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April 27, 1983

WRITER'S DIRECT DIAL NUMBER
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Thomas S. Moore
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Chairman, Atomic Safety and
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U.S. Nuclear Regulatory
Commission
Washington, D.C. 20555

Dr. W. Reed Johnson
Administrative Judge
Atomic Safety and Licensing
Appeal Board
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Commission
Washington, D.C. 20555

Dr. Reginald L. Gotchy
Administrative Judge
Atomic Safety and Licensing
Appeal Board
U.S. Nuclear Regulatory
Commission
Washington, D.C. 20555

In the Matter of
Wisconsin Electric Power Company
(Point Beach Nuclear Plant, Unit 1)
Docket No. 50-266 (OLA-2)

Dear Administrative Judges:

On behalf of Wisconsin Electric Power Company ("Licensee"), I am herewith submitting the information requested in the Appeal Board's Order of March 22, 1983. The information is simultaneously being submitted to the NRC Staff, at its request, in conjunction with its independent review of Licensee's application for steam generator repair at Point Beach Nuclear Plant, Unit 1.

DS03

Certain of the enclosed information is proprietary to Westinghouse Electric Corporation, and the NRC Staff has been requested to withhold it from public disclosure pursuant to 10 C.F.R. § 2.790. The Service List distribution will include nonproprietary versions of the information submitted to the Appeal Board.

While Licensee is not objecting to providing the requested information to the Appeal Board, the request raises the interesting question of whether the Appeal Board has jurisdiction to exercise sua sponte review of the merits of this particular application. In ALAB-719, the Appeal Board affirmed the dismissal by the Licensing Board of the sole petition for leave to intervene and request for a hearing on the repair amendment. The Commission, through issuance of its notice of opportunity for a hearing, 47 Fed. Reg. 30,125 (July 12, 1982) did not find of its own accord that a hearing would be required in the public interest, 10 C.F.R. § 2.104(a), but rather offered an opportunity for members of the public to request a hearing, 10 C.F.R. § 2.105(a) and (d). The denial of the petition, affirmed by ALAB-719 as a result of an appeal by petitioner pursuant to 10 C.F.R. § 2.714a, returns the application to the status of one as to which there is no petition for leave to intervene.

Since there is no petition for leave to intervene which has been granted or is pending before the Commission, this is no longer a contested proceeding. 10 C.F.R. § 2.4(n). (The petitioner has recently petitioned for discretionary Commission review of ALAB-719, but it is the request for review of the denial of the intervention petition, not the intervention petition itself, which is pending before the Commission.) Because an appeal under the narrow provisions of secition 2.714a does not encompass substantive determinations on the merits of an application, and because we believe Commission regulations do not otherwise provide Appeal Board jurisdiction over uncontested proceedings involving operating license amendments, there is a question of whether, and the extent to which, the Appeal Board's sua sponte jurisdiction pursuant to 10 C.F.R. § 2.785(b)(2) is applicable in this case.

Licensee is not now requesting a ruling on this question. We point it out only to assure that, by submitting the requested information, Licensee does not waive its rights to raise the jurisdictional question.

Respectfully submitted,

Bruce W. Churchill
Delissa A. Ridgway
Counsel for Licensee

cc: Service List

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

Before the Atomic Safety and Licensing Appeal Board

In the Matter of	)	
	)	
WISCONSIN ELECTRIC POWER COMPANY	)	Docket No. 50-266 (OLA-2)
	)	
(Point Beach Nuclear Plant,	)	
Unit 1)	)	

CERTIFICATE OF SERVICE

This is to certify that copies of "Licensee's Responses to Questions in the March 22, 1983 Appeal Board Order" were served, by deposit in the United States mail, first class, postage prepaid, to all those on the attached Service List, this 27th day of April, 1983.

Bruce W. Churchill

Dated: April 27, 1983

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

Before the Atomic Safety and Licensing Appeal Board

In the Matter of	)	
	)	
WISCONSIN ELECTRIC POWER COMPANY	)	Docket No. 50-266-OLA2
	)	
(Point Beach Nuclear Plant,	)	
Unit 1)	)	

SERVICE LIST

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April 27, 1983

Mr. H. R. Denton, Director
Office of Nuclear Reactor Regulation
U. S. NUCLEAR REGULATORY COMMISSION
Washington, D. C. 20555

Attention: Mr. R. A. Clark, Chief
Operating Reactors Branch 3

Gentlemen:

DOCKET NO. 50-266
STEAM GENERATOR REPAIR
POINT BEACH NUCLEAR PLANT, UNIT 1

By Order dated March 22, 1983, the Atomic Safety and Licensing Appeal Board requested certain information related to the repair of the Unit 1 steam generators. That information has also been requested by the NRC Staff and is enclosed herewith.

The enclosed information contains certain information which is proprietary to Westinghouse Electric Corporation. The proprietary information has been identified by brackets. In conformance with the requirements of 10 CFR Section 2.790 of the Commission's regulations, we are requesting withholding this proprietary material from public disclosure and enclose an affidavit from Westinghouse Electric Corporation in support of that application. The affidavit sets forth the basis on which the information should be withheld from public disclosure.

Very truly yours,

C. W. Fay
Vice President-Nuclear Power

Enclosure

cc: Service List
NRC Resident Inspector

Westinghouse Electric Corporation

Water Reactor Divisions

Box 355
Pittsburgh Pennsylvania 15230

April 27, 1983

CAW-83-35

Mr. Harold R. Denton, Director
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
Phillips Building
7920 Norfolk Avenue
Bethesda, MD 20014

Reference: Wisconsin Electric Power Company Letter (C. W. Fay to H. R. Denton), dated April 27, 1983 "Docket 50-266 Point Beach Nuclear Plant Unit 1 Steam Generator Repair"

Dear Mr. Denton:

The proprietary material for which withholding is being requested by the Wisconsin Electric Power Company is further identified in an affidavit signed by the owner of the proprietary information, Westinghouse Electric Corporation. the affidavit, which accompanies this letter sets forth the basis on which the information may be withheld from public disclosure by the Commission and addresses specifically the considerations listed in paragraph (b)(4) of 10CFR Section 2.790 of the Commission's regulations.

Accordingly, this letter authorizes the utilization of the accompanying affidavit in support of the Wisconsin Electric Power Company.

Correspondence with respect to the proprietary aspects of the application for withholding or the Westinghouse affidavit should reference this letter, CAW-83-35, and should be addressed to the undersigned.

Very truly yours,

Robert A. Wiesemann

R. A. Wiesemann, Manager
Regulatory and Legislative Affairs

/wpc

cc: E. C. Shomaker, Esq.
Office of the Executive Legal Director, NRC

CAW-83-35

AFFIDAVIT

COMMONWEALTH OF PENNSYLVANIA:

ss

COUNTY OF ALLEGHENY:

Before me, the undersigned authority, personally appeared Robert A. Wiesemann, who, being by me duly sworn according to law, deposes and says that he is authorized to execute this Affidavit on behalf of Westinghouse Electric Corporation ("Westinghouse") and that the averments of fact set forth in this Affidavit are true and correct to the best of his knowledge, information, and belief:

Robert A. Wiesemann

Robert A. Wiesemann, Manager
Regulatory and Legislative Affairs

Sworn to and subscribed
before me this 27th day
of April 1983.

Genevieve Kish

GENEVIEVE KISH, NOTARY PUBLIC
MONROEVILLE BORO, ALLEGHENY COUNTY
MY COMMISSION EXPIRES SEPT. 3, 1984
Member, Pennsylvania Association of Notaries

(1) I am Manager, Regulatory and Legislative Affairs, in the Nuclear Technology Division, of Westinghouse Electric Corporation and as such, I have been specifically delegated the function of reviewing the proprietary information sought to be withheld from public disclosure in connection with nuclear power plant licensing or rule-making proceedings, and am authorized to apply for its withholding on behalf of the Westinghouse Water Reactor Divisions.

(2) I am making this Affidavit in conformance with the provisions of 10CFR Section 2.790 of the Commission's regulations and in conjunction with the Westinghouse application for withholding accompanying this Affidavit.

(3) I have personal knowledge of the criteria and procedures utilized by Westinghouse Nuclear Energy Systems in designating information as a trade secret, privileged or as confidential commercial or financial information.

(4) Pursuant to the provisions of paragraph (b)(4) of Section 2.790 of the Commission's regulations, the following is furnished for consideration by the Commission in determining whether the information sought to be withheld from public disclosure should be withheld.

(i) The information sought to be withheld from public disclosure is owned and has been held in confidence by Westinghouse.

