University of Missouri

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April 20, 2020

ATTN: Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

REFERENCE: Docket No. 50-186
University of Missouri-Columbia Research Reactor
Renewed Facility Operating License No. R-103

SUBJECT: Written communication as required by University of Missouri Research Reactor Technical Specification 6.6.c(3) regarding a deviation from Technical Specifications 3.2.a and 3.2.f.8

The attached document provides the University of Missouri-Columbia Research Reactor (MURR) Licensee Event Report (LER) for an event that occurred on April 8, 2020, that resulted in a deviation from MURR Technical Specifications 3.2.a and 3.2.f.8.

If you have any questions regarding this report, please contact Bruce A. Meffert, the facility Reactor Manager, at (573) 882-5118.

Sincerely,

J. David Robertson, PhD
Reactor Facility Director

JDR/jlm

Enclosure

cc: Reactor Advisory Committee
Reactor Safety Subcommittee
Dr. Mark McIntosh, Vice Chancellor for Research, Graduate Studies and Economic Development
Mr. Geoffrey Wertz, U.S. Nuclear Regulatory Commission
Mr. Craig Bassett, U.S. Nuclear Regulatory Commission

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U.S. Nuclear Regulatory Commission
April 20, 2020

Licensee Event Report No. 20-01 – April 8, 2020
University of Missouri Research Reactor

Introduction

On April 8, 2020, with the reactor operating at 10 MW in the automatic control mode, control room operators noticed that reactor power level was slowly decreasing even though the reactor was in the automatic control mode, which should have been maintaining power level at 10 MW automatically without any operator intervention. Approximately one (1) minute later, the regulating blade was deemed inoperable when the rod position indication (RPI) encoder drive chain was found off its sprockets. The reactor was then immediately shut down by manual scram, and all immediate and subsequent actions of reactor emergency procedures REP-2, "Manual Scram," and REP-7, "Rod Position Indication System Failure," were completed. Failure of the regulating blade to be operable during reactor operation resulted in a deviation from Technical Specification (TS) 3.2.a, which states, "*All control blades, including the regulating blade, shall be operable during reactor operation.*" Additionally, the regulating blade failure prevented the "≤ 10% withdrawn" rod run-in function from being operable. Therefore, a deviation from TS 3.2.f.8 had also occurred. TS 3.2.f.8 specifies that "*The reactor shall not be operated unless the following rod run-in functions are operable. Each of the rod run-in functions shall have 1/N logic where N is the number of instrument channels required for the corresponding mode of operation.*" Rod Run-In Function No. 8 under this specification requires that the two (2) rod run-in functions, "≤ 10% withdrawn" or "bottomed," associated with the regulating blade must be operable when the reactor is in operation.

Description of the Regulating Blade and Drive Mechanism

The reactivity of the reactor is controlled by five (5) neutron-absorbing control blades. Four (4) of the control blades, referred to as the shim blades, are used for coarse adjustments to the neutron density of the reactor core. The fifth control blade is the regulating blade. The low reactivity worth of this blade allows for very fine adjustments in the neutron density in order to maintain the reactor at the desired power level.

The regulating blade is constructed of stainless steel with an overall length of approximately 30 inches, occupying about 18° of the circular arc around the outer reactor pressure vessel. The blade is driven at 40 inches per minute in both the inward and outward directions by its associated drive mechanism. The regulating blade drive mechanism consists of a servomotor, a reduction gearbox, and a lead screw assembly. The lead screw assembly converts the rotating motion of the servomotor to the linear motion of the regulating blade. The drive mechanism, through a slave sprocket and chain arrangement, also drives an RPI encoder transducer and a rotary limit switch assembly. The encoder transducer provides an analog signal to the RPI chassis, which converts the analog signal to a digital readout that is displayed on the control room instrument panel and control console. The rotary limit switch assembly actuates two (2) regulating blade position alarm functions (20% and 60% withdrawn) and a rod run-in (≤ 10% withdrawn). A second rod run-in is initiated by a limit switch, which is independent of the rotary limit switch assembly, when the regulating blade is fully inserted or "bottomed."

