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FEB 12 1980

MEMORANDUM FOR: Roger J. Mattson, Director
Division of Systems Safety

FROM: Darrell G. Eisenhut, Acting Director
Division of Operating Reactors

SUBJECT: PRE-OL STEAM GENERATOR MODIFICATIONS

We have reviewed your memo for H. R. Denton regarding steam generator replacement and modification. Although we agree with the recommendations in the memo, I have not concurred because I believe that additional measures are required to minimize degradation in steam generators and to maintain worker radiation exposure as low as reasonably achievable (ALARA).

In Operating Experience Memorandum No. 25 (attachment 1), dated January 23, 1980, we made several recommendations which will help to reduce tube degradation and minimize occupational exposures associated with inspection, repair or replacement of steam generators should degradation ever occur rereplacement be deemed necessary. Specifically included in our recommendations are provision for greater accessibility and inspectibility of steam generator internals, crevice elimination, elimination of high tube residual stresses, proper secondary system mechanical design and materials selection, improved blowdown design and flow distribution, provisions for chemical cleaning, and provisions for steam generator replacement. Your memo addresses only two of these subjects: provision for steam generator replacement and crevice elimination. The other recommendations listed above are equally important and should be incorporated in new plants to the extent practicable depending on the stage of design and fabrication.

More detailed discussions of this subject may be beneficial and my staff and I are available for such discussions.

Original signed by
Darrell G. Eisenhut

Darrell G. Eisenhut, Acting Director
Division of Operating Reactors

L-4-1, Pt.5

Contact: B. D. Liaw
X27354

XRD-72

Enclosure: As stated

DOR
DEisenhut
2/12/80

*See previous yellow for additional concurrences.

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DATE ▶					

MEMORANDUM FOR: Roger J. Mattson, Director
Division of Systems Safety

FROM: Darrell G. Eisenhut, Acting Director
Division of Operating Reactors

SUBJECT: PRE-OL STEAM GENERATOR MODIFICATIONS

We have reviewed your memo for H. R. Denton regarding steam generator replacement and modification. Although there is some merit in your proposal, I have not concurred because I believe the memo has somewhat mischaracterize the nature and extent of problems that have been experienced by PWR operators in both U.S. and in foreign nations. In addition, the proposed measures for pre-OL units are not extensive enough in order to minimize the degradation in steam generators and to maintain worker radiation exposure as low as resonably achievable (ACARA).

For those Post-CP and Pre-OL PWR facilities, the steam generators are essentially similar to those in the present operating PWRs, in terms of the mechanical design and operational characteristics. Therefore, we have no reasons to believe that they would perform better and would not encounter the types of degradation such as tube denting and its associated problems.

In Operating Experience Memorandum No. 25 (attachment 1), dated January 1980, we made several recommendations which will help to reduce signifi- repa- degradation and occupational exposures associated with inspection, replac- are prove- placement of steam generators should degradation ever occur or intervals, -ed necessary. Specifically included in our recommendations proper secon- greater accessibility and inspectibility of steam generator blowdown desig- ination, elimination of high tube residual stresses, and provisions f- two of these subje- chanical design and materials selection, improved elimination. The o- ibution, provisions for chemical cleaning, and should be incorpor- replacement. Your memo addresses only on the stage of design a- the extent practicable depending

More detailed discussions of steam generator replacement and crevice I are available for such discu- listed above are equally important

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NRC FORM 318 (80) NRCM 0240 ☆ U.S. GOVERNMENT PRINTING OFFICE: 1979 -

Enclosure: As stated

irector

ATTACHMENT 1

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

JAN 2 1 1980

MEMORANDUM FOR: F. Schroeder, Acting Director
Division of Systems Safety

FROM: D. G. Eisenhut, Acting Director
Division of Operating Reactors

SUBJECT: OPERATING EXPERIENCE MEMORANDUM NO. 25
STEAM GENERATOR TUBE DEGRADATION

PROBLEM

Steam generator tube degradation has been and continues to be a major problem in operating pressurized water reactors (PWRs). Major forms of degradation include local thinning or wastage, denting, deep crevice corrosion, stress corrosion cracking, U-bend cracking, erosion-corrosion and circumferential fatigue cracking (Attachment 1).