(ii) The information is of a type customarily held in confidence by Westinghouse and not customarily disclosed to the public. Westinghouse has a rational basis for determining the types of information customarily held in confidence by it and, in that connection, utilizes a system to determine when the whether to hole certain types of information in confidence. The application of that system and the substance of that system constitutes Westinghouse policy and provides the rational basis required.

Under that system, information is held in confidence if it falls in one or more of several types, the release of which might result in the loss of an existing or potential competitive advantage, as follows:

(a) The information reveals the distinguishing aspects of a process (or component, structure, tool, method, etc.) where prevention of its use by any of Westinghouse's competitors without license from Westinghouse constitutes a competitive economic advantage over other companies.

(b) It consists of supporting data, including test data, relative to a process (or component, structure, tool, method, etc.), the application of which data secures a competitive economic advantage, e.g., by optimization or improved marketability.

(c) Its use by a competitor would reduce expenditure of resources or improve his competitive position in the design, manufacture, shipment, installation, assurance of quality, or licensing a similar product.

(d) It reveals cost or price information, production capacities, budget levels, or commercial strategies of Westinghouse, its customers or suppliers.

(e) It reveals aspects of past, present, or future Westinghouse or customer funded development plans and programs of potential commercial value to Westinghouse.

(f) It contains patentable ideas, for which patent protection may be desirable.

(g) It is not the property of Westinghouse, but must be treated as proprietary by Westinghouse according to agreements with the owner.

There are sound policy reasons behind the Westinghouse system which include the following:

(a) The use of information by Westinghouse gives Westinghouse a competitive advantage over its competitors. It is, therefore, withheld from disclosure to protect the Westinghouse competitive position.

(b) It is information which is marketable in many ways. The extent to which such information is available to competitors diminishes the Westinghouse ability to sell products and services involving the use of the information.

(c) Use by our competitor would put Westinghouse at a competitive disadvantage by reducing his expenditure of resources at our expense.

(d) Each component of proprietary information pertinent to a particular competitive advantage is potentially as valuable as the total competitive advantage. If competitors acquire components of proprietary information, any one component may be the key to the entire puzzle, thereby depriving Westinghouse of a competitive advantage.

(e) Unrestricted disclosure would jeopardize the position of prominence of Westinghouse in the world market, and thereby give a market advantage to the competition in those countries.

(f) The Westinghouse capacity to invest corporate assets in research and development depends upon the success in obtaining and maintaining a competitive advantage.

(iii) The information is being transmitted to the Commission in confidence and, under the provisions of 10CFR Section 2.790, it is to be received in confidence by the Commission.

(iv) The information sought to be protected is not available in public sources to the best of our knowledge and belief.

(v) The proprietary information sought to be withheld in this submittal is that which is marked in the proprietary version of the document entitled, "Docket 50-266 Point Beach Nuclear Plant Unit 1 Steam Generator Repair" from the non-proprietary version of the same report.

This information provides details of equipment design and comprehensive plant data that were developed at significant expense. This information has substantial commercial value to Westinghouse in connection with competition with other vendors for service contracts and performance evaluations.

The subject information could only be duplicated by competitors if they were to invest time and effort equivalent to that invested by Westinghouse provided they have the requisite talent and experience.

Public disclosure of this information is likely to cause substantial harm to the competitive position of Westinghouse because it would simplify design and evaluation tasks without requiring a commensurate investment of time and effort.

Further the deponent sayeth not.

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

Before the Atomic Safety and Licensing Appeal Board

In the Matter of	)	
WISCONSIN ELECTRIC POWER COMPANY	)	Docket No. 50-266 OLA-2
(Point Beach Nuclear Plant, Unit 1)	)	

LICENSEE'S RESPONSES TO QUESTIONS IN THE MARCH 22, 1983 APPEAL BOARD ORDER

QUESTION

1. The use of "hydraulic" tube expansion in the new steam generators provides for contact between the tube and tubesheet along the full length of the tubesheet holes, and eliminates the crevice between the tube and tubesheet. This result ostensibly lessens the potential for corrosion. But, this new design also subjects the tube to several stresses that appear to converge at the location where the tube emerges from, and is anchored by, the tubesheet. These stresses are: (1) residual stress resulting from the expansion process; (2) cyclic stress associated with thermal expansion and contraction during normal operation; (3) high frequency cyclic stress due to flow-induced vibrations of the tubes; and (4) stress resulting from accident loadings (e.g., LOCA, steamline break, SSE). The top of the tubesheet also appears to be where the most corrosive environment on the secondary side may be found as a result of sludge deposits collecting there.

   In view of these factors, we request applicant to provide the following information:

   1.a) A description of the analyses which lead to the conclusion that tubes of the new, fully expanded tube design steam generator are adequate to withstand the concentration of loading and fatigue at the top of the tubesheet.

RESPONSE

For the Point Beach replacement steam generators, the tubes will be secured to the tubesheet by a hydraulic tube expan-

sion process extending the full length of the tubesheet. The purpose of the hydraulic expansion process is to minimize the crevice between the tube and the tubesheet. An evaluation of tube stresses at the expansion transition at the top of the tubesheet for transient/normal operation loadings has been performed to verify that the maximum stress intensity range and cumulative fatigue usage factor were less than the ASME Boiler and Pressure Vessel Code allowables. The stresses considered in the ASME Code stress analysis were: 1) normal operating stresses, 2) cyclic stress associated with thermal expansion and contraction of the tube during normal operation, 3) high frequency cyclic stress due to flow induced vibration of tubes, and 4) stress resulting from accidental loading (e.g., LOCA, steamline break, SSE).

Residual stresses are not specifically required to be considered in the Code analysis. These stresses are recognized by the Code where they are relevant, such as in fatigue analysis where the cyclic stress range allowables specified by the Code include an allowance for the presence of a mean stress in addition to cyclic stresses. For the Code design analysis, residual stresses are not required to be considered because these stresses do not affect the load carrying capability of the component. However, the effects of residual stresses are addressed in corrosion testing programs described in the response to Question 1.b).

The transients analyzed for units similar to the Point Beach replacement steam generators are summarized in Table 1.a-1. Flow induced vibration, while included in the

analysis, is not included in Table 1.a-1 because tube stresses resulting from this load are negligible. For each of the loading conditions, the potential interaction of the flow distribution baffle with the tubesheet is considered. This interaction includes the relative tubesheet-to-flow distribution baffle hole alignment due to radial thermal growth and tubesheet rotation. The data provided in Table 1.a-1 are for Model 44F replacement steam generators and the results and conclusions are applicable to the Point Beach replacement steam generators .

Several conservative assumptions were made in the tube stress analysis. These assumptions were:

1. Thermal tube stresses are evaluated based on the temperature difference between the primary inlet temperature, T_{hot}, and the subcooled secondary side fluid temperature with no allowance for effects of heat transfer.
2. The pressure stresses in the tube are calculated using thin wall cylinder equations. Both the pressure stresses and stresses due to the tubesheet/flow baffle differential growth are calculated for a tube in a thinned condition.
3. A stress concentration factor is used in the fatigue evaluation. This factor accounts for any scratches or marks which may be present on the tubes' surface.

All the mentioned stresses were combined for each of the transient/operation loadings and the maximum stress intensity was evaluated - results are summarized in Table 1.a-2 for Model 44F replacement steam generators.

The maximum primary plus secondary stress intensity range occurred between the Loss of Load and the Secondary Leak Test Transients and was equal to [ ]$^{a, c, e}$ KSI. The maximum stress intensity range allowed by the ASME Boiler and Pressure Vessel Code is equal to 79.8 KSI. Finally, the results of the fatigue evaluation for various transient combinations are shown in Table 1.a-3. Based on analysis, the cumulative fatigue usage factor was calculated to be [ ]$^{a, c, e}$ - considerably below the 1.0 allowable factor.

