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JUL 1 9 1982

50-289

MEMORANDUM FOR: Rick Jacobs
Operating Reactors Branch #4
Division of Licensing

FROM: Conrad McCracken, Section Leader
Chemical Engineering Branch
Division of Engineering

SUBJECT: DOCUMENTS RECEIVED FROM GPUN, ASSOCIATED WITH TMI NO. L S.G. REPAIRS

Enclosed are two documents which I received as a result of the June 15, 1982 meeting in Parsippany.

1. OTSG tube repair specification "preliminary" 1101-22-006 6/11/82

2. Explosive expansion qualification requirements 61-11134292-00 6/2/82

Both of these documents are subject to change but were provided to FRC for use in their preliminary review effortt. By copy of this memo, I am distributing these two documents our othersstaff reviewers and consultants are placing them in the PDR.

All documents provided to me by GPUN are now in the PDR. In the future, I will distribute all documents received to the same distribution listed in this memo.

Conrad McCracken, Section Leader
Chemical Engineering Branch
Division of Engineering

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UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

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PRELIMINARY

GPU Nuclear

SPECIFICATION NO. 1101-22-006

TITLE: OTSG TUBE REPAIR

REV	SUMMARY OF CHANGE		APPROVAL	DATE
	Paragraph	Change		
1	All Pages	Changed specification number from SP-1101-22-0006 to 006 to reflect correct numbering system.	[signature] H W Zitzelsberger [signature]	6/11/82 6/11/82
	3.6.2	Add a cross reference to the electrochemical tests defined in paragraph 4.6.2.	[signature]	6/11/82
	3.8.2	The long term design life goal is revised from 40 years to 35 years to reflect the fact that TMI-1 has already operated about 5 years.	[signature]	6/11/82
	3.10.2	Added the word qualification to clarify the intent.	[signature]	6/11/82
	3.10.3	Deleted the requirement to hold for witnessing results. Witness points will be established but it will not be necessary to holdup work.	[signature]	6/11/82
	4.3.2	Added requirement for some pullout load testing at elevated temperatures.	[signature]	6/11/82
	4.4.5	Changed I.D. to 10 to correct typographical error.	[signature]	6/11/82
	4.6.1	Changed contaminants concentrations for crevice corrosion tests and added several additional samples.	[signature]	6/11/82
	4.6.2.1	Deleted the hard roll-over, a kinetically expanded transition since this is not part of reference design.	[signature]	6/11/82
	Table 1	Corrected a typographical error in that the cycles in right hand column are for 40 years rather than 35 years.	[signature]	6/11/82
	3.9.1	Acceptable contaminant levels and expanded contaminant listing to differentiate between fluids used for final cleaning, other fluids and solid materials.	[signature] B Clam [signature]	6/11/82 6/11/82

PRELIMINARY

GPU Nuclear	Short Form Specification	SP 1101-22-006	Rev 1
Spec. Title OTSG TUBE REPAIR		QA Concur GPUN HWZitzelsberger 06-11-82	Page 1 of 17
Project Title TMI-1 OTSG TUBE REPAIR	Task No. N/A	Prepared by/Date AE GPUN [signature] 6/11	Approved by/Date AE GPUN B. Elam 6/11/82

1. BACKGROUND

1.1 OTSG tube leaks have been found at TMI-1. Failure analysis has resulted in the conclusion that sulfur contamination caused intergranular attack of the TMI-1 OTSG tubes. The attack is inside diameter initiated and circumferential in geometry. The majority of the cracking has been located by EDDY Current Testing (ECT) in the upper end of the Inconel 600 tube at or near the weld heat affected zone (HAZ) and the roll transition. Since the failure analysis results continue to indicate that the areas of tubes free of ECT indications can be successfully returned to service, a repair process has been selected which kinetically expands the existing tube against the upper tubesheet hole. The objective is to expand the OTSG tube with sufficient length below any defects to form a new load carrying and essentially leak tight joint.

2. SCOPE

2.1 This specification is written to define the performance requirements for the OTSG tube repair. It also includes the performance requirements for the tube repair process qualification program. It is likely that all tubes which will remain in service in both OTSG's will be kinetically expanded within the upper tubesheet by the repair process regardless of whether or not they are cracked. The total number of tubes to be expanded is approximately 31,000. The design life of the tube repair will be based on the qualification program.

2.2 One objective of the qualification program is to statistically demonstrate that the repair process provides adequate leaktightness and strength. Target confidence levels and probabilities are provided herein for these parameters as goals to enable GPUN to achieve this objective.

3. OTSG TUBE REPAIR

3.1 Steps/Sequence

The TMI-1 OTSG repair process is as follows. It should be recognized that Step 2 may become a part of Step 6 pending the outcome of preliminary qualification testing.

Step	Description
1	Flush the secondary side tube to upper tubesheet crevice.
2	Clean tube inside diameter in the area of the repair.
3	Heat crevice to drive out moisture (vaporize water).
4	Maintain crevice in the repair area at a temperature at least 10°F higher than the dew point for OTSG secondary side conditions.
5	Kinetically expand tubes.
6	Cleanup debris from kinetic expansion.
7	Leak test OTSG.
8	Roll/flush (if required to repair leaking tubes).

3.2 Codes and Standards

3.2.1 The repair shall satisfy all applicable design parameters originally used for the TMI-1 OTSG. The applicable steam generator design parameters shall be extracted from the TMI-1 Steam Generator Functional Specification CS(F)-3-33/NSS-5/0369 dated 5/15/70 and Appendices and the General Functional Specification for R.C. System Components for TMI-1 CS(F)-3-9/2NSS-5-0770 dated 7/15/70 and Appendices. In addition, the TMI-1 OTSG Stress Report and TMI-1 FSAR shall be used to confirm that the applicable design parameters have been identified.

3.2.2 The repaired tube is a Seismic Category I component in accordance with Regulatory Guide 1.29 and a Class I component in accordance with Regulatory Guide 1.26. The Seismic boundary for the expansion is the steam generator tube up to and including the bottom 4" of the new expansion and the OTSG tubesheet.

3.2.3 ASME B & PV Code as follows:

Section III - "Rules for Construction of Nuclear Vessels", including Addenda thru Summer 1967, and applicable Code Cases as of June 30, 1967, for Class A Vessels (or later).

Section XI - 1974 Edition thru 1975 Winter Addenda (or later), Applicable sections of Article IWA 4000 - "Repair Procedures".

3.2.4 10 CFR 21 - "Report on Defects and Non-Compliance".

3.2.5 10 CFR 50 - Appendix B "Quality Assurance Criteria for Nuclear Power Plants".

3.2.6 ANSI N45.2.1 - 1980 "Cleaning of Fluid Systems and Associated Components for Nuclear Power Plants".

3.2.7 ANSI N45.2.6 - 1978 "Qualification of Inspection, Examination and Testing Personnel for Nuclear Power Plant".

3.3 OTSG/Plant Performance

3.3.1 The effects of both repaired and plugged tubes on the thermal and hydraulic performance of the plant and on the structural and vibrational adequacy of the steam generator shall be evaluated and shall be within the acceptance criteria for both normal operating and design basis accident conditions as specified in the licensing basis documents.

3.4 Repair Location/Length

3.4.1 The tubes will be kinetically expanded from the top surface of the upper tubesheet to 10 ± 1/4" below the top surface of the upper tubesheet. There will be a full expansion over this length with the exception of transition zones at either end. The transition zones can be included in this overall expansion length.

3.4.2 The repair configuration shall accomodate future sleeve installation.

3.5 Load Conditions

3.5.1 The expansion shall be designed to the loading conditions stated herein and the documents referenced in paragraph 2.1. The loading conditions to be considered shall include: operating pressure; thermal stresses; flow induced vibration; seismic accelerations and displacements; and faulted conditions such as loss of coolant (LOCA) and main steam line break (MSLB). The stress limits in Section III of the ASME B & PV Code shall be used for the load combinations/ conditions specified.

3.5.2 The repaired tube shall sustain the maximum design basis axial tensile load of 3140 lb from the generic 177 FA MSLB accident analysis. Since this is a thermally induced load, satsfying this criteria requires no relative movement (slippage) between the expanded area and the tubesheet at the axial strain corresponding to this load (about .0016 in/in). However, GPUN wants to avoid (if possible) taking credit for conservatisms in the TMI-1 design basis. BAW-1588 assumes the tube responds in a purely elastic mode to arrive at the 3140 lb load and this load is retained as the design objective. Satisfying this objective requires no slippage at 3140 lb load.

