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B&W OWNERS GROUP
RESPONSE TO NRC QUESTIONS CONCERNING
GENERIC IMPLICATIONS OF
OCONEE 3 MAKEUP PUMP EVENT

Prepared for

Duke Power Company
Entergy Operations, Inc.
Florida Power Corporation
GPU Nuclear Corporation
Tooledo Edison Company

by

Framatome Technologies, Inc.
Lynchburg, VA

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B&WOG RESPONSE TO NRC QUESTIONS CONCERNING POSSIBLE GENERIC IMPLICATIONS OF THE OCONEE 3 MAKEUP PUMP EVENT

I. INTRODUCTION

During the shutdown of Oconee 3 on May 2, 1997, two of the three Makeup/High Pressure Injection (MU/HPI) pumps were damaged as a result of inadequate water inventory in the Letdown Storage Tank (LDST) caused by inaccurate LDST level indication. The NRC postulated that the third MU/HPI pump could have been damaged had the HPI system been called upon to respond to an Engineered Safeguards (ES) signal. In this scenario a complete loss of high pressure make-up capability could have occurred.

As a result of this event, the NRC staff asked the B&WOG to address the potential for common mode failure of the HPI system and address proposed solutions to any problems. Specifically, they asked for a response to seven questions. Each plant of the B&WOG provided its input for each of the seven questions. This response is a compilation of those inputs. Before responding to these questions, it is helpful to provide a brief, general description of the various components of concern. Simplified P&IDs of the MU/HPI system for each plant of the B&WOG are attached. More detailed information regarding MU/HPI can be found in the SARs for each plant.

A. Normal MU and HPI System Lineups

All plants of the B&WOG except Davis-Besse have three combined MU/HPI pumps. These three pumps serve to provide makeup capability during normal operation. They also serve to provide high pressure injection capability during certain postulated accidents. The primary suction sources for these three pumps are the Makeup Tank (MUT, which is called the LDST at Oconee) and the Borated Water Storage Tank (BWST).

For Oconee, the normal makeup train is all three MU/HPI pumps supplied with suction from the LDST. The operating MU pump provides normal makeup to the RCS and seal injection to the RCPs. The standby MU pump will automatically start on low seal injection flow. During an ES actuation, the BWST outlet valves open, and the BWST becomes the suction source for all three MU/HPI pumps. The outlet of the LDST is not automatically closed on an ES actuation. HPI minimum flow recirculation is to the LDST and is not isolated on an ES actuation.

For ANO-1, CR-3, and TMI-1, the normal makeup train is two MU/HPI pumps supplied with suction from the Makeup Tank (MUT). These two pumps are also the second ES train during an ES actuation. The operating MU pump provides normal makeup to the RCS and seal injection flow to the RCPs. The standby MU pump is not

automatically started on low seal injection flow. The third pump, the first ES train pump, is isolated from the normal makeup train with its suction aligned to the BWST. At ANO-1 and TMI-1, the discharge piping is also isolated from the normal makeup train. At CR-3, the discharge piping for all three MU/HPI pumps is cross-connected.

During an ES actuation, the first ES train pump will automatically start. Depending on which pump is pre-selected, the second ES train pump will either be the operating MU pump or the standby MU pump, and the BWST outlet valves will open for those two pumps. For all three plants, the MUT outlet valve does not automatically close on an ES actuation, and HPI recirculation to the MUT is automatically isolated on an ES actuation. At ANO-1, operator action is required to close the MUT outlet valve. Analyses have been performed at CR-3, Oconee, and TMI-1 to demonstrate that the MUT outlet valve does not have to be closed as long as the BWST is the suction source for the HPI pumps.

For Davis-Besse, the normal makeup train is two MU pumps supplied with suction from the Makeup Tank. During normal operation, one MU pump is operating and the other is in standby. Each MU pump can also be aligned to take suction from the BWST through a three-way valve. The standby MU pump is not automatically started on low seal injection flow. The operating MU pump (and the standby MU pump) will automatically switch to the BWST on low MUT level indication. The redundant ES trains at Davis-Besse are separate from the normal makeup train. The two HPI pumps take suction from the BWST; they do not take suction from the MUT. Both HPI pumps are automatically started on an ES actuation.

B. <u>MUT (LDST) Instrumentation</u>

1. MUT Level

The plants of the B&WOG have redundant MUT (LDST) level transmitters. These level transmitters provide for indication in the Control Room, high and low level annunciators in the Control Room, and high and low alarms on the Plant Process Computer. CR-3 and TMI-1 have an alarm for monitoring the MUT pressure/level operating point versus allowable limits to prevent gas entrainment or inadequate NPSH.

