U. S. NUCLEAR REGULATORY COMMISSION

REGION III

Report No.: 50-461/90005(DRS)

Docket No.: 50-461 License No.: NPF-62

Licensee: Illinois Power Company
500 South 27th Street
Decatur, IL 62525

Facility Name: Clinton Power Station

Inspection At: Clinton Site, Clinton, IL 61727

Inspection Conducted: March 14 through May 14, 1990

Inspectors: J. F. Schapker, Team Leader
Region III

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Approved By: D H Danielson 5/30/90
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Materials and Processes Section

Inspection Summary

Inspection on March 14 through May 14, 1990 (Report No. 50-461/90005(DRS))
Areas Inspected: Special, announced team inspection of a licensee identified reportable event of inadequate design flow through components using the Shutdown Service Water (SX) System for cooling water, and actions associated with Generic Letter (GL) 89-13, "Service Water System Problems Affecting Safety-Related Equipment".
Results: Of the areas inspected, three apparent violations were identified; multiple examples of inoperable SX and Control Room Ventilation System components (Paragraphs 2.f. and 4.); inadequate corrective action (Paragraph 2.a.); and inadequate test control (Paragraph 2.c.). Based on the results of this inspection, the following weaknesses were noted:

- The licensee's corrective action upon identification of low flow rate through a safety-related component in the SX System was not prompt, and therefore unduly extended the inability of the SX component to perform its design function in case of a design basis accident (DBA).

- The inability of engineers to recognize the safety significance of the above deficiency was apparently the cause of the lack of corrective action.

- Engineering errors in the development and implementation of the preoperational test contributed to the SX System being outside its design basis since startup of the plant.

- Inaccurate design input, supplied by the equipment manufacturer, was used to calculate operational flow requirements through one model of a heat exchanger, used in the SX and Control Room Ventilation Systems. The inaccuracies contributed to these components having inadequate flow to meet their design requirements as stated in the Clinton USAR.

DETAILS

1. Persons Contacted

   Illinois Power Company (IP)

   *J. S. Perry, Vice President
   *F. A. Spangenberg, Manager, Licensing and Safety
   *J. G. Cook, Manager, Clinton Power Station
   *J. A. Miller, Manager, Nuclear Safety Engineering Department
   *R. E. Wyatt, Manager, Quality Assurance
   *R. W. Morgenstern, Manager, Scheduling and Outage Management
   *J. F. Palchak, Manager, Nuclear Planning and Support
   *S. P. Hall, Director, Nuclear Program Assessment Group
   *R. S. Frantz, Staff Engineer, Licensing and Safety
   *K. A. Baker, Supervisor, Inspection and Enforcement Interface
   *J. D. Palmer, Manager, Nuclear Training Department
   F. C. Edler, Project Manager, Heat Exchangers
   K. C. Moore, Director, Plant Technical
   J. A. Brownell, Project Specialist, Licensing

   Sargent and Lundy Engineers (S&L)

   J. Blattner, Project Site Manager
   M. Stout, HVAC Project Manager

   U. S. Nuclear Regulatory Commission (U. S. NRC)

   *J. Schapker, Team Leader, Region III
   M. Huber, Reactor Inspector, Region III
   *M. Ring, Branch Chief, Engineering Branch, Region III
   P. Brochman, SRI, Clinton Power Station, Region III
   S. Ray, RI, Clinton Power Station, Region III
   R. Bernhard, Reactor Inspector, Region II
   D. Jarrel, Consultant (Battelle)

   *Denotes those present during the exit interview conducted on April 26, 1990.

   Other members of the plant staff and contractors were contacted during the course of this inspection.

2. Inspection of Shutdown Service Water (SX) System Low Flow Rates

   a. Background

      The SX System provides a reliable source of cooling water for station auxiliaries which are essential to safe shutdown of the station following a design basis loss of coolant accident. The SX System consists of three divisions which correspond to the three electrical safety divisions. Any two of these divisions, operating together, are adequate to ensure safe shutdown of the station. This system is also designed such that no single failure of a component will compromise the ability of the system to safely shut down the station.

In response to Generic Letter (GL) 89-13, "Service Water System Problems Affecting Safety-Related Equipment", the licensee's plan was to open, inspect, and obtain baseline data on safety-related heat exchangers (HX) and develop a program to monitor the performance of the heat exchangers for the life of the plant.

In late December 1989, after approximately three years of commercial operation, a Division I emergency diesel expansion tank high level was observed. The high level was caused by apparent in-leakage from the SX system (having a line pressure of approximately 100 psig) to the emergency diesel generator (EDG) engine closed cooling water system (slightly above atmospheric pressure), reference Enclosure 2. The Division I EDG was declared inoperable and, during the subsequent Limiting Condition for Operation (LCO) of 72 hours, the licensee examined the suspect HX and found through wall pitting in one tube of the dual HX units. The defective tube was replaced with a new tube of like material (90/10 Cu/Ni), the HX was tested, and the EDG was returned to service.

Approximately one week later, a similar tube failure occurred. The HX was repaired, eddy current tested and approximately half of the tubes were cleaned, within a 72 hour LCO. A third failure took place on January 15, 1990, at which time the licensee completely retubed and hydrostatically tested both Division I EDG HX units. A consultant associated with the Electric Power Research Institute (EPRI) was called in to examine the degraded HXs and identified the degradation mechanism as local Microbiologically Induced Corrosion (MIC) accelerated by the thermal and stagnation environment present in the EDG HX tubes.