3.5.3 The repaired tube tensile preload shall not be changed by more than ± 30 lbf at ambient temperature. Previous test data and analysis may be utilized to satisfy this design objective.

3.5.4 Analysis will be performed to confirm that the repair process does not result in tubesheet stresses or bowing that are not in compliance with the design parameters of the OTSG.

3.6 Transition Stresses

3.6.1 One design objective is to minimize tensile stress in the transition region between the expanded and unexPanded portions of the tube. Since an abrupt transition results in higher residual stresses and larger stress concentrations, it is required that the transition length be greater than 0.1". A transition length between 1/8" and 1/4" has been established as a goal. The transition zone will be established by the qualification program.

3.6.2 An additional objective of maintaining residual tensile stresses (both circumferential and axial) in the transition less than 45% of the .2% offset yield stress at room temperature has been established. Once the geometry and charge loading of the kinetically expanded inserts to be used at TMI-1 has been established by preliminary qualification testing, residual stress measurements of the transition region will be documented during the qualification program. The electro chemical tests defined in paragraph 4.6.2 with 10% caustic solution will also provide evidence of acceptably low residual tensile stresses.

3.7 Leakage

3.7.1 A design objective for the kinetic expansion is to produce a joint which will limit total primary to secondary leakage from the TMI-1 OTSG's to 1 lb/hour or less under plant operating conditions. In order to achieve this objective, it is our goal to demonstrate the capability to produce joints under laboratory conditions whose aggregate leakage would be less than .1 lb/hour if extrapolated to all repaired tubes (approximately 31,000). It is recognized that this is a very stringent requirement, especially considering the fact that a significant percentage of the tubes do not have through wall defects. However, concerns over future crack propagation in the expanded area are minimized if our goal is met.

3.7.2 The leakage design criteria is that the maximum allowable primary to secondary leakage rate for normal operation shall be as low as reasonably achievable and allow plant operation within the radioactive effluent limit of the TMI-1 Technical Specifications.

3.8 Repair Life/Cyclic Loading

3.8.1 The initial design life objective for the tube kinetic expansion is 5 years. Sufficient cyclic testing and/or analysis will be performed during the qualification program to satisfy this objective. The key transient parameters which can affect the joint integrity (such as thermal cycling) will be tested as part of the qualification program. The range of key transient parameters and number of cycles will be based on those used in the original design. The rate of change of the key parameters can be greater than the rate of change which will be experienced inservice for the entire plant as long as the rate of change experienced by the joint being qualified does not expose it to a strain which is unrepresentative of in service conditions.

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3.8.2 A design life of 35 years has been established as a goal. The qualification program will include test specimens for cyclic testing to a 40 year life separate from those used to qualify the repair for 5 year life. These specimens can be tested in parallel or in series with the 5 year life specimens. These specimens will be tested using the same key parameters but with greater numbers of cycles in order to satisfy the 40 year life goal.

3.8.3 A summary of the transient cycles to be used from OTSG Functional Specification CS(F)-3-33 is attached as Table 1. Thermal transients with a range and rate equivalent to the transient cycles identified will be included in the qualification program. Where the identified transients produce thermal transients which cause an insignificant effect on joint integrity than others already being tested, the qualification program may rely on analysis for repair qualification.

3.8.4 Thermal cyclic conditioning shall include the following for the 5 year life:

30 heatup/cooldown cycles 70°-610°-70°
8 reactor trip cycles 70°-610°-70°

In order to ensure that the joint is not subject to plastic strain unrepresentative of in service conditions, the T between tube and tubesheet shall be maintained at equal to or less than 100°F during cyclic thermal testing. In addition, the rate of temperature change of the tubes shall not exceed 10°F/min.

One (1) Stuck open turbine bypass valve cycle 600-400°F in 10 minutes or one (1) MSLB thermal cycle if it is a more severe cooldown transient (B&W to determine). The maximum T between the tube and tubesheet shall be maintained at 0°F to 30°F greater than that expected in service.

3.8.5 The analysis for cyclic life will include a quantitative evaluation of the differential thermal growth expected between the tube and tubesheet in the repaired area. The evaluation will consider the possibility of relaxation of the contact pressure between the tube and tubesheet during thermal cycles. If more stringent operational limits are required, they will be recommended.

3.9 Cleanliness

3.9.1 The steam generator and reactor coolant system cleanliness shall be maintained. The kinetic expansion process shall not expose the inside of the steam generator to the following levels of contaminants.

For fluids to be used for final cleaning of OTSC primary surfaces:

sulfur	1 ppm maximum
halogens	1 ppm maximum total
heavy metals (Pb, Cd, Hg, etc.)	0.1 ppm maximum

For other fluids (lubricating oils, flush water, etc.) which will be followed by a solvent surface cleaning prior to operation:

sulfur	100 ppm maximum
halogens	100 ppm maximum total
heavy metals	1 ppm maximum

For solid materials (gaskets, seals, etc.) the levels for total contaminants shall be as follows:

sulfur	200 ppm maximum
halogens	200 ppm maximum
heavy metals	1 ppm maximum

Criteria for final cleaning fluids are based on acceptable levels of contaminants per ASTM Boiler & Pressure Vessel Code, Section V, Paragraph T-644 in liquid penetrant materials.

The presence of trace contaminants down to 100 ppb will be documented for materials used in the kinetic expansion process. Subsequent testing to determine leachability may be required by GPUN. The documentation will be provided for GPUN approval to use the material. This documentation will be mass spectrographic analysis of samples from each lot of material. In both cases a material control program with quality controls is required to confirm that material is not introduced inside the steam generator without assurance that its constituents are known and acceptable.

3.9.2 Compounds such as oils, grease, coatings, cleaning fluids and cleaning devices, rubber and plastics which contain sulfur and chlorides and other halogens shall not be present on the final cleaned surfaces of components which are exposed to reactor coolant.

3.9.3 Materials (such as neoprene rubber) compounded from chemical compounds containing halides or sulphur are prohibited.

3.9.4 Chlorinated solvents are prohibited.

3.9.5 The use of cloth, paper or cardboard products for temporary plugging and capping purposes is prohibited. Lint-free cloth may be used for wiping/cleaning.

3.9.6 Polyvinylchloride compounds, fluorocarbon compounds or teflon shall not be used in the R C system.

3.9.7 Lubricants or other materials used on components exposed to reactor coolant shall be the acceptable material for nuclear service.

3.9.8 Following completion of the repair process, the OTSG will be cleaned to Class B cleanliness in accordance with ANSI N45.2.1 -- 1980.

3.10 Quality Assurance Requirements

3.10.1 The contractor shall have a GPUNC approved quality assurance program which meets the requirements of 10 CFR 50, Appendix B.

3.10.2 Qualification work performed at Contractor's locations shall be performed in accordance with a Quality Assurance Program approved by GPUNC.

3.10.3 Contractor shall submit the qualification specification and procedures for GPUNC approval and coordinate with GPUNC QA to establish witness points for the proposed qualification program.

3.10.4 The results of analysis, design calculation, and testing activities shall be documented.

3.10.5 Documents and records which provide evidence that a task was performed in accordance with code requirements and this specification shall be provided to GPUNC.

3.10.6 GPUNC reserves the rights of reasonable access to Contractor's or its subcontractor's facilities and the QA activities performed at contractor or subcontractor locations related to the qualification tests as specified in this specification.

3.10.7 All records shall be of legible quality.

3.10.8 Personnel performing testing and inspection activities shall be qualified in accordance with ANSI N45.2.6 - 1978.

3.10.9 Submit QA program with proposal or identify the program if previously sumitted.

3.10.10 Contractor shall provide a listing of the documents to be submitted to GPUN as part of their proposal.

4. OTSG Tube Repair Qualification Program

4.1 Intent/Philosophy

4.1.1 The overall intent of the qualification program is to perform sufficient analysis and statistically based testing to result in a high degree of confidence that the kinetic expansion process will satisfy the design objective/criteria.

4.1.2 The overall philosophy of the qualification program is to test independent affects separately whenever practicable and to rely on previous analytical or empirical data when it can be correlated to the TMI-1 repair process.

