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October 21, 1988
Fort St. Vrain
Unit No. 1
P-88366

U.S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, D.C. 20555

Attention: Mr. Jose A. Calvo
Director, Project Directorate IV

Docket No. 50-267

SUBJECT: Fulfillment of Helium Circulator Outage
Commitments and Status of Certain Other
Circulator-Related Corrective Actions

REFERENCE: 1) PSC Letter, Williams to Calvo,
dated September 21, 1987 (P-87327)

2) NRC Letter, Heitner to Williams,
dated November 20, 1987 (G-87419)

3) PSC Letter, Williams to Calvo,
dated January 22, 1988 (P-88019)

4) NRC Letter, Heitner to Williams,
dated June 15, 1988 (G-88219)

5) NRC Memorandum, Heitner to Calvo,
dated March 9, 1988 (G-88071)

6) NRC Letter, Clark to Millen, dated
April 26, 1976 (G-76038)

7) NRC Letter, Wagner to Lee, dated
March 8, 1983 (G-83104)

Dear Mr. Calvo:

This letter discusses the fulfillment of committed helium circulator outage corrective actions and provides clarification and status of certain other committed circulator-related corrective actions. The specific commitments to be discussed herein were established in Reference 1 (with NRC concurrence provided in Reference 2), Reference

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3 (NRC concurrence provided in Reference 4) and Reference 5. By the fulfillment of certain commitments, as indicated in this letter, FSV is no longer committed to have all four circulators necessarily operating at power levels above 35 percent (Reference 1). Future helium circulator operability requirements will be in accordance with the Fort St. Vrain Technical Specifications. Please note, however, that the usual practice at FSV is to operate all four circulators above 35 percent power level under normal conditions.

The circulator-related problems and issues that were identified as a result of the steam-end damage to Circulator C-2101 last year have been resolved by modifications and associated activities accomplished during the recent outage. These completed activities provide increased assurance of reliable circulator operation and the ability of all circulators to perform their intended safety functions. For the remaining circulators inspected during the recent circulator outage, no damage was found outside the scope of the original Reference 3 evaluation of the Circulator C-2101 damage which would necessitate further corrective actions. Summarized below are the significant activities performed during the recent circulator outage, including an update of outage commitments where outage activities may have departed from the planned activities previously described to the NRC:

A. Circulator C-2101 Report

A report (Reference 3) has been submitted which addressed the damage (including cause) and repairs associated with Circulator C-2101 and Steam Inlet and Water Piping Assembly S/N 2001. The report also provided information relative to design changes (corrective actions) to be implemented on the helium circulators as a result of the damage to C-2101. Also discussed in the report were circulator inspections, speed and wobble monitoring and water chemistry controls (to be discussed further below).

A final inspection report on Circulator C-2101 is in preparation and is currently planned for NRC submittal in January 1989 as part of the circulator final report.

B. Helium Circulator Outage Accomplishments

The primary cause of failure of the steam-end parts in C-2101 was found to be stress corrosion cracking (SCC) resulting from a high-caustic environment (Reference 3). To reduce the risk of repeated component failure similar to that which occurred in C-2101, the decision was made to change the materials of certain steam-end components (mostly threaded fasteners) to materials known to be more resistant to caustic SCC and to reduce, where possible, preload stress. Also it was decided to discontinue use of molybdenum disulfide lubricants in the circulator although the possible breakdown of these lubricants was not considered to be a major contributor towards the failures. These circulator

hardware changes are in addition to tighter water chemistry controls on caustic levels and improved preventive maintenance and inspection.

PSC committed to making the circulator steam-end hardware changes during a dedicated outage as soon as the new parts were available. PSC Change Notice (CN) 2715 specified and justified the changes to be made. These changes have been implemented during the recent outage which began in early July.

The steam-end inspections, observations, corrective actions and modifications per CN-2715 completed for each circulator and steam inlet and water piping assembly are summarized below:

Circulator C-2101

This circulator is currently installed in PCRV 'B' penetration replacing C-2105.

C-2101 original steam-end damage discovered in July 1987 was the initiating event for the overall circulator evaluations.

Inspection, repairs and modifications were performed by General Atomics, San Diego, as reported in Reference 3.

Observations and Repairs:

Steam ducting strut welds were cracked and a crack was discovered in the steam ducting (scroll piece) bolt hole area. These cracks were weld repaired.

Damaged insulation assembly, steam turbine rotor and other parts (documented in Reference 3) were replaced as required.