While redundant transmitters are installed, they are both connected to single pairs of taps in the MUT. All plants except TMI-1 use wet reference legs; TMI-1 uses dry reference legs. For all plants except Oconee, the tubing is immediately split for the two transmitters at the elevation of the tap locations, thereby providing separate reference legs. This arrangement precludes the loss of reference legs in both transmitters due to a leak in one of the transmitters. It does not preclude the loss of reference legs in both transmitters due to a break at the tap. It is expected, and plant

operating experiences indicate, that if there is a leak in one of the reference legs, the divergence in indicated level can be detected.

The arrangement at Oconee is a single reference leg for both transmitters. This arrangement does not preclude the loss of reference leg due to a leak in one of the transmitters. Oconee is providing redundant reference legs as a corrective action from the Unit 3 event.

At TMI-1, each reference leg is drained to separate drain pots. Any condensation that might occur in the sensing line is collected below the transmitter and does not affect the level indication. If, for any reason the sensing line were to become flooded, the indicated level for that transmitter would be lower than actual. Again, the divergence in indicated level can be detected.

Various levels of surveillance on the level indications and the reference legs exist among the plants. Typically, the MUT level instrumentation loop calibrations are verified once per refueling. The plants compare both level indicators, or verify that the MUT level/pressure operating point is within the acceptable operating region, or otherwise monitor the operation of the MUT at least once per operating shift. At least one plant requires quarterly filling of the reference legs. At TMI-1, the drain pots on the dry reference legs are drained three times per year. This surveillance interval is based on a history of little or no water being drained from the pots.

2. MUT Pressure

MUT pressure is monitored by a single pressure transmitter, and indication is available in the Control Room. High and low pressure annunciators are available in the Control Room, as well as high and low pressure alarms from the Plant Process Computer. A failure of the pressure transmitter would be detected by a high or low pressure alarm or the indication of the MUT level/pressure operating point outside the allowable operating region. Oconee is providing a redundant pressure transmitter as a corrective action from the Unit 3 event.

The plants of the B&WOG do not employ automatic pressure regulation of the MUT. The operator is responsible for adding Hydrogen gas if MUT pressure is too low and venting if the MUT pressure is too high. An automatic relief valve also protects the MUT from overpressure.

II. RESPONSES TO NRC QUESTIONS

Q1: Are there any single failure vulnerabilities in the make-up tank level instrumentation, pressure instrumentation, or cover gas pressure controller that

could cause all high pressure injection (HPI) to be lost during normal operation or following an accident?

A1: Each plant of the B&WOG has evaluated its MUT level and pressure instrumentation and the cover gas pressure controller to determine whether single failure vulnerabilities exist that could cause loss of all HPI pumps during normal operation or following an accident. Based on the discussion of the MUT instrumentation in Section B of the introductory material above, all plants except Oconee have determined that no credible single failure causing the loss of MUT level indication could cause the loss of all MU/HPI pumps. Also, no single failure in the cover gas system, nor the failure of the MUT pressure indication would result in a condition that could cause the loss of all MU/HPI pumps.

The Oconee Unit 3 event has demonstrated that a single failure in the LDST level transmitters' reference leg can cause a loss of LDST level indication that results in the loss of two of the three MU/HPI pumps. Oconee has also determined that the failure of the pressure transmitter could result in loss of two MU/HPI pumps. However, no single failure could cause the loss of all three MU/HPI pumps during normal operation. An additional ES actuation to start the third MU/HPI pump would have been necessary to cause the loss of that pump. Modifications have been made to the LDST level instrumentation for Oconee Units 2 & 3 to provide redundant reference legs, one for each transmitter. Redundant LDST pressure transmitters have been installed on Oconee Units 2 and 3. Oconee Unit 1 still has a single reference leg for its redundant LDST level transmitters and is vulnerable to single failure. Reference leg integrity is currently being verified daily and is being filled weekly until the unit is shut down for modifications to the LDST level and pressure instrumentation. That shutdown is currently scheduled for mid-June 1997.

Q2: If vulnerabilities are identified, please describe the following: a. consequences, b. procedural guidance to handle the situation, c. possible recovery actions, d. how these single failures are addressed in the design basis for the plant.

A2: Even though no single failure vulnerabilities were found to exist that could cause loss of all MU/HPI, each plant has operational guidance, e.g., Abnormal Operating Procedures, that provides instructions to the operators in dealing with loss of makeup. The use of these procedures should preclude the loss of any additional MU/HPI pumps because no plant except Oconee automatically starts a second MU/HPI pump on loss of makeup (e.g., low seal injection flow). These procedures require the cause for the loss of makeup and the adequacy of the MUT as a suction source for the standby MU/HPI pump both be determined before the standby pump is started. At Davis-Besse, the suction for the operating MU pump (and the standby MU pump) is automatically shifted to the BWST should the MUT level indication be too low. Since

the HPI pumps are always aligned to take suction from the BWST, they will not be affected by any vulnerability of the MUT instrumentation.

