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SUBJECT: Forwards response to unresolved items noted in SSF Insp Rept 50-220/88-201 & revised core spray calculations.

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NIAGARA MOHAWK

NIAGARA MOHAWK POWER CORPORATION/301 PLAINFIELD ROAD, SYRACUSE, N.Y. 13212/TELEPHONE (315) 474-1511

March 28, 1989
NMP1L 0377

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

Re: Nine Mile Point Unit 1
Docket No. 50-220
DPR-63

Gentlemen:

Enclosed is Niagara Mohawk's response to the Unresolved Items noted in the Nuclear Regulatory Commission (NRC) Safety System Functional Inspection report 50-220/88-201. Also enclosed, in response to discussions with the NRC are revised calculations related to Core Spray system flow performance and an evaluation of the susceptibility of the core spray system to water hammer as a result of initiation.

With regard to the SSFI issues these calculations and the water hammer evaluation complete the Niagara Mohawk actions necessary to resolve the SSFI responses for "Quick-Look" Letter Items 1.b(1), 1.b(2), 1.b(3), 1.b(5), 1.c(2) and 1.f affecting core spray system operability. In accordance with our discussion, the evaluation of the revised calculations on the 10CFR Part 50 Appendix K Loss-of-Coolant Accident analysis will be completed prior to plant startup.

Very truly yours,

NIAGARA MOHAWK POWER CORPORATION

C. D. Terry
Vice President
Nuclear Engineering and Licensing

LWW/pns
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Enclosures

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Ms. M. M. Slosson, Project Manager "
Regional Administrator, Region I (with calculations)
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Response
to
Unresolved Items
Nuclear Regulatory Commission Inspection 50-220/88-201
Safety System Functional Inspection
for
Nine Mile Point Unit 1

March 1989

List of Acronyms

ASME	American Society of Mechanical Engineers
APLHGR	Average Planar Linear Heat Generation Rate
CST	Condensate Storage Tank
DBM	Disc Bypass Margin
ECCS	Emergency Core Cooling System
FSAR	Final Safety Analysis Report
GE	General Electric
HPCI/FW	High Pressure Coolant Injection/Feedwater
INPO	Institute of Nuclear Power Operations
INPO SER	INPO Significant Experience Report
IST	Inservice Testing
LCO	Limiting Condition for Operation
LER	Licensee Event Report
LHGR	Linear Heat Generation Rate
LOCA	Loss of Coolant Accident
MAPLHGR	Maximum Average Planar Linear Heat Generation Rate
MCC	Motor Control Center
MCPR	Minimum Critical Power Ratio
MOV	Motor Operated Valve
MOVATS	MOTOR OPERATED VALVE ANALYSIS AND TESTING SERVICE
NPSH	Net Positive Suction Head
NRC	Nuclear Regulatory Commission
OEA	Operational Experience Assessment
OP	Operating Procedure
RBCLC	Reactor Building Closed Loop Cooling
RPV	Reactor Pressure Vessel
SER	Safety Evaluation Report
SSFI	Safety System Functional Inspection
SIL	Service Information Letter
SOER	Significant Operating Experience Report

NCR Finding

Unresolved Item 88-201-01

Concern A

The inspection team reviewed the licensee's analysis to demonstrate compliance with 10 CFR 50.46, "Acceptance Criteria for Emergency Core Cooling Systems for Light Water Nuclear Power Reactors," for the next operating cycle. General Electric (GE) Report NEDC-31446P, "Nine Mile Point Unit One SAFER/CORECOOL/ GESTR-LOCA Loss of Coolant Accident Analysis," was issued in June 1987 and fully complied with the requirements of 10 CFR 50, Appendix K, "ECCS Evaluation Models." This report showed that the calculated peak clad temperature, peak local oxidation, and core-wide metal-water reaction were below the 10 CFR 50.46 limits for the proposed fuels under the analyzed spectrum of accidents. The licensee had reviewed the GE Report and revised the Technical Specifications for the fuel limits based on the results of the report. In August 1987, during the licensee's review, personnel in both the Design Engineering and Operations organizations identified that the GE report assumed that both core spray loops were always available, although this assumption was inconsistent with a Technical Specification Limiting Condition for Operation (LCO) for the system. Technical Specification 3.1.4.d allowed continued plant operations for up to seven days with one core spray loop inoperable. The core spray system was designed so that no single failure would take a loop out of service so the single loop situation was not considered by the LOCA Analysis. The team concluded that the 7-day LCO was less conservative than any postulated single failure to the core spray system and was an unanalyzed condition.

Concern B

Before the inspection started, the licensee developed a draft Technical Specification interpretation (dated August 23, 1988) to require shutdown within 10 hours if a core spray loop was inoperable, and was in the process of developing a change to the Technical Specifications to be implemented after restart. The team disagreed with the licensee's schedule for corrective actions and concluded that problems with the Technical Specification should be resolved before the system was declared operable.

At the inspection followup meeting the licensee committed to revise the core spray system Technical Specification before declaring the system operable. The licensee will evaluate the possibility of a Technical Specification to allow continued plant operation with one core spray loop operable after plant restart. The apparent failure by the licensee to translate LOCA Analysis assumptions into Technical Specification requirements will remain unresolved pending followup by the NRC.

Concern C

Additionally, previous LOCA analyses had also assumed that two core spray loops were always available. The inspection team identified one instance, on November 11, 1987, where the licensee entered the 7-day LCO with the reactor at power for a 17-hour period to repair a leaking check valve. As discussed in Section 3.8.1 of this report, it appeared that the licensee had not taken adequate corrective actions to investigate and report the full scope of this identified problem.

Response to Unresolved Item 88-201-01

Niagara Mohawk response to the three items identified as concern A, B and C will be addressed with the response to Unresolved Item 88-201-09. This response will be submitted by April 14, 1989.

NCR Finding
Unresolved Item 88-201-02

Concern A

The inspection team reviewed the analyses supporting the assertions made in the FSAR, Technical Specification and safety analyses about core spray system performance and identified the following concerns:

> The system resistance curves did not account for the resistances associated with the piping from the torus to the discharge of the topping pumps, system flow orifice, pump suction grating, system strainer and one check valve. Collectively, these additional resistances could significantly increase the resistance coefficient for the system curves.
>
> The system flow analysis did not consider the flow that may be diverted from the reactor through the minimum flow relief valve during system operations. Design input provided to the team indicated that the valve reseat pressure could be as low as 280 psig which could divert flow from the reactor to the torus during core spray system operation.
>
> The text in Section VII of the FSAR stated that each set of pumps was capable of providing 3400 gpm to the spray nozzles at 299 psig, but this point appeared to be above FSAR Figure VII-2, "Core Spray Pump Characteristics." The curve shown in Figure VII-2 was used for determining acceptable pump performance during surveillance testing.

At the inspection followup meeting, the licensee stated that calculations were found after the onsite inspection which supported the system performance curves and assumptions about flow diversion. The curves would be validated at several flow points by system testing before declaring the system operable. These calculations were submitted to the NRC and are currently being reviewed.

Concern B

The inspection team reviewed the licensee's analysis that showed the core

spray pumps had sufficient net positive suction head (NPSH) for the full range of anticipated system operating conditions. The analysis asserted that adequate NPSH would be provided for the pumps; however, the team identified the following deficiencies with the assumptions used in the calculations:

(1) The pressure drop through the pump suction grating in a loaded condition was not considered in the calculations.

(2) The calculation for maximum torus water temperature achieved during the LOCA assumed a torus water temperature of 90°F at the beginning of the event. However, Technical Specification 3.3.2.e allowed the initial torus water temperature to be as high as 110°F before the reactor was required to be scrammed.

(3) The calculations assumed that the containment atmosphere would always be saturated at the temperature of the suppression chamber water. Therefore, the pressure would always be the saturation pressure corresponding to this temperature plus the partial pressure increase of the air caused by the temperature rise. However, should the containment spray system be actuated, such an equilibrium condition may not exist. The atmospheric temperature and the conditions of saturation in the containment could be significantly lower than the torus water temperature at the pump suctions, thereby providing less total pressure to contribute to available NPSH.

The team was concerned that the design of the core spray system prevented throttling flow to prevent cavitation. The core spray motor operated isolation valves received an open signal upon system initiation that was "sealed in," thus preventing later throttling. At the inspection followup meeting, the licensee stated that calculations had been performed which showed that adequate NPSH was available.

Concern C

The inspection team was concerned that the present configuration of the core

spray system appeared susceptible to water hammer during large-break LOCA situations. In the present design, the keep-fill lines join the core spray piping at points downstream of Injection Check Valves 40-03 and 40-13. This filled the piping from these valves to Inboard Isolation Valves, 40-01, 40-09, 40-10 and 40-11. However, the piping upstream of the injection check valves was not supplied by the keep-fill system. Much of the piping was above the torus level and free to drain back to the torus through the pumps by way of the topping pump discharge check valve bypass lines. This design would create voids when the system was not running and create conditions conducive to water hammer upon system initiation in response to a large-break LOCA.

With a large-break LOCA situation, the pumps would start soon after the break, and because the vessel would depressurize very quickly, the injection valves would start to open almost immediately before sufficient time would have passed for the air to have been removed through the relief valves. In this case, the water front in the pipe would travel very quickly toward the reactor vessel until it would reach the injection valves or other abrupt flow discontinuities, at which point the water hammer would occur. This situation could simultaneously occur in both lines and prevent the core spray system from fulfilling its safety function.

The licensee stated that no problems with water hammer had been observed during system surveillance testing. The team was concerned that existing tests did not simulate large-break LOCA conditions. At the inspection followup meeting, the licensee stated that a special test would be performed before startup to demonstrate that water hammer would not occur during worst-case system initiation conditions.

Concern D

The inspection team was concerned that core spray system alarm setpoints were at values that would be expected during LOCA situations and that alarm response procedures directed actions that were not in the best interest of safety. The following observations lead the team to this concern:

The core spray loop low-pressure alarm was set at 225 psig, decreasing, as sensed by a pressure switch downstream of the flow element. The purpose of the alarm was to detect a failure of system piping, but during a LOCA condition the alarm would be received as the RPV depressurized. Procedure OP-2, "Core Spray System," Revision 17, instructed the operator to check for various failure conditions, and if the opposite loop was operating normally, to shut down the affected loop. With the current knowledge that both loops of the system were required, this response could place the plant in an unanalyzed condition. In addition, when the alarm was received in one loop, it should soon be received in the opposite loop.

The core spray pump low suction pressure alarm was set at 2.5 psig, decreasing. The function of the alarm was to warn the operator of impending cavitation, but according to the team's calculations, this setpoint was well above the required NPSH for the entire range of anticipated pump flow conditions. Procedure OP-2 directed operators to secure the train of pumps in which the alarm was received after ensuring that the other train in that loop was running. In an accident condition this would unnecessarily reduce the system capability.

Additionally, if the alarm were received in one train, it could be imminent in the other train. After securing of the first train, the flow in the second train would increase, thereby lowering its suction pressure. This suction pressure drop could actuate the alarm in that train. A better response, were it available, would be to throttle flow to reduce the suction pressure required and to increase the pressure available. However, as previously described, the system design has no provisions for throttling the system isolation valves.

The strainer high differential pressure alarm for the large strainers between the core spray and topping pumps was set at 5 psid, increasing. The purpose of the alarm was to alert operators to strainer loading during surveillance tests and LOCA conditions, however the setpoint

appeared to be too low for this purpose. In the past, several work requests had been written to clean the strainers due to alarms received during testing at 3000 gpm flow, but no fouling was observed when the strainers were inspected.

Procedure OP-2 directed that the affected train be secured upon receiving the alarm. As with the low suction pressure alarm, to secure the affected train of pumps with both trains operating would probably cause the alarm to actuate in the opposite train because of the resulting increased flow.

It appeared that the alarm setpoints and response procedures were intended to provide guidance for abnormal conditions during surveillance testing and not during actual accident response situations. At the inspection followup meeting the licensee stated that calculations to support new alarm setpoints had been performed for accident conditions and these new values would be implemented before the core spray system was declared operable. The calculations supporting the new setpoints were provided to the NRC and are currently being reviewed. THe NRC staff expressed concern at the meeting that procedures contained action statements that operators were prepared to ignore under certain circumstances because the responses were inappropriate for the situation. The licensee committed to review other safety-related systems to identify where response to system alarms differs for testing and accident situations and make the necessary changes to procedures.

Concern E

The control room flow instrumentation did not appear adequate to cover the full range of expected system flows. The range of the installed instrument was 0 to 5000 gpm and according to the licensee's analysis, the expected flow with two pump sets running in the loop was approximately 6400 gpm. Regulatory Guide 1.97, "Instrumentation for Light Water Cooled Nuclear Power Plants to Assess Plant Conditions During and Following an Accident," specified that the range of the control room flow measuring instrumentation for emergency core cooling systems to be 0 to 110 percent of the maximum anticipated flow. At the inspection followup meeting, the licensee committed to increase the range of the core spray system flow instrumentation before declaring the core spray system operable.

Response to Unresolved item 88-201-02

Concern A

Niagara Mohawk letters NMP1L 0331, dated December 8, 1988, NMP1L 0342 dated January 10, 1989, NMP1L 0346 dated January 13, 1989, and NMP1L 0353 dated January 31, 1989, transmitted calculations that responded to the core spray system flow concerns, net positive suction head (NPSH) concerns and to the core spray alarm concerns. As a note of clarification, the system resistance calculations submitted were new calculations following current procedures, not the original design calculations found after the inspection. However, the original design calculations found were consistent with the new calculations.

Subsequent to the submittals listed above, the calculations for Core Spray system resistance and by-pass flow have been revised. The revisions included a new calculated sparger resistance, bypass flow assuming a relief valve reseat pressure of 280 psig, bypass flows from other sources, (i.e. core spray pump seal and motor cooler, check valve bypass line) and strainer pressure drop values based on recent testing. These revised calculations are included with this transmittal. Calculation S14-81-F003 Rev. 1, "Core Spray System Hydraulic Resistance from Torus to Topping Pump tee" and S14-81-F001 "Core Spray Pump Suction Hydraulic Resistance" assume a partial blockage (50%) of the free area of the suction pipe grating. Other piping components, i.e., orifice, check valve, gate valve and core spray sparger are included in calculations S14-81-F003 Rev. 1, S14-40-F003 Rev. 1, S14-81-F005 and S14-40-F004 Rev. 1. Niagara Mohawk is evaluating the Cycle 10/Reload 11 LOCA analyses using core spray sparger flows consistent with the revised calculations. A Technical Specification amendment will be submitted to account for the impact of the revised calculations and to allow margin for IST trending of test data.

The text in Section VII of the FSAR that states, "Each set of pumps (one core spray pump and one topping pump) is sized to deliver 3400 GPM to the spray nozzles at a combined pump developed head of 697 feet of water (299 psig)" is in error. The statement is based only on addition of the combined

flow-head curves provided by the manufacturer of the core spray system pumps and does not consider the system's physical design. FSAR Figure VII-2 is the curve developed for surveillance testing of the core spray system pumps and accounts for differences such as elevation at the point at which the surveillance data is taken and the pump elevations. The erroneous statement and the curve in the FSAR will be revised based on data obtained from our core spray pump validation testing commitment in response to the NRC "Quick Look" letter Item 1.b(4).

Concern B

The revised NPSH calculations included with this submittal (Attachment 1 and calculations S14-81-F001, S14-81-F003 and S14-81-F004) indicate that under the design assumption of Regulatory Guide 1.1, with one pump set in operation and a torus pressure of 0 psig, the NPSH available is less than the NPSH required. To account for this condition, the core spray flow is assumed to be limited to the flow for which sufficient NPSH exists. Under these conditions some cavitation may occur. However, no effect on pump operability is expected since these conditions exist for a short period of time (6 hours) until containment spray heat exchangers reduce the water temperature to 118°F. This condition only occurs with one pump set operation, since two pump set operation results in higher combined flow but lower flow rates from the individual pump sets. Niagara Mohawk does not currently plan to change the core spray valve design to allow throttling control. Consistent with our previous submittal the revised NPSH calculations included with this submittal utilize a maximum torus water temperature during the LOCA of 140°F based on a torus water temperature of 90°F at the beginning of the event. Although Technical Specification 3.3.2.e allows torus water temperature to be as high as 110°F for a period of 24 hours before shutdown is required, Niagara Mohawk does not believe that the NPSH calculations should be based on this initial water temperature. When the torus water temperature is greater than 90° F, the plant is operated in a limiting condition for operation that is allowed for a short period of time, which does not constitute a design value for initial water temperature. Niagara Mohawk believes this to be consistent with other Mark I containment designs.

Concern C

As presented at the February 21, 1989 meeting with the NRC, Niagara Mohawk believes that the current "keep fill" system and vacuum breaker (check valves) will prevent voids that could cause water hammer and that this is adequately demonstrated by current surveillance testing. Enclosed as Attachment 2 is Niagara Mohawk's evaluation of the water hammer concern.

Concern D

As indicated in our previous submittal, (Letter NMP1L 0333, Response to 1.c(1), 1.c(2) and 1.c(3)) Niagara Mohawk is revising core spray alarm setpoints to prevent nuisance alarms from occurring during system operation during LOCA conditions. Alarm response procedures are also being revised to provide appropriate responses to alarms which occur during operation under LOCA conditions and alarms occurring during surveillance testing if they should be different. Niagara Mohawk is reviewing the alarm setpoint for the strainer high differential pressure alarm based on recent system testing. The schedule for alarm setpoint responses groups those systems required to support core reload for completion prior to reload and the remaining systems for completion prior to plant restart.

Concern E

The Control Room flow instrumentation is being modified to cover the full range of expected core spray flow.

Concern 1.g

Niagara Mohawk's response to item 1.c(3) of the NRC "Quick Look" letter addressed an NRC concern with the core spray pump high discharge pressure alarm. This is identified as Item 1.g in the Inspection Report Executive Summary Section but is not listed as a concern in the body of the report. Niagara Mohawk's initial response (Letter NMPIL 0333 dated December16, 1988) erroneously stated that the purpose of this alarm was to indicate a failed closed relief valve and that the setpoint would be lowered such that the alarm would occur if the relief valve failed to open, but not during system

operation during a LOCA. Niagara Mohawk's further evaluation has determined that the purpose of this alarm is to indicate system overpressure due to leakage through the closed core spray injection valves. The current alarm setting of 445 psig is appropriate for this purpose. The alarm response procedure will be revised to specify the appropriate operator actions on receiving the alarm.

NRC Finding
Open Item 88-201-03

Concern A

The inspection team reviewed the licensee's analyses that supported the statements in the Technical Specification Bases about HPCI/FW system performance and identified the following discrepancies:

> The Technical Specification Bases asserted that each train of the HPCI/FW system could deliver 3800 gpm to the reactor vessel at reactor pressure. The team determined that the calculation supporting this assertion failed to account for the higher elevation of the feedwater nozzles from the condenser hotwell. During the inspection, the licensee stated that with the correction of this error, the analysis still showed acceptable results.
>
> The Technical Specification Bases asserted that at reactor pressures up to 450 psig, the condensate and feedwater booster pumps were capable of supplying 3800 gpm to the reactor vessel. Calculations performed by the inspection team and the licensee during the inspection revealed that these two pumps alone were incapable of delivering any flow to the reactor vessel at 450 psig. At the inspection followup meeting, the licensee stated that calculations were performed which indicated that 3800 gpm flow could be provided at 337 psig. The licensee stated that the Technical Specification Bases would be revised to reflect the correct pressure.
>
> The Technical Specification Bases specified that condenser hotwell level not be less than 75,000 gallons and inventory in the condensate storage tanks (CSTs) not be less than 105,000 gallons. However, during the onsite inspection, the licensee did not have an analysis to show that these values were adequate to support the spectrum of small-break LOCAs that the HPCI/FW system was intended to mitigate. The inspection team was concerned that under worst-case conditions with the condenser vacuum lost, the gravity feed-flow rate from the CSTs to the hotwell would not provide sufficient water for the pumps. Once the hotwell was empty, the condensate pumps could be damaged and the HPCI/FW system would be

inoperable. At the inspection followup meeting the licensee stated the calculations were performed that showed adequate transfer of water from the CST to the hotwell would be achieved to support the HPCI/FW system upon a loss of condenser vacuum.

Concern B

The Technical Specification Bases stated that the motor-driven feedwater pumps would trip if a reactor high-water level was sustained for 10 seconds and the associated flow and low-flow control valves were closed. This modification was accomplished in 1984 to prevent over filling the reactor vessel to the point of spilling into the emergency condenser and main steam lines. The licensee recognized that frequent cycling of the feedwater pump motors was not desirable, therefore, a one-out-of-two-taken-twice control logic was included in the design to prevent cycling caused by a spurious signal. However, the licensee had no analysis to determine whether excessive cycling would not occur during a normal system response to various small-break LOCA conditions.

The feedwater pump motors were rated at 2500 horsepower and normally, large motors of this size can be restarted one time at the normal running temperature, but then must be cooled down for at least one hour before subsequent restarts. To restart more frequently could cause overheating of the motor and possible failure. The team was concerned that cycling the pumps would damage the motors and decrease the reliability of the HPCI/FW system. At the inspection followup meeting the licensee stated that pump cycling would occur only if the flow control valves would fail. Provisions for manual control of the flow control valves would be included in the system operating guidance. The inspection team considered these actions adequate.

Response to Open Item 88-201-03

Concern A

The calculations for HPCI pump performances were submitted to the NRC with Niagara Mohawk letter NMP1L 0331 dated December 8, 1988. Included with these calculations were those for High Pressure Coolant Injection/Feedwater (HPCI/FW) pumps capacity using the condensate and feedwater booster pumps and for transfer of condensate from condensate storage to the hotwell. The proposed Technical Specification Bases change for HPCI/FW was submitted to the NRC in Niagara Mohawk letter No. NMP1L 0357 dated February 13, 1989.

Concern B

Response to item 1.i in Niagara Mohawk letter NMP1L 0333 dated December 16, 1988 addresses feedwater pump motor cycling.

NRC Finding

Unresolved Item 88-201-04

The inspection team identified the following instances where design information was not properly translated into operating, test and safety study guidance:

Concern A

In 1978, the licensee modified the motor-driven feedwater pumps to replace the pump impeller. The licensee determined and stated in the safety evaluation that new impeller was equivalent to the old impeller, However, the team determined that the new impeller design provided 200 feet less head at rated flow (3800 gpm) and 500 feet at maximum flow. The licensee had not updated their design pump head curves to account for this impeller change.

Concern B

GE Study NEDE 30241, "Performance Evaluation of the Nine Mile Point Unit 1 Core Spray Sparger," used design flow inputs of 5020 gpm at 30 psia RPV pressure and 4860 gpm at 55 psia RPV pressure for core spray flow from one pump set. These values appeared inconsistent with the inputs for GE study NEDC-31446P which identified run out flow at 4800 gpm for each core spray pump set.

Concern C

In 1984, changes were made to the Technical Specifications which raised the setpoint for reactor vessel low-low-low level from elevation 294 feet-10 inches to 296 feet-6 inches. This is the setpoint at which the automatic depressurization system is actuated. The following corresponding design documents were not changed:

(a) Drawing Number C-35843-C, Revision 1, dated July 24, 1985, "Reactor Vessel Instrumentation, Level Ranges, Actuation Points, and Water Volumes."

(b) Drawing Number C-18015-C, Revision 87-039-C1, dated November 3, 1987, "Vessel Instrumentation, Piping and Instrumentation Diagram."

The team found applicable operating and test procedures were properly updated and the low-low-low level alarm was properly set in the plant and at the simulator.

Concern D

The original design of the feedwater system had the reactor feedwater auxiliary oil pump motors being powered from a non-vital power board that could only be fed from offsite power. In 1972, the power supplies for the auxiliary oil pump motors were moved from Motor Control Center (MCC) 151 to MCC 1671, which was capable of being powered from the onsite diesel generators. Neither Figure IX-1 of the FSAR nor the Electrical System Description document was revised to show this change in power supply for the reactor feedwater auxiliary oil pumps.

The original design of the core spray system had all safety-related 4160 Vac motors being stripped from Power Boards 102 and 103. In 1971, this design was modified to leave one core spray pump on each bus following an undervoltage condition so that they would be ready to start when the diesel generator was connected to the bus. Neither FSAR Figure IX-1 and text, nor Surveillance Test Procedure NI-ST-R2, "Loss of Coolant and Emergency Diesel Generator Simulated Automatic Initiation Test" were modified to show that one core spray pump motor on each bus did not trip on undervoltage conditions.

Response to Unresolved Item 88-201-04

Concern A

Calculations have been performed that demonstrate that the new impeller design provides sufficient flow and head to meet the HPCI design basis requirements.

Niagara Mohawk in Letter No. NMP1L 0333 dated December 16, 1988, (Response to Item 1.e(4)) committed to revising the HPCI/FW pump curves and, to avoid recurrence of this concern, and to control the curves through the Nine Mile Point Unit 1 Configuration Management System. This action is to be completed prior to declaring the HPCI System Operational.

Concern B

General Electric Topical Report NEDE 30241, "Performance evaluation of the Nine Mile Point Unit 1 Core Spray Sparger" was a flow distribution evaluation in a steam environment that bounded maximum potential core spray sparger flow capacities (Table A of NEDE 30241, Actual Core Spray System Flow). Earlier core spray tests were conducted in an air environment and used the surveillance test curve core spray sparger flows which are less than the maximum flow. NEDE 30241 confirmed that adequate core spray distribution was achieved at both maximum flow and surveillance test curve core spray sparger flow rates. For the maximum flow evaluation GE used the Nine Mile Point Unit 1 combined pump curve (core spray plus core spray topping pump) provided by Niagara Mohawk but chose to use GE's own system resistance curve rather than Niagara Mohawk's conservative core spray resistance curve that is used to determine core spray flow for the LOCA analysis. The core spray sparger flow rates used in the LOCA analyses (NEDC-31446 P) supporting the Cycle 10/Reload 11 licensing submittal were based on the conservative Niagara Mohawk core spray sparger flow rates rather than the higher flow rates developed by General Electric in NEDE 30241. Consequently the two values of runout flow are different since different system resistances are used. The lower GE System resistance resulted in a higher calculated core spray pump run out flow at 0 reactor pressure.

Concerns C and D

Inconsistencies within the plant licensing documentation are being corrected. The next scheduled FSAR revision (June 1989) will update the HPCI and Core Spray and supporting sections of the FSAR.

NRC Finding
Unresolved Item 88-201-05

The inspection team reviewed the licensee's EOPs to determine whether adequate guidance was provided for operating the core spray and HPCI/FW systems under emergency conditions. The following deficiencies were identified during this review:

> Procedure EOP-4, "Primary Containment Control," Revision 0, Step 7.1, contained instructions to maintain torus water level between 10 and 11.5 feet, the normal operating band. If the water level dropped below 10 feet, the operator was referred to Procedure OP-2, "Core Spray System," Step I.21.d., to add water to the torus. This step directed the operator to restore water level to within the operating band utilizing the core spray keep-fill system which required securing one loop of the core spray system. The team determined that this was acceptable for normal operating circumstances, but was unacceptable in the post-LOCA condition when both core spray loops could be required. Additionally, the outside isolation valves and the test return line valves could not be repositioned without overriding system initiation signals to accomplish the fill operation. Thus, the specified procedure was deficient in specifying a means to add water to the torus during a LOCA event. The licensee concurred and prepared a revision to the procedure to supply water from an alternative source.
>
> The EOP General Instructions, EOP-1, Item 6, described the various limitations of the RPV level instrumentation under post-accident conditions. The team determined that the instruction was deficient in that no warning was provided concerning the limitations of low-low-low Level Instruments LI 36-19 and LI 36-20 when the core spray system was injecting into the vessel. The lower legs of these instruments were connected to the core spray lines so that the dynamic and back pressure effects of injection flow would make the instruments inaccurate. The team was concerned that the erroneous indication could produce operator confusion during an accident, even though these instruments were not used by the operators for casualty management during training evolutions.

Graphs 2.1 and 2.2 in EOP-2, "Reactor Pressure Vessel Control," provided NPSH limitations for individual core spray pump operation. However, available flow indication in the control room was for combined pump flow, and there was no guidance in the procedure alerting operator's to this fact.

Response to Unresolved Item 88-201-05

Niagara Mohawk responded to these concerns in Letter NMP1L 0333 dated December 16, 1988, in response to finding 1.d. In that response Niagara Mohawk stated that the EOP's would be revised prior to February 28, 1989. These revisions are in the approval process which will be completed by March 31, 1989.

NCR Finding
Unresolved Item 88-201-06

Concern A

The inspection team identified the following deficiencies with the operating procedures that provided guidance for the core spray and HPCI/FW systems:

There did not appear to be a requirement to cross-reference setpoints, key instructions, and other vital information between plant drawings, procedures, training manuals, design documents or other controlled documents to ensure consistency following changes in any one document. It appeared, and was confirmed in discussions with licensee personnel, that a formal process to review the impact on other documents was not used when temporary changes or permanent changes were made to controlled documents.

Procedures OP-2, "Core Spray System," and OP-16, "Feedwater System Booster Pump to Reactor," had numerous typographical errors, differences between control room indication labels and procedure descriptions, and differences between system drawings and procedure valve lineup sheets. Examples of the differences included:

(a) Valves CRS 743, 745, 734, 736, 747, 709, and 711 on Procedure OP-2 valve lineup sheets, Table 1, were inconsistent with the core spray system drawing regarding normal position requirements (i.e., closed or capped and closed vs. locked-closed);

(b) Procedure OP-2, Section I.7, did not direct shutdown of Core Spray Topping Pump 111 if Core Spray Pump 111 tripped, which could result in pump damage;

(c) In Procedure OP-2, Table 1, Valves CRS 305, 307, and 767 were incorrectly identified as System 112 valves instead of System 111 valves. This could lead to operator confusion during the conduct of a valve lineup or verification;

(d) Procedure OP-16, Table 1, had discrepancies between actual valve requirements and procedural valve requirements (i.e., locked open/closed versus open/closed). Additionally, Table 1 specified position for valve 50-64 was open while the drawing requirement was to have the valve locked-open.

Condenser hotwell level alarm setpoints provided in Procedure OP-15A, "Condensate System," appeared to be inconsistent with Technical Specification requirements and actual plant setpoints. Procedure OP-15A specified the condenser hotwell level high alarm at 66 inches and the low alarm at 42 inches while the Technical Specifications required the level to be maintained above 57 inches. During the inspection, the licensee determined that the instrument calibration procedure set the low-level alarm at 60 inches and the high-level alarm at 70 inches, which appeared consistent with the Technical Specifications. A change was initiated to the procedure to correct the error. This error had also been programmed into the simulator, where the low level alarm was actually set at 42 inches. Corrective action was initiated by the licensee to correct the simulator alarm setpoints to agree with the actual plant configuration.

Procedure OP-46, "High Pressure Coolant Injection," included a description of the system operation following limited restoration of the 115 kV grid after a loss-of-offsite-power event. Notes were present describing some of the automatic and manual support systems which must operate to allow operation of the HPCI/FW system. The procedure did not provide guidance for the reactor building closed loop cooling (RBCLC) system, which cooled the condensate booster pump bearings, the feedwater pump lube oil and the instrument air system, which were required for proper operation of the HPCI/FW systems, or the emergency service water system, which cooled the RBCLC system. Both the RBCLC and emergency service water systems had to be manually loaded onto the emergency diesel generator by the operator.

Procedure OP-2, Section 1.24, directed actions to be taken by the operator in case Annunciator K2-4-7, "Core Spray Pumps Discharge Pressure High," was activated by high pressure (445 psig) because of a stuck closed relief valve on the common discharge header of the core spray topping pumps. The procedure directed the operator to remove the system from service by placing the pump switches in the "pull-to-lock" position, but no direction was provided to re-initiate the system once reactor pressure decreased below 365 psig and the inboard isolation valves opened to allow vessel injection. The team was also concerned that consideration would be given to shutting down the pumps before it was firmly established that the core spray system was not required.

Concern B

Procedure S-SUP-Q6, "Control of Operator Aids," was used by the licensee to provide for the control, authorization, documentation and review of operator aids to ensure they were current and complete and to prevent personnel from using unauthorized operating and maintenance information in the performance of their duties. The team reviewed the implementation of this program and found that the program was appropriately implemented and the required reviews were conducted. The team was concerned that the number of active operator aids was excessive; 130 at the time of the inspection. Many of the operator aids appeared to be panel labels and instructions that could be made permanent. Additionally, the log of operator aids did not contain a copy of the aid. If an aid was damaged or destroyed, it would be difficult to replace exactly without such information on file. Operator aids were employed on the main control room panels to correlate the readings between the various water level instruments used by the operator during startup, normal operations and emergency conditions. The aids had been active since 1984, and consisted of paper copies taped to the panels between the instruments. The aid which correlated the RPV level fuel zone instrument reading to the top and bottom of the active fuel was very hard to read. Another RPV water level aid had informational portions cut away to enable it to fit between the instruments. Problem Report 258 was generated by the licensee in March 1988 to address the removal of operator aids from the control room

and replace them with permanent labels, but no action had been taken by the time of the inspection. The licensee committed to review and revise the operator aids program to address the concerns identified by the inspection before restart.

Concern C

Based on the number of deficiencies identified above and previous alarm response procedure issues discussed in Section 3.1.6 of this report, the team was concerned about the adequacy of station operating procedures and operator compliance with the procedures.

Response to Unresolved Item 88-201-06

Concern A

The NMPC configuration Management System requires a review of controlled documentation, including operating procedures, for changes made to the design configuration. To correct oversights made before implementation of the formalized configuration management program, a design basis reconstruction program has been established and will work through configuration management to correct inconsistencies.

A review of annunicator response procedures has been completed by licensed operators to ensure consistency between setpoints for annunciators and computer alarms, between specified setpoints and calibration data, and between actions desired for normal and emergency situations. Engineers are independently reviewing ECCS Annunciator Response Procedures to ensure the setpoint and the actions are consistent with the design basis of the system. The operators and engineers then work together to resolve any discrepancies in their findings.

A rewrite of all operating procedures is also currently underway to bring the procedures up to the industry standards as defined in the writer's guide. This will resolve concerns with human factors and typographical errors, as well as technical content.

Concern B

The control of operation aids will be maintained through Procedure SUP-6 as identified by the inspection team. This procedure will require limited use of temporary operator aids and correct the other deficiencies noted. The procedure will apply as a site wide procedure so that the use of temporary operator aids at Unit 2 is similarly controlled.

Concern C

Niagara Mohawk has addressed the inspection team concern related to procedural adequacy through the procedure review process identified above. This rewrite effort is intended to identify and eliminate those procedural actions wherein a specified operator response is inappropriate. Major site management emphasis is placed on procedural adequacy and operator compliance since this is recognized as a major site action where improvement is required to support restart of Nine Mile Point Unit 1.

NRC FINDING
UNRESOLVED ITEM 88-201-07

Concern A

The pump curve used for the LOCA analysis did not appear to be effectively translated into surveillance test acceptance values to determine core spray system pumps operability. The Technical Specification acceptance values were determined from the design basis pump curve specified in Section VII of the FSAR, which was taken from GE Report NEDE-30241, "Performance Evaluation of the Nine Mile Point Unit 1 Core Spray Sparger." An uncontrolled copy of this curve was maintained in the Control Room for use by station operators in determining the operability of the core spray system pumps. The test acceptance values were determined by adding and subtracting an instrument error to the curve to define an acceptance band and operators were trained to verify that the pumps test data plotted within this band. The team was concerned that the instrument error band should only have been added to the curve to obtain the minimum pump acceptance values. It appeared that previous pump test values falling within the identified band could indicate that the pump might not deliver the flow assumed by the LOCA analysis.

Concern B

Pump testing practices did not appear to agree with statements made in an NRC Safety Evaluation Report (SER) for core spray effectiveness in a steam environment. The SER, dated July 24, 1985, states that, "The surveillance test procedure for core spray operability as presently written verifies that core spray pump performance characteristics over the full range of pressure and flow rates have not degraded. This range includes both pressure vs. flow points (i.e., 125 psia vs. 3400 gpm and 30 psia vs. 5020 gpm)." Procedure N1-ST-Q1, "Core Spray Pumps and Motor Operated Valves Operability Test," Revision 2, tested the core spray system pumps at only one point determined by a throttle valve position on the test line to the torus. This throttle position was such that test flows were approximately 3000 gpm at 300 psig pump discharge pressure, which was less than the flow range specified in the SER.

The licensee stated that single point testing had always been the practice for core spray system surveillance testing. Previously, test flow rates of 4000 gpm were achieved; however, excessive vibration in test line piping necessitated reducing the test flow.

Concern C

The Technical Specification acceptance values for some core spray system MOVs appeared to be inconsistent with their safety function. Core Spray System Outside Isolation Valves 40-02 and 40-12 and Test Line Isolation Valves 40-05 and 40-06 were designed to reposition upon receipt of an initiation signal during system testing. Core Spray System Inside Isolation Valves 40-01, 40-09, 40-10, and 40-11 were designed to reposition upon receipt of an initiation signal during a normal standby system lineup. The team was concerned because the stroke time acceptance values for these valves with similar functions were different; Valves 40-01, 40-09, 40-10, and 40-11 had stroke time acceptance values of 20 seconds while Valves 40-02, 40-12, 40-50, and 40-60 had stroke time acceptance values of 25 seconds. During the inspection, the licensee could not resolve the difference in stroke time acceptance values for these valves with similar functions. The team reviewed previous test data for all the valves and determined that the actual stroke times were less than 20 seconds for all the valves.

Concern D

Hydrostatic tests were conducted at insufficient pressure on the regions of the core spray system between the Core Spray Suction Isolation Valves 81-01, 81-02, 81-21, and 81-22, and the Core Spray Topping Pump Stop Valves 81-09, 81-10, 81-29, and 81-30. Procedure N1-ISI-HYD-424, "Reactor Core Spray System Hydrostatic Pressure Test," Revision 1, which was conducted every inspection interval and after system maintenance or alteration, required only an 80 psig test. The ASME Code, Section XI required this area of the core spray system to be hydrostatically tested to 1.25 times system design pressure if the design temperature was greater than 200°F, and there were no system relief valves. There were two design pressure regions within the hydrostatic test

boundary described above. From the core spray pump suction isolation valves to the suction of the core spray topping pump, the design pressure was 340 psig, and, from the core spray topping pump suction to the topping pump stop valves, the design pressure was 465 psig. The team noted that by conducting the hydrostatic test at 1.25 times design pressure, the licensee would not only comply with ASME Code Section XI, but would also ensure a conservative test of system integrity that was consistent with the high pressures experienced downstream of the core spray pumps upon system initiation.

Concern E

The licensee had not implemented the IST program on the HPCI/FW system because it was not considered a safety-related system. The team was particularly concerned because it appeared that check valves at the discharge of the feedwater and booster pumps were not adequately tested or inspected. A gross functional check of the motor-driven feedwater pump discharge check valve was conducted quarterly when testing the pumps, but this test did not accurately measure the integrity of the valve internal components. Failure of the feedwater pump discharge check valves could cause a loss of the motor-driven pump because of reverse rotational damage. Such a loss had previously occurred on November 5, 1983, and was reported by LER 83-35. Undetected failure of both the feedwater and booster pump discharge check valves could result in inadvertent overpressurization of condensate system low-pressure piping.

Concern F

The licensee could not adequately implement ASME Code Section XI testing and trending on core spray system MOVs and pumps because of insufficient margin between the design characteristics and the Technical Specification operability requirements. Before flow from the core spray system pumps were to degrade to the alert range of 93 percent of the baseline flow, the pumps would be declared inoperable because they would not meet the Technical Specification requirements. Similarly, before MOV stroke times degraded by 25 percent to

the action range, the valve would be declared inoperable by Technical Specification requirements. This design feature made performance trending by the licensee ineffective.

Concern G

The licensee did not specify the required inlet pressure for their core spray pumps as required by ASME Code, Section XI. The inlet pressure for the core spray pumps did not vary appreciably during testing because the pumps take suction on the torus, and the torus level was maintained in a narrow bank by the Technical Specifications. Because of this consistency, the team did not consider this deficiency to be significant.

Concern H

The data obtained during pump flow testing was inconsistent with the pump curves. The licensee only measured pump flow and not pump head during testing. It was assumed that the system resistance was fixed by the throttled position of the test valves. However, the team reviewed the test results and concluded that the measured flow variations could mean that the pump head was fluctuating by as much as 15 psig. A possible explanation was that the pump mini-flow relief valve was unexpectedly opening or leaking, thereby diverting flow from the reactor and changing system resistance. The licensee stated that this should not occur because the relief setpoint (320 psig) was above the pump test pressure (300 psig).

Response to Unresolved Item 88-201-07

Concern A

Core spray system surveillance test results are addressed in calculation S14-81.1-F001 included with this response. Figure 2 of this response shows that all core spray surveillance test results plotted above the surveillance curve so that the flow assumed in the LOCA Analysis was demonstrated by the surveillance test. The minimum acceptance level will be deleted from the revised pump surveillance curve to avoid possible acceptance of a low core spray flow test.

Concern B

Niagara Mohawk's response to items 1.b(4) and 1.b(5) in Letter No. NMP1L 0333, dated December 16, 1988, address the NRC concerns related to the core spray pump curves, testing practices and the potential effect of bypass flow. As was stated in those responses, the pump curves will be validated at several flow rates using the test return line to the torus. Test flow will be limited to a maximum flow of about 3000 gpm because of test line capacity. Subsequent quarterly surveillance testing would continue present practice, i.e. verifying a single point (flow, pressure) on the pump curve.

Concern C

The surveillance test acceptance values for Core Spray injection valves 40-02 and 40-12 have been revised to 20 seconds.

Concern D

Procedure N1-ISI-HYD-424 was revised to require the piping hydrostatic test to be performed at 405 psig (390 psig + 15 psig for variance in head) which is 1.25 times the design pressure of 310 psig. Although there are two design pressure regions within the hydrostatic test boundary, testing at pump suction side design value (405 psig) meets the ASME Code Section XI requirements. This hydrostatic test will be made during the current outage.

Concern E

Niagara Mohawk will prior to plant restart review incorporating the HPCI/FW system check valves into the IST program to control surveillance testing. HPCI/FW system capability is demonstrated as the feedwater system is in continuous service during plant operation. The standby pump and its associated discharge check valve are put into service on at least a quarterly basis. Niagara Mohawk will prior to plant restart, prepare a surveillance test for the feedwater pump check valves that will be performed as part of the quarterly surveillance of the standby pump train. Niagara Mohawk's response (NMP1L 0333 December 16, 1988) to "Quick-Look" item 1.e(4) stated that the HPCI/FW pump test curves would be controlled prior to declaring the system operational through the Unit 1 Configuration Management System and that post maintenance test procedures would be revised to included validation of pump performance following major maintenance that might affect pump flow capability.

Concern F

The LOCA accident analysis is being revised to reflect lower core spray sparger flow rates than were used in the analyses documented in NEDC-31446P. This reduction in core spray flow accounts for potential bypass flows and will provide margin for pump degradation. This latter allowance will consider flow margin for possible IST trending purposes. Niagara Mohawk will evaluate valve design changes or analytical changes to allow additional margin on motor operated valve stroke times to provide margin for trending purposes.

Concern G

Niagara Mohawk agrees with the inspection team conclusion that it is not necessary to specify core spray suction pressure for surveillance tests since it is governed by torus water level, which is essentially constant because of Technical Specification requirements on torus water level.

Concern H

Niagara Mohawk believes the flow variations that occurred in core spray system pump testing resulted from variations in position of the test line throttling valve. Administrative controls will be put in place to ensure the test line throttling valve position is not changed between tests. Testing currently in process on the core spray system will verify that the mini-flow relief valve does not open during surveillance tests.

NRC FINDING
UNRESOLVED ITEM 88-201-08

The inspection team reviewed the testing program for determining the operability of pumps, valves, storage-tank level, system initiation and automatic trips for the HPCI/FW system. The test program for determining HPCI/FW system operability appeared acceptable with one exception.

The acceptance values for determining HPCI/FW pump operability did not appear to accurately measure system performance. The Technical Specification requirements specified that the HPCI/FW system must be capable of meeting the pump head versus flow curve. The licensee limited testing to the motor-driven feedwater pumps and the curves used in the control room to determine operability were not adequately controlled. The curves used in the control room were not part of a controlled document and could not be verified to be consistent with the existing equipment installed in the plant. The team was also concerned that the actual performance of the HPCI/FW System was the combined performance of the condensate pumps, the booster pumps, and the feedwater pumps. The performance of the condensate and booster pumps were never checked with a surveillance procedure. Therefore, the actual total performance of the HPCI/FW system was never verified.

The licensee's position was that if the performance of the condensate or booster pumps were deteriorating, it would be detected during normal operation by the inability of the system to supply adequate flow to the reactor vessel. The team disagreed with this position because deterioration in pump performance could be very gradual, which would not necessarily be noticed, and the system had excess capacity to provide water to the reactor during normal operation. Any deterioration would be covered by wider opening of the feedwater control valves which, again, would not necessarily be noticed. Even if it were noticed, there was currently no procedure to quantify the deterioration and compare it with acceptable limits.

At the inspection followup meeting, the licensee committed to issue controlled system pump curves, including booster and condensate pump performance, and validate the curves at several setpoints.

Response to Unresolved Item 88-201-08

Niagara Mohawk responded to this concern in item 1.e(4) of Letter No. NMP1L 0333, dated December 16, 1988.

NRC FINDING

UNRESOLVED ITEM 88-201-09

The inspection team reviewed the licensee's corrective actions taken with regard to the concern about the adequacy of the 7-day LCO for the core spray system discussed in Section 3.1.1 of this report. The inspection team determined that the following sequence of events were pertinent:

- In 1974, Technical Specification 3.1.4 was issued for the core spray system as part of the initial license. The system contained two loops with two pump sets per loop and was thought to be 400 percent redundant. The LCOs were established at 15 days for one disabled pump set and 7 days for one loop out of service.

- In October 1975, the initial 10 CFR 50, Appendix K LOCA Analysis was performed assuming two core spray loops were always available. The analysis used the SAFE/CHASTE Computer Model which identified the small break LOCA as the limiting condition for reaching the 10 CFR 50.46 limits for peak clad temperature (2200°F). This analysis became the bases for a proposed amendment to the Technical Specification fuel limits submitted on October 31, 1975. The core spray system LCOs were not identified for revision to be consistent with the LOCA analysis design inputs as part of this proposed amendment.

- In 1983, GE Report NEDE 30241, "Performance Evaluation of the Nine Mile Point Unit 1 Core Spray Sparger," was performed using a new SAFER/CORECOOL Computer Model to evaluate core spray sparger operation in a steam environment. Although not formally used as a bases for Technical Specification limits, this more accurate analysis showed that the small break LOCA was no longer the limiting condition for meeting 10 CFR 50.46 limits; analyzed peak clad temperature for the small-break LOCA was now approximately 300°F below the limit.

- In June 1987, 10 CFR 50, Appendix K LOCA Analysis (NEDC 31446P) was performed using the SAFER/CORECOOL/GESTR Model to determine Technical Specification limits for the next operating cycle. The analysis assumed that two core spray loops were always available to support LOCAs.

- On August 17, 1987, personnel from Operations, Engineering and Licensing met to discuss a potential problem with an existing Technical Specification LCO for the core spray system and NEDC 31446P assumptions. The concern was that the 15-day LCO should be reduced to a 7-day LCO to be consistent with NEDC 31446P. Internal memoranda dated August 19 and 25, 1987, documented the meeting results and indicated that the group decided the existing 15-day LCO was acceptable under the new analysis. The adequacy of the existing 7-day LCO for NEDC 31446P was not discussed at the meeting. The licensee had contacted GE prior to the meeting and was told that the LCOs were both adequate as written.

- On September 1, 1987, Engineering issued an internal memorandum which identified that the 7-day LCO for core spray system may be an unanalyzed condition by NEDC 31446P and require revision before the next operating cycle. This memo was distributed to Operations personnel but not the Licensing organization.

- On September 22, 1987, Licensing issued a memorandum in response to concerns raised at the August meeting which stated that the 15-day LCO should be changed to a 7-day LCO to be consistent with NEDC 31446P and other LCOs. The memo also identified that previous 10 CFR 50, Appendix K LOCA analyses had assumed two loops of the core spray system to always be available. The existing 7-day LCO was not discussed as being an unanalyzed condition.

- On November 10, 1987, operators took one loop of the core spray system out-of-service for 17 hours to repair a leak from a check valve. The operators entered the 7-day LCO without realizing it was an unanalyzed condition.

- On December 19, 1987, the plant entered an extended outage after a feedwater transient event.

- On August 23, 1988, after realizing that the 7-day LCO was an unanalyzed condition, the licensee drafted a Technical Specification Interpretation that prevented entering the 7-day LCO for the core spray system. This interpretation was still in the review process at the time of this inspection, but was to be issued before startup.

- On September 15, 1988, the NRC inspection team determined that the 7-day LCO was an unanalyzed condition by the licensee's 10 CFR 50, Appendix K LOCA analyses and that the plant had entered the 7-day LCO when operating on November 10, 1987. The licensee completed the proper investigation and NRC reports upon notification by the team.

- In a September 22, 1988 letter to the licensee, GE confirmed that using only one core spray loop and the previous 10 CFR 50, Appendix K LOCA analyses assumptions, the SAFE/CHASTE Model Analyses would yield a higher analyzed peak clad temperature then previously determined. This new value would be above the 10 CFR 50.46 limits. However, the GE letter also stated that previously used conservative design input assumptions concerning pump delivery pressure could be changed to reduce the analyzed peak clad temperature below the 10 CFR 50.46 limits. The team agreed with this assessment and concluded that the previous SAFE/CHASTE Model Analysis could be revised to indicate acceptable results with one core spray loop.

Concern A

The inspection team was concerned about the licensee's corrective actions in this situation and drew the following conclusions about the sequence of events:

(1) The licensee's corrective action program was ineffective for resolving a potentially significant deficiency identified with the Technical Specifications for the core spray system that would allow plant operation

in an unanalyzed condition. Collectively, sufficient information was available with the licensing, operations and engineering organizations to determine that the existing 7-day LCO was an unanalyzed condition before the plant unknowingly entered the 7-day LCO on November 10, 1987. The team found no evidence to suggest that the licensee realized this fact until after the plant entered the current outage.

(2) The licensee failed to take adequate corrective action to investigate and report the problems with the 7-day LCO when it was first realized in approximately August 1988. The corrective actions were limited to drafting a Technical Specification Interpretation. No investigation of previous operations was conducted to determine whether the plant had previously been operated in an unanalyzed condition; the NRC was not notified in accordance with 10 CFR 50.72 and 10 CFR 50.73; and a Technical Specification change was not promptly initiated.

(3) The initial cause of the problem appeared to be the improper translation of the 1975 10 CFR 50 Appendix K LOCA Analysis assumptions into Technical Specification requirements as required by 10 CFR 50.46.

The licensee's failure to properly implement the requirements of 10 CFR 50.46 to revise its Technical Specifications to conform with the LOCA analyses specified in 10 CFR 50, Appendix K and the failure to take adequate corrective action and make necessary reports to the NRC will remain unresolved as part of an overall unresolved item on the licensee's corrective action program

Concern B

During a review of the MOV stroke time test results for core spray and HPCI/FW system valves, the inspection team identified three valves which appeared to have stroke times in excess of the Technical Specification limits; Core Spray System Vent Valves 40-30 and 40-31 and Feedwater Isolation Valve 31-07. In LER 88-14 (May 10, 1988), the licensee identified that Valve 40-30 stroke times had been out of specification since 1986. The root cause of the problem was that indicating lights used to measure valve stroke times and the limit switch contacts used for the torque switch bypass function were driven from the same limit switch rotor. The limit switches were adjusted to provide

adequate torque switch bypass functions but no adjustments were made for the valve stroke time determinations.

The inspection team review applied the same criteria described in LER 88-14 for determining actual valve stroke time from the measured stroke time during testing. For Feedwater Isolation Valve 31-07, the most recent MOVATs testing in 1986 indicated a disc bypass margin (DBM) of .886 (52.2 sec/58.9 sec). The DBM was the fraction of valve travel measured by the indicating lights. Therefore, applying this DBM to a Technical Specification limit of 60 seconds for valve 31-07 would yield a measured acceptance valve limit of 53.2 seconds. A review of test results for Valve 31-07 revealed measured stroke time of 55.8 seconds on January 25, 1986, 56.0 seconds on June 14, 1986, and 55.0 seconds on October 21, 1987. The team concluded that each of these stroke times were above the Technical Specification limits. For Valve 40-31, no MOVATs data was available for the most recent limit switch setpoints, but data from the licensee's September 18, 1986 response to NRC Bulletin 85-03, "Motor Operated Valve Common Mode Failures During Plant Transients Due to Improper Settings," indicated that the closed torque switch was bypassed by 23 percent yielding a DBM of .77. Applying this calculated DBM to a Technical Specification limit of 30 seconds yielded a measured acceptance valve of 23.1 seconds. This measured acceptance value had been exceeded 17 times during monthly stroke time tests since August 1986. This issue of adequate investigation of reportable events will remain unresolved as part of an overall unresolved item on the adequacy of the licensee's corrective action program.

Response to Unresolved Item 88-201-09

Concern A

The response to this Unresolved Item will be submitted in a separate letter which is scheduled for April 14, 1989.

Concern B

During the course of the investigation of core spray vent valve 40-30 exceeding its technical specification stroke time limit (LER 88-14), Niagara Mohawk reviewed all containment isolation valves, including valves 31-07 and 40-31, for a similar problem. No other valves (other than 40-30) were outside Technical Specification Limits.

Niagara Mohawk has initiated a design modification to eliminate the problem of valve position light adjustments from affecting the valve stroke time measurement. This modification separates the valve position light switch and torque bypass switch so that they may be adjusted independently of each other. Previous adjustment made to set the torque bypass switch also affected the switch setting for the valve position light.

NRC FINDING
UNRESOLVED ITEM 88-201-10

The team reviewed the adequacy of the licensee's Operational Experience Assessment (OEA) Program which included the review of documents such as NRC Information Notices and Circulars, INPO SOERs and SERs, and General Electric Company Services Information Letters (SILs), as well as interviews with licensee personnel involved in the OEA program. Overall, the licensee's OEA program was weak. Discussions with licensee personnel revealed that the program was formalized around 1982 and responsibilities were assigned to the Technical Support Group as part of their job responsibilities without establishing a separate OEA group. This mode of operation continued until August 1988, when a group with specific responsibilities for OEA was established. The following specific concerns were identified during the inspection team's review:

> Internal Memorandum NMP 31552 of March 10, 1988, closed out 11 related NRC Information Notices, INPO SOERs and INPO SERs concerning valve mispositioning because of human error during operations and maintenance activities. The response addressed the specific issue of valve mispositioning, but did not address the broader concerns of equipment, instrument and component labeling identified by NRC Information Notice 87-25 and INPO SOER 85-2. Plant walkdowns conducted by the team revealed a labeling program that was below industry standards, and there did not appear to be a significant effort being made by the licensee to improve plant labeling. Additionally, the licensee stated in NMP 31552 that training of non-licensed operators in the manipulation of all of the major types of valves installed in the plant was conducted in theory lesson NLT-20, "Nuclear Power Plant Fundamentals - Valves, Traps and Pipes," and included training on how to position the valve and how to verify its position when performing a valve lineup. Review of the lesson plan, which was renumbered as OPS-1-NLO-002-T20-01, revealed that this information was not included in the plan; rather, the licensee relied on on-the-job training activities to teach new operators this information. The information in the OEA memorandum appeared to be in error. The team

was concerned about this error because an NRC Augmented Inspection Team had identified a similar concern at Nine Mile Point Unit 2 as a contributing cause to an event as discussed in Inspection Report 50-410/88-01.

Internal Memorandum NMP 30292 of March 14, 1988, closed out 22 related NRC Information Notices, INPO SERs and an INPO SOER concerning undetected check valve failures. The response concentrated on INPO SOER 86-3, "Check Valve Failures or Degradation." The team did not determine whether the INPO document encompassed all the issues identified by the other documents. INPO SOER 86-3 discussed undetected check valve failures due to misapplication of the valve in the system and inadequate preventive maintenance. The SOER made recommendations for improved testing and inspection of check valves and a design review to determine whether the proper valves were installed in the correct locations for the intended functions. The recommendations were to be applied to the main steam, nuclear service water, diesel starting air, suppression pool support, main feedwater and residual heat removal systems. The team identified the following concerns with the licensee's internal response:

(a) The memorandum referenced five related check valve failures at NMP1 from the period of August 1982 to June 1986, and concluded that this was an acceptable performance for ten years of operation. The team was concerned because it appeared that the number of check valve failures was increasing as the plant aged.

(b) The response to the recommendation for improved testing and inspection of check valves was to state that the present preventive maintenance practices for check valves were in compliance with the regulatory requirements of 10 CFR 50, Appendix B and ASME Code, Section XI and that all the recommended systems were included in the program. Therefore, no additional testing was required. This response appeared inconsistent with licensee practices since HPCI/FW system check valves were not included as part of the IST program.

(c) The licensee performed a review of plant isometric diagrams, purchase orders and some visual inspections of check valves to satisfy the design review recommendation. Although this review identified several instances of improper location and orientation of check valves, the design deficiencies were dismissed because no problems with these valves had previously been identified in the maintenance history.

The team concluded that the licensee was not taking advantage of the information available on check valve maintenance, testing and design because NMP1 had not experienced similar failures.

IE Circular 78-15 advised of problems with Anchor Darling tilting disc valves failing to close when installed vertically and requested licensees to verify the installation of similar valves to ensure adequate operation. The licensee closed this document with an internal memorandum dated November 17, 1978, which stated in part that, "All check valves installed at Nine Mile Point Unit 1 are horizontally installed Chapman Tilting Disc Check Valves." Contrary to this statement, the team noted during plant walkdowns that the Core Spray Topping Pump Discharge Check Valves (81-07, 81-08, 81-27, and 81-28) were installed in the vertical position, along with check valves on the discharge piping of the RBCLC pumps and the condensate booster pumps. Thus, the team concluded that the licensee's review of the concerns of IE Circular 78-15 appeared to be inadequate.

GE SIL 375 addressed concerns with potential water hammer effects caused by inadequacies in the keep-fill subsystems for emergency core cooling (ECCS) systems on BWR-4, 5, and 6 designs. The licensee closed this document with an internal memorandum that noted that the concern was not pertinent to NMP1 since it was not one of the specified reactor designs. At the top of the file memo was note indicating that the plant did have a keep-fill subsystem for the core spray system, but no further evaluation was evidently made. The design review conducted as part of this inspection identified in Section 3.1.5 of this report the potential for

water hammer during a LOCA because of the location of the injection point for the keep-fill system. The team concluded that an adequate review of the subject document was not made, resulting in the conclusion that the document was not applicable.

The team identified several instances where closure documentation was either not in the file or the closure documentation had notes that indicated the response was not acceptable for closure. Examples of these were GE SIL 300, 323, and 375 and IN 84-37 and 85-76. The licensee had not resolved these discrepancies by the close of the inspection.

At the time of the inspection, the licensee had approximately 336 OEA items remaining open. The licensee had increased its staff with contractors to review each OEA item before startup. This review, however, would not include past responses to industry items.

At the inspection followup meeting, the licensee stated that the inspection team's findings were examples of past practices of industry information review and not indicative of the current program. The team agreed that the current program was not adequately reviewed by the inspection sample, but was concerned that previous responses were not being reviewed. This issue will remain unresolved pending NRC followup review of the licensee's program for evaluating industry information.

Response to Unresolved Item 88-201-10

Niagara Mohawk responded to these concerns as responses to items 2b and 2e in Letter No. NMP1L 0333, dated December 16, 1988.

ATTACHMENT 1
TO
NIAGARA MOHAWK POWER CORPORATION'S RESPONSE TO
SAFETY SYSTEM FUNCTIONAL INSPECTION REPORT 88-201

MPR ASSOCIATES, INC.

February 24, 1989

Mr. Lee A. Klosowski
Niagara Mohawk Power Corporation
301 Plainfield Road
Syracuse, NY 13212

Subject: NMP-1 Safety System Functional Inspection
Core Spray System Calculations

Dear Mr. Klosowski:

Enclosed is a final copy of the current revision of all calculations performed by MPR in connection with SSFI - IR 88-201-01 (Quick Look Finding 1.b). Several of the calculations have been revised as discussed below.

1. Core Spray Flow. The core spray flow rate calculations have been revised to account for bypass flow around the check valve at the discharge of the idle topping pump during one pump set operation, and bypass flow for topping pump seal and motor cooling and core spray pump motor cooling. The net core spray flow into the reactor vessel was conservatively assumed to be reduced by the magnitude of the bypass flows. In addition, a new value for the sparger resistance was used based on independent calculations performed by MPR. Previously, the value for sparger resistance was taken from a proprietary 1981 GE report in connection with the Oyster Creek overhead sparger. The new value for sparger resistance calculated by MPR is about 20 percent lower than the value reported by GE in the above mentioned report. Also, a new value for the strainer resistance was used based on measured ΔPs across the strainer obtained during core spray system tests performed during the week of February 5, 1989. Previously, the value for strainer resistance was taken from the equipment specification. The new value for strainer resistance based on the test results is about 3.4 times higher than the previous value. However, the effect of the higher strainer resistance on the calculated core spray flow rates is slight because the strainer resistance is only a small fraction of total system resistance. Finally, the safety valve on the pump recirculation line was assumed to close at an inlet pressure of 280 psig rather than 290 psig. The net effect of the above changes is that the maximum flow through the core spray pumps was calculated to increase by about 170 gpm for one pump set operation and by about 400 gpm for two pump set operation. The revised core spray flow rate calculations are contained in Attachment 1 of the enclosure.

Revised
February 24, 1989

MPR ASSOCIATES, INC.

RESPONSE TO SSFI -IR 88-201-01
QUICK LOOK FINDING 1.b

SSFI ISSUE 1.b

Analyses were inadequate and testing of the core spray system did not demonstrate system performance as described in the licensing documents for the following reasons:

(1) Net positive suction head (NPSH) for the pumps may not be adequate to support the flows expected during large break LOCAs with containment sprays in operation.

(2) Vortexing analyses did not account for the interactive effects of the two pump suctions which are in close proximity to each other.

(3) System resistance curves did not account for all the components in the system.

(4) System pump curves did not appear to be controlled or validated by testing over the full range of expected flows.

(5) Potential flow diversion from the reactor through the combined pump discharge relief valve was not considered in any analyses.

NMPC RESPONSE

Core Spray Flow

A schematic diagram of the core spray system is shown in Figure 1-1. The core spray system consists of two independent loops; each with redundant pumps and valves.

The core spray flow (per loop) is a function of the number of pump sets in operation, the individual core spray and core spray topping pump head/flow curves, the system resistance, and the reactor vessel pressure. [Note: A pump set consists of one core spray pump and its associated topping pump.] The core spray pump head/flow curves for one pump set in operation and the system resistance curves for reactor vessel pressures of 0, 160, and 365 psig are shown in Figure 1-2. Results for two pump sets in operation are shown in Figure 1-3. In these figures,

2. NPSH. The higher calculated flow rate through the core spray pumps also affects the required and available NPSH at the pump suction. At the previous maximum pump flow rate of 4830 gpm, the required NPSH was 37 ft and the available NPSH was 37 ft At the higher maximum pump flow rate of 5000 gpm, the required NPSH is 39 ft. and the available NPSH is 36 ft. However, the adverse effects on core spray system performance of the available NPSH being slightly less than the required NPSH would be minimal for the following reasons.

   o The calculations were performed for the maximum calculated flow rate through the pump of 5000 gpm. At a flow rate of 4800 gpm, the available NPSH would be equal to the required NPSH. Thus, the actual flow rate would be somewhere between 4800 and 5000 gpm. The flow would not drop below 4800 gpm since the available NPSH would be equal to the required NPSH at that flow. The slight increase in cavitation due to the low suction pressure would have a minimal impact on pump degradation over the time period that the core spray pumps would be running in this mode.

   o The calculations were performed for an assumed torus pressure of 0 psig (which corresponds to an air temperature of 90°F) in accordance with NRC Regulatory Guide 1.1. This is considered conservative. At a torus pressure of 1.3 psig, the available NPSH would be equal to the required NPSH. A torus air temperature of 114°F at the time the torus water temperature is 140°F would be sufficient to produce a torus pressure of 1.3 psig.

   o The calculations were performed for the maximum torus water temperature following a LOCA of 140°F. This temperature would not exist for the long-term following a LOCA due to torus cooling via the containment spray heat exchangers. At a torus temperature of 118°F, the available NPSH would be equal to the required NPSH. The torus water temperature would be reduced to 118°F about 6 hours after the accident.

   Thus, the effect of the low suction pressure on the core spray flow rate would be slight (less than 4 percent) and would exist only in the short-term. Pump degradation during this period would be minimal. The revised NPSH calculations are contained in Attachment 2 of the enclosure.

