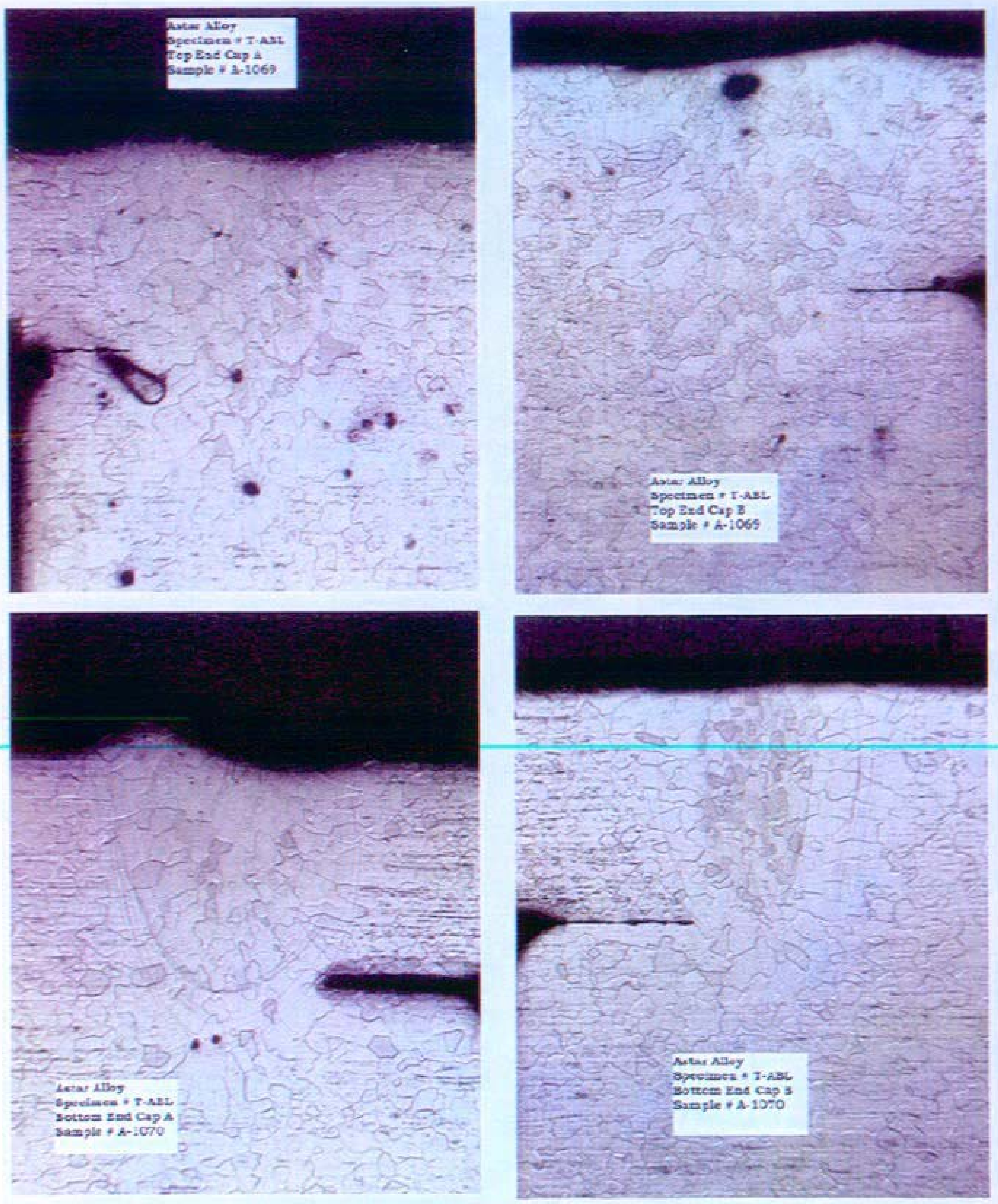
Bottom End Cap A
Sample # A-1068


Astar Alloy
Specimen # T-ABK
Bottom End Cap B
Sample # A-1068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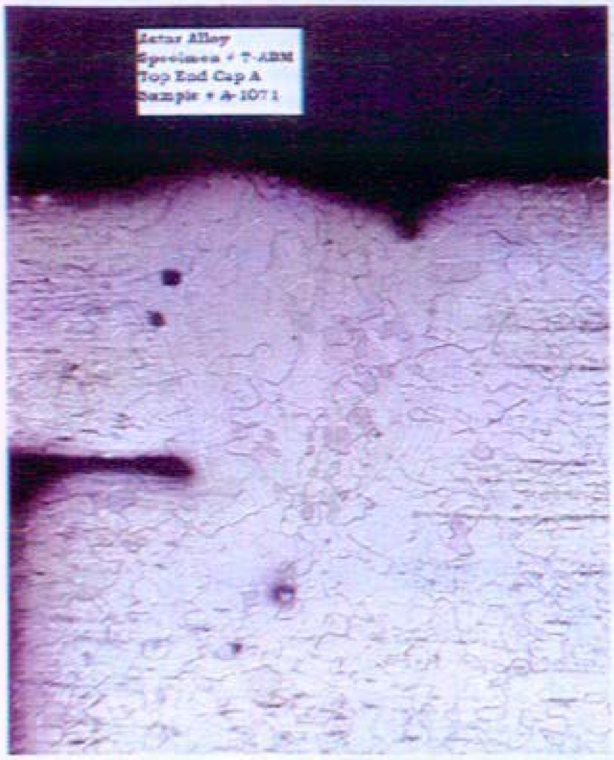
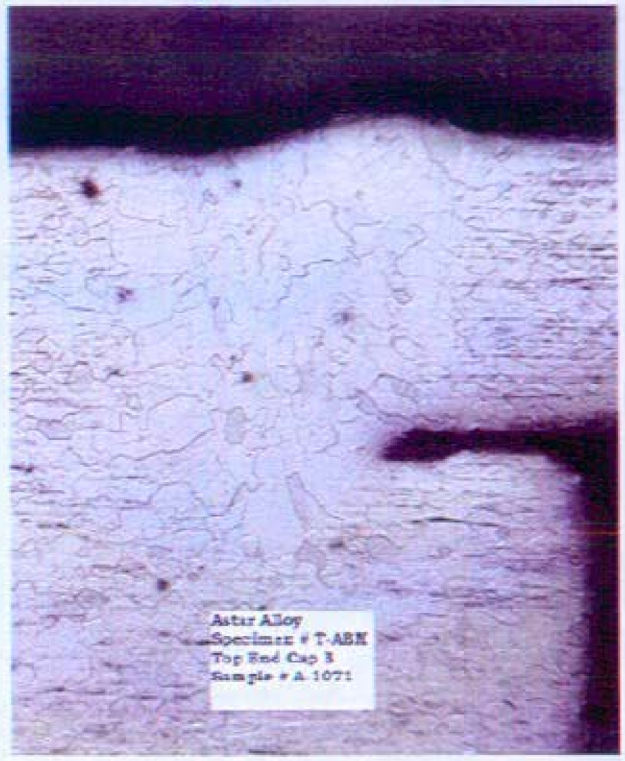
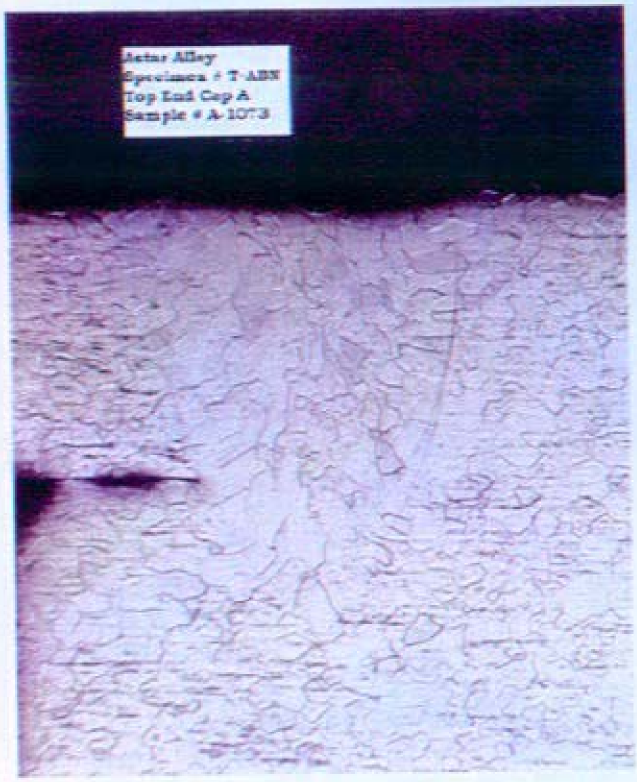
Specimen # T-ABL
Top End Cap A
Sample # A-1069
Astar Alloy
Specimen # T-ABL
Top End Cap B
Sample # A-1069
Astar Alloy
Specimen # T-ABL
Bottom End Cap A
Sample # A-1070
Astar Alloy
Specimen # T-ABL
Bottom End Cap B
Sample # A-1070

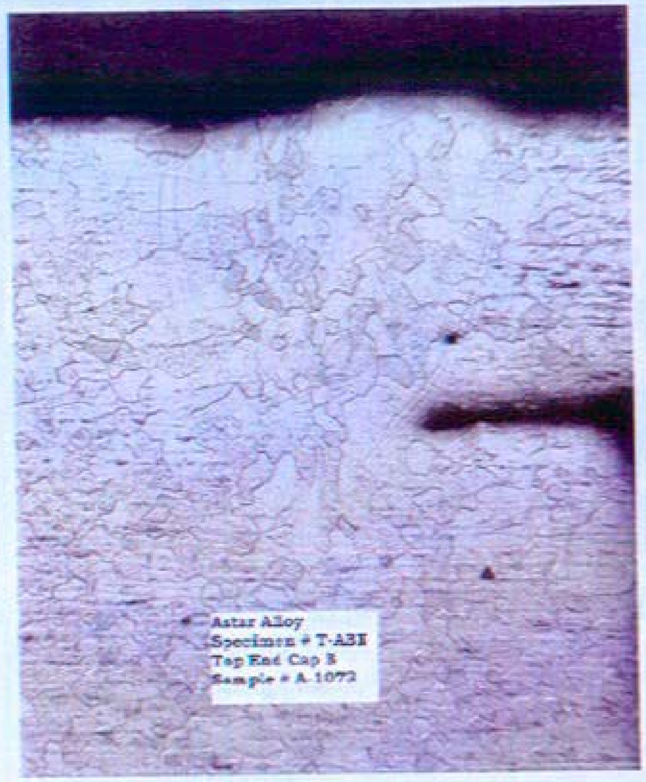

Astar Alloy
Specimen # T-ABM
Top End Cap A
Sample # A-1071


Astar Alloy
Specimen # T-ABN
Top End Cap B
Sample # A-1071


Astar Alloy
Specimen # T-ABN
Bottom End Cap A
Sample # A-1072


Astar Alloy
Specimen # T-ABN
Bottom End Cap B
Sample # A-1072


Astar Alloy
Specimen # T-ABN
Top End Cap A
Sample # A-1073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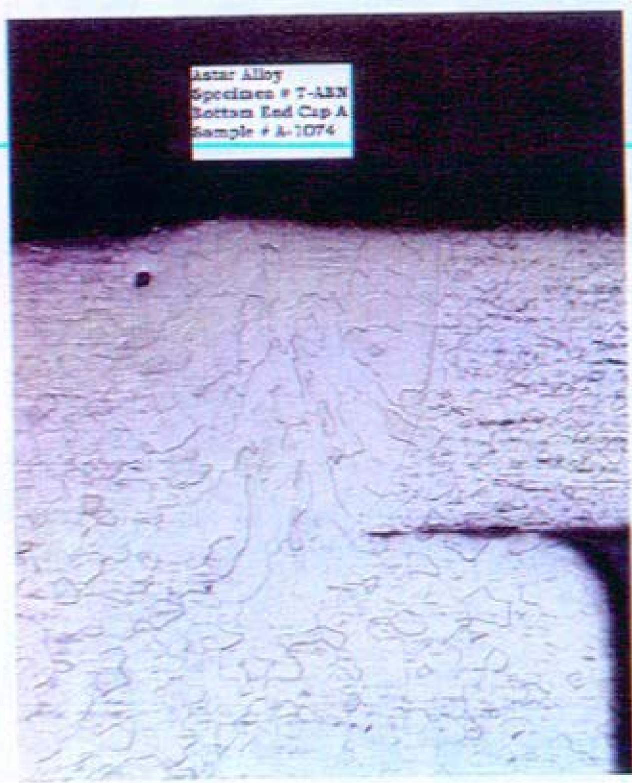
Specimen # T-ABE
Top End Cap B
Sample # A-1073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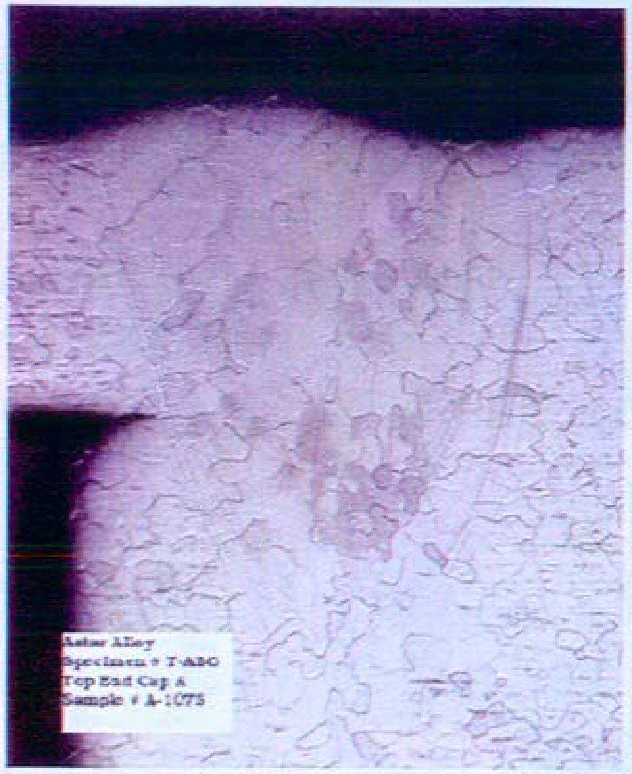
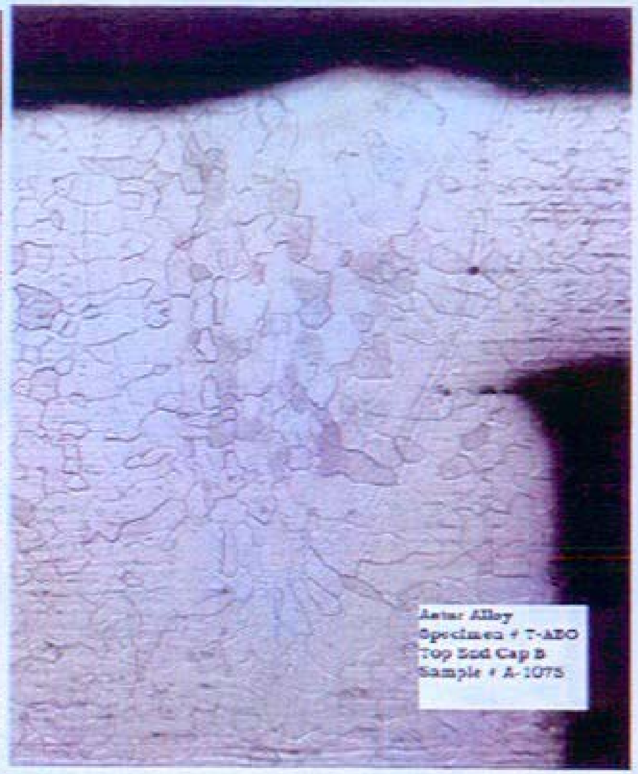
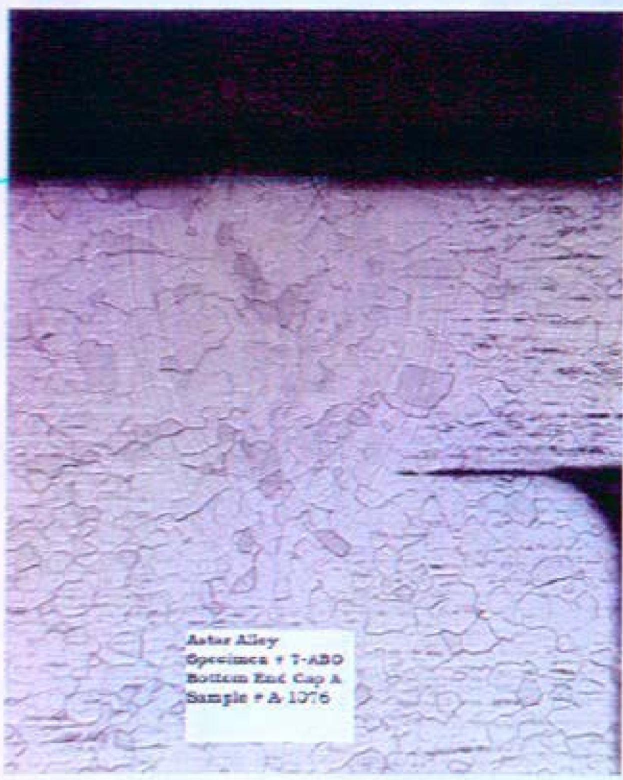
Specimen # T-ABN
Bottom End Cap A
Sample # A-1074


Astar Alloy
Specimen # T-ABE
Bottom End Cap B
Sample # A-1074


Astar Alloy
Specimen # T-ABO
Top End Cap A
Sample # A-1075


Astar Alloy
Specimen # T-ABO
Top End Cap B
Sample # A-1075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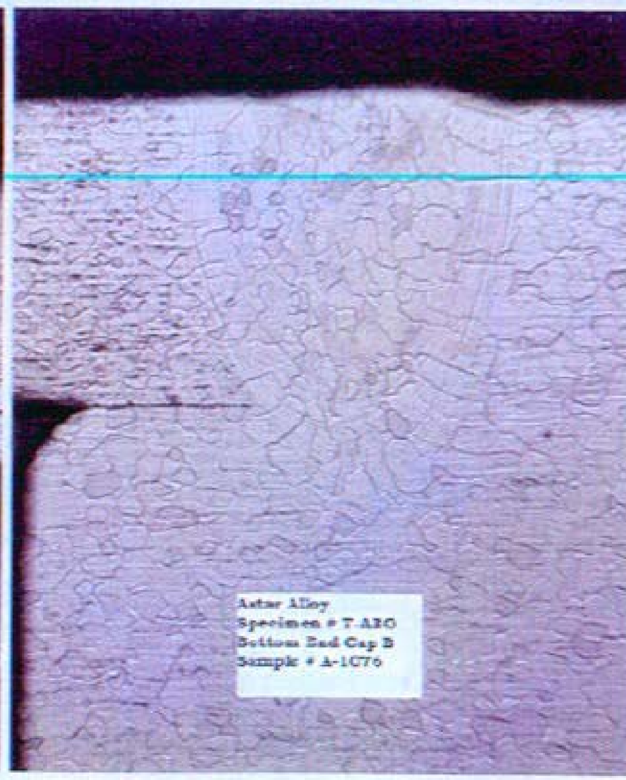
Specimen # T-ABO
Bottom End Cap A
Sample # A-1076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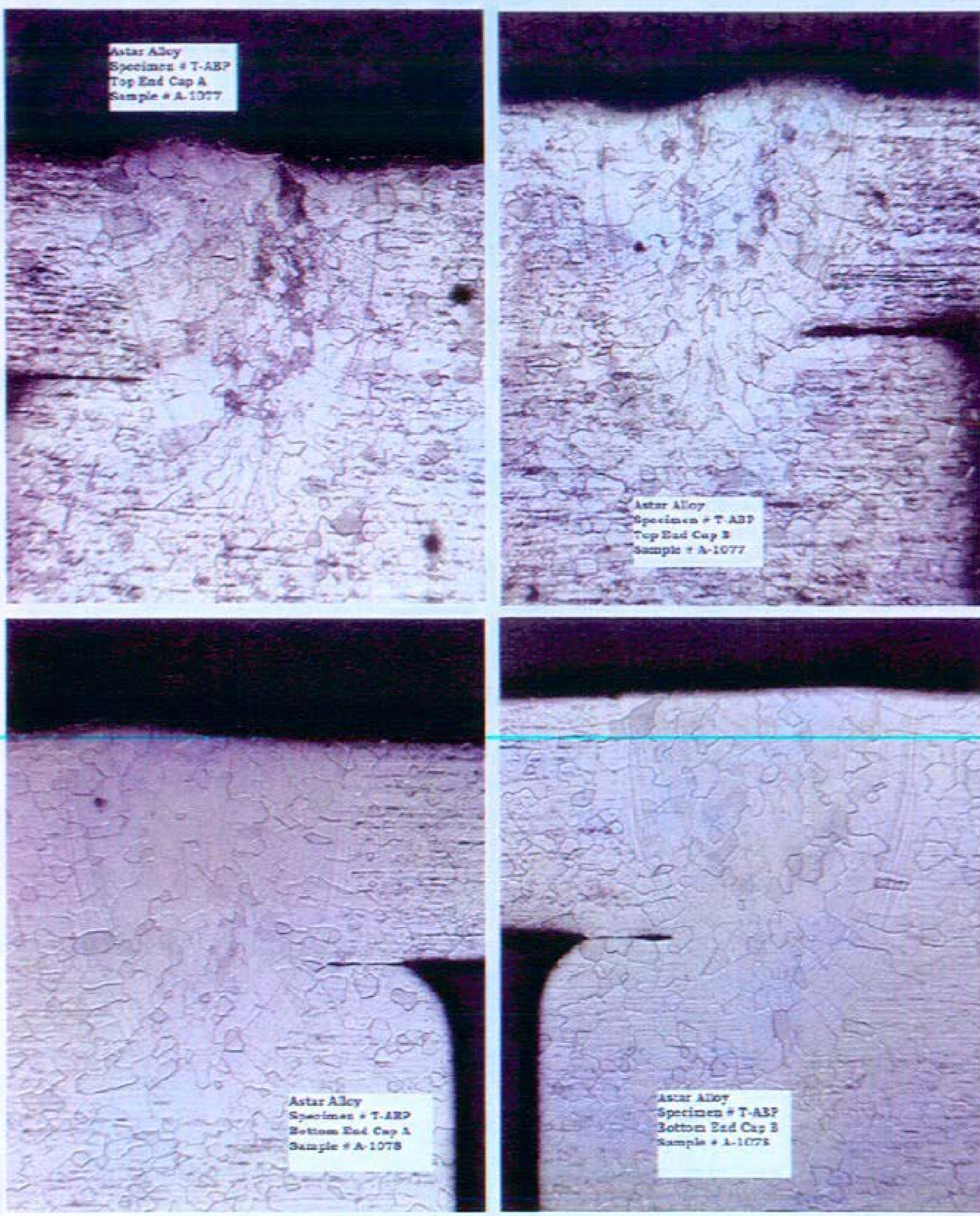
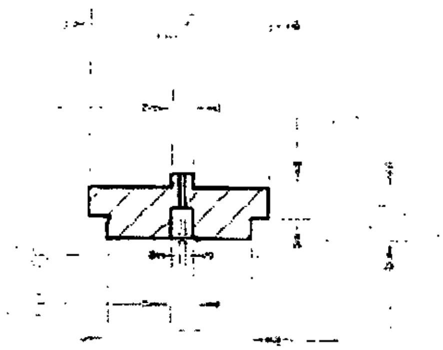
Bottom End Cap B
Sample # A-1076


Astar Alloy
Specimen # T-ABP
Top End Cap A
Sample # A-1077
Astar Alloy
Specimen # T-ABP
Top End Cap B
Sample # A-1077
Astar Alloy
Specimen # T-ABP
Bottom End Cap A
Sample # A-1078
Astar Alloy
Specimen # T-ABP
Bottom End Cap B
Sample # A-1078

TEST ENGINEERING BATTELLE NORTHWEST P.O. BOX 999 RICHLAND, WA 99352	WELDING PROCEDURE LASER WELDING PROCESS



MATERIAL	Astar Alloy (Ta)
THICKNESS:	0.03
PRE-CLEANING:	Yes
COVER GLASS:	Quartz
MACHINE MAKE:	Korad
MACHINE MODEL	KWD
ADDITIONAL INFO	Evacuate and back fill with UHP helium three times prior to welding.

DRAWING NUMBER	JOINT ASSEMBLY NO.	DATE	WELDING OPERATOR
5015996	N/A	11 Oct. 2005	Asa Jones

SEE WELDING PROCEDURE DESCRIPTION Bettis IV # PNNL-SPP-05-004 FOR QUALITY REQUIREMENTS

PROCESS VALUES

ROD TYPE & I.D. NO.	Nd:YAG	VOLTAGE	3.6
APERTURE	100	SPOT SIZE	0.747
ATTENUATOR	0	JOULES / PULSE	N/A
MONITOR VOLTS	194-197	ATMOSPHERE	Helium
SCALE FACTOR	N/A	PRESSURE	0-3000 PSIG
FOCUS LENS	6"	PULSE WIDTH	Position # 3
NO. OF PULSES	1 or more		

PREPARED BY: Asa Jones	ORIGNAL ISSUE	11 Oct. 2005
	REV. NO.	
	REV. NO.	
	REV. NO	

APPROVED FOR TEST ENGINEERING N/A due to rejection	PROCEDURE NO. Bettis - Laser - 204

5/05

WELDING PROCEDURE DEMONSTRATION RECORD

Procedure No. Bettis – Laser - 204	Prepared by: A.A. Jones Date: 11 Oct. 2005
No. of Samples Required 6	Welding Operator Name Asa Jones
RDT Section 8 Category 4	Welds Made on: 20 Oct. 2005 [signature]
Sample Identification Nos See Remarks	Welding Equipment ID EBW S/N 601
Component Inspection Report Nos N/A	Welding to Procedure Witnessed by N/A
Material ID and Heat No Astar Alloy (Ta)	PROGRAM Bettis Biaxial Creep Specimens

CHARACTERISTIC	REFERENCED SPECIFICATION	NO. OF SAMPLES REQUIRED	REPORT NO. OR LAB ID NO.	ACC	REJ	TECH. OR INSPECTOR	DATE	REMARKS
Comp. Cleaned	Bettis Procedure # N/A	6				N/A		
Visual (Weld)	NE F6-2t Sec. 6 Para. 6.3.2	6		✓		[signature]	10/20/05	
Helium Leak Test	NE F6-2t Sec. 6 Para. 6.3.6	N/A				N/A		
Radiography	NE F6-2t Sec. 6 Para. 6.3.4	N/A				N/A		
Pressure Test	Bettis Procedure # N/A	N/A				N/A		
Metallography	NE F6-2t Sec. 6 Para 6.3.7	6			✓	[signature]	11/1/05	
Dimensional	Drawing requirements	6			✓	[signature]	11/1/05	

Record Data Required For Procedure Qualification Package	Yes	No	Completed
Metallography Report and Mount Nos.	X		✓
Metallography Photos (Information)	X		✓
Radiography Report		X	—
Helium Leak Rate		X	—
Copy of the Procedure	X		✓
Pressure Test Data		X	
Pressure Test Specimens		X	
Tensile Test Data		X	
Tensile Test Specimens		X	

Remarks

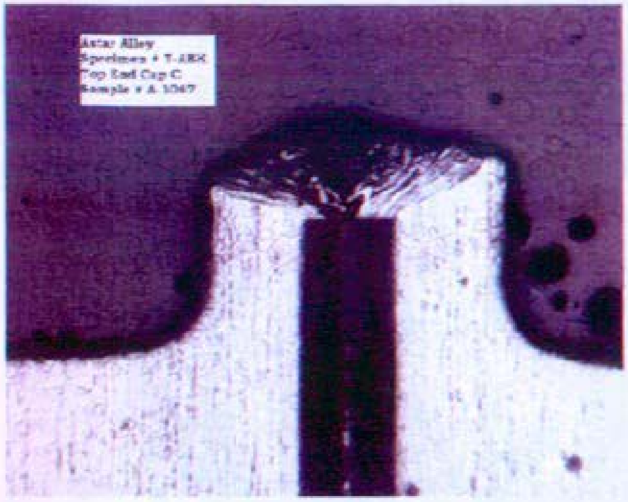
Specimen Numbers	Sample #'s
T-ABK	A-1115
T-ABL	A-1116
T-ABM	A-1117
T-ABN	A-1118
T-ABO	A-1119
T-ABP	A-1120

Approval:

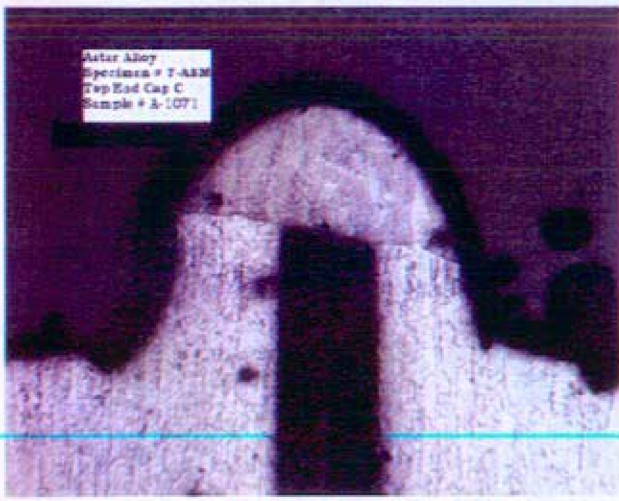
TA Delucchi N/A due to rejection

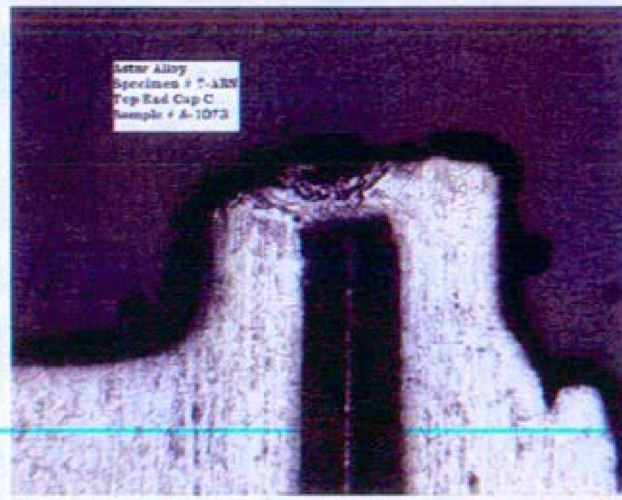
DM Paxton N/A due to rejection

TD Hays N/A


Astar Alloy
Specimen # T-ABK
Top End Cap C
Sample # A-1067


Astar Alloy
Specimen # T-ABL
Top End Cap C
Sample # A-1069


Astar Alloy
Specimen # T-ABM
Top End Cap C
Sample # A-1071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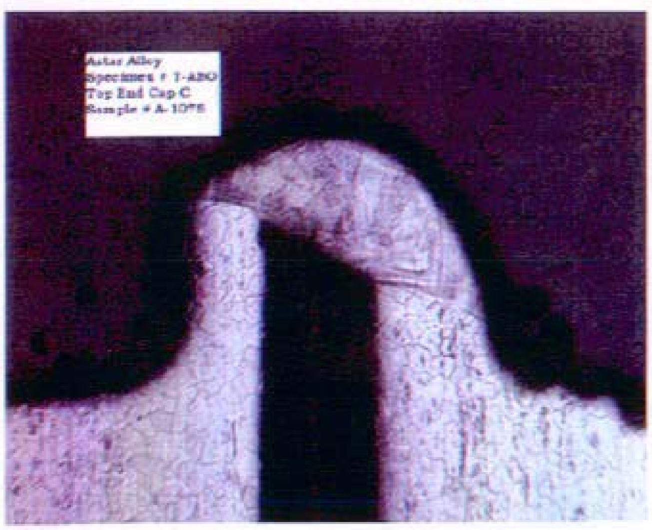
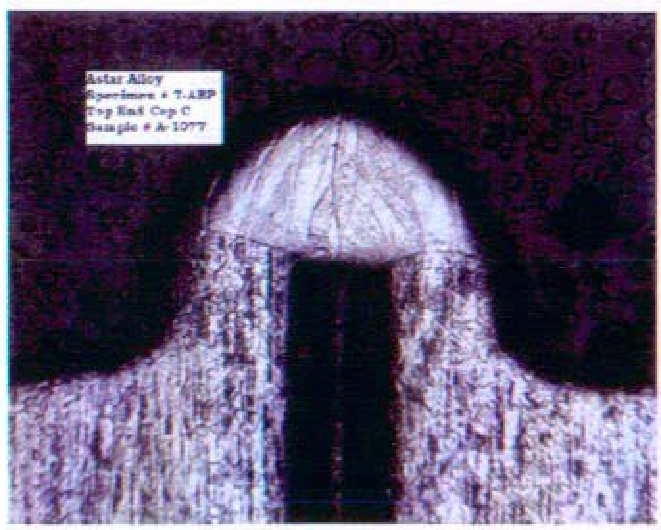
Specimen # T-ABN
Top End Cap C
Sample # A-1073


Astar Alloy
Specimen # T-ABO
Top End Cap C
Sample # A-1075


Astar Alloy
Specimen # T-ABP
Top End Cap C
Sample # A-1077

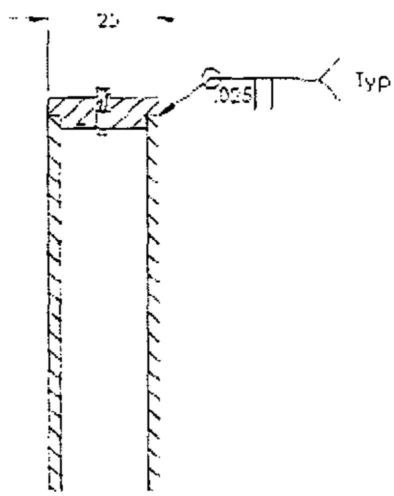
ATTACHMENT 6

Weld Demonstration Data Package

for

FS-85

Test Engineering Battelle Northwest P.O. Box 999 Richland, WA 99352	WELDING PROCEDURE Electron Beam Welding Process



Base Material & Form: **FS-85 Alloy (Nb) Tube and Bar**

Filler Material, Form, Size: **N/A**

Preheat: **N/A** Postheat: **N/A**

Weld Position: **1G**

No. of Passes: **1**

"Cosmetic" Pass Used: **Yes**

Gun Type: **CLR 32**

Lap-Over (in/deg) **90° Min.**

Type Backing: **Intergral**

Machine Make or S/N: **Hamilton Std. EBW S/N 601**

Additional Info.: **Favor tube all by approx .002**

Drawing Number	Joint Assembly Number	Date	Welding Operators
5015996	N/A	20 Oct. 2005	A. Asa Jones

"Penetration Pass"

PROCESS VALUES

Voltage (KV)	110	Deflection	Circle
Beam Current (ma)	4.5	Type	5 div.
Beam Focus From Work Surface	Over 30	Size	.015
Heat Shield From Work Distance	5 3/8"	Frequency (Hz)	60 Hz
Weld Speed (sec/rev)	2	Modulation Set	N/A
Weld Speed (in/min)	24	Puddling Set	N/A
Weld Time Set Cycle (Sec.)	3.5	Vacuum (torr)	10^{-5}
Rise Set	Min.	Beam-to-Joint Offset	None
Fall Set	x 1 @ 2	Position Beam at or	Center of joint
Rotation Spd Setting	2 sec.		

This procedure is in accordance with:

Bettis IV # PNNL-SPP-05-004

Original Issue:

Rev. No. 0
Rev. No. ___
Rev. No. ___

Prepared by

A. Asa Jones

Approved by

[signature] 11/10/05

Procedure No.

Bettis – EB- 105

WELDING PROCEDURE (Continuation Sheet)

"Cosmetic Pass"			
PROCESS VALUES			
Voltage (KV)	100	Deflection	Circle
Beam Current (ma)	4.5	Type	10 div.
Beam Focus From Work Surface	Over 40	Size	.030
Heat Shield From Work Distance	5 3/8"	Frequency (Hz)	60 Hz
Weld Speed (sec/rev)	2	Modulation Set	N/A
Weld Speed (in/min)	24	Puddling Set	N/A
Weld Time Set Cycle (Sec.)	3.5	Vacuum (torr)	10^{-5}
Rise Set	Min.	Beam-to-Joint Offset	None
Fall Set	x1 @ 2	Position Beam at or	Center of Joint
Rotation Spd-Pot Setting	2 sec.		

This procedure is in accordance with: Bettis IV # PUUC SPR-05-004	Original Issue: Rev. No. 0 Rev. No. ____ Rev. No ____

WELDING PROCEDURE DEMONSTRATION RECORD

Procedure No. Bettis - EB- 105	Prepared by: A.A. Jones Date: 11 Oct. 2005
No. of Samples Required 6	Welding Operator Name Asa Jones
RDT Section 8 Category 4	Welds Made on: 20 Oct 2005
Sample Identification Nos See Remarks	Welding Equipment ID EBW S/N 601
Component Inspection Report Nos N/A	Welding to Procedure Witnessed by N/A
Material ID and Heat No FS-85 Alloy (Nb)	PROGRAM Bettis Biaxial Creep Specimens

CHARACTERISTIC	REFERENCED SPECIFICATION	NO. OF SAMPLES REQUIRED	REPORT NO. OR LAB ID NO.	ACC	REJ	TECH. OR INSPECTOR	DATE	REMARKS
Comp. Cleaned	Bettis Procedure # N/A	6				N/A		
Visual (Weld)	NE F6-2t Sec. 6 Para. 6.3.2	6		✓		[signature]	10/26/05	
Helium Leak Test	NE F6-2t Sec. 6 Para. 6.3.6	N/A				N/A		
Radiography	NE F6-2t Sec. 6 Para. 6.3.4	6				See Enclosed		
Pressure Test	Bettis Procedure # N/A	N/A				N/A		
Metallography	NE F6-2t Sec. 6 Para 6.3.7	6		✓		[signature]	11/16/05	
Dimensional	Drawing requirements	6		✓		[signature]	11/16/05	

Record Data Required For Procedure Qualification Package	Yes	No	Completed
Metallography Report and Mount Nos.	X		✓
Metallography Photos (Information)	X		✓
Radiography Report	X		No
Helium Leak Rate		X	✓
Copy of the Procedure	X		✓
Pressure Test Data		X	
Pressure Test Specimens		X	
Tensile Test Data		X	
Tensile Test Specimens		X	

Remarks

Sample #'s

Specimen Numbers	Top	Bottom
N-AAR	A-1079	A-1080
N-AAO	A-1081	A-1082
N-AAP	A-1083	A-1084
N-AAS	A-1085	A-1086
N-AAT	A-1087	A-1088
N-AAW	A-1089	A-1090

Approval:

TA Delucchi [signature] 11/16/05

DM Paxton [signature] 11/18/05

TD Hays N/A

AREVA

COGEMA-05-0162

Mr. Dean Paxton
Battelle
Post Office Box 999, MSIN K2-44
Richland, Washington 99352

November 8, 2005

Dear Mr. Paxton,

CONTRACT NO. 16052 - CONSULTING SERVICES OF DELUCCHI / CASTO

As requested, this letter outlines the success and short-comings of the radiography of the pressurized specimens.

- The nickel-based materials, even though the x-ray grooves in the end caps were not square and undersized in some of the samples, were examined in accordance with the requirements and found to be acceptable.

- The niobium alloy materials may have been properly examined; however, the x-ray grooves were not machined to the proper size. This would have made radiography results inconclusive since the groove in the test exposures of the non-welded samples was very faint in one end cap and non-existent in the other. The 160 kV x-ray system appears to be at its penetration limit for this material at this thickness (wall thickness measured at approximately 0.025") as the inner wall was not resolved to the level it should have been. However, in the opinion of COGEMA, Inc. Level III certified radiographer, this type of pressurized specimen material could have been successfully examined.

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Unfortunately, this cabinet's shielding is not adequate for the more penetrating 450 kV x-ray system that would be required to examine the tantalum type of materials. COGEMA, Inc. has explored the possibility of building a suitable shielded vault to house the 450 kV x-ray system, but currently we have not been able to identify enough business to make construction of a facility economically viable.

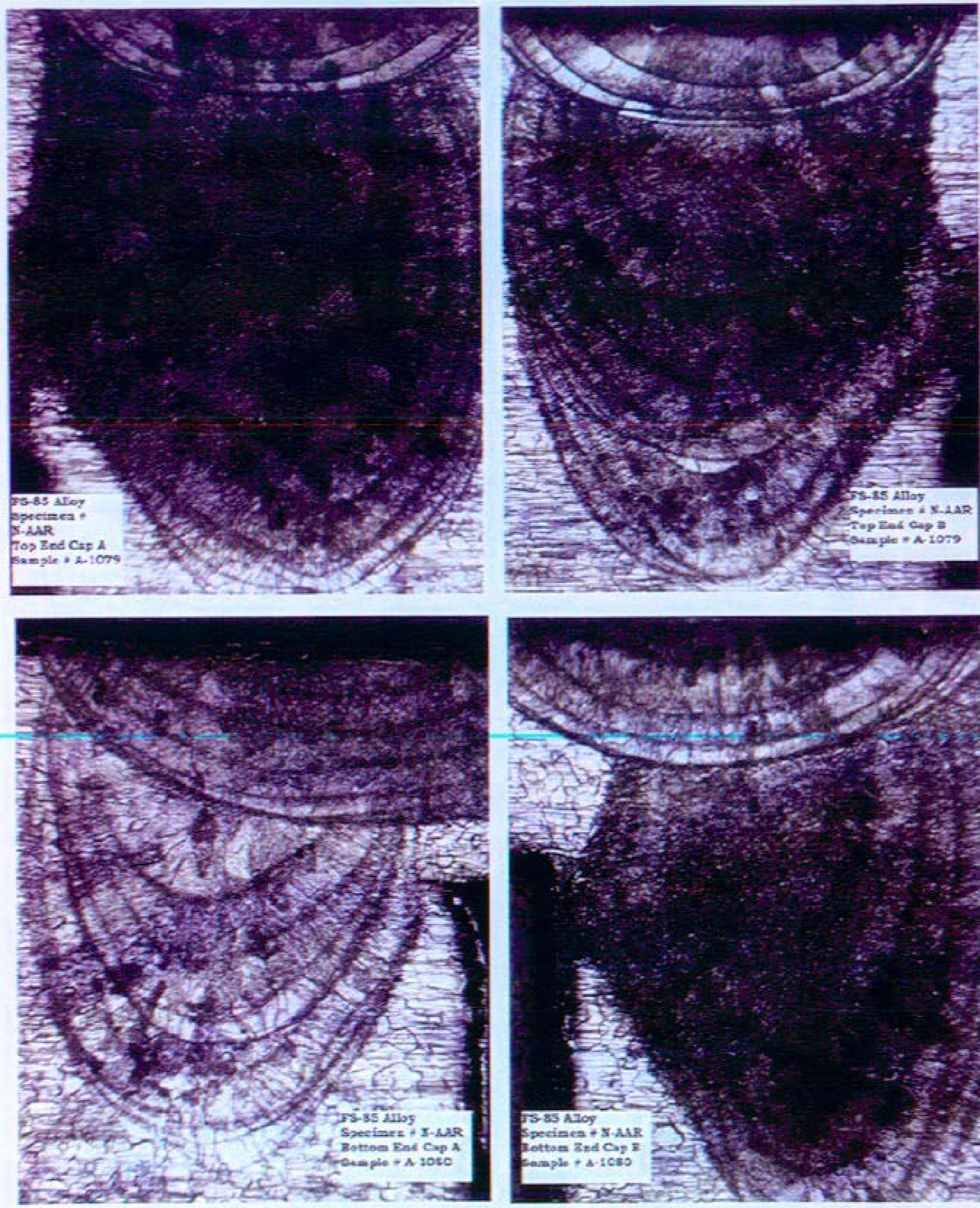
If you have any questions or require additional information, please feel free to contact Mr. John Keve at 375-4003.

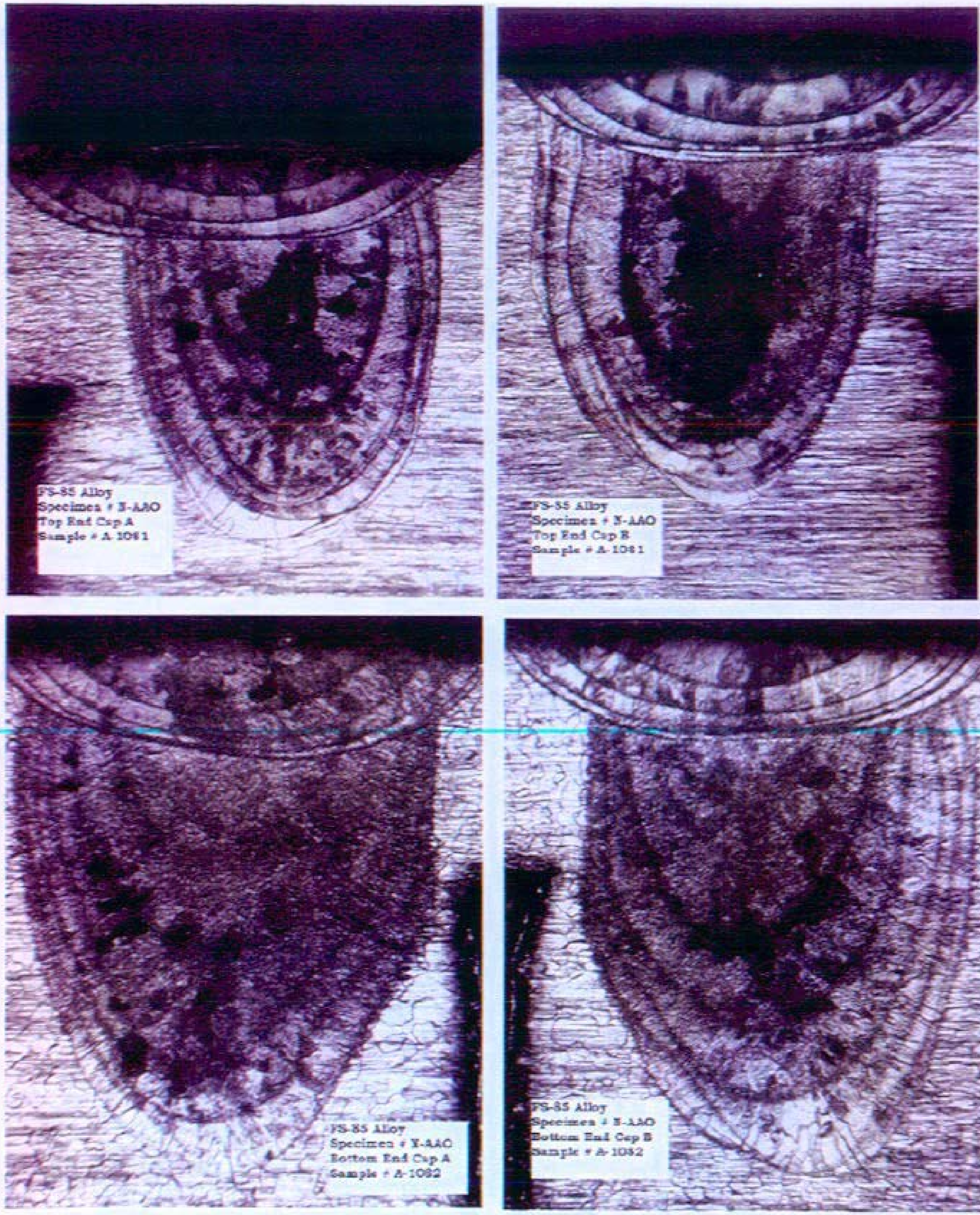
Sincerely,

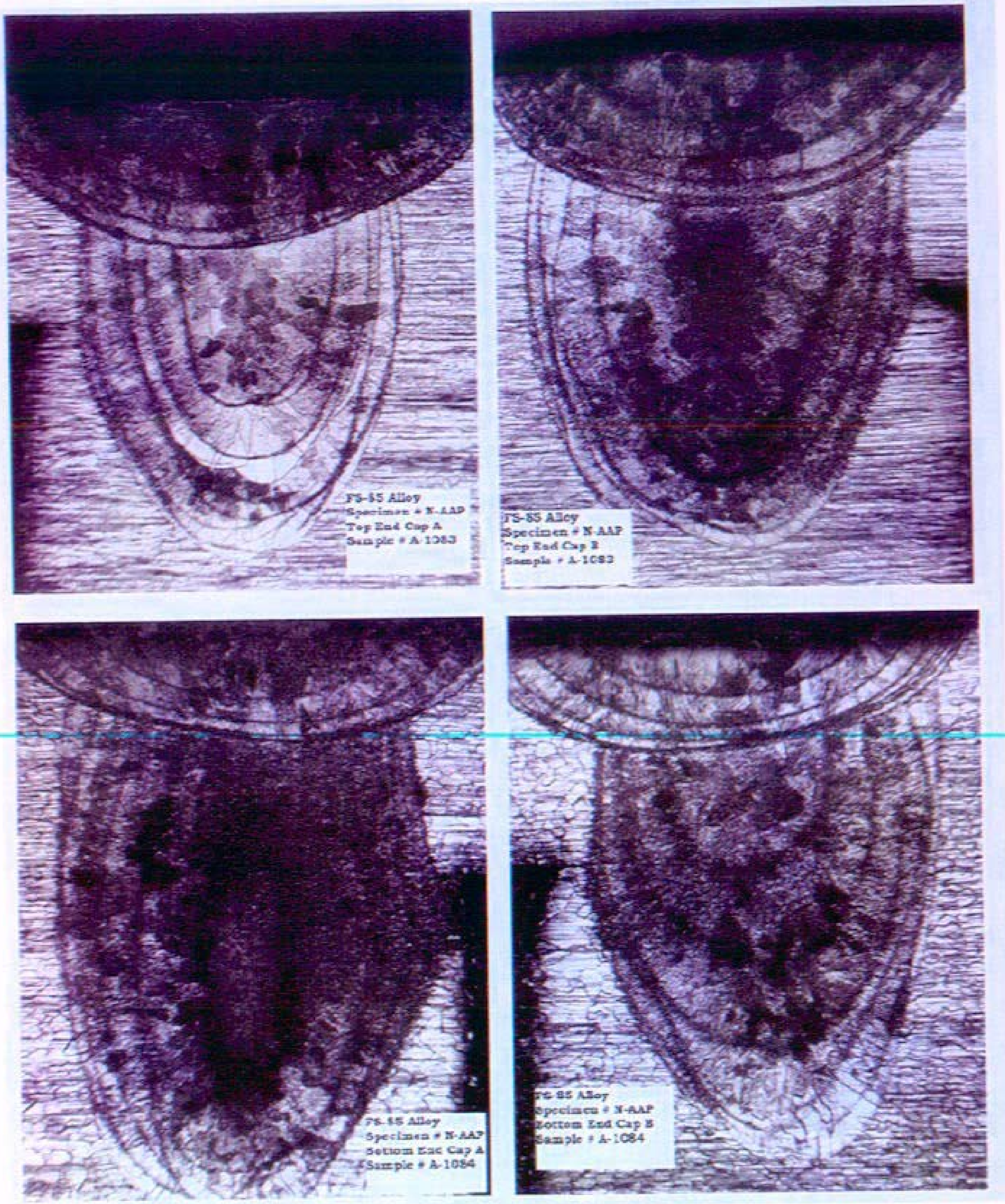
Mark D. Rickenbach
Director, Services
COGEMA, Inc.
Richland Office

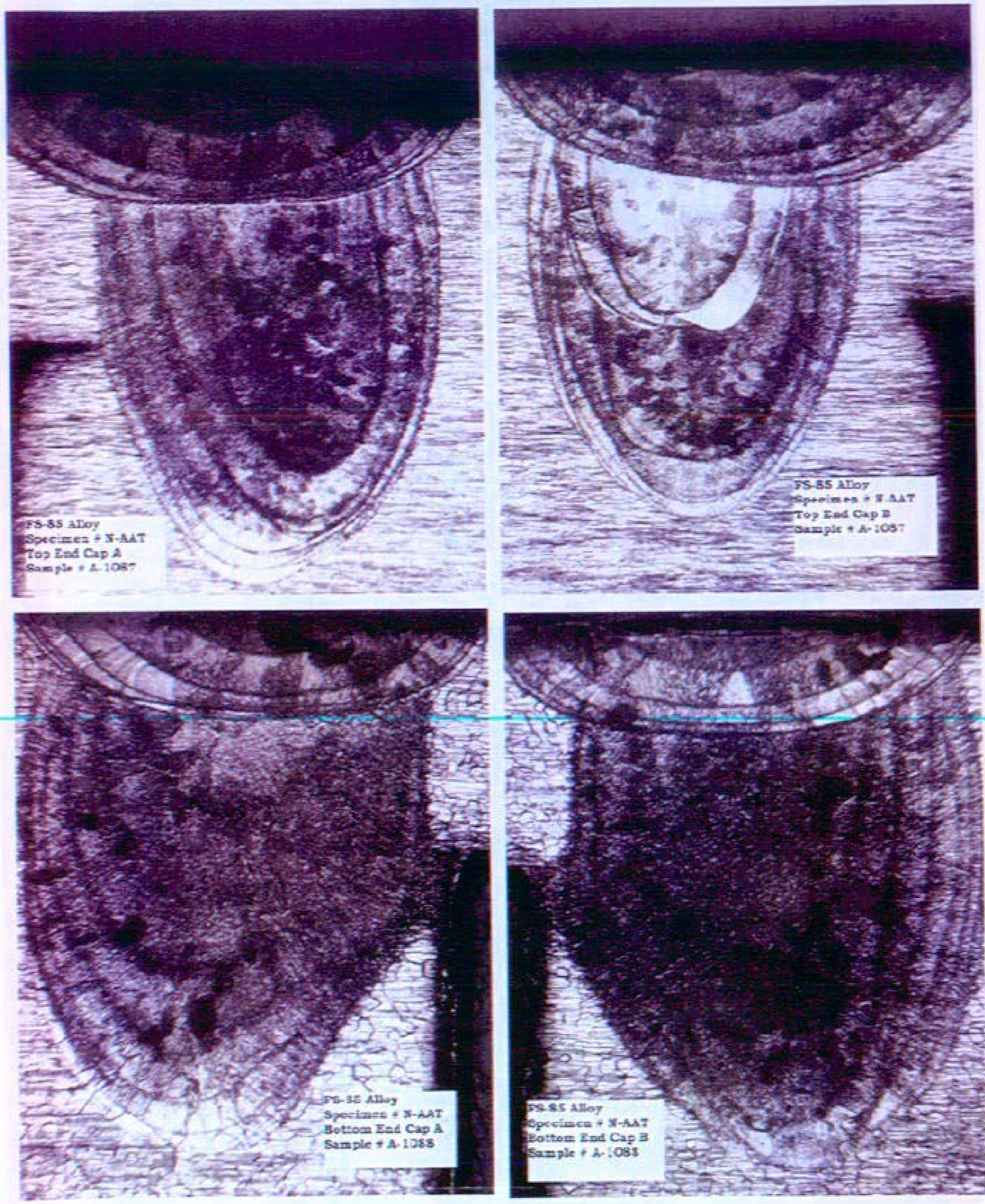
CONCURRENCE:

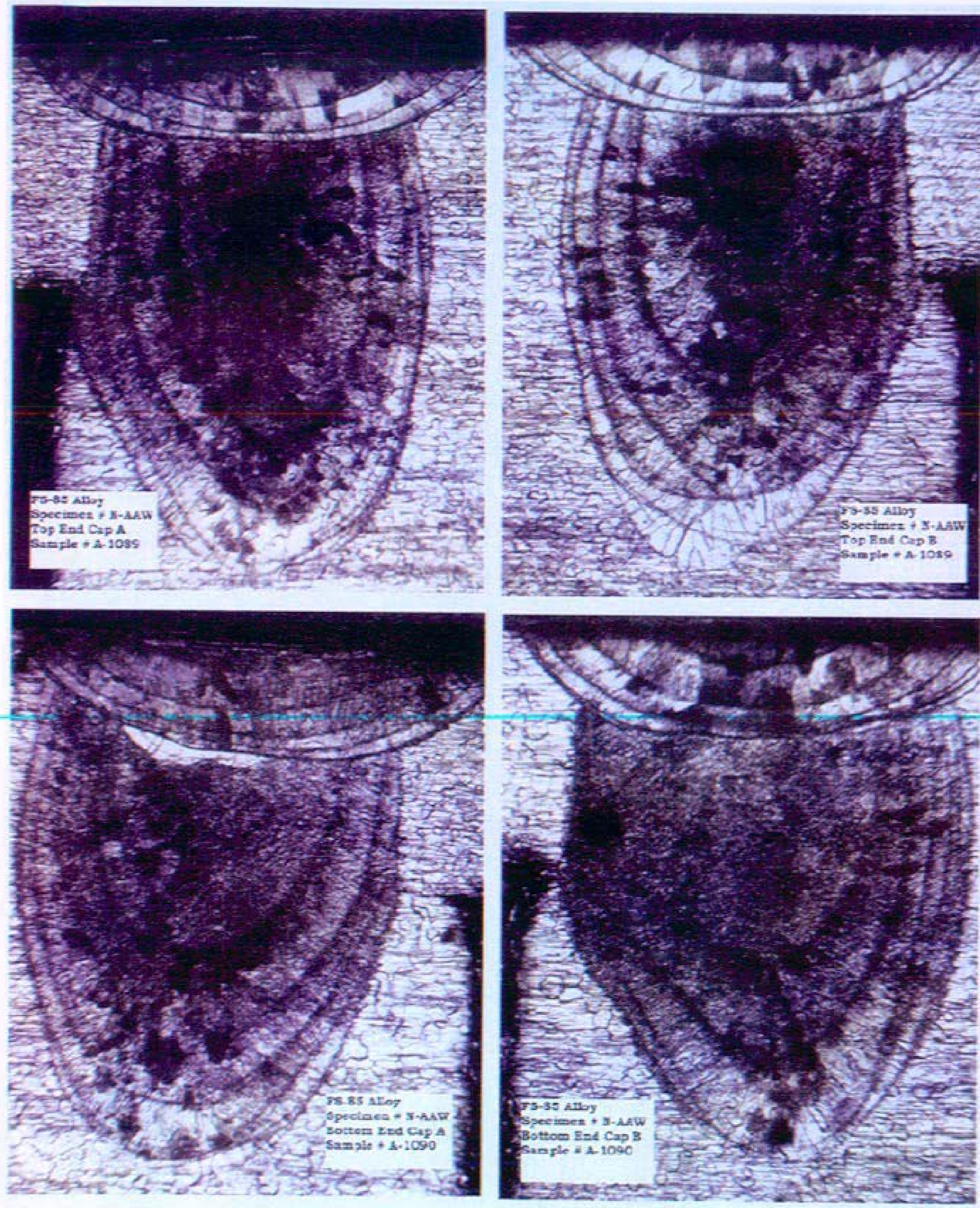
John K. Keve, NDE Level III
COGEMA, Inc.


