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Title INTERIM BWOG REPORT ON HPI/MU NOZZLE CRACKING

PREPARED BY:		REVIEWED BY:	
Name	CJ MCGAUGHY	Name	DR COFFLIN
Signature	CJ McGaughy, Date 6/5/97	Signature	David R Cofflin (DRC), Date 6/5/97

Technical Manager Statement: Initials [signature]

Reviewer is Independent.

Remarks:

Purpose:

The purpose of this interim report is to collect information relative to the cracking found in the high pressure injection/makeup nozzle at Oconee Unit 2 in April, 1997. This report represents the first phase of a program to determine the root cause behind the cracking. This interim report does not attempt to determine the root cause behind the cracking. This report provides partial response to the Request for Information transmitted the NRC on 5/27/97 (Attachment 1).

Table of Contents

Prepared by: OM 6/5/97

Reviewed by: PAG 6/5/97

List of Tables

Prepared by: OM 6/5/97

Reviewed by: PAG 6/5/97

List of Figures

1. Introduction

1.1. Purpose

The purpose of this interim report is to collect information relative to the cracking found in the high pressure injection/makeup nozzle at Oconee Unit 2 in April, 1997. This report represents the first phase of a program to determine the root cause behind the cracking. This interim report does not attempt to determine the root cause behind the cracking. This report provides partial response to the Request for Information transmitted by the NRC on 5/27/97 (Attachment 1).

1.2. Background (Reference 13)

On April 21, 1997, at 2245 hours, a reactor coolant system (RCS) leak was detected in Oconee Unit 2. The control room operator noted a level change in the letdown storage tank and a reactor building air particulate monitor went into alarm. An RCS leakage calculation was made and the leak was observed in the area of the 2A1 reactor coolant pump. Due to the location, nature of the leak, and the dose rates, the leaking component could not be positively identified. A power reduction on Oconee Unit 2 was initiated at 0352 hours on April 22, 1997. The leak was subsequently identified as a crack in the weld for the pipe to safe end connection at the RCS nozzle for the high pressure injection (HPI) system A1 injection line.

1.3. Scope

This report provides information relative to the B&WOG operating plants and the HPI/MU nozzle cracking problem found at Oconee Unit 2. The B&WOG operating plants included in this report are as follows:

1. Oconee Units 1, 2 and 3
2. Three Mile Island Unit 1 (TMI-1)
3. Crystal River Unit 3 (CR-3)
4. Arkansas Nuclear One Unit 1 (ANO-1)
5. Davis Besse Unit 1 (DB-1)

Information to be provided in this report includes the following:

1. History of HPI/MU Nozzle Failures
2. Comparison of as-built designs found in each HPI/MU nozzle
3. Modifications that have been made to each of the HPI/MU nozzles found at the B&WOG plants
4. Recent inspection results for each of the HPI/MU nozzle assemblies
5. General information on HPI/MU system operation
6. Past recommendations and their bases
7. Implementation of past recommendations
8. HPI/MU nozzle design bases

Prepared by: OM 6/5/97

Reviewed by: DRC 6/5/97

2. B&WOG Plants HPI/MU Nozzle History

There have been several problems at B&W Owner's Group (B&WOG) plants associated with the high pressure injection (HPI-only) and high pressure injection/makeup (HPI/MU) nozzles, thermal sleeves and safe ends. These problems have included cracking at the safe end, loosening or complete dislodging of the thermal sleeve and failure of the thermal sleeve through fatigue cracking. The following discussion provides information about each of the component failures.

2.1. Crystal River Unit 3 - 1982 (Reference 1)

In January, 1982, normal monitoring of the Crystal River Unit 3 reactor coolant system indicated an unexplained loss of coolant. After a plant shutdown was completed, the double-duty high pressure injection and makeup nozzle check valve MUV-43 was identified as the source. Upon further inspection, the valve, valve-to-safe end weld, safe end, and thermal sleeve were found to be cracked. The check valve to safe end weld contained a through-wall circumferential crack which was the origin of the leak. Following the removal of the valve, visual inspection of the safe end and thermal sleeve revealed that both components were cracked and worn (extensive wear was found on the safe end ID and the thermal sleeve OD in the region of contact expansion of the sleeve into the safe end). Inspection of the three HPI-only nozzles indicated that no cracking or wear was present.

Following the incident at CR-3, inspections were performed at all B&WOG operating plants to determine whether the problem was site-specific or generic in nature. Below is a listing of the problems found as discussed in reference 1.

Oconee Unit 1:

No abnormal conditions were present in any of the four HPI/MU nozzles.

Oconee Unit 2:

Loop A1: (HPI/MU)	No abnormal conditions were present.
Loop A2: (HPI/MU)	Inspection revealed that safe end was cracked and thermal sleeve was loose.
Loop B1: (HPI)	Inspection revealed 1/32 inch gap between thermal sleeve and safe end.
Loop B2: (HPI)	Inspection revealed that thermal sleeve was tight but contained a circumferential crack in the contact expanded area.

Oconee Unit 3:

Loop A1: (HPI/MU)	No abnormal conditions were present.
Loop A2: (HPI/MU)	Inspection revealed that thermal sleeve was loose. The upstream weld beads had been worn away and downstream weld buttons were worn.
Loop B1: (HPI)	Inspection revealed 0.030 inch gap between thermal sleeve and safe end.
Loop B2: (HPI)	No abnormal conditions were present.

TMI-1:

No abnormal conditions were present in any of the four HPI/MU nozzles.

CR-3:

Loop A1: (HPI/MU)	Failure occurred at the safe end to valve weld. Inspection revealed that safe end and thermal sleeve were cracked and worn.
Loop A2: (HPI)	No abnormal conditions were present.
Loop B1: (HPI)	No abnormal conditions were present.
Loop B2: (HPI)	No abnormal conditions were present.

ANO-1:

Loop A: (HPI)	Inspection revealed that the thermal sleeve was loose and the outboard weld buttons were worn away (reference 16).
Loop B: (HPI)	Inspection revealed a partial gap between thermal sleeve and safe end.
Loop C: (HPI)	No abnormal conditions were present.
Loop D: (HPI/MU)	Inspection revealed that thermal sleeve contained a circumferential crack in the contact expanded area.

DB-1:

No abnormal conditions were present in any of the four HPI/MU nozzles. Note that all thermal sleeves were hard rolled in 1977 during construction after determining that one of the previously installed contact expanded thermal sleeves was loose.

2.2. Davis Besse Unit 1 - 1988 (Reference 2)

In July, 1988, during a refueling outage, two pieces of metal were discovered by video inspection, one on the lower grid and the other below the reactor vessel core support grid. The two pieces were each about 3 inches long and when placed together, formed a hollow cylinder with a diameter of 1.75 inches. Fiberscope inspections showed that the hollow cylinder was actually a portion of the HPI/MU nozzle (A1) thermal sleeve. The thermal sleeve had failed at the nozzle weld buttons, which are approximately 3 inches from the downstream end of the thermal sleeve. The failure was initiated by one through-wall circumferential crack and two through-wall longitudinal cracks. The circumferential crack ran 360 degrees around the thermal sleeve approximately 3 inches from the end and adjacent to the thermal sleeve collar. The two longitudinal cracks occurred about 180 degrees apart and ran the entire length of the failed section. This thermal sleeve failure affected the downstream end of the sleeve, whereas the Crystal River-3 failure affected the upstream end of the sleeve.

Following the discovery of the HPI/MU nozzle thermal sleeve failure, inspections were also performed on the nozzle. Inspection of the nozzle's interior clad surface showed crack like indications throughout the area where the thermal sleeve had failed.

2.3. Oconee Unit 2 - 1997 (Reference 13)

In April, 1997, normal monitoring of the Oconee Unit 2 reactor coolant system indicated an

unexplained loss of coolant. After a plant shutdown was completed, the double-duty high pressure injection and makeup nozzle pipe-to-safe end weld at loop A1 was identified as the source. Upon further inspection, the pipe, pipe-to-safe end weld, safe end, and thermal sleeve were found to be cracked. The pipe-to-safe end weld contained a through-wall circumferential crack which was the origin of the leak. Following the removal of the components, inspection revealed that all components were cracked/worn (extensive wear was found on the safe end ID and the thermal sleeve OD in the region of contact expansion of the sleeve into the safe end). Inspection of the other HPI/MU nozzle and two HPI-only nozzles indicated that no cracking or wear was present, and no sleeve movement had occurred.

2.4. Oconee Unit 3 - 1997 (Reference 13)

In May, 1997, subsequent to the HPI/MU nozzle safe end-to-pipe weld failure at Oconee Unit 2, an outage was begun to inspect for possible damage to the HPI/MU nozzles and thermal sleeves. Inspection of the loop 3A1 nozzle revealed that the thermal sleeve was tight at the contact roll location and that the thermal sleeve contained small holes near the collar region and cracks throughout its length. The safe end, safe end-to-pipe weld and the adjoining pipe spool piece also contained damage. It was also found that the cladding in the nozzle bore contained cracks near the thermal sleeve collar region. Inspection of the other HPI/MU nozzle and two HPI-only nozzles indicated that no cracking or wear was present, and no sleeve movement had occurred.

3. HPI/MU Nozzle/Safe End/Thermal Sleeve Design and Configuration

There are four basic designs of safe ends and thermal sleeves found in the B&WOG plants as discussed below. Table 1 lists the type of design in each nozzle for each plant along with the date that any modification was made. Section 4 discusses the modifications in greater detail and gives the reasons for those modifications. The materials used in the construction of the HPI/MU nozzles, safe ends, thermal sleeves and welds vary slightly due to time of construction or modification and other factors. Table 2 lists the materials used for each component in each HPI/MU and HPI-only nozzle assembly.

3.1. Original Standard Design

There are minor dimensional differences in the original standard design HPI-only and HPI/MU nozzle assemblies installed at the B&WOG plants. A typical depiction of the original standard design HPI-only and HPI/MU nozzle is shown in Figures 3-1 and 3-2 and contains the following design features:

1. Carbon steel nozzle body with stainless steel cladding
2. NiCrFe weld between nozzle body and safe end
3. Stainless steel safe end
4. Stainless steel weld between safe end and attached pipe or valve
5. Stainless steel thermal sleeve attached to safe end by contact roll at outboard (upstream end of the nozzle) end with 0.5 inch wide collar around the circumference containing a .010 to .015 inch diametral clearance to the nozzle body cladding at the inboard end (downstream end of the nozzle) (reference 1). The contact expansion length at the outboard end is approximately 2 inches long and wall thinning was not specified.
6. Four weld buttons were added to the cladding downstream of the collar and four weld beads are added upstream of the thermal sleeve contact expansion region. The intent of these weld buttons and beads is to provide axial restraint to prevent displacement of the thermal sleeve (reference 1).

3.2. Variations on Original Standard Design

<u>TMI-1:</u>

The HPI-only and HPI/MU nozzles installed at TMI-1 are the same as the original standard design shown in Figures 3-1 and 3-2 except for the following design features:

1. NiCrFe safe end
2. NiCrFe weld between safe end and attached valve

<u>Oconee Unit 1:</u>

The double thermal sleeve design HPI/MU nozzle used at Oconee Unit 1 is shown in Figure 3-3 and 3-4 and contains the following design features:

1. Carbon steel nozzle body with stainless steel cladding
2. NiCrFe weld between nozzle body and safe end
3. Stainless steel safe end
4. Stainless steel weld between safe end and attached pipe
5. Double stainless steel thermal sleeve - Original thermal sleeve is attached to safe end by contact roll at outboard end with 0.5 inch wide collar around the circumference containing a .010 to .015 inch diametral clearance to the nozzle body

cladding at the inboard end (reference 1). The contact expansion length at the outboard end is approximately 2 inches long and wall thinning is not specified. A second thermal sleeve is added to move the HPI/MU injection point farther into the RCS flow. The second thermal sleeve is attached to the original thermal sleeve and safe end by contact roll at the outboard end. The contact expansion length at the outboard end is approximately 2.375 inches long and wall thinning is not specified.

6. Four weld buttons are deposited on the nozzle cladding downstream of the thermal sleeve collar and four weld beads are added upstream of the contact expansion region to keep the outer thermal sleeve in place. Four more weld beads are added at the outboard end to prevent upstream displacement of the inner thermal sleeve. The intent of these weld buttons and beads is to provide axial restraint to prevent displacement of the thermal sleeves (reference 1). The inner thermal sleeve also contains a flange at the outboard end to prevent downstream displacement.

3.3. Modifications Made to Original Standard Design During Construction

As discussed in reference 1, Davis Besse Unit 1 was found to contain a loose thermal sleeve during construction in 1977. The outboard ends of all thermal sleeves at Davis Besse were subsequently hard rolled at that time with wall thinning of 3% (reference 1). The HPI-only and HPI/MU nozzle assemblies installed originally at DB-1 are similar to the original standard design shown in Figures 3-1 and 3-2 except that the outboard end is hard rolled.

3.4. Improved Design

A typical depiction of the improved design HPI-only and HPI/MU nozzle thermal sleeve and safe end are shown in Figures 3-5 and 3-6. There are minor differences in the improved design HPI-only and HPI/MU nozzle assemblies installed at the B&WOG plants. The nozzle body is unchanged from the original standard design shown in Figure 3-1 except for weld preparation machining at the safe end to nozzle joint (references 33, 34). The improved design HPI-only and HPI/MU nozzle assembly contains the following design improvements:

1. Stainless steel thermal sleeve attached to safe end by hard roll at outboard end with a 1.5 inch wide collar around the circumference contact expanded against the nozzle body cladding at the inboard end. The hard roll expansion length at the outboard end is approximately 2.72 inches long and recommended wall thinning is 5% (reference 1). The outboard end also contains a bell shaped region that provides additional stability.
2. The thermal sleeve is slotted to receive four weld beads upstream of the hard roll expansion region. The intent of these weld beads is to provide axial restraint to prevent displacement of the thermal sleeve.

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Reviewed by: DRC 6/5/97

4. Component Modifications

Various modifications have been made at each plant since the time of construction. The following lists the modifications made to each nozzle, when those modifications were made and the reason. Each of the modifications are as recommended in reference 1. Note that this is historical data provided for information only. This information is provided in Table 1 and reference 2 with exceptions as noted.

Oconee Unit 1:

No modifications or repairs have been made to any of the four HPI/MU nozzles.

Oconee Unit 2:

Loop A1: (HPI/MU)	No modifications or repairs made until failure occurred in 1997. Note that this nozzle contained the original standard design HPI/MU nozzle assembly with the contact expanded thermal sleeve and stainless steel safe end.
Loop A2: (HPI/MU)	Improved safe end and thermal sleeve design installed in 1982 after inspection revealed that safe end was cracked and thermal sleeve was loose.
Loop B1: (HPI)	Original standard design rerolled at the outboard end (hard roll) after radiographic inspection in 1982 revealed 1/32 inch gap between thermal sleeve and safe end.
Loop B2: (HPI)	Original safe end was bored and improved design thermal sleeve was installed (hard roll) in 1982 after inspection revealed that thermal sleeve was tight but contained a circumferential crack in the contact expanded area.