Q3: Describe the extent to which instrumentation associated with the make-up tank is relied on to protect the HPI pumps both during normal operation and following an accident. If instrumentation is relied on to protect the HPI pumps, how many pumps could be damaged by a failure of the instrumentation during normal operation and following an accident.

A3: The instrumentation associated with the MUT (LDST) was described in Section B of the introductory material above. The level and pressure instrumentation are relied upon to maintain the MUT pressure/level operating point within the acceptable operating region during normal operation. As long as the operating point is within the acceptable operating region, the MU/HPI pumps will not experience inadequate NPSH or gas entrainment in the limiting scenarios.

As described in Section B above, Oconee, CR-3, and TMI-1 have performed analyses that demonstrate that operating within the allowable operating region will not result in inadequate NPSH or gas entrainment. For these plants, it is not necessary to isolate the MUT outlet isolation valve during an accident while the BWST is available. For ANO-1, closure of the MUT outlet isolation valve is necessary, but adequate procedural guidance and time for the operators to determine the need for isolation and perform that isolation is available. At Davis-Besse, the MU pumps automatically switch to the BWST on low MUT level; this action may also be performed manually, as in the case of a reactor scram. The three-way valve would switch suction from the MUT to the BWST, thereby isolating the MUT.

Based on the discussion of the MUT instrumentation in the introductory material above, it is highly unlikely that a single instrument failure will cause a loss of MUT inventory that would threaten the operability of the operating MU pump. In addition to the MUT instrumentation, annunciators, and alarms, Control Room indications and/or alarms on MU/HPI pump discharge pressure, MU/HPI pump running current, and seal injection flow are available to the operators to aid them in assessing such an event. However, should a loss of MUT inventory occur and remain undetected, it is possible to damage the operating MU/HPI pump (the operating MU pump at Davis-Besse).

For the non-Oconee plants, procedures are in place and instrumentation are available to the operators to protect the standby MU/HPI pump (second MU pump at Davis-Besse) from damage; i.e., the operator would not start the standby MU/HPI pump (second MU pump at Davis-Besse) from the MUT, but would align it to the BWST. If the operator believes the standby MU/HPI pump should not be started, he still has the ES pump with its suction from the BWST available. For the Oconee plants, all of which have the auto-start of the standby MU/HPI pump on low seal injection flow, it is

possible to damage both the operating MU/HPI pump and the standby MU/HPI pump should a loss of LDST inventory go undetected.

It is even more unlikely that a loss of MUT inventory event and an ES actuation event would both occur. However, should this scenario occur, the two HPI pumps at Davis-Besse would get an ES signal to start. Since they are completely separate from the MU system, it is not possible for them to be damaged by a loss of MUT inventory. At ANO-1, CR-3, and TMI-1, the ES pump and either the operating MU/HPI pump or the standby MU/HPI pump would get an ES signal to start. It is possible to damage both the operating MU/HPI pump (due to the loss of MUT inventory) and the standby MU/HPI pump if it is the second HPI pump that is started. Damage to the standby pump would depend on the amount of gas entrained in its suction piping and any delay in the opening of the BWST outlet valve. The ES pump would not be affected because its suction source is the BWST.

At Oconee, all three MU/HPI pumps are cross-tied to the LDST, and all three pumps also receive a start signal on an ES event. With this configuration, it is possible to damage all three MU/HPI pumps. Two pumps could be damaged by the low LDST level event, and the third pump could be damaged on the ES start, depending on the amount of gas entrainment and any delay in the opening of the BWST outlet valve.

Q4: Is the make-up tank instrumentation safety related? Single failure proof? How are the GDC 24 requirements regarding separation of protection and control system met?

A4: None of the instrumentation associated with the MUT is safety related or single failure proof. No protection system instrumentation loops are involved in the MUT instrumentation. The requirements of GDC 24 (or its equivalent for some of the plants) do not apply to the MUT (LDST) instrumentation because that instrumentation does not provide a control function.

Q5: Describe the role of the make-up tank during a LOCA. How does the HPI system interact with the make-up tank during a LOCA?

A5: The MUT has no active or credited role in accident mitigation, such as a LOCA. However, the MUT is not automatically isolated during a LOCA. Except at Davis-Besse, the MUT “floats” on the BWST during a LOCA. As discussed in the answer to Question #3, some plants have performed analyses to demonstrate that closure of the MUT outlet isolation valve is not necessary as long as the BWST is available (level greater than minimum required for switchover to the Containment Sump), while others may require manual closure while still on the BWST.

A second interaction between the MUT (LDST) and HPI during a LOCA is HPI recirculation flow. For Davis-Besse, HPI recirculation is to the BWST. For all other plants, HPI recirculation is to the MUT (LDST). Oconee is the only plant that does not isolate HPI recirculation to the MUT on an ES actuation. HPI recirculation to the MUT does not cause an inventory control problem in the MUT long as the MUT outlet valve is open.

