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July 11, 1988

U.S. Nuclear Regulatory Commission
Att: Document Control Desk
Washington, D.C. 20555

Subject: Dresden Station Units 2 and 3
Quad Cities Station Units 1 and 2
Zion Station Units 1 and 2
LaSalle County Station Units 1 and 2
Byron Station Units 1 and 2
Braidwood Station Units 1 and 2
Response To NRC Bulletin 88-04
Docket Nos. 50-237/249, 50-254/265,
50-295/304, 50-373/374, 50-454/455,
50-456/457

Reference (a) NRC Bulletin No. 88-04 Dated
May 5, 1988.

Dear Sir

The above referenced NRC Bulletin requested that licensees investigate and correct as applicable two miniflow design concerns. The first concern involves the potential for the dead-heading of one or more pumps in safety-related systems that have a miniflow line common to two or more pumps or other piping configurations that do not preclude pump-to-pump interaction during miniflow operation. A second concern is whether or not the installed miniflow capacity is adequate for even a single pump in operation.

Commonwealth Edison has completed its review pursuant to the request outlined in NRC Bulletin 88-04 for Dresden, Quad Cities, Zion, LaSalle County, Byron, and Braidwood Stations. This information is attached in enclosures 1-4.

To the best of my knowledge and belief, the statements contained above are true and correct. In some respect these statements are not based on my personal knowledge, but obtained information furnished by other Commonwealth Edison employees, contractor employees, and consultants. Such information has been reviewed in accordance with company practice, and I believe it to be reliable.

IE11
1/1

Please address any questions that you or your staff may have concerning this response to this office.

Respectfully,

Wayne E Morgan

W.E. Morgan
Nuclear Licensing Administrator

rf

Attachments

cc: A.B. Davis
Resident Inspectors - D/QC/LSC/Z/BY/BW

Subscribed and Sworn to
before me this 11th day
of July, 1988

Lilia G. Mayo
Notary Public

ATTACHMENT 1
DRESDEN AND QUAD CITIES RESPONSE
TO NRC BULLETIN 88-04

This attachment provides the Dresden/Quad Cities Station's initial response to the subject NRC Bulletin. Following is the status of the six action items requested.

Item 1: Determine whether any safety related (SR) systems have minimum flow configurations that preclude pump to pump interactions.

Response: Both Dresden and Quad Cities stations have SR systems with configurations as described in the Bulletin. These are listed in the attached engineering evaluation.

Item 2: Evaluate the systems identified in action item 1. Determine if one pump could degrade to the point that it is deadheaded (through their common minimum flow line) by the other.

Response: Based upon calculations, the issue of one pump deadheading the other is not of concern to either Dresden or Quad Cities.

Item 3: Evaluate the adequacy of minimum flow bypass lines with respect to damage resulting from operation and testing in the minimum flow mode.

Response: Action is in progress, with completion expected to take about three months. A summary of actions taken to date, is included as attachment 2 to the Engineering Evaluation.

Item 4.
(a) Summarize the problems and systems affected,

(b) Identify short and long term modifications planned,

(c) Provide a schedule for long term resolutions for the Bulletin's concerns, and

(d) Provide a Justification for Continued Operation.

Response:
(a) The problems and systems affected are listed in the attached engineering evaluation.

(b) To date, no modifications have been identified as being necessary for correction of any minimum flow concern. The review which covers action item 3 may reveal the need for modifications, though this is not expected to be the case.

(c) A full modification study, typically takes six to nine months to complete. Installation of any required modifications could be accomplished over two to three operating cycles, depending principally on the extent and location of required piping changes. No firm schedule can be established until the determination is made, under action item 3, as to the nature and extent of any required modifications.

(d) Commonwealth Edison endorses the JCO provided (generically) by the BWR Owner's Group. A copy of the BWROG response is attached.

Items 5 & 6 are long term, and require no action at this time.

ENGINEERING EVALUATION

In response to NRC Bulletin No. 88-04, an engineering review was performed of the safety-related pumps for the following two concerns:

(1) Potential of deadheading a pump with a common minimum flow recirculation line
(2) Adequacy of the installed minimum flow capacities

NRC Concern (1) Deadheading Pump in Minimum Flow

Attachment 1 contains a detailed discussion of the analytical approach used to evaluate the possibility of deadheading Emergency Core Cooling System (ECCS) pumps in minimum flow mode. We conclude, based on the results of our calculations, that deadheading is not a problem for these pumps. Pump degradation of over 90% would be required to cause a pump sharing a recirculation line to deadhead.

NRC Concern (2) Minimum Flow to Prevent Damage

Attachment 2 contains a detailed discussion of the analytical approach used to evaluate the adequacy of minimum flow line capacities for ECCS pumps. We are still awaiting some vendor responses. However, the current recommendations from the pump vendors indicate that the minimum flow recirculation lines may not be sized to prevent impeller recirculation damage. This concern is currently undergoing additional review.

6. JUSTIFICATION FOR CONTINUED OPERATION

The NRC concerns stated in Reference 1 are summarized as:

1. With two pumps operating in parallel in the minimum flow mode, one of the pumps may be dead-headed resulting in pump damage or failure.

2. Installed minimum pump flows may not be adequate to preclude pump damage or failure.

These concerns are addressed by the responses below which provide the basis for concluding that continued operation of BWRs is justified.

A. The potential for pump excessive wear attributable to minimum flow operation and/or dead-heading is negligible. Pump vendors suggest minimum flow guidelines for intermittent operation, defined as less than two hours of minimum flow operation in any 24-hour period. For a plant design life of 40 years, this is equivalent to approximately 30,000 hours of low flow operation. However, system operation in the minimum flow mode is limited to pump startup during startup testing, monthly surveillance testing, and during system start on a LOCA signal. This equates to less than one percent of the 30,000 hour limit implied by pump vendors. Since dead-heading is a low flow phenomenon, the potential for dead-heading is also less than one percent of the limit.

B. BWR operating experience demonstrates that short-term operation in the minimum flow mode and/or dead-heading has little or no impact on pump life. Recent inspections of BWR RHR pumps have indicated no pump impeller excessive wear due to minimum flow. It is estimated that the pumps had been operating for up to 30 hours in the minimum flow mode in the period since the previous inspection.

There have been occurrences where pumps have been operated dead-headed inadvertantly. These pumps have continued to function normally with no apparent adverse performance effects.

C. Pump wear attributable to minimum flow and/or dead-heading is not a significant contributor to total system unavailability. Other factors (such as loss of emergency power, loss of cooling, etc.) are more significant. BWR operating history indicates no occurences of system unavailability due to pump excessive wear attributable to low flow operation

D. For the RHR and core spray pumps, the only design basis events that would lead to pumps running in the minimum flow mode and/or dead-heading are events that result in an ECCS initiation signal while the reactor is at high pressure (above the pump shutoff head). These events are normally small break LOCAs and loss of drywell cooling isolation events. Of these, only certain small break LOCAs actually require ECCS injection from LPCI or core spray after running at low flow.

Once initiated, the maximum duration that a LPCI or core spray pump may operate in the minimum flow mode for the spectrum of hypothetical LOCAs is less than 30 minutes. This is derived from postulated small break LOCAs, wherein reactor depressurization to below the shut-off head of these pumps is delayed. For large break LOCAs, where the full complement of ECC systems is more fully utilized, the reactor inherently depressurizes through the break. The present minimum flow bypass line is expected to provide adequate protection for these pumps for the short durations postulated during both the small and large break LOCAs.