The regulating blade may be operated from the control console in either one (1) of two (2) modes: manual or automatic. In the automatic control mode, the regulating blade controls reactor power by comparing the output signal from the Nuclear Instrument (NI) Wide Range Monitor (WRM) with the setting of the power schedule potentiometer as determined by the reactor operator. If a mismatch does exist, a positive or negative output signal is generated and sent to the servomotor of the regulating blade drive mechanism, which repositions the regulating blade, stepwise, in a direction which minimizes the discrepancy between the power schedule setting and the actual power level. Over the course of the week, while in the automatic control mode, the regulating blade frequently repositions to make minor adjustments to maintain power at the desired level.

Detailed Event Description

At 00:58 on April 8, 2020, control room operators noted that the NI power range monitors (PRMs) indications were slowly lowering below 100%. These same PRMs indicated a power level of approximately 102% less than a minute earlier. At 00:59, a reactor operator on the reactor pool upper bridge found the regulating blade drive mechanism RPI encoder drive chain was off its sprockets. The console operator immediately initiated a manual reactor scram, and all immediate and subsequent actions of reactor emergency procedures REP-2, "Reactor Scram," and REP-7, "Rod Position Indication System Failure," were completed.

Failure of the regulating blade to be operable resulted in a deviation from TS 3.2.a, which states, "*All control blades, including the regulating blade, shall be operable during reactor operation.*" Additionally, with the RPI encoder drive chain disengaged, the regulating blade drive mechanism cannot move the rotary limit switch assembly sprockets. Therefore, a deviation from TS 3.2.f.8 had also occurred. TS 3.2.f.8 specifies that "*The reactor shall not be operated unless the following rod run-in functions are operable. Each of the rod run-in functions shall have 1/N logic where N is the number of instrument channels required for the corresponding mode of operation.*" Rod Run-In Function No. 8 under this specification requires that the two (2) rod run-in functions, "≤ 10% withdrawn" or "bottomed," associated with the regulating blade must be operable when the reactor is in operation. The "≤ 10% withdrawn" rod run-in function was not operable during this event.

Initial investigation revealed that the regulating blade drive mechanism RPI encoder drive chain had disengaged. The regulating blade drive mechanism was removed and taken to the Instrumentation Support Shop for further inspection and troubleshooting. Examination revealed a broken pin inside the regulating blade drive mechanism gearbox, which holds the drive gear to the gearbox output shaft. Therefore, the regulating blade drive mechanism motor could run, but no corresponding movement of the regulating blade occurred because the gear was spinning freely on the gearbox output shaft.

After replacing the regulating blade drive mechanism gearbox and placing the RPI encoder drive chain back on its associated sprockets, the RPI encoder drive chain alignment and tension seemed to be normal and satisfactory. After further inspection, it was noted that the rotary limit switch drive chain alignment needed adjustment. The upper RPI encoder sprocket, which drives the rotary limit switch slave sprocket, was lowered to align the chain correctly.

There is no way now to determine whether the RPI encoder drive chain falling off or the gear pin breaking in the gearbox occurred first. It is plausible that the RPI encoder drive chain falling off might have caused sufficient binding to break the gear pin. It is also plausible that the gear pin partially shearing caused a jerking motion to the chain sprocket, which could have led to the drive chain falling off.

Safety Analysis

Preceding the failure, the reactor had been at full-power operation with the regulating blade properly maintaining reactor power level in the automatic control mode since April 6, 2020, for a period of approximately 32.5 hours. A review of the NI WRM and PRMs reactor power data confirms that the regulating blade was operational and maintaining reactor power from 16:31 on April 6 to 00:58 on April 8, 2020. A few seconds after 00:58, reactor power level on all NI channels started to decrease below 100%; therefore, it appears that the regulating blade was inoperable for a period of approximately one (1) minute before the reactor was shut down at 00:59.