For certain small break LOCAs (which are extremely unlikely to occur), the HPI system is still in operation at the time the BWST is isolated on low level. At this point in time, the MUT outlet valve is closed or has already been closed at ANO-1 but remains open at CR-3, Oconee, and TMI-1, and the suction source for the HPI pumps is switched to the discharge of the LPI pumps which take their suction from the Containment Sump. In this configuration, called "piggyback", the MUT outlet check valve is closed by the discharge pressure of the LPI pumps. In this configuration, there are several options, if the need to throttle HPI flow occurs. Davis-Besse and TMI-1 do not throttle HPI flow below the minimum allowed flow, and therefore do not have to open HPI recirculation. Oconee throttles HPI flow but has a secondary recirculation path to the suction of the LPI pumps rather than to the LDST. ANO-1 and CR-3 throttle HPI flow, but the recirculation path is to the MUT. At ANO-1, the recirculation to the MUT eventually causes high level, at which point the MUT is drawn down. At CR-3, the MUT is allowed to fill. CR-3 is considering a design change to have a secondary recirculation path to the Containment sump.

Q6: Where is the system boundary of the HPI system? How is it isolated from other systems?

A6: The HPI system consists of suction piping from the BWST, the three MU/HPI pumps (two HPI pumps at Davis-Besse), and discharge piping to the four HPI injection lines into the RCS, and HPI recirculation piping. At Davis-Besse, the HPI system takes suction from the BWST only and is isolated from the MU system. For the rest of the plants, the HPI system is not isolated initially from MUT on an ES actuation. At Oconee, the HPI recirculation valves to the LDST remain open and the LDST outlet valve remains open. At CR-3, and TMI-1, the HPI recirculation valves are closed but the MUT outlet valve remains open. At ANO-1, the HPI recirculation valves are closed and the MUT outlet valve also is closed (manually).

Q7: To what extent are these failures modeled in the plant IPEs?

A7: IPEs, also termed PRAs (Probabilistic Risk Assessments) or PSAs (Probabilistic Safety Assessments) by some of the plants, have been performed by each plant of the B&WOG. The MUT (LDST) level instrumentation failure was not specifically modeled in any of the IPEs, PRAs, or PSAs. This failure is being considered at ANO-1 to support their MOV prioritization efforts. The CR-3 PSA model

includes consideration of related multiple failure sequences. One such sequence was the failure of the BWST suction valve associated with the MU/HPI pump aligned to the MUT, which could fail concurrent with the failure of the MU/HPI pump aligned to the BWST. At Davis-Besse, common cause failure of the MU pumps to start on demand or failure to run were included in their IPE. At TMI-1, the failure of individual active components is modeled in their PRA. The PRA recommended further evaluation of operation with a common suction header (cross-connects open). That evaluation concluded the common suction header configuration resulted in a slightly lower CDF. At Oconee, the IPEs do not directly address failure of the LDST instrumentation. However, more encompassing failures such as loss of the entire BWST suction path and failure of all HPI pumps have been considered in the IPEs. These failures envelop LDST instrumentation failures.

III. FURTHER ACTIONS BY THE PLANTS OF THE B&WOG

Based on the information provided in the Introduction and the responses to the seven NRC questions provided above, the event at Oconee Unit 3, the damaging of two MU/HPI pumps, is unlikely to occur at the non-Oconee plants. Further, the postulated scenario, where all three MU/HPI pumps could be damaged is possible at Oconee, is highly unlikely at the non-Oconee plants. The redundant MUT level instrumentation and the lack of automatic starting of the standby MU/HPI pump makes the loss of two MU/HPI pumps unlikely, and the separation of the ES train pump from the MUT and the other two MU/HPI pumps makes the loss of all three MU/HPI pumps highly unlikely. At Davis-Besse, the possibility of damaging both MU pumps, which take their suction from the MUT or the BWST, is unlikely. Since the HPI pumps do not use the MUT as a suction source, they will be unaffected by a MUT instrumentation failure.

Oconee is implementing changes to the LDST instrumentation on all three plants. Those corrective actions will reduce the likelihood of damaging all MU/HPI pumps as a result of a single failure in the LDST instrumentation. The non-Oconee plants are satisfied that their designs are satisfactory to preclude damage to all MU/HPI pumps as a result of a single failure in the MUT instrumentation. As an additional measure, they will review the corrective actions implemented at Oconee for applicability to their individual plant.