CN-2715 steam-end modifications made:

<u>Item No.</u>	<u>Component</u>	<u>Change</u>
1	Lockwasher for labyrinth seal mounting bolts	Material changed from 430 stainless steel (SST) Inconel 600.
2	Bolt, 3/4", steam ducting to bearing cart-ridge	Preloading method changed from 400-410 ft-lb applied torque to 0.0080" \pm 0.0010" applied stretch (measured ultrasonically).

<u>Item No.</u>	<u>Component</u>	<u>Change</u>
3	Bolt, 3/4", pressure-tap, steam ducting to bearing cartridge	Preloading method changed from 400-410 ft-lb applied torque to apply torque to the average torque value required to stretch the 14 ea. non-pressure-tap bolts to their specified stretch. Thru-hole diameter reduced from 1/4" to 1/8".
4	Hex head bolt, 1/4", labyrinth seal to steam ducting	Material changed from 410 SST to Inconel X-750 w/ special heat treat to minimize potential for SCC. Torque reduced from 7.5 ft-lb to 38-42 in-lb.
5	Socket head capscrew, 1/4", steam stator to steam ducting	Same changes as for Item 4.
6	Spring plunger (locking mechanism for insulation cover)	Material changed from carbon steel to Inconel X-750. Second spring plunger added for locking redundancy.
7	Socket head capscrew, 1/4", steam stator lower labyrinth seal to water deflector	Same changes as for Item 4.
8	Socket head capscrew, 1/4", steam stator alignment sleeve to alignment ring	Same changes as for Item 4.
9	Insulation cover	Revised location of spring plunger hole to provide clockwise engagement (same direction as steam turbine rotation).
10	Forging for steam ducting weldment	Added chamfer to lower edge of 13/16" diameter thru holes to eliminate contact stress with 3/4" bolt head fillet radius.

<u>Item No.</u>	<u>Component</u>	<u>Change</u>
11	Hex head bolt, 1/2", lower thermal sleeve to upper thermal sleeve	Material changed from 4140 to Inconel X-750 w/ special heat treat. Torque specified at 22-24 ft-lb.
12	Thread lubricant	Changed from molybdenum disulfide (Cerac SP-111) to Never-Seez Pure Nickel Special (nuclear grade).

Circulator C-2102

This circulator is currently installed in PCRV 'A' penetration.

Inspections and Observations:

Cracks found by liquid penetrant inspection in steam ducting strut welds were weld repaired.

Liquid penetrant examination of the Pelton wheel revealed no indications. The Pelton wheel was reused.

Magnetic particle examination of the steam turbine rotor and labyrinth seal and spacer revealed no indications. These parts were reused.

A new, modified (per CN-2715) insulation cover was installed.

CN-2715 steam-end modifications made:

Modifications made were the same as for C-2101, except a second spring plunger is to be added during future refurbishment (as indicated in Reference 3, this could not be accomplished in-situ during the circulator outage).

Circulator C-2103

This circulator is currently installed in PCRV 'C' penetration.

Inspections and Observations:

Liquid penetrant examination of the steam ducting strut welds revealed cracks which were subsequently weld repaired.

The Pelton wheel has experienced considerable bucket erosion; however, C-2103 was still passing the surveillance test which demonstrates its ability to meet safe-shutdown cooling requirements. The Pelton wheel was replaced with that from spare Circulator C-2105 for improved efficiency.

The following damage was found in the insulation cover area of the circulator:

Approximately 75% of the insulation cover was missing as a result of metal-to-metal contact with the steam turbine rotor.

The top side of the steam turbine rotor was found having several circumferential grooves worn into the rotor disk from contact with loose debris from insulation cover assembly. There was no blade damage.

The labyrinth seal was warped at the bayonet tab area. Outer edge and seal surface showed some rub damage.

Approximately 95% of the bearing and turbine-side insulation was missing.

The backing plate was missing except for a few pieces found on top of the steam turbine rotor along with other debris.

Two adjacent 1/4"-20 labyrinth seal mounting bolts were missing.

By inspection and subsequent evaluation it is believed that the above damage was incurred as a result of the insulation cover dropping down onto the steam turbine rotor. It would appear that the insulation cover rotated out of its bayonet locking tabs as a result of lack of engagement of the spring plunger into the insulation cover. This conclusion was reached by the fact that the spring plunger was found intact and in good working order.

A magnetic particle examination of the steam turbine rotor showed no rejectable indications. The depth of the smooth grooves were such that calculated stresses are less than 50% of material yield strength at 150% rated speed. Maximum credible speed is 135% of rated speed (FSAR, Section A.14.5). The steam turbine rotor was therefore reused.

The labyrinth seal, insulation cover, backing plate, insulation, 1/4"-20 bolts and lockwashers were all replaced with new.

