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SUBJECT: Part 21 rept re util Units 1 & 2 & root cause investigation by Tioga Pipe Supply.

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May 28, 1992

Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Subject: Root Cause Investigation by Tioga Pipe Supply

Reference: Florida Power and Light St. Lucie Units 1 and 2
Docket Nos. 50-335 and 50-389
10CFR21

Tioga Pipe has concluded its investigation concerning the above referenced reports. This investigation, as detailed herein, encompasses examinations of other material of the same alloy, further examination of the defective material, evaluation for Root Cause, and proposed Corrective Actions.

Initially, samples of a product meeting the alloy and heat treat cycle were tested in order to determine if other products of the same alloy which were heat treated at the same time were defective. This testing was performed on three SB564 UNS N04400 ANSI B16.11 3" 90 Degree Elbows and one SB564 UNS N04400 3" 90 Degree Elbow solid forging. All 90 Degree Elbows tested were Heat Code "KP". Testing of the 90 Degree Elbows included Dye Penetrant, Tension Testing, ASTM E112 Grain Size Determination, and Microstructure Evaluation. The results of the testing on the 90 degree elbows are listed below in Table #1.

TABLE #1

The material was 100% Liquid Penetrant inspected in accordance with L.T.I. Procedure LP-III-1, Rev. 4 dated 5/28/91 using the Visible Dye method and three pieces were found to be acceptable with no indications observed.

SERIAL NO.	TENSILE STRENGTH	YIELD (.2%) STRENGTH	ELONGATION (IN 4D)
CMTR RESULTS	86,000 PSI	39,000 PSI	42%
REQUIRED	70,000 PSI	25,000 PSI	35.0%
1	80,278 PSI	39,364 PSI	45.3%
2	82,998 PSI	40,903 PSI	46.4%
3	81,387 PSI	40,000 PSI	42.5%

NOTE: .250" SUB-SIZE TENSILE SPECIMENS WERE USED FOR TESTING.

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TABLE #1 (continued)

A Grain Size Examination was performed on the submitted Test Specimens in accordance with ASTM E-112, Comparison Method with the following results :

SERIAL NO.	GRAIN SIZE INSIDE DIAMETER	GRAIN SIZE OUTSIDE DIAMETER
1	ASTM #2.5	ASTM #7.0
2	ASTM #2.0	ASTM #5.0
3	ASTM #2.0	ASTM #5.0

A Microstructure evaluation was performed with the following results :

SERIAL #1:	Inside -	No grain boundary particles; twins
	Outside -	No grain boundary particles; twins
SERIAL #2:	Inside -	No grain boundary particles; twins
	Outside -	No grain boundary particles; twins
SERIAL #3:	Inside -	No grain boundary particles; twins
	Outside -	No grain boundary particles; twins

FORGING HEAT CODE / AREA ID	TENSILE STRENGTH	YIELD (.2%) STRENGTH	ELONGATION (IN 4D)
KP-1	78,758 PSI	34,068 PSI	45.4%
KP-2	78,973 PSI	36,037 PSI	44.2%

NOTE: .250" sub-size tensile specimens were used for testing per Customer's drawing.

A Grain Size examination was performed on the submitted Test Specimens in accordance with ASTM E-112, Comparison Method with the following results:

HEAT CODE / AREA ID	GRAIN SIZE
KP-1 (INSIDE)	ASTM #2
KP-2 (OUTSIDE)	ASTM #2

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TABLE #1 (continued)

A Microstructure evaluation was performed on the submitted Test Specimens with the following results:

HEAT CODE #KP: KP-1 (Inside) - No grain boundary particles;twins
KP-2 (Outside)- No grain boundary particles;twins

Next, the seven 3" 3000# SB564 NO4400 Tees of Heat Code "MA" were replaced by Tioga Pipe with seven tees of Heat Code "HW". Heat Code "HW" was produced from billet material supplied by a different melter but was forged by the original forger within the same parameters as Heat Code "MA" except that the finished forging temperature was dropped from 2150 Degree F. to 2050 Degree F. The temperature at which the 90 Degree Elbows Heat Code "KP" and the Tees Heat Code "MA" were forged was 2150 Degree F. Independent testing of the representative 3" Tee forging (1 forging of the 8 manufactured) is reflected in the results found in Table #2.

