UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

Before the Atomic Safety and Licensing Board

In the Matter of	)	
	)	
METROPOLITAN EDISON COMPANY, ET AL.	)	Docket No. 50-289-OLA
	)	ASLBP 83-491-04-OLA
(Three Mile Island Nuclear Station, Unit No. 1)	)	(Steam Generator Repair)
	)	

LICENSEE'S TESTIMONY OF DON K. CRONEBERGER AND F. SCOTT GIACOBBE ON ISSUE 1.d (CONTENTION 1.a)

To Mr. Croneberger:

Q1. Please state your name and address and describe your involvement with the TMI-1 steam generator tube repair program.

A2. My name is Don K. Croneberger. I am employed by GPU Nuclear Corporation, 100 Interpace Parkway, Parsippany, New Jersey 07054. As the director of Engineering and Design, I provided technical management oversight of the failure analysis and repair activities, with special emphasis on evaluation of the steam generator's mechanical design and the impact of the repair on the response of the components. My department also provided engineering support in the areas of Materials Engineering/Failure Analysis, Chemical Engineering and Chemistry, Mechanical Engineering and Engineering Mechanics.

A statement of my professional qualifications is attached.

To Mr. Giacobbe:

Q2. Please state your name and address, and describe your involvement with the TMI-1 steam generator tube repair program.

A2. My name is F. Scott Giacobbe. I am employed by GPU Nuclear Corporation, P.O. Box 1018, Reading, Pennsylvania 19603. As Manager of Materials Engineering/Failure Analysis, I have been involved in the planning and management of the failure analysis activities, corrosion testing programs, materials evaluation and tube sampling and removal programs associated with the steam generator tube repair program.

A statement of my professional qualifications is attached.

To all witnesses:

Q3. What is the purpose of your testimony?

A3. The purpose of this testimony is to address Issue 1.d of Contention 1.a as enumerated at page 23 of the Board's Memorandum and Order (Rulings on Motions for Summary Disposition, dated June 1, 1984), in which the Licensing Board stated:

> 1. The rationale underlying certain proposed license conditions should be addressed, with attention to:
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> *****
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> d. Adequacy of simulation of operating conditions by long-term corrosion tests.

Q4. What was the purpose of the long term corrosion test program?

A4. The purpose of the long term corrosion test program, the operations phase of which has now been completed, is to verify that sulfur-induced intergranular stress-assisted cracking (IGSAC) will not reinitiate or propagate in the TMI-1 OTSGs under actual operating conditions. The tests were designed to confirm that the metallurgical, environmental, geometric and surface conditions which exist after the repair of the tubes are not detrimental to tube integrity. From the test program it will be possible to conclude whether or not the proposed chemistry limits are acceptable, whether the peroxide cleaning itself was beneficial or damaging, and, more importantly, whether the changes in electrochemical potential during operations will cause reinitiation of corrosion.

The long term corrosion tests are accordingly related to the kinetic expansion repair process, but only insofar as they verify that the repair did not render the OTSGs susceptible to reinitiation of IGSAC. (This is tested by including kinetically expanded tube samples in the test loops.) Except in this one respect, the long term corrosion tests have no relationship to the adequacy of the kinetically expanded joint. The tests were <u>not</u> designed to confirm that Licensee has provided reasonable assurance against the possibility of mechanically induced tube ruptures caused by various transients, as alleged by Contention 1.a, and, in fact, the tests provide no information one way or the other on this subject.

Q5. Did the tests adequately simulate operating conditions so as to provide reasonable assurance that corrosion will not reinitiate?

A5. Yes. The long term corrosion test program includes tests which closely simulate the typical operating environment of the steam generator tubing during steady state and transient conditions. This program will enable Licensee to predict the performance of actual TMI-1 tubes in the steam generators prior to return to operation. The program also includes comparative tests which closely simulate OTSG operation but use tubes with high residual sulfur levels (non-peroxide cleaned) and expose the tube samples to the contaminant which originally caused the IGSAC damage (thiosulfate). All tests simulated "worst case" chemistry conditions for controlled contaminants (within chemistry specification limits) in order to conservatively address the parameters known to influence stress assisted cracking.

