NUCLEAR REACTOR LABORATORY

AN INTERDEPARTMENTAL CENTER OF
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

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April 29, 1983

Mr. James M. Allan, Acting Administrator
Region 1
U.S. Nuclear Regulatory Commission

Attn: Mr. W. Kinney, Reactor Inspector
631 Park Avenue
King of Prussia, PA 19406

Subject: Reportable Occurrence 50-20/1983-1, License R-37
Failure of Ventilation Valve Actuator

Gentlemen:

Massachusetts Institute of Technology hereby submits the 10-day report of an occurrence at the MIT Research Reactor, in accordance with paragraph 7.13.2(d) of the Technical Specifications. An initial report of this occurrence was made by telephone to Region 1 on April 20, 1983.

The format of the following report is based on Regulatory Guide 1.16, Revision 1.

1. Report No: 50-20/1983-1

2a. Report Date: 29 April 1983

2b. Occurrence Date: 19 April 1983

3. Facility: MIT Nuclear Reactor Laboratory
138 Albany Street
Cambridge, MA 02139

4. Identification of Occurrence:

The penetrations for the ventilation system of the reactor containment building are sealed by the closing of two 30 inch hydraulically-actuated butterfly valves which form gas-tight seals with rubber gaskets. During a series of routine checks of containment isolation prior to a scheduled reactor startup the main intake valve was closed and could not be reopened. Inspection of the operating mechanism showed that the piston rod of the hydraulic cylinder on this valve had ruptured near its rod eye, leaving the valve in the closed position.

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5. Conditions Prior to Occurrence:

As is normally the case, the reactor had been shutdown for the previous weekend. The shutdown extended through Monday 18 April since that day was a holiday in Massachusetts. The failure occurred when the reactor was being prepared for startup in accordance with the standard full power startup checklists. The reactor was shut down at the time of the occurrence.

6. Description of the Occurrence:

A portion of the full power startup checklist requires that the four effluent monitors in the ventilation exhaust plenum be tested to assure that the ventilation isolation valves will close automatically in the event of abnormal amounts of airborne radioactive material in the effluent. The test consists of lowering the trip setting to the background level indicated by the monitor, acknowledging the alarm, checking that the valves both close, resetting the trip, and finally reopening the valves. Three out of the four plenum monitors had been tested successfully using the above procedure. The last monitor was tested and it was found that the ventilation valves closed successfully but one could not be reopened. The valve in question was the main intake damper. It had failed in the closed position. Investigation of the operating mechanism revealed that the 1-3/8" diameter piston rod of the valve's hydraulic cylinder had ruptured where its diameter reduces to 7/8". The fracture occurred approximately 1/4" from where it is threaded so that it can be connected to the rod eye. (See attached diagram.)

7. Description of Apparent Cause of Occurrence:

The failure occurred in the piston rod of a hydraulic cylinder manufactured by the Miller Fluid Power Division of Flick-Reedy Corp., Bensenville, Illinois. The failed cylinder was a Model H81B with the following nameplate data: bore 3-1/4", stroke 10", 3000 psi severe service, 5000 psi moderate service, serial no. 76163872. It had been installed new in September of 1976 and is estimated to have operated in the vicinity of 4000 complete cycles (i.e., extend plus retract.) Virtually all these cycles were for test purposes.

The piston rod is screwed into a rod eye which is in turn connected to the valve lever arm as shown in the attached diagram. The force from the hydraulic pressure is transmitted via the piston rod and the rod eye to the valve lever which rotates 90° from the OPEN position to the CLOSED position. The valve lever is attached to the shaft of the valve by means of a hub and a 1/2" key. The isolation valve is a steel butterfly valve with a diameter of thirty inches. It is five inches thick where it is attached to the shaft. A steel lever attached to the end of the shaft of the isolation valve operates two micro-switches which indicate the true position of the valve in the control room independently of the operating mechanism. A gas-tight seal

is formed by a rubber gasket which is held on by bolts along the perimeter edge of the butterfly valve. The actuating oil pressure is 1200 psi and the valve rotates from the fully open position to the fully closed position in less than a second.