SAFETY SIGNIFICANCE

Steam generator tubing comprises over 50% of the reactor coolant pressure boundary in pressurized water reactors. Tube ruptures during normal operation have resulted in primary to secondary leak rates as high as 390 gpm. Orderly plant shutdowns have been effected in major tube failure incidents with no adverse affects on public health and safety. However, these incidents do present an undesirable challenge to plant operators and systems.

Response of degraded steam generator tubes during postulated accidents is of major concern. The steam generator tubing will be subjected to the worst loading conditions under postulated MSLB or LOCA and failure of tubes during such accidents can have serious adverse effects including the potential for steam binding during a LOCA or offsite releases of radiation in excess of allowable limits during a MSLB. Design basis accidents do not include postulated concurrent steam generator tube failures. It is therefore necessary to ensure that steam generator tube integrity will be adequately maintained during postulated accident conditions.

In addition, plugging of degraded tubes has led to derating in power and extended outages for steam generator replacement at some plants. Steam generator tube degradation also results in frequent plant shutdowns, more inservice inspection, and increased personnel exposure.

RECOMMENDED REMEDIAL ACTIONS

Operating experience has identified many improvements in mechanical and materials design and operating methods which can improve steam generator inspectibility and eliminate or reduce tube degradation. These improvements include provisions for greater accessibility and inspectibility of steam generator internals,

elimination of high tube residual stresses, proper secondary system mechanical design and materials selection, improved blowdown design and flow distribution, provisions for chemical cleaning, and finally, provisions for steam generator replacement.

ACCESSIBILITY AND INSPECTIBILITY

For some forms of degradation which have occurred, eddy current testing and tube gauging alone are not sufficient to assess and monitor tube degradation. Several operating plants have found it necessary to install access and inspection ports in their steam generators, in order to assess and monitor the condition of secondary side tube supports. These installations result in extended outages and additional personnel radiation exposure when they are performed in the field on a "hot" unit. Therefore, these ports should be installed in steam generators before they are put into operation. At a minimum, ports should be installed just above the upper tube support plate and between the tubesheet and the lower support plate. These ports should be located such that inspection of the upper support plate and inner row "U-bends" and the lower support plate and secondary face of the tubesheet can be made. The inspection ports should be of adequate size to allow tube specimen removal, when necessary. Ports at intermediate elevations are also advisable, depending upon the design.

A second requirement which would improve quality assurance associated with inservice inspection is the numbering of tubes on the primary surface of the tubesheet. Many plants have misplugged tubes; therefore, easy tube identification along with photographic verification will improve the tube plugging procedures.

CREVICE ELIMINATION

Mechanical components subject to aggressive environments should be free of crevice geometries which serve as a concentrator for aggressive chemicals and enhance or compound corrosion phenomena.

Corrosion of tube support plates with drilled tube holes has resulted in a widespread form of degradation known as "denting." Denting occurs when support plate corrosion products build up in the tube to tube support plate crevice and exert sufficient forces to dent the tube diametrically. Alternate designs of support plates without the tight crevice geometry have not resulted in tube denting. These designs include the Combustion Engineering "egg crate" design and the Babcock and Wilcox broached plate design. New steam generators should have similarly designed support plates which eliminate the tight crevice geometry and minimize the potential for concentration of aggressive chemicals and tube denting.

A second form of degradation known as "deep crevice corrosion" has resulted in intergranular attack and stress corrosion cracking in the tube to tubesheet crevice of some units. The exact mechanism of this form of corrosion is not well understood. The crevice exist in those units where the tubes were only

partially rolled in the tubesheet. Full depth expansion of the tubes in the tubesheet has been performed in the field and should be required for all steam generators prior to operation.