Suspecting that a global MIC condition could exist in the SX System, the licensee commenced an inspection of all Division I HXs (see Enclosure 3) to assess their physical condition. The remaining Division I HXs exhibited only minor tube wall pitting (maximum depth of 20% wall), along with moderate general corrosion and light siltation. The lack of evidence of widespread MIC attack supports the theory that the combination of thermal and stagnation conditions found in the EDG HXs promoted micro-organism growth and the resulting degradation of the copper-nickel tube wall.

On January 24, 1990, with the plant in Mode 1 at 100% power, licensee test engineers were performing HX performance testing to establish the as-found system flow conditions. Flow measurements of Division I SX System pump room cooling coil 1VH07SA disclosed as-found flow of 32 gallons per minute (gpm). This as-found flow was significantly lower than the 82 gpm required by design documents. The test engineers did not report these values to the Shift Supervisor because they did not believe the test equipment was providing a correct indication of flow. The test engineers reported the flow test results to engineering for trending purposes to indicate the condition of the cooling coil prior to the inspection and cleaning of SX Division 1 heat exchangers.

On January 23, 25, and 29, 1990, four additional SX heat exchangers were tested for flow rates and the results reported to Engineering in a letter to the Project Manager for Heat Exchangers on January 30, 1990. The OVG07SB heat exchanger tested on January 23, 1990, was reported within the design required flows. The 1VH07SA heat exchanger tested on January 24, 1990, was reported as exceeding alarm values, the 1VX135A heat exchanger tested on January 25, 1990, was reported at an alert value, and the 1VX06CA tested on January 29, 1990, was reported as exceeding alarm values. These values were calculated using a formula for determining heat exchanger performance. This formula came from a contractor (MPR Associates, Inc.) who prepared a performance testing monitoring program for the licensee.

On February 13, 1990, the plant entered Mode 4 (Cold Shutdown) because of a failure to meet primary containment integrity.

On February 15, 1990, the flow test data for 1VH07SA was reviewed by the Supervisor, Plant Testing, and he determined that the Shift Supervisor (SS) should be notified of the as-found flow rate. The SS was immediately notified of this condition and directed test engineers to calibrate the test equipment and measure the flow rate again. After verifying instrument calibration, test engineers measured the flow rate at three different locations and found it to be 55 gpm. At 1343 hours, the SS directed the Area Operator to restore design flow through 1VH07SA by adjusting flow through valve 1SX009A to approximately 85 gpm and relocking the valve. The SS further requested that engineering evaluate the operability of cooling coil 1VH07SA.

On February 24, 1990, test engineers notified the SS that performance testing of the Division I Reactor Core Isolation Cooling System [BN] pump room cooling coil identified an as-found flow through the cooling coil of 12 gpm. Design documents require a flow of 18 gpm through this cooler. The SS directed engineering to determine the heat removal capability of the cooling coil at the as-found flow rate and directed that this condition be resolved prior to increasing reactor pressure above 150 pounds per square inch gauge (psig). The SS further directed that engineering coordinate proper corrective actions with Plant Engineering if failures of other heat exchanger performance tests were identified.

On March 2, 1990, engineering held a meeting and discussed flow balancing of the SX system. At this meeting, Sargent and Lundy (S&L), the Clinton Power Station architect-engineer, was assigned responsibility for developing appropriate acceptance criteria and techniques for flow balancing the SX system.

On March 5, 1990, while developing the criteria and technique for flow balancing, S&L identified that the acceptance criteria used in preoperational test PTP-SX-01 of the SX system prior to initial plant operation was not consistent with specifications. The acceptance criteria used in PTP-SX-01 for cooling coil 1VH07SA was a differential pressure of 18.1 inches water gauge while the design/procurement specification indicated a differential pressure of 58.8 inches water gauge. The use of the 18.1 inches water gauge value caused the flow rate to be set incorrectly for cooling coil 1VH07SA.

On March 6, 1990, while reviewing SX system CRs, a system engineer identified that Division II SX System pump room cooling coil 1VH07SB could have the same problem as 1VH07SA and therefore, could also have its flow rate incorrectly set.

On March 6, 1990, at 1500 hours, engineering notified the SS that the flow rate acceptance criteria used in PTP-SX-01 for Divisions I and II SX System cooling coils 1VH07SA and 1VH07SB was not correct and therefore, the required design flow rate was not met. Engineering further identified that the SX System had been outside design basis since initial plant operation as a result of using the incorrect acceptance criteria.

On March 6, 1990, at 1620 hours, at the direction of the SS, the Area Operator adjusted flow through valve 1SX009B to provide a flow rate of approximately 85 gpm through cooling coil 1VH07SB. The SS also directed that flow through 1VH07SA be determined and corrected as necessary. In addition, the SS determined that the flow rate problem was reportable as a Licensee Event Report (LER) under the provisions of 10 CFR 50.73(A)(2)(ii)(B) because the flow rate problem resulted in the plant being in a condition outside its design basis.