4.2 General Testing Requirements

4.2.1 An evaluation of the fabrication, operating history, TMI-1 Failure Analysis data and repair process steps/sequence will be conducted to determine key material paremeters or conditions to be simulated in the qualification program. Parameters to be simulated or bracketed include but are not necessarily limited to:

- corrosion in the tubesheet crevice since the crevice surface condition can affect joint integrity.

- temperature conditions expected in the crevice during repair.

- the tubing to be used for qualification testing will be subject to the OTSG fabrication stress relief temperatures for sufficient time to result in residual stress and material properties comparable to the tubing installed in the TMI-1 OTSG.

- tube strength (yield stress) and clearances, tubesheet to tube and tube to kinetic expansion insert. In this case it may be possible to select the most adverse combination and test it vice bracketing the variance.

- sequentially expanding adjacent tubes.

4.2.2 A 4" length of kinetically expanded tube is to be qualified for leak tightness, load carrying capability and any other design requirements where minimum joint length results in the most adverse condition. This length will enable us to repair tubes with defects from 0" to 6" below the upper face of the upper tubesheet using the 10" long kinetic expansion insert.

4.3 Load Testing

4.3.1 The test program objective is to document with 99% probability at a confidence level of 99% that the kinetically expanded 4" long joint being tested meets the load carrying requirements. The pullout load capability for qualification purposes is to be documented subsequent to cyclic and leak-rate testing. The various thermal cyclic transients required will be conducted in series prior to pullout load testing. Pullout load is defined as the first indication of relative motion between the joint and the tubesheet as indicated by a decrease in the applied load caused by tube movement.

4.3.2 The pullout load testing will include the following:

- Determine pullout loads for tube joint specimens at ambient temperatures and at elevated temperatures for some of the samples.

- Determine stress-strain curve for each group of pullout load specimens by using specimens from the same tube.

- Evaluate each pullout load test to verify that the axial strain at pullout exceeds the maximum axial strain for MSLB.

- Determine pullout loads for 10 joint specimens which have not been thermally cycled. This data will be compared to that obtained after thermal cycling.

- Tubes in each test block will be expanded sequentially to simulate the OTSG installation sequence.

4.3.3 The pullout load test profile is as follows:

- Condition and heat treat material.

- Kinetically expand tube.
- Apply a proof axial load of 300 lbf to all joint specimens.
- Determine pullout loads/strain for 10 joint specimens
- Thermally cycle remaining joint specimens
- Bubble test joint specimens at a secondary to primary ΔP of 125 psi using N_2. Make a video record of any bubbles noticed visually.
- Leak test joint specimens (Assuming same specimens are being used for leaktightness).
- Determine pullout loads for 10 joint specimens at elevated temperatures (300 - 500°F: preferably as high as praticable).
- Determine pullout loads/strain for 30 joint specimens at ambient temperature.

4.3.4 Pullout load tests will be conducted on at least 6 samples whose crevice corrosion condition is different than the crevice being tested. The intent is to document for later statistical consideration how critical the crevice condition is with regard to pullout load capability. An uncorroded crevice, a less corroded crevice and a more corroded crevice will be tested. Key parameters that are known (such as tubesheet and tube material, gun drilled holes) will be maintained the same as the qualification test pullout specimens.

4.4 Leakage Testing

4.4.1 The test program objective is to document with 99% probability at a 99% confidence level that the kinetically expanded 4" long joint being tested will have leakage less that 3.2×10^{-6} lb/Hr-tube at operating conditions (primary temperature 604°F, primary pressure 2155 psig, and secondary pressure 925 psig). The leak rate can be determined based on pressure decay of a know volume test system at constant ambient temperature. The leak rate thus determined will be corrected to that expected at operating conditions. It is recognized that this is a more severe test than testing at elevated temperatues since differential thermal growth between the inconel tube and tubesheet should actually result in a more leaktight joint at high temperatures.

4.4.2 During the leakrate testing an initial period of time will be allowed for the joints to "season" in recognition of the fact that tight mechanical joints of this nature tend to self seal with time. The amount of time allowed for "seasoning" will be determined empirically during the test program by plotting pressure decay (leakrate) versus time. Qualification record data will commence when there is a noticeable rate reduction (knee formed) in the leakrate versus time curve or after 3 days (whichever comes first). The differential pressure used during leakrate testing will start out high enough so that the average ΔP during the expected test duration will be comparable to the normal operating ΔP of 1275 psi.

4.4.3 The number of tubes tested will initially be at least 30 with statistical analysis identifying whether or not more samples are needed. If additional samples are needed, they can be taken from the 40 year test specimens as a timely first source. The leak test duration will be that required to reduce the measurement error to a value which will enable us to satisfy the statistical objective.

4.4.4 A ten tube sample will be leak tested following completion of approximately 10% of the required thermal cycles or after 1 week of cycling,whichever comes later. The results from this leak test are intended to provide reasonable assurance that the leakage objective will be met, These testing results may also be used in describing status to the ACRS/NRC or third party review group.

4.4.5 10 samples will be leak tested with a secondary to primary ΔP of 1275 psi. 10 samples will be leak tested with a primary to secondary ΔP of 2500 psi.

4.5 Impurities

4.5.1 The residue remaining following kinetic expansion will be identified quantitatively by Auger. An assessment of whether or not this residue will deleteriously affect the OTSG tubes will be documented. A subsequent optical (SEM) evaluation of residue remaining following the cleanup process to be used in Step 6 will be documented to confirm the adequacy of the process selected. An optical evaluation is acceptable assuming there are no trace contaminants which require more stringent cleanup limits based on concentration per unit area. In addition, optical evaluation or the organic polyethylene residue is required since it cannot be identified quantitatively as a polymer.

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4.6 Corrosion Testing

4.6.1 Secondary side crevice corrosion tests will be conducted to assess the corrosive effects of heat-up of the secondary side crevice in the presence of contaminants. This heatup is planned to dry the crevice prior to expansion.

4.6.1.1 Two phases of testing will be conducted using the following initial conditions:

- Specimen: Tube/tubesheet mockup with Inconel 600 tubes and carbon steel tubesheet (17" thick). Duplicate specimens to be run for each test solution. Tubes to be model boiler tubes.
- Temperature: Ambient - 350°F Heat up until crevice dries out (4 days minimum).
- Solutions: The annuluses between the tubes and tubesheet will be filled with the following solutions:

Tube No.	B (ppm)	SO_4^- (ppm)	Cl^- (ppm)	N_2H_4 (ppm)	$S_2O_3^=$	Li^+	FeS
1	-	880	1	200	-	-	-
2	-	100	1	200	-	-	-
3	-	10	1	200	-	-	-
4	2350	880	1	200	-	.6	-
5	2350	10	1	200	-	.6	-
6	-	-	1	200	10	-	-
7	2350	-	1	200	10	.6	-
8	-	-	1	200	-	-	810
9	-	-	-	200	-	-	-

4.6.1.2 The test sequence for Phase I is as follows:

- All tubes are to be initially hard rolled at the tubesheet face to seal the crevice at one end.
- With the tubesheet upside down, the secondary side crevices shall be filled with the above solutions: two tubes to be filled with eech solution.

- Thermocouples shall be attached to the tubesheet and several tubes to monitor temperature profile.
- Heat the tubesheet using thermal blankets to 350°F. Heat-up rate shall duplicate the anticipated heat-up rate for the actual generator tubesheet heat-up prior to repair.
- Hold at temperature for 4 days minimum or until all fluid has evaporated out of the crevices.
- Cool down and remove one of each of the pairs of test specimens.
- Conduct metallurgical investigation on samples.
- Proceed to Phase II.

4.6.1.3 Phase II testing will be performed on the remaining tube samples in the tubesheet. The test sequence for Phase II is as follows:

- Kinetically expand the remaining tubes using techniques developed for the repair process.
- Place expanded tube/tubesheet sample in an autoclave.
- Subject sample to secondary side steam environment cycling the temperature from 170°F to 600°F using typical OTSG heat-up and cool-down ramps. Run through 5 cycles.
- Cool down to ambient and remove samples for metallurgical investigation.
- Examine condition of all tubesheet crevices for evidence of tubesheet damage.

