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Safety Upgrades To The NRU Research Reactor

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The NRU (National Research Universal) Reactor is a 135 MW thermal research facility located at Chalk River Laboratories. AECL owns and operates the multi-purpose research reactor that serves as the primary R & D facility for supporting the CANDU business. The reactor is also a major producer of the world's medical radioisotopes.

Since NRU was started up in 1957, it has operated in a consistent and safe manner with an overall annual capacity factor of approximately 80 %. The demands on the operation to perform experiments and produce radioisotopes were increased significantly when the NRX (National Research Experimental) shut down in 1992. Radioisotope customers demand an uninterrupted supply of short-lived radioisotopes e g Molybdenum-99, while experimental researchers require frequent shutdowns to accommodate fuel and materials programs.

A two year systematic review and assessment of NRU to determine the condition and state of the facility was completed in 1991. This engineering assessment was complemented by safety analyses which focused on systems and components critical to safety. Reactor aging, obsolescence, current codes, and hazards vulnerability (especially, seismic) were emphasized during the analyses.

This initial assessment concluded that the overall condition of NRU was good and there was no undue risk to the public or environment with the present operation. In addition, seven major upgrades were identified to enhance reactor safety to satisfy modern standards. In 1992, the AECL executive approved the Upgrades Project.

Implementation of the seven upgrades were then included in the Facility Authorization document that defines the limiting conditions for safe operation with the Chalk River site license. The Atomic Energy Control Board would approve and license the upgrades under the change control provisions of the FA. Each upgrade and/or assessment recommendation (minor modification) had to be implemented without adversely affecting the current operation, had to demonstrate an enhancement in safety, and had to meet design and performance specifications.

The major safety upgrades include:

Qualified Emergency Response Center (QUERC)

The Qualified Emergency Response Centre (QUERC) is an all hazards qualified alternative location within the reactor building to monitor the safe shutdown of the reactor should the main control room become uninhabitable. It provides the necessary separation from Group 1 safety systems that are located in the main control room and Group 2 safety systems that are monitored from the QUERC.

The Group 2 safety systems include the implemented upgrades. Each group of safety systems is capable of shutting down the reactor safely. That is, the reactor core is adequately cooled and any release of fission products is confined. The benefit of having these two groups of safety systems is that common mode failures and interfacial connections do not restrict the safe shutdown of the reactor. (Figure 1)

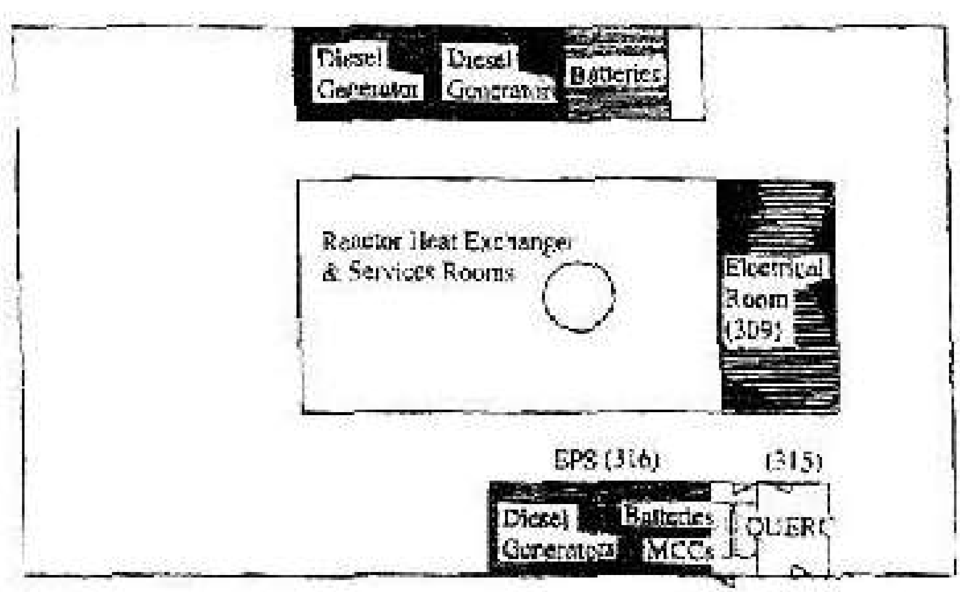

Figure 1 **QUERC Location**

Liquid Confinement Vented Confinement (LCVC)

The NRU reactor was designed with a well defined confinement boundary enclosing the reactor structure, primary circuit, and active drainage room. The LCVC upgrade establishes a confinement boundary that will prevent the uncontrolled release of radioactive material to the reactor hall and/or environment. In the event of an accident, these areas are exhausted through an Emergency Filtration Building where iodines and particulates are removed.