CN-2715 steam-end modifications made:

Modifications made were the same as for C-2101, except for the second spring plunger to be added during future refurbishment.

Circulator C-2104

This circulator is currently installed in PCRV 'D' penetration.

Inspections and Observations:

Liquid penetrant examination of the steam ducting strut welds revealed cracks which were subsequently weld repaired.

Liquid penetrant examination of the Pelton wheel revealed no indications. The Pelton wheel was reused.

Magnetic particle examination of the steam turbine rotor and labyrinth seal and spacer revealed no indications. These parts were reused.

A new, modified (per CN-2715) insulation cover was installed.

CN-2715 steam-end modifications made:

Modifications made were the same as for C-2101, except for the second spring plunger to be added during future refurbishment.

Circulator C-2105

This circulator, currently designated as spare, was removed from PCRV 'B' penetration (replaced by C-2101) due to a shutdown seal supply leak. The circulator was sent to GA for troubleshooting and repair of the leak.

Inspections and Observations:

Liquid penetrant examination of the steam ducting strut welds revealed cracks which were subsequently weld repaired.

The following steam-end parts were found damaged upon disassembly:

Lower labyrinth of bearing cartridge: Broken bayonet tabs.

Insulation cover: Broken bayonet tabs.

Lockwasher (1 ea.) for labyrinth seal mounting bolts: Bent ends broken off.

Labyrinth seal mounting bolt (1/4") (1 ea.): Hex head broken off.

Labyrinth seal mounting bolt (1/4") (2 ea.): Backed out of holes; thread damage.

Spring plunger: Tip of plunger broken off.

Insulation, bearing side: Excessive crush due to misinstallation.

Backing plate: Dented by 3/4" bolt head due to misinstallation.

Insulation, turbine side: Gouge from broken bayonet tab.

3/4" bolts, steam ducting to bearing cartridge (14 ea.): Possessed thru-hole similar to pressure-tap bolt.

The majority of the damage in the above parts was attributed to misinstallation of the insulation assembly and a dimensional out-of-tolerance condition of the bayonet tabs. It must be recognized that none of the above damage had any impact on the operation of the circulator.

During removal of one of the steam ducting to bearing cartridge 3/4" bolts, the bolt seized and broke. Once removed, however, the hole threads were salvageable to accept a new bolt.

All of the above damaged parts except the lower labyrinth were replaced with new. The lower labyrinth was deemed acceptable for continued use after performance of an indication-free liquid penetrant examination.

Liquid penetrant examination of the Pelton wheel revealed no indications. The Pelton wheel was used as a replacement for the eroded wheel from Circulator C-2103.

Magnetic particle examinations of the steam turbine rotor and labyrinth seal and spacer were performed. No indications were found. These parts were reused.

CN-2715 steam-end modifications made:

Modifications made were the same as for C-2101, except for the second spring plunger to be added during future refurbishment.

Steam Inlet and Water Piping Assembly S/N 2000

This piping assembly, currently installed in PCRV 'C' penetration with Circulator C-2103, was removed from PCRV 'C' penetration during the outage.

Observations:

Spacer grooves in the outer pipe were found with approximately 3/32" to 5/32" gap at the top end of spacer fit. This condition was evaluated and the assembly was deemed acceptable for reuse as is.

No other significant problems were found.

CN-2715 modifications made:

Modifications made were the same as for S/N 2001 (see below).

Piping Assembly S/N 2001

This piping assembly, currently installed in PCRV 'B' penetration with Circulator C-2101, was previously designated as a spare assembly.

This assembly was recently refurbished by GA including the following modifications per CN-2715:

<u>Item No.</u>	<u>Component</u>	<u>Change</u>
1	Hex head bolt, 3/8", pelton nozzle bracket to nozzle bolting bar	Material changed from 5% chrome to Inconel X-750 w/ special heat treat. Torque specified at 22-24 ft-lb.
2	Socket head capscrew, #10-32, pelton nozzle support to 15" upper ring	Material changed from 4140 to Inconel X-750 w/ special heat treat. Torque specified at 34-36 in-lb.
3	Thread lubricant	Changed from molybdenum disulfide (Cerac SP-111) to Never-Seez Pure Nickel Special (nuclear grade).

Piping Assembly S/N 2002

This piping assembly, currently designated as a spare, was removed from PCRV 'B' penetration during the outage.

Upon removal, this assembly was sent to GA for implementation of previously-authorized modifications plus modifications per CN-2715 (same as for S/N 2001).

By liquid penetrant inspection, GA discovered cracks in the 18" bellows. The bellows was replaced.

Upon return of this assembly to Fort St. Vrain, flange alignment problems were discovered which required the unit to be returned to GA for rework.