PREPARED BY: D A Downtain

D. A. DOWNTAIN

REVIEWED BY: WN Prillaman

W. N. PRILLAMAN

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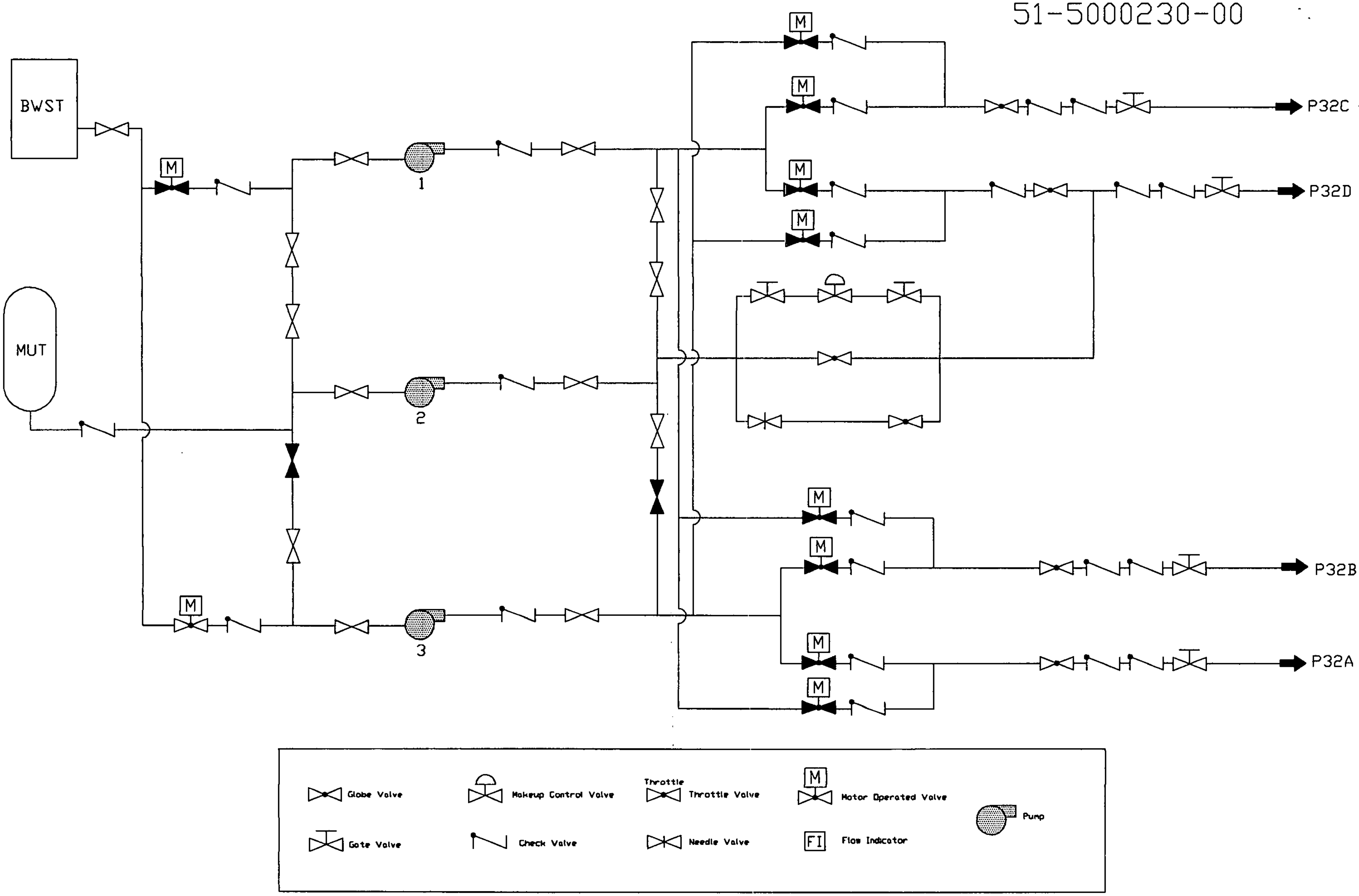

