UNIVERSITY *of* MISSOURI

RESEARCH REACTOR CENTER

October 1, 2014

U.S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Mail Station P1-37
Washington, DC 20555-0001

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

SUBJECT: Written communication as required by University of Missouri Research Reactor Technical Specification 6.1.h(2) regarding a deviation from Technical Specifications 3.2.a and 3.4.c

The attached document provides the University of Missouri-Columbia Research Reactor (MURR) Licensee Event Report (LER) for an event that occurred on September 4, 2014 that resulted in a deviation from MURR Technical Specifications 3.2.a and 3.4.c

If you have any questions regarding this report, please contact John L. Fruits, the facility Reactor Manager, at (573) 882-5319.

Sincerely,

Ralph A. Butler, P.E.
Director

Signed before me 9/30/14
Margee P. Stout

NOTARY PUBLIC NOTARY SEAL STATE OF MISSOURI

MARGEE P. STOUT
My Commission Expires
March 24, 2016
Montgomery County
Commission #12511436

RAB:jlb

Enclosure
xc: Reactor Advisory Committee
Reactor Safety Subcommittee
Dr. Kenneth Dean, Interim Provost
Dr. Robert Hall, Associate Vice Chancellor for Research
Mr. Geoffrey Wertz, U.S. NRC
Mr. Johnny Eads, U.S. NRC

IE22
NRR

1513 Research Park Drive Columbia, MO 65211 Phone: 573-882-4211 Fax: 573-882-6360 Web: www.murr.missouri.edu
Fighting Cancer with Tomorrow's Technology

Licensee Event Report No. 14-04 – September 4, 2014
University of Missouri Research Reactor

Introduction

On September 4, 2014, with the reactor operating at 10 MW in the automatic control mode, a "Channel 4, 5 or 6 Downscale" annunciation was received. This alarm is initiated when any one of the three Nuclear Instrumentation (NI) Power Range Monitor (PRM) channels decrease below a power level set point of 95%. All PRM channels indicated a decreasing reactor power level. All primary and pool coolant system pressure, temperature and flow indications were normal. Investigation revealed a mechanical failure in the regulating blade drive mechanism reduction gearbox. Upon discovery of this failure, the reactor was immediately shut down by manual scram and all actions of reactor emergency procedure REP-2, "Reactor Scram," 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, with the regulating blade in an inoperable state, a deviation from TS 3.4.c had also occurred. TS 3.4.c 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.*" This specification requires that the two (2) rod run-in functions, "<10% withdrawn" and "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 neutron-absorbing control blades. Four 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, a lead screw assembly and an overload clutch. 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 gear

and chain arrangement, also drives a rod position indication (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 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 of two modes: manual or automatic. In the automatic control mode, the regulating blade controls reactor power by comparing the output signal from the 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 shims to make minor adjustments to maintain power at the desired level.

Detailed Event Description

At 21:34 on September 4, 2014, with the reactor operating at 10 MW in the automatic control mode, a "Channel 4, 5 or 6 Downscale" annunciation was received. This alarm is initiated when any one of the three NI PRM channels decrease below a power level set point of 95%. All PRM channels indicated a decreasing reactor power level. All primary and pool coolant system pressure, temperature and flow indications were normal. No additional annunciations were received and no rod motion was in progress. The Lead Senior Reactor Operator (LSRO) directed a second operator to the reactor bridge to monitor conditions near the control and regulating blade drive mechanisms. This operator heard the regulating blade drive motor vibrating but no movement of the drive mechanism was observed. At 21:38 the LSRO shifted the reactor to the manual control mode and attempted to operate the regulating blade in the inward direction. No motion was observed. The LSRO immediately initiated a manual reactor scram and all actions of reactor emergency procedure REP-2, "Reactor Scram," 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 regulating blade in an inoperable state and unable to drive in either the outward or inward directions, a deviation from TS 3.4.c had also occurred. TS 3.4.c 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." This specification requires that the two (2) rod run-in functions, "<10% withdrawn" and "bottomed," associated with the regulating blade must be operable when the reactor is in operation.

