BOILING WATER REACTOR

CONTROL ROD DRIVE SYSTEM

VESSEL INVENTORY MAKE-UP RATE

ASPECTS OF NUREG-0619

A brief study Prepared by the Licensing Review Group

5B
3/24/82

INTRODUCTION

NUREG-0619 makes recommendations based on NRC concerns that the Control Rod Drive (CRD) Hydraulic System represents an important source of coolant inventory make-up to the reactor vessel for certain degraded scenarios. The Licensing Review Group (LRG) has independently reviewed these concerns, primarily because significant design modifications will have to be implemented in order to comply with the NUREG-0619 recommendations as they stand.

The NRC has recommended that nuclear power plants apply the principle of defense in depth with respect to plant safety. Since the Browns Ferry Unit 1 fire, NRC regulations have applied this principle in the enforcement of fire prevention/protection and separation criteria for safety related equipment. Furthermore, post TMI regulations have required the implementation of Emergency Procedure Guidelines and improvements to the Emergency Core Cooling Systems to further increase their reliability and availability. The LRG believes that these measures, as they have been implemented for the LRG plants, provide an equivalent level of protection to the recommendations outlined in NUREG-0619. They have concluded that the CRD system as designed adequately meets its design basis. Additionally, this premise is verified as a part of standard preoperational testing programs. The bases for this belief are outlined in greater detail below.

CRD SYSTEM DESIGN

The Control Rod Drive (CRD) system provides water to

1) maintain the CRD scram accumulators in a charged condition,
2) drive the control rods in and out of the core, and
3) cool the CRD mechanisms

Verification of functional requirements including control room flow and pressure indications, is confirmed during preoperational testing.

The CRD return line was designed to provide a reactor pressure reference to the CRD system and to return to the reactor vessel water exhausted from CRD movement or for water in excess of system demands. In response to the discovery of cracking in the CRD return line nozzle, some BWRs under construction chose to modify the CRD system by total removal of the CRD return line and capping of the CRD return line nozzle. Although no credit has been taken for the CRD system high pressure inventory make-up capability in any previous safety analyses, the NRC staff believed the CRD coolant makeup capability of the system was a necessary redundant core cooling system and therefore made the recommendations outlined in NUREG-0619. Section 8.1 of NUREG-0619 recommends that those BWR's without a dedicated return line piped to the reactor vessel demonstrate system capacity equivalent to the vessel coolant make-up required forty minutes following a reactor scram.

The CRD pumps were designed to simultaneously: 1) deliver a high discharge head for maintaining the scram accumulator charged and 2) deliver a relatively low coolant flow rate to the CRDs at operating reactor pressure. Performing as a high pressure make-up system was not a criterion considered when the CRD pump performance characteristics were specified.

The CRD system discharge piping was sized based on a maximum pump discharge flow rate of approximately 100 GPM. At the increased flow rates necessary to meet the recommendations of NUREG-0619, the piping pressure losses can increase as much as 300%. The impact of the increased flow rate recommended by NUREG-0619 is most evident when compared to the increase in piping pressure losses (Table 1). While the system piping is capable of meeting the system functional requirements, it may not have the capability to meet the vessel make-up inventory recommendations of NUREG-0619.

The combined effect of the CRD pump and system piping not meeting the flow recommendations of NUREG-0619 is demonstrated in Figure 1. Figure 1 shows an actual CRD system resistance curve plotted on top of its pump performance curve for a typical 251 BWR/5 plant. The system was optimized to produce the least flow resistance. Figure 1 illustrates that with both CRD pumps operating simultaneously and all system valves fully open, a maximum flow rate of 130 GPM is obtained. This flow rate is considerably lower than the 180 GPM required (for this typical plant) based on the recommendations of NUREG-0619. The make-up benefit gained from the presence of a CRD return line has also been plotted on Figure 1. Figure 1 shows that for this typical plant, the flow requirement recommended in NUREG 0619 could not be met even with the return line installed. Neither the CRD pumps nor the CRD system piping were designed to provide flow for core cooling, but this coincidental flow source is metered in the control room.