3. Combined Head/Flow Curve. The effect of bypass flow around the check valve at the discharge of the topping pump and bypass flow for pump seal and motor cooling also affects the calculated combined head/flow curve at the pressure indicator at the discharge of the topping pumps. This curve is used to evaluate the surveillance test results. A revised combined pump head/flow curve is given in the calculations contained in Attachment 3 of the enclosure.

4. Vortex Formation. The higher calculated flow rate through the core spray pumps also affects the vortex calculations. For one pump set operation, the Froude No. is increased from 1.03 to 1.07. For two pump set operation, the Froude No. is increased from 0.67 to 0.72. However, the previous conclusions with regard to vortex formation and the potential for air entrainment are not affected by the slightly higher calculated Froude Nos.

The enclosed revised calculations include all those transmitted to you by our letter dated December 1, 1988, and subsequently submitted to the NRC by Niagara Mohawk letter dated December 8, 1988. They supercede the calculations transmitted to you by our letter dated February 2, 1989.

Please contact me if you have any questions on the enclosed calculations.

Sincerely,

John Johnson

John W. Johnson

Enclosure

system resistance curves are provided for both a clean strainer and a partially blocked (50 percent) strainer. From Figures 1-2 and 1-3, the calculated core spray flows into the reactor vessel are as follows.

ONE PUMP SET OPERATION

Strainer Condition	Flow into Reactor Vessel (gpm)		
	0 psig	160 psig	365 psig
Clean	4670[1]	3580[2]	160[3]
50% Blocked	4670[1]	3530[2]	160[3]

Notes:
1. Safety valve is closed. Bypass flow is approximately 70 gpm for motor and seal cooling and 60 gpm around the idle topping pump check valve.
2. Safety valve is closed. Bypass flow is approximately 70 gpm for motor and seal cooling and 70 gpm around the idle topping pump check valve.
3. Safety valve is open. Bypass flow is approximately 385 gpm through the safety valve, 70 gpm for motor and seal cooling, and 90 gpm around the idle topping pump check valve.

During one pump set operation at a reactor pressure of 0 psig, the total flow through the core spray pump was calculated to be 5000 gpm with a clean strainer and 4920 gpm with a 50 percent blocked strainer. This would result in net flows to the reactor vessel of 4870 and 4790 gpm, respectively, for a clean and 50 percent block strainer. However, in the above table, the total flow through the core spray pump at 0 psig reactor pressure was assumed to be limited to 4800 gpm due to the available suction pressure at the pump for this condition. The effect of the suction pressure on the core spray flow rate is discussed in more detail in the following section (Net Positive Suction Head, p. 5) of this report.

TWO PUMP SET OPERATION

Strainer Condition	Flow into Reactor Vessel (gpm)		
	0 psig	160 psig	365 psig
Clean	6560[1]	4630[2]	730[3]
50% Blocked	6520[1]	4590[2]	720[3]

Notes:

1. Safety valve is closed. Bypass flow is approximately 140 gpm for motor and seal cooling.
2. Safety valve is open. Bypass flow is approximately 350 gpm through the safety valve and 140 gpm for motor and seal cooling.
3. Safety valve is open. Bypass flow is approximately 385 gpm through the safety valve and 140 gpm for motor and seal cooling.

As indicated in the above tables, flow blockage of the strainer up to 50 percent only reduces the core spray flow into the reactor vessel by 1 to 2 percent. Thus, the core spray flow is relatively insensitive to flow blockages up to 50 percent in the strainer.

The core spray flow rate (per loop) used by General Electric (GE) as input to the SAFER/CORECOOL/GESTR - LOCA Loss-of-Coolant Accident analyses performed in accordance with 10 CFR 50, Appendix K, is shown in Figure 1-4 (Reference 1). Also shown on Figure 1-4 are the calculated core spray flow rates from the above tables. As shown in Figure 1-4, the calculated core spray flow rates are essentially equal to the flow rates used by GE in the licensing basis LOCA analyses (i.e., within 3 percent at 0 psig reactor pressure). [Note: The above flow rates are for one core spray system. The LOCA analyses assume two systems are in operation.]

The system resistance curves shown in Figures 1-2 and 1-3 included the following core spray system components.

- All core spray piping, fittings, and valves from the torus to the reactor vessel. The grate across the end of the suction pipe in the torus was assumed to be 50 percent blocked.
- The simplex strainer located between the core spray and core spray topping pumps. The strainer Δp is calculated to be 1.7 psi at 3400 gpm based on recent surveillance test results. The strainer Δp is assumed to be proportional to the flow squared and inversely proportional to the flow area squared.
- The core spray sparger located inside the reactor vessel. The sparger Δp is calculated to be 47 psi at 3400 gpm. This includes the Δp associated with the internal piping, header, and flow nozzles. The sparger Δp is assumed to be proportional to the flow squared.

Bypass flow through the pump recirculation line has been accounted for in the calculations. The safety valve in the recirculation line is assumed to open at 320 psig (the setpoint) and close at 280 psig (88 percent of the opening pressure). Flow through the safety valve is 380 gpm at an inlet pressure of 400 psig (Reference 2). Flow through the safety valve is assumed to be proportional to the square root of the inlet pressure. Automatic core spray initiation is such that the pumps will startup before the isolation valves inside the drywell open which will result in the opening of the safety valve upon system initiation. Bypass flow is assumed to exist at core spray flows which result in a system pressure at the inlet to the safety valve greater than 280 psig. With one pump set in operation, this occurs at reactor pressures greater than 200 psig. With two pump sets in operation, this occurs at reactor pressures greater than 0 psig. The discharge into the torus from the recirculation line is located at elevation 214'-0" (3'-6" above the minimum torus water level) and 4'-6" horizontally from the centerline of the core spray suction. The discharge is parallel with the suction pipe (i.e., in a horizontal direction). Therefore, interactive effects between the recirculation line discharge and the core spray suction are considered negligible.

The core spray flow rate calculations also take into account the bypass flow through the bypass line around the check valve at the discharge of the idle topping pump during one pump set operation, and the bypass flow

for pump motor and seal cooling. These bypass flows are conservatively subtracted from the total flow through the pumps to get the net flow to the reactor vessel.

Core spray flow rate calculations are given in Attachment 1.

Net Positive Suction Head (NPSH)

The required and available NPSH for the core spray pumps are calculated in Attachment 2. This calculation determines NPSH values for four conditions as shown below:

Condition	Torus Pressure (psig)	Torus Temperature (°F)
Surveillance Test	0	90
LOCA Condition 1	22	140
LOCA Condition 2	3.5	140
NRC Regulatory Guide 1.1	0	140

LOCA Condition 1 is at the time of maximum torus pressure due to the design basis LOCA (Reference 3). LOCA Condition 2 is late post-LOCA when the torus air space is assumed to be pressurized due to the increase in the torus air temperature from 90°F to 140°F. The fourth condition is prescribed by NRC Regulatory Guide 1.1 and assumes no increase in containment pressure above that which existed prior to the LOCA. Results of the calculations are provided below.

Condition	Max Pump Flow (gpm)	NPSH (feet) Required	NPSH (feet) Available
Surveillance Tests (Flow Through Return Line)	3400	26	46
LOCA Condition 1			
1 Pump Set	5000	39	88
2 Pump Sets	3350	26	93
LOCA Condition 2			
1 Pump Set	5000	39	44
2 Pump Sets	3350	26	50
NRC Regulatory Guide 1.1			
1 Pump Set	5000	39	36
2 Pump Sets	3350	26	41

As shown in the above table, the available NPSH at the core spray pump suction meets or exceeds the required NPSH for all conditions except NRC Regulatory Guide 1.1 conditions during one pump set operation. For this condition, the available NPSH is 36 ft versus a required NPSH of 39 ft.

However, the adverse effects of the available NPSH being slightly less than the required NPSH would be minimal for the following reasons.

- The calculations were performed for the maximum calculated flow rate through the pump of 5000 gpm. At a flow rate of 4800 gpm, the available NPSH would be equal to the required NPSH. Thus, the actual flow rate would be somewhere between 4800 and 5000 gpm. The slight increase in cavitation due to the low suction pressure would have a minimal impact on pump degradation over the time period that the core spray pumps would be running in this mode.

- The calculations were performed for an assumed torus pressure of 0 psig (which corresponds to a torus air temperature of 90°F) in accordance with NRC Regulatory Guide 1.1. At a torus pressure of 1.3 psig, the available NPSH would be equal to the required NPSH. A torus air temperature of 114°F at the time the torus water temperature is 140°F would be sufficient to produce a torus pressure of 1.3 psig.

- The calculations were performed for the maximum torus water temperature following a LOCA of 140°F. This temperature would not exist for the long-term following a LOCA due to torus cooling via the containment spray heat exchangers. At a torus

temperature of 118°F, the available NPSH would be equal to the required NPSH. The torus water temperature would be reduced to 118°F about 6 hours after the accident (Reference 4).

Thus, the effect of the low suction pressure on the core spray flow rate would be slight (less than 4 percent) and would exist only in the short-term. Pump degradation during this period would be minimal.

The maximum torus water temperature following a LOCA is assumed to be 140°F based on an initial water temperature of 90°F (Reference 5). NMP-1 operating procedures control the torus water temperature during normal operation to 80°F. The maximum torus water temperature permitted by the plant Technical Specifications for extended operation is 90°F. The plant Technical Specifications permit the torus water temperature to exceed 90°F under the following conditions.

- The torus temperature may exceed the Technical Specification limit of 90°F for a maximum of 24 hours. If the time the torus water temperature is above 90°F exceeds 24 hours, then the reactor must be shutdown using normal shutdown procedures. If the torus water temperature reaches 110°F, the reactor must be scrammed from any operating condition.
- During testing of safety relief valves, the torus water temperature may exceed the Technical Specification limit of 90°F by 10°F, provided the temperature is reduced within 24 hours to a value below the Technical Specification limit.

Since the torus water temperature will be below 90°F for normal plant operation, and is only permitted to exceed 90°F for short periods of time (maximum of 24 hours), an initial torus water temperature of 90°F is considered appropriate for LOCA analyses.

Surveillance Test Results

Surveillance requirements for the core spray pumps are as follows.

- At each major refueling outage, automatic startup of one set of pumps in each core spray system is demonstrated.
- At least once per quarter, pump operability is checked.

The combined core spray pump head/flow curve (one pump set in operation) at the pressure indicator at the discharge of the core spray topping pumps has been calculated in Attachment 3 and is shown in Figure 1-5. The combined pump head/flow curve is equal to the sum of the individual core spray and core spray topping pump head/flow curves minus the elevation, velocity, and system losses from the surface of the torus water level (minimum elevation 210′-6") to the pressure indicator (elevation 245′-9"). Results are presented for both a clean strainer and a 50 percent blocked strainer. The effects of bypass flow around the check valve at the discharge of the idle topping pump, and bypass flow for pump motor and seal cooling have been accounted for in the combined curve. The effect of bypass flow through the pump recirculation line has also been accounted for in the combined curve. The safety valve in the recirculation line is assumed to open at an inlet pressure of 320 psig (the safety valve setpoint). Also shown in Figure 1-5 is the current surveillance test curve (Reference 6). [Note: During surveillance testing, the pumps are started up with the test return line open. At the typical surveillance test flows of 2900 to 3400 gpm, the pressure at the inlet to the safety valve in the pump recirculation line is less than the setpoint (320 psig). Therefore, the safety valve remains closed during the surveillance test.]

The core spray pump operability test consists of measurement of the pressure and flow at the discharge of the core spray topping pumps. Results of pump operability tests from 1976 to present have been evaluated in Attachment 3 and are plotted on the combined pump head/flow curve in Figure 1-6. As shown in Figure 1-6, all surveillance test points lie above the clean strainer head/flow curve, and therefore indicate acceptable pump performance.

Vortex Formation and Effects

The potential to form vortices and its effect on the core spray pump performance has been evaluated. Results of full size tests of BWR emergency core cooling pump suctions are reported in Reference 7. In this report, hydraulic performance parameters of interest (i.e., vortex

type, air entrainment, swirl angle, and inlet loss coefficient) were determined as a function of the Froude Number (Fr).

$$F_r = \frac{u}{\sqrt{gs}}$$

where u = velocity of the flow
s = submergence
g = acceleration of gravity

Results applicable to NMP-1 can be summarized as follows:

- o At Froude Nos. less than or equal to 0.8, air entrainment was essentially zero for all tests.
- o At a Froude No. equal to 1.06, air entrainment was less than 0.5 percent for uniform approach flows, and 3-4 percent for non-uniform approach flows (imposed swirl patterns in the test tank).
- o Swirling flow in the suction pipe could affect pump performance if the pump is located relatively close to the inlet. However, for the NMP-1 configuration, the core spray pumps are located approximately 30 feet from the inlet. Therefore, swirl effects are considered negligible.
- o Inlet loss coefficients were low and agreed with hydraulic handbook values (Reference 10). [Note: In the calculations of flow and NPSH, a conservative handbook value was used for the inlet loss coefficient and the grate across the inlet pipe was assumed to be 50 percent blocked.]

Froude Nos. for the NMP-1 suction pipe configuration and core spray flows are calculated in Attachment 4 and summarized below.

Pump Sets in Operation	Max Flow[1/] (gpm)	Velocity (ft/sec)	Submergence (ft)	Froude No.
1	5000	14.1	5.4	1.07
2	3350	9.4	5.4	0.72

Note: 1. Flow per suction

With one pump set in operation, the calculated Froude No. is 1.07. Air entrainment would be expected to be less than 0.5 percent (uniform approach flows) based on the test results reported in Figure 4 of Reference 7. This is acceptable since air entrainments up to 2 percent would have a negligible effect on pump performance (References 8 and 9). Results for non-uniform approach flows (3-4 percent air entrainment) reported in Reference 7 are not considered applicable for the NMP-1 suction pipe configuration. That is, there is no identified feature in the NMP-1 configuration (suction piping or torus) which would cause the flow to swirl continuously in the manner imposed during the full scale tests. Thus, the non-uniform approach flow patterns tested in Reference 7 are not considered to be representative of the approach flow patterns that would exist at NMP-1 during a LOCA.

With two pump sets in operation, the calculated Froude No. for each individual suction pipe is 0.72 which would result in essentially zero air entrainment based on the test results reported in Reference 7. To evaluate the effects of interaction between the two suction pipes, which are spaced 3.5 feet apart, results of tests of typical containment emergency sump configurations reported in Reference 10 were reviewed. In particular, one series of tests used two 12-inch pipes (same size as NMP-1 suction pipes) and the spacing between the pipes was varied from 4 to 16 feet. The test results indicate air entrainment was less than 1 percent for all pipe spacings for Froude Nos. up to 1.21 (Figures 4-39 and 4-40 of Reference 10). For the particular test with a pipe spacing of 4 feet (approximately equal to the NMP-1 suction pipe spacing), the air entrainment was essentially zero for Froude Nos. up to 1.21. Further, there is no apparent correlation between the measured air entrainment and the spacing between the suction pipes. Therefore, based on the test results with two suction pipes reported in Reference 10, the interactive effects between the two suction pipes are considered to have a negligible impact on air entrainment.

References

1. General Electric Company Letter from C. H. Stoll to D. K. Greene (Niagara Mohawk Power Corporation), Dated October 26, 1988.

2. NMPC Purchase Specification N1-347, Core Spray System Safety Valves, January 23, 1967.

3. Nine Mile Point Unit 1 FSAR, p. VI-3.

4. Nine Mile Point Unit 1 FSAR, Appendix E, p. E-88.

5. Nine Mile Point Unit 1 FSAR, 5th Supplement (Additional Information), p. 121.

6. Updated Nine Mile Point Unit 1 FSAR, Rev. 6, Fig. VII-2.

7. NUREG/CR-2772, Hydraulic Performance of Pump Suction Inlets for Emergency Core Cooling Systems in BWRs, Sandia National Labs., June 1982.

8. NUREG/CR-2792, An Assessment of Residual Heat Removal and Containment Spray Pump Performance Under Air and Debris Ingesting Conditions, Creare, Inc., September 1982, p. 90.

9. NRC Regulatory Guide 1.82, Appendix A, Guidelines for Review of Sump Design and Water Sources for Emergency Core Cooling, p. 1.82-8.

10. NUREG/CR-2758, A Parametric Study of Containment Emergency Sump Performance, Sandia National Labs., June 1982.

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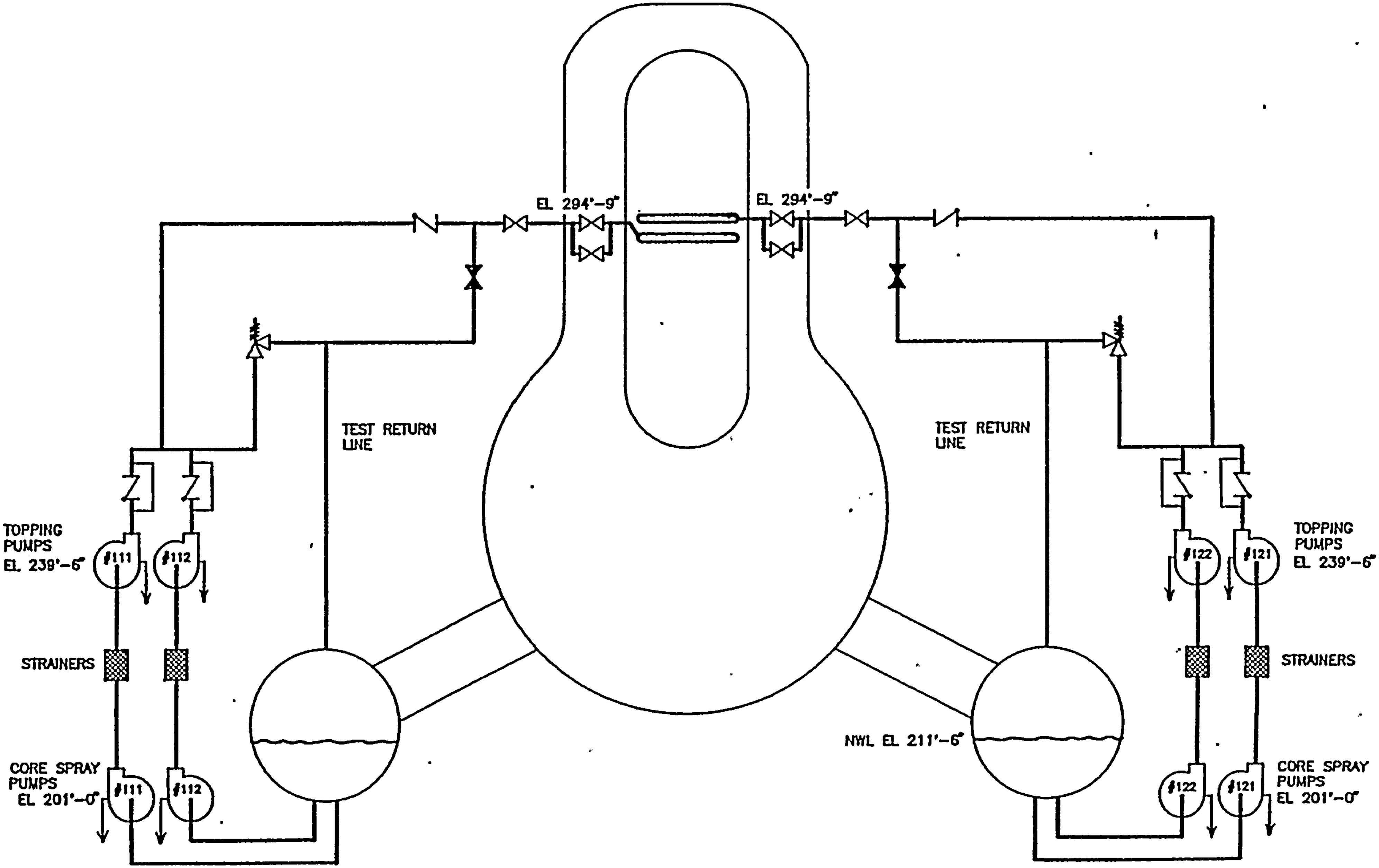


NMP-1 CORE SPRAY SYSTEM

FIGURE 1-1

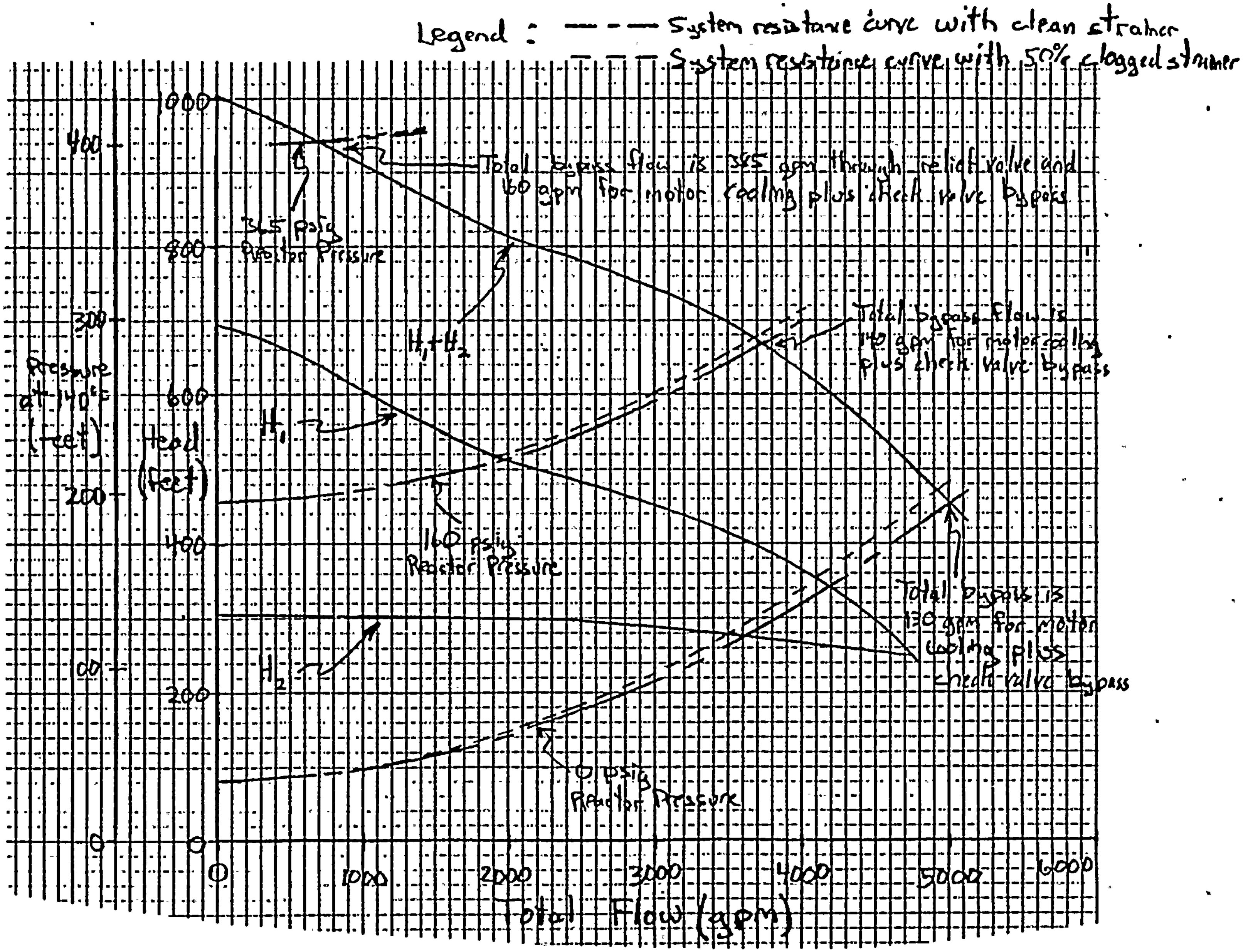
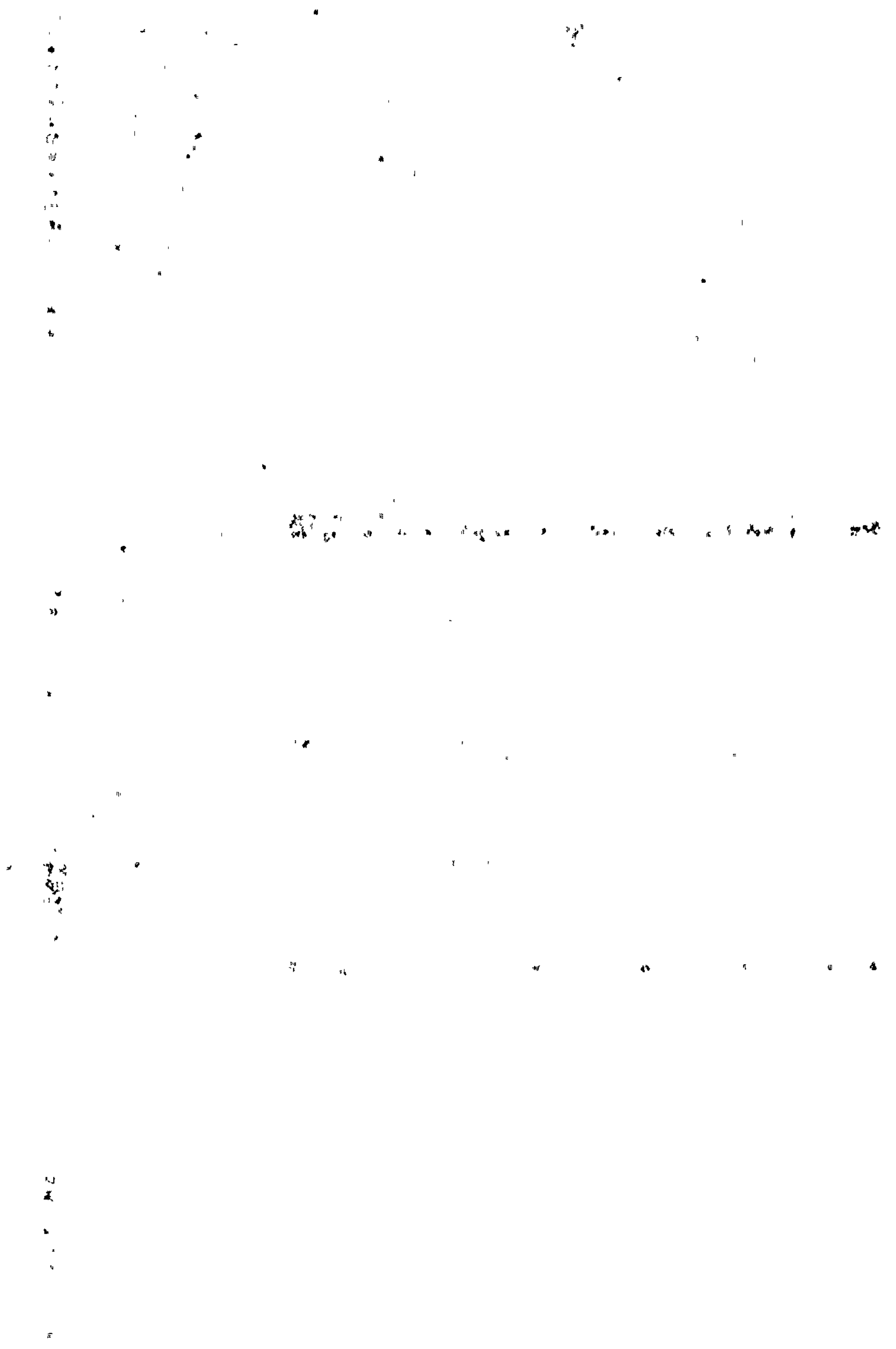


Figure 1-2. Head vs. Total Flow.
One Pump Set Operation.



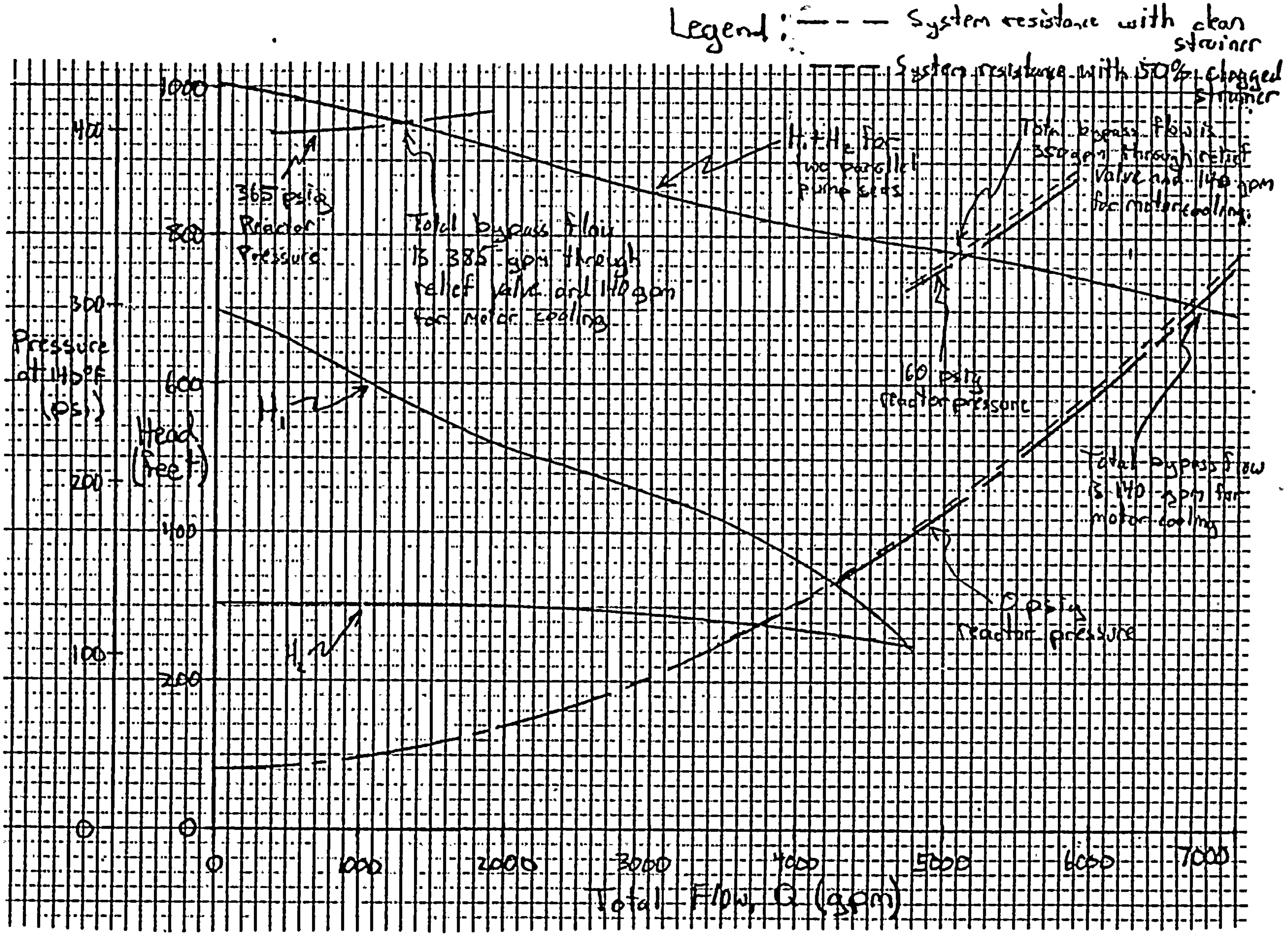


Figure 1-3. Head vs. Total Flow.
Two Pump Set Operation.

ATTACHMENT 2
TO
NIAGARA MOHAWK POWER CORPORATION'S RESPONSE TO
SAFETY SYSTEM FUNCTIONAL INSPECTION REPORT 88-201

March 22, 1989

WATERHAMMER EVALUATION
NMP-1 CORE SPRAY SYSTEM

INTRODUCTION

This report summarizes the results of evaluations performed to assess the effects of core spray system initiation during a LOCA on the core spray piping, pipe supports, and core spray sparger inside the reactor vessel. A schematic diagram of the NMP-1 core spray system is shown in Figure 1. The core spray system consists of two independent loops; each with redundant pumps and valves.

In the standby condition, the outside isolation valves are locked open and the inside isolation valves are closed. System initiation during a LOCA is as follows. On either a high drywell pressure or low-low reactor water level, the core spray pumps start in the following sequence.

t = 0 sec	Core Spray Pumps 111 and 112
t = 7 sec	Topping Pumps 111 and 112
t = 13 sec	Core Spray Pumps 121 and 122
t = 20 sec	Topping Pumps 121 and 122

A flow path for pump recirculation flow (approx. 380 gpm) during this time is provided through the safety valve (setpoint 320 psig) and the test return line back to the torus. When the reactor vessel pressure drops to 365 psig, the inside isolation valves open (20 second stroke time) allowing water to flow into the reactor vessel. The calculated core spray flow rate as a function of reactor pressure is shown in Figure 2.

A keep fill system keeps the core spray piping from the header check valve to the inside isolation valves full of water. The keep fill system is a gravity feed system from the condensate system. Any leakage past the header check valve will drain into the torus. Note that 0.75 inch bypass lines are provided around the check valves at the discharge of the core spray topping pumps to allow the water to drain.

The primary purpose of the keep fill system is to allow surveillance testing (stroke time) of the motor operated isolation valves inside the drywell during power operation. Keeping the pipe between the inside isolation valves and the header check valve filled prevents water slugs from accelerating and impacting the check valve when the inside isolation valves are opened during surveillance testing with the reactor at pressure. Vacuum breaker check valves allow air/N_2 from the torus to fill the piping upstream of the header check valve down to the normal water level of the torus (211′-6"). The volume of air/N_2 contained in this piping (approx. 240 ft of 12 Inch Std pipe) is about 190 ft^3. The portions of the core spray piping filled with water and the portions filled with air/N_2 during standby are shown in Figure 3.

During system initiation, the pumps will start and fill the piping upstream of the header check valve with water, thereby compressing the air/N_2 to the shutoff head of the pumps minus the elevation head (approx. 974 ft/420 psig). The air/N_2 will be compressed to about 6 ft^3 (approx. 8 ft). The portions of the piping filled with water and air/N_2 at this time are shown in Figure 4. When the reactor pressure drops to 365 psig, the inside isolation valves will open allowing water to flow into the reactor vessel. As the flow commences, first water, then air/N_2, then water will flow through the core spray sparger. The time for the air/N_2 trapped in the line to pass through the core spray sparger is about 0.5 to 1 second. For large break LOCAs in which the reactor vessel could depressurize to 365 psig in about 15 seconds, the inside isolation valves will open at about the same time that core spray pumps 121 and 122 start. However, the flow through the core spray sparger in this loop will be the same (i.e., water-air/N_2- water) as described above. During the time air/N_2 is flowing through the core spray sparger, the flow will not increase significantly due to the momentary loss of the sparger resistance since the time for the air/N_2 to flow through the sparger is short (0.50 to 1 sec) and the total mass of water in the core spray piping is large (approx. 24,000 lbm).

Thus, the air/N_2 volume maintained in the core spray piping by the vacuum breaker check valves acts as a soft spring which prevents a sudden deceleration of flow when the pumps start with the inside isolation valves closed. This prevents waterhammer events. When the inside isolation valves are open, the system flow rates are a function of system resistance. Loading during system initiation results only from dynamic loads due to changes in direction as water flows through elbows and tees to fill the piping.

SUMMARY

Results of Analyses

Calculations have been performed to determine the dynamic loads and its effect on the core spray piping, pipe supports, and core spray sparger inside the reactor vessel during a core spray initiation due to a LOCA. The dynamic loads are in addition to any internal pressure loads that may exist during system initiation.

During transients when the pumps start with the inside isolation valves closed, the flow will initially approach the runout flow of the pumps (approx. 5500 gpm per pump set). If the piping between the pumps and the header check valve were initially voided (i.e., vacuum conditions), then a classic waterhammer would be expected when the slug of water impacted the portion of the core spray piping filled with water downstream of the check valve. The resulting loads would be large. However, because of the large volume (190 ft^3) if air/N_2 in the piping between the pumps and the header check valves, the flow will be reduced gradually to the pump recirculation flow (380 gpm) due to the back pressure produced by the compression of the air/N_2. For this case, resulting waterhammer-type loads are not expected.

The only significant unbalanced dynamic loads during core spray system initiation will be those due to the change in momentum of the flow at elbows and tees. These loads are calculated from:

$$F = \frac{\rho v^2 A}{g_c}$$

where F = force
ρ = density of fluid
v = velocity of fluid
A = area of pipe (inside)
g_c = dimensional conversion factor

Pressure loads (i.e., PA) are balanced and result in longitudinal and circumferential stresses in the pipe which are relatively low at typical core spray injection pressures.

For the piping between the core spray pumps and the header check valve, the maximum flow may approach the runout flow of the pumps when the inside isolation valves are closed, as previously stated, because the resistance to flow is small until the air/N_2 volume is significantly compressed. At the runout flow condition, the internal pressure in the piping will be small.

When the inside isolation valves are open, or during transients when the valves open before or coincident with pump start, the maximum flow will be limited to that shown in Figure 2 since the pumps will be pumping against the full core spray system resistance. Note that the core spray sparger represents about 63 percent of the total system resistance. The internal pressure in the piping will be approximately equal to the reactor pressure plus the elevation and friction losses from the reactor to the header check valve.

A summary of the maximum expected flows and dynamic loads for the various portions of the core spray piping is given in Table 1. The resulting stresses in the pipe are tabulated in Table 2. The calculated stresses due to the dynamic loads assume a dynamic load factor of 2.0 for a suddenly applied load. As shown in Table 2, the pipe stresses due to these dynamic loads are low and when combined with the pressure stresses are well within typical ASME Code allowables. The dynamic loads on the

pipe supports due to startup of the core spray system are comparable to the seismic loads for the core spray system. Stresses in the pipe supports are low and are also well within typical AISC Code allowables.

A summary of the maximum expected flows and loads on the core spray sparger components is given in Table 3. The sparger net pressure load (i.e., internal pressure minus external pressure) will be approximately equal to the frictional losses from the reactor to the inlet pipe (thermal sleeve). When the slug of water behind the air/N_2 bubble trapped in the pipe reaches the sparger, the sparger net pressure load will be essentially zero since the pressure losses due to air/N_2 flowing through the sparger will be small. Thus, the only significant loads on the sparger components during this time will be the dynamic flow-induced loads. The resulting stresses are tabulated in Table 4. As shown in Table 4, the highest stresses in the core spray sparger occur in the 5 inch pipe (bending). The maximum calculated bending stress in the 5 inch pipe is 24.8 ksi which is slightly less than ASME Code allowable for primary bending of 25.4 ksi (1.5 S_m) for Type 304 stainless steel pipe at 550°F. Furthermore, the calculation is conservative since it takes no credit for additional support of the 5 inch pipe from the thermal sleeve. Thus, the stresses in the 5 inch pipe and other core spray sparger components are considered acceptable. Furthermore, the load calculations are considered conservative since they are based on the maximum calculated core spray flow at a reactor pressure of 0 psig, whereas when the core spray flow starts, the reactor pressure would be 365 psig and decreasing. Thus, actual core spray flows during a LOCA would be expected to be less than those assumed in these calculations.

Results of Surveillance Tests

Operator Surveillance Test N1-ST-Q1, Core Spray Pumps and Motor Operated Valves Operability Test, is performed quarterly. In this test the inside and outside isolation valves are closed and the isolation valve in the test return line is opened. The pumps are started (one pump set at a time) and water is pumped from the torus through the test return line and back to the torus. When the pumps are started, all piping above the

torus water elevation is filled with air/N_2. Initially, the flow will approach the runout flow of the pumps (5500 gpm) since the pressure drop due to air flowing through core spray pipe and test return line will be small. However, when the water slug reaches the flow control valve in the test return line, the flow will be suddenly reduced to about 3000 gpm due to the resistance of the flow control valve rather than the gradual reduction expected when the air/N_2 volume is compressed. The sudden change in flow would be expected to cause dynamic loads on the core spray piping upstream of the header check valve that are much larger that those expected during startup of the core spray pumps with the inside isolation valves closed and air/N_2 trapped in the line. No problems (i.e., excessive pipe displacements, pipe support failures, etc.) have been reported to date during these tests.

In addition, in response to NRC IE Bulletin 88-04, pump minimum flow tests are planned to determine the adequacy of the recirculation lines when the pumps are running with the inside isolation valves closed. During these tests, both sets of core spray and topping pumps will be started simultaneously with the inside isolation valves closed and air/N_2 in the line like during LOCA initiation. These tests will provide additional verification that waterhammer is not a concern for the core spray piping up to the header check valve.

During each major refueling outage, Operator Surveillance Test N1-ST-R9, Core Spray System Operability Using Demineralized (CST) Water, is performed. In this test, the inside and outside isolation valves are opened, the pumps (one pump set in each loop) take suction from the condensate storage tanks, and pump demineralized water into the reactor vessel at 0 psig. Since the condensate storage tanks are at a higher elevation (261'-0") in the plant than the normal torus water level, when the valve from the condensate storage tanks to the pump suction is opened, the water level in the core spray piping will rise partially compressing the initial volume of air/N_2 in the lines. The duration of the test is about 20 seconds due to reactor water level limitations. During the test, the flow is expected to approach the calculated flow for

one pump set operation at 0 psig reactor pressure (4670 gpm) from Figure 2. The flow through the sparger will be like that during a system initiation during a LOCA (i.e., water-air/N_2-water) since the test procedure is such that the air/N_2 bubble is trapped in the line prior to startup of the pumps. Note that the flow during this test with one pump set running (4670 gpm) is less that the maximum flow for two pump set operation (6560 gpm). However, the actual flows during a LOCA with two pump set operation would be expected to be lower than those during this test for the following reasons.

- During a LOCA, flow to the reactor vessel starts when the reactor pressure is at 365 psig decreasing, whereas in this test, reactor pressure is 0 psig.
- The inside isolation valves which open to allow flow into the reactor vessel have an opening time of 20 seconds which will limit the flow during this time. By the time the valve is fully open, the air/N_2 bubble would have passed through the sparger. During the test, the inside isolation valves are fully open prior to startup of the pumps.

Thus, the above test is considered conservative with respect to the dynamic loading on the core spray spargers, and no problems have been reported to date during these tests.

CONCLUSIONS

Based on the analytic evaluations and core spray system tests described above, the dynamic loading on the core spray piping, pipe supports, and sparger during system initiation during a LOCA are considered acceptable. No further tests are planned other than the normal surveillance tests and the pump minimum flow tests described above.

Table 1

DYNAMIC LOADS DURING PUMP STARTUP CORE SPRAY PIPING

Pipe	Flow (gpm)	Velocity (ft/sec)	Load (lbf)	Pressure[1] (psig)
CS Pump to Tee (12.750" OD x 0.375")	5,500	15.6	370	99
Tee to Check Valve (12.750" OD x 0.375")	11,000	31.2	1,480	99
Check Valve to 6" (12.750" OD x .622")	6,560	20.2	570	275
6" to Reactor (6.625" OD x 0.432")	6,560	80.7	2,280	275

1. At time of maximum flow.

Table 2

PIPE STRESSES[1]

Pipe	Stresses Due to Pressure (psi)		Stresses Due to[2] Dynamic Load (psi)	
	σ_ℓ	σ_t	σ_ℓ	σ_ℓ'
CS Pump to Tee	770	1580	50	1,010
Tee to Check Valve	770	1580	200	4,040
Check Valve to 6 Inch	1,210	2,540	50	1,000
6 Inch to Reactor	850	1,830	540	8,930

<u>Notes</u>:

1. σ_ℓ = Longitudinal membrane stress.
   σ_t = Tangential membrane stress.
   σ_ℓ' = Longitudinal bending stress.
2. Assumes a dynamic load factor (DLF) of 2.0 for a suddenly applied load.
3. Pipe support stresses are not significant.

Table 3

DYNAMIC LOADS DURING PUMP STARTUP CORE SPRAY SPARGER

Component	Flow (gpm)	Velocity (ft/sec)	Load (lbf)	Pressure[1] (psig)
Thermal Sleeve	6,560	105.1	2,960	~0
6 Inch Inlet Pipe (6.625" OD x 0.280")	6,560	72.7	2,050	~0
5 Inch Inlet Pipe (5.563" OD x 0.258")	3,280	52.6	740	~0
3.5 Inch Header (4.000" OD x 0.226")	1,640	53.2	380	~0

1. At time of maximum flow.

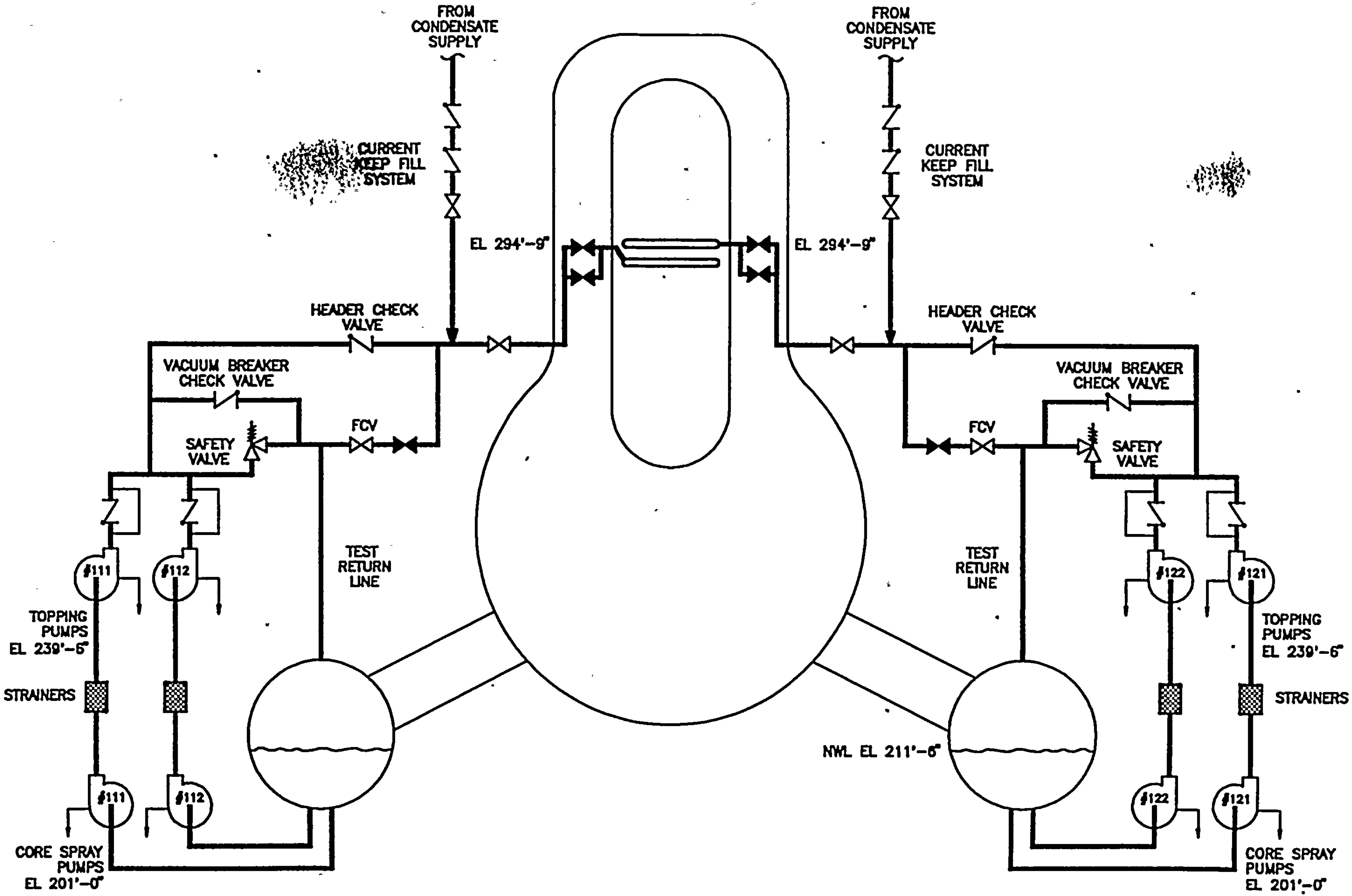
Table 4

SPARGER STRESSES

Component	Stress[1] (psi)
Thermal Sleeve:	
Tension	1,380
Weld Shear	3,950
6 Inch Inlet Pipe:	
Tension	730
Bending	2,890
5 Inch Inlet Pipe:	
Tension	350
Bending (From 6")	24,810
Bending	10,880
Torsion	6,270
Weld Shear	240
Junction Box:	
Tension	350
Bending (End Cap)	5,660
Weld Shear	960
Sparger Header:	280
Tension	2,870
Bending (End Cap)	

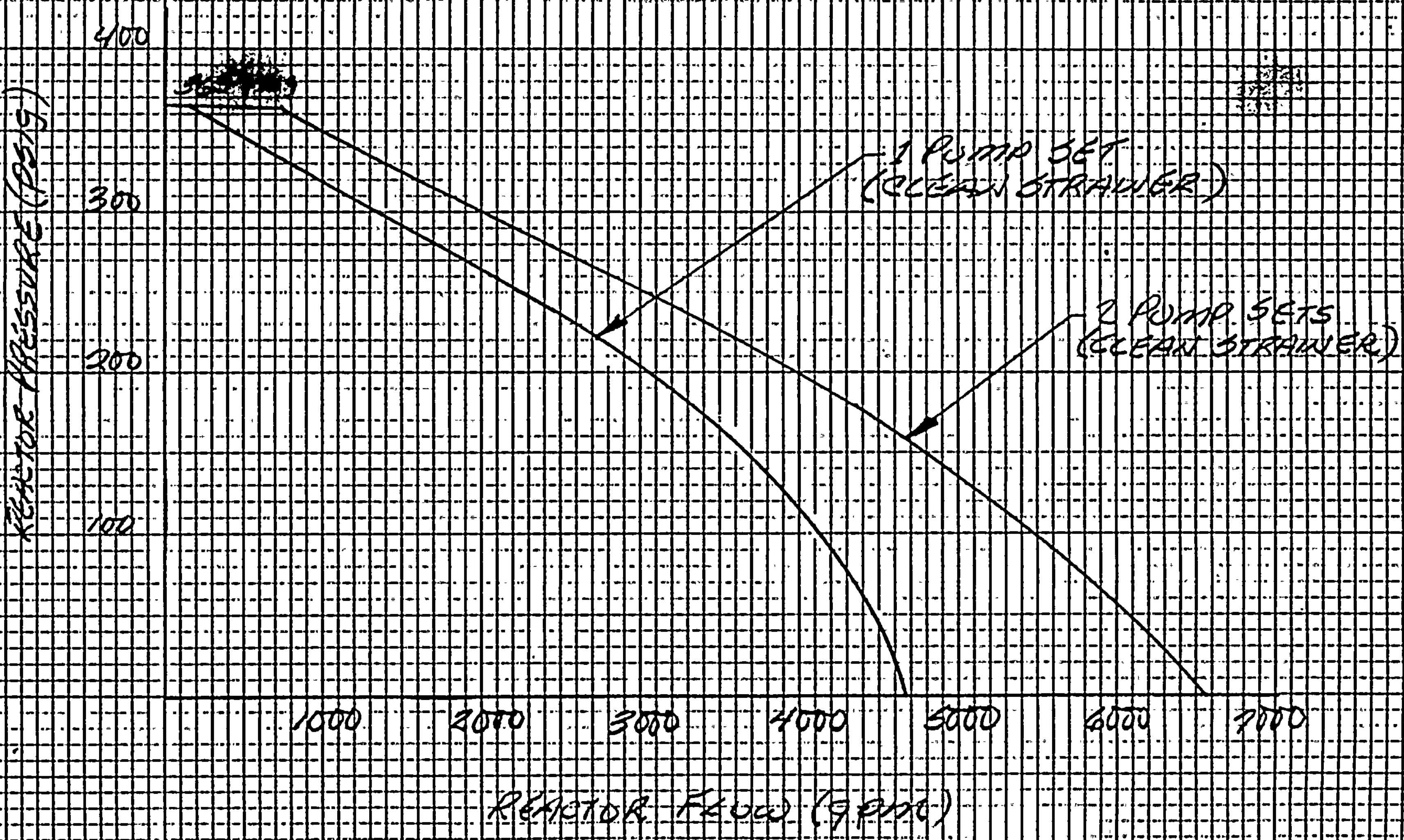
<u>Note</u>:

1. Assumes a dynamic load factor of 2.0 for a suddenly applied load.

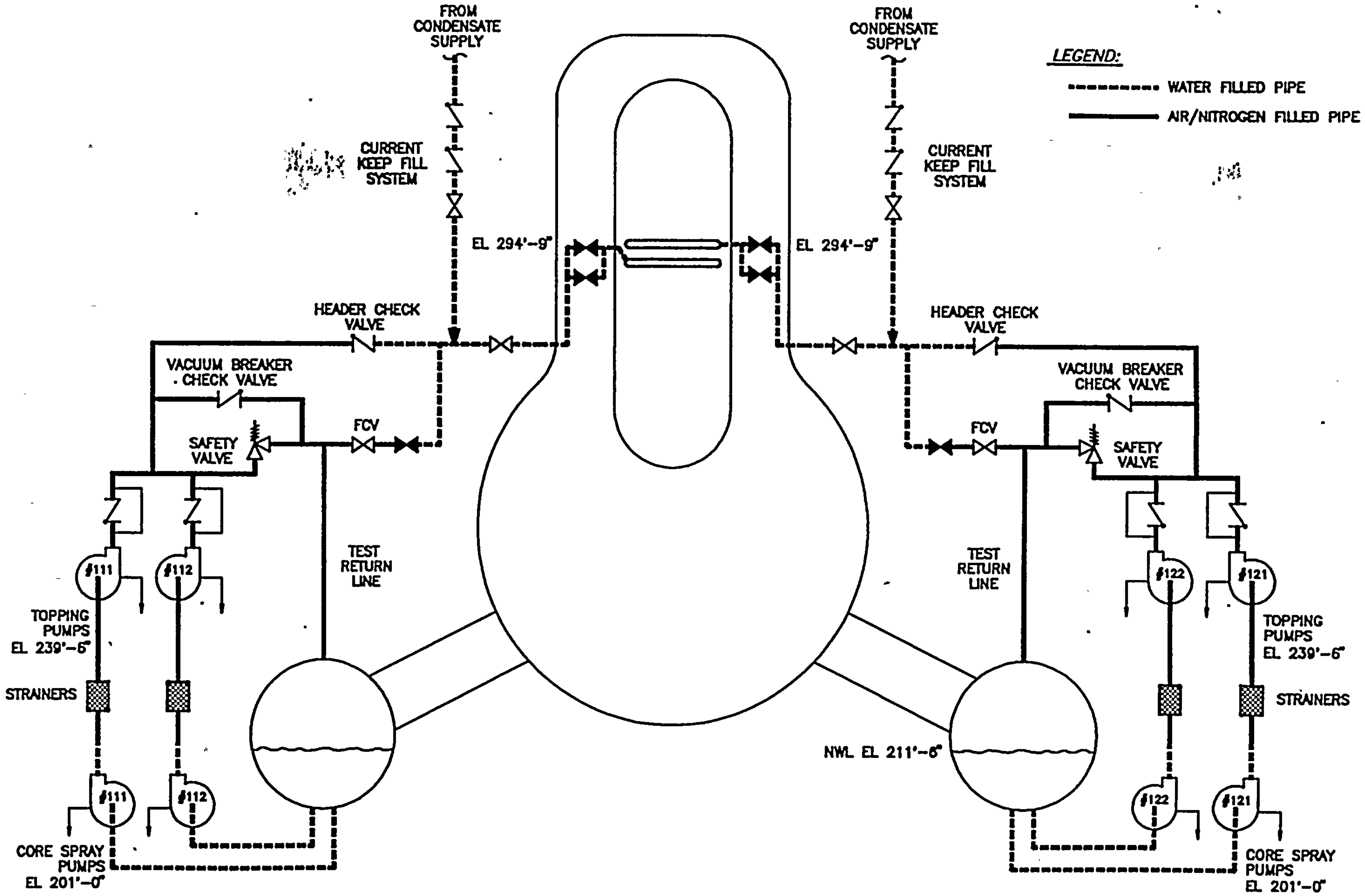


NMP-1 CORE SPRAY SYSTEM

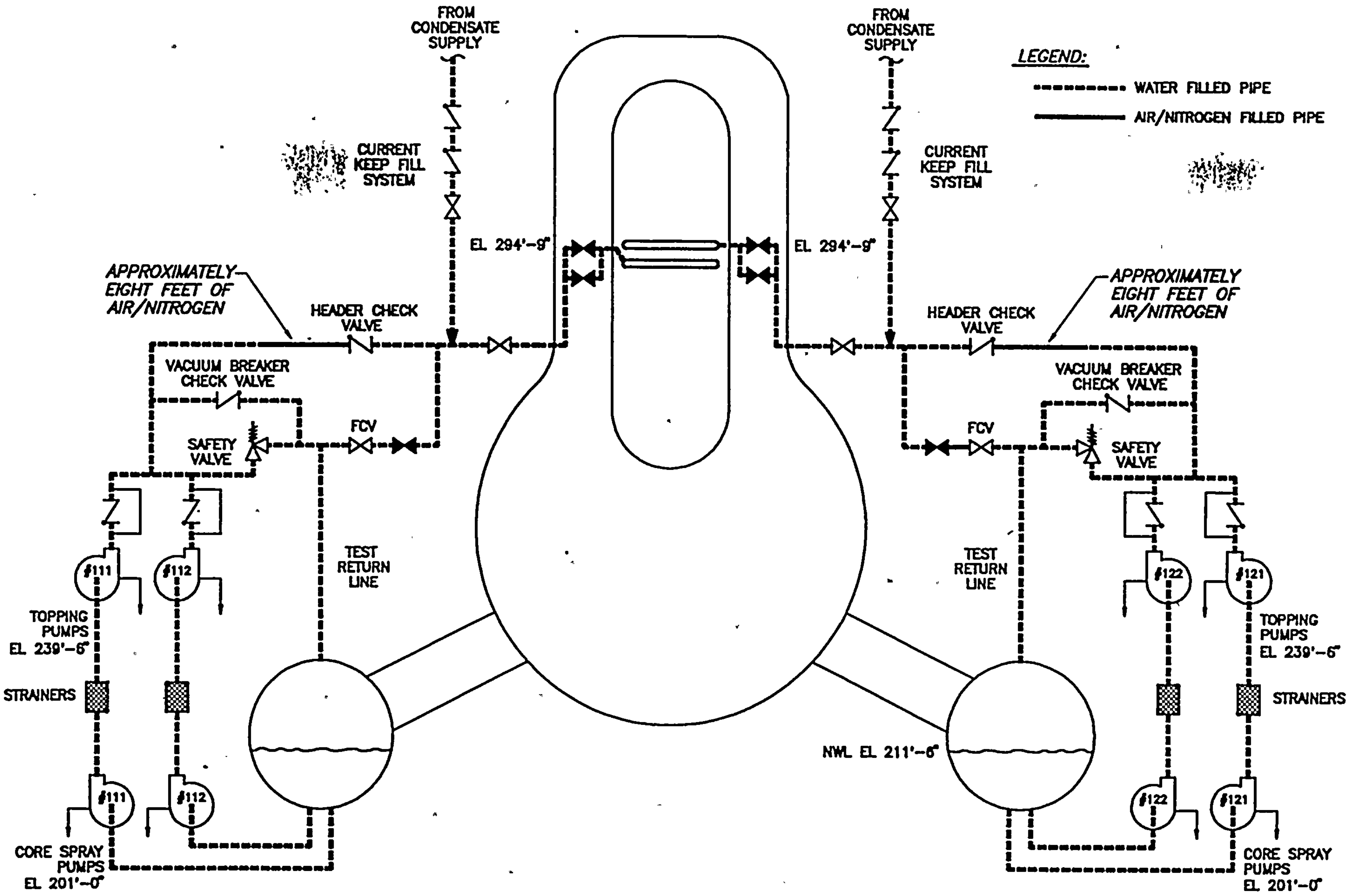
FIGURE 1



REACTOR FLOW VS. REACTOR PRESSURE
FIGURE 2



NMP-1 CORE SPRAY SYSTEM
STANDBY CONFIGURATION
FIGURE 3



NMP-1 CORE SPRAY SYSTEM
AT PUMP SHUTOFF CONDITIONS
FIGURE 4

NIAGARA MOHAWK

CALCULATION COVER SHEET

NUCLEAR ENGINEERING & LICENSING

DISCIPLINE: MECHANICAL

PAGE 1A

PROJECT: NINE MILE POINT NUC. STA.-UNIT I

CALC. NO. S14-40-F003

SUBJECT: CORE SPRAY SYSTEM - HYDRAULIC RESISTANCE - TOPPING PUMP TO RX

BUILDING: REACTOR

FLOOR ELEV.: VARIOUS

INDEX NO.: 3-N2.1-S14

ORIGINATOR(S): MPR ASSOCIATES, INC.

TOTAL SHT'S. ~~11~~ 21

CHECKER(S): MPR ASSOCIATES, INC.

LAST SHT. NO: ~~10~~ 20

RECORD OF ISSUES

REV.	DESCRIPTION	M.O.#	BY	DATE	CHKD.	DATE	APPD.	DATE	DATE FILMED:
0	C.S. TOPPING PUMP TO RX HYDRAULIC RESISTANCE	2988.	T. LESTINA	11/29/88	K.M. LEE	11/30/88	LAK	12/2/88	
1	REVISED SPARGER RESISTANCE, ACCOUNTED FOR ADDN'L BY-PASS FLOW	2988	T. LESTINA	1/12/89	M. KENNEDY	1/13/89	L.A. KLOSOWSKI	1/26/89	
1	supercedes rev 0 in its entirety								

COMPUTER OUTPUT YES ☐ NO ☒

SAFETY RELATED YES ☒ NO ☐

DRAWINGS REFERENCED:

DWG. NO. INDEX SHT. REV.

SEE PAGE 10

REFERENCES:

SEE PAGE 10

KEYWORDS: NMP 1, SSFI, CORE SPRAY, FLOW

CROSS REF.: 85-87-TGL4

S14-40-F003
rev 1

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CALCULATION TITLE PAGE

CLIENT Niagara Mohawk	PAGE 1 OF 20
PROJECT Core Spray SSFI	TASK NO. 85-87
CALCULATION TITLE Hydraulic Resistance of NMP1 Core Spray Topping Pump Discharge Piping to the Reactor	CALCULATION NO. (OPTIONAL) 85-87-T6L4

PREPARER(S)/DATE	CHECKER(S)/DATE	REVIEWER(S)/DATE	REV. NO.
T. Lestina 11/29/88	Kasey M Lee 11/30/88	J Johnson 11/30/87	0
T. Lestina 1/12/89	M J Kennedy 1/13/89	William McCurry 1/16/89	1

S14-40-F003 rev1

CALCULATION NO.	PREPARED BY	CHECKED BY	PAGE
85-87-TGL4	T. Lestina		2

Purpose: The purpose of this calculation is to determine the resistance of the core spray piping and fittings from the discharge of the topping pumps to the reactor vessel.

