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March 4, 1988

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Director
Office of Enforcement
U.S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington D.C. 20555

Subject: University of Virginia Reactor Facility
Docket No. 50-62 and License No. R-66
Follow-up Report on Neutron Radiography Facility
Improvements Made following July 2, 1987 Incident

Gentlemen:

Please find enclosed a supplementary report on recent operational data taken and additional safety related improvements made in regards to the Neutron Radiography (NR) facility, which is operated in conjunction with the University of Virginia Reactor (UVAR). This report appears to be the definitive and final document sent to the NRC to close out the potential personnel overexposure incident of July 2, 1987. Also, this report sheds light on a second possible origin for that incident, The information provided could be of benefit to other non-power reactor licensees operating similar radiography facilities.

Sworn to and subscribed before me this 14th
day of March, 1988
Witness my hand and official seal.
Delores E. Van Notary Public

My Commission Expires 9/17/89.

Yours truly,

Robert U. Mulder, Director
U. Va. Reactor Facility

Brian G. Copcutt
U. Va. Rad. Safety Officer

Enclosure: Update on Neutron Radiography Facility

cc: U.S. NRC Region II Regional Administrator
Mr. Al Adams, U. Va. Project Manager, U.S. NRC, Wash. D.C.

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UPDATE ON UVA NEUTRON RADIOGRAPHY FACILITY

Introduction

The water shield in the north beamport nosepiece and associated drain/fill system have been closely monitored since July 2, 1987, when a partial drain of the shield was discovered and a potential for personnel overexposure created. Previous U.Va. Reactor Facility reports to the NRC listed inadvertent actuation of the drain/fill pump as the most likely cause of that event. The purpose of the close monitoring of the neutron radiography (NR) beamport fill status was to check for the possible existence of another mechanism for self-drainage. As a result of this vigilance, a second possible explanation for the July 2 event was discovered. However, it is now impossible to ascertain which of the two mechanisms was the true cause of the incident.

Construction on the NR facility was finished in the early fall of 1987. On November 9, 1987, a spontaneous slow small drain of water from the nosepiece to the reservoir tank was observed. At this time, the NR facility was available for routine use, but had not been operated in the preceding three weeks. Because of prior improvements made to the NR facility, and the adoption of detailed experimental methods, this partial drain did not result in a potential for accidental personnel overexposures, violations of procedures or of federal regulations, as on July 2, 1987.

The Reactor Director was notified and his personal lock was put on the NR blockhouse to prevent entry without his knowledge. Next, at his direction and with the assistance of the neutron radiography principal investigator, the reactor staff developed and reviewed written methods for a series of tests, to find out the mechanism for the second nosepiece self-drain. The findings are summarized below. Other minor details are recorded in memos to the Reactor Safety Committee.

New Facts

Information about the set-up of NR facility and the north beam tube nosepiece's fill/drain system were furnished to the NRC inspectors at the time of the July and August 1987 NRC inspections. A diagram of the drain/fill system as it was in November of 1987 is attached to this report, but reference may have to be made to prior reports, for a background to the July 2 event. In brief, draining of water from the north beamport's nosepiece is by way of the lower aluminum exit line which is connected to a clear rubber hose extending to the water and helium cover gas reservoir tank. This flexible hose passes through the drain/fill pump, which operates on the basis of a rolling mechanism. Depending on the position of the rollers, a drain path can exist when a perfect seal at the point at which the rollers pinch the flexible hose is not made. However, given that the reservoir is located at a level higher than that of the beamtube, it had previously been thought that a drain not involving the pump would in all cases be from the reservoir to the beamtube nosepiece, i.e. a "fail-safe" situation.

Nevertheless, a drain against gravity from the nosepiece to the reservoir was observed to develop in November, after the NR facility had not been operated for about three weeks. (It is interesting to note that this period corresponds approximately to the period that this facility was not operated prior to the July 2 event). As the pump had not been operated, it was conjectured that a driving force was working against gravity, to displace water out of the beamport nosepiece, by way of the lower line passing through the fill/drain pump and its rollers. Gas formation inside the nosepiece seemed the most likely reason, however, it was puzzling that degassing was not observed with the south beamport.