In summary, the CRD system meets its functional requirements and this is verified during preoperational testing. The pumps and piping were not assigned to provide core cooling makeup flow. No significant differences in flow capability exists with or without CRD returnline. Therefore, the two pump testing is shown to be unnecessary. Although the LRG recognizes the CRD system as a potential source for reactor coolant make-up, it is meager when compared to HPCI/HPCS, RCIC and feedwater make up flow rates. No credit is taken for the CRD system coolant make-up capability in any plant safety analysis, but the proposed Emergency Procedure Guidelines will employ this system and all other potential inventory make-up systems if demanded by emergency operating symptoms.

BW PLANT AND OPERATIONS IMPROVEMENTS

Many plant improvements have been made since the incidents at Browns Ferry, Oyster Creek and Three Mile Island. The modifications listed below and discussed on the following pages act as major mitigators to the situations which prompted the NRC staff to recommend a particular CRD coolant vessel makeup rate in NUREG-0619.

- Fire Prevention and Protection Upgrades:
  - Increased fire barriers protection.
  - Fast acting fire suppression systems.
  - Physical separations of safety equipment and cabling.
  - Exceptional fire prevention systems and engineering.
- Physical Separation of Safety Equipment and Systems to withstand:
  - Disasters: Flooding, Earthquake, etc.
  - Catastrophic component failure
- Emergency Procedure Guidelines (EPG's) that anticipate scenarios considered in NUREG 0619.
- ECCS/RCIC/HPCI Systems Upgrades
  - Automatic Reset (RCIC)
  - Automatic Restart (HPCS/HPCI)
  - Break Detection Logic (RCIC/HPCI)

EMERGENCY PROCEDURE GUIDELINES (EPGs)

The Emergency Procedure Guidelines developed after the Three Mile Island (TMI) Unit 2 accident, specify operator actions based on symptoms observed during a plant emergency. The actions specified cover severely degraded conditions including multiple failures and operator errors. Even for remote or unlikely event/failure combinations the operator is given guidelines in the Emergency Procedure Guidelines based on the symptoms which are occurring.

The emergency procedures are organized with main sections on reactor control and containment control. Within the reactor control section are subsections on level, pressure, and power control. If plant symptoms are not being maintained in acceptable ranges, contingencies are included to give additional guidance.

During the Browns Ferry 1 fire, the operator took some actions which were consistent with those later specified in the Emergency Procedures Guidelines (EPGs). The main actions taken to control reactor pressure and water level after scram simply stated were:

- o Controlled RPV blowdown
- o Low pressure injection system actuation when RPV was depressurized,
- o Use of alternate depressurization systems in an attempt to keep RPV pressure low, and
- o RPV depressurization when relief valve capability was restored and maintenance of RPV water level with low pressure injection systems.

The currently proposed EPGs would have given a success path even if the actual CRD flow during the Browns Ferry 1 fire had been decreased or non-existant. The initial depressurization would have occurred sooner or with a more rapid blowdown, and the low pressure systems still would have injected in time to restore RPV water level without uncovering the top of the active fuel (TAF). When the relief valve capability was lost and the reactor started to repressurize, if all of the plant's normal injection systems were lost, the operator could have used readily available alternate injection systems in conjunction with supplemental depressurization systems to allow the low pressure injection systems to maintain level.

The EPGs list of normal injection systems includes:

- o Condensate/feedwater system
- o CRD system
- o RCIC system
- o HPCI system (HPCS system)
- o LPCS system
- o LPCI system

The EPGs list of alternate injection systems includes:

- o RHR service water crosstie
- o Fire Protection System
- o Interconnections with other units
- o ECCS keep-full systems
- o Standby Liquid Control (test tank)
- o Standby Liquid Control (boron tank)

The list of supplemental depressurization systems (in addition to SRVs) includes:

- o Main Steam Condenser
- o RHR (Steam Condensing Mode)
- o Main Steam line drains (actually used during Browns Ferry fire)
- o Reactor Water Cleanup (blowdown mode)
- o HPCI steam line
- o RCIC steam line
- o Head vent

Each plant would include their specific systems to address plant unique capability in their training and procedure implementation.

In summary, the EPGs have considered a very broad range of event/failure combinations by making the guidelines symptom oriented. The plant operator will be directed to all of the normal and alternate injection systems available, such as the CRD system, and to a long list of supplemental depressurization systems. When the EPGs have been incorporated into a plant's training and procedures, the plant operators will be much better equipped to deal with an emergency and to utilize the plant's total capability. We believe these measures are more than adequate to insure prevention of the degraded conditions that were the concern of NUREG-0619.