4.6.2 Primary and secondary side electrochemical tests will be conducted to evaluate the effects of roller/explosive expansion on the generator tube material susceptability to stress corrosion cracking and compare this with existing data on tubes which have been stress relieved after expanding.

4.6.2.1 The electrochemical tests initial conditions are as follows:

Specimens: Tube/tubesheet mock-ups using Inconel 600 archive material and Inconel 600 tubesheets in the following conditions:

- Kinetically expanded only.
- Kinetically expanded with hard roll within 3" of the end of expanded region but not over the kinetic expansion transition.

4.6.2.2 The tests to be conducted are as follows:

Test 1:	Temperature:	550°F
	Solution:	Secondary chemistry plus 10% NaOH
	Duration:	5 days maximum
	Potential:	Cracking potential
Test 2:	Temperature:	170°F
	Solution:	B - 2350 ppm Li - .6 ppm S_2O_3 - 100 ppm
	Duration:	5 days maximum
	Potential:	Cracking potential
Test 3:	Temperature:	170°F
	Solution:	B - 2350 ppm Li - .6 ppm S_2O_3 - 10 ppm
	Duration:	5 days maximum
	Potential:	Cracking potential
Test 4:	Temperature:	170°F
	Solution:	B - 2350 ppm Li - .6 ppm S_2O_3 - 1 ppm
	Duration:	5 days maximum
	Potential:	Cracking potential

Test 5:	Temperature:	170°F
	Solution:	B - 2350 ppm
		Li - .6 ppm
		S_2O_3 - 1 ppm
	Duration:	5 days maximum
	Potential:	Cracking potential
Test 6:	Temperature:	130°F
	Solution:	B - 100 ppm
		Li - .6 ppm
		S_2O_3 - 1 ppm
	Duration:	5 days maximum
	Potential:	Cracking potential
Test 7:	Temperature:	550°F
	Solution:	B - 100 ppm
		Li - .6 ppm
	Duration:	5 days maximum
	Potential:	Cracking potential

4.6.2.3 At the completion of each test, all samples are to be evaluated for evidence of cracking. Samples not exhibiting visual cracks shall be examined by metallography/bending techniques.

TABLE 1

Operating Transient Cycles

Transient Number	Transient Description (ASME Category)			Design Cycles 5 YEARS	Design Cycles 40 YEARS
1A	Heatup from 70°F to 8% Full Power	(Normal)		30	240
1B	Cooldown from 8% Full Power	(Normal)		30	240
2	Power change 0 to 15% and 15 to 0%	(Normal)		180	1,440
3	Power Loading 8% to 100% Power	(Normal)		6,000	48,000
4	Power Unloading 100% to 8% Power	(Normal)		6,000	48,000
5	10% Step Load Increase	(Normal)		1,000	8,000
6	10% Step Load Decrease	(Normal)		1,000	8,000
7	Step Load Reduction (100% to 8% Power)	(Upset)			
	Resulting from turbine trip		20		
	Resulting from electrical load rejection		20		
	Total			40	320
8	Reactor Trip	(Upset)			
	Type A		5		
	Type B		20		
	Type C		11		
	Trips included in transient numbers 11, 15, 16, 17 and 21		14		
	Total			50	400
9	Rapid Depressurization	(Emergency)		5	40
10	Change of Flow	(Upset)		3	24
11	Rod Withdrawal Accident (Upset)	(Upset)		5	40
12	Hydrotests	(Test)		3	24
13	Steady-State Power Variations	(Normal)			
14	Control Rod Drop	(Upset)		5	40
15	Loss of Station Power	(Upset)		5	40
16	Steam Line Failure	(Faulted)		1	1
17A	Loss of Feedwater to One Steam Generator	(Upset)		3	24
17B	Stuck Open Turbine Bypass Valve	(Emergency)		1	8
18	Loss of Feedwater Heater	(Upset)		5	40
19	Feed and Bleed Operations	(Normal)		5,000	40,000
20	Miscellaneous A	(Normal)		3,750	
	Miscellaneous B			2,500	
	Miscellaneous C			5×10^5	
21	Loss of Coolant	(Faulted)		1	1
22	Test Transients - High Pressure Injection System	(Test)		5	40
	Core Flooding Check Valve			30	240
23	Steam Generator Filling, Draining, Flushing and Cleaning	(Normal)			
	Steam Generator Secondary Side Filling				
	Condition 1		15		
	Condition 2		15		
	Steam Generator Primary Side Filling				
	Condition 1		15		
	Condition 2		15		
	Flushing		5		
	Chemical Cleaning		3		
	Total			68	544
24	Hot Functional Testing	(Test)		1	8

1

Babcock & Wilcox
a McDermott company

Nuclear Power Generation Division
3315 Old Forest Road
P.O. Box 1260
Lynchburg, Virginia 24505-1260
(804) 385-2000

June 15, 1982
GPUN-82-158

6/18/82
CC: TO
R. JACOBS
J. RAJAN

Mr. D. G. Slear
TMI-1 Project Engineering Manager
GPU Nuclear
100 Interpace Parkway
Parsippany, N.J. 07054

Dear Mr. Slear:

In accordance with your request during our telephone conversation on June 15th, the attached material has been forwarded to Lawrence Leonard, FRC, and to Conrad McCracken, USNRC.

Very truly yours,

J. F. Pearson, Jr.
TMI-1 OTSG Recovery
Program Manager

JFP/dsv
Attachment

cc: R.E. Kosiba
R.J. Baker
L.J. Stanek
M.H. Fish
J.R. Concklin

ATTACHMENTS:

Drawing No. 1134900, Induced Strain Test Mockup, dated 5/21/82

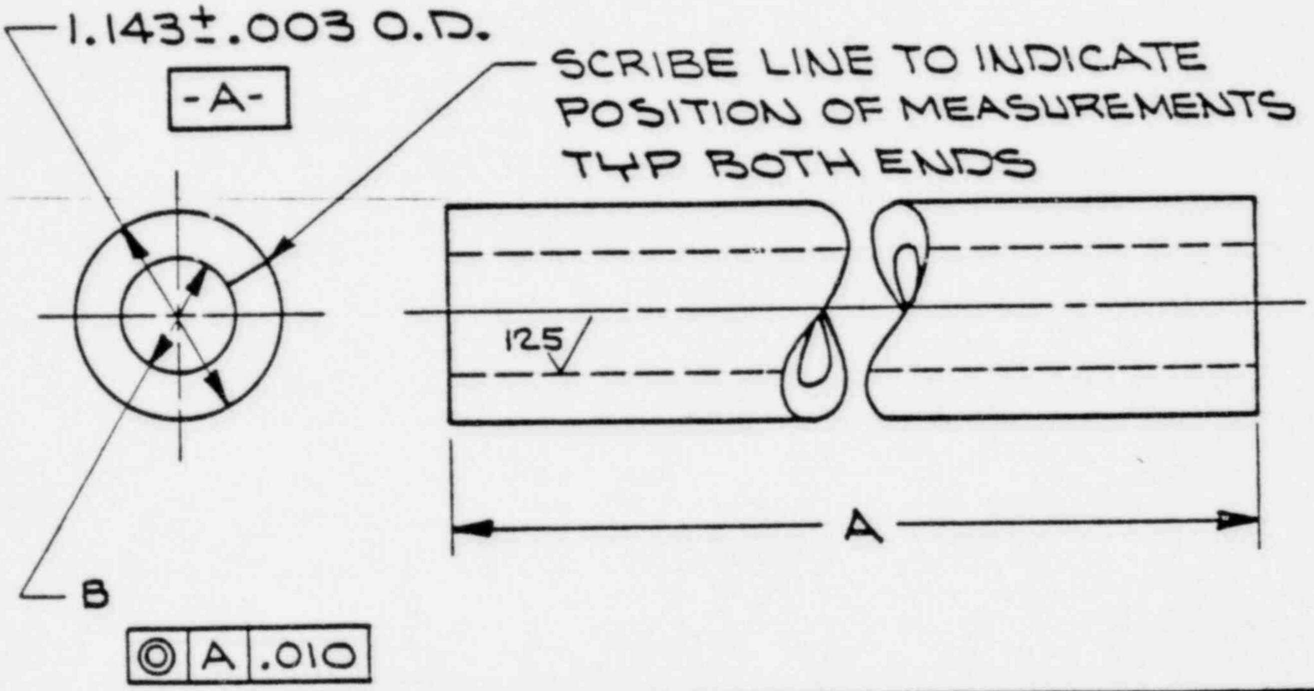
Explosive Expansion Qualification Requirements for Mechanical Testing, 61-0034292-00, for Explosive Expansion Repair of TMI-1 OTSG's