In establishing operating parameters, to simulate both hot functional testing (HFT) and subsequent operation, time periods were chosen of approximately 40 days for the HFT cycle and 66 days for each of the six heatup/cooldown cycles expected in a year of operation. The test loops are once-through in design, with primary coolant water chemistry flowing on the inside of the tubes, just as in the OTSGs. The test cycles allowed for periodic examination of test specimens to monitor for evidence of corrosion damage.

All six heatup/cooldown cycles have been completed. Final metallographic examinations of test specimens are now in progress. This program will enable Licensee to predict the performance of actual TMI-1 tubes in the steam generators prior to return to operation.

TEST PARAMETERS

The tests reproduced all the parameters which influence IGSAC, i.e., susceptible material, environment, and stress.

Susceptible Material

To assure that the influence of prior operation and layup on tubing was adequately represented, only tube sections removed from the TMI-1 steam generators were used as specimens. These specimens were selected from various regions of each OTSG including tube sections which had known defects. The use of actual OTSC tubes precluded any possibility that test specimens would not duplicate exactly the TMI-1 material.

The specific tube sections for the long term corrosion test were selected from tubes that had been previously removed from the steam generators for use in the failure analyses. Within the available material, the tube sections were selected to provide a maximum range of properties. These included:

1) Chemistry - test specimens were selected from representative heats of material removed from the generator. This provided a range of chemistry typical of most steam generator tubes.

2) Mechanical Properties - yield strengths of the specimens spanned the range of those tubes present in the steam generators.

3) Material susceptibility - specimens for testing were selected from tubes which displayed various levels of susceptibility to corrosion damage. Some came from tubes

with no defects and others from tubes with up to eight indications.

The test samples also contain a representative sample of tubes from various axial locations within each steam generator. The largest portion of the samples are from the upper tubesheet area, which contained the most defects. There are also samples from the lower face of the upper tubesheet, 15th tube span, and 9th tube support plate areas.

Subsequently, certain of the samples were subjected to the explosive expansion process using mockup tube sheets and then subjected to a peroxide cleaning process. This ensured that the influence of these processes on the inside surface condition was produced. Certain other samples were not peroxide cleaned, in order to test what could occur if Licensee had not undertaken the cleaning process, given the larger quantities of residual sulfur that would have remained on the tube surfaces.

C-ring samples made from actual TMI-1 tubes were also included in the test program. These samples provided a means for metallographically examining test specimens during the testing phase to look for any microstructural changes or incipient cracking.

Environment

Environmental chemistry parameters were selected to either simulate, or be more aggressive than, the water chemistry which will be maintained in the RCS. In three of the four test loops, 100 ppb of sulfate, the maximum permitted under chemistry specifications, was used. In the fourth test loop, 100 ppb thiosulfate was put in solution. In addition, to ensure adequate conservatism, the levels of chloride and fluoride were set at the maximum amount permitted by Licensee's operating chemistry specifications (100 ppb each).

Because the testing and operation of the plant necessitates heating up and cooling down of the steam generators, the tests included typical temperature cycles. Temperatures were raised from ambient temperature to the normal operating temperature of approximately 600°F. Temperatures were held constant at operating temperature to assess any high temperature corrosion phenomenon. Periodically, the tests were cycled between 600°F and 500°F to simulate unit load changes.

The test loops were also subjected to cooldown cycles, some of which included the introduction of oxygen (as would occur when the RCS was open for inspection) and some of which did not (as would occur during normal shutdown). These cycles provided the most rigorous test sequence in view of the fact that primary-side sulfur corrosion is a low temperature phenomenon in which oxygen has a major influence.