FS-85 Alloy
Specimen #
N-AAR
Top End Cap A
Sample # A-1079
FS-85 Alloy
Specimen # N-AAR
Top End Cap B
Sample # A-1079
FS-85 Alloy
Specimen # N-AAR
Bottom End Cap A
Sample # A-1080
FS-85 Alloy
Specimen # N-AAR
Bottom End Cap B
Sample # A-1080

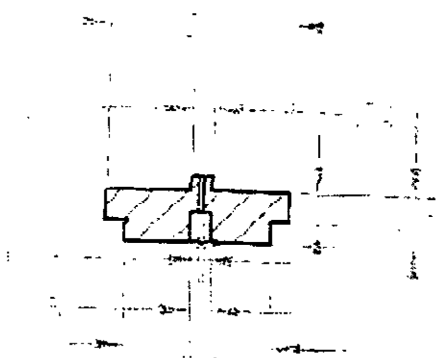

FS-85 Alloy
Specimen # X-AAO
Top End Cap A
Sample # A-1081
FS-85 Alloy
Specimen # X-AAO
Top End Cap B
Sample # A-1081
FS-85 Alloy
Specimen # X-AAO
Bottom End Cap A
Sample # A-1082
FS-85 Alloy
Specimen # X-AAO
Bottom End Cap B
Sample # A-1082


FS-85 Alloy
Specimen # N-AAP
Top End Cap A
Sample # A-1083
FS-85 Alloy
Specimen # N-AAP
Top End Cap B
Sample # A-1083
FS-85 Alloy
Specimen # N-AAP
Bottom End Cap A
Sample # A-1084
FS-85 Alloy
Specimen # N-AAP
Bottom End Cap B
Sample # A-1084


FS-85 Alloy
Specimen # N-AAT
Top End Cap A
Sample # A-1087
FS-85 Alloy
Specimen # N-AAT
Top End Cap B
Sample # A-1087
FS-85 Alloy
Specimen # N-AAT
Bottom End Cap A
Sample # A-1088
FS-85 Alloy
Specimen # N-AAT
Bottom End Cap B
Sample # A-1088


FS-85 Alloy
Specimen # N-AAW
Top End Cap A
Sample # A-1089
FS-85 Alloy
Specimen # N-AAW
Top End Cap B
Sample # A-1089
FS-85 Alloy
Specimen # N-AAW
Bottom End Cap A
Sample # A-1090
FS-85 Alloy
Specimen # N-AAW
Bottom End Cap B
Sample # A-1090

TEST ENGINEERING BATTELLE NORTHWEST P.O. BOX 999 RICHLAND, WA 99352	WELDING PROCEDURE LASER WELDING PROCESS



MATERIAL:	FS-85 Alloy (Nb)
THICKNESS:	0.03
PRE-CLEANING:	Yes
COVER GLASS:	Quartz
MACHINE MAKE:	Korad
MACHINE MODEL:	KWD
ADDITIONAL INFO	Evacuate and back fill with UHP helium three times prior to welding.

DRAWING NUMBER	JOINT ASSEMBLY NO.	DATE	WELDING OPERATOR
5015996	N/A	11 Oct. 2005	Asa Jones

SEE WELDING PROCEDURE DESCRIPTION Bettis IV # PNNL-SPP-05-004 FOR QUALITY REQUIREMENTS.

PROCESS VALUES

ROD TYPE & I.D. NO.	Nd:YAG	VOLTAGE	3.6
APERTURE	100	SPOT SIZE	0.747
ATTENUATOR	0	JOULES / PULSE	N/A
MONITOR VOLTS	194-197	ATMOSPHERE	Helium
SCALE FACTOR	N/A	PRESSURE	0-3000 PSIG
FOCUS LENS	6"	PULSE WIDTH	Position # 3
NO. OF PULSES	1 or more		

PREPARED BY. Asa Jones	ORIGNAL ISSUE 11 Oct. 2005 REV. NO. REV. NO REV. NO
APPROVED FOR TEST ENGINEERING N/A due to rejection	PROCEDURE NO. Bettis - Laser - 205

5.05

WELDING PROCEDURE DEMONSTRATION RECORD

Procedure No. Bettis – Laser - 205	Prepared by: A.A. Jones Date: 11 Oct. 2005
No. of Samples Required 6	Welding Operator Name Asa Jones
RDT Section 8 Category 4	Welds Made on: 20 Oct. 2005
Sample Identification Nos See Remarks	Welding Equipment ID EBW S/N 601
Component Inspection Report Nos N/A	Welding to Procedure Witnessed by N/A
Material ID and Heat No FS-85 (Nb)	PROGRAM Bettis Biaxial Creep Specimens

CHARACTERISTIC	REFERENCED SPECIFICATION	NO. OF SAMPLES REQUIRED	REPORT NO. OR LAB ID NO.	ACC	REJ	TECH. OR INSPECTOR	DATE	REMARKS
Comp. Cleaned	Bettis Procedure # N/A	6				N/A		
Visual (Weld)	NE F6-2t Sec. 6 Para. 6.3.2	6		✓		[signature]	[illegible]	
Helium Leak Test	NE F6-2t Sec. 6 Para. 6.3.6	N/A				N/A		
Radiography	NE F6-2t Sec. 6 Para. 6.3.4	N/A				N/A		
Pressure Test	Bettis Procedure # N/A	N/A				N/A		
Metallography	NE F6-2t Sec. 6 Para 6.3.7	6			✓	[signature]	11/1/05	
Dimensional	Drawing requirements	6			✓	[signature]	11/1/05	

Record Data Required For Procedure Qualification Package	Yes	No	Completed
Metallography Report and Mount Nos.	X		✓
Metallography Photos (Information)	X		✓
Radiography Report		X	
Helium Leak Rate		X	
Copy of the Procedure	X		✓
Pressure Test Data		X	
Pressure Test Specimens		X	
Tensile Test Data		X	
Tensile Test Specimens		X	

Remarks

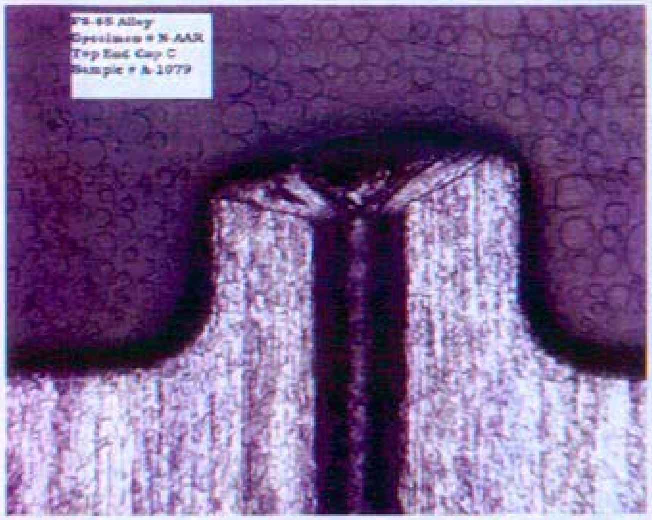
Specimen Numbers	Sample #'s
N-AAR	A-1121
N-AAO	A-1122
N-AAP	A-1123
N-AAS	A-1124
N-AAT	A-1125
N-AAW	A-1126

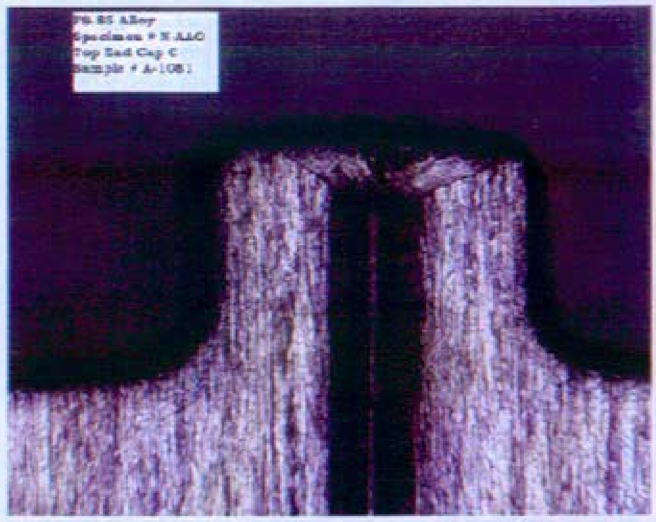
Approval:

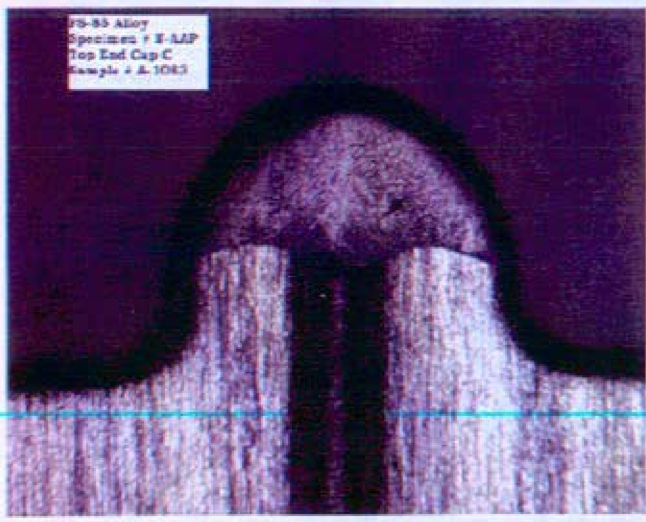
TA Delucchi N/A due to rejection

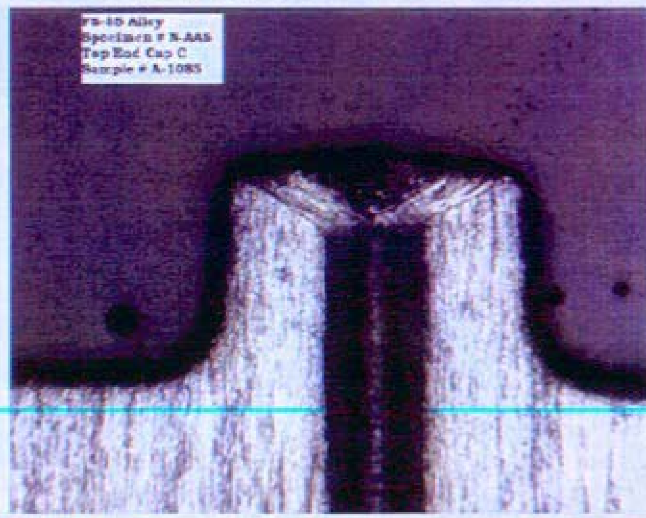
DM Paxton N/A due to rejection

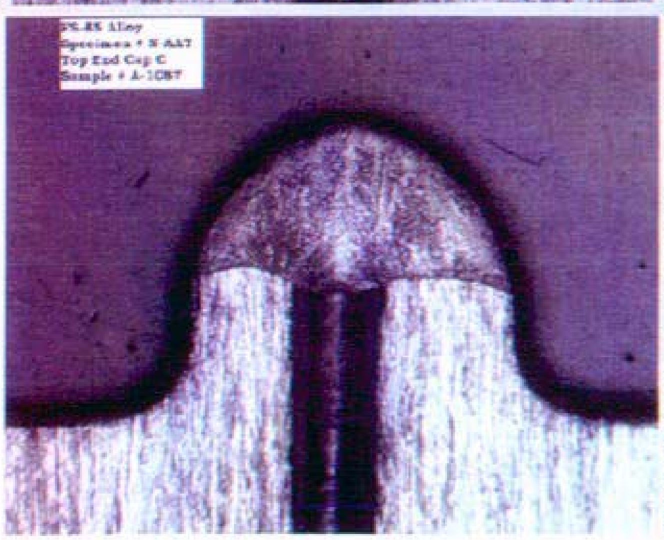
TD Hays N/A

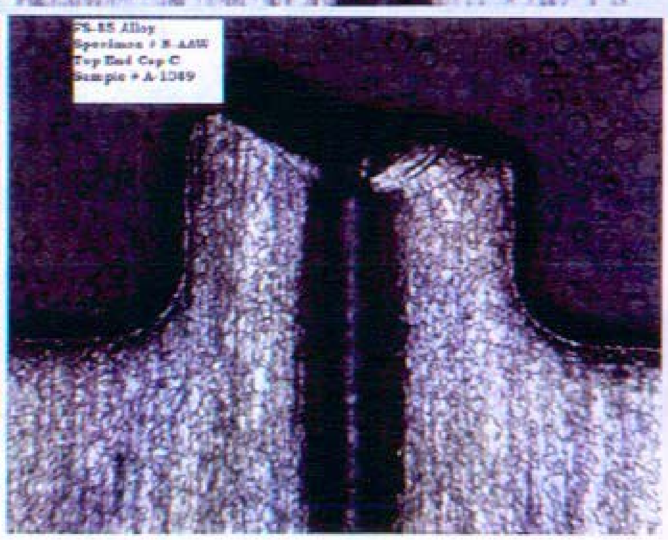

FS-85 Alloy
Specimen # N-AAR
Top End Cap C
Sample # A-1079


FS-85 Alloy
Specimen # N-AAO
Top End Cap C
Sample # A-1081


FS-85 Alloy
Specimen # N-AAP
Top End Cap C
Sample # A-1083


FS-85 Alloy
Specimen # N-AAS
Top End Cap C
Sample # A-1085


FS-85 Alloy
Specimen # N-AAT
Top End Cap C
Sample # A-1087


FS-85 Alloy
Specimen # N-AAW
Top End Cap C
Sample # A-1089

ATTACHMENT 7

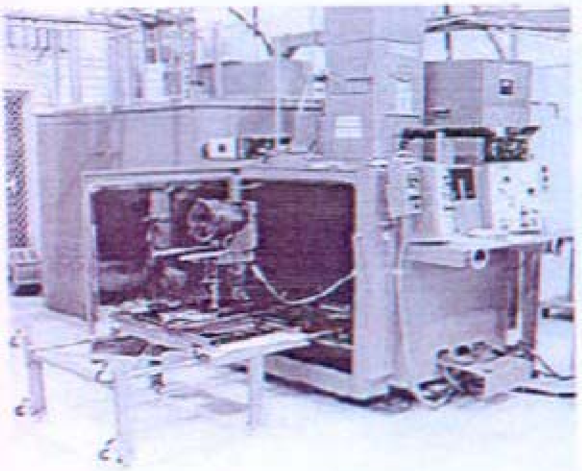
Biaxial Creep Specimen Fabrication at PNNL

D. M. Paxton

In 2004, PNNL acquired an electron beam welding station, a laser engraving system, and a laser welder from Fluor Hanford, Inc., a DOE contractor on the Hanford Site. This equipment and capability were originally developed by the Westinghouse Hanford Company during the 1970's to fabricate large quantities of pressurized tube biaxial creep specimens for obtaining mechanical properties data on cladding alloys for several government funded reactor development programs, including the Advanced Alloy Development Program supporting liquid metal fast breeder reactor development. In the 1980's, this capability and expertise were used to fabricate and test biaxial creep specimens for the SP-100 space reactor development program. In 1994, Fluor Hanford, Inc., assumed responsibility for operation of certain fabrication facilities on the Hanford Site, including all of the equipment used to fabricate pressurized tubes. In the years since 1994, Cogema personnel, as a subcontractor to Fluor Hanford, fabricated biaxial creep specimens for several DOE-funded laboratories using this equipment.

Included in the acquisition by PNNL were several one-of-a-kind fixtures designed and built specifically for welding large quantities of biaxial creep specimens, namely the 24-multi-head fixture used with the electron beam welder and the 12-tube gas pressurization system associated with the laser welder. Photographs of the equipment in PNNL facilities are shown in Figures 7-1 through 7-4. In addition to acquiring the equipment, PNNL hired the senior welding operator responsible for operation and maintenance of this equipment, who brings 22 years of welding and fabrication experience to PNNL as a full-time staff member. Since its acquisition, the electron beam welder and laser welder have been used extensively to perform qualified welds on radioisotope components for the Department of Energy. The laser engraving system and the pressurization system have been set up in dedicated laboratory space but have not been actively used for fabrication of specimens due to the unique nature of their application to pressurized tubes. PNNL staff have conducted recent research including diametral measurements and thermal testing of biaxial creep specimens fabricated by Cogema as part of the DOE Fusion Materials Program. PNNL has a laser profilometry system and vacuum furnace used for this work, as well as operators with many years of experience handling, heat treating and characterizing biaxial creep specimens.

Figure 7-1. Electron Beam Welder and Multi-head Welding Fixture.



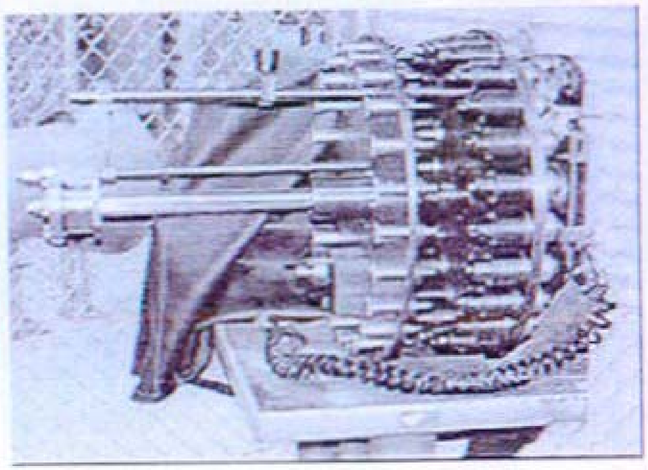


Figure 7-2. Laser Engraving System

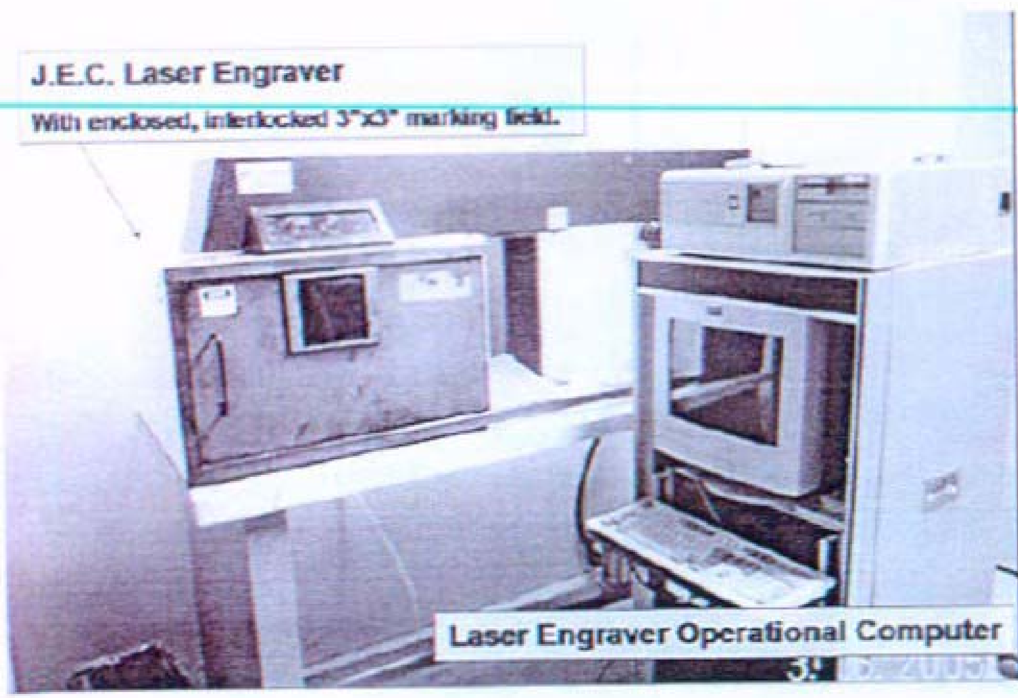


Figure 7-3. Laser Welder and Pressurization System.

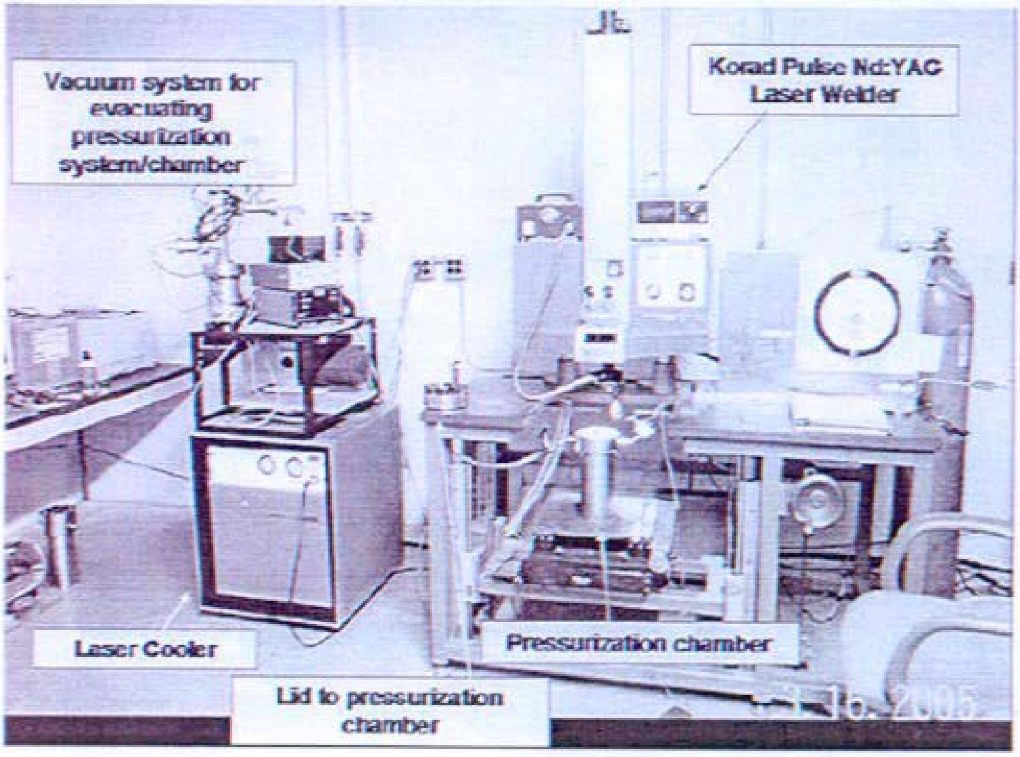
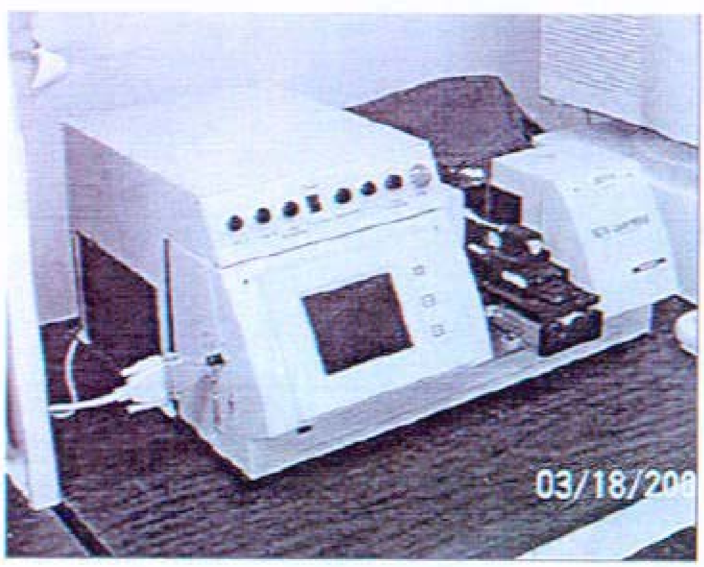


Figure 7-4. Laser Profilometer



ATTACHMENT 8

List of Measurement & Test Equipment (M&TE) Calibrations

for

NRPCT IV # PNNL-SPP-05-004

M&TE Description	M&TE Control No.	Location	Calibration Date	Calibration Due	Calibration Agency	Remarks
Mettler AE163	C24167	PSL 251	9/4/2005	Aug 2006	Q.C.S	Balance
Heise Gauge	CM-8337	PSL 251	7/6/2005	July 2006	Energy NW	Pressure Chamber
EB Welder	EBW 601	APEL	8/3/2005	Aug 2006	Instrumentation Services & Tech	EB Welder
Type K Thermocouple	TC-K-4994	338	6/11/2004	June 2007	Q.C.S	Vacuum Furnace
Type K Thermocouple	TC-K-4996	338	6/11/2004	June 2007	Q.C.S	Vacuum Furnace
BA2 Sentorr Controller Ion Gauge Tube	LIJ10442	338	3/23/2005	Mar 2006	Varian	Vacuum Furnace
Chart Recorder	13157	338	7/27/2005	July 2006	PNNL	Vacuum Furnace

ATTACHMENT 9

List of Equipment & Supplies Purchased

for

NRPCT IV # PNNL-SPP-05-004

1. Hydraulic Lift for loading 24 multi-head fixture into EB system
2. Hardware to fabricate new controller for 24-multi-head welding fixture
3. New laser rod for KORAD pulse laser
4. New optical mounts for KORAD pulse laser
5. Laser service to install new rod and mounts
6. Spare digital pressure gauge
7. Molybdenum 3/8" bar stock for spud fabrication
8. Material to fabricate holding fixture for pressure vessel
9. Pressure system repair & certification
10. Gas bottle cart
11. Specimen staging carts
12. Lab supplies

Attachment C

Radiograph Examination Procedure

COGEMA-SVRT-PRC-006 Rev. 2

Pacific Northwest National Laboratory

Operated by Battelle for the U.S. Department of Energy

August 9, 2005

KAPL Inc.
Attn: Steve Hayden (M/S 111)
P.O. Box 1072
Schenectady, NY 12301

Dear Mr. Hayden:

TRANSMITTAL OF BIAXIAL CREEP SPECIMEN RADIOGRAPHIC PROCEDURE

Three attachments are provided herein which describe radiographic inspections of biaxial creep specimens to be performed by *Cogema Engineering* in Richland, WA under subcontract to PNNL. The NRPCT provided approval of the documents with comments in the Information-to-Vendor (IV): *Biaxial Creep Specimen Fabrication*, PNNL-SPP-05-0004 Revision 2, dated August 2, 2005. The comments have been incorporated and additional information summarized below.

Attachment 1, NRPCT Comment 1. Fuji 25 x-ray film will be used for this radiographic inspection, and the inspection will be performed using a Philips 160 kV x-ray system.

Attachment 2. No NRPCT Comments

Attachment 3, NRPCT Comment 1. After discussion with NRPCT technical contacts, this comment was revised to be as stated in Attachment 3.

As requested, I have included this transmittal letter in triplicate, 5 hard copies of the attachments, and 2 electronic copies of the attachments. If you have questions, please contact Dean Paxton at (509) 375-2620.

Sincerely,

Chad Painter
Project Manager
Space Reactor Materials Irradiation Testing Project

CLP/cs

Attachments (3)

902 Battelle Boulevard • P.O. Box 999 • Richland, WA 99352

Telephone (509) 372-4112 ■ Email chad.painter@pnl.gov ■ Fax (509) 372-6421

Attachment 1

Radiograph Examination Procedure, COGEMA-SVRT-PRC-006

COGEMA ENGINEERING

POLICIES AND PROCEDURES APPROVAL RECORD

COGEMA
NOV 14 2003
Records Management
(Leave Blank)

Document Number: COGEMA-SVRT-PRC-006 **Revision:** 2

Title: RADIOGRAPHIC EXAMINATION PROCEDURES

Approval	Name	Signature	Date
Originator	J. K. Keve	[signature]	11/11/03
President	M. D. Talbot	[signature]	11/11/03
Chief Financial Officer	G. W. Whitney	N/A	
Director, Business Development	Open		
Director, Contracts & Procurement	M. D. Talbot	N/A	
Director, Engineering & Technology	E. A. Nelson	N/A	
Director, Quality Assurance	D. W. Duncan	[signature]	11/12/03
Director, Human Resources	M. A. Smith	[signature]	11/11/03
Director, Services	M. D. Rickenbach	[signature]	11/12/03
Manager, NDE Services	D. D. Tate	[signature]	11/11/03

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Editorial Change: ☐ **Technical Change:** ☒ **Update Required Reading:** Yes/No

Description of Change and Purpose for Change:

Rewrite

Document Type:	Business Sensitive	☐	Quality Assurance	☐	Other	☒
Retention Period:	Non-Permanent	☒	Lifetime	☐	Project File	☐

Revised: 07/11/02

Controlled Copy No. 25

COGEMA ENGINEERING

RADIOGRAPHIC EXAMINATION PROCEDURES

TABLE OF CONTENTS

APPENDICES

COGEMA ENGINEERING

RADIOGRAPHIC EXAMINATION PROCEDURES

1.0 PURPOSE

This procedure establishes the requirements for the control of radiographic examination of materials, welds and assemblies.

2.0 SCOPE

This procedure has three basic parts which are used in conjunction with one another for each examination. These parts consist of Request/Instruction for Nondestructive Test Services (R/I) form, COGEMA-SVAD-PRC-001; requirements applicable to all radiography; and appendices for specific requirements applicable to specific Codes, Standards, and specialized radiographic techniques.

3.0 RESPONSIBILITIES

3.1 Nondestructive Examination Personnel

COGEMA Engineering procedure COGEMA-SVCP-PRC-014, *Qualification and Certification of Nondestructive Examination Personnel* describes the responsibilities and requirements for personnel performing nondestructive examinations.

4.0 INSTRUCTIONS

4.1 Request/Instruction for Nondestructive Test Services

The following additional requirements shall be included or directly referenced in the R/I and shall be considered as part of this procedure for the specific job requested.

- The extent of examination required
- Material, part, or weld identification for each object
- The acceptance criteria
- Any additional requirements

4.2 Radiation Safety

All radiographic examinations shall be conducted in compliance with NDE's' safe operation and emergency procedures (COGEMA-SVSO-PRC-011 and COGEMA-SVEP-PRC-012).