The LCVC improved the liquid drainage system, added over-pressure protection for high energy LOCAs (loop pipe failures), provided automatic 'box-up' controls (high sump level, radioactive release, and high pressure), improved boundary monitoring and access controls, and installation of new structural modifications. (Figures 2 and 3)

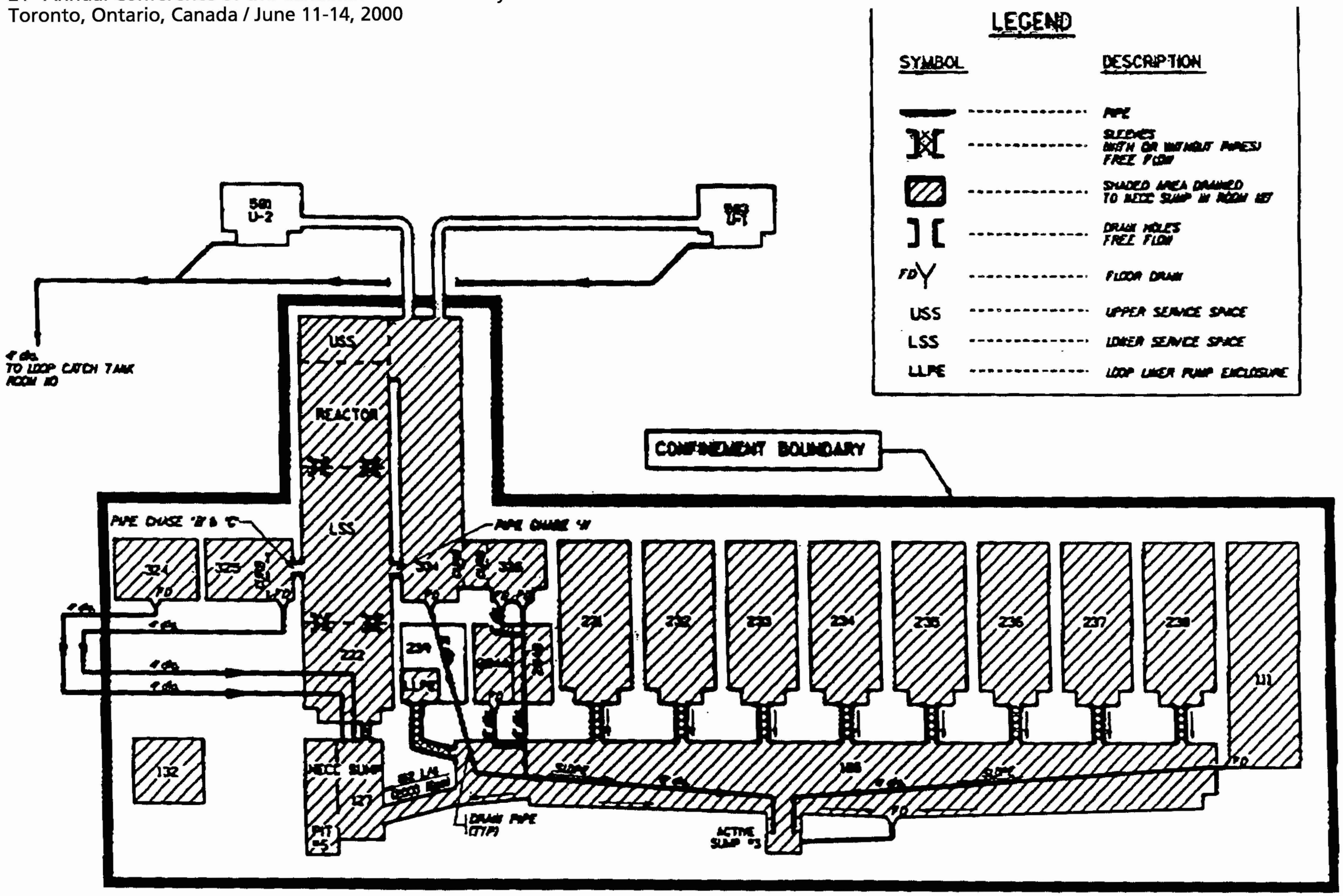

Figure 2 **Liquid Drainage**

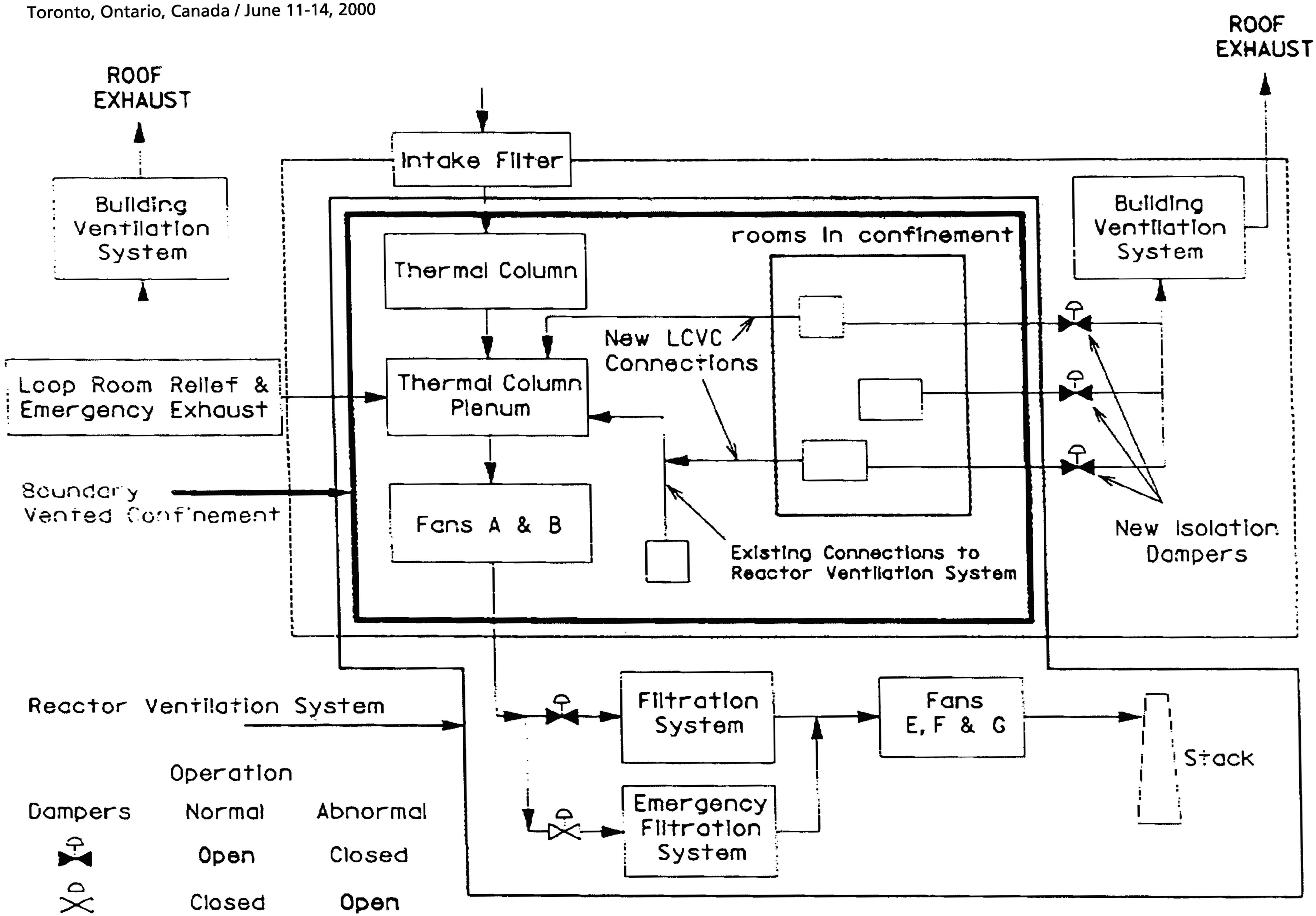

Figure 3 **Ventilation Diagram**

Second Trip System (STS)

The original NRU trip and shutdown system has operated successfully and reliably for more than 40 years. During the assessment phase of the Project, a decision was made to incorporate a set of new independent trips (set of trip chains) into the existing reactor shutdown system (rod release mechanism).

The STS provides an all hazards qualified independent shutdown system using four automatic trip parameters: high neutron power, high log rate of neutron power, loss of Class 4 power, and high ground motion vibration (seismic). The STS is independent of the First Trip System and reactor control system. Features of the STS include channel separation, and the ability to withstand adverse effects of extreme environmental conditions. (Figure 4)