POST TMI MODIFICATIONS

Several modifications are being made in response to post TMI requirements. Some of the modifications which improve the availability and reliability of the emergency core cooling systems are discussed below:

1) Reactor Core Isolation Cooling (RCIC) system automatic reset:

   This modification allows the RCIC system to restart at the low RPV water level indication point (level 2) following a trip on high water level (level 8). The modification thus improves the likelihood that a high pressure make up system will initiate when needed.

2) High Pressure Core Cooling (HPCS/HPCI) system automatic restart:

   The control logic of the HPCS/HPCI system provides for automatic restarting following operator termination. This allows the HPCS/HPCI to automatically restart on low reactor vessel water level after the operator stops the pump. As a result of this modification, the HPCS/HPCI availability is improved.

3) RCIC and HPCI system break detection logic modification:

   By adding time delay logic to the steam line break detection logic, the potential for a failure to start due to a spurious steam flow transient has been decreased. Thus, the high pressure make up system reliability is improved.

   The implementation of these design changes will add further assurance that the redundant high pressure safety systems will automatically perform their function despite the possibility of operator errors. These changes, in conjunction with the separation and fire protection/prevention measures discussed below, will reduce the likelihood of operator dependence on non-safety related sources of coolant make-up and depressurization.

SEPARATION CRITERIA FOR SAFETY RELATED SYSTEMS

Redundant safety related systems are separated from each other so that a single failure of a component or channel will not interfere with the proper operation of its redundant/diverse counterpart. The affected equipment is separated so that systems important to safety are protected from the following hazards:

a) Dynamic affects due to pipe breaks
b) Environmental effects as a result of pipe breaks
c) Flooding effects as a result of pipe breaks
d) Missiles
e) Fires capable of damaging redundant safe shutdown equipment

The methods used to protect the redundant safety related systems are further discussed in the plant unique FSAR. However, the relative probability for common cause power failure is obviously reduced because of the physical and electrical separation currently being employed.

FIRE PREVENTION/PROTECTION

Implementation of fire prevention/protection has been based on a balance of the following factors:

1) Preventing fires from starting,

2) Detecting and quickly extinguishing fires and limiting their damage and;

3) Designing the plant to minimize the potential effects of fires on safety related function.

Fire resistant cables are utilized throughout the plant. Sensitive fire detection systems are installed in all areas of high cable concentration and where multidivisional cables are within close proximity of each other. Areas that have the potential for fire from oils or other combustibles are isolated from other areas of the plant by suitable fire barriers and/or automatic sprinkler protection. Safety related cabling is physically separated into different divisions.

Measures like these discussed above prevent or mitigate the consequences of a potentially severe fire. They increase the probability of operation of redundant equipment and the capability of achieving a safe shutdown of the reactor without relying on non-safety related makeup systems.

CONCLUSION

The LRG position is that the measures described in this paper are more than an equivalent level of protection to the recommendations outlined in NUREG-0619 and therefore the two pump CRD makeup test or any additional analysis is not necessary. This equivalency is consistent with the present NRC application of the defense-in-depth principal with respect to plant safety. Defense-in-depth starts with the recent fire prevention/protection and separation enhancements. If necessary, a significant number of diverse vessel coolant injection systems are available. Since the Browns Ferry fire, enhanced availability and reliability has been built into the Licensing Review Group plants. Symptom-based Emergency Procedure guidelines direct the operator to inventory make-up sources. Integrated operator training assures optimum utilization of multiple water sources prior to any reliance on coolant inventory make-up from the CRD system. We believe these measures are more than adequate to insure prevention of the degraded conditions that were the concern of NUREG-0619.

TABLE 1

CRD SYSTEM FLOW REQUIREMENTS

	251 BWR 4/5	218-BWR/6	251-BWR/6	Browns Ferry
Max. CRD System Functional Discharge Flow Requirement	93 GPM	79 GPM	100 GPM	98 GPM
Vessel Make-Up Flow Rate Based on NUREG-0619 Recommendation	180 GPM	165 GPM	215 GPM	100 GPM(2)
Increased Piping(1) Loss Due to Increased Flow	360%	336%	380%	0%

(1) Flow through a two-inch nominal diameter pipe assumed. Calculation based on a comparison of the piping losses due to the maximum CRD system flow requirement and the NUREG-0619 flow recommendation.