Drawing No. 1134899 D, Rev. 2, 10 Tube Leak and Load Test Fixture

THE BABCOCK & WILCOX COMPANY

POWER GENERATION GROUP

REVISIONS			MICRO-FILM
DASH NO.	DATE	DESCRIPTION	ORIG.
1	5-?-81	ADDED "B" DIM.	
		[illegible]	



TEST	A	B	QUAN.
RESIDUAL STRESS	6 ± 1/32	.644 ± .001	8
INDUCED STRAIN	12 ± 1/16	.644 ± .001	5
INDUCED STRAIN	12 ± 1/16	.632 ± .001	3

MATERIAL: SA 508 CL2

R. RHODES (DWN. BY)	[illegible] (CHK'D)	INDUCED STRAIN TEST MOCKUP	SCALE FULL, DATE 5-21-82
PASSED BY: [illegible]	APP'D [illegible]		DRWG. NO. 1134900, A-1

K&E NO. 19-1183

FORM BOM 1087 A-4

EXPLOSIVE EXPANSION

QUALIFICATION REQUIREMENTS

FOR MECHANICAL TESTING

61-1134292-00

FOR EXPLOSIVE EXPANSION REPAIR

OF TMI-1 OTSG's.

6/2/82

PREPARED BY M.W. Alex 6/2/82

REVIEWED BY Larry Dixon 6/2/82

REVIEWED BY John R. Conecki 6/2/82

APPROVED BY C.W. Chagnon for J.W. Mitchem 6-2-82

CONTENTS

1.0 INTRODUCTION AND BACKGROUND

Steam Generator tube leaks were identified at Three Mile Island Unit 1 in November, 1981 during pressurization for functional testing following an extended cold shutdown period. The leaks were first identified based on increased steam generator secondary side activity when the primary side had been pressurized to 40 psig. Subsequent bubble tests identified 90 leaking tubes in the A-OTSG and 44 in the B-OTSG. A primary side fiber optic examination of selected leaking tubes has identified circumferential cracks in the tubes within the thickness of the upper tubesheet.

The chosen repair technique is to install load carrying leak tight tube expansions within the upper tubesheet. These expansions will be made by an explosive forming process. A backup roll expansion is provided in the event that the explosive expansion fails to meet the design requirements.

2.0 PURPOSE AND SCOPE

2.1 Purpose

The purpose of these tests is to verify that the explosive expansions meet design requirements and to obtain documentable information relating to the behavior of the repair expansion. The purpose of this document is to provide the supplier with requirements for these tests.

2.2 Scope

These requirements apply to the mechanical qualification testing of the explosive expansion process and equipment to be used in the repair of the TMI-1 steam generator.

2.3 Definitions

2.3.1 Supplier - used in this document, supplier is the organization performing the qualification testing or analysis.

2.3.2 NPGD - Nuclear Power Generation Division of B&W.

2.4 Test Program Summary

The testing program is summarized in Attachment I, B&W Document Number 02-1134880D "Testing Program".

3.0 QUALIFICATION TECHNICAL REQUIREMENTS

3.1 Mechanical Tests

3.1.1 General Requirements

3.1.1.1 Tests are to be conducted using expansion equipment identical to that which will be used for the actual steam generator work, except that aspects of the equipment such as remote manipulators need not be utilized.

3.1.1.2 Tube material is to be SB-163, Inconel 600, surplus OTSG tubing. Samples will be made from the following heat and lot numbers of tubing: heat no. 93452 lot no. 5060 having a minimum tested yield strength of 54,700 psi prior to stress relief and heat no. 93542 lot no. 5001 having a minimum tested yield strength of 41,500 psi prior to stress relief. Min ID of tubing will be .543" for inter face with the explosive expanders. A certificate of conformance is required for the diameter of the explosive expanders.

3.1.1.3 Tubesheet material for mockups is to be SA 508-64-CL.2. Where single hole mockups are used the tubesheet block is to be 1.143 in O.D. (Ref. 9.2).

3.1.1.4 Both tubing and tubesheet material for tests are to be heat treated as follows to simulate OTSG stress relief; furnace charts are to be kept:

For Inconel 600 tubes, mill annealed at $>1600^{o}F$

Heatup: ambient temperature to $900^{o}F$, no restrictions on rate

$900^{o}F$ - $1100^{o}F$, $>8^{o}F/hr$ $<50^{o}F/hr$

Hold: $1100^{o}F$ - $1150^{o}F$, 18hr $\pm$ 1hr

Cooldown: $1100^{o}F$ - $900^{o}F$, $>8^{o}F/hr$ $<50^{o}F/hr$

$900^{o}F$ - ambient, no restrictions

Stress relief is to be done in an inert atmosphere for tubing.

For SA 508, Cl 2, tubesheet material, quenched and tempered:

Heatup: ambient temperature to $900^{o}F$, no restrictions on rate

$900^{o}F$ - $1100^{o}F$, $>8^{o}F/hr$ $<50^{o}F/hr$

Hold: $1100^{o}F$ - $1150^{o}F$, 18hr $\pm$ 1hr

Cooldown: $1100^{o}F$ - $600^{o}F$, $>8^{o}F/hr$ $<50^{o}F/hr$

$600^{o}F$ to ambient temperature, no restrictions on rate

3.1.1.5 All mockups will be fabricated on a "build to print" basis using drawings supplied by NPGD engineering. A certificate of conformance is to be provided in the Data Package.

3.1.1.6 Material test reports for all mockup components directly related to the qualification testing (i.e., not including end caps) are to be included in the Data Package to be provided with the pieces.

3.1.1.7 Jigs and fixtures have no requirements placed on them except as defined in 4.2A.

3.1.2 Leak and Axial Load Tests

3.1.2.1 Samples will simulate the corrosion of the tubesheet ID and tube O.D. by exposure to air at 900°F for 20 - 100 hours as required to duplicate TMI-1 oxide thickness. The final length of time will be approved by B&W/NPGD.

3.1.2.2 Explosive expansions will be 10" long starting at the primary surface of the tubesheet mockups. Tubes will be installed in the tubesheet holes as follows:

- one piece of tubing will be inserted from the primary face. This piece of tubing will project above the primary face 3/16" ± 1/64" and end 6" below the primary face. This piece of tubing will be roll expanded at the primary end to 55 in-lb. for a depth of 1 1/4" from the tube end.

- a second piece of tubing will be inserted from the secondary face to butt against the first piece of tubing.

3.1.2.3 Tests will be done in 10 hole mockups (Ref. 9.3). The hole diameter is to be the average tube OD + .016" ± .001". The pitch of the holes is to match that in the TMI-1 OTSG's. A total of 6, ten-hole mockups will be tested. The tubing used will be heat no. 93452 lot no. 5060 for the 10 hole mockups.

3.1.2.4 10 tube samples are to be lettered A through F for the purpose of traceability. Samples are to be subjected to various tests according to the flow chart on Attachment 1.

3.1.2.5 For the portion of this test determining the effects of adjacent expansions on a central previous expansion (blocks A & B) leak rate will be measured for the central tube in question prior to and after individually expanding all adjacent tubes.

3.1.2.6 For the portion of this test determining the effect of expanding a tube twice (block A), the leak rate will be measured for the individual tube in question prior to and after the second expansion. Results of this test may invalidate this test block from the overall leak rate data base. This decision will be made by NPGD engineering pending the results of this test.

3.1.2.7 Leak rates will be determined at 70°F ± 15°F for a primary to secondary pressure differential of 1275 ± 5 psi and 2500 ± 10 psi depending on the specimen being tested. Where applicable, the secondary to primary leak rate will be determined for a pressure differential of 1275 ± 5 psi. The same samples, provided leakage is present, used for the sec-pri pressure test will be subjected to a secondary to

3.1.2.7 primary side bubble test using 125 ± 10 psi N_2.