After the reactor was shut down and secured, the regulating blade drive mechanism was removed for inspection. It was determined that the gearbox output shaft had sheared which prevented movement of the servomotor from being transferred to the lead screw assembly, thus preventing the regulating blade from being able to drive in the outward and inward directions.

Safety Analysis

Preceding the failure, the reactor had been at continuous full power operation with the regulating blade properly maintaining power level in the automatic control mode for a period of 78 hours and 5 minutes since the last scheduled startup on September 1, 2014. The regulating blade had been fully operational during that period. A review of the WRM and PRM strip-chart recorders indicated that the power decrease was a direct result of the gearbox output shaft shear and occurred immediately prior to receiving the "Channel 4, 5 or 6 Downscale" annunciator alarm; therefore, it appears that the regulating blade was inoperable for a period of approximately 4 minutes from the time the annunciator was received until the reactor was shut down.

The regulating blade and its associated rod run-in features are not part of the reactor safety system as defined by TS 1.18, which states, "*The safety system is that combination of sensing devices, circuits, signal conditioning equipment electronic equipment and electro-mechanical devices that serves to effect a reactor scram, initiate a containment building isolation or activate the primary coolant siphon break system.*" 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 rod. 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. On August 25, 2014, the regulating blade drive mechanism had been refurbished with the exception of replacing the drive mechanism housing and brass adapter, which connects the output shaft of the gearbox to the lead screw assembly (See attached drawing, Part No. 4, Page 6). Refurbishment of the regulating blade drive mechanism was a corrective action for LER 14-03 (dated August 29, 2014), which describes a similar failure of the gearbox output shaft. At that time the adapter was not included in the spare parts inventory that was maintained for the regulating blade drive mechanism; therefore, one was obtained with the intent to replace it in the near future.

After the reactor was shut down and secured, the regulating blade drive mechanism was removed for repairs. The new adapter was installed along with replacement of the gearbox. The regulating blade drive mechanism was thoroughly inspected and no other anomalies noted. Electronic Shop maintenance procedure EMP-12B, "Regulating Blade," was completed satisfactorily. The applicable sections of compliance procedure CP-14, "Regulating Rod 10% and Rod Bottom Rod Run-In Rod Not in Contact with Magnet Rod Run-In," and the "Regulating Blade Operation And Rod Run-In Function Test" portion of form FM-57, "Long Form Startup Checksheet," were completed satisfactorily to verify proper operation of the regulating blade rotary limit switch assembly.

The cause of the output shaft sheer was the repeated radial stresses applied by the misalignment between the regulating blade gearbox output shaft and the center of the adapter (see attached picture, Page 7). Although some of the misalignment might have been attributed to the old upper thrust bearing (which was replaced on August 25, 2014 as explained in LER 14-03), it appears the most significant misalignment was caused by the adapter. The inner radius of the adapter had worn to a point where tightening of the ball screw plunger against the output shaft caused the output shaft to become non-centered within the adapter shaft opening. This side load on the shaft and non-centered rotation caused excessive stress on the output shaft to the point of shear. Records indicate that this adapter had been in service since original installation of the regulating blade drive mechanism. To prevent any further failures of this type, the regulating blade drive mechanism preventative maintenance procedures have been revised such that alignment between the gearbox output shaft and the lead screw assembly adapter are verified any time the gearbox is separated from the regulating blade drive mechanism. In addition, the overhaul (every four years) preventive maintenance procedure for the regulating blade drive mechanism is being updated to inspect the adapter and replace, if necessary. Additionally, this event has been entered into the MURR Corrective Action Program as

CAP entry No. 14-0051 and any additional improvements or corrective actions will be considered.

If there are any questions regarding this LER, please contact me at (573) 882-5319. I declare under penalty of perjury that the foregoing is true and correct.