The licensee's test engineers identified low flows through the SX System pump room heat exchanger 1VH07SA on January 24, 1990. No further action was taken by the test engineers to verify the accuracy of the test data found but the data was reported to engineering. Licensee engineering also took no action, and apparently did not recognize the safety significance of the reported low flows. The Clinton Power Station was in Mode 1 on January 24, 1990, at 100% power. Not until February 15, 1990, when the supervisor of plant testing reported the low flows to the Shift Supervisor, was any action taken to verify the accuracy of the flow measurements, and corrective measures initiated to restore flow to the affected heat exchanger.

The lack of timeliness of the licensee to implement corrective actions in response to the identification of apparent low flow through a safety-related component necessary to mitigate the consequences of a design basis accident, was identified as an apparent violation of 10 CFR 50, Criterion XVI, Corrective Action. Criterion XVI requires, in part: "Measures shall be established to assure that conditions adverse to quality, such as failures, malfunctions, deficiencies, deviations, defective material and equipment, and nonconformances are promptly identified and corrected." (461/90005-01)

b. Inspection

A special team inspection was conducted during the period of March 14 through May 14, 1990, to evaluate the licensee's corrective action prior to restart, to assess the safety significance of the as-found low flow rates through the SX System, and to determine the root cause of the deficiency.

The NRC inspectors performed observations of the licensee's activities of the inspection of heat exchangers for cleanliness, fouling, flow rate measurements, and flow balancing of the SX System. Reviews of the licensee's preoperational procedure for testing of the SX System were performed and review of the architect-engineer's (S&L) calculations of required flow rates was made by a consultant to the NRC.

c. Service Water System Preoperational Testing

The NRC inspectors reviewed the preoperational testing of the SX System in order to evaluate the testing methodology and determine whether test results and acceptance criteria were within design specifications. The review encompassed preoperational test PTP-SX-01, Revision 2, "Shutdown Service Water System", completed on April 26, 1986, a review of vendor drawings and manuals, design specifications, additional vendor supplied data, and discussions with the licensee and S&L engineers.

Preoperational procedure PTP-SX-01 was performed to demonstrate the ability of the SX System to supply cooling to the various components that it serves, in addition to demonstrating that the interlocks and automatic actuations operated properly. The flow path of the SX System was to be verified by placing system flow through all components of the system and then measuring the flow through each component to verify compliance to design criteria. The technique used for verifying proper system flows was either: (1) measurement of the flow through the cooler using a clamp-on flowmeter; or (2) measurement of the pressure drop across the cooler and ensuring that the pressure drop was comparable to the drop associated with the required flow. The measurements were taken with the entire system in operation while simultaneously throttling the flow through each cooler to achieve the desired flow rates. This testing methodology is acceptable; however, the subsequent discovery that the service water system flows were inadequate is the result of a complex series of events, which are detailed below.

Following the completion of the flow balancing of SX System, Division I, the licensee determined that flow orifices were necessary to restrict flows for the RHR and Fuel Pool Cooling (FPC) heat exchangers, to their design requirements. The flow orifices were designed, installed in the system and tested to verify that the heat exchanger flows were within design requirements.

The problems noted by the inspectors with respect to the testing are detailed below:

(1) Flow Rate Acceptance Criteria

The flow rate acceptance criteria used in the testing procedure were provided by the Nuclear Station Engineering Department at Clinton. These criteria were supposed to be based on K-spec data, vendor manuals and drawings, or vendor supplied data. Since the largest percentage of flow measurements were taken using instruments to measure differential pressures across the individual SX System coolers, pressure drop values that corresponded to the desired flow rates were needed for incorporation into the procedure. However, for the cooling coils provided by American Air Filter (AAF) Company, Inc., no pressure drop data was provided to Clinton and additional communication between S&L and AAF was required. Several letters were sent to S&L which provided the cooling coil performance data on computer printouts for the AAF coils utilized in the SX System, and the pressure drops were included in the performance data. AAF provided data, however, that was not appropriate for the type of cooling coils purchased and installed by the licensee. Specifically, the data did not include appropriate head losses for clean-out plugs included on the AAF model which was installed as room coolers for Engineered Safety Feature Systems. This contributed to less than design specified cooling water flow being supplied to the cooling coils of the room coolers. Subsequently, S&L issued a Design Information Transmittal, DIT-CP-HVAC-0293 to Clinton to provide the water flow requirements and pressure drops for all HVAC equipment supplied in the service water system, except for the Service Water System Pump Room and Main Steam Isolation Valve (MSIV) Leakage Inboard Room Cooling Coils.

The NRC inspectors verified that the incorrect vendor specified pressure drops were used in the service water system testing and found that all the vendor supplied data was incorporated in the test procedure except for the Service Water System Pump Room Cooler, which used a pressure drop of 18 inches instead of 30 inches. No basis for this error could be determined.

(2) ±10% Tolerance Band

The licensee specified a ±10% tolerance on the flow rates for which the inspectors could determine no basis for inclusion in the preoperational procedure. Based on discussions with the licensee, it was determined that the acceptable flow rates specified in the preoperational test procedure were minimums, and therefore, the -10% tolerance should not have been included. Several of the SX System flow rates through the heat exchangers and coolers were less than the design flow rate but all were within the ±10% tolerance during preoperational testing.