4.3 Component Handling

As a general rule, care should be exercised so soft metals such as lead and aluminum do not come in contact with stainless steel and high nickel alloys being radiographed. Additional restrictions as well as specific handling and cleanliness instructions shall be specified in the R/I or documents directly referenced therein.

4.4 Image Quality Indicator Design

In general, the image quality of radiographic film for examinations performed to the American Society of Mechanical Engineers (ASME), *ASME Boiler and Pressure Vessel Code* requirements shall be determined by conventional ASME penetrameters. Special image quality indicating standards or templates may be used in conjunction with the ASME penetrameters or alone, for non-Code-related examinations, as specified in the R/I or documents directly referenced therein.

4.4.1 Manufacturing Specifications

Penetrameters shall be manufactured to the requirements of the ASME Boiler and Pressure Vessel Code, Section V (SE-747 and SE-1025).

4.4.2 Metrological Verification

Before their initial use, all penetrameters shall be inspected or certified by the manufacturer or other independent Laboratory for conformance to their dimensional specifications as required by ASME Boiler and Pressure Vessel Code, SE-1025, *Standard Practice for Design, Manufacture, and Material Grouping Classification of Hole-Type Image Quality Indicator (IQI) Used For Radiology* and Code, SE-747, *Standard Practice for Design, Manufacture, and Material Grouping Classification of Wire Image Quality Indicators (IQI) Used for Radiology*. Penetrameters shall be identified with a nonrepetitive code of letters, numbers, or combinations to signify acceptance for as long as the penetrameter is retained.

4.4.3 Maintenance

Penetrameters and shims shall be examined before use and shall be periodically cleaned to keep them free of dirt, grease, tape residue, and other contaminants that could adversely affect radiography. Loose or missing penetrameter identification numbers shall be replaced. Damaged penetrameters or shims shall be discarded.

4.5 Film Viewing

4.5.1 Film Viewing Equipment

Equipment used to view radiographs for interpretation shall include a variable high-intensity light source sufficient for viewing the essential penetrameter hole and for the specific density range of the area of interest. The viewing conditions shall be such that light from around the outer edge of the radiograph or coming through low-density portions of the radiograph does not interfere with the interpretation.

4.5.2 Film Viewing Facilities

Viewing facilities shall provide subdued background lighting of an intensity and type that will not cause troublesome reflections, shadows, or glare on the radiographic film.

4.6 Examination Surface

4.6.1 Surface Irregularities

When in the judgment of the NDE Level II or III Radiographer, such action is necessary, the weld surface or other irregularities on accessible surfaces of materials or assemblies shall be removed by the customer or his agent before acceptance examination. This removal will be to a degree that the resulting radiographic image cannot mask or be confused with the image of any discontinuity of interest.

4.6.2 Surface Finish

The finished surface of welded joints may be flush with the base material or may have a reasonably uniform crown with reinforcement, concavity, or undercut, provided it is within the specified limits of the referenced Code or Standard section listed on the R/I.

4.7 Technique Considerations

When practical, single-wall radiography shall be used.

4.7.1 Single-Wall Technique

The radiation beam must pass through only one wall of the component, material, or weld that is viewed for acceptance on the radiograph. An adequate number of exposures shall be made to demonstrate that the required coverage has been obtained.

4.7.2 Double-Wall Technique

When it is not practical to use a single-wall technique, one of the following double-wall techniques shall be used:

- Single-wall viewing

In single-wall viewing the radiation beam must pass through two walls of the object, but only the weld on the film side is viewed for acceptance. A minimum of three exposures taken 120 degrees apart shall be made; however, additional exposures may be required to demonstrate that the required coverage has been obtained; i.e., four exposures at 90 degrees apart.

- Double-wall viewing

The radiation beam must pass through both walls of a component or weld, and both walls must be viewed for acceptance. The material or weld shall be 3-1/2 inches or less in nominal outside diameter. A source side penetrameter shall be used. Care should be exercised to ensure that the required geometric unsharpness is not exceeded. Either the offset or superimposed radiographic technique may be used.

- Offset Radiographic Technique. The radiation beam may be offset from the weld at an angle sufficient to separate the images of the source side and film side portions of the weld so that there is no overlap of the areas to be interpreted. A minimum of two exposures taken 90 degrees to each other shall be made. Additional exposures shall be made if the required radiographic coverage is not obtained; i.e., three exposures at 60 degrees apart.

- Superimposed Radiographic Technique. The radiation beam may be positioned so that the images of both walls are superimposed. A minimum of three exposures taken at either 60 degrees or 120 degrees to each other shall be made. Additional exposures shall be made if the required radiographic coverage is not obtained; i.e., four exposures at 45 degrees apart.

4.8 Geometric Unsharpness

The geometric unsharpness limits stipulated in the appendices of this procedure shall be based on the maximum distance the area of interest is from the film.

Geometric unsharpness of the radiograph shall be determined in accordance with:

$$Ug = Fd/D$$

Where: Ug = Geometrical unsharpness.

F = Source size, in inches, maximum projected dimension of the radiating source (or effective focal spot) in the plane perpendicular to the distance D from the weld or object being radiographed.

d = Distance, in inches, from the source side of weld or object being radiographed to the film.

D = Distance, in inches, from the source of radiation to weld or object being radiographed.

4.9 Radiation Sources

4.9.1 Energy Selection

Where practical, the radiation source should be an X-ray machine of appropriate voltage as defined in Figure 1 (a, b, and c). Figure 1 is to be used as guidance and may be exceeded provided the proper penetrameter sensitivity is demonstrated.

4.9.2 Direction of Radiation Beam

Whenever possible, the direction of the central beam of radiation shall be centered on the area of interest.

4.9.3 Focal Spot Size

The focal spot size and condition of each X-ray generating machine may be determined by the pinhole method. The effective source size of each radioisotope shall be certified by the manufacturer or determined before its use.

4.9.4 Primary Beam Filters

The use of techniques to filter, restrict, or collimate the primary radiation is permitted.

4.10 Film and Associated Materials

4.10.1 Film

Radiographs shall be made using industrial radiographic film that is classified by the manufacturer as meeting the requirements of ASME Boiler and Pressure Vessel Code, Section V (SE-1815). Film system classes Special, I, II, III, W-A, and W-B are permitted.

Film techniques with two or more films of equal or different speeds in the same holder will be permitted provided the appropriate penetrameter sensitivity and density for the specific area is demonstrated.

For acceptance radiography only one copy of film is required provided it meets all the requirements of this procedure. If two or more films in the same cassette are exposed simultaneously, the extra film(s) are not required to meet all of the procedural requirements. Even though the extra film(s) may not meet all of the procedural requirements, and therefore cannot be used to evaluate the area of interest for acceptance, they may be used to evaluate film blemishes such as scratches, crimps, static marks, and lint marks, provided these blemishes are not large enough to interfere with film interpretation or can mask relevant indications in the area of interest.

4.10.2 Film Processing

Film processing shall be done in accordance with the film manufacturers instructions and/or with guidance from ASME Boiler and Pressure Vessel Code, Section V, Article 22, SE-999, *Standard Guide for Controlling the Quality of Industrial Radiographic Film Processing*, or SE-94, Part III of the *Standard Practice for Radiographic Testing*.

4.10.3 Intensifying Screens

The use of fluorescent screens for acceptance radiography shall be prohibited.

The recommended thickness and combination of lead-intensifying screens are shown in Table 1.

The screens shall be free of foreign material or other irregularities that would cause blemishes to appear on the film in the area of interest to the extent they could either mask or confuse the interpretation of the radiographs.

Table 1. Lead Screen Thickness in Thousandths of an Inch.

Energy or Source	Front Screen	Interleaving Screen	Back Screen
125-450 kV	5-10	0-5	5-10

4.10.4 Film Holders

Film holders may be identified by a nonrepetitive code of lead numbers/letters one-inch high by at least 1/16-inch thick located at one corner of the holder. Film holders shall be free of irregularities and contaminants that would produce extraneous images.

4.10.5 Backscatter

A minimum thickness of 1/16-inch of lead backing is recommended to be placed on the backside of the film holder. A lead letter "B", a minimum of ½-inch high and 1/16 inch thick, shall be attached to the back of each film holder during the exposure to evaluate the adequacy of protection from backscatter radiation.

4.10.6 Masking

Masking or blocking, which surrounds components or covers thin sections with an absorptive material, may be employed. Such material may be employed to either reduce scattered radiation or equalize the absorption of different sections. Masking and blocking materials shall be compatible with the component being radiographed.

4.11 Location Markers

Location markers are to appear as radiographic images on the film. They shall be placed on the part and not on the film holder or cassette. Their locations shall be marked permanently on the surface of the part being radiographed , or on a map in a manner permitting the area of interest on a radiograph to be accurately located on the part for the required retention period of the radiograph. Location markers also provide evidence that the required area of interest was examined.

4.11.1 Single-Wall Viewing

Source side location markers shall be used when radiographing the following:

- Flat components or longitudinal joints in cylindrical or conical components. As an alternate film side markers may be used when the radiograph shows at least 1 inch of coverage beyond the location markers for materials 1-1/2 inches or less in thickness and when the source to film distance is at least two times the film marking internal.

- Curved components whose concave side is toward the source and when the source-to-material distance is less than the inside radius of the component.

- Curved or spherical components whose convex side is toward the source.

Film side markers

- Film side location markers shall be used when radiographing either curved or spherical components whose concave side is toward the source and when the source-to-material distance is greater than the inside radius.

Either side markers

- Location markers may be placed on either the source side or film side when radiographing either curved or spherical components whose concave side is toward the source and the source-to-material distance equals the inside radius of the component.

4.11.2 Double-Wall Viewing

At least one location marker shall be placed on the source side surface adjacent to the weld (or on the material in the area of interest) for each radiograph.

4.11.3 Location Marking With a Map

When inaccessibility or other limitations prevent the location of markers as stipulated above, a dimensional map of the geometric arrangement including marker locations shall accompany the radiographs to show that the required coverage has been obtained.

4.12 Penetrameters

4.12.1 Penetrameter Selection

The penetrameter selection shall be based on the nominal single-wall material thickness in the area of interest. For welds this thickness may include the estimated or actual weld reinforcement, provided the reinforcement does not exceed the limit of the referencing Code section. Backing rings or strips shall not be considered as part of the thickness in penetrameter selection. A thinner penetrameter for those thickness ranges listed in Appendix B, Tables 2 and 3; Appendix C, Table 1; and Appendix D, Table 1, may be used.

A smaller hole in a thicker penetrameter or a large hole in a thinner penetrameter may be substituted for any section thickness listed in the tables above, provided the equivalent penetrameter sensitivity (EPS) is maintained and all other requirements for radiography are met (ASME Boiler and Pressure Vessel Code, Section V, SE-1025).

It is permissible to use a penetrameter material with less radiation absorption than the material being radiographed. For other material considerations refer to ASME Boiler and Pressure Vessel Code, Section V, SE-1025.

- ASME Section V penetrameter selection

  For radiography of materials meeting ASME Boiler and Pressure Vessel Code, Section V requirements for single- and double-wall radiography, the penetrameters shall be selected from Appendix B, Table 2.

- ASME Section III penetrameter selection

  For radiography of materials meeting ASME Boiler and Pressure Vessel Code, Section III requirements for single- and double-wall radiography, the penetrameter shall be selected from Appendix B, Table 3.

4.12.2 Penetrameter Placement

Except as provided below, penetrameters shall be placed on the source side of the material or component at a location directly adjacent to the region of interest furthest from the film and oriented so that the plane of the penetrameter is normal to the radiation beam.

- Film side penetrameters placement

In cases where inaccessibility prevents source side placement of the penetrameters, the appropriate penetrameter shall be placed on the film side of the object with a lead letter "F" at least as high as the penetrameter identification number and be placed either adjacent to or on the penetrameter but shall not mask the essential penetrameter hole.

- Weld penetrameter placement

When radiographing welds, penetrameters shall either be placed adjacent to or on the weld. The identification number and the lead letter "F", when used, shall not be in the area of interest. In instances where the weld metal is not radiographically similar to the base material or the geometric configuration makes it impractical, the penetrameter identification number and the lead letter "F" may be placed over the weld metal.

- Materials or components other than welds

- Penetrameters with identification number(s) and the lead letter "F", when used, may be placed in the area of interest.
- Wire-type penetrameter placement
- The wire-type penetrameter(s) shall be placed on the weld so that the length of the wires is perpendicular to the length of the weld. The identification numbers and, when used, the lead letter "F", shall not be in the area of interest, except when geometric configuration makes it impractical.
- Hole-type penetrameter block placement
- When configuration or size prevent placing the penetrameter(s) as described above, it may be placed on a separate block (or preferably a part-like product) provided all other radiography requirements are met.
- The block material shall be radiographically similar to the test material and be placed as close as possible to the item being examined. The block dimensions shall exceed the penetrameter dimensions such that the outline of at least three sides of the penetrameter image shall be visible on the radiograph.
- Hole-type penetrameter shim

- A shim of material radiographically similar to the weld metal shall be placed between the part and the penetrameter, if needed, so that the area of interest is no more than -15 percent from (lighter than) the radiographic density through the penetrameter. Shims shall exceed the penetrameter dimensions such that the outline of at least three sides of the penetrameter image shall be visible on the radiograph. Refer to paragraph 4.13.2 for specific film density requirements.

4.12.3 Number of Penetrameters

One or more penetrameter(s) shall be used for each radiograph. Each penetrameter shall represent an area of essentially uniform radiographic density as judged by a densitometer. If the density of the radiograph anywhere through the area of interest varies by more than -15 or +30 percent from the density through the body of the penetrameter or adjacent to the designated wire of a wire-type penetrameter, then an additional penetrameter shall be used for each exceptional area or areas and the radiograph retaken. When calculating the allowable variations in density, the calculations may be rounded to the nearest 0.1 within the range specified in paragraph 4.13.2.

If more than one penetrameter is used, one shall be representative of the lightest area of interest and the other the darkest area of interest, provided the density requirements of 4.13.2 are met. The intervening densities on the radiograph shall be considered as having acceptable density. The additional penetrameter is not required to be normal to the radiation source.

Where more than one film holder or cassette is used for an exposure, a penetrameter image shall appear on each radiograph, except where the source is placed on the center axis of the object and the complete circumference is radiographed with a single exposure. In which case at least three equally spaced (approximately 120 degrees apart) penetrameters shall be used. When an array of objects in a circle is radiographed, at least one penetrameter shall show on each test object image.

Where sections of longitudinal welds adjoining the circumferential weld are being examined simultaneously with the circumferential weld, an additional penetrameter shall be placed on each longitudinal weld at the end of the section most remote from the junction with the circumferential weld being radiographed.

4.13 Results of Examination

4.13.1 Technique Qualification

Compliance with the density and penetrameter image requirements shall be considered evidence of qualification of the technique.

4.13.2 Film Requirements

Film quality

Radiographs shall be evaluated for film quality before presentation for analysis and interpretation. All radiographs shall be free from mechanical, chemical, or other blemishes to the extent that they do not mask and are not confused with the image of any discontinuity in the area of interest on the object being radiographed. Such blemishes include, but are not limited to:

- Fogging.
- Processing defects such as streaks, water marks, or chemical stains.
- Scratches, finger marks, crimps, dirtiness, static marks, smudges, or tears.
- False indications because of dirty or defective screens.
- If the image of the lead letter "B" appears as a light image on the radiograph, protection from backscatter is insufficient, and the radiograph shall be considered unacceptable. An additional thickness of lead backing shall be required. A dark image of the letter "B" is indicative of pressure and shall not be cause for rejection unless it interferes with the film interpretation.
- Densitometer linearity and calibration

  Densitometers shall be used for ensuring compliance with film density requirements. The densitometer shall be warmed up and operated in accordance with the manufacturers' operating manual. Densitometers used in evaluating radiographic film density shall be linear throughout the density range of 0.30 through 4.0 Hurter and Driffield (H&D) units. The linearity shall be verified by measuring density values closest to 0.30, 3.0, and 3.9 H&D units on a calibrated step wedge. The readings shall be recorded on the Radiographic Procedure and Test Report form (Figure 2). The measured and calibrated step wedge density values shall not vary more than ± 0.05. The linearity calibration shall be performed for each job, after 8 hours of continuous operation, after change of operators, or a change in apertures.

- Film density

Except for the requirements of Appendix C and Appendix D, the film density through the body of a hole-type penetrameter(s) or adjacent to the designated wire of a wire-type penetrameter, as well as through the area of interest of the radiographic image, shall be between 1.8 and 4.0 H&D units for X-ray and between 2.0 and 4.0 H&D units for gamma ray sources. For composite viewing of multiple film exposures, each film of the composite set shall have a minimum density of 1.3 with the composite set having a maximum density of 4.0 H&D units. A tolerance of 0.05 in density is allowed for variations between densitometer readings.

The film density through the area of interest shall not vary more than -15 or +30 percent from the density through a hole-type penetrameter or adjacent to the designated wire of a wire-type penetrameter. When calculating the allowable variations in density, the calculations may be rounded to the nearest 0.1.

When shims are used, the +30 percent restriction may be exceeded, providing the required penetrameter sensitivity is displayed and the film density in the area of interest is less than 4.0 H&D units. If more than one penetrameter is used, one shall be representative of the lightest area of interest and the other the darkest area of interest The intervening densities on the radiograph shall be considered as having acceptable density.

- Coverage

Radiographic examinations shall be conducted with sufficient overlap, to ensure 100 percent coverage of the area of interest at the specified film density and penetrameter image resolution. When any material or component cannot be fully inspected as specified on the R/I, or documents referenced therein, the extent of examination performed and description of conditions preventing the full examination shall be recorded on the Radiographic Procedure and Test Report (Figure 2).

- Film identification

A system for radiograph identification shall be used to produce permanent identification on the radiograph traceable to the contract, object, weld or weld seam, or part numbers, as appropriate. In addition, the manufacturer's symbol or name and date of the radiograph shall be plainly and permanently included on the radiograph. This identification system does not necessarily require that the information appear as radiographic images. In any case, this information shall not obscure the area of interest. Traceability shall also provide that the examination report, the radiographs, the object, and the area examined can be identified with respect to each other at any time.

- Film interpretation

  Presentation of final radiographs for interpretation shall be in the form of a technical package which include radiograph(s) of acceptable film quality; a report of the specific examination parameters; the radiographic sketch and, where required, special technique information. Images noted on the film, which could be construed to be defects, but which are suspected to be surface irregularities, shall be verified by visual examination of the part. Such images and verifications will be recorded on the Radiographic Procedure and Test Report form. When such images could mask defects, the irregularity shall be removed and the area re-radiographed. Alternate radiographic or other NDE techniques may be used to clarify acceptability of such regions. Defect images occurring on the film and outside the region of interest specified shall be recorded on the Radiographic Procedure and Test Report form. Film artifact images noted on one film only, in the area of interest, shall be identified by an arrow placed on the film, out of the area of interest.

4.14 Object Acceptance

Radiographic object acceptance shall be based on the acceptance criteria specified by the R/I for the region of interest.

5.0 RECORDS

None.

6.0 FIGURES AND APPENDICES

Figure 1.	Recommended X-ray Voltage
Figure 2.	Radiographic Procedure and Test Report
Appendix A	Examination Records
Appendix B	American Society of Mechanical (ASME) Code
Appendix C	Capsule, Fuel, and Absorber Pin Radiography
Figure C-1.	Beam Filtration
Figure C-2.	X-ray Voltage Selection
Figure C-3.	Geometric Unsharpness
Figure C-4.	Number of Views Chart
Figure C-5.	Primary Block Thickness
Figure C-6.	Secondary Block Thickness
Appendix D	Casting Radiography
Appendix E	American Welding Society (AWS) Code

7.0 REFERENCES

American Society of Mechanical Engineers (ASME), *ASME Boiler and Pressure Vessel Code.*

COGEMA-SVCP-PRC-014, *Qualification and Certification of Nondestructive Examination Personnel.*

Figure 1. Recommended X-ray Voltage

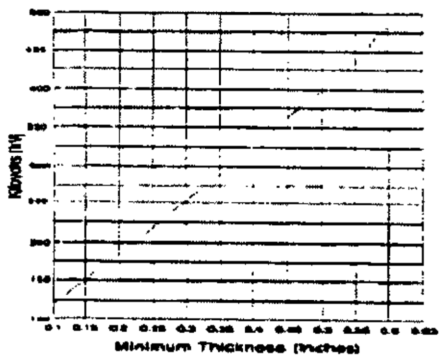

Figure 1a. X-ray Voltage for Steel

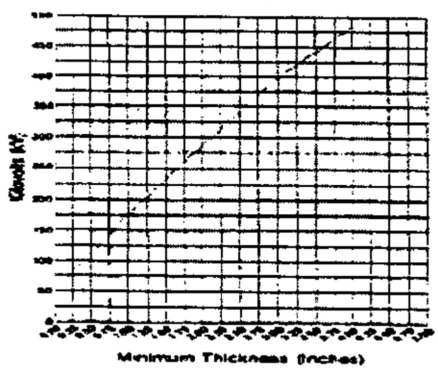

Figure 1b. X-ray Voltage for Aluminum

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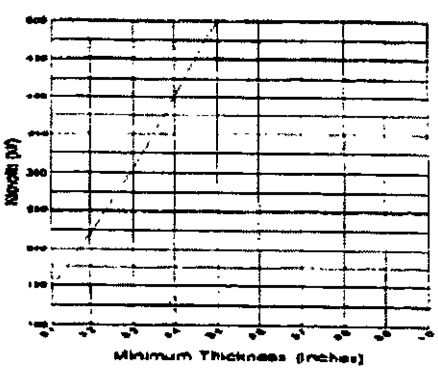


Figure 1c. X-ray Voltage for Copper and High-Nickel Alloys.

Figure 2. Radiographic Procedure and Test Report (Example)
(sheet 1 of 2) (A-6002-663)

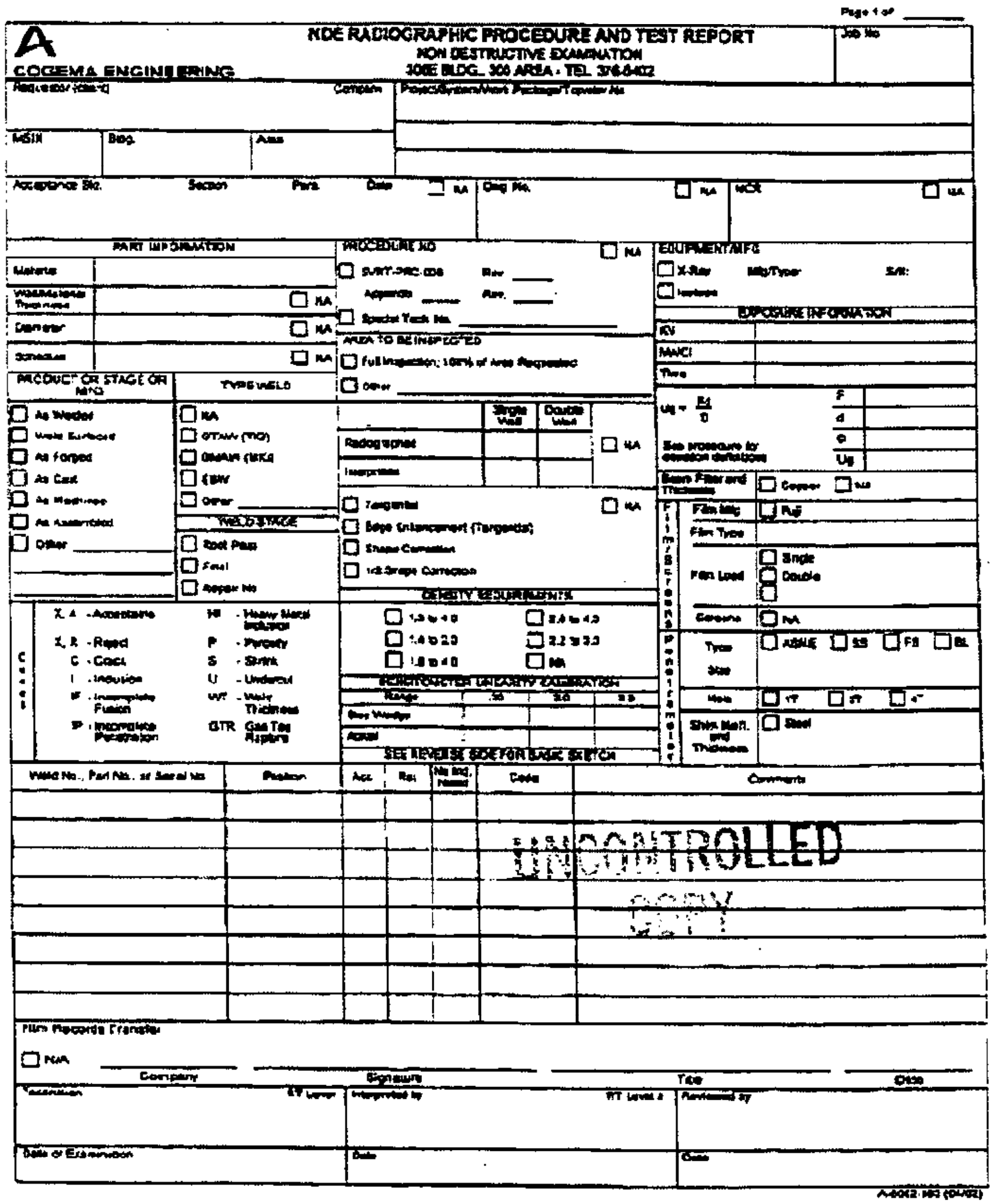
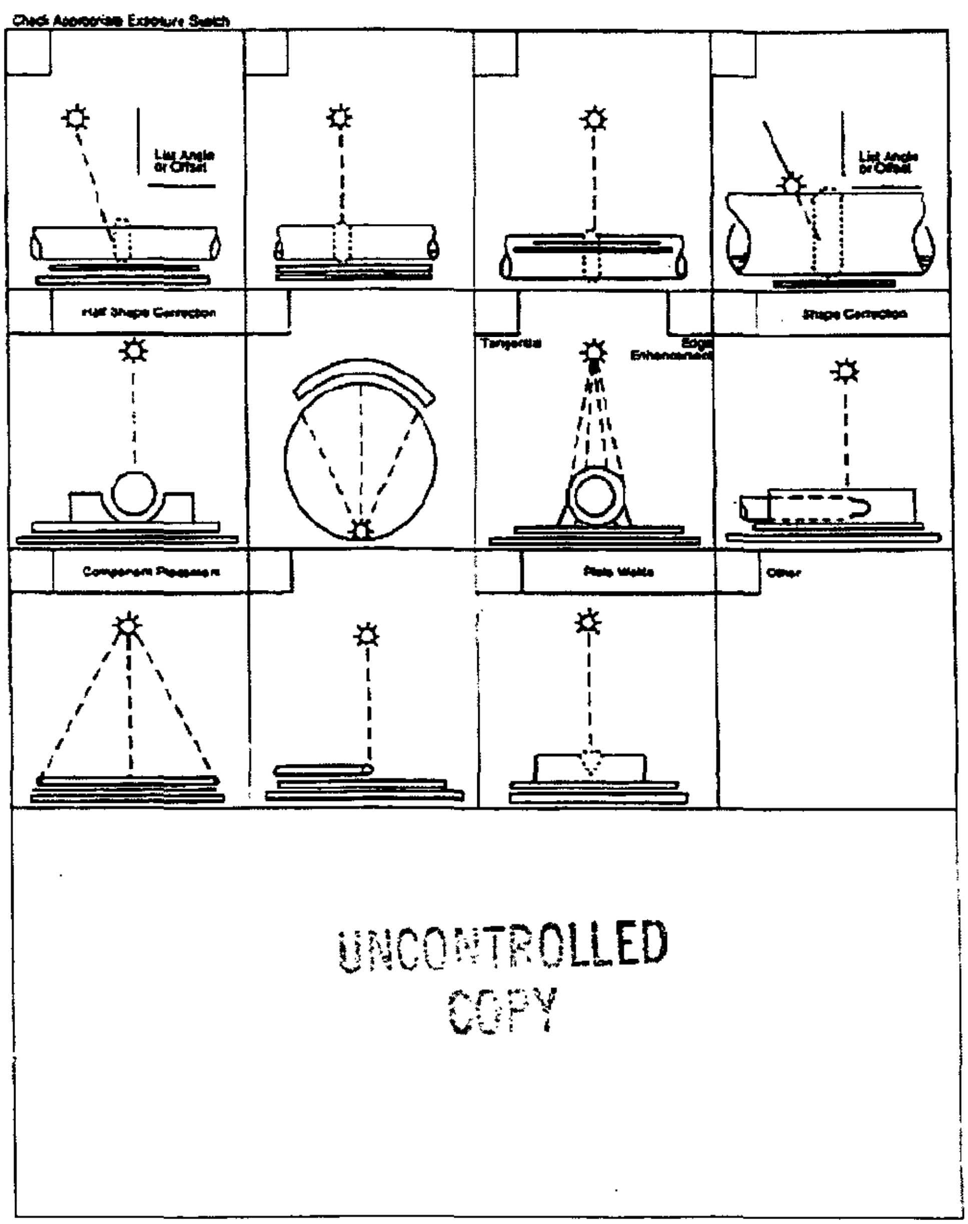


Figure 2. Radiographic Procedure and Test Report
(sheet 2 of 2) (A-6002-663)



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APPENDIX A
EXAMINATION RECORDS

1.0 RECORD CONTENTS

The record of examination shall consist of the radiographic technique (sketch), the report defining specific examination parameters, the results of examination, and the radiograph(s).