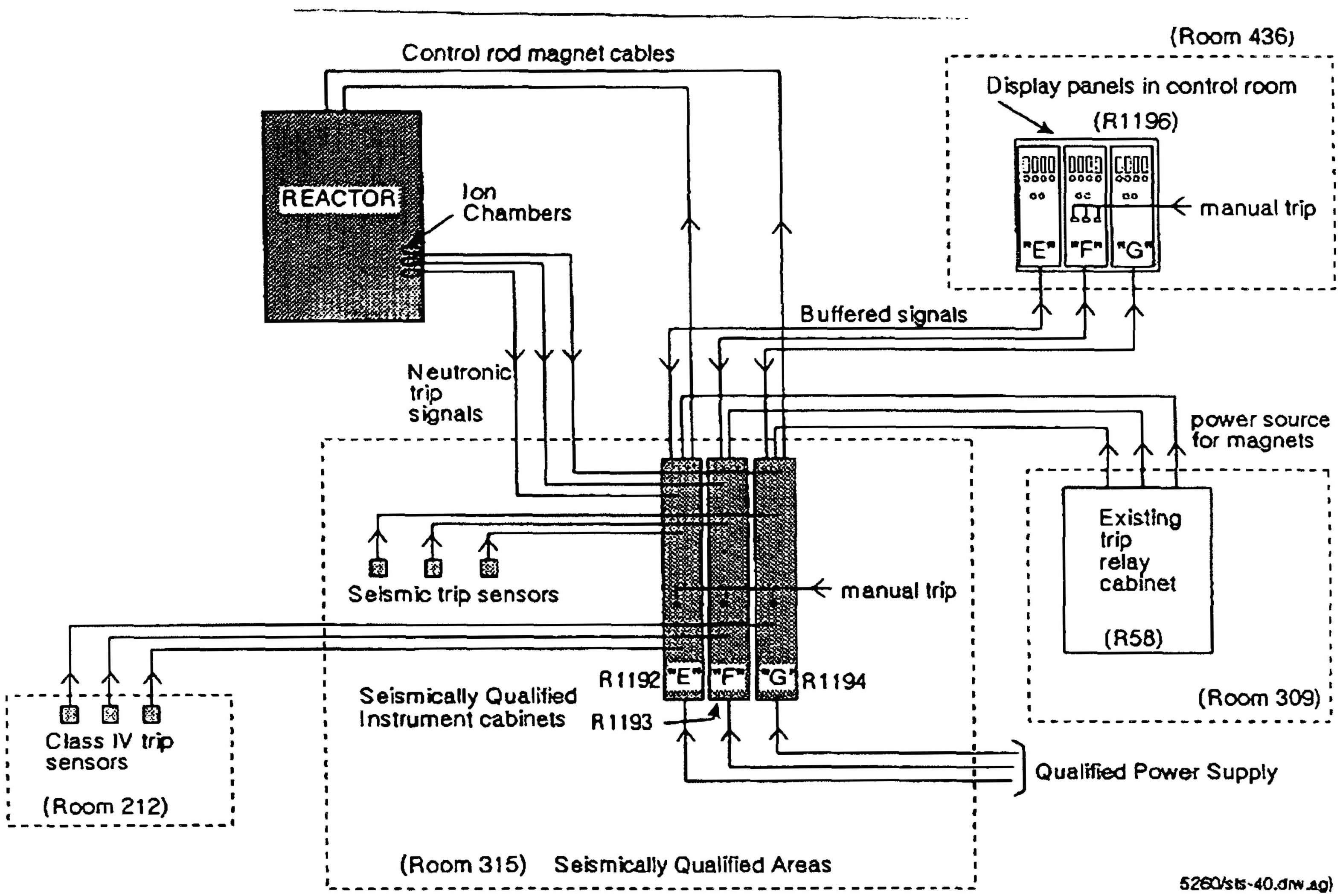

Figure 4 STS Panel Diagram

Main Pump Flood Protection (MPFP)

The MPFP upgrade enables the continued operation of the two emergency heavy water pumps in the event of a large process water leak. These two pumps are required to be operated for core cooling.

The main feature of this upgrade is a passive, seismically qualified means for draining floodwaters from the NRU building. Drainage openings in the basement walls provide a drainage path that leads to an external basin. From this basin, a seismically qualified line is installed that connects to an existing effluent line that is also seismically qualified. (Figure 5)