Sincerely,

John L. Fruits
Reactor Manager

ENDORSEMENT:
Reviewed and Approved,

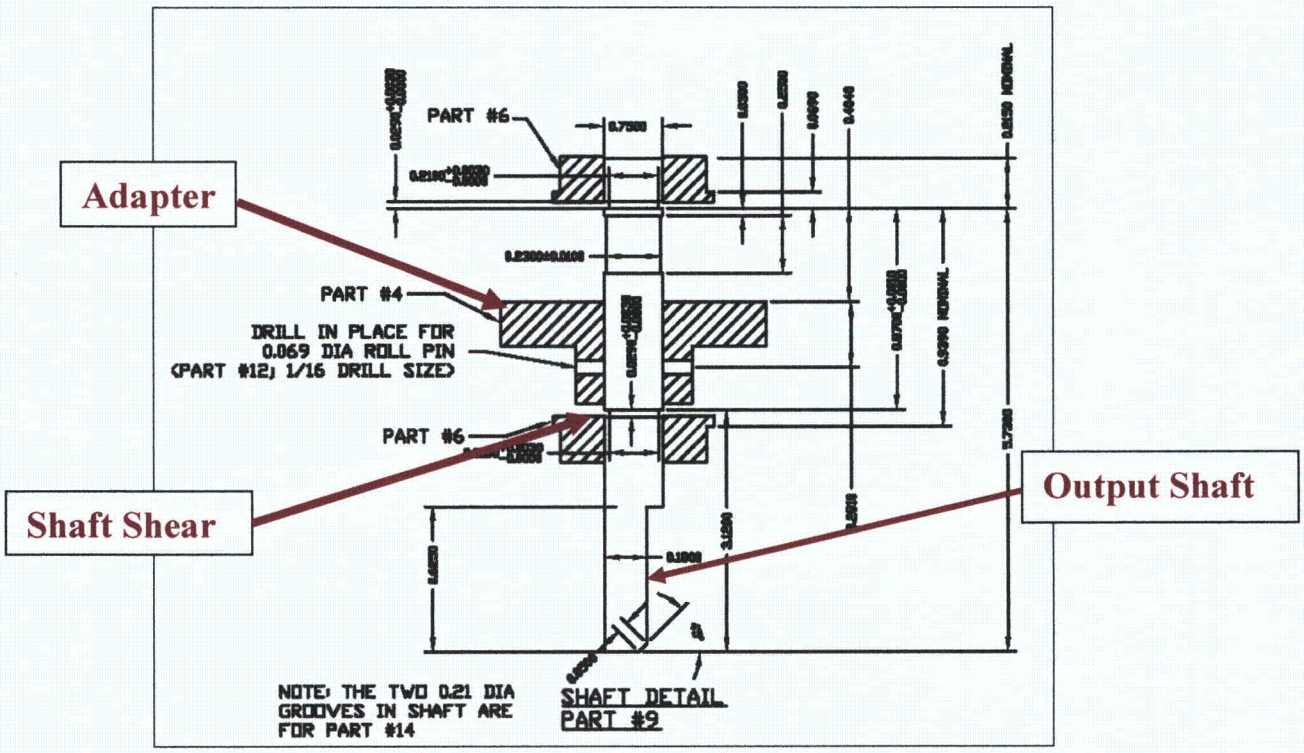