For other scenarios, there is adequate time to secure the RHR and core spray pumps, and restart them as necessary, precluding extended operation in the minimum flow mode. As an example, analyses performed demonstrating compliance to 10CFR50 Appendix R have taken credit for LPCI or core spray injection several hours after a LOCA signal would have been generated. In this case, the operator would secure the RHR or core spray pumps when it is recognized that they are not immediately needed, per the plant Emergency Procedure Guidelines. The pumps would be restarted when vessel injection becomes necessary.

E. As discussed in item D above, only certain small break LOCAs actually require ECCS injection for LPCI or core spray where the pumps may be operated in the minimum flow mode. However, because of the excess ECCS capacity that is available, limiting LOCA scenarios for most BWRs do not depend on both pumps of a pair of parallel pumps to operate in order to satisfy 10CFR50.46 and 10CFR50 Appendix A, General Design Criteria 35 requirements. In fact, a realistic LOCA analysis would show that only one low pressure ECCS pump is typically necessary to satisfy core-cooling requirements during and following a LOCA. For those plants that require both pumps to operate (see section 3.2), it is demonstrated that the limiting calculated PCT would not be affected, even in the unlikely event that pump operability is affected by dead-heading.

F. Routine inspection, maintainence, and surveillance practices should detect any pump excessive wear well before system performance is degraded.

DRESDEN/QUAD CITIES

Attachment 1 - Resolution of Dead-Heading Concern of NRC Bulletin No. 88-04

NRC Bulletin No. 88-04 raises a concern that operation of two safety-related pumps with a common minimum flow recirculation line could cause one to dead head.

This concern was addressed by a flow series analysis of the ECCS pumps which share a recirculation line at Dresden and Quad Cities. The following pumps were studied:

Dresden 2 & 3	Quad Cites 1 & 2
LPCI	RHR
	Core Spray

The pumps in these systems are grouped in pairs with a common minimum flow recirculation line as depicted in Figure 1. To perform the flow series analysis, system data was compiled. Piping system walkdowns were performed at both Dresden and Quad Cities to determine the piping configurations. Trips were made to the central files at Dresden and Quad Cities to obtain pump test data for each of the 20 pumps in the above systems and to find information on pressure break-down orifices and key valves.

The following assumptions were made:

(1) Some of the Quad Cities Core Spray piping was inaccessible and could not be traced during the walkdown. Pipe routings were estimated based on an examination of the piping drawings.

(2) Details of the suppression chamber suction header were not available. The distance from the suction line header tee to the header inlet was estimated to be one quarter of the ring header circumference. Pressure losses at the header inlet strainer were approximated as 1 psi at the system design flow.

(3) There was insufficient data on valves, so standard valve loss tables were used.

(4) Each pump was found to have a pressure reduction orifice. The only orifice data available was for the Quad Cites Core Spray Pump minimum flow lines, which produces an L/D loss of 6.5/f. For other lines the orifice loss was assumed to be a similar value of 10/f.

It was found that essentially all of the system pressure losses occurred upsteam of the junction of the two minimum flow lines. As shown in Figure 1, this loss was caused by the orifice, check valve, and socket-welded elbows. Table 1 contains a summary of the flow series analysis.

Calculations indicated that a pump degradation of over 90% would have to occur before any of the ECCS pumps would dead-head. Thus dead-heading is not a problem for Dresden and Quad Cities ECCS pumps operating in the minimum flow mode.

Attachment 2 – Resolution of Impeller Recirculation Concern of NRC Bulletin No. 88-04

NRC Bulletin No. 88-04 raises a concern that minimum flow lines have been designed only to preclude temperature rise, but not to allow the higher flows necessary to prevent damaging impeller recirculation. Impeller recirculation can cause excessive vibration and cavitation and thus reduce the component's reliability and life.

The following systems were considered in the review of the impeller recirculation concern:

Dresden 2 & 3	Quad Cities 1 & 2
pumps with common recirc. line:	pumps with common recirc. line:
LPCI (Bingham)	RHR (Bingham) Core Spray (Bingham)
pumps with individual recirc. line:	pumps with individual recirc. line:
Core Spray (Bingham) Shutdown Cooling (Ingersoll-Rand) HPCI (Byron-Jackson)	HPCI (Byron-Jackson) RCIC (Bingham)

Records at the Dresden and Quad Cities central files were reviewed to find the original minimum flow requirements. In most cases (See Table 3) the minimum flow requirements had to be inferred from minimum flow initiation and alarm set points.

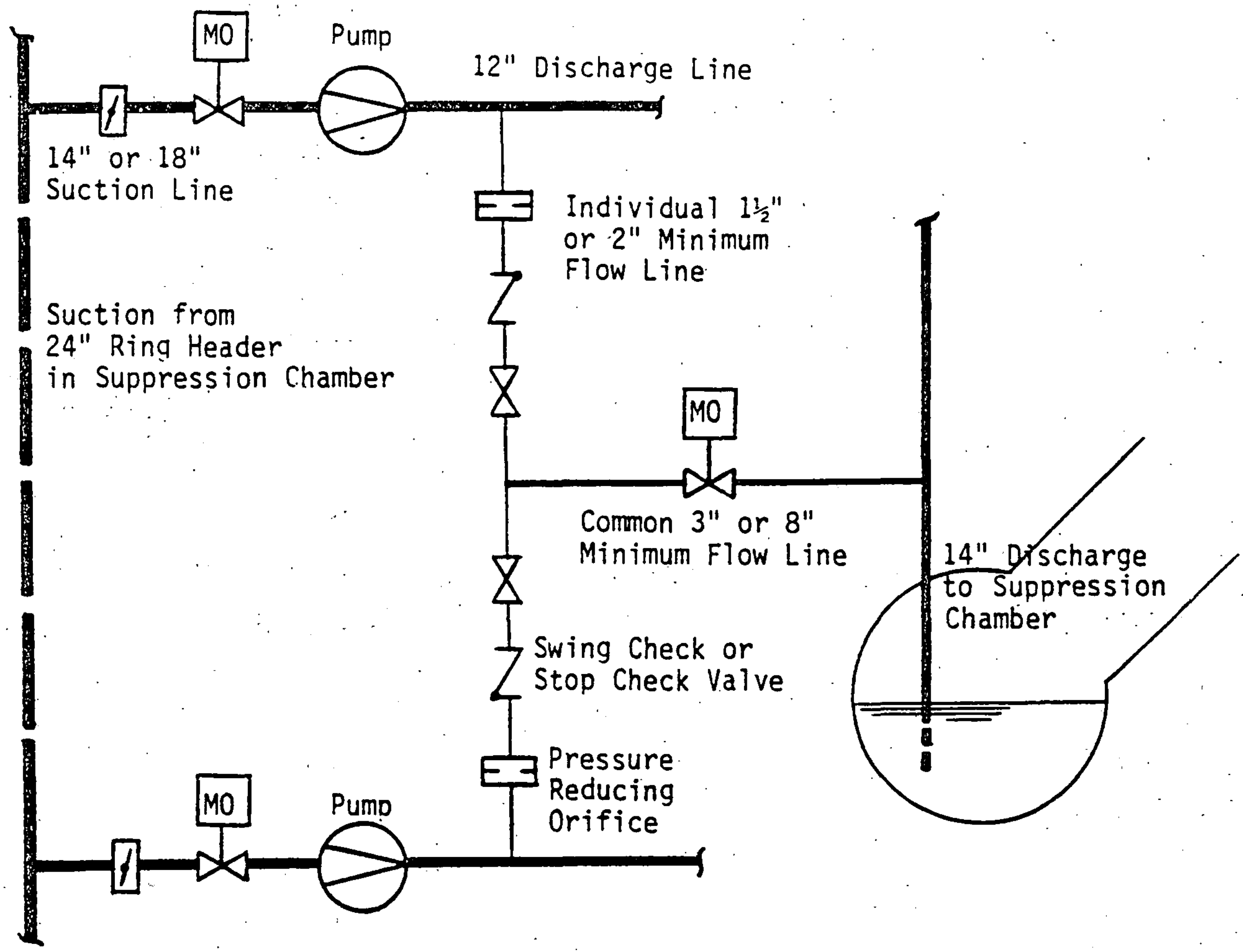
Vendors were requested to provide minimum flow recommendations which account for impeller recirculation. In developing their flow recommendations, vendors were asked to assume minimum flow operations of 30 min. duration for a total of 300 hours of operation throughout the plant life. This operational profile is consistent with Item D of the BWROG response to NRC Bulletin 88-04, dated June 7, 1988. Table 2 contains the pump identification numbers by vendor.