(3) Affect of Instrumentation on Acceptance Criteria

It was noted during the review that the acceptable flow rate values supplied by engineering made no additional allowances for any pressure drops between the taps for differential pressure measuring devices and the cooling coils. The vendor supplied pressure drop data was accountable only for the pressure drop across the coil. The actual locations of the instrumentation used during the preoperational tests could not be established, but assumptions were made of the possible pressure tap locations and additional line losses should have been accounted for. (Reference: Enclosure 4)

(4) Post Flow Balance Modification Testing

As previously discussed, flow restriction orifices were installed on the discharge lines of the FPC and RHR Heat Exchangers to eliminate the need for throttling of the FPC and RHR valves to obtain required flow through these heat exchangers. The subsequent testing of the SX System following the completion of the SX flow balancing (PTP-SX-01) was not well documented. In fact, several problems were noted with the testing and are discussed below:

- No specific flow rates were recorded following the modifications.
- The licensee did not consider the impact of the addition of the flow orifice to the discharge line of the RHR Heat Exchanger on flow to the RHR Heat Exchanger 1A Room Cooler. The orifice was located downstream of the point where the discharge piping from the room cooler taps into the RHR Heat Exchanger piping and therefore, the orifice would reduce the flow through the room cooling coil. No documentation was found to support any testing performed to reverify that the room cooling coil flow rate was adequate.
- No SX system rebalance was performed following the installation of the flow restricting orifices.

The licensee was informed at the exit interview that these deficiencies identified in the preoperational procedure were apparent violations of 10 CFR 50, Appendix B, Criterion XI, Test Control, which requires, in part: "A test program shall be established to assure that all testing required to demonstrate that structures, systems, and components will perform satisfactorily in service is identified and performed in accordance with written test procedures which incorporate the requirements and acceptance limits contained in applincable design documents. Test procedures shall include provisions for assuring that all prerequisites for the given test have been met, that adequate test instrumentation is available and used . . ." (461/90005-02)

The NRC inspectors reviewed preoperational test results for a sample of three other systems to determine if similar problems may exist. No additional problems were discovered during the review. The licensee also conducted a review of other preoperational tests to determine if similar problems existed. No additional deficiencies were identified in those reviews.

d. Review of Flow Measurement Accuracy Using Ultrasonic Devices

Until 1989, Clinton, like most utilities, primarily depended on differential pressure (DP) measurements to balance and ensure adequate mass flow to the multiple parallel heat exchangers in the SX System (see Enclosure 4). Vendor measurements of pressure drop as a function of mass flow through the individual HX tubing were used in conjunction with a temporarily installed differential pressure transducer to adjust a throttling valve located on the inlet side of most of the HX components. This approach to determining component mass flow presents several possible generic mechanism problems which were discussed in Paragraph 2.c. of this report. With the advent of high accuracy nonintrusive liquid velocity measurement devices, a check on the original methodology is now available.

Two liquid flow velocity meters were utilized to provide mass flow values for system components:

For pipe sizes in excess of six inches, a Leading Edge Flow Measurement device, Model-801A (LEFM-801A) with strap-on transducers (manufactured by Westinghouse Corporation) was used. Discussions with the Westinghouse representative established the instrument accuracy at 0.5% of the indicated velocity. By measuring pipe wall thickness (using a calibrated ultrasonic testing gauge) and circumference, pipe flow area may be determined to an accuracy of 8.75% for an 8-inch pipe and to 2.36% for a 30-inch pipe. This accuracy accounts for both the actual pipe wall thickness, and allows for a 1/8 inch uniform corrosion plus variable nodule layer as was observed to exist. The fluid density will vary with temperature, but over the limited range expected during the measurement process, it is considered negligible. The continuity equation is then used to calculate the mass flow from the measured fluid velocity in the pipe.

The resulting total root mean square (rms) uncertainty in large bore mass flow measurement is then:

For 30" pipe --------- 2.41%
For 8" pipe --------- 8.76%

For small bore piping (less than six inches), a Polysonics model DHT-P was used. This device works on a high frequency doppler shift principle, and the instrument is specified as accurate to 5% of range. For determining the mass flow in small bore pipe, site personnel use nominal pipe data, which has a diameter tolerance of approximately 5%. This translates to a flow area uncertainty of 9.75%. Again, assuming a 1/8 inch crud layer and moderate variable tuberculation in the pipe, an additional 19.2% uncertainty in flow area is introduced. Utilizing the rms value for independent uncertainties gives a total mass flow measurement uncertainty for the 2½-inch schedule 40 test case of 22.1%. This is the smallest pipe, and consequently, the largest uncertainty (barring geometric anomalies and measurements in non-fully developed flow regions) that would commonly be expected in the SX System.