TABLE 1.a-1

(TRANSIENT SUMMARY)

MODEL 44F

TRANSIENT	CYCLES a,c,e
1) HEATUP/COOLDOWN	
2) PLANT LOADING/UNLOADING	
3) STEP LOAD DECREASE	
4) STEP LOAD INCREASE	
5) REACTOR TRIP	
6) 40% STEP LOAD DECREASE	
7) LOSS OF FLOW	
8) LOSS OF LOAD	
9) PRIMARY HYDRO	
10) PRIMARY PRESSURE TEST	
11) SECONDARY HYDRO	
12) SECONDARY PRESSURE TEST	
13) PRIMARY LEAK TEST	
14) SECONDARY LEAK TEST	
15) HOT STANDBY	
16) STEADY STATE FLUCTUATIONS	
17) POWER BLACKOUT	

TABLE 1.a-2

PRIMARY PLUS SECONDARY STRESSES, KSI-HOT LEG SIDE AT THE TOP OF TUBESHEET

MODEL 44F

TRANSIENT	$(\sigma_A - \sigma_R)$	$(\sigma_H - \sigma_R)$	$(\sigma_A - \sigma_R)$ [a,c,e]
1) HEATUP/COOLDOWN			
2) PLANT LOADING/UNLOADING			
3) STEP LOAD DECREASE			
4) STEP LOAD INCREASE			
5) REACTOR TRIP			
6) 40% STEP LOAD DECREASE			
7) LOSS OF FLOW			
8) LOSS OF LOAD			
9) PRIMARY HYDRO			
10) PRIMARY PRESSURE TEST			
11) SECONDARY HYDRO			
12) SECONDARY PRESSURE TEST			
13) PRIMARY LEAK TEST			
14) SECONDARY LEAK TEST			
15) HOT STANDBY			
16) STEADY STATE FLUCTUATIONS			
17) POWER BLACKOUT			

TABLE 1.a-3

CUMULATIVE FATIGUE USAGE FACTOR - HOT LEG SIDE AT THE TOP OF THE TUBESHEET

MODEL 44F

TRANSIENT COMBINATION	S_{alt} (ksi)	n (Cycles)	N (Cycles)	$U_i = \frac{n}{N}$
1-2-8-11				
1-2-8-14				
1-2-8-12				
1-2-8				
1-2-6				
2-6-8				
9				
2-7				
2-17				
13				
10				
2				
5				
7				
6				

a,c,e

QUESTION

1. b) A description of the analyses and/or tests that establish the adequacy of the in-service corrosion resistance of the tubes in the regions of high stress at the top of the tubesheet.

RESPONSE

A summary of the development of the hydraulic expansion process, residual stresses resulting from the hydraulic expansion, and the corrosion tests conducted to verify the improved corrosion resistance of thermally treated Inconel 600 tubing is provided in Section 2.2.1.3 of the Point Beach Nuclear Plant Unit No. 1 Steam Generator Repair Report, August 1982, Amendment 1 ("Repair Report"). These tests and analyses demonstrate the adequacy of the tube expansion process and the corrosion resistance of the thermally treated Inconel 600.

Stresses which could occur during accident conditions are of short duration relative to stresses which are present during normal operation. Thus, stresses due to accident conditions are not considered directly in corrosion testing programs since they would not be present long enough to affect the corrosion process. Stresses resulting from normal operation, including residual stresses due to tube expansion, have been addressed in the corrosion testing programs. The stress corrosion tests of hydraulically expanded specimens subjected the tubing to the maximum tensile stresses representative of normal operation. Additional confirmation was obtained from plastically stressed C-ring specimens.

A detailed description of tests conducted to establish the basis for selection of a tube-to-tubesheet expansion process

is provided in Appendix A. These tests demonstrate that the hydraulic expansion process results in the lowest residual stresses of the available tube expansion processes. This is due to the minimal metal deformation and the gentle transition contours in the expansion transition compared to conventional mechanical rolling expansion processes. Figure 3 of Appendix A provides profiles of a typical hydraulic expansion transition. Figure 5 of Appendix A provides the results of tests conducted to determine residual stresses resulting from various expansion processes. These results demonstrate that stresses resulting from hydraulic expansion are only in the order of one-half those from a mechanical rolling process.

The special thermal treatment of Inconel 600 was specifically developed to enhance the stress corrosion cracking resistance of the tubing to both primary ("pure" water) and secondary side contaminated environments (caustic and sulphates). An extensive laboratory test program conducted by Westinghouse and others over the past six to eight years has demonstrated the benefits of this thermal treatment.(1)

A combination of extensive cold work and high temperature is used during testing to accelerate any cracking tendency and reduce the time to crack to several weeks or months compared to many years (if at all) at the 603°F maximum primary water temperature of Point Beach. Accelerating the time to initiate cracking in laboratory specimens by utilizing several high test

----

(1) [

]a, c, e

temperatures, and then extrapolating the time to cracking at lower temperatures, is an accepted technique provided the cracking mechanism remains the same. Mill-annealed Inconel 600 may be susceptible to stress corrosion under certain conditions of extensive cold work (very high stress) in pure water or primary coolant containing Li, B, and H_2. When extensively strained by cutting the tubing longitudinally and reverse bending over a small diameter mandrel, U-bends of mill annealed tubing can be made to crack reproducibly in 680°F pure or primary coolant water. When the tubing was thermally treated and then reverse bent and tested in this manner, no cracking was observed in any heat of tubing after extended exposure.(1) Since there was no cracking in the thermally treated specimens at high temperature, it was not possible to determine the time to crack at the lower operating temperatures. It is expected however, that the hydraulically expanded transitions, being stressed to a much less degree than the reverse U-bends, will not be susceptible to primary water stress corrosion cracking in operation, based upon the laboratory tests demonstrating the effects of the thermal treatment in providing primary water stress corrosion cracking resistance under conditions more severe than those during operation.

On the secondary side, the normal environment is all volatile treatment (AVT); however, the ingress of contaminants,

(1) It is possible to cause thermally treated Inconel 600 to crack at high temperatures in pure or primary coolant water, but it requires a degree of cold work substantially in excess of that used in the laboratory tests.

possibly caustic forming, may occur to varying degrees. The thermally treated Inconel 600 has also been demonstrated in extensive testing to have additional resistance to caustic stress corrosion cracking, particularly in the highly stressed condition. Figure 1.b-1 presents the results of one of a series of laboratory experiments comparing the caustic cracking rate of mill annealed and thermally treated Inconel 600 as a function of temperature and stress. The environment selected, 10% caustic, is believed to be one of the more agressive environments which theoretically could form beneath sludge deposits on the secondary side. As shown in Figure 1.b-1, the thermally treated tubing is essentially unaffected at the T_{Hot} operating temperature of 603°F, even in the overstressed conditions of [ ]$^{a, c, e}$ of yield stress. Additional resistance of thermally treated over mill annealed material (as used originally in Point Beach Unit 1) is reproducible over a number of tubing heats and laboratory test conditions.

The tests described above relate to standardized laboratory specimens, selected to accelerate the potential for attack. Additional tests have been performed on actual transition zones of hydraulically expanded thermally treated tubing. Production tubing was expanded into simulated tubesheets, internally pressurized to [ ]$^{a, c, e}$ psi hoop stress (representative of the maximum tensile stress to which the tubes are subjected in normal operation) and immersed in 10% caustic at 600°F and 650°F, such that the solution contacted the OD of the tubing. Several mechanically expanded and unex-

panded specimens (both thermally treated and mill annealed) were included as controls. At 600°F, the thermally treated specimens did not crack after about one year of exposure, whereas the two unexpanded mill annealed specimens cracked after 46 days. Table 1.b-1 presents the detailed test data for the 600°F tests.

At 650°F, the higher temperature produced cracking in the containers holding the test specimens, often resulting in premature termination of the tests. Even under these conditions, the superiority of the thermally treated and hydraulically expanded specimens was confirmed.

The conclusions from these tests are (1) thermally treated Inconel 600 provides greater resistance to both primary and secondary environments compared to mill-annealed Inconel 600, and (2) cold working such as that experienced in the hydraulic expansion process does not negate the benefits of the thermal treatment.

TABLE 1.b-1

600°F Test Results

Specimen	Description	Exposure, days	Results

a,c,e

FIGURE 1.b-1

Temperature °F

QUESTION

1. c) An explanation of the extent, if any, that the tube expansion process (i.e., cold working) alters the "corrosion resistant metallurgical structure: of heat treated Inconel 600 (see Repair Report, Section 2.2.1.4).

RESPONSE

As stated in Section 2.2.1.4 of the Repair Report, the increased corrosion resistance of the thermally treated Inconel 600 is associated with grain boundary precipitate morphology. The effect of cold working on the metallurgical structure of Inconel 600 would be to elongate the metal grains. The grain boundary precipitates would not be affected by this process. Thus, the corrosion resistant metallurgical structure should not be affected except for the residual stresses associated with cold working. Tests and analyses described in the response to Question 1.b) have demonstrated that stresses from hydraulic expansion are acceptably low and that the additional corrosion resistance of thermally treated Inconel 600 is retained.