3.1.2.8 Water used for the leak testing will be demineralized.

3.1.2.9 Thermal cyclic conditioning will consist of 38 cycles of the tube/tubesheet sample from 70° ± 5° to 610° ± 5° to 70° ± 5°F. Heating and cooling rates are not critical provided the tube and tubesheet temperatures do not differ by more than 50°F at any time. Thermocouples will be placed as a minimum on the tube ID surface and the tubesheet OD surface in the center of the expansion. An additional thermal change from 610°F to 400°F in 10 minutes will be applied to those samples which are to be thermally cycled. No maximum temperature difference between tube and tubesheet applies to this single thermal change.

3.1.2.10 Axial load cyclic conditioning will consist of the following independent sets done at 70° ± 10°F:

100 cycles 780 lbs. compression to 1110 lbs. tension
180 cycles 635 lbs. compression to 175 lbs. tension
6000 cycles 510 lbs. compression to 125 lbs. compression

Cycles are to be applied at not more than 1Hz. Tolerance on all forces in cyclic conditioning is ± 5 lbs.

3.1.2.11 The axial tensile load which causes the expansion to slip will be measured and recorded such that elastic (or plastic) extension of the tube will not be confused with gross movement.

3.1.2.12 When assembled, the mockups will be monitored for deformation of adjacent holes due to the explosive expansion. This will be done for at least 3 of the 10 hole blocks.

3.1.2.13 After assembly of the 10-tube mockups a gas leak test is to be made using the pressures that each mockup will be subjected to to determine that the seal welds of the end caps to the body are leak tight.

3.1.2.14 Test procedures are to be submitted to B&W NPGD for approval prior to use.

3.1.3 Induced Strain Test Requirements

3.1.3.1 Explosive expansions will be 10" long.

3.1.3.2 Two samples each will be made using heat no. 93452, lot no. 5060 in single hole tubesheet mockups with a .016" diametral annulus, and heat no. 93542, lot no. 5001 with a .003" diametral annulus. (Ref. 9.4)

3.1.3.3 Mockups will simulate tube to tubesheet weld location and active tube length such that the tube end at weld location is free to move axially away from the tubesheet.

3.1.3.4 The tube is to be in tension initially, 100 lbs. $\pm$ 10 lbs.

3.1.3.5 Simulated tube compliance must be greater than or equal to 3.17×10^{-4} in/lb which is the calculated value for steam generator tubes. (i.e., a weight could be used to produce the preload.)

3.1.3.6 Motion of the tube to tubesheet weld tube end and active tube length end of the sample caused by the expansion will be measured to .0005".

3.1.3.7 The overall tube length across the expansion will be measured to .0005" before and after the tubesheet is split following the expansion.

3.1.3.8 Test procedures are to be submitted to B&W/NPGD for approval prior to use.

3.1.4 Yield Stress Test Requirements

3.1.4.1 A stress-strain curve is to be made for each piece of tubing used to make test samples.

3.1.4.2 Each curve is to show, as a minimum, the .2% offset yield and should continue to ultimate tensile strength.

3.1.4.3 Test procedures are to be submitted to B&W/NPGD for approval prior to use.

4.0 DOCUMENTATION REQUIREMENTS

4.1 Qualification Plan

The Supplier is to provide a Qualification Plan to B&W/NPGD. This plan shall present an overview depicting the major events, tests, analyses and schedules for each leading to the qualification of the subject equipment.

By means of the plan, the Company shall be able to, as a minimum:

A. Determine what tests or analyses are to be performed and for what purpose.

B. Determine if and how the Vendor intends to combine the results of individual tests or analyses to arrive at combined effects.

C. Where critical, define the sequence in which the program is to be performed.

D. Define the acceptance criteria to be employed.

E. Identify any assumptions and provide acceptable justification.

The qualification plan shall be submitted to the Company for approval.

4.2 Qualification Procedures

These procedures, coupled with the qualification plan, shall form a complete picture of the program to be conducted. Because the procedures become part of the qualification file, the procedures shall as a minimum:

A. Require complete identification of all equipment to be used in in testing and/or analyses including type, make, model, manufacturer, specifications, etc.

B. Provide complete test setup description including:

1. Mounting arrangements.
2. Interface simulation so that the test configuration simulates the required actual field installation where necessary.
3. Connection requirements.

C. Identify equipment parameters to be monitored.

D. Identify the environmental parameters (including margin) to be monitored and the methods to be employed.

E. Identify the parameters to be simulated during the test and identify the range, duration, etc. of the test parameters and methods of monitoring.

F. Identify the requirements that the test or analysis is intended to verify.

G. Indicate the number and identification of test specimens to be employed for each test.

H. Identify the sequence in which the test is to be conducted.

I. Identify the method of processing and disposition of failures and anomalies that may occur during testing.

J. Provide step by step procedures for conducting the test.

These qualification procedures shall be submitted to the Company for approval.

4.3 Qualification Reports

Qualification reports shall serve as auditable data sources to support the final qualification. To serve its purpose, each qualification report shall as a minimum:

A. Reference the related qualification procedure which serves as its basis.

B. Contain all data required by the qualification procedure.

C. Contain all analytical methods and models utilized for qualification.

D. Contain data collected during the qualification effort.

E. Contain the acceptance criteria.

F. Demonstrate performance in terms of acceptance criteria.

G. Report and analyze all anomalies to provide demonstratable proof that the anomaly does not invalidate the qualification results.

H. Cite any precautions, restrictions, or limitations which must be taken into account by the ultimate user of the qualified equipment in order to maintain the validity of the qualification.

I. Contain vendor signatures and dates indicating review and approval of the report.

The qualification report shall be submitted to the Company for approval. The Company will obtain Owner's approvals.

5.0 QUALITY ASSURANCE (QA) REQUIREMENTS

5.1 QA requirements are outlined in the Quality Requirements Matrix (QRM) Document #48-1120199. This document advises the supplier of the documentation that must be forwarded to and/or approved by B&W/NPGD during the performance of the order or contract.

5.1.1 The quality assurance for the fabrication of component parts of the tube/tubesheet mockup assemblies, non-production explosive devices, jigs, fixture, etc. which are considered by this document to be non-safety related is to be performed in accordance with NPGD QA Spec 09-1212 as amended by Contract Technical Requirements (CTR) Document 24-1134284-00.

Specific requirements for documentation are limited to those in the body of this document and on the QRM.

5.1.2 QA for the performance of qualification testing and the final assembly of tube/tubesheet mockups which is safety related is to be in accordance with NPGD QA Spec 09-1212 as amended by CTR document 24-1134283-00 except where the testing is performed by a B&W R&D facility (i.e., Alliance or Lynchburg Research Center) in which case QA is in accordance with NPGD QA Spec 09-1427-00, "QA Requirements for R&D". Specific requirements for documentation are limited to those in the body of this document and on the QRM(s). ARC and/or LRC are to submit Quality Assurance plans for any testing they do. Equivalent articles of 09-1427-00 may be used to respond to the requirements of 09-1212 as modified above.

5.2 Variation in the manufacturing of components for mockups, mockup assemblies or explosive expanders from the requirements in this document are to be submitted to NPGD engineering for review and approval. The disposition of the parts is to be determined by NPGD engineering. Approved documentation is to be included in the Data Package if the ~~price(s)~~ piece(s) which varied from the requirements are allowed to be used.

6.0 INSPECTION AND WITNESSING

B&W/NPGD Engineering and Quality Assurance reserve the right to witness tests and to inspect the Supplier's test facilities.

The Supplier will give sufficient notice in advance of the performance of tests to allow B&W to exercise this option. (i.e., notification will be made sufficiently in advance to allow arrangements to be made by B&W to have personnel on hand.)

7.0 DISPOSITION OF FAILURES

B&W/NPGD Project Management is to be notified in writing of the failure of any test during qualification. Failures will be analyzed and such analyses documented. The analysis is to include:

- A description of the failure, including the failure mode and the effect on performance.
- Summary of test conditions just prior to equipment failure.
- Mode of failure.
- Cause of failure.
- Recommended corrective action to prevent reoccurrence of the failure.
- Recommendations for qualification retesting.

8.0 TEST SPECIMENS STORAGE

The Supplier is to have or to develop specific written procedures for the maintenance and preservation of test specimens in a condition such that the specimen, or parts of specimens in the event of destructive testing, can be used for future testing if required. Specimens are to be kept in this condition until written direction for the final disposal of them is obtained from B&W/NPGD.

