A PORTABLE BACKUP POWER SUPPLY TO ASSURE EXTENDED DECAY HEAT REMOVAL DURING NATURAL PHENOMENA-INDUCED STATION BLACKOUT

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ABSTRACT

The High Flux Isotope Reactor (HFIR) is a light water cooled and moderated flux-trap type research reactor located at Oak Ridge National Laboratory (ORNL). Coolant circulation following reactor shutdown is provided by the primary coolant pumps. DC-powered pony motors drive these pumps at a reduced flow rate following shutdown of the normal ac-powered motors. Forced circulation decay heat removal is required for several hours to preclude core damage following shutdown. Recent analyses identified a potential vulnerability due to a natural phenomena-induced station blackout. Neither the offsite power supply nor the onsite emergency diesel generators are designed to withstand the effects of seismic events or tornadoes. It could not be assured that the capacity of the dedicated batteries provided as a backup power supply for the primary coolant pump pony motors is adequate to provide forced circulation cooling for the required time following such events. A portable backup power supply added to the plant to address this potential vulnerability is described.

PLANT DESCRIPTION

The High Flux Isotope Reactor is a light water cooled and moderated flux-trap type research reactor located at Oak Ridge National Laboratory on the DOE Oak Ridge Reservation. The reactor, rated at 85 megawatts (MW), was originally designed as part of the overall program to produce trans-uranic isotopes for use in heavy-element research.

The reactor is housed in a reinforced concrete confinement building. Within the building, the reactor vessel is located in a pool containing approximately 85,000 gallons of water. The reactor cooling system, shown schematically in Figure 1, includes four pump-heat exchanger loops (three in operation, one in standby) which circulate coolant through the core and reject heat to the secondary cooling system during reactor operation. The secondary cooling system transfers heat to the atmosphere by way of the induced draft cooling tower located near the reactor confinement.

Reactor coolant enters the reactor vessel through two pipes near the top of the vessel and after passing through the core exits via a pipe near the bottom of the vessel. Nominal primary coolant flow rate is 16,000 gallons per minute (gpm) with a core inlet temperature of 120 degrees Fahrenheit (F) and an outlet temperature of 155 F. The water-solid system is maintained at an operating pressure of 468 pounds per square inch (psig) by one of two centrifugal pressurizer pumps and a system of letdown valves.

Decay heat removal following reactor shutdown is normally accomplished by driving the primary cooling pumps with large AC motors. If AC power is not available, the primary pumps can be operated at a reduced flow until the level of