QUESTION

1. d) (The replacement steam generators incorporate two design features to reduce the buildup of sludge on the tubesheet: a flow distribution baffle and an improved blowdown system [see Repair Report, Sections 2.2.1.1, 2.2.1.2].) A discussion of the data relating to sludge buildup that have been obtained from the operation of steam generators incorporating these features.

RESPONSE

Replacement steam generators utilizing the flow distribution baffle and the improved blowdown system have been installed in Surry Units 1 and 2 and in Turkey Point Unit 3. Visual examination by fibreoptics and sludge measurement techniques at Surry Unit 2 have shown no significant sludge accumulation after approximately 24 months of operation. Data from Surry Unit 1 and Turkey Point Unit 3 are not available presently. Although field verification of the flow distribution baffle and modified blowdown system is limited, the correlation of sludge buildup on the tubesheet with lateral flow velocity has been verified for steam generators without a flow distribution baffle - see Figure 1.d-1.

Based on the computer analysis model, CHARM, low flow velocities ($\leq$ [ ]$^{a, c, e}$ ft/sec) are predicted off center of the tube lane, i.e., away from the blowdown intake. Furthermore, the measured sludge profile height has been correlated with low tube gap velocities - apparently, below [ ]$^{a, c, e}$ ft/sec sludge particles may settle. Therefore, to minimize the number of tubes exposed to a low crossflow velocity, a flow distribution baffle and a modified blowdown system have been incorporated

into the Point Beach replacement steam generators. The hydraulics at the tubesheet with a flow distribution baffle are illustrated in Figure 1.d.-2. Based on the computer code analysis, the flow distribution baffle has been designed with the objective of limiting the number of tubes exposed to a sludge settling environment and to limit low crossflow velocities to the center of the tube bundle near the blowdown system.

The correlation of sludge buildup on the tubesheet with lateral flow velocity has also been experimentally verified using a flow visualization model at the Carnegie-Mellon University (see Figure 1.d-3). The Carnegie-Mellon flow visualization model was composed of 120 tubes in both the hot and cold legs arranged in a 4 x 30 array. The model included a tubesheet, wrapper wall, and a single tube support plate. The model did not include a flow distribution baffle. Sludge particle deposition was simulated using particulate material in a working fluid of Refrigerant 113. This test also confirmed the correlation of measured sludge height with low tube gap velocities.

a,c,e

Height of Deposit, Inches

Lateral Velocity, fps

Hot Leg Tube Rows

℄ Tubelane

Cold Leg Tube Rows

FIGURE 1.d-1

SLUDGE/LATERAL VELOCITY PROFILES AT THE TUBESHEET WITHOUT FLOW DISTRIBUTION BAFFLE FOR POINT BEACH UNIT 1

FIGURE 1.d-2 INFLUENCE OF FLOW DISTRIBUTION BAFFLE ON TUBESHEET LATERAL VELOCITY

[ ] a,c,e

WITHOUT FLOW DISTRIBUTION BAFFLE

[ ] a,c,e

WITH FLOW DISTRIBUTION BAFFLE

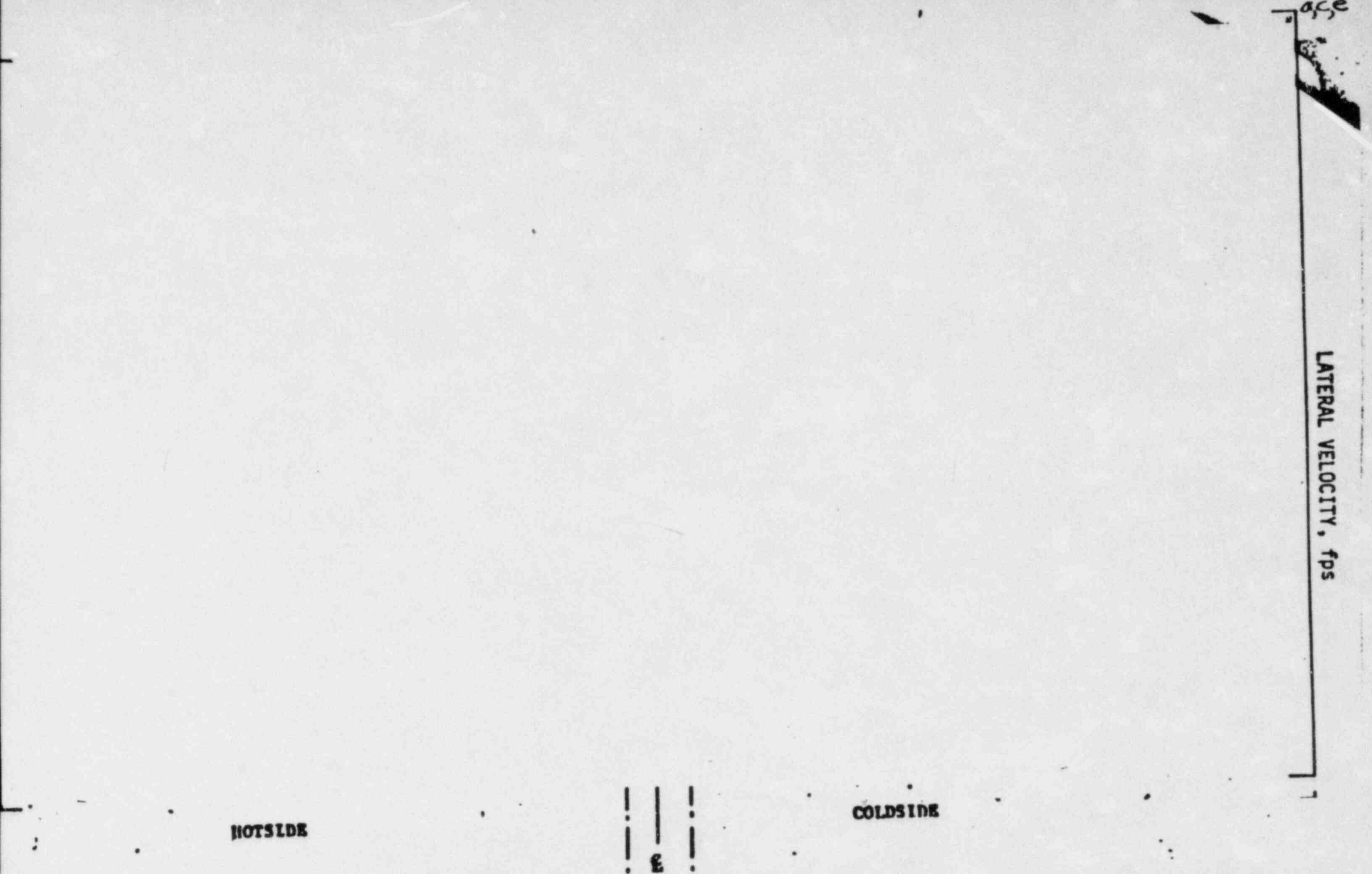


FIGURE 1.d-3

CMU FLOW MODEL RESULTS
NO FLOW DISTRIBUTION BAFFLE

QUESTION

1. e) A discussion of the adequacy of eddy current testing, or any other means of in-service inspection, for detecting and assessing steam generator tube degradation taking place in the region where the fully expanded tube emerges from the tubesheet.

RESPONSE

The routine inspection of steam generator tubing is carried out by using a standard bobbin type probe and a multi-frequency eddy current system which uses multi-parameter techniques for minimizing interference signals. This system has adequate sensitivity for detecting and estimating tube degradation in regions not involving any significant tube deformation. However, inspection of the tubes in the hydraulic expansion transition region at the tubesheet interface requires the reduction of the interference signals from the expansion transition, tubesheet edge and possible sludge. The signals from the tubesheet edge and the sludge are routinely minimized in the field by using the multi-frequency eddy current technique for signal processing while using the standard bobbin type eddy current probe. This technique provides adequate sensitivity to detect tube degradation near the top of the tubesheet and at a tube support plate in the absence of significant tube deformation. At the position of the tube expansion transition, the detectability of tube degradation is reduced, since the standard bobbin type probe is very sensitive to any changes in the inside diameter of the tube. A change in the inside diameter results in a large signal which could interfere with a signal from the tube degradation. However, the standard bobbin type

probe can be used to establish a baseline signature of the hydraulically expanded region of the tube which can then be compared to eddy current signals from subsequent inspections. It is expected that steam generator tube degradation in the hydraulically expanded region would result in a change in the baseline signature.