Table 3 lists the minimum flow information gathered to date. A comparison of the minimum flows estimated in Table 1 with the requirements in Table 3 shows that minimum flow lines are generally designed to carry the originally required minimum flow, but they may not be designed to carry the larger flows required to preclude damaging impeller recirculation.

Table 1 shows that for the pumps which share recirculation lines, the flow can be increased by 6 to 35% by removing the pressure break-down orifices.

The existence of any actual problems with impeller recirculation could be assessed if operational data logs were available on ECCS pump performance in the minimum flow mode. Preliminary information from Dresden and Quad Cities Station personnel indicate that vibration and cavitation test data on pumps in the minimum flow mode are not available. However, no major problems have been encountered to date. An engineering evaluation is currently on-going to address the impeller recirculation concern.

TYPICAL ECCS PUMP SYSTEM WITH SHARED MINIMUM FLOW LINE



Major System Pressure Losses	
Fitting	(L/D)
Orifice	6.5/f
Orifice	10.0/f
Stop Check	300
Swing Check	50
Socket-Weld 90^{0} Elbow	45

Distribution of Pressure Losses

For systems with 8" common minimum flow line, 99% of pressure loss occurs in individual mini-flow lines

For systems with 3" common minimum flow line, 70-75% of pressure loss occurs in individual mini-flow lines

FIGURE 1

TABLE 1
ECCS Pump Dead-Heading in Minimum Flow

Plant	Pump	Calculated Minimum Flow (gpm)	Calculated Minimum Flow w/o Orifice (gpm)	Maximum Allowable Degradation of Weakest Pump
Quad Cities	RHR 1A/1B	374	461	>90%
	RHR 1C/1D	385	482	>90%
	RHR 2A/2B	413	560	>90%
	RHR 2C/2D	408	537	>90%
Quad Cities	Core Spray 1A/1B	183	195	>99%
	Core Spray 2A/2B	185	198	>99%
Dresden	LPCI 2A/2B	442	567	>90%
	LPCI 2C/2D	435	547	>90%
	LPCI 3A/3B	461	601	>90%
	LPCI 3C/3D	472	619	>90%

TABLE 2

DRESDEN AND QUAD CITIES ECCS PUMPS

Bingham Pumps

Dresden - Low Pressure Core Injection Pumps
2A, 2B, 2C, 2D, 3A, 3B, 3C, and 3D - 1502
Serial Nos: 260811-260818 12x14x14 1/2 CVDS

Dresden - Core Spray Pumps
2A, 2B, 3A, and 3B - 1401
Serial Nos: 260803, 04, 08, and 10 12x16x14 1/2 CVDS

Quad Cities - Residual Heat Removal Pumps
1A, 1B, 1C, 1D, 2A, 2B, 2C, and 2D - 1002
Serial Nos: 270419-270426 12x14x14 1/2 CVDS

Quad Cities - Core Spray Pumps
1A, 1B, 2A, and 2B - 1401
Serial Nos: 260873-260876 12x16x14 1/2 CVDS

Quad Cities - Reactor Core Isolation Cooling Pump
1 and 2 - 1302
Serial Nos: 270606 and 270425 4x6x9 B MSD (5 stg)

Byron-Jackson

Dresden - High Pressure Coolant Injection Pumps
2 and 3 - 2302
Booster Pump Serial Nos: 671-S-0998 and 671-S-0999
12x14x23 DVS
Main Pump Serial Nos: 671-S-1002 and 671-S-1003
10x12x15 DVMX (2 stg)

Quad Cities - High Pressure Coolant Injection Pumps
1 and 2 - 2302
Booster Pump Serial Nos: 671-S-1000 and 671-S-1001
12x14x23 DVS
Main Pump Serial Nos: 671-S-1004 and 671-S-1005
10x12x15 DVMX (2 stg)

Ingersoll-Rand

Dresden - Shutdown Cooling Pumps
2A, 2B, 2C, 3A, 3B, and 3C - 1002
Serial Nos: 0667-112 - 0067-117 12NA

TABLE 3
ECCS PUMP MINIMUM FLOWS

Plant	Pump	Manufacturer	Original Minimum Flow Report	Revised Minimum Flow Report
Quad Cities	RHR	Bingham	150*	1350**
Quad Cities	Core Spray	Bingham	250*	1350**
Quad Cities	HPCI	Byron-Jackson	Not Available	Awaiting Vendor Response
Quad Cities	RCIC	Bingham	Not Available	Awaiting Vendor Response
Dresden	LPCI	Bingham	500*	1350**
Dresden	Core Spray	Bingham	280	1350**
Dresden	Shutdown Cooling	Ingersoll-Rand	250	Awaiting Vendor Response
Dresden	HPCI	Byron-Jackson	1200*	Awaiting Vendor Response

* Original minimum flow data was not available, so leakage alarm and minimum flow initiation set points are listed.

** Preliminary data is listed.

ATTACHMENT 2
LASALLE COUNTY STATION RESPONSE
TO NRC BULLETIN 88-04

This attachment provides the LaSalle County Station Response to the subject NRC Bulletin.

The NRC concern regarding dead-heading of one or more pumps pertains only to pumps B and C of the LaSalle RHR system. An engineering analysis has investigated the situation and found the degree of pump interaction to be minimal. All calculated minimum flow rates were found to meet the pump design specification requirements. The result of these analyses are documented in the engineering evaluation.

The bulletin's second concern, inquiring whether or not the installed minimum flow capacity was adequate, was also analyzed and found to be acceptable for all safety-related system minimum flow rates. Routinely performed operating surveillances indicate that safety-related pump degradation has not occurred in any of the applicable systems. LaSalle Station is currenly reviewing its emergency and normal operating procedures to ensure that the procedures consider securing ECCS pumps whenever it is possible for the pumps to operate at minimum flow for extended periods of time.

ENGINEERING EVALUATION

NRC Concern #1 (common minimum flow lines):

There is one occurrence for each unit where two pumps have a common minimum flow line.

A common minimum flow line is shared by RHR pumps E12-C002B and E12-C002C. Both pumps can simultaneously operate during various modes. The minimum flow rates based on both pumps operating on the pump curve and with one pump degraded based on information available from the LaSalle County Trend Analysis Document LOS-RH-01 (Quality Surveillance Inspection) has been evaluated. Each pump has a minimum flow discharge line that is individually orificed prior to the junction of the minimum flow lines. The pump to pump interaction is significantly minimized because of individual orificing. The change in flow rates is primarily due to the reduced pump discharge pressure obtained from LOS-RH-01, Quality Surveillance Inspection.