The manufacturer's catalogue data show that the piston rod is made of steel with a yield strength of 90,000 to 110,000 psi. The piston rod is turned down from 1-3/8" diameter to 1" diameter at the end to allow for a 1"-14 thread. A distance of about 1/4" between the 1-3/8" main diameter and the 1" threaded diameter is undercut to a 7/8" diameter. A rod eye piece is pinned to the isolation valve lever arm and the threaded end of the piston rod is screwed into the rod eye. The rupture occurred at the transition from 1-3/8" to 7/8" diameter.

The immediate cause of failure was found to be an interference, which developed over time under normal usage, between the valve lever arm and the rod eye. Evidence of contact between the above two parts was found when disassembling the failed mechanism. The interference is believed to have been caused by the normal wear and tear of the valve gasket. The valve lever arm has to travel further to form a tight seal as the rubber gasket becomes worn. It is probably because of this extra throw which is required to close the damper tightly that the interference occurred. The damper is designed with gasket adjustment clamps which can be tightened to push a section of the rubber gasket out further from its channel to form a round tight seal. These gasket adjustment clamps can be adjusted to insure that sufficient clearance exists between the valve lever arm and the rod eye.

The rupture surfaces were examined under optical microscopes and two distinct zones were found. The central zone has a very coarse texture which is indicative of a very high strain rate rupture mechanism. The circumferential zone has a fine texture which indicates that it was caused by one of the fatigue failure mechanisms. Slight discoloration, but not heavy oxidation or corrosion, was also found in this zone. This observation shows that the surfaces had not been exposed to air for too long but nevertheless long enough to accumulate some initial oxidation which shows up as discoloration. In addition, the texture in this zone is not fine enough to be classified as high cycle fatigue. Low cycle fatigue is, therefore, the mechanism that is responsible for the surface in the circumferential zone. The transition from the circumferential zone to the central zone is abrupt and distinctive. Brittle rupture is the failure mechanism that formed the coarse texture in the central zone.

In conclusion, the interference between the valve lever arm and the rod eye produces a bending moment and a shear force in the piston rod. The transition of the rod diameter from 1-3/8" to 7/8" where the radius of curvature of the surface is the minimum, is where the stress concentration is at its maximum. The tensile stresses in the top half of the piston rod, which were a direct result of the bending moment induced by the interference, coupled with the shear stress initiated a micro-crack normal to

the surface of the rod at this transition point. The crack grew and propagated along the circumference of the rod due to the fatigue cyclic loadings. This circumferential fatigue zone continued to progagate toward the center of the rod until the strength of the rod had decreased to the point that the rupture stress was reached. The rod finally failed by brittle rupture and the central zone formed.

8. Analysis of the Occurrence:

The main ventilation isolation valves are backed up by auxiliary valves which will close automatically within ten seconds after a high radiation signal from any one of the plenum effluent monitors if the corresponding main isolation valve has failed to close. The auxiliary valves can also be operated manually at the valve location and remotely in the control room. Operability of the auxiliary valves is tested at least monthly and the delay time for automatic closing is measured at least annually. The automatic closing function of the auxiliary intake valve was tested shortly after the failure of the main intake valve and the interlock was found to function satisfactorily.

The main intake valve was failed in the closed position although whether the valve was sealed tightly enough to meet the containment leak rate requirement is not known. Given the redundant protection provided by the auxiliary isolation valves and the unlikely release of dangerous amounts of radioactive materials within the containment, the probability of a potential hazard to the general public from failure of an isolation valve in the manner experienced is extremely low.

9. Corrective Action:

The immediate corrective action was to replace the defective hydraulic cylinder's shaft, test its operation, and verify, using standard procedures, that the valve was sealing. (Note: Replacement of the cylinder's shaft did not affect the degree to which the valve sealed. A recently completed Containment Building Pressure Test had shown that leakage from the building, and hence from this valve, was well within specification.)

Once the failed mechanism had been studied, further corrective action was taken. This consisted of adjusting the gasket on the isolation valve, shortening the throw on the valve lever arm, and relieving the rod eye by 1/16" to insure sufficient clearance between the rod eye and the valve lever arm. Given that these repairs might have affected the degree to which the valve sealed, a pressure test was performed after the repair in order to verify the proper adjustment of the throw on the valve lever arm and the valve gasket. The test was conducted in accordance with previously established standard procedures. It showed that the leakage through the repaired valve was well within the specified limits. In addition, specific steps have been added to the standard maintenance procedures to check that the clearance between the rod eye and the valve lever arm is sufficient when the isolation valve is in the closed position.