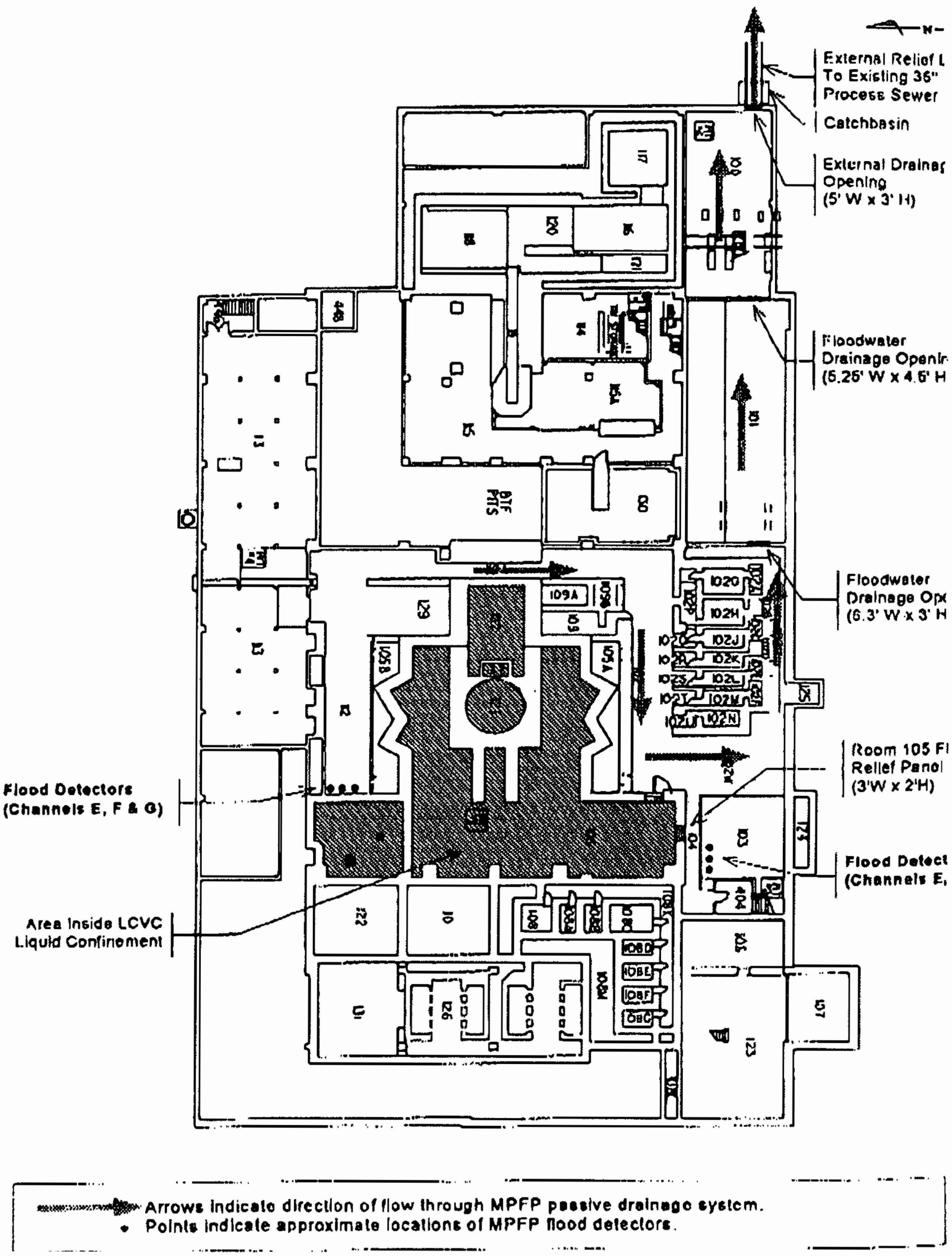

Figure 5 MPFP Drainage Flowpaths in NRU 3rd Basement

Another feature of MPFP is a system of float switches and interlocks to trip the reactor and shut down the process water pumps in the Power House. Secondary cooling to the main heavy water heat exchangers would be provided by the Qualified Emergency Water Supply upgrade. (Figure 6)

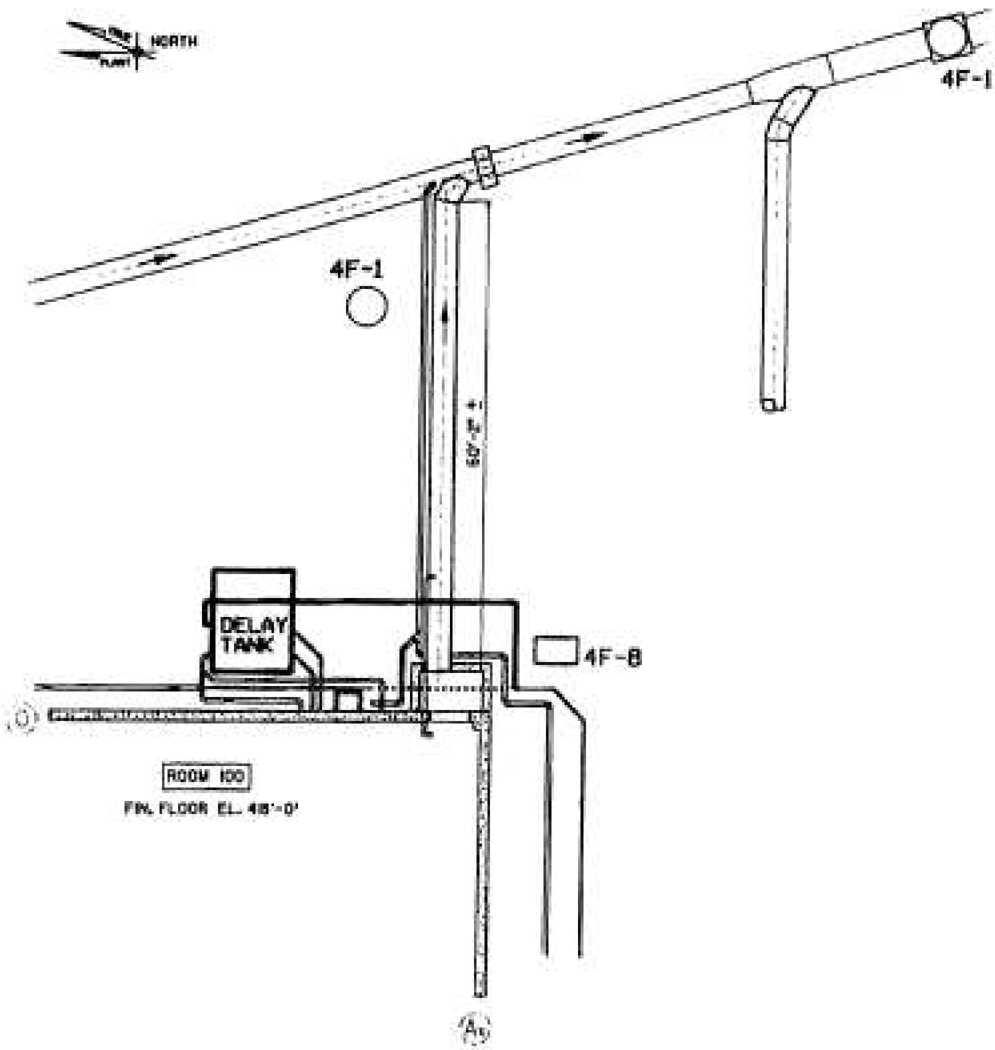

Figure 6 **MPFP External Drainage Plan**

Qualified Emergency Water Supply (QEWS)

NRU is cooled by heavy water circulated by the main heavy water pumps. The heavy water is cooled in heat exchangers which use process water as the heat sink. In a loss of heat sink accident, the reactor would trip on high heavy water temperature but decay heat from the fuel is still being produced. This waste heat must be removed from the coolant to maintain core cooling. The existing process water and emergency process water cooling supplies are not hazards qualified.

