Westinghouse
Electric Corporation

Power Generation
Group

Steam Turbine Division

Lester Branch Box 9175
Philadelphia Pennsylvania 19113

December 20, 1979

Mr. J. W. Ross
Operating Reactors Branch
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Mr. Ross:

In response to the requests made at the December 17, 1979 meeting with you, supplemented by the written excerpt received from you December 19, 1979, the following information and relevant attachments have been compiled for your review.

Restating the first request, by December 20, 1979 the information presented in this meeting should be updated, and the staff provided with a status report of the inspection program that includes a complete list of nuclear power plants already inspected and information related to rotors where cracks have been observed.

- Attachment A titled Update to Notes on the Presentation fulfills the first part of your request, and references the applicable sections of the Notes on The Presentation by Westinghouse to Electric Utility Executives, Charlotte, North Carolina, October 30, 1979.
- Attachment B titled LP Disc Inspection Report contains the status report of the inspection program.

The second request states, if agreeable to Westinghouse and utilities, Westinghouse will take the lead in forming an owners group to address turbine disc cracks. The status of this group should be reported to W. J. Ross (301) 492-7134 or A. Schwencer (301) 492-7810 by December 20, 1979. Information requested from each utility on December 14 (summary of actions taken in response to Westinghouse presentation of October 30, 1979) may be funneled through this group for transmittal to the staff by December 27, 1979.

- Westinghouse has initiated discussions with a number of utilities for the specific purpose of formulating an owners group structure and identifying responsible leadership from among its members. The utilities contacted were:

1741 104

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Florida Power and Light
Public Service Electric and Gas
Carolina Power and Light
Northern States Power
Commonwealth Edison
Rochester Gas and Electric

Other owners are being contacted, but it appears that the group will not be fully structured to act as a funnel for utility responses to your staff by December 27, 1979.

Additionally, we have determined to form a Westinghouse support team headed by a full time cognizant manager, to provide the communication link between the company and the owners group as soon as such group is established.

Until such group becomes operative, the support team will act in response to direct requests from NRC and owner sources.

The fourth request as it relates to information requested by December 20, 1979 calls for us to re-evaluate inspection schedule for "AA" and "A" categories.

- This information is provided as Attachment C. This information is supplied as proprietary information and is so designated on the attachment. It is requested, and expected, that you will treat this as proprietary in view of the specific technical nature of its disclosures with respect to our turbine design parameters and that you will not disclose it to any other persons.

Your third request asks that we respond to staff requests for additional information. We have received draft copies of specific questions and will begin formulating responses immediately.

Respectfully yours,

V. S. Andersen

V. S. Andersen

1741 105

Westinghouse
Electric Corporation

Power Generation
Group

Steam Turbine Division

Lester Branch Box 9175
Philadelphia Pennsylvania 19113

January 7, 1980

Mr. Vincent Noonan
Inspection and Enforcement
US Nuclear Regulatory Commission

Attached is the de-classified (to non-proprietary) attachment "C" of V. S. Andersen's letter to J. W. Ross dated December 20, 1979.

V. S. Andersen

V. S. Andersen, Manager
Projects Department

1741 106

Attachment

Attachment C

1741 107

METHOD FOR SETTING PRIORITIES OF UNITS

The priority index for inspection of the units is defined by the ratio of expected crack depth to the critical crack size. Expected crack depth is a complex function involving several factors. The most important of these factors have been identified and used as a basis for ranking the units.

Operating time, yield strength of the disc and severity of environment are considered to be the important factors. Since the exact functional relationships between crack depth and these factors cannot be rigorously defined, for the purposes of relative ranking, the following assumptions were made:

(a) The crack depth increases [ ] a,c

(b) The higher the yield strength, the greater the crack depth. This relationship between yield strength and crack depth is depicted here:

Yield Strength [ ] e, h	Relative Factor
	1
	2
	4

(c) The more severe the environment the greater the crack depth. Available information on deposit analysis, steam chemistry, water treatment questionnaire and steam generator blow-down chemistry was reviewed and the environmental factor was judged as being

1741 108

[ ]

Most Severe	-	4
Medium	-	2
Least Severe	-	1

The critical crack size for the keyways was calculated using the fracture mechanics expression:

$$a_{cr} = \frac{Q}{1.21\pi} \left(\frac{K_{IC}}{\sigma} \right)^2$$

Where

a_{cr} = critical crack depth

Q = flaw shape parameter. Depth to length ratio of flaw was assumed to be [ ]a,c

K_{IC} = fracture toughness of disc

σ = maximum bore stress (centrifugal force + shrink fit) at design overspeed.