ANO-1

HPI/MU Piping and Valve Locations

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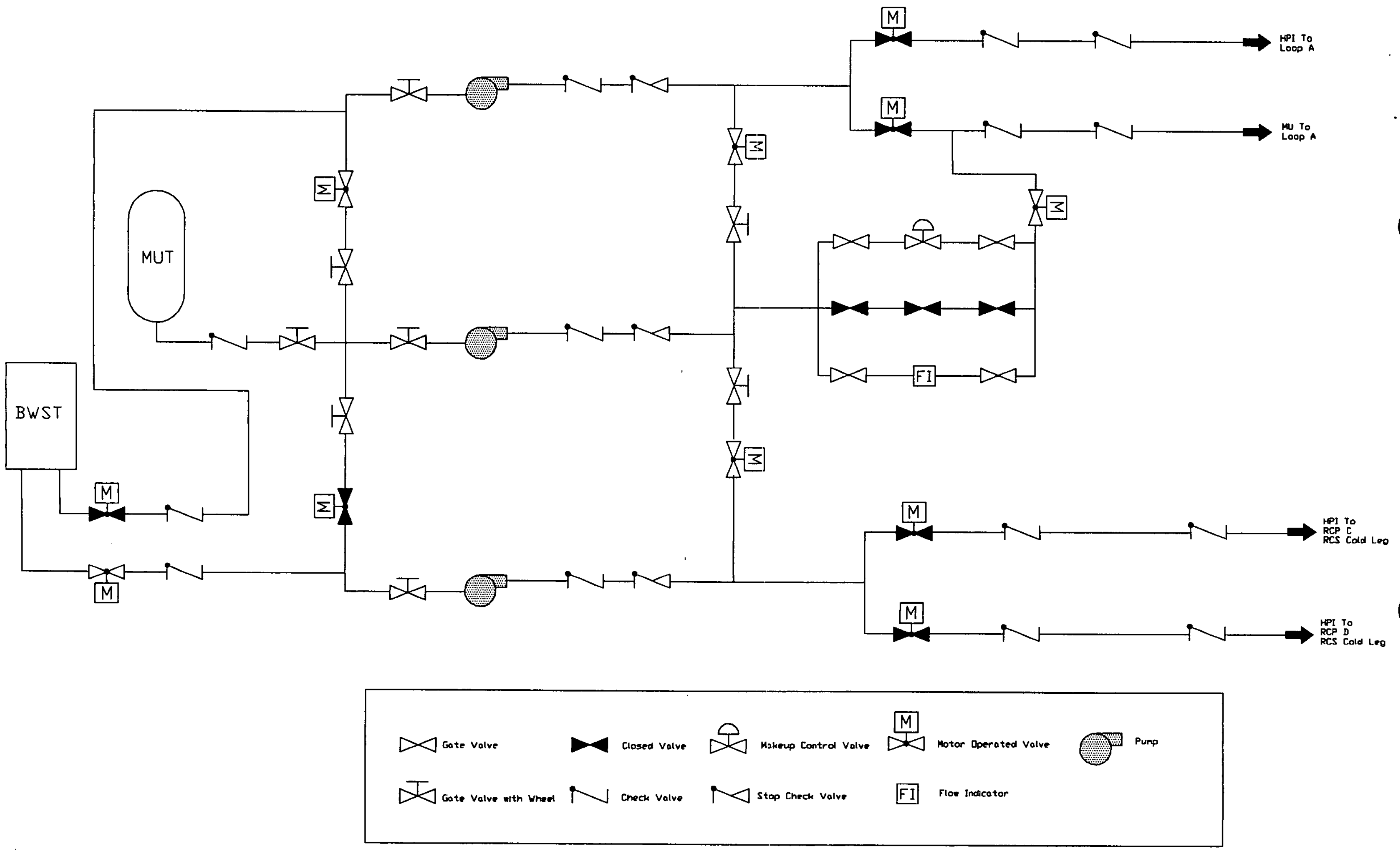

Crystal River

HPI/MU Piping and Valve Locations

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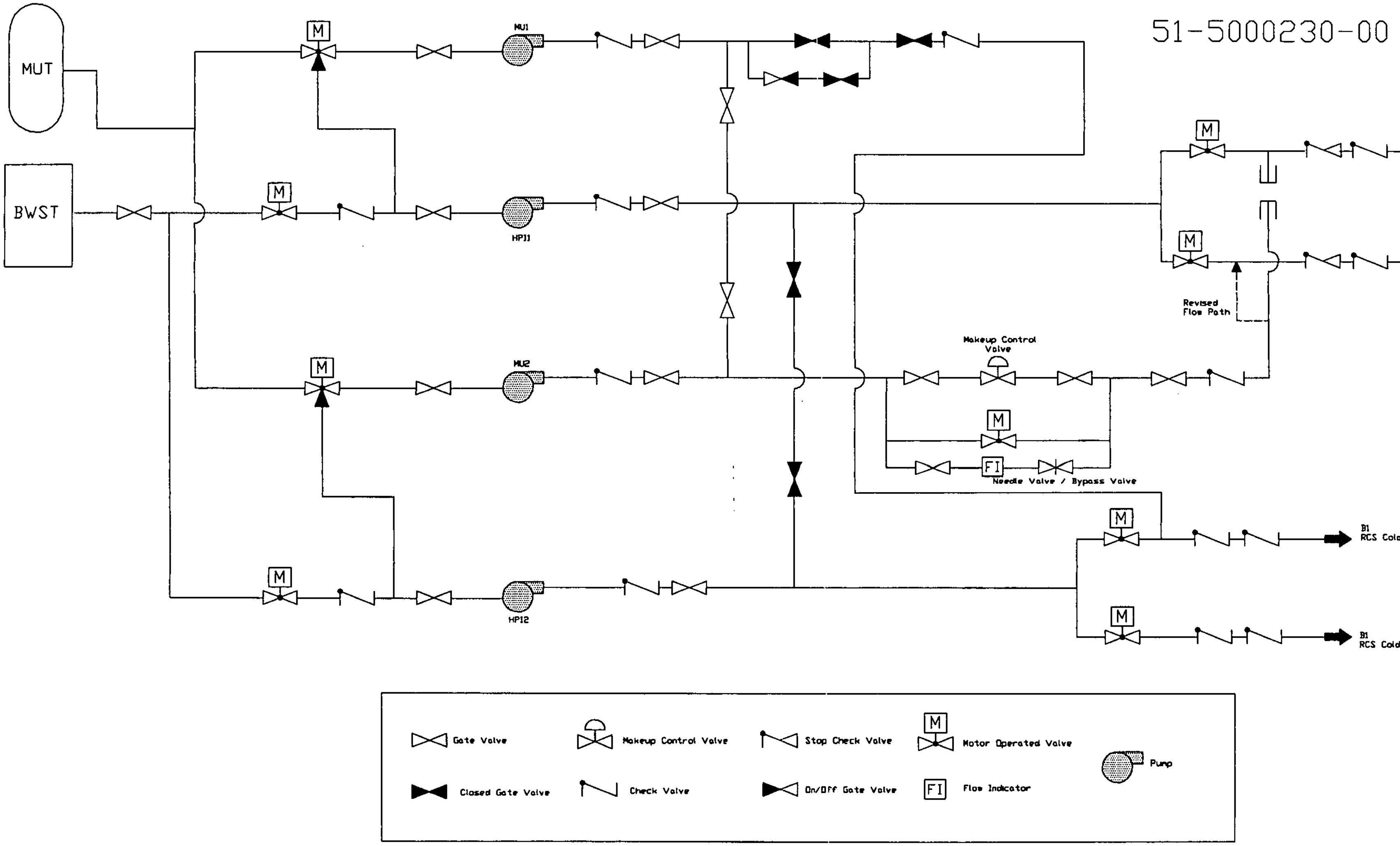