TABLE #2

HEAT CODE / AREA ID	TENSILE STRENGTH	YIELD (.2%) STRENGTH	ELONGATION (IN 4D)
CMTR RESULTS	83,500 PSI	36,000 PSI	44.0%
REQUIRED	70,000 PSI	25,000 PSI	35.0%
HW-3	76,351 PSI	31,164 PSI	44.0%
HW-4	76,212 PSI	31,864 PSI	43.2%

NOTE: . 250" sub-size tensile specimens were used for testing per Customer's drawing. CMTR results are from a forged test bar.

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TABLE 2 (continued)

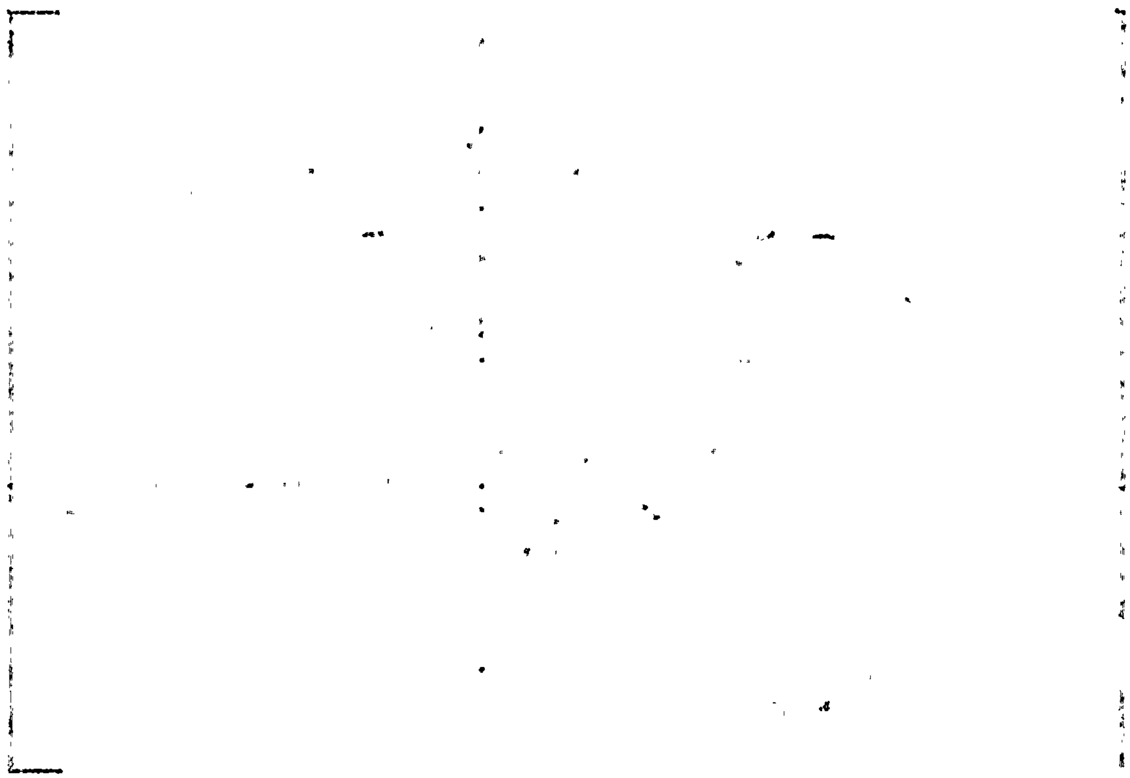
Microstructure evaluation was performed on the submitted Test Specimens with the following results:

HEAT CODE #HW:HW-4 (Inside) - No grain boundary particles; twins
HW-3 (Outside)- No grain boundary particles; twins

A Grain Size examination was performed on the submitted Test Specimens in accordance with ASTM E-112, comparison Method with the following results:

HEAT CODE / AREA ID	GRAIN SIZE
HW-4 (Inside)	ASTM #2
HW-3 (Outside)	ASTM #2

The forging manufacturer also tested a section of the same representative forging with the following results; Tensile Strength 78,000 PSI, Yield Strength (0.2%) 33,000 PSI, Elongation (4D) 41.0%, Specimen Size .252 round.



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Shown in Table #3 are the results of comparison Tension Tests performed by the forging manufacturer on a representative forged test bar and a production forging of the same Heat Lot. This testing was performed on SB564 NO4400 products of various sizes and configurations:

TABLE #3

HT CODE	TENSILE(PSI)	YIELD(PSI)	ELONGATION	FORGING	TEST BAR
54	84,500	38,000	47.0		(.505RD)X
54	82,000	34,000	43.0	(.255RD)X	
H1319	79,000	30,000	47.0		X
H1319	81,000	36,000	42.0	X	
GT	83,500	35,200	43.0		(.255RD)X
GT	80,500	34,800	42.0	(.253RD)X	
H1321	79,000	30,600	47.0		(.505RD)X
H1321	81,500	40,600	44.0	(.255RD)X	

The conclusions from the testing results contained in Tables 1, 2, and 3 are as follows:

A) All material tested met the material specification requirements.