Piping Assembly S/N 2003

This piping assembly, currently installed in PCRV 'D' penetration with Circulator C-2104, was removed from PCRV 'D' penetration during the outage.

Observations:

No significant problems were found.

CN-2715 modifications made:

Modifications made were the same as for S/N 2001.

Piping Assembly S/N 2004

This piping assembly, currently installed in PCRV 'A' penetration with Circulator C-2102, was removed from PCRV 'A' penetration during the outage.

Observations:

No significant problems were found.

CN-2715 modifications made:

Modifications made were the same as for S/N 2001.

C. Examination of Steam-End Fasteners Replaced During Outage

PSC plans to perform liquid penetrant and/or metallographic examination of a representative sample of the steam-end fasteners replaced in all machines. These examinations will commence as time and manpower becomes available. Currently, PSC plans to submit to the NRC a report of the findings of these examinations by the end of January 1989. As the fastener examination

proceeds, findings can be verbally communicated to the NRC prior to submittal of the final report. Also, representative fastener samples can be submitted for NRC independent analysis, if so desired.

D. Water Chemistry

To minimize the potential of caustic-induced stress corrosion cracking in plant components exposed to steam, in light of the Circulator C-2101 steam-end failures attributed to SCC last year, PSC has implemented tighter control of the allowable sodium levels in the steam from the auxiliary boiler and in the condensate/feedwater system. These planned controls were reported in Reference 3.

The applicable water chemistry specification procedures have been revised to reflect those sodium limits identified in Reference 3 for both the condensate/feedwater at the demineralizer outlet and the auxiliary boiler steam. Corrective actions are required whenever the limits are exceeded to bring sodium back within limits in a reasonable period of time.

A modification design package has been completed to install a permanent auxiliary boiler steam sampling station for the purpose of obtaining auxiliary steam samples for analysis of sodium content. Installation of this sampling station is tentatively scheduled to begin by the end of 1988. Meanwhile, grab samples of auxiliary steam are being taken via a temporarily-configured sampling line.

E. Circulator Wobble Monitoring

Circulator shaft wobble continues to be monitored on an interim basis with the use of dedicated oscilloscopes. Data is recorded daily. Wobble is also checked after any unplanned circulator speed changes. The data accumulated to date has not shown any significant wobble increase.

On a weekly basis, the cables to the speed modifiers are balanced. Since completion of speed cable/connector work, the rate of drift of balance has gone down significantly. Also, due to improvement in the quality of the circulator speed signals, it has been determined that a changeout of the cables or splices is not required and that an automatic balance circuit for the speed modules will not be required.

Four vendor bids for a continuous-monitor speed/wobble computer have been evaluated. It appears that the most viable option is utilization of two digital oscilloscopes (Nicolet 4094) equipped with an alarm function. The oscilloscopes would provide an alarm at a specified wobble level and could also provide storage of input signals. Use of the oscilloscope monitor requires the

development of a frequency multiplier to maintain synchronization during speed changes. A circulator simulator would be used in the design, development and testing of the multiplier. If the system appears feasible it would be moved to the Auxiliary Electric Room where actual circulator speed signals would be test-monitored for a period of time to be determined.

F. Circulator Inspections

Circulator Surveillance Technical Specifications SR 5.2.17 and SR 5.2.18 were created by Tech. Spec. Amendment 12 (Reference 6). SR 5.2.17 specified Pelton wheel examination at the time of the first main turbine-generator overhaul. SR 5.2.18 specified, at the time of first main turbine-generator overhaul and at subsequent ten-year intervals, examination of circulator bearing and seal surfaces, brake system, buffer seal system, labyrinth seals, compressor rotor, steam turbine rotor and Pelton wheel of one circulator.

Circulator S/N C-2102 was inspected in 1979/80 in conformance with SR 5.2.17 and SR 5.2.18 (Amend. 12).

SR 5.2.17 (Amend. 12) was deleted and SR 5.2.18 (Amend. 12) was revised by Amendment 33 (Reference 7), which established the wording currently in effect (later Amendment 51 affected SR 5.2.18 page number only).

The current Tech. Spec. SR 5.2.18 (Amend. 33/51) calls for inspection for surface and subsurface defects of the compressor rotor, steam turbine rotor and Pelton wheel of a previously uninspected circulator at ten calendar-year intervals following the first complete circulator inspection per SR 5.2.18 (Amend. 12). Other circulator components, accessible without further disassembly than required to inspect these wheels, are to be visually examined.

Since the first circulator inspection per SR 5.2.18 (Amend. 12) was performed on C-2102 in 1979/80, the next inspection per SR 5.2.18 (Amend. 33/51) is due about 1989/90.