2.0 INSTRUCTIONS

2.1 Radiographic Procedure and Test Report

The examination report is divided into two sections: the documentation of specific examination parameters and the results of the examination. The documentation of specific examination parameters shall contain, but not be limited to, the following information as applicable:

- Job number
- Requester and address
- Contractor
- Project or system identification
- Part description and/or identification
- Work package or traveler number
- Material type and thickness
- Weld description and identification
- Procedure and technique numbers and revisions
- Location marker maps
- Maximum source or focal spot size
- Isotope or maximum X-ray voltage
- Minimum source-to-film distance
- Source intensity (milliamperes or curies)
- Beam filtration material and thickness
- Single- or double-wall exposure
- Single- or double-wall viewing
- Film manufacturer and type
- Number of films per cassette
- Lead screen placement and thickness
- Number or listing of exposures
- Densitometer linearity check
- Penetrameter description
- Penetrameter resolution and density requirements
- Shim material and thickness
- Date of examination

- Radiographer's name and certification level
- Interpreter's name and certification level
- Level III (or NDE Manager) review and signature

Locations on the report form that are not applicable to a specific examination shall be shown as N/A (not applicable).

2.2 Technique Sketch

Either a specific or a generalized technique (sketch) documenting the specific examination setup shall be either referenced by, attached to, or included as part of the Radiographic Procedure and Test Report.

APPENDIX B
AMERICAN SOCIETY OF MECHANICAL (ASME) CODE

1.0 PURPOSE

This appendix establishes the requirements for radiography in accordance with the American Society of Mechanical Engineers (ASME), *ASME Boiler and Pressure Vessel Code*, Sections III and V.

2.0 SCOPE

This appendix is supplemental and shall be used in conjunction with the main body of this procedure.

3.0 INSTRUCTIONS

3.1 ASME Boiler and Pressure Vessel Code, Sections III and V.

Table 1. Geometric Unsharpness Limitations.

Material Thickness, Inches	Geometric Unsharpness Maximum, Inches
Under 2	0.020
2 through 3	0.030
Over 3 through 4	0.040
Greater than 4	0.070

NOTE: Material thickness is the thickness on which the penetrameter is based.

APPENDIX B
AMERICAN SOCIETY OF MECHANICAL (ASME) CODE

3.2 ASME Boiler and Pressure Vessel Code, Section V.

Table 2. Penetrameter Chart.

	Source Side			Film Side		
Nominal Single Wall Material Thickness Range, in	Hole Type Designation	Essential Hole	Wire Diameter, in	Hole Type Designation	Essential Hole	Wire Diameter, in
Up to 0.25, incl	12	2T	0.008	10	2T	0.006
Over 0.25 through 0.375	15	2T	0.010	12	2T	0.008
Over 0.375 through 0.50	17	2T	0.013	15	2T	0.010
Over 0.50 through 0.75	20	2T	0.016	17	2T	0.013
Over 0.75 through 1.00	25	2T	0.020	20	2T	0.016
Over 1.00 through 1.50	30	2T	0.025	25	2T	0.020
Over 1.50 through 2.00	35	2T	0.032	30	2T	0.025
Over 2.00 through 2.50	40	2T	0.040	35	2T	0.032
Over 2.50 through 4.00	50	2T	0.050	40	2T	0.040
Over 4.00 through 6.00	60	2T	0.063	50	2T	0.050
Over 6.00 through 8.00	80	2T	0.100	60	2T	0.063
Over 8.00 through 10.00	100	2T	0.126	80	2T	0.100
Over 10.00 through 12.00	120	2T	0.160	100	2T	0.126
Over 12.00 through 16.00	160	2T	0.250	120	2T	0.160
Over 16.00 through 20.00	200	2T	0.320	160	2T	0.250

3.3 ASME Boiler and Pressure Vessel Code, Section III.

Table 3. Penetrameter Chart.

	Source Side				Film Side			
Single-Wall Material Thickness Range, in	Designation	Hole Size	Essential Hole	Required Wire Diameter - IQI	Designation	Hole Size	Essential Hole	Required Wire Diameter IQI
Up to 1/4 incl	5	0.040	4T	0.006	5	0.040	4T	0.006
Over 1/4 - 3/8	7	0.040	4T	0.006	7	0.040	4T	0.006
Over 3/8 - 1/2	10	0.040	4T	0.010	10	0.040	4T	0.010
Over 1/2 - 5/8	12	0.050	4T	0.013	12	0.050	4T	0.013
Over 5/8 - 3/4	15	0.060	4T	0.016	12	0.050	4T	0.013
Over 3/4 - 1	20	0.040	2T	0.016	17	0.035	2T	0.013
Over 1 - 1 1/4	25	0.050	2T	0.020	17	0.035	2T	0.013
Over 1 1/4 - 1 1/2	30	0.060	2T	0.025	20	0.040	2T	0.016
Over 1 1/2 - 2	35	0.070	2T	0.032	25	0.050	2T	0.020
Over 2 - 2 1/2	40	0.080	2T	0.040	30	0.060	2T	0.025
Over 2 1/2 - 3	45	0.090	2T	0.040	35	0.070	2T	0.032
Over 3 - 4	50	0.100	2T	0.050	40	0.080	2T	0.040
Over 4 - 6	60	0.120	2T	0.063	45	0.090	2T	0.040
Over 6 - 8	80	0.160	2T	0.100	50	0.100	2T	0.050
Over 8 - 10	100	0.200	2T	0.126	60	0.120	2T	0.063
Over 10 - 12	120	0.240	2T	0.160	80	0.160	2T	0.100
Over 12 - 16	160	0.320	2T	0.250	100	0.200	2T	0.126
Over 16 - 20	200	0.400	2T	0.320	120	0.240	2T	0.160

NOTE
(1) Hole (plaque) type penetrameters may be used on flat plates and on objects with geometries such that the penetrameter hole image is not distorted.

APPENDIX C
CAPSULE, FUEL, AND ABSORBER PIN RADIOGRAPHY

1.0 PURPOSE

This appendix contains the requirements for beam-filtered tangential, shape correction, plus fuel and absorber pin radiography.

2.0 SCOPE

This appendix is supplemental and shall be used in conjunction with the main body of this procedure.

3.0 INSTRUCTIONS

- **Beam-Filtered Tangential Radiography**. A technique used on cylindrical shaped parts or welds by which filters (usually copper) are placed in front of the X-ray radiation beam to remove the longer wavelength component of the beam. Because the area of interest (weld) is located in the tangent of the tube wall, this filtration will minimize the effects of edge burnout (undercut) caused by scattered radiation.

- **Shape Correction Radiography**. A technique that surrounds the cylindrical test object with material so edge burnout (undercut) is eliminated by masking the film from scattered radiation.

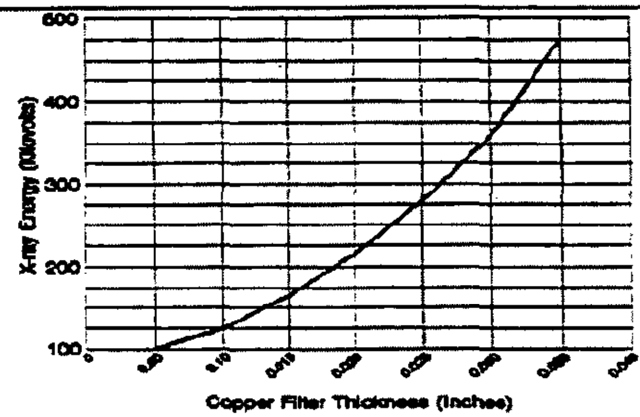
3.1 Requirements for Beam-Filtered Tangential Radiography

3.1.1 Beam Filtration

Copper filters placed in front of the X-ray radiation beam should be at least one half value layer in thickness (Figure C-1).

If edge burnout (undercut) exceeds 0.005 inch as measured by a 7X magnifier on the capsule tube wall near the weld, then more beam filtration may be required. However, investigation into other sources of scattered radiation may also be beneficial.

Figure C-1. Beam Filtration.



3.1.2 Energy Selection

The energy selection in Figure C-2 is a guide to be used for steel parts. When conditions exist that require the use of an isotope or x-ray voltage in excess of Figure C-2, the technique shall be consider qualified if the proper penetrameter sensitivity is demonstrated.

Figure C-2. X-Ray Voltage Selection.

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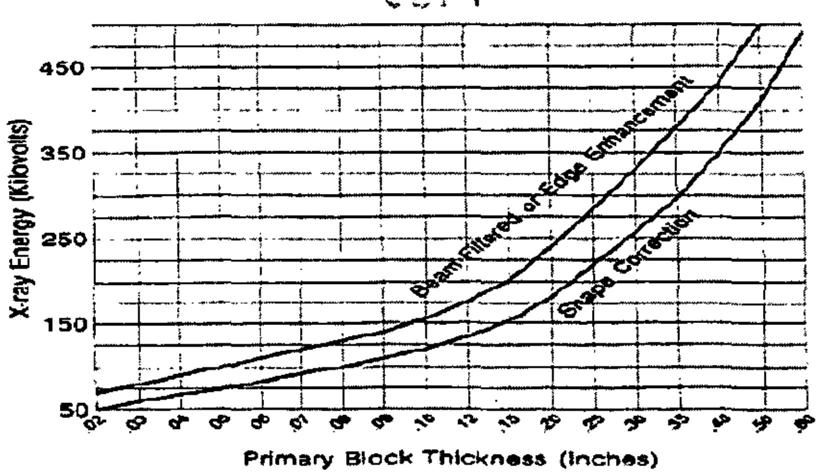
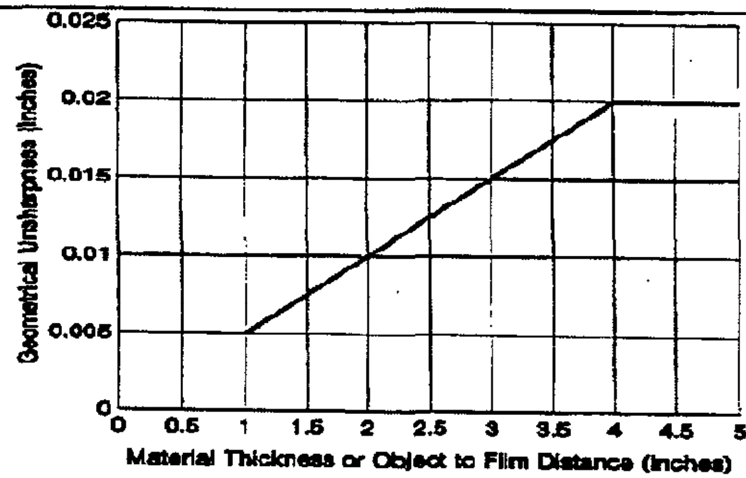


3.1.3 Geometric Unsharpness

Maximum geometric unsharpness shall be as shown in Figure C-3.

Figure C-3. Geometric Unsharpness.



3.1.4 Extent of Examination

Unless otherwise stated in the Request/Instruction for Nondestructive Test Services (R/I) form (COGEMA-SVAD-PRC-001), the extent of examination shall be 100 percent coverage and shall be determined by Figure C-4.

3.1.5 Selection of Penetrameter Block Thickness

Penetrameter for the beam filter technique shall be placed on a block of material, which is radiographically similar to the test object, and placed near the outer most capsules (end capsules). There shall be at least two penetrameter blocks, a primary and a secondary block, and they shall be selected from Figures C-5 and C-6.

3.1.6. Penetramter Selection

Penetrameter selection shall be based on the primary and secondary block thickness and selected from Table 1.

Table 1. Penetrameter Chart.

Primary and Secondary Block Thickness Taken From Figures C-5 and C-6	Penetrameter	
	Thickness Designation	Essential Hole
Up to 1/4 inch	5	2T
Over 1/4 thru 3/8	7	2T
Over 3/8 thru 1/2	10	2T
Over 1/2 thru 5/8	12	2T
Over 5/8 thru 3/4	15	2T
Over 3/4 thru 7/8	17	2T
Over 7/8 thru 1	20	2T
Over 1 thru 1-1/4	25	2T
Over 1-1/4 thru 1-1/2	30	2T

3.1.7 Film Selection

Industrial x-ray film, Type 1, extra fine grain or better, shall be used.

3.1.8 Film Density

To establish a technique, the film density measured through the body of the penetrameter shall not be less than 1.4 nor greater than 4.0 Hurter and Driffield (H&D) units. Since the primary penetrameter block thickness represents the thickest portion of the weld, a secondary penetrameter block shall be selected to represent the thinnest area of interest. The intervening film densities on the radiograph shall be considered as having acceptable density.

If the test object tube wall thickness is less than 0.010 inch thick, the primary penetrameter block shall be calculated by Equation 1.

Equation 1

$$P_b = \sqrt{OD^2 - ID^2}$$

Where: P_b = Primary penetrameter block thickness
OD = Outside diameter of tube
ID = Inside diameter of tube

3.2 Specific Requirements For Shape Correction Radiography

3.2.1 Shape Correction Forms

There are two basic types of shape correction forms: block types and tube types. The block type may be either full or partial section thickness of the test object. The tube (edge enhancement) type can be either a whole tube slightly larger than the test object or one that is split longitudinally down the length of the tube (one-half tube).

Shape correction forms shall be made of materials compatible with the test object; however, they normally should not be made of materials more dense than the test object.

3.2.2 Thickness of Shape Correction Forms

The block-type shape correction form should be manufactured so that the drilled holes in the block are as close as practical to the full block thickness. As a guide, the tube-type (edge enhancement) shape correction form wall thickness should be between 0.5 and 1.5 times the thickness of the test object tube wall. However, at times, experimentation may be required to determine the proper tube wall thickness.

3.2.3 Energy Selection

The energy selection in Figure C-2 is a guide to be used for steel parts. When conditions exist that require the use of x-ray voltage in excess of Figure C-2, the technique shall be consider qualified if the proper penetrameter sensitivity is demonstrated.

3.2.4 Geometric Unsharpness

Maximum geometric unsharpness shall be as shown in Figure C-3.

3.2.5 Extent of Examination

Unless otherwise stated in the R/I form, the extent of examination shall be 100 percent coverage and shall be determined by Figure C-4.

3.2.6 Selection of Penetrameter Block Thickness

Penetrameter block selection may be determined by measuring the film density through the area of interest (weld area) and matching that density to a block of radiographically similar material (see Paragraph 3.2.9 for measuring film densities) or based upon the thickness of the shape correction form. Block thickness for the tube-type (edge enhancement) shape correction form can be estimated by determining the primary block thickness of the test object from Figure D-5 plus the thickness of the tube shape correction form as determined in Figure D-6. If necessary, the thickness of the penetrameter block may be adjusted to achieve the proper film density range (see Paragraph 3.2.9).

3.2.7 Penetrameter Selection

Penetrameter selection shall be based on the thickness of the block(s) as determined in Paragraph 3.2.6 and shall be selected from Table 1.

3.2.8 File Type

Industrial x-ray film, Type 1, extra fine grain or better shall be used.

3.2.9 Film Density

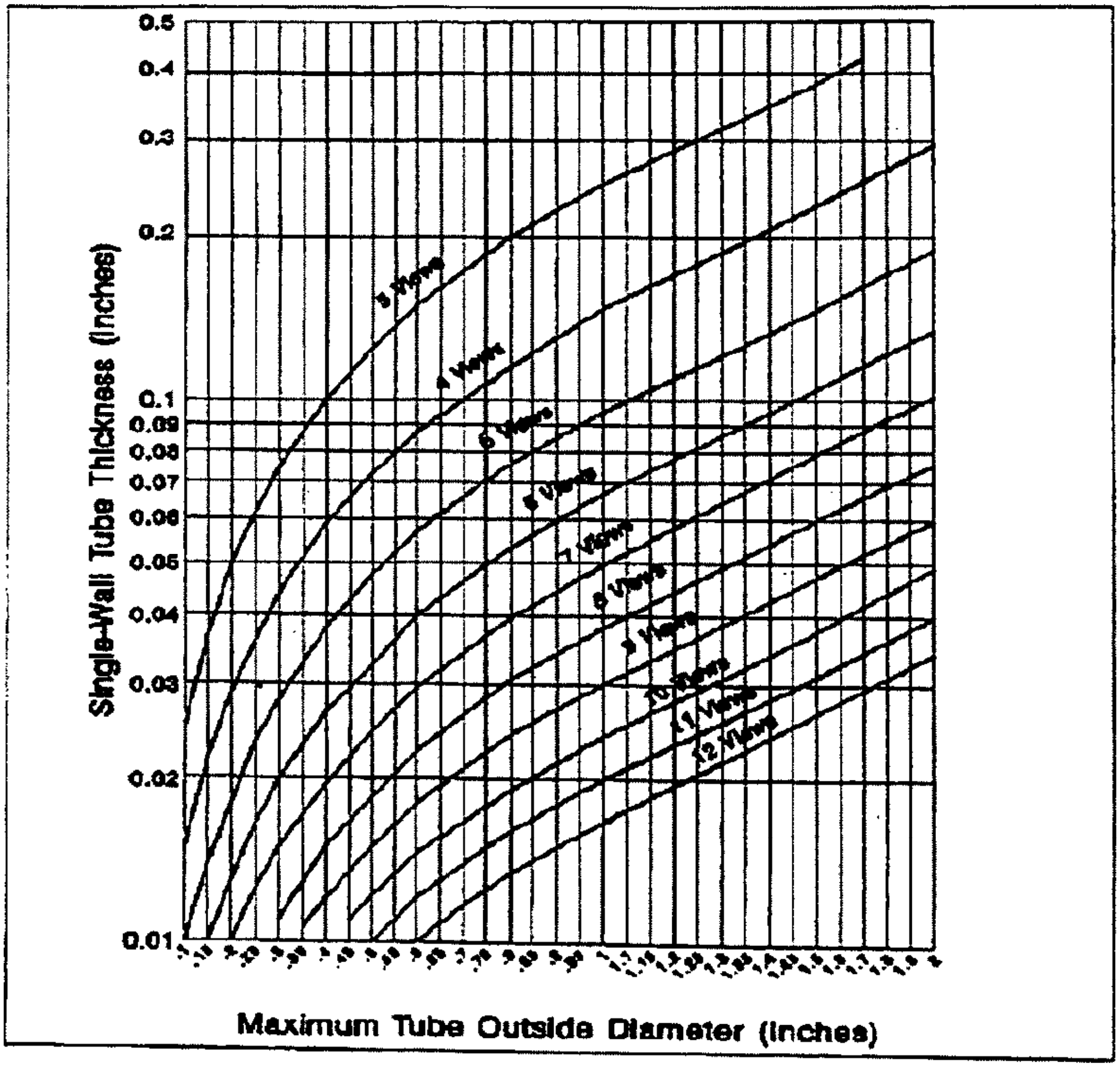
To establish a technique, the film density measured through the area of interest (weld area) and also through the body of the penetrameter shall not be less than 1.8 nor greater than 4.0 H&D units. The film density through the area of interest shall not vary more than -15 or +30 percent from the density through the penetrameter. If the densities vary more than -15 or +30 percent, additional penetrameters shall be used for the exceptional areas. When two or more penetrameters are used, the intervening film density shall be considered acceptable provided the penetrameter densities are not less than 1.8 nor greater than 4.0 H&D units.

If the test objects tube wall thickness is less than the diameter of the densitometer aperture, the density measurement may be taken through the body of the penetrameter provided the primary penetrameter block is either calculated by Equation 1 or taken from Figure D-5 plus the amount represented by the shape correction form through the area of interest (weld area).

Once a technique is established, density measurements need only to be made through the body of the penetrameter provided the essential technique parameters remain the same.

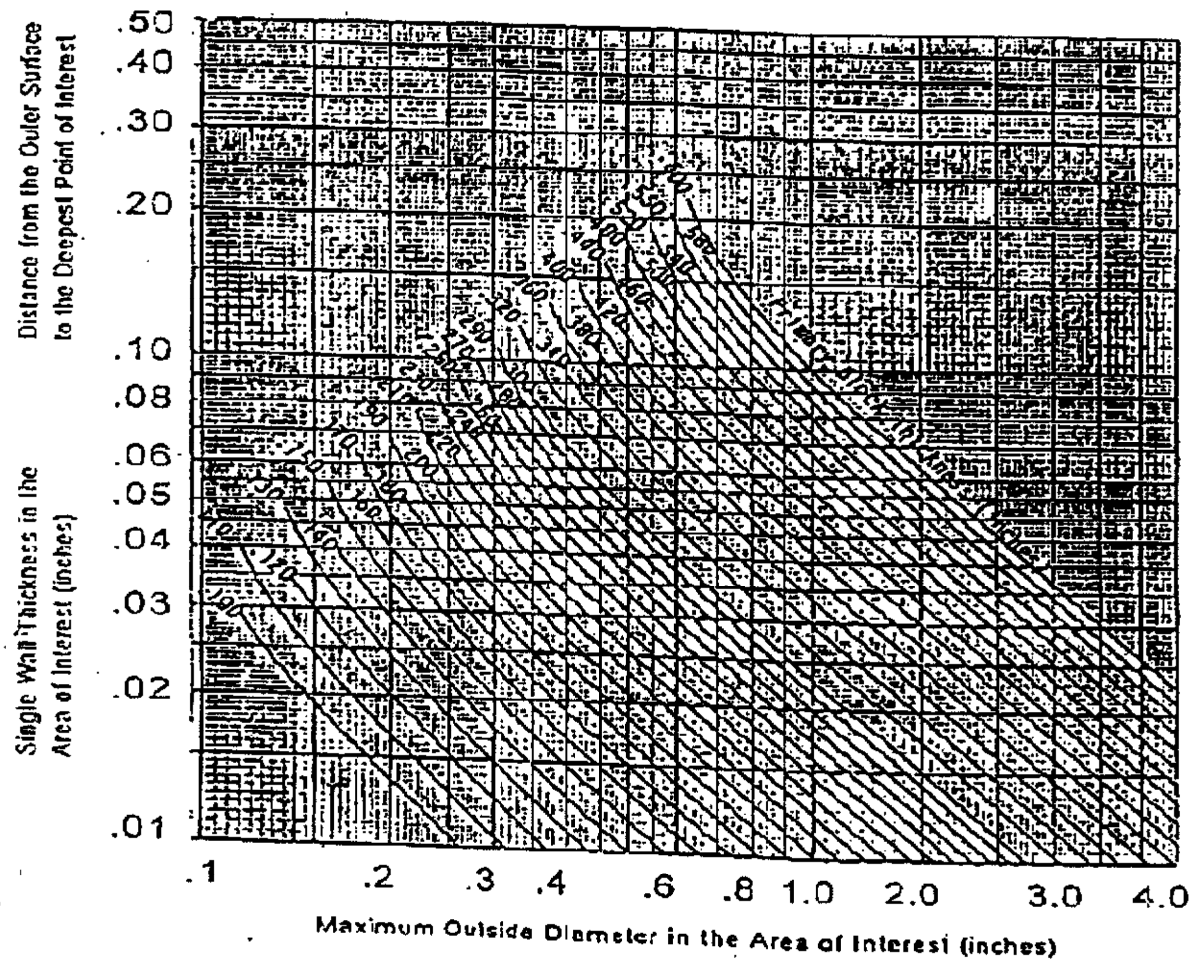
During qualification, the standards shall be located in the outermost pin position. After qualification the radiographic standards are not required to be used.

Figure C-4. Number of Views Chart



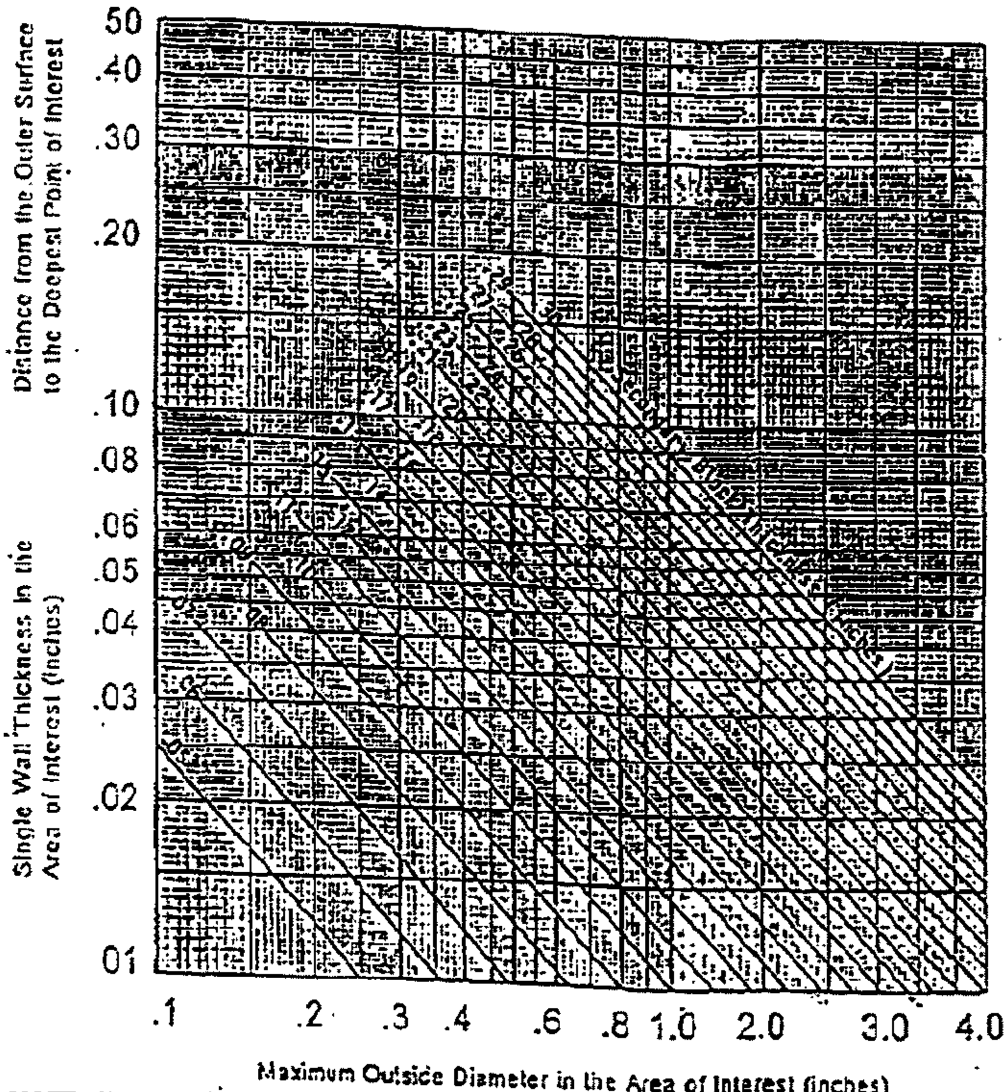
NOTE: Where OD-wall thickness considerations indicate a fractional number of views, between two values, the larger number of views shall be used.

Figure C-5. Primary Block Thickness



NOTE: The primary block thickness used for tangential radiography without shape correction shall equal or exceed that defined by the relationships plotted above. Block thickness values used may be interpolated when block thicknesses between the values plot are indicated

Figure C-6. Secondary Block Thickness



NOTE: The secondary block thickness used for tangential radiography without shape correction shall be equal to or less than that defined by the relationships plotted above. Block thicknesses lying between the value plotted shall be visually interpolated to within ± 0.010 inch.

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APPENDIX D
CASTING RADIOGRAPHY

1.0 PURPOSE

This appendix establishes the requirements for radiography of metallic castings in accordance with the American Society of Mechanical Engineers (ASME), *ASME Boiler and Pressure Vessel Code*, Section V.

2.0 SCOPE

This appendix shall be used in conjunction with the main body of this procedure.

3.0 SPECIFIC CASTING REQUIREMENTS

3.1 Film Identification

In addition to the general radiography procedure, the radiographs shall also be plainly and permanently identified with the job or heat number and, if applicable, repair numbers.

3.2 Penetrameters

The penetrameter shall be based on the single-wall thickness of the casting.

3.2.1. Casting Areas Before Finish Machining

The penetrameter shall be based on a thickness that does not exceed the finished thickness by more than 20 percent or 1/4 inch, whichever is greater. In no case shall a penetrameter size be based on a thickness greater than the thickness being radiographed.

3.2.2 Casting Remaining in As-Cast Condition

The penetrameter shall be based on the thickness being radiographed.

Table 1. Penetrameter Chart.

	Source Side			Film Side		
Nominal Single Wall Material Thickness Range, in.	Hole Type Designation	Essential Hole	Wire Diameter, in.	Hole Type Designation	Essential Hole	Wire Diameter, in.
Up to 0.25, incl.	12	2T	0.008	10	2T	0.006
Over 0.25 through 0.375	15	2T	0.010	12	2T	0.008
Over 0.375 through 0.50	17	2T	0.013	15	2T	0.010
Over 0.50 through 0.75	20	2T	0.016	17	2T	0.013
Over 0.75 through 1.00	25	2T	0.020	20	2T	0.016
Over 1.00 through 1.50	30	2T	0.025	25	2T	0.020
Over 1.50 through 2.00	35	2T	0.032	30	2T	0.025
Over 2.00 through 2.50	40	2T	0.040	35	2T	0.032
Over 2.50 through 4.00	50	2T	0.050	40	2T	0.040
Over 4.00 through 6.00	60	2T	0.063	50	2T	0.050
Over 6.00 through 8.00	80	2T	0.100	60	2T	0.063
Over 8.00 through 10.00	100	2T	0.126	80	2T	0.100
Over 10.00 through 12.00	120	2T	0.160	100	2T	0.126
Over 12.00 through 16.00	160	2T	0.250	120	2T	0.160
Over 16.00 through 20.00	200	2T	0.320	160	2T	0.250

3.2.3 Placement of Penetrameters

If practical, the penetrameters shall be placed on the source side of the part. When it is not practical, a separate block may be used, provided the penetrameter and area of interest density requirements are met; the penetrameter on the source side of the separate block shall be placed no closer to the film than the source side of the casting being radiographed; the separate block shall be placed as close as possible to the casting being radiographed. Where inaccessibility prevents source side placement, it is permissible to use film side placement provided all other general radiographic requirements are met.