The General Electric design specification requirements require a minimum flow rate of 550 gpm for the RHR pumps. The calculated minimum flow rates are:

659 gpm - both pumps on the pump curve

579 gpm - one pump on the pump curve and one pump degraded 23% per LOS-RH-01.

The required minimum flow as confirmed by Ingersoll-Rand is 550 gpm.

NRC Concern 2: (Minimum Flow to Prevent Pump Damage)

The safety related pumps with minimum flow lines are the HPCS, LPCS, RCIC and RHR pumps. Ingersoll-Rand Corporation is the pump manufacturer for the HPCS, LPCS, and RHR pumps. Bingham-Willamette Corporation is the pump manufacturer for the RCIC pump. Both pump manufacturers were contacted when NRC Information Notice No. 87-59 was addressed. The pump minimum flow requirements are best addressed by pump manufacturer:

Bingham-Willamette
RCIC Pump 1E51-C001, 2E51-C001
Serial No. 210013/14 6X6X10-1/2B-CP 4 stage
Turbine Driven Pump

It is concluded that the 75 gpm minimum flow is acceptable, because the RCIC pump is turbine driven and operates at 75 gpm minimum flow for relatively short time periods only. This conclusion is based on the evaluation of Bingham-Willamette's recommendation of minimum continuous flow of 250 gpm and additionally General Electric's analysis that stated that the 75 gpm is acceptable based on the fact that the startup transients through minimum flow to near rated flow are normally short and the benefit of increasing the minimum flow is minimal.

Ingersoll-Rand

High Pressure Core Spray Pump
1E22-C001, 2E22-C001
Serial No. 0972-126   12X20KD-8

Low Pressure Core Spray Pump
1E21-C001, 2E21-C001
Serial No. 0273-103   29APKD-5

Residual Heat Removal Pumps
1E12-C002A,B,C; 2E12-C002A,B,C
Serial No. 1272-29/30/31   29APKD-3

Ingersoll-Rand confirmed that the current minimum flow rates for the above pumps originally supplied by General Electric are acceptable. Ingersoll-Rand based their acceptance of the GE specified minimum flow rates on the assumption that the pumps operate for short durations only at the minimum flow rates. Current industry pump design practice requires minimum flows at 25% to 50% of the best efficiency flow for extended operation. Since these pumps are operated at the GE specified minimum flows for only short durations, this limit is not applicable.

We have discussed with Ingersoll-Rand what duration of continuous operation at the specified minimum flows is acceptable. Ingersoll Rand is evaluating the issue generically and is developing an analytical model to predict pump life as a function of cumulative time spent at various flows. This model will not be available for several months.

Until further information is available from Ingersoll-Rand, the BWROG interim response to NRC Bulletin No. 88-04 justifying existing minimum flow rates will be adopted. Exhibit 1 is the BWROG justification for continued operation.

Exhibit 2 provides a tabulation of the design point, minimum flow, % of design flow, and % of the best efficiency point for the above pumps.
4913K

6. JUSTIFICATION FOR CONTINUED OPERATION

The NRC concerns stated in Reference 1 are summarized as:

1. With two pumps operating in parallel in the minimum flow mode, one of the pumps may be dead-headed resulting in pump damage or failure.

2. Installed minimum pump flows may not be adequate to preclude pump damage or failure.

These concerns are addressed by the responses below which provide the basis for concluding that continued operation of BWRs is justified.

A. The potential for pump excessive wear attributable to minimum flow operation and/or dead-heading is negligible. Pump vendors suggest minimum flow guidelines for intermittent operation, defined as less than two hours of minimum flow operation in any 24-hour period. For a plant design life of 40 years, this is equivalent to approximately 30,000 hours of low flow operation. However, system operation in the minimum flow mode is limited to pump startup during startup testing, monthly surveillance testing, and during system start on a LOCA signal. This equates to less than one percent of the 30,000 hour limit implied by pump vendors. Since dead-heading is a low flow phenomenon, the potential for dead-heading is also less than one percent of the limit.

B. BWR operating experience demonstrates that short-term operation in the minimum flow mode and/or dead-heading has little or no impact on pump life. Recent inspections of BWR RHR pumps have indicated no pump impeller excessive wear due to minimum flow. It is estimated that the pumps had been operating for up to 30 hours in the minimum flow mode in the period since the previous inspection.

There have been occurrences where pumps have been operated dead-headed inadvertantly. These pumps have continued to function normally with no apparent adverse performance effects.

C. Pump wear attributable to minimum flow and/or dead-heading is not a significant contributor to total system unavailability. Other factors (such as loss of emergency power, loss of cooling, etc.) are more significant. BWR operating history indicates no occurences of system unavailability due to pump excessive wear attributable to low flow operation

D. For the RHR and core spray pumps, the only design basis events that would lead to pumps running in the minimum flow mode and/or dead-heading are events that result in an ECCS initiation signal while the reactor is at high pressure (above the pump shutoff head). These events are normally small break LOCAs and loss of drywell cooling isolation events. Of these, only certain small break LOCAs actually require ECCS injection from LPCI or core spray after running at low flow.

Once initiated, the maximum duration that a LPCI or core spray pump may operate in the minimum flow mode for the spectrum of hypothetical LOCAs is less than 30 minutes. This is derived from postulated small break LOCAs, wherein reactor depressurization to below the shut-off head of these pumps is delayed. For large break LOCAs, where the full complement of ECC systems is more fully utilized, the reactor inherently depressurizes through the break. The present minimum flow bypass line is expected to provide adequate protection for these pumps for the short durations postulated during both the small and large break LOCAs.

For other scenarios, there is adequate time to secure the RHR and core spray pumps, and restart them as necessary, precluding extended operation in the minimum flow mode. As an example, analyses performed demonstrating compliance to 10CFR50 Appendix R have taken credit for LPCI or core spray injection several hours after a LOCA signal would have been generated. In this case, the operator would secure the RHR or core spray pumps when it is recognized that they are not immediately needed, per the plant Emergency Procedure Guidelines. The pumps would be restarted when vessel injection becomes necessary.

E. As discussed in item D above, only certain small break LOCAs actually require ECCS injection for LPCI or core spray where the pumps may be operated in the minimum flow mode. However, because of the excess ECCS capacity that is available, limiting LOCA scenarios for most BWRs do not depend on both pumps of a pair of parallel pumps to operate in order to satisfy 10CFR50.46 and 10CFR50 Appendix A, General Design Criteria 35 requirements. In fact, a realistic LOCA analysis would show that only one low pressure ECCS pump is typically necessary to satisfy core-cooling requirements during and following a LOCA. For those plants that require both pumps to operate (see section 3.2), it is demonstrated that the limiting calculated PCT would not be affected, even in the unlikely event that pump operability is affected by dead-heading.

F. Routine inspection, maintainence, and surveillance practices should detect any pump excessive wear well before system performance is degraded.

EXHIBIT 2

Pump	Design Point (ft/gpm)	Design Minimum Flow (gpm)	% of Design Flow	% of BEP Flow
HPCS	662/6942 2830/1564	1000[1]	14.4/64	23.5%
LPCS	725/6350	635[1]	10.0	11.0
RCIC	Variable	75 gpm[1,2]	Variable	
RHR	280/7450	550[1]/579[3]	7.4	10.0

1. General Electric Specification
2. Bingham-Willamette Recommends 250 gpm
3. Calculated worst case

<u>ATTACHMENT 3</u>
ZION STATION RESPONSE
TO NRC BULLETIN 88-04

The attachment provides the Zion Station Response to the subject NRC Bulletin.