If a change from the baseline signature of the expansion transition is observed, this region can be inspected with specialized probes. There are at least four other probe configurations capable of enhancing the detection of tube degradation in expansion transitions. One such probe is the cross-wound coil probe. This probe is insensitive to discontinuities with 360 degrees symmetry, thus minimizing the interference signals from the expansion transition and also the tubesheet edge since they both possess the 360 degree symmetry. In the event that the expansion transitions do not possess exact 360 degree symmetry, the eddy current signals using the cross-wound coil probe at two different frequencies are processed using multi-frequency, multi-parametric techniques for minimizing the remaining signal from the expansion transition. This technique results in sensitivity for tube degradation at the expansion transition such that a 20% through wall flat bottom drill hole, equivalent in volume to ASME standards, can be detected. This system is currently being used with success for the inspection of the expansion transition regions of sleeved tubes in steam generators which have similar hydraulic expansion transitions.

A probe consisting of multiple coils riding along the inside surface of the tube can also be used for the inspection of such regions. Since the coils ride along the tube surface, they are insensitive to the deformation of the tube wall and thus produce clear signals from any significant degradation of the tubewall. Such probes have also been used with success for inspecting such regions in the field.

Another system which is available for the inspection of the expansion transitions uses a three-phase oscillator which drives three coils, placed 120 degrees apart. This system also is insensitive to the discontinuities with 360 degree symmetry and produces the desired result of minimizing the interference from such factors as the tubesheet edge and the expansion transition.

QUESTION

2. The new steam generator design has ferritic stainless steel (SA-240 Type 405) tube support plates, with quatrefoil-type tube passages (see Repair Report, Section 2.2.1.7 and Figure 2-3). The method by which the quatrefoil holes are formed is not specified, but their irregular shape suggests that, as a result of the forming process, residual stresses may exist in the region of these penetrations.

   The applicant should describe the analyses and/or tests performed that relate to the possibility of stress corrosion in the region of the quatrefoil penetrations, and indicate whether stresses in the support plates associated with normal operation of the new steam generators were included in the analyses or tests.

RESPONSE

Laboratory tests conducted by Westinghouse utilizing highly stressed Type 405 stainless steel U-bends exposed to caustic and chloride environments, and heated crevice and model boiler tests utilizing actual broached quatrefoil samples exposed to the environments which caused tube denting and cracking of the carbon steel support plates, as well as literature searches, have verified that Type 405 stainless steel, as fabricated, is not susceptible to stress corrosion cracking in the steam generator operating environment.

The fabrication of the Type 405 stainless steel support plates does not produce significant residual stresses. The plate material is initially strengthened by heat treatment and tempered at 1325-1375°F. While the purpose of these heat treatments is to optimize the mechanical properties and corrosion resistance of the material, the tempering operation also minimizes any residual stresses which may be present in the plate material. Small holes are then drilled at the required locations for the quatrefoil openings. The quatrefoil openings are produced by

broaching; an operation involving multiple shaving, i.e., progressively removing small amounts of metal by utilizing a tool with stepped cutting edges, which removes less and less metal with each step. The residual stresses caused by the broaching operation have not been analyzed, but are judged, based on the metal removal process, to be low. Although some general corrosion has been observed at tube support lands in certain accelerated heat transfer corrosion tests, there has been no appearance of stress corrosion cracking indicative of high residual stresses.

APPENDIX A

BASIS OF SELECTION OF TUBE/TUBESHEET EXPANSION PROCESS FOR THE MODEL F STEAM GENERATOR

BASIS OF SELECTION OF TUBE/TUBESHEET EXPANSION PROCESS FOR THE MODEL F STEAM GENERATOR

INTRODUCTION

Field experience with operating units in which the tubes were only part-rolled into the tubesheet indicated that full depth expansion may add margin to minimize crevice corrosion. Various processes have been developed for performing full depth expansion. Processes used by Westinghouse have included mechanical rolling, explosive expansion and hydraulic expansion. Since late 1978, all units manufactured at Westinghouse have been hydraulically expanded. This has included some Model D's and E's and all Models 44F, 51F, and F. The purpose of this report is to summarize the more important reasons for selecting the hydraulic method as the reference process.

GENERAL REQUIREMENTS

Any viable process must satisfy concerns relating to:

- o technical objectives
- o manufacturability
- o quality control

It is the desire - indeed, the need - to optimize the balance in these various requirements which leads to the selection of one process over another. Manufacturability and quality control also impact technical objectives. This is because each process has its own characteristics which are to be controlled so as not to preclude attainment of the technical objectives. Process selection is based first and foremost on achievement of the technical objectives.

There are four (4) technical aspects which are common to all tube expansion processes. These relate to:

- o crevice depth
- o residual stresses
- o joint tightness
- o tube material properties

Following a brief description of the expansion processes, these four (4) technical aspects will be discussed and comparisons made between the different processes.

PROCESS DESCRIPTION

The main steps associated with each expansion process are depicted schematically in Fig. 1, and include:

- o insertion of tubing
- o tack expansion
- o tube to tubesheet welding
- o leak testing
- o full depth expansion
- o final quality control (QC) inspection

Following the tubing process (insertion of tubes through support plates and tubesheet) the tubes are tack expanded for a depth of about 3/4" on the primary side to facilitate tube to tubesheet welding. Tack expansion is accomplished with either mechanical rolling or urethane expansion. The tube to tubesheet weld (actually tube to tubesheet cladding) serves as both a seal weld, preventing leakage between primary and secondary sides, and a strength weld, supporting the service imposed loads. After leak testing of the welds, the tubes are full depth expanded.

For mechanical rolling, expansion is incremental - the rollers being about 1" long - and expansion begins at the primary side. Mechanical rolling induces considerable redundant metal working - the tube is locally worked as one roller then another passes around the circumference and then the transition zone at the edge of each step is rolled out by the next roll step. The hydraulic and explosive processes, by contrast, produce a rather uniform

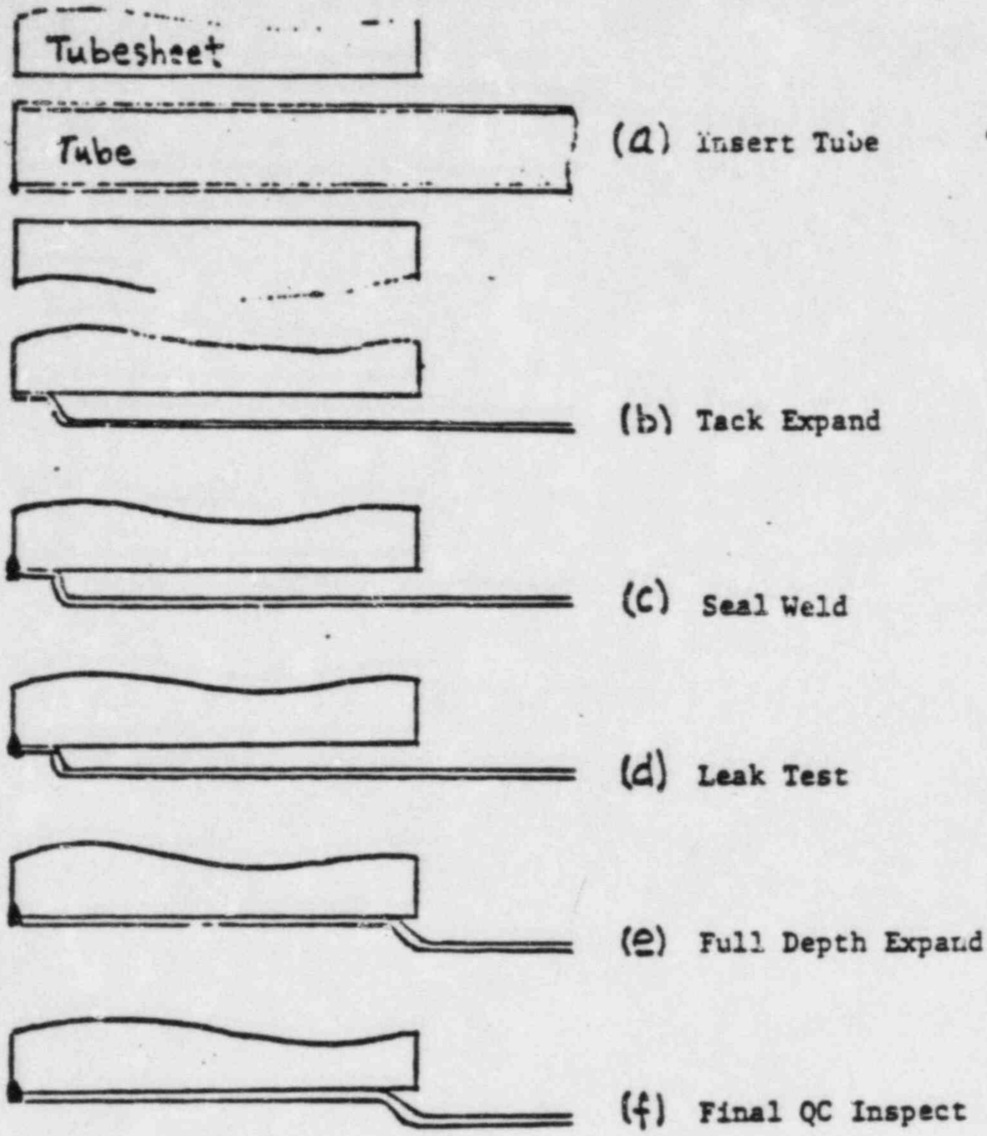


Fig. 1. Illustration of major steps involved in full depth tube to tubesheet expansion process.

radial expansion which occurs simultaneously along the full thickness of the tubesheet. For all expansion processes, the tube length first decreases as the tube is expanded out to contact with the tubesheet, and then increases with further expansion due to the tube wall thinning. The net effect is that the tube elongates during mechanical rolling (the tube wall thins about 2 mils) but shortens during hydraulic or explosive expansion (wall thinning is only a fraction of a mil).