(2) Actual CRD System contribution during Browns Ferry Fire, 40 minutes following reactor scram. Vessel pressure was subsequently reduced and vessel coolant make-up provided by the low pressure injection systems.

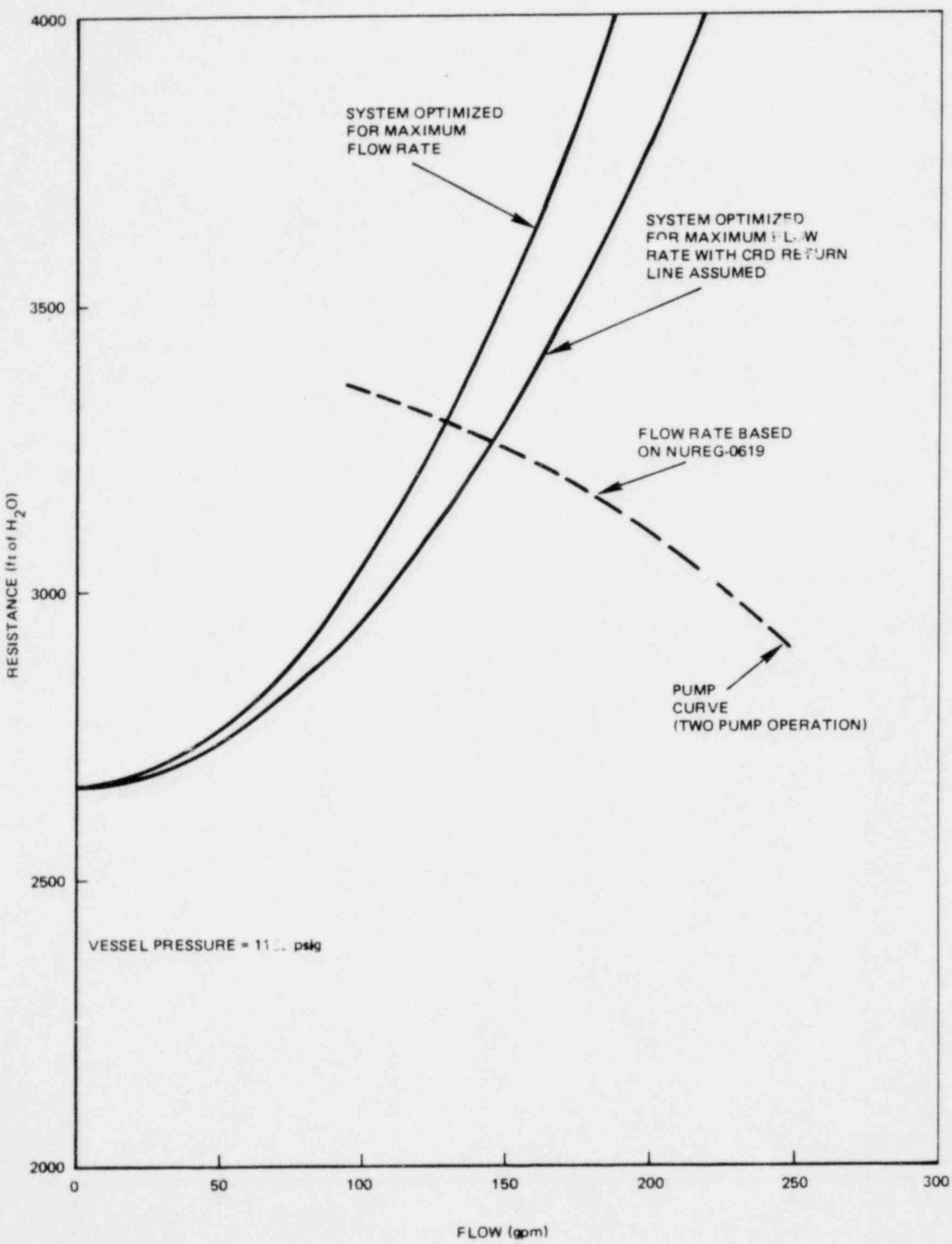

FIGURE 1
TYPICAL 251 - BWR/5 CRD SYSTEM RESISTANCE CURVES
SUPERIMPOSED ON PUMP HEAD-CAPACITY CURVE