Oconee Unit 3:

Loop A1: (HPI/MU)	No modifications or repairs made until inspection in 1997 revealed that the thermal sleeve and safe end contained cracks and wear. Note that this nozzle contained the original standard design HPI/MU nozzle assembly with the contact expanded thermal sleeve and stainless steel safe end.
Loop A2: (HPI/MU)	Improved safe end and thermal sleeve design installed in 1982 after inspection revealed that thermal sleeve was loose. The upstream weld beads had been worn away and downstream weld buttons were worn.
Loop B1: (HPI)	Original standard design rerolled at the outboard end (hard roll) after radiographic inspection in 1982 revealed 0.030 inch gap between thermal sleeve and safe end.
Loop B2: (HPI)	No modifications or repairs have been made to this nozzle.

TMI-1:

No modifications or repairs have been made to any of the four HPI/MU nozzles.

Prepared by: CM 6/5/97

Reviewed by: DRC 6/5/97

CR-3:

Loop A1: (HPI/MU)	Improved safe end and thermal sleeve design installed in 1982 after failure occurred at the safe end to valve weld. Inspection revealed that safe end and thermal sleeve were cracked and worn.
Loop A2: (HPI)	Improved safe end and thermal sleeve design installed in 1996. This was done as preventive maintenance. (Ref. 15)
Loop B1: (HPI)	Improved safe end and thermal sleeve design installed in 1996. This was done as preventive maintenance. (Ref. 15)
Loop B2: (HPI)	Improved safe end and thermal sleeve design installed in 1994. Augmented radiographic inspection indicated potential problem with thermal sleeve. (Ref. 15)

ANO-1:

Loop A: (HPI)	Improved safe end and thermal sleeve design installed in 1982 after inspection revealed that the thermal sleeve was loose and the outboard weld buttons were worn away (reference 16).
Loop B: (HPI)	Original standard design rerolled at the outboard end (hard roll) after radiographic inspection in 1982 revealed a partial gap between thermal sleeve and safe end.
Loop C: (HPI)	No modifications or repairs have been made to this nozzle.
Loop D: (HPI/MU)	Improved safe end and thermal sleeve design installed in 1982 after inspection revealed that thermal sleeve contained a circumferential crack in the contact expanded area.

DB-1:

Note that all thermal sleeves were hard rolled in 1977 during construction after determining that one of the previously installed contact expanded thermal sleeves was loose. After the damaged thermal sleeve noted below was found in 1988 during the fifth refueling outage, makeup flow was rerouted to Loop A2 in 1990 during the sixth refueling outage.

Loop A1: Pre-1990 (RFO 6) (HPI/MU), Post-1990 (RFO 6)(HPI)

Improved safe end and thermal sleeve design installed in 1988 after inspection revealed that thermal sleeve had broken at inboard end. Original thermal sleeve was tight and without gaps at hard roll expansion area (reference 17).

Loop A2: Pre-1990 (RFO 6)(HPI), Post-1990 (RFO 6)(HPI/MU)

Improved safe end and thermal sleeve design installed in 1988. No damage to original components.

Loop B1: (HPI)	No modifications or repairs have been made to this nozzle.
Loop B2: (HPI)	No modifications or repairs have been made to this nozzle.

Prepared by: CRN 6/5/97

Reviewed by: DRC 6/5/97

5. Recent Inspection Results

Table 3 provides a list of the most recent inspections performed for each HPI-only and HPI/MU nozzle assembly for all of the B&WOG plants except Oconee Units 1, 2 and 3. None of the inspections listed nor any previous inspections since a repair (i.e. hard roll of original thermal sleeve) or replacement (i.e. installation of improved design thermal sleeve and safe end) have found any adverse conditions in any of the HPI-only or HPI/MU nozzles at the B&WOG plants. This is also the case for those nozzles listed that have not required repair or replacement since original construction. The inspection data are taken from references 14 through 17. Attachment 2 (taken from reference 13) gives the complete inspection history for all of the HPI/MU nozzles at Oconee Units 1, 2 and 3. Those tables indicate that RT examinations have shown gaps in the thermal sleeve contact expansion regions.

A clear inspection as listed in Table 3 is defined as follows:

UT:	No recordable indications are found in the area of examination.
RT:	No gap is found in the thermal sleeve expansion region and the thermal sleeve is in the correct position.
PT:	No cracks are found in the examined surface of the component examined.
Visual:	No cracks or wear are found in any of the components inspected which would include the thermal sleeve and safe end.

6. System Operation

Schematic drawings of the high pressure injection and makeup systems for each plant are provided in Figures 6-1 through 6-5. These drawings show the HPI/MU systems between the discharge side of the HPI/MU pumps and the RCS injection points. Table 4 provides the normal makeup flow rate for each plant along with the minimum bypass flow. Table 5 provides operational modifications that have been made since the 1982 CR-3 failure. Table 6 provides a listing of the type of configuration used for each plant for bypass flow. Table 7 provides HPI/MU system modifications made in response to the 1982 CR-3 failure. Below is a brief discussion of the HPI/MU system typical flow rates for each plant and an assessment of the possibility at each plant for backflow of hot RCS fluid from one loop to another. Backflow typically occurs when the loops are "cross-connected" (i.e. a direct route is provided for flow from one cold leg to another through the HPI/MU system piping) without proper isolation.

Oconee Units 1: Schematic Dwg - Figure 6-1

Oconee Unit 1 has a nominal total letdown flow of approximately 70 gpm. This varies during plant startups and cooldowns due to RCS volume changes. The Unit 1 Westinghouse RC pumps are given a seal injection of approximately 8 gpm each (total of 32 gpm) of which 3 gpm each (total of 12 gpm) is returned to letdown or controlled bleedoff resulting in a total makeup to the RCS through the seals of 20 gpm. The nominal makeup to each of the two double duty HPI/MU nozzles is 22 gpm with the bypass providing an additional flow of 3 gpm for a total to each nozzle of 25 gpm.

Figure 6-1 shows that the loop B1 and B2 HPI-only nozzles are "cross-connected" as are the loop A1 and A2 HPI/MU nozzles. This means that backflow from the loop B1 HPI-only nozzle to the loop B2 HPI-only nozzle is possible if one of the two check valves separating the two nozzle leaks. The reverse situation is also possible. The same situation is possible for the loop A1 and A2 HPI/MU nozzles. The bypass lines which enter the HPI/MU lines just upstream of the loop A1 and A2 HPI/MU nozzles are also "cross-connected". With this configuration, bypass flow can be diverted to the line with the highest differential pressure which can occur during single RC pump operation.

Oconee Units 2 and 3: Schematic Dwg - Figure 6-1

Oconee Unit 2 has a nominal total letdown flow of approximately 70 gpm. This varies during startups and cooldowns due to RCS volume changes. The Unit 2 Bingham RC pumps are given a seal injection of approximately 10 gpm each (total of 40 gpm) of which 1 gpm each (total of 4 gpm) is returned to letdown or controlled bleedoff resulting in a total makeup to the RCS through the seals of 36 gpm. The nominal makeup flow to each of the two double duty HPI/MU nozzles is 14 gpm with the bypass providing an additional flow of 3 gpm for a total to each nozzle of 17 gpm.

Figure 6-1 shows that the loop B1 and B2 HPI-only nozzles are "cross-connected" as are the loop A1 and A2 HPI/MU nozzles. This means that backflow from the loop B1 HPI-only nozzle to the loop B2 HPI-only nozzle is possible if one of the two check valves separating the two nozzle leaks. The reverse situation is also possible. The same situation is possible for the loop A1 and A2 HPI/MU nozzles. The bypass lines which enter the HPI/MU lines just upstream of the loop A1 and A2 HPI/MU nozzles are also "cross-connected". With this configuration, bypass flow can be diverted to the line with the highest differential pressure

Prepared by: Cm 6/5/97

Reviewed by: DRC 6/5/97

which can occur during single RC pump operation.

TMI-1: Schematic Dwg - Figure 6-2

TMI-1 has a nominal total letdown flow of approximately 40 gpm. This varies during plant startups and cooldowns due to RCS volume and pressure changes. The TMI-1 Westinghouse RC pumps are given a seal injection of approximately 8 gpm each (total of 32 gpm) of which 3 gpm (total of 12 gpm) is returned to letdown or controlled bleedoff resulting in a total makeup to the RCS through the seals of 20 gpm. The bypass makeup flow is set while at cold shutdown to at least 3.5 gpm and the bypass flow is verified daily by operator logs. The nominal total makeup flow to the one double duty HPI/MU nozzle is approximately 20 gpm. The minimum total makeup flow through the makeup nozzle is typically 15 gpm during reactor power operation.

Figure 6-2 shows that the loop A and C HPI-only nozzles are "cross-connected" as are the loop D HPI-only and loop B HPI/MU nozzles. This means that backflow from the loop A HPI-only nozzle to the loop C HPI-only nozzle is possible if one of the two check valves separating the two nozzle leaks. The reverse situation is also possible. The same situation is possible for the loop D HPI-only and loop B HPI/MU nozzles except that there is an extra check valve upstream of the loop B HPI/MU nozzle.

CR-3: Schematic Dwg - Figure 6-3

CR-3 has a nominal total letdown flow of approximately 75 gpm. This varies during plant startups and cooldowns due to RCS volume and pressure changes. The CR-3 Byron Jackson RC pumps are given a seal injection of approximately 10 gpm each (total of 40 gpm) of which approximately 1.5 gpm (total of 6 gpm) is returned to letdown or controlled bleedoff resulting in a total makeup to the RCS through the seals of 34 gpm. The bypass flow through the needle valve is set while at cold shutdown to 15 gpm. The nominal total makeup flow to the one double duty HPI/MU nozzle is approximately 40 gpm.

Figure 6-3 shows that none of the HPI/MU nozzles are "cross-connected". Therefore, backflow from one loop to another is not a concern.

ANO-1: Schematic Dwg - Figure 6-4

ANO-1 has a nominal total letdown flow of approximately 78 gpm. This varies during plant startups and cooldowns due to RCS volume and pressure changes. The ANO-1 Byron Jackson RC pumps are given a seal injection of approximately 10 gpm each (total of 40 gpm) of which 1.75 gpm (total of 7 gpm) is returned to letdown or controlled bleedoff resulting in a total makeup to the RCS through the seals of 33 gpm. The bypass flow is set when the makeup system is placed in service. When the RCS is at low pressure, bypass flow rates of 10 to 20 gpm are typically obtained. The nominal total makeup flow to the one double duty HPI/MU nozzle varies from 35 to 45 gpm.

Figure 6-4 shows that none of the HPI/MU nozzles are "cross-connected". Therefore, backflow from one loop to another is not a concern. Prior to 1989, there was a "cross-connection" and a number of backflow events occurred. At that time, system modifications were made to eliminate the possibility of backflow.

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DB-1: Schematic Dwg - Figure 6-5

DB-1 has a nominal total letdown flow of approximately 37 gpm. This varies during plant startups and cooldowns due to RCS volume changes. The DB-1 Byron Jackson RC pumps are given a seal injection of approximately 7.5 gpm each (total of 30 gpm) of which 4.25 gpm is returned to letdown or controlled bleedoff resulting in a total makeup to the RCS through the seals of 13 gpm. The bypass flow is set while at cold shutdown to 12 gpm. The nominal total makeup flow to the one double duty HPI/MU nozzle is approximately 24 gpm.

Figure 6-5 shows that none of the HPI/MU nozzles are "cross-connected". Therefore, backflow from one loop to another is not a concern

7. Recommendations

7.1. Recommendations Made Following CR-3 Failure

The following recommendations were made in the B&WOG Safe End Task Force Report (reference 1).

1. In terms of future repairs, it is recommended that:

   Nozzles with Original Design Thermal Sleeves:

   Reroll the upstream end of the thermal sleeve when inspections indicate that a gap exists. A 5% wall reduction is suggested to achieve an adequate interfacial residual stress and avoid stress corrosion cracking of the thermal sleeve.

   Nozzles with Modified Design Thermal Sleeve:

   Repair and/or replace the damaged components if inspections reveal that abnormal conditions are present.

   In either case, the affected utility should also verify that the components attached to the safe end meet the design constraints used in the stress analysis.

2. In order to ensure proper HPI/MU system operation, it is recommended that:

   A. A continuous makeup flow via bypass of the Pressurizer Level Control Valve should be maintained.

   B. A known amount of bypass flow which is greater than 1.5 gpm should be maintained and checked frequently (increased flows of up to about 10 - 15 gpm may be preferable depending upon plant configuration and operating practices).

   C. There should be a consistent set of procedures to initiate continuous bypass flow:
      - RCS Temperature
      - RCS Pressure
      - Bypass Flow Rate
      - Frequency of adjustment and calibration

   D. The makeup tank temperature should be maintained within the proper control band as determined by other plant parameters.

   E. In the event that future anomalies are discovered, proper logging of HPI initiations will be invaluable. This procedure should include:
      - Nozzles used
      - Temperature of BWST
      - Temperature of cold leg before and after HPI initiation
      - Pressure

- Flow rate
- Duration of HPI flow

3. An augmented inservice inspection plan as stated in Section 7.2 should be implemented.

4. A detailed stress analysis of a nozzle with a modified thermal sleeve design should be performed to justify long term operation.

7.2. Recommended Augmented Inservice Inspection Plan

This recommended augmented inspection plan is taken from the B&WOG Safe End Task Force Report (reference 1).

Makeup Nozzles (HPI/MU)

1. Unrepaired Nozzles

RT during the next five refueling outages to ensure that the thermal sleeve is in the proper location and no gap exists between the thermal sleeve and the safe end. Ensure RT is comparable with "baseline" first RT taken. Perform RT every fifth refueling outage thereafter.

UT the safe end and some length of adjacent pipe/valve during the next five refueling outages to ensure no cracking. Perform UT every fifth refueling outage thereafter.

2. Repaired Nozzles (New Sleeve Design)

RT during the first refueling outage to ensure that the thermal sleeve is in the proper location and no gap has formed.

UT safe end, cold leg ID nozzle knuckle transition, and adjacent piping/valve during the first refueling outage to ensure no cracking exists.

RT and UT again at third and fifth refueling outages after repair and every fifth outage thereafter.

3. Repaired Nozzles (with re-rolling)

RT during the next five refueling outages to ensure that the thermal sleeve is in the proper location and no gap exists between the thermal sleeve and safe end. Ensure RT is comparable with "baseline" first RT taken. Perform RT every fifth refueling outage thereafter.

HPI-Only Nozzles

1. Unrepaired Nozzles

RT during the next five refueling outages to ensure that the thermal sleeve is in the proper location and no gap exists. Ensure RT is comparable with

"baseline" first RT taken. Perform RT every fifth refueling outage thereafter.

2. Repaired Nozzles (Improved Design)

   A. RT during the first refueling outage to ensure that the thermal sleeve is in the proper location and no gap has formed. RT during third and fifth refueling outages and every fifth refueling outage thereafter.

   B. UT the ID nozzle/cold leg transition knuckle area during the first refueling outage to assure that no cracking is present. UT during the third and fifth refueling outages thereafter.

3. Repaired Nozzles (with rerolled original thermal sleeve design)

   RT during the next five refueling outages and every fifth refueling outage thereafter to ensure a gap does not form.