9.0 REFERENCE DOCUMENTS

9.1 NPGD Qual. Class. System 07-1000584

9.2 ARC LR.75:2257-01:1

9.3 B&W Dwg #1134899D

9.4 B&W Dwg #1134900A

TESTING PROGRAM FOR EXPLOSIVE EXPANSION

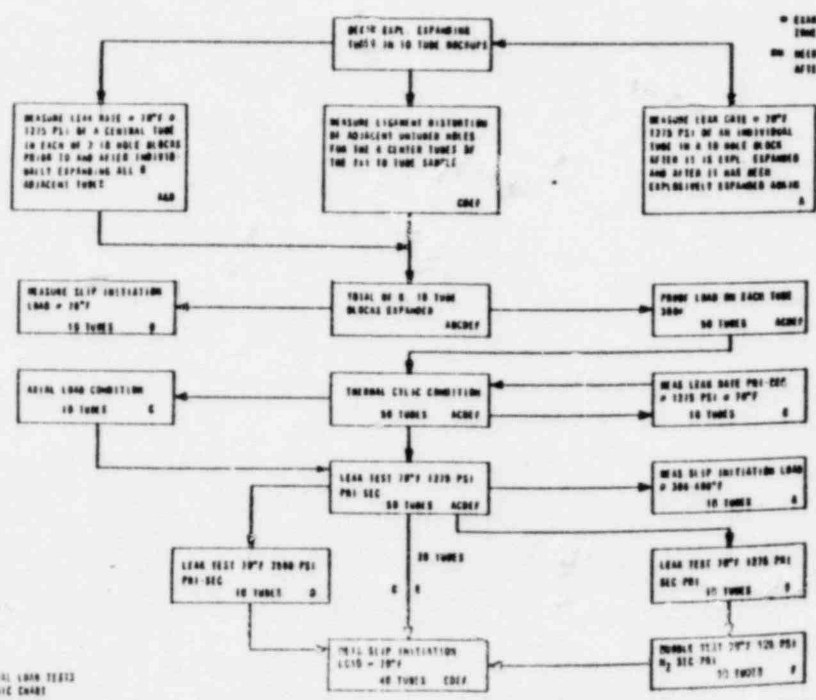
TEST TITLE	TEST OBJECTIVE(S)	TEST DESCRIPTION	NO. OF SAMPLES	TEST PARAMETERS	DATA RECORDED	RESPONSIBLE ORGANIZATION
1) EXPL. EXP. LOAD TEST	DETERMINE THE PARAMETERS REQUIRED TO PRODUCE A LOAD CARRYING EXPL. EXP. DETERMINE OPTIMUM EXPANSION TRANSITION	MEASURE THE MINIMUM AXIAL LOAD WHICH CAUSES THE EXPANSION TO SLIP MAKE SEVERAL EXPANSIONS. EXAMINE OPTIMUM EXPANSION F/M RESIDUAL STRESSES*	100	4" LONG EXPANSION INITIAL SLIP LOAD TARGET: 3100# REF. GPUN SPEC. SEC. 19.3	MINIMUM AXIAL LOAD (LBF) REQUIRED TO INITIATE MOVEMENT	FOSTER WHEELER
2) EXPL. EXPANSION RESIDUE TEST	1) DETERMINE THE AMOUNT OF EXPLOSIVE RESIDUE EXPECTED FROM ALL EXP'S. IN STEAM GENERATOR INCLUDING THE TOP OF THE TUBESHEET 2) DETERMINE PROBABLE CLEANING METHOD	MEASURE RESIDUE FROM SEVERAL SAMPLES & EXTRAPOLATE FOR TOTAL TRY SEVERAL TECHNIQUES FOR REMOVING RESIDUE	~6 20	10" EXPANSION. CHARGE DEFINED ABOVE CONTAMINATION EFFECTS FLUSH. SOAK. HYDROLAZED	VOLUME OR WEIGHT OF RESIDUE ANALYSIS OF RESIDUE RELATIVE CLEANNESS	GPUN/LPC/FRC
2) CRACK CHANGE TEST	1) DETERMINE THE CHANGES IN EXISTING CRACKS DUE TO EXPANSION 2) DETERMINE THE EFFECT ON CLEANING OF EXPL. EXP. 3) DETERMINE THE NATURE OF EXPL. RESIDUE	EXPL. EXP. OVER DEFECTS & METALLOGRAPHICALLY EXAMINE FOR CHANGES COMPARE EXP. SAMPLES WHICH WERE & WERE NOT CLEANED BEFORE EXPANSION. BEFORE AND AFTER COMPARISON OF NON-CLEANED EXP. SAMPLE. ANALYZE RESIDUE	2-3	HEAT TINT COMPARISON FOR CRACK CHANGE. LOWER, SODIUM AZIDE & TRIPS SAMPLES USED FOR COMPARISONS & DETERMINATION OF RESIDUE 30 GRAINS PER FOOT CHARGE	PHYSICAL DIM'S. OF CRACKS CHEMICAL TYPE & CONCENTRATION	GPUN/LRC/ARC
2) LEAK AND AXIAL LOAD TEST	1) MEASURE LEAK RATE PAST EXPANSION PSI SEC/SEC PSI 2) SHOW THAT EXP. DON'T SLIP FROM EXPECTED LOAD 3) MEASURE LOAD WHICH WILL CAUSE EXP. TO SLIP 4) DETERMINE LIGAMENT DISTORTION WHEN ASSEMBLING MOCKUPS 5) DETERMINE THE EFFECT ON EXPL. EXP'S OF ADJACENT EXPANSIONS 6) DETERMINE RELATIONSHIP BETWEEN GAS LEAK RATE & WATER LEAK RATE 7) DETERMINE THE EFFECTS OF DOUBLE EXPANDING A TUBE	SEE LOGIC CHART	SEE LOGIC CHART	10" LONG EXPANSIONS. 7 PART TUBES TESTS AT 70°. DEMINERALIZED WATER CYCLIC CONDITIONING 30. 70°-610°-70°F 1. 610°-400°F IN 10 MIN 100. [illegible] C 1110°F 100. [illegible] C 1154°F } 10 SAMPLES 1000. 510# C 1264°C } ## ΔP NORMAL = 1275 PSI ΔP MAX = 2500 PSI TARGET AXIAL LOAD 3100# REF. GPUN SPEC. SEC. 19.3 125 PSI NITROGEN FOR BUBBLE TEST	LEAK RATES (LBM HR) BY PRESSURE DECAY FORCE (LBF)/STRAIN (IN/IN) DIMENSIONS: DIAMETER DEPTH BUBBLE SIZE, FREQUENCY	FOSTER WHEELER 8) GPUN
3) INDUCED STRAIN TESTS	1) DETERMINE THE EFFECTS ON THE TUBESHEET WELD AND ACTIVE TUBE LENGTH OF THE EXPANSION 2) DETERMINE THE TOTAL STRAIN STORED IN THE EXPANSION WHICH COULD BE RELEASED LATER	MEASURE THE DISPLACEMENT AT EACH END OF AN EXPANSION SIMULATING WELD LOC. AND ACTIVE TUBE LENGTH MEASURE THE CHANGE IN TOTAL LENGTH OF AN EXPANSION WHEN RELEASED FROM THE TUBESHEET	4	10" LONG EXP.'S 2 SAMPLES. STRONGEST TUBE/ .005" DIA ANNULUS 2 SAMPLES WEAKEST TUBE / .005" DIA ANNULUS	CHANGE IN LENGTH & DISPLACEMENT	FOSTER WHEELER
4) YIELD STRENGTH TEST	1) DETERMINE STRESS STRAIN CHARACTERISTICS OF EACH TUBE USED FOR SAMPLES	PRODUCE STRESS STRAIN CURVES ON INSTRON OR EQUIV. MACHINES. DETERMINE .2% OFFSET YIELD	ALL TUBES	MINIMUM OF ONE TEST DONE ON EACH PIECE OF TUBING USED AS A SAMPLE	STRESS VS STRAIN	FOSTER WHEELER
5) VARY CREVICE CORROSION TEST	DETERMINE EFFECTS OF VARIOUS AMOUNTS OF CREVICE CORROSION ON LEAK RATE AND LOAD	LEAK TEST & AXIAL LOAD SPECIMENS W/VARIOUS CREVICE CORROSION	~8	CLEAN, CORRODED (NOM), LESS CORRODED, MORE CORRODED, TUBE AND TUBESHEET	LEAK RATE AXIAL LOAD	GPUN/ARC
6) EXPANSION CORROSION	DETERMINE WHETHER RESIDUAL STRESSES CAUSE LOCALIZED ATTACK IN THE TRANSITION	ACCELERATED CORROSION TESTS OF EXPANDED SAMPLES. EXPLODED. EXPLODED ROLLED. EXPLODED ROLLED OVERLAPPING	6	RELATIVE CORROSION RATE OF ROLLED VS. EXPLODED TRANSITION	METALLURGICAL EXAMINATION	GPUN/ARC

* EXAMINATION TO INCLUDE X-RAY DEFRACTION OF TRANSITION ZONE AND DESTRUCTIVE EXAMINATION OF EXPANSION.