Ralph A. Butler, P.E.
Director

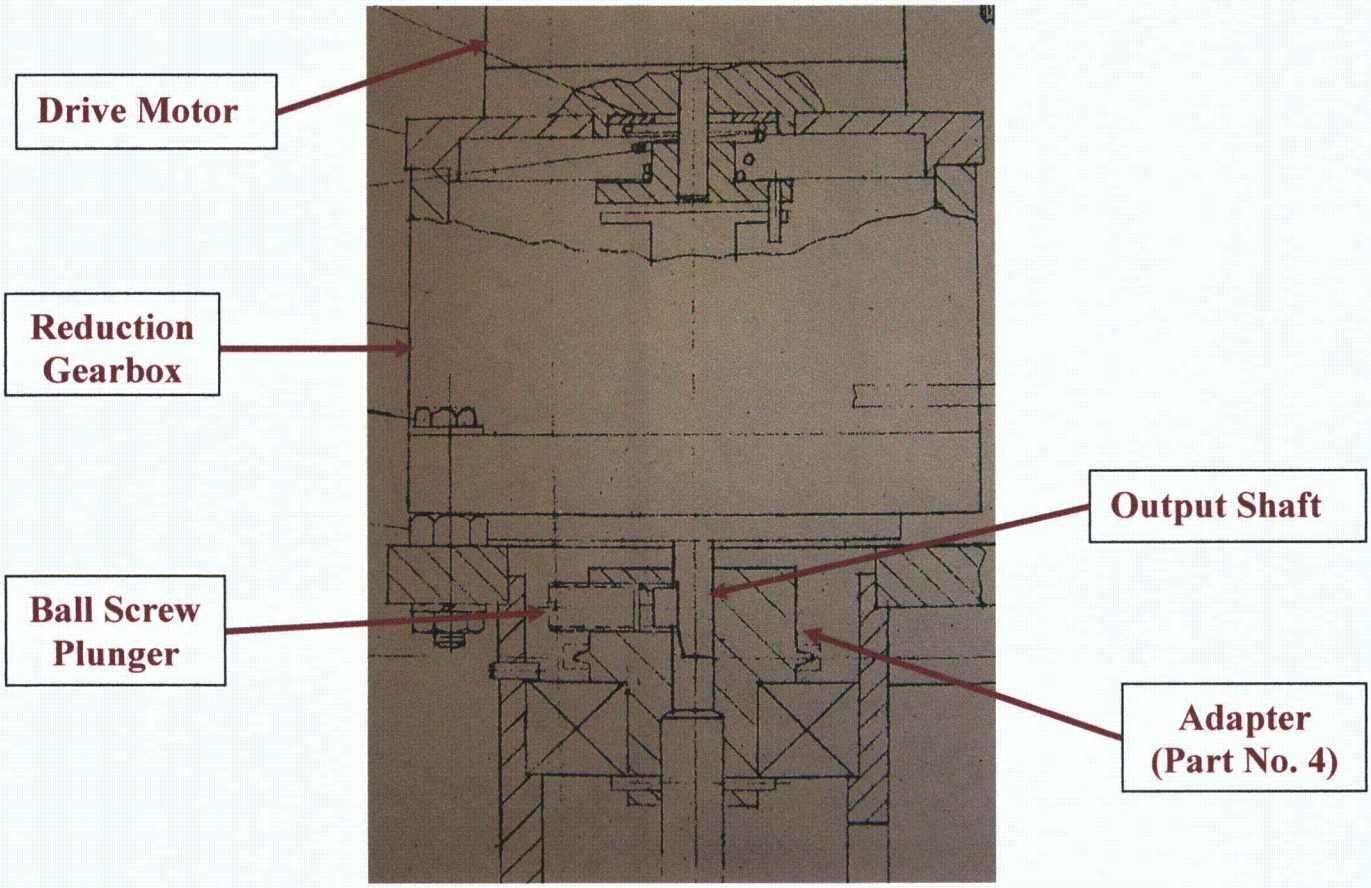
Signed before me, 9/30/14
Margee P. Stout