The QEWS is a manual system that provides a seismically qualified source of cooling to the secondary side of the main heat exchangers 4 and 5 (heat sink). Two circuits, each incorporating a pump and valve, recirculate cooling water supplied from a reservoir in Room 122. (Figure 7)

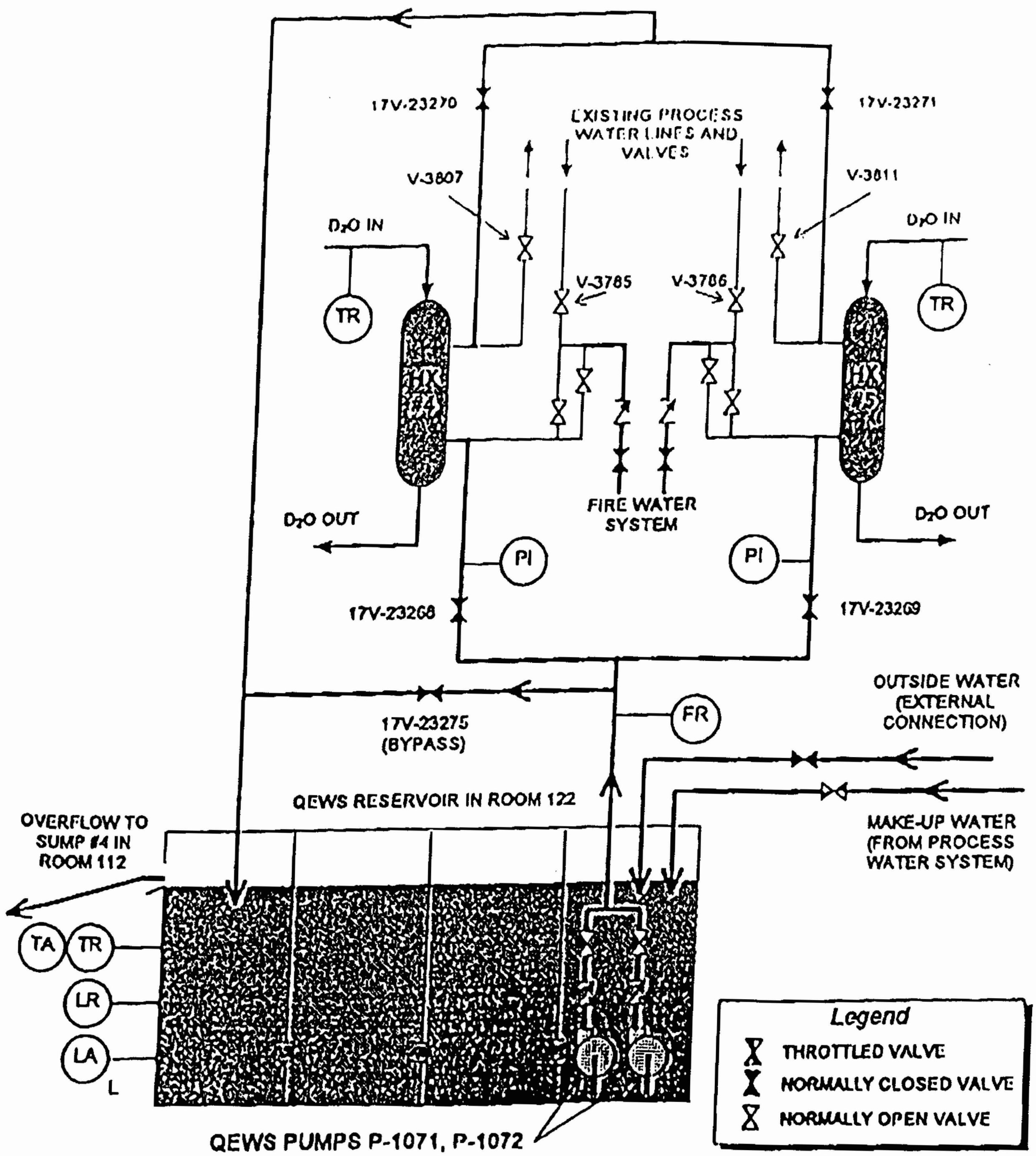

Figure 7 Simplified QEWS Flowsheet

New Emergency Core Cooling (NECC)

The existing emergency cooling system is an open loop system that provides cooling of reactor fuel for as long as the heavy water level in the vessel can be maintained at 2 feet. When this level can not be maintained, emergency process river water is supplied to the suction side of Main Heavy Water Pumps 4 and 5. The existing system is not hazards qualified.