Subsequent to the 1979/80 inspection of C-2102, although not required by the Tech. Specs., three more circulators have been completely disassembled, inspected and refurbished: C-2105 (1980/81), C-2104 (1984/85) and C-2101 (1987/88). C-2105 was removed from service due to leakage in the shutdown seal system; C-2104 was removed to repair damage to the steam turbine; and C-2101 experienced parts failure in the steam turbine area.

Upon disassembly and inspection of the bearing cartridge assembly from each of the three circulators, nothing was found within the bearing cartridge as a result of normal service conditions which

could have led to misoperation of the circulator for normal or emergency, safe-shutdown cooling service requirements.

The failure of parts in the steam turbine area of C-2101 has resulted in a newly-planned steam-end inspection and parts replacement program based on hours of machine operation (in addition to certain steam-end component material changes per SN-2715 implemented during the recent outage and tighter water chemistry controls on sodium). The final details of this new inspection/replacement plan, initially reported in Reference 3, are still under development and will be included in the final circulator report currently scheduled for January 1989.

Nothing was found within the bearing assembly of C-2101 which would indicate a need to require disassembly and inspection of future circulators beyond the current SR 5.2.18 (Amend. 33/51) ten calendar-year inspection requirements. Therefore, it is anticipated that the Tech. Specs. will be revised to encompass only the addition of the steam-end inspection/replacement program as a result of the damage found in C-2101. This will enhance the Tech. Specs. with regard to circulator inspection.

At this time, it is planned to use Circulator C-2105 to meet the required 1989/90 SR 5.2.18 (Amend. 33/51) inspection specification. PSC's original plans called for replacement of Circulator C-2103 (in 'C' penetration) and, in conjunction with this plan, C-2103 would have been used for the SR 5.2.18 inspection. Because of the shutdown seal supply leakage problem on Circulator C-2105, PSC replaced C-2105 in lieu of C-2103. Circulator C-2105 is an acceptable substitution for C-2103 for the SR 5.2.18 inspection for the following reasons:

The compressor rotor and steam turbine rotor, including blades, are original components of C-2105 and have experienced at least as many hours of operation as those from C-2103.

The Pelton wheel currently on C-2105 was taken from C-2103 during the recent outage (Reference Section B of this letter) and has seen service since 1974.

G. Deviations to Quality Requirements of Attachment 1 to Reference 3

Certain deviations to the quality assurance requirements outlined in Attachment 1 to Reference 3 as well as needed clarifications were identified by NRC Region IV inspection activities documented in Inspection Reports 88-15 and 88-23. These deviations will be specifically addressed in our response to these inspection reports. In addition, our final circulator report will clarify the quality requirements to be applied for future circulator-related fastener procurements.

H. PSC Review of General Atomics' Scroll and Strut Weld Repairs for C-2101

As discussed at the NRC-PSC management meeting on October 3, 1988, prior to exceeding 35 percent power PSC agreed to review General Atomics' welding program which was utilized to weld repair the scroll and struts on Circulator C-2101, and to reach a PSC determination on the operability of C-2101. Based on a preliminary review, PSC has concluded that the deviations which were identified in the GA welding program did not affect the integrity or acceptability of the C-2101 weld repairs and that Circulator C-2101 is operable. PSC is finalizing the documentation and the results of our recent inspection activities at General Atomics' facilities. PSC will submit a summary letter report to the NRC on the review by October 28, 1988.

I. Circulator Final Report (January 1989)

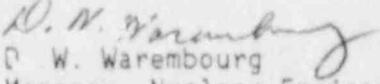
The final report of circulator-related activities as a result of component failure in Circulator C-2101, currently scheduled for submittal in January 1989, will, at a minimum, provide the following information:

- 1) Results of nondestructive and metallographic examinations of a representative sample of circulator steam-end fasteners removed and replaced during the 1988 circulator outage.
- 2) Better definition and clarification of the following:
 - a) The application and documentation of quality assurance requirements relative to procurement of circulator-related fasteners.
 - b) Circulator-related fastener replacement policy.
 - c) Circulator periodic inspection and parts replacement program including planned Technical Specification revision.
- 3) Status of development of continuous wobble monitoring system.
- 4) Final inspection report on Circulator C-2101.

October 21, 1988

If you should have any questions concerning the circulator-related subject matter of this letter, please call Mr. M. H. Holmes at (303) 480-6960.

Very truly yours,


D. W. Warembourg
Manager, Nuclear Engineering Division

DWW/TSE:eje

cc: Regional Administrator, Region IV
ATTN: Mr. T. F. Westerman
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