After careful consideration and planning, a valve located at the beamport nosepiece's lower exit line was closed. This permitted the observation of the drainage rate. In this new configuration, water could be displaced from the nosepiece to the reservoir only through the beamport's upper exit line. The attached schematic indicates that a second transparent TYGON hose links the beamport nosepiece's upper line with the reservoir tank. The amount of water displaced from the nosepiece was then measurable from the movement of the gas/liquid interface within the TYGON hose, until the moment when the interface reached the reservoir tank. The closing of the valve on the lower line clearly had no safety significance, for any expansion caused by gas in the beamtube nosepiece could be relieved to the reservoir tank.

In this fashion, it was determined that gas was indeed forming in the north beamport nosepiece at a rate of 3 ml/hr with the UVAR secured (not operating), and a rate of 30 ml/hr with the UVAR at 2 MW_{th}. Clearly, it appeared that gamma radiation from the UVAR, both at shutdown and at power, was associated with the phenomena.

Two possibilities were identified to explain gas formation in the nosepiece. (1) Radiolysis is known to occur when water is irradiated. The free radical intermediates H^+ and OH^- are produced, which in turn recombine to give the primary molecular products H_2, H_2O_2, and H_2O. After some time the H_2 gas concentration in a closed system stabilizes (saturation is reached), for H_2O is regenerated by recombination reactions. Appreciable quantities of oxygen gas are not produced with radiolysis, an important fact of safety significance. The literature suggests that the radiolysis rate is strongly affected by the impurities in the water. (2) Since helium is used as a cover gas in the reservoir tank and a displacement gas in the nosepiece, helium gas transfer between the reservoir and the beamport nosepiece, by dissolution and diffusion in the water in the lines linking the reservoir and the beamport, was also considered as a potential but likely insignificant source for gas formation. It was suggested that thermal gradients resulting in degassing within the nosepiece could account for a driving force.

The puzzle as to why gas formation was being observed in the north beamport nosepiece and not in the south beamport nosepiece was resolved with a water change of both beamports, made by reactor staff according to written and approved methods. When fresh demineralized pool water (at a pH of 6.4 and conductivity of 3.0 umho/cm) was inserted, the level of gas formation in the north beamport nosepiece was reduced. The remaining small displacement of water from the beamport nosepieces was observed to be largely a function of

water temperature (thermal expansion). The south and north beamports now behaved identically.

The approximately three week time lag between last nosepiece filling and the first observation of radiation in the NR blockhouse can also be explained. Frequent operation of the beamport results in complete nosepiece filling and transfer of gas in the nosepiece to the reservoir. Therefore, a period of non-use is required, for enough gas to form and to displace water for the effect to manifest itself.

Samples of the original water from both beamport nosepieces were taken and compared. The water from the north beamport, which had not been changed since 1982, had a pH of 6.0 and a conductivity of 25 umho/cm. The water from the south beamport had never been cycled, and its pH was 6.2 and conductivity was 10 umho/cm. It appears that cycling of water in the closed system increases the levels of dissolved solids, and consequently results in increased amounts of gas to be produced in radiolysis.

It was concluded that water in the north beamport nosepiece should be changed periodically, to avoid a repeat of the situation. An annual frequency has been adopted by the reactor staff, and its suitability will be determined from a close observation of the future beamport behavior.

Additional Measures

The installation of an area gamma radiation monitor inside the NR blockhouse was considered, to serve as a second indicator of "beamport open" status (in addition to the present sightglass indicators monitored by photosensors). Plans were made to hook the monitor into the NR blockhouse personnel access control system. It was hoped that this monitor could be installed in the NR blockhouse at a location off the neutron beam axis, and calibrated in this position to the mixed neutron and gamma field existing whenever the beamport is open. Details for the proposed installation, together with the appropriate 10 CFR 50.59 safety analysis and installation and testing procedures, were submitted to the Reactor Safety Committee (RSC) for review and approval. Meanwhile, until a final resolution of the new issues had been reached, the Reactor Director maintained personal control, by virtue of lock and key, over access to the interior of the NRF blockhouse.