Summary: The head loss due to the hydraulic resistance of the core spray piping from the topping pump discharge to the reactor is:

$$h_L = R_2 Q^2$$

where
R_2 = hydraulic resistance (ft/gpm²)
Q = volumetric flow rate, (gpm)
h_L = head loss (ft)

$$R_2 = 1.35530(10^{-5}) \text{ ft/gpm}^2$$

Calculation

The hydraulic resistance, R_2, is calculated from the tee at the discharge of topping pumps #121 and 122 to the reactor vessel.

$$h_L = R_2 Q^2 \quad \text{where} \quad h_L = K\frac{V^2}{2g} \quad \text{from Reference (1)}$$

Calculating K-factors

From Reference (1),

a. For fittings:

$$K = \left(\frac{L}{D}\right)_{effective} f_T$$

where $(L/D)_{effective}$ and f_T are tabulated

b. For reducers: (assuming inside angle $\theta \approx 90°$)

- enlarging: $K_2 = \frac{(1-\beta^2)^2}{\beta^4}$ where $\beta = d_1/d_2$

(subscript 1 refers to smaller pipe, subscript 2 refers to larger pipe)

- reducing: $K_2 = \frac{.4204(1-\beta^2)}{\beta^4}$

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rev 1

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CALCULATION NO.	PREPARED BY	CHECKED BY	PAGE
85-87-T6L4	T. Lestina		4

c. For straight pipe:

$$Re = \frac{VD}{\nu} \qquad \nu = .514(10^{-5})\ ft^2/s$$ at 140°F from Reference (2)

assume 3400 gpm

for 12" STD pipe,

$$Re = \frac{(3400\ gpm)\left(\frac{1\ min}{60\ s}\right)\left(\frac{1\ ft^3}{7.4805\ g}\right)\left(\frac{1}{.7854\ ft^2}\right)\left(\frac{12}{12}\ ft\right)}{0.514(10^{-5})\ ft^2/s} = 1.88(10^6)$$

From Reference (1), p. A-25 $f \approx .014$

for 12" .622" min. wall,

$$ID = 12.75 - 2(.622) = 11.506''$$

$$A = \frac{\pi}{4}(11.506)^2 = 103.98\ in^2 = .7221\ ft^2$$

$$Re = \frac{(3400\ gpm)\left(\frac{1\ min}{60\ s}\right)\left(\frac{1\ ft^3}{7.4805\ g}\right)\left(\frac{1}{.7221\ ft^2}\right)\left(\frac{11.506}{12}\ ft\right)}{0.514(10^{-5})\ ft^2/s} = 1.96(10^6)$$

From Reference (1), p. A-25 $f \approx .014$

(The nominal pipe wall thickness is .684" however the differences in the calculated flows between the two wall thicknesses is negligible)

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rev1

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CALCULATION NO.	PREPARED BY	CHECKED BY	PAGE
85-87-T6L4	T. Lestina	M.	5

for 6" 80S pipe,

$$Re = \frac{(3400\ \text{gpm})\left(\frac{1\ \text{min}}{60\ \text{s}}\right)\left(\frac{1\ \text{ft}^3}{7.4805\ \text{g}}\right)\left(\frac{1}{.1810\ \text{ft}^2}\right)\left(\frac{5.761}{12}\ \text{ft}\right)}{0.514(10^{-5})\ \text{ft}^2/\text{s}} = 3.91(10^6)$$

From Reference (1), p. A-25 $f \approx .015$

d. For pipe size changes:

$$K_1 = K_2\left(\frac{d_1}{d_2}\right)^4$$

This is necessary to account for different size fittings in a piping run

The calculation of R_2 is broken up into two parts, R_2' and R_{sp}, such that

$$R_2 = R_2' + R_{sp}$$

R_2' = hydraulic resistance from topping pump discharge to reactor vessel nozzle

R_{sp} = hydraulic resistance from reactor vessel nozzle to the sparger discharge.

CALCULATION NO.	PREPARED BY	CHECKED BY	PAGE
85-87-TGL4	T. Lestma		6

Calculating R_2' (from topping pump discharge to reactor nozzle)

Component (from reference (6)) K-factor (12", .622 min wall)

~39' Straight Pipe 12" STD $.014 \frac{39}{12/12} = .546$ 12" STD or .46 12", .622 min wall

3 - 90° Elbow - 12" STD
r/d = 1.5 $3 \cdot 14 f_T = 14(.013)3 = 0.546$ 12" STD or .46 12", .622 min wall

Tee - 12" STD
run flow $20 f_T = 20(.013) = .26$, 12" STD or .22 12", .622 min. wall

Check Valve - 12", .622" min wall
(tilting disc type, assume α° = 15°)(this is conservative) $90 f_T = 90(.013)$ = 1.17

~13.0' Straight Pipe 12", .622 min wall
$.014 \frac{13.0}{11.506/12}$ = 1.90

45° ~~Elbow~~ - 12", .622 min. wall
r/d = 1.5
(assume 1/2 of 90° elbow) $7 f_T = 7(.013)$ = .09

2 Gate Valves - 12", .622 min wall
$2 \cdot 8 f_T = 2 \cdot 8(.013)$ = .21

6 90° Elbow - 12", .622 min wall
$6 \cdot 14 f_T = 6(14)(.013)$ = 1.09

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CALCULATION NO.	PREPARED BY	CHECKED BY	PAGE
85-87-TGL4	T. Lestina		7

Component	K-factor (12", .622 min. wall)
2 Tees - 12", .622 min wall	
branch flow $2 \cdot 60 f_T = 2 \cdot 60(.013) =$	1.56
90° Bend 12", .622 min wall	
r/d = 5 $15.5 f_T = 15.5(.013) =$	.20
2 45° Bend 12", .622 min wall	
r/d = 5 $2 \cdot 7.75 f_T = 15.5(.013) =$ (assume 1/2 of 90° elbow)	.20
12x6 Reducer (reducing) $\frac{.4204(1-.5007^2)}{.5007^4} =$	5.01
~11' Straight Pipe 6" 80S	
$.015\frac{11}{5.761/12} = .34$ for 6" 80S pipe or	5.41 12", .622 min wall
90° Bend 6" 80S	
r/d = 6 $17 f_T \doteq .015(17) = .255$ for 6" 80S or	4.06 12", .622 min wall

Total K-factor for R_2' without flow orifice 22.04 12", .622 min. wall

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CALCULATION NO.	PREPARED BY	CHECKED BY	PAGE
85-87-TGL4	T. Lestina		8

Flow Orifice K-factor:

From conversations with plant personnel, the orifice diameter is 8.08". From Reference (1),

$$K = \frac{1-\beta^2}{C^2\beta^4} \qquad \beta = \frac{8.08}{12} = .6733 \qquad C = .685$$

$$K = \frac{1-.6733^2}{.685^2(.6733)^4} = 5.67 \text{ for 12" STD pipe}$$

$$K_{or} = 4.79 \text{ for 12" .622 min wall pipe}$$

Calculating R_2'

$$h_L = K\frac{V^2}{2g} = R_2'Q^2$$

$$= \frac{K\left[\left(\frac{1\,\text{min}}{60\,\text{s}}\right)\left(\frac{1\,\text{ft}^3}{7.4805\,\text{g}}\right)\left(\frac{1}{.7221\,\text{ft}^2}\right)\left(Q\,\text{gpm}\right)\right]^2}{2\cdot 32.2\,\text{ft/s}^2}$$

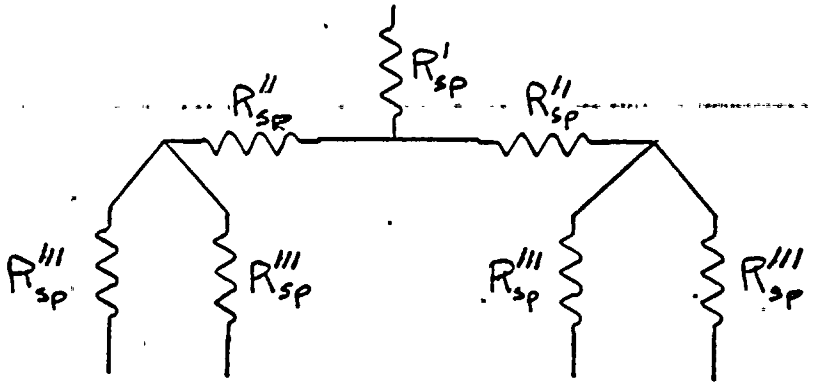
Ref. (1)

$$= 1.47828(10^{-7})\left[4.79+22.04\right]Q^2$$

$$R_2' = 3.96623(10^{-6})\ \text{ft/gpm}^2$$

Sparger Resistance, R_{sp}

The schematic configuration of the core spray piping and sparger inside the reactor vessel is shown below (from references (7) and (8))



Using expressions for series resistances $\left(R_{equiv.} = R_a + R_b\right)$ and expressions for parallel resistances $\left(1/R_{equiv.} = 1/R_a + 1/R_b\right)$, the sparger resistance is:

$$R_{sp} = R'_{sp} + \frac{R''_{sp} + R'''_{sp}/4}{4}$$

CALCULATION NO.	PREPARED BY	CHECKED BY	PAGE
85-87-TGL4	T. Lestma	mJKennedy	10

Rev (1)

Calculating R'_{sp}

For 5" Sch. 40 pipe,

$$Re = \frac{(3400\text{ gpm})\left(\frac{1\text{ min}}{60\text{ s}}\right)\left(\frac{1\text{ ft}^3}{7.4805\text{ g}}\right)\left(\frac{1}{.1390\text{ ft}^2}\right)\left(\frac{5.047}{12}\text{ ft}\right)}{0.514(10^{-5})\text{ ft}^2/\text{s}}$$

$$Re = 4.46(10^6) \qquad f \approx .016$$

For 6" schedule 40 pipe,

$$Re = \frac{(3400\text{ gpm})\left(\frac{1\text{ min}}{60\text{ s}}\right)\left(\frac{1\text{ ft}^3}{7.4805\text{ g}}\right)\left(\frac{1}{.2006\text{ ft}^2}\right)\left(\frac{6.065}{12}\text{ ft}\right)}{0.514(10^{-5})\text{ ft}^2/\text{s}}$$

$$Re = 3.71(10^6) \qquad f \approx .015$$

Component (from references (7) and (9))	K-factor
6×5 Sudden contraction (from 6" 80S pipe to 5" Sch. 40 at reactor nozzle)	.25 (6" sch. 40)

$K = 0.5(1-\beta_1^2)$ where $\beta_1 = \frac{5.047}{5.761}$,

$= .12$ for 5" sch. 40 pipe

S14-40-F003 rev1

CALCULATION NO.	PREPARED BY	CHECKED BY	PAGE
85-87-T6L4	T. Lestina		11

Rev (1)

Component (from references (7) and (9))	K-factor
Straight Pipe 5" Sch. 40 2.5' $f\frac{L}{D} = .016\left(\frac{2.5}{5.047/12}\right) = .10$ 5" Sch. 40	.21 (6" Sch. 40)
6x5 Reducing 90° Elbow (5" Sch. 40 to 6" Sch. 40) model this as a 6" Sch. 40 elbow plus a 5x6 increaser	.21 (6" Sch. 40)
6" Sch. 40 Elbow ($r/d = 1.5$) $14 f_T = 14(.015)$ 5X6 increaser $K = \frac{(1-\beta^2)^2}{\beta^4} = \frac{(1-.8322^2)^2}{(.8322)^4}$	.20 (6" Sch. 40)
Straight Pipe 6" Sch. 40 ~5' $f\frac{L}{D} = .015\left(\frac{5}{6.065/12}\right)$	.15 (6" Sch. 40)
45° Elbow 6" Sch. 40 $r/d = 1.5$ (assume 1/2 90° Elbow) $7 f_T = 7(.015)$	.11 (6" Sch. 40)
Tee-branch flow 6" STD wt. (same ID as Sch. 40) $60 f_T = 60(.015)$	.90 (6" Sch. 40)
Total K for R'_{sp}	2.03 (6" Sch. 40)

$$R'_{sp} = \frac{2.03\left[\left(\frac{1\ ft^3}{7.4805\ g}\right)\left(\frac{1}{.2006\ ft^2}\right)\left(\frac{1\ min}{60\ s}\right)\right]^2}{2\cdot 32.2\ ft/s^2} = 3.88852(10^{-6})\frac{ft}{gpm^2}$$

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Calculating R''_{sp}

For 5" Sch. 40 pipe,

$$Re = \frac{\left(\frac{3400}{2}\,gpm\right)\left(\frac{1\ min}{60\ s}\right)\left(\frac{1\ ft^3}{7.4805\ g}\right)\left(\frac{1}{.1390\ ft^2}\right)\left(\frac{5.047}{12}ft\right)}{.514(10^{-5})\ ft^2/s}$$

$Re = 2.23(10^5)$ $\quad f \approx .016$

Component (from reference (7))	K-factor
6" x 5" Eccentric Reducer reducing, assuming $K = \frac{.4204(1-\beta^2)}{\beta^4}\beta^4$	.13 (5" Sch. 40)
90° Bend 5" Sch. 40 $\frac{r}{d} = \frac{93\frac{5}{8}}{5} = 18.7$ use $\frac{r}{d} = 20$ $50f_T = 50(.016)$	.80 (5" Sch. 40)
45° Elbow (2) 5" Std. Wt. (same ID as Sch. 40) $r/d = 1.5$ (assume ½ of 90° elbow) $2 \cdot 7f_T = 2 \cdot 7(.016)$	.22 (5" Sch. 40)
90° Elbow 5" Std. Wt. (same ID as Sch. 40) $r/d = 1.5$ $14f_T = .14(.016)$ short radius	.22 (5" Sch. 40)

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Rev (1)

Component (from reference (7))	K-factor
90° Elbow 5" Std. Wt. (same ID as Sch. 40) r/d = 5 long radius use 15.5 f_T = 15.5(.016)	.25 (5" Sch. 40)
Straight Pipe 5" Sch. 40 ~2' $f\frac{L}{D} = .016\frac{2}{5.047/12}$	.08 (5" Sch. 40)

The discharge "box" at the intersection between R''_{sp} and R'''_{sp} is modeled as a tee (branch flow) for R''_{sp} and a sharp edged entrance for R'''_{sp}

Component (from reference (7))	K-factor
Tee - branch flow $60 f_T = 60(.016)$	.96 (5" Sch. 40)
Total K for R''_{sp}	2.66

$$K\frac{V^2}{2g} = R''_{sp}Q^2$$

$$R''_{sp} = \frac{2.66\left[\left(\frac{1\ ft^3}{7.4805\ g}\right)\left(\frac{1}{.1390\ ft^2}\right)\left(\frac{1\ min}{60\ s}\right)\right]^2}{2\cdot 32.2\ ft/s^2} = 1.06121(10^{-5})\frac{ft}{gpm^2}$$

Calculating R'''_{sp}

For 3½" Sch. 40 pipe,

$$Re = \frac{\left(\frac{3400}{4}\,gpm\right)\left(\frac{1\ min}{60\ s}\right)\left(\frac{1\ ft^3}{7.4805\ g}\right)\left(\frac{1}{.06870\ ft^2}\right)\left(\frac{3.548}{12}\,ft\right)}{.514(10^{-5})\ ft^2/s}$$

$Re = 1.59(10^6)$ $f \approx .017$

Component (from reference (7))	K-factor
Entrance loss (from 5"×3½" "box")	0.50 (3½" Sch. 40)
45° Bend 3½" Sch. 40 (This is the average path traversed by water exiting from nozzles) $r/d = 90/3½ = 25.7$ (assume ½ of 90° Bend with $r/d = 20$ is appropriate) $½\,50 f_T = ½\,50(.017)$	0.43 (3½" Sch. 40)
Total K-factor for R'''_{sp} without nozzle attachment losses	0.93 (3½" Sch. 40)

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$$\left(R'''_{sp}\right)_{w/o\ nozzles} = \frac{0.93\left[\left(\frac{1\ ft^3}{7.4805\ g}\right)\left(\frac{1}{.06870\ ft^2}\right)\left(\frac{1\ min}{60\ s}\right)\right]^2}{2\cdot 32.2\ ft/s^2}$$

$$= 1.51887(10^{-5})\ ft/gpm^2$$

Each segment of R'''_{sp} consists of $56/4 = 14$ spray nozzle attachments and $56/4 = 14$ attachments with the spray nozzles removed. These attachments are connected in parallel.

For attachments without spray nozzles:

Component (from reference (7))	K-factor
Entrance loss	0.50
90° Elbow (2) 1" (assume 0.91 ID per ANSI B16.3) $2\cdot 30\, f_T = 2\cdot 30(.023) = 1.38$	1.38 (0.91" ID)
Discharge loss (loss of velocity head)	1.00
Total K-factor of attachments without spray nozzles	2.88 (0.91" ID)

$$\left(R'''_{sp}\right)_{w/o\ spray} = \frac{2.88\left[\left(\frac{1\ ft^3}{7.4805\ g}\right)\left(\frac{1}{\pi/4\ (.91/12)^2}\right)\left(\frac{1\ min}{60\ s}\right)\right]^2}{2\cdot 32.2\ ft/s^2}$$

$$= 1.08823(10^{-2})\ ft/gpm^2$$

For attachments with spray nozzles:

The total hydraulic loss of the attachment is equal to the loss of the attachment w/o spray nozzles (minus the discharge loss coefficient) plus the loss of the spray nozzle.

The loss of the spray nozzle is calculated as follows from the flows and pressures from reference (5).

Pressure Drop (psi)	Capacity (gpm)	$\Delta P/Q^2$ psi/gpm^2
3	8.0	.0469
5	10.2	.0481
7	12.0	.0486
10	14.2	.0496
15	17.1	.0513
20	19.4	.0531
30	24	.0521
40	27	.0549
60	32	.0586
80	37	.0584
100	41	.0595
150	50	.0600

average $\Delta P/Q^2 = .0534 \text{ psi/gpm}^2$

$$R_{\text{spray nozzles}} = h_L/Q^2 = \frac{\Delta P}{\rho\ Q^2}$$

use $\rho = 61.38 \text{ lb/ft}^3$ at

$$= \frac{.0534 \frac{\text{lb}}{\text{in}^2 \cdot \text{gpm}^2}\left(\frac{144 \text{ in}^2}{1 \text{ ft}^2}\right)}{61.38 \text{ lb/ft}^3} = .125279 \text{ ft/gpm}^2$$

The total resistance for the spray nozzle attachment is,

$$\left(R'''_{sp}\right)_{\text{w/ spray}} = \frac{(2.88-1)\left[\left(\frac{1 \text{ ft}^3}{7.4805 \text{ g}}\right)\left(\frac{1}{\frac{\pi}{4}\left(\frac{.91}{12}\right)^2 \text{ft}^2}\right)\left(\frac{1 \text{ min}}{60 \text{ s}}\right)\right]^2}{2 \cdot 32.2 \text{ ft/s}^2}$$

$$+ .125279$$

$$= .132383 \text{ ft/gpm}^2$$

Using expressions for parallel and series hydraulic resistances,

$$\left(R'''_{sp}\right) = \left(R'''_{sp}\right)_{\text{w/o nozzles}} + \frac{1}{\left[\frac{14}{\sqrt{\left(R'''_{sp}\right)_{\text{w/ spray}}}} + \frac{14}{\sqrt{\left(R'''_{sp}\right)_{\text{w/o spray}}}}\right]^2}$$

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$$R_{sp}''' = 1.51887(10^{-5}) + \frac{1}{\left[\frac{14}{\sqrt{.132383}} + \frac{14}{\sqrt{1.08823(10^{-3})}}\right]^2}$$

$$R_{sp}''' = 4.87240(10^{-5}) \text{ ft/gpm}^2$$

R_{sp} becomes:

$$R_{sp} = 3.88852(10^{-6}) + \frac{1.06121(10^{-5}) + \frac{4.87240(10^{-5})}{4}}{4}$$

$$R_{sp} = 9.58680(10^{-6}) \text{ ft/gpm}^2$$

<u>Calculating R_2</u>

$$R_2 = R_2' + R_{sp} = 3.96623(10^{-6}) + 9.58680(10^{-6})$$
$$= 1.35530(10^{-5}) \text{ ft/gpm}^2$$

References

1. Crane Technical Paper No. 410, "Flow of Fluids Through Valves, Fittings, and Pipe", 1982.

2. Daugherty, R.L. and Franzini, J.B. Fluid Mechanics with Engineering Applications, McGraw Hill Book Company, New York 1977.

3. Deleted

4. Deleted

5. Industrial Catalog 26A, Spraying Systems Co., North Avenue at Schmale Road, Wheaton, Illinois 60187, 1973.

6. Niagara Mohawk Drawing No. C-26844-C, "Reactor Core Spray System No. 40 Piping Isometric" Rev. 8.

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CALCULATION NO.	PREPARED BY	CHECKED BY	PAGE
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Rev. (1)

References (continued)

7. GE Drawing 706E231, "Shroud for Core Structure",
SHT. 1 Rev. 5
SHT. 2 Rev. 3.

8. GE Drawing 104R859 "Arrangement and Assembly of, Reactor", Rev. 8,

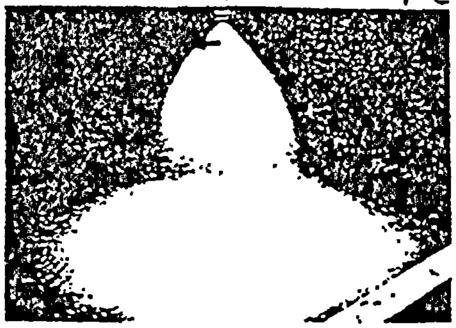
9. GE Drawing 112C2901, "Core Spray Connection", Rev. 0.

514-40-F003
rev 1

FullJet NOZZLES

Reference 5

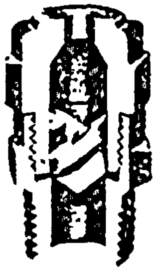
Spray Characteristics—Good distribution throughout full cone spray pattern, due to Spraying Systems Co. internal vane design.
Construction—Internal, removable vanes. Types G and GG have removable caps. All nozzles made of bar stock. See page 14 for larger capacity cast type nozzles.
Materials—Supplied in choice of brass, steel and type 303 or 316 stainless steel . . . other materials on special order. See page .21 for PVC FullJet Nozzles.



FULL CONE
SPRAY PATTERN

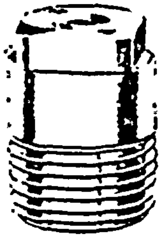
Type G
female connection
removable cap

All FullJet Nozzles made with internal vanes as shown in cut-away below



Type GG
male connection
removable cap

Type H
female connection
one-piece body



Type HH
male connection
one-piece body

Nozzle No.		Pipe Conn. NPT	Orifice Diam. Nom.	*Free Passage* Maximum Size Particle*	CAPACITY GPM (gallons per minute) at p.s.i. (pounds per square inch)												SPRAY ANGLE**		
Female Conn.	Male Conn.				3 p.s.i.	5 p.s.i.	7 p.s.i.	10 p.s.i.	15 p.s.i.	20 p.s.i.	30 p.s.i.	40 p.s.i.	60 p.s.i.	80 p.s.i.	100 p.s.i.	150 p.s.i.	7 p.s.i.	20 p.s.i.	80 p.s.i.
1/8G1	1/8GG1	1/8"	1/32"	.025"				.10	.12	.14	.17	.19	.23	.26	.30	.36		58°	53°
1/8G1.5	1/8GG1.5	1/8"	3/64"	.025"			.13	.15	.16	.21	.25	.29	.35	.40	.44	.53	52°	65°	59°
1/8G2	1/8GG2	1/8"	3/64"	.040"		.14	.17	.20	.24	.28	.34	.38	.46	.53	.59	.70	43°	50°	46°
1/8G3	1/8GG3	1/8"	1/16"	.040"	.17	.22	.26	.30	.36	.42	.50	.57	.69	.79	.88	1.1	52°	65°	59°
1/8G3.5	1/8GG3.5	1/8"	1/16"	.050"	.20	.25	.30	.35	.42	.48	.58	.67	.81	.92	1.0	1.3	43°	50°	46°
1/8G5	1/8GG5	1/8"	5/64"	.050"	.28	.36	.42	.50	.60	.69	.82	.95	1.2	1.3	1.5	1.8	52°	65°	59°
1/4G6.5	1/4GG6.5	1/4"	3/32"	1/16"	.37	.47	.55	.65	.78	.89	1.1	1.3	1.5	1.7	1.9	2.3	45°	50°	46°
	1/4HH6.5	1/4"	3/32"	1/16"	.37	.47	.55	.65	.78	.89	1.1	1.3	1.5	1.7	1.9	2.3	45°	50°	46°
1/4G10	1/4GG10	1/4"	7/64"	1/16"	.57	.73	.85	1.0	1.3	1.4	1.7	1.9	2.4	2.7	3.0	3.6	58°	67°	61°
	1/4HH10	1/4"	7/64"	1/16"	.57	.73	.85	1.0	1.3	1.4	1.7	1.9	2.4	2.7	3.0	3.6	58°	67°	61°
3/8G9.5	3/8GG9.5	3/8"	7/64"	3/32"	.54	.69	.80	.95	1.2	1.3	1.6	1.8	2.2	2.5	2.8	3.4	45°	50°	46°
	3/8HH9.5	3/8"	7/64"	3/32"	.54	.69	.80	.95	1.2	1.3	1.6	1.8	2.2	2.5	2.8	3.4	45°	50°	46°
3/8G15	3/8GG15	3/8"	9/64"	3/32"	.84	1.1	1.3	1.5	1.8	2.1	2.5	2.9	3.5	4.0	4.4	5.3	64°	67°	61°
	3/8HH15	3/8"	9/64"	3/32"	.84	1.1	1.3	1.5	1.8	2.1	2.5	2.9	3.5	4.0	4.4	5.3	64°	67°	61°
3/8G22	3/8GG22	3/8"	11/64"	7/64"	1.3	1.6	1.9	2.2	2.7	3.0	3.7	4.2	5.1	5.8	6.4	7.8	87°	90°	82°
	3/8HH22	3/8"	11/64"	7/64"	1.3	1.6	1.9	2.2	2.7	3.0	3.7	4.2	5.1	5.8	6.4	7.8	87°	90°	82°
1/2G16	1/2GG16	1/2"	9/64"	1/8"	.89	1.2	1.4	1.6	1.9	2.2	2.7	3.1	3.7	4.3	4.7	5.7	48°	50°	46°
1/2G25	1/2GG25	1/2"	3/16"	1/8"	1.4	1.8	2.1	2.5	3.0	3.5	4.2	4.8	5.8	6.7	7.4	8.9	64°	67°	61°
	1/2HH25	1/2"	3/16"	1/8"	1.4	1.8	2.1	2.5	3.0	3.5	4.2	4.8	5.8	6.7	7.4	8.9	64°	67°	61°
1/2G32	1/2GG32	1/2"	13/64"	9/64"	1.8	2.3	2.7	3.2	3.9	4.4	5.3	6.1	7.4	8.5	9.4	11.3	72°	75°	68°
1/2G40	1/2GG40	1/2"	1/4"	9/64"	2.3	2.9	3.2	4.0	4.8	5.5	6.6	7.6	9.2	10.6	11.8	14.3	88°	91°	83°
	1/2HH40	1/2"	17/64"	9/64"	2.3	2.9	3.2	4.0	4.8	5.5	6.6	7.6	9.2	10.6	11.8	14.3	88°	91°	83°
3/4H2.5	3/4HH2.5	3/4"	3/16"	11/64"	1.7	2.1	2.5	3.0	3.6	4.1	4.9	5.6	6.8	7.8	8.6	10.4	48°	50°	46°
3/4H4	3/4HH4	3/4"	1/4"	11/64"	2.7	3.4	4.0	4.7	5.7	6.5	7.8	8.9	10.7	12.4	13.7	16.6	67°	70°	63°
3/4H7	3/4HH7	3/4"	3/8"	13/64"	4.7	6.0	7.0	8.3	10.0	11.4	13.8	15.8	19.1	22	24	29	89°	92°	84°
1H4.2	1HH4.2	1"	19/64"	7/32"	2.8	3.6	4.2	5.0	6.0	6.8	8.2	9.4	11.5	13.1	14.5	17.6	48°	50°	46°
1H7	1HH7	1"	21/64"	7/32"	4.7	6.0	7.0	8.3	10.0	11.4	13.8	15.8	19.1	22	24	29	67°	68°	62°
1H10	1HH10	1"	13/32"	7/32"	6.8	8.6	10.0	12.0	14.5	16.5	19.9	23	27	31	35	42	75°	78°	71°
1H12	1HH12	1"	15/32"	1/4"	8.0	10.2	12.0	14.2	17.1	19.4	24	27	32	37	41	50	89°	92°	84°

*Foreign matter with maximum diameter as listed can pass through nozzle without clogging.

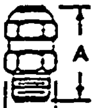
**See page 3 for spray angle data.

WHEN ORDERING—specify complete Nozzle No. and material.
Example: 1/8G5 FullJet Nozzle, steel.

See pages 54 through 61 for spray nozzle accessories.

Patent Nos. 3,146,674, 3,104,829 and Foreign Patents.

Type G



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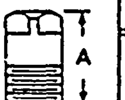

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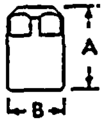

Type H

Nozzle No.	Net Weight	A	B
1/8G1 1/8G1.5 1/8G2 1/8G3	1 oz.	1 3/32"	9/16" Hex.
1/8G3.5 1/8G5	3/4 oz.	1 1/8"	9/16" Hex.
1/4G	1 1/2 oz.	1 11/32"	11/16" Hex.
3/8G	2 1/4 oz.	1 17/32"	13/16" Hex.
1/2G	4 1/2 oz.	1 7/8"	1" Hex.
1/8GG1 1/8GG1.5 1/8GG2 1/8GG3	3/4 oz.	1 9/32"	9/16" Hex.

Nozzle No.	Net Weight	A	B
1/8GG3.5 1/8GG5	3/4 oz.	1 3/16	9/16 Hex.
1/4GG	1 1/2 oz.	1 7/16	11/16" Hex.
3/8GG	2 1/4 oz.	1 9/16	13/16 Hex.
1/2GG	4 1/2 oz.	1 7/8	1 Hex.
1/4HH	1/2 oz.	7/8	17/32 Diam.
3/8HH	3/4 oz.	15/16	21/32 Diam.
1/2HH	1 1/2 oz.	1 9/32	13/16 Diam.
3/4HH	3 1/2 oz.	1 17/32	1 1/16 Diam.
1HH	7 1/4 oz.	2 1/32	1 5/16 Diam.
3/4H	7 oz.	2 3/16	1 1/4 Diam.
1H	12 oz.	2 11/16	1 1/2 Diam.

NIAGARA MOHAWK

CALCULATION COVER SHEET

NUCLEAR ENGINEERING & LICENSING

DISCIPLINE: MECHANICAL

PAGE 1A

PROJECT: NINE MILE POINT NUC. STA.-UNIT I

CALC. NO. S14-40-F004

SUBJECT: CORE SPRAY SYSTEM FLOW – TWO PUMP SETS

BUILDING: REACTOR

FLOOR ELEV.: VARIOUS

INDEX NO.: 3-N2.1-S14

ORIGINATOR(S): MPR ASSOCIATES, INC.

TOTAL SHT'S. ~~19~~ 22

CHECKER(S): MPR ASSOCIATES, INC.

LAST SHT. NO: ~~18~~ 21

RECORD OF ISSUES

REV.	DESCRIPTION	M.O.#	BY	DATE	CHKD.	DATE	APPD.	DATE	DATE FILMED:
0	CORE SPRAY SYSTEM FLOW – 2 PUMP SETS (PARALLEL)	2988	T. LESTINA	11/29/88	K.M. LEE	11/30/88	LAK	12/2/88	
1	REVISED FLOW BASED ON NEW SYS. RESIST. AND BY PASS FLOW	2988	T. LESTINA	2/23/89	L. STINLOUS	2/24/89	LAK	3/3/89	
1	supercedes rev 0 in its entirety								

COMPUTER OUTPUT YES ☐ NO ☒

SAFETY RELATED YES ☒ NO ☐

DRAWINGS REFERENCED:

DWG. NO:	INDEX.	SHT.	REV.
SEE PAGES ~~17 & 18~~ 20 + 21 △			

REFERENCES:

CALC. S14-40-F003

SEE PAGES ~~17 & 18~~ 20 + 21 △

KEYWORDS: NMP I, SSFI, CORE SPRAY, FLOW

CROSS REF.: 85-87-TGL6

12/84

EIP-091

S14-40-F004 Rev. 1

MPR ASSOCIATES, INC.
1050 Connecticut Ave., NW-Washington, DC 20036

CALCULATION TITLE PAGE

CLIENT Niagara Mohawk	PAGE 1 OF 21
PROJECT Core Spray SSFI	TASK NO. 85-87
CALCULATION TITLE Core Spray System Flows With Two Sets of Pumps Operating in Parallel	CALCULATION NO. (OPTIONAL) 85-87-TGL6

PREPARER(S)/DATE	CHECKER(S)/DATE	REVIEWER(S)/DATE	REV. NO.
T. Lestina 11/29/88	Kang M Lee 11/30/88	J Johnson 11/30/88	0
T. Lestina 2/23/89	L. Stevens 2/24/89	John Johnson 2/23/89	1

CALCULATION NO.	PREPARED BY	CHECKED BY	PAGE
85-87-TGL6	T. Lestina	L. Stevens	2

Purpose: The purpose of this calculation is to determine the core spray flows for different reactor pressures with two sets of core spray pumps operating parallel.

Summary: The reactor flows for different reactor pressures and strainer clogging are shown below:

Reactor Pressure (psig)	Reactor Flows (gpm)	
	Clean Strainer	50% Clogged Strainer
0[1]	6560	6520
160[2]	4630	4590
365[3]	730	720

Notes: 1. With the reactor pressure at 0 psig, bypass flow through the relief valve is 0 gpm and bypass flow for the pump seals and motor cooling is 140 gpm (70 gpm for one pump set)

2. With the reactor pressure at 160 psig, bypass flow through the relief valve is about 350 gpm and the bypass flow for the pump seals and motor cooling is 140 gpm (70 gpm for one pump set).

3. With the reactor pressure at 365 psig, bypass flow through the relief valve is about 385 gpm and the bypass flow for the pump seals and motor cooling is 140 gpm (70 gpm for one pump set).

These flows are determined from Figure 1, Head Versus Total Flow, and the calculations herein. A multibranch computer code FLONET is used to verify the calculated results.

S14-40-F004 (PV1

Figure 1 is a plot of total developed, combined pump head for two sets of pumps operating in parallel (calculated by doubling the flow at a given head for one pump set) and system resistance $\left(\left(P/\rho\right)_r - \left(P/\rho\right)_T + \left(Z_r - Z_T\right) + \frac{R_1}{4}Q^2 + R_2\left(Q - Q_{Bypass}\right)^2\right)$.

The intersection of the total combined head and system resistance is the total flow (reactor flow plus bypass flow).

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CALCULATION NO. 85-87-T6L6
PREPARED BY T. Lestina
CHECKED BY
PAGE 5

SIH-40-F004 rev

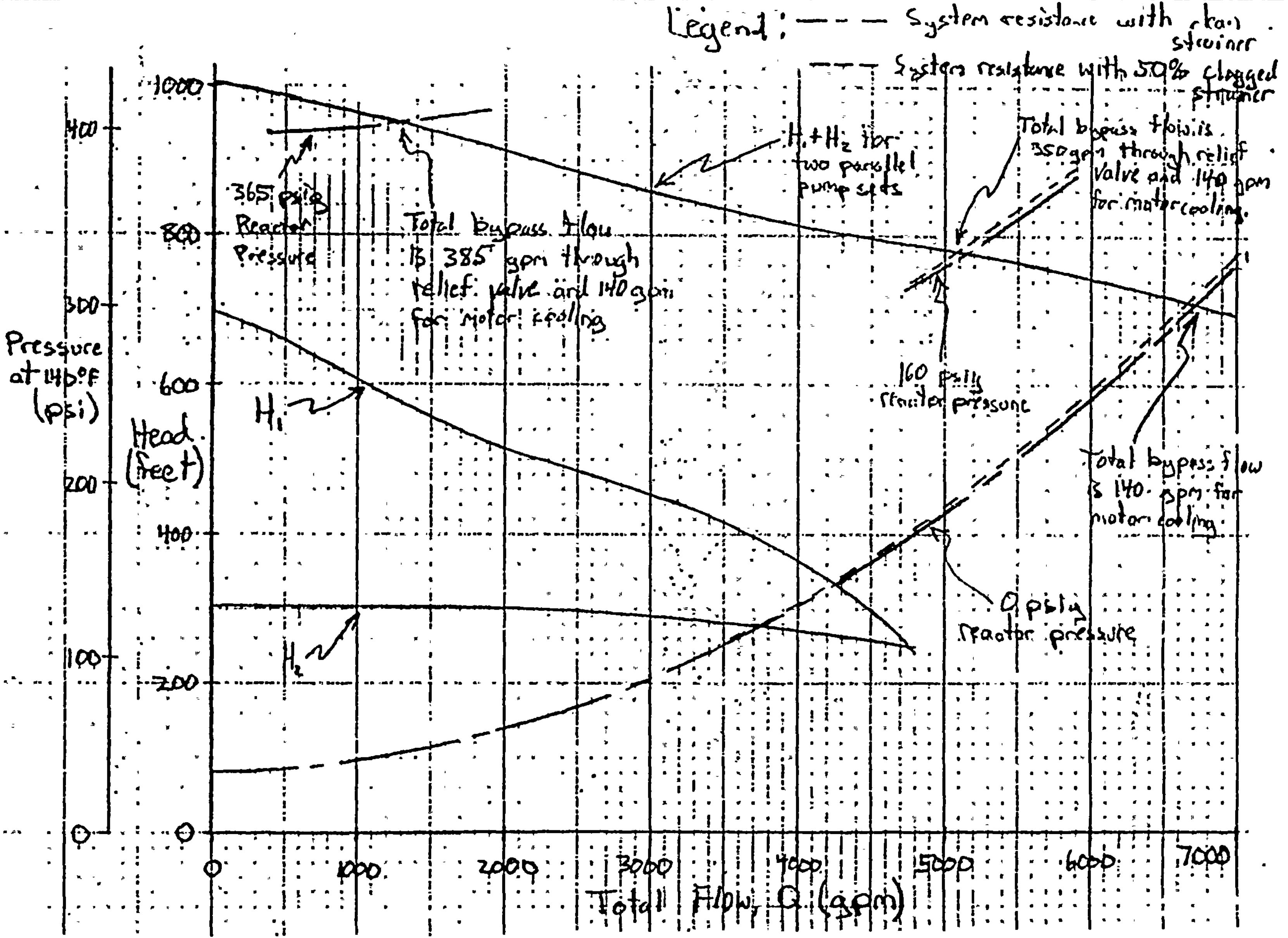
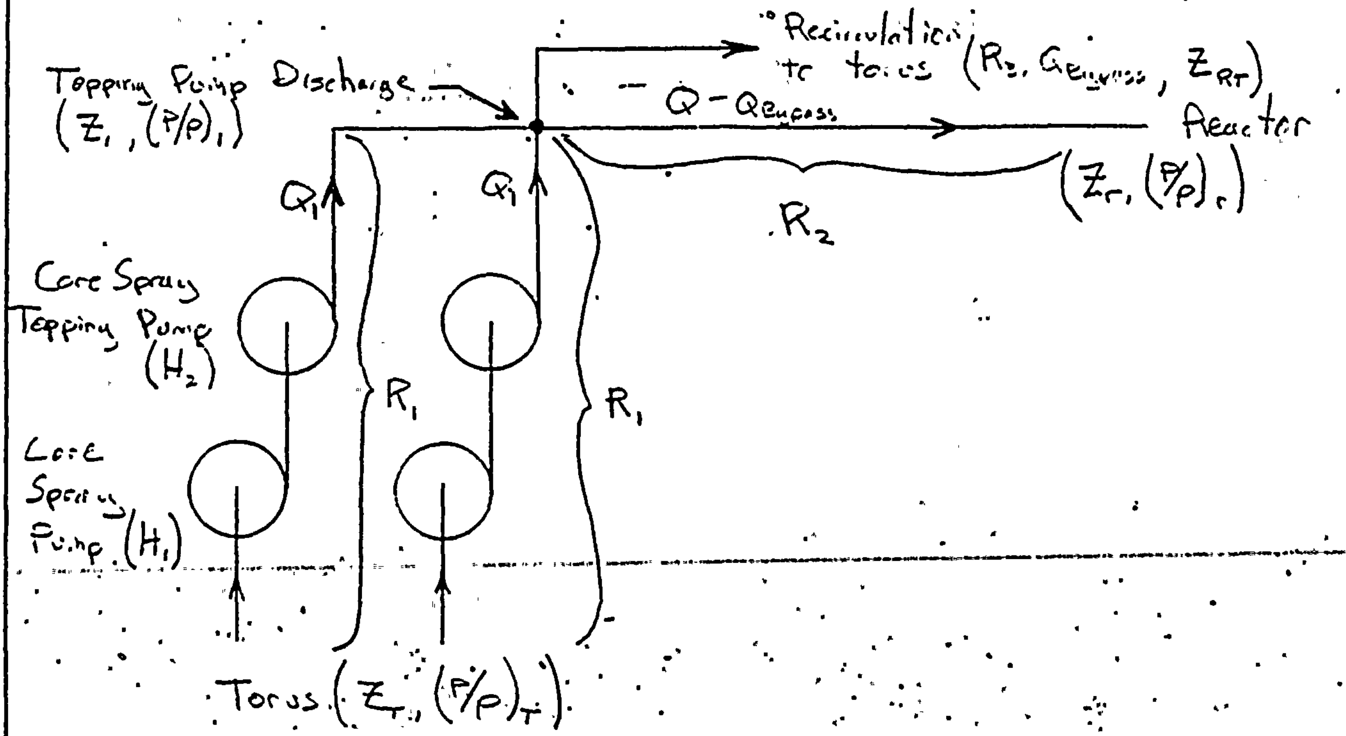


Figure 1 - Head Versus Reactor Flow

CALCULATION NO.	PREPARED BY	CHECKED BY	PAGE
85-87-TGL6	T. Lestina		6

Calculation



Applying the energy equation for one of the pump risers,

$$\left(\frac{P}{\rho}\right)'_T + Z_T + \left(\frac{V^2}{2g}\right)_T + \left(H_1 + H_2\right) = \left(\frac{P}{\rho}\right)'_r + Z_r + \left(\frac{V^2}{2g}\right)_r + R_1 Q_1^2 + R_2\left(Q - Q_{bypass}\right)^2$$

where

$\left(\frac{P}{\rho}\right)'_T, \left(\frac{P}{\rho}\right)'_r, \left(\frac{P}{\rho}\right)'_1$ = pressure head in feet for torus, reactor and topping pump discharge, respectively.

$\left(\frac{V^2}{2g}\right)_T, \left(\frac{V^2}{2g}\right)_r, \left(\frac{V^2}{2g}\right)_1$ = velocity head in feet at the torus and reactor, respectively.

$\left(\frac{P}{\rho}\right)_T, \left(\frac{P}{\rho}\right)_r, \left(\frac{P}{\rho}\right)_1$ = sum of velocity head and pressure head such that

$$\left(\frac{P}{\rho}\right)_T = \left(\frac{P}{\rho}\right)'_T + \left(\frac{V^2}{2g}\right)_T, \left(\frac{P}{\rho}\right)_r = \left(\frac{P}{\rho}\right)'_r + \left(\frac{V^2}{2g}\right)_r$$

$$\left(\frac{P}{\rho}\right)_1 = \left(\frac{P}{\rho}\right)'_1 + \left(\frac{V^2}{2g}\right)_1$$

H_1, H_2 = total developed head in feet of core spray pump and topping pump, respectively.

R_1 = hydraulic resistance of pump suction and riser piping in ft/gpm^2

R_2 = hydraulic resistance of piping from topping pump discharge to reactor in ft/gpm^2

R_3 = hydraulic resistance of relief valve pump recirculation piping in ft/gpm^2

Q = total volumetric flow in gpm

Q_{Bypass} = volumetric flow of pump recirculation in gpm

Q_1 = volumetric flow through one set of pumps in gpm.

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Assumptions

1. The flow of each pump set is essentially the same. Therefore $Q = 2Q_1$.

2. The hydraulic resistance of the suction and riser piping for each pump set is essentially the same.

3. The pump recirculation flow through the relief valve branches off at the tee where the flows combine for the two pump sets. Piping isometrics, reference (8), indicate that recirculation piping is close enough to the tee to neglect losses.

4. The velocity head at the torus and reactor (following sparger discharge) is zero such that $\left(\frac{P}{\rho}\right)_T = \left(\frac{P}{\rho}\right)'_T$ and $\left(\frac{P}{\rho}\right)_r = \left(\frac{P}{\rho}\right)'_r$. Dissipation of velocity head is included in the calculation of R_2.

5. Torus pressure is 0 psig. This is conservative since torus pressure increases during a design basis accident.

6. The relief valve in the recirculation piping is closed when the total pressure, $(P/\rho)_1$, is less than 280 psig (from conversations with plant operators) and the valve is fully open at pressures greater than 280 psig. The differences between $(P/\rho)_1'$ and $(P/\rho)_1$ due to the velocity head are negligible compared to the conservative assumption that the relief valve is fully opened at all pressures greater than 280 psig.

$$\text{velocity head} = \frac{V^2}{2g} = \frac{\left[(6700\,\text{gpm})\left(\frac{1\,\text{ft}^3}{7.4805\,\text{g}}\right)\left(\frac{1\,\text{min}}{60\,\text{s}}\right)\left(\frac{1}{.7854\,\text{ft}^2}\right)\right]^2}{2\cdot 32.2\,\text{ft/s}^2}$$

$$= 5.61\ \text{ft.}$$

This velocity head has no impact on relief valve flows used to calculate reactor flows at 0, 160 and 365 psig reactor pressures.

7. The bypass flow for the pump seal and motor cooling are assumed to have a negligible impact on system resistance, however the reactor flow is reduced by the flows shown on p. 16.

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Rearranging the energy equation;

$$H_1 + H_2 = (P/\rho)_{r^\circ} - (P/\rho)_T + (Z_r - Z_T) + \frac{R_1}{4}Q^2 + R_2(Q - Q_{bypass})^2$$

Z_r = 292.5 ft. from Reference (12)

Z_T = 210.5 ft. from Reference (13)

Z_1 = 245.83 ft. from most recent revision of Reference (8).

$(P/\rho)^\circ_T$ = 0 ft.

ρ = 61.38 lbf/ft³ at 140°F from Reference (2).

From reference (3)

$R_1 = 1.56824(10^{-6})$ ft./gpm² clean strainer

$= 2.57291(10^{-6})$ ft./gpm² 50% clogged strainer

From reference (4)

$R_2 = 1.35530(10^{-5})$ ft./gpm²

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Reactor Pressure = 0 psig

Assume $Q_{Bypass} = 0$ gpm

Total Flow from Figure 1 = 6700 gpm

$$(P/\rho)_1 = (P/\rho)_r + (Z_r - Z_1) + R_2 Q^2$$

$$= 46.67 + 1.35530(10^{-5})(6700)^2 = 655 \text{ ft.}$$

$$P_1 = \frac{61.38}{144}(655) = 279 \quad < 280 \text{ psig}$$

From energy equation,

$$H_1 + H_2 = (P/\rho)_r + (Z_r - Z_T) + \left(\frac{R_1}{4} + R_2\right)Q^2$$

$$H_1 + H_2 = 82.0 + \left(\frac{R_1}{4} + R_2\right)Q^2$$

The solution to this equation is shown in Figure 1 for both clean and 50% clogged strainer.

Reactor Pressure = 160 psig

Assume $Q_{Bypass} \neq 0$ gpm. The following two step approach is used to calculate the resistance curve:

Step 1. Apply the energy equation between point 1 and the reactor,

$$(P/\rho)_1 = (P/\rho)_r + (Z_r - Z_1) + R_2(Q - Q_{Bypass})^2$$

$$= 422.04 + 1.35530(10^{-5})(Q - Q_{Bypass})^2$$

(P_1 is checked to ensure it is greater than 280 psig)

Step 2. Apply the energy equation between point 1 and the torus discharge (through the recirc. line)

$$(P/\rho)_T + Z_{RT} + R_3 Q_{Bypass}^2 = (P/\rho)_1 + Z_1$$

$(P/\rho)_T = 0$ ft. $\quad Z_{RT} = 214.0$ ft. from reference (8)

$R_3 = 6.32571(10^{-3})$ ft./gpm^2 from reference (5)

$$\bar{Q}_{Bypass} = \sqrt{\frac{(P/\rho)_1 + (Z_1 - Z_{RT})}{R_3}}$$

$$Q_{Bypass} = \sqrt{\frac{(P/\rho)_1 + 31.83}{6.32571(10^{-3})}}$$

This approach permits the calculation of $(P/\rho)_1$ independent of H_1 and H_2 so that a system resistance curve can be calculated.

$Q - Q_{Bypass}$ gpm	$(P/\rho)_1$ feet (psig)	Q_{Bypass} gpm	Q gpm
4000	638.89 (272)	0	4000
4500	696.49 (297)	339	4839
5000	760.87 (324)	354	5354
5500	832.02 (355)	370	5870
6000	909.95 (388)	386	6386

The system resistance curve is calculated from these values and the energy equation:

$$H_1 + H_2 = (P/\rho)_c + (Z_c - Z_T) + R_0/4\ Q^2 + R_2(Q - Q_{Bypass})^2$$

$$H_1 + H_2 = 457.37 + R_1/4\ Q^2 + R_2(Q - Q_{Bypass})^2$$

The solution to the equation is shown in Figure 1 for both clean and 50% clogged strainer.

Reactor Pressure = 365 psig

Assume $Q_{Bypass} \neq 0$ gpm. The same two-step approach used for a reactor pressure of 160 psig is employed here.

Step 1.

$$(P/\rho)_1 = (P/\rho)_r + (Z_r - Z_1) + R_2(Q - Q_{Bypass})^2$$

$$= 902.98 + 1.3553(10^{-5})(Q - Q_{Bypass})^2$$

Step 2.

$$(P/\rho)_T + Z_{RT} + R_3 Q_{Bypass}^2 = (P/\rho)_1 + Z_1$$

$$Q_{Bypass} = \sqrt{\frac{(P/\rho)_1 + 31.83}{6.32571(10^{-2})}}$$

This approach permits the calculation of $(P/\rho)_1$ independent of H_1 and H_2 so that a system resistance curve can be calculated.

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$Q-Q_{Bypass}$ gpm	$(P/\rho)_1$ feet (psig)	Q_{Bypass} gpm	Q gpm
0	902.98 (385)	384	384
500	906.37 (386)	385	885
1000	916.53 (391)	387	1387
1500	933.47 (398)	391	1891

The system resistance curve is calculated from these values and the energy equation:

$$H_1 + H_2 = (P/\rho)_r + (Z_r - Z_T) + R_1/4\,Q^2 + R_2(Q - Q_{Bypass})^2$$

$$H_1 + H_2 = 938.31 + R_1/4\,Q^2 + R_2(Q - Q_{Bypass})^2$$

The solution to the equation is shown in Figure 1 for both clean and 50% clogged strainer.

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Correction to Calculated Reactor Flow Due to Pump Motor and Seal Cooling Flow

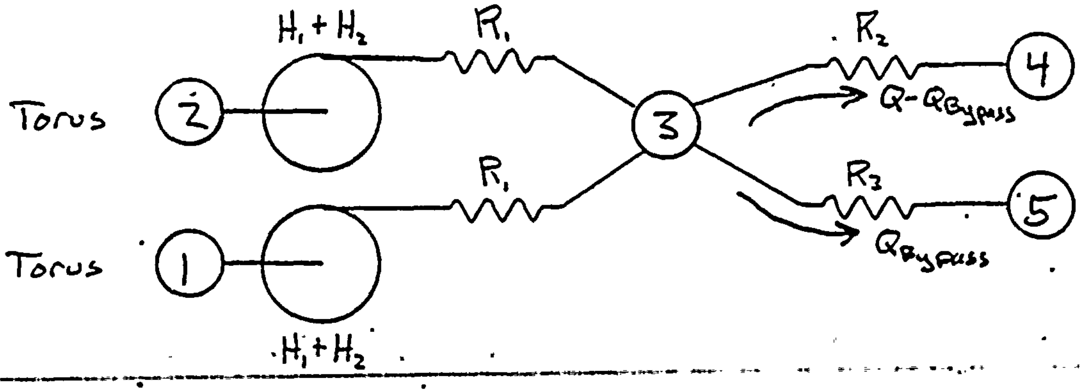
For this analysis, it is assumed that bypass flow for pump motor and seal cooling does not change system resistance. Rather, the reactor flow is corrected by subtracting calculated bypass flows from reactor flows calculated from p. 1 to 15. This method is conservative because the system resistance is reduced due to these bypass flows and thus the total flow is increased.

From reference (11),

Topping pump motor and seal cooling flow = 30 gpm

Core spray pump motor cooling flow = 40 gpm

FLONET model



Elevations

Node 1: 210.5'
Node 2: 210.5'
Node 3: 245.83'
Node 4: 292.50'
Node 5: 214.00'

Pressures

Node 1: 0 psig
Node 2: 0 psig
Node 3: variable
Node 4: 0, 160, 365 psig
Node 5: 0 psig

Resistances

$R_1 = 1.56824 (10^{-4})$ ft. of H_2O/gpm^2 clean strainer
$R_2 = 1.35530 (10^{-5})$ ft. of H_2O/gpm^2
$R_3 = 6.32571 (10^{-3})$ ft. of H_2O/gpm^2

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$H_1 + H_2$ is inputted into FLONET as a head-flow curve. The following values of flow and head are used as the basis for the head flow curve input (from References (6) and (7)):

Flow for one pump set (gpm)	Total Developed Head (feet) ($H_1 + H_2$)
0	1001
500	963
1000	909
1500	858
2000	813
2500	781
3000	742
3500	695
4000	632
4500	553
4800	491

FLONET interpolates between inputted head-flow values during the iterative solution.

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By Fixing the pressures of nodes 1, 2, 4 and 5, the flows are exactly determined. FLONET provides a feature where flow can be turned off in a connector. With pressures at node 3 less than 280 psig, $Q_{Bypass} = 0.$ gpm.

The calculated reactor flows are then corrected due to pump seal and motor cooling. These flows (shown on p. 16) are subtracted from the FLONET calculated flows as a post-processing step.

References

1. Crane Technical Paper No. 410, "Flow of Fluids Through Valves, Fittings and Pipe", 1982.

2. Daugherty, R.L. and Franzini, J.B. Fluid Mechanics with Engineering Applications, McGraw Hill Book Company, New York, 1977.

3. MPR Calculation 85-87-TGL5, "Hydraulic Resistance of NMP1 Core Spray Pump and Topping Pump Suction and Riser Piping", Rev. 1, 2/23/89.

4. MPR Calculation 85-87-TGL4, "Hydraulic Resistance of NMP1 Core Spray Topping Pump Discharge Piping to the Reactor", Rev. 1, 1/12/89

5. MPR Calculation 85-87-TGL3, "Hydraulic Resistance of NMP1 Core Spray Recirculation Piping", Rev. 0 11/29/88.

6. NMP1 Core Spray Pump Head-Flow Curve, Worthington Corp. Curve DEN-21274, 3/13/68. (ATTACHED)

7. NMP1 Core Spray Topping Pump Head-Flow Curve, Worthington Corp. Curve, 3/7/68. (ATTACHED)

8. Niagara Mohawk Drawing No. C-26845-C, "Reactor Core Spray System 81 & 81.1 Piping Isometric", Sheet 3, Rev. 10.

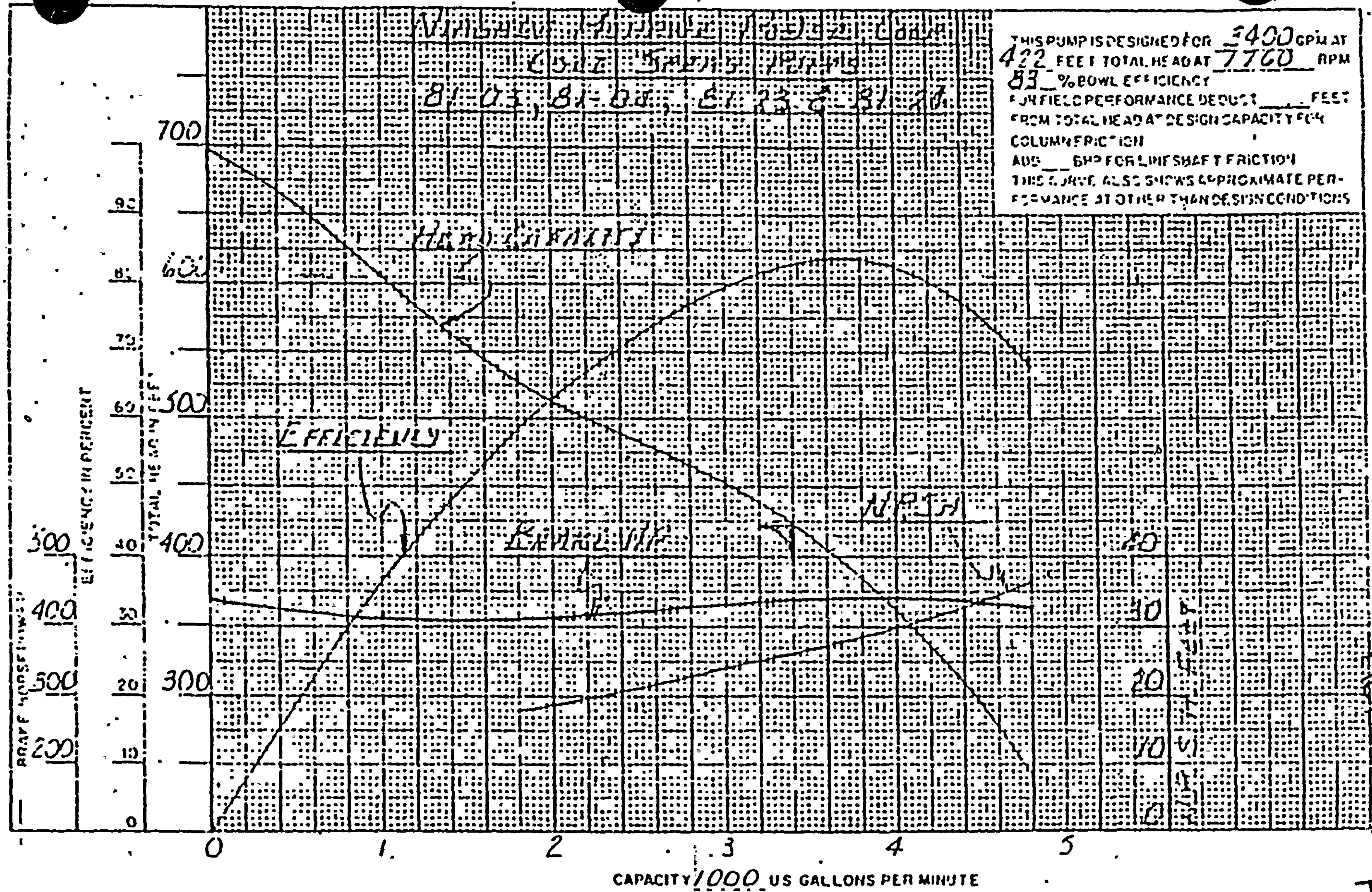
9. Niagara Mohawk Drawing No. C-26844-C, "Reactor Core Spray System 40 Piping Isometric", Rev. 8.

10. Niagara Mohawk P&I Diagram C-18007-C, "Reactor Core Spray", Rev. 33.

11. MPR Calculation 85-87-TGL2, "Core Spray System Flows With One Set of Pumps Operating", Rev. 1, 1/18/89

12. GE Drawing 104R859, "Arrangement and Assembly of Reactor", Rev. 8.

13. MPR Calculation, "Minimum Normal Torus Water Level", CS Schlusman, 9/21/88.



THIS PUMP IS DESIGNED FOR 3400 GPM AT 422 FEET TOTAL HEAD AT 1760 RPM
83 % BOWL EFFICIENCY
FOR FIELD PERFORMANCE DEDUCT ___ FEET FROM TOTAL HEAD AT DESIGN CAPACITY FOR COLUMN FRICTION
ADD ___ BHP FOR LINESHAFT FRICTION
THIS CURVE ALSO SHOWS APPROXIMATE PERFORMANCE AT OTHER THAN DESIGN CONDITIONS

CAPACITY 1000 US GALLONS PER MINUTE

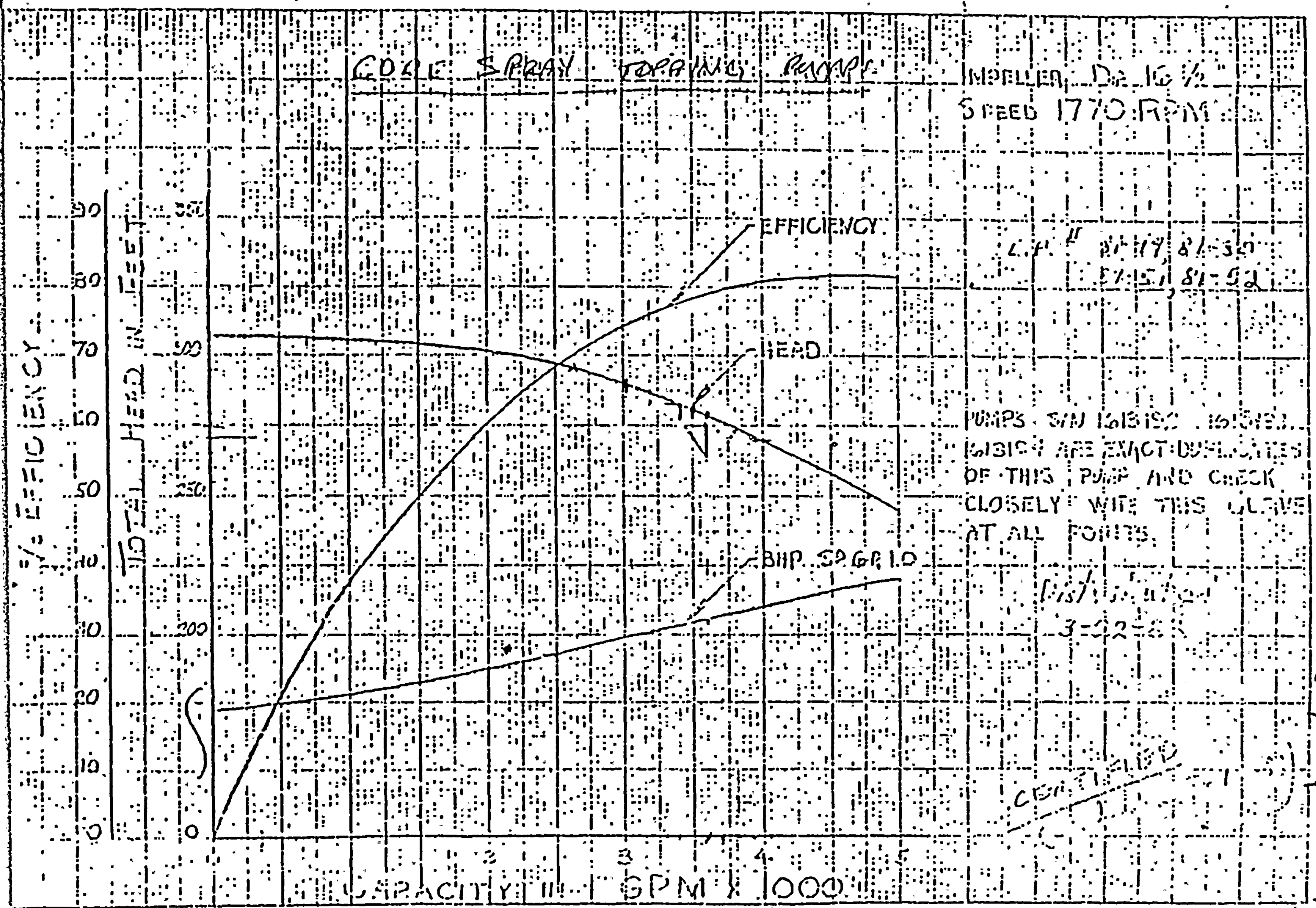
IMPELLER	BOWL	15H11340 PUMP	WORTHINGTON CORPORATION	3-13-68 DATE	VTP 11964-61 SERIAL NO
IMP DIA	450 DRIVER	6 NO OF STAGES	VERTICAL PUMP DIVISION	NT-155 CUST NO	DTP 26998 ORDER NO
TEST NO.	1760 RPM	DRAWN BY	DENVER, COLORADO U S A ALHAMBRA, CALIFORNIA U S A	QUOTE NO	DEN-51274 CURVE NO.

3-NZ-816.9

S14-40-FD04 rev 1

Replace P. 1 of 1

81-49, 50, 51
& 52



IMPELLER Dia 16 ½"
SPEED 1770 RPM

C.P. # 81-49, 81-50
81-51, 81-52

PUMPS S/N 1613192 . 1613193
1613194 ARE EXACT DUPLICATES
OF THIS PUMP AND CHECK
CLOSELY WITH THIS CURVE
AT ALL POINTS.

[illegible]
3-22-65

CERTIFIED

Refuel 7 P. 1 of 1

S14-40-F004 rev 1

TESTED:	CAPACITY. 3600 GPM	DRIVER 4 COMP TEST	SPEED 1775 - 1786	DRIVE DIRECT
[illegible]	WORTHINGTON CORPORATION	NEW YORK	P-45D105	

NIAGARA MOHAWK

CALCULATION COVER SHEET

NUCLEAR ENGINEERING & LICENSING

DISCIPLINE: mechanical

PAGE 1A

PROJECT: NINE MILE POINT NUC. STA.-UNIT I

CALC. NO. S14-81-F008

SUBJECT: Core Spray strainer-hydr. resist.