Each HFT or operating cycle included a hold step for a minimum of one week in which the loop was aerated and maintained at a temperature between 130° and 150°F. This portion of the cycle simulated the aeration-temperature conditions which existed during the propagation of the original sulfur-induced IGSAC.

Stress

During heatup, operation, and cooldown, tubes in the actual OTSG undergo changes in stress. A net axial tensile stress could exist in the tubes during cold shutdown and steady state operation. The stress is reduced during heatup and increased during cooldown due to differential thermal expansion effects.

In order to simulate the changes in axial load, full tube specimens were loaded at a level corresponding to steady state loads during heatup, cold shutdown, and operation. During cooldown, the loads were increased to approximate the maximum allowed cooldown rate.

Residual stresses induced by the explosive expansion are also a source of loads on the tubes. Therefore, full tube specimens simulating repaired joints were kinetically expanded using the same process as in the actual steam generators to ensure representative residual stresses. These specimens were also exposed to the axial loads described above so that the worst case combination of loads was tested.

The C-ring specimens were intended to give an early indication of possible problems. Therefore, they were loaded to a level just slightly below yield, which is significantly higher than the load seen by the tubes in actual service. This would make them more susceptible to IGSAC than are the actual OTSG tubes.

SUMMARY

The long term corrosion test program includes tests which provide a valid simulation of the conditions that the OTSG tubing will experience in future TMI-1 operations. For comparison, tests have also been included which simulate what could occur if Licensee had not taken the corrective measures of peroxide cleaning and removal of possible sources of thiosulfate. Parameters known to influence corrosion and more specifically IGSAC were reproduced to the greatest extent possible. This test program provides a clear basis for empirically evaluating steam generator tube performance over approximately a one year period.

PROFESSIONAL QUALIFICATIONS

Don K. Croneberger
Director - Engineering & Design
GPU Nuclear Corporation

GPU Experience:

Technical responsibility for the Mechanical, Electrical, Civil/Structural, Chemical, Radwaste and Materials Engineering support for all nuclear generating stations for the GPU Systems.

1978 to 1980 was Manager - Design and later Manager - Engineering & Design with GPU Service Corporation. Directed design engineering activities for all nuclear and fossil power generating facilities and modifications assigned to GPUSC.

Other Experience:

Prior work experience included a number of positions at Gilbert/Commonwealth during the period 1963 to 1978. The last position was Manager Structural Engineering. It included technical responsibility for structural engineering mechanics for all nuclear and fossil generating facilities. Some of the other positions included Project Manager for balance of plant studies for a liquid metal fast breeder reactor demonstration plant. Other positions as Project Structural Engineer included responsibility for technical supervision of structural engineering and engineering mechanics for a number of domestic nuclear power plants. Earlier experience with the U.S. Navy included engineering and construction of radio telescope and ancillary experience.

Industry affiliations have included the EPRI Steam Generator Owners Group, ASME Section 3 Division 2 (former Chairman) and other industry nuclear standards activities including Nuclear Structures and Plant Design Against Missiles.

Education and training includes a B.S. degree in Civil Engineering from Pennsylvania State University, 1959. Other technical training includes courses at U.C.L.A., M.I.T. and the University of Michigan.

I have been involved in the Steam Generator tube failure issue from the beginning. I provided technical management oversight of failure analysis and repair activities. Special emphasis was placed on understanding the mechanical design of the Steam Generators and applying that understanding to the repair program and the understanding of the impact of the repair on the response of the components.

My department provided engineering support in the areas of Materials Engineering/Failure Analysis, Chemical Engineering and Chemistry, Mechanical Engineering and Engineering Mechanics.

STATEMENT OF QUALIFICATIONS AND EXPERIENCE

F. SCOTT GIACOBBE

I, F. Scott Giacobbe, am employed by General Public Utilities Nuclear Corporation as Manager, Materials Engineering/Failure Analysis. I have been in this position since July of 1982.

