NRC FORM 366 (04-02-2024) U.S. NUCLEAR REGULATORY COMMISSION

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LICENSEE EVENT REPORT (LER)

(See Page 2 for required number of digits/characters for each block)

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1. Facility Name		2. Docket Number	3. Page
Calvert Cliffs Nuclear Power Plant, Unit 2	☒ 050 ☐ 052	05000318	1 OF 5

4. Title

Manual Reactor Trip Due to 22 Steam Generator Feed Pump Trip

5. Event Date			6. LER Number			7. Report Date			8. Other Facilities Involved		
Month	Day	Year	Year	Sequential Number	Revision No.	Month	Day	Year	Facility Name	☐ 050	Docket Number
02	24	2024	2024	- 001 -	01	08	20	2024	Facility Name	☐ 052	Docket Number

9. Operating Mode	10. Power Level

11. This Report is Submitted Pursuant to the Requirements of 10 CFR §: *(Check all that apply)*

10 CFR Part 20	☐ 20.2203(a)(2)(vi)	**10 CFR Part 50**	☐ 50.73(a)(2)(ii)(A)	☐ 50.73(a)(2)(viii)(A)	☐ 73.1200(a)
☐ 20.2201(b)	☐ 20.2203(a)(3)(i)	☐ 50.36(c)(1)(i)(A)	☐ 50.73(a)(2)(ii)(B)	☐ 50.73(a)(2)(viii)(B)	☐ 73.1200(b)
☐ 20.2201(d)	☐ 20.2203(a)(3)(ii)	☐ 50.36(c)(1)(ii)(A)	☐ 50.73(a)(2)(iii)	☐ 50.73(a)(2)(ix)(A)	☐ 73.1200(c)
☐ 20.2203(a)(1)	☐ 20.2203(a)(4)	☐ 50.36(c)(2)	☒ 50.73(a)(2)(iv)(A)	☐ 50.73(a)(2)(x)	☐ 73.1200(d)
☐ 20.2203(a)(2)(i)	**10 CFR Part 21**	☐ 50.46(a)(3)(ii)	☐ 50.73(a)(2)(v)(A)	**10 CFR Part 73**	☐ 73.1200(e)
☐ 20.2203(a)(2)(ii)	☐ 21.2(c)	☐ 50.69(g)	☐ 50.73(a)(2)(v)(B)	☐ 73.77(a)(1)	☐ 73.1200(f)
☐ 20.2203(a)(2)(iii)		☐ 50.73(a)(2)(i)(A)	☐ 50.73(a)(2)(v)(C)	☐ 73.77(a)(2)(i)	☐ 73.1200(g)
☐ 20.2203(a)(2)(iv)		☐ 50.73(a)(2)(i)(B)	☐ 50.73(a)(2)(v)(D)	☐ 73.77(a)(2)(ii)	☐ 73.1200(h)
☐ 20.2203(a)(2)(v)		☐ 50.73(a)(2)(i)(C)	☐ 50.73(a)(2)(vii)		

☐ **OTHER** (Specify here, in abstract, or NRC 366A).

12. Licensee Contact for this LER

Licensee Contact	Phone Number (Include area code)
Larry D Smith, Regulatory Assurance Manager	667-313-6503

13. Complete One Line for each Component Failure Described in this Report

Cause	System	Component	Manufacturer	Reportable to IRIS		Cause	System	Component	Manufacturer	Reportable to IRIS
B	SJ	P	B580	Y						

14. Supplemental Report Expected		15. Expected Submission Date	Month	Day	Year
☒ No	☐ Yes (If yes, complete 15. Expected Submission Date)				

16. Abstract (Limit to 1326 spaces, i.e., approximately 13 single-spaced typewritten lines)

On February 24, 2024 at 1546, Calvert Cliffs Nuclear Power Plant Unit 2 initiated a manual reactor trip from 100 percent power in response to a trip of the 22 Steam Generator Feed Pump. Following the manual reactor trip, the 21 Steam Generator Feed Pump tripped due to high discharge pressure. Operations promptly performed a manual actuation of Auxiliary Feedwater to supply feedwater to both Steam Generators. The cause of the initiating event was the failure of the 22 Steam Generator Feed Pump coupling that connects the pump to its steam turbine driver, such that the pump and steam turbine were effectively disconnected. Immediate corrective actions taken by the site included replacing the coupling, making repairs and adjustments to a piping support on the discharge line of the 22 Steam Generator Feed Pump to address potential pipe strain on the pump casing, and engaging third-party vendor specialists to ensure proper alignment and securement of the pump. Initial forensics performed on the coupling suggest the failure occurred due to a combined effect of cyclic flexing due to misalignment (such as angular misalignment) and elevated stress associated with axial displacement / thrust. The Root Cause Evaluation confirmed piping strain caused misalignment from the pump to turbine casing which led to the catastrophic failure of the 22 Steam Generator Feed Pump coupling.