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Reviewed by: DRC 6/5/97

7.3. Basis for Recommended Inspections

Note that this is historical information provided for background only.

Makeup Nozzles (HPI/MU)

1. Unrepaired Nozzles

The RT was required to verify the thermal sleeve was still in expansion contact and at its original location with respect to the nozzle safe end. Comparison to baseline results was to be reviewed to determine whether the thermal sleeve was loosening.

The UT was required to search for ID initiated flaws. The UT was to cover the safe end, pipe to safe end weld, and some length of pipe upstream of the pipe to safe end weld. The UT was performed since the mechanism causing the failures in other HPI/MU nozzles requiring safe end and thermal sleeve replacement may not have been fully known.

2. Repaired Nozzles (Improved Design)

The RT was required to verify the thermal sleeve was still in roll expansion contact and at its original location with respect to the nozzle safe end. Comparison to baseline results was to be reviewed to determine whether thermal sleeve was loosening.

The UT was required to search for ID initiated flaws. The UT was to cover the nozzle to RC piping transition area, nozzle bore, safe end to nozzle weld, entire safe end, safe end to pipe weld and some length of pipe upstream of the pipe to safe end weld. Since the thermal sleeve may not have been performing its intended function for some time period, this exam was to verify damage did not occur in the areas to be protected by the thermal sleeve in addition to the purpose indicated above for unrepaired nozzles. The nozzle bores were PT examined after removal of the original thermal sleeve.

3. Repaired Nozzles (with rerolled original thermal sleeves)

The RT was required to verify the thermal sleeve was still in roll expansion contact and at its original location with respect to the nozzle safe end. Comparison to baseline results was to be reviewed to determine whether thermal sleeve was loosening.

HPI-Only Nozzles

1. Unrepaired Nozzles

The RT was required to verify the thermal sleeve was still in roll expansion contact and at its original location with respect to the nozzle safe end. Comparison to baseline results was to be reviewed to determine whether thermal sleeve was loosening.

2. Repaired Nozzles (Improved Design)

The RT was required to verify the thermal sleeve was still in roll expansion contact and at its original location with respect to the nozzle safe end. Comparison to baseline results was to be reviewed to determine whether thermal sleeve was loosening.

The UT was required to search for ID initiated flaws. The UT was to cover the nozzle to RC Piping transition area, nozzle bore and safe end to nozzle weld. Since the thermal sleeve may not have been performing its intended function for some time period, this exam was to verify damage did not occur in the areas to be protected by the thermal sleeve. The nozzle bores were PT examined after removal of the original thermal sleeve.

3. Repaired Nozzles (with rerolled original thermal sleeves)

The RT was required to verify the thermal sleeve was still in roll expansion contact and at its original location with respect to the nozzle safe end. Comparison to baseline results was to be reviewed to determine whether thermal sleeve was loosening.

7.4. Basis for Recommended Inspection Frequencies

The two most significant scenarios for the cause of the anomalies in the makeup nozzles were that 1) thermal cycling was causing fatigue damage and/or loosening of the sleeve and 2) improper initial installation of the thermal sleeve may have led to flow induced vibration and thermal events in the degraded condition not anticipated in the original design. The fatigue damage was attributed to the intermediate cycling high thermal stress conditions resulting from insufficient makeup flow or interrupted makeup flow. The solution to remedy these potential problems was to improve the make-up flow reliability, determine the extent of degradation and return the hardware to, essentially, the original design condition.

The inspection frequency and types of inspections were based on the above scenarios. The RT verification for contact of the thermal sleeve with the safe end was to verify both proper installation and the absence of loosening due to service conditions. The latter concern was not expected if makeup flow was maintained but could not be completely ruled out without the future checks for verification. UT examinations were to verify that makeup flow conditions had been established to prevent new thermal fatigue damage and that crack growth was not occurring from potential existing cracks. Thermal fatigue or crack growth was not expected if the makeup flow was maintained. The inspection period was felt to be sufficient to detect either an inadequate makeup flow or a faster acting unknown cause.

The HPI-only nozzle failure scenarios were slightly different than that of the makeup nozzle and were that 1) the isolation valve(s) for the HPI line may have been leaking resulting in thermal cycling similar to that of a makeup nozzle with inadequate flow and 2) the thermal sleeve was improperly installed or became loose under service conditions. This latter scenario would be the same as the makeup nozzle except that

the known HPI test condition could lead to temporary loosening of the thermal sleeve.

The inspections were modified for the HPI nozzle due to the lower probability that harmful thermal cycling was being caused by leaking isolation valves. The inspections were focused on the confirmation that the thermal sleeve design configuration was being maintained and UT checks were only performed for known or potential prior damage.

Prepared by: KB Stuetzy 6-5-97

Reviewed by: HBehnke 6-5-97

8. Utility Implementation of Recommendations

Oconee Units 1, 2, 3:

1. All repairs made to any of the Oconee Units 2 and 3 HPI/MU nozzles have been as recommended in reference 1. All thermal sleeve and/or safe end replacements made were as suggested in reference 1. No repairs have been required for any of the Oconee Unit 1 HPI/MU nozzles.

2. Oconee Units 1, 2 and 3 maintain a bypass flow of 3 gpm which is within the range of flows recommended in reference 1. Oconee is investigating the possibility of occurrence of reduced bypass flow rates in certain operational situations. The makeup tank temperature is maintained within the proper control band as dictated by other plant parameters.

3. Oconee Units 1, 2 and 3 implemented an augmented inservice inspection program by including the HPI/MU nozzles in their inservice inspection schedules as discussed in reference 3. Attachment 2 contains the complete inspection history for each plant.

4. Results from the stress analysis of record for the Oconee Units 1, 2 and 3 HPI/MU nozzle and safe end are discussed in Section 9.

TMI-1:

1. No repairs have been required for any of the TMI-1 HPI/MU nozzles.

2. TMI-1 maintains a bypass flow of at least 3.5 gpm which is within the range of flows recommended in reference 1. The makeup tank temperature is maintained within the proper control band as dictated by other plant parameters.

3. TMI-1 implemented an augmented inservice inspection program by including the HPI/MU nozzles in their inservice inspection schedules as discussed in reference 4. Section 5 discusses the most recent inspection and type made of each location/component of interest.

4. Results from the stress analysis of record for the TMI-1 HPI/MU nozzle and safe end are discussed in Section 9.

CR-3:

1. All thermal sleeve and safe end replacements made were as suggested in reference 1.

2. CR-3 maintains a bypass flow of 15 gpm which is within the range of flows recommended in reference 1. The makeup tank temperature is maintained within the proper control band as dictated by other plant parameters.

3. CR-3 included the HPI/MU nozzles in their augmented inservice inspection schedule as discussed in reference 5. Section 5 discusses the most recent inspection and type made of each location/component of interest.

4. Results from the stress analysis of record for the CR-3 HPI/MU nozzle and safe end are discussed in Section 9.

ANO-1:

1. All repairs made to any of the ANO-1 HPI/MU nozzles have been as recommended in reference 1. All thermal sleeve and/or safe end replacements made were as suggested in reference 1.

2. ANO-1 maintains a bypass flow of at least 8 gpm which is within the range of flows recommended in reference 1. The makeup tank temperature is maintained within the proper control band as dictated by other plant parameters.

3. ANO-1 implemented an augmented inservice inspection program by including the HPI/MU nozzles in their inservice inspection schedules as discussed in reference 6. Section 5 discusses the most recent inspection and type made for each location/component of interest.

4. Results from the stress analysis of record for the ANO-1 HPI/MU nozzle and safe end are discussed in Section 9.

DB-1:

1. All repairs made to any of the DB-1 HPI/MU nozzles have been as recommended in reference 1. All thermal sleeve and/or safe end replacements made were as suggested in reference 1.

2. DB-1 maintains a bypass flow of 12 gpm which is within the range of flows recommended in reference 1. The makeup tank temperature is maintained within the proper control band as dictated by other plant parameters.

3. DB-1 implemented an augmented inservice inspection program by including the HPI/MU nozzles in their inservice inspection schedules as discussed in reference 7. Section 5 discusses the most recent inspection and type made of each location/component of interest. In the augmented inservice inspection plan, DB-1 committed to inspect the HPI/MU nozzles as recommended in reference 1 with the following exception (reference 17):

   Radiographic examination (RT) would be done during the second, third, fifth and seventh refueling outages and every fifth refueling outage thereafter.

   Note that, as listed in Table 3, DB-1 has recently completed a full inspection sequence of all four of the HPI/MU nozzles at the plant. Those inspections found no abnormal indications.

4. Results from the stress analysis of record for the DB-1 HPI/MU nozzle and safe end are discussed in Section 9.

Prepared by: CMM 6/5/97

Reviewed by: DRC 6/5/97

9. Design Basis

9.1. Stress/Fatigue Analysis

The stress analysis of record for each plant was reviewed to determine the limiting cumulative usage factor for each nozzle. Input to those analyses included specific transients for the HPI/MU nozzles and the HPI-only nozzles. The design basis transients for each plant are discussed below and may be found in references 23 - 27. Table 8 provides the usage factor for each of the HPI-only nozzles for each applicable significant transient and the design basis number of cycles for that transient along with the cumulative fatigue usage factor.

HPI/MU System Design Transients

The double-duty HPI/MU nozzles for each of the B&WOG plants are designed for the following heatup, cooldown and normal operation transients of the HPI/MU system as well as other upset, emergency and faulted transients. Note that none of the normal or upset level transients considered in the design basis stress analyses result in significant cumulative fatigue usage factor for the double-duty HPI/MU nozzles.

Transient 1A/(B):	Heatup(Cooldown) 70 F to 8%(8% to 70 F)
Transient 2A(B):	Heatup(Cooldown) 0% to 15% (15% to 0%)
Transient 3(4):	Heatup(Cooldown) 8% to 100%(100% to 8%)
Transient 20A:	Miscellaneous Makeup Transients
Transient 20B:	Miscellaneous Makeup Transients

The double-duty HPI/MU nozzles were not considered to have a cycling frequency during heatup or cooldown. These were considered as 1 cycle per heatup/cooldown event in which the makeup temperature did not change significantly; only the flow rate changed. The minimum flow rate used in those events was considered to be sufficient to keep the nozzle at temperature (essentially a steady state temperature distribution). Therefore, fatigue was not a concern for heatup or cooldown.

The double-duty HPI/MU nozzles have two separate "at-power" design basis cycling periods as shown in Figure 9-1. The transient depicted in Figure 9-1 is typical of the normal operation miscellaneous transients considered in the design basis of the double-duty HPI/MU nozzles (references 23 - 27). They have a period of approximately 5 minutes and 20 minutes, respectively. The 5 minute transient is considered to occur for 4 million cycles over the design life of the plant and the 20 minute transient is considered to occur for 30000 cycles over the design life of the plant. These transients were intended to consider unknown transients such as valve cycling.

The ANO-1 HPI/MU nozzle was analyzed separately for transients caused by a backflow condition and a loss of makeup flow which led to a usage factor 0.582 (reference 11).

Recent data from the Oconee Unit 2 1997 heatup suggests that, with their current HPI/MU system configuration (See Figure 6-1), changes in minimum flow rate and RCS backflow may occur due to single RC pump operation resulting in overheating of the safe end, safe end to pipe weld and a portion of the attached piping (reference 13). Reestablishment of normal flow cools the components. This results in a thermal cycle that is not included in the design basis stress analysis.

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Reviewed by: [signature] 6/5/97

HPI System Design Transients

The HPI-only nozzles for each of the B&WOG plants are designed for the following transients of the HPI system as well as other upset, emergency and faulted transients. Inadvertent initiation of the HPI system is included in the number of design cycles.

Transient 8C:	Reactor Trip with HPI Initiation
Transient 9:	Rapid Depressurization with HPI Initiation
Transient 22:	HPI Test

Table 8 lists the individual transients for each plant and the number of cycles considered in the design basis analysis for that transient along with the applicable fatigue usage factor.

HPI System Initiations

Table 9 lists the actual number of HPI system actuations for each of the B&WOG plants. This includes inadvertent actuations, NSSS transient induced actuations and system tests.

9.2. Fracture Mechanics Analysis

Limited fracture mechanics analyses have been done for these nozzles on an as-needed basis. Davis Besse, ANO-1 and Oconee Unit 2 have had fracture mechanics analyses performed and the results are discussed below.

ANO-1:

A fracture mechanics analysis of the HPI/MU nozzle (safe end to pipe weld) was done in reference 19 to demonstrate acceptability of the nozzle for anticipated future transients per the design basis. This was done following the backflow events discussed in Section 9.1 above. The analysis was to consider the maximum undetectable flaw size (after a UT examination found no indications in 1989) and to determine the number of allowable cycles of the design basis transients. The backflow events were not considered as possible future transients due to hardware modifications made at the site. As the maximum undetectable flaw size was not established, the initial flaw size was assumed to be that portion of the pipe that was yielded due to the HPI Initiation transient which resulted in an initial flaw size of 41.7% of the wall thickness. The allowable flaw size was limited to 50% of the wall thickness. This assumption was confirmed to be reasonable since limit load analysis showed that a 55% through wall flaw was acceptable based on faulted loading. The allowable number of HPI initiation and heatup/cooldown cycles was determined to be 1225.

DB-1:

A fracture mechanics analysis of the HPI/MU nozzle (nozzle body knuckle region) was done to demonstrate acceptability of the nozzle for anticipated future transients per the design basis. This was done in response to the flaws detected after a broken thermal sleeve was found in 1988 (See Section 2.2). The analysis was to consider a bounding undetectable flaw size of 0.25 inches in depth after an enhanced UT examination found no indications greater than 0.125 inches in depth. The analysis considered the future anticipated heatup and cooldown transients to determine the number of allowable cycles. The flaw size was predicted to grow 0.096 inches in depth during the remaining life of the plant. A safety factor of 4 versus a required safety factor of 3.16 was shown for normal and upset conditions (reference 20). For emergency and faulted conditions, a safety factor of 7.6 was demonstrated on a postulated flaw of 0.28 inches in depth versus a required safety factor of 1.4 (reference 21).

Oconee Unit 3:

A fracture mechanics analysis was performed in reference 22 to establish an acceptable initial flaw size in the HPI/MU nozzle for the nozzle bore region, just outboard of the nozzle body knuckle region. This was done after a PT examination of the inside surface revealed crack-like indications, about 1.5 inches in length, in the cladding. An analysis was performed to determine an acceptable base metal flaw size that would bound the actual flaw indications. (Later UT examination showed the depth of these flaws was less than the thickness of the cladding.)

An initial base metal flaw depth of 0.50 inches was found to be acceptable per Section XI of the ASME Code, considering a 6:1 semi-elliptical flaw shape, with a total cladding plus base metal depth of 0.6875 inches and a surface length of 4.125 inches. It was shown that this flaw would grow to 0.61 inches in over 470 cycles of a bounding

Prepared by: Cm 6/5/97

Reviewed by: AD Nana 6/5/97

cooldown transient. This number of cycles included 360 design life heatup/cooldown cycles and 110 design life normal and upset HPI initiations.