ELIMINATION OF HIGH TUBE RESIDUAL STRESSES

Cracking of the tight U-bends in Westinghouse designed steam generators has been observed in some foreign and domestic plants. It is suspected that high residual manufacturing stresses are a main contributor to this problem. Laboratory tests and operating experience has indicated that high residual stresses can lead to stress corrosion cracking in Inconnel. Therefore, future design should minimize those geometries and manufacturing processes which introduce high residual stress, and stress relief annealing should be required when necessary. Recent experience has demonstrated that, row 1 tubes in Westinghouse steam generators have high residual stresses and are particularly susceptible to cracking. Procedures for stress relieving tubes with small bend radii prior to operation should be investigated and required if practicable.

SECONDARY SYSTEM MECHANICAL DESIGN AND MATERIALS SELECTION

Operating experience has also shown that steam generator tube degradation is primarily affected by secondary system component integrity and materials selection. Contamination of the secondary coolant by inleakage of condenser cooling water is related to the various tube degradation phenomena mentioned above and resin break through from demineralizers has recently caused denting at a Westinghouse unit. Carbon steel support plates are particularly susceptible to corrosion, and copper ions in the presence of a chloride environment are related to the denting reaction. The primary source of copper ions is corrosion of condenser tubes and feedwater heaters made of copper alloys. Therefore, although it is not included in the NRC scope of review, the licensees should be made aware of the significance of the secondary system on steam generator degradation and should be encouraged to use improved designs. Specifically, condenser design should be such to minimize leaks, support plates should be made from corrosion resistant materials, and copper alloys should be avoided throughout the secondary system. Demineralizers can be beneficial and should be encouraged when properly designed and operated; however, resin break through and contaminant ingress from demineralizers are deleterious. Mechanical design should minimize the potential for such incidents and performance of demineralizing systems should be carefully monitored.

IMPROVED BLOWDOWN AND PROVISIONS FOR CHEMICAL CLEANING

Corrosion product deposition as sludge is a major cause for concentration of feedwater impurities in operating steam generators. Design and operational methods for the control and removal of sludge have not received their deserved attention. Generally the control of concentration of bulk water impurities has been based on mass balance with zero or minimum blowdown. Based on this principle PWR steam generators have been designed with inadequate blowdown capacity.

Little can be done to improve the blowdown capacity for plants that are now in operation. However, in new designs, the positioning of blowdown line entries (in areas where flow stagnation is suspected) should be required to facilitate the removal of corrosion product deposition. To control the mass balance of bulk water in the steam generator, new plants should be required to have maximum blowdown efficiency or be required to operate with a continuous blowdown. Return lines should be routed back to the condensate for waste clean-up in the fullflow condensate demineralizers of the feedwater system.

As discussed briefly earlier, a large fraction of corrosion products and other insoluble impurities in the feedwater generally stay in the steam generators at zero or low blowdown. To remove these deposits in present operating recirculating and once-through type PWR steam generators, chemical cleaning will be necessary to minimize existing or potential tube degradation. If chemical cleaning is not encouraged, to arrest initiating corrosion in PWR plants, the service life of the equipment will be seriously reduced. Once significant tube degradation has occurred, chemical cleaning may be ineffective. This is particularly true when dealing with the denting phenomenon.

High pressure steam generation has high potential for component degradation in steam generators and particularly in turbines. Therefore, regardless of material selection or unit design, the emphasis on system cleanlines is of far greater importance than chemical control of the feedwater and chemical cleaning will need to be extensive and thorough. Future PWR steam generators should be designed to facilitate preoperational and periodic chemical cleaning during operation to extend the service life for 40 years.

PROVISIONS FOR STEAM GENERATOR REPLACEMENT

Tube plugging due to extensive denting has resulted in a prolonged outage at Surry Unit 2 to replace the degraded steam generators. Plans have also been made for replacement at Surry Unit 1 and possibly Turkey Point Units 3 and 4 because of extensive tube plugging due to denting. Deep crevice corrosion at Point Beach Unit 1 has also resulted in extensive tube plugging during the past year and, unless the degradation can be arrested, steam generator replacement may be necessary. Many units with less than half their intended operating life have significant percentages of their tubes plugged. Therefore, future replacement or repair of steam generators has a finite possibility and provisions should be made for these type of operations. These provisions should include containment designs which allow easy access to the steam generators and equipment hatches which allow movement of steam generators in and out of containment. Regarding the steam generator itself many designs exist and improvements can be made to facilitate steam generators replacement. Features which can facilitate replacement include removable upper shells and assemblies and removable tube bundles and tubesheets.