K_{IC} was calculated from impact data of each disc using the Begley-Logsdon relationship. The impact value at room temperature and the value above 95% ductile failure were both determined and the lower value used for upper shelf energy. [

1741 109

]a,c

[ ]

The unit priority index was then calculated as:

[ ]a,c

The operating time (as of August, 1979), yield strength factor, environmental factor, effective critical crack size and priority index for the units in the AA category are shown in attached Table I.

We are currently reviewing the Category A units to determine if anything learned since the October 30 meeting changes our inspection recommendations for these units.

1741 110

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TABLE I - PRIORITY RATINGS

Utility	Station	Effective Critical Crack Size Ins.	Operating Time Hrs.	Environmental Factor	Yield Strength Factor	Priority Index X 10^{-5}
Florida P&L	Turkey Point 3		43,968			9.3
Consolidated Ed.	Indian Point 2		33,500			5.7
PASNY	Indian Point 3		22,800			5.7
VEPCO	Surry 1		38,040			2.9
Arkansas P&L**	Nuclear One		28,944			2.2
Commonwealth Ed.	Zion 1		38,856			2.2
So. Calif. Ed.	San Onofre 1		77,726			2.0
Yankee A.P.*	Rowe 1					-
Wisc. Mich. Pwr.	Point Beach 1		63,720			1.9
Nebraska PPD	Cooper 1		39,336			1.8
Carolina P&L	Robinson 2		33,984			1.6
Commonwealth Ed.	Zion 2		34,512			1.4
Consumers Pwr.	Palisades 1		38,544			1.3
Florida P&L	Turkey Pt. 4		39,000			1.2
Wisc. Mich. Pwr.	Point Beach 2		55,008			1.1
Main Yankee**	Bailey Point 1		47,496			1.0
Rochester G&E	Ginna 1		63,264			0.5
Northern States**	Prairie Island 1		38,736			0.3
Wisc. P.S.	Kewaunee 1		38,376			0.3

1741 111

*Impact tests were not required at the time of manufacture. ** Based [illegible]

RE-EVALUATION OF OCTOBER 30, 1979 INSPECTION SCHEDULE

The recommended inspection schedule, as described at page 26 of Westinghouse's "Notes on....Presentation....October 30, 1979" consisted of inspection of all 1500/1800 rpm shrunk-on disc construction units within five years after having been placed in service or sooner if significant corrosion problems become evident. This inspection schedule has been re-examined in light of the field inspection results subsequent to the October 30, 1979 meeting and Westinghouse believes that no change in this inspection schedule is necessary at this time; with one exception involving one unit [ ] a,c which we now believe should be inspected sooner than spring outage of 1980. Our rationale for the above position is discussed below in detail.

As reported to the NRC on December 17, 1979, the significant changes since the October 30, 1979 meeting are:

1. Several additional disc keyway cracks have been found including some after 42 months' operation whereas, prior to October 30, 1979, no cracking was observed until after 72 months' operation.
2. A crack in the disc bore has been detected in one case whereas no cracks were observed before. (On December 17, 1979, Westinghouse advised the NRC that two such discs had bore crack indications. Subsequently, the one crack indication was confirmed to be due to a radial hole drilled during manufacturing and not due to a crack.)

The impact of both findings on our original recommendations are examined below:

1. <u>Impact of Keyway Crack Findings</u> 1741 112

   (a) Fourteen discs have shown keyway cracks ranging in depth from 0.010-0.378 in. The critical crack size was calculated in each

[ ]

case employing conservative values of K_{IC} and flaw shape parameter (depth to length ratio of [ ]a,c for cracks) and using the procedure described in the prior section on Method for Setting Priorities of Units. The details of units, discs, crack depth, effective critical crack size and ratio of crack depth to effective critical crack size are summarized in Table II. The ratio of crack depth to effective critical crack size vs. service time is shown in Fig. 2. It is clear that, except in one case (discussed below) the crack depths are less than one fourth the critical crack size. Additionally, the ratio of the crack depth does not show any trend towards increasing with time. The one exception concerns [ ]d,g Unit. Although this unit had not seen [ ]d,g,h service, it was inspected for keyway cracking, in accordance with Westinghouse recommendations, because of indications of environmental damage to the discs and because of the high yield strength of the disc material. Specifically the [ ]d,g Unit had experienced extensive corrosion damage on the periphery of the disc. Also, this unit has the highest yield strength discs with the lowest calculated effective critical crack size. All other machines in the AA category have effective critical crack sizes substantially larger than in the case of the [ ]d,g Unit. In fact, the depth of the keyway cracks observed in this [ ]d,g Unit are less than the effective critical size for any other machine. Also, the fact that the disc did not burst indicates that our critical crack size estimates are conservative.

[ ]

(b) [ ]^{a,c,h} This occurred in a unit after [ ]^{h} Assuming that all AA category units which have not yet been inspected propagate cracks at this rate, the size of cracks that might exist by the end of June 1980 was calculated using the formula:

[ ]^{a,c}

8000 hrs. are added to operating hrs. accumulated up to Aug. 1979 in order to project the total operating time by June 1980.