** NEED FOR 5000 CYCLE LOAD TEST TO BE DETERMINED AFTER RESIDUAL STRESS DATA IS AVAILABLE.

NOTE # OF SAMPLES MAY CHANGE DUE TO SCATTER OF RESULTS.

NOTE: ONE SAMPLE IS EQUIVALENT TO ONE TUBE



ATTACHMENT I

REV	DESCRIPTION	DATE
3	REV & REDRAWN	
4	DELETED CORROSION TEST 1, REVISED ** NOTE	

20 TUBES WERE 10 TUBE @ D-3, C WA[illegible] @ D-4

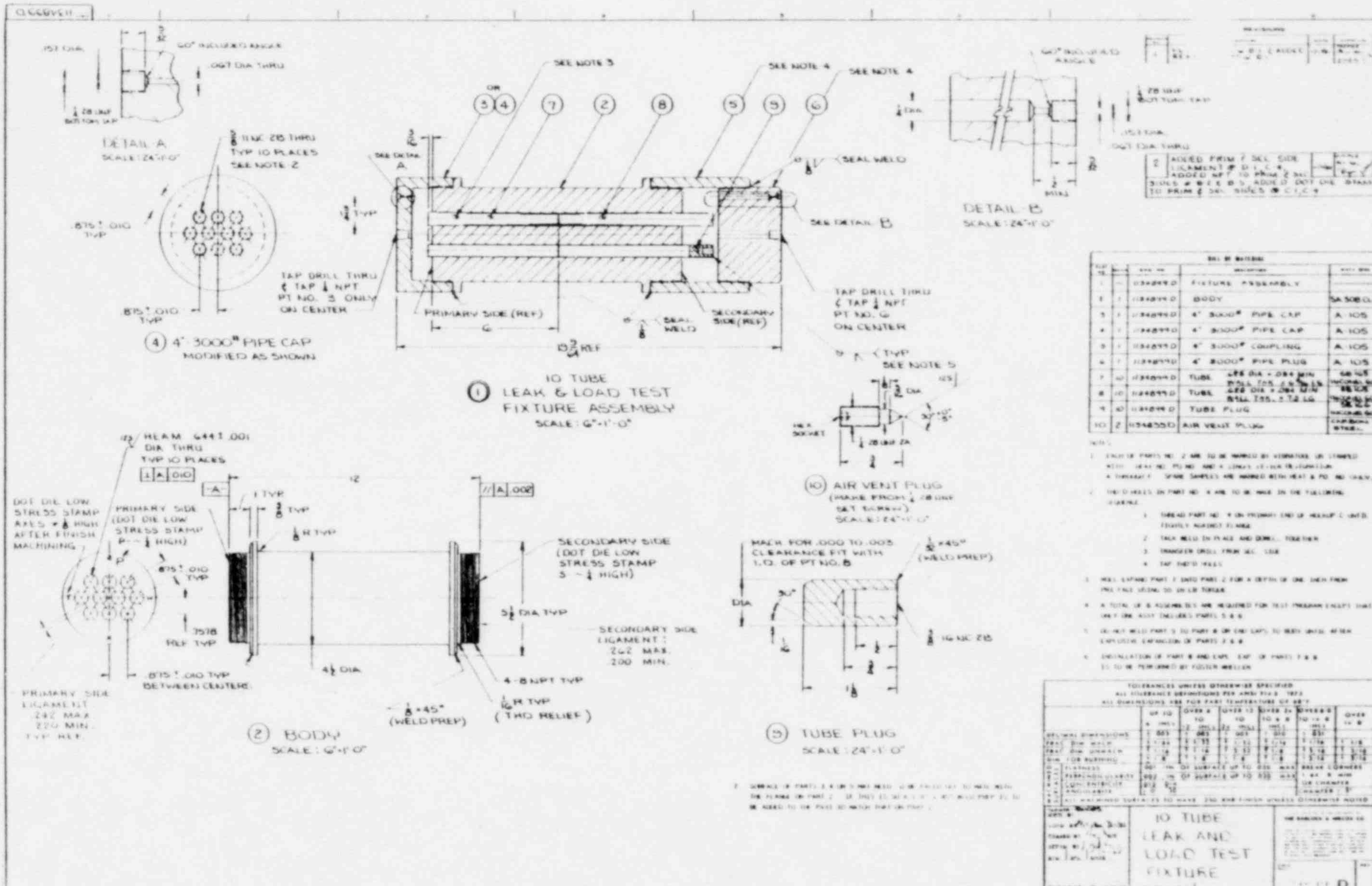
FOR ORIGINAL SIGNATURES SEE MICROFILM IN RECORDS CENTER

TESTING PROGRAM

M ALES
L DIXON

THE BABCOCK & WILCOX

1134880



DETAIL A
SCALE: 24"=1'-0"
3/8-11 UNC 2B THRU
TYP 10 PLACES
SEE NOTE 2
.875 ± .010 TYP
4 4" 3000# PIPE CAP
MODIFIED AS SHOWN
SEE NOTE 3
SEE NOTE 4
SEAL WELD
SEE DETAIL A
SEE DETAIL B
TAP DRILL THRU
℄ TAP 1/4 NPT
PT NO. 3 ONLY
ON CENTER
PRIMARY SIDE (REF)
SECONDARY SIDE (REF)
PT NO. 6
ON CENTER
13 3/4 REF
1 10 TUBE
LEAK & LOAD TEST
FIXTURE ASSEMBLY
SCALE: 6"=1'-0"
SEE NOTE 5
HEX SOCKET
10 AIR VENT PLUG
(MAKE FROM 1/4-28 UNF SET SCREW)
SCALE: 24"=1'-0"
DETAIL B
SCALE: 24"=1'-0"
60° INCLUDED ANGLE
.067 DIA THRU
.151 DIA
REAM .644 ± .001
DIA THRU
TYP 10 PLACES
DOT DIE LOW
STRESS STAMP
AXES × 1/8 HIGH
AFTER FINISH
MACHINING
PRIMARY SIDE
(DOT DIE LOW
STRESS STAMP
P — 1/8 HIGH)
.875 ± .010 TYP
.7578 REF TYP
.875 ± .010 TYP
BETWEEN CENTERS
PRIMARY SIDE
LIGAMENT
.242 MAX
.220 MIN
TYP REF
SECONDARY SIDE
(DOT DIE LOW
STRESS STAMP
S — 1/8 HIGH)
5 1/2 DIA TYP
SECONDARY SIDE
LIGAMENT:
.262 MAX.
.200 MIN.
4 1/2 DIA
4-8 NPT TYP
1/8 × 45°
(WELD PREP)
1/16 R TYP
(THD RELIEF)
2 BODY
SCALE: 6"=1'-0"
MACH FOR .000 TO .005
CLEARANCE FIT WITH
I.D. OF PT NO. 8
1/8 × 45°
(WELD PREP)
3/8-16 UNC 2B
9 TUBE PLUG
SCALE: 24"=1'-0"
2 ADDED PRIM & SEC SIDE LIGAMENT ...
BILL OF MATERIAL
FIXTURE ASSEMBLY
BODY SA 508 CL 2
4" 3000# PIPE CAP A 105
4" 3000# PIPE CAP A 105
4" 3000# COUPLING A 105
4" 3000# PIPE PLUG A 105
TUBE
TUBE
TUBE PLUG
AIR VENT PLUG
TOLERANCES UNLESS OTHERWISE SPECIFIED
10 TUBE
LEAK AND
LOAD TEST
FIXTURE
D