The new emergency core cooling system provides guaranteed long term reactor core cooling in a loss of coolant accident. This fully automated system utilizes new qualified power supplies and improved drainage and leak collection provision (LCVC). Two identical piping circuits, seismically qualified, each incorporating a pump and injection valve, recirculate cooling water from the NECC sump back into the primary coolant circuits. All the existing heavy water piping has been inspected and seismically qualified to the DBE. (Figure 8)

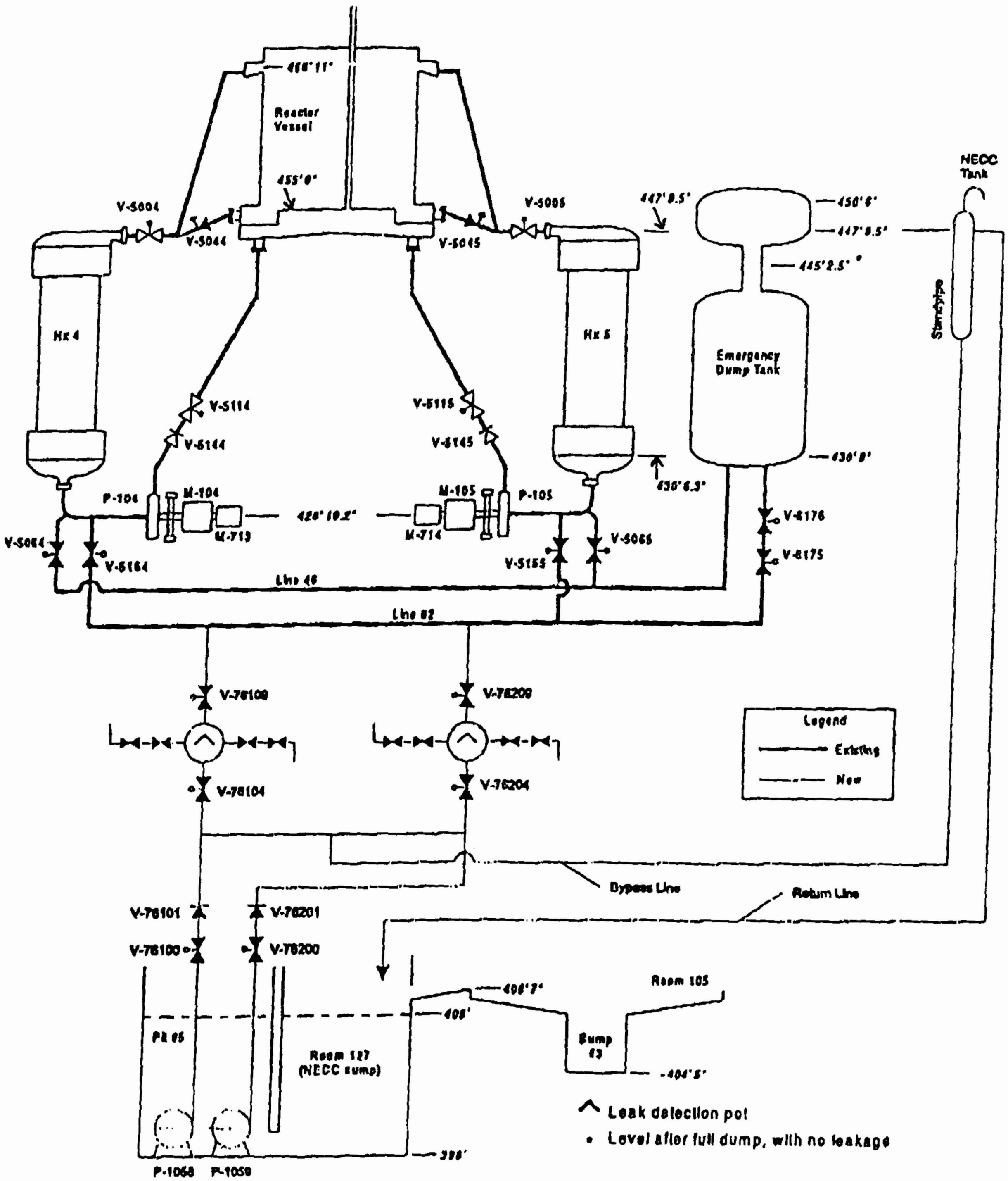

Figure 8 Simplified NECC Flowsheet

Emergency Power Supply (EPS)

The emergency power supply is an all hazards qualified system to provide continuity of electrical power in the event of Class 4 (OPG grid) power failures. EPS includes Class 2 and Class 3 power for the safety upgrades (except for LCVC) and Class 1 power for MHWPs P-104 and
P-105. The EPS will support the operation of core cooling and other upgrades following seismic events. The separation of the two electrical distribution systems of the EPS provides improved protection against all hazardous events.