At the time of installation of the area gamma radiation monitor in the NR blockhouse, it was determined that the neutron to gamma radiation field ratio depended on the amount of water shield present in the nosepiece, the variable scattering off of the experimental apparatus located in front of the beam, and the monitor's position relative to the tightly collimated neutron beam. It became evident that calibration of this monitor was simply impossible, and that its use, if attempted, would likely result in future NRC violation citations. The RSC was informed of this, and the attempt to install the area radiation monitor was aborted.

Not satisfied with this outcome, the reactor staff next considered the viability of placing a neutron sensor in the neutron beamtube's annulus.

Placed in this position, the sensor can function as a highly sensitive detector of a draining beamport nosepiece, and not be affected by experimental conditions in the blockhouse. An important feature of the neutron sensor idea is that its intended use did not require its calibration to a range of dose rates. In fact, given the non-linear response of the sensor, an available BF-3 tube, and its location within the beamport (no personnel access possible), this would not be reasonable. The experimenter's BF-3 counter, which was had formerly been employed to measure the presence of neutrons in the NR blockhouse, was no longer needed and could be removed. (Information about the radiation field inside the blockhouse is obtained with calibrated survey instruments, when needed.)

After a written method had been developed for a test of this idea, it was determined by experiment that a BF-3 tube placed within the beamport would indeed respond to neutrons with a high degree of sensitivity, and would alert workers of a draining beam long before a high radiation area in the blockhouse would be developed. This was checked with the simultaneous placement of gamma and neutron survey meters in front of the beamtube during remotely video monitored drainings, at which time a comparison of neutron count rates and total dose rates was done, to determine what could be considered a gross "one-point calibration" point, corresponding to a dose rate below that of a high radiation area, beyond which a reactor scram, warning light and audible alarm would be enabled.

Reactor Safety Committee approval was obtained for the neutron sensor proposal. The unit has now been installed, hooked into the reactor scram system, and tested. The BF-3 counter readout is made on a source range drawer commonly used in research reactor consoles.

An additional device was installed to further preclude unintentional drains. Since the drain/fill pump would permit leakage from the nosepiece to the reservoir by way of the lower line, whenever a tight seal was not made by the pump's rollers on the flexible rubber hose, approval was obtained for the installation in this line of a pneumatically operated ball valve. This valve is normally closed, and opens only when the pump is energized. With the additional safety features in place, the Reactor Director returned the neutron radiography facility to routine use.