The minimum component mass flows shown in Enclosure 6 are then found by subtracting the measurement uncertainty from the indicated measurement value. For example, the first entry (1VH07SA) had a component design flow rate of 82 gpm, while the as-found flow (sonic transducer measurement prior to any flow adjustment) was measured at 20.5 gpm. The minimum possible flow is then found by substracting the uncertainty in the measurement from the registered value. This means that the flow could have been as low as 16.0 gpm. Following the flow balance, the component had a flow measured by sonic transducer of 102 gpm.

e. Review of Heat Transfer Correlations

It should be noted that the flow through the HX is not a direct measure of the calculated heat removal capacity of the component. The basic relationship for water to air heat exchangers is shown in Enclosure 5. This enclosure indicates that, at least in a generic case, a reduction to only 20% of the design liquid flow for the HX results in the component still being able to remove approximately 40% of its design heat load. A second observation that should be made is the difference between the heat exchanger design heat removal capacity (design heat load), which is the manufacturer's performance guarantee for rate flows and temperatures, and the maximum heat rejection rate required during a loss of coolant accident (LOCA) or other potential core damage sequence (required emergency load). The required emergency load is the value (Btu/hr) required by Technical Specifications to avoid exceeding the ambient temperature limitations of equipment in the proximity of the HX, and is considerably lower than the HX design load. This difference in capacity allows for variations such as lower than design flow rates, fouling of heat transfer surfaces, and the like, while still providing protection to the local equipment.

As previously mentioned, the task of determining the actual heat transfer capability of a heat exchanger requires a substantial thermal load to be placed on the component. Without differential temperatures of at least five to ten degrees, inaccuracies in temperatures and flow quickly render the measurement useless. The alternative used here is to calculate the projected heat removal rates based on an analytical model of the heat transfer process.

This discussion focuses on heat exchangers which must transfer compartment or room heat loads to the SX system, i.e., room coolers. The calculated heat transfer capacity of room cooler units for both SX divisions was prepared by S&L engineers using the PC-COILSYM program developed by Professor F. C. McQueston of the Oklahoma State University. The documentation which explains the code was well written, and appeared to be both correct and complete. Dr. McQueston is well recognized for his work in heating, ventilation, and air conditioning (HVAC) teaching and texts.

The COILSYM program is a flexible and technically comprehensive code for liquid to vapor heat transfer processes. It necessarily places a responsibility on the user to clearly define the process variables. Much of the consultant's effort was focused on the verification of these input variables. While it was not possible to check all the data, nevertheless, geometry factors from design prints, materials from manufacturer's specifications, fluid flows, input temperatures, and fouling factors were spot checked on several runs. In addition, "sanity checks" were performed on the output data to show that the calculated result fell within the bounds of reason. The viability of all questionable results were challenged.

All checked input data was found to be accurate, and, with the exception discussed below, calculated results were found to be reasonable.

One non-conservatism was found to exist in the input data, in that there was no reduction in the secondary (air) side heat transfer coefficient to account for possible fouling of the room cooler heat transfer surfaces. Fouling of the primary (water) side was set at 0.002 which was shown to be appropriate.

On the conservative side, 95°F cooling (SX) water was assumed for all computed runs. Actual Lake Clinton temperature has never exceeded 91°F which would have the effect of increasing the cooler capacity.

f. <u>Operability Conclusions</u>

(1) <u>Current Operability Conclusions</u>

Based on the review of the measured fluid flow to each of the Divisions I, II, and III heat exchangers, the accuracy of the measurements, and the calculations performed, the Clinton SX

System is capable of removing the emergency heat load (as indicated in Enclosure 6) from all of the safety-related shutdown components serviced by the system.

(2) SX System Operability with As-Found Flows

Applying the same analysis techniques discussed in Paragraph 2.e., calculations of projected SX System heat removal capability under the component flow values in the as-found (flow balanced using differential pressure cell measurements) were conducted. The as-found flow values were measured using the sonic flowmeters previously described. The same series of calculational checks were used in the post-flow balance conditions.

All but one of the pre-flow balance calculated heat removal capacities were found to be accurate, with the previously mentioned caveat of no allowance of decreased heat transfer due to fouling on the secondary side of the room coolers.

The reasonableness of one of the calculations was found to be in question. The as-found flow to the Combustible Gas Control System room cooling coil cabinet (1VR09S) was measured at 7.1 gpm using the ultrasonic detector. Without any allowance for instrument accuracy, the code indicated that the coil could still remove the emergency heat load.

With a 5.8 inch tube diameter (ID), an apparent flow velocity of 0.6 feet per second was calculated by the code. Hand calculations show the velocity to be 0.41 feet per second. An assumption required by the code is that the liquid flow inside the tube should be fully turbulent. A Reynolds (Re) number of 2500 or less will abort the run based on non-turbulent flow conditions. Hand calculations did, in fact, show the Reynolds number to be approximately 2600. Reference texts indicate that the desired flow regime probably would not exist at this velocity. A subsequent run using an input flow rate of 7.0 gpm tripped the low Re logic and would not compute a heat removal capacity. Allowing for a measurement accuracy of +/- 22.1% gives a minimum possible flow of 5.53 gpm which will produce a heat removal rate which is clearly below the required emergency limit. The as-measured flow rates for all remaining code runs provide a clear indication of a valid turbulent flow regime.

Prior to flow balancing using ultrasonic velocity detection devices described previously in this report, the following Divisions I and II heat exchangers in the safety-related portion of the SX System were calculated to have insufficient cooling capacity to meet the LOCA and/or cooldown requiremnets as specified by the Clinton USAR. The conclusions reflect the pre-flow balanced condition as measured by the ultrasonic flow velocity transducers, and instrument accuracy has been accounted for in all calculations.