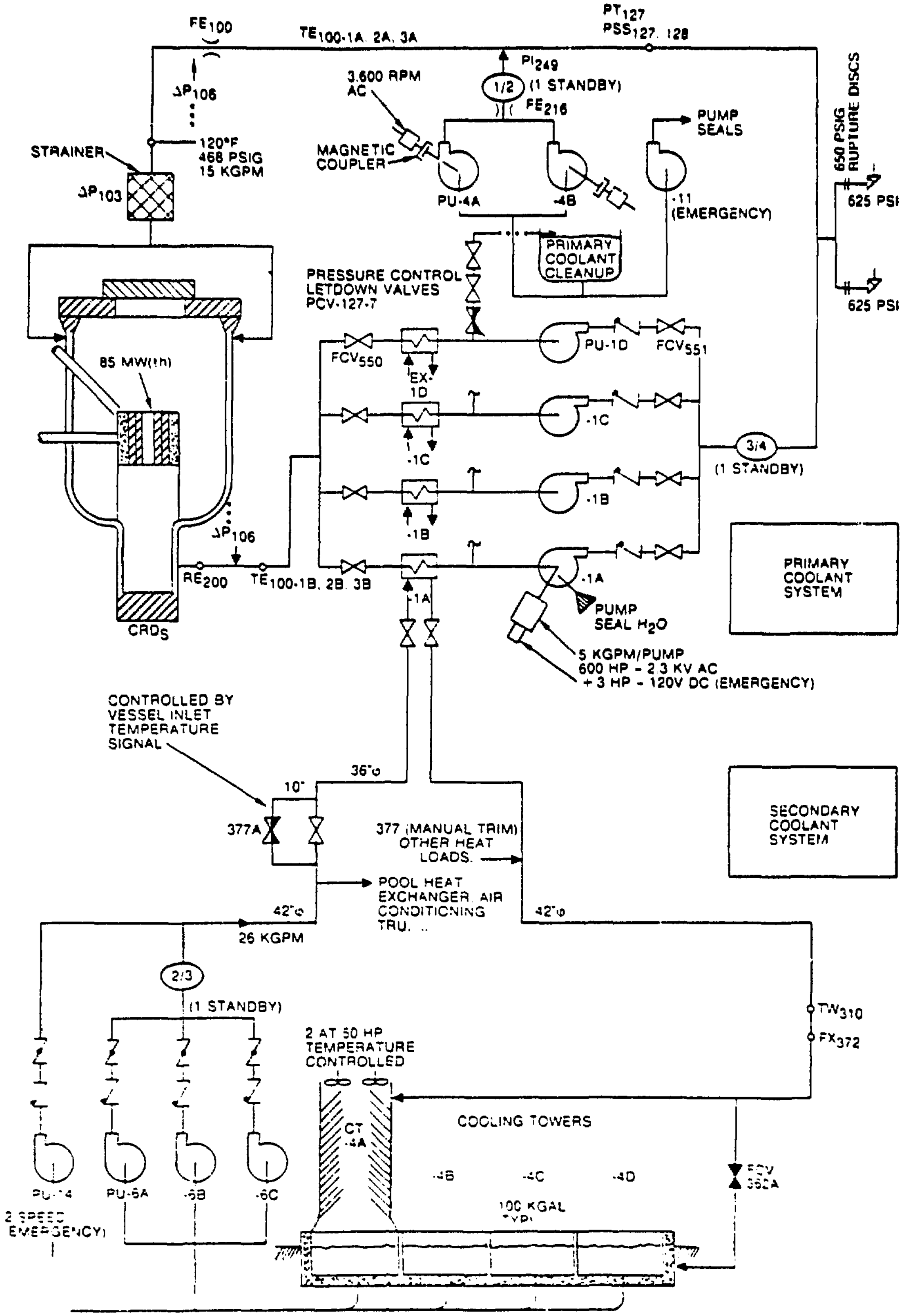

FIGURE 1. SIMPLIFIED HFIR PROCESS FLOW DIAGRAM

decay heat is such that natural circulation in the reactor and convective heat transfer to the pool can remove the heat generated. An auxiliary DC motor called a "pony motor" is coupled to the main motor shaft of each primary coolant pump to accomplish this reduced flow decay heat removal. One pony motor driven pump is sufficient to remove the decay heat; although three are normally in operation during shutdown conditions. The secondary cooling system is not required during this time.

THE NEED FOR EXTENDED DECAY HEAT REMOVAL

During the recent shutdown of the HFIR, it was considered prudent to re-examine various analyses upon which the plant Safety Analysis is based. The early analyses indicated that transition from forced circulation to natural circulation cooling could be accomplished when decay heat reached 1 MW. However a review of these analyses resulted in a concern that the time necessary to reach the transition point may be longer than that originally estimated in the Accident Analysis. Therefore, an extensive analytical effort was initiated to determine the time period in which forced circulation would be required. The analytical approach used in the effort was application of a power reactor thermal analysis code, RELAP5, modified to represent the HFIR conditions. Best-estimate calculations using this approach indicated that forced circulation would be necessary for 2 to 4 hours following reactor shutdown from the rated 85 MW power level. However, because of uncertainties in the analysis models, input parameters, and correlations, the calculated time could not be conservatively bounded without experimental validation. Development of such experimental data would be time consuming and difficult to accomplish in the near term.

The pony motors on the primary coolant pumps are normally powered through inverters from the offsite ac power supply, with backup from the onsite emergency diesel generators. Dedicated batteries are also provided in the event both offsite and onsite ac power are lost. The dedicated batteries have been shown to be able to supply adequate power to run the pony motors (and thus provide forced circulation) for a period of 6 to 7 hours. With proper operator actions to stage the number of operating pumps, this can be extended to a minimum of 12 hours.

For any accident in which offsite power is available or in which the onsite emergency diesel generators are available, it can be assured that forced primary coolant circulation would be provided for as long as is necessary. However, for events in which these sources of power are not available, power for the pony motors must be provided from the dedicated batteries. The design of the offsite power feeders and the onsite emergency diesel generators is not adequate to assure that they would survive extreme natural phenomena such as tornadoes or earthquakes. Thus, it is likely that it would be necessary to rely on the dedicated batteries to power the pony motors for such events. This type of event is analogous to an extended "station blackout" condition recently addressed by the Nuclear Regulatory Commission.