My education includes a Bachelor's Degree in Mechanical Engineering from Villanova University in 1970 and a Master's Degree in Materials Engineering from Drexel University in 1975.

My work experience has provided me many years of direct involvement in the materials evaluation and failure analysis of power plant components; early in my career it also provided a very intense involvement in heat exchanger tubing evaluations.

In 1970, I began my employment with Westinghouse Electric Corporation in their Heat Transfer Division as a Materials Engineer. In this position I worked on the materials selection, corrosion evaluations and failure analysis of heat exchanger components such as feedwater heaters, condensors, radioactive waste evaporators and other secondary side heat exchangers. In particular, I was responsible for assuring that tubing utilized in the Westinghouse heat exchangers was properly specified and manufactured. This function provided me with in-depth knowledge of heat exchanger tubing fabrication practices, corrosion resistant properties and failure mechanisms.

In 1977 I left Westinghouse to join General Public Utilities as a Senior Engineer in their metallurgical laboratory. This position afforded me the opportunity to expand my areas of expertise to include materials selection, corrosion evaluation and failure analysis of other components of both nuclear and fossil power plants, and to gain a broader understanding of power plant operation.

In 1978 I was promoted to supervisor of the metallurgical laboratory. This was a first line supervising position which gave me the responsibility for the daily operation of the laboratory and supervision of the technicians and engineers reporting to me. This position also carried with it a large technical responsibility which kept me heavily involved in the day-to-day materials engineering problems.

My career took on a slight change in direction in 1980 when the company reorganized and formed the Nuclear Corporation. At that time I became Materials and Welding Manager in the Nuclear Assurance Division. With this position I essentially had the same functions as before, with the added responsibility for welding at the nuclear power stations. While in this position I was responsible for the technical and metallurgical aspects of the development of the Nuclear Corporation welding program. During this time I was still supervising all failure analysis activities, including the TMI spent fuel pool pipe cracking incident.

In July 1982, another reorganization took place. At this time my section merged with the materials engineering section in the Technical Functions Division and I took over management of that newly formed section. In this position I now had functional responsibility for the materials configuration control of both GPU nuclear power plants as well as welding engineering and failure analysis. In addition, my section still provided failure analysis services to the fossil companies.

I have been involved in the steam generator tube failure issue from the beginning. I participated directly in the initial decision-making regarding the tube sampling and removal operations and was present to perform the initial visual evaluations of the removed tubing. I personally planned and oversaw the failure analysis activities performed by the outside laboratories. I also developed the corrosion testing programs which GPUN implemented to gain insight and understanding into the failure mechanism and responsible corrodants. It was also my responsibility to coordinate the input from all our technical consultants as well as plant experience and formulate the current failure scenario.

During the steam generator repair, my section also provided materials evaluation and consultation on all aspects of the repair including explosive expansion, flushing, peroxide cleaning, and so forth. My section also developed and implemented the long term corrosion testing program and is evaluating the results as the testing progresses.

Lastly, during the course of the steam generator repairs, I was responsible for making all presentations to the NRC on corrosion testing and failure analysis activities.

Over the years I have kept fully abreast with the state-of-the-art in corrosion technology through my attendance and participation in technical seminars and conferences, and through attending training sessions. I am a member of the Edison Electric Institute Materials, Piping, Welding and Corrosion Task Force, a group of industry representatives who meet to share and develop solutions to corrosion problems in the field of materials and welding in the power industry. In addition, I am a member of the American Society for Metals.

Publications

1. F. S. Giacobbe, "Examination, Evaluation and Repair of Stress Corrosion Cracking in a PWR Borated Water Piping System", NACE Corrosion 81.

2. F. S. Giacobbe, J.D. Jones, R. L. Long, D. G. Slear, "Repairs of TMI-1 OTSG Tube Failures" Plant/Operations Progress AICHE, July 1983, Vol. 2, No. 3.