<u>Item 1</u>

Determine whether or not any safety-related system with a pump and piping system configuration that does not preclude pump-to-pump interaction during miniflow operation and could therefore result in dead-heading of one or more of the pumps.

<u>Response:</u> The following safety-related pumps were evaluated for this phenomenon. Selection was based upon existence of a recirculation line.

Charging
Safety Injection
Containment Spray
Auxiliary Feedwater
Residual Heat Removel

Based on our review, it is our conclusion that no pump-to-pump interaction would be exhibited for the Charging, Safety Injection, Containment Spray, and Auxiliary Feedwater pumps. This conclusion is due to the fact that the individual pump recirculation lines contain flow orifices or check valves which would eliminate the potential for dead-heading caused by a stronger pump.

However, with regard to the Residual Heat Removal (RHR) Pumps, there seems to be theoretical evidence that interaction is possible.

<u>Item 2</u>

If the situation described in item 1 exists, evaluate the system for flow division taking into consideration (a) the actual line and component resistances for the as-built configuration of the identified system; (b) the head versus flow characteristics of the installed pumps, including actual test data for "strong" and "weak" pump flows; (c) the effect of test instrument error and reading error; and (d) the worst case allowances for deviations of pump test as allowed by ASME Section XI, Paragraph IWP-3100.

<u>Response:</u> The RHR pumps are the only pumps which may exhibit pump-to-pump interaction. To date there have been been no failures or evidence of pump degradation attributed to this phenomenon. These pumps have been run in parallel on numerous occasions during safeguards testing with a minimum 5 minute run time (performed every refueling) and inadvertent Safety Injections with a minimum 1 minute run time.

However, in order to adequately address this issue, PWR Engineering is presently investigating additional analytical techniques and has recommended to Zion that a test be performed specifically testing the pumps for interaction while in a parallel configuration. Based on these results, we will be able to determine whether any further action is necessary. The results of the analysis and testing with an action plan (if necessary) will be submitted in a supplemental report by September 2, 1988.

Item 3

Evaluate the adequacy of the minimum flow bypass lines for safety-related centrifugal pumps with respect to damage resulting from operation and testing in the minimum flow mode. This evaluation should included consideration of the effects of cumulative operating hours in the minimum flow mode over the lifetime of the plant and during the postulated accident scenario involving the largest time spent in this mode. The evaluation should be based on best current estimates of potential pump damage form operation of the specific pump models involved, derived from pertinent test data and field experience on pump damage. The evaluation should also include verification from the pump suppliers that current miniflow rates (or any proposed modifications to miniflow systems) are sufficient to ensure that there will be no pump damage from low flow operation. If the test data does not justify the existing capacity of the bypass lines (e.g., if the data does not come from flows comparable to the current capacity) or if the pump supplier does not verify the adequacy of the current miniflow capacity, the licensee should provide a plan to obtain additional test data and/or modify the miniflow capacity as needed.

Response: Attached is a copy of a table showing for each of the pumps under review what the actual recirculation flows are and the duration both normal operation and post-accident. This same table has been sent to the pump vendors for concurrence that the recirculation flow is adequate. Additionally, pump vibration data obtained from Zion's vibration monitoring program has been evaluated for vibration resulting from pump hydraulic instability. The data was obtained while the pumps were on miniflow operation. It is PWR Engineering opinion that this information more accurately reflects whether or not a pump is experiencing hyraulic instability rather than relying on pump vendor minimum flow recommendations when making that determination. Based on this data, we believe that the current recirculation flows are adequate at Zion. However, we are still pursuing vendor information in order to fully meet the direction given in the bulletin.

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NRC BULLETIN 88-04
POTENTIAL SAFETY RELATED PUMP LOSS

Pump	Serial No.		GPM of Miniflow	Duration of Miniflow Norm P.T.	Duration of Miniflow Accident	Remarks
Containment Spray	45790 45791 45792 45793 45794 45795		3000	30 min. every month	N/A	
Auxiliary Feedwater	45800 45796 45797 45801 45798 45799		50 90*	30 min. every month	N/A	* TURBINE DRIVEN PUMP RECIRCULATION FLOW IS 90 GPM
Safety Injection	52282 45649 45650 45648		29	30 min. every month	15 minutes maximum	MSLB duration per Figure 14.2.5-2 is approximately 40 sec.
Centrifugal Charging	49777 45610 45601 45616		60	30 min. every month	N/A	Total duration of miniflow over 40 years is estimated by Westinghouse to be 480 hours.
Residual Heat Removal	037047 A6934 A6933 037048		450	30 min. every month	48 hours	

ATTACHMENT 4
BYRON AND BRAIDWOOD STATIONS RESPONSE
TO THE SUBJECT NRC BULLETIN

This attachment provides the Byron and Braidwood Station's Response to the subject NRC Bulletin.

Item 1:

Promptly determine whether or not its facility has any safety-related system with a pump and piping system configuration that does not preclude pump-to-pump interaction during miniflow operation and could therefore result in dead-heading of one or more of the pumps.

Response:

The following systems at Byron/Braidwood Stations have piping configurations which do not preclude pump to pump interaction during miniflow operation and could result in the dead heading of one or more of the pumps. These systems include Safety Injection (SI), Chemical and Volume Control (CV), Residual Heat Removal (RH) and Auxiliary Feedwater (AF).

Item 2:

If the situation described in Item 1 exists, evaluate the system for flow division taking into consideration (a) the actual line and component resistances for the as-built configuration of the identified system; (b) the head versus flow characteristics of the installed pumps, including actual test data for "strong" and "weak" pump flows: (c) the effect of test instrument error and reading error; and (d) the worst case allowances for deviation of pump test parameters as allowed by the American Society of Mechanical Engineers Boiler and Pressure Vessel Code (ASME Code) Section XI, paragraph IWP-3100.

Response:

Auxiliary Feedwater (AF)

The AF System consists of two independent trains. A simplified depiction of the relevant portion of the system is provided as Figure 1. Train A contains one motor-driven pump and Train B contains one diesel-driven pump. Each pump has a two-inch miniflow line that connects between the pump's discharge check Valve and the first potential isolation valve. An orifice is installed in each miniflow line. Each miniflow path may be directed to the Condensate Storage Tank supply header through independent lines, or may be combined into a single line directed to the Essential Service Water return header. The two-inch miniflow lines returning to the Condensate System run approximately one hundred feet before combining into a three-inch diameter pipe common to both trains. The two-inch miniflow lines returning to the Essential Service Water System run less than fifty feet before combining into a three-inch diameter pipe common to both trains.

Tracing the miniflow for the AF pumps (P&ID's M-37, M-39-1, 42-3) identifies two possible pump-to-pump interaction points. One interaction can occur during normal operation of the AF pumps (taking suction from the Condensate Storage (CD) System) at the point where the miniflow paths join upstream of the CD header. The other potential interaction occurs at the Essential Service Water (SX) System header used to recirculate AF water through the SX System back to the AF System. This flow path is used when the SX System is used as the suction source for the AF System. These flow paths are discussed in detail below.

