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NOTE TO: D. F. Ross, Jr., Assistant Director for Reactor Safety, DSS

FROM: Ashok C. Thadani, Reactor Systems Branch, DSS

As a result of comments from Standards and MEB, we have uncovered a lack of Steam Generator structural criteria which could have serious potential economic impact. Basically, if we apply the ATWS "Emergency Stress Intensity" limit for steam generator tube plugging, the number of tubes plugged may be very large and thus the severe economic impact.

The attachment discusses the impact of present limit (i.e. Emergency) and the possibility of adopting faulted limit for the Steam Generator tubes. Yet another consideration, not included in the attachment, is the possibility of sticking with present limits but for plants where steam generator tube problems become severe, increase the number of pressurizer safety valves (perhaps two more valves) such that the peak pressures shall not exceed 1.1 X P_{Design}. This may be the least expensive acceptable alternative.

In any case an immediate decision on the limits or an interim position is needed.

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DRAFT

PWR Steam Generator Tube Plugging Criteria vs. ATWS Considerations

Imposition of ATWS as a design basis event requires that the effects of this event be taken into consideration in some manner for evaluating the suitability of degraded steam generator tubes for further operation. At the present time the guidelines of R. G. 1.121 are followed for determining the minimum wall thickness that must be present for continued operation. Addition of ATWS together with its required Emergency Stress Criterion can be expected to have a severe economic impact on PWR plants of existing design as discussed in (A) below.

On the other hand, an alternate approach that could be considered would be the use of the faulted stress limit for evaluating degraded tubing for a continued operation in lieu of the Emergency limit. However, this approach is not without problems of its own as discussed in (B) below.

A) Effect of ATWS (Emergency Stress Limit) Tube Plugging Criterion

Imposition of the Emergency Stress Limits under an ATWS is likely to have a major impact on the tube plugging criteria and guidelines stated in Reg. Guide 1.121. The number of additional tubes that would require plugging as a result of these limits would perhaps be unacceptably large for a majority of PWR operating plants. The impact of using ATWS as a design basis event (in conjunction with emergency stress limits) is also likely to be highly significant on the design of the newer model Westinghouse Steam Generators, the Models F and H as well as CE and B&W steam generators. It was found that the tubes in these steam generators were unable to meet the

emergency stress limits during an ATWS even if lower estimates of pressures are used during this event. Preliminary calculations indicate that the controlling criterion for determining minimum acceptable tube wall thickness is invariably the ATWS emergency stress limit. The wall thicknesses required to meet faulted stress limits during postulated LOCA plus SSE and Main Steam Line Break Accident (MSLBA) plus SSE were found to be lower for the Westinghouse, B&W and CE steam generators in operation. The minimum wall thickness required to withstand ATWS and other postulated accident conditions are given in Table 1 for the various tube sizes currently in use and being proposed by one of the three steam generator manufacturers. Two pressure differentials were considered in the ATWS evaluation; 2200 psig and 3200 psig.. Minimum tube wall thickness required to meet the emergency stress limits (S_y = 27.9 ksi at 600°F), and faulted stress limits (0.7 S_u - 52.5 ksi) were determined for both the pressure differentials. Thus, for example, to meet the current emergency stress limits with a pressure differential, ΔP, of 2200 psi during an ATWS; Westinghouse Series 51 steam generators would require a tube wall thickness of 0.0375 in. The original nominal wall thickness for this model is 0.050 in. resulting in an allowable tube wall degradation of 25%. This is substantially less than the allowable degradation for LOCA + SSE (48%) and MSLBA + SSE (58%). In order to determine the plugging limit, the operational allowance which includes both the corrosion allowance (as defined in Reg. Guide 1.121) and an allowance for the inaccuracy associated with the eddy current measurement, is subtracted from the allowable limit.

In the Prairie Island testimony provided by the NRC staff, an operating allowance of 10% was recommended. Using this value, the plugging limit is determined to be (25% - 10%) or 15%.