Prepared by: CM 6/5/97

Reviewed by: AD Nana 6/5/97

10. Other Thermal Sleeves With Similar Designs

The pressurizer for each B&WOG plant contains contact expanded thermal sleeves in the spray line and surge line nozzles. Although the thermal sleeves in the pressurizer nozzles are installed by contact roll expansion similar to the original standard design HPI/MU thermal sleeves, the pressurizer nozzle thermal sleeves do not extend into a flow stream. The surge line thermal sleeve is held in place via a weld to the diffuser which is supported by three legs welded to the pressurizer cladding. The spray line thermal sleeve is enclosed within the piping welded to the spray nozzle. In both of these cases the pressurizer thermal sleeves are not subjected to vibratory cross flow type loads that could assist in the overall wear mechanism along the contact expansion region. Furthermore, there has not been any operating experience to indicate loose thermal sleeves or cracking of the pressurizer nozzles or safe ends. Note that there are aging management programs in place for the pressurizer nozzle and safe end components.

Prepared by: KB Stuckey 6-5-97

Reviewed by: JBehnke 6-5-97

11. Thermocouple Data

As shown in Table 10, only Oconee Unit 1, TMI-1 and ANO-1 have recorded thermocouple data on the HPI-only and/or HPI/MU lines. Table 11 provides typical values recorded at ANO-1 during "at-power" operation. Table 12 shows approximate peak thermocouple readings taken during a heatup at Oconee Unit 1. Data for TMI-1 could not be located for inclusion in this report.

12. References

B&WOG Reports

1. FTI Document No. 77-1140611-00, "B&W 177 Fuel Assembly Owner's Group Safe End Task Force Report on Generic Investigation of HPI/MU Nozzle Component Cracking".

2. FTI Document No. 47-1179998-00, "B&W 177 Fuel Assembly Owner's Group HPI/MU Nozzle Thermal Sleeve Design Assessment Report" (FTI Proprietary).

B&WOG ISI Program Documentation

Duke Power Co. Oconee 1, 2, 3 ISI Plan (See Note)

3. Oconee Third Interval Ten Year Inservice Inspection Plan

GPU TMI-1 ISI Plan (See Note)

4. GPU Inservice Inspection Program Documentation
   A. GPU Document No. TMI-1-ISI-003, Revision 22, "Second 10 Year Inservice Inspection Schedule - Augmented Examination Program".
   B. GPU Document No. TMI-1-ISI-001, Revision 22, "Second 10 Year Inservice Inspection Schedule - Component".

Florida Power Corp. CR-3 ISI Plan (See Note)

5. ASME Section XI Inspection Program - Augmented Exams

Entergy ANO-1 ISI Plan (See Note)

6. Entergy Inservice Inspection Program Documentation
   A. Entergy Document No. 5000.006, "Inservice Inspection Program Administration".
   B. Entergy Document No. 5120.200, "Inservice Inspection Program Implementation".
   C. Entergy Document No. 5120.201, "Control of Inservice Inspection Program Documents".

Toledo Edison DB-1 ISI Plan (See Note)

7. Davis Besse ISI Program Basis Document - Second 10 Year Interval

B&WOG Usage Factor Summaries

8. FTI Document No. 51-1235058-00, "Fatigue Usage Summary", Applicable to Oconee Units 1, 2 and 3 (FTI Proprietary).

9. FTI Document No. 32-1175115-02, "HPI Nozzle Analysis", Applicable to TMI-1, (FTI Proprietary).

10. FTI Document No. 51-1235060-00, "Fatigue Usage Summary", Applicable to CR-3 (FTI Proprietary).

11. FTI Document No. 32-1179820-01, "Fatigue Analysis HPI/MU Nozzles", Applicable to ANO-1 (FTI Proprietary).

Prepared by: C/M 6/5/97

Reviewed by: DRC 6/5/97

12. FTI Document No. 12-1228236-00, "DB-1 RCS Component CUF Summary", Applicable to DB-1 (FTI Proprietary).

B&WOG Customer Input

13. FTI Document No. 38-1247319-01, "ONS Info. For BWOG HPI Report".

14. FTI Document No. 38-1247318-01, "TMI-1 Info. For BWOG HPI Report".

15. FTI Document No. 38-1247316-01, "CR-3 Info. For BWOG HPI Report".

16. FTI Document No. 38-1247320-01, "ANO-1 Info. For BWOG HPI Report".

17. FTI Document No. 38-1247317-01, "DB-1 Info. For BWOG HPI Report".

Other Documents

18. FTI Document No. 51-1212842-00, "Oconee Stratif. Data - 6/90 HU", Applicable to Oconee Unit 1 (FTI Proprietary).

19. FTI Document No. 32-1178900-00, "ANO-1 HPI Nozzle Evaluation", Applicable to ANO-1 (FTI Proprietary).

20. FTI Document No. 32-1172763-00,01,02,03,04, "HPI Nozzle Flaw Evaluation", Applicable to DB-1 (FTI Proprietary).

21. FTI Document No. 32-1173039-00,01,02, "HPI Nozzle Flaw Evaluation for Emergency/Faulted Conditions", Applicable to DB-1 (FTI Proprietary).

22. FTI Document No. 32-5000178-00, "Makeup/HPI Nozzle Bore Flaw Evaluation", Applicable to Oconee Unit 3.

RCS Functional Specifications

23. FTI Document 18-1130828-04, "RCS Functional Spec.", Oconee Units 1, 2 and 3.

24. FTI Document 18-1173549-02, "RCS Functional Spec.", TMI-1.

25. FTI Document 18-1005812-03, "RCS Functional Spec.", CR-3.

26. FTI Document 18-1173987-02, "RCS Functional Spec. for ANO-1", ANO-1.

27. FTI Document 18-1149327-01, "Functional Spec. - Reactor Coolant System", DB-1.

Prepared by: OM 6/5/97

Reviewed by: DRC 6/5/97

Nozzle Assembly Material Listing

28. FTI Document 51-5000252-00,"HPI/MU Nozzle Component Materials". (FTI Proprietary)

Nozzle Assembly Drawings

29. FTI Drawing 02-146629E-7, "Assembly & Detail for 2-1/2" Pressure Injection Nozzle", Oconee Unit 2.

30. FTI Drawing 02-131924E-9, "Assembly & Detail for 2-1/2" Pressure Injection Nozzle", Oconee Unit 1.

31. FTI Drawing 02-1130007A-4, "Thermal Sleeve", Oconee Unit 3 Loop 3A1 Replacement.

32. FTI Drawing 02-1135927A-2, "Spare Safe End", Oconee Unit 3 Loop 3A1 Replacement.

33. FTI Drawing 02-1243205E-1, "Oconee 2 & 3 HPI Nozzle Repair".

34. FTI Drawing 02-1243206D-1, "Oconee 2 & 3 HPI Thermal Sleeve Roll Expansion".

Note: These references are not retrievable from the FTI document control system. These references may be retrieved from the applicable utility's document control system. Therefore, these are valid references for this contract per FTI Procedure FTI-0402-01, Appendix 2.

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Project Manager

Table 1: Present Component Design

Plant	Loop ID	Nozzle Type	Design
Oconee 1 (Ref. 13)	A1	HPI/MU	Original SE & Dual TS, Double contact expansion
	A2	HPI/MU	Original SE & Dual TS, Double contact expansion
	B1	HPI	Original SE & Dual TS, Double contact expansion
	B2	HPI	Original SE & Dual TS, Double contact expansion
Oconee 2 (Ref. 13)	A1	HPI/MU	Original SE & TS (Leak at Pipe to Safe End weld - 1997), Contact expansion
	A2	HPI/MU	New SE & TS (1982), Hard roll
	B1	HPI	Original SE & TS rerolled outboard end (1982), Hard roll
	B2	HPI	Original SE bored, new TS installed (1982), Hard roll
Oconee 3 (Ref. 13)	A1	HPI/MU	Original SE & TS (Cracks and wear in TS and SE discovered - 1997), Contact expansion
	A2	HPI/MU	New SE & TS (1982), Hard roll
	B1	HPI	Original SE & TS rerolled outboard end (1982), Hard roll
	B2	HPI	Original SE & TS, Contact expansion
TMI-1 (Ref. 14)	A	HPI	Original Alloy 600 SE & TS, Contact expansion
	B	HPI/MU	Original Alloy 600 SE & TS, Contact expansion
	C	HPI	Original Alloy 600 SE & TS, Contact expansion
	D	HPI	Original Alloy 600 SE & TS, Contact expansion
CR-3 (Ref. 15)	A1	HPI/MU	New SE & TS (1982), Hard roll
	A2	HPI	New SE & TS (1996), Hard roll
	B1	HPI	New SE & TS (1996), Hard roll
	B2	HPI	New SE & TS (1994), Hard roll
ANO-1 (Ref. 16)	A	HPI	New SE & TS (1982), Hard roll
	B	HPI	Original SE & TS (TS rerolled outboard end (1982)), Hard roll
	C	HPI	Original SE & TS, Contact expansion
	D	HPI/MU	New SE & TS (1982), Hard roll
DB-1 (Ref. 17)	A1	HPI	New SE & TS (1988) - Formerly HPI/MU nozzle, MU removed after 1988 damage, Hard roll
	A2	HPI/MU	New SE & TS (1988) - No damage to original, MU since 1988, Hard roll
	B1	HPI	Original SE & TS, Original hard roll
	B2	HPI	Original SE & TS, Original hard roll

Prepared by: CM 6/5/97

Reviewed by: DRC 6/5/97

Table 2: HPI/MU Nozzle Component Materials (Reference 28)

Plant	Loop ID	Nozzle Type	Thermal Sleeve	Safe End	Nozzle	Safe End to Nozzle Weld	Safe End to Pipe Weld	Attached Pipe/Valve
Oconee 1	A1	HPI/MU	ASTM A-336 Cl. F8M	ASTM A-336 Cl. F8M	ASTM A-105 Grade II	NiCrFe	Stainless Steel	SA-376 TP 316H
	A2	HPI/MU	ASTM A-336 Cl. F8M	ASTM A-336 Cl. F8M	ASTM A-105 Grade II	NiCrFe	Stainless Steel	SA-376 TP316H
	B1	HPI	ASTM A-336 Cl. F8M	ASTM A-336 Cl. F8M	ASTM A-105 Grade II	NiCrFe	Stainless Steel	SA-376 TP316H
	B2	HPI	ASTM A-336 Cl. F8M	ASTM A-336 Cl. F8M	ASTM A-105 Grade II	NiCrFe	Stainless Steel	SA-376 TP316H
Oconee 2	A1	HPI/MU	ASTM A-336 Cl. F8M	ASTM A-336 Cl. F8M	ASTM A-105 Grade II	NiCrFe	Stainless Steel	SA-376 TP316
	A2	HPI/MU	ASME SA-479 TP 316	ASME SA-479 TP 316	ASTM A-105 Grade II	NiCrFe	Stainless Steel	SA-376 TP316
	B1	HPI	ASTM A-336 Cl. F8M	ASTM A-336 Cl. F8M	ASTM A-105 Grade II	NiCrFe	Stainless Steel	SA-376 TP316
	B2	HPI	ASME SA-479 TP 316	ASTM A-336 Cl. F8M	ASTM A-105 Grade II	NiCrFe	Stainless Steel	SA-376 TP316

Prepared by: Gm 6/5/97

Reviewed by: JDa 6/5/97

Table 2: HPI/MU Nozzle Component Materials (Reference 28) - continued

Plant	Loop ID	Nozzle Type	Thermal Sleeve	Safe End	Nozzle	Safe End to Nozzle Weld	Safe End to Pipe Weld	Attached Pipe/Valve
Oconee 3	A1	HPI/MU	ASTM A-336 Cl. F8M	ASTM A-336 Cl. F8M	ASTM A-105 Grade II	NiCrFe	Stainless Steel	SA-376 TP 316
	A2	HPI/MU	ASME SA-479 TP 316	ASME SA-479 TP 316	ASTM A-105 Grade II	NiCrFe	Stainless Steel	SA-376 TP 316
	B1	HPI	ASTM A-336 Cl. F8M	ASTM A-336 Cl. F8M	ASTM A-105 Grade II	NiCrFe	Stainless Steel	SA-376 TP 316H
	B2	HPI	ASTM A-336 Cl. F8M	ASTM A-336 Cl. F8M	ASTM A-105 Grade II	NiCrFe	Stainless Steel	SA-376 TP 316H
TMI-1	A	HPI	ASTM A-336 Cl. F8M	ASME SB-166 (Alloy 600)	ASTM A-105 Grade II	NiCrFe	NiCrFe	A-351 CF8M
	B	HPI/MU	ASTM A-336 Cl. F8M	ASME SB-166 (Alloy 600)	ASTM A-105 Grade II	NiCrFe	NiCrFe	A-351 CF8M
	C	HPI	ASTM A-336 Cl. F8M	ASME SB-166 (Alloy 600)	ASTM A-105 Grade II	NiCrFe	NiCrFe	A-351 CF8M
	D	HPI	ASTM A-336 Cl. F8M	ASME SB-166 (Alloy 600)	ASTM A-105 Grade II	NiCrFe	NiCrFe	A-351 CF8M

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Table 2: HPI/MU Nozzle Component Materials (Reference 28) - continued

Plant	Loop ID	Nozzle Type	Thermal Sleeve	Safe End	Nozzle	Safe End to Nozzle Weld	Safe End to Pipe Weld	Attached Pipe/Valve
CR-3	A1	HPI/MU	SA-479 TP316	SA-479 TP316	ASTM A-105 Grade II	NiCrFe	Stainless Steel	SA-312 TP 316
	A2	HPI	SA-479 TP316	SA-479 TP316	ASTM A-105 Grade II	NiCrFe	Stainless Steel	SA-312 TP 316
	B1	HPI	SA-479 TP316	SA-479 TP316	ASTM A-105 Grade II	NiCrFe	Stainless Steel	SA-312 TP 316
	B2	HPI	SA-479 TP316	SA-479 TP316	ASTM A-105 Grade II	NiCrFe	Stainless Steel	SA-312 TP 316
ANO-1	A	HPI	ASME SA-479 TP 316	ASME SA-479 TP 316	ASTM A-105 Grade II	NiCrFe	Stainless Steel	A-403 WP 316
	B	HPI	ASTM A-336 Cl. F8M	ASTM A-336 Cl. F8M	ASTM A-105 Grade II	NiCrFe	Stainless Steel	A-403 WP 316
	C	HPI	ASTM A-336 Cl. F8M	ASTM A-336 Cl. F8M	ASTM A-105 Grade II	NiCrFe	Stainless Steel	A-403 WP 316
	D	HPI/MU	ASME SA-479 TP 316	ASME SA-479 TP 316	ASTM A-105 Grade II	NiCrFe	Stainless Steel	A-403 WP 316

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Table 2: HPI/MU Nozzle Component Materials (Reference 28) - continued