Davis-Besse 1

HPI/MU Piping and Valve Locations

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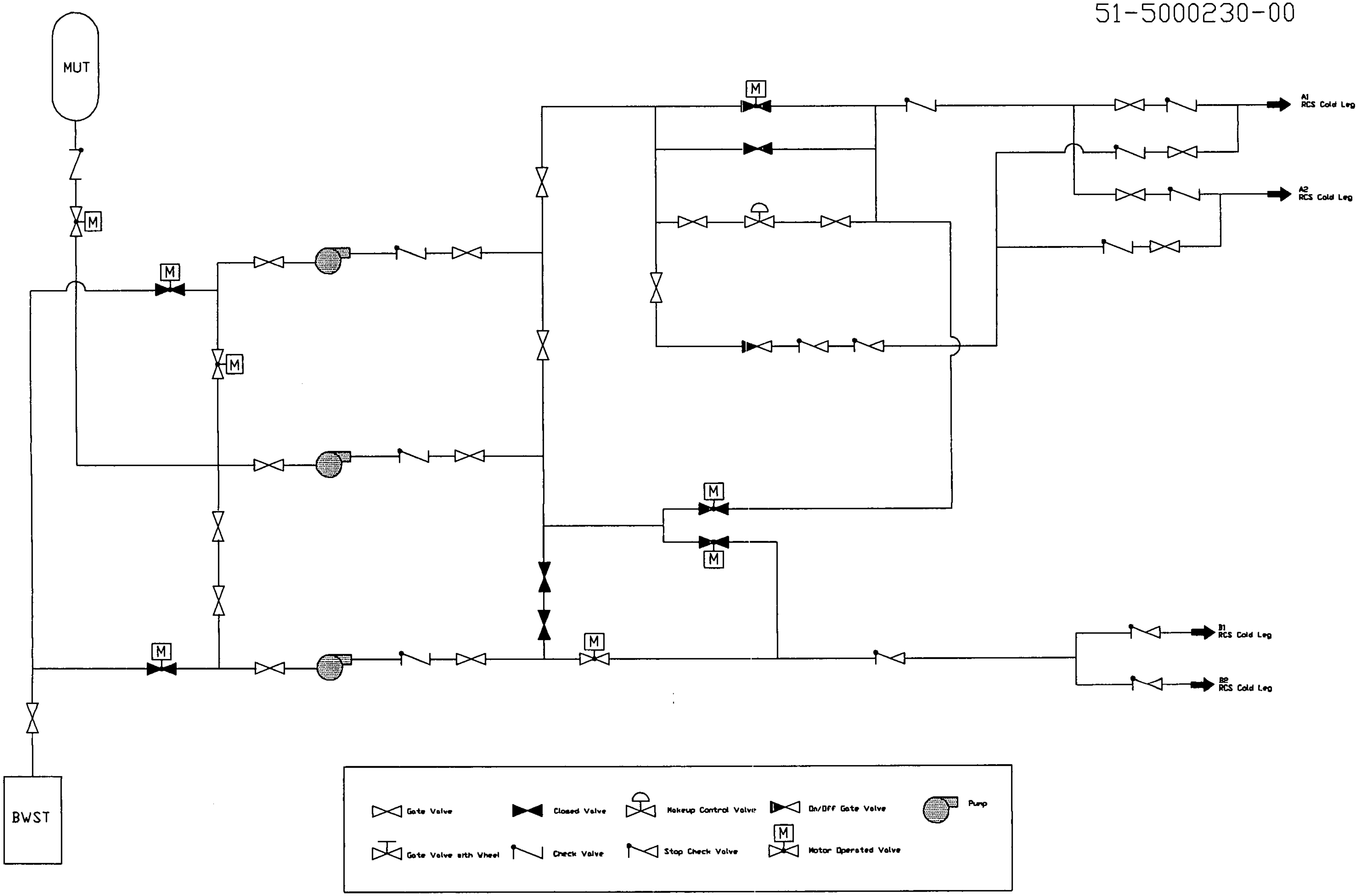