Finally, QC inspections (in-process and final) are performed to verify the expansion process and to identify abnormal conditions. Of the four essential technical aspects previously mentioned, and discussed in the following section, QC inspection usually measures only the crevice depth. Tube to tubesheet joint tightness can be measured by ultrasonic techniques but this is not an industry-wide practice. Residual stresses, joint tightness and tube material properties are assessed by analytical/experimental laboratory process development and qualification programs prior to production usage.

TECHNICAL REQUIREMENTS

The expansion processes which will be considered here include:

Tack Expansion

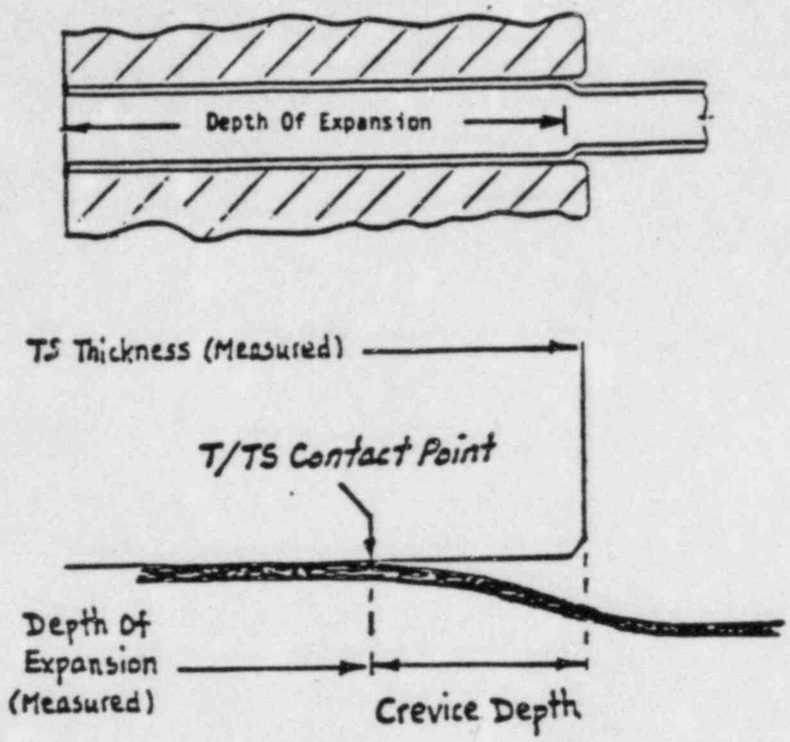
- mechanical rolling
- urethane expansion

Full Depth Expansion

- mechanical rolling
- explosive expansion
- hydraulic expansion

CREVICE DEPTH

Crevice depth, and the complementary measure, depth of expansion, are defined by the sketch in Fig. 2. Depth of expansion, hence crevice depth, is controlled by the expansion process parameters. For each process, these parameters are optimized to provide proper balance of competing effects. In



Crevice Depth = Tubesheet Thickness - Depth Of Expansion

Fig. 2. Definitions of "depth of expansion" and "crevice depth".

hydraulic expansion, for example, crevice depth is controlled primarily by mandrel length. Too short a mandrel gives a deeper crevice; too long a mandrel could produce overexpansion in the tube just above the tubesheet. Hence, mandrel length is optimized so as to minimize crevice depth while simultaneously precluding the occurrence of overexpansion. A unique distribution of crevice depths is obtained for each controlled expansion process. A rather large data base consisting of accurate crevice depth measurements on production units exists for the hydraulic expansion process. For earlier units expanded by mechanical rolling and explosive expansion, process control was the basis for controlling crevice depth. A subjective assessment is as follows:

Process	Max. Crevice Depth, inch	Mean Crevice Depth, inch	Approx. Transition Length, inch
Mechanical Roll	1/4	1/8	1/8 - 1/4
Explosive expansion	1/2	1/4	1/2
Hydraulic expansion	1/4	1/8	1/4

A typical hydraulic transition zone profile is shown in Fig. 3. The transition zone length is usually 0.25 to 0.3 inch long.

Crevice depth data for the hydraulic expansion process follow a Gaussian distribution. Westinghouse experience in expanding more than 1/4 million tubes by the hydraulic expansion process has demonstrated that crevice depth can be controlled to give a mean depth of about 1/8 inch and a maximum depth less than 1/4 inch.

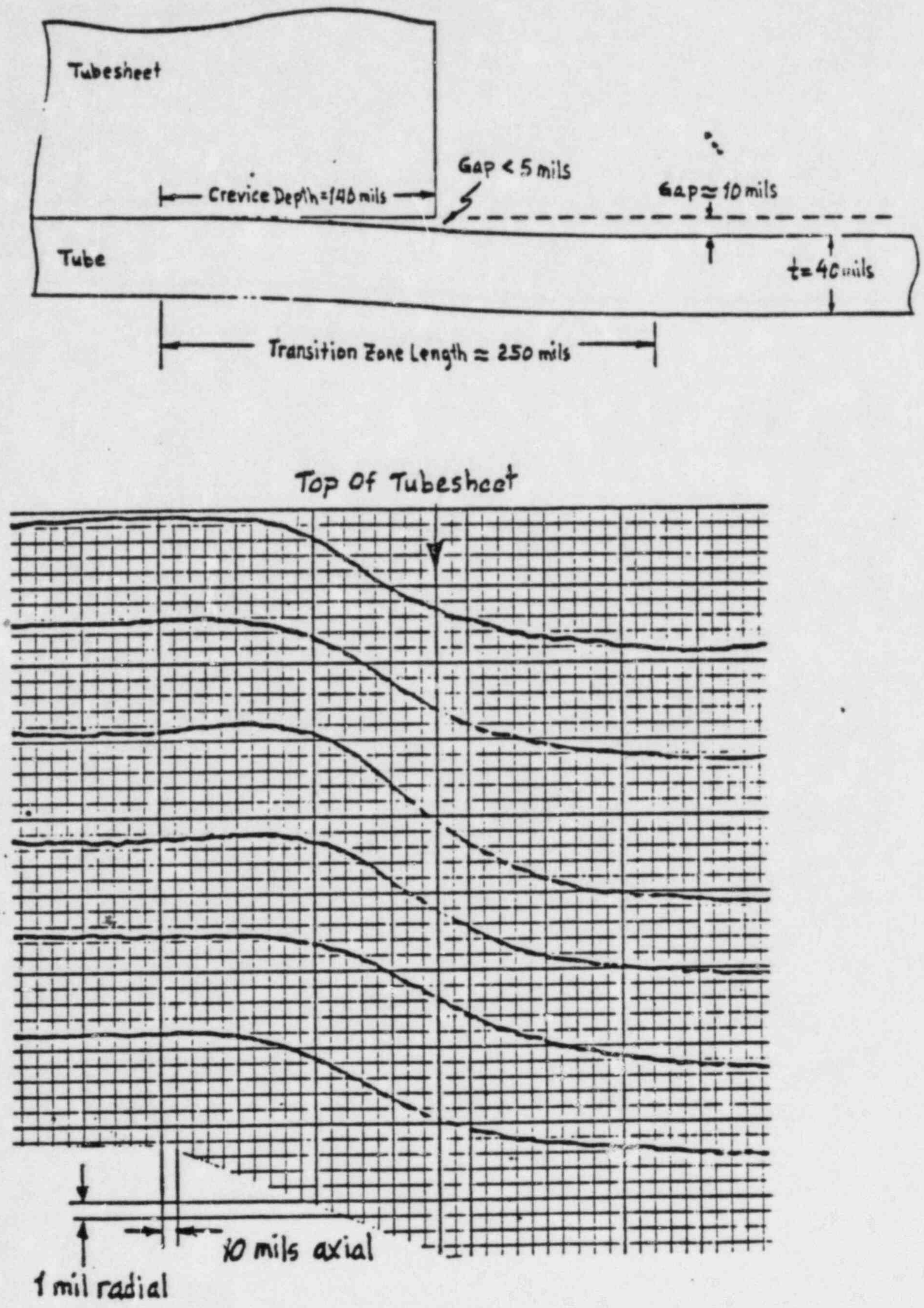


Fig. 3. Hydraulic expansion transition zone profile schematic at top is at 13X magnification. Traces at bottom are actual radial profile traces from a recent production unit.