10. Failure Data:

A similar failure occurred on 30 August 1976 and was reported as ROR 50-20/1976-4.

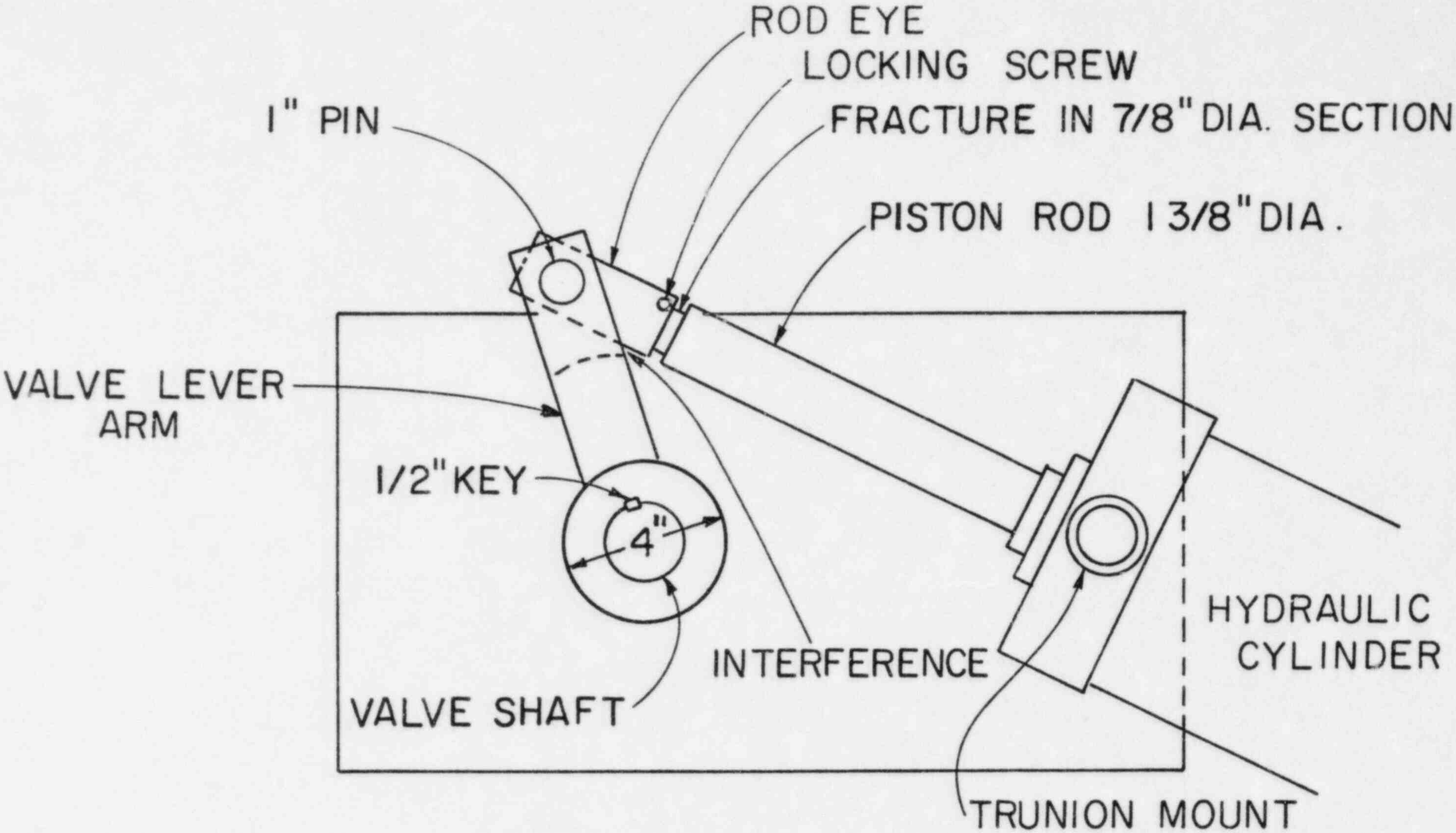
Sincerely,

Kwan Kwok
Assistant Superintendent

Lincoln Clark, Jr.
Director of Reactor Operations

KK/gw

xc: MITRSC
USNRC-OMIPC



ISOLATION VALVE ACTUATING MECHANISM