Oconee 1,2, & 3

HPI/MU Piping and Valve Locations

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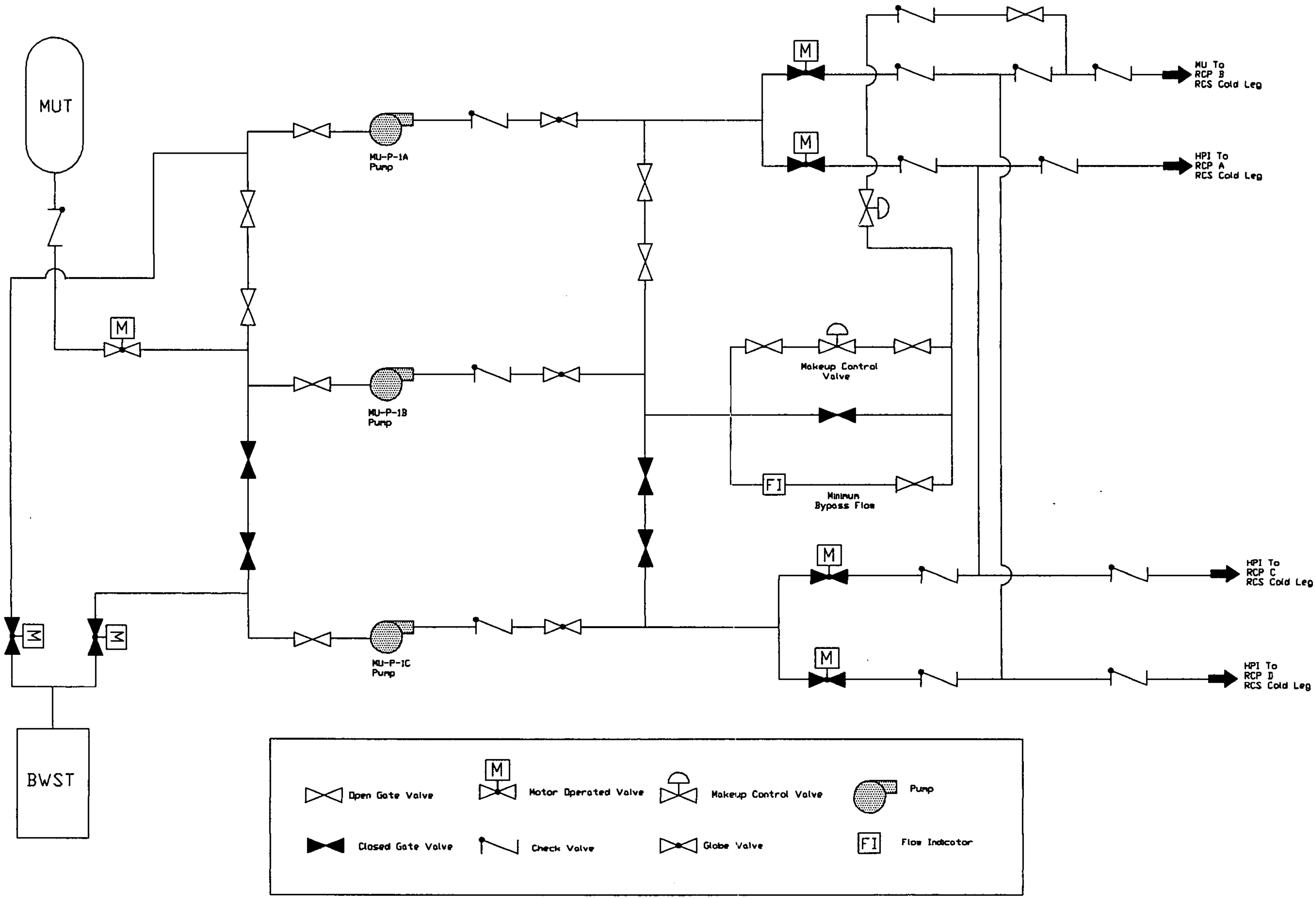

TMI 1

HPI/MU Piping and Valve Locations