RECONFIGURATION OF THE NRAD DELAY LOOP FOR PROPOSED 1 MW OPERATIONS

by

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Argonne National Laboratory-West is located near Idaho Falls, Idaho, and is operated by the University of Chicago for the United States Department of Energy in support of the Liquid Metal Fast Breeder Reactor Program, LMFBR.

The Hot Fuel Examination Facility, HFEF, is one of several facilities located at the Argonne Site. HFEF comprises a large hot cell where both non-destructive and destructive examination of highly-irradiated reactor fuels are conducted in support of the LMFBR program. One of the non-destructive examination techniques utilized at HFEF is neutron radiography.

Neutron radiography is provided by the NRAD reactor facility, which is located beneath the HFEF hot cell. The NRAD reactor is a TRIGA reactor and is operated at a steady-state power level of 250 kw solely for neutron radiography and the development of radiography techniques.

When the NRAD facility was designed and constructed, an operating power level of 250 kw was considered to be adequate for obtaining radiographs of the type of specimens envisaged at that time. A typical radiograph required approximately a twenty-minute exposure time. Specimens were typically single fuel rods placed in an aluminum tray.

Since that time a second radiography station was installed and the thickness of the specimens being radiographed is greater than was initially envisaged. Radiography of subassemblies as thick as 12.5 inches is presently being planned. A typical exposure time for such a subassembly is 90 minutes. In order to decrease exposure times, the reactor power level is to be increased to 1 Mw.

Because the NRAD reactor tank is relatively small (6 feet 5.5 inches in diameter and 11 feet 5.5 inches in depth), internal delay loops on the primary cooling system and the demineralizer system were installed to allow for the decay of N\textsuperscript{16} prior to the primary water exiting the NRAD reactor room.

The present primary delay loop is a 12-inch diameter aluminum U-shaped pipe about 20 feet in length. This delay loop provides for a 54-second delay of the water, at 120 gpm, to allow for N\textsuperscript{16} decay (7.5 second half-life) from the time the water enters the delay loop until it reaches the pump suction. An additional delay of 20 seconds is provided by the transport time of the water exiting the core to the delay loop suction, assuming no action from the in-tank diffuser. An additional delay of 3 seconds due to the length of primary piping in the reactor room results in a total delay time of 77 seconds. This delay limits radiation levels to less than 1 MR/hr where the primary piping exits the reactor room.

If the present delay loop were to be used at 1 Mw operation, it would only provide for a 13.5 second delay of the water at 480 gpm primary flow. An additional delay of 11.1 seconds would be provided by the transport time of the water exiting the core to the delay loop suction and .75 seconds due to the length of primary piping in the reactor room. The total delay time would only be 25.4 seconds. The shorter delay and the increased flux in the reactor core would increase the specific activity of N\textsuperscript{16} leaving the
reactor room to approximately 300 times greater than it is at 250 kw operations. Because the passage way where the primary piping exits the reactor room is an unrestricted area, the radiation levels must be maintained less than 1 MR/hr. This would not be possible with the present delay loop.

To determine the amount of delay required to maintain less than 1 MR/hr at 1 Mw operation, it was first necessary to calculate the specific activity of N16 from oxygen in the primary cooling water:

\[ A_s = \phi \sigma O_2 N_{O_2} (1 - e^{-\lambda t}) \]

where:

- \( A_s \) = \( N^{16} \) dis/sec per cc
- \( \phi \) = Total flux = \( 1 \times 10^{13} \) n/cm\(^2\)-sec
- \( \sigma O_2 \) = Cross section \( O_2 \) (typical TRIGA reactor spectrum) = \( 2.1 \times 10^{-29} \) cm\(^2\)
- \( N_{O_2} \) = Number of \( O_2 \) atoms/cc = \( 3.3 \times 10^{22} \)
- \( \lambda \) = Decay constant = 0.0973/sec
- \( t \) = Time in core = 3.63 sec

Therefore, the specific activity \( (A_s) = 2.06 \times 10^6 \) dis/sec per cc of water at core outlet.

Previous calculations in the NRAD SAR showed that a specific activity of cooling water leaving the reactor room of \( 1.4 \times 10^2 \) dis/sec per cc of water would maintain the radiation levels in the passage way at less than 1 MR/hr.

By applying the above information, the delay necessary to maintain the radiation levels below 1 MR/hr in the passage was calculated by the following formula:

\[ A_s l = A_s \times F_C/F_t \times e^{-\lambda t} \]

where:

- \( A_s l \) = Specific activity of \( N^{16} \) of water leaving the reactor room = \( 1.4 \times 10^2 \) dis/sec per cc of water
- \( A_s \) = Specific activity of \( N^{16} \) of water at core outlet = \( 2.06 \times 10^6 \) dis/sec per cc of water
- \( F_C \) = Calculated average flow through the core at 1 MW = 110 gpm
- \( F_t \) = Primary flow rate into the reactor tank at 1 MW = 480 gpm
- \( \lambda \) = Decay constant for \( N^{16} \) = .0973/sec

Solving for "t" it was determined that a delay of 83.5 seconds is necessary to maintain radiation levels less than 1 MR/hr in the passage.

To obtain a delay of 83.5 seconds before the primary water exits the reactor room using the present internal delay loop system would require two more delay loops of the same size to be placed in series with the
present delay loop. Because the NRAD reactor tank is only 6 feet 5.5 inches in diameter, this is not possible; therefore, the delay must take place external to the reactor tank.

Because the NRAD reactor room is very small (11.5 feet by 12 feet in height), it cannot accommodate a delay loop or tank of sufficient size. The delay loop will have to be located in a shielded area to allow the decay of N16.

The best location for the delay tank will be in the east radiography cell. A baffled tank 2 feet deep, 6 feet wide and 7.5 feet in height could be located behind the specimen elevator in the radiography cell. A tank this size would provide a delay of 84.16 seconds and also provide an excellent beam stop for the east beam tube. Installation in this area could be accomplished easily without having to locate a shielded tank elsewhere. A delay of 11.1 seconds would be provided by the transport time of the water exiting the core to the primary pump suction line. An additional delay of 2.74 seconds would be provided due to the length of new primary piping from the reactor tank and through the radiography cell. The total delay time would be 98.0 seconds. This is 14.5 seconds greater than needed to maintain radiation levels less than 1 MR/hr in the passage.