Plant	Loop ID	Nozzle Type	Thermal Sleeve	Safe End	Nozzle	Safe End to Nozzle Weld	Safe End to Pipe Weld	Attached Pipe/Valve
DB-1	A1	HPI	ASME SA-336 Cl. F316	ASME SA-336 Cl. F316	ASTM A-105 Grade II	NiCrFe	Stainless Steel	SA-403 WP 316
	A2	HPI/MU	ASTM A-336 Cl. F8M	ASTM A-336 Cl. F8M	ASTM A-105 Grade II	NiCrFe	Stainless Steel	SA-403 WP 316
	B1	HPI	ASTM A-336 Cl. F8M	ASTM A-336 Cl. F8M	ASTM A-105 Grade II	NiCrFe	Stainless Steel	SA-403 WP 316
	B2	HPI	ASME SA-336 Cl. F316	ASME SA-336 Cl. F316	ASTM A-105 Grade II	NiCrFe	Stainless Steel	SA-403 WP 316

Prepared by: Cm 6/5/97

Reviewed by: JJa 6/5/97

Table 3: Recent Clear Inspections

Plant	Loop ID	Nozzle Type	Latest Clear Inspection, Type, Component
TMI-1 (Ref. 14)	A	HPI	1990: SE to Valve - UT, PT TS - RT 1991: TS - Visual 1993: SE to Valve - PT SE to Nozzle - UT & PT 1995: SE to Nozzle - UT
	B	HPI/MU	1988: TS - Visual 1990: SE to Valve - UT, PT 1991: TS - Visual 1993: TS - RT 1995: SE to Nozzle - UT, PT SE to Valve - PT
	C	HPI	1990: SE to Valve - UT, PT SE to Nozzle - UT, PT 1993: TS - RT SE to Valve - PT 1995: SE to Nozzle - UT
	D	HPI	1988: TS - RT 1990: SE to Valve - UT, PT SE to Nozzle - UT, PT TS - RT 1993: TS - Visual 1995: SE to Nozzle - UT

Table 3: Recent Clear Inspections - continued

Plant	Loop ID	Nozzle Type	Latest Clear Inspection, Type, Component
CR-3 (Ref. 15)	A1	HPI/MU	1994: TS - RT 1996: SE to Nozzle - PT
	A2	HPI	New - 1996 TS - RT
	B1	HPI	New - 1996 TS - RT
	B2	HPI	New - 1994 TS - RT
ANO-1 (Ref. 16)	A	HPI	1988: TS - Visual SE Welds - Visual 1990: SE to Nozzle - RT, UT, PT Elbow to SE - UT
	B	HPI	1988: TS - Visual SE Welds - Visual 1990: SE to Nozzle - RT, UT Elbow to SE - UT
	C	HPI	1988: TS - Visual SE Welds - Visual Elbow to SE - PT 1990: SE to Nozzle - RT, UT, PT Elbow to SE - UT
	D	HPI/MU	1988: TS - Visual SE Welds - Visual 1990: SE to Nozzle - RT, UT, PT Elbow to SE - UT, PT 1992: Elbow to SE - PT 1995: Elbow to SE - UT, PT SE to Nozzle - UT, PT

Prepared by: CM 6/5/97

Reviewed by: P.A. Gilberstadt

Table 3: Recent Clear Inspections - continued

Plant	Loop ID	Nozzle Type	Latest Clear Inspection, Type, Component
DB-1 (Ref. 17)	A1	HPI	1997: SE to Nozzle - UT Elbow to SE - UT TS - RT
	A2	HPI/MU	1997: SE to Nozzle - UT Elbow to SE - UT TS - RT
	B1	HPI	1997: SE to Nozzle - UT, PT Elbow to SE - UT TS - RT
	B2	HPI	1997: SE to Nozzle - UT, PT Elbow to SE - UT TS - RT

Table 4: Operational Characteristics

Plant	Total Normal Makeup Flow	Bypass (Warming) Flow
Oconee 1 (Ref. 13)	25 gpm / nozzle	3 gpm / nozzle
Oconee 2 (Ref. 13)	17 gpm / nozzle	3 gpm / nozzle
Oconee 3 (Ref. 13)	17 gpm / nozzle	3 gpm / nozzle
TMI-1 (Ref. 14)	20 gpm	> 3.5 gpm (Note 1)
CR-3 (Ref. 15)	40 gpm	15 gpm
ANO-1 (Ref. 16)	35 - 45 gpm	10 - 20 gpm (Note 2)
DB-1 (Ref. 17)	24 gpm	10 - 12 gpm

Note 1: Operational data attached shows makeup flow rate did not decrease below 15 gpm between 8/1988 and 1/1990. This indicates that TMI-1 is likely to be unaffected by low bypass flow rate.

Note 2: These bypass flows are measured with the RCS at low pressure giving a high differential pressure across the bypass valve. Actual operating conditions bypass flow rates are reduced (minimum 8 gpm).

Table 5 Operational Modifications Made Since 1982 CR-3 Failure

Plant	Operational Modifications
Oconee 1 (Ref. 13)	None
Oconee 2 (Ref. 13)	None
Oconee 3 (Ref. 13)	None
TMI-1 (Ref. 14)	None
CR-3 (Ref. 15)	Makeup bypass flow increased from 1 gpm to 15 gpm
ANO-1 (Ref. 16)	Makeup bypass flow increased from 1 gpm to at least 8 gpm
DB-1 (Ref. 17)	Makeup bypass flow increased to 12 gpm

Table 6 Bypass Flow Configuration

Plant	Bypass Flow Configuration
Oconee 1 (Ref. 13)	Separate line enters bottom of HPI/MU line
Oconee 2 (Ref. 13)	Separate line enters bottom of HPI/MU line
Oconee 3 (Ref. 13)	Separate line enters bottom of HPI/MU line
TMI-1 (Ref. 14)	Bypass around makeup valve
CR-3 (Ref. 15)	Bypass around makeup valve
ANO-1 (Ref. 16)	Bypass around makeup valve
DB-1 (Ref. 17)	Bypass around makeup valve

Table 7 System Modifications Made in Response to 1982 CR-3 Failure

Plant	System Modifications
Oconee 1 (Ref. 13)	None
Oconee 2 (Ref. 13)	None
Oconee 3 (Ref. 13)	None
TMI-1 (Ref. 14)	None
CR-3 (Ref. 15)	Check valves attached at the upstream end of each nozzle were relocated to reduce stresses at the safe end weld.
ANO-1 (Ref. 16)	1) Added valves, present configuration contains 3 check valves and motor operated valves to prevent RCS back leakage through HPI lines 2) Makeup flow control valve internals upgraded to prevent flow oscillations 3) Seal injection control valve internals upgraded to improve control response
DB-1 (Ref. 17)	1) Makeup flow rerouted from loop A1 to A2 2) Makeup flow control valve internals upgraded and detuned to prevent flow oscillations

Table 8 HPI Nozzle Fatigue Analysis Design Basis

Plant		Transient 8C Cycles/ Usage Factor	Transient 9 Cycles/ Usage Factor	Transient 22 Cycles/ Usage Factor	Other Transients Cycles/ Usage Factor	Cumulative Usage Factor
Oconee 1 (Ref. 8)		70 (1)/ 0.47	40/ 0.22	40/ 0.05	N/A	0.74
Oconee 2, 3 (Ref. 13)		70 (1)/ 0.56	40/ 0.25	40/ 0.07	N/A	0.88
TMI-1 (Ref. 9)		(3)		(3)	(3)	(3)
CR-3 (After 1982) (Ref. 10)		11 (2)/ (4)		40/ (4)	N/A	0.995
ANO-1 (Ref. 11)	A	110 (2)/ 0.265		40/ (6)	74378 (7) /0.495	0.76
	B	110 (2,8)/ 0.74		40/ 0.06	58698 (7)/ 0.004	0.80
	C	110 (2,8)/ 0.74		40/ 0.06	58698 (7)/ 0.004	0.80
DB-1 (Ref. 12)		40 (2,5)/ 0.513		40 (5)/ 0.114	N/A	0.627

Notes:

1. This includes 30 cycles of operating basis earthquake loads.
2. Transients 8C and 9 are considered together.
3. The "other transient" listed is a TMI-1 specific HPI test transient. The cumulative usage factors calculated for the two transients considered is determined as follows with the maximum allowable number of HPI initiations (Transients 8C, 9) being 150 and the maximum allowable number of test transients being 250.

   (Cycles of Transient 8C,9)/150 + (Cycles of Test Transient)/250 = 1.0

   As shown in Table 9, the actual number of transients that have occurred to-date are as follows:
   TMI-1 Specific HPI Tests = 72
   HPI Initiations = 2
4. The usage factor caused by the individual number of HPI Injection and Test transients was not available. The total cumulative usage factor is 0.995.
5. The cumulative usage factors calculated for the two transients considered is calculated as follows with the maximum allowable number of HPI initiations (Transients 8C, 9) being 78 and the maximum allowable number of test transients being 350.

   (Cycles of Transient 8C,9)/78 + (Cycles of Test Transient)/350 = 1.0
6. Test transients included with "other transients".
7. Includes all small backflow transients, operating basis earthquake and all piping load ranges.
8. Includes 16 large backflow transients with HPI initiation.

Prepared by: CPM 6/5/97 ~~75~~ 46 CPM

Reviewed by: [signature] 6/5/97

Table 9 HPI Tests and Initiations

Plant	HPI Initiations (1)	HPI Tests (2)
Oconee 1 (Ref. 13)	19 (5)	(5)
Oconee 2 (Ref. 13)	18 (5)	(5)
Oconee 3 (Ref. 13)	11 (5)	(5)
TMI-1 (Ref. 14)	14 (6)	72
CR-3 (Ref. 15)	(4)	(4)
ANO-1 (Ref. 16)	29	19
DB-1 (Ref. 17)	(3)	(3)

Notes:

1. HPI initiations includes inadvertent actuations and NSSS transient induced actuations.
2. HPI tests are typically performed at low temperature although the design basis stress analysis considers that these tests are performed at near-normal operating conditions. TMI-1 performs these tests at approximately 370 F and 600 psi and was analyzed for that case.
3. This information is not available as of this document's release date.
4. This information is not available as of this document's release date. It should be noted that two of the CR-3 HPI-only nozzles' thermal sleeves and safe ends were replaced in 1996 which indicates that they have had no HPI initiations or tests since replacement. The third CR-3 HPI-only nozzle's thermal sleeve and safe end was replaced in 1994 which indicates that it has had a limited number of HPI initiations and tests. The HPI/MU nozzle's thermal sleeve and safe end was replaced in 1982 but HPI initiation and test transients are not significant events for this nozzle as bypass flow is maintained at all times.
5. Oconee Units 1, 2 and 3 perform HPI system tests during outages when the RCS is at low temperature and pressure. Since these tests do not contribute to the fatigue usage of the HPI nozzles, the tests are not logged. Any tests performed at elevated temperature are considered as HPI initiations and included in that count.
6. Reference 14 indicates that there have been 2 inadvertent HPI initiations and a maximum of 12 HPI initiations. Therefore, these values are added for the total number of HPI initiations.

Table 10 Thermocouple Data

Plant	Thermocouple Data
Oconee 1 (Ref. 13)	Both HPI only lines and 1 HPI/MU line upstream and downstream of first isolation valve
Oconee 2 (Ref. 13)	Thermocouples were installed during the 1997 outage for HPI/MU nozzle repair. Data for those thermocouples are not available as of the release date of this report.
Oconee 3 (Ref. 13)	None
TMI-1 (Ref. 14)	HPI lines attached to loops A and C to determine extent of backflow. Data from these measurements can not be retrieved at this time.
CR-3 (Ref. 15)	No data subsequent to 1982 efforts.
ANO-1 (Ref. 16)	All 4 HPI/MU nozzles and each HPI line's first check valve from RCS for stratification monitoring purposes
DB-1 (Ref. 17)	None

Table 11 Typical Values of Recorded Data Taken from ANO-1 During Power Operation (Reference 16)

Location	Top Temperature (F)	Bottom Temperature (F)
Upstream of Loop A HPI Nozzle	470.8	451.2
Upstream of Loop A Check Valve	117	103.5
Upstream of Loop B HPI Nozzle	518.4	501.3
Upstream of Loop B Check Valve	124.7	112.6
Upstream of Loop C HPI Nozzle	493.2	496.2
Upstream of Loop C Check Valve	127.4	121.5
Upstream of Loop D HPI/MU Nozzle	169.5	136.4
Upstream of Loop D Check Valve	118.9	118.2

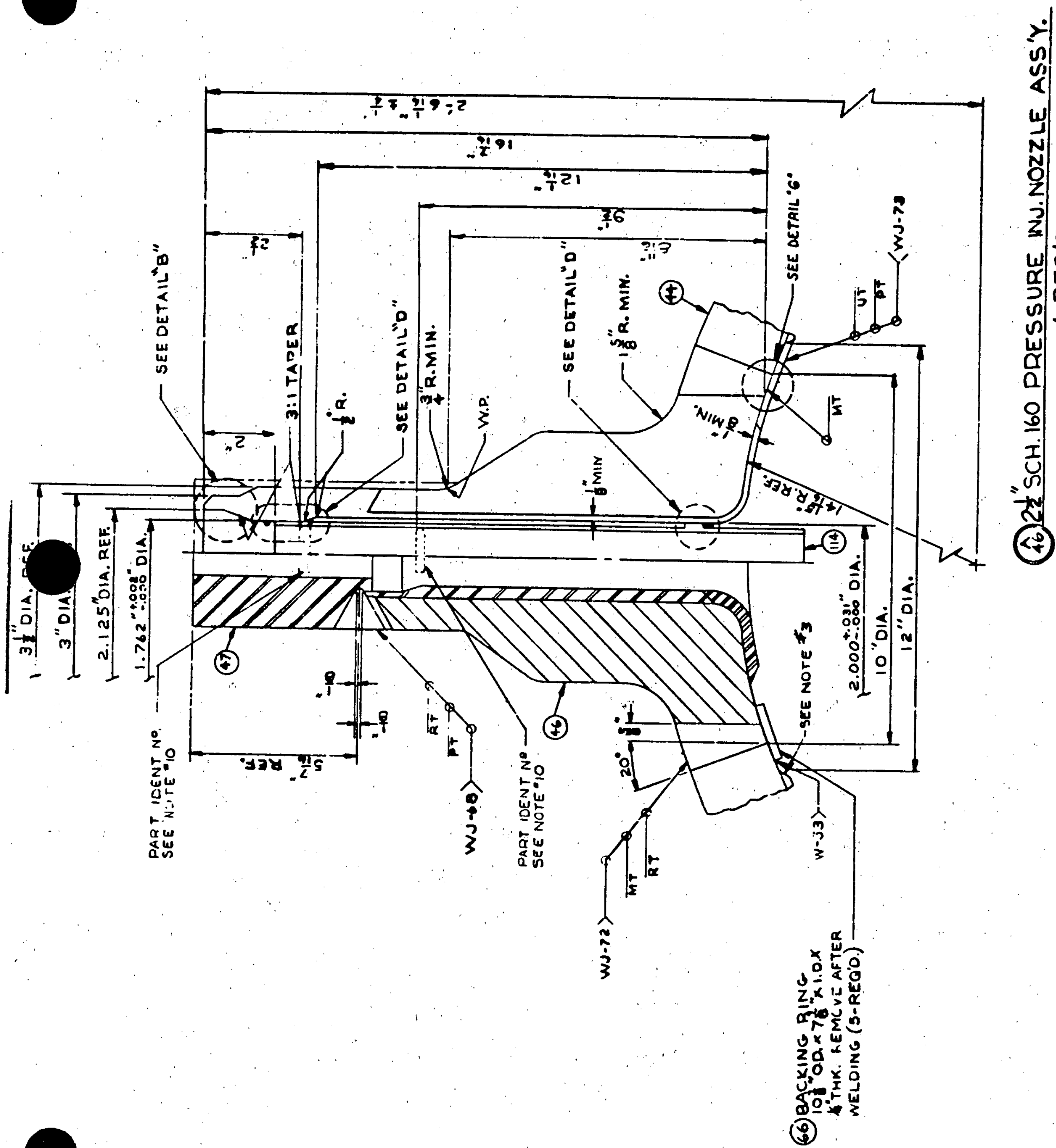
Table 12 Peak Values of Recorded Data Taken from Oconee Unit 1 During Heatup (Reference 18)