Due to the uncertainty in the decay heat calculations and the uncertainty associated with restoration of offsite power or repair of the onsite emergency power supply, it could not be established that the capacity of the dedicated batteries would be sufficient to provide forced circulation for the required time. Failure to provide the necessary forced circulation could lead to core damage in the reactor. Although this would not be expected based on the best-estimate calculations, it was determined that it would be appropriate to undertake additional measures to assure that adequate decay heat removal would be provided for the unlikely event of an extended station blackout.

OPTIONS CONSIDERED

Various options were considered in developing a plan to address this potential vulnerability. The first option investigated was the possibility of procuring larger capacity batteries. It was determined that the space requirements for replacement batteries were larger than the space available. In addition, due to the uncertainty associated with the decay heat calculations, it was not certain what battery capacity would be adequate. This option was not pursued further.

The feasability of removing the top hatch from the reactor after an appropriate time was investigated. This would allow establishment of a natural convective flow from the reactor to the pool. However, it was determined that the weight of the hatch is greater than the capacity of the manual bridge crane. Of course, power for the overhead crane would not be available in such situations. Therefore this option was discarded.

A variation of this option was also considered. The possibility of removing the hatch over the target area was considered. It was determined that it could not be assured that adequate flow area would be available unless the target tower was also removed. Removal of the target tower requires the overhead crane; thus, this option was also dismissed.

The cost of upgrading the emergency diesel generators and associated equipment was also investigated. This option would have essentially required complete replacement of the current equipment and structures. Therefore this course of action was considered to be too expensive.

The final option considered and the option chosen was to procure an auxiliary power source to provide forced primary coolant circulation via the pony motors. This was to be accomplished by a set of portable diesel generators. These would be stored near the site such that they would be accessible in the unlikely event that both offsite and onsite ac power were lost for an extended time. The siting criteria for the units was to include a requirement that the units would have a high probability of surviving severe natural phenomena, such as earthquakes or tornadoes. The units would be moved to the site and connected to the pony motor circuits. The system was designated the Auxiliary Emergency Power Generator System (AEPGS).

DESCRIPTION OF AUXILIARY EMERGENCY POWER GENERATOR SYSTEM

The AEPGS consists of two mobile, redundant diesel generator units each capable of meeting the power requirements of the four pony motor battery chargers and associated equipment during station blackout conditions. Each portable generator has a 50-kW continuous duty rating to assure that adequate power is provided. Each unit is capable of being positioned and manually connected to the existing pony motor electrical supply system in less than six hours.

During a station blackout condition, one of the two portable generators will be positioned near the pony motor battery room. Five 300-foot long trail cables supply power from the AEPGS to the four pony motor battery chargers and the battery room exhaust fan as required. Each generator is equipped with a 50-gallon fuel tank which provides approximately 15 hours of operation. Portable, flexible, 100-foot long fuel lines are also included and can be connected to the existing, seismically qualified 4,000-gallon underground diesel fuel tank to provide an extended fuel supply for up to 49 days of operation. The only change to the existing facility was the addition of quick connect/disconnect fittings and a check valve to the existing 4,000-gallon diesel fuel tank supply and return lines and modification of the electrical supply for the battery room exhaust fan to allow operation from the AEPGS.

One of the two AEPGS generators is stored outside at the Molten Salt Reactor

(MSR) site approximately 1,700 feet north of the HFIR. The second generator is stored at the ORNL main complex, approximately 5,000 feet east-northeast of the MSR and 6,500 feet northeast of the HFIR. Both generators are secured to the ground with quick release cables to keep them from turning over during a severe wind storm. Power has been provided at the storage locations for battery chargers and water jacket heaters on the AEPGS units to maintain operational readiness.

Analyses were completed by EQE [1], under contract to ORNL, to evaluate the vulnerability of the AEPGS to seismic events and tornadoes. The approach taken was to combine deterministic analyses, field evaluations, probabilistic analyses, and application of EQE's earthquake experience data base. The evaluation concluded that the system is capable of surviving the 0.15 g HFIR evaluation earthquake and that the probability of concurrent damage to all emergency power sources due to the 150 mph evaluation tornado is acceptably small, approximately 2 E-6 per year.