DIVISION I

Heat Exchanger	Designation	As-Found Capability Meets Requirements For: LOCA	Cooldown
Low Pressure Core Spray Pump Room Cooler	1VY01S	Yes	No
Residual Heat Removal Pump Room Cooler	1VY02S	Yes	No
Residual Heat Removal Heat Exchanger Room Cooler	1VY03S	No	No
Reactor Core Isolation Cooling Pump Room Cooler	1VY04S	No	No
Service Water System Pump Room Cooler	1VH07SA	No	N/A
Standby Gas Treatment Room Cooler	0VG05SA	No	N/A
Combustion Gas Control System Room Cooler	1VR09S	No	N/A

DIVISION II

Heat Exchanger	Designation	As-Found Capability Meets Requirements For: LOCA	Cooldown
Residual Heat Removal Heat Exchanger Room Cooler	1VY05S	No	No
Standby Gas Treatment Room Cooler	0VG05SB	No	N/A
H_2 Recombiner Room Cooler	0VG07SB	No	N/A

The licensee was informed at the exit interview that this condition is an apparent violation of the Clinton Power Station Technical Specifications, Paragraph 3.7.1.1, which states: "The shutdown service water (SX) loop(s) shall be operable during times when its associated system(s) or components are required to be operable." This includes Modes 1, 2, 3, 4, 5, and when handling irradiated fuel in the Fuel Handling Building or primary containment.

The SX System was apparently inoperable from June 21, 1986 to April 6, 1990, due to inadequate design flow rates through several safety-related heat exchangers (reference the above listed SX System heat exchangers) could not meet the LOCA and/or cooldown heat capacity requirements as specified by the Clinton USAR. (461/90005-03)

The licensee informed the NRC that an analysis of the safety significance of the SX System low flows through the components necessary for mitigating the consequences of a design basis accident (DBA) is currently in the process and will be completed by May 25, 1990.

g. Observations of SX Inspections and Flow Balancing

The NRC inspectors observed the licensee's activities to restore adequate flow through the SX heat exchangers, inspection of heat exchanger and piping for fouling and degradation, and observations of cleaning and treatment of the diesel generator heat exchangers for microbiologically induced corrosion. The inspectors observed the use of ultrasonic flow detector measurements of component flows using the LEFM-801A, for piping in excess of six inches ID. For piping sizes less than six inches ID, the Polysonics, Model DHT-P was used. The Polysonics model was licensee owned and calibrated in accordance with the licensee's procedure and manufacturer's requirements. The LEFM-801A was not the licensee's equipment, but was contracted for and inspection services provided by Caldon Incorporated, who supplied operators/inspectors and calibration specifications for use of the equipment. The licensee, in evaluating heat exchanger performance testing, initially used the polysonic and parametric flow meters for measurements of flows within the SX System. The parametrics flowmeter was used for information only (for the flow measurements during this inspection, as calibration of the equipment was not current).

However, during flow verification inspections, the polysonic flowmeter demonstrated increased inaccuracies for large bore piping flows (piping in excess of six inches). This was established during flow measurements of large bore piping adjacent to the Division I SX pump, where a flow indicating differential pressure (DP) cell is installed in the system. This DP cell indicated flows in excess of the polysonic flowmeter. The licensee determined that the doppler shift principle for measuring flows in the large bore piping was not providing accurate flow measurements. This inaccuracy was attributed to the concentration of particles in the water influencing meter accuracy. In an established flow profile, the flow at a point near the center of the flow stream travels at a faster rate. As the concentration of reflectors increases, the instrument averages more of the slower moving reflectors since the depth of sound penetration is reduced. All doppler flowmeters are influenced by flow profile. For this reason, the licensee explored other non-intrusive flow measuring devices and contracted for the services of Caldon Inc., to perform flow measurements on the piping in excess of six inches in diameter. The LEFM flowmeter does not use the doppler principle for flow measurement.

The LEFM flow measurement is based on the principle that the speed of propagation of acoustic energy in a fluid is influenced by the rate of flow of that fluid. The LEFM-801A uses this measured line velocity to determine the volume flow rate. Flow measurements in large bore pipe were performed and found accuracies corresponded to the DP cell indications of flow. The NRC inspectors explored the accuracies of these non-intrusive acoustic flow measuring devices which is discussed in Paragraph 2.d. of this report.

With the aid of these flow measuring devices, the licensee restored flows to the SX components as required.

A pipe routing modification was necessary to restore adequate flow to RHR system heat exchanger cooling coils 1VY03S and 1VY05S of Divisions I and II. The NRC inspector's review of this modification concluded that the licensee's action to restore flow to the heat exchangers complied with the Clinton USAR and regulatory requirements. The modification was necessitated by an inadequate post flow balancing inspection after installation of the RHR orifice during preoperational testing.

3. Review of Licensee's Response to Generic Letters

(Open) Generic Letter (GL) 89-13-01: "Service Water System Problems Affecting Safety-Related Equipment"

In response to GL 89-13, the licensee planned to open, inspect, and obtain baseline data on safety-related HX's and develop a program to monitor the performance of the HX for the life of the plant. This inspection was planned for the plant's second refueling outage in the Fall of 1990. The inspections were accelerated when leaks due to microbiological corrosion were discovered in the Divisions I and II diesel generators heat exchangers.