For the first flow path high pressure fluid from each AF pump flows separately through breakdown orifices AF01MA, MB and into two separate 2 inch CD lines. These two lines empty into a 4 inch header. This line reduces to a 3 inch line with a check valve and runs into a 4" line used to return the AF miniflow as well as the miniflow from the CD make-up pump. This flow returns to the 20 inch CD header. See Figure 1.

The second potential flow path occurs when the miniflow from each AF pump passes through the breakdown orifices and discharges into a 3 inch SX header. The path continues through the SX System returning to the AF pump suction via the SX System. This flow path is shown in Figure 1. The point of potential interaction is past the check valves at the SX header.

The above flow paths potentially could experience pump-to-pump interaction. From the Pre-Op Tests and station test data the greatest difference in total developed head between an A and B pump is approximately 270 psig (Byron Unit 2). The miniflow rate for all of the AF pumps are between 89 and 92 gpm. The above flow scenario will not cause the B pump to dead-head the A pump due to a breakdown orifice installed in each miniflow line.

The breakdown orifice reduces pressure of the fluid by channeling it through one or more small openings. The pressure drop for the orifices is approximately 2000 psig.

Dead heading of the A pump will not occur due to these installed orifices. Fluid Pressures downstream of the orifices are approximately 200-300 psig. The pressure cannot dead head an AF pump with a shut off head of greater than 2000 psig. The systems that the miniflow discharges to will also not cause dead-heading of the pumps due to the low pressure of the systems. Design pressure of the CD System is 100 psig and the SX System has a design pressure of 125 psig.

Based on the above, the AF System for the Byron and Braidwood Stations are not susceptable to dead heading in miniflow due to pump-to-pump interaction or system pressures.

Chemical and Volume Control (CVC):

A simplified flow diagram of the CVC System is presented in Figure 2. The relevant portion of the system consists of two High Head Safety Injection pumps, each having an orificed miniflow path. The figure indicates that two potential pump-to-pump interaction flow paths exist: 1) the flow path which connects the discharge of the charging/safety injection pumps at the common charging header and, 2) the common miniflow path to the charging pump suction header via the seal water heat exchanger.

Flow path 1) is not considered to be a potential for pump-to-pump interaction due to the presence and location of the check valves in the downstream portion of the pump discharge header. These check valves prevent direct pump-to-pump interaction and are located so neither pump can be isolated from its miniflow path. The pump miniflow paths do, however, connect into a common return (flow path 2) to the charging suction header. This common return path was evaluated for possible pump-to-pump interaction during miniflow operation. A calculation has been performed verifying that the vendor supplied miniflow orifices will maintain weak pump miniflow within design capacity during pump anticipated mismatch conditions. In summary, the Chemical and Volume Control System is not considered susceptible to the potential for dead-heading due to pump-to-pump interaction.

Residual Heat Removal (RHR):

A simplified flow diagram of the RHR System is presented in Figure 3. The system is a two train design with each Residual Heat Removal pump having a dedicated miniflow path. A review of the system indicated that possible pump-to-pump interaction could occur during miniflow operation due to the location of the check valve upstream of the miniflow return branch. This check valve location, between the pump and its miniflow branch at the pump discharge, could provide a pressure isolation boundary and prevent the weaker pump from operating on its miniflow.

Westinghouse has determined for the configuration described above that the miniflow path for the weaker pump will allow the transmission of the stronger pump's discharge pressure to the suction of the weaker pump via the weaker pump's miniflow line. This, in conjunction with the presence of the check valve upstream of this point which provides a pressure isolation boundary, will increase the weaker pump suction pressure. The weaker pump suction pressure increases until the pressure and developed head of the pump equal the steady state pressure in the discharge header. Both pumps would then operate on miniflow in an equilibrium state. This phenomenon has been verified by calculation. In summary, the Residual Heat Removal System is not susceptible to the potential for dead-heading due to pump-to -pump interaction.

Safety Injection (SI):

A simplified flow diagram of the SI System is presented in Figure 4. The system is a two train design with each Intermediate Head Safety Injection pump having an orificed miniflow path. The figure indicates that two potential pump-to-pump interaction flow paths exist: 1) the flow path which connects the discharge of the intermediate head safety injection pumps at the common header to the cold leg injection points and, 2) the common miniflow path to the RWST. Flow path 1) is not considered a potential pump-to-pump interaction due to the presence and location of the check valves in the downstream portion of the pump discharge header. These check valves prevent direct pump-to-pump interaction and are located so neither pump can be isolated from it miniflow path. The pump miniflow paths do, however, connect into a common return (flow path 2) to the RWST. This common return path was evaluated for possible pump-to-pump interaction during miniflow operation. A calculation has been performed verifying that the vendor supplied miniflow orifices will maintain weak pump miniflow within design capacity during pump anticipated mismatch conditions. In summary, the Safety Injection System is not susceptible to the potential for dead-heading due to pump-to-pump interaction.

Summary of Item 2 Responses:

Since none of the aforementioned pumps are susceptible to the potential for dead-heading due to pump-to-pump interaction, General Design Criterion 35 of Appendix A to 10CFR50 remains satisfied without additional justification.

Item 3:

Evaluate the adequacy of the minimum flow bypass lines for safety-related centrifugal pumps with respect to damage resulting from operation and testing in the minimum flow mode. This evaluation should include consideration of the effects of cumulative operating hours in the minimum flow mode over the lifetime of the plant and during the postulated accident scenario involving the largest time spent in this mode. The evaluation should be based on best current estimates of potential pump damage from operation of the specific pump models involved, derived from pertinent test data and field experience on pump damage. The evaluation should also include verification from the pump suppliers that current miniflow rates (or any proposed modifications to miniflow systems) are sufficient to ensure that there will be no pump damage from low flow operation. If the test data do not justify the existing capacity of the bypass lines (e.g., if the data do not come from flows comparable to the current capacity) or if the pump supplier does not verify the adequacy or the current miniflow capacity, the licensee should provide a plan to obtain additional test data and/or modify the miniflow capacity as needed.

Response:

In-Service Inspection surveillance results have been reviewed for all pumps addressed in the response to Requested Action #2. These surveillances are conducted quarterly to satisfy ASME Section XI pump performance requirements. Specifically, the pump vibration test results were reviewed. With the exception of the RHR pumps at Byron Station, all pump vibration readings were in specification. The out-of -specification vibration test results for the RHR pumps at Byron Station were caused by inadequate motor supports, which were modified to correct the problem.

Pump vibration results provide an indication of acceptable pump performance during miniflow operation. The acceptable results of the pump tests indicate that operation of the pumps, identified under requested action #2, during miniflow has not degraded the pumps or reduced their ability to operate as designed.

To more completely analyze the pump performance, the pump suppliers have been contacted to verify that current miniflow rates are sufficient to ensure that there will be no pump damage from low flow operation.