3.2.4 Film Density Requirements

The film density as judged by a densitometer and measured through the body of the penetrameter and the area of interest shall be a minimum of 1.5 and a maximum of 4.0 Hurter and Driffield (H&D) units for single film viewing. For composite viewing of multiple film exposures, each film of the composite set shall have a minimum density of 1.0 with the composite having a maximum density of 4.0 H&D units. A tolerance of 0.05 in density is allowed.

3.3 Geometric Unsharpness Limitations

Table 2. Geometric Unsharpness Limitations

Material Thickness, Inches	Geometric Unsharpness Maximum, Inches
Under 2	0.020
2 through 3	0.030
Over 3 through 4	0.040
Greater than 4	0.070

COGEMA ENGINEERING

APPENDIX E
AMERICAN WELDING SOCIETY (AWS) CODE

1.0 PURPOSE

This appendix establishes the requirements for radiography in accordance with the American Welding Society (AWS), *Structural Welding Code - Steel*, D1.1.

2.0 SCOPE

This appendix shall be used in conjunction with the main body of this procedure.

3.0 INSTRUCTIONS

3.1 AWS *Structural Welding Code - Steel*, D1.1.

Table 1. Geometric Unsharpness Limitations.

Material Thickness, Inches	Geometric Unsharpness Maximum, Inches
Under 2	0.020
2 through 3	0.030
Over 3 through 4	0.040
Greater than 4	0.070

NOTE: Material thickness is the thickness on which the penetrameter is based.

APPENDIX E
AMERICAN WELDING SOCIETY (AWS) CODE

3.2 AWS *Structural Welding Code - Steel*, D1.1.

Table 2. Penetrameter Chart.

	Source Side			Film Side[2]		
Nominal Single Wall Material Thickness[1] Range, in	Designation	Essential Hole	Max. Wire Diameter, in	Designation	Essential Hole	Max. Wire Diameter, in.
Up to 0.25, incl.	10	4T	0.010	7	4T	0.008
Over 0.25 through 0.375	12	4T	0.013	10	4T	0.010
Over 0.375 through 0.50	15	4T	0.016	12	4T	0.013
Over 0.50 through 0.625	15	4T	0.016	12	4T	0.013
Over 0.625 through 0.75	17	4T	0.020	15	4T	0.016
Over 0.75 through 0.875	20	4T	0.025	17	4T	0.020
Over 0.875 through 1.00	20	4T	0.025	17	4T	0.020
Over 1.00 through 1.25	25	4T	0.025	20	4T	0.020
Over 1.25 through 1.50	30	2T	0.025	25	2T	0.020
Over 1.50 through 2.00	35	2T	0.032	30	2T	0.025
Over 2.00 through 2.50	40	2T	0.040	35	2T	0.032
Over 2.50 through 3.00	45	2T	0.050	40	2T	0.040
Over 3.00 through 4.00	50	2T	0.050	45	2T	0.040
Over 4.00 through 6.00	60	2T	0.063	50	2T	0.050
Over 6.00 through 8.00	80	2T	0.100	60	2T	0.063

NOTE:

(1) Single-wall radiographic thickness (for tubulars

(2) Applicable to tubular structures only.

3.3 Weld Reinforcement

When weld reinforcement or backing, or both, is not removed, or wire Image Quality Indicator (IQI) alternate placement is not used, steel shims which extend at least 1/8 inch beyond three sides of the required hole or wire IQI, so that the total thickness of steel between the hole IQI and the film is approximately equal to the average thickness of the weld measured through its reinforcement and backing.

3.4 Source-to-Subject Distance

The source-to-subject distance shall not be less than the total length of film being exposed in a single plane. In addition, this distance shall not be less than seven times the thickness of weld plus reinforcement and backing, if any, nor such that the inspecting radiation shall penetrate any portion of the weld represented in the radiograph at an angle greater than 26.5 degrees from a line normal to the weld surface.

APPENDIX E
AMERICAN WELDING SOCIETY (AWS) CODE

3.5 IQI Selection and Placement

IQIs shall be selected from Table 2. The number of IQIs on the radiograph shall be as specified in Table 3.

Table 3. Number of IQIs Required

	Equal T ≥ 10 in. L		Equal T < 10 in. L		Unequal T ≥ 10 in. L		Unequal T < 10 in. L	
IQI Types	Hole	Wire	Hole	Wire	Hole	Wire	Hole	Wire
Number of IQIs Nontublar	2	2	1	1	3	2	2	1
Pipe Girth[3]	3	3	3	3	3	3	3	3
Selected From Table	2	2	2	2	2	2	2	2

T = Nominal base metal thickness (See Notes 1 and 2 below).
L= Weld length in area of interest of each radiograph.

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Notes:

1. Steel backing shall not be considered part of the weld or weld reinforcement in IQI selection.
2. T may be increased to provide for the thickness of allowable weld reinforcement provided shims are used under hole IQIs.
3. When a complete circumferential pipe weld is radiographed with a single exposure and the radiation source is placed at the center of the curvature, at least three equally spaced hole type IQIs shall be used.

3.6 Film Length

Film shall have sufficient length and placed to provide at least □ inch of film beyond the projected edge of the weld.

3.7 Weld Transitions

When weld transitions have a ratio of the thickness of the thicker section to the thickness of the thinner section is 3 or greater, the radiographs should be exposed to produce single film densities of 3.0 to 4.0 in the thinner section. When this done, the minimum film density requirements (1.8 X-ray and 2.0 Gamma-ray) may be waived.

AREVA

NDE REQUEST/INSTRUCTION FOR NONDESTRUCTIVE TEST SERVICES

Requestor	MSIN	Bldg.	Phone No.	Company
Dean Paxton	K2-44	PSL	375-2620	PNNL

Project/System Identification
Biaxial Creep Specimens

Work Package/Traveler No.

Financial Information, i.e., CACN/COA, Work Order, Contract No.

Drawing No.
Bettis - 5D15996

Acceptance	Code/Specification	Section	Paragraph	Date
☒ NDE	Radiography NE F6-2T	6.3.4	B	July 1973
☐ Client				

Special Instructions (handling requirements, allowed markings, etc.)

Latex gloves supplied by the customer.

Safety/Radiological Conditions

None

- ☐ Penetrant (PT)
- ☐ Magnetic Particle (MT)
- ☐ Leak Testing (LT)
- ☐ Ultrasonic (UT)
- ☒ Radiography (RT)
- ☐ Electro Magnetic (ET)
- ☐ Underground Surveys

Part Location	2460 Bldg.
Contact (PIC)	Ace Jones
Phone No.	372-6021
Bldg/Room	N/A

Part Information

Capsules will be 0.250" Dia. with a wall thickness of 0.025".
The end cap groove is 0.005" X 0.010".
100% radiography coverage is required.
Radiographic Procedure will be COGEMA-SVRT-PRC-006 App. C, Rev. 2

RESERVED FOR NDE USE ONLY

Request Accepted By	NDE Job No.

Attachment 3

RDT F 6-2T, Section 6.3.4 Radiographic Examination:
Applicable unacceptable conditions are listed below

Welds that are shown by radiography to have any of the following discontinuities are unacceptable.

1. Any type of crack or zone of incomplete fusion or penetration.

2. Any pore with a maximum dimension greater than 20% of "T," where "T" is the specified weld thickness.

3. Pores that are separated from one another by less than 3/16" center to center.

4. Radiographic examination shall reveal 100% joint penetration with evidence of melt through on the root side of Electron Beam welds.

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Attachment D

Qualification Test Plan for Biaxial Creep Specimen Electron Beam and Laser Seal Welding

SRM-PLAN-005

Pacific Northwest
National Laboratory
Operated by Battelle for the
U.S. Department of Energy

August 12, 2005

KAPL Inc.
Attn: Steve Hayden (M/S 111)
P.O. Box 1072
Schenectady, NY 12301

Dear Mr. Hayden:

TRANSMITTAL OF BIAXIAL CREEP SPECIMEN WELD QUALIFICATION TEST PLAN

Attached is Revision 0 of SRM-PLAN-005, *Qualification Test Plan for Biaxial Creep Specimen Electron Beam and Laser Seal Welding*. The NRPCT provided approval of the document with comments in the Information-to-Vendor: *Biaxial Creep Specimen Fabrication*, PNNL-SPP-05-0004 Revision 2, dated August 2, 2005. All comments have been implemented in Revision 0 of SRM-PLAN-005.

As requested, I have included this transmittal letter in triplicate, 5 hard copies of the attached plan, and 2 electronic copies of the plan.

If you have any questions, please contact Dean Paxton at (509) 375-2620.

Sincerely,

Chad Painter
Project Manager
Space Reactor Materials Irradiation Testing Project

cc: Dean Paxton, PNNL
Tom Hays, PNNL
Ken Buxton, PNNL
05-011

902 Battelle Boulevard • P.O. Box 999 • Richland, WA 99352

Telephone (509) 372-4112 ■ Email chad.painter@pnl.gov ■ Fax (509) 372-6421

Space Reactor Materials (SRM) Irradiation Testing Project

Qualification Test Plan for Biaxial Creep Specimen Electron Beam and Laser Seal Welding

SRM-PLAN-005

Revision No. 0

Issue Date: August 2005

Client: Knolls Atomic Power Laboratory

Project No: 48552

Prepared By: Dean M Pardo for T.A. Delucchi — 8/11/05
SRM Weld Engineer — **Date**

Reviewed By: Dean M Pardo — 8/11/05
SRM Biaxial Creep Task Manager — **Date**

Reviewed By: T.D. [signature] — 8/12/05
SRM QA Specialist — **Date**

Approved By: [signature] — 8/11/05
SRM Project Manager — **Date**

Review By: [signature] — 8/12/05
SRM Authorized Derivative Classifier — **Date**

Revision Record

Rev. No.	Date	Change Description	Pages Changed
Draft	07/11/2005	Original submittal to NRPCT	All originals
0	8/9/2005	a. Change flow chart to have radiography done after Post EB anneal b. Clarify pressure levels of specimens during qualification c. Change mbar to torr for vacuum units d. Change rework requirements	a. Page 4, Chart b. Page 5, 7.1.8 c. Attachment 1 d. Attachment 8

Contents

Qualification Test Plan for Biaxial Creep Specimen Electron Beam and Laser Seal Welding

1.0 APPLICABILITY

This test plan applies to the development and qualification of weld parameters using the Electron Beam (EB) welding and Laser Beam welding processes. This plan describes the general process for developing and qualifying welds for reactor core components. This test plan is based on guidance found in *Welding of Reactor Core Components and Test Assemblies* (RDT F6-2T). This test plan applies to the development of new weld parameters as well as redevelopment and requalification of welds and parameters developed and used from previous work scopes. Completion of the Data Sheet, Welding Procedure Sheet, and the Welding Procedure Qualification Record through this process and acceptance of those documents by the responsible staff will establish the qualification of a new weld joint and/or the qualification of the parameters of the welding procedure for that specific weld joint.

2.0 RESPONSIBLE STAFF

2.1. Project Manager: Responsibility for overall management of the Space Reactor Materials Irradiation Project.

2.2. Task Manager: Responsibility for fabrication of biaxial creep specimens.

2.3. Quality Engineer: Responsibility for oversight of fabrication operations and verification of documentation associated with fabrication and inspection.

2.4. Weld Engineer: Responsibility for preparing weld qualification plan and perform periodic inspection of weld integrity.

2.5. Welding Technologist: Responsibility for operating automatic welding equipment

3.0 DESIGN SPECIFICATIONS AND DRAWINGS

The documents listed below are applicable to fabrication of biaxial creep pressurized tube specimens. The documents listed are subject to revision, and the current revision will be used in all instances as defined in the applicable version of Reference 3.1 below. Reference 3.2 below shall be used as a guide for the fabrication of biaxial creep specimens and will be supplemented with instructions defined in Reference 3.1. In the event of a conflict between References 3.1 and 3.2, those listed in Reference 3.1 shall take precedence. A list of clarifications and exceptions to Reference 3.2 is provided in Attachment 7.

3.1. KAPL, Inc. Information-to-Vendor, *Biaxial Creep Specimen Fabrication*, PNNL-SPP-05-0004

3.2. RDT Standard, *Welding of Reactor Core Components and Test Assemblies*, RDT (NE) F 6-2T, dated July 1973 and PNNL exceptions to application of standard

3.3. Battelle Pacific Northwest National Laboratory, Space Reactor Materials (SRM) Irradiation Testing Project Quality Assurance Plan, SRM-PLAN-002

3.4. Bechtel Bettis Inc. Drawing, *Biaxial Creep Specimen Straight Wall*, SK-DPM1060997

Qualification Test Plan for Biaxial Creep Specimen Electron Beam and Laser Seal Welding

3.5. Bechtel Bettis, Inc. Drawing, Biaxial Creep Specimen Inspection Groove Bottom End Cap, SK-DPM1051705

3.6. Bechtel Bettis, Inc. Drawing, Biaxial Creep Specimen Inspection Groove Top End Cap/Protrusion, SK-DPM3051705

3.7. Bechtel Bettis, Inc. Drawing, NRPCT / JOYO-1 Biaxial Creep Specimen Assembly, 5D15996

4.0 WELD REQUIRMENTS

4.1. All welding shall be performed using RDT NE F6-2t for guidance. Not all sections are applicable, and Attachment 7 lists the sections not applicable or exception taken.

4.2. Electron Beam Welding (EBW) process shall be classified as "Automatic Welding" as defined by NE F6-2t.

4.3. Laser Beam Welding (LBW) process shall be classified as "Automatic Welding" as defined by NE F6-2t.

5.0 PREREQUISITES

5.1. Welding systems shall have current calibrations.

5.2. Weld qualification samples shall be of the same material and heat or lot number used in the production parts.

5.3. Weld Qualification samples shall be the same configuration used for production parts.

5.4. Weld qualification samples shall be cleaned by the supplier and packaged adequately to insure that cleanliness is maintained during shipping.

5.5. Cleaned weld samples shall be handled using clean, nonporous, talc-free gloves or materials.

5.6. Refractory metals shall be handled with above described gloves or materials and tools coated or rapped with refractory metal coating or foil. (Tantalum is prohibited.)

5.7. Cleaned weld samples shall be kept in sealed containers for protection.

5.8. Any weld fixtures used in the weld chamber that causes magnetic interference with the electron beam must be removed or shielded.

5.9. Prior to placing components within EBW fixtures, the welding operator shall perform a final wipe down of the weld joint area using a CLEAN texwipe and ethanol alcohol.

5.10. Weld fixturing which contacts refractory metal components shall be constructed of refractory metal. (Tantalum is prohibited.)

6.0 WELD DEVELOPMENT

Weld development is an iterative process where the essential variables are manipulated in an attempt to achieve the desired results. The process flow of weld qualification specimens is shown in Figure 6.1. Test welds are made and examined according to the guidelines in this section until a successful set of welding parameters is established. The successful weld development parameters established in the weld development section become the input to the Welding Procedure found in the Weld Procedure Qualification section below.

6.1. Weld parameters for each test weld shall be documented on the appropriate Weld Data sheet (EBWD or LBWD) as shown in Attachments 1 and 2.

6.2. A set of welding parameters are recorded on the Weld Data Sheet. Those parameters are used to produce a single test weld which will be examined and evaluated.

6.3. Each weld sample shall be prototypic or a duplicate of the production specimen components. Prototypic or duplicate samples shall be provided by the customer.

6.4. Each weld sample shall be identified with a unique number and logged into the welding log book.

6.5. ID Number shall be marked with a vibra-tool, permanent ink marker, or on the part container for each weld sample.

6.6. Each weld sample shall be examined in a manner that evaluates the effectiveness of the welding parameters.

6.7. Development welds shall be made in this manner until the weld requirements are satisfied.

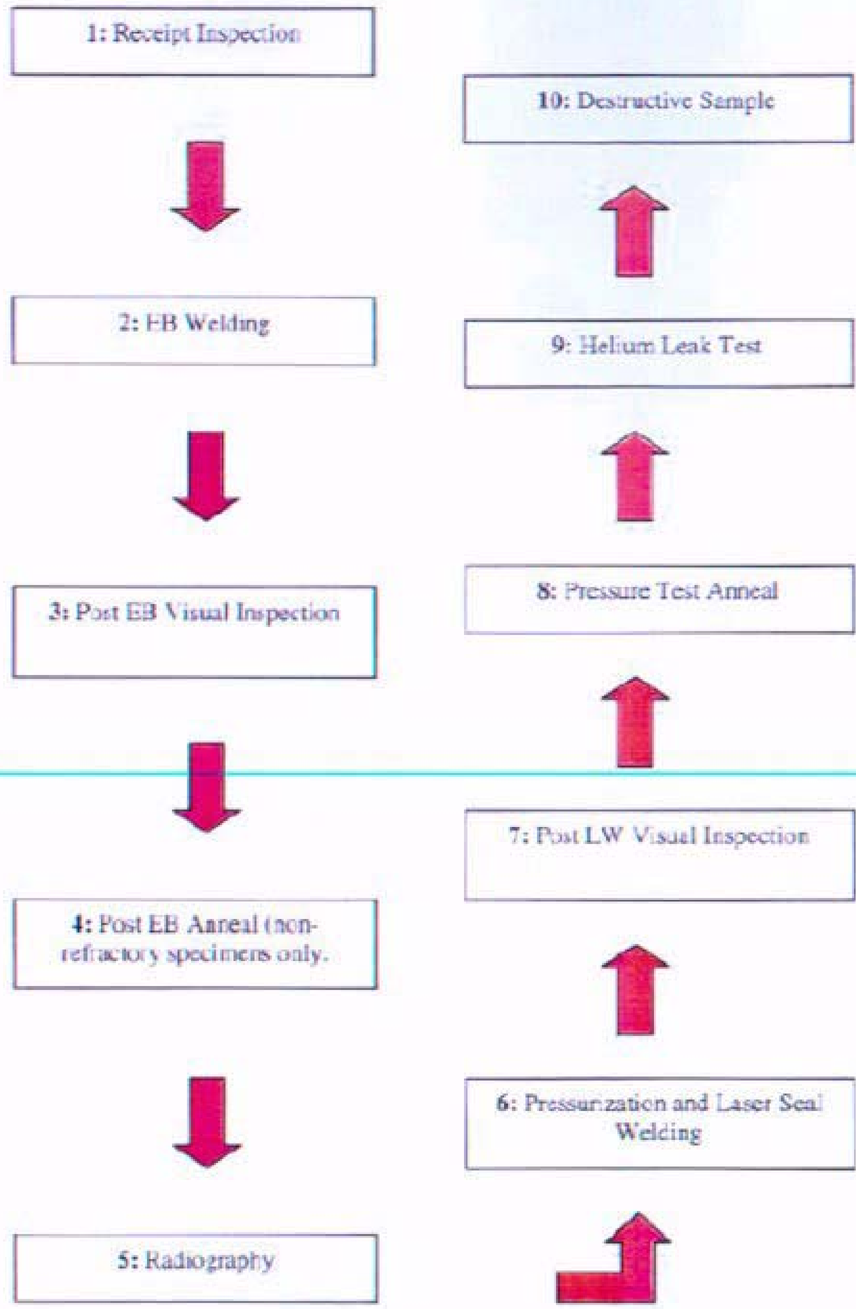

Figure 6.1. Biaxial Creep Specimen Fabrication Flowchart for Qualification

7.0 WELD PROCEDURE QUALIFICATION

7.1. Electron Beam & Laser Beam Welding

7.1.1. Parameters from the Weld Data sheets are entered onto the Welding Procedure forms. The approval signature in the "Approved By" block on Attachments 3 and 4 occurs at the completion of the weld qualification process.

7.1.2. A unique number is assigned to the new welding procedure and logged into the welding log book.

7.1.3. ID Number shall be marked with a vibra tool, permanent ink marker, or on the part container for each weld sample.

7.1.4. The weld qualification inspections and verifications as specified on the Welding Procedure Qualification Record form are documented as they are completed.

7.1.5. The Welding Procedure form and the Welding Procedure Qualification Record form are used together to form a cumulative welding record package.

7.1.6. The Welding Procedure Qualification Record form (Attachment 5) is the traveler used to follow the qualification process.

7.1.7. NE F6-2t contains eight sections. These sections address general or specific welding requirements for various reactor core components.

7.1.8. Biaxial Creep Pressurized Specimens shall be qualified in accordance with Sections 1, 2, 6 and 8 Category 4. (Electrical continuity test shall not be performed.) Pressure levels shall be determined for each alloy at the time of qualification based on collaboration among the PNNL weld engineers and the NRPCT technical contacts.

7.1.9. Six top and bottom consecutive welds shall be performed for procedure qualification in accordance with NE F6-2t Sections 6 and 8 Category 4 (Automatic welding).

7.1.10. Each weld sample shall be identified with a unique number, and logged into the welding log book. A weld sample may consist of one tube and top and bottom end caps.

7.1.11. Qualification welds shall be inspected in accordance NE F6-2T, section 6 (with Attachment 7 exceptions taken) and the Ordering Data (Assembly Drawing).

7.1.12. Caution: Qualification specimens will be de-pressurized as part of the metallographic evaluation per a Depressurization Work Instruction.

7.1.13. Upon satisfactory completion of all qualification testing requirements the Weld Engineer, Task Manager, and Quality Assurance Specialist sign in the approval block of the Welding Procedure and Welding Qualification Record.

7.1.14. Quality Assurance reviews and approves the Welding Qualification Record Card verifying that all required inspections and verifications have been performed and are acceptable.

7.1.15. The weld is now Qualified for production welding.

NOTE: If any of the weld samples fail to meet testing requirements, a new Welding Procedure Qualification Record will be generated for a second batch of qualification weld samples. If any of the second set fails to meet testing requirements, return to the Weld Development section of this test plan and proceed with additional weld development activities before additional attempts are made to qualify the weld.

7.2. Weldability Test

7.2.1. A weldability test shall be performed in the event that a different combination of base material heats is used, within an alloy group other than those qualified per the Welding Procedure.

7.2.2. One weldability test specimen shall be welded (two welds) using a duplicate of the production weld joint configuration and applicable Welding Procedure. One weld specimen consists of one tube and two end caps.

7.2.3. This weld sample shall be subjected to the same requirements as the weld qualification except only metallographic examination is performed.

7.2.4. This will be documented on Attachment 6, Weldability Procedure Qualification Record.

7.2.5. Metallographic examination shall be evaluated in accordance with NE F6-2t, Section 6, Paragraph 6.3.7. If metallographic examination reveals unacceptable welds, these base metals shall be subjected to the welding procedure qualification process and qualified as a new procedure.

7 3. Electron Beam Welding Essential variables

A change in any one of the variables listed below which is outside the range used in the procedure qualification will be cause for requalification:

beam current (±5%)

beam voltage (±2%)

welding speed (±2%)

gun to work distance (±5%)

beam focus point (±1/16")

a change in frequency of oscillation

a change in size or shape of filament

a change in beam deflection pattern

the addition of a cosmetic pass

a change of welding from one side to welding from both sides and vice versa

a change in welding position

the omission or addition of integral backing the addition or omission of filler metal to the joint

the addition or omission of non-fusing metal retainers

the addition or omission of heat sinks.

7.4. Laser Beam Welding Essential Variables

NE-F6-2t does not specifically address essential variables for LBW. The following is a list of process parameters which, if arbitrarily modified, will adversely affect weld quality (any deviation from the following listed parameters shall require procedure qualification. Compliance with NE F6-2t, Section 6, Table 2, Sub-Section 1 and 3 shall be mandatory):

material type

rod type

aperture

attenuat

monitor volts (±2%)

focus lens

number of pulses

spot size

atmosphere

pulse width.

8.0 QUALITY ASSURANCE REQUIREMENTS

The PNNL Space Reactor Project Quality Assurance Plan SRM-PLAN-002 references the NRPCT and PNNL driven quality assurance requirements and their application to all of the PNNL Space Reactor Materials Project work scopes including biaxial creep specimen fabrication. The referenced QA Plan specifically lists the procedures selected to implement the quality assurance requirements.

Attachment 1 - Electron Beam Weld Data Sheet

EBW S/N:	Recorded By:
Date:	Page:
Operator:	Material:
	Procedure:

Weld No. / Date Welded						
Voltage (KV)						
Beam Current (ma)						
Beam Current Level (set)						
Focus Height (from workpiece)						
Distance (workpiece to heat shield)						
Focus Setting						
Weld Speed sec/rev						
Weld Speed in/min.						
Weld Time (set)						
Rise:						
Fall:						
Deflection: Ham. Std. PPG IKE						
DC only						
Circle / Dia.						
Harm. "X" / Length						
Harm. "Y" / Length						
Normal or Expanded						
Pattern						
Dia.						
Width						
Height						
Puddling / Size						
Modulate / No %						
Spin Frequency Set						
Motor CCW / CW						
Speed RPM						
Filament Current, Peaked						
Vacuum (torr)						

Attach Sketch of Weld Joint to this Table

Attachment 2 - Laser Beam Weld Data Sheet

Attach Sketch of weld joint to this Table

Date:	
Recorded by:	
Operator:	
Drawing No.	
Weld No.	
LBW Machine Type	
LBW System Manufactured By:	
LBW S/N:	
Material Type	
Thickness	
Pre-cleaning	
Cover Glass Yes No Type	
Rod Type and ID #:	
Aperture	
Attenuator	
Monitor Volts	
Scale Factor	
Focus Lens	
Number of Pulses	
Voltage	
Spot Size	
Joules/Pulse	
Pulse width	
Atmosphere: Cover Gas Chamber	
Chamber Pressure	
Remarks:	Joint Sketch:

Attachment 3 - Electron Beam Welding Procedure

ELECTRON BEAM WELDING PROCEDURE

	Base Material & Form:
	Filler Material, Form, Size:
	Preheat: Postheat:
	Weld Position:
	No. of Passes:
	"Cosmetic" Pass Used:
	Gun Type:
	Lap-Over (in/deg)
	Type Backing:
	Machine Make or S/N:
	Additional Information:

Drawing Number	Joint Assembly Number	Date	Welding Operators

Penetration Pass

PROCESS VALUES

Voltage (KV)		Deflection	
Beam Current (ma)		Type	
Beam Focus From Work Surface		Size	
Heat Shield From Work Distance		Frequency (Hz)	
Weld Speed (sec/rev)		Modulation Set	
Weld Speed (in/min)		Puddling Set	
Weld Time Set Cycle (Sec.)		Vacuum (torr)	
Rise Set		Beam-to-Joint Offset	
Fall Set		Position Beam at or	
Rotation Spd-Pot Setting			

Original Issue:	
Prepared by	**Procedure No.**
Approved by	

Attachment 3 - Electron Beam Welding Procedure (Continuation Sheet)

Cosmetic Pass			
PROCESS VALUES			
Voltage (KV)		Deflection	
Beam Current (ma)		Type	
Beam Focus From Work Surface		Size	
Heat Shield From Work Distance		Frequency (Hz)	
Weld Speed (sec/rev)		Modulation Set	
Weld Speed (in/min)		Puddling Set	
Weld Time Set Cycle (Sec.)		Vacuum (torr)	
Rise Set		Beam-to-Joint Offset	
Fall Set		Position Beam at or	
Rotation Spd-Pot Setting			
This procedure is in accordance with: The applicable Sections of NE F6-2t (guidance) and PNNL Biaxial Creep Specimen Electron Beam and Laser Seal Weld Qualification Plan.		Original Issue:	
(this area will expand as data is entered)			

Attachment 4 - Laser Beam Weld Procedure

TEST ENGINEERING BATTELLE NORTHWEST P.O. BOX 999 RICHLAND, WA 99352	WELDING PROCEDURE LASER WELDING PROCESS
	MATERIAL: THICKNESS: PRE-CLEANING: COVER GLASS: MACHINE MAKE: MACHINE MODEL: ADDITIONAL INFO

DRAWING NUMBER	JOINT ASSEMBLY NO.	DATE	WELDING OPERATOR

SEE WELDING PROCEDURE DESCRIPTION ______________ FOR QUALITY REQUIREMENTS.