Due to the deficiencies discovered during the course of this inspection, the licensee has performed extensive system verification, i.e., flow measurements, through each heat exchangers, inspections, cleaning, and piping and orifice modifications to assure adequate flow through the SX heat exchangers. Further, inspection, cleaning and orifice modifications are planned to be implemented in the next refueling outage (September 1990).

The licensee's action in response to the GL appears to be adequate to resolve the issues contained therein. Corrective actions to address the recommended action contained in GL 89-13 are in progress. These corrective actions will be reviewed during a future NRC inspection.

4. American Air Filter (AAF) Heat Exchangers Installed in the Control Room Ventilation (VC) System

The licensee inspected the flow rates through the AAF heat exchangers installed in other plant systems due to the differential pressure (DP) deficiency described in Paragraph 2.c.(1) of this report. The result of this inspection identified low flow rates through the following VC heat exchangers:

- Equipment Room Cooler OVC18AA

- Equipment Room Cooler OVC18AB

The licensee took corrective measures and restored the proper flows to the above heat exchangers. Mr. F. A. Spangenberg was informed by telecon on May 14, 1990, that the inadequate flow rates through the above identified VC heat exchangers from June 21, 1986 to April 3, 1990, is an apparent violation of the Clinton Technical Specifications, Section 3/4.7.2, "Control Room Ventilation System", Paragraph 3.7.2, which states: "Two independent Control Room Ventilation Systems shall be Operable." Applicability: "All Operational Conditions and when irradiated fuel is being handled in the secondary containment." (461/90005-04)

The licensee reported to the NRC the AAF differential pressure errors under 10 CFR Part 21 on March 29, 1990, and documented the notification in a letter to the NRC on April 3, 1990. The NRC has subsequently issued Information Notice No. 90-26, "Inadequate Flow of Essential Service Water to Room Coolers and Heat Exchangers for Engineered Safety-Feature Systems", to all holders of operating licenses or construction permits for nuclear power reactors to alert licensees of potential problems from using differential pressure drop to measure flow through heat exchangers.

5. Exit Interview

The NRC team leader met with licensee representatives (denoted in Paragraph 1) at the conclusion of the inspection on April 26, 1990, and via telecon on May 14, 1990. The NRC team leader summarized the scope and findings of the inspection noted in this report. The NRC team leader also discussed the likely informational content of the inspection report with regard to documents or processes reviewed by the NRC team leader during the inspection. The licensee did not identify any such documents or processes as proprietary.