BUILDING: Reactor

FLOOR ELEV.: various

INDEX NO.: 3-N2.1- S14

ORIGINATOR(S): MPR Associates

TOTAL SHT'S. 11

CHECKER(S): MPR Associates

LAST SHT. NO: 9

RECORD OF ISSUES									
REV.	DESCRIPTION	M.O.#	BY	DATE	CHKD.	DATE	APPD.	DATE	DATE FILMED:
0	initial issue	2988	T. Lestina	2/23/89	L. Stevens	2/24/89	L.A. Kuszewski	3/2/89	

COMPUTER OUTPUT YES ☐ NO ☒

SAFETY RELATED YES ☒ NO ☐

DRAWINGS REFERENCED:

DWG. NO.	INDEX	SHT.	REV.
see page 9			

REFERENCES:

see page 9

KEYWORDS: NMP I, SSFI, core spray, hydraulic, resistance, strainer

CROSS REF.: 85-104-TGL8

S14-81-F008 rev 0

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CALCULATION TITLE PAGE

CLIENT Niagara Mohawk	PAGE 1 OF 9
PROJECT Core Spray SSFI	TASK NO. 85-104
CALCULATION TITLE Hydraulic Resistance of NMP1 Core Spray Strainer	CALCULATION NO. (OPTIONAL) 85-104-T6L8

PREPARER(S)/DATE	CHECKER(S)/DATE	REVIEWER(S)/DATE	REV. NO.
T. Lestina 2/23/89	L. Stevens 2/24/89	J Johnson 2-24-89	0

Purpose: The purpose of this calculation is to determine the hydraulic resistance of the core spray strainer, installed between the core spray pump and topping pump, from measured test data.

Summary: The head loss due to the hydraulic resistance of the core spray strainer is:

$$h_L = K_{ST}\frac{V^2}{2g} = R_{ST}Q^2$$

where R_{ST} = hydraulic resistance, (ft/gpm²)
Q = volumetric flow rate, (gpm)
V = flow velocity, (ft/s)
g = acceleration due to gravity (ft/s²)
h_L = head loss (ft.)
K_{ST} = resistance coefficient or K-factor of strainer

514-81-F008 revO

CALCULATION NO.	PREPARED BY	CHECKED BY	PAGE
85-104-TGL8	T. Lestina	L. Stevens	3

$K_{ST} = 2.68$ for 12" ID pipe
$R_{ST} = 3.34890(10^{-7})$ ft./gpm² } clean strainer

$K_{ST} = 10.72$ for 12" ID pipe
$R_{ST} = 1.33956(10^{-6})$ ft./gpm² } 50% clogged strainer

Calculation:

The K-factor for the strainer is calculated from the test data for pump set 122, reference (2). The measured data is shown in Table 1 and plotted in Figure 1. A best fit curve of the data is plotted in Figure 1 in accordance with the following equation:

$$\Delta P = .0459 + 1.447(10^{-7})Q^2$$

with ΔP in psi, Q in gpm

(This equation is calculated using a linear least mean square curve fit using ΔP vs. Q^2)

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CALCULATION NO.	PREPARED BY	CHECKED BY	PAGE
85-104-T6L8	T. Lestina	L. Stewart	4

Table 1

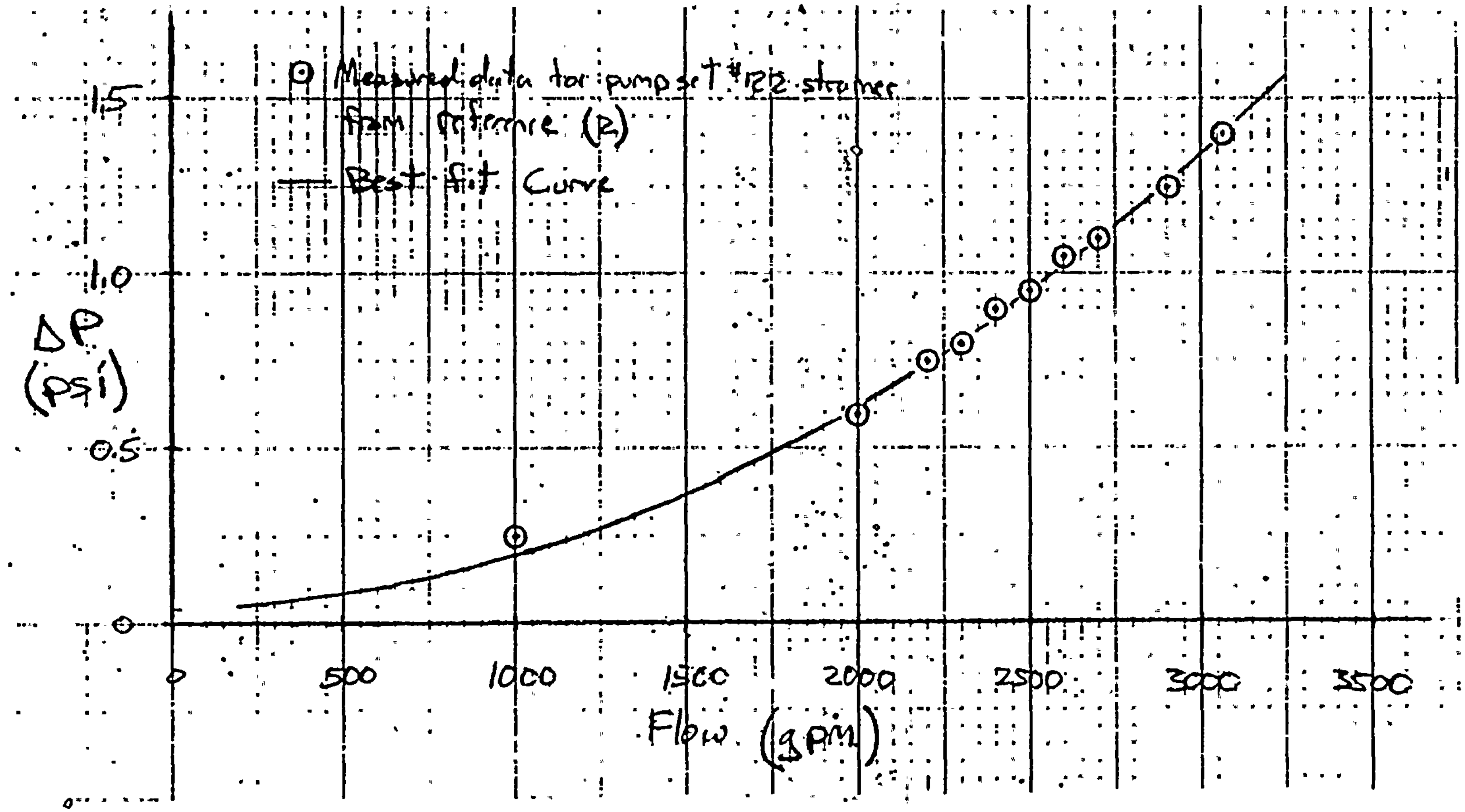
Pump Set #122

Differential Pressure Across Core Spray Strainer

Measured Flow lb/hr, (gpm)[1]		Measured ΔP psi
153 × 10⁴	(3062)	1.4
145 × 10⁴	(2902)	1.25
135 × 10⁴	(2702)	1.1
130 × 10⁴	(2602)	1.05
125 × 10⁴	(2502)	0.95
120 × 10⁴	(2401)	0.90
115 × 10⁴	(2301)	0.80
110 × 10⁴	(2201)	0.75
100 × 10⁴	(2001)	0.60
50 × 10⁴	(1001)	0.25

Note: 1. With a fluid temperature of 70°F (measured at pump discharge during test) conversion between lb/hr and gpm becomes:

$$\left(\frac{\text{lb}}{\text{hr}}\right)\left(\frac{1\ \text{ft}^3}{62.3\ \text{lb}}\right)\left(\frac{7.4805\ \text{g}}{1\ \text{ft}^3}\right)\left(\frac{1\ \text{hr}}{60\ \text{min}}\right) = \text{gpm}$$



Core Spray Strainer Differential Pressure Versus Flow

Figure 1

CALCULATION NO.	PREPARED BY	CHECKED BY	PAGE
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Since the non-zero offset (.0459 psi) is less than the measurement uncertainty of the data, it is assumed to be negligible and the measured hydraulic resistance is

$$R_{ST} = 1.447(10^{-7})\ \mathrm{psi/gpm^2}$$

Due to the location of the differential pressure gage taps, this resistance includes the losses due to 16x12 reducers (both increasing and reducing), several feet of straight pipe and an elbow.

$$K_{ST} = \frac{\Delta P/\rho}{\frac{V^2}{2g}} = \frac{\Delta P}{Q^2}\cdot\left(\frac{A^2\,2g}{\rho_{70°F}}\right) = R\left(\frac{A^2\,2g}{\rho_{70°F}}\right)$$

$$= 1.447(10^{-7})\,\frac{\mathrm{psi}}{\mathrm{gpm^2}}\cdot\frac{(.7854\ \mathrm{ft^2})^2(60\ \mathrm{s/min})^2(7.4805\ \mathrm{g/ft^3})^2\,2\cdot 32.2\ \mathrm{ft/s^2}}{62.3\ \mathrm{lb/ft^3}}\cdot 144\ \mathrm{in^2/ft^2}$$

$$= 2.68 \text{ for 12'' ID pipe}$$

Assuming that the strainer K-factor, $(K_{ST})_{clogged}$, is related to the clean strainer K-factor by the following

$$(K_{ST})_{clogged} = \frac{(K_{ST})}{(A_{free})^2}$$

where A_{free} = % free area.

This equation assumes that the strainer losses are dominated by the pressure losses across the screen; therefore pressure losses are proportional to V^2 (or the inverse square of the free area) in accordance with Darcy's Law.

$$(K_{ST})_{50\%\,clogged} = \frac{2.68}{(.50)^2} = 10.72 \text{ for } 12\text{" ID pipe}$$

Calculating R_{ST}:

$$h_L(\text{ft. of } H_2O) = K_{ST}\frac{V^2}{2g} = R_{ST}Q^2$$

$$h_L = \frac{K_{ST}\left(\frac{1\,min}{60\,s}\right)^2\left(\frac{1\ ft^3}{7.4805\ g}\right)^2\left(\frac{1}{.7854\ ft^2}\right)^2(Q, gpm)^2}{2(32.2)\ ft/s^2}$$

514-81-F008

CALCULATION NO.	PREPARED BY	CHECKED BY	PAGE
85-104-T6L8	T. Lestina	L. Stevens	8

$$h_L = 1.24959(10^{-7})\, K_{ST}\, Q^2$$

with clean strainer $R_{ST} = 3.34890(10^{-7})$ ft./gpm²

with 50% clogged strainer $R_{ST} = 1.33956(10^{-6})$ ft./gpm²

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CALCULATION NO.	PREPARED BY	CHECKED BY	PAGE
85-104-TGL8	T. Lestina	L. Stevens	9

References

1. MPR Calculation 85-87-TGL5, Hydraulic Resistance of NMP1 Core Spray Pump and Topping Pump Suction and Riser Piping, Rev. 0.

2. Test Results for Core Spray Pump Set #122, 2/9/89, from Temporary Procedure No. N1-88-6-12.

3. Daugherty R.L. and Franzini, J.B. *Fluid Mechanics with Engineering Applications*, McGraw Hill Book Company, New York 1977.

BG 2-9-89

PWS 2-9-89

TABLE 1

DATA SHEET FOR DETERMINING CORE SPRAY SURVEILLANCE REFERENCE FLOW (TEST PART 1)

PUMP SET # 122
2-9-89

PERSON RECORDING DATA ______________________

Desired Flow (lb/hr)	Measured Flow* (lb/hr)	Drag Valve Stroke (in)	Topping Pump Discharge Pressure▼ (psig)		Pipe Vibration (in/s)	Core Spray Suction Pressure (psig)	Core Spray Pump Vibration (mils)	Filter Differential Pressure (psid)	Topping Pump Vibration (mils)	Strainer Inlet Pressure (psig)
			cl	local						
Full Flow	153×10^4		310	310	1.4	2.3	.55	1.4	2.3	198
145×10^4	145×10^4		318	319	1.2	2.7	.5	1.25	1.9	206
135×10^4	RV starting to lift 135×10^4		321	329	0.7	2.9	.48	1.1	1.4	213.5
130×10^4	Fluct some 130×10^4		328	331	.47	3.0	.47	1.05	1.0	212/216
125×10^4	125×10^4		329	329	.35	3.1	.47	.96	0.8	212
120×10^4	120×10^4		330	330	.24	3.2	.47	.90	0.75	213
115×10^4	115×10^4		330	336	.16	3.3	.47	.8	0.6	218
110×10^4	110×10^4		340	341	.12	3.35	.47	.75	0.65	224
100×10^4	100×10^4		351	356	.11	3.4	.47	.6	0.6	237
50×10^4	50×10^4		360	381	.09	3.7	.47	.25	0.7	259

* Indicated on K panel in Control Room.

Reference (2) SI4-81-E002 rev 0 p. 1 of 1

NIAGARA MOHAWK

CALCULATION COVER SHEET

NUCLEAR ENGINEERING & LICENSING

DISCIPLINE: Mechanical

PAGE 1A

PROJECT: NINE MILE POINT NUC. STA.-UNIT I

CALC. NO. S14-40-M006

SUBJECT: Evaluation of Core Spray Strainer Hi ΔP Alarm Set Point

BUILDING: Reactor

FLOOR ELEV.: Various

INDEX NO.: 3-N2.1-S14

ORIGINATOR(S): MPR Associates (J. Johnson)

TOTAL SHT'S. 14

CHECKER(S): MPR Associates (T. Lestina)

LAST SHT. NO.: 13

RECORD OF ISSUES

REV.	DESCRIPTION	M.O.#	BY	DATE	CHKD.	DATE	APPD.	DATE	DATE FILMED:
0	Evaluation of Core Spray Strainer High ΔP Alarm	2988	J. Johnson	1/26/89	T. Lestina	1/26/89	L.A. Klosowski	1/28/89	
1	revised in its entirety	2988	Johnson	2/24/89	A.D. Russell	3/1/89	L.A. Klosowski	3/8/89	

COMPUTER OUTPUT YES ☐ NO ☒

SAFETY RELATED YES ☒ NO ☐

DRAWINGS REFERENCED:

DWG. NO.	INDEX	SHT.	REV.

REFERENCES:

See page 13

NMPC Calc's
S14-81-F005 Rev. 1
S14-40-F004 Rev 1

KEYWORDS: NMP I Core Spray, Strainer, Set Point, Alarm,

CROSS REF.: 85-104, 85-104-E

514-40-M006 rev 1

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CALCULATION TITLE PAGE

CLIENT NIAGARA MOHAWK	PAGE 1 OF 13.
PROJECT SSFI SUPPORT	TASK NO. 85-104
CALCULATION TITLE EVALUATION OF STRAINER HIGH ΔP ALARM SETPOINT.	CALCULATION NO. (OPTIONAL) 85-104-05

PREPARER(S)/DATE	CHECKER(S)/DATE	REVIEWER(S)/DATE	REV. NO.
John Johnson 1-26-89	S. Sestini 1/26/89	S. Sestini 1/26/89	0
John Johnson 2-24-89	Alan B Russell 3-1-89	Alan B. Russell 3-1-89	1

S14-40-M006 rev 1

CALCULATION NO.	PREPARED BY	CHECKED BY	PAGE 2
85-104-05	JHolman	A.B. Russell	

PURPOSE

THE PURPOSE OF THIS CALCULATION IS TO DETERMINE THE Δp ACROSS THE CORE SPRAY STRAINERS FOR VARIOUS FLOW CONDITIONS.

RESULTS

ONE PUMP SET OPERATION

FLOW THROUGH STRAINER = 4960 gpm

ΔP (CLEAN) = 3.51 psi

ΔP (50 % BLOCKED) = 12.7 psi

FLOW BLOCKAGE @ 5.0 psi = 18 PERCENT

TWO PUMP SET OPERATION

FLOW THROUGH STRAINER = 3310 gpm

ΔP (CLEAN) = 1.56 psi

ΔP (50% BLOCKED) = 5.66 psi

FLOW BLOCKAGE @ 5.0 psi = 41 PERCENT

SI4-40-M006 rev 1

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CALCULATION NO.	PREPARED BY	CHECKED BY	PAGE 3
85-104-05	J Johnson	a.B. Russell	

SURVEILLANCE TEST

FLOW THROUGH STRAINER ≈ 2410 gpm

ΔP (CLEAN) = 0.83 psi

ΔP (50% BLOCKED) = 3.00 psi

FLOW BLOCKAGE @ 5.0 psi = 62 PERCENT

S14-40-M006 rev 1

CALCULATION NO.	PREPARED BY	CHECKED BY	PAGE 4
85-104-05	J Johnson	a. B. Russell	

CALCULATIONS

FROM P.3 OF REFERENCE 1, THE LOSS COEFFICIENT FOR THE STRAINER (CLEAN) IS

K = 2.68 (BASED ON 12" ID PIPE)

DUE TO THE LOCATION OF THE DIFFERENTIAL PRESSURE TAPS, THIS LOSS COEFFICIENT INCLUDES THE LOSS COEFFICIENTS FOR:

ONE 16X12 REDUCER (ENLARGING) AT STRAINER INLET	K = 0.15	FOR 12" ID PIPE
ONE 16X12 REDUCER (REDUCING) AT STRAINER OUTLET	K = 0.16	"
APPROX. 2FT OF 12" ST. PIPE	K = 0.03	"
	K_{PIPE} = 0.34	"

(NOTE: THE LOSS COEFFICIENTS FOR THE ABOVE PIPING COMPONENTS ARE FROM P. 7 OF REFERENCE 2.)

THEREFORE, STRAINER LOSS COEFICIENT IS

K_{ST} = 2.34 FOR 12" ID PIPE

CALCULATION NO.	PREPARED BY	CHECKED BY	PAGE
85-104-05	J Johnson	d. B. Russell	5

AT A FLOW OF $q = 3400$ gpm

$$A(12'' \text{ ID PIPE}) = \frac{\pi}{4}\left(\frac{12.000}{12}\right)^2 = 0.7854 \text{ ft}^2$$

$$v = \frac{3400 \text{ gal}}{\text{min}} \cdot \frac{1 \text{ min}}{60 \text{ sec}} \cdot \frac{1 \text{ ft}^3}{7.481 \text{ gal}} \cdot \frac{1}{0.7854 \text{ ft}^2}$$

$$= 9.644 \text{ ft/sec}$$

$$\rho = 61.4 \text{ lb/ft}^3 \text{ @ } 140\,°\text{F}$$

$$\Delta P_{ST} = \frac{K_{ST}\,\rho\, v^2}{2g} = \frac{2.34 \cdot 61.4 \cdot 9.644^2}{2 \cdot 32.2}$$

$$= 207 \text{ lb/ft}^2 = 1.44 \text{ psi}$$

$$\Delta P_{PIPE} = \frac{K_{PIPE}\,\rho\, v^2}{2g} = \frac{0.34 \cdot 61.4 \cdot 9.644^2}{2 \cdot 32.2}$$

$$= 30.1 \text{ lb/ft}^2 = 0.21 \text{ psi}$$

$\Delta P_{ST} = 1.44$ psi @ 3400 gpm

$\Delta P_{PIPE} = \underline{0.21}$ psi "

$\Delta P = 1.65$ psi "

S14-40-M006 rev 1

CALCULATION NO.	PREPARED BY	CHECKED BY	PAGE
85-104-05	J Johnson	A. B. Russell	6

FOR THE STRAINER, ASSUME

$$\Delta P_{ST} = \frac{K_{ST}\,\rho\,V^2}{2g} = \frac{K_{ST}\,\rho\,(q/A)^2}{2g}$$

K_{ST} = STRAINER LOSS COEFFICIENT
ρ = DENSITY
q = VOLUMETRIC FLOW
A = FLOW AREA STRAINER
g = ACCELERATION OF GRAVITY

IN THE FOLLOWING, STATE ① CORRESPONDS TO A CLEAN STRAINER AND STATE ② CORRESPONDS TO A PARTIALLY BLOCKED STRAINER.

$$\frac{\Delta P_2}{\Delta P_1} = \frac{\dfrac{K_{ST}\,\rho\,(q_2/A_2)^2}{2g}}{\dfrac{K_{ST}\,\rho\,(q_1/A_1)^2}{2g}} = \frac{(q_2/q_1)^2}{(A_2/A_1)^2}$$

$$\left(\frac{A_2}{A_1}\right) = \left(\frac{q_2}{q_1}\right)\sqrt{\frac{\Delta P_1}{\Delta P_2}}$$

$$\text{FLOW BLOCKAGE (PERCENT)} = \left(1 - \frac{A_2}{A_1}\right) \times 100$$

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CALCULATION NO.	PREPARED BY	CHECKED BY	PAGE 7
85-104-06	J Johnson	A.B. Russell	

FOR ONE PUMP SET OPERATION. AT A FLOW BLOCKAGE OF 50 PERCENT THE ΔP ACROSS THE STRAINER IS:

$q_2 = 4960$ gpm (MAX FLOW THROUGH STRAINER FROM REF. 3)

$(A_2/A_1) = 0.50$

$\Delta P_1 = 1.44$ psi @ $q_1 = 3400$ gpm

$$\Delta P_2 = \Delta P_1 \cdot \frac{(q_2/q_1)^2}{(A_2/A_1)^2} = 1.44 \cdot \frac{(4960/3400)^2}{(0.50)^2}$$

$= 12.26$ psi (FOR STRAINER)

THE LOSSES IN THE CONNECTING PIPE ARE:

$q_2 = 4960$ gpm

$\Delta P_1 = 0.21$ psi @ $q_1 = 3400$ gpm

$$\Delta P_2 = \Delta P_1 \left(\frac{q_2}{q_1}\right)^2 = 0.21 \cdot \left(\frac{4960}{3400}\right)^2$$

$= 0.45$ psi (FOR THE PIPE)

THE TOTAL ΔP ACROSS THE STRAINER DIFFERENTIAL PRESSURE TAPS IS

$\Delta P = 12.26 + 0.45 = 12.7$ psi @ 4960 gpm

CALCULATION NO.	PREPARED BY	CHECKED BY	PAGE
85-104-05		A.B. Russell	8

AT THE PRESENT HIGH ΔP ALARM SETPOINT OF 5.0 PSI, THE FLOW BLOCKAGE IN THE STRAINER WOULD BE:

$$\Delta P = \Delta P_{ST} + \Delta P_{PIPE}$$

$$\Delta P_{PIPE} = 0.21 \cdot \left(\frac{4960}{3400}\right)^2 = 0.45$$

$$\therefore \Delta P_{ST} = 5.00 - 0.45 = 4.55 \text{ psi}$$

$$\frac{A_2}{A_1} = \left(\frac{q_2}{q_1}\right) \sqrt{\frac{\Delta P_1}{\Delta P_2}}$$

$$\Delta P_1 = 1.44 \text{ psi @ } q_1 = 3400 \text{ gpm}$$

$$\Delta P_2 = 4.55 \text{ psi @ } q_2 = 4960 \text{ gpm}$$

$$\frac{A_2}{A_1} = \frac{4960}{3400} \sqrt{\frac{1.44}{4.55}} = 0.821$$

$$\text{FLOW BLOCKAGE} = \left(1 - \frac{A_2}{A_1}\right) \cdot 100 = (1 - 0.821)\, 100$$

$$= 17.9\ \%$$

FOR TWO PUMP SET OPERATION. AT A FLOW BLOCKAGE OF 50 PERCENT, THE ΔP ACROSS THE STRAINER IS

$q_2 = 3310$ gpm (MAX FLOW THROUGH STRAINER FROM REF. 4)

$A_2/A_1 = 0.50$

$\Delta P_1 = 1.44$ psi @ $q_1 = 3400$ gpm

$$\Delta P_2 = \Delta P_1 \frac{(q_2/q_1)^2}{(A_2/A_1)^2} = 1.44 \cdot \frac{(3310/3400)^2}{(0.50)^2}$$

$= 5.46$ psi (FOR STRAINER)

THE LOSSES IN THE CONNECTING PIPE ARE:

$q_2 = 3310$ gpm

$\Delta P_1 = 0.21$ psi @ $q_1 = 3400$ gpm

$$\Delta P_2 = \Delta P_1 \left(\frac{q_2}{q_1}\right)^2 = 0.21 \left(\frac{3310}{3400}\right)^2$$

$= 0.20$ psi (FOR THE PIPE)

THE TOTAL ΔP ACROSS THE STRAINER DIFFERENTIAL PRESSURE TAPS IS:

$\Delta P = 5.46 + 0.20 = 5.66$ psi

AT THE PRESENT HIGH ΔP ALARM SETPOINT OF 5.0 psi, THE FLOW BLOCKAGE IN THE STRAINER WOULD BE:

$$\Delta P = \Delta P_{ST} + \Delta P_{PIPE}$$

$$\Delta P_{PIPE} = 0.21\left(\frac{3310}{3400}\right)^2 = 0.20 \text{ psi}$$

$$\therefore \Delta P_{ST} = 5.00 - 0.20 = 4.80 \text{ psi}$$

$$\frac{A_2}{A_1} = \frac{q_2}{q_1}\sqrt{\frac{\Delta P_1}{\Delta P_2}}$$

$$\Delta P_1 = 1.44 \text{ psi} @ q_1 = 3400 \text{ gpm}$$

$$\Delta P_2 = 4.80 \text{ psi} @ q_1 = 3310 \text{ gpm}$$

$$\frac{A_2}{A_1} = \frac{3310}{3400}\sqrt{\frac{1.44}{4.80}} = 0.533$$

$$\text{FLOW BLOCKAGE} = \left(1 - \frac{A_2}{A_1}\right)\cdot 100 = (1 - 0.533)\cdot 100$$

$$= 46.7\ \%$$

DURING SURVEILLANCE TESTING. AT A FLOW BLOCKAGE OF 50 PERCENT, THE ΔP ACROSS THE STRAINER IS:

$q_2 \approx 2410$ gpm [APPROX. FLOW THROUGH STRAINER WHEN FLOW AT FLOW METER READS 2200 gpm, THE NEW REFERENCE FLOW FOR SURVEILLANCE TESTING]

$A_2/A_1 = 0.50$

$\Delta P_1 = 1.44$ psi @ $q_1 = 3410$ gpm

$$\Delta P_2 = \Delta P_1 \cdot \frac{(q_2/q_1)^2}{(A_2/A_1)^2} = 1.44 \cdot \frac{(2410/3410)^2}{(0.50)^2}$$

$= 2.89$ psi (FOR THE STRAINER)

THE LOSSES IN THE CONNECTING PIPE ARE:

$q_2 = 2410$ gpm

$\Delta P_1 = 0.21$ psi @ $q_1 = 3410$ gpm

$$\Delta P_2 = \Delta P_1 \left(\frac{q_2}{q_1}\right)^2 = 0.21 \left(\frac{2410}{3410}\right)^2$$

0.11 psi (FOR THE PIPE)

THE TOTAL ΔP ACROSS THE STRAINER DIFFERENTIAL PRESSURE TAPS IS

$\Delta P = 2.89 + 0.11 = 3.00$ psi

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CALCULATION NO.	PREPARED BY	CHECKED BY	PAGE 12
85-104-05	J Johnson	a.B. Russell	

AT THE PRESENT HIGH ΔP ALARM SETPOINT OF 5.0 psi, THE FLOW BLOCKAGE IN THE STRAINER WOULD BE:

$$\Delta P = \Delta P_{ST} + \Delta P_{PIPE}$$

$$\Delta P_{PIPE} = 0.21\left(\frac{2410}{3400}\right)^2 = 0.11$$

$$\therefore \quad \Delta P_{ST.} = 5.00 - 0.11 = 4.89 \text{ psi}$$

$$\frac{A_2}{A_1} = \frac{q_2}{q_1}\sqrt{\frac{\Delta P_1}{\Delta P_2}}$$

$$\Delta P_1 = 1.44 \text{ psi} \ @ \ q_1 = 3400 \text{ gpm}$$

$$\Delta P_2 = 4.89 \text{ psi} \ @ \ q_2 = 2410 \text{ gpm}$$

$$\frac{A_2}{A_1} = \frac{2410}{3400}\sqrt{\frac{1.44}{4.89}} = 0.385$$

$$\text{FLOW BLOCKAGE} = \left(1 - \frac{A_2}{A_1}\right)100 = (1 - 0.385)100$$

$$= 62\%$$

REFERENCES

1. MPR CALCULATION NO. 85-104-TGL8, REV.0, HYDRAULIC RESISTANCE OF NMP-1 CORE SPRAY STRAINER, T. LESTINA, 2-23-89.
2. MPR CALCULATION NO. 85-87-TGL5, REV.1, HYDRAULIC RESISTANCE OF NMP-1 CORE SPRAY PUMP AND TOPPING PUMP SUCTION AND RISER PIPING, T. LESTINA, 2-23-89.
3. MPR CALCULATION NO. 85-87-TGL2, REV.1, CORE SPRAY SYSTEM FLOWS WITH ONE SET OF PUMPS OPERATING, T. LESTINA, 2-23-89.
4. MPR CALCULATION NO. 85-87-TGL6, REV.1 CORE SPRAY SYSTEM FLOWS WITH TWO SETS OF PUMPS OPERATING IN PARALLEL, T. LESTINA, 2-23-89.

NIAGARA MOHAWK

CALCULATION COVER SHEET

NUCLEAR ENGINEERING & LICENSING

DISCIPLINE: MECHANICAL

PAGE 1A

PROJECT: NINE MILE POINT NUC. STA.-UNIT 1

CALC. NO. S14-81-F001

SUBJECT: CORE SPRAY PUMP SUCTION HYDRAULIC RESISTANCE

BUILDING: REACTOR

FLOOR ELEV.: VARIOUS

INDEX NO.: 3-N2.1-S14

ORIGINATOR(S): MPR ASSOCIATES, INC.

TOTAL SHTS. 6

CHECKER(S): MPR ASSOCIATES, INC.

LAST SHT. NO.: 5

RECORD OF ISSUES

REV.	DESCRIPTION	M.O.#	BY	DATE	CHKD.	DATE	APPD.	DATE	DATE FILMED:
0	C.S. PUMP HYDRAULIC RESISTANCE	2988	T. LESTINA	11/29/88	L. STEVENS	11/30/88	LAK	12/3/88	

COMPUTER OUTPUT YES ☐ NO ☒

SAFETY RELATED YES ☒ NO ☐

DRAWINGS REFERENCED:

DWG. NO.	INDEX	SHT.	REV.
SEE PAGE 5			

REFERENCES:

SEE PAGE 5

KEYWORDS: NMP1, SSFI, CORE SPRAY, FLOW

CROSS REF.: 85-87-TGL7

S14-81-F001 rev0

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CALCULATION TITLE PAGE

CLIENT Niagara Mohawk	PAGE 1 OF 5
PROJECT Core Spray SSFI	TASK NO. 85-87
CALCULATION TITLE Hydraulic Resistance of NMP1 Core Spray Pump Suction Piping	CALCULATION NO. (OPTIONAL) 85-87-TGL7

PREPARER(S)/DATE	CHECKER(S)/DATE	REVIEWER(S)/DATE	REV. NO.
T. Lestina 11/29/88	L. Stevens 11/30/88	J Johnson 11/30/88	0

CALCULATION NO. 85-87-T16L7	PREPARED BY T. Lestina	CHECKED BY L. Stevens	PAGE 2

Purpose: The purpose of this calculation is to determine the hydraulic resistance of the core suction piping at Nine Mile Point Unit 1.

Summary: The head loss due to the hydraulic resistance of the suction piping is:

$$h_L = K_s \frac{V^2}{2g} = R_s Q^2$$

where
R_s = hydraulic resistance,
Q = volumetric flow rate,
V = flow velocity,
g = acceleration due to gravity,
h_L = head loss,
K_s = resistance coefficient or K-factor of suction piping & fittings

$$R_s = 3.79876(10^{-7}) \text{ ft. of } H_2O/\text{gpm}^2$$

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rev0

Calculations:

The core spray pump suction resistance, R_s, is calculated from the torus to the inlet flange of the core spray pump for pump set #122.

$$h_L = K_s \frac{V^2}{2g} = R_s Q^2$$

The fitting K-factors are copied from Reference (1) which have been calculated from Reference (2).

Component		K-factor
Entrance Screen (50% clogged)		1.61 (12")
Entrance reducer 20"x12"		.10 (12")
7' Straight Piping 12" STD	$.014 \frac{7}{(12/12)}$	.10 (12")
14x12 Reducer (enlarging)		.03 (12")
40' Straight Piping 14" STD	$.014 \frac{40}{(13.25/12)} = .51$ (14") =	.34 (12")
Gate Valve 14" STD		.07 (12")
3 90° Elbows 14" STD r/d = 1.5		.37 (12")

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rev 0

Component	K-factor
45° Elbow 14" STD	.06 (12")
14"x12" Reducer (reducing)	.08 (12")
Tee - run flow 12" STD	.28 (12")
Total	3.04 (12")

Calculating R_s:

$$h_L\,(\text{ft. of } H_2O) = K_s \frac{V^2}{2g} = R_s Q^2$$

$$h_L\,(\text{ft. of } H_2O) = K_s \frac{\left[\left(\frac{1 \text{ min}}{60 \text{ s}}\right)\left(\frac{1 \text{ ft}^3}{7.4805 \text{ g}}\right)\left(\frac{1}{.7854 \text{ ft}^2}\right) Q \cdot \text{gpm}\right]^2}{2(32.2)\ \text{ft/s}^2}$$

$$= 1.24959(10^{-7})\, K_s Q^2$$

$$R_s = 3.79876(10^{-7})\ \text{ft. of } H_2O / \text{gpm}^2$$

514-81-F001
rev.0

CALCULATION NO.	PREPARED BY	CHECKED BY	PAGE
85-87-TGL7	T. Lestina	F. Stevens	5

References

1. MPR Calculation 85-87-TGL5, "Hydraulic Resistance of NMP1 Core Spray Pump and Topping Pump Suction and Riser Piping" Rev. 0, 11/21/88.

2. Crane Technical Paper No. 410, "Flow of Fluids Through Valves, Fittings, and Pipe", 1982.

3. Niagara Mohawk Drawing No. C-26845-C, Sh. 3, "Reactor Core Spray System 81 & 81.1 Piping Isometric", Rev. 7 3/7/85.

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Reference 2 p. 1 of 9

FLOW OF FLUIDS

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Nomenclature

Unless otherwise stated, all symbols used in this book are defined as follows:

A = cross sectional area of pipe or orifice, in square feet
a = cross sectional area of pipe or orifice, or flow area in valve, in square inches
B = rate of flow in barrels (42 gallons) per hour
C = flow coefficient for orifices and nozzles = discharge coefficient corrected for velocity of approach = $C_d / \sqrt{1-\beta^4}$
C_d = discharge coefficient for orifices and nozzles
C_v = flow coefficient for valves; expresses flow rate in gallons per minute of 60 F water with 1.0 psi pressure drop across valve
D = internal diameter of pipe, in feet
d = internal diameter of pipe, in inches
e = base of natural logarithm = 2.718
f = friction factor in formula $h_L = fLv^2/D2g$
f_T = friction factor in zone of complete turbulence
g = acceleration of gravity = 32.2 feet per second per second
H = total head, in feet of fluid
h = static pressure head existing at a point, in feet of fluid
h_g = total heat of steam, in Btu per pound
h_L = loss of static pressure head due to fluid flow, in feet of fluid
h_w = static pressure head, in inches of water
K = resistance coefficient or velocity head loss in the formula, $h_L = Kv^2/2g$
k = ratio of specific heat at constant pressure to specific heat at constant volume = c_p/c_v
L = length of pipe, in feet
L/D = equivalent length of a resistance to flow, in pipe diameters
L_m = length of pipe, in miles
M = molecular weight
MR = universal gas constant = 1545
n = exponent in equation for polytropic change $(p'V_a^n = \text{constant})$
P = pressure, in pounds per square inch gauge
P' = pressure, pounds per square inch absolute

(see page 1-5 for diagram showing relationship between gauge and absolute pressure)

p' = pressure, in pounds per square foot absolute
Q = rate of flow, in gallons per minute
q = rate of flow, in cubic feet per second at flowing conditions
q' = rate of flow, in cubic feet per second at standard conditions (14.7 psia and 60F)
q'_d = rate of flow, in millions of standard cubic feet per day, MMscfd
q'_h = rate of flow, in cubic feet per hour at standard conditions (14.7 psia and 60F), scfh
q_m = rate of flow, in cubic feet per minute at flowing conditions
q'_m = rate of flow, in cubic feet per minute at std. conditions (14.7 psia and 60F), scfm
R = individual gas constant = MR/M = $1545/M$
R_e = Reynolds number
R_H = hydraulic radius, in feet
r_c = critical pressure ratio for compressible flow
S = specific gravity of liquids at specified temperature relative to water at standard temperature (60 F)
S_g = specific gravity of a gas relative to air = the ratio of the molecular weight of the gas to that of air
T = absolute temperature in degrees Rankine $(460 + t)$
t = temperature, in degrees Fahrenheit
$\bar{V}$ = specific volume of fluid, in cubic feet per pound
V = mean velocity of flow, in feet per minute
V_a = volume, in cubic feet
v = mean velocity of flow, in feet per second
v_s = sonic (or critical) velocity of flow of a gas, in feet per second
W = rate of flow, in pounds per hour
w = rate of flow, in pounds per second
w_a = weight, in pounds
x = percent quality of steam = 100 minus per cent of moisture
Y = net expansion factor for compressible flow through orifices, nozzles, or pipe
Z = potential head or elevation above reference level, in feet

Greek Letters

Beta

β = ratio of small to large diameter in orifices and nozzles, and contractions or enlargements in pipes

Delta

Δ = differential between two points

Epsilon

ϵ = absolute roughness or effective height of pipe wall irregularities, in feet

Mu

μ = absolute (dynamic) viscosity, in centipoise
μ_e = absolute viscosity, in pound mass per foot second or poundal seconds per sq foot
μ'_e = absolute viscosity, in slugs per foot second or pound force seconds per square foot

Nu

ν = kinematic viscosity, in centistokes
ν' = kinematic viscosity, square feet per second

Rho

ρ = weight density of fluid, pounds per cubic ft
ρ' = density of fluid, grams per cubic centimeter

Theta

θ = angle of convergence or divergence in enlargements or contractions in pipes

Subscripts for Diameter

(1)...defines smaller diameter
(2)...defines larger diameter

Subscripts for Fluid Property

(1)...defines inlet (upstream) condition
(2)...defines outlet (downstream) condition

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General Energy Equation
Bernoulli's Theorem

The Bernoulli theorem is a means of expressing the application of the law of conservation of energy to the flow of fluids in a conduit. The total energy at any particular point, above some arbitrary horizontal datum plane, is equal to the sum of the elevation head, the pressure head, and the velocity head, as follows:

$$Z + \frac{144P}{\rho} + \frac{v^2}{2g} = H$$

If friction losses are neglected and no energy is added to, or taken from, a piping system (i.e., pumps or turbines), the total head, H, in the above equation will be a constant for any point in the fluid. However, in actual practice, losses or energy increases or decreases are encountered and must be included in the Bernoulli equation. Thus, an energy balance may be written for two points in a fluid, as shown in the example in Figure 1-4.

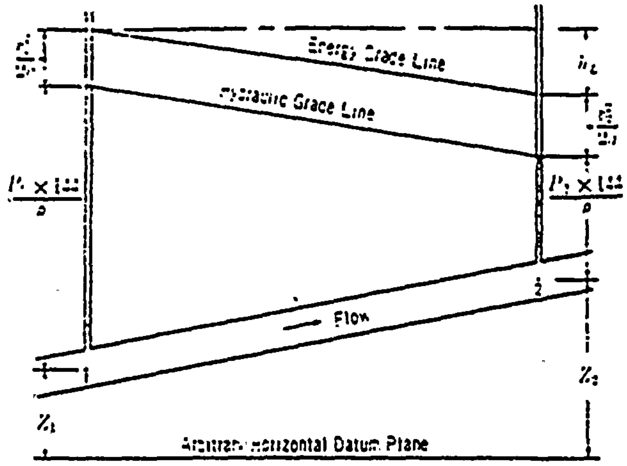

Figure 1-4
Energy Balance for Two Points in a Fluid

By permission, from *Fluid Mechanics*[19] by R. A. Dodge and M. J. Thompson. Copyright 1937, McGraw-Hill Book Company, Inc.

Note the pipe friction loss from point 1 to point 2 is h_L foot pounds per pound of flowing fluid; this is sometimes referred to as the head loss in feet of fluid. The equation may be written as follows:

Equation 1-3

$$Z_1 + \frac{144P_1}{\rho_1} + \frac{v_1^2}{2g} = Z_2 + \frac{144P_2}{\rho_2} + \frac{v_2^2}{2g} + h_L$$

All practical formulas for the flow of fluids are derived from Bernoulli's theorem, with modifications to account for losses due to friction.

Measurement of Pressure

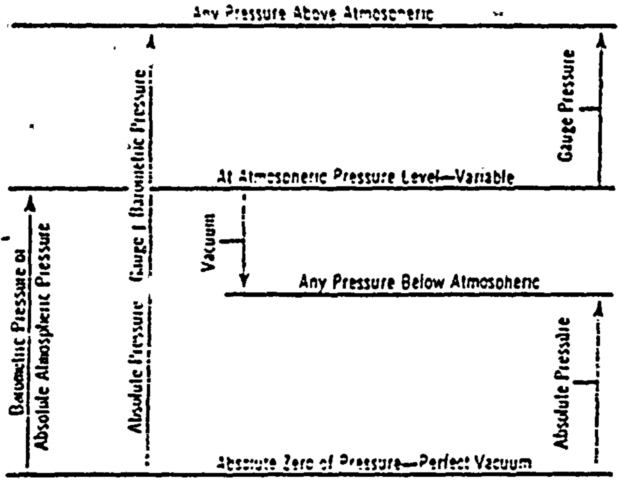

Figure 1-5
Relationship Between Gauge and Absolute Pressures

Figure 1-5 graphically illustrates the relationship between gauge and absolute pressures. Perfect vacuum cannot exist on the surface of the earth, but it nevertheless makes a convenient datum for the measurement of pressure.

Barometric pressure is the level of the atmospheric pressure above perfect vacuum.

"*Standard*" *atmospheric pressure* is 14.696 pounds per square inch, or 760 millimeters of mercury.

Gauge pressure is measured above atmospheric pressure, while absolute pressure always refers to perfect vacuum as a base.

Vacuum, usually expressed in inches of mercury, is the depression of pressure below the atmospheric level. Reference to vacuum conditions is often made by expressing the absolute pressure in inches of mercury; also millimeters of mercury and microns of mercury.

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*All superior figures used as reference marks refer to the Bibliography; see second page of book.

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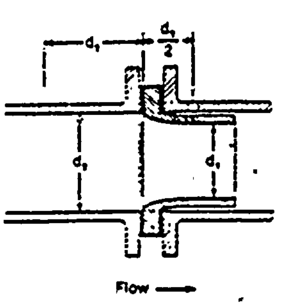
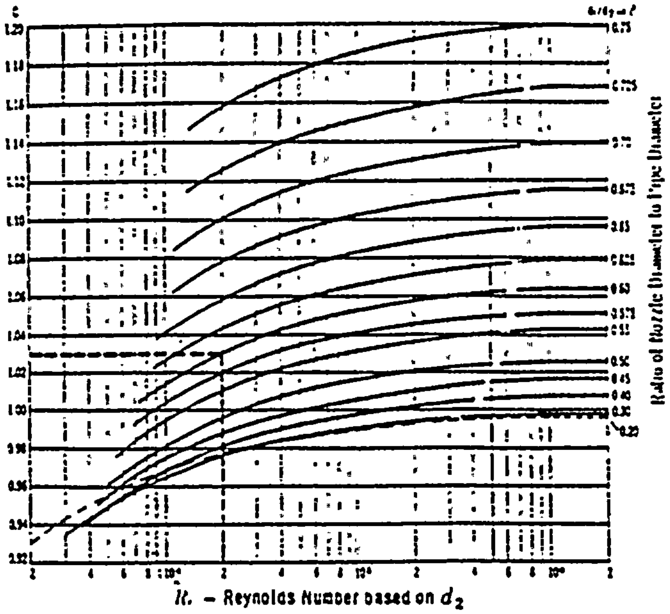
Flow Coefficient C for Nozzles[9]

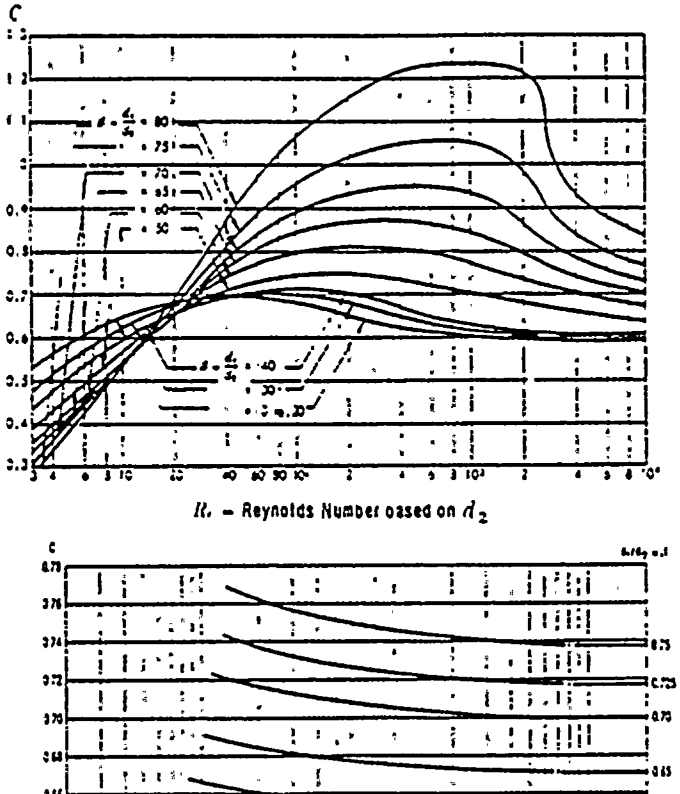


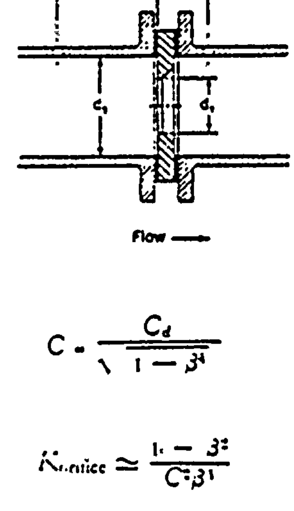


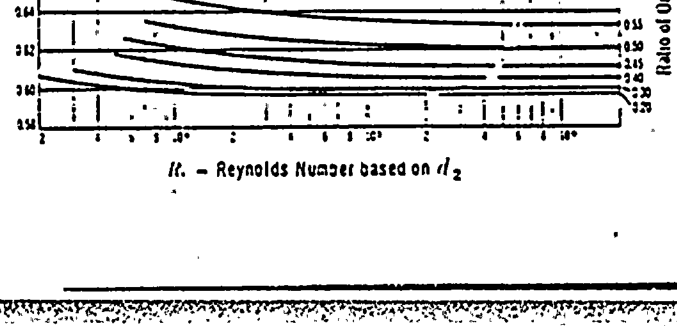
$$C = \frac{C_d}{\sqrt{1-\beta^4}}$$

Example: The flow coefficient C for a diameter ratio β of 0.60 at a Reynolds number of 20,000 (2 × 10⁴) equals 1.03.

Flow Coefficient C for Square-Edge Orifices[9,17]



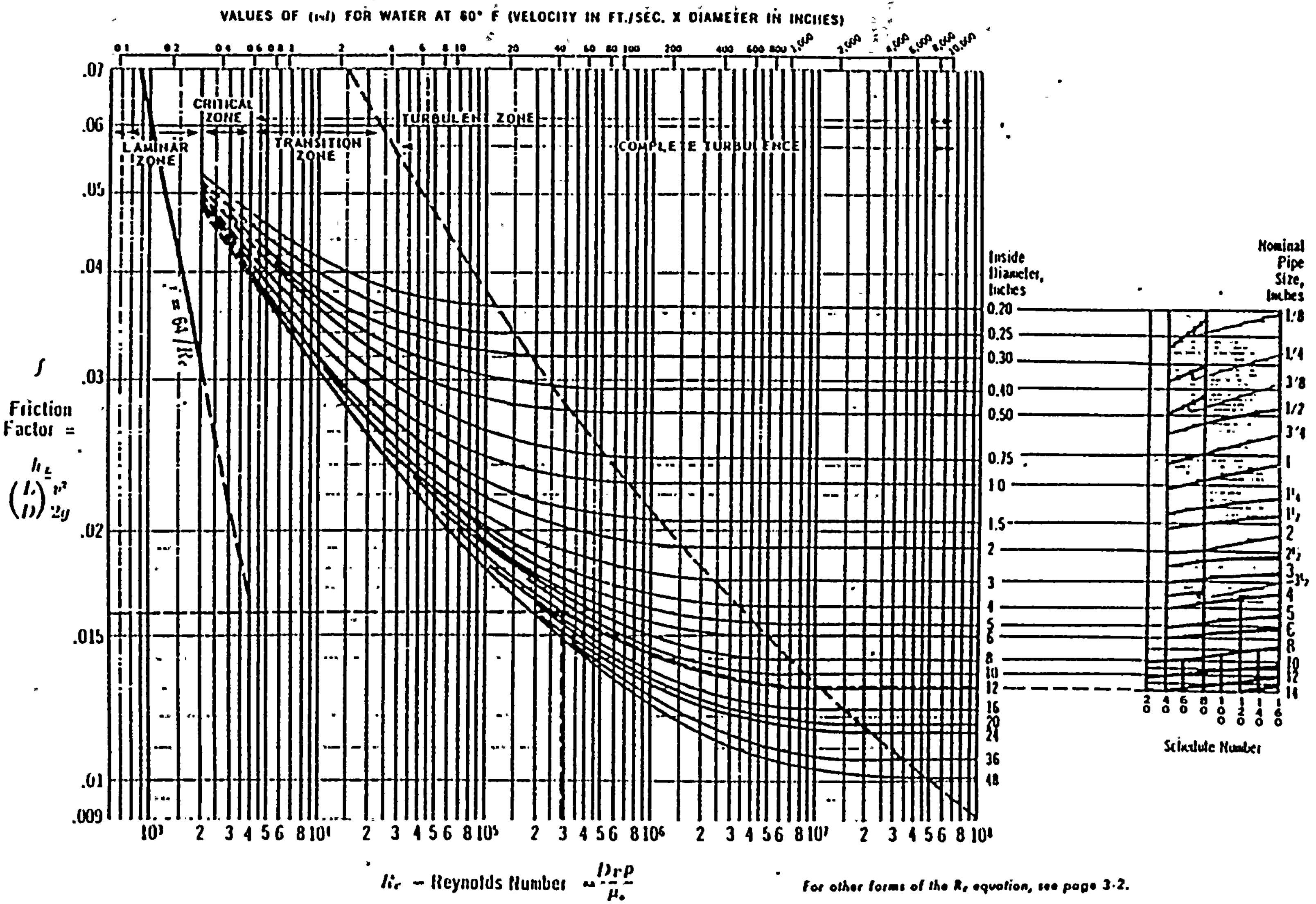




$$C = \frac{C_d}{\sqrt{1-\beta^4}}$$

$$K_{\text{orifice}} \simeq \frac{1-\beta^2}{C^2\beta^4}$$

Friction Factors for Clean Commercial Steel Pipe[18]



For other forms of the Re equation, see page 3-2.

Problem: Determine the friction factor for 12-inch Schedule 40 pipe at a flow having a Reynolds number of 300,000.

Solution:
The friction factor (f) equals 0.016.

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"K" FACTOR TABLE—SHEET 1 of 4

Representative Resistance Coefficients (K) for Valves and Fittings

("K" is based on use of schedule pipe as listed on page 2-10)

PIPE FRICTION DATA FOR CLEAN COMMERCIAL STEEL PIPE WITH FLOW IN ZONE OF COMPLETE TURBULENCE

Nominal Size	½"	¾"	1"	1¼"	1½"	2"	2½, 3"	4"	5"	6"	8-10"	12-16"	18-24"
Friction Factor (f_T)	.027	.025	.023	.022	.021	.019	.018	.017	.016	.015	.014	.013	.012

FORMULAS FOR CALCULATING "K" FACTORS* FOR VALVES AND FITTINGS WITH REDUCED PORT

(Ref: Pages 2-11 and 3-4)

- **Formula 1**

$$K_2 = \frac{0.8\left(\sin\frac{\theta}{2}\right)(1-\beta^2)}{\beta^4} = \frac{K_1}{\beta^4}$$

- **Formula 2**

$$K_2 = \frac{0.5\,(1-\beta^2)\sqrt{\sin\frac{\theta}{2}}}{\beta^4} = \frac{K_1}{\beta^4}$$

- **Formula 3**

$$K_2 = \frac{2.6\left(\sin\frac{\theta}{2}\right)(1-\beta^2)^2}{\beta^4} = \frac{K_1}{\beta^4}$$

- **Formula 4**

$$K_2 = \frac{(1-\beta^2)^2}{\beta^4} = \frac{K_1}{\beta^4}$$

- **Formula 5**

$$K_2 = \frac{K_1}{\beta^4} + \text{Formula 1} + \text{Formula 3}$$

$$K_2 = \frac{K_1 + \sin\frac{\theta}{2}\left[0.8\,(1-\beta^2) + 2.6\,(1-\beta^2)^2\right]}{\beta^4}$$

- **Formula 6**

$$K_2 = \frac{K_1}{\beta^4} + \text{Formula 2} + \text{Formula 4}$$

$$K_2 = \frac{K_1 + 0.5\sqrt{\sin\frac{\theta}{2}}\,(1-\beta^2) + (1-\beta^2)^2}{\beta^4}$$

- **Formula 7**

$$K_2 = \frac{K_1}{\beta^4} + \beta\,(\text{Formula 2} + \text{Formula 4}) \text{ when } \theta = 180°$$

$$K_2 = \frac{K_1 + \beta\left[0.5\,(1-\beta^2) + (1-\beta^2)^2\right]}{\beta^4}$$

$$\beta = \frac{d_1}{d_2}$$

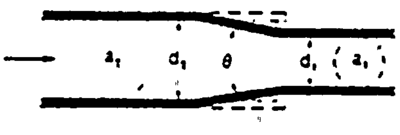
$$\beta^2 = \left(\frac{d_1}{d_2}\right)^2 = \frac{a_1}{a_2}$$

Subscript 1 defines dimensions and coefficients with reference to the smaller diameter.

Subscript 2 refers to the larger diameter.

*Use "K" furnished by valve or fitting supplier when available.

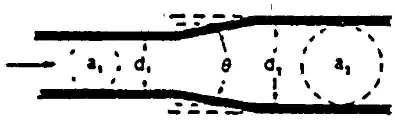
SUDDEN AND GRADUAL CONTRACTION



If: $\theta \leq 45°$ .... K_2 = Formula 1

$45° < \theta \leq 180°$ ... K_2 = Formula 2

SUDDEN AND GRADUAL ENLARGEMENT



If: $\theta \leq 45°$ .... K_2 = Formula 3

$45° < \theta \leq 180°$ ... K_2 = Formula 4

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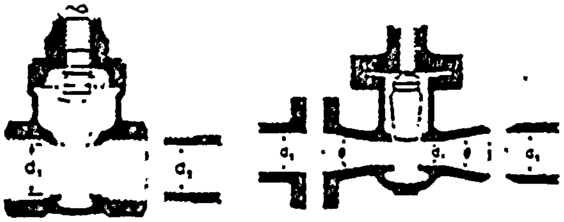
"K" FACTOR TABLE—SHEET 2 of 4

Representative Resistance Coefficients (K) for Valves and Fittings

(for formulas and friction data, see page A-26)

("K" is based on use of schedule pipe as listed on page 2-10)

GATE VALVES
Wedge Disc, Double Disc, or Plug Type



If: $\beta = 1,\ \theta = 0$ .... $K_1 = 8\,f_T$

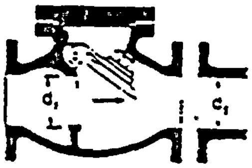
$\beta < 1$ and $\theta \leq 45°$ .... K_2 = Formula 5

$\beta < 1$ and $45° < \theta \leq 180°$ ... K_2 = Formula 6

SWING CHECK VALVES

$K = 100\,f_T$

Minimum pipe velocity (fps) for full disc lift $= 35\sqrt{\bar{V}}$

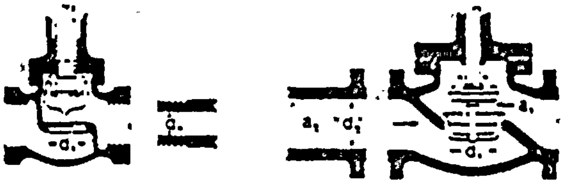


$K = 50\,f_T$

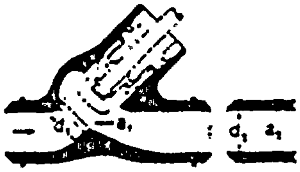
Minimum pipe velocity (fps) for full disc lift $= 60\sqrt{\bar{V}}$ except

U/L listed $= 100\sqrt{\bar{V}}$

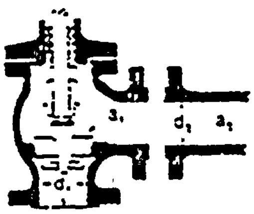
GLOBE AND ANGLE VALVES



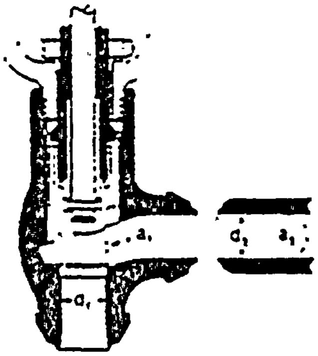
If: $\beta = 1$. $K_1 = 340\,f_T$



If: $\beta = 1 \ldots K_1 = 55\,f_T$



If: $\beta = 1$. $K_1 = 150\,f_T$

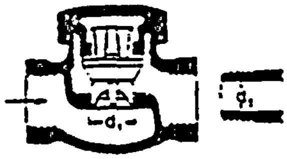


If: $\beta = 1$. $K_1 = 55\,f_T$

All globe and angle valves, whether reduced seat or throttled,

If: $\beta < 1 \ldots K_2$ = Formula 7

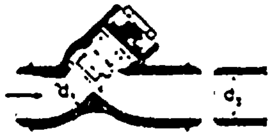
LIFT CHECK VALVES



If: $\beta = 1 \ldots K_1 = 600\,f_T$

$\beta < 1 \ldots K_2$ = Formula 7

Minimum pipe velocity (fps) for full disc lift $= 40\,\beta^2\sqrt{\bar{V}}$

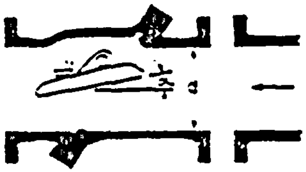


If: $\beta = 1 \ldots K_1 = 55\,f_T$

$\beta < 1 \ldots K_2$ = Formula 7

Minimum pipe velocity (fps) for full disc lift $= 140\,\beta^2\sqrt{\bar{V}}$

TILTING DISC CHECK VALVES



	$\alpha = 5°$	$\alpha = 15°$
Sizes 2 to 8" .. K =	$40\,f_T$	$120\,f_T$
Sizes 10 to 14" .. K =	$30\,f_T$	$90\,f_T$
Sizes 16 to 48" .. K =	$20\,f_T$	$60\,f_T$
Minimum pipe velocity (fps) for full disc lift =	$80\sqrt{\bar{V}}$	$30\sqrt{\bar{V}}$

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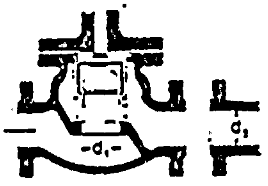
"K" FACTOR TABLE—SHEET 3 of 4

Representative Resistance Coefficients (K) for Valves and Fittings

(for formulas and friction data, see page A-26)

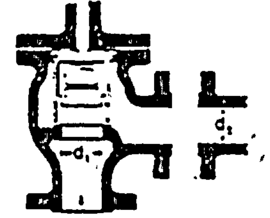
("K" is based on use of scheduled pipe as listed on page 2-10)

STOP-CHECK VALVES
(Globe and Angle Types)



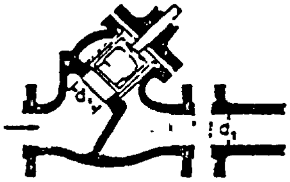
If:
$\beta = 1 \ldots K_1 = 400\,f_T$
$\beta < 1 \ldots K_2 =$ Formula 7

Minimum pipe velocity for full disc lift
$= 55\,\beta^2\sqrt{\bar{V}}$

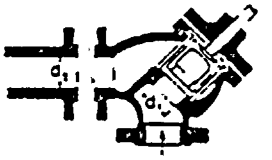


If:
$\beta = 1 \ldots K_1 = 200\,f_T$
$\beta < 1 \ldots K_2 =$ Formula 7

Minimum pipe velocity for full disc lift
$= 75\,\beta^2\sqrt{\bar{V}}$



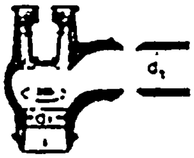
If:
$\beta = 1 \ldots K_1 = 300\,f_T$
$\beta < 1 \ldots K_2 =$ Formula 7



If:
$\beta = 1 \ldots K_1 = 350\,f_T$
$\beta < 1 \ldots K_2 =$ Formula 7

Minimum pipe velocity (fps) for full disc lift
$= 60\,\beta^2\sqrt{\bar{V}}$

If:
$\beta = 1 \ldots K_1 = 55\,f_T$
$\beta < 1 \ldots K_2 =$ Formula 7



If:
$\beta = 1 \ldots K_1 = 55\,f_T$
$\beta < 1 \ldots K_2 =$ Formula 7

Minimum pipe velocity (fps) for full disc lift
$= 140\,\beta^2\sqrt{\bar{V}}$

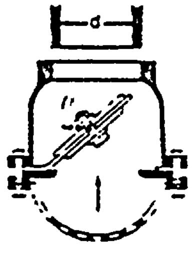
FOOT VALVES WITH STRAINER

Poppet Disc

$K = 420\,f_T$

Minimum pipe velocity (fps) for full disc lift
$= 15\sqrt{\bar{V}}$

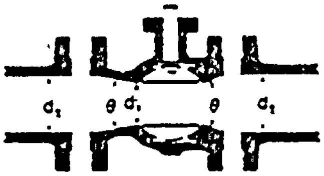
Hinged Disc



$K = 75\,f_T$

Minimum pipe velocity (fps) for full disc lift
$= 35\sqrt{\bar{V}}$

BALL VALVES



If: $\beta = 1,\ \theta = 0 \ldots\ldots\ldots\ldots\ldots K_1 = 3\,f_T$
$\beta < 1$ and $\theta \leq 45° \ldots\ldots\ldots K_2 =$ Formula 5
$\beta < 1$ and $45° < \theta \leq 180° \ldots K_2 =$ Formula 6

BUTTERFLY VALVES

Sizes 2 to 8"...$K = 45\,f_T$
Sizes 10 to 14"...$K = 35\,f_T$
Sizes 16 to 24"...$K = 25\,f_T$

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"K" FACTOR TABLE—SHEET 4 of 4

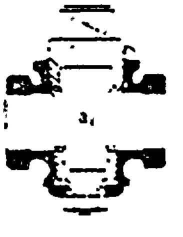
Representative Resistance Coefficients (K) for Valves and Fittings

(for formulas and friction data, see page A-26)

("K" is based on use of schedule pipe as listed on page 2-10)

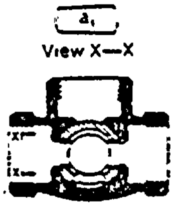
PLUG VALVES AND COCKS

Straight-Way

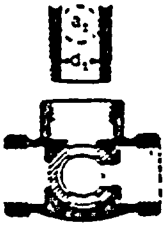


If: $\beta = 1$,
$K_1 = 18 f_T$

3-Way



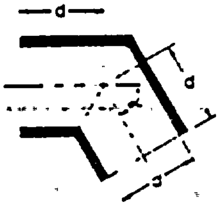
If: $\beta = 1$,
$K_1 = 30 f_T$



If: $\beta = 1$,
$K_1 = 90 f_T$

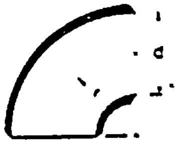
If: $\beta < 1 \ldots K_2$ = Formula 6

MITRE BENDS



α	K
0°	$2 f_T$
15°	$4 f_T$
30°	$8 f_T$
45°	$15 f_T$
60°	$25 f_T$
75°	$40 f_T$
90°	$60 f_T$

90° PIPE BENDS AND FLANGED OR BUTT-WELDING 90° ELBOWS



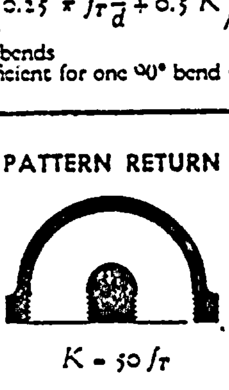
r/d	K	r/d	K
1	$20 f_T$	8	$24 f_T$
1.5	$14 f_T$	10	$30 f_T$
2	$12 f_T$	12	$34 f_T$
3	$12 f_T$	14	$38 f_T$
4	$14 f_T$	16	$42 f_T$
6	$17 f_T$	20	$50 f_T$

The resistance coefficient, K_B, for pipe bends other than 90° may be determined as follows:

$$K_B = (n - 1)\left(0.25\ \pi\ f_T \frac{r}{d} + 0.5\ K\right) + K$$

n = number of 90° bends
K = resistance coefficient for one 90° bend (per table)

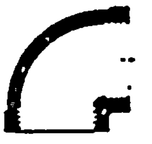
CLOSE PATTERN RETURN BENDS



$K = 50 f_T$

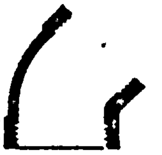
STANDARD ELBOWS

90°



$K = 30 f_T$

45°



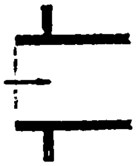
$K = 16 f_T$

STANDARD TEES

Flow thru run. . . . . .$K = 20 f_T$
Flow thru branch. . . .$K = 60 f_T$

PIPE ENTRANCE

Inward Projecting

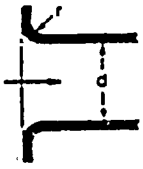


$K = 0.78$

r/d	K
0.00*	0.5
0.02	0.28
0.04	0.24
0.06	0.15
0.10	0.09
0.15 & up	0.04

*Sharp-edged

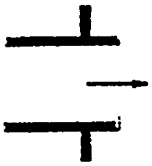
Flush



For K, see table

PIPE EXIT

Projecting

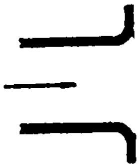


$K = 1.0$

Sharp-Edged

$K = 1.0$

Rounded



$K = 1.0$

NIAGARA MOHAWK

CALCULATION COVER SHEET

NUCLEAR ENGINEERING & LICENSING

DISCIPLINE: Mechanical

PAGE 1A

PROJECT: NINE MILE POINT NUC. STA.-UNIT 1

CALC. NO. S14-81-F002

SUBJECT: Core Spray System Recirculation Piping Hydraulic Resistance

BUILDING: Reactor

FLOOR ELEV.: Various

INDEX NO.: 3-N2.1-S14

ORIGINATOR(S): MPR Associates, Inc.