PROCESS VALUES

ROD TYPE & I.D. NO.		VOLTAGE	
APERTURE		SPOT SIZE	
ATTENUATOR		JOULES / PULSE	
MONITOR VOLTS		ATMOSPHERE	
SCALE FACTOR		PRESSURE	
FOCUS LENS		PULSE WIDTH	
NO. OF PULSES			

PREPARED BY:	ORIGNAL ISSUE ______ REV. NO. ______ REV. NO. ______ REV. NO ______
APPROVED FOR TEST ENGINEERING ______________	PROCEDURE NO. MT5- ______________

Attachment 5 - Welding Procedure Qualification Record

Procedure No.______________________

No. of Samples Required__________

Section____________ Category____________

Sample Identification Nos.______________________

Component Inspection Report Nos.______________

Material ID and Heat No.______________________

Prepared by:______________________
Date_______

Welding Operator Name______________________

Welds Made on:______________________

Welding Equipment ID______________________

Welding to Procedure Witnessed by______________

PROGRAM

Inspection	REFERENCED SPECIFICATION	SAMPLES REQUIRED	REPORT /LAB #.	ACC	REJ	TECH. OR INSPECTOR	DATE	REMARKS
Comp. Cleaned	PNNL Instruction	6						
Visual (Weld)	NE F6-2t Sec. 6 Para. 6.3.2 as amended	6						*NOTE
Post EB Weld Anneal	PNNL Work Instruction	6						Non-Refractory Only
Pressure Test	PNNL Work Instruction	6						
Helium Leak Test	NE F6-2t Sec. 6 Para. 6.3.6 as amended and Cogema Procedure	6						
Radiography	NE F6-2t Sec. 6 Para. 6.3.4 and Cogema Procedure	6						
Metallography	NE F6-2t Sec. 6 Para 6.3.7 and Customer Ordering Data (IV)	6						
Dimensional	Customer Ordering Data (IV)	6						Metallographic Exam

Record Data Required For Procedure Qual Package	Yes	No	Completed	Remarks
Metallography Report and Mount Nos.	X			*NOTE: Specific Visual Inspection criteria is contained within PNNL Space Reactor Biaxial Creep Specimen MAQP
Metallography Photos (Information)	X			
Radiography Report	X			
Helium Leak Rate	X			
Copy of the Procedure	X			
Pressure Test Data	X			
Pressure Test Specimens	X			
QA Review	X			

Approvals: Weld Engineer______________ Task Manager______________ Quality Engineer______________

Attachment 6 - Weldability Procedure Qualification Record

Procedure No.____________________

No. of Samples Required__________

Section__________ **Category**__________

Sample Identification Nos.____________________

Component Inspection Report Nos.__________

Material ID and Heat No.____________________

Prepared by:____________________
Date______

Welding Operator Name____________________

Welds Made on:____________________

Welding Equipment ID____________________

Welding to Procedure Witnessed by____________________

PROGRAM

Inspection	REFERENCED SPECIFICATION	SAMPLES REQUIRED	REPORT /LAB #.	ACC	REJ	TECH. OR INSPECTOR	DATE	REMARKS
Comp. Cleaned	PNNL Instruction							
Visual (Weld)	NE F6-2t Sec. 6 Para. 6.3.2 as amended							*NOTE
Post EB Weld Anneal	PNNL Work Instruction							Non-Refractory Only
Pressure Test	PNNL Work Instruction							
Helium Leak Test	NE F6-2t Sec. 6 Para. 6.3.6 as amended and Cogema Procedure							
Radiography	NE F6-2t Sec. 6 Para. 6.3.4 and Cogema Procedure							
Metallography	NE F6-2t Sec. 6 Para 6.3.7 and Customer Ordering Data (IV)							
Dimensional	Customer Ordering Data (IV)							Metallographic Exam

Record Data Required For Procedure Qual Package	Yes	No	Completed
Metallography Report and Mount Nos.	X		
Metallography Photos (Information)	X		
Radiography Report	X		
Helium Leak Rate	X		
Copy of the Procedure	X		
Pressure Test Data	X		
Pressure Test Specimens	X		
QA Review	X		

Remarks

*NOTE: Specific Visual Inspection criteria is contained within PNNL Space Reactor Biaxial Creep Specimen MAQP

Approval: Weld Engineer__________ Task Manager__________ Quality Engineer__________

Attachment 7 – Exceptions to RDT

APPLICATION OF RDT STANDARD RDT F6-2T, JULY 1973, WELDING OF REACTOR CORE COMPONENTS AND TEST ASSEMBLIES TO BIAXIAL CREEP SPECIMEN FABRICATION, INSPECTION AND TESTING

Prepared by: T.D. Hays, PNNL
Approved by: T.A. Delucchi, Cogema

PNNL intends to use the referenced standard for the development and application of Electron Beam welding processes and procedures except as noted herein.

General:

1) Biaxial creep specimens are test specimens. Therefore, the applicable sections of the Standard applicable to Test Assemblies will be used. Specifically, sections addressing reactor core components (Sections 4, 5, and 7) are not applicable and requirements in other general sections not addressing Test Assemblies are not applicable.
2) 3.3.1: Base materials will not comply with referenced tables. Base materials will be Customer Furnished materials as described in latest revision of IV.
3) 3.3.2: NA, no welding materials (filler material) will be used in the EB and laser weld processes.
4) 3.5: Cleanliness shall meet NRPCT requirements not RDT F5-1. Cleaning procedure will be prepared if required by NRPCT.
5) 3.6: Joint design of EB welded components has integral backing.
6) 3.10: Preheat will not be used. Any post-heat treatments will be per direction of NRPCT.
7) 3.13: Nondestructive examinations shall meet requirements mutually agreed upon with PNNL, PNNL NDE subcontractor, and NRPCT.
8) 3.15: The non destructive examination (NDE) methods required for the Biaxial Creep specimens are visual test (VT), radiographic test (RT) and helium leak test (HLT). No cleaning is will be required for these NDE processes. Analysis is not planned for other contacting materials.
9) 3.17; .2) No filler materials used in welding process. .4) No weld maps used, but each weld on a specimen will be assigned specific number and be tracked by traveler. General) Many of the requirements listed will be recorded in a summary manner for all or groups of welds.
10) 4.1-4.4: Entire section is N/A
11) 5.1- 5.4: Entire section is N/A
12) 6.1.1.1 – 6.1.1.5: NDE will be limited to VT, RT and HLT for procedure and welding operator qualification. penetrant test (PT), ultrasonic test (UT) and tension test will not be used.
13) 6.1.2 b, LP is N/A.
14) 6.1.2 c. HLT will be performed in accordance with procedure submitted by PNNL (Cogema Engineering).
15) 6.1.2 d: Electron beam weld joints (shell to caps) will be radiographed per procedure submitted by PNNL (Cogema Engineering).
16) 6.1.3.a: Metallographic examination will be performed on one specimen form each EB welding load. Requirements for starts and stops are N/A.
17) 6.1.3.b: Tension testing is N/A.
18) 6.1.4: Welding procedure specification (WPS) shall be submitted as required to NRPCT for approval.
19) Table 1; Only the information applicable to EB and laser welding will be included.
20) Table 2, #1, General, All Welding Processes: Only the information applicable to EB and laser welding will be included.
21) Table 2 #2, Manual Welding is N/A.
22) Table 2, #4, Gas Tungsten Arc Welding is N/A.
23) 6.1.4.d, d.3 is N/A.
24) 6.1.4.e: No chart recordings will be made.
25) 6.1.5.4: The EB and laser welds will be made by one individual. The initials of that welder will be indicated on travelers for each specimen. No number, letter, or symbol will be placed on any specimen.
26) 6.1.5.b is N/A.
27) 6.1.5.d: The PNNL welding operator who prepares acceptable qualification welds will not be required to requalify unless 1 year (365 days) has elapsed.
28) 6.2.1: Weld sample quantity is specified in the Weld Qualification Plan.

Qualification Test Plan for Biaxial Creep Specimen Electron Beam and Laser Seal Welding

29) 6.2.2: Cleaning shall be as specified by NRPCT and/or Manufacturing and Quality Plan (MAQP).
30) 6.2.3: Handling and storage of cleaned materials prior to and during welding and subsequent to welding will be specified in MAQP.
31) 6.2.4: N/A. All materials and weld joint surfaces are furnished ready to weld by customer.
32) 6.2.5, 6.2.6: Fitting and alignment of joints will be accomplished using a fixture which will be detailed in the weld qualification plan and report.
33) 6.2.7 is N/A
34) 6.2.8: Vacuum welding process does not apply.
35) 6.2.9, 6.2.10, 6.2.11: All welds are single welded joints. Root pass is N/A and will not be examined.
36) 6.2.12. 6.2.13 are N/A.
37) 6.2.14: No repairs on base material. If repairs on welds are allowed, weld qualification plan and report will specify details.
38) 6.3.1.a: All nondestructive testing (RT, HLT) will be performed and accepted in accordance with procedures submitted by PNNL (Cogema Engineering).
39) 6.3.1.c: All inspection and NDE required will be specified in MAQP and on travelers.
40) 6.3.1.d: Visual examination and radiography will be performed prior to any anneal/heat treatment or pressurization of specimen.
41) 6.3.2: See Attachment 8 for visual examination for EB and laser welds. The joint preparation is to be acceptable as customer furnished material and will be checked for damage during receipt inspection only with trial fit ups.
42) 6.3.3 is N/A.
43) 6.3.4: Radiography will be performed per procedure submitted by PNNL (Cogema Engineering). Acceptance criteria will specified in MAQP.
44) 6.3.5 is N/A.
45) 6.3.6: Helium leak testing will be conducted using "bell jar" method (pressurized specimens placed in vacuum chamber).
46) 6.3.7: Metallographic examination shall be performed as specified by customer in IV.
47) Section 7: Entire section is N/A.
48) 8.1: Only section 8.1.4 applies.
49) 8.4: Based materials are customer furnished material
50) 8.5 is N/A.
51) 9.0: All applicable information (base material, NDE, weld chamber vacuum, metallographic, helium leak testing) are specified by customer. Filler material information, halogen and sulfur content, disposition of welds, tensile testing, first and last weld, wrap wire weld, projection welding, spot welding, tensile shear tests are N/A.
52) Table 5: Test Assembly Category 4 only.

Attachment 8 - Application of RDT Standard RDT F6-2T

Section 6.3.2 Visual Examination

Visual Weld Examination Requirements for Electron Beam and Laser Welding

Prepared by: T.D. Hays, PNNL
Approved by: T.A. Delucchi

- Visual weld examination shall be performed after completion of electron beam and laser welding and prior to subsequent operations; radiography, anneal, weight, dimensional and helium leak testing.

- Final accessible weld surface and adjacent base metal heat affected zones shall be examined.

- Examination shall be performed by qualified personnel who have visual acuity which meets 20/20 vision, natural or corrected stereo acuity and who have normal color vision.

- Results of examinations shall be documented. Documentation shall include the following minimum information: date of examination, examiner name and certification as applicable, description of welds examined, reference to examination requirements, measuring and test equipment used and calibration status as applicable, and results of examination.

Examinations shall be performed in accordance with the following requirements:

1) Welds examined at 1× and 7× (nominal). If a potential weld discontinuity is observed, examine at 10× to confirm.

2) Use direct examination with appropriate lighting (100 FC minimum), angle and distance of vision not greater than 24" between eye and surface to be examined and not less than 30 degree angle form examiner line of sight to the surface

3) Surface finish of welds are to be examined for surface discontinuities including proper seam tracking, weld contour and reinforcement

4) Welds joints and base metal heat affected zones which are shown by visual examination to have any of the following discontinuities are considered unacceptable:

   A) any cracks or fissures

   B) any incomplete fusion

   C) any incomplete penetration

   D) any shrinkage voids

   E) any inclusion larger than 20% of weld designed joint penetration or more than 3 inclusions of any size in weld length

   F) any single porosity larger than 20% of weld designed joint penetration or more than 3 porosity of any size in weld length

   G) gross spatter (minor individual or group accumulations of spatter acceptable)

H) excessive undercut (minor undercut acceptable as long as edges of welds blend smoothly and gradually into the adjacent base metal)

I) under-fill except for EB welds where maximum concavity shall not exceed .003"

Note: Minor joint concavity is expected with autogenous E-Beam welding.

J) weld face reinforcement in excess of .005"

Note: Overlap of the weld start point and weld finish point is permitted and desired.

K) oxidation or excessive dross

Note: Black or gray spalling or loose particles not acceptable. Iridescent temper films and dark metallic vapor deposits adjacent to weld are acceptable and may be removed by approved cleaning procedures when appropriate and accessible.

No rework by welding shall be permitted on any specimens. No rework shall be performed at all on refractory specimens. The only rework that shall be permitted will be the filing of cosmetic anomalies in non-refractory specimens.

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Attachment E

Manufacturing and Quality Plan for Fabrication of Biaxial Creep Specimens

SRM-PLAN-004

Pacific Northwest National Laboratory
Operated by Battelle for the
U.S. Department of Energy

August 16, 2005

KAPL Inc.
Attn: Steve Hayden (M/S 111)
P.O. Box 1072
Schenectady, NY 12301

Dear Mr. Hayden:

TRANSMITTAL OF MANUFACTURING AND QUALITY PLAN (MAQP) FOR FABRICATION OF BIAXIAL CREEP SPECIMENS

Attached is Revision 0 of SRM-PLAN-004, *Manufacturing and Quality Plan (MAQP) for Fabrication of Biaxial Creep Specimens*. The NRPCT provided approval of the document with comments in the Information-to-Vendor: *Biaxial Creep Specimen Fabrication*, PNNL-SPP-05-0004 Revision 3, dated August 10, 2005. All comments have been implemented in Revision 0 of SRM-PLAN-004.

As requested, I have included this transmittal letter in triplicate, five hard copies of the attached plan, and two electronic copies of the plan.

If you have any questions, please contact Dean Paxton at (509) 375-2620.

Sincerely,

Chad Painter
Project Manager
Space Reactor Materials Irradiation Testing Project

cc: Dean Paxton, PNNL
Tom Hays, PNNL
Ken Buxton, PNNL
05-013

902 Battelle Boulevard • P.O. Box 999 • Richland, WA 99352

Telephone (509) 372-4112 ■ Email chad.painter@pnl.gov ■ Fax (509) 372-6421

Space Reactor Materials Irradiation Testing Project

Manufacturing and Quality Plan for Fabrication of Biaxial Creep Specimens

SRM-PLAN-004

Revision No. 0

August 2005

Submitted By:	[signature] **SRM Task Manager**	8/16/05 **Date**
Reviewed By:	T.D. [signature] **SRM Quality Specialist**	8/16/05 **Date**
Approved By:	[signature] **SRM Project Manager**	8/16/05 **Date**
Reviewed By:	[signature] **SRM Authorized Derivative Classifier**	16 Aug 05 **Date**

Revision record

Rev. No.	Date	Change Description	Pages Changed
Draft	**07/14/2005**	**Original submittal to NRPCT**	**All originals**
0	**8/16/2005**	Revision to incorporate multiple NRPCT comments – editorial, clarification and some additional work.	Multiple

Contents

1.0 INTRODUCTION

This plan describes the activities at Pacific Northwest National Laboratory (PNNL) pertaining to the manufacturing, inspection, and certification requirements for the fabrication of biaxial creep specimens. These specimens consist of tube sections with welded end caps which are sealed under pressure to create pressurized tubes used to generate biaxial creep strength data on alloys of interest. The manufacturing process at PNNL begins with the receipt of government furnished materials consisting of top and bottom end caps fitted to a stock tube section in a matched set for welding and pressurization.

2.0 DESIGN SPECIFICATIONS AND DRAWINGS

The documents listed below are applicable to fabrication of biaxial creep pressurized tube specimens. The documents listed are subject to revision, and the current revision will be used in all instances as defined in the applicable version of Reference 2.1 below. Reference 2.2 below shall be used as a guide for the fabrication of biaxial creep specimens and will be supplemented with instructions defined in Reference 2.1. In the event of a conflict between References 2.1 and 2.2, those listed in Reference 2.1 shall take precedence. A list of clarifications and exceptions to Reference 2.2 is provided in Appendix A.

2.1 KAPL, Inc. Information-to-Vendor, *Biaxial Creep Specimen Fabrication*, PNNL-SPP-05-0004

2.2 RDT Standard, *Welding of Reactor Core Components and Test Assemblies*, RDT (NE) F 6-2T, dated July 1973 and PNNL exceptions to application of standard

2.3 Bechtel Bettis Inc. Drawing, *Biaxial Creep Specimen Straight Wall*, SK-DPM1060997

2.4 Bechtel Bettis, Inc. Drawing, *Biaxial Creep Specimen Inspection Groove Bottom End Cap*, SK-DPM1051705

2.5 Bechtel Bettis, Inc. Drawing, *Biaxial Creep Specimen Inspection Groove Top End Cap/Protrusion*, SK-DPM3051705

2.6 Bechtel Bettis, Inc. Drawing, *NRPCT / JOYO-1 Biaxial Creep Specimen Assembly*, 5D15996

2.7 Battelle Pacific Northwest National Laboratory, *Space Reactor Materials Irradiation Testing Project – Quality Assurance Plan*, SRM-PLAN-002

2.8 Battelle Pacific Northwest National Laboratory, *Space Reactor Materials Irradiation Testing Project – Biaxial Creep Specimen Electron Beam and Laser Seal Weld Qualification Test Plan*, SRM-PLAN-003

3.0 DESCRIPTION OF WELDING, INSPECTION, AND TESTING STEPS

The following subsections describe all of the steps required to fabricate, inspect, certify, and deliver biaxial creep specimens. Some steps in the fabrication process are specific to certain types of alloys and are identified as such. A flow chart summary of the fabrication and inspection process for biaxial creep specimens is provided in Figure 1. A detailed fabrication and inspection flow chart is provided in Appendix B.

3.1 Receiving

Receipt inspection will include checks for shipping damage and verification of the number of specimens and unique identification markings on one of the end caps for each set with the enclosed packing slip. Matched sets of samples will be supplied to PNNL, with each set consisting of a tubing section and two fitted end caps as described in the respective drawings listed in Section 2.0. PNNL will perform a visual inspection of the individual components and perform a cleanliness and fit-up verification of the matched sets prior to electron beam welding. A receipt inspection report (RIR) will document these activities and is included in Appendix C. Refractory alloy specimens shall not contact any non-refractory metals. It is assumed that specimens will be supplied in a cleaned condition requiring no further processing prior to welding except for a final alcohol rinse.

3.2 Electron Beam (EB) Welding

Attachment of the top and bottom end caps will be accomplished using circumferential electron beam welding at the interface between each end cap and the tube section using a Hamilton Standard Electron Beam Welder. The weld will be a full penetration weld and cover the entire circumference of the end cap and tube section interface. Each specimen set will be loaded into the 24-tube holding fixture which will allow each specimen to be rotated at a constant speed for circumferential welding while in the vacuum chamber. Per the handling procedure, refractory alloy specimens will be held by molybdenum holding fixtures ("spuds") and non-refractory alloy specimens will be held by stainless steel fixtures. Refractory alloy specimens will not be welded in the same load as non-refractory specimens.

The ambient cold leak rate of the weld chamber will be measured at the start of the day before EB welding and compared against the established acceptable cold leak rate. The weld chamber will be pumped down to maximum target atmospheres of 5×10^{-5} torr and 1×10^{-4} torr for refractory and non-refractory alloy specimens, respectively. Both the cold leak rate and pump down pressure requirements will be documented on the specimen travelers and data sheets (Appendix C). All EB welding parameters will also be documented in the welding procedure and will be attached to the specimen traveler.

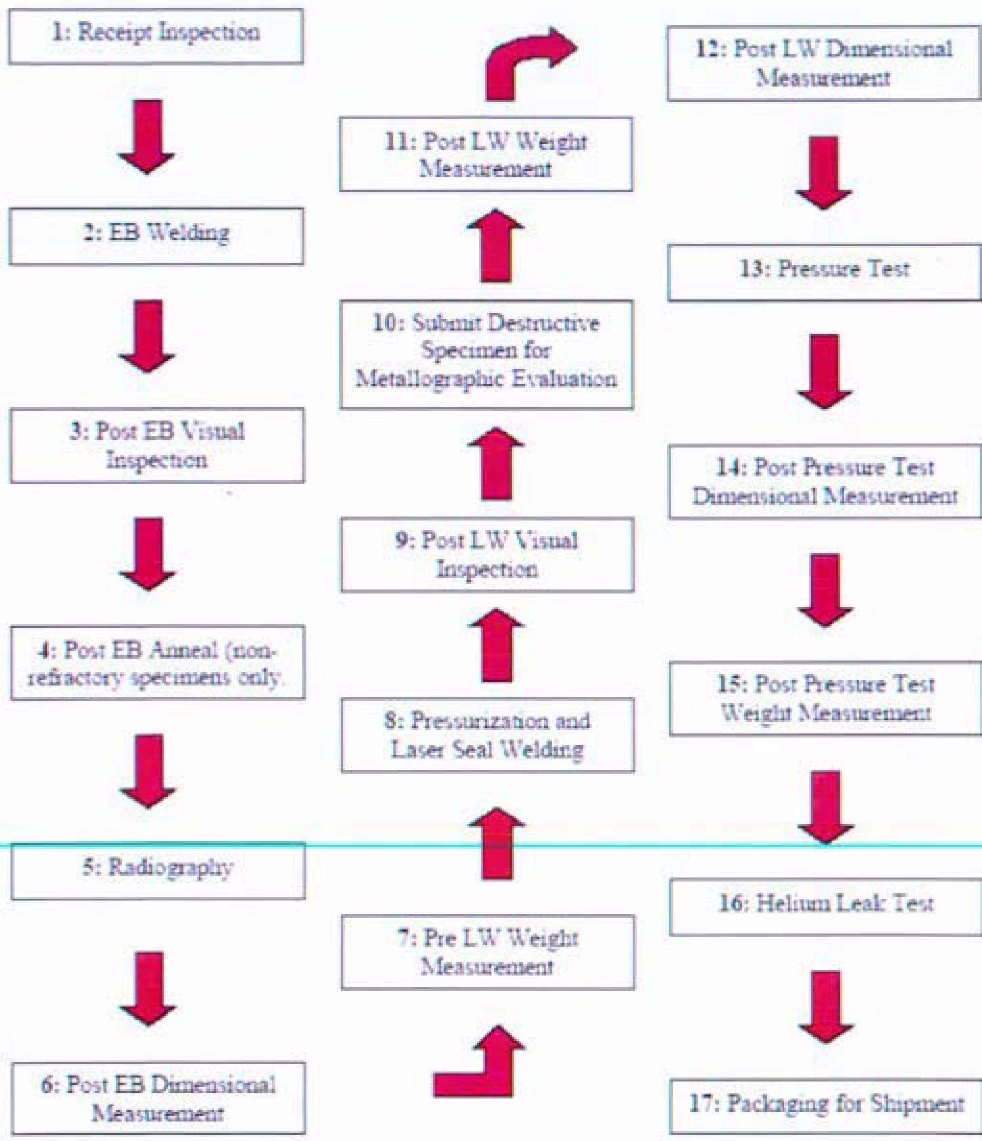


Figure 3-1. Summary Flow Chart of Biaxial Creep Specimen Fabrication and Inspection.

3.3 Post EB Visual Examinations

Visual weld inspection will be performed after attachment of the end caps by EB welding. This inspection will be performed by a second technician, supervisor, inspector or consultant. The results of this inspection will be documented on the specimen traveler data sheet (Appendix C). The criteria to be used for visual acceptance are described in Appendix D.

3.4 Post EB Weld Anneal

Selected non-refractory alloy specimens may require post EB weld annealing to a maximum of 1523 K. The furnace to be used for this anneal is a Centorr Model U16 with resistance heated refractory metal elements and a cryogenic vacuum pump which is backed up by a dry scroll pump. The annealing time and temperature parameters will be provided by NRPCT. Applicable anneal parameters will be documented on specimen traveler (Appendix C).

3.5 Post EB Radiography

Radiographic inspection will be performed by Cogema Engineering under subcontract to PNNL to assess weld quality. This inspection will be performed according to the Cogema Engineering procedure after approval by the NRPCT. The first radiography of each alloy set shall contain two tubes with end caps press-fit but not welded. These unwelded specimens will serve as comparators to verify the detection of the unwelded radiography groove. Results from the radiographic inspection will be documented on the specimen traveler data sheet (Appendix C).

3.6 Post EB Diameter Measurements

At the beginning of the diameter measurement campaign, a series of standards shall be measured prior to any production specimens being measured. The series of standards will consist of a 0.25 inch gage pin as well as 3 gage pins that have incrementally smaller diameters than 0.25 inch and 3 gage pins that have incrementally larger diameters than 0.25 inch. Measurements will be made using slice program at five evenly spaced axial positions (center -0.4 inch, center -0.2 inch, center, center +0.2 inch, center −0.4 inch). The standard gage pins shall be provided by the NRPCT. The deviations from the standards shall be plotted and a correction to the laser micrometer system shall be made if the gage pin measurements indicate that this is necessary. After the initial series of standards has been measured, the 0.25 inch gage pin shall be measured after every 10 production specimens have been measured to ensure that the system remains accurate. All gage pin measurement data shall be provided to the NRPCT along with the production specimen data.

The diameter of each specimen will be measured after attachment of the end caps and subsequent inspections and annealing (for non-refractory alloys) using a Beta LaserMike Model 162 laser micrometer. Measurements will be made using slice program at five evenly spaced axial positions (center -0.4 inch, center -0.2 inch, center, center +0.2 inch, center +0.4 inch). Grips are required to hold specimens during the measurements. Refractory alloy grips shall be used for refractory alloy specimens.

There shall be a minimum of 180 measurements taken at 1° intervals at each axial location. Each specimen shall be measured once and the specimen shall be cleaned with alcohol and a lint-free cloth before the measurement is taken. The following items shall be recorded for each measurement: time, room temperature, fixture temperature, and humidity. If, in the judgment of PNNL personnel, unexpected measurement results are received, the NRPCT shall be consulted to determine if additional measurements need to be taken. The diametral measurements will be recorded by the measurement equipment and attached to the specimen traveler (Appendix C). An electronic copy of this data will be provided NRCPT.

3.7 Pre Laser Seal Welding Weight Measurement

Following pressurization and laser seal welding, each specimen will be weighed a minimum of three times on a Mettler Balance Model AE163 which is calibrated and provides a reading of ±0.00001 grams. Weight measurements will be recorded on the specimen traveler data sheet (Appendix C).

3.8 Pressurization and Laser Seal Welding

Specimens will be pressurized with certified high purity helium gas (>99.999% He). Refractory and non-refractory specimens shall not be mixed in the 12-tube chamber for pressurization. Refractory alloy specimens shall be held by a refractory alloy holder during pressurization and laser seal welding using a KORAD KWD laser welder. Prior to the start of each pressurization run, the chamber shall be evacuated and backfilled at least twice with helium. The backfill pressure shall be less than the minimum fill pressure for that group of specimens. Each specimen will be sealed at the designated pressure level by laser welding of the top end cap fill hole. A second technician, engineer, supervisor, consultant or QA representative will be present to verify that the target fill pressures were obtained for individual specimens. The gage used to record the specimen the gas pressure in the chamber will be calibrated and the gage accuracy certified. The laser welding parameters and the fill pressures will be recorded on the Laser Welding Procedure and attached to the specimen traveler (Appendix C).

3.9 Post Laser Seal Welding Visual Inspection

Visual weld inspection will be performed after pressurization and sealing by laser welding. This inspection will be performed by a second technician, supervisor, inspector or consultant. The results of this inspection will be documented on the specimen traveler data sheet. The criteria to be used for visual acceptance are described in Appendix D.

3.10 Destructive Testing

One specimen from each EB welding load will be destructively evaluated using metallographic techniques to evaluate weld quality. In order to avoid having to de-pressurize the specimen, one tube section per load will be randomly selected by a second technician, supervisor, consultant, or NRPCT engineer and a through-wall hole will be drilled in the tube. The specimen will go through the pressurization and seal welding steps, but no pressure will be retained in the tube due to through-wall hole. Metallographic sectioning will be performed to evaluate the laser seal weld and both top and bottom end cap welds. A visual evaluation of actual metallographic specimens will be performed by the weld engineer or designated alternate within 2 weeks of the seal weld. If abnormalities are identified, the NRPCT cognizant engineer will be immediately notified.

3.11 Post Laser Seal Welding Weight Measurement

Following pressurization and laser seal welding, each specimen will be weighed a minimum of three times on a Mettler Balance Model AE163 which is calibrated and provides a reading of ±0.00001 grams. Weight measurements will be recorded on the specimen traveler data sheet (Appendix C).

3.12 Post Laser Seal Welding Diameter Measurements

The diameter of each specimen will be measured before the pressure test at temperature of the end caps using a Beta LaserMike Model 162 laser micrometer. Measurements will be made using slice program at five evenly spaced axial positions (center -0.4 inch, center -0.2 inch, center, center +0.2 inch, center +0.4 inch). Grips are required to hold specimens during the measurements. Refractory alloy grips shall be used for refractory alloy specimens. There shall be a minimum of 180 measurements taken at 1° intervals at each axial location. Each specimen shall be measured once and the specimen shall be cleaned with alcohol and a lint-free cloth before the measurement is taken. The following items shall be recorded for each measurement: time, room temperature, fixture temperature, and humidity. If, in the judgment of PNNL personnel, unexpected measurement results are received, the NRPCT shall be consulted to determine if additional measurements need to be taken. The diameter measurements will be recorded by the measurement equipment and attached to the specimen traveler (Appendix C). An electronic copy of this data will be provided NRCPT.

3.13 Pressure Test at Temperature

Refractory and non-refractory pressurized specimens will undergo a pressure test anneal at or above the irradiation test service temperature for one hour (±5 min). This test will be performed in a Thermal Technology model 121224M-MS high vacuum furnace with resistance-heated molybdenum elements with a turbo pump backed up by a scroll pump. The refractory and non-refractory specimens will be annealed separately. The vacuum during the pressure test anneal will be 5×10^{-5} torr or better and an adequate cold leak rate will be demonstrated before each anneal. The anneal temperature will be the target irradiation test temperatures (±25 K) and will be provided by NRPCT at a later date.

Prior to running the first refractory alloy specimens, the furnace will be baked out for 2 hours at temperature that is 50–100 K higher than the highest anneal temperature. The refractory specimens will be wrapped in refractory metal foil. If non-refractory specimens are annealed in the same furnace, an additional bake out will be performed (2 hours at temperature that is 50–100 K higher than the highest anneal temperature). Applicable anneal parameters will be documented on specimen traveler (Appendix C).

3.14 Post Pressure Test Diameter Measurements

The diameter of each specimen will be measured after operational pressure test using a Beta LaserMike Model 162 laser micrometer. Measurements will be made using slice program at five evenly spaced axial positions (center -0.4 inch, center -0.2 inch, center, center +0.2 inch, center +0.4 inch). The number of measurements to be made at each location will be provided by NRPCT. Grips are required to hold specimens during the measurements. Refractory alloy grips shall be used only for refractory alloy specimens. There shall be a minimum of 180 measurements taken at 1° intervals at each axial location. Each specimen shall be measured once and the specimen shall be cleaned with alcohol and a lint-free cloth before the measurement is taken. The following items shall be recorded for each measurement: time, room temperature, fixture temperature, and humidity. If, in the judgment of PNNL personnel, unexpected measurement results are received, the NRPCT shall be consulted to determine if additional measurements need to be taken. The diameter measurements will be recorded by the measurement equipment and attached to the specimen traveler (Appendix C). An electronic copy of this data will be provided NRCPT.