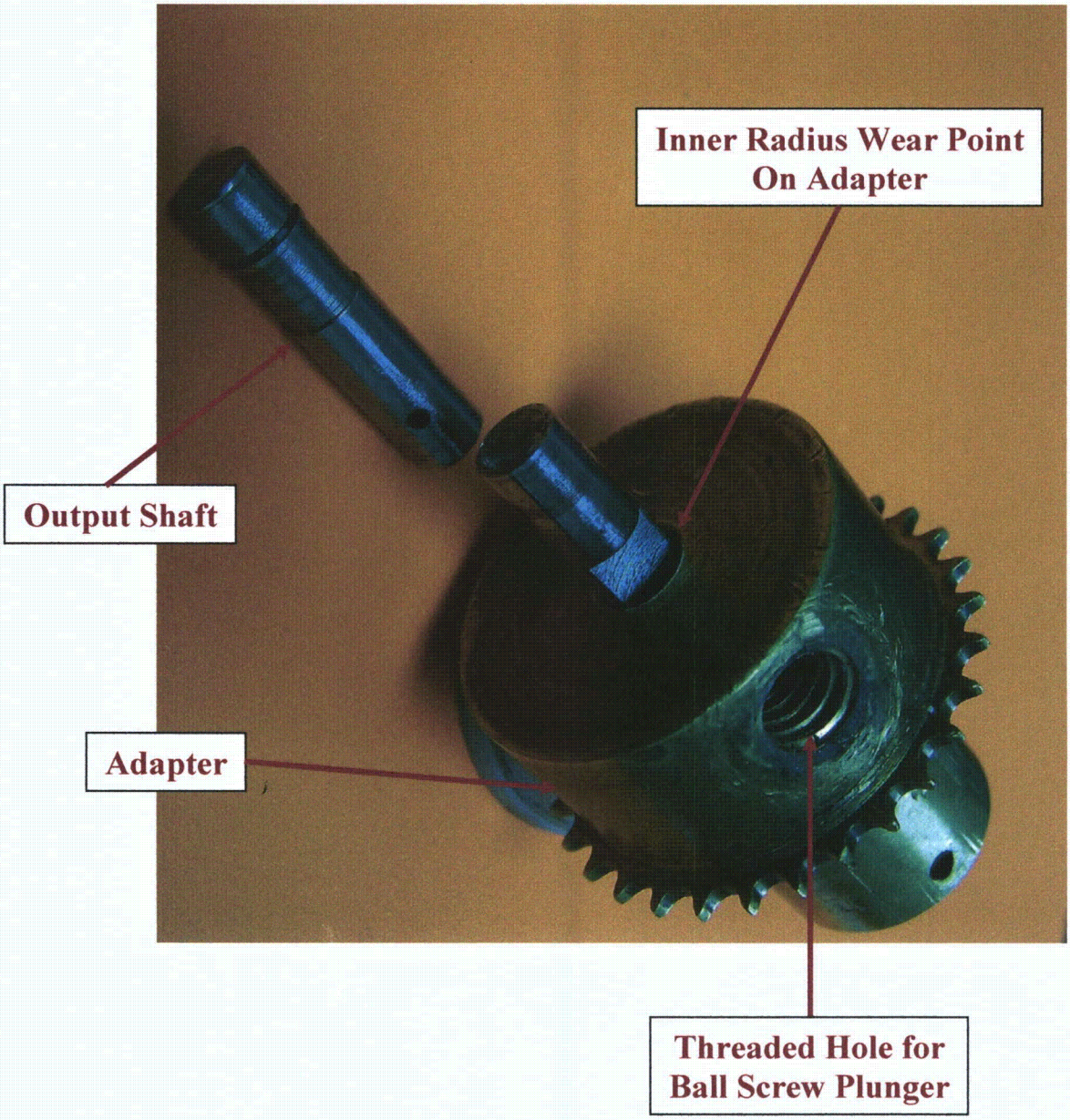
NOTARY PUBLIC
NOTARY SEAL
STATE OF MISSOURI

MARGEE P. STOUT
My Commission Expires
March 24, 2016
Montgomery County
Commission #12511436

Regulating Blade Gearbox






Inner Radius Wear Point
On Adapter
Output Shaft
Adapter
Threaded Hole for
Ball Screw Plunger