LICENSEE EVENT REPORT (LER) CONTINUATION SHEET

1. FACILITY NAME		2. DOCKET NUMBER	3. LER NUMBER		
			YEAR	SEQUENTIAL NUMBER	REV NO.
Calvert Cliffs Nuclear Power Plant, Unit 2	■ 050 ☐ 052	05000318	2024	- 001	- 01

NARRATIVE

PLANT AND SYSTEM IDENTIFICATION

Calvert Cliffs Nuclear Power Plant, Unit 2, is a Combustion Engineering Pressurized Water Reactor with a licensed maximum power level of 2737 megawatts thermal. The Energy Industry Identification System code used in the text is identified as [SJ].

A. CONDITION PRIOR TO EVENT

Unit: 2
Date: February 24, 2024
Power level: 100
Mode: Unit 2 was in Mode 1 when the event occurred.

B. DESCRIPTION OF EVENT

At 1546 on 02/24/2024, the Unit 2 reactor was manually tripped (scrammed) based on lowering Steam Generator (SG) levels following the trip of the 22 Steam Generator Feed Pump (SGFP). Shortly after the manual trip, the other turbine-driven SGFP, 21 SGFP, tripped on high discharge pressure. The Operations crew manually initiated Auxiliary Feedwater (AFW) to the SGs by starting the motor-driven 23 AFW Pump. During performance of post-trip recovery actions, the 21 SGFP was successfully re-started, and Main Feedwater was re-initiated to the SGs. Once satisfactory operation of the 21 SGFP was confirmed, the 23 AFW Pump was secured. Heat removal remained via the normal turbine bypass valves to the main condenser throughout the duration of the event.

Unit 2 is equipped with three SGFPs:

- Two turbine-driven pumps – 21 and 22 SGFPs – that supply the required feedwater flow rate to the SGs to match the steam flow demand by the plant turbine generator and auxiliaries. Unit 2 can only operate on a single turbine-driven SGFP up to a reactor power level of approximately 70%.
- One standby, motor-driven feedwater pump – 23 SGFP - is also installed to prevent a reactor trip on low steam generator level upon the loss of a single turbine-driven feedwater pump. The standby feedwater pump automatically starts upon the loss of a turbine-driven feedwater pump at power levels of 70% or greater. The standby feedwater pump provides adequate flow with a single operating turbine-driven feedwater pump to support power levels between 70% and approximately 90% rated power. In the event of a turbine-driven feedwater pump trip at rated power, a down power is required to power levels below 90% to prevent a reactor trip on low steam generator level.

At the time of the trip of the 22 SGFP, the 23 SGFP was unavailable based on being in a procedurally required STOP/LOCKOUT status due to an unrelated electrical bus outage that was in progress in support of the Unit 1 planned refueling outage (RFO) that was also occurring on the date of the trip. The STOP/LOCKOUT status of the 23 SGFP was required based on load limitations imposed by the original engineering design for the

standby, motor-driven feedwater pump based on the off-normal electrical bus alignments that were present in support of the RFO-based electrical work scope.

C. DATES AND APPROXIMATE TIMES OF MAJOR OCCURRENCES

(Times are taken from Plant Computer data and Operations Logs)

February 24, 2024

- 15:45:19: The 22 SGFP trips due to failure of its coupling. The Unit 2 Control Room receives the following alarms / annunciators:
  - 22 SGFPT SPD CONTR SYS TROUBLE
  - 21 SGFPT SPD CONTR SYS TROUBLE
  - 22 SGFPT Trip

  Upon identification of the 22 SGFP trip based on the received alarms / annunciations, the Operations crew promptly implements the applicable abnormal operating procedure and makes one attempt to restart the 22 SGFP.
- 15:46:11: The Operations crew initiates a manual trip of Unit 2 based on reaching trip criteria for lowering SG levels.
- 15:46:15: The 21 SGFP trips due to high discharge pressure.
- 15:49:00: The Operations crew manually starts the 23 AFW Pump (manual actuation of AFW) to restore feedwater to the SGs.
- 17:02: The Operations crew restarts the 21 SGFP and restores Main Feedwater to the SGs.
- 18:04: The Operations crew secures the 23 AFW Pump.
- 18:08: The Shift Manager completes Event Notification #56991 to satisfy the requirements of 10CFR50.72(b)(2)(iv)(B) and 10CFR50.72(b)(3)(iv)(A).

D. CAUSE OF EVENT

The method of discovery for this event was self-revealing and is documented in the site's Corrective Action Program (CAP) under IR 04752936. The Unit 2 reactor was manually tripped based on reaching trip criteria for lowering SG levels following the trip of the 22 SGFP. The cause of the 22 SGFP trip was the failure of its coupling located between the pump and the steam turbine driver. Forensics performed on the coupling identified that the pump-end coupling diaphragm exhibited cracking that was consistent with fatigue. Cracking occurred in an irregular pattern across the diaphragm, with the overall pattern suggesting axial displacement or thrust was a contributor to the failure. The pattern of cracking and evidence of fatigue suggested the failure occurred due to a combined effect of cyclic flexing due to misalignment (such as angular misalignment) and elevated stress associated with axial displacement / thrust.