TOTAL SHT'S. 6

CHECKER(S): MPR Associates, Inc.

LAST SHT. NO: 5

RECORD OF ISSUES

REV.	DESCRIPTION	M.O.#	BY	DATE	CHKD.	DATE	APPD.	DATE	DATE FILMED:
0	C.S. Recirculation Piping Hydraulic Resistance	2988	T. Lestina	11/29/88	K. Lee	11/30/88	LAK	12/5/88	

COMPUTER OUTPUT YES ☐ NO ☒

SAFETY RELATED YES ☒ NO ☐

DRAWINGS REFERENCED:

DWG. NO.	INDEX	SHT.	REV.
See page 5			

REFERENCES:

See page 5

KEYWORDS: NMP1, SSFI, Core Spray, Flow

CROSS REF.: 85-87-TGL3

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MPR ASSOCIATES, INC.
1050 Connecticut Ave., NW-Washington, DC 20036

CALCULATION TITLE PAGE

CLIENT Niagara Mohawk	PAGE 1 OF 5
PROJECT Core Spray SSFI	TASK NO. 85-87
CALCULATION TITLE Hydraulic Resistance of NMP1 Core Spray Recirculation Piping	CALCULATION NO. (OPTIONAL) 85-87-T6L3

PREPARER(S)/DATE	CHECKER(S)/DATE	REVIEWER(S)/DATE	REV. NO.
T. Lestina 11/29/88	Kasey M. Leo 11/30/88	J Johnson 11/30/88	0

S14-81-F002 rev 0

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CALCULATION NO.	PREPARED BY	CHECKED BY	PAGE
85-87-T6L3	T. Lestina		2

Purpose: The purpose of this calculation is to determine the resistance of the core spray recirculation piping.

Summary: The head loss due to the hydraulic resistance of the core spray recirculation piping is:

$$h_L = K_3 \frac{V^2}{2g} = R_3 Q^2$$

where
R_3 = hydraulic resistance (ft/gpm^2)
Q = volumetric flow rate (gpm)
V = flow velocity, (ft/s)
g = acceleration due to gravity (ft/s^2)
h_L = head loss (ft)
K_3 = resistance coefficient or K-factor of core spray recirculation piping

$$R_3 = 6.32571 (10^{-3}) \text{ ft. of } H_2O/\text{gpm}^2$$

Calculation: From Reference (2), the relief valve is a Crosby style JB-35 size 2H3 with a pressure setting of 320 psig. From reference (3), the rated full flow of the valve is 382 gpm with 25% overpressure (400 psig). (Reference (2) specifies approximately 380 gpm at 400 psig)

From reference (1),

$$\Delta P = \rho K_{rv} \frac{V^2}{2g}$$

$\rho = 62.4 \frac{\text{lbf}}{\text{ft}^3}$ at 60°F from Reference (4)

Assuming backpressure = 0 psig

(Reference (2) assumes that the backpressure is 35 psig, however assuming a backpressure of 0 psig is consistent with these design bases calculations and is conservative.)

$$K_{rv} = \frac{\left(144 \ \text{in}^2/\text{ft}^2\right) 2 \cdot \left(32.2 \ \text{ft/s}^2\right)\left(400 \ \text{psi}\right)}{\left[\left(382 \ \text{gpm}\right)\left(\frac{1 \ \text{min}}{60 \ \text{s}}\right)\left(\frac{1}{.05130 \ \text{ft}^2}\right)\left(\frac{1 \ \text{ft}^3}{7.4805 \ \text{g}}\right)\right]^2 62.4 \frac{\text{lbf}}{\text{ft}^3}}$$

$$K_{rv} = 215.97 \text{ for } 3'' \text{ 40S pipe}$$

Calculating R_{rv}

It is assumed that the relief valve is the principle hydraulic loss. More specifically, neglecting other losses in the recirculation piping defines a minimum hydraulic loss and thus a maximum bypass flow. (This is conservative)

$$h_L \left(\text{ft. of } H_2O\right) = K_{rv}\frac{v^2}{2g} = R_3 Q^2$$

$$h_L \left(\text{ft. of } H_2O\right) = \frac{K_{rv}\left[\left(\frac{1 \text{ min}}{60 \text{ sec}}\right)\left(\frac{1 \text{ ft}^3}{7.4805 \text{ g}}\right)\left(\frac{1}{.05130 \text{ ft}^2}\right)\left(Q_{gpm}\right)\right]^2}{2 \cdot 32.2 \text{ ft/s}^2}$$

$$= 2.92897\left(10^{-5}\right) K_{rv} Q^2$$

$$R_3 = 6.32571\left(10^{-3}\right) \text{ ft. of } H_2O/\text{gpm}^2$$

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CALCULATION NO.	PREPARED BY	CHECKED BY	PAGE
85-87-TGL3	T. Lestina	M. Lee	5

References

1. Crane Technical Paper No. 410, "Flow of Fluids Through Valves, Fittings, and Pipe", 1982.

2. Niagara Mohawk Purchase Specification N1-347, Core Spray System Relief Valves, 1/23/67.

3. Crosby Valve Catalog 301, "Safety Relief Valves", 1968.

4. Daugherty, R.L. and Franzini, J.B. Fluid Mechanics with Engineering Applications, McGraw Hill Book Company, New York 1977.

514-81-F002TEVO

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FLOW OF FLUIDS

THROUGH

VALVES, FITTINGS, AND PIPE

By the Engineering Division

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Nomenclature

Unless otherwise stated, all symbols used in this book are defined as follows:

A = cross sectional area of pipe or orifice, in square feet
a = cross sectional area of pipe or orifice, or flow area in valve, in square inches
B = rate of flow in barrels (42 gallons) per hour
C = flow coefficient for orifices and nozzles = discharge coefficient corrected for velocity of approach = $C_d / \sqrt{1-\beta^4}$
C_d = discharge coefficient for orifices and nozzles
C_v = flow coefficient for valves; expresses flow rate in gallons per minute of 60 F water with 1.0 psi pressure drop across valve
D = internal diameter of pipe, in feet
d = internal diameter of pipe, in inches
e = base of natural logarithm = 2.718
f = friction factor in formula $h_L = fLv^2/D2g$
f_T = friction factor in zone of complete turbulence
g = acceleration of gravity = 32.2 feet per second per second
H = total head, in feet of fluid
h = static pressure head existing at a point, in feet of fluid
h_g = total heat of steam, in Btu per pound
h_L = loss of static pressure head due to fluid flow, in feet of fluid
h_w = static pressure head, in inches of water
K = resistance coefficient or velocity head loss in the formula, $h_L = Kv^2/2g$
k = ratio of specific heat at constant pressure to specific heat at constant volume = c_p/c_v
L = length of pipe, in feet
L/D = equivalent length of a resistance to flow, in pipe diameters
L_m = length of pipe, in miles
M = molecular weight
MR = universal gas constant = 1545
n = exponent in equation for polytropic change ($P'V_a^n$ = constant)
P = pressure, in pounds per square inch gauge
P' = pressure, pounds per square inch absolute
(see page 1-5 for diagram showing relationship between gauge and absolute pressure)
p' = pressure, in pounds per square foot absolute
Q = rate of flow, in gallons per minute
q = rate of flow, in cubic feet per second at flowing conditions
q' = rate of flow, in cubic feet per second at standard conditions (14.7 psia and 60F)
q'_d = rate of flow, in millions of standard cubic feet per day, MMscfd
q'_h = rate of flow, in cubic feet per hour at standard conditions (14.7 psia and 60F), scfh
q_m = rate of flow, in cubic feet per minute at flowing conditions
q'_m = rate of flow, in cubic feet per minute at std. conditions (14.7 psia and 60F), scfm
R = individual gas constant = MR/M = $1545/M$
R_e = Reynolds number
R_H = hydraulic radius, in feet
r_c = critical pressure ratio for compressible flow
S = specific gravity of liquids at specified temperature relative to water at standard temperature (60 F)
S_g = specific gravity of a gas relative to air = the ratio of the molecular weight of the gas to that of air
T = absolute temperature, in degrees Rankine ($460 + t$)
t = temperature, in degrees Fahrenheit
$\bar{V}$ = specific volume of fluid, in cubic feet per pound
V = mean velocity of flow, in feet per minute
V_a = volume, in cubic feet
v = mean velocity of flow, in feet per second
v_s = sonic (or critical) velocity of flow of a gas, in feet per second
W = rate of flow, in pounds per hour
w = rate of flow, in pounds per second
W_a = weight, in pounds
x = percent quality of steam = 100 minus per cent of moisture
Y = net expansion factor for compressible flow through orifices, nozzles, or pipe
Z = potential head or elevation above reference level, in feet

Greek Letters

Beta
β = ratio of small to large diameter in orifices and nozzles, and contractions or enlargements in pipes

Delta
Δ = differential between two points

Epsilon
ϵ = absolute roughness or effective height of pipe wall irregularities, in feet

Mu
μ = absolute (dynamic) viscosity, in centipoise
μ_e = absolute viscosity, in pound mass per foot second or poundal seconds per sq foot
μ'_e = absolute viscosity, in slugs per foot second or pound force seconds per square foot

Nu
ν = kinematic viscosity, in centistokes
ν' = kinematic viscosity, square feet per second

Rho
ρ = weight density of fluid, pounds per cubic ft
ρ' = density of fluid, grams per cubic centimeter

Theta
θ = angle of convergence or divergence in enlargements or contractions in pipes

Subscripts for Diameter
(1)...defines smaller diameter
(2)...defines larger diameter

Subscripts for Fluid Property
(1)...defines inlet (upstream) condition
(2)...defines outlet (downstream) condition

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General Energy Equation
Bernoulli's Theorem

The Bernoulli theorem is a means of expressing the application of the law of conservation of energy to the flow of fluids in a conduit. The total energy at any particular point, above some arbitrary horizontal datum plane, is equal to the sum of the elevation head, the pressure head, and the velocity head as follows:

$$Z + \frac{144\,P}{\rho} + \frac{v^2}{2g} = H$$

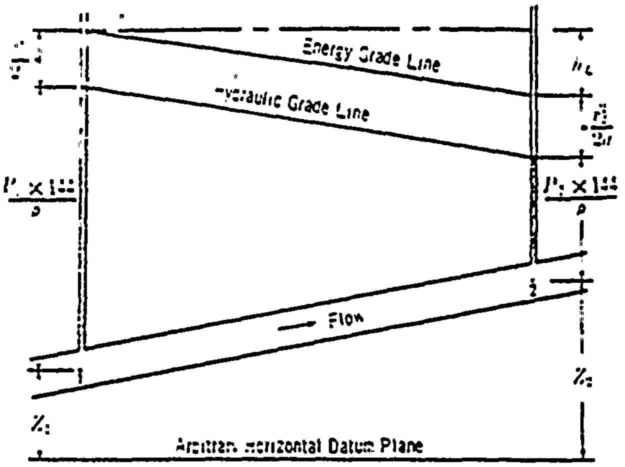

Figure 1-4
Energy Balance for Two Points in a Fluid

By permission, from *Fluid Mechanics*[1] by R. A. Dodge and M. J. Thompson. Copyright 1937, McGraw-Hill Book Company, Inc.

If friction losses are neglected and no energy is added to, or taken from, a piping system (i.e., pumps or turbines), the total head, H, in the above equation will be a constant for any point in the fluid. However, in actual practice, losses or energy increases or decreases are encountered and must be included in the Bernoulli equation. Thus, an energy balance may be written for two points in a fluid, as shown in the example in Figure 1-4.

Note the pipe friction loss from point 1 to point 2 is h_L foot-pounds per pound of flowing fluid; this is sometimes referred to as the head loss in feet of fluid. The equation may be written as follows:

Equation 1-3

$$Z_1 + \frac{144\,P_1}{\rho_1} + \frac{v_1^2}{2g} = Z_2 + \frac{144\,P_2}{\rho_2} + \frac{v_2^2}{2g} + h_L$$

All practical formulas for the flow of fluids are derived from Bernoulli's theorem, with modifications to account for losses due to friction.

Measurement of Pressure

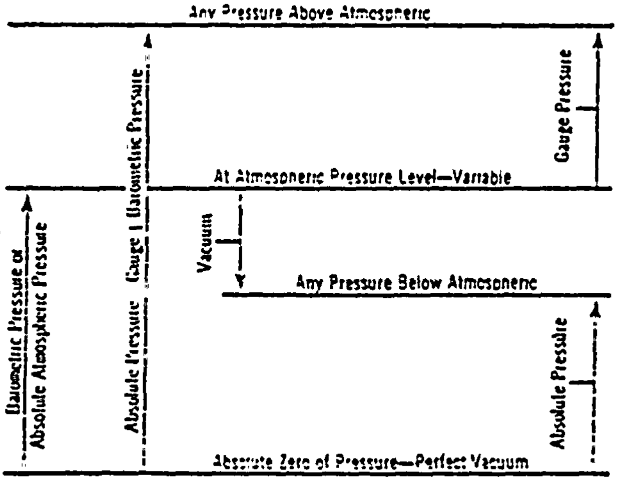

Figure 1-5
Relationship Between
Gauge and Absolute Pressures

Figure 1-5 graphically illustrates the relationship between gauge and absolute pressures. Perfect vacuum cannot exist on the surface of the earth, but it nevertheless makes a convenient datum for the measurement of pressure.

Barometric pressure is the level of the atmospheric pressure above perfect vacuum.

"*Standard*" *atmospheric pressure* is 14.696 pounds per square inch, or 760 millimeters of mercury.

Gauge pressure is measured above atmospheric pressure, while absolute pressure always refers to perfect vacuum as a base.

Vacuum, usually expressed in inches of mercury, is the depression of pressure below the atmospheric level. Reference to vacuum conditions is often made by expressing the absolute pressure in inches of mercury; also millimeters of mercury and microns of mercury.

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*All superior figures used as reference marks refer to the Bibliography; see second page of book.

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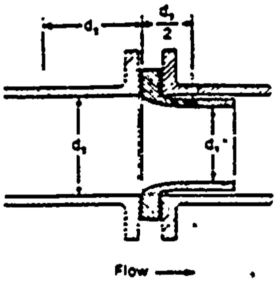
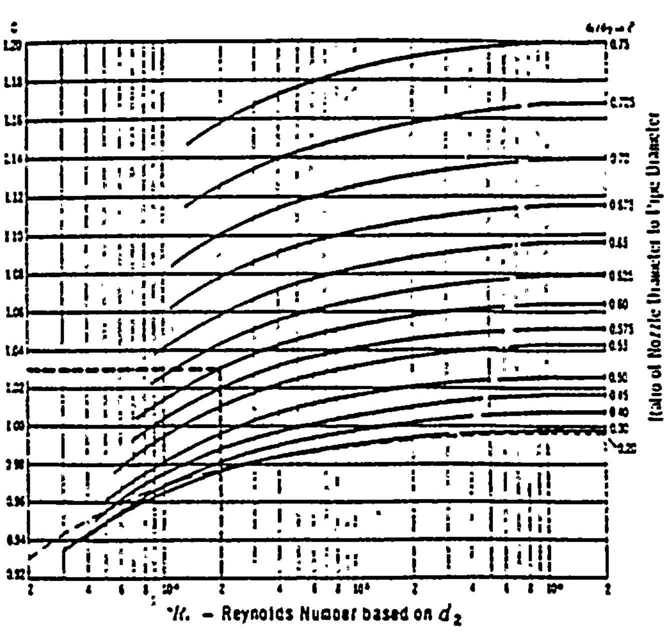
Flow Coefficient C for Nozzles[9]

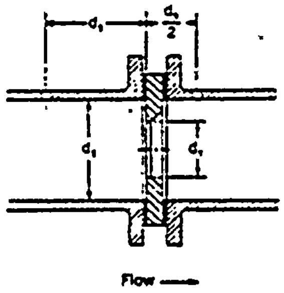


$$C = \frac{C_d}{\sqrt{1 - \beta^4}}$$

Example: The flow coefficient C for a diameter ratio β of 0.60 at a Reynolds number of 20,000 (2 × 10⁴) equals 1.03.

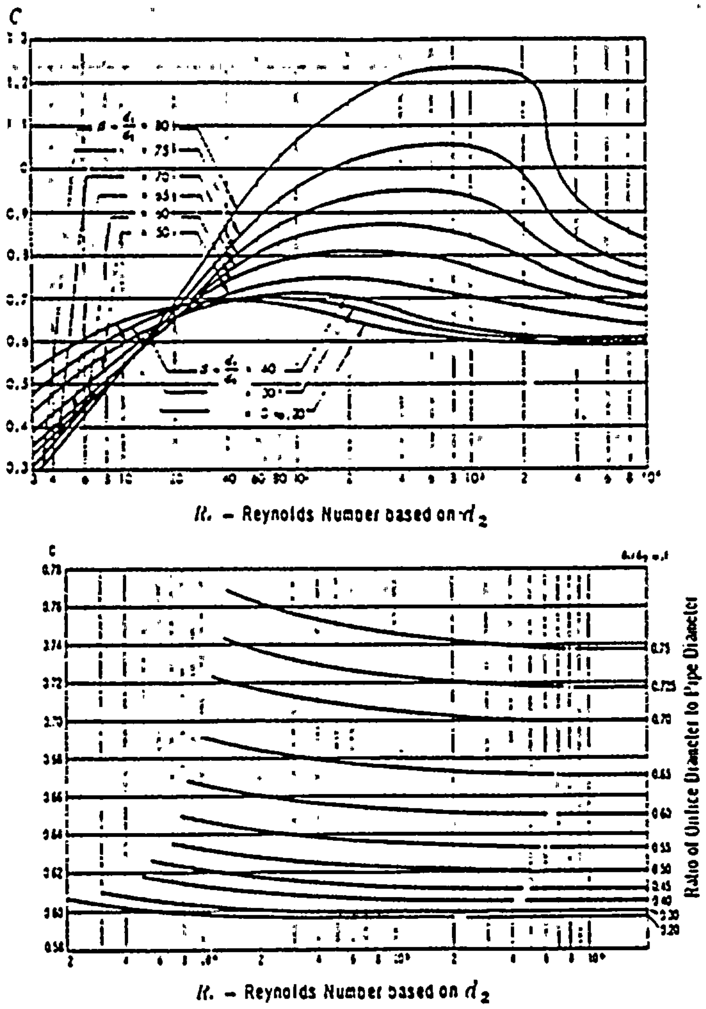


Flow Coefficient C for Square-Edge Orifices[9,17]

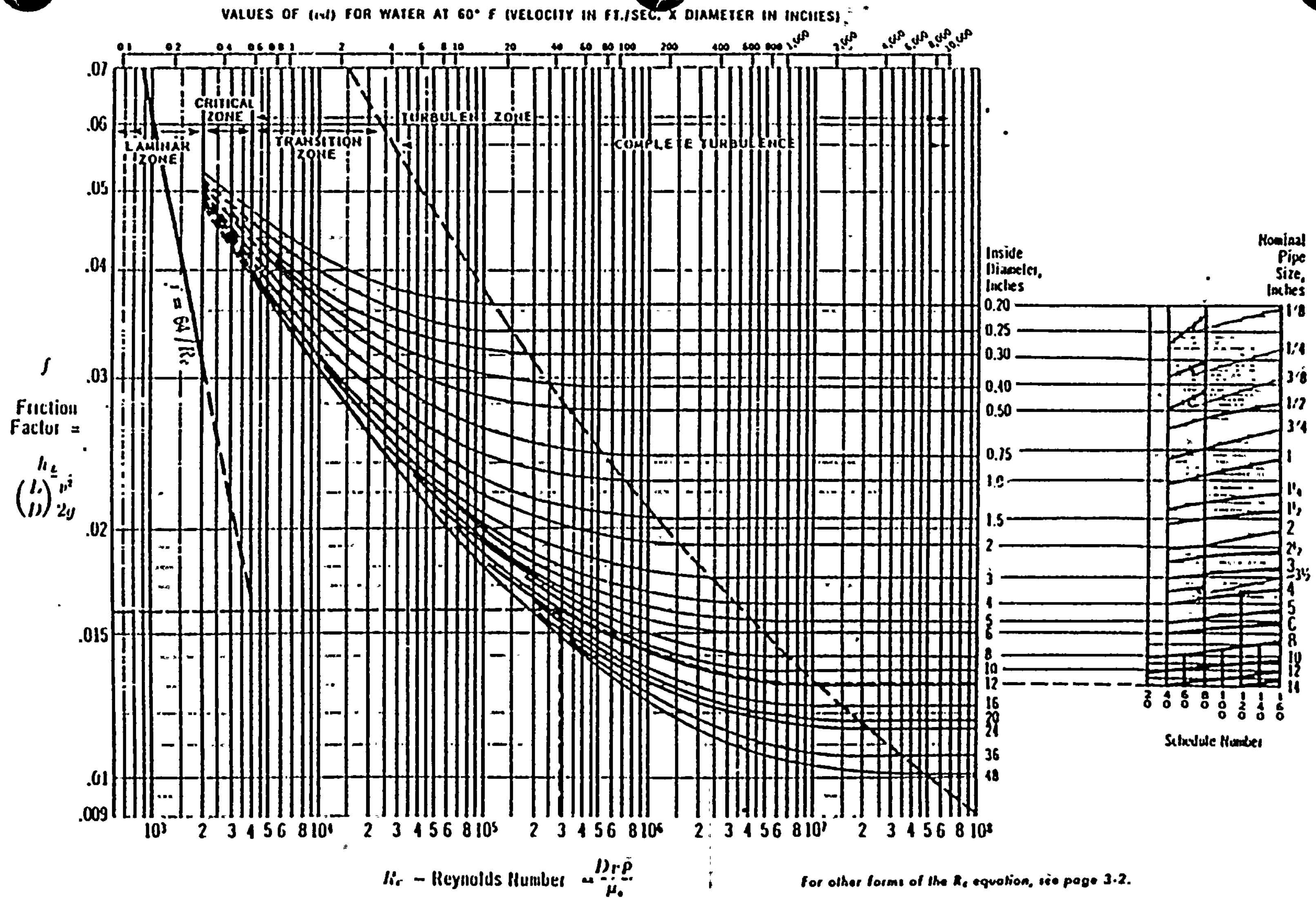


$$C = \frac{C_d}{\sqrt{1 - \beta^4}}$$

$$K_{orifice} \simeq \frac{1 - \beta^2}{C^2 \beta^4}$$



Friction Factors for Clean Commercial Steel Pipe[18]



R_e — Reynolds Number $= \frac{D v \rho}{\mu_e}$

For other forms of the R_e equation, see page 3-2.

Problem: Determine the friction factor for 12-inch Schedule 40 pipe at a flow having a Reynolds number of 300,000.

Solution:
The friction factor (f) equals 0.016.

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"K" FACTOR TABLE—SHEET 1 of 4

Representative Resistance Coefficients (K) for Valves and Fittings

("K" is based on use of schedule pipe as listed on page 2-10)

PIPE FRICTION DATA FOR CLEAN COMMERCIAL STEEL PIPE WITH FLOW IN ZONE OF COMPLETE TURBULENCE

Nominal Size	½"	¾"	1"	1¼"	1½"	2"	2½, 3"	4"	5"	6"	8-10"	12-16"	18-24"
Friction Factor (f_T)	.027	.025	.023	.022	.021	.019	.018	.017	.016	.015	.014	.013	.012

FORMULAS FOR CALCULATING "K" FACTORS* FOR VALVES AND FITTINGS WITH REDUCED PORT

(Ref: Pages 2-11 and 3-4)

- **Formula 1**

$$K_2 = \frac{0.8\left(\sin\frac{\theta}{2}\right)(1-\beta^2)}{\beta^4} = \frac{K_1}{\beta^4}$$

- **Formula 2**

$$K_2 = \frac{0.5\,(1-\beta^2)\sqrt{\sin\frac{\theta}{2}}}{\beta^4} = \frac{K_1}{\beta^4}$$

- **Formula 3**

$$K_2 = \frac{2.6\left(\sin\frac{\theta}{2}\right)(1-\beta^2)^2}{\beta^4} = \frac{K_1}{\beta^4}$$

- **Formula 4**

$$K_2 = \frac{(1-\beta^2)^2}{\beta^4} = \frac{K_1}{\beta^4}$$

- **Formula 5**

$$K_2 = \frac{K_1}{\beta^4} + \text{Formula 1} + \text{Formula 3}$$

$$K_2 = \frac{K_1 + \sin\frac{\theta}{2}\left[0.8\,(1-\beta^2) + 2.6\,(1-\beta^2)^2\right]}{\beta^4}$$

- **Formula 6**

$$K_2 = \frac{K_1}{\beta^4} + \text{Formula 2} + \text{Formula 4}$$

$$K_2 = \frac{K_1 + 0.5\sqrt{\sin\frac{\theta}{2}}\,(1-\beta^2) + (1-\beta^2)^2}{\beta^4}$$

- **Formula 7**

$$K_2 = \frac{K_1}{\beta^4} + \beta\,(\text{Formula 2} + \text{Formula 4}) \text{ when } \theta = 180°$$

$$K_2 = \frac{K_1 + \beta\left[0.5\,(1-\beta^2) + (1-\beta^2)^2\right]}{\beta^4}$$

$$\beta = \frac{d_1}{d_2}$$

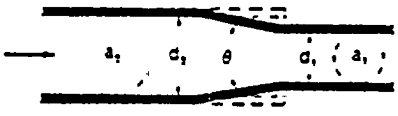
$$\beta^2 = \left(\frac{d_1}{d_2}\right)^2 = \frac{a_1}{a_2}$$

Subscript 1 defines dimensions and coefficients with reference to the smaller diameter.

Subscript 2 refers to the larger diameter.

*Use "K" furnished by valve or fitting supplier when available.

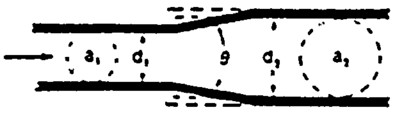
SUDDEN AND GRADUAL CONTRACTION



If: $\theta \leq 45°$ .... K_2 = Formula 1

$45° < \theta \leq 180°$ ... K_2 = Formula 2

SUDDEN AND GRADUAL ENLARGEMENT



If: $\theta \leq 45°$ .... K_2 = Formula 3

$45° < \theta \leq 180°$ ... K_2 = Formula 4

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"K" FACTOR TABLE—SHEET 2 of 4

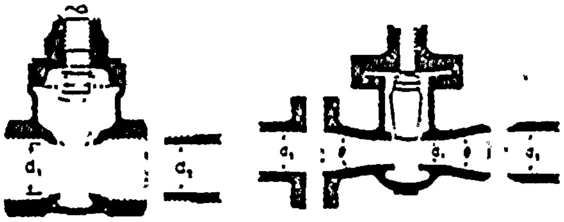
Representative Resistance Coefficients (K) for Valves and Fittings

(for formulas and friction data, see page A-26)

("K" is based on use of schedule pipe as listed on page 2-10)

GATE VALVES

Wedge Disc, Double Disc, or Plug Type

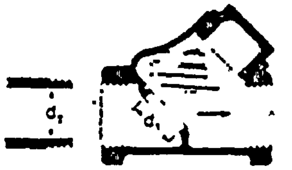


If: $\beta = 1, \theta = 0$ . . . . $K_1 = 8 f_T$

$\beta < 1$ and $\theta \leq 45°$ . . . . K_2 = Formula 5

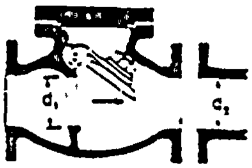
$\beta < 1$ and $45° < \theta \leq 180°$ . . . K_2 = Formula 6

SWING CHECK VALVES



$K = 100 f_T$

Minimum pipe velocity (fps) for full disc lift $= 35 \sqrt{\bar{V}}$

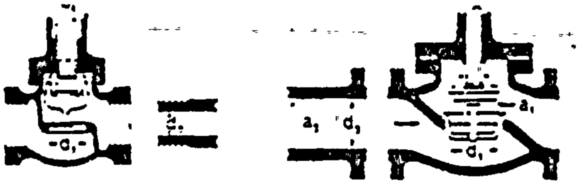


$K = 50 f_T$

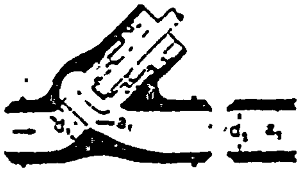
Minimum pipe velocity (fps) for full disc lift $= 60 \sqrt{\bar{V}}$ except

U/L listed $= 100 \sqrt{\bar{V}}$

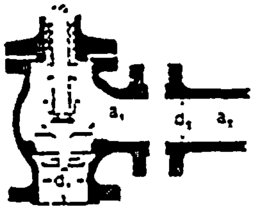
GLOBE AND ANGLE VALVES



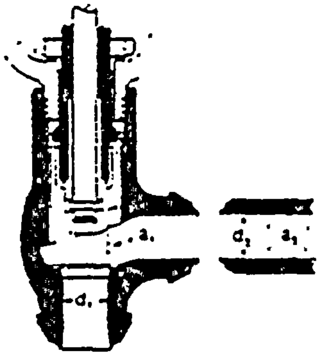
If: $\beta = 1$ . . $K_1 = 340 f_T$



If: $\beta = 1$ . . . $K_1 = 55 f_T$



If: $\beta = 1$ . . $K_1 = 150 f_T$

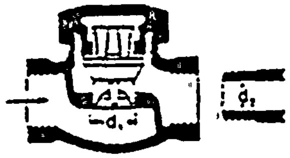


If: $\beta = 1$ . . $K_1 = 55 f_T$

All globe and angle valves, whether reduced seat or throttled,

If: $\beta < 1$ . . K_2 = Formula 7

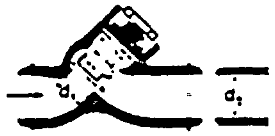
LIFT CHECK VALVES



If: $\beta = 1$ . . . $K_1 = 600 f_T$

$\beta < 1$ . . . K_2 = Formula 7

Minimum pipe velocity (fps) for full disc lift $= 40 \beta^2 \sqrt{\bar{V}}$

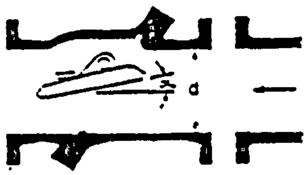


If: $\beta = 1$ . . . $K_1 = 55 f_T$

$\beta < 1$ . . K_2 = Formula 7

Minimum pipe velocity (fps) for full disc lift $= 140 \beta^2 \sqrt{\bar{V}}$

TILTING DISC CHECK VALVES



	$\alpha = 5°$	$\alpha = 15°$
Sizes 2 to 8" . . . K =	$40 f_T$	$120 f_T$
Sizes 10 to 14" . . K =	$30 f_T$	$90 f_T$
Sizes 16 to 48" . K =	$20 f_T$	$60 f_T$
Minimum pipe velocity (fps) for full disc lift =	$80 \sqrt{\bar{V}}$	$30 \sqrt{\bar{V}}$

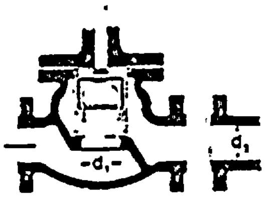
"K" FACTOR TABLE—SHEET 3 of 4

Representative Resistance Coefficients (K) for Valves and Fittings

(for formulas and friction data, see page A-26)

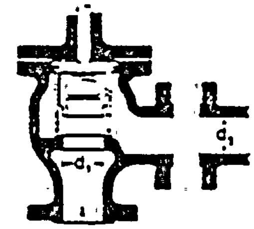
("K" is based on use of scheduled pipe as listed on page 2-10)

STOP-CHECK VALVES (Globe and Angle Types)



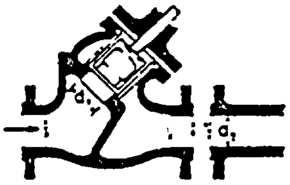
If:
$\beta = 1 \ldots K_1 = 400\, f_T$
$\beta < 1 \ldots K_2 =$ Formula 7

Minimum pipe velocity for full disc lift
$= 55\, \beta^2 \sqrt{\bar{V}}$

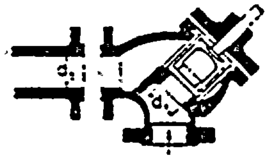


If:
$\beta = 1 \ldots K_1 = 200\, f_T$
$\beta < 1 \ldots K_2 =$ Formula 7

Minimum pipe velocity for full disc lift
$= 75\, \beta^2 \sqrt{\bar{V}}$

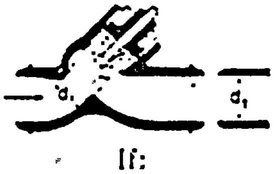


If:
$\beta = 1 \ldots K_1 = 300\, f_T$
$\beta < 1 \ldots K_2 =$ Formula 7

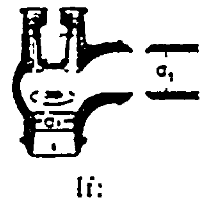


If:
$\beta = 1 \ldots K_1 = 350\, f_T$
$\beta < 1 \ldots K_2 =$ Formula 7

Minimum pipe velocity (fps) for full disc lift
$= 60\, \beta^2 \sqrt{\bar{V}}$



If:
$\beta = 1 \ldots K_1 = 55\, f_T$
$\beta < 1 \ldots K_2 =$ Formula 7



If:
$\beta = 1 \ldots K_1 = 55\, f_T$
$\beta < 1 \ldots K_2 =$ Formula 7

Minimum pipe velocity (fps) for full disc lift
$= 140\, \beta^2 \sqrt{\bar{V}}$

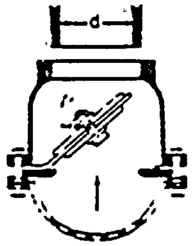
FOOT VALVES WITH STRAINER

Poppet Disc

$K = 420\, f_T$

Minimum pipe velocity (fps) for full disc lift
$= 15 \sqrt{\bar{V}}$

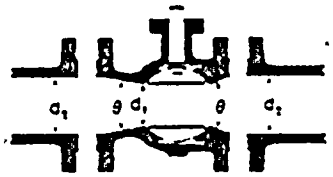
Hinged Disc



$K = 75\, f_T$

Minimum pipe velocity (fps) for full disc lift
$= 35 \sqrt{\bar{V}}$

BALL VALVES



If: $\beta = 1, \theta = 0 \ldots\ldots\ldots\ldots K_1 = 3\, f_T$
$\beta < 1$ and $\theta \leq 45^\circ \ldots\ldots\ldots K_2 =$ Formula 5
$\beta < 1$ and $45^\circ < \theta \leq 180^\circ \ldots K_2 =$ Formula 6

BUTTERFLY VALVES

Sizes 2 to 8" … $K = 45\, f_T$
Sizes 10 to 14" … $K = 35\, f_T$
Sizes 16 to 24" … $K = 25\, f_T$

514-81-F002 rev0
P. 9 of 9

"K" FACTOR TABLE—SHEET 4 of 4

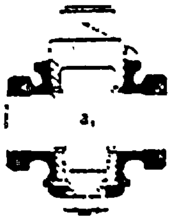
Representative Resistance Coefficients (K) for Valves and Fittings

(for formulas and friction data, see page A-26)

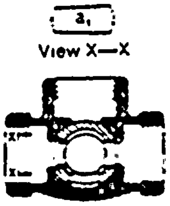
("K" is based on use of schedule pipe as listed on page 2-10)

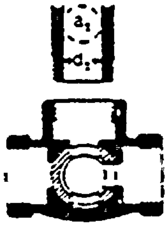
PLUG VALVES AND COCKS

Straight-Way



3-Way





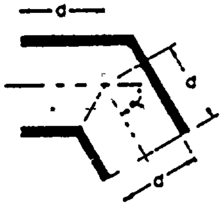
If: $\beta = 1$, $K_1 = 18 f_T$

If: $\beta = 1$, $K_1 = 30 f_T$

If: $\beta = 1$, $K_1 = 90 f_T$

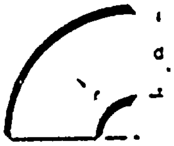
If: $\beta < 1 \ldots K_2 =$ Formula 6

MITRE BENDS



α	K
0°	$2 f_T$
15°	$4 f_T$
30°	$8 f_T$
45°	$15 f_T$
60°	$25 f_T$
75°	$40 f_T$
90°	$60 f_T$

90° PIPE BENDS AND FLANGED OR BUTT-WELDING 90° ELBOWS



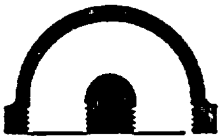
r/d	K	r/d	K
1	$20 f_T$	8	$24 f_T$
1.5	$14 f_T$	10	$30 f_T$
2	$12 f_T$	12	$34 f_T$
3	$12 f_T$	14	$38 f_T$
4	$14 f_T$	16	$42 f_T$
6	$17 f_T$	20	$50 f_T$

The resistance coefficient, K_B, for pipe bends other than 90° may be determined as follows:

$$K_B = (n - 1)\left(0.25\ \pi f_T \frac{r}{d} + 0.5\ K\right) - K$$

n = number of 90° bends
K = resistance coefficient for one 90° bend (per table)

CLOSE PATTERN RETURN BENDS



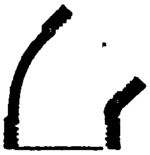
$K = 50 f_T$

STANDARD ELBOWS

90°

$K = 30 f_T$

45°



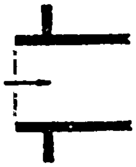
$K = 10 f_T$

STANDARD TEES

Flow thru run........ $K = 20 f_T$
Flow thru branch.... $K = 60 f_T$

PIPE ENTRANCE

Inward Projecting

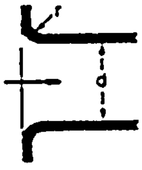


$K = 0.78$

r/d	K
0.00*	0.5
0.02	0.28
0.04	0.24
0.06	0.15
0.10	0.09
0.15 & up	0.04

*Sharp-edged

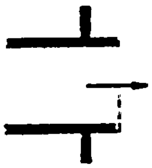
Flush



For K, see table

PIPE EXIT

Projecting

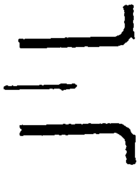


$K = 1.0$

Sharp-Edged

$K = 1.0$

Rounded



$K = 1.0$

S14-81-F002 rev0

Reference 2 p. 1 of 4

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

[illegible]-162-SPE M.P.C.	Relief Valves - Core Spray System	17.33-1136

STONE & WEBSTER ENGINEERING CORPORATION

P. O. BOX 64 LYCOMING, NEW YORK 13093

P.O. NO.	11-347
PAGE	1 - 4
J.O. NO.	11000

THE ABOVE PURCHASE ORDER AND JOB ORDER NUMBERS MUST APPEAR ON ALL INVOICES AND CORRESPONDENCE.

Crosby Valve & Gage Co.
c/o Murphy & Morse Inc.
P.O. Box 2717
Buffalo, New York 14226
Attn: Mr. R. P. Morse

DATE 1/23/67

TERMS 1% 10 Days, Net 30 Days

F.O.B. Wrentham, Mass. with F/A to Job Site

PREPAY CHARGES IF PURCHASED F.O.B. DESTINATION

SHIPMENT DUE Within 20 weeks after Drawing approval

TO
Niagara Mohawk Power Corporation
Stone & Webster Engineering Corp., Agent
Nine Mile Point Nuclear Station
Town of Scriba, N. Y. (East of Oswego, N. Y.)

ADDRESS ALL CORRESPONDENCE TO THE ABOVE ADDRESS.

SEND INVOICE IN TRIPLICATE TO

NIAGARA MOHAWK POWER CORPORATION
STONE & WEBSTER ENGINEERING CORPORATION, AGENT
P. O. BOX 64, LYCOMING, NEW YORK 13093

VIA Motor Freight

NO.	QUANTITY	DESCRIPTION OF MATERIAL	UNIT PRICE	AMOUNT

THE SELLER, BY ACCEPTING THIS ORDER, AGREES TO THE SEVERAL CONDITIONS PRINTED ON THE REVERSE SIDE HEREOF AND MUST SIGN THE ACCEPTANCE COPY OF THIS ORDER AND RETURN AT ONCE TO THE ABOVE ADDRESS.

2①

Crosby style JB-35, size 2 x H x 3, pressure relief valves ~~for service on a~~ reactor core water spray system. Valves are to be fabricated of carbon steel with stainless steel trim.

Valves are to have Class A, screwed type caps, closed bonnets and bellow seals.

Inlet shall be 2" flanged with two (2) concentric "O" ring grooves in face of flange and 1/4" tapped hole between rings (for leakage test) and include two (2) "O" rings.

Outlet shall be 3" flanged connection 150# ASA standard, otherwise the same as inlet including "O" rings.

Pressure Setting: 320 psig Design Temp: 205°F Max.
Normal Max. Press.: 290 psig Normal Temp: 140°F Max.

Backpressure on valve discharge line: 35 psig.

Approx. Flow at 25% over pressure (400 psig): 380 GPM

(Mark: 1 valve E.P. No. 81-11, 1 valve E.P. No. 81-31)

3442 9.

NIAGARA MOHAWK POWER CORPORATION
STONE & WEBSTER ENGINEERING CORPORATION, AGENT

C. A. Nelson LOCAL PURCHASING AGENT

P O NO 11-347

MMK. ~~~ ITEM NO

DWG NO

STORES REQUISITION ☒
MATERIAL DELIVERY ORDER ON WAREHOUSE ☐

	DESCRIPTION	P. O. REF	QUANTITY	UNIT MEAS	UNIT PRICE	AMOUNT
1	CROSBY SIZE 2H3, JB-35 NI-347 STEEL RELIEF VALVE TAGGED #81-11		1		SECT. "C" BIN #20 M.R. #13,745	

TO BE USED FOR SYSTEM # 81

~~7??~~ 748

MATERIAL ISSUED BY

MATERIAL ISSUED BY:

APPROVED BY Ronald Shelton

STORES REQUISITION

DATE April 20, 1968 ITEM NO.

№ 6560

S/O NO DWG. NO.

STORES REQUISITION ☒
MATERIAL DELIVERY ORDER ON WAREHOUSE ☐

	DESCRIPTION	P. O. RE	QUANTITY	UNIT MEAS.	UNIT PRICE	AMOUNT	DEBIT	CREDIT
?	CROSBY VALVE, SIZE 2H3 NI-341 TAGGED 81-31		1		SECT. "#" BIN #20 M.R. #14,194			

TO BE USED FOR SYSTEM # 81

(76)

P. DONATO

P. 2 of 4

S14-81-F002 rev D

S14-81-F002 rev C
P. 3 of 4

MATERIAL RECEIPT
A4970 1

STONE & WEBSTER ENGINEERING CORPORATION

J. O. NO. 11000 P. O. NO. NH-347

RECEIVED FROM Crosby Valve ~~& Gage~~ Gage Co. REQ NO. ~~NM~~-162 OF N.M.P.C.

SHIPPED BY Same SHIPPING POINT Wrentham Mass SHIPPER NO. #2402

DELIVERED BY Associated Transport VIA Truck C. L. L. C. L.

DATE RECEIVED	CAR NUMBER	PRO NUMBER	PREPAID	COLLECT	WEIGHT
2/21/68		Fee of Stray	$ 19.91	$	200#

NUMBER AND TYPE OF UNITS RECEIVED 1 bx
(SPECIFY E. G. BOXES, BARRELS, CARTONS, CRATES, ETC.)

PARTIAL ✓ COMPLETE

ITEM NO.	QUANTITY	UNIT	DESCRIPTION (LIST SERIAL NO'S OF EQUIPMENT, CYLINDER, DRUMS, REELS, ETC.)	STORAGE LOCATION
	1	EA	Crosby Valve, size 2H3,	Sect N Bin 20
			Style JB35A Set 320 PSIG,	
			Cap 382 GPM water, over Press 25%	
			Tag 81-31.	

REMARKS P/L Rec'd
F/B Rec'd

#14194

RECEIVED BY CW Stuart

S14-81-F002 rev 0

p. 4 of 4

[illegible].

STONE & WEBSTER ENGINEERING CORPORATION

J. O. NO. 11600 P. O. NO. NY-47

ED Crosby Valve & Gage Co REQ. NO. [illegible] OF Chg #1 [illegible]

D Same SHIPPING POINT Buffalo, NY SHIPPERS NO. 7C24C2

RED Associated Transport Inc VIA Truck C. L. L. C. L.

E RECEIVED	CAR NUMBER	PRO NUMBER	PREPAID	COLLECT	WEIGHT
2-1-68			$	$	

AND TYPE RECEIVED (SPECIFY E. G.: BOXES, BARRELS, CARTONS, CRATES, ETC.)	PARTIAL	COMPLETE

QUANTITY	UNIT	DESCRIPTION (LIST SERIAL NO'S OF EQUIPMENT, CYLINDERS, DRUMS, REELS, ETC.)	STORAGE LOCATION
1	EA	Crosby size 2H3, JO-[illegible]	Sect C
		Steel Relief Valve [illegible]	Bin 20
		Set 220 psig Cap 383 GPM water	
		Over press. 25% Temp 205°F	
		Tag EP 1-11	
		[redacted]	
		Note refer to MR. 13143	
		for I/B Information	

OVED SHORT
EXCEPTIONS (ETC.) [illegible]

RECEIVED BY V.K. [illegible] MATERIAL DEPARTMENT

13145

514-81-F002 revO

Reference 3 p.1 of 2 Catalog 301

Capacity Tables

STYLES
JB
JO
JW
JMB

WATER CAPACITIES

Gallons per Minute at Set Pressure plus 25% Accumulation
(For 10% Accumulation, Multiply by 0.6;
For other Accumulations see Figure 3, Page 80)

TABLE 6
WATER
3—490#

Set Pressure PSI-Gage	SIZE OR ORIFICE LETTER AND EFFECTIVE AREA, SQ. IN.													
	¾" JMB D 0.110	[illegible] JMB E 0.196	F 0.307	G 0.503	H 0.785	J 1.287	K 1.838	L 2.853	M 3.600	N 4.340	P 6.379	Q 11.045	R 16.000	T 26.000
3	5.2	9.2	14.5	23.7	37.0	60.6	86.6	134	170	204	301	520	754	1225
4	6.0	10.7	16.7	27.3	42.7	70.0	100	155	196	236	347	601	870	1414
5	6.7	11.9	18.7	30.6	47.8	78.3	112	173	219	264	388	672	973	1582
NOTE: For 5 lbs. and below special construction may be required. Advise full details.														
6	7.3	13.1	20.5	33.5	52.3	85.7	122	190	240	289	425	736	1066	1732
7	7.9	14.1	22.1	36.2	56.5	92.6	132	205	259	312	459	795	1151	1871
8	8.5	15.1	23.6	38.7	60.4	99.0	141	219	277	334	491	850	1231	2000
9	9.0	16.0	25.1	41.0	64.1	105	150	233	294	354	521	901	1306	2122
10	9.5	16.9	26.4	43.2	67.5	111	158	245	310	373	549	950	1376	2236
20	13.4	23.8	37.3	61.1	95.5	157	224	347	438	528	776	1343	1946	3162
30	16.4	29.2	45.7	74.9	117	192	274	425	536	647	950	1645	2383	3873
40	18.9	33.7	52.8	86.5	135	221	316	491	619	747	1098	1900	2752	4472
50	21.2	37.7	59.0	96.7	151	247	354	549	692	835	1227	2124	3077	5000
60	23.2	41.3	64.7	106	165	271	387	601	758	914	1344	2327	3371	5478
70	25.0	44.6	69.9	114	179	293	418	649	819	988	1452	2514	3641	5916
80	26.8	47.7	74.7	122	191	313	447	694	876	1056	1552	2687	3892	6325
90	28.4	50.6	79.2	130	203	332	474	736	929	1120	1646	2850	4129	6709
100	29.9	53.3	83.5	137	214	350	500	776	979	1180	1735	3004	4352	7072
110	31.4	55.9	87.6	143	224	367	525	814	1027	1238	1820	3151	4564	7417
120	32.8	58.4	91.4	150	234	383	548	850	1072	1293	1900	3290	4767	7747
130	34.1	60.8	95.2	156	244	399	570	885	1116	1346	1978	3425	4962	
140	35.4	63.1	98.8	162	253	414	592	918	1158	1397	2053	3554	5149	
150	36.7	65.3	102	167	262	429	613	950	1200	1446	2126	3680	5330	
160	37.8	67.4	106	173	270	443	633	982	1239	1493	2195	3800	5505	
170	39.0	69.5	109	178	279	456	652	1012	1277	1539	2263	3918	5674	
180	40.2	71.5	112	183	287	470	671	1041	1314	1584	2329	4032	5839	
190	41.2	73.5	115	188	294	482	689	1069	1349	1627	2391	4140	5999	
200	42.3	75.4	118	193	302	495	707	1097	1385	1669	2454	4248	6155	
210	43.4	77.2	121	198	310	507	725	1124	1419	1711	2514	4353	6306	
220	44.4	79.1	124	203	317	519	742	1151	1452	1751	2573	4455	6455	
230	45.4	80.9	127	207	324	531	759	1177	1485	1791	2632	4557	6600	
240	46.3	82.6	129	212	331	542	775	1202	1517	1829	2688	4654	6742	
250	47.3	84.3	132	216	338	553	791	1227	1548	1866	2743	4750	6880	
260	48.2	85.9	135	220	344	564	806	1251	1578	1903	2797	4843	7018	
270	49.2	87.6	137	225	351	575	822	1275	1609	1940	2851	4936	7155	
280	50.1	89.2	140	229	357	586	837	1298	1638	1975	2903	5026	7282	
290	51.0	90.8	142	233	364	596	852	1321	1668	2010	2955	5116	7411	
300	51.8	92.3	145	237	370	606	866	1344	1696	2045	3005	5203	7538	
310	52.7	93.9	147	241	376	616	881	1366	1724	2079	3056	5290		
320	53.5	95.4	149	245	382	626	895	1388	1752	2112	3104	5375		
330	54.4	96.9	152	248	388	636	909	1410	1779	2145	3153	5459		
340	55.2	98.3	154	252	394	645	922	1431	1806	2177	3200	5540		
350	56.0	99.7	156	256	400	655	936	1452	1832	2209	3247	5621		
360	56.8	101	158	259	405	664	949	1472	1858	2239	3292	5700		
370	57.6	103	161	263	411	673	962	1493	1884	2271	3339	5780		
380	58.3	104	163	266	416	682	975	1512	1908	2301	3382	5855		
390	59.1	105	165	270	422	691	988	1532	1934	2331	3427	5933		
400	59.8	107	167	274	427	700	1000	1552	1958	2361	3470	6008		
410	60.6	108	169	277	433	709	1013	1571	1983	2390	3514	6084		
420	61.3	109	171	280	438	717	1025	1590	2006	2419	3555	6154		
430	62.1	111	173	284	443	726	1037	1609	2031	2448	3599	6231		
440	62.8	112	175	287	448	734	1049	1628	2054	2477	3640	6303		
450	63.5	113	177	290	453	742	1061	1646	2077	2504	3680	6372		
460	64.2	114	179	293	458	751	1073	1664	2100	2532	3722	6444		
470	64.9	116	181	296	463	759	1084	1682	2123	2559	3762	6513		
480	65.4	117	183	300	468	767	1096	1700	2145	2586	3802	6582		
490	66.2	118	185	303	473	775	1107	1718	2168	2614	3842	6651		

NOTE: Where constant back pressure exists, use instead of set pressure, the difference between the set pressure and the back pressure.

For liquids of specific gravity other than 1.0 (Water = 1), multiply above capacities by correction factor K_{sg} found in Figure 2 on Page 80.

For valve details: Styles JB and JO—Pages 14-27; Style JW—Pages 28 & 29; Style JMB—Pages 30 & 31.

Red line indicates pressure limits of Style JW Cast Iron Valves.

S14-81-F002 rcvd
P. 3 of 3

Full Nozzle Safety-Relief Valves

CROSBY

ORIFICE
H
0.785 Sq. In. Area

STYLES JO and JB
SIZES, PRESSURE — TEMPERATURE LIMITS

	VALVE SIZE Inlet x Orifice x Outlet	STYLE		STD. CONNECTIONS ASA FLANGES RAISED FACE		PRESSURE RATINGS (psig)							
						INLET				OUTLET			
										100F		300F	
		WITHOUT BELLOWS	WITH BELLOWS	INLET	OUTLET	100F*	450F	800F	1000F	JO	JB	JO	JB
CARBON STEEL BODY, BONNET, & CAP CARBON STEEL SPRING Max. Temp. 450 F	1½H3	JO-25	JB-25	150	150	275	165			230	230	190	190
	1½H3	JO-25-3	JB-25-3	300	150	275	275			230	230	190	190‡
	2H3	JO-35	JB-35	300	150	720	650			230	230	190	190
	2H3	JO-55	JB-55	600	150	1440	1305			230	230	190	190
	2H3	JO-55-9	JB-55-9	900	150	2160	1955			230	230	190	190
	2H3	JO-75	JB-75	1500	300	2750	2750			600	415	560	415‡
ALLOY STEEL BODY, BONNET, & CAP, ALLOY STEEL SPRING Max. Temp. 800 F	1½H3	JO-26	JB-26	150	150		165	92		230	230	190	190
	1½H3	JO-26-3	JB-26-3	300	150		275	275		230	230	190	190‡
	2H3	JO-36	JB-36	300	150		650	365		230	230	190	190
	2H3	JO-56	JB-56	600	150		1305	730		230	230	190	190
	2H3	JO-56-9	JB-56-9	900	150		1955	1100		230	230	190	190
	2H3	JO-66	JB-66	1500	300		2750	1830		600	415	560	415‡
ALLOY STEEL BODY, BONNET, & CAP, ALLOY STEEL SPRING Max. Temp. 1000 F	2H3	JO-37	JB-37	300	150			410	215	230	230	190	190
	2H3	JO-47	JB-47	600	150			815	430	230	230	190	190
	2H3	JO-57-9	JB-57-9	900	150			1225	645	230	230	190	190
	2H3	JO-67	JB-67	1500	300			2040	1070	600	415	560	415

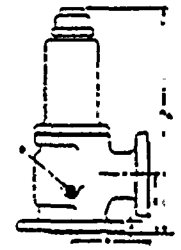
DIMENSIONS & WEIGHTS

SIZE	STYLE	STYLES JO & JB			STYLE JO				STYLE JB			
		CENTER TO FACE		USE TO FIND BOLT LENGTH X	APPROXIMATE HEIGHT			APPROX. NET WT. (TYPE A) LBS.	APPROXIMATE HEIGHT			APPROX. NET WT. (TYPE A) LBS.
		INLET E	OUTLET F		H_A	H_C	H_D		H_A	H_C	H_D	
1½H3	JO & JB-25, 26	5⅛	4⅞	1 7/16	15⅞	16⅞	18½	55	18⅜	19⅜	21⅛	65
1½H3	JO & JB-25-3, 26-3	5⅛	4⅞	1½	15⅞	16⅞	18½	55	18⅜	19⅜	21⅛	65
2H3	JO & JB-35, 36, 37, 47	5⅛	4⅞	1⅝	18⅛	19⅛	20⅞	65	18⅜	19⅜	21⅛	65
2H3	JO & JB-55, 56	6 1/16	6⅜	1 11/16	22⅝	23¾	24⅞	90	22⅞	24	25⅛	90
2H3	JO & JB-55-9, 56-9, 57-9	6 1/16	6⅜	2 3/16	22⅝	23¾	24⅞	95	22⅞	24	25⅛	95
2H3	JO & JB-75, 66, 67	6 1/16	6⅜	2 3/16	23¾	24⅜	25⅝	110	24	24⅝	25⅞	110

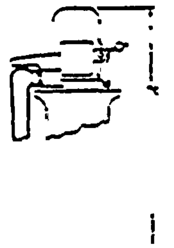
*Styles JO and JB-( )5 may be used to maximum pressures listed at temperatures to minus 20F.

‡Pressure limit less than ASA Flange Limit as graphed on Page 27.

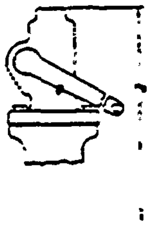
DRAIN HOLE (D)=½" N. P. T.



TYPE A
Screwed Cap



TYPE C
Regular Lifting Gear



TYPE D
Packed Lifting Gear

S481-F002 rev. 0

Reference 4 p. 1 of 2

FLUID MECHANICS With Engineering Applications

SEVENTH EDITION

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McGRAW-HILL BOOK COMPANY
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Panama Paris São Paulo Singapore Sydney Tokyo Toronto

94-81-F002 rev0

p. 2 of 2

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APPENDIX

THREE

USEFUL TABLES

Table A.1*a*. Physical properties of water in English units

Temp. F	Specific weight γ, lb/ft³	Density ρ, slugs/ft³	Viscosity $\mu \times 10^5$, lb·s/ft²	Kinematic viscosity $\nu \times 10^5$, ft²/s	Surface tension $\sigma \times 10^2$ lb/ft	Vapor pressure p_v, psia	Vapor pressure head p_v/γ, ft	Bulk modulus of elasticity $E_v \times 10^{-3}$, psi
32	62.42	1.940	3.746	1.931	0.518	0.09	0.20	293
40	62.43	1.940	3.229	1.664	0.514	0.12	0.28	294
50	62.41	1.940	2.735	1.410	0.509	0.18	0.41	305
60	62.37	1.938	2.359	1.217	0.504	0.26	0.59	311
70	62.30	1.936	2.050	1.059	0.500	0.36	0.84	320
80	62.22	1.934	1.799	0.930	0.492	0.51	1.17	322
90	62.11	1.931	1.595	0.826	0.486	0.70	1.61	323
100	62.00	1.927	1.424	0.739	0.480	0.95	2.19	327
110	61.86	1.923	1.284	0.667	0.473	1.27	2.95	331
120	61.71	1.918	1.168	0.609	0.465	1.69	3.91	333
130	61.55	1.913	1.069	0.558	0.460	2.22	5.13	334
140	61.38	1.908	0.981	0.514	0.454	2.89	6.67	330
150	61.20	1.902	0.905	0.476	0.447	3.72	8.58	328
160	61.00	1.896	0.838	0.442	0.441	4.74	10.95	326
170	60.80	1.890	0.780	0.413	0.433	5.99	13.83	322
180	60.58	1.883	0.726	0.385	0.426	7.51	17.33	318
190	60.36	1.876	0.678	0.362	0.419	9.34	21.55	313
200	60.12	1.868	0.637	0.341	0.412	11.52	26.59	308
212	59.83	1.860	0.593	0.319	0.404	14.70	33.90	300

NIAGARA MOHAWK

CALCULATION COVER SHEET

NUCLEAR ENGINEERING & LICENSING

DISCIPLINE: MECHANICAL

PAGE 1A

PROJECT: NINE MILE POINT NUC. STA.-UNIT 1

CALC. NO. S14-81-F003

SUBJECT: CORE SPRAY SYSTEM HYDRAULIC RESISTANCE FROM TORUS TO TOPPING PUMP TEE

BUILDING: REACTOR

FLOOR ELEV.: VARIOUS

INDEX NO.: 3-N2.1-S14

ORIGINATOR(S): MPR ASSOCIATES, INC.

TOTAL SHT'S. ~~17~~16

CHECKER(S): MPR ASSOCIATES, INC.

LAST SHT. NO. ~~13~~12

RECORD OF ISSUES

REV.	DESCRIPTION	M.O.#	BY	DATE	CHKD.	DATE	APPD.	DATE	DATE FILMED
0	C.S. HYDRAULIC RESISTANCE FROM TORUS TO TOPPING PUMP TEE	2988	T. LUSTINA	11/29/88	L. STEVENS	11/30/88	LAK	12/3/88	
1	revised in its entirety	2988	Testina	2/23/89	L. Stevens	2/24/89	L.A. Kusansky	3/2/89	

COMPUTER OUTPUT YES ☐ NO ☒

SAFETY RELATED YES ☒ NO ☐

DRAWINGS REFERENCED:

DWG. NO.	INDEX	SHT.	REV.

~~SEE PAGES 12 & 13~~

see pages 11 + 12

REFERENCES:

~~SEE PAGES 12 + 13~~

see pages 11 + 12

KEYWORDS: NMP1, SSFI, CORE SPRAY, FLOW

CROSS REF.: 85-87-TGL5

S14-81-F003 Rev. 1

MPR ASSOCIATES, INC.
1050 Connecticut Ave., NW-Washington, DC 20036

CALCULATION TITLE PAGE

CLIENT Niagara Mohawk	PAGE 1 OF 12
PROJECT Core Spray SSFI	TASK NO. 85-87
CALCULATION TITLE Hydraulic Resistance of NMP1 Core Spray Pump and Topping Pump Suction and Riser Piping	CALCULATION NO. (OPTIONAL) 85-87-TGL5

PREPARER(S)/DATE	CHECKER(S)/DATE	REVIEWER(S)/DATE	REV. NO.
T. Lestina 11/29/88	L. Stevens 11/30/88	J Johnson 11/30/88	0
T. Lestina 2/23/89	L. Stevens 2/24/89	J Johnson 2/23/89	1

CALCULATION NO.	PREPARED BY	CHECKED BY	PAGE
85-87-TGL5	T. Lestina	L. Stevens	2

Purpose The purpose of this calculation is to determine the hydraulic resistance of the core spray pump and topping pump suction piping and riser piping at Nine Mile Point Unit 1.