B) Subsequent testing of production forgings and forged test bar for comparison testing of products would be inconclusive without first determining the parameters for size, configuration, temperature, and time at temperature.

C) Comparison results generally reflect that the supplied product is representative of the certifications. The Yield Strengths and Elongation generally vary less than the Tensile results. The variations in the Yield Strength may be attributed to working during machining of a test specimen. The Tensile results vary the least in Table #3.

Evaluation of the subsequent test results did not reveal any evidence that products other than the 3" 3000# SB564 N04400 Tees with Heat Code "MA" were defective. The forging manufacturer had reported that this had been the first time that fittings of alloy SB564 N04400 of this size, specification, and configuration had been manufactured by their company. In light of the above, the Root Cause Investigation then focused on the starting material and forging practices associated with these tees.

Florida Power & Light had already performed tension tests on one of the tees. The remaining six tees were returned by Florida Power & Light. These six tees and a tee solid were subjected to Grain Size Examination and Microstructure Evaluation for Tioga Pipe. The results of these tests are reported in Table #4. Note: Serial #7 is the solid tee forging. The serial numbers correspond to the serialized Tension Test Results in the Florida Power and Light Final Report.

TABLE #4

A Grain Size examination was performed on the submitted Test Specimens in accordance with ASTM E-112, Comparison Method with the following results: *Adjacent areas not photographed, Grain size 2 to 3.

SERIAL NO.	GRAIN SIZE INSIDE DIAMETER	GRAIN SIZE OUTSIDE DIAMETER
1	ASTM #0.5	ASTM #0.5
2	ASTM #1.0	ASTM #3.0
3	ASTM #1.0	ASTM #6.0*
4	ASTM #0	ASTM #1.0
5	ASTM #0.5	ASTM #1.0
6	ASTM #0.5	ASTM #0.5
7	ASTM #1.0	ASTM #1.0

A Microstructure Evaluation was performed on the submitted Test Specimens with the following results:

SERIAL #1 - #8 inclusive
Inside - Particles in boundaries; twins
Outside - Particles in boundaries: twins

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Subsequent testing of the solid Tee (Serial #7) with Heat Code "MA" was performed with variations on specimen location and orientation. The results of this testing is shown in Table #5.

TABLE #5

HEAT CODE/ AREA ID	TENSILE STRENGTH	YIELD (.2%) STRENGTH	ELONGATION (IN 4D)
REQUIRED	70,000 PSI	25,000 PSI	35.0%
MA-1	*67,143 PSI	33,126 PSI	*22.0%
MA-1 (Retest)	*68,657 PSI	31,263 PSI	*20.2%
MA-3	75,865 PSI	33,797 PSI	39.0%

*Under minimum specification requirements.

NOTE: .250" sub-size tensile specimens were used for testing

A Grain Size examination was performed on the submitted Test Specimens in accordance with ASTM E-112, comparison Method with the following results:

HEAT CODE/ AREA ID	GRAIN SIZE
MA-3 (Inside)	ASTM #1
MA-1 (Outside)	ASTM #2

A Microstructure evaluation was performed on the submitted Test Specimens in accordance with Customer's instructions with the following results:

HEAT CODE #MA: MA-3 (Inside) - Grain boundary particles; twins
MA-1 (Outside) - Grain boundary particles; twins

An initial SEM/EDS Examination was performed by Florida Power and Light as part of their Failure Analysis. This Examination found a high sulphur content on the surface of the cracked area of the forged tee. Quantitative chemical analysis were acceptable.

Also, an initial SEM/EDS Examination was performed by an independent lab on behalf of the material melter on a portion of the forged tee identified as Serial Number 2. This Serial Number was found, by the forging manufacturer, to exhibit a deep crack. The examination found debris at the crack enriched with SN, C, O, SI, and AL.