The root cause for the trip of the 22 SGFP due to the failed coupling was piping strain has caused misalignment from pump to turbine casing leading to catastrophic failure of the coupling.

E. SAFETY ANALYSIS

The subject event satisfies the criteria in NUREG-1022, Revision 3, for any event or condition that resulted in manual or automatic actuation of any of the systems listed in 10CFR50.73, paragraph (a)(2)(iv)(B). Specifically, for this event, the Reactor Protection System and the Auxiliary Feedwater System actuated. Therefore, this event is reportable pursuant to 10CFR50.73(a)(2)(iv)(A). There were no safety consequences as a result of the event. All safety systems functioned and operated as designed.

F. CORRECTIVE ACTIONS

During the forced outage following the February 24, 2024 Unit 2 manual trip, the following immediate corrective actions were taken prior to returning the 22 SGFP to service:

- The failed coupling was replaced with an equivalent spare.
- A broken pipe support on the 22 SGFP discharge piping was repaired, and minor modifications were made to the pipe support to eliminate potential pipe strain conditions being imposed on the pump casing that could impact achievement and sustainability of proper alignment of the pump to the turbine.
- Extensive efforts were taken, with the support of third-party vendor specialists, to achieve proper alignment of the pump casing and ensure proper securement to the pump's base/pedestal.

Prior to restarting the 22 SGFP, the site developed and implemented an Adverse Condition Monitoring Plan (ACMP) to monitor for and capture the actions to take in response to the early indications of a potential 22 SGFP coupling failure. The monitored parameters include the following:

- 22 SGFP pump and thrust bearing differential temperatures (including rate of change values)
- 22 SGFP pump and thrust bearing overall temperatures
- 22 SGFP pump and turbine bearing vibration indications

The 22 SGFP was restored to operation by paralleling it with the 21 SGFP on March 2, 2024.

Additional corrective actions developed included development and implementation of an engineering change to allow manual start of the third SGFPs down to 60% power, collection of Operating Deflection Shape data for the 22 SGFP to identify mechanical issues, and performance of two PIPESTRESS models (based on existing ME-101 evaluations) to understand stress effects on the system and piping lines.

G. PREVIOUS OCCURRENCES

A review of Calvert Cliffs' events was performed. Similar events involving the trip of the 22 SGFP due to pump-to-turbine coupling failures occurred on May 21, 2013, as reported in LER 318-2013-004, and on December 1, 2015, as reported in LER 318-2015-001. A summary of the causes associated with each of these previous occurrences is summarized below (as taken from the associated LERs):

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NARRATIVE

- May 21, 2013 event: The trip of 22 SGFP occurred due to a failed pump coupling that connects the pump to its steam turbine driver, such that the pump and steam turbine were effectively disconnected. Inspection of the pump end of the coupling assembly revealed mechanical damage and separation along a weld seam. Failure analysis identified areas of incomplete weld fusion on the turbine end of the coupling dating to the original component manufacture. These pre-existing manufacturing flaws combined with stresses induced by high cycle stress and SGFP start/stop cycles over the life of the coupling resulted in fatigue failure.

- December 1, 2015 event: A switch to use stud tensioning technology on the SGFPs was first made during Unit 1 2014 refueling outage; however, it was only used on 12 SGFP. During the Unit 2 2015 refueling outage, the same stud tensioning technology was used on both SGFPs. Prior to the original use of this technology, Engineering performed an equivalency evaluation that allowed use of studs to hold down the SGFP pump casing to its pedestal in place of previously used cap screws. However, because the evaluation did not rigorously follow Engineering standards and applicable processes, the evaluation justified the use of the stud tensioning technology without adequate review and identification of the critical parameters associated with use of the stud tensioning technology. As a result, an opportunity to identify the vendor's incorrect hydraulic pressure values was missed. Additionally, the Engineering evaluation failed to ensure formal, systematic notification was made to Maintenance concerning the change. This resulted in a missed opportunity to incorporate Electric Power Research Institute bolted joint guidance into the applicable maintenance work practice that would have helped identify critical parameters that must be obtained or followed by Maintenance to ensure proper stud tensioning is applied.

The Root Cause Evaluation for the February 24, 2024 trip of the 22 SGFP due to the failure of its coupling looked holistically at all three coupling failures from 2013, 2015, and 2024 to identify any common causes. The available root cause investigations conducted in 2013 and 2015 concluded factors other than pipe strain were the main failure modes however they did discuss the contributing effect pipe strain had on proper pump to turbine alignment. The 2024 failure had a similar signature compared to previous events indicating a common failure mode was not properly identified and rectified to prevent future recurrence.

H. COMPONENT FAILURE DATA

Component	IEEE 803 FUNCTION ID	IEEE805 SYSTEM ID
Steam Generator Feed Pump	P	SJ