RESIDUAL STRESSES

Agreement is unanimous within the industry that residual stresses should be minimized because of their potential role in stress corrosion cracking. This led Westinghouse to develop alternatives to conventional mechanical rolling.

Measurement Techniques

Various techniques have been used to assess the residual stresses in the transition zone between the expanded and unexpanded portions of the tube, which is the region of prime interest. Strain gage relaxation and X-ray diffraction techniques have given ambiguous results - partly because of difficulty in performing the tests, and partly because of inherent difficulties in interpreting the results. Analytical calculations have been made using finite element analyses. This technique is more suitable for hydraulic expansion than mechanical rolling because it is easier to model the physics of the process for hydraulic expansion. These techniques - strain gages, X-rays and finite element analyses - attempt to determine absolute values of residual stresses. The most widely used technique, however, employs stress corrosion cracking (SCC) tests which yield primarily qualitative results although the results, in principle, can be quantitative.

In SCC tests the tubing is first given a sensitization heat treatment which renders its microstructure sensitive to SCC when stressed and exposed to a specific corrosive environment. Samples are prepared, say mechanically rolled and hydraulically expanded and exposed to the corrosive environment. In time, the samples crack; the longer the time the lower the residual stresses. Thus, the test provides a relative comparison of the residual stresses from different expansion processes, or for different parameters of a given process. It further identifies the location of the highest tensile residual stress (point where crack occurs) and the direction of the stress (normal to the orientation of the crack).

The test can be made quantitative by calibration. For this purpose, specimens of sensitized tubing are stressed to various known applied stress levels (no residual stresses) and tested in the corrosive environment as depicted in

Fig. 4. The specimens may be uniaxial tensile specimens but more often are C-ring specimens loaded to a given outer fiber stress. The results give a curve (called C-ring curve for C-ring specimens) of applied stress versus time to crack initiation. Samples having only residual stresses are then prepared and tested. Using the time to cracking, the C-ring or calibration curve is entered at that time to determine the magnitude of the residual stress as depicted in Fig. 4.

Inconel 600 tubing is tested in polythionic acid at room temperature. However, in order to sensitize the microstructure it is usually necessary to solution anneal the tubing prior to aging and this gives a coarse grain size. Thus, the sensitized tubing has mechanical properties different from the properties of regular steam generator tubing, and for this reason the results are only semi-quantitative.

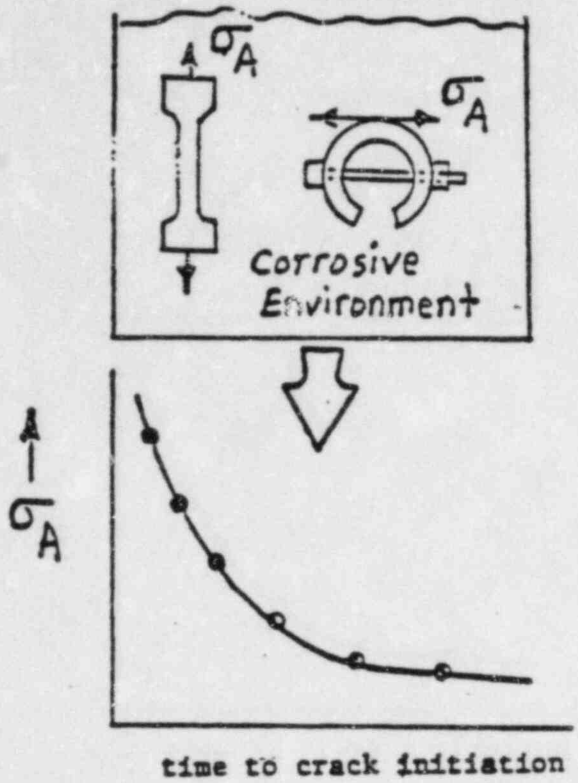
As an alternative to Inconel 600 in polythionic acid, tests may be run on stainless steel tubing in boiling magnesium chloride. This is a more difficult test to perform but has the advantage that the stainless steel tubing has a fine grain size. Since the two types of tubing have similar mechanical properties, results on stainless steel should be qualitatively applicable to evaluation of Inconel 600.

SCC Results

The residual stresses are somewhat higher on the ID than on the OD. The relative magnitude of the residual stresses for various expansion processes are compared in Fig. 5. The comparison uses polythionic acid test results and the C-ring curve but should be viewed only in a relative qualitative sense. The residual stresses in the transition zone are highest for hard (high torque) mechanical rolling and lowest for hydraulic expansion. Though the data are limited, the residual stresses for explosive expansion (called WEXTEX by Westinghouse, i.e., Westinghouse Explosive Tube Expansion) are low, similar to hydraulic expansion.

A comparison of the ID residual stresses at the tack expansion transition is also shown in Fig. 5 for soft (low torque) tack rolling and urethane tack

(a) Establish experimental calibration curve.



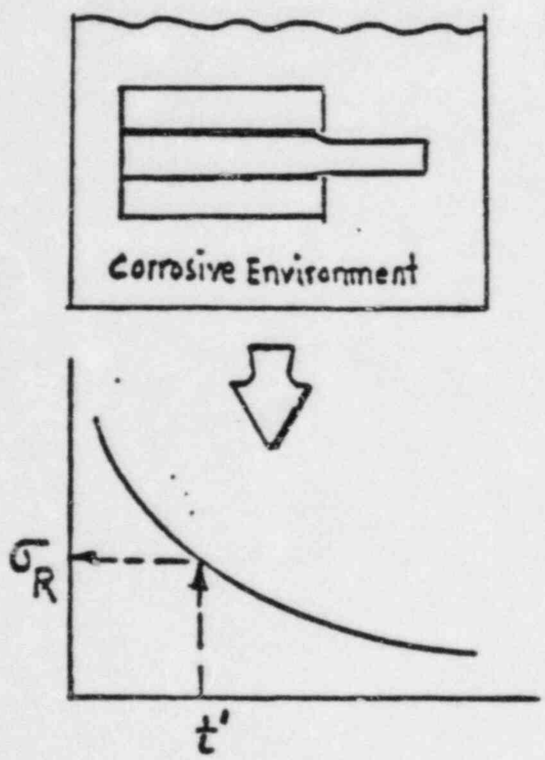
Heat treat tubing to respond to SCC in corrosive environment.

Place test specimens in corrosive environment and load to known stress levels.

Determine times to crack initiation.

Plot calibration curve of applied stress versus time to cracking.

(b) Test component (expanded sample)



Prepare sample and place in corrosive environment.

Determine time t' for residual stress to cause SCC.

Enter calibration curve at time t' to get residual stress σ_R.

Fig. 4 Illustration of how residual stresses are determined by stress corrosing cracking tests.