Such a plugging limit would, most likely, result in plugging an unacceptably large number of tubes even in plants with an excellent operating history. Any decrease in the current plugging allowable tube wall degradation is likely to result in a sharp increase in the number of tubes that would require plugging. This is apparent in a qualitative sense, from an assumed distribution of defects in a typical steam generator with a history of tube wall degradation, shown in Fig. 1. The current plugging limit is approximately located at A-A on this curve. All defects greater than this limit would fall in the shaded area. Imposition of the emergency stress limit under an ATWS would probably shift the plugging limit to the region B-B of the curve. The total number of plugged tubes under such conditions may be 50% or higher for such steam generators. It must be emphasized, however, that these conclusions are qualitative in nature since the distribution of defects are highly random. A quantitative estimate of the additional plugged tubes would require a thorough evaluation based on actual eddy current inspection data from several plants.

B) ATWS (Faulted Stress Limit) Tube Plugging Criterion

The Faulted limit could be adopted as the acceptance criterion for

establishing minimum wall thickness for degraded tubes under ATWS and a fairly substantial technical justification could probably be provided for its use. However, adopting the Faulted limit for any component in the reactor coolant pressure boundary is in direct violation with the Emergency Stress limit criterion established in WASH-1270 as required for ATWS events. Additionally, it would be extremely difficult to justify, on any technical basis, why the Faulted limit is appropriate for establishing the adequacy of steam generator tubes, but not for other components in the reactor coolant system. Strong suggestions for the use of the Faulted limit for ATWS have been made by at least two of the four NSSS vendors over the last three years of discussions on ATWS and have been summarily rejected by the staff each time as being nonconservative for sustained pressure loading.

TABLE 1

	51 Series Westinghouse 0.875 in. OD x 0.50 in.		Model F Westinghouse 0.6875 in. OD x 0.040 in.	
	t_r*	A.D.*	t_r	A.D.
ATWS ΔP = 2200 psi S_y = 27.9 ksi	.0376	25%	.0245	26%
ATWS ΔP = 3200 psi Stress Limit = S_y	.050	-	.040	-
ATWS ΔP = 3200 psi Faulted Limit 0.7 S_u	.030	40%	.02377	40%
LOCA + SSE 0.7 S_u	.026	48%	NA	NA
MSLBA + SSE 0.7 S_u	.020	60%	NA	NA
Fac. of Safety = 3 against burst	.024	52%	.0156	60%

NOTE: t_r = thickness required to meet the designated stress limit.

A.D. is the percentage allowable degradation. The minimum allowable degradation at any given time is arrived at by subtracting the "operational allowance" from this.