The assignment of loads to the EPS is based on the division of safety related systems into Groups 1 and 2. Group 1 includes existing systems as the First Trip System. Group 2 includes all of the upgrades except LCVC. To maintain separation between the groups, all of the Group 2 systems are powered by EPS, including the LCVC panel in the QUERC. (Figure 9)

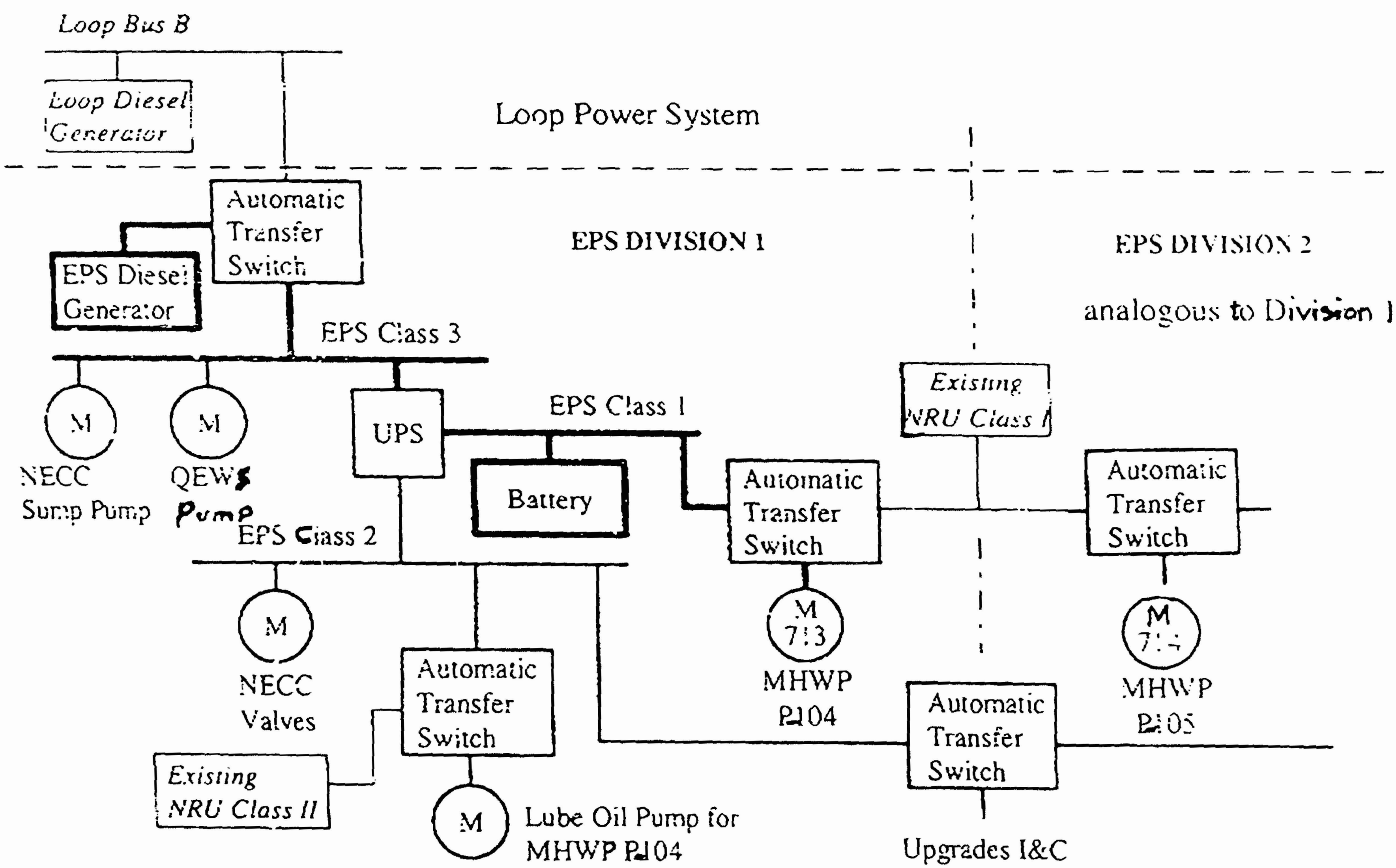

Figure 9 **EPS Functional Block Diagram**

Conclusions

These upgrades provide a net improvement in safety and have no adverse effects on the current operation. Design, procurement, installation, and commissioning of the new upgrades is being done to current Canadian nuclear quality assurance standards. The strong team environment and cooperation between the Upgrades and Operations resulted in practical and effective engineering designs. In some cases, the upgrades have facilitated the site in obtaining Certificates of Authorization eg N285 C of A for ASME Section III Class 3. In addition, new technologies and equipment are introduced to maximize safety and operational efficiency.

The QUERC, LCVC, STS, and MPFP upgrades have implemented and declared in service. Progress in continuing on in the QEWS, NECC, and EPS upgrades all of which must be completed in Y2000 to satisfy the site license. Implementation of these upgrades will significantly enhance the safety capability of NRU to guarantee operation until 2005 December.