The regulating blade and its associated rod run-in features are not part of the reactor safety system as defined by TS 1.24, which states, "*The reactor safety system is that combination of sensing devices, electronic circuits and equipment, signal conditioning equipment, and electro-mechanical devices that serves to either effect a reactor scram, or activates the engineered safety features.*" When a reactor scram or rod run-in occurs, the regulating blade is automatically shifted to manual control to prevent it from operating to maintain power.

The basis for the rod run-in features associated with the regulating blade is to assure termination of a transient which, in automatic operation, is causing a rapid insertion of the regulating blade. The regulating blade "≤ 10% withdrawn" rod run-in is not required to prevent reaching a Limiting Safety System Setting (LSSS). The redundant regulating blade "bottomed" rod run-in was operable during the time the "≤ 10% withdrawn" rod run-in was inoperable.

Corrective Action

The reactor was shut down by manual scram when it was determined that the regulating blade was inoperable. The regulating blade drive mechanism was removed for inspection and troubleshooting. After replacing the regulating blade drive mechanism gearbox and placing the RPI encoder drive chain back on its associated sprockets, the RPI encoder drive chain alignment and tension seemed to be normal and satisfactory. After further inspection, it was noted the rotary limit switch drive chain alignment needed adjustment. The upper RPI encoder sprocket, which drives the rotary limit switch slave sprocket, was lowered to align the chain correctly.

The regulating blade drive mechanism was cycled across its full range several times in a test stand in the Instrumentation Support Shop prior to re-installation. Then, the regulating blade drive mechanism was reinstalled and connected to the regulating blade. The regulating blade was cycled across its full range several times prior to pre-startup checks. No visual or audible abnormalities with the chain, sprockets, shafts, RPI, or rotary switch operation were noted during these cycle tests.

The "Regulating Blade Operation And Rod Run-In Function Test" portion of form FM-57, "Long Form Startup Checksheet," was completed satisfactorily as a pre-startup final test of proper operation of the regulating blade drive mechanism and its rotary limit switch assembly. Permission to restart the reactor was obtained from the Reactor Facility Director in accordance with TS 6.6.c.

The long-term corrective action of relocating the regulating blade rotary limit switch functions directly to the drive mechanism lead screw assembly actuated by linear limit switches, as described in LER Nos. 15-01, 17-04, 19-05, and 19-06, was implemented on April 13, 2020. This new, current regulating blade drive mechanism design incorporates flexible shaft couplings that allow for slight misalignments, industry standard linear microswitches that replace the antiquated rotary limit switch assembly, a more robust gearbox that is directly coupled to the servomotor, and no drive chains. The new design eliminates the difficulties associated with aligning and providing the correct tension for multiple drive chains, sprocket assemblies, and idler arms on the same component. Additionally, this new regulating blade drive mechanism went through an extensive and thorough benchtop testing program, which simulated over six (6) months of hard service, prior to its implementation.

Additionally, this event has been entered into the MURR Corrective Action Program as CAP No. 20-0042, and any additional improvements or corrective actions will be considered and documented in that CAP entry.

If there are any questions regarding this LER, please contact me at (573) 882-5118. I declare under penalty of perjury that the foregoing is true and correct.

Sincerely,

Bruce A. Meffert
Reactor Manager

ENDORSEMENT:
Reviewed and Approved,

J. David Robertson, PhD
Reactor Facility Director

Attachments:

1. Regulating Blade Drive Assembly Diagram
2. Regulating Blade Drive Assembly

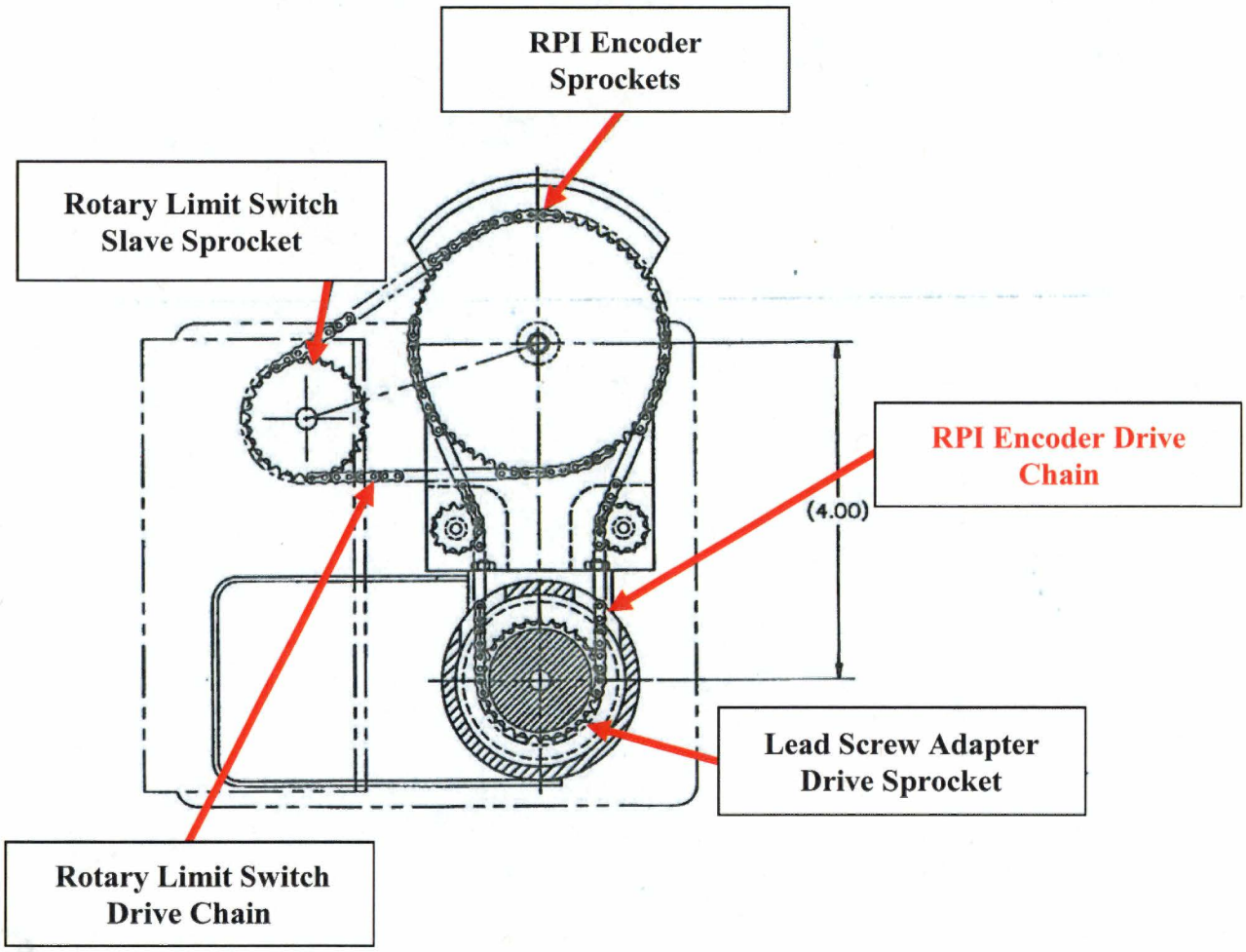
State of Missouri
County of Boone
Subscribed and sworn to before me this 20 day of April, 2020

Jacqueline L Matyas
JACQUELINE L. MATYAS, Notary Public
My Commission Expires: March 26, 2023