Location	Peak Temperature (F)
Upstream of Loop 1A1 HPI /MU Nozzle	480
Downstream of Loop 1A1 Check Valve	480
Upstream of Loop 1A1 Bypass Line/HPI/MU Line Connection on Bypass Line	130
Upstream of Loop 1A1 check valve	450

Prepared by: CM 6/5/97

Reviewed by: DRC 6/5/97

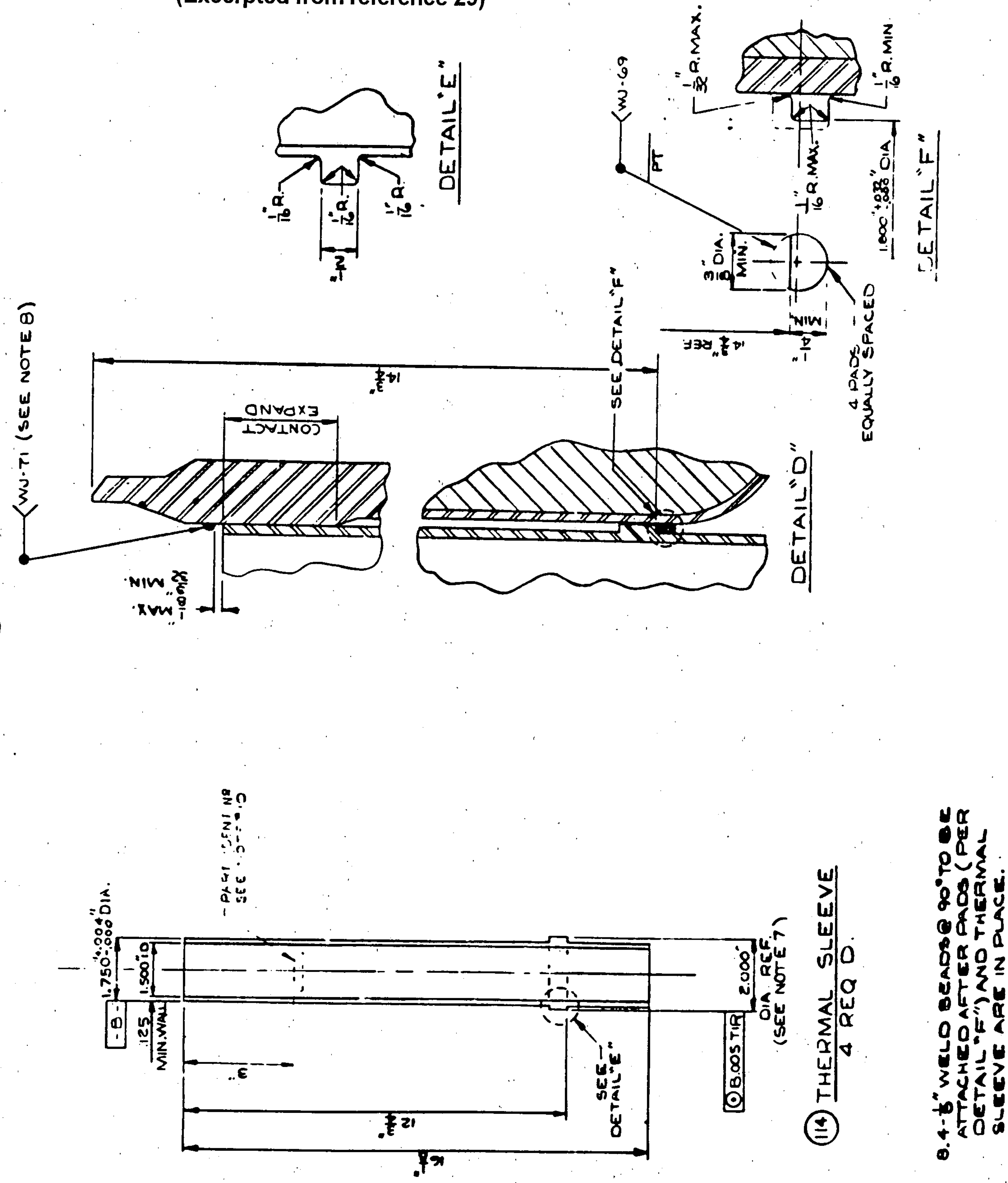
Figure 3-1 Original Standard Design HPI/MU Nozzle
(Excerpted from reference 29)



Prepared by: CJM 6/5/97

Reviewed by: DRC 6/5/97

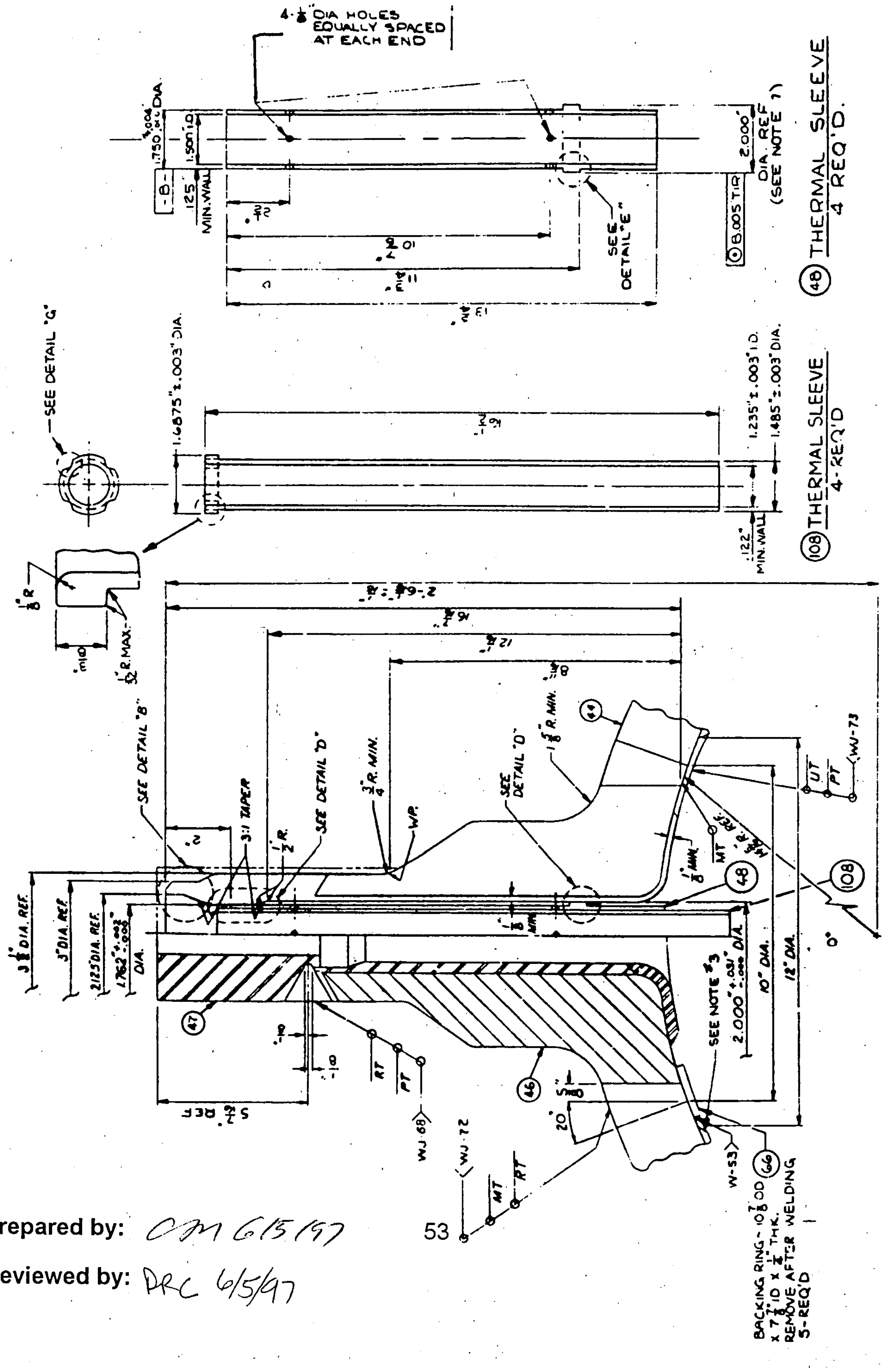
Figure 3-2 Original Standard Design HPI/MU Nozzle Thermal Sleeve Details (Excerpted from reference 29)



Prepared by: OM 6/5/97

Reviewed by: DRC 6/5/97

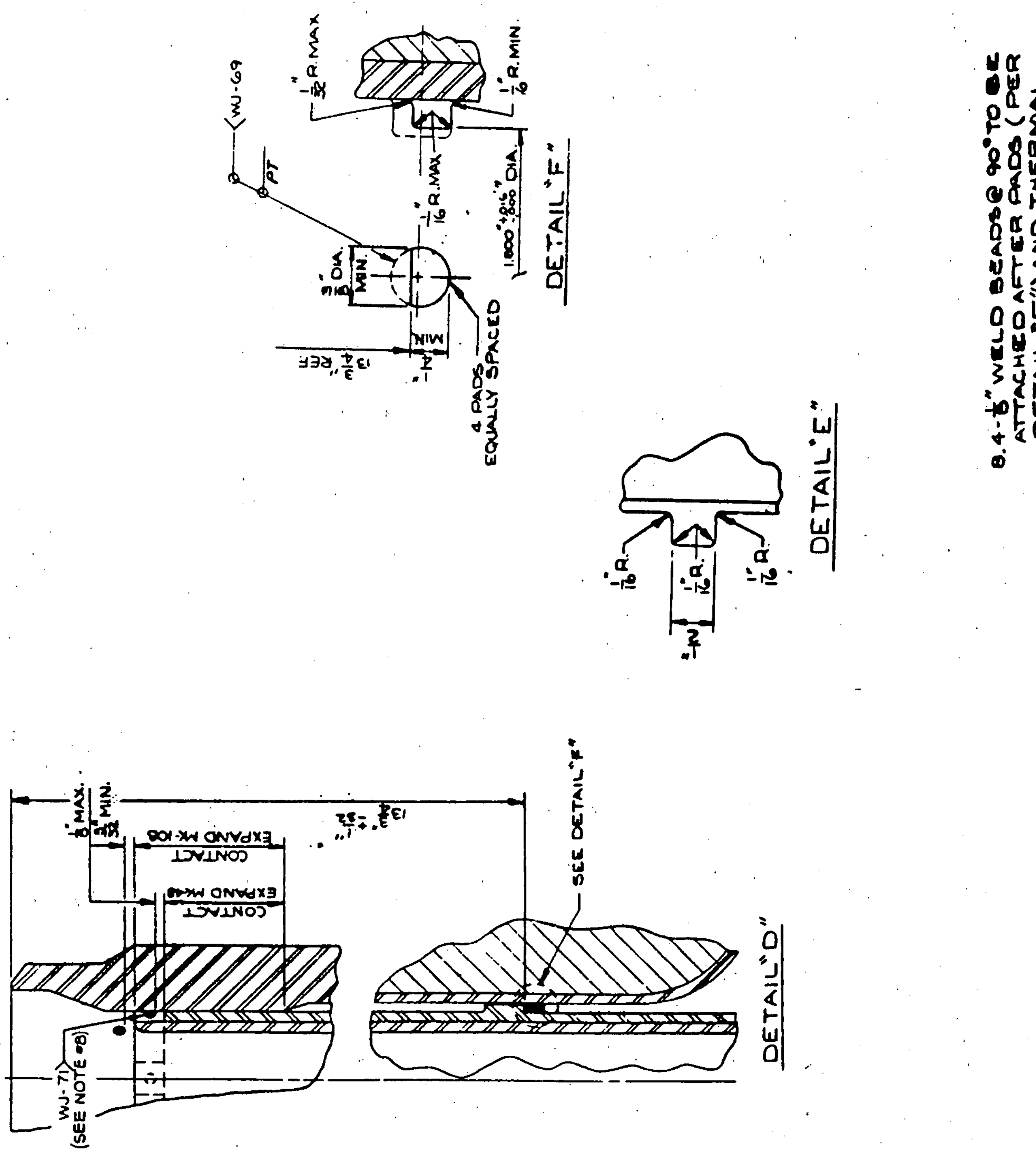
Figure 3-3 Oconee Unit 1 Double Thermal Sleeve HPI/MU Nozzle (Excerpted from reference 30)



Prepared by: CM 6/5/97

Reviewed by: RRC 6/5/97

Figure 3-4 Oconee Unit 1 Double Thermal Sleeve HPI/MU Nozzle Thermal Sleeve Details
(Excerpted from reference 30)



Prepared by: CD4 6/5/97 54

Reviewed by: DRC 6/5/97

Figure 3-5 Improved HPI/MU Nozzle Design Thermal Sleeve (Excerpted from reference 31)