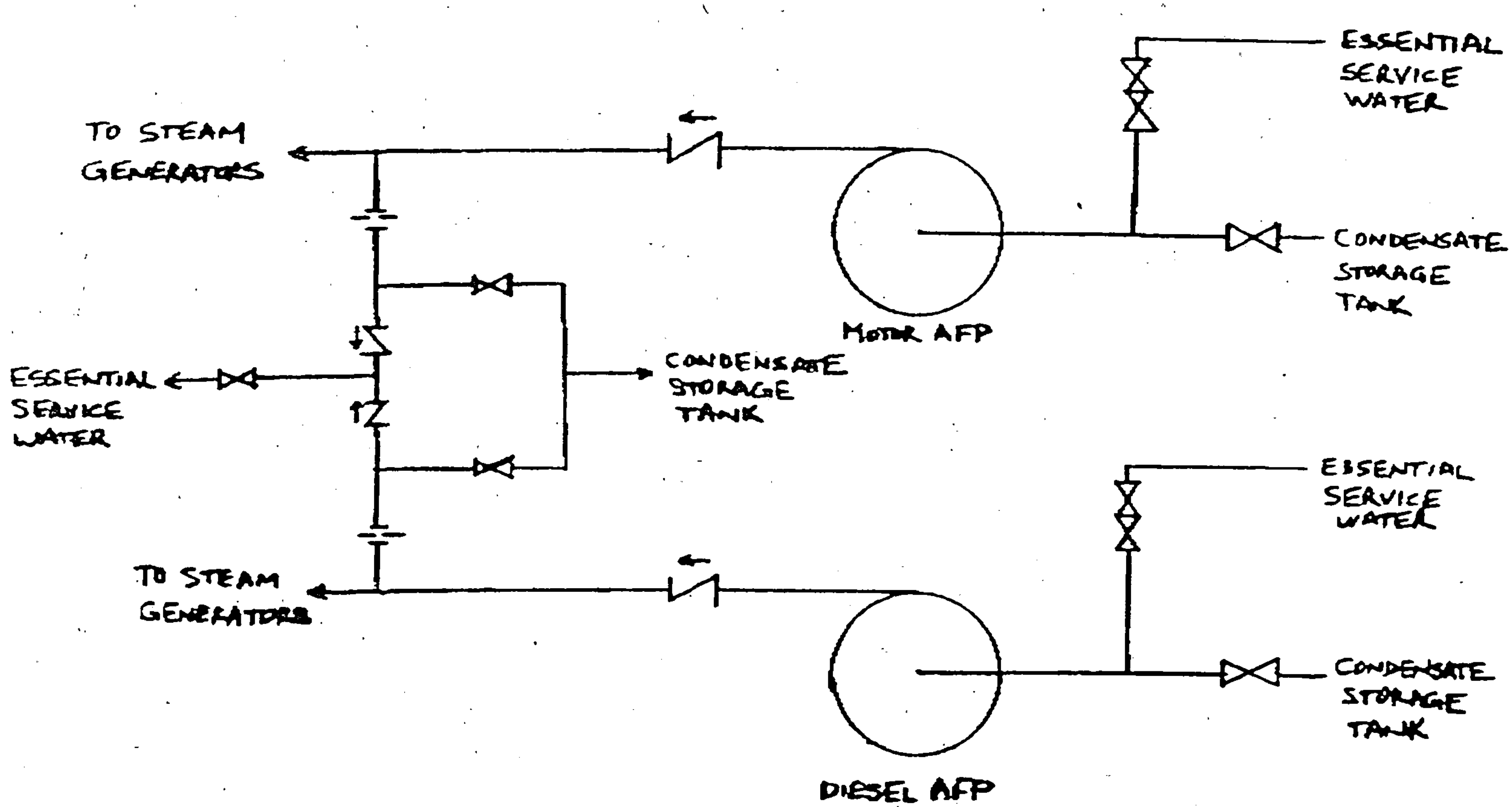

FIGURE 1 - AUXILIARY FEEDWATER PUMPS

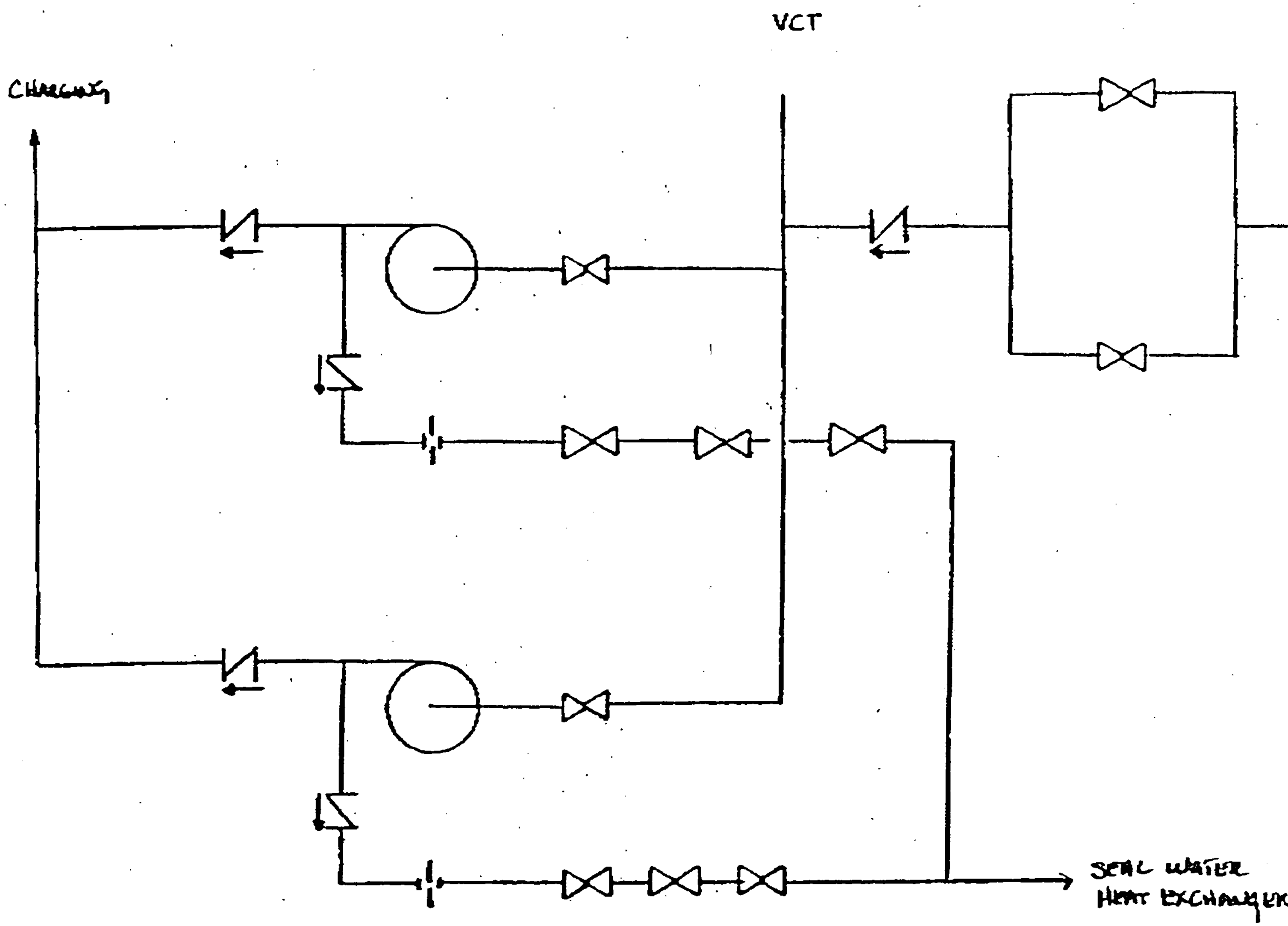

FIGURE 2 – CHEMICAL AND VOLUME CONTROL