Discussion

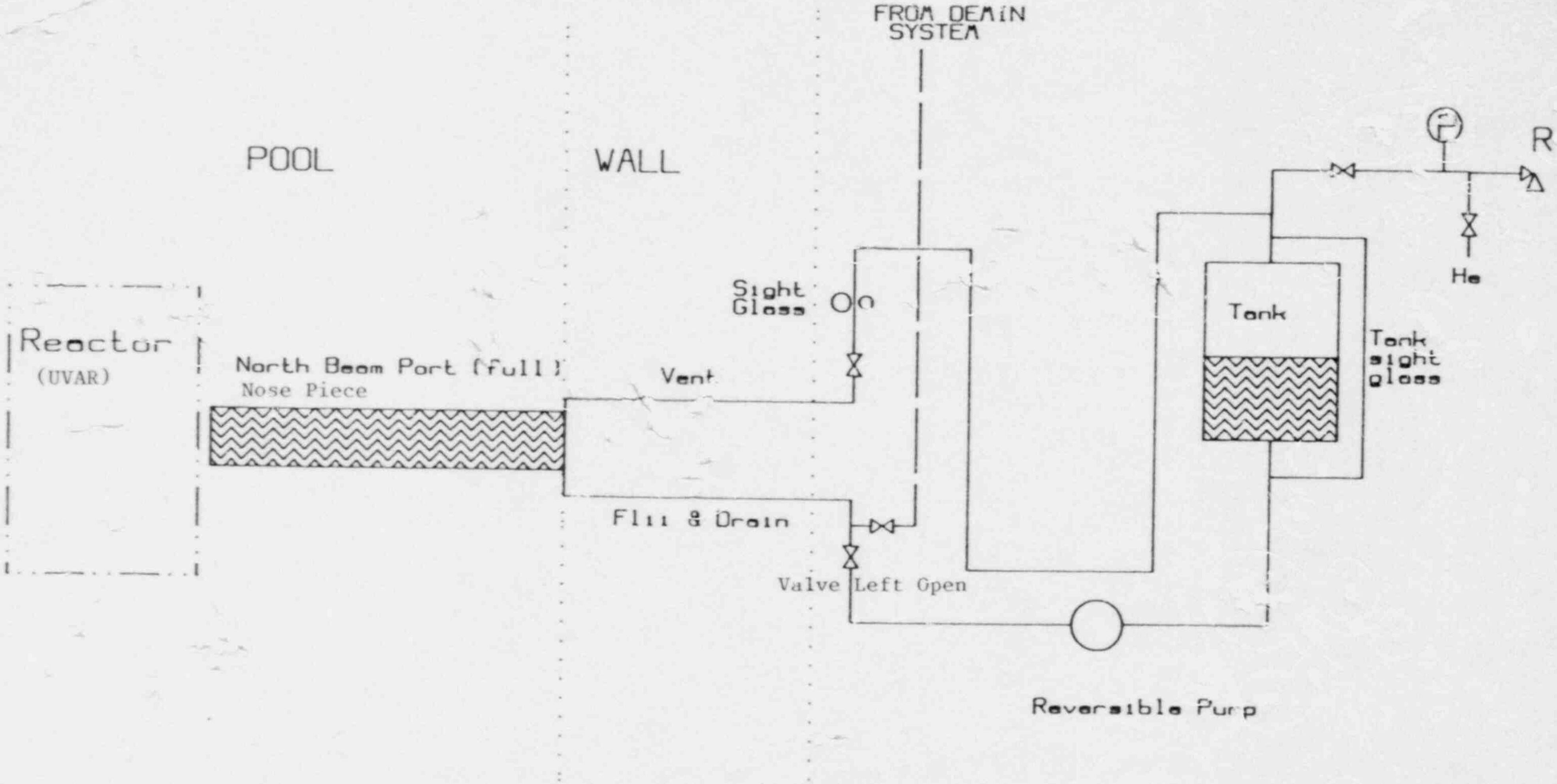
The verified displacement of water against gravity, from the beamport nosepiece to the reservoir tank, suggests a second possible explanation for the July 2 unanticipated partial drain, which has been assumed to have occurred due to an inadvertent actuation of the fill/drain pump. This second scenario is consistent with the state of the beamport during both occasions (not operated for about 3 weeks). Until there is sufficient displacement of water from the nosepiece, so that a single large gas bubble exists along upper part of the entire nosepiece barrel, little radiation exits through the beamport. After that point is reached, radiation levels can rise quickly.

Despite the new data, the circumstances for the July 2, 1987 partial drain can never be totally determined, and the inadvertent actuation of the drain/fill pump is not ruled out as a possible cause. In our recent response to the NRC, we indicated this to be the likely reason for the incident.

The Reactor Director has documented the new findings, maintained the RSC informed, and personally supervised the NR facility improvements. This (final) follow-up report to the NRC is sent now that all safety related measures taken for the NRF have been completed, and all outstanding issues have been resolved.