Summary: The head loss due to the hydraulic resistance of the suction and riser piping is:

$$h_L = K_1 \frac{V^2}{2g} = R_1 Q^2$$

where R_1 = hydraulic resistance (ft/gpm^2)
Q = volumetric flow rate, (gpm)
V = flow velocity, (ft/s)
g = acceleration due to gravity (ft/s^2)
h_L = head loss (ft)
K_1 = resistance coefficient or K-factor of suction and riser piping and fittings

$R_1 = 1.56824(10^{-6})$ ft. of H_2O/gpm^2, clean strainer
$= 2.57291(10^{-6})$ ft. of H_2O/gpm^2, 50% clogged strainer

Calculation

The hydraulic resistance, R_1, is calculated from the torus to the tee downstream of the topping pump for pump set #122.

$$h_L = K_1 \frac{V^2}{2g} = R_1 Q^2$$

Calculating K-factor, K_1: Reference (1),

a. For fittings:

$$K = \left(\frac{L}{D}\right)_{effective} f_T$$

where $(L/D)_{effective}$ and f_T are tabulated

b. For reducers: (assuming inside angle $\theta = 90^\circ$)

enlarging $K_2 = \frac{(1-\beta^2)^2}{\beta^4}$ where $\beta = d_1/d_2$

(subscript 1 refers to smaller pipe, subscript 2 refers to larger pipe.)

reducing $K_2 = \frac{.4204(1-\beta^2)}{\beta^4}$

c. For straight pipe:

$Re = \frac{VD}{\nu}$ $\nu = .514(10^{-5})$ ft²/s at 140°F from Reference (2)

assume 3400 gpm

c. For 10" STD pipe,

$$Re = \frac{(3400\ \text{gpm})\left(\frac{1\ \text{min}}{60\ \text{s}}\right)\left(\frac{1\ \text{ft}^3}{7.4805\ \text{g}}\right)\left(\frac{1}{.5475\ \text{ft}^2}\right)\left(\frac{10.02}{12}\ \text{ft}\right)}{0.514(10^{-5})\ \text{ft}^2/\text{s}} = 2.25(10^6)$$

From Reference (1), p. A-25, $f \approx .014$

for 12" STD pipe,

$$Re = \frac{(3400\ \text{gpm})\left(\frac{1\ \text{min}}{60\ \text{s}}\right)\left(\frac{1\ \text{ft}^3}{7.4805\ \text{g}}\right)\left(\frac{1}{.7854\ \text{ft}^2}\right)\left(\frac{12\ \text{ft}}{12}\right)}{0.514(10^{-5})\ \text{ft}^2/\text{s}} = 1.88(10^6)$$

From Reference (1), p. A-25 $f \approx .014$

for 14" pipe,

$$Re = \frac{(3400\ \text{gpm})\left(\frac{1\ \text{min}}{60\ \text{s}}\right)\left(\frac{1\ \text{ft}^3}{7.4805\ \text{g}}\right)\left(\frac{1}{.9575\ \text{ft}^2}\right)\left(\frac{13.25\ \text{in}}{12}\right)}{0.514(10^{-5})\ \text{ft}^2/\text{s}} = 1.70(10^6)$$

From Reference (1), p. A 25 $f \approx .014$

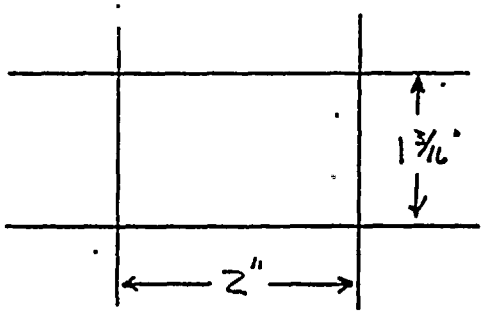
d. For pipe size changes:

$$K_1 = K_2\left(\frac{d_1}{d_2}\right)^4$$

This is needed to account for different size fittings in a piping run

Entrance screen losses:

The screen free area can be calculated from the dimensions from Reference (6)



Gary welded steel grating GW-75-2 main bar and bearing bar thickness is 3/16" from Reference (7).

$$\frac{\text{free area}}{\text{total area}} = \frac{(2-.1875)(1.1875-.1875)}{2\cdot 1.1875} = .763$$

Assume 50% of the free area is blocked

$$\text{free area}/\text{total area} = .763/2 = .382$$

Assuming a 50% blocked grating is hydraulically similar to a perforated plate entrance, using Reference (3) p. 132,

$$K_{screen} = 12.4 \quad \text{for 20 inch ID entrance}$$

$$K_{screen} = 12.4\left(\frac{12}{20}\right)^4 = 1.61 \quad \text{for 12" STD pipe}$$

S14-81-F003 rev 1

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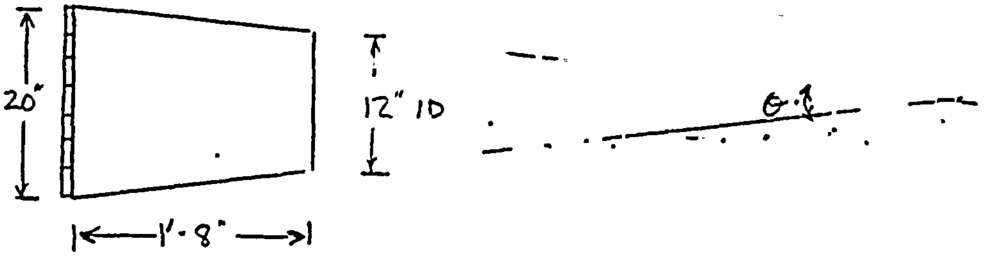
CALCULATION NO.	PREPARED BY	CHECKED BY	PAGE
85-87-T6L5	T. Lestina	L Stevens	6

Entrance Reducer Losses:

The dimensions of the reducer from Reference (6),



$$\text{inside angle } \theta = 2\tan^{-1}\left[\frac{(20-12)/2}{20}\right] = 22.6^\circ$$

From Reference (1)

$$K = 0.8\left(\sin\theta/2\right)\left[1-\left(12/20\right)^2\right] = .10 \text{ for } 12'' \text{ STD pipe}$$

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CALCULATION NO.	PREPARED BY	CHECKED BY	PAGE
85-87-T6L5	T. Lestina	L Stevens	7

A complete list of fittings from Reference (8) for core spray line #122,

Component		K-factor
Entrance screen (50% clogged)		1.61 (12")
Entrance reducer 20"x12" θ=22.6°		.10 (12")
114' Straight Pipe - 12"	$.014 \frac{114}{(12/12)} =$	1.60 (12")
14 x 12 Reducer (enlarging)	$\frac{(1-.906^2)^2}{.906^4} \cdot .906^4 =$	.03 (12")
40' Straight Pipe - 14"	$.014 \frac{40}{(13.25/12)} = .51\ (14'') =$	.34 (12")
14 x 12 Reducer (reducing)	$\frac{.4204(1-.906^2)}{.906^4} \cdot (.906)^4 =$	.08 (12")
3 - 90° Elbows 14" r/d = 1.5 - ANSI B16.9	$3(14 f_T) = 3(14)(.013) = .55(14'') =$	.37 (12")
45° Elbow 14" (assume ½ of 90° Elbow)	$7 f_T = 7(.013) = .09(14'') =$	.06 (12")
Gate Valve 14"	$8 f_T = 8(.013) = .10(14'') =$	.07 (12")
Tee - run flow 12"	$20 f_T = 20(.014) =$	.28 (12")
7' straight pipe 10"	$.014\left(\frac{7}{10.02/12}\right) = .12(10'') =$	.24 (12")
2-12x10 Reducer (enlarging)	$2 \cdot \frac{(1-.835^2)^2}{.835^4} \doteq$	.38 (12")
7 90° Elbows 12" r/d = 1.5	$7 \cdot 14 f_T = 7 \cdot 14 \cdot .013 =$	1.27 (12")

S14-81-F003 (?)

Component		K-factor
16 x 12 Reducer (enlarging)	$\frac{(1-.787^2)^2}{(.787)^4}\cdot(.787)^4 =$	.15 (12")
16 x 12 Reducer (reducing)	$\frac{.4204(1-.787^2)}{(.787)^4}(.787)^4 =$	.16 (12")
12 x 10 Reducer (reducing)	$\frac{.4204(1-.835^2)}{.835^4} =$	.26 (12")
45° Elbow - 10"	$7 f_T = 7(.014) = .10 (10")$ = (assume ½ of 90° elbow)	.21 (12")
90° Elbow - 10"	$14 f_T = 14(.014) = .20 (10")$ =	.41 (12")
90° Bend - 12" r/d=5	$15 f_T = 15(.013)$ =	.20 (12")
Check Valve - 12" (assume tilting disk with tilt angle: $\alpha = 15°$) This is conservative.	$90 f_T = 90(.013)$ =	1.17 (12")
Gate Valve - 12"	$8 f_T = 8(.013)$ =	.10 (12")
Tee - Branch flow - 12"	$60 f_T = 60(.013)$ ≐	.78 (12")

(the losses due to ball joints is considered negligible)

Total K-factor without strainer — 9.87 (12)

Strainer K-factor:

From Reference (4), the strainer K-factor is 2.68 for 12" ID pipe for a clean strainer and 10.72 for a 50% clogged strainer.

Total K-factor, K_1:

The total K-factor for the core spray pump and topping pump suction and riser piping is:

$K_1 = 9.87 + 2.68 = 12.55$ for 12" ID pipe with clean strainer

$K_1 = 9.87 + 10.72 = 20.59$ for 12" ID pipe with 50% clogged strainer

S14-21-F003

Calculating R_1

$$h_1 \, (\text{ft. of } H_2O) = K_1 \frac{V^2}{2g} = R_1 Q^2$$

$$h_1 \, (\text{ft. of } H_2O) = K_1 \frac{\left(\frac{1 \text{ min}}{60 \text{ s}}\right)^2 \left(\frac{1 \text{ ft}^3}{7.4805 \text{ g}}\right)^2 \left(\frac{1}{.7854 \text{ ft}^2}\right)^2 (Q, \text{gpm})^2}{2 \, (32.2) \text{ ft/s}^2}$$

$$= 1.24959 \, (10^{-7}) \, K_1 \, Q^2$$

with clean strainer $R_1 = 1.56824 (10^{-6}) \frac{\text{ft. of } H_2O}{\text{gpm}^2}$

with 50% clogged strainer $(R_1)_{50\%} = 2.57291 (10^{-6}) \frac{\text{ft. of } H_2O}{\text{gpm}^2}$

CALCULATION NO.	PREPARED BY	CHECKED BY	PAGE
85-87-TGL5	T. Lestina	L. Stevens	11

References

1. Crane Technical Paper No. 410, "Flow of Fluids Through Valves, Fittings, and Pipe", 1982.

2. Daugherty R.L. and Franzini, J.B. Fluid Mechanics with Engineering Applications, McGraw Hill Book Company, New York 1977.

3. I.E. Idelchik, Handbook of Hydraulic Resistance, Hemisphere Publishing Corp., 1986; translated from second Russian edition.

4. MPR Calculation 85-104-TGL8, "Hydraulic Resistance of NMP1 Core Spray Strainer", Rev 0, 2/23/89

5. Deleted

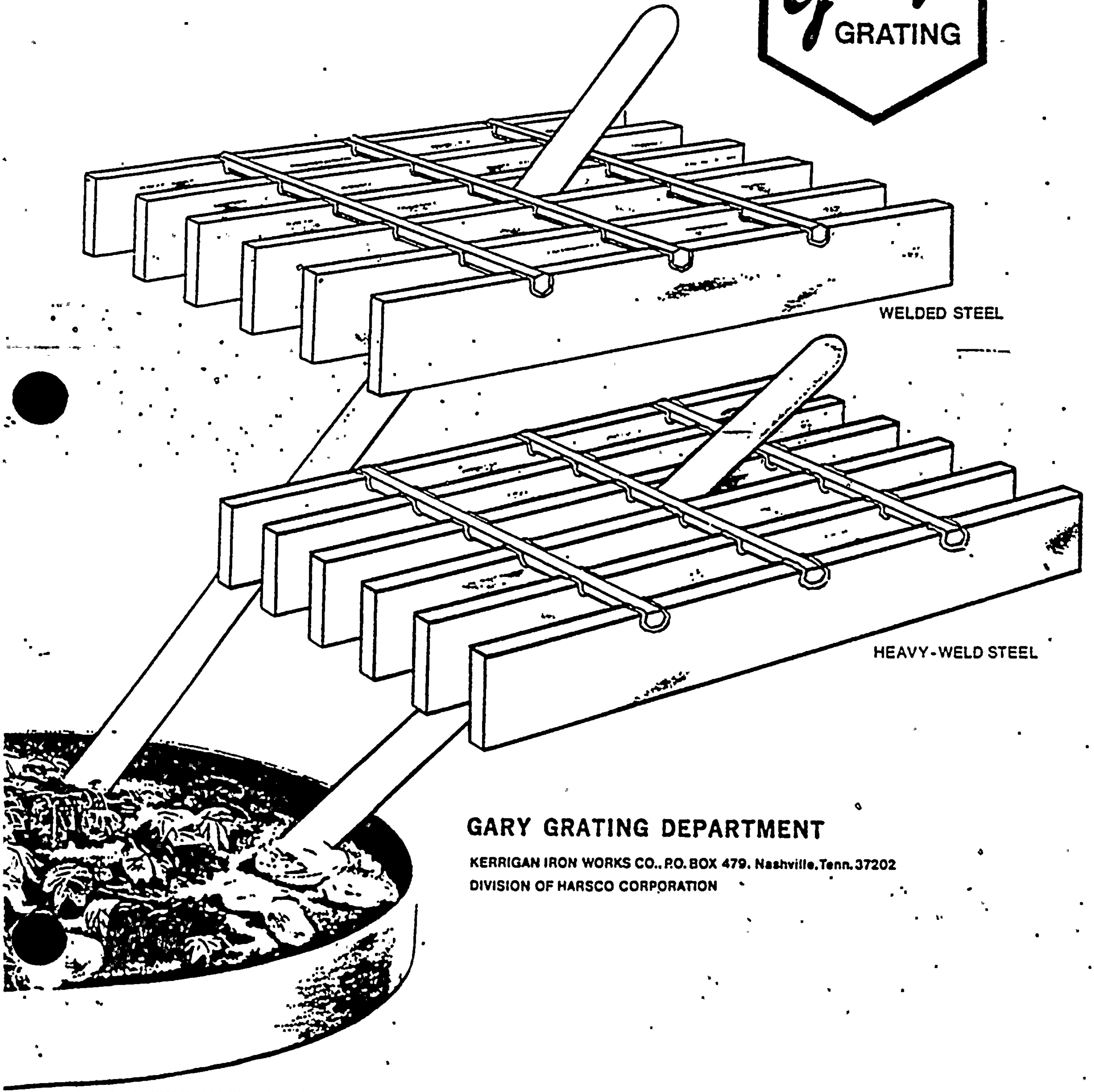
6. Niagara Mohawk Drawing No. C-18364-C, "Core Spray Piping Plan at El 198'-0" and 218'-0"", Rev 16.

7. Gary Grating Catalog No. G667, p. 12-13. (ATTACHED)

8. Niagara Mohawk Drawing No C-26845-C, "Reactor Core Spray System 81 & 81.1 Piping Isometric", Sheet 3, Rev. 10.

S14-81-F003 rev 1
Reference 7 p. 1 of 3
IF/HA
WILLIAM E. SYLVESTER, JR.

Gary
GRATING



GARY GRATING DEPARTMENT

KERRIGAN IRON WORKS CO., P.O. BOX 479, Nashville, Tenn. 37202
DIVISION OF HARSCO CORPORATION

S14-81-F003 rev
P. 2 of 3

Welded Steel Grating . .

MAXIMUM PANEL WIDTH as indicated. For wider areas, grating will be made in two or more panels.

PANEL WIDTHS

No. Bars	GW 1 3/16" c-c 3/16" & 1/8" Bar	SGW 15/16" c-c 3/16"-Bar	SGW 15/16" c-c 1/8" Bar	SSGW 11/16" c-c 3/16" & 1/8" Bar
2	1 3/8"	1 1/8"	1 1/8"	7/8"
3	2 9/16	2	2	1 9/16
4	3 3/4	2 15/16	2 15/16	2 1/4
5	4 15/16	3 7/8	3 7/8	3
6	6 1/8	4 3/4	4 3/4	3 5/8
7	7 5/16	5 11/16	5 11/16	4 3/8
8	8 1/2	6 5/8	6 5/8	5 1/16
9	9 11/16	7 1/2	7 1/2	5 3/4
10	10 7/8	8 7/16	8 7/16	6 7/16
11	1'-0 1/16	9 3/8	9 3/8	7 1/8
12	1'-1 1/4	10 1/4	10 1/4	7 7/8
13	1'-2 7/16	11 3/16	11 3/16	8 9/16
14	1'-3 5/8	1'-0 1/8	1'-0 1/8	9 1/4
15	1'-4 7/8	1'-1	1'-1	9 15/16
16	1'-6 1/16	1'-1 15/16	1'-1 15/16	10 5/8
17	1'-7 1/4	1'-2 13/16	1'-2 13/16	11 5/16
18	1'-8 7/16	1'-3 3/4	1'-3 3/4	1'-0
19	1'-9 5/8	1'-4 11/16	1'-4 11/16	1'-0 3/4
20	1'-10 13/16	1'-5 9/16	1'-5 9/16	1'-1 7/16
21	2'-0	1'-6 1/2	1'-6 1/2	1'-2 1/8
22	2'-1 1/4	1'-7 7/16	1'-7 7/16	1'-2 13/16
23	2'-2 7/16	1'-8 5/16	1'-8 5/16	1'-3 1/2
24	2'-3 5/8	1'-9 1/4	1'-9 1/4	1'-4 1/4
25	2'-4 13/16	1'-10 3/16	1'-10 3/16	1'-4 15/16
26	2'-6	1'-11 1/16	1'-11 1/16	1'-5 5/8
27	2'-7 3/16	*2'-0	2'-0	1'-6 5/16
28	2'-8 3/8	2'-0 7/8	2'-0 15/16	1'-7
29	2'-9 5/8	2'-1 3/4	2'-1 13/16	1'-7 11/16
30	2'-10 13/16	2'-2 11/16	2'-2 3/4	1'-8 3/8
31	3'-0	2'-3 5/8	2'-3 11/16	†1'-9 1/16
32		2'-4 1/2	2'-4 9/16	†1'-9 13/16
33		2'-5 7/16	2'-5 1/2	†1'-10 1/2
34		2'-6 3/8	2'-6 7/16	†1'-11 3/16
35		2'-7 1/4	2'-7 5/16	†1'-11 7/8
36		2'-8 3/16	2'-8 1/4	
37		2'-9 1/16	2'-9 3/16	
38		2'-9 15/16	2'-10 1/16	
39		2'-10 7/8	2'-11	
40		2'-11 3/4	2'-11 7/8	

Max. width for 1 1/2" or less main bars

** Maximum Width for 1 3/4" or Greater Main Bar*
† For SSGW-100-2 Only

SYMBOLS and WEIGHTS

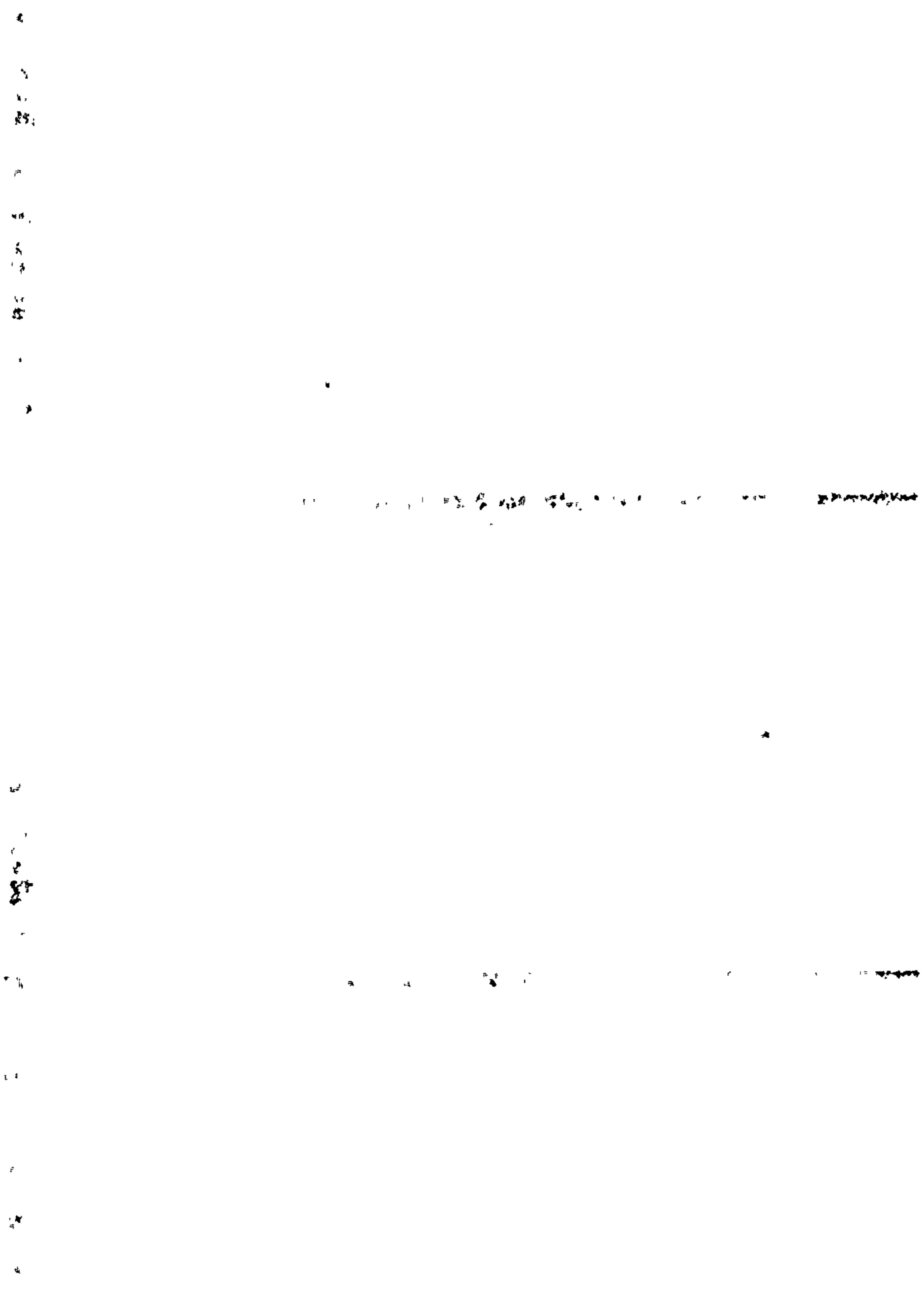
Main Bar Size	GW SERIES		GW-2 SERIES	
	Symbol	Wt. Lbs. Sq. Ft.	Symbol	Wt. Lbs. Sq. Ft.
3/4" x 1/8"	GW-75A	4.1	GW-75A-2	4.8
3/4" x 3/16"	GW-75	5.7	GW-75-2	6.4
1" x 1/8"	GW-100A	5.2	GW-100A-2	5.9
1" x 3/16"	GW-100	7.4	GW-100-2	8.1
1 1/4" x 1/8"	GW-125A	6.3	GW-125A-2	7.0
1 1/4" x 3/16"	GW-125	9.1	GW-125-2	9.8
1 1/2" x 1/8"	GW-150A	7.4	GW-150A-2	8.1
1 1/2" x 3/16"	GW-150	10.8	GW-150-2	11.5
1 3/4" x 3/16"	GW-175	12.5	GW-175-2	13.2
2" x 3/16"	GW-200	14.1	GW-200-2	14.8
2 1/4" x 3/16"	GW-225	15.7	GW-225-2	16.4
2 1/2" x 3/16"	GW-250	17.4	GW-250-2	18.1

Main Bar Size	SWG SERIES		SGW-2 SERIES	
	Symbol	Wt. Lbs. Sq. Ft.	Symbol	Wt. Lbs. Sq. Ft.
3/4" x 1/8"	SGW-75A	5.0	SGW-75A-2	5.7
3/4" x 3/16"	SGW-75	7.2	SGW-75-2	7.9
1" x 1/8"	SGW-100A	6.4	SGW-100A-2	7.1
1" x 3/16"	SGW-100	9.3	SGW-100-2	10.0
1 1/4" x 1/8"	SGW-125A	7.9	SGW-125A-2	8.6
1 1/4" x 3/16"	SGW-125	11.5	SGW-125-2	12.2
1 1/2" x 1/8"	SGW-150A	9.3	SGW-150A-2	10.0
1 1/2" x 3/16"	SGW-150	13.7	SGW-150-2	14.4
1 3/4" x 3/16"	SGW-175	15.8	SGW-175-2	16.5
2" x 3/16"	SGW-200	18.0	SGW-220-2	18.7
2 1/4" x 3/16"	SGW-225	20.0	SGW-225-2	20.7
2 1/2" x 3/16"	SGW-250	22.2	SGW-250-2	22.9

Main Bar Size	SSGW SERIES		SSGW-2 SERIES	
	Symbol	Wt. Lbs. Sq. Ft.	Symbol	Wt. Lbs. Sq. Ft.
3/4" x 3/8"	SSGW-75	9.1	SSGW-75-2	9.8
1" x 1/8"	SSGW-100A	8.2	SSGW-100A-2	8.9
1" x 3/16"	SSGW-100	12.0	SSGW-100-2	12.7
1 1/4" x 1/8"	SSGW-125A	10.0	SSGW-125A-2	10.7
1 1/4" x 3/16"	SSGW-125	14.8	SSGW-125-2	15.5
1 1/2" x 1/8"	SSGW-150A	12.0	SSGW-150A-2	12.7
1 1/2" x 3/16"	SSGW-150	17.6	SSGW-150-2	18.4
1 3/4" x 3/16"	SSGW-175	20.4	SSGW-175-2	21.1
2" x 3/16"	SSGW-200	23.2	SSGW-200-2	23.9
2 1/4" x 3/16"	SSGW-225	25.8	SSGW-225-2	26.6
2 1/2" x 3/16"	SSGW-250	28.7	SSGW-250-2	29.4

Stock Length 20'-0

**Stock Width*



514-81-F003 rev 1
p. 3 of 3

ENGINEERING DATA

LOAD TABLE
Gary Welded Steel Grating Type GW
WITH BEARING BARS 1 3/16" c/c

Bearing Bar Size and Wt.	Symbol		SPAN 2'-0"	2'-6"	3'-0"	3'-6"	4'-0"	4'-6"	5'-0"	5'-6"	6'-0"	6'-6"	7'-0"	8'-0"
¾" × ⅛" 4.1 lbs.	GW 75A	U	386	247	172	126	96	76						
		D	.096	.150	.216	.294	.382	.485						
		C	386	309	257	221	193	172						
		D	.077	.120	.173	.235	.307	.388						
¾" × 3/16" 5.7 lbs.	GW 75	U	581	372	258	190	145	115						
		D	.096	.150	.216	.294	.382	.485						
		C	581	465	387	332	290	258						
		D	.077	.120	.173	.235	.307	.388						
1" × ⅛" 5.2 lbs.	GW 100A	U	686	439	305	224	172	136	110	91	76			
		D	.072	.112	.162	.220	.289	.365	.451	.545	.646			
		C	686	549	458	392	343	305	274	250	229			
		D	.058	.090	.130	.176	.230	.292	.360	.436	.519			
1" × 3/16" 7.4 lbs.	GW 100	U	1030	659	458	336	257	203	165	136	114			
		D	.072	.112	.162	.220	.289	.365	.451	.545	.646			
		C	1030	824	686	588	515	458	412	374	343			
		D	.058	.090	.130	.176	.230	.292	.360	.436	.519			
1¼" × ⅛" 6.3 lbs.	GW 125A	U	1072	686	477	350	268	212	172	142	119	102	88	
		D	.058	.090	.130	.176	.230	.292	.360	.435	.516	.607	.704	
		C	1072	858	715	613	536	477	429	390	358	330	306	
		D	.046	.072	.104	.141	.184	.233	.288	.348	.415	.486	.562	
1¼" × 3/16" 9.1 lbs.	GW 125	U	1610	1031	716	526	403	318	258	213	179	152	131	
		D	.058	.090	.130	.176	.230	.292	.360	.435	.516	.607	.704	
		C	1610	1288	1074	920	805	716	644	586	537	496	460	
		D	.046	.072	.104	.141	.184	.233	.288	.348	.415	.486	.562	
1½" × ⅛" 7.4 lbs.	GW 150A	U	1544	988	686	504	386	305	247	204	172	146	126	96
		D	.048	.075	.108	.147	.192	.243	.300	.363	.432	.506	.587	.765
		C	1544	1236	1030	882	772	686	618	562	515	475	441	386
		D	.038	.060	.086	118	.154	.194	.240	.291	.346	.405	.470	.614
1½" × 3/16" 10.8 lbs.	GW 150	U	2320	1485	1031	758	580	458	371	307	258	220	189	145
		D	.048	.075	.108	.147	.192	.243	.300	.363	.432	.506	.587	.765
		C	2320	1856	1547	1326	1160	1031	928	844	773	714	663	580
		D	.038	.060	.086	.118	.154	.194	.240	.291	.346	.405	.470	.614
1¾" × 3/16" 12.5 lbs.	GW 175	U	3158	2021	1404	1031	790	624	505	418	351	299	258	197
		D	.041	.064	.093	.126	.165	.208	.257	.312	.370	.435	.505	.557
		C	3158	2526	2105	1805	1579	1404	1263	1148	1053	972	902	790
		D	.033	.051	.074	101	.132	.167	.206	.249	.296	.348	.403	527
2" × 3/16" 14.1 lbs.	GW 200	U	4125	2640	1833	1347	1031	815	660	545	458	390	337	258
		D	.036	.056	.081	.110	.144	.182	.225	.272	.324	.380	.441	.576
		C	4125	3300	2750	2357	2062	1833	1650	1500	1375	1269	1178	1031
		D	.029	.045	.065	.088	.115	.146	.180	.218	.259	.304	.353	.461
2¼" × 3/16" 15.7 lbs.	GW 225	U	5221	3341	2320	1704	1305	1031	835	690	580	494	426	326
		D	.032	.050	.072	.098	.128	.162	.200	.242	.288	.338	.392	.512
		C	5221	4176	3480	2983	2610	2320	2088	1898	1740	1606	1492	1305
		D	.026	.040	058	.078	.102	.130	.160	.194	.230	.270	.314	.410
2½" × 3/16" 17.4 lbs.	GW 250	U	6445	4125	2864	2104	1611	1273	1031	852	716	610	526	403
		D	.029	.045	065	.088	.115	.140	.180	.218	.259	.304	.353	.461
		C	6445	5156	4297	3683	3222	2864	2578	2344	2148	1983	1841	1611
		D	.023	.036	.052	.070	.092	.117	.144	.174	.207	243	.282	.369

U — Uniform Load-Pounds per Sq. Ft.

C — Concentrated Load-Pounds per Ft. of Width

D — Deflection-Inches.

Unit Stress — 18,000 lbs. per Sq. In.

Spans to left of heavy line produce a deflection of ¼" or less under a uniform load of 100 pounds per sq. ft. This deflection is recommended as the maximum to provide pedestrian comfort. It can be exceeded at the discretion of the engineer.

Gary

CONVERSION FACTORS FOR GARY WELDED GRATING

1. For other than 1 3/16" c/c of bearing bars, or for unit stress other than 18,000 lb. per sq. in., the conversion for load (U or C) is directly proportional
2. Deflection (D), for other than 1 3/16 c/c of bearing bars, remains same as tabulated provided the unit stress remains 18,000 lb. per sq. in.
3. Deflection (D), for other loads, or unit stress, is directly proportional

NIAGARA MOHAWK

CALCULATION COVER SHEET

NUCLEAR ENGINEERING & LICENSING

DISCIPLINE: MECHANICAL

PAGE 1A

PROJECT: NINE MILE POINT NUC. STA.-UNIT 1

CALC. NO. S14-81-F004

SUBJECT: CORE SPRAY PUMP NPSH AVAILABLE VS. REQUIRED)

BUILDING: REACTOR

FLOOR ELEV.: VARIOUS

INDEX NO.: 3-N2.1-S14

ORIGINATOR(S): MPR ASSOCIATES, INC.

TOTAL SHT'S. ~~8~~12

CHECKER(S): MPR ASSOCIATES, INC.

LAST SHT. NO: X9

RECORD OF ISSUES

REV.	DESCRIPTION	M.O.#	BY	DATE	CHKD.	DATE	APPD.	DATE	DATE FILMED:
0	CORE SPRAY PUMP NPSH AVAILABLE VS. REQUIRED	2988	H.W. McCurdy	11/29/88	C.S. Schasowin	11/29/88	LAK	12/3/88	
1	revised in its entirety	2988	HW McCurdy	2/23/89	J Johnson	2/23/89	L.A. Klosowski	3/2/89	

COMPUTER OUTPUT YES ☐ NO ☒

SAFETY RELATED YES ☒ NO ☐

DRAWINGS REFERENCED:

DWG. NO.	INDEX	SHT.	REV.
SEE PAGE 6			

REFERENCES:

SEE PAGE 6

KEYWORDS: NMP 1, SSFI, CORE SPRAY, FLOW

CROSS REF.: 85-104-HWM1

12/84

EIP-091

S14-81-F004 rev1

MPR ASSOCIATES, INC.
1050 Connecticut Ave., NW-Washington, DC 20036

CALCULATION TITLE PAGE

CLIENT NIAGARA MOHAWK	PAGE 1 OF 9
PROJECT NMP-1 CORE SPRAY SYSTEM	TASK NO. 85-104
CALCULATION TITLE AVAILABLE AND REQUIRED NPSH FOR CORE SPRAY PUMPS	CALCULATION NO. (OPTIONAL) 85-104-HWM1

PREPARER(S)/DATE	CHECKER(S)/DATE	REVIEWER(S)/DATE	REV. NO.
HWMcCURDY 11/29/88	11-29-88	J Johnson 11/30/88	0
HWMcCURDY 2/23/89	John Johnson 2/23-89	John Johnson 2/23/89	1

S14-81-F004 rev 1

CALCULATION NO.	PREPARED BY	CHECKED BY	PAGE 2
85-104-HWM1	HWMcCURDY		

THE PURPOSE OF THIS CALCULATION IS TO DETERMINE THE AVAILABLE NPSH FOR THE NMP-1 CORE SPRAY PUMPS AT VARIOUS TORUS PRESSURES AND WATER TEMPERATURES.

THE AVAILABLE NPSH IS GIVEN BY,

$$NPSH = \frac{(P_T - P_V) \cdot 144 \frac{IN^2}{FT^2}}{\rho_T} + (H_T - H_P) - H_S$$

WHERE,

P_T = TORUS PRESSURE, PSIA

P_V = VAPOR PRESSURE, PSIA

ρ_T = TORUS WATER DENSITY, LB/FT^3

H_T = WATER ELEVATION IN TORUS, FT.

H_P = ELEVATION OF PUMP FIRST-STAGE IMPELLER INLET, FT.

H_S = HEAD LOSS IN PUMP SUCTION PIPING, FT.

THE PARAMETERS ARE,

$H_T = 210.5$ FT (REFERENCE 1)

$H_P = 192.5$ FT. (REFERENCES 2 AND 6)

$H_S = 3.799 \cdot 10^{-7} \frac{FT}{GPM^2} \times (\dot{Q}(GPM))^2$ (REFERENCE 3)

THE AVAILABLE NPSH IS,

$$NPSH = \frac{(P_T - P_V) \cdot 144}{\rho_T} + 18.0 - 3.799 \cdot 10^{-7} \dot{Q}^2$$

CALCULATE THE NPSH FOR VARIOUS CASES,

① TORUS PRESSURE = 14.7 PSIA (0 PSIG)
TORUS TEMPERATURE = 90°F

$$NPSH = \frac{(14.7 - 0.70) \cdot 144}{62.1} + 18.0 - 3.799 \cdot 10^{-7} \dot{Q}^2$$

$$NPSH = 50.5 - 3.799 \cdot 10^{-7} \dot{Q}^2$$

② TORUS PRESSURE = 18.2 PSIA (3.5 PSIG)
TORUS TEMPERATURE = 140°F

$$NPSH = \frac{(18.2 - 2.89) \cdot 144}{61.38} + 18.0 - 3.799 \cdot 10^{-7} \dot{Q}^2$$

$$NPSH = 53.9 - 3.799 \cdot 10^{-7} \dot{Q}^2$$

S14-81-F004 rev1

CALCULATION NO.	PREPARED BY	CHECKED BY	PAGE 4
85-104-HWM1	H W McCURDY		

③ TORUS PRESSURE = 36.7 PSIA (22 PSIG)
TORUS TEMPERATURE = 140°F

$$NPSH = \frac{(36.7-2.89)\cdot 144}{61.4} + 18.0 - 3.799\cdot 10^{-7}\dot{Q}^2$$

$$NPSH = 97.3 - 3.799\cdot 10^{-7}\dot{Q}^2$$

④ TORUS PRESSURE = 14.7 PSIA (0 PSIG)
TORUS TEMPERATURE = 140°F

$$NPSH = \frac{(14.7-2.89)\cdot 144}{61.4} + 18.0 - 3.799\cdot 10^{-7}\dot{Q}^2$$

$$NPSH = 45.7 - 3.799\cdot 10^{-7}\dot{Q}^2$$

THE AVAILABLE NPSH IS CALCULATED FOR THE FOLLOWING CONDITIONS,

CONDITION	TORUS PRESSURE (PSIG)	TORUS TEMPERATURE (°F)
SURVEILLANCE TEST	0	90
LOCA CONDITION 1	22	140
LOCA CONDITION 2	3.5 (SEE NOTE 1)	140
LOCA CONDITION 3	0 (SEE NOTE 2)	140

S14-81-F004 rev 1

CALCULATION NO.	PREPARED BY	CHECKED BY	PAGE 5
85-104-HWM1	HW McCURDY	J Johnson	

THE AVAILABLE NPSH FOR THESE CONDITIONS IS PROVIDED IN THE FOLLOWING TABLE. ALSO SHOWN IS THE REQUIRED NPSH (FROM REF. 4) FOR THE SPRAY PUMP FLOW RATES DETERMINED IN REFERENCES 5 AND 7 FOR LOCA CONDITIONS 1, 2 AND 3 AND IN REFERENCE 3 FOR THE SURVEILLANCE TEST.

CONDITION	FLOW PER PUMP (GPM)	NPSH (FEET)	
		REQUIRED	AVAILABLE
SURVEILLANCE TEST	3400	26	46.1
LOCA CONDITION 1			
- W/ ONE PUMP SET	5000	39	87.8
- W/ TWO PUMP SETS	3350	26	93.0
LOCA CONDITION 2			
- W/ ONE PUMP SET	5000	39	44.4
- W/ TWO PUMP SETS	3350	26	49.6
LOCA CONDITION 3			
- W/ ONE PUMP SET	5000	39	36.2
- W/ TWO PUMP SETS	3350	26	41.4

514-81-F004 revi

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CALCULATION NO.	PREPARED BY	CHECKED BY	PAGE 6
85-104-HWM1	HWMcCURDY	J Johnson	

NOTE THAT FOR LOCA CONDITION 3, W/ONE PUMP SET, THE AVAILABLE NPSH (36.2 FT) IS LESS THAN THE REQUIRED NPSH (39 FT.). HOWEVER, THE AVAILABLE NPSH WOULD BE SUFFICIENT IF:

① THE FLOW RATE IS REDUCED FROM 5000 GPM TO 4800 GPM. AT THIS FLOW RATE, THE REQUIRED NPSH EQUALS THE AVAILABLE NPSH.

② THE TORUS WATER TEMPERATURE IS REDUCED TO 118°F WHEN THE PRESSURE IS REDUCED TO 0 PSIG.

- FOR A TORUS PRESSURE OF 0 PSIG AND TORUS WATER TEMPERATURE OF 118°F:

$$NPSH = \frac{(14.7 - 1.60) \cdot 144}{61.77} + 18.0 - 3.799 \cdot 10^{-7} \cdot (5000)^2$$

$$NPSH = 39.0 \text{ FT}$$

THIS AVAILABLE NPSH EQUALS THE REQUIRED NPSH. FROM FIGURE E-33 OF THE NMP-1 FSAR, APPENDIX E, THIS TEMPERATURE OCCURS AT $2 \cdot 10^4$ SECONDS (5.56 HRS) AFTER THE ACCIDENT.

S14-S1-F004 REV 1

③ THE TORUS AIR/STEAM TEMPERATURE IS 114°F. BASED ON NOTE 1, THE TORUS PRESSURE IS,

$$P_T = 14.0 \cdot \frac{460+114}{460+90} + 1.43$$

$$P_T = 16.0 \text{ PSIA.}$$

BASED ON THIS TORUS PRESSURE AND TORUS WATER TEMPERATURE OF 140°F, THE AVAILABLE NPSH IS,

$$NPSH = \frac{(16.0-2.89)\cdot 144}{61.38} + 18.0 - 3.799 \cdot 10^{-7} \cdot (5000)^2$$

$$NPSH = 39.3 \text{ FT.}$$

THIS AVAILABLE NPSH IS ESSENTIALLY EQUAL TO THE REQUIRED NPSH.

S14-81-F004 REV 1

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CALCULATION NO.	PREPARED BY	CHECKED BY	PAGE 8
85-104-HWM1	HW McCURDY	T Johnson	

REFERENCES:

(1) MPR CALCULATION DATED 9/21/88, "MINIMUM NORMAL TORUS WATER LEVEL." (ATTACHED.)

(2) NIAGARA MOHAWK PIPING ISOMETRIC DIAGRAM C-26845-C, "REACTOR CORE SPRAY SYSTEM".

(3) MPR CALCULATION NO. 85-87-TGL7, REV. 0, "HYDRAULIC RESISTANCE OF NMP-1 CORE SPRAY PUMP SUCTION PIPING," T. LESTINA, 11-29-88.

(4) WORTHINGTON CORP., "CHARACTERISTIC CURVES FOR CORE SPRAY PUMPS 81-03, 81-04, 81-23 + 81-24." (ATTACHED).

(5) MPR CALCULATION NO. 85-87-TGL2, REV. 1, "CORE SPRAY SYSTEM FLOWS WITH ONE SET OF PUMPS OPERATING," T. LESTINA, 2-23-89.

(6) WORTHINGTON CORP. DRAWING DEN-17377 DATED 12/13/65.

(7) MPR CALCULATION NO. 85-87-TGL6, REV. 1, "CORE SPRAY SYSTEM FLOWS WITH TWO SETS OF PUMPS OPERATING IN PARALLEL," T. LESTINA, 2-23-89.

NOTES:

(1) FOR THIS LOCA CONDITION, THE TORUS PRESSURE IS ESTIMATED AS FOLLOWS.
THE INITIAL TORUS CONDITIONS ARE ASSUMED TO BE:
- PRESSURE = 14.7 PSIA
- TEMPERATURE = 90°F
- RELATIVE HUMIDITY = 100%

THE TORUS PRESSURE IS GIVEN BY,

$$P_T = P_A + P_S$$

WHERE,

P_A = AIR PARTIAL PRESSURE, PSIA

P_S = STEAM (WATER VAPOR) PARTIAL PRESSURE, PSIA

THE INITIAL PARTIAL PRESSURES ARE,

P_{S_0} = 0.70 PSIA (AT 90°F FROM ASME STEAM TABLES)

$P_{A_0} = 14.7 - 0.70 = 14.0$ PSIA

FOR THE LOCA CONDITION, THE PARTIAL PRESSURES ARE,

P_S = 2.9 PSIA (AT 140°F)

$$P_A = 14.0 \cdot \left(\frac{460+140}{460+90}\right) = 15.3 \text{ PSIA}$$

THE TORUS PRESSURE IS,

$P_T = 2.9 + 15.3 = 18.2$ PSIA (3.5 PSIG)

(2) THE TORUS PRESSURE OF 0 PSIG (14.7 PSIA) IS PRESCRIBED IN NRC SAFETY GUIDE 1.

S14-81-F004 rev 1

MPR ASSOCIATES, INC.
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Title: MINIMUM NORMAL TORUS WATER LEVEL
Calculated by: W Schlaseman **Date:** 9-21-88
Checked by: J Regan **Date:** 9/21/88
Reviewed by: J Regan **Date:** 9/21/88

Project: NMP-1

Page 1 **of** 1

I. PURPOSE: To calculate the minimum normal water level in the Nine Mile Point Unit 1 torus (suppression chamber)

II. RESULTS: The minimum normal torus water level is 10 ft.

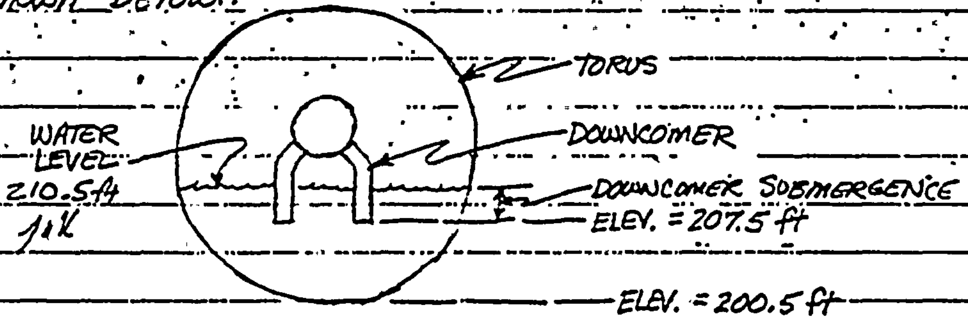
III. REFERENCES:

1. CBI dwg. 9-1370 sh. 313, NMPC Index 3-N2-S22.4

2. NMP1 Tech. Spec. Section 3.3.2

IV. CALCULATION:

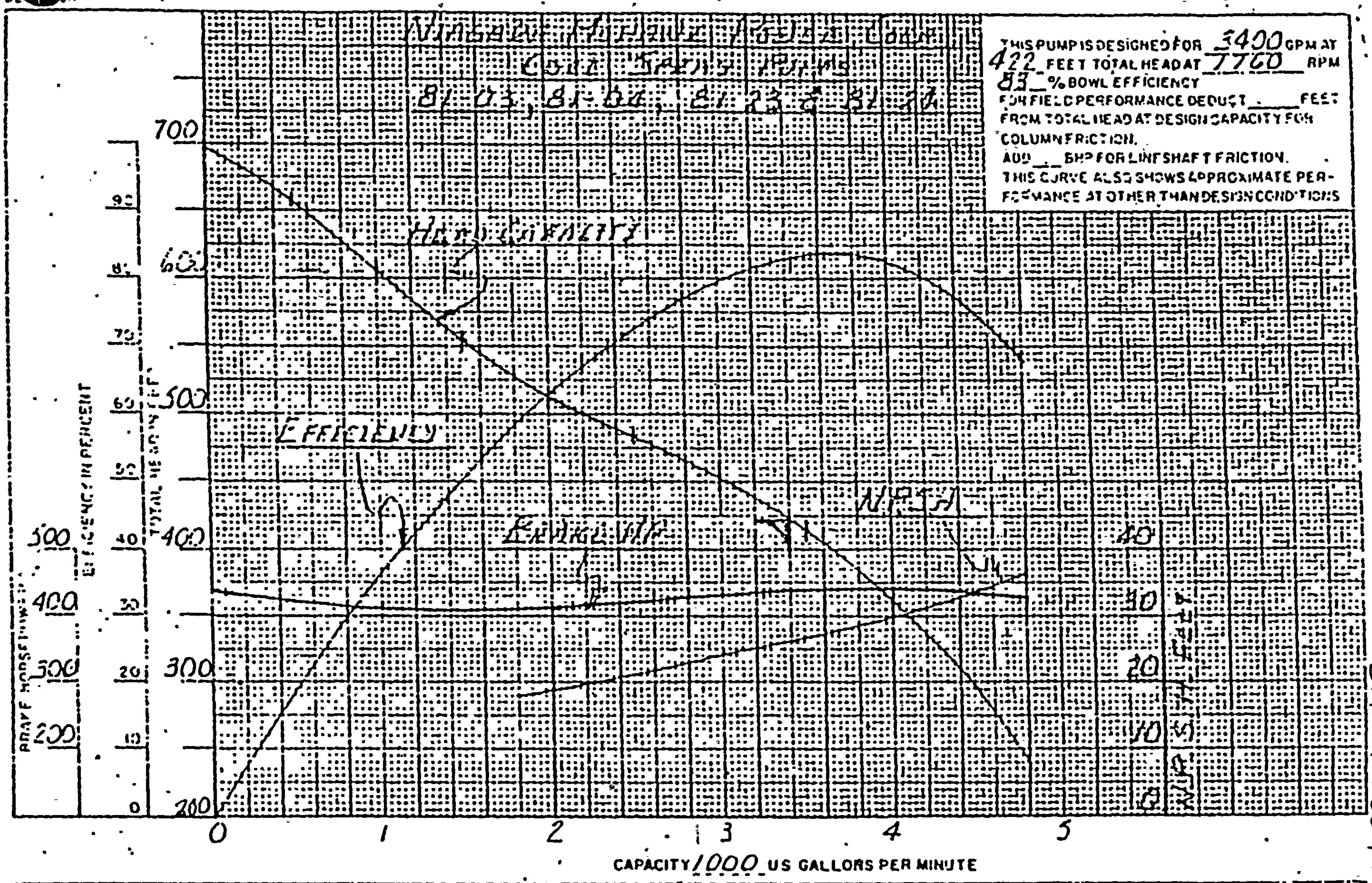
From Ref. 1, an elevation view of a torus cross-section is shown below:



From Ref. 2, the minimum downcomer submergence is 3 ft.

∴ Minimum normal torus water level =

$$3ft + [207.5 ft - 200.5 ft] = 10 ft$$



THIS PUMP IS DESIGNED FOR 3400 GPM AT 422 FEET TOTAL HEAD AT 1760 RPM 83 % BOWL EFFICIENCY
FOR FIELD PERFORMANCE DEDUCT ____ FEET FROM TOTAL HEAD AT DESIGN CAPACITY FOR COLUMN FRICTION.
ADD ___ BHP FOR LINESHAFT FRICTION.
THIS CURVE ALSO SHOWS APPROXIMATE PERFORMANCE AT OTHER THAN DESIGN CONDITIONS

IMPELLER	BOWL	15H113-40 PUMP	**WORTHINGTON CORPORATION**	3-13-68 DATE	VTP 11961-67 SERIAL NO
IMP DIA	450 DRIVER	6 NO OF STAGES	VERTICAL PUMP DIVISION	NT-155 CUST NO	DTP 26993 ORDER NO
TEST NO.	1760 RPM	DRAWN BY	DENVER, COLORADO U.S.A. ALHAMBRA, CALIFORNIA U.S.A.	QUOTE NO	DEN-21274 CURVE NO

3-N2-S16.9

S14-81-F004 rev 1, 72

NIAGARA MOHAWK

CALCULATION COVER SHEET

NUCLEAR ENGINEERING & LICENSING

DISCIPLINE: MECHANICAL

PAGE 1A

PROJECT: NINE MILE POINT NUC. STA.-UNIT 1

CALC. NO. S14-81-F005

SUBJECT: CORE SPRAY SYSTEM FLOW - ONE PUMP SET

BUILDING: REACTOR

FLOOR ELEV.: VARIOUS

INDEX NO.: 3-N2.1-S14

ORIGINATOR(S): MPR ASSOCIATES, INC.

TOTAL SHTS. ~~17~~ 40

CHECKER(S): MPR ASSOCIATES, INC.

LAST SHT. NO: ~~16~~ 39

RECORD OF ISSUES

REV.	DESCRIPTION	M.O.#	BY	DATE	CHKD.	DATE	APPD.	DATE	DATE FILMED:
0	CORE SPRAY SYSTEM FLOW - ONE PUMP SET	2988	T. LESTINA	11/29/88	K.M. LIFE	11/30/88	LAK	12/3/88	
1	REVISED FLOW BASED ON NEW SYS. RESISTANCE AND BYPASS FLOW	2988	T. LESTINA	2/23/89	L. STEVENS	2/24/89	L.A. Kusowski	3/2/89	
1	ADDED APPENDIX TO ADDRESS UNCERTAINTY IF SYS. RESIST.								
1	supercedes rev 0 in its entirety								

COMPUTER OUTPUT YES ☐ NO ☒

SAFETY RELATED YES ☒ NO ☐

DRAWINGS REFERENCED:

DWG. NO.	INDEX	SHT.	REV.
SEE PAGE 15 & 16.			

REFERENCES:

CALC. S14-40-F003

SEE PAGE 15 & 16

KEYWORDS: NMP1, SSFI, CORE SPRAY, FLOW

CROSS REF.: 85-87-TGL2

S14-81-F005 Rev. 1

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CALCULATION TITLE PAGE

CLIENT Niagara Mohawk	PAGE 1 OF 39
PROJECT Core Spray SSFI	TASK NO. 85-87
CALCULATION TITLE Core Spray System Flows With One Set of Pumps Operating	CALCULATION NO. (OPTIONAL) 85-87-T6L2

PREPARER(S)/DATE	CHECKER(S)/DATE	REVIEWER(S)/DATE	REV. NO.
T. Lestina 11/29/88	11/30/88	J Johnson 11/30/88	0
T. Lestina 2/23/89	L. Stevens 2/24/89	John Johnson 2/23/89	1

S14-81-F005 rev 1

CALCULATION NO.	PREPARED BY	CHECKED BY	PAGE
85-87-TGLZ	T. Lestina	L. Stevens	2

Purpose: The purpose of this calculation is to determine the core spray flows for different reactor pressures with one set of core spray pumps operating.

Summary: The reactor flows for different reactor pressures and strainer cloggings are shown below:

Reactor Pressure (psig)	Reactor Flow (gpm)	
	Clean Strainer	50% clogged Strainer
0 [1]	4870	4790
160 [2]	3580	3530
365 [3]	160	160

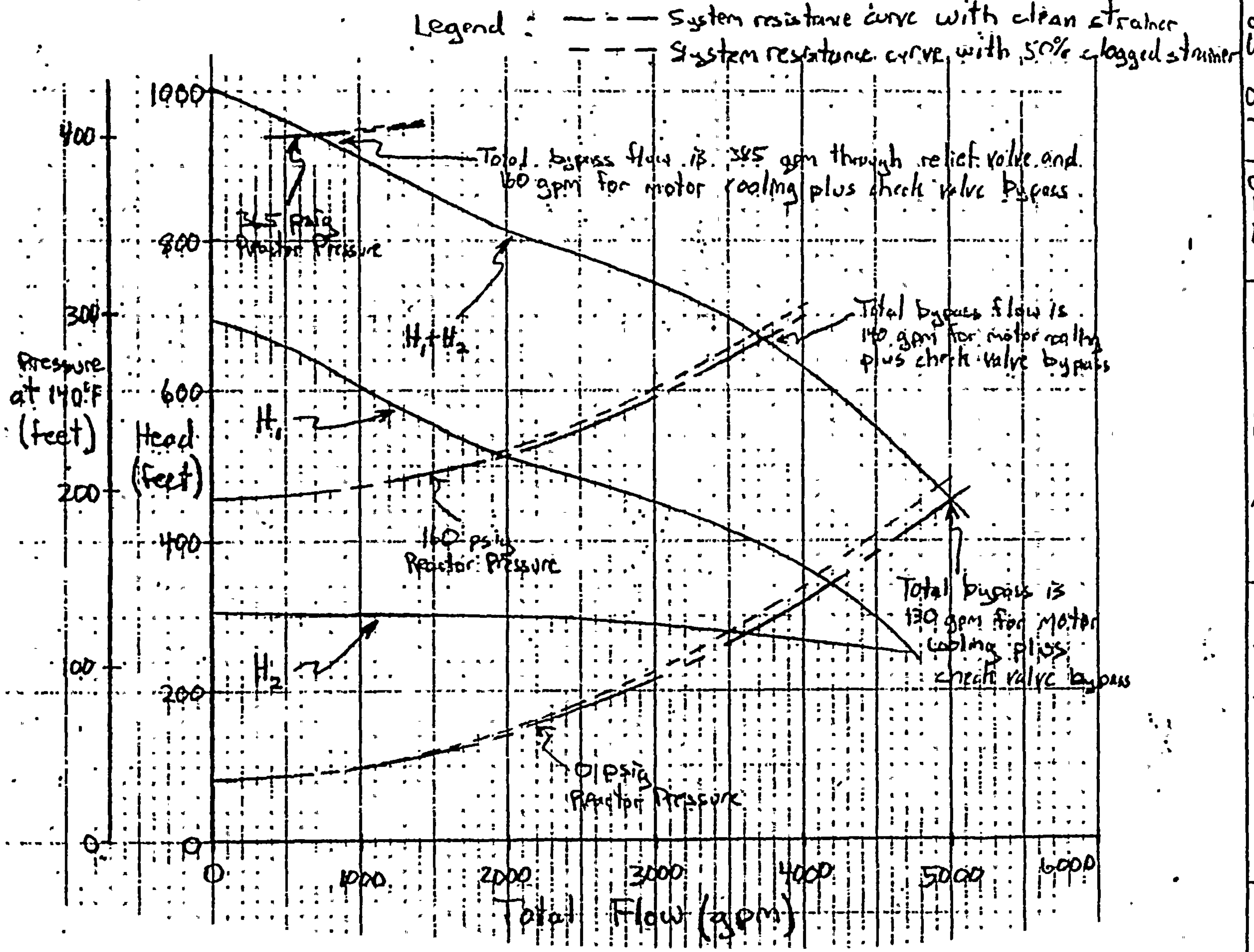
Notes:

1. With the reactor pressure at 0 psig, bypass flow through the relief valve is 0 gpm and the bypass flow for the pump seal and motor cooling plus bypass flow around the idle topping pump check valve is 130 gpm.
2. With the reactor pressure at 160 psig, bypass flow through the relief valve is 0 gpm and the bypass flow for the pump seal and motor cooling plus the bypass flow around the idle topping pump check valve is 140 gpm.
3. With the reactor pressure at 365 psig, bypass flow through the relief valve is 385 gpm and the bypass for the pump seal and motor cooling plus bypass flow around the idle topping pump check valve is 160 gpm.

These flows are determined from Figure 1, Head Versus Total Flow, and the calculations herein. A multibranch computer code FLONET is used to verify calculated results.

Figure 1 is a plot of total developed head $(H_1 + H_2)$ and system resistances $\left((P/\rho)_r - (P/\rho)_T + R_1 Q^2 + R_2(Q - Q_{Bypass})^2\right)$. The intersection of the total head and system resistance is the total flow (reactor flow plus bypass flow).

Figure 2 is a plot of reactor pressure versus reactor flow.



Head Versus Total Flow

Figure 1

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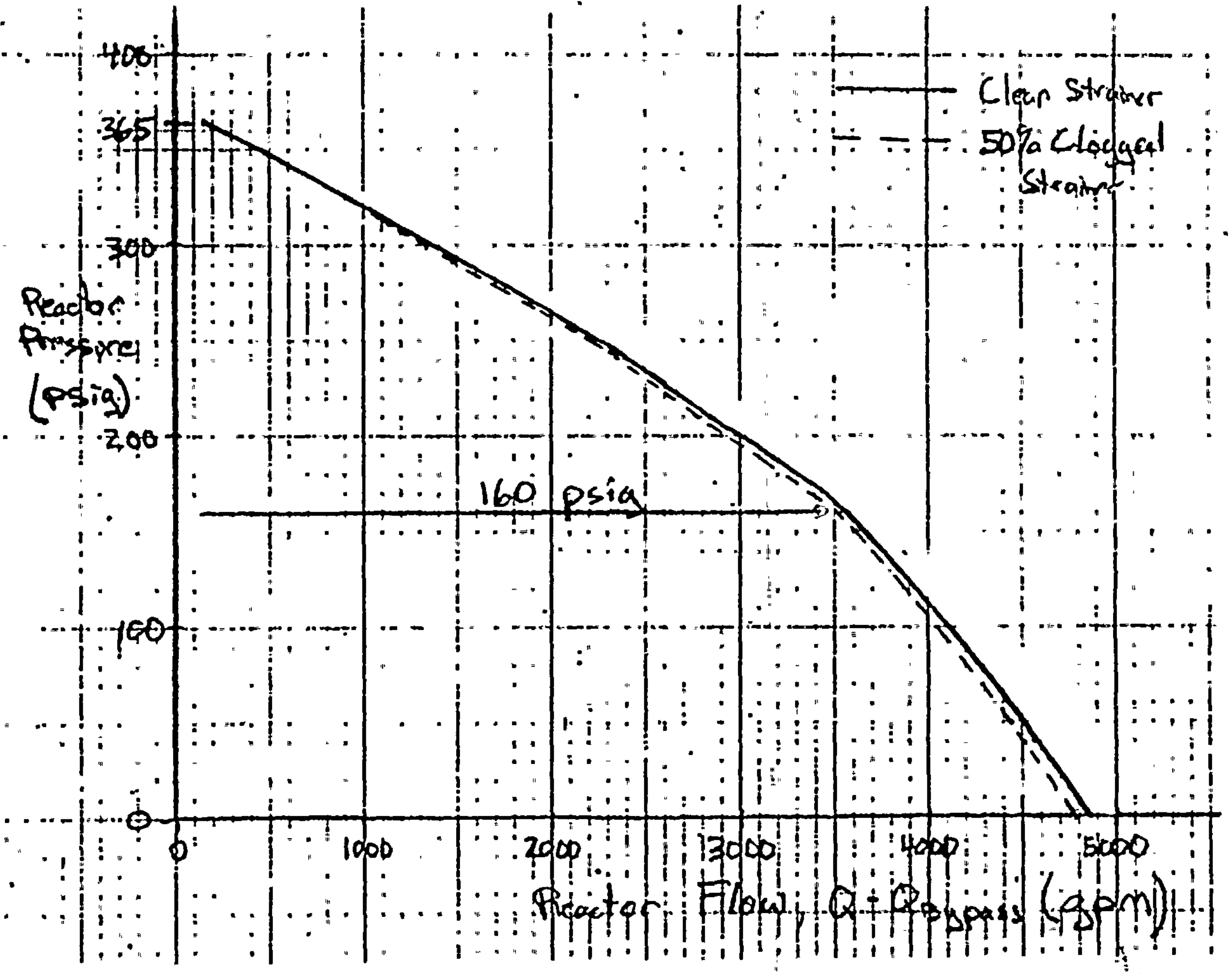

Reactor Pressure Versus Reactor Flow
Figure. 2

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CALCULATION NO.	PREPARED BY	CHECKED BY	PAGE
85-87-T6L-2	T. Lestina	P. Stevens	6

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CALCULATION NO.	PREPARED BY	CHECKED BY	PAGE
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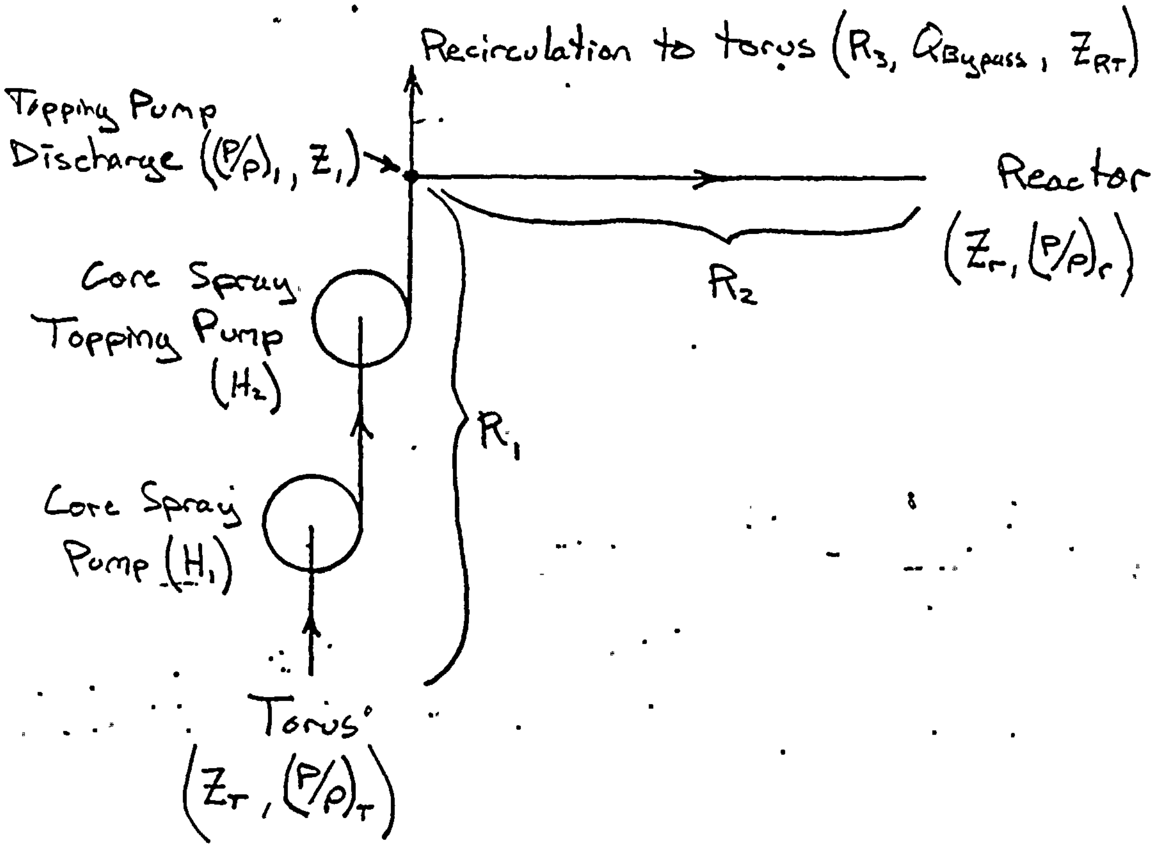
Calculation:



Applying the energy equation for incompressible fluids, from Reference (1):

$$\left(\frac{P}{\rho}\right)'_T + \left(\frac{V^2}{2g}\right)_T + Z_T + H_1 + H_2 = \left(\frac{P}{\rho}\right)'_r + Z_r + \left(\frac{V^2}{2g}\right)_r + R_1 Q^2 + R_2\left(Q - Q_{Bypass}\right)^2$$

where

$\left(\frac{P}{\rho}\right)'_T$, $\left(\frac{P}{\rho}\right)'_r$, $\left(\frac{P}{\rho}\right)'_1$ = pressure head in feet for torus reactor, and topping pump discharge, respectively.