3.15 Post Pressure Test Weight Measurement

Following pressure test anneal, each specimen will be weighed a minimum of three times on a Mettler Balance Model AE163 which is calibrated and provides a reading of ±0.00001 grams. Weight measurements will be recorded on the specimen traveler data sheet (Appendix C).

3.16 Helium Leak Check

Helium leak testing of individual pressurized specimens will be performed by Cogema Engineering under subcontract to PNNL to assess weld quality. This testing will be performed according to the Cogema Engineering procedure. The acceptance criteria for this test are a leak rate that does not exceed 1×10^{-8} std cc/sec of helium. Results of this testing will be recorded on the specimen traveler data sheet (Appendix C).

3.17 Packaging and Shipping

Packaging and shipping will be the final process step for the individual specimens and is described in Section 5.0.

3.18 Certification

A certification package will be prepared for each specific alloy group. The certification process is described in Section 10.

4.0 IDENTIFICATION OF SPECIAL PROCESSES

Both the EB and laser seal welds are designated as special processes. Each weld will be qualified on a per alloy basis as describe in the PNNL Reference SRM-PLAN-003, Qualification Test Plan for Biaxial Creep Specimen Electron Beam and Laser Seal Welding. The results of this qualification effort will be reported in a qualification report for each alloy.

5.0 HANDLING, PACKAGING AND SHIPPING REQUIREMENTS

Refractory alloy specimens shall not come in contact with any non-refractory alloy specimens during any step in the process. All component handling shall be performed with clean, nonporous, talc-free gloves or materials. Allowable contact materials are on the NRPCT-issued contact list attached as Appendix E. PNNL will conduct contingency cleaning, as required, in the event of loss of cleanliness of the NRPCT specimens in accordance with NRPCT requirements summarized in Attachment F. Upon final inspection, the specimens will be wrapped in a clean texwipe in preparation for shipping. Wrapped specimens will be loaded in sealed steel pipe containers with swagelock fittings on each end for shipping. The sealed pipes will be packaged in an outer container for shipment to NRPCT. A letter detailing the final production specimens shipping information (i.e., numbers, types, certifications) shall be provided in parallel to the NRPCT cognizant engineer.

6.0 QUALIFICATION, TRAINING AND CERTIFICATION OF PERSONNEL

All PNNL personnel who perform activities in support of the fabrication of biaxial creep specimens shall be appropriately qualified, trained, and as applicable, certified. Applicable functional personnel include, but are not limited to, the following: task manager, welding operators, welding consultants, anneal technicians, weight and dimensional technicians, shipping and handling personnel, and administrative support personnel (document control, training, records management, etc).

Specific requirements for qualification, training and certification of personnel are described in SRM-Plan-002, Space Reactor Materials Irradiation Testing Project, Quality Assurance Plan and/or implementing procedures.

Personnel that require certifications are the welding operator and nondestructive testing personnel (radiography and helium leak testing). The customer has not required certified personnel to conduct visual weld examinations. However, PNNL intends to use an American Welding Society Certified Welding Inspector in an oversight role for visual weld examination of electron beam and laser welding.

7.0 QUALITY ASSURANCE REQUIREMENTS

The PNNL Space Reactor Project Quality Assurance Plan SRM-PNL-002 references the NRPCT and PNNL driven quality assurance requirements and their application to all of the PNNL Space Reactor Project work scopes including biaxial creep. The referenced QA Plan specifically lists the procedures selected to implement the quality assurance requirements.

The biaxial creep work scope will be implemented and the processes controlled using the PNNL Project Management Plan, referenced QAP, QAP implementing procedures, biaxial creep developed weld qualification plans/reports, nondestructive testing procedures, Manufacturing and Test Plan (MAQP), work instructions and travelers (route cards). Each specimen will have its own traveler traceable to the specimen. Travelers will stay with the specimen and will be in the process operation area where process is being performed. The status of the specimen will be evident at all times. Tags and segregation will be used to differentiate acceptable and nonconforming hardware. An example of a traveler (route card) and attachment for recording quantitative information is attached as Appendix D.

PNNL Quality Assurance personnel will monitor and assess compliance to NRPCT Contract and PNNL SRP requirements.

8.0 NONCONFORMING PROCESSES AND/OR MATERIALS

Any discrepant process or hardware adversely affecting compliance will be immediately documented in accordance with internal PNNL process and procedures and if applicable documented on NRPCT form Degradation of Specification Requirement (DSR) or Repair Approval Request (RAR).

PNNL will not rework or repair any material without the consent of NRPCT. PNNL does not consider re-welding as a rework or a repair but part of the EB welding process.

9.0 CERTIFICATION

PNNL quality assurance personnel will review and determine the acceptability of each specimen based on physical verification and review of document package developed for individual biaxial creep specimens. This physical verification and document review will assure the specimens were fabricated in accordance with customer requirements including NRPCT approved documents; MAQP, welding plan, NDE procedures, PNNL QA Plan, etc.

PNNL will prepare and issue a test report and issue certifications as required by NRPCT Form KPPQAR-1, Laboratory Procurement Quality Assurance Requirements, QA Clauses 16, 17 and 18.

10.0 APPENDIXES

Appendixes B, C and D are provided for information and may be changed as necessary to improve work flow.

A – Exceptions to RFT (NE) F6-2T

B – Detailed Fabrication and Inspection Flow Diagrams

C – Fabrication and Inspection Traveler

D – Visual Weld Examination Requirements

E– Detrimental Materials List

MANUFACTURING AND QUALITY PLAN FOR BIAXIAL CREEP SPECIMENS

Appendix A – Exceptions to RDT F6-2T

Application of RDT Standard RDT F6-2t, July 1973, Welding of Reactor Core Components and Test Assemblies to Biaxial Creep Specimen Fabrication, Inspection and Testing

Prepared by: T.D. Hays, PNNL
Approved by: T.A. Delucchi, Cogema

PNNL intends to use the referenced standard for the development and application of Electron Beam welding processes and procedures except as noted herein.

General:

1) Biaxial creep specimens are test specimens. Therefore, the applicable sections of the Standard applicable to Test Assemblies will be used. Specifically, Sections addressing reactor core components (Sections 4, 5, and 7) are not applicable and requirements in other general sections not addressing Test Assemblies are not applicable.

2) 3.3.1: Base materials will not comply with referenced tables. Base materials will be Customer Furnished materials as described in latest revision of IV.

3) 3.3.2: NA, no welding materials (filler material) will be used in the EB and laser weld processes.

4) 3.5: Cleanliness shall meet NRPCT requirements not RDT F5-1. Cleaning procedure will be prepared if required by NRPCT.

5) 3.6: Joint design of EB welded components has integral backing.

6) 3.10: Preheat will not be used. Any post-heat treatments will be per direction of NRPCT.

7) 3.13: Nondestructive examinations shall meet requirements mutually agreed upon with PNNL, PNNL nondestructive examination (NDE) subcontractor and NRPCT.

8) 3.15: The NDE methods required for the Biaxial Creep specimens are visual test (VT), radiographic test (RT) and helium leak test (HLT). No cleaning is will be required for these NDE processes. Analysis is not planned for other contacting materials.

9) 3.17: .2) No filler materials used in welding process. .4) No weld maps used but each weld on a specimen will be assigned specific number and be tracked by traveler General) Many of the requirements listed will be recorded in a summary manner for all or groups of welds.

10) 4.1-4.4: Entire section is N/A

11) 5.1- 5.4: Entire section is N/A

MANUFACTURING AND QUALITY PLAN FOR BIAXIAL CREEP SPECIMENS

Appendix A – Exceptions to RDT F6-2T

12) 6.1.1.1 – 6.1.1.5: NDE will be limited to VT, RT and HLT for procedure and welding operator qualification. penetrant test (PT), ultrasonic test (UT) and tension test will not be used.

13) 6.1.2 b, LP is N/A.

14) 6.1.2 c, HLT will be performed in accordance with procedure submitted by PNNL (Cogema Engineering).

15) 6.1.2 d: Electron beam weld joints (shell to caps) will be radiographed per procedure submitted by PNNL (Cogema Engineering).

16) 6.1.3.a: Metallographic examination will be performed on one specimen form each EB welding load. Requirements for starts and stops are N/A.

17) 6.1.3.b: Tension testing is N/A.

18) 6.1.4: Welding procedure specification (WPS) shall be submitted as required to NRPCT for approval.

19) Table 1: Only the information applicable to EB and laser welding will be included.

20) Table 2, #1, General, All Welding Processes: Only the information applicable to EB and laser welding will be included.

21) Table 2 #2, Manual Welding is N/A.

22) Table 2, #4, Gas Tungsten Arc Welding is N/A.

23) 6.1.4.D, d.3 is N/A.

24) 6.1.4.E: No chart recordings will be made.

25) 6.1.5.4: The EB and laser welds will be made by one individual. The initials of that welder will be indicated on travelers for each specimen. No number, letter, or symbol will be placed on any specimen.

26) 6.1.5.b is N/A.

27) 6.1.5.d: The PNNL welding operator who prepares acceptable qualification welds will not be required to re-qualify unless 1 year (365 days) has elapsed.

28) 6.2.1: Weld sample quantity is specified in the Weld Qualification Plan.

29) 6.2.2: Cleaning shall be as specified by NRPCT and/or Manufacturing and Quality Plan (MAQP)

MANUFACTURING AND QUALITY PLAN FOR BIAXIAL CREEP SPECIMENS

Appendix A – Exceptions to RDT F6-2T

30) 6.2.3: Handling and storage of cleaned materials prior to and during welding and subsequent to welding will be specified in MAQP.

31) 6.2.4: N/A. All materials and weld joint surfaces are furnished ready to weld by customer.

32) 6.2.5, 6.2.6: Fitting and alignment of joints will be accomplished using a fixture which will be detailed in the weld qualification plan and report.

33) 6.2.7 is N/A.

34) 6.2.8: Vacuum welding process does not apply.

35) 6.2.9, 6.2.10, 6.2.11: All welds are single welded joints. Root pass is N/A and will not be examined.

36) 6.2.12, 6.2.13 are N/A.

37) 6.2.14: No repairs on base material. If repairs on welds are allowed, weld qualification plan and report will specify details.

38) 6.3.1.a: All nondestructive testing (RT, HLT) will be performed and accepted in accordance with procedures submitted by PNNL (Cogema Engineering).

39) 6.3.1.c: All inspection and NDE required will be specified in MAQP and on travelers.

40) 6.3.1.d: Visual examination and radiography will be performed prior to any anneal/heat treatment or pressurization of specimen.

41) 6.3.2: See Appendix D for visual examination for EB and laser welds. The joint preparation is to be acceptable as customer furnished material and will be checked for damage during receipt inspection only with trial fit ups.

42) 6.3.3 is N/A.

43) 6.3.4: Radiography will be performed per procedure submitted by PNNL (Cogema Engineering). Acceptance criteria will specified in MAQP.

44) 6.3.5 is N/A.

45) 6.3.6: Helium leak testing will be conducted using "bell jar" method (pressurized specimens placed in vacuum chamber).

46) 6.3.7: Metallographic examination shall be performed as specified by customer in IV.

47) Section 7: Entire section is N/A.

MANUFACTURING AND QUALITY PLAN FOR BIAXIAL CREEP SPECIMENS

Appendix A – Exceptions to RDT F6-2T

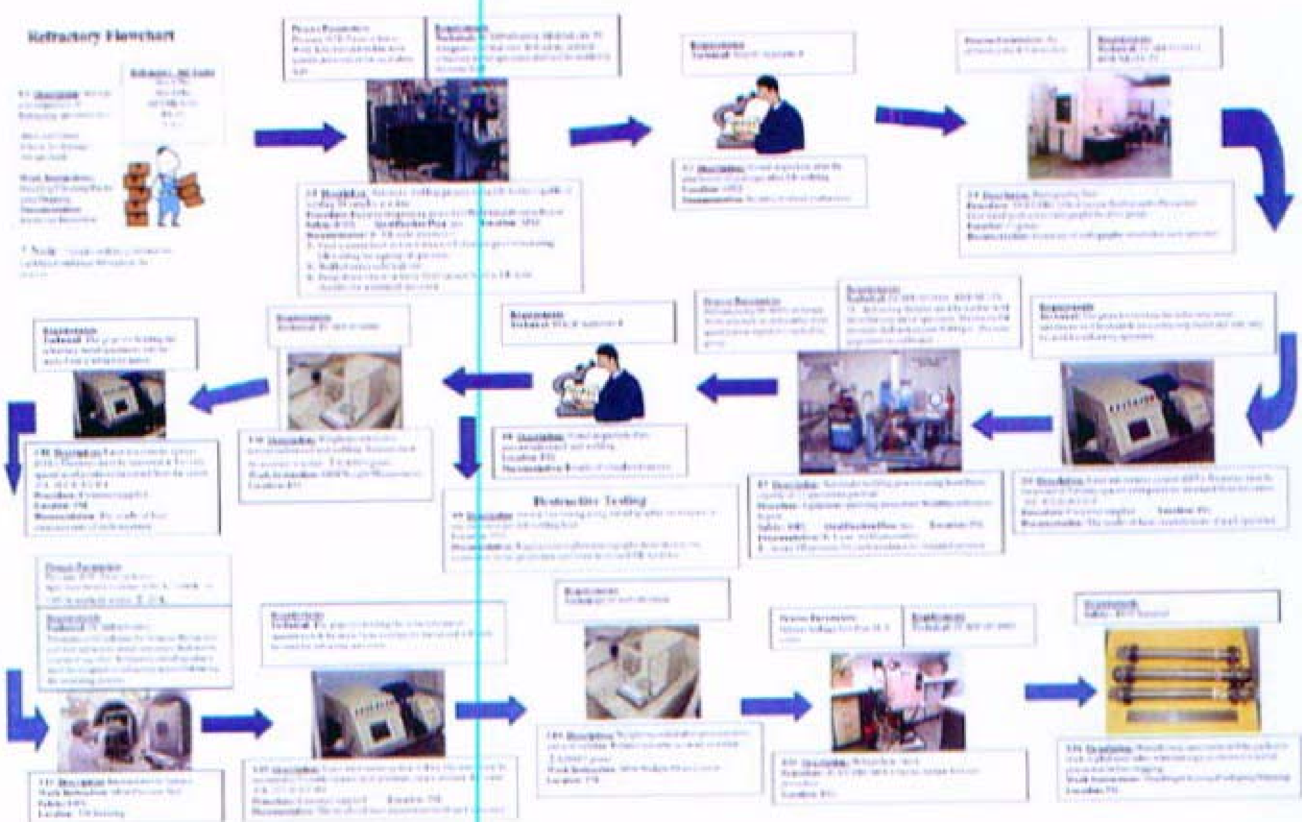
48) 8.1: Only section 8.1.4 applies.

49) 8.4: Based materials are customer furnished material

50) 8.5 is N/A.

51) 9.0: All applicable information (base material, NDE, weld chamber vacuum, metallographic, helium leak testing) is specified by customer. Filler material information, halogen and sulfur content, disposition of welds, tensile testing, first and last weld, wrap wire weld, projection welding, spot welding, tensile shear tests are N/A.

52) Table 5: Test Assembly Category 4 only.


Refractory Flowchart
Destructive Testing

MANUFACTURING AND QUALITY PLAN FOR BIAXIAL CREEP SPECIMENS

Appendix B – Non-Refractory Flow Chart

B-2

Step	Process Description	Requirement	Verify Completion	Data Recording & Comments
1	Receipt Inspection	SRM-PLAN-004 MAQP, Section 3.1		Record information on Receiving Inspection Report (RIR)
2	Electron Beam (EB) Welding	SRM-PLAN-004 MAQP, Section 3.2 SRM-PLAN-005 Weld Qualification Test Plan Attachment 3 SRM-PLAN-xxx Weld Qualification Report		EB weld parameters per welding procedure (Attached). Vacuum Level Before Weld. Time to pump down chamber: Adequate cold leak rate
3	Post EB Visual Inspection	SRM-PLAN-004 MAQP, Section 3.3		Record on specimen NDE data sheet.
4	Post EB Anneal (non-refractory specimens only)	SRM-PLAN-004 MAQP, Section 3.4		Cold Leak Rate: Time Max Temp Max Pressure
5	Radiography	SRM-PLAN-004 MAQP, Section 3.5 Cogema Procedure SVRT-PRC-006		Record on specimen NDE data sheet. Radiography Report for each specimen (attached)
6	Post EB Dimensional Measurement	SRM-PLAN-004 MAQP, Section 3.6		Record on specimen NDE data sheet. Laser Micrometer Report for each specimen (attached)
7.	Pre Laser Weld (LW) Weight Measurement	SRM-PLAN-004 MAQP, Section 3.7		Record on specimen weight measurement data sheet.
8	Pressurization & Laser Seal Welding (LW)	SRM-PLAN-004 MAQP, Section 3.8 SRM-PLAN-005 Weld Qualification Test Plan Attachment 4 SRM-PLAN-xxx (TBD) Weld Qualification Report		Record on specimen pressurization data sheet. Laser weld parameters per welding procedure (attached).

Step	Process Description	Requirement	Verify Completion	Data Recording & Comments
9.	Post LW Visual Inspection	SRM-PLAN-004 MAQP, Section 3.9		Record on specimen NDE data sheet.
10.	Select Destructive Specimen and Submit for Metallographic Evaluation	SRM-PLAN-004 MAQP, Section 3.10		Specimen # : Photomicrographs in Destructive Data Sheet (attached)
11.	Post LW Test Weight Measurement	SRM-PLAN-004 MAQP, Section 3.11		Record on specimen weight measurement data sheet.
12.	Post LW Dimensional Measurement	SRM-PLAN-004 MAQP, Section 3.12		Record on specimen NDE data sheet. Laser Micrometer Report for each specimen (attached)
13.	Pressure Test at Temperature	SRM-PLAN-004 MAQP, Section 3.13		Cold Leak Rate Time: Temp: Pressure:
14.	Post Pressure Test Dimensional Measurement	SRM-PLAN-004 MAQP, Section 3 14		Record on specimen NDE data sheet. Laser Micrometer Report for each specimen (attached)
15.	Post Pressure Test Weight Measurement	SRM-PLAN-004 MAQP, Section 3.15		Record on specimen weight measurement data sheet.
16.	Helium Leak Test	SRM-PLAN-004 MAQP, Section 3 16 Cogema Procedure SLRT-PRC-003		Record on specimen NDE data sheet. He Leak Report for each specimen (attached)
17.	Packaging for Shipment	SRM-PLAN-004 MAQP, Section 3.17		Specimens packaged for shipment are recorded in the Certificate of Compliance (C of C)

Specimen ID Numbers Included this Batch Traveler:

1.	13.
2.	14.
3.	15
4	16
5.	17
6.	18
7.	19
8.	20.
9.	21.
10	22.
11.	23
12.	24

Attachments to this Batch Traveler Will Include:

A. Receiving Inspection Report (RIR)
B. EB Welding Procedure
C. Specimen NDE Data Sheet
D. Laser Micrometer Data Report - Post EB Dimensional
E. Cogema Radiography Report
F. Specimen Pressurization Data Sheet
G. Laser Welding Procedure
H. Laser Micrometer Data Report – Post LW Dimensional
I. Destructive Data Sheet - Photomicrographs
J. Specimen Weight Measurement Data Sheet
K. Laser Micrometer Data Report – Post Pressure Anneal
L. Cogema He Leak Report

MANUFACTURING AND QUALITY PLAN FOR BIAXIAL CREEP SPECIMENS

Appendix C – Fabrication & Inspection Traveler

Biaxial Creep Specimen Receiving Inspection Report (RIR)

Performed by (Print/Sign/Date):	

Specimen ID No. / No. of Specimen per Package	Inspected for Shipping Damage (A/R)*	Inspected and Recorded Specimen ID No. (A/R)*	Inspected for Cleanliness (A/R)*	Inspected for Adequate Fit-up (A/R)*
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Shipping container was undamaged? [ ] Yes [ ] No
Number of Specimen received matches number of specimen ordered? [ ] Yes [ ] No
Information on shipping slip matches actual shipment? [ ] Yes [ ] No
Comments:

*A/R = Accept/Reject
Inspection performed in accordance with PNNL SBMS, Inspecting and Accepting Received Items, Part 1 and SRM-PLAN-004, Manufacturing and Quality Plan for Biaxial Creep Specimen.

MANUFACTURING AND QUALITY PLAN FOR BIAXIAL CREEP SPECIMENS

Appendix C – Fabrication & Inspection Traveler

Specimen ID No. / No. of Specimen per Package	Inspected for Shipping Damage (A/R)*	Inspected and Recorded Specimen ID No. (A/R)*	Inspected for Cleanliness (A/R)*	Inspected for Adequate Fit-up (A/R)*
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*A/R = Accept/Reject

Inspection performed in accordance with PNNL SBMS, Inspecting and Accepting Received Items, Part 1 and SRM-PLAN-004, Manufacturing and Quality Plan for Biaxial Creep Specimen.

MANUFACTURING AND QUALITY PLAN FOR BIAXIAL CREEP SPECIMENS

Appendix C – Fabrication & Inspection Traveler

Biaxial Creep Specimen NDE Data Sheet

Specimen ID	Visual Top EB Weld (A/R)	Visual Bottom EB Weld (A/R)	Visual Performed by	Radiography (A/R)	Radiography Performed by	Post EB Dimensional Performed By	Visual of Laser Weld (A/R)	Visual Performed by	Post LW Dimensional Performed by	Post Pressure Test Dimensional Performed by	He Leak (A/R)	He Leak Performed by
A1												
A2												
A3												
A4												
A5												
A6												
A7												
A8												
A9												
A10												
A11												
A12												
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A14												
A15												
A16												
A17												
A18												
A19												
A20												
A21												
A22												
A23												
A24												

A/R = Accept/Reject
Laser Micrometer #:
Laser Micrometer Cal. Due Date:
Standard Cal. Due Date:

Time:
Room Temp:
Fixture Temp:
Humidity:

Time:
Room Temp:
Fixture Temp:
Humidity:

MANUFACTURING AND QUALITY PLAN FOR BIAXIAL CREEP SPECIMENS

Appendix C – Fabrication & Inspection Traveler

Biaxial Creep Specimen Pressurization Data Sheet

Pressure Gage #:
Pressure Gage Cal. Due Date:

Specimen ID	Pressurization Target (PSI)	Pressurization Actual (PSI)	Performed by	Verified by
Group #1				
A1				
A2				
A3				
A4				
A5				
A6				
A7				
A8				
A9				
A10				
A11				
A12				
Group #2				
A13				
A14				
A15				
A16				
A17				
A18				
A19				
A20				
A21				
A22				
A23				
A24				

MANUFACTURING AND QUALITY PLAN FOR BIAXIAL CREEP SPECIMENS

Appendix C – Fabrication & Inspection Traveler

Biaxial Creep Specimen Weight Measurement Data Sheet

Balance #:
Balance Cal. Due Date:

	Pre LW Weight Measurement				Post LW Weight Measurement				Post Pressure Test Weight Measurement			
Specimen ID	Weight #1 (grams)	Weight #2 (grams)	Weight #3 (grams)	Measurement Performed by	Weight #1 (grams)	Weight #2 (grams)	Weight #3 (grams)	Measurement Performed by	Weight #1 (grams)	Weight #2 (grams)	Weight #3 (grams)	Measurement Performed by
A1												
A2												
A3												
A4												
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Appendix D – Visual Weld Examination Requirements

Application of RDT Standard RDT F6-2T
Section 6.3.2 Visual Examination

Space Reactor Project
Biaxial Creep Specimen Fabrication

Visual Weld Examination Requirements
For Electron Beam and Laser Welding

- Visual weld examination shall be performed after completion of electron beam and laser welding and prior to subsequent operations; radiography, anneal, weight, dimensional and helium leak testing.
- Final accessible weld surface and adjacent base metal heat affected zones shall be examined.
- Examination shall be performed by qualified personnel who have visual acuity which meets 20/20 vision, natural or corrected stereo acuity and who have normal color vision.
- Results of examinations shall be documented. Documentation shall include the following minimum information: date of examination, examiner name and certification as applicable, description of welds examined, reference to examination requirements, measuring and test equipment used and calibration status as applicable, and results of examination.

Examinations shall be performed in accordance with the following requirements:

1) Welds examined at 1× and 7× (nominal). If a potential weld discontinuity is observed, examine at 10× to confirm.

2) Use direct examination with appropriate lighting (100 FC minimum), angle and distance of vision not greater than 24" between eye and surface to be examined and not less than 30 degree angle form examiner line of sight to the surface

3) Surface finish of welds are to be examined for surface discontinuities including proper seam tracking, weld contour and reinforcement

4) Welds joints and base metal heat affected zones which are shown by visual examination to have any of the following discontinuities are considered unacceptable:

   A) any cracks or fissures

   B) any incomplete fusion

   C) any incomplete penetration

MANUFACTURING AND QUALITY PLAN FOR BIAXIAL CREEP SPECIMENS

Appendix D – Visual Weld Examination Requirements

D) any shrinkage voids

E) any inclusion larger than 20% of weld designed joint penetration or more than 3 inclusions of any size in weld length

F) any single porosity larger than 20% of weld designed joint penetration or more than 3 porosity of any size in weld length

G) gross spatter (minor individual or group accumulations of spatter acceptable)

H) excessive undercut (minor undercut acceptable as long as edges of welds blend smoothly and gradually into the adjacent base metal)

I) under-fill except for EB welds where maximum concavity shall not exceed .003"

Note: Minor joint concavity is expected with autogenous E-Beam welding.

J) weld face reinforcement in excess of .005"

Note: Overlap of the weld start point and weld finish point is permitted and desired.

K) oxidation or excessive dross

Note: Black or gray spalling or loose particles not acceptable. Iridescent temper films and dark metallic vapor deposits adjacent to weld are acceptable and may be removed by approved cleaning procedures when appropriate and accessible.

Rework by welding or other accepted methods to correct any of the above mentioned defects is acceptable and is not by itself a reason for rejection of the weld.

Prepared by: T.D. Hays, PNNL
Approved by: T.A. Delucchi, Cogema

MANUFACTURING AND QUALITY PLAN FOR BIAXIAL CREEP SPECIMENS

Appendix E – Detrimental Materials List

The following detrimental materials are prohibited from contact all biaxial creep specimens – both refractory and non-refractory alloys.

Contact with antimony, arsenic, bismuth, cadmium, lead, tin and zinc, and consumable products, such as lubricants and marking materials, containing these low melting point materials in excess of 250 parts per million (ppm) in each is prohibited. This prohibition on low melting point materials applies during thermal treatments and to the finished or cleaned surfaces of tubes offered for acceptance. Products do not need to be analyzed when product manufacturers certify that low melting point materials in excess of 250 ppm are not present in the products. Contact with mercury and consumable products that contain more than 10 ppm mercury is prohibited. Products do not need to be analyzed when product manufacturers certify that mercury in excess of 10 ppm is not present in the product, or certify that mercury and mercury compounds have not been added to the product and have not come in contact with the product during processing. Marking materials containing phosphorous or sulfur in excess of 250 ppm each shall not be used during thermal treatments and on finished or cleaned surfaces of tubes offered for acceptance.

Detrimental Material Effect

1. Mercury – Embrittlement and stress corrosion attack at room temperature in stressed metal.

2. Low-Melting Point Metals (e.g. lead, tin, etc.) – Contact may cause embrittlement during thermal treatment and could induce weld cracks and reduced corrosion resistance.

3. Aluminum – Causes cracking during heat treatment of some nickel base alloys.

4. Sulfur/Phosphorous/Boron – Cause embrittlement and cracking if present during heat treatment, welding, or hot forming of stainless steels or high nickel alloys. Also, if sulfur is present during heat treatment of some stainless steels, loss of corrosion resistance can result. Arsenic has much the same effect.

5. Carbonaceous Materials (such as lubricants) – Increasing carbon content of some stainless steels increases the vulnerability of the steel to corrosion, and if present during heat treatment above 1400 degrees F, can cause surface embrittlement.

6. Halogens – Halogens and their compounds, particularly chlorine and its compounds, will cause corrosion cracking of stainless steels in aqueous environments.

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FORM 76082
4/1999

CONCURRENCE RECORD SHEET

- DOCUMENT NUMBER: B-MT(SRME)-50
- THIS DOCUMENT CONTAINS INFORMATION WHICH SHOULD BE CONSIDERED FOR PATENT DISCLOSURES ☐ YES ☒ NO
- THIS DOCUMENT CONTAINS INFORMATION WHICH MEETS BETTIS WORK CATEGORIES [A,B,C,D or (N/A)] N/A

CONCURRENCE SIGNATURES (Activity must be included) - RESOLVE COMMENTS BEFORE SIGNING

SIGNATURE/ACTIVITY	DATE	TYPE	DETAILS OF REVIEW REQUESTED (if necessary)

TYPE OF REVIEWS (to be determined by author) [See table at end of instructions for definitions.]

1-Peer:Summary 2-Peer:Intermediate 3-Peer:Detail 4-Independent 5-Informal Committee 6-Formal Committee 7-Specialist 8-Interface

NAME TYPED AND SIGNATURE OF NEXT HIGHER MANAGER NOT SIGNING ON LETTER — DATE

J. E. Hack, Manager, Advanced Materials Technology — 2/8/06

- CONTRIBUTORS AND IMPACTED PARTIES NOT REQUESTED TO CONCUR AND WHY:

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TJ Mueller, 08R/8033
MD Natale, 08I/8024
CH Oosterman, 08C/8017
TN Rodeheaver, 08I/8024
SJ Rodgers, 08E/8019
SJ Trautman, 08V/8037

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CF Dempsey, 111
M Lane
DF McCoy, 111
G Newsome
SA Simonson, 081
MJ Wollman, 111

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RF Hanson