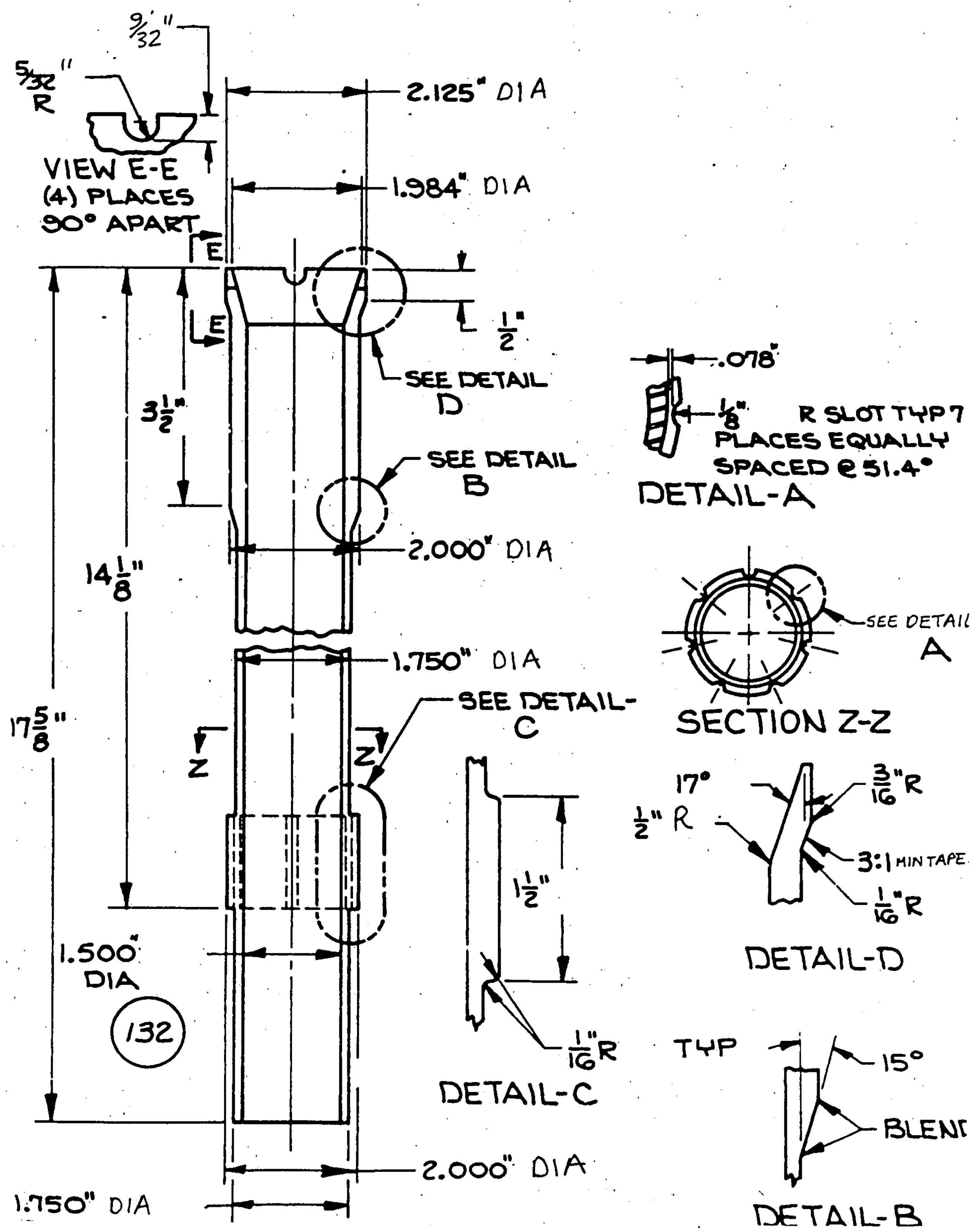
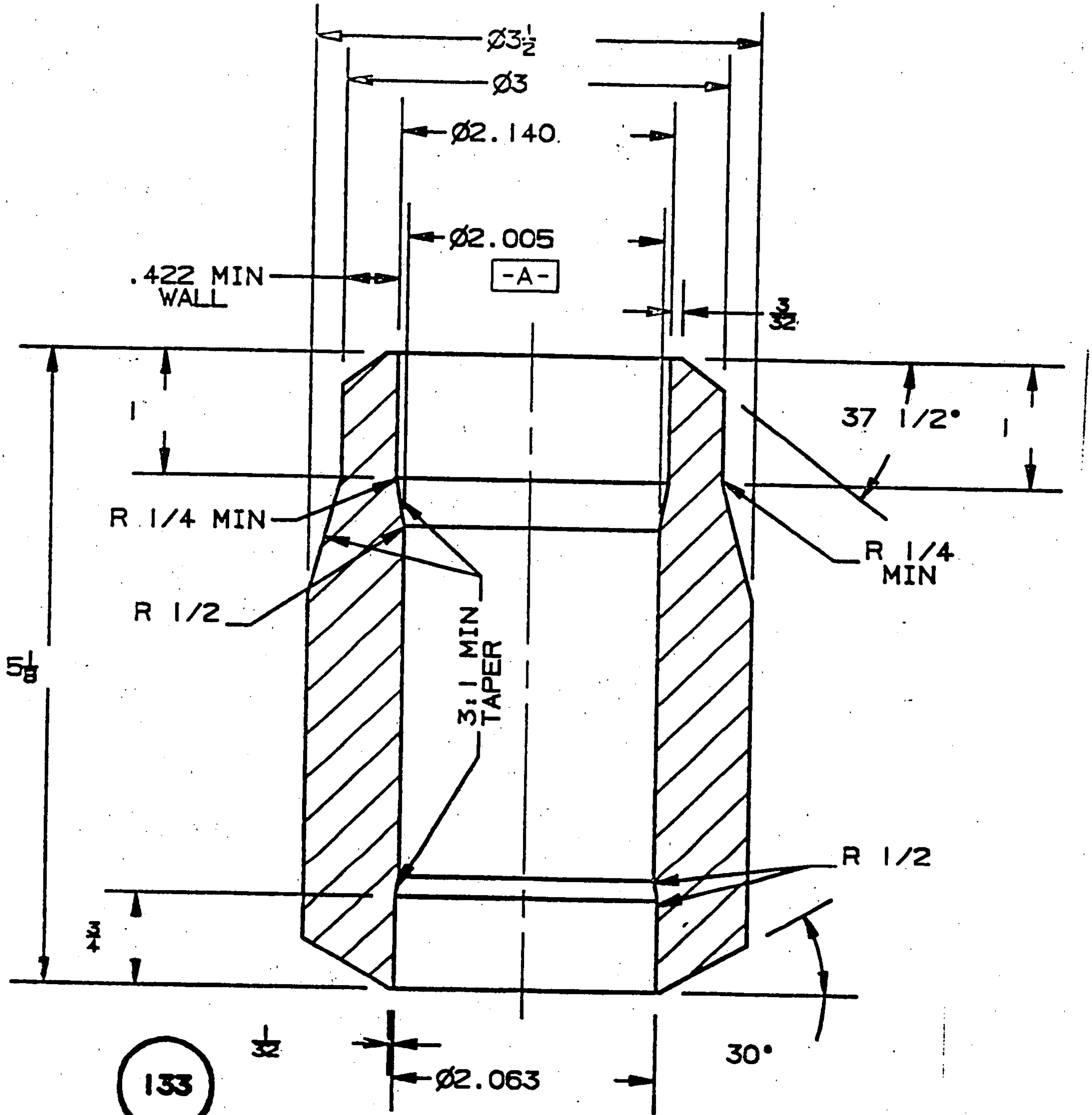


Figure 3-6 Improved HPI/MU Nozzle Design Safe End
(Excerpted from reference 32)