$\left(\frac{V^2}{2g}\right)_T, \left(\frac{V^2}{2g}\right)_r, \left(\frac{V^2}{2g}\right)_1$ = velocity head in feet at the torus and reactor, respectively.

$\left(\frac{P}{\rho}\right)_T, \left(\frac{P}{\rho}\right)_r, \left(\frac{P}{\rho}\right)_1$ = sum of velocity head and pressure head such that

$$\left(\frac{P}{\rho}\right)_T = \left(\frac{P}{\rho}\right)'_T + \left(\frac{V^2}{2g}\right)_T, \left(\frac{P}{\rho}\right)_r = \left(\frac{P}{\rho}\right)'_r + \left(\frac{V^2}{2g}\right)_r$$

$$\left(\frac{P}{\rho}\right)_1 = \left(\frac{P}{\rho}\right)'_1 + \left(\frac{V^2}{2g}\right)_1$$

H_1, H_2 = total developed head in feet of core spray pump and topping pump, respectively.

R_1 = hydraulic resistance of pump suction and riser piping in ft/gpm^2

R_2 = hydraulic resistance of piping from topping pump discharge to reactor in ft/gpm^2

R_3 = hydraulic resistance of relief valve pump recirculation piping in ft/gpm^2.

Q = total volumetric flow in gpm

Q_{Bypass} = volumetric flow of pump recirculation in gpm

Assumptions:

1. The pump recirculation flow through the relief valve branches off at the tee where the flows combine from the two pump sets. Piping isometrics, reference (8), indicate that recirculation piping is close enough to the tee to neglect losses.

2. The velocity head at the torus and reactor (following sparger discharge) is zero such that $\left(\frac{P}{\rho}\right)_T = \left(\frac{P}{\rho}\right)'_T$ and $\left(\frac{P}{\rho}\right)_r = \left(\frac{P}{\rho}\right)'_r$. Dissipation of velocity head is included in the calculation of R_2.

3. Torus pressure is 0 psig $\left(\left(\frac{P}{\rho}\right)_T = 0 \text{ ft.}\right)$: This is conservative since torus pressure increases during a design basis accident.

4. The relief valve in the recirculation piping is closed when the total pressure, $(P/\rho)_1$, is less than 280 psig (from conversations with operating personnel) and the valve is fully open at pressures greater than 280 psig. The differences between $(P/\rho)'_1$ and $(P/\rho)_1$ due to the velocity head are negligible compared with the conservative assumption that the

relief valve is fully opened at all pressures greater than 280 psig.

$$\text{velocity head} = \left(\frac{V^2}{2g}\right)_1 = \frac{\left[(5000\,\text{gpm})\left(\frac{1\,\text{ft}^3}{7.4805\,\text{g}}\right)\left(\frac{1\,\text{min}}{60\,\text{s}}\right)\left(\frac{1}{.7854\,\text{ft}^2}\right)\right]^2}{2\cdot 32.2\,\text{ft}/\text{s}^2}$$

$$= 3.12\,\text{ft.}$$

This velocity head has a negligible impact on relief valve closing used to prepare Figure 2.

5. The bypass flow around the idle topping pump check valve and the pump seal and motor cooling are assumed to have a negligible impact on system resistance, however the reactor flow is reduced by the flows calculated on p. 16-29. This assumption is conservative since these flows tend to reduce system resistence and thus increase total flow.

Figure 1

Rearranging the energy equation,

$$H_1 + H_2 = (P/\rho)_r - (P/\rho)_T + Z_r - Z_T + R_1 Q^2 + R_2 (Q - Q_{Bypass})^2$$

Z_r = 292.5 ft. from Reference (15) for the top sparger discharge

Z_T = 210.5 ft. from Refrence (14)

Z_1 = 245.83 ft. from most recent revision of Reference (8)

$(P/\rho)_T = 0$ ft.

ρ = 61.38 lbf/ft^3 at 140°F from Reference (c)

From reference (3)

$R_1 = 1.56824(10^{-6})$ ft./gpm^2 clean strainer

$= 2.57291(10^{-6})$ ft./gpm^2 50% clogged strainer

From reference (4)

$R_2 = 1.35530(10^{-5})$ ft./gpm^2

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Reactor pressure = 0 psig

Assume $Q_{Bypass} = 0$ gpm

Total flow from Figure 1 = 5000 gpm

$$(P/\rho)_1 = (P/\rho)_r + (Z_r - Z_1) + R_2 Q^2$$

$$= 46.67 + 1.35530(10^{-5})Q^2 = 385 \text{ ft.}$$

$$P_1 = \frac{61.38}{144}(385) = 164 < 280 \text{ psig}$$

$$\therefore Q_{Bypass} = 0 \text{ gpm}$$

From energy equation,

$$H_1 + H_2 = (P/\rho)_r + (Z_r - Z_T) + (R_1 + R_2) Q^2$$

$$H_1 + H_2 = 82.0 + (R_1 + R_2) Q^2$$

The solution to this equation is shown in Figure 1 for both clean and 50% clogged strainer.

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Reactor Pressure = 160 psig

Assume $Q_{Bypass} = 0$ gpm

Total flow from Figure 1 = 3720 gpm

$$(P/\rho)_1 = (P/\rho)_r + (Z_r - Z_1) + R_2 Q^2$$

$$= \frac{160(144)}{61.38} + 46.67 + 1.35530(10^{-5})(3720)^2 = 610 \text{ ft.}$$

$$P_1 = \frac{61.38}{144}(610) = 260 < 280 \text{ psig}$$

From energy equation,

$$H_1 + H_2 = (P/\rho)_r + (Z_r - Z_T) + (R_1 + R_2)Q^2$$

$$H_1 + H_2 = 457.37 + (R_1 + R_2)Q^2$$

The solution to this equation is shown for both clean and 50% clogged strainer.

Reactor Pressure = 365 psig

Assume $Q_{Bypass} \neq 0$. The following two step approach is used to calculate the resistance curve:

Step 1. Apply the energy equation between point 1 and the reactor,

$$\left(P/\rho\right)_1 = \left(\frac{P}{\rho}\right)_r + \left(Z_r - Z_1\right) + R_2\left(Q - Q_{Bypass}\right)^2$$

$$= 902.98 + 1.35530(10^{-5})\left(Q - Q_{Bypass}\right)^2$$

(P_1 is checked to ensure it is greater than 280 psig)

Step 2. Apply the energy equation between point 1 and the torus discharge (through the recirc. line)

$$\left(P/\rho\right)_T + Z_{RT} + R_3\, Q_{Bypass}^2 = \left(P/\rho\right)_1 + Z_1$$

$\left(P/\rho\right)_T = 0$ ft. $Z_{RT} = 214.0$ ft. from reference (8)

$R_3 = 6.32571(10^{-3})$ ft/gpm^2 from reference (5)

$$Q_{Bypass} = \sqrt{\frac{\left(P/\rho\right)_1 + \left(Z_1 - Z_{RT}\right)}{R_3}}$$

$$\bar{Q}_{Bypass} = \sqrt{\frac{(P/\rho)_1 + 31.83}{6.32571(10^{-3})}}$$

This approach permits the calculation of $(P/\rho)_1$ independent of H_1 and H_2 so that a system resistance curve can be calculated.

$Q - Q_{Bypass}$ gpm	$(P/\rho)_1$ Feet (psig)	Q_{Bypass} gpm	Q gpm
0	902.98 (385)	384	384
200	903.52 (385)	385	585
400	905.15 (386)	385	785
600	907.86 (387)	385	985
800	911.65 (389)	386	1186
1000	916.53 (391)	387	1387

The system resistance curve is calculated from these values and the energy equation:

$$H_1 + H_2 = (P/\rho)_r + (Z_r - Z_T) + R_1 Q^2 + R_2 (Q - Q_{Bypass})^2$$

$$H_1 + H_2 = 938.31 + R_1 Q^2 + 1.35530(10^{-5})(Q - Q_{Bypass})^2$$

The solution to this equation is shown in Figure 1 for both clean and 50% clogged strainer.

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Correction to Calculated Reactor Flow Due To Pump Motor and Seal Cooling Flow and Check Valve Bypass Flow

For this analysis, it is assumed that bypass flow for pump motor and seal cooling and bypass flow around the idle topping pump discharge check valve does not change system resistance. Rather, the reactor flow is corrected by subtracting calculated bypass flows from reactor flows calculated from p. 1 to 15.

This method is conservative because the system resistance is reduced due to these bypass flows and thus the total flow is increased.

Reactor Pressure	Check Valve Bypass Flow	Topping Pump Motor and Seal Cooling Flow	Core Spray Pump Motor Cooling Flow
0	60	30	40
160	70	30	40
365	90	30	40

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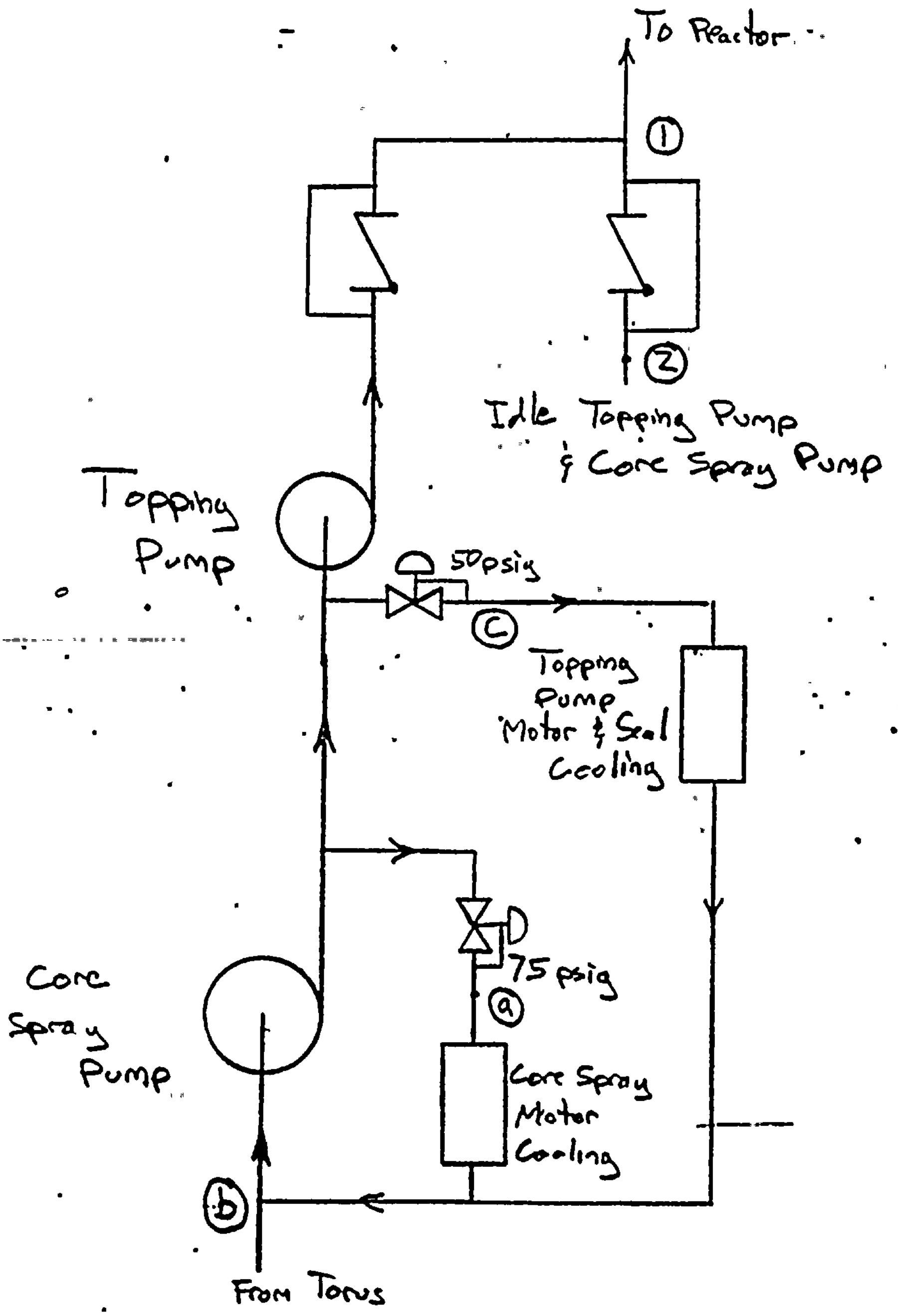
CALCULATION NO.	PREPARED BY	CHECKED BY	PAGE
85-87-T6L2	T. Lestina	J Johnson	17



Schematic Configuration of Core Spray Pump Motor Cooling, Topping Pump Motor and Seal Cooling and Topping Pump Check Valve Bypass

Calculation of Bypass Flow Around Idle Topping Pump Check Valve

Point 1 is the topping pump discharge (downstream of check valve)
Point 2 is the idle topping pump discharge (upstream of check valve)

From reference (1),

$$Z_1 + \frac{P_1}{\rho} + \frac{V_1^2}{2g} = Z_2 + \frac{P_2}{\rho} + \frac{V_2^2}{2g} + h_L$$

assume $Z_1 - Z_2$ and $\frac{V_1^2}{2g} - \frac{V_2^2}{2g}$ can be neglected. Assume $P_2 = 0$ psig $= 0$ ft.

$$\therefore \frac{P_1}{\rho} = h_L = K\frac{V^2}{2g} = R_{cv} Q^2_{cv\,Bypass}$$

$$Q_{cv\,Bypass} = \sqrt{\frac{P_1}{\rho R_{cv}}}$$

where P_1 is the pressure at topping pump discharge

Using reference (1) to calculate R_{cv}

$$K = \left(\frac{L}{D}\right)_{effective} f_T \quad \text{for fittings}$$

$$K = \frac{L}{D} f \quad \text{for straight pipe}$$

From references (10), (11) 3/4 inch schedule 160 pipe

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CALCULATION NO.	PREPARED BY	CHECKED BY	PAGE
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$$Re = \frac{\bar{V}D}{\nu}, \quad \nu = .514(10^{-5})\ ft^2/s \text{ at } 140°F \text{ from Reference (2)}$$

assume 75 gpm

Area from p. B-16 Reference (1).

$$Re = \frac{(75\ gpm)\left(\frac{1\ min}{60\ s}\right)\left(\frac{1\ ft^3}{7.4805\ g}\right)\left(\frac{1}{.00206\ ft^2}\right)\left(\frac{.612}{12}\right)ft}{0.514(10^{-5})\ ft^2/s} = 8.05(10^5)$$

From Reference (1) p. A-25. $f \approx .027$

Component (from Reference (11))	K-factor (3/4")
Entrance loss (assume sharp edge)	0.50 (.612" ID)
Straight Pipe (assume 7') $f = .027$ $.027 \frac{7}{.612/12}$	3.71 (.612" ID)
90° Elbow (2) - socket welded use $30 f_T$ $\quad 2 \cdot 30 \cdot .025$ $f_T = .025$	1.50 (.612" ID)
Discharge loss (lost velocity head)	1.00
Total K	6.71 (.612" ID)

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$$h_L = K\frac{V^2}{2g} = R_{cv}Q^2_{CVBypass}$$

$$h_L = K\frac{\left(\frac{1\ min}{60\ s}\right)^2\left(\frac{1\ ft^3}{7.4805\ g}\right)^2\left(\frac{1}{.60206\ ft^2}\right)^2\left(Q\ gpm\right)^2}{2(32.2)\ ft/s^2}$$

$$h_L = 1.81642(10^{-2})K\,Q^2$$

$$R_{cv} = .121882\ ft/gpm^2$$

From previous page,

$$Q_{CVBypass} = \sqrt{\frac{P_1}{\rho\ R_{cv}}}$$

$\rho = 61.38\ lbf/ft^3$ at 140°F from Reference (2)

$$Q_{CVBypass} = \sqrt{\frac{P_1\left(lb/in^2\right)\left(\frac{144\ in^2}{1\ ft^2}\right)}{\left(61.38\ \frac{lb}{ft^3}\right)\left(.121882\ \frac{ft}{gpm^2}\right)}} = 4.38731\sqrt{P_1}$$

with P_1 in psig

From p. 12-15

$P_1 = 164$ psig with reactor pressure = 0 psig

$Q_{CV\,Bypass} = 4.38731\sqrt{164} = 56.2$ gpm

$P_1 = 260$ psig with reactor pressure = 160 psig

$Q_{CV\,Bypass} = 4.38731\sqrt{260} = 70.7$ gpm

$P_1 = 385$ psig with reactor pressure = 365 psig

$Q_{CV\,Bypass} = 4.38731\sqrt{385} = 86.1$ gpm

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Calculation of Core Spray Motor Cooling Flow

Point a is downstream of the motor cooling pressure control valve (see sketch in p. 17)

Point b is at the discharge of the motor cooling at the core spray pump suction

From reference (1),

$$Z_a + \frac{P_a}{\rho} + \frac{V_a^2}{2g} = Z_b + \frac{P_b}{\rho} + \frac{V_b^2}{2g} + h_L$$

assume $Z_a - Z_b$ and $\frac{V_a^2}{2g} - \frac{V_b^2}{2g}$ can be neglected.

assume $P_b = 0$ psig (for this analysis only)

$P_a = 75$ psig from Reference (10)

$$\frac{P_a}{\rho} = h_L = K\frac{V^2}{2g} = R_{CS}\, Q_{CS\,Bypass}^2$$

$$Q_{CS\,Bypass} = \sqrt{\frac{P_a}{\rho\, R_{cs}}}$$

Using reference (1) to calculate R_{cs}:

$K = \left(\frac{L}{D}\right)_{effective} f_T$ for fittings

$K = \frac{L}{D} f$ for straight pipe

From references (12), (13) 3/8 inch and 3/4 inch schedule 40 pipe

$Re = \frac{VD}{\nu}$ $\nu = .514(10^{-5})$ ft²/s at 140°F from reference (2)

assume 40 gpm

$$Re = \frac{(40\text{ gpm})\left(\frac{1\text{ min}}{60\text{ s}}\right)\left(\frac{1\text{ ft}^3}{7.4805\text{ g}}\right)\left(\frac{1}{.00133\text{ ft}^2}\right)\left(\frac{.493}{12}\right)\text{ft}}{.514(10^{-5})\text{ ft}^2/\text{s}} = 5.36(10^5)$$

for 3/8" pipe

From Reference (1) p. A-25 f ≈ .028

$$Re = \frac{(40\text{ gpm})\left(\frac{1\text{ min}}{60\text{ s}}\right)\left(\frac{1\text{ ft}^3}{7.4805\text{ g}}\right)\left(\frac{1}{.00371\text{ ft}^2}\right)\left(\frac{.824}{12}\right)\text{ft}}{.514(10^{-5})\text{ ft}^2/\text{s}} = 3.21(10^5)$$

for 3/4" pipe

From Reference (1) p. A-25 f ≈ .024

<u>Component</u> (from Reference (13)) — <u>K-Factor (3/4")</u>

3/4" Straight Pipe (assume 25') f = .024 — 8.74 (.824" ID)

$f\left(\frac{L}{D}\right) = .024\left(\frac{25}{.824/12}\right)$

3/8" Straight Pipe (assume 1') f = .028

$f\left(\frac{L}{D}\right) = .028\left(\frac{1}{.493/12}\right) = .68$ for 3/8" pipe — 5.31 (.824" ID)

$$K_{3/4"} = \left(\frac{d_{3/4"}}{d_{3/8"}}\right)^4 K_{3/8"} = \left(\frac{.824}{.493}\right)^4 .68 = 5.31$$

90° Elbows (assume 7) socket welded — 5.25 (.824" ID)

use 30 f_T $7 \cdot 30 \cdot (.025) = 5.25$

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Component (continued)	K-factor	
45° Elbows (assume 2) socket welded use $16f_T$ $2 \cdot 16 \cdot .025 = .80$	0.80	(.824"ID)
Tee - run flow (assume 1) $20f_T = 20 \cdot .025 = .50$	0.50	(.824"ID)
Total K-factor (neglecting motor cooling heat exchanger losses)	20.60	(.824"ID)

$$\therefore \quad h_L = K\frac{V^2}{2g} = R_{cs}\, Q^2_{csBypass}$$

$$h_L = \frac{K\left(\frac{1\ \text{min}}{60\ \text{s}}\right)^2\left(\frac{1\ \text{ft}^3}{7.4805\ \text{g}}\right)^2\left(\frac{1}{.00371\ \text{ft}^2}\right)^2\left(Q_{gpm}\right)^2}{2(32.2)\ \text{ft/s}^2}$$

$$h_L = K\left(5.60019(10^{-3})\right)Q^2$$

$$R_{cs} = .115364\ \text{ft}/\text{gpm}^2$$

From previous page,

$$Q_{csBypass} = \sqrt{\frac{P_a}{\rho\, R_{cs}}}$$

P_a = 75 psig from Reference (10)

(With reactor pressure = 0 psig, Q ≈ 4800 gpm and the core spray discharge pressure is less than 75 psig as is indicated in Reference (6), however the 75 psig assumption is conservative for this analysis.)

$$Q_{csBypass} = \sqrt{\frac{(75\ psig)\left(\frac{144\ in^2}{1\ ft^2}\right)}{\left(61.38\ lb/ft^3\right)\left(.115364\ ft/gpm^2\right)}}$$

$$Q_{csBypass} = 39.1\ gpm$$

Calculation of Topping Pump Motor and Seal Cooling Flow

Seal flow is neglected since it is a small value (less than 10 gpm*). More specifically, the conservative margin in the calculation of the motor cooling flow accounts for the seal cooling. *From conversations with Worthington

Point c is downstream of the motor cooling pressure control valve (see sketch on p. 17)

Point b is at the discharge of the motor cooling at the core spray pump suction

From reference (1),

$$Z_c + \frac{P_c}{\rho} + \frac{V_c^2}{2g} = Z_b + \frac{P_b}{\rho} + \frac{V_b^2}{2g} + h_L$$

assume $Z_c - Z_b = 239.5 - 201 = 38.5$ ft. = difference in centreline elevations of pumps

assume $\frac{V_c^2}{2g} - \frac{V_b^2}{2g} = 0$, assume $P_b = 0$

$$\frac{P_c}{\rho} + (Z_c - Z_b) = h_L = K\frac{V^2}{2g} = R_{TP} Q^2_{TPBypass}$$

$$Q_{TPBypass} = \sqrt{\frac{P_c/\rho + (Z_c - Z_b)}{R_{TP}}}$$

Using reference (1) to calculate R_{TP}:

$$K = \left(\frac{L}{D}\right)_{effective} f_T$$ for fittings

$$K = \left(\frac{L}{D}\right) f$$ for straight pipe

From references (10), (12), (13) 3/8" and 3/4" schedule 40 pipe

$Re = \frac{VD}{\nu}$ $\nu = .514(10^{-5})$ ft²/s at 140°F from reference (2)

assume 30 gpm

$$Re = \frac{(30\,gpm)\left(\frac{1\,min}{60\,s}\right)\left(\frac{1\,ft^3}{7.4805\,g}\right)\left(\frac{1}{.00133\,ft^2}\right)\left(\frac{.493}{12}\right)ft}{.514(10^{-5})\,ft^2/s} = 4.02(10^5)$$

From Reference (1) p. A-25 $f \approx .028$

$$Re = \frac{(30\,gpm)\left(\frac{1\,min}{60\,s}\right)\left(\frac{1\,ft^3}{7.4805\,g}\right)\left(\frac{1}{.00371\,ft^2}\right)\left(\frac{.824}{12}\right)ft}{.514(10^{-5})\,ft^2/s} = 2.41(10^5)$$

From Reference (1) p. A-25 $F \approx .024$

Component (from Reference (13))	K-factor 3/4"
3/4" Straight Pipe (assume 11' upstream of motor and 38.5' downstream of motor. Sketches in reference (13) do not show piping downstream of motor and therefore piping to account for elevation head is assumed.)	17.30

$$F\,L/D = .024\left(\frac{49.5}{.824/12}\right) = 17.30$$

Component (continued)	K-factor
3/8" Straight Pipe (assume 1') $f\frac{L}{D} = .028\left(\frac{1}{.493/12}\right) = .68$ (3/8" pipe)	5.31 (.824" ID)
$K_{3/4"} = \left(\frac{d_{3/4"}}{d_{3/8"}}\right)^4 K_{3/8"} = \left(\frac{.824}{.493}\right)^4 .68 = 5.31$	
90° Elbows (assume 4) use $30f_T$ $4\cdot30(.025)$	3.00
Tee - run flow (assume 1) $20f_T$ $20(.025)$	0.50
Total K-factor (neglecting heat exchanger losses)	26.11

$$h_L = K\frac{v^2}{2g} = R_{TP}\,Q^2_{TP\,Bypass}$$

$$h_L = \frac{K\left(\frac{1\text{ min}}{60\text{ s}}\right)^2\left(\frac{1\text{ ft}^3}{7.4805\text{ g}}\right)^2\left(\frac{1}{.00371\text{ ft}^2}\right)^2\left(Q_{gpm}\right)^2}{2\,(32.2)\text{ ft/s}^2}$$

$$h_L = 5.60019(10^{-3})\,K\,Q^2$$

$$R_{TP} = .146221\text{ ft}/\text{gpm}^2$$

As derived earlier,

$$Q_{TP\,Bypass} = \sqrt{\frac{P_c/\rho + (Z_c - Z_b)}{R_{TP}}}$$

$\bar{P}_c$ = 50 psig from Reference (10)

(With reactor pressure = 0 psig, Q ≈ 4800 gpm and the topping pump suction pressure is less than 50 psig, however the 50 psig assumption is conservative for this analysis)

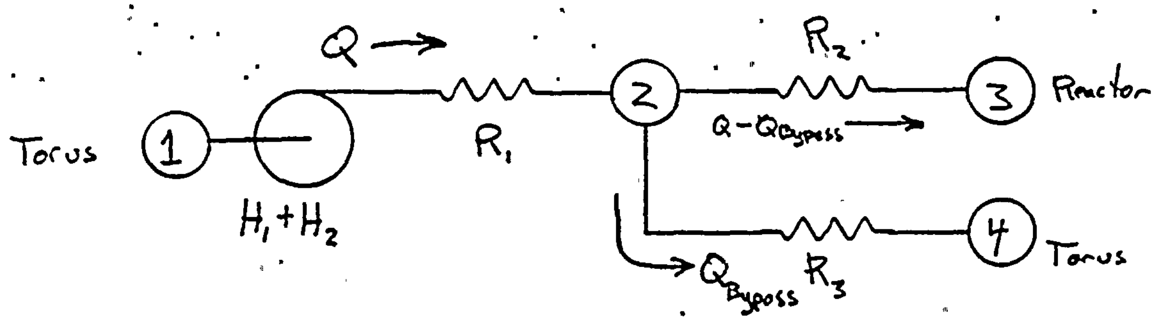
$$Z_c - Z_b = 38.5 \text{ ft}$$

$$Q_{TPBypass} = \sqrt{\frac{\frac{(50 \text{ psig})}{(61.38 \text{ lb/ft}^3)}\left(144 \frac{\text{in}^2}{\text{ft}^2}\right) + 38.5 \text{ ft}}{.146221 \text{ ft/gpm}^2}}$$

$$= 32.6 \text{ gpm}$$

Figure 2. Reactor Pressure (P_r) versus Reactor Flow ($Q - Q_{Bypass}$)

Three points on Figure 2 (reactor pressure = 0, 160 and 365 psig) are from Figure 1. The remaining points on Figure 2 are calculated using a multibranch hydraulic analysis code, FLONET. The following network was used as input to FLONET



Elevations

Node 1: 210.5'
Node 2: 245.83'
Node 3: 292.5'
Node 4: 214.00'

Pressures

Node 1: 0 psig
Node 2: variable
Node 3: 365 psig to 0 psig
Node 4: 0 psig

Resistances

$R_1 = 1.56824 (10^{-4})$ ft. of H_2O/gpm^2 -- clean strainer
$R_2 = 1.35530 (10^{-5})$ ft. of H_2O/gpm^2
$R_3 = 6.32571 (10^{-3})$ ft. of H_2O/gpm^2

CALCULATION NO.	PREPARED BY	CHECKED BY	PAGE
85-87-TGL2	T. Lestina	K.M. Lee	31

$H_1 + H_2$ is inputted into FLONET as a head-flow curve. The following values of flow and head are used as the basis for the head flow curve input (from References (6) and (7))

Flow (gpm)	Total Developed Head (feet) $H_1 + H_2$
0	1001
500	963
1000	909
1500	858
2000	813
2500	781
3000	742
3500	695
4000	632
4500	553
4800	491

FLONET interpolates between inputted head-flow values during the iterative solution.

By establishing constant pressures at nodes 1, 3 and 4, the flows are exactly determined

Assumptions:

1. Flow is calculated for clean strainers and 50% clogged.
2. Torus water temperature is 140°F. ($\rho = 61.38\ lb/ft^3$)
3. With pressures at node 2 less than 280 psig, the relief valve flow is 0 gpm.
4. Bypass flow around idle topping pump check valve and for motor cooling is calculated as a post processing from p. 16. The reactor flows shown below have been corrected for all bypass flows.

Reactor Pressure (psig)	Reactor Flow (gpm) Clean Strainer	50% Clogged Strainer	Relief Valve Bypass Flow (gpm)	Total Bypass flow for motor cooling and check valve bypass (gpm)
>365	0	0	~385	~160
365	160	160	385	160
350	460	460	380	150
300	1380	1350	360	150
250	2270	2230	340	150
210	2840	2790	330	140
160	3580	3530	0	140
150	3680	3620	0	140
100	4120	4060	0	140
50	4510	4450	0	130
40.3 (55 psia)	4570	4510	0	130
15.3 (30 psia)	4750	4670	0	130
0 (14.7 psia)	4870	4790	0	130

S14-81-F005 rev 1

CALCULATION NO.	PREPARED BY	CHECKED BY	PAGE
85-87-TGL2	T. Lestina		33

References

1. Crane Technical Paper No. 410, "Flow of Fluids Through Valves, Fittings, and Pipe.", 1982.
2. Daugherty, R.L. and Franzini, J.B. Fluid Mechanics with Engineering Applications, McGraw Hill Book Company, New York 1977.
3. MPR Calculation 85-87-TGL5, "Hydraulic Resistance of NMP1 Core Spray Pump and Topping Pump Suction and Riser Piping", Rev. 1, 2/23/89.
4. MPR Calculation 85-87-TGL4, "Hydraulic Resistance of NMP1 Core Spray Topping Pump Discharge Piping to the Reactor", Rev. 1, 1/12/89.
5. MPR Calculation 85-87-TGL3, "Hydraulic Resistance of NMP1 Core Spray Recirculation Piping", Rev. 0 11/29/88.
6. NMP1 Core Spray Pump Head - Flow Curve, Worthington Corp. Curve DEN-21274, 3/13/68. (ATTACHED)
7. NMP 1 Core Spray Topping Pump Head - Flow Curve, Worthington Corp. Curve, 3/7/68. (ATTACHED)

8. Niagara Mohawk Drawing No. C-26845-C, "Reactor Core Spray System 81 & 81.1 Piping Isometric", Sheet 3, Rev. 10.

9. Niagara Mohawk Drawing No. C-26844-C, "Reactor Core Spray System 40 Piping Isometric", Rev. 8.

10. Niagara Mohawk P&I Diagram C-18007-C, "Reactor Core Spray", Rev. 33.

11. Telecopy from L.A. Klosowski (Niagara Mohawk) to J. Johnson (MPR Associates) showing sketch of core spray topping pump check valve bypass, 12/12/88 (ATTACHED)

12. Piping Specifications for Reactor Core Spray System, Rev. 1.

13. Telecopy from L. Klosowski (Niagara Mohawk) to J. Johnson (MPR Associates) showing sketch of core spray pumps and topping pump motor cooling piping, 12/16/88. (ATTACHED)

S14-81-F005 r=1.

CALCULATION NO.	PREPARED BY	CHECKED BY	PAGE
85-87-TGL2	T. Lestina	L. Steiner	35

14. MPR Calculation, "Minimum Normal Torus Water Level", C.S. Schlaseman, 9/21/88.

15. GE Drawing 104R859, "Arrangement and Assembly of Reactor", Rev. 8.

16. MPR Calc. 85-104-CSS1, "Topping Pump Pressures During Surveillance Testing", Rev. 1, 12/24/88.

Appendix A -- Estimation of Analysis Uncertainty

From the energy equation, the terms which provide a source of uncertainty are: pressures, elevations, pump heads and system resistances (R).

a. Pressures -- the assumption of 0 psig in the torus is conservative since the torus pressure will rise during a design basis accident

b. Elevation -- the assumed elevations are considered to be accurate to within one foot.

c. Pump Heads -- the pump surveillance data (reference (16)) indicates that the certified pump head (references (6) and (7)) are less than measured pump head. Therefore, the analysis is conservative with respect to pump head

d. System Resistance -- this is the principle uncertainty in the analysis. Using the system resistances with 50% clogged strainer as the nominal conditions, the

S14-81-F005 rev 1

MPR ASSOCIATES, INC.
1050 Connecticut Ave., NW–Washington, DC 20036

CALCULATION NO.	PREPARED BY	CHECKED BY	PAGE
85-87-TGLZ	T. Lestina	L. Stuut.	37

system resistance curve is increased by 15%.

$$(R_2)_{+15\%} = 1.15(1.35530(10^{-5})) = 1.55860(10^{-5}) \text{ ft/gpm}^2$$

$$(R_1)_{+15\%} = 1.15(2.57291(10^{-4})) = 2.95885(10^{-6}) \text{ ft./gpm}^2$$

The reactor flows are calculated using FLONET as described on pages 30-32.

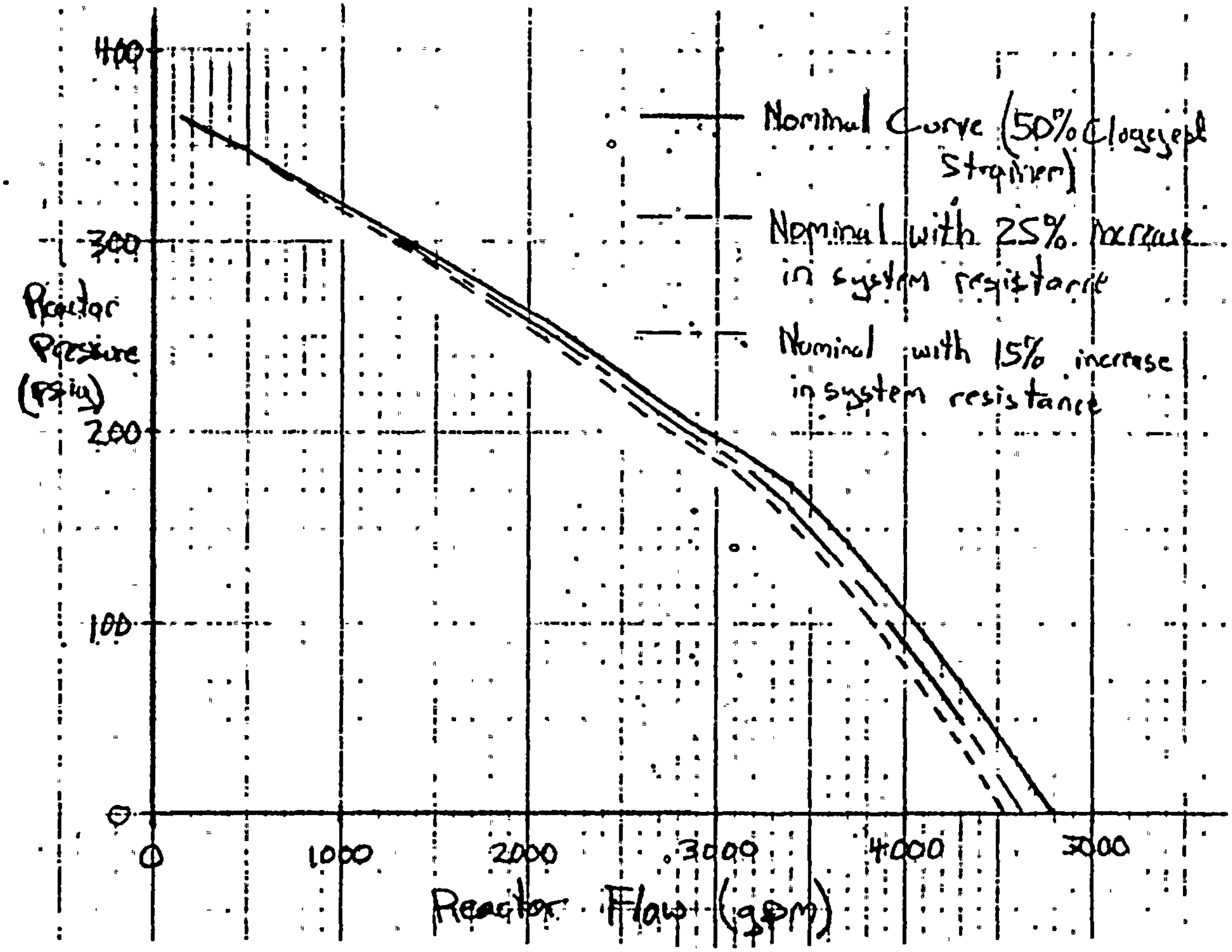
Reactor Pressure (psig)	Reactor Flow (gpm)	Relief Valve Bypass Flow (gpm)	Total Bypass flow for motor cooling and check-valve bypass (gpm)
>365	0	~385	~160
365	160	385	160
350	450	380	150
300	1310	360	150
250	2140	340	150
210	2680	330	140
160	3400	0	140
150	3490	0	140
100	3920	0	140
50	4300	0	130
40.3 (55 psia)	4370	0	130
15.3 (30 psia)	4530	0	130
0 (14.7 psia)	4620	0	130

Increasing the system resistance curve by 25%.

$$(R_2)_{+25\%} = 1.25\left(1.35530(10^{-5})\right) = 1.69413(10^{-5})\ \text{ft/gpm}^2$$

$$(R_1)_{+25\%} = 1.25\left(2.57291(10^{-6})\right) = 3.21614(10^{-6})\ \text{ft/gpm}^2$$

Reactor Pressure (psig)	Reactor Flow (gpm)	Relief Valve Bypass Flow (gpm)	Total Bypass Flow for motor cooling and check valve bypass (gpm)
>365	0	~385	~160
365	150	385	160
350	440	380	150
300	1290	360	150
250	2090	340	150
210	2610	330	140
160	3320	0	140
150	3410	0	140
100	3840	0	140
50	4210	0	130
40.3 (55 psia)	4280	0	130
15.3 (30 psia)	4440	0	130
0 (14.7 psia)	4530	0	130



Reactor Pressure Versus Reactor Flow for Assumed Increased System Resistance

MPR ASSOCIATES, INC.
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CALCULATION NO. 85-87-TGL2

PREPARED BY T. Lestina

CHECKED BY J. [illegible]

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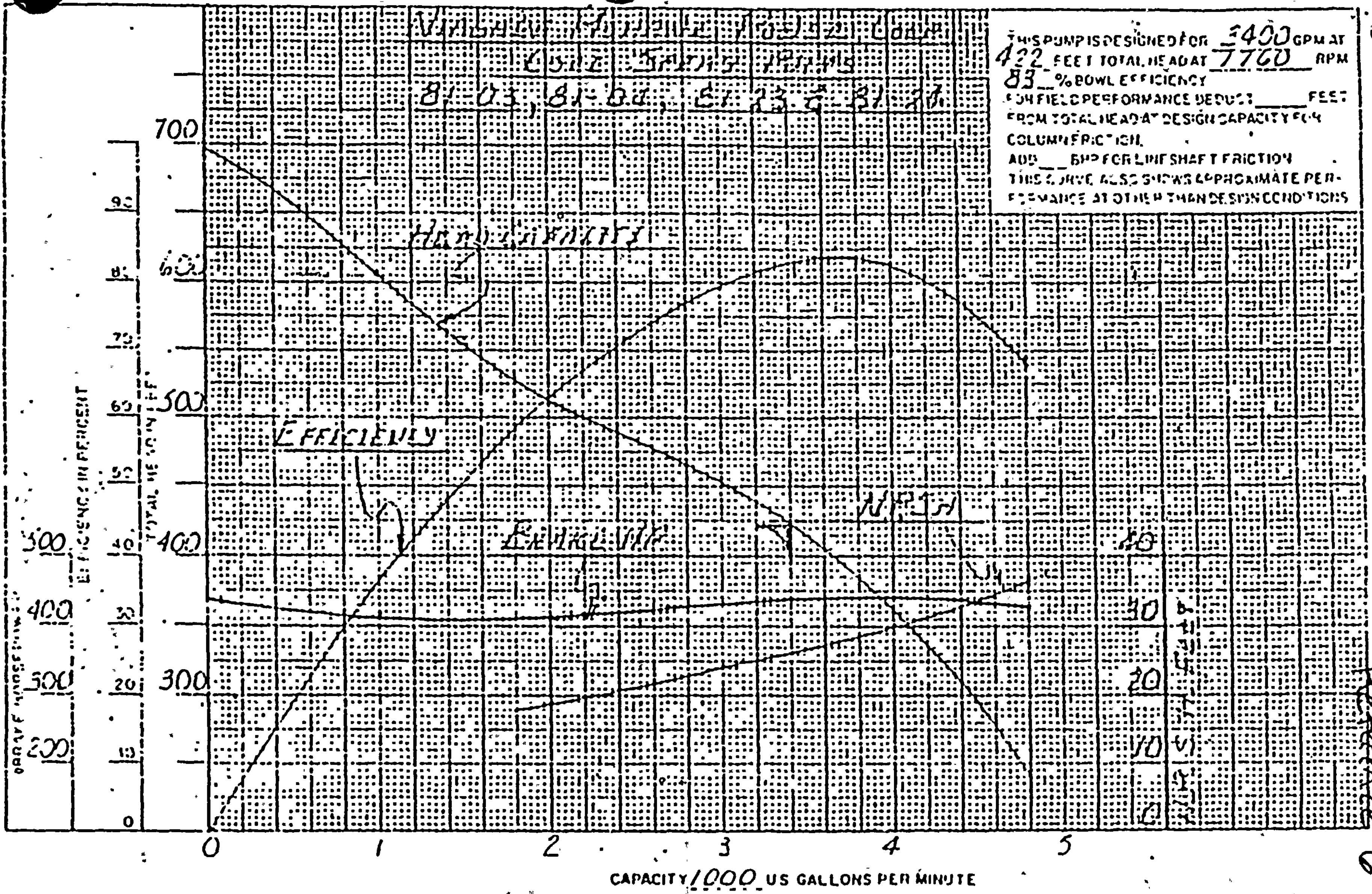


THIS PUMP IS DESIGNED FOR 3400 GPM AT 422 FEET TOTAL HEAD AT 1760 RPM
83 % BOWL EFFICIENCY
FOR FIELD PERFORMANCE DEDUCT _____ FEET FROM TOTAL HEAD AT DESIGN CAPACITY FOR COLUMN FRICTION.
ADD ___ BHP FOR LINE SHAFT FRICTION
THIS CURVE ALSO SHOWS APPROXIMATE PERFORMANCE AT OTHER THAN DESIGN CONDITIONS

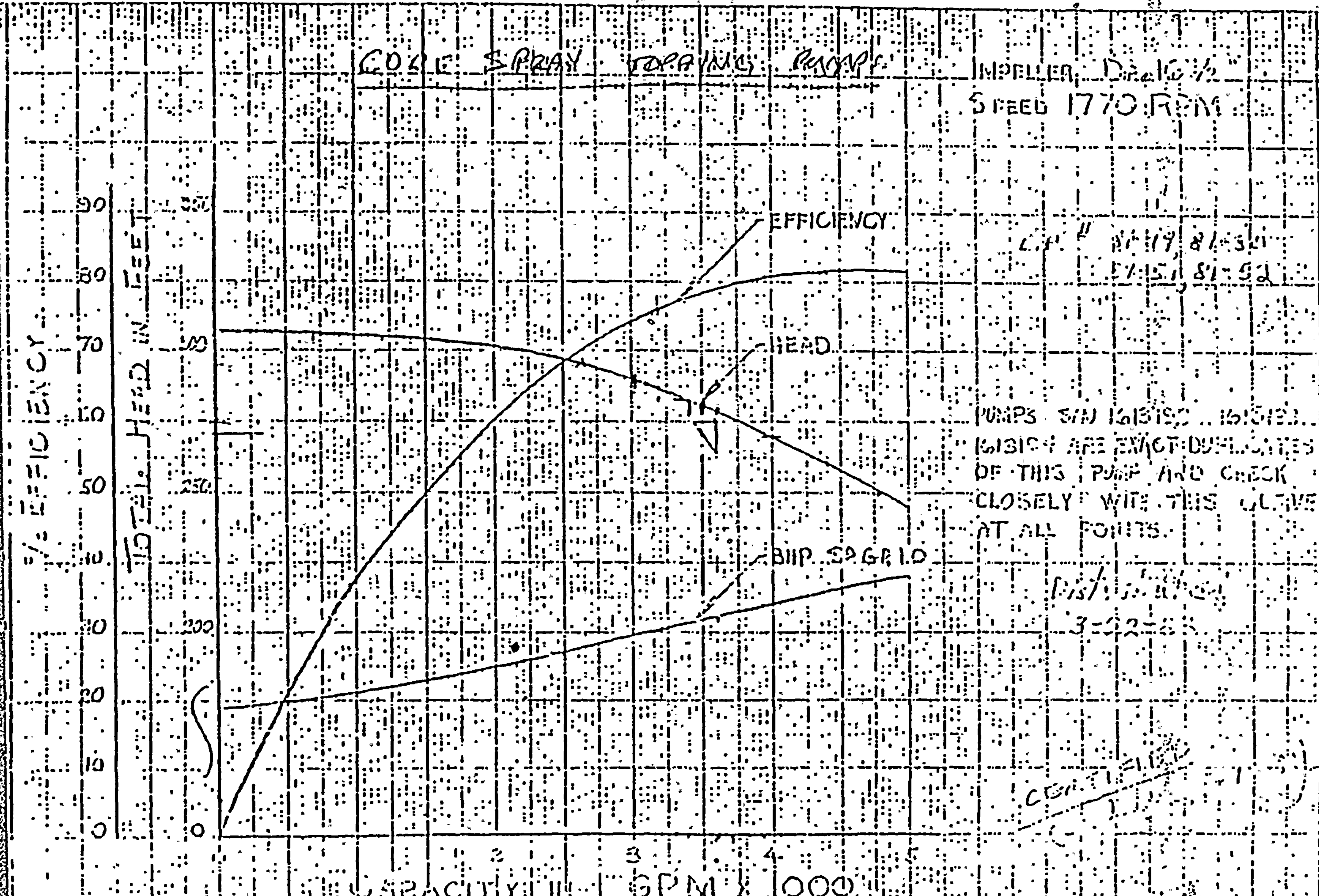
CAPACITY/1000 US GALLONS PER MINUTE

		15H11340	WORTHINGTON CORPORATION	3-13 68	VTP 17964-17
IMPELLER	BOWL	PUMP		DATE	SERIAL NO
	450	6		N7-155	DTP 26993
IMP DIA	DRIVER	NO OF STAGES	VERTICAL PUMP DIVISION	CUST NO.	ORDER NO
	1760		DENVER, COLORADO U.S.A. ALHAMBRA, CALIFORNIA U.S.A		DEN-61274
TEST NO.	RPM	DRAWN BY		QUOTE NO	CURVE NO.

3-N2-316.9

Reference 6
SH-81-F005 rev 1
P. 1 of 1

81-49, 50, 51 & 52



C.P. # 81-49, 81-50
81-51, 81-52

PUMPS S/N 161313[illegible] . 161313[illegible]
161313[illegible] ARE EXACT DUPLICATES
OF THIS PUMP AND CHECK
CLOSELY WITH THIS CURVE
AT ALL POINTS.

[illegible]
3-22-[illegible]

CERTIFIED

[illegible]	CAPACITY 3600 GPM	DRIVER 1 COMP TEST/IN SPEED 1770 - 1780	DRIVE DIRECT
[illegible]	WORTHINGTON CORPORATION	NEW YORK	[illegible]

SIL-81-F005 rev1

Reframe 7 P. 1 of 1

S14-81-F005 rev
Reference 11 p. 1 of 2

NIAGARA MOHAWK

NIAGARA MOHAWK POWER CORPORATION. 301 PLAINFIELD ROAD. SYRACUSE N Y 13212 TELEPHONE 315-4[illegible]

TELECOPY TRANSMITTAL

TO: MPR Assoc.
John Johnson

FROM: L. A. Klusowski
NUCLEAR DIVISION
NIAGARA MOHAWK POWER CORPORATION
301 PLAINFIELD ROAD
SYRACUSE, NEW YORK 13212

WE ARE TRANSMITTING ON A RAPICOM 210 (AUTOMATIC). TELECOPIER PHONE NUMBER IS (315) 428-7225. IF YOU HAVE ANY QUESTIONS, PLEASE CALL MAIL CENTER AT (315) 428-7423.

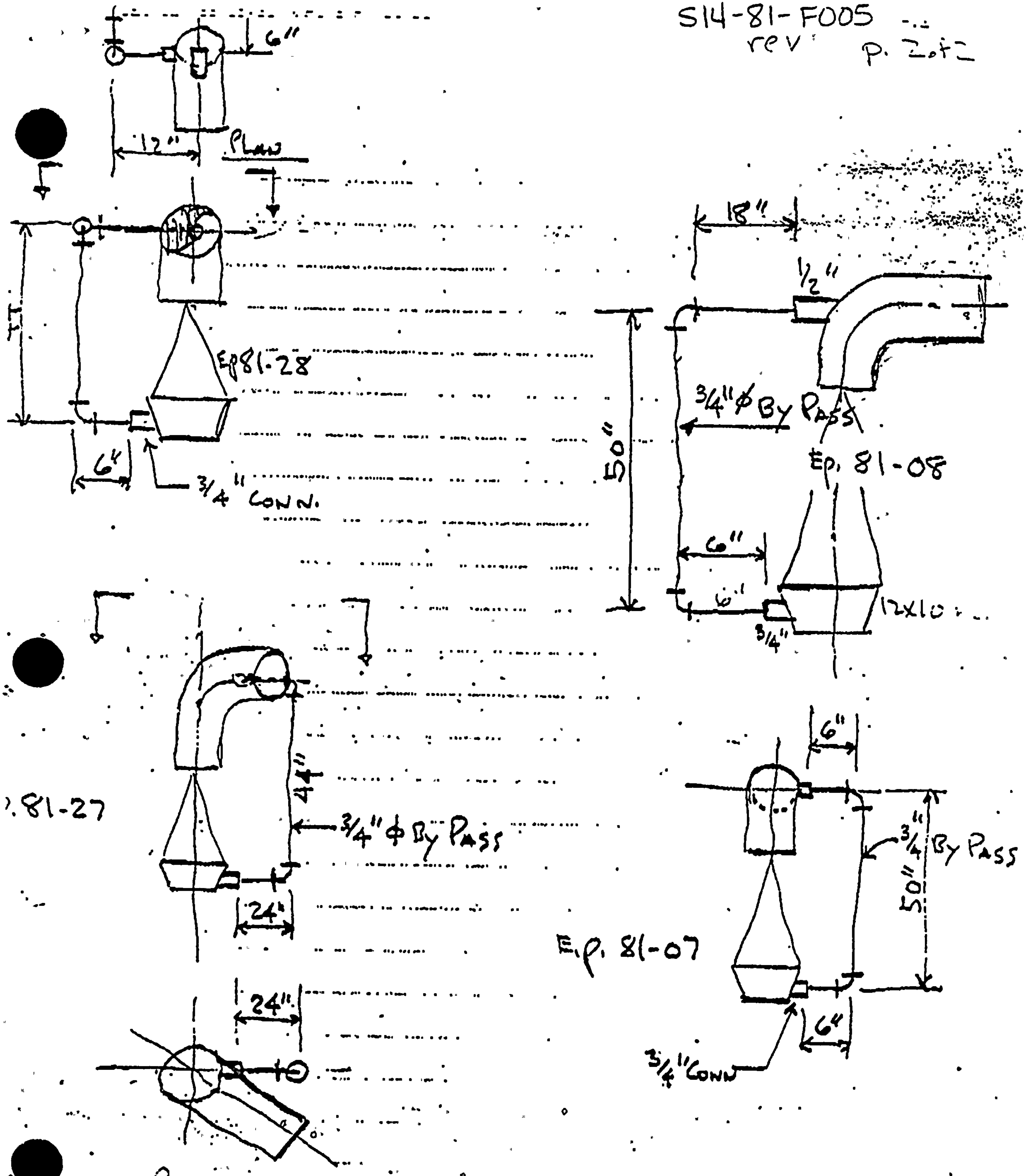
THANK YOU.

DATE: ____

TIME: ____

TOTAL PAGES: ONE
(INCLUDING TRANSMITTAL)

S14-81-F005
rev p. 2 of 2



CORE SPRAY SYS. CHECK
VALVE BY-PASS

S14-81-F005 Rev1
Reference 13 p. 1 of 9

NIAGARA MOHAWK

NIAGARA MOHAWK POWER CORPORATION 301 PLAINFIELD ROAD SYRACUSE N.Y. 13212 TELEPHONE 315 [illegible]

TELECOPY TRANSMITTAL

TO: JOHN JOHNSON
MPR ASSOC. ㉓

FROM: L. KLOSOWSKI
NUCLEAR DIVISION
NIAGARA MOHAWK POWER CORPORATION
301 PLAINFIELD ROAD
SYRACUSE, NEW YORK 13212

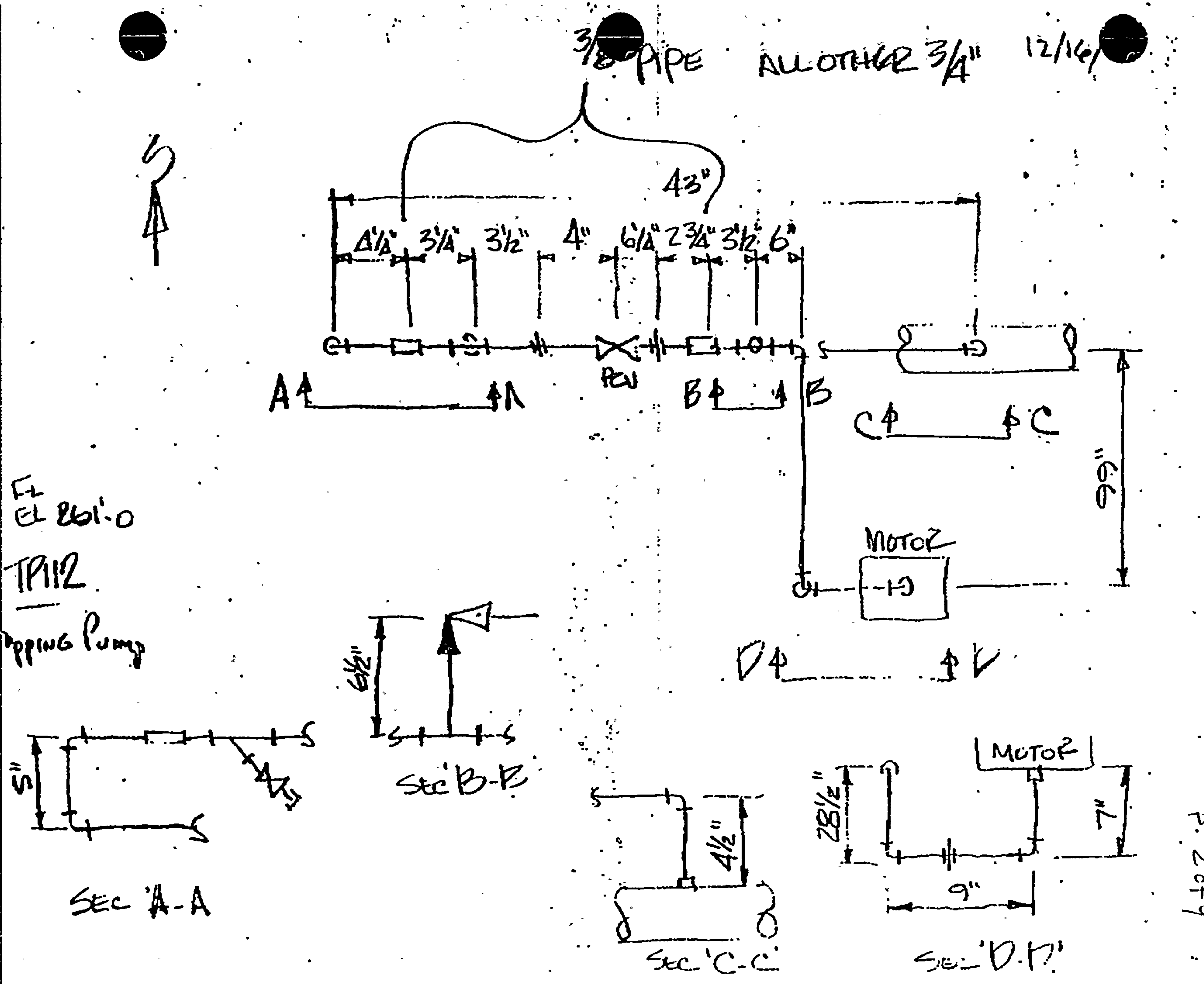
WE ARE TRANSMITTING ON A RAPICOM 210 (AUTOMATIC). TELECOPIER PHONE NUMBER IS (315) 428-7225. IF YOU HAVE ANY QUESTIONS, PLEASE CALL MAIL CENTER AT (315) 428-7423.

THANK YOU.