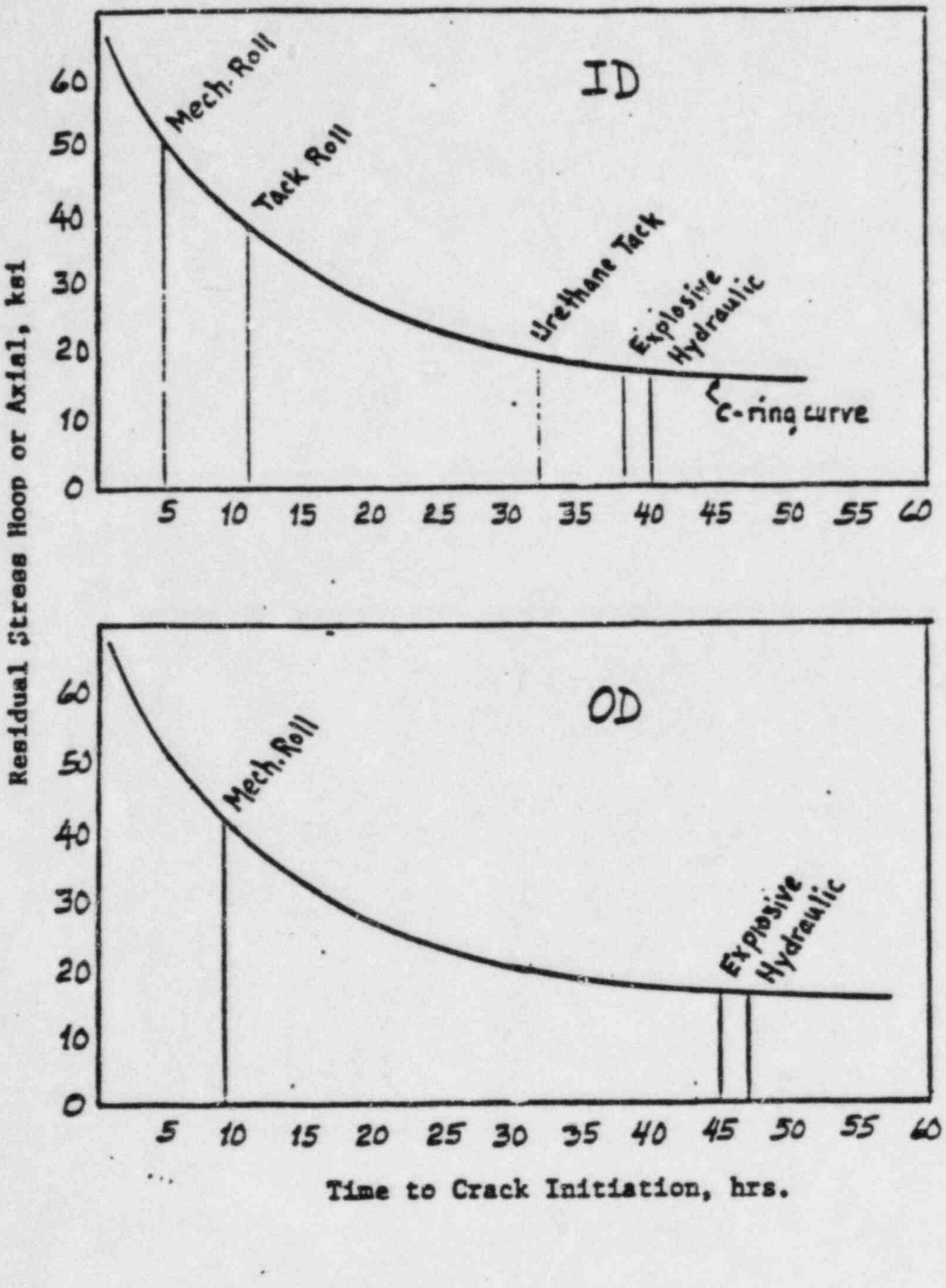


Fig. 5 Relative comparison of residual stresses for various expansion processes. Though stress and time scales are given to provide perspective, the figure is intended to be more schematic than quantitative.

expansion. The residual stresses are much lower for urethane tack expansion, which is the process currently used at Westinghouse.

Finite Element Analysis

Results of a finite element analysis of the hydraulic expansion process are summarized in Fig. 6. The locations and orientations of the maximum residual tensile stresses are in good agreement with the experimental SCC results.

JOINT TIGHTNESS

All of the full depth expansion processes used by Westinghouse close the gap between tube and tubesheet to virtually zero. This minimizes the potential for initiation of OD stress corrosion cracking of tubing within the tubesheet region and enhances the strength of the tube to tubesheet joint. However, the tube to tubesheet weld at the primary side of the tubesheet provides the primary barrier to leakage between primary and secondary sides, and also provides the required structural strength - no credit is taken for frictional resistance along the tube to tubesheet joint.

TUBE MATERIAL PROPERTIES

Inconel 600 Westinghouse Steam generator tubing is specially thermally treated to impart enhanced corrosion resistance. Tube expansion must not degrade this corrosion resistance. Intuitively, it might be reasoned that hydraulic expansion would have the least effect. Test results confirm that hydraulic expansion does not degrade the inherent corrosion resistance of the thermally treated tubing.

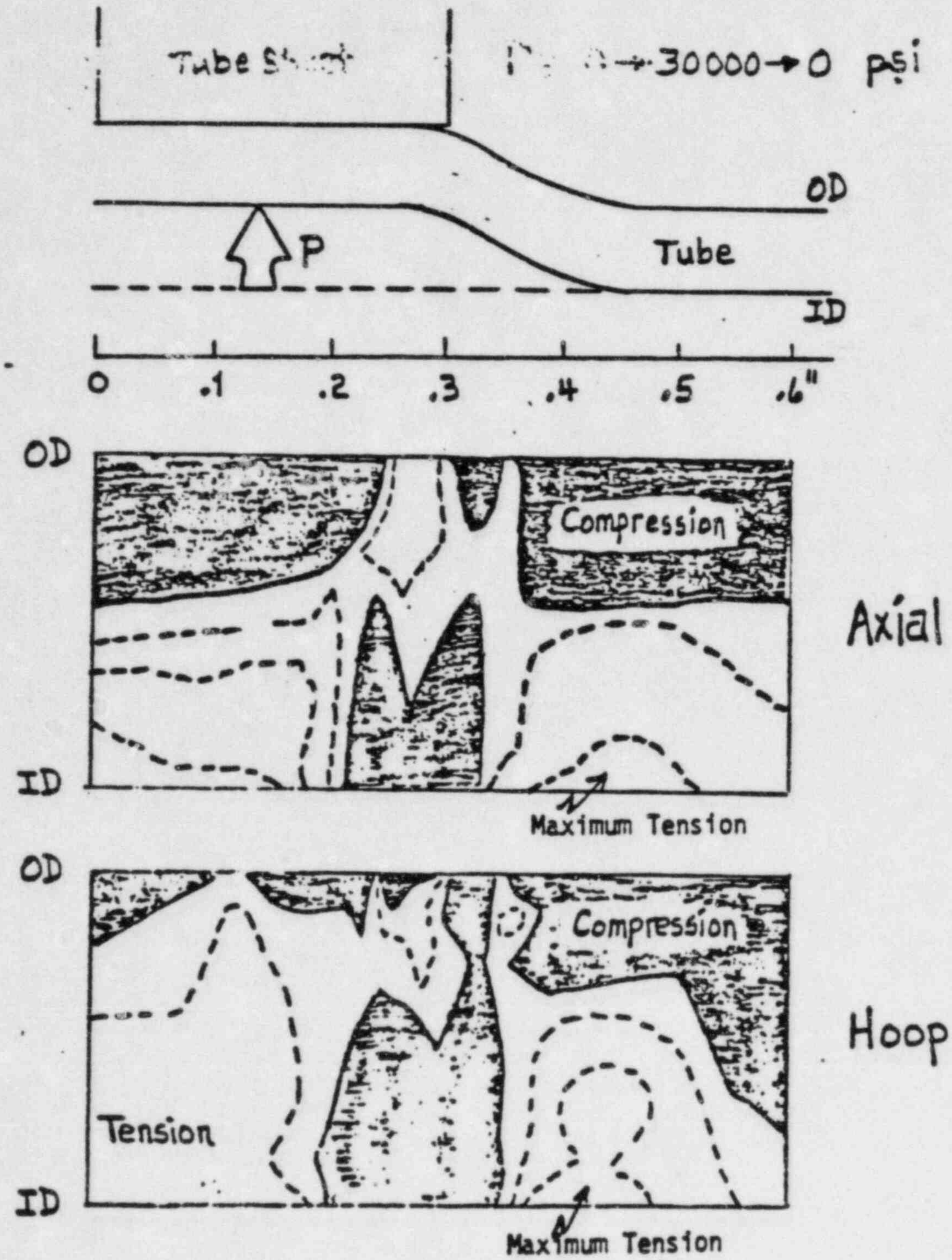


Fig. 6 Results of finite element analysis of residual stresses in hydraulically expanded transition.

SUMMARY

At Westinghouse, the current practice is to expand tubes full depth through the thickness of the tubesheet to provide added margin against crevice corrosion. The present hydraulic expansion process was selected over the former processes of explosive expansion or mechanical rolling because hydraulic expansion provides optimum balance in the attainment of the technical objectives relating to minimal crevice depth, low residual stresses, and adequate joint tightness.