Prepared by: CM 6/5/97
Reviewed by: DRC 6/5/97

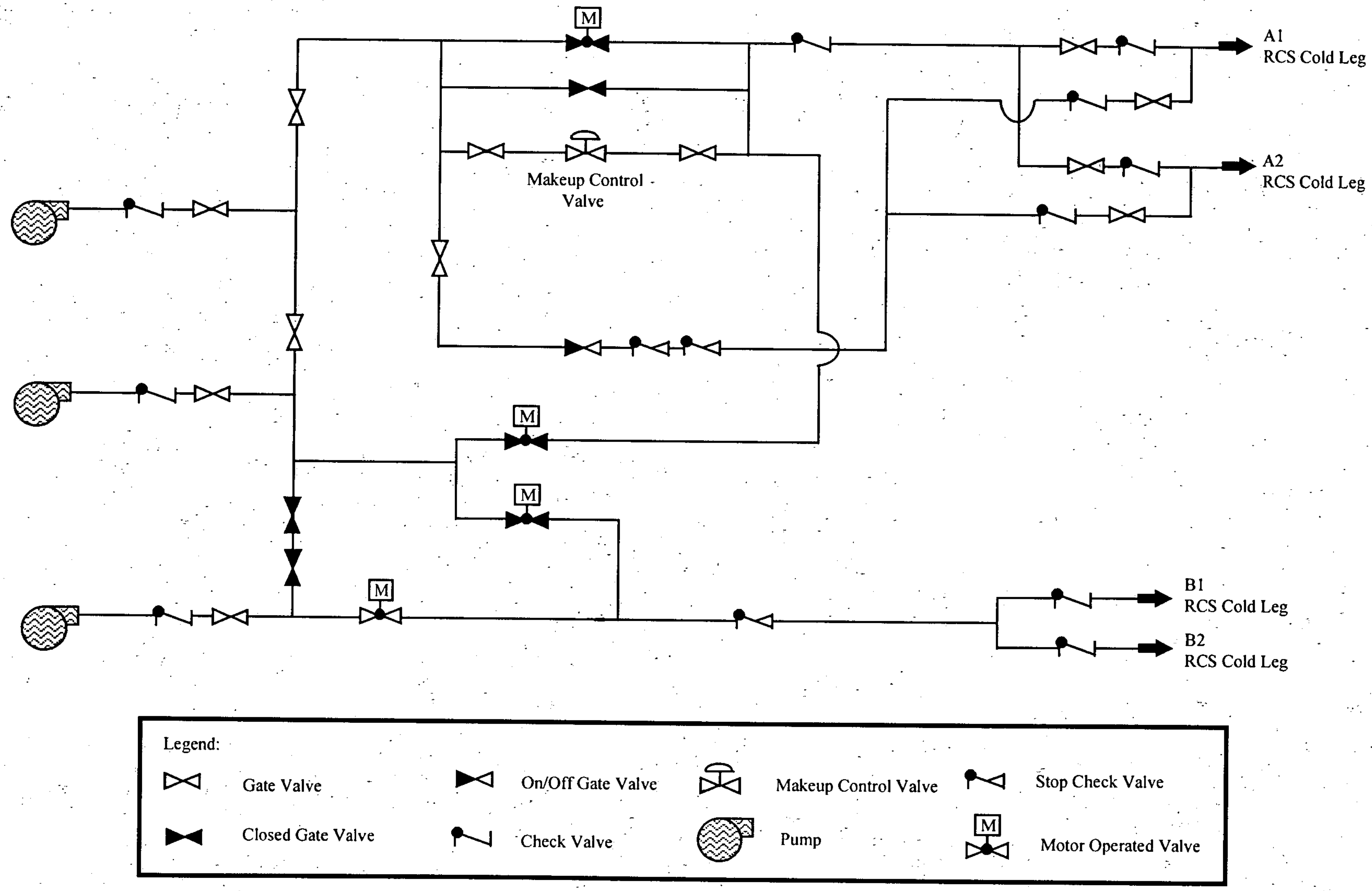


Figure 6-1 Oconee 1,2, & 3 HPI/MU System Schematic

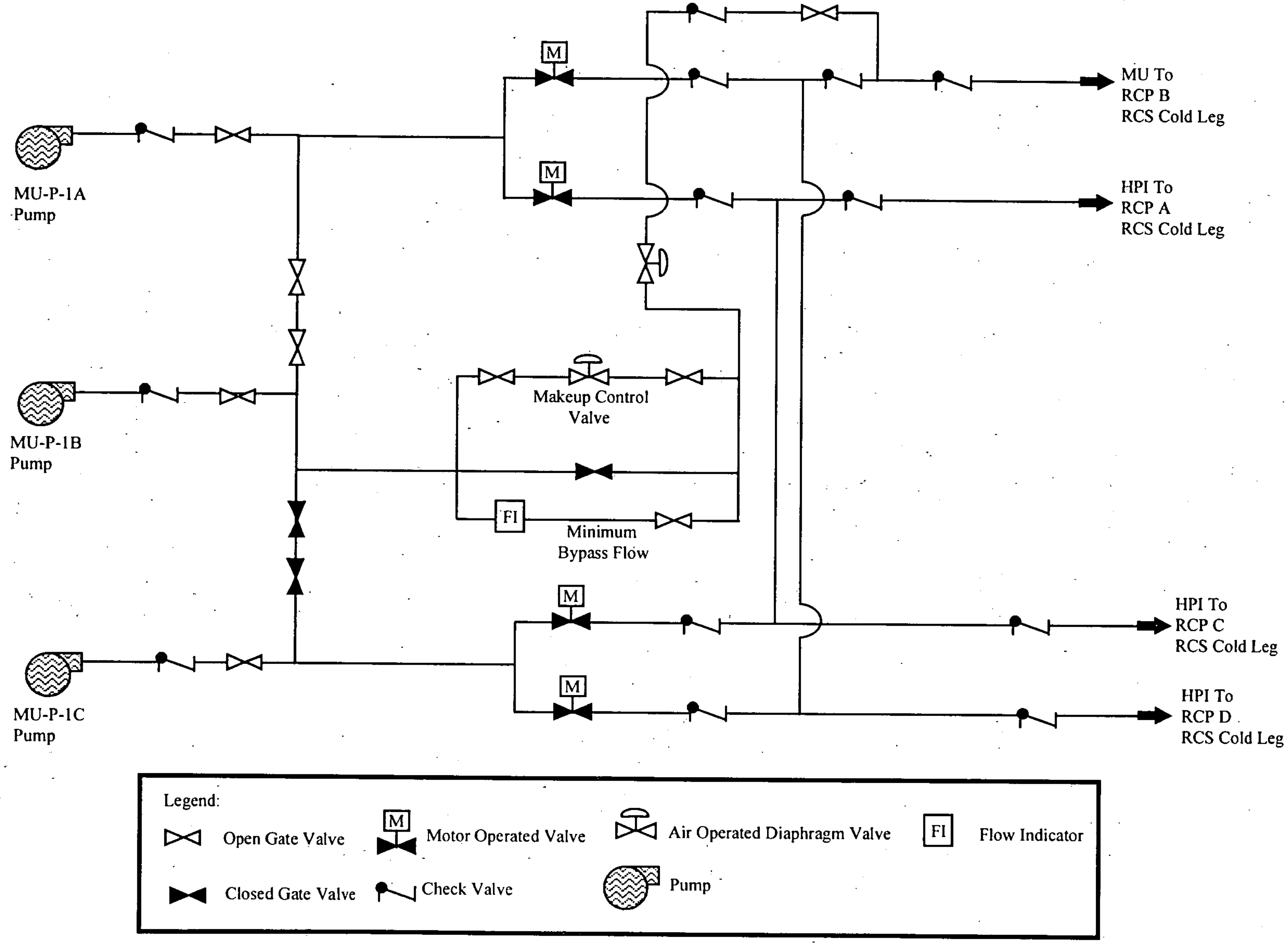


Figure 6-2 TMI 1 HPI/MU System Schematic

Prepared by: CM 6/5/97

Reviewed by: DRE 6/5/97

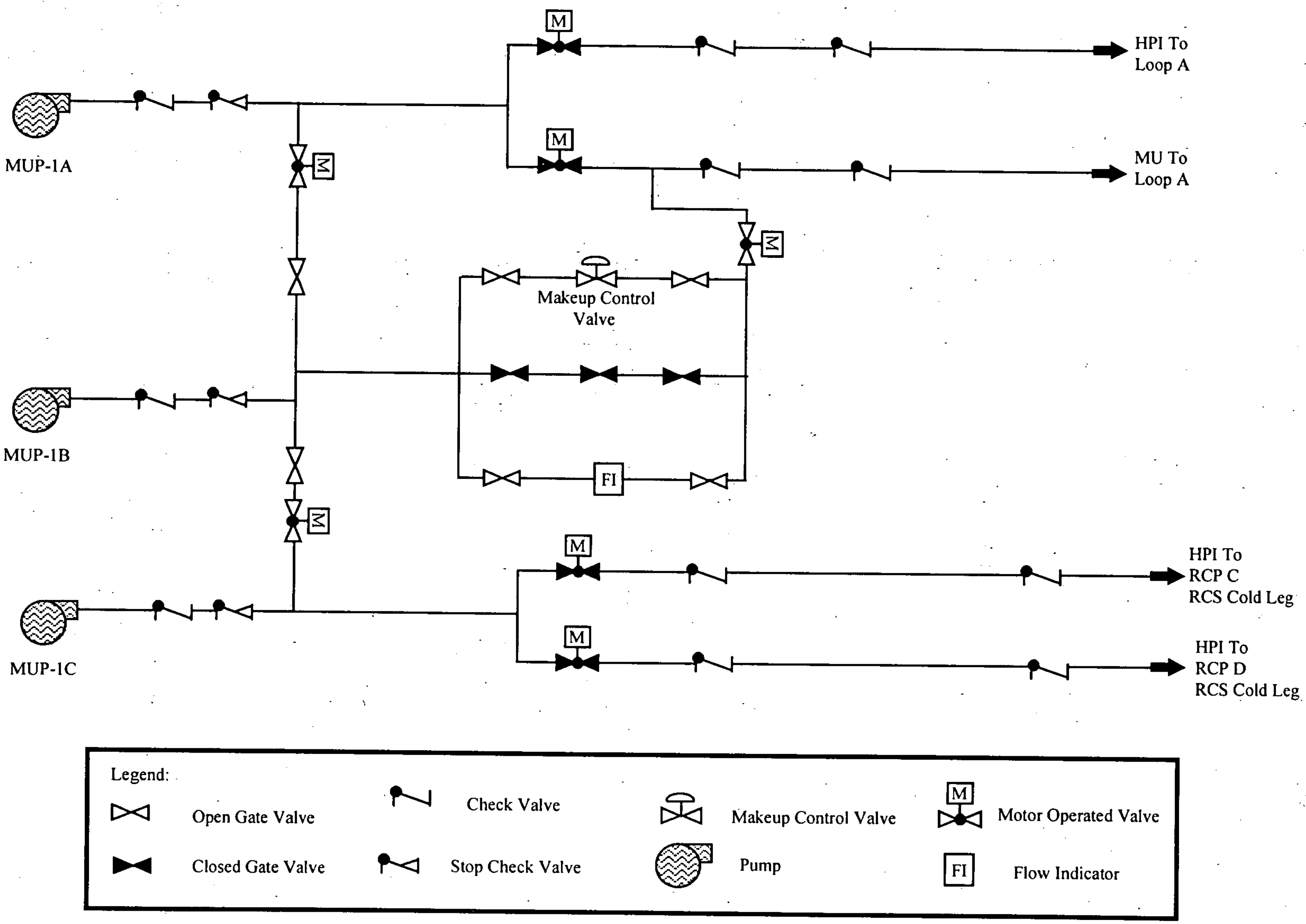


Figure 6-3 CR-3 HPI/MU System Schematic

Prepared by: [illegible] 6/5/97

Reviewed by: DRC 6/5/97

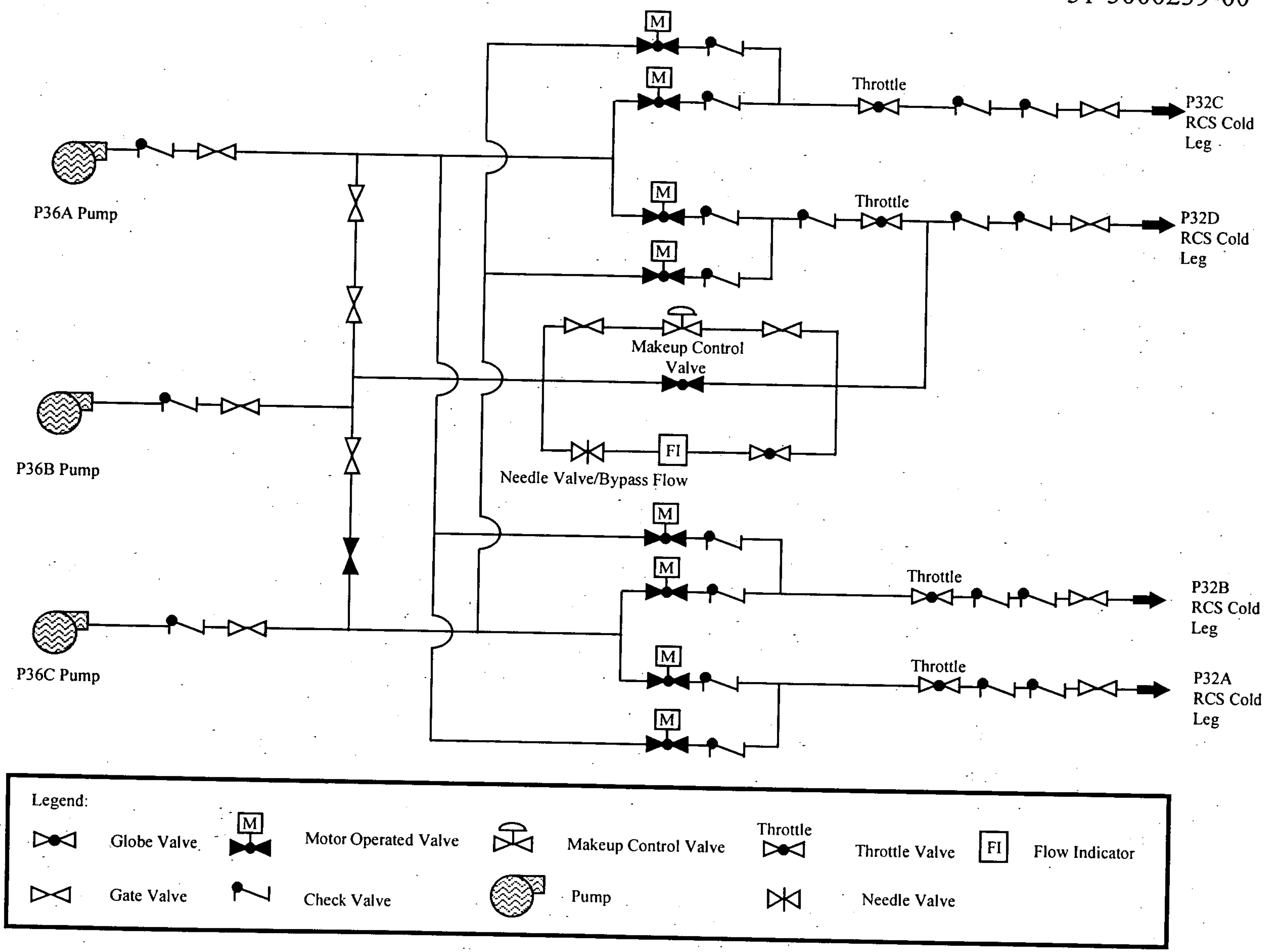


Figure 6-4 ANO-1 HPI/MU System Schematic

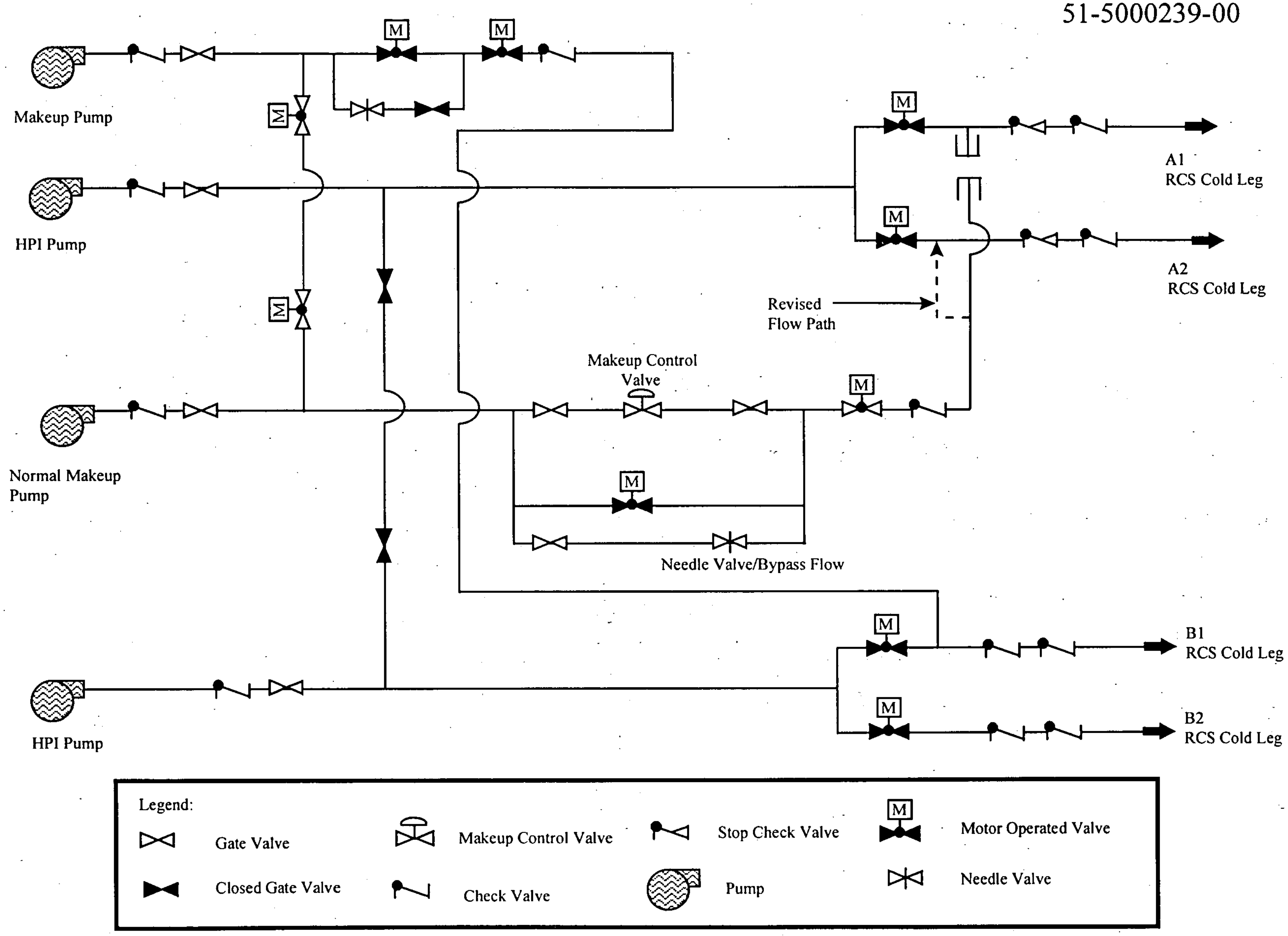
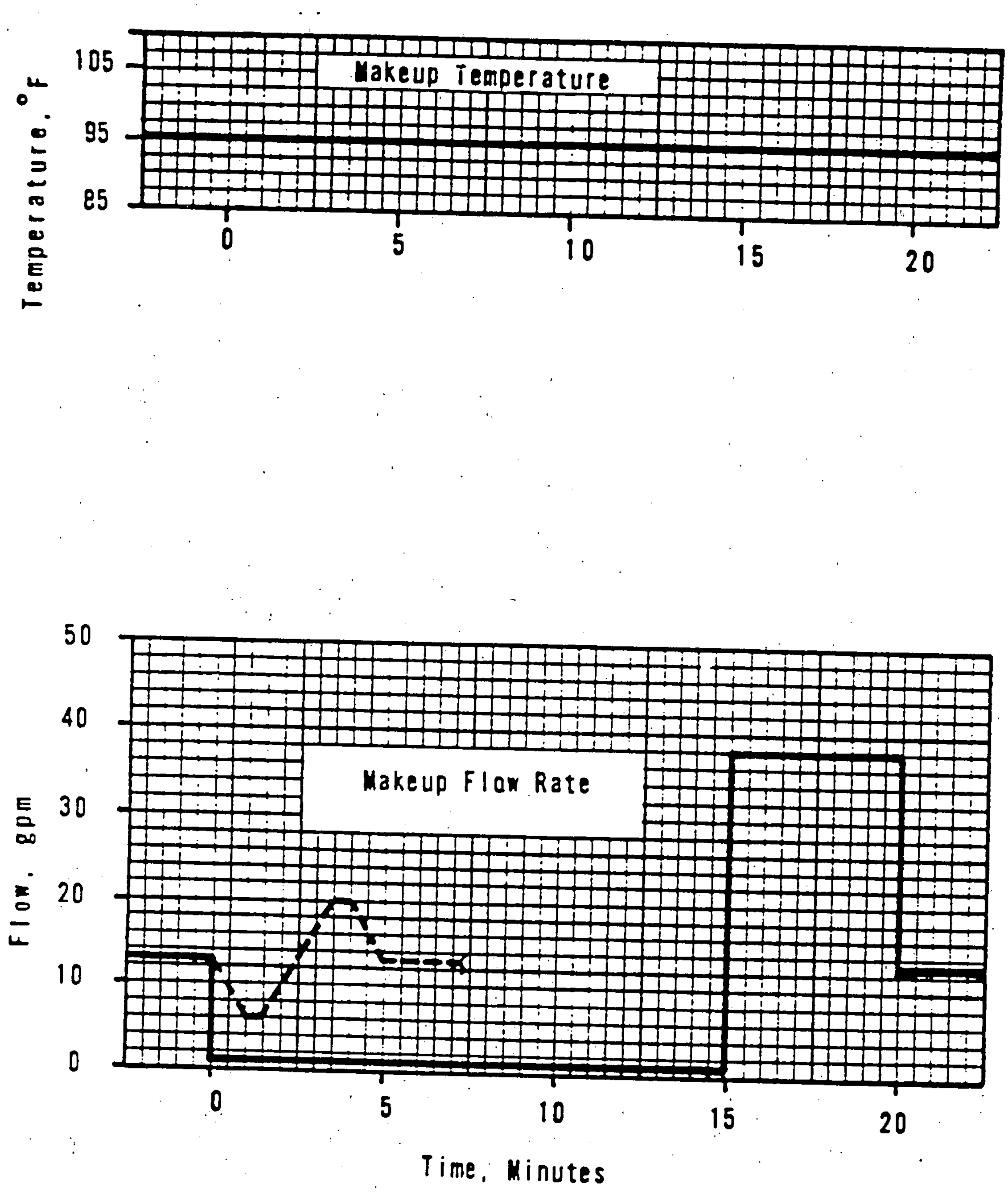


Figure 6-5 DB-1 HPI/MU System Schematic

Prepared by: [signature] 6/5/97
Reviewed by: DRC 6/5/97

Figure 9-1 Transient 20 Makeup Flow and Temperature



Prepared by: [handwritten initials] 6/5/97

Reviewed by: DRC 6/5/97

Attachment 1:

NRC Amended Request for Information Dated 5/27/97

Prepared by: CM 6/5/97

Reviewed by: DRC 6/5/97