These computed crack depths for the discs most susceptible to cracking (discs 2 & 3 for BB 80 & 81 and discs 1 & 2 for BB 281) are compared against critical crack sizes and the ratio of computed crack depth to critical crack size calculated (Table III.) Examination of Table III shows that except for the [ ]^{d,g} machine, this ratio is not expected to exceed [ ]^{h} for any of the units by June 1980. Therefore, even under the worst case analysis, the calculations indicate that the units listed in the AA category with the exception of [ ]^{d,g} may run through the June of 1980.

2. Impact of Bore Crack Finding

The preliminary metallurgical analyses show this crack to be not typical of classical stress corrosion cracking. At this point it is not possible to define the mechanism of cracking and is still under investigation. However, taking the actual geometry of the crack (1.22 in. deep by 1.6 in. long) into account, the critical crack size was calculated for that

 [ ]

disc. The critical crack size is [ ]^h in. and the actual crack is only [ ]^h of this critical crack size. The machine had run for 78 months (38,856 actual operating hrs.) [ ]^a,c,h

the expected crack depths and the ratio of expected crack depth to critical bore crack sizes were calculated for the susceptible discs (discs 2 & 3 of BB 80 & 81 and discs 1 & 2 of BB 281) of all the AA category machines not yet inspected. The bore crack size that might exist by the end of June 1980 was calculated using the formula:

[ ]^a,c

8000 hrs. are added to operating hrs. accumulated up to Aug. 1979 in order to project the total operating time by June 1980.

These results are shown in Table IV and show the critical depths are not expected to be exceeded by June 1980.

1741 115

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TABLE II

Utility	Unit	LP	Gov./Gen.	Disc No.	Crack Depth, in. a	Critical Crack Depth, a_{cr}	$\frac{a}{a_{cr}}$
Wisc. Mich. Pwr.	Point Beach 1	1	Gov.	2	.25		
Consumers Pwr.	Palisades 1	1	Gen.	2	.095		
Consumers Pwr.	Palisades 1	2	Gov.	2	.236		
Consumers Pwr.	Palisades 1	2	Gov.	4	.113		
PASNY	Indian Pt. 3	1	Gov.	2	.126		
PASNY	Indian Pt. 3	1	Gov.	3	.378		
PASNY	Indian Pt. 3	1	Gen.	2	.347		
PASNY	Indian Pt. 3	2	Gen.	2	.308		
PASNY	Indian Pt. 3	3	Gov.	2	.378		
Common. Ed.	Zion 1	2	Gov.	2	.120		
VEPCO	Surry 2	1	Gen.	2	.360		
VEPCO	Surry 2	2	Gov.	3	.300		
Carolina P&L	Robinson 2	2	Gov.	3	.010		
Carolina P&L	Robinson 2	2	Gen.	3	.120		

1741 116

TABLE III

Utility	Unit	Operating Hrs. to 6/80	DISC NO. 1 a	DISC NO. 1 a_{cr}	DISC NO. 2 a	DISC NO. 2 a_{cr}	DISC NO. 3 a	DISC NO. 3 a_{cr}	Highest a/a_{cr}
Wisc. Mich. Pwr.	Point Beach 2	63,008							
Rochester G&E	Ginna 1	71,264							
So. Cal. Ed.	San Onofre 1	85,726							
Wisc. P. S.	Kewaunee 1	46,376							
Northern States	Prairie Island 1	46,736							
Carolina P&L	Robinson 2	41,984					New Disc		
Neb. PPD	Cooper 1	47,336							
Fla. P&L	Turkey Pt. 4	47,000							
VEPCO	Surry 1	46,040							
Maine Yankee	Bailey Pt. 1	55,496							
Con. Ed.	Indian Pt. 2	41,500							
Comm. Ed.	Zion 2	42,512							
Ark. P&L	Nuclear 1	36,944							

] d,g

a,c,h

a = Estimated crack depths using [
= [ ] a,c ins.

a_{cr} = Effective critical crack depth , ins.

[ ]

1741 117

TABLE IV

Utility	Unit	Operating Hr. to 6/80	DISC NO. 1 a	DISC NO. 1 a_{cr}	DISC NO. 2 a	DISC NO. 2 a_{cr}	DISC NO. 3 a	DISC NO. 3 a_{cr}	Highest a/a_{cr}
Wisc. Mich. Pwr.	Point Beach 2	63,008							
Rochester G&E	Ginna 1	71,264							
So. Cal. Ed.	San Onofre 1	85,726							
Wisc. P. S.	Kewaunee 1	46,376							
Northern States	Prairie Island 1	46,736							
Carolina P&L	Robinson 2	41,984					New Disc		
Neb. PPD	Cooper 1	47,336							
Fla. P&L	Turkey Pt. 4	47,000							
VEPCO	Surry 1	46,040							
Maine Yankee	Bailey Pt. 1	55,496							
Con. Ed.	Indian Pt. 2	41,500							
Comm. Ed.	Zion 2	42,512							
Ark. P&L	Nuclear 1	36,944							

]d,g   a,c,h

a = Estimated crack depths using [ ]d,g

= [ ]a,c ins.

a_{cr} = Critical crack depth for bore, ins.