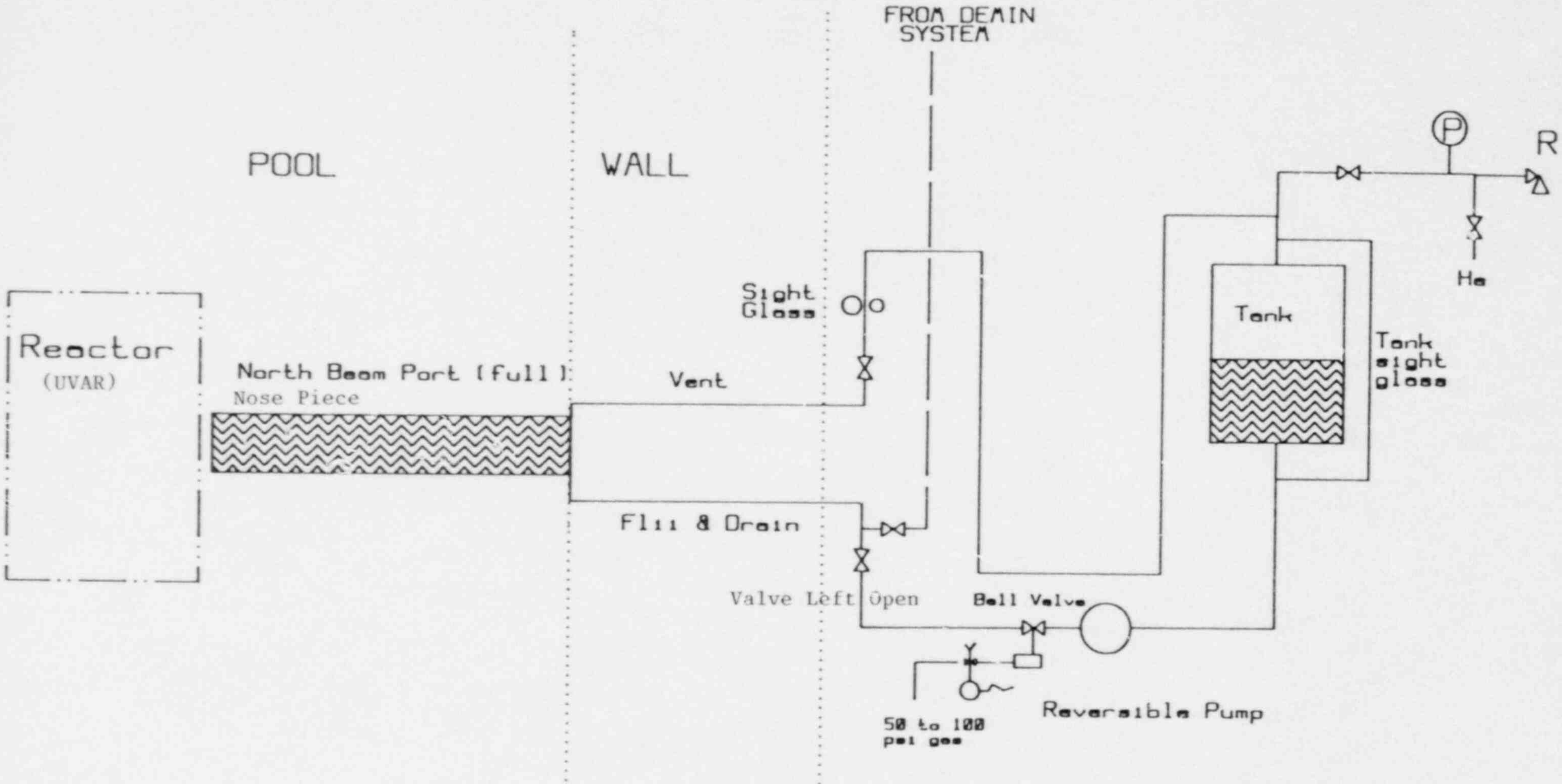
NOVEMBER 1987

NEUTRON RADIOGRAPHY WATER SHIELD FILL/DRAIN SYSTEM



February 1988

NEUTRON RADIOGRAPHY WATER SHIELD FILL/DRAIN SYSTEM



Update to show a addition of automatic BALL VALVE 2/23/88 BH