BASES FOR CHOOSING THIS OPTION

The selection of a portable auxiliary power supply was based on considerations of practicality, cost, and industry precedent. All major components in the system are commercial grade items and are thus readily available. A minimum amount of modification to the portable diesel generator units was required to provide the connections necessary for mating the system with the existing electrical supply for the pony motors. Similarly, only minor modifications were required in existing equipment and structures to accommodate the addition of the AEPGS. From a cost-benefit standpoint, this made the option an attractive alternative. Use of commercial grade components avoided the extra cost of procuring "nuclear qualified" components. The cost of additional major modifications to existing equipment and structures was also avoided. Finally, if subsequent experimental data are developed to demonstrate that the transition from forced circulation to natural circulation cooling can be accomplished within the 6-hour capacity of the dedicated batteries, use of the portable, AEPGS can be discontinued without significant economic penalty.

The consideration of industry precedent took the form of a review of guidance from the Nuclear Regulatory Commission regarding design requirements for station blackout and onsite power supplies. Documents reviewed included guidance in the Standard Review Plan for Safety Analysis Reports [2] and Regulatory Guide 1.155 [3]. In particular, it was noted that guidance in Regulatory Guide 1.155 allows an alternate AC power supply in the form of commercial grade, portable diesel generator units. The AEPGS conceptual design was compared to the guidance in the Regulatory Guide and the Standard Review Plan and found to meet or exceed all requirements [4].

BENEFIT RESULTING FROM THE AEPGS

A Probabilistic Risk Assessment of the HFIR had been completed for ORNL by Pickard, Lowe, and Garrick (PLG) [5]. However, the study was issued prior to the determination that the time required for forced circulation may have been underestimated in the Safety Analysis. Therefore, the effect of the AEPGS was not included in that study. To estimate the reduction in core damage frequency attributable to the AEPGS, the system was evaluated by PLG for three event severities [6]. Effects of component failure, human error, and inability to move the units to the site were considered in the evaluation.

The least severe event considered was a station blackout which affects the HFIR area only. This type of event could be caused by a fire in the electrical equipment building which damages the offsite power feeders and the onsite emergency diesel generators. The second level of event severity was a station blackout which affects the overall ORNL area and results in minor damage to access routes leading to HFIR. Such an event could be characterized by the HFIR evaluation earthquake. The final and most severe event considered was a station blackout event affecting the overall ORNL area in combination with significant damage to the HFIR area and other areas at ORNL, including partial blocking of access routes.

The probability that at least one of the two AEPGS units could be connected to the pony motor battery system within six hours and would operate for an additional 18 hours was calculated for the three event severity levels. Results of the analysis indicated that the conditional unavailability of the AEPGS ranged from about 1.6 E-2 for the least severe event category, to about 1.7 E-2 for the second severity level, to about 6.0 E-2 for the most severe event category. These are believed to be somewhat conservative; since results of emergency drills have indicated that the units could be transported to the site and connected in about a third of the time assumed in the probabilistic analysis. Blockage of access routes was not simulated in the emergency drills, however.

The effect that the AEPGS has on reducing core damage frequency can be seen by considering the following. Under the assumptions of the PRA, the HFIR evaluation earthquake would lead to a station blackout because neither the offsite power supply nor the onsite emergency diesels are qualified to withstand the event. Since it can not be assured that the capacity of the dedicated batteries is sufficient to provide forced circulation for the required time, a core damage event is assumed to result. Therefore the frequency of the event is also the core damage frequency contribution. For HFIR, the evaluation earthquake has a frequency of about 1.4 E-3 per year. By adding the AEPGS, this contribution to core damage frequency would thus be reduced by a factor of about fifty-nine (i.e. AEPGS conditional unavailability for this severity level, 1.7 E-2, times the earthquake frequency).

CONCLUSION

A portable auxiliary power supply to backup the offsite and onsite power supplies provides a high level of assurance that forced circulation will be available for the required time period following reactor shutdown. This approach is consistent with guidance from the commercial nuclear power industry. It is a cost-effective means of achieving the desired capability. If experimental data are developed in the future such that the capability is no longer needed, the plant can easily be restored to the original configuration if desired.

REFERENCES

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[3] U.S. NRC Regulatory Guide 1.155 Revision 1, "Station Blackout," August 1988.

[4] "Applicability of Regulatory Guide 1.155 (Station Blackout) and Standard Review Plan 8.3.1 to the High Flux Isotope Reactor Auxiliary Emergency Power Generator," ORNL/RRD/INT-18, September 1988.

[5] "The High Flux Isotope Reactor Probabilistic Risk Assessment," ORNL/RRD/INT-36, January 1988.

[6] "High Flux Isotope Reactor Auxiliary Emergency Power Generator Study," Pickard, Lowe, and Garrick, Inc. March 3, 1989.