[ ]

1741 118

WESTINGHOUSE ELECTRIC CORPORATION CURVE NO. ______

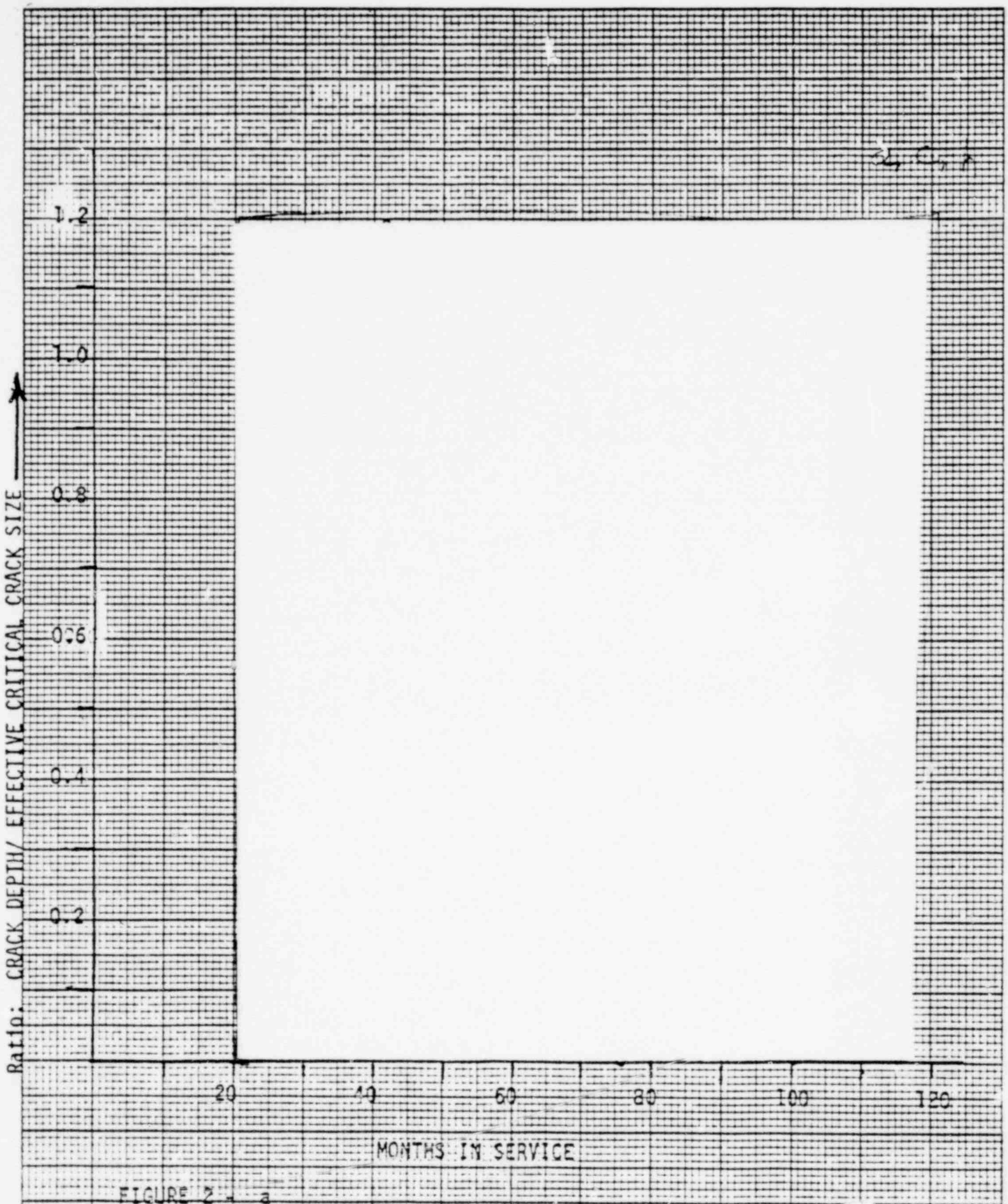

FIGURE 2 - $\frac{a}{a_{cr}}$ vs Months in Service

SIGNATURE ______ DATE ______ CURVE NO. ______

1741 119

FORM 42748