CHARGING PUMPS

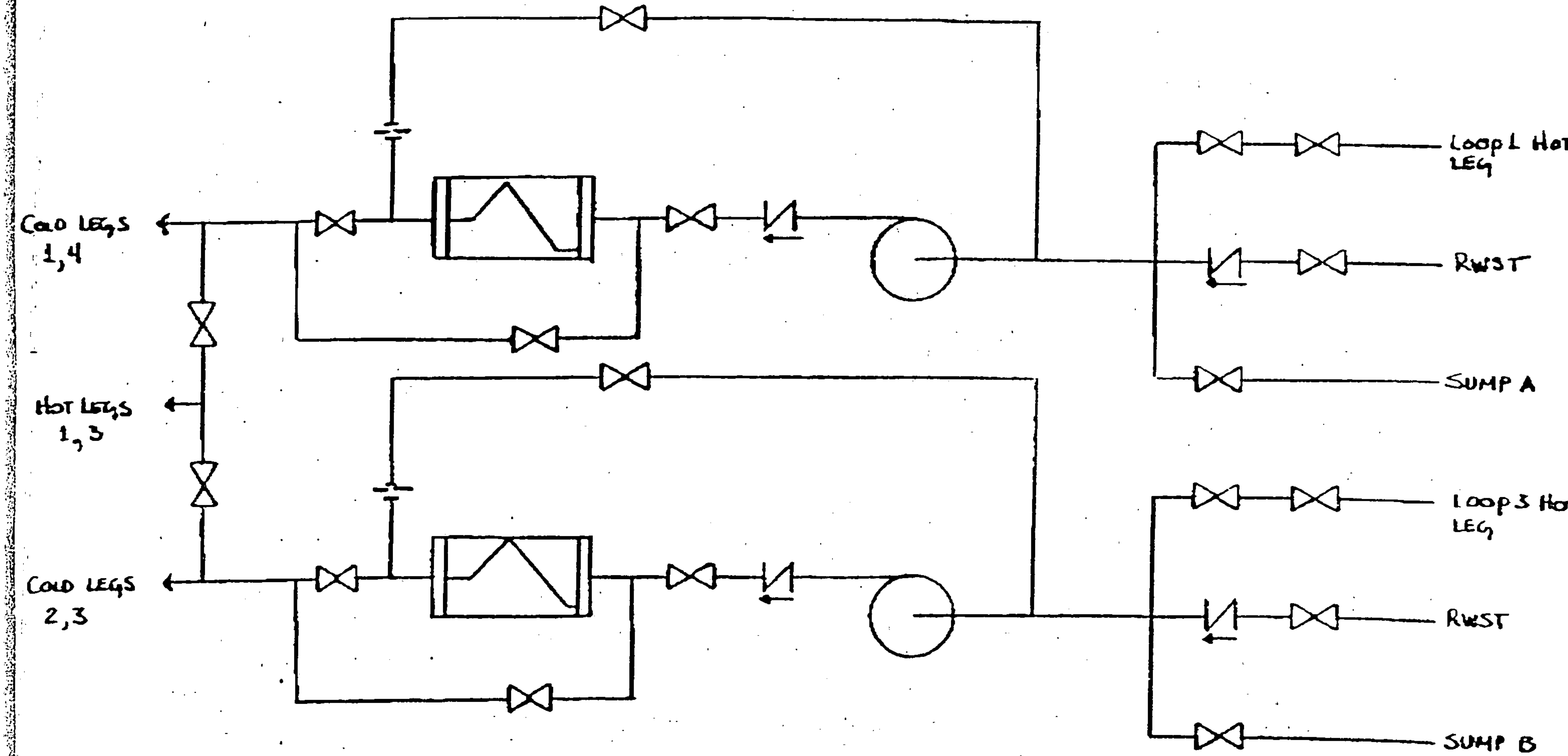

FIGURE 3 — RESIDUAL HEAT REMOVAL SYSTEM

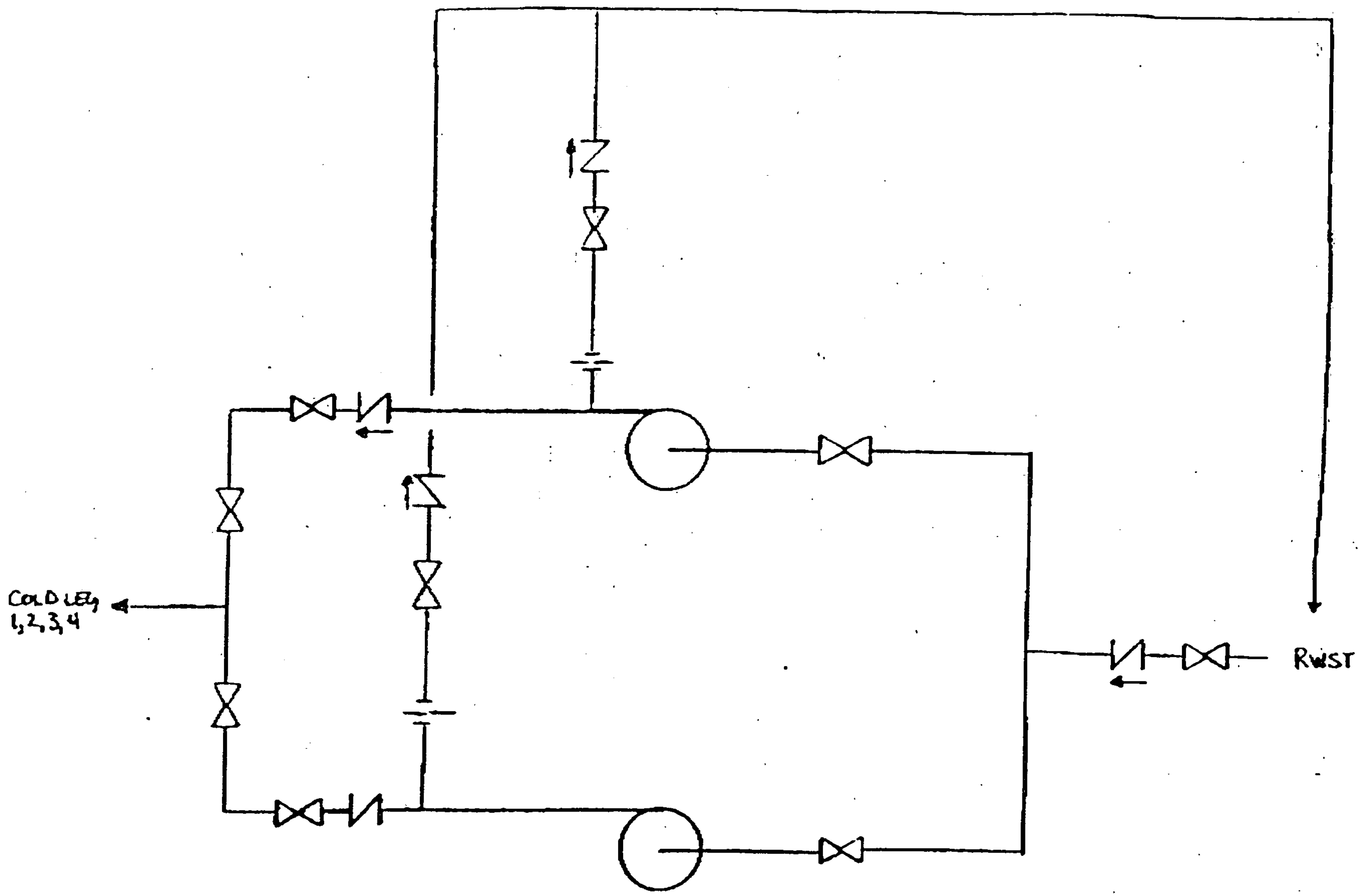

FIGURE 4 - SAFETY INJECTION SYSTEM