Only after a Visible Dye Penetrant Examination had been performed on Serial Number 5 was a significant indication found. This indication was visually examined and determined to be a through the wall crack. Subsequent SEM/EDS Examination was performed by the material melter's independent laboratory on a portion of this specimen. Also, this same laboratory evaluated the mounted specimens and the broken tension specimens previously identified as Serial Numbers 6 and 7 which were supplied by Tioga Pipe. Serial number 5 and 6 represented low tension results and Serial Number 7 represented acceptable tension results. The written results of these examinations as summarized by the material melter are quoted, in part, herein:

> "We examined fracture surfaces from forging #5 as well as tensile test fractions from forgings #5, #6, and #7. We also examined micros obtained from forgings #6 and #7 from Tioga Pipe but the particles observed at grain boundaries turned out to be pits, apparently from etching, so no identification could be made.
>
> The EDS evaluation of the fracture surface of forging #5 agrees with the Florida Power & Light findings of sulfur. The alloy's content of sulfur was very low and besides we are unaware of any tendency of sulfur to migrate to grain boundaries so it seems likely that this came from an outside source.

The EDS of the tensile specimen fractures shows elevated aluminum and silicon which is puzzling since no significant aluminate or silicate inclusions have been seen in any of the microscopic specimens examined. Again, these are elements that are not expected to migrate to grain boundary locations. This alloy does contain significant aluminum and silicon levels.

The carbides found in the grain boundaries would be the result of the thermal history of the forging. We do not believe that the presence of carbides at grain boundaries is significant to the problem.

...At this time we do not feel that this testing has shed any new light on the problem. Since we did not find any evidence of tin in these samples, it would appear that our original results may have been due to contamination."

In an excerpt from the material melter's independent laboratory, the following characterization of particles found are stated herein:

"The particles are of at least two types. The larger particles (which were seen on all of the fracture surfaces examined) are on the order of 2-4μ in diameter and are thought to be carbides. This spectrum indicates elevated levels of carbon, and perhaps, Fe, when compared with a spectrum of the metallic matrix. The second type of particle, which was encountered on the fracture surface of the low ductility tension specimen, contains elevated levels of Si and Al. These particles are usually smaller than the carbon-rich particles, on the order of 2μ and less in diameter. Also .... a spectrum was taken of a large area of the low ductility tensile fracture surface. This spectrum indicates elevated levels of Sl and Al on this surface. The microstructure of this fracture surface exhibits many small fracture nucleation sites which presumably contain particles. These particles are very small and were not able to be probed to obtain meaningful EDS data.

These data suggest to me that there may exist a grain boundary film that is causing reduced ductility in this material. I am unable to characterize the suspected film beyond the suggestion that it may contain elevated Si and Al."

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Since, in the Summer of 1991, the material melter decided for commercial reasons to no longer produce this alloy, no further Corrective Action by the melter, if needed, can be taken at this time.

Based on the results of the examinations, Tioga Pipe cannot document that the Root Cause of the problem was due to raw material defects. Therefore Tioga Pipe concurs with the Florida Power and Light conclusion that the forging process may have been conducted improperly.

The forging manufacturer contends that raw material defects are the Probable Cause and believes this contention can be supported by their interpretation of the objective evidence.

Addressing Corrective Action to preclude reoccurrence, the forging manufacturer has committed to the following actions:

1) "Forging temperatures for Monel 400 have been reduced to 2050 Degree F. max rather than 2150 Degree F. max. This will reduce the grain size and preclude the possibility of localized overheating.

2) To avoid the possibility of detrimental imperfections - for example those exceeding ASME SA182 Section 11 - All Nuclear Monel 400 fittings will be liquid penetrant inspected according to Ideal procedures."

Tioga Pipe Supply considers these Corrective Actions as effective measures and believes such measures should help to preclude the reoccurrence of this type of defect. Since there does not appear to be any direct correlation between (a) maximum grain size and product specification conformance or (b) tensile testing of a forged test bar vs. tensile testing of a production forging and product specification conformance, the invocation of such additional requirements would not be effective as an overall solution for all sizes and configurations.

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Although an absolute documented Root Cause may never be established to the satisfaction of all concerned, the actions taken to isolate this problem and preclude reoccurrence address and follow acceptable quality practices. Unless additional concerns develop subsequent to this Report that may have an effect on these conclusions, Tioga Pipe considers this investigation closed, with no further action required other than verification of implementation of Corrective Action.

If there are any questions on this Report, please contact the undersigned.

Douglas M. Vickery
Quality Assurance Manager

DMV:bd

cc: Florida Power and Light - Jon Priolo
Alloy Stainless Products - Annemarie Appleton
Ideal Forging - Jim Oberholtzer
Slater Steel - Daniel Schram