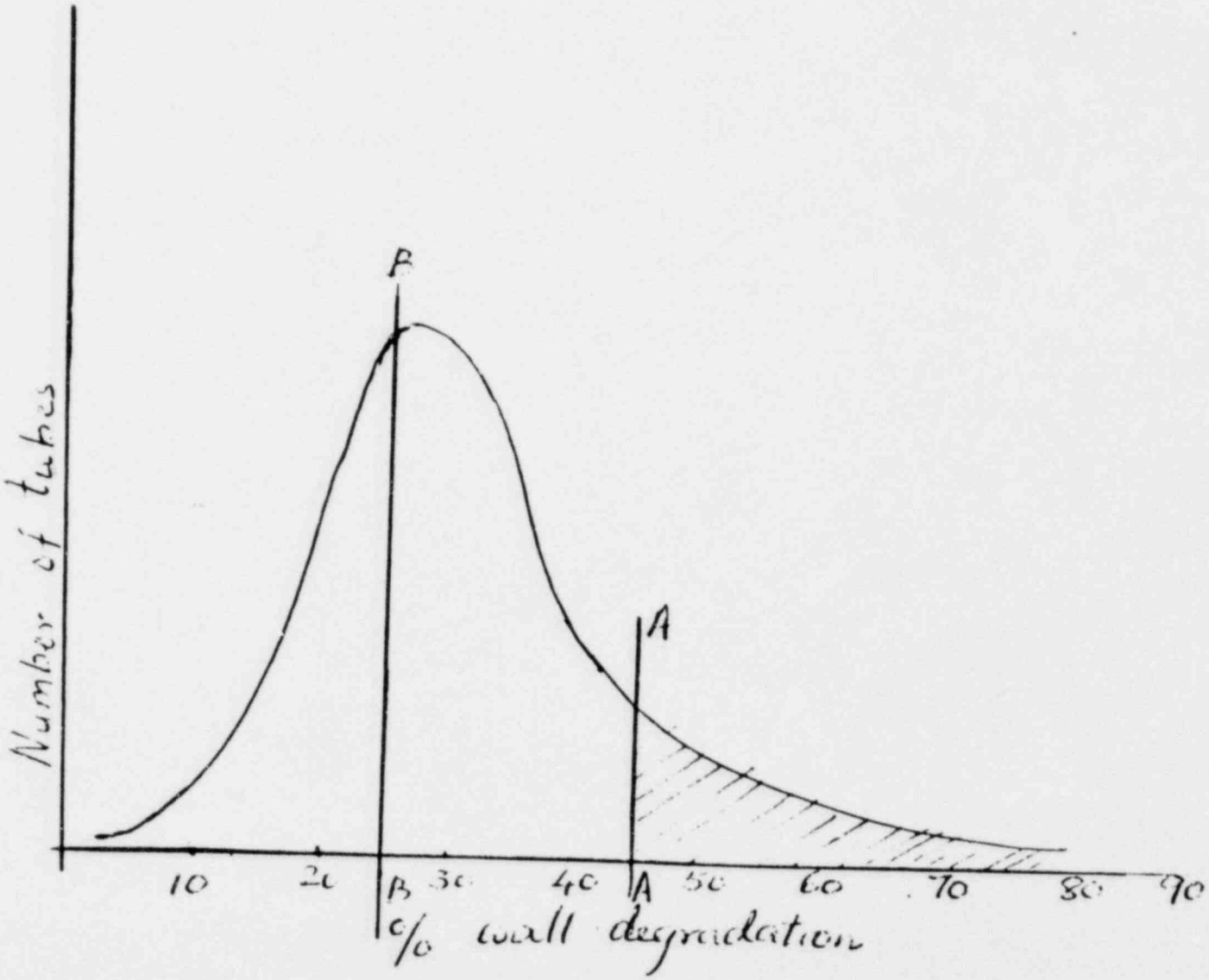
Number of tubes
B
A
10
20
B
30
40
A
50
60
70
80
90
% wall degradation

Fig 1

1977 ATWS

11/25/77	Memo to R. Mattson from M. Ernst re EXPANDED OUTLINE FOR ATWS I-V ANALYSIS
11/25/77	Note to D. Ross from A. Thadani re meeting held with F. Cherny D. Ross and myself on steam generator tube structural criteria.
11/25/77	Note to R. Mattson from D. Ross re ATWS STATUS AS OF 11/28/77
11/23/77	Note to S. Hanauer, R. Mattson, D. Ross from A. Thadani results of meeting held with Probabilistic Analysis Branch
11/23/77	Note to D. Ross from A. Thadani re results of comments from Standards and MEB on PWR STEAM GENERATOR TUBE PLUGGING CRITERIA VS. ATWS CONSIDERATIONS
11/22/77	Note to A. Thadani from S. Hanauer re comments on topics requested in meeting.
11/21/77	Memo to R. Mattson from V. Stello re COMMENTS ON THE STAFF'S DRAFT ATWS REPORT
11/18/77	Note to A. Thadani from J. Kudrick re IDENTIFICATION OF PROPRIETARY INFORMATION IN TECHNICAL REPORT ON ATWS
11/11/77	Note to D. Ross from A. Thadani re suggested plan for preparing a draft DSS ATWS report
11/10/77	Memo to T. Novak from D. Bunch re ATWS DRAFT DRAFT PAPER
11/9/77	Memo to R. Mattson from S. Hanauer re ATWS Subsection 2.2.2.13
11/4/77	Memo to T. Novak from R. Tedesco re ATWS COMMENTS
11/4/77	Memo to T. Novak from R. Bosnak re REVIEW OF "TECHNICAL REPORT ON ANTICIPATED TRANSIENTS WITHOUT SCRAM"- DRAFT DATE 10/17/77
11/4/77	Memo to T. Novak from W. Minners re COMMENTS ON FIRST DRAFT OF ATWS REPORT
11/3/77	Memo to S. Hanauer from L. Abramson and D. Lurie re DRAFT ATWS PAPER
11/2/77	Memo to R. Mattson from H. Denton re COMMENTS ON ATWS REPORT