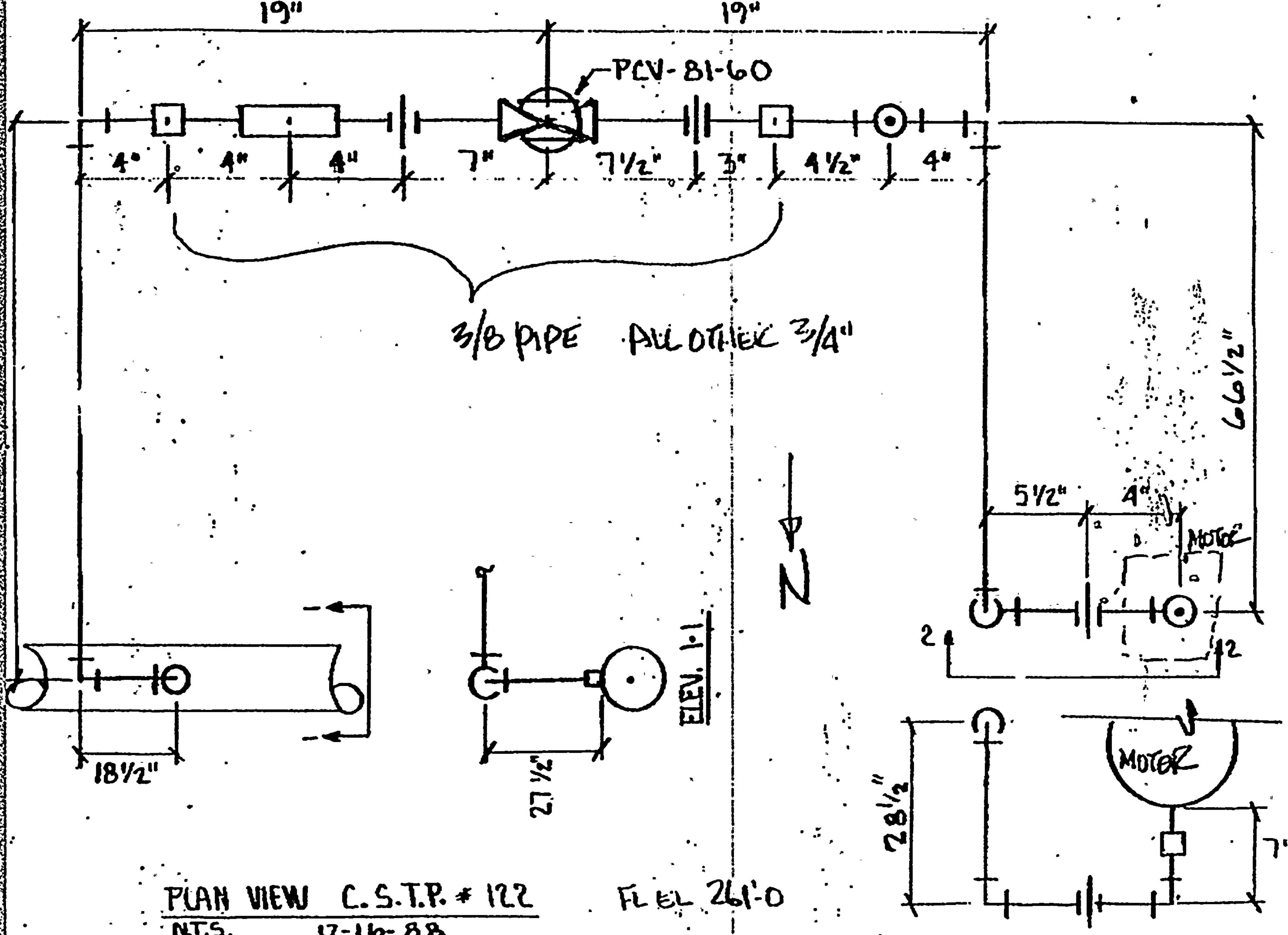
DATE: ____________ TOTAL PAGES: ____________

TIME: ____________ (INCLUDING TRANSMITTAL)

3/8" PIPE ALL OTHER 3/4" 12/16/



SIH-81-F005 rev1
P. 2 of 9



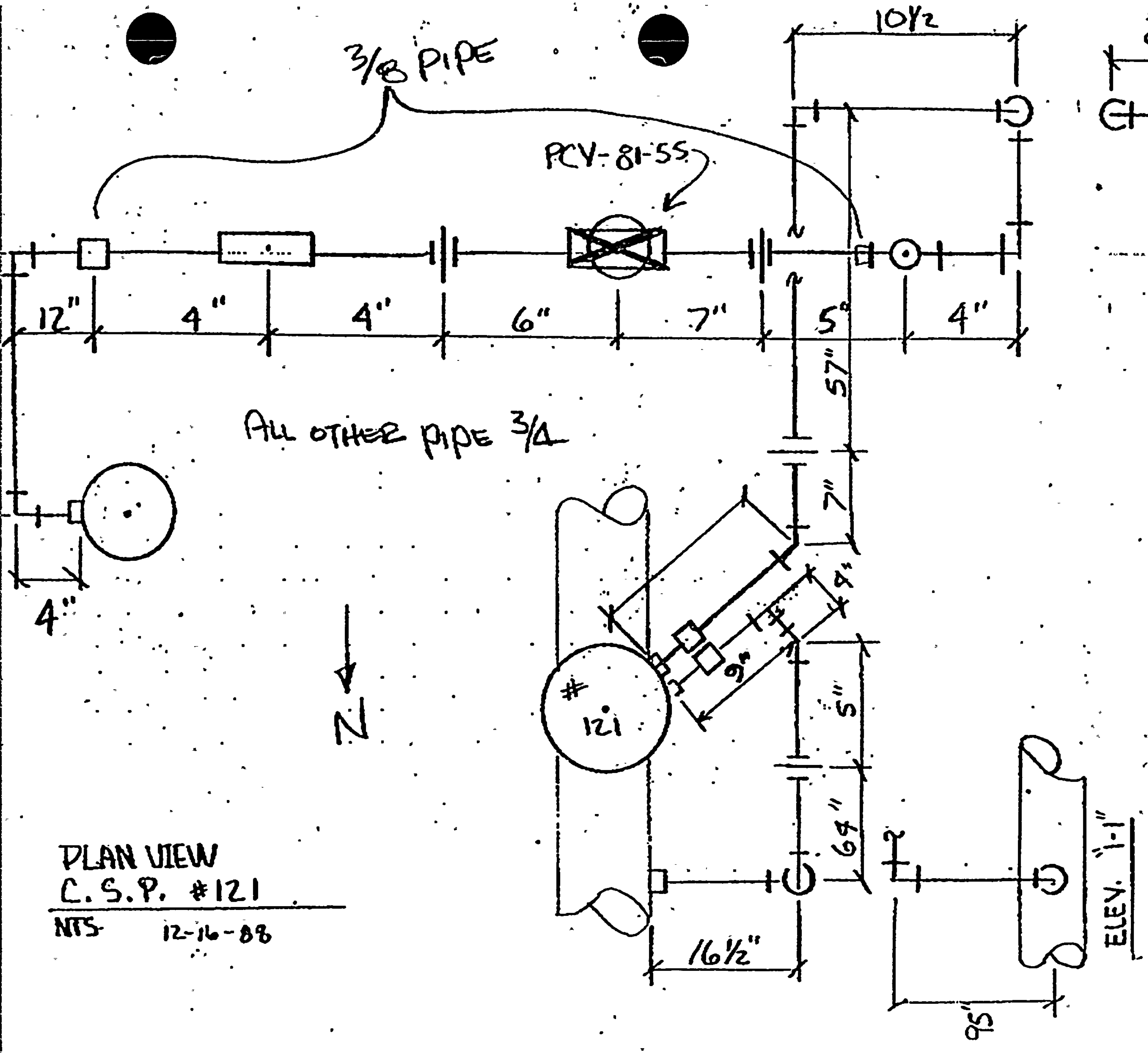
PLAN VIEW C.S.T.P. # 122
N.T.S. 12-16-88

FL EL 261'-0

ELEV. 2-2

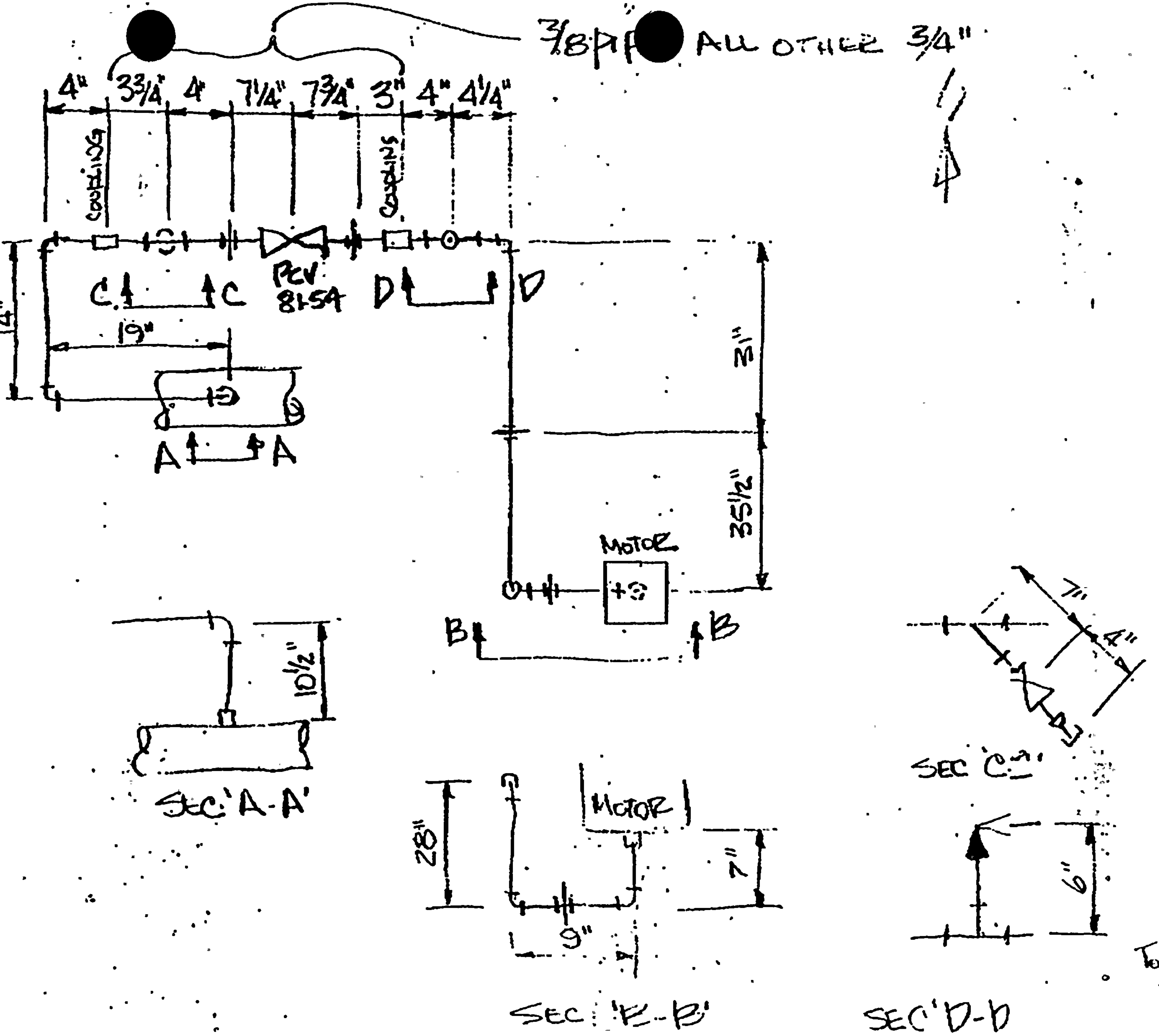
SH-81-F005 rev 1

P. 3 of 9



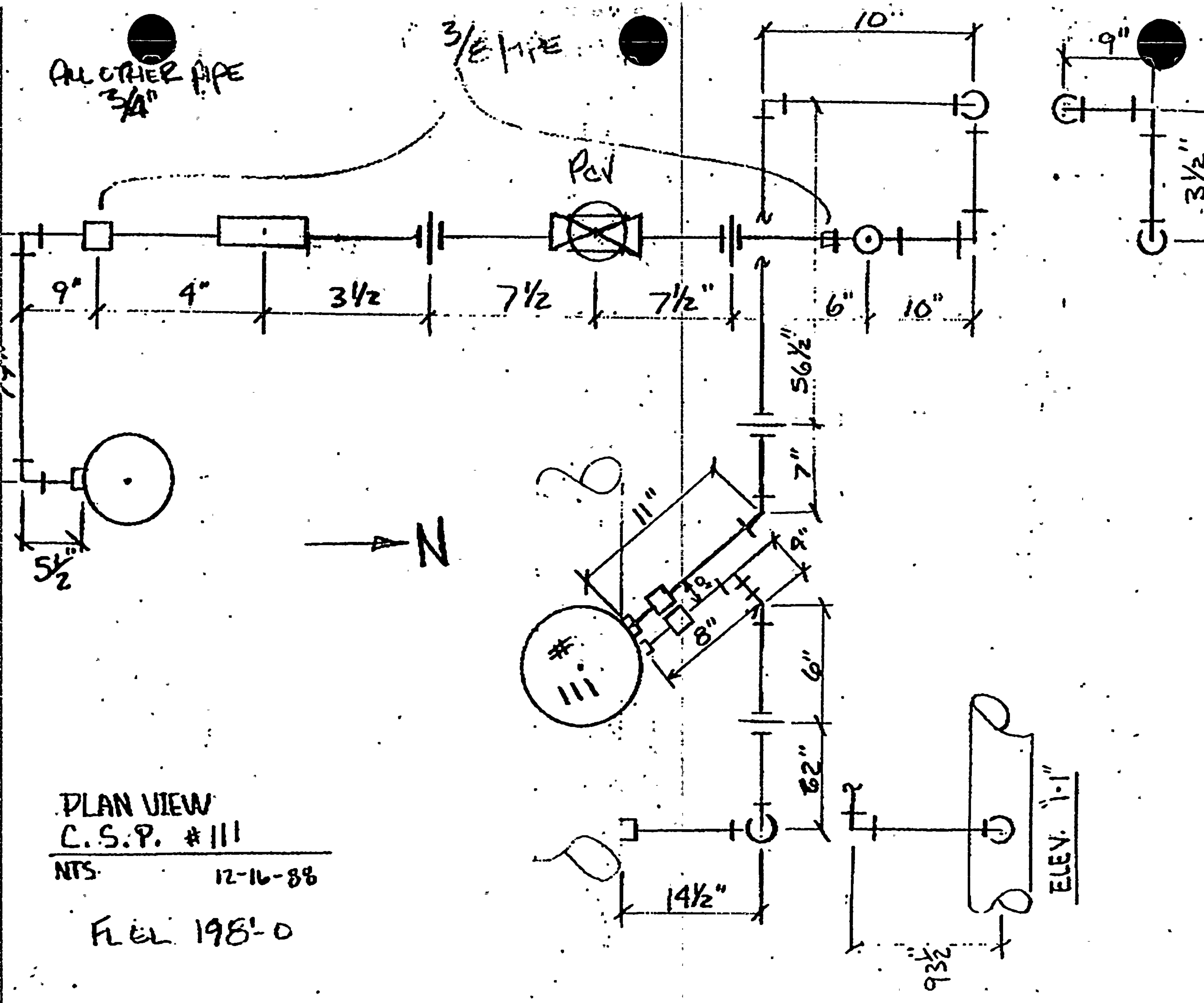
PLAN VIEW
C.S.P. #121
NTS 12-16-88

SW-81-F005
rev 1 P.5 of 9



FL EL 261'0

Topping pump
TP 102



PLAN VIEW
C.S.P. #111
NTS 12-16-88

FL EL 198'-0

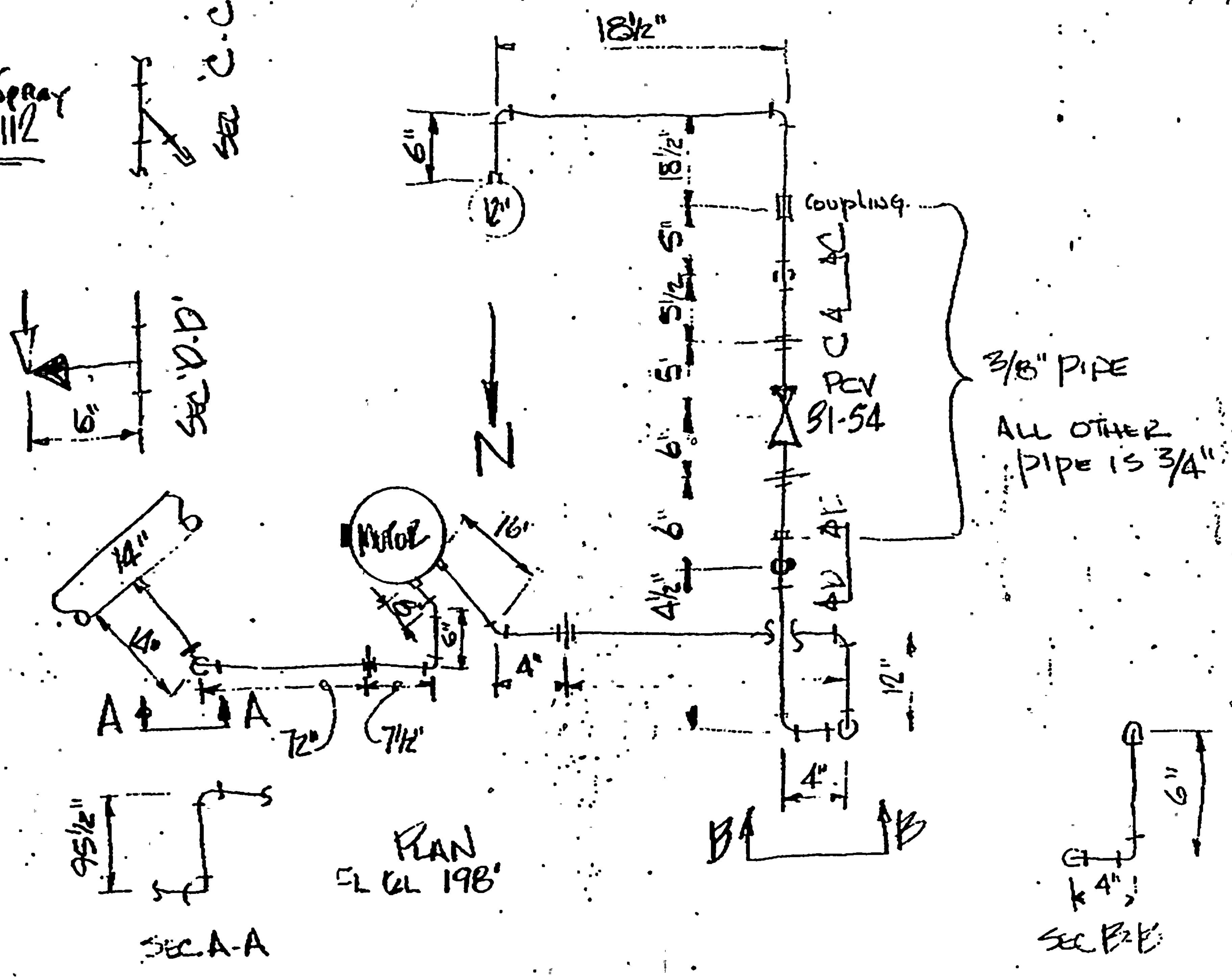
SIH-81-F005 rev 1
P. 6 of 9

SI4-81-F005 rev 1

P. 7 of 9

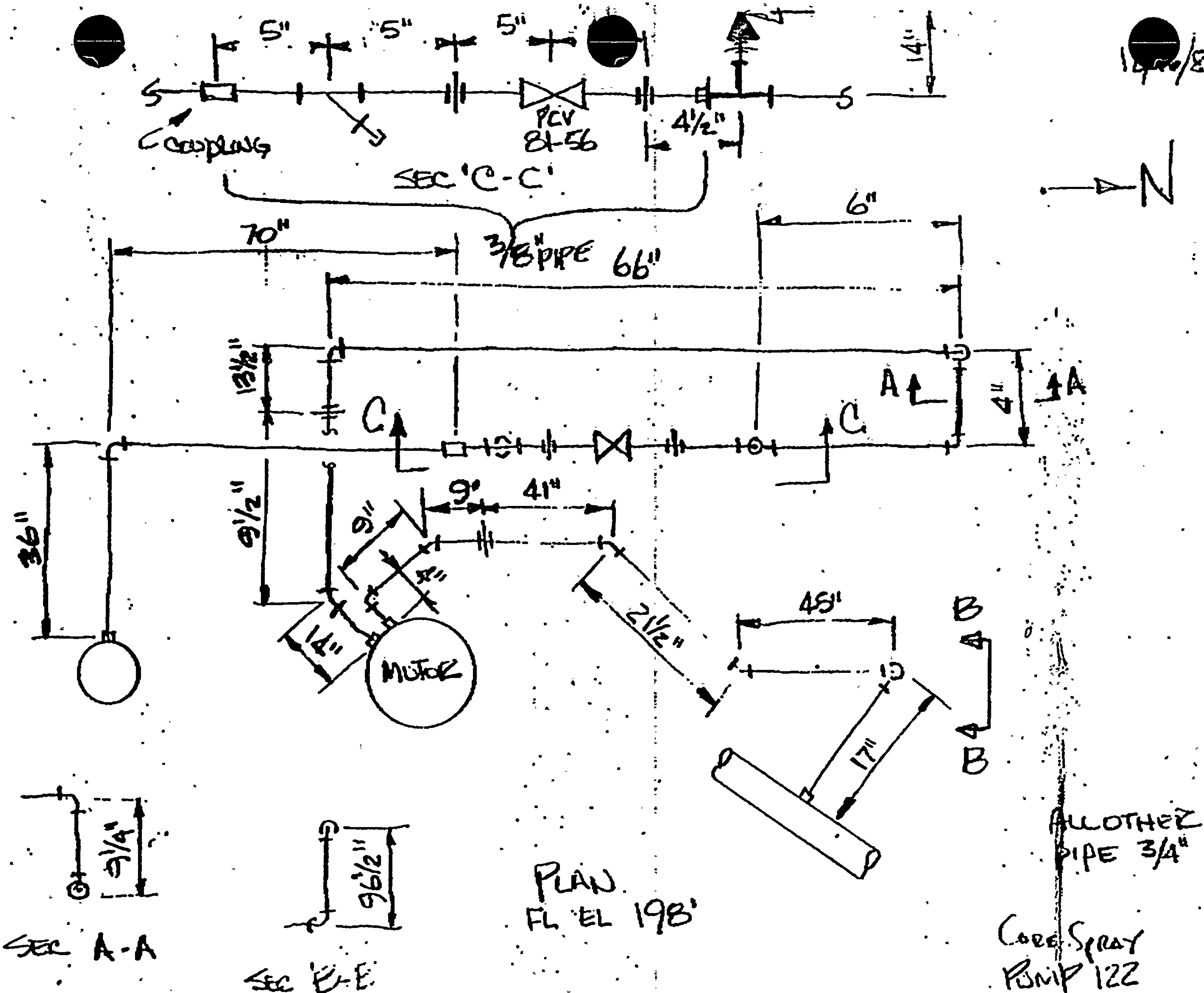
/16/85.

ore Spray pump 112



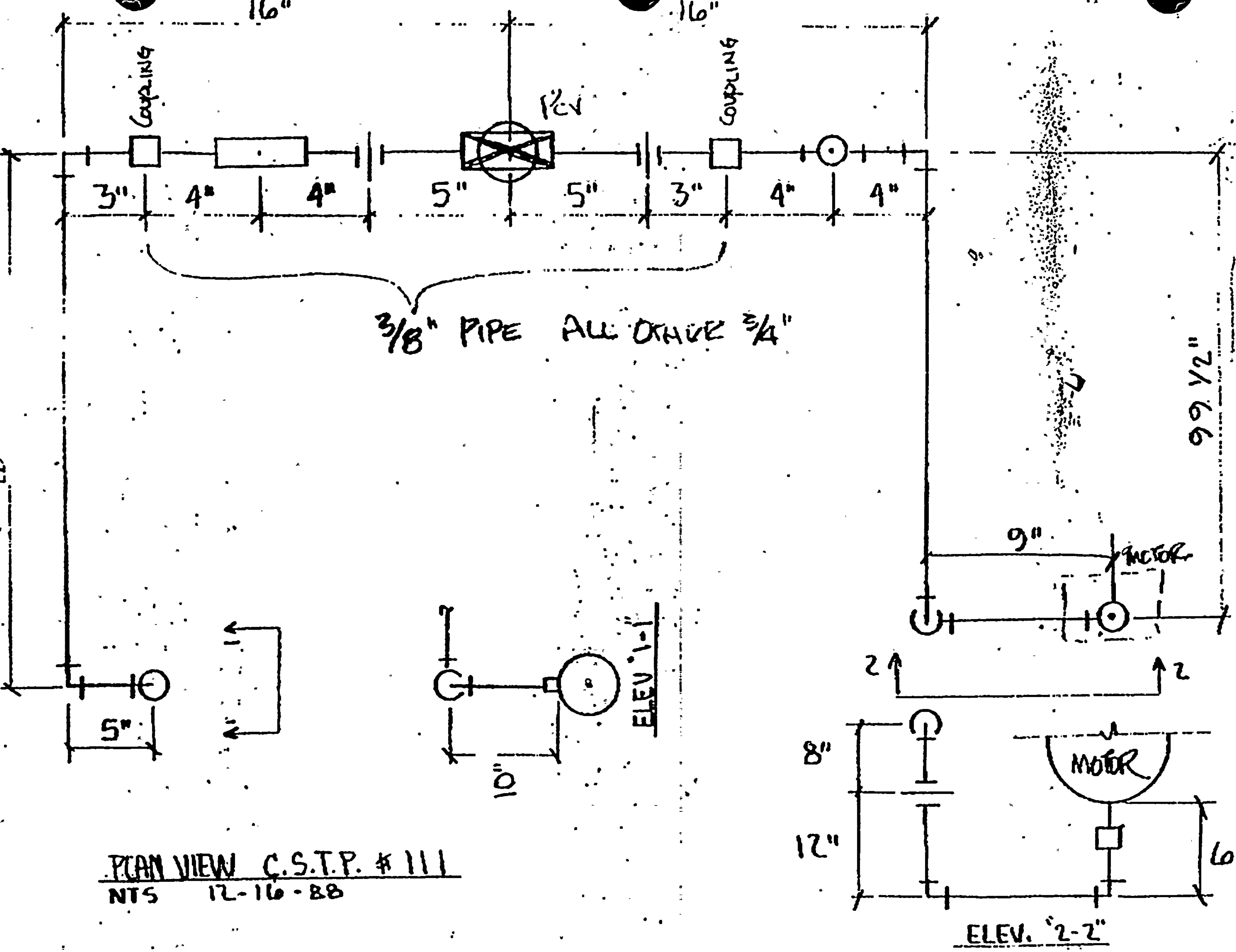
S14-81-F005 rev1

p. 8 of 9



PLAN
FL EL 198'

Core Spray
Pump 122



PLAN VIEW C.S.T.P. # 111
NTS 12-16-88

ELEV. "2-2"

SYRACUSE NUCLEAR DIVISION

SIL81-F005. REV1
P. 9 of 9

NIAGARA MOHAWK

CALCULATION COVER SHEET

NUCLEAR ENGINEERING & LICENSING

DISCIPLINE: MECHANICAL

PAGE IA

PROJECT: NINE MILE POINT NUC. STA.-UNIT I

CALC. NO. S14-81-F006

SUBJECT: CORE SPRAY SUCTION FROUDE NUMBERS

BUILDING: REACTOR

FLOOR ELEV.: VARIOUS

INDEX NO.: 3-N2.1-S14

ORIGINATOR(S): MPR ASSOCIATES, INC.

TOTAL SHT'S. 5

CHECKER(S): MPR ASSOCIATES, INC.

LAST SHT. NO: 4

RECORD OF ISSUES

REV.	DESCRIPTION	M.O.#	BY	DATE	CHKD.	DATE	APPD.	DATE	DATE FILMED:
0	CORE SPRAY SUCTION FROUDE NUMBERS	2988	C.S. Schlaseman	11/23/88	K.A. Briggs	11/29/88	LAK	12/3/88	
1	REVISED IN ITS ENTIRETY	2988	C.S. Schlaseman	2/24/89	J. Johnson	2/24/89	L.A. Kusowski	3/2/89	

COMPUTER OUTPUT YES ☐ NO ☒

SAFETY RELATED YES ☒ NO ☐

DRAWINGS REFERENCED:

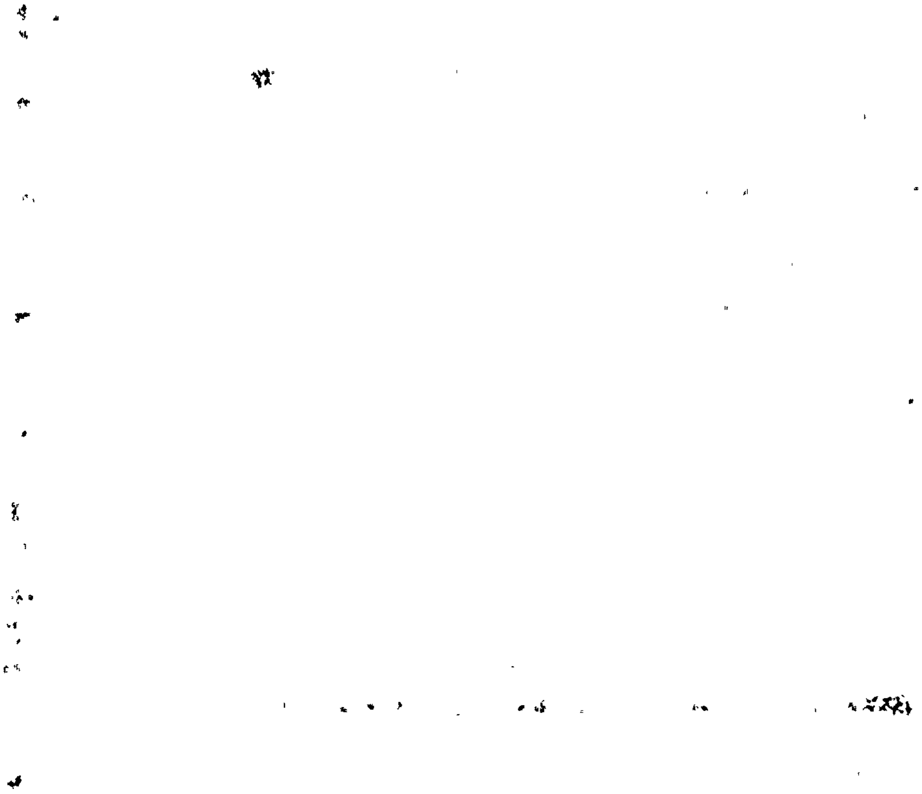
DWG. NO.	INDEX	SHT.	REV.
SEE PAGE 2.			

REFERENCES:

SEE PAGE 2

KEYWORDS: NMP I, SSFI, CORE SPRAY, FLOW

CROSS REF.: 85-104-CSS2



S14-81-F006 rev 1

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1050 Connecticut Ave., NW–Washington, DC 20036

CALCULATION TITLE PAGE

CLIENT NMPC	PAGE 1 OF 4
PROJECT NMP-1 SSFI	TASK NO. 85-104
CALCULATION TITLE FROUDE NUMBERS FOR 1 & 2 PUMP SET OPERATION – NMP-1 CORE SPRAY SYSTEM	CALCULATION NO. (OPTIONAL) 85-104-CSS2

PREPARER(S)/DATE	CHECKER(S)/DATE	REVIEWER(S)/DATE	REV. NO.
AJ Schlaseman 11-23-88	R.A. Briggs / 11-29-88	J Johnson 11/29/88	0
AJ Schlaseman 2-24-89	John Johnson 2-24-89	John Johnson 2-24-89	1

S14-21-F006 rev 1

MPR ASSOCIATES, INC.
1050 Connecticut Ave., NW–Washington, DC 20036

CALCULATION NO.	PREPARED BY	CHECKED BY	PAGE
85-104-CSS2	Schlaseman	JJohnson	2

I. <u>PURPOSE:</u> TO CALCULATE THE FROUDE NUMBERS FOR SINGLE AND TWO PUMP OPERATION OF THE CORE SPRAY SYSTEM.

II. <u>RESULTS</u>: FROUDE NUMBERS FOR THE CORE SPRAY SYSTEM ARE THE FOLLOWING:

1 PUMP SET: Fr = 1.07
2 PUMP SETS: Fr = 0.72

FOR SINGLE PUMP SET OPERATION, FOR THE Fr = 0.80, THE SUBMERGENCE MUST BE = 9.6ft

III. <u>REFERENCES:</u>

1. MIRONER, A., <u>ENGINEERING FLUID MECHANICS</u>, 1979.
2. MPR CALCULATION No. 85-87-TGL2, "CORE SPRAY SYSTEM FLOW WITH ONE SET OF PUMPS OPERATING." (REV. 1)
3. MPR CALCULATION No. 85-87-TGL6, "CORE SPRAY SYSTEM FLOWS WITH TWO SETS OF PUMPS OPERATING IN PARALLEL." (REV. 1)
4. NMPC DWG. # C-18364-C, "CORE SPRAY PIPING PLAN AT EL. 198'-0" & 218'-0."
5. MPR CALCULATION "MINIMUM TORUS WATER LEVEL," BY C.S. SCHLASEMAN, DATED 9/21/88. (ATTACHED).

S14-81-F006 rev 1

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CALCULATION NO.	PREPARED BY	CHECKED BY	PAGE
85-104-C552		J Johnson	3

IV. CALCULATION:

FROM p. 462 OF REF. 1, THE DIMENSIONLESS FROUDE NUMBER IS THE FOLLOWING:

$$Fr = \frac{U}{\sqrt{g\,s}}$$

where: U = pipe flow velocity = Q/A
s = submergence
g = gravitational constant
Q = pipe flow rate
A = cross-sectional area

FROM REF. 2 & 3, THE MAXIMUM FLOW RATES AT THE PUMP SUCTION ARE:

$$\text{1 PUMP SET FLOW} = 5000\,\text{gpm}\left(\frac{1\,\text{ft}^3/\text{sec}}{448.83\,\text{gpm}}\right) = \underline{11.14\,\text{ft}^3/\text{sec}} = Q_1$$

$$\text{2 PUMP SET FLOW} = \left(\frac{6700}{2}\right)\text{gpm}\left(\frac{1\,\text{ft}^3/\text{sec}}{448.83\,\text{gpm}}\right) = \underline{7.46\,\text{ft}^3/\text{sec}} = Q_2$$

FROM REF. 4, PUMP SUCTION IS 20" X 12" REDUCER COVERED WITH A STEEL GRATE. CROSS-SECTIONAL AREA OF 12-inch END IS:

$$A = \frac{\pi}{4}d^2 = \frac{\pi}{4}(1\,\text{ft})^2 = \underline{0.79\,\text{ft}^2}$$

CHECK AREA OF 20"φ END, ACCOUNTING FOR GRATING AREA AND 50% BLOCKAGE; ASSUME GRATING BLOCKS 25% OF OPENING:

$$A_{20} = \frac{\pi}{4}\left(\frac{20\,\text{in}}{12\,\text{in}/\text{ft}}\right)^2(0.75)(0.50) = 0.82\,\text{ft}^2 > 0.79\,\text{ft}^2 \therefore$$

CONSERVATIVE TO USE 12"φ

FLOW VELOCITIES ARE:

$$\text{1 PUMP SET VELOCITY} = \frac{11.14\,\text{ft}^3/\text{sec}}{0.79\,\text{ft}^2} = \underline{14.10\,\text{ft}/\text{sec}}$$

$$\text{2 PUMP SET VELOCITY} = \frac{7.46\,\text{ft}^3/\text{sec}}{0.79\,\text{ft}^2} = \underline{9.44\,\text{ft}/\text{sec}}$$

AVAILABLE SUBMERGENCE IS:

S = MIN. TORUS WATER LEVEL – MAX. SUCTION ℄ ELEV.

FROM REF. 5 & 4, S = 210.5 ft – 205.07 ft = 5.4 ft

FROUDE NUMBERS ARE:

1 PUMP SET: $$F_r = \frac{14.10\ \text{ft/sec}}{\sqrt{(32.2\ \text{ft/s}^2)(5.4\ \text{ft})}} = \underline{\underline{1.07}}$$

2 PUMP SETS: $$F_r = \frac{9.44\ \text{ft/sec}}{\sqrt{(32.2\ \text{ft/s}^2)(5.4\ \text{ft})}} = \underline{\underline{0.72}}$$

FOR SINGLE PUMP OPERATION, CALCULATE SUBMERGENCE REQUIRED FOR $F_r = 0.80$:

$$F_r = \frac{u}{\sqrt{gs}}$$

$$\sqrt{gs} = \frac{u}{F_r}$$

$$s = \frac{1}{g}\left(\frac{u}{F_r}\right)^2 = \frac{1}{32.2\ \text{ft/s}^2}\left(\frac{14.10\ \text{ft/sec}}{0.80}\right)^2 = \underline{\underline{9.6\ \text{ft}}}$$

S14-81-F006 rev 1

MPR ASSOCIATES, INC.
1050 Connecticut Ave., NW – Washington, DC 20036

Title: MINIMUM NORMAL TORUS WATER LEVEL
Calculated by: Date: 9-21-88
Checked by: Date: 9/21/88
Reviewed by: Date: 9/21/88

Project: NMP-1

Page 1 of 1

I. PURPOSE: To calculate the minimum normal water level in the Nine Mile Point Unit 1 torus (suppression chamber).

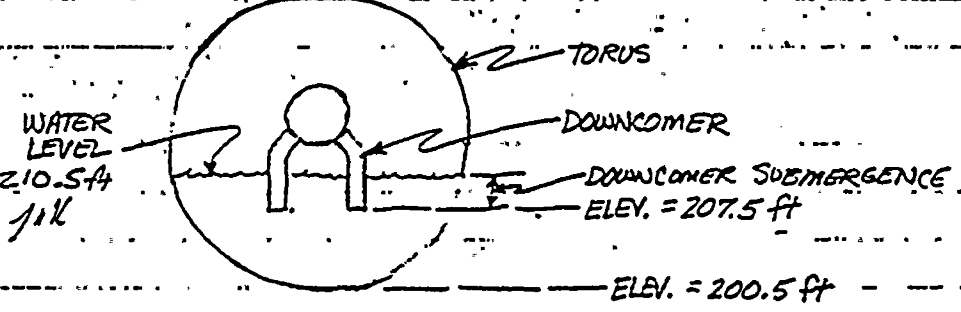
II. RESULTS: The minimum normal torus water level is 10 ft.

III. REFERENCES:

1. CBI dwg. 9-1370 sh. 313, NMPC Index 3-N2-S22.4
2. NMP-1 Tech. Spec. Section 3.3.2.

IV. CALCULATION:

From Ref. 1, an elevation view of a torus cross-section is shown below:



From Ref. 2, the minimum downcomer submergence is 3 ft.

∴ Minimum normal torus water level =

$$3\,\text{ft} + [207.5\,\text{ft} - 200.5\,\text{ft}] = \underline{\underline{10\,\text{ft}}}$$

NIAGARA MOHAWK

CALCULATION COVER SHEET

NUCLEAR ENGINEERING & LICENSING

DISCIPLINE: MECHANICAL

PAGE 1

PROJECT: NINE MILE POINT NUC. STA.-UNIT I

CALC. NO. S14-81.1-F001

SUBJECT: CORE SPRAY SURVEILLANCE TEST PRESSURES

BUILDING: REACTOR

FLOOR ELEV.: VARIOUS

INDEX NO.: 3-N2.1-S14

ORIGINATOR(S): MPR ASSOCIATES, INC.

TOTAL SHT'S. X14

CHECKER(S): MPR ASSOCIATES, INC.

LAST SHT. NO: 6

RECORD OF ISSUES

REV.	DESCRIPTION	M.O.#	BY	DATE	CHKD.	DATE	APPD.	DATE	DATE FILMED:
0	C.S. SURVEILLANCE TEST PRESSURES	2988	C.S. SCHLASEMAN	11/29/88	J. DREWES	11/29/88	LAK	12/5/88	
1	revised in its entirety	2988	C.S. Schlaseman	2/24/89	J. Johnson	2/24/89	L.A. Klosowski	3/2/89	

COMPUTER OUTPUT YES ☐ NO ☒

SAFETY RELATED YES ☒ NO ☐

DRAWINGS REFERENCED:

DWG. NO.	INDEX	SHT.	REV.
SEE PAGE 2			

REFERENCES:

SEE PAGE 2

KEYWORDS: NMP I, SSFI, CORE SPRAY, FLOW

CROSS REF.: 85-104-CSS1

S14-81.1-F001 rev 1

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1050 Connecticut Ave., NW-Washington, DC 20036

CALCULATION TITLE PAGE

CLIENT NMPC	PAGE 1 OF 6
PROJECT NMP1 SSFI	TASK NO. 85-104
CALCULATION TITLE TOPPING PUMP DISCHARGE PRESSURES DURING SURVEILLANCE TESTING	CALCULATION NO. (OPTIONAL) 85-104-C551

PREPARER(S)/DATE	CHECKER(S)/DATE	REVIEWER(S)/DATE	REV. NO.
11-29-88	11/29/88	J Johnson 11-30-88	0
2-24-89	J Johnson 2-24-89	J Johnson 2-24-89	1

S14-81.1-F001 rev 1

CALCULATION NO.	PREPARED BY	CHECKED BY	PAGE
85-104-CSS1		J Johnson	2

PURPOSE

TO CALCULATE PRESSURES AT THE DISCHARGE OF THE CORE SPRAY TOPPING PUMP DURING SURVEILLANCE TESTING.

RESULTS

FLOWS AND PRESSURES AT THE DISCHARGE OF THE TOPPING PUMP ARE TABULATED ON P. 5, AND SHOWN ON FIGURES 1 & 2. FIGURE 1 INCLUDES THE CURRENT SURVEILLANCE TEST CURVE. FIGURE 2 INCLUDES RECENT SURV. TEST RESULTS.

REFERENCES

1. MPR CALC., "MIN. TORUS WATER LEVEL," BY C.S. SCHLIESMAN, DATED 9-21-88.
2. NMPC PIPING ISOMETRIC DWGS, "CORE SPRAY SYSTEM" DWG NO. C-26845-C, SHT. 3, REV. 8.
3. MPR CALC., "HYDRAULIC RESISTANCE OF NMP1 CORE SPRAY PUMP AND TOPPING PUMP SUCTION AND RISER PIPING," 75-27-TGL5, DATED 2-23-89 REV. 1.
4. CROSBY VALVE MANUAL, CATALOG 301, WATER CAPACITY TABLE.
5. WORTHINGTON PUMP CURVE DEN-21274, "NMPC CORE SPRAY PUMPS 81-03, 81-04, 81-23 & 81-24," DATED 3-13-68.
6. WORTHINGTON PUMP CURVE, "CORE SPRAY TOPPING PUMPS, 81-49, 50, 51 & 52."
7. NINE MILE POINT NUCLEAR STATION #1, CORRECTED SYSTEM CURVE FOR CORE SPRAY & TOPPING PUMPS, 11/19/74, LMP.
8. MPR CALC., "CORE SPRAY SYSTEM FLOWS WITH ONE SET OF PUMPS OPERATING," 85-87-TGL2, DATED 2-23-89, REV 1.

S14-81.1-F001 rev 1

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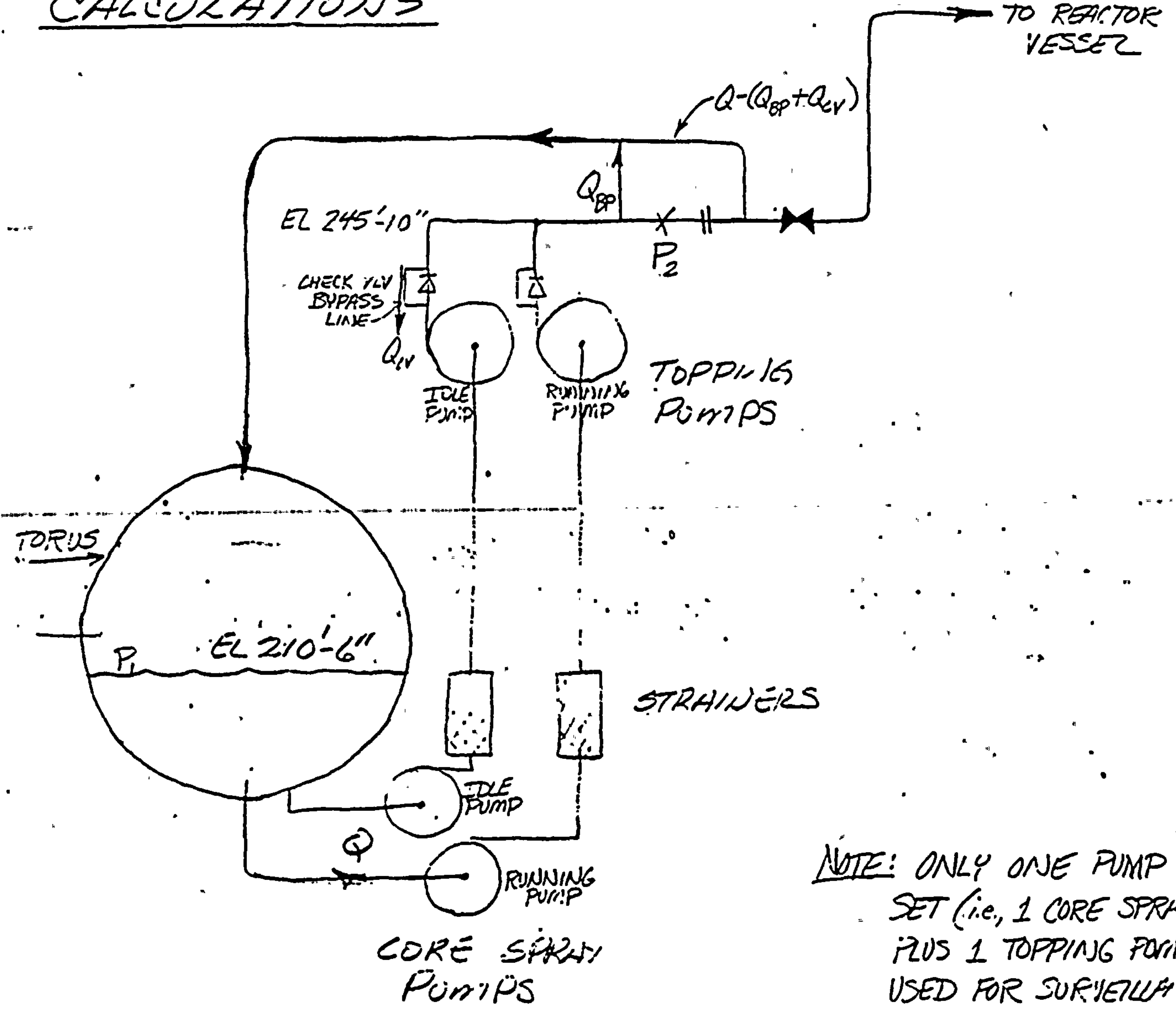
1050 Connecticut Ave., NW–Washington, DC 20036

CALCULATION NO.	PREPARED BY	CHECKED BY	PAGE
85-104-CSS1	C. Schlaseman	J M Diewes	3.

CALCULATIONS



NOTE: ONLY ONE PUMP SET (i.e., 1 CORE SPRAY PLUS 1 TOPPING PUMP) USED FOR SURVEILLANCE TESTING.

(CORE SPRAY CONFIGURATION)

CALCULATION NO.	PREPARED BY	CHECKED BY	PAGE
85-104-CS51	DSchiemann	JM Drewes	4

THE GOVERNING EQUATION IS:

$$\frac{P_1}{\rho} + z_1 + \frac{V_1^2}{2g} + (H_1 + H_2) = \frac{P_2}{\rho} + z_2 + \frac{V_2^2}{2g} + h_L$$

WHERE:

P_1 = Torus Pressure = 0 psig (Surveillance Test Conditions)
ρ = Density @ 90°F = 62.1 lb/ft³ (Surveillance Test Conditions)
z_1 = Minimum Torus Water Elevation = 210.5 ft (REF. 1)
V_1^2 = Velocity at Torus Water Level = 0 ft/sec
g = 32.2 ft/s²
H_1 = Core Spray Pump Head in ft.
H_2 = Topping Pump Head in ft.
P_2 = Pressure @ Pres. Meter - Disch. of Topping Pump
z_2 = Elevation @ Pres. Meter = 245.8 ft (REF 2)
V_2^2 = Velocity @ Pres. Meter = Q/A
h_L = Losses from ① to ② = $Q^2 R_{1-2}$

AND: Q = Flow in gpm
A = Cross-sectional area = $\pi(1\,\text{ft})^2/4$ = 0.785 ft²
R_{1-2} = 1.32 E-6 ft/gpm² (FOR CLEAN STRAINER - REF 3)
= 1.58E-6 ft/gpm² (50% BLOCKED STRAINER - REF 3)

REWRITE EQUATION USING CONSTANTS:

$$\cancelto{0}{\frac{0\,\text{psig}\,(144\,\text{in}^2/\text{ft}^2)}{62.1\,\text{lb}/\text{ft}^3}} + 210.5\,\text{ft} + \cancelto{0}{\frac{(0\,\text{ft}/\text{s})^2}{2(32.2\,\text{ft}/\text{s}^2)}} + H_1 + H_2 = \frac{P_2\,(144\,\text{in}^2/\text{ft}^2)}{62.1\,\text{lb}/\text{ft}^3} + 245.8\,\text{ft} + \frac{(Q/.785\,\text{ft}^2)^2}{2(32.2\,\text{ft}/\text{s}^2)} + Q^2 R_{1-2}$$

SOLVE FOR P_2:

$$P_2 = \left(\frac{62.1\,\text{lb}/\text{ft}^3}{144\,\text{in}^2/\text{ft}^2}\right)\left[(210.5\,\text{ft} - 245.8\,\text{ft}) + H_1 + H_2 - \frac{\left(Q\left(\frac{1\,\text{ft}^3/\text{s}}{448.83\,\text{gpm}}\right)\right)^2}{39.73\,\text{ft}^5/\text{s}^2} - Q^2 R_{1-2}\right]$$

$$P_2 = \left(.431\,\frac{\text{psi}}{\text{ft}}\right)\left[(-35.3\,\text{ft}) + H_1 + H_2 - \frac{Q^2}{8\times10^6}\,\text{ft} - Q^2 R_{1-2}\right]$$

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CALCULATION NO. 85-104-CS31	PREPARED BY	CHECKED BY	PAGE 42

DURING SURVEILLANCE TESTING, ONLY ONE PUMP SET OPERATES WITHIN EACH LOOP. BYPASS FLOW AROUND THE CHECK VALVE OF THE NON-OPERATING PUMP MUST BE SUBTRACTED FROM THE FLOW GOING THROUGH THE FLOW METER. FROM REF. 8:

$$Q_{\text{CHECK VALVE}} = \sqrt{\frac{P_2\,(144\ \text{in}^2/\text{ft}^2)}{\rho R}}\ , \text{ WHERE } R = .121882\ \text{ft}/\text{gpm}^2$$

$$\therefore\ Q_{CV} = \sqrt{\frac{P_2\,(144\ \text{in}^2/\text{ft}^2)}{(62.1\ \text{lb}/\text{ft}^3)(.121882\ \text{ft}/\text{gpm}^2)}}$$

[NOTE: IN THESE CALCULATIONS, THE RECIRCULATION FLOW FOR MOTOR COOLING (APPROX. 70 gpm) IS NEGLECTED BECAUSE:

① IT IS SMALL COMPARED TO THE NOMINAL SURVEILLANCE TEST FLOW (~3000 gpm), and

② IF INCLUDED, IT WOULD RESULT IN A HIGHER CALCULATED PRESSURE AT TOPPING PUMP DISCHARGE, P_2, WHICH WOULD BE LESS CONSERVATIVE.]

514-81.1-F001

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CALCULATION NO.	PREPARED BY	CHECKED BY	PAGE
85-104-CSS1		J Johnson	5

DURING SURVEILLANCE TESTING, THE TEST LINE TO THE TORUS IS OPEN WHEN THE PUMPS START, SO THE INITIAL FLOW CONDITION IN THE DISCHARGE HEADER IS HIGH FLOW WITH LOW HEAD (UNLIKE THE POSTULATED LOCA INITIAL CONDITION OF HIGH HEAD, LOW FLOW). THE RELIEF VALVE, THEREFORE, IS NOT EXPECTED TO OPEN DURING SURVEILLANCE TESTING. FOR THE PURPOSES OF THIS CALCULATION, HOWEVER, FLOW THROUGH THE RELIEF VALVE WILL BE ACCOUNTED FOR PRESSURES HIGHER THAN THE 320 psig SET POINT.

$$Q_{BYPASS} = 380\,gpm\sqrt{\frac{P_2}{400\,psig}} \quad (REF\ 4)$$

ASSUME Q, AND CALCULATE P_2 FOR $R_{1\text{-}2:\,LEAN} = 1.57E\text{-}6\ ft/gpm^2$:

Q (gpm)	H_1 (ft) (REF 5)	H_2 (ft) (REF 6)	(psig) P_2	Q_{CV}	Q_{BP}	$Q_{FLOW\ METER}$ $(Q-Q_{BP}-Q_{CV})$
500	660	305	401	87	380	33
1000	605	305	376	85	370	545
1500	555	305	354	82	360	1058
2000	515	300	333	80	350	1570
2500	485	295	316	78	340	2082
3000	450	290	297	75	—	2925
3500	415	280	275	73	—	3427
4000	360	270	245	68	—	3932
4500	295	260	209	63	—	4437

FOR 50% BLOCKED STRAINER, $R_{1\text{-}2} = 2.57E\text{-}6\ ft/gpm^2$

Q	H_1	H_2	P_2	Q_{CV}	Q_{BP}	$Q_{FLOW\ METER}$
500	660	305	401	87	380	33
1000	605	305	376	85	370	545
1500	555	305	353	82	360	1058
2000	515	300	331	80	350	1570
2500	485	295	314	78	340	2082
3000	450	290	293	75	—	2925
3500	415	280	270	72	—	3428
4000	360	270	238	67	—	3933
4500	295	260	200	62	—	4438

CALCULATION NO.	PREPARED BY	CHECKED BY	PAGE
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THE PRESSURES AND FLOWS CALCULATED ON THE PREVIOUS PAGE ARE PLOTTED IN FIGURE 1. ALSO SHOWN IN FIGURE 1 IS THE SURVEILLANCE TEST CURVE CURRENTLY USED BY NMP-1 (REF. 7).

FIGURE 2 IS AN ENLARGEMENT OF THE CURVES ON FIGURE 1 BETWEEN FLOWS OF 2900 gpm AND 3400 gpm. ALSO SHOWN ON THIS FIGURE ARE QUARTERLY SURVEILLANCE TEST RESULTS TABULATED IN APPENDIX A.

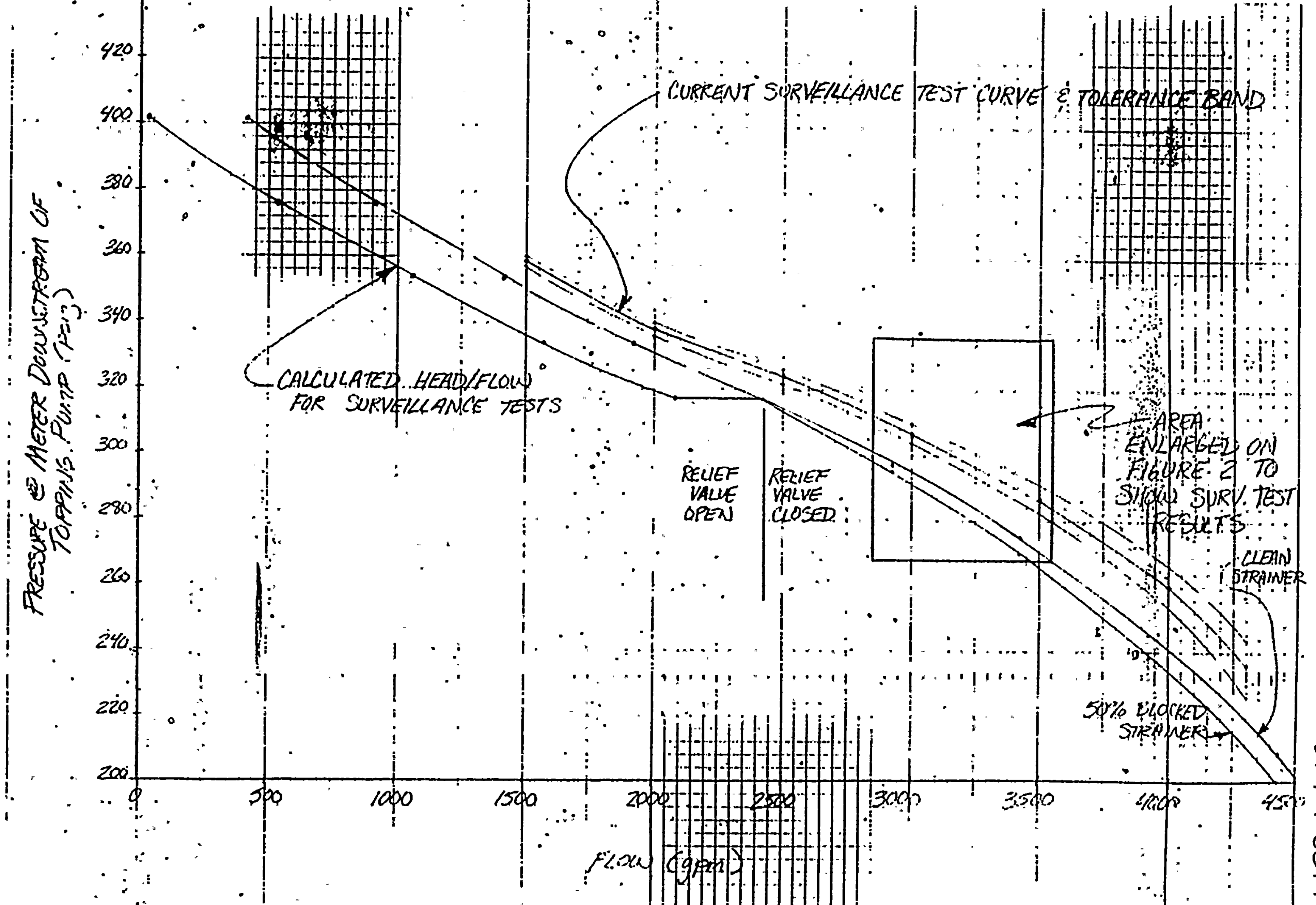


FIGURE 1

SI4-81.1-F001 Rev

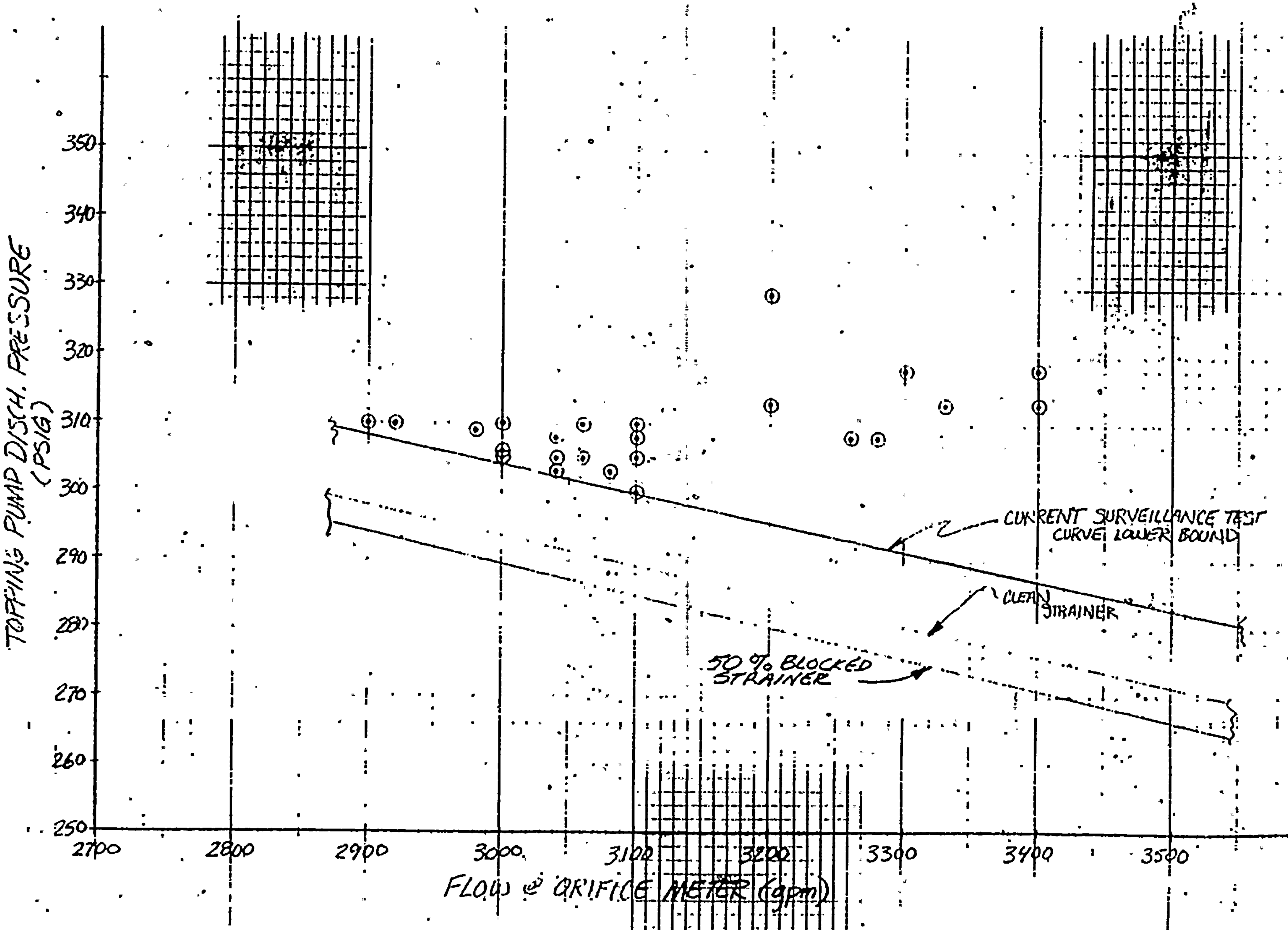


FIGURE 7

SI4-81.1-F001 rev. 1

S14-81.1-F001 rev 1

MPR ASSOCIATES, INC.
1050 Connecticut Ave., NW – Washington, DC 20036

Title: Core Spray Pump Verification Testing
Calculated by: Date: 9/19/88
Checked by: Date: 9/21/88
Reviewed by: Date: 11/30/88

Project: NMP-1 Core Spray System SSFI Support

APPENDIX A P.1 of 2

CORE SPRAY PUMP VERIFICATION TEST RESULTS

Date	Pump Set #111		Pump Set #112		Pump Set #121		Pump Set #122	
	(gpm)	(psig)	(gpm)	(psig)	(gpm)	(psig)	(gpm)	(psig)
2/12/76	3400	313	3200	329	3100	308	3100	308
		(7234 ft)		(760.4 ft)		(711.9 ft)		(711.9 ft)
5/15/76	3400	318	3200	313	3100	308	3100	308
		(733.7 ft)		(722.2 ft)		(710.7 ft)		(711.5 ft)
8/12/76	3300	318	3330	313	3260	308	3280	308
		(734.4 ft)		(723.3 ft)		(711.3 ft)		(711.58 ft)
11/15/76	3100	300	3080	303	3100	300	3100	300
5/10/78	3100	305	3100	305	3100	305	3100	305
2/9/78	3100	305	3000	310	–	–	–	–
11/13/78	3100	305	3100	305	3100	310	3100	310
5/01/86	3040	305	3040	305	3000	305	3000	305
8/12/86	3040	308	3000	306	3040	305	3000	310
11/12/86	3000	305	3000	305	3000	305	3100	305
2/18/86	3040	305	3000	306	2980	309	3020	306
5/10/87	2920	310	2900	310	3000	305	3100	30.5
8/12/87	2900	310	2900	310	3000	310	3000	310
11/09/87	3000	305	3000	305	3000	310	3000	310
2/09/87	3000	305	3000	305	3000	305	3000	305
2/15/88	3000	305	3040	303	3060	305	3060	310

The tabulated results were obtained from data sheets from Surveillance Test N1-ST-Q1.

Early data sheets recorded pump outlet pressure in feet
Conversion psi = feet / 2.308

SI4-81.1-F001 rev 1

MPR ASSOCIATES, INC.
1050 Connecticut Ave., NW – Washington, DC 20036

Title: Core Spray Pump Verification Testing
Calculated by: M Russell Date: 9/19/89
Checked by: Date: 9/21/89
Reviewed by: Date: 11/30/85

Project: NMP-1 Core Spray System SSFI Support

APPENDIX A p.2 of 2

Summary of Core Spray Pump Verification Tests

Flow (gpm)	Pressure (psig) Range	Pressure (psig) Average
2900	310	310
2920	310	310
2980	309	309
3000	305	307
	306	
	310	
3040	303	305
	305	
	308	
3060	305	308
	310	
3080	303	308
3100	300	305
	305	
	308	
	310	
3200	313	321
	329	
3260	308	308
3280	308	308
3300	318	318
3330	313	313
3400	313	316
	318	

The test pressure is summarized from values on previous page

S14-81.1-F001

MPR ASSOCIATES, INC.
1050 Connecticut Ave., NW – Washington, DC 20036

Title: MINIMUM NORMAL TORUS WATER LEVEL
Calculated by: Date: 9-21-88
Checked by: Date: 9/21/88
Reviewed by: Date: 9/21/88
Project: NMP-1
Page 1 of 1

I. PURPOSE: To calculate the minimum normal water level in the Nine Mile Point Unit 1 torus (suppression chamber)

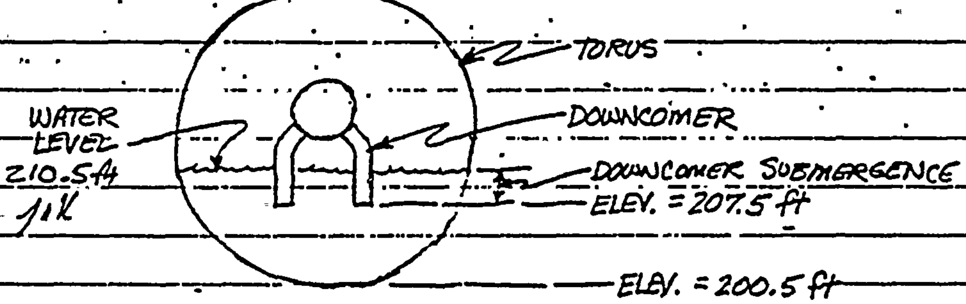
II. RESULTS: The minimum normal torus water level is 10 ft.

III. REFERENCES:

1. CBI dwg. 9-1370 sh. 313, NMPC Index 3-N2-S22.4
2. NMP-1 Tech. Spec. Section 3.3.2

IV. CALCULATION:

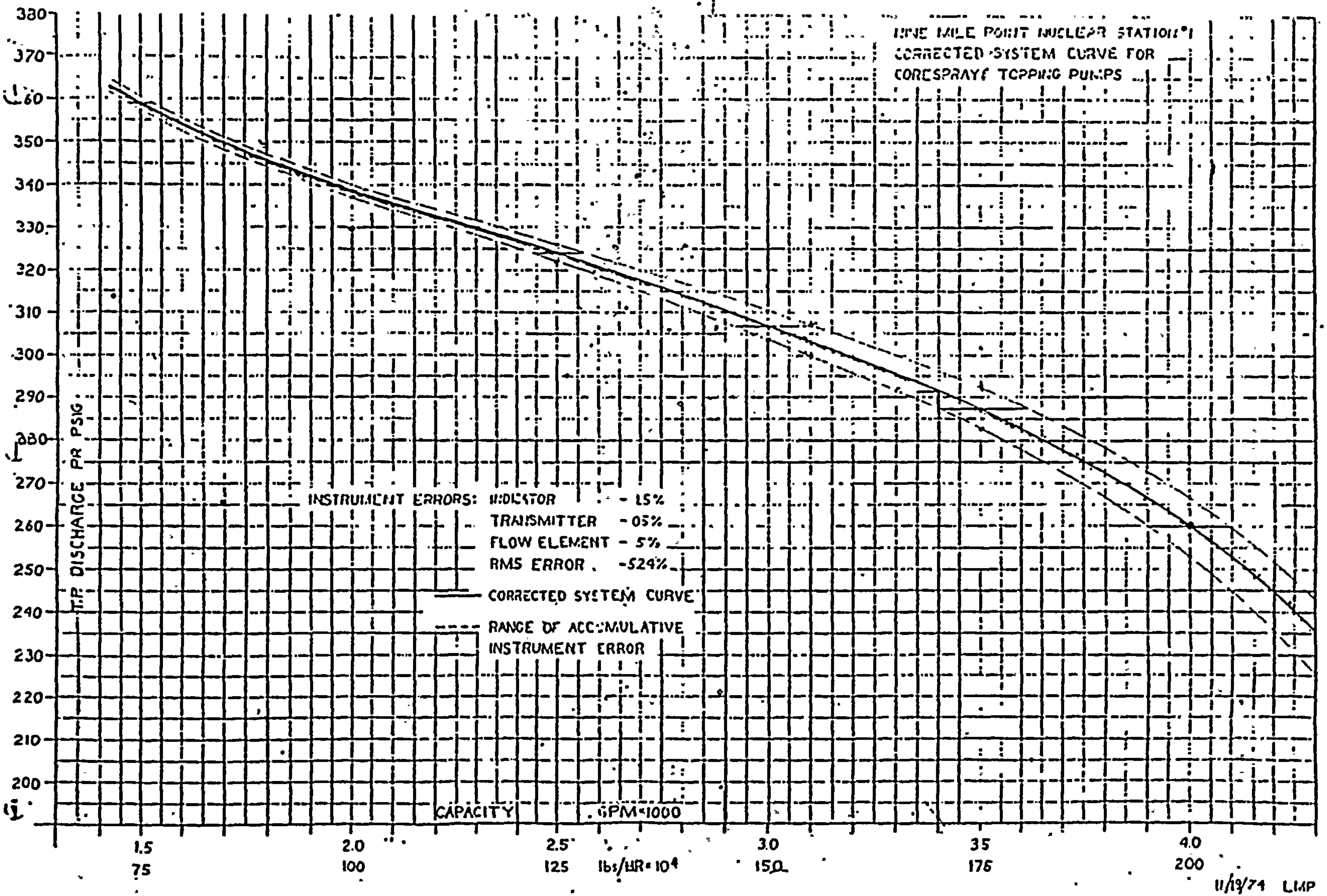
From Ref. 1, an elevation view of a torus cross-section is shown below:



From Ref. 2, the minimum downcomer submergence is 3 ft.

∴ Minimum normal torus water level =

$$3\text{ft} + [207.5\text{ft} - 200.5\text{ft}] = \underline{\underline{10\text{ ft}}}$$



NINE MILE POINT NUCLEAR STATION #1
CORRECTED SYSTEM CURVE FOR
CORESPRAY TOPPING PUMPS

11/13/74 LMP

SH-81.1-F001 rev 1