JAN 2 3 1980

F. Schroeder -5-

DOR ACTIONS

DOR has expended a great deal of effort in monitoring and evaluating steam generator operation. The main mechanisms for ensuring adequate steam generator tube integrity are inservice inspection, tube plugging, and primary to secondary leak rate limits. For units with excessive tube degradation the frequency of inservice inspection has been increased, more conservative plugging criteria and leak rate limits have been imposed, and more stringent limits have been applied to primary coolant activity levels.

Unfortunately many corrective actions which could improve and prolong steam generator operation are impossible or impracticable in operating reactors. The result, as mentioned previously, is that some units are facing replacement of steam generators or derating in power levels.

DOR is also actively participating in Task Action Plans A-3, A-4, and A-5 regarding steam generator tube integrity. These task action plans will address steam generator tube degradation problems on a generic basis and recommend improved licensing criteria.

RECOMMENDATIONS

It is important to recognize that a systems approach, properly integrating the above considerations, is necessary to solve steam generator tube degradation problems. No one "super" material, water chemistry, or design alone will produce a trouble free steam generator. The combination of materials, water chemistry, and design should be reviewed in a holistic manner to ensure safety and optimum performance.

We recommend that the above items be considered in the design of new plants and to the extent possible in plants already designed and under construction. The DOR staff is available to discuss the above subjects in greater length and detail.

Principal DOR Personnel

B. D. Liaw, Section B Leader, Engineering Branch
W. S. Hazelton, Section A Leader, Engineering Branch
J. Strosnider, A-3 and A-5 Task Manager
F. Almeter, A-4 Task Manager

Original signed by
Darrell G. Eisenhut

Darrell G. Eisenhut, Acting Director
Division of Operating Reactors

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JAN 23 1980

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SUMMARY OF STEAM GENERATOR ADVERSE EXPERIENCE

11/28/78

NSSS	PLANT NAME	WASTAGE	U BEND FRETTING	SECONDARY SIDE CRACKING		DENTING				U BEND CRACK	CONSIDERATION FOR REPLACEMENT OR RETUBING
				DEEP CREVICE CORROSION	SCC*	TUBE DENTING	SP HOUR GLASSING	SP CRACKING OR ISLANDING	LEAKING DENTS		
CE	MAINE YANKEE					X MINOR					
	MILLSTONE 2					X MODERATE		X			
	PALISADES	X			X	X MINOR					X (Tube Sleeving)
	ST. LUCIE 1					X MINOR					
W	HADDAM NECK	X	X		X	X MINOR					
	R.E. GINNA 1	X		X	X	X MINOR					
	INDIAN POINT 2					X MODERATE	X	X	X		
	INDIAN POINT 3					X MINOR			X		
	NORTH ANNA 1									X	
	POINT BEACH 1	X		X	X	X MODERATE					
	POINT BEACH 2	X				X MODERATE			X (?)		
	H.B. ROBINSON 2	X		X	X	X MINOR					
	SAN ONOFRE 1	X	X	X		X EXTENSIVE	X	X	X		
	SURRY 1	X				X EXTENSIVE	X	X	X	X	X
	SURRY 2	X				X EXTENSIVE	X	X	X	X	X
	TROJAN									X	
	TURKEY POINT 3	X				X EXTENSIVE	X	X	X		X
	TURKEY POINT 4	X				X EXTENSIVE	X	X	X	X	X
	YANKEE ROW				X						

*SCC - CAUSTIC STRESS CORROSION CRACKING

NOTES: 1. TO DATE THERE ARE 33 OPERATING PWR UNITS (NOT INCLUDING INDIAN POINT 1) WHICH UTILIZE RECIRCULATION TYPE OF STEAM GENERATORS.

2. 17 HAVE BEEN FOUND TO HAVE ONE OR MORE FORM(S) OF DEGRADATION AS SUMMARIZED ABOVE.

3. TROJAN AND D.C. COOK HAVE HAD INDICATIONS OF LIMITED DEGRADATION IN RECENT INSPECTIONS.