NOTARY PUBLIC NOTARY SEAL STATE OF MISSOURI

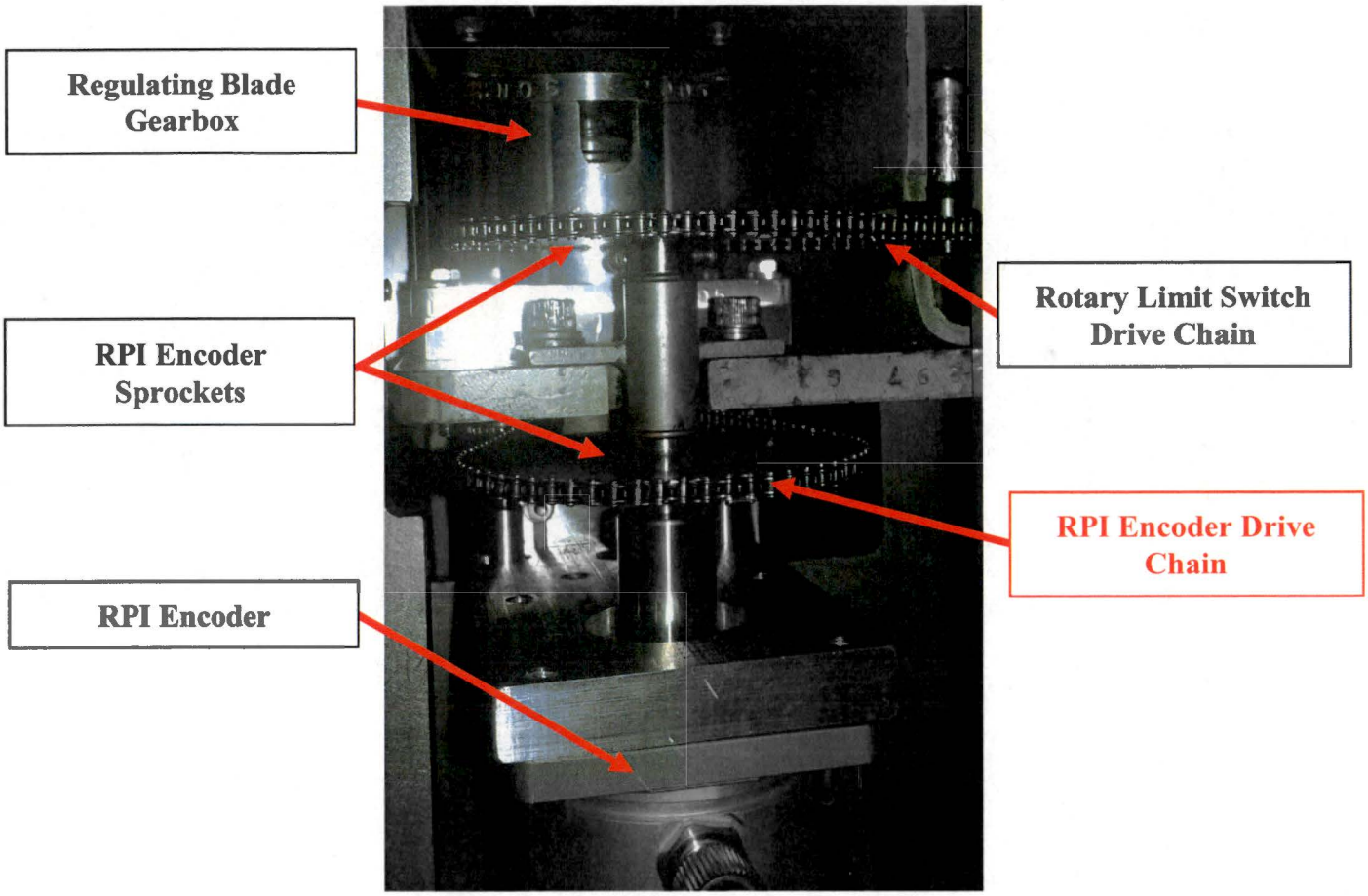
JACQUELINE L. MATYAS
My Commission Expires
March 26, 2023
Howard County
Commission #15634308

ATTACHMENT 1



Regulating Blade Drive Assembly Diagram

ATTACHMENT 2



Regulating Blade Drive Assembly