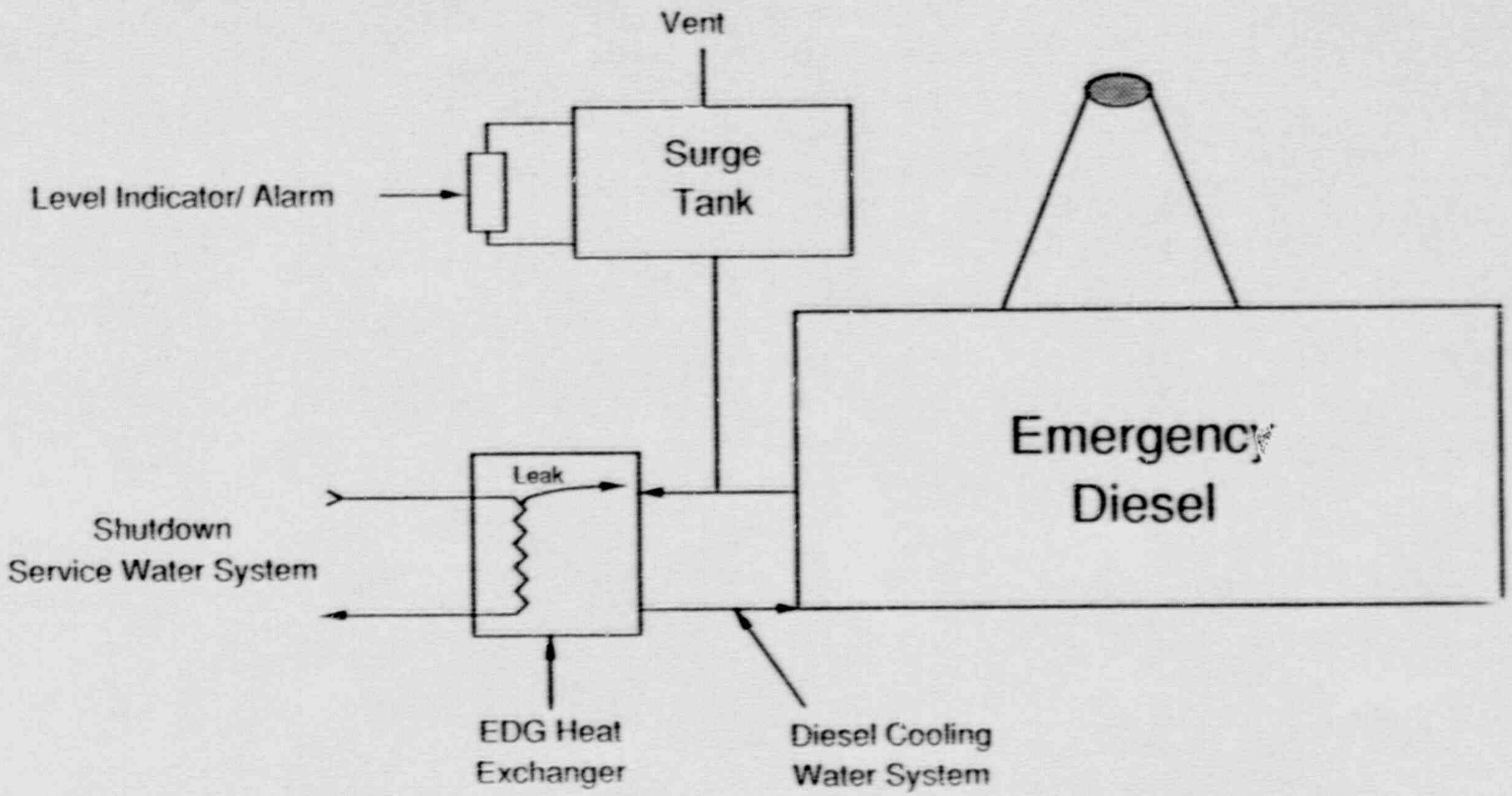

FIGURE 1. **Emergency Diesel - SX System Interface**

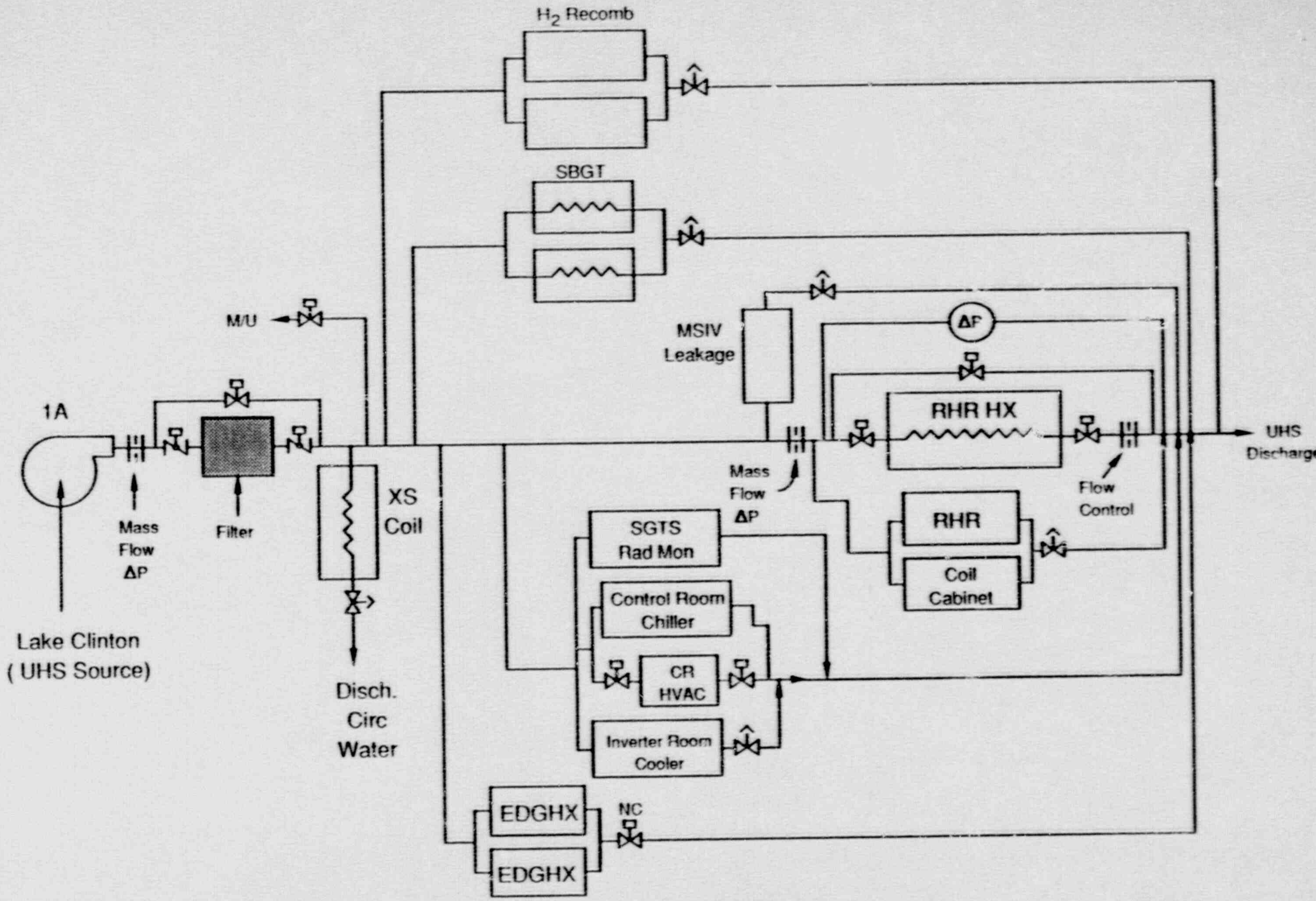

FIGURE 2. Simplified SX Division 1 Schematic
(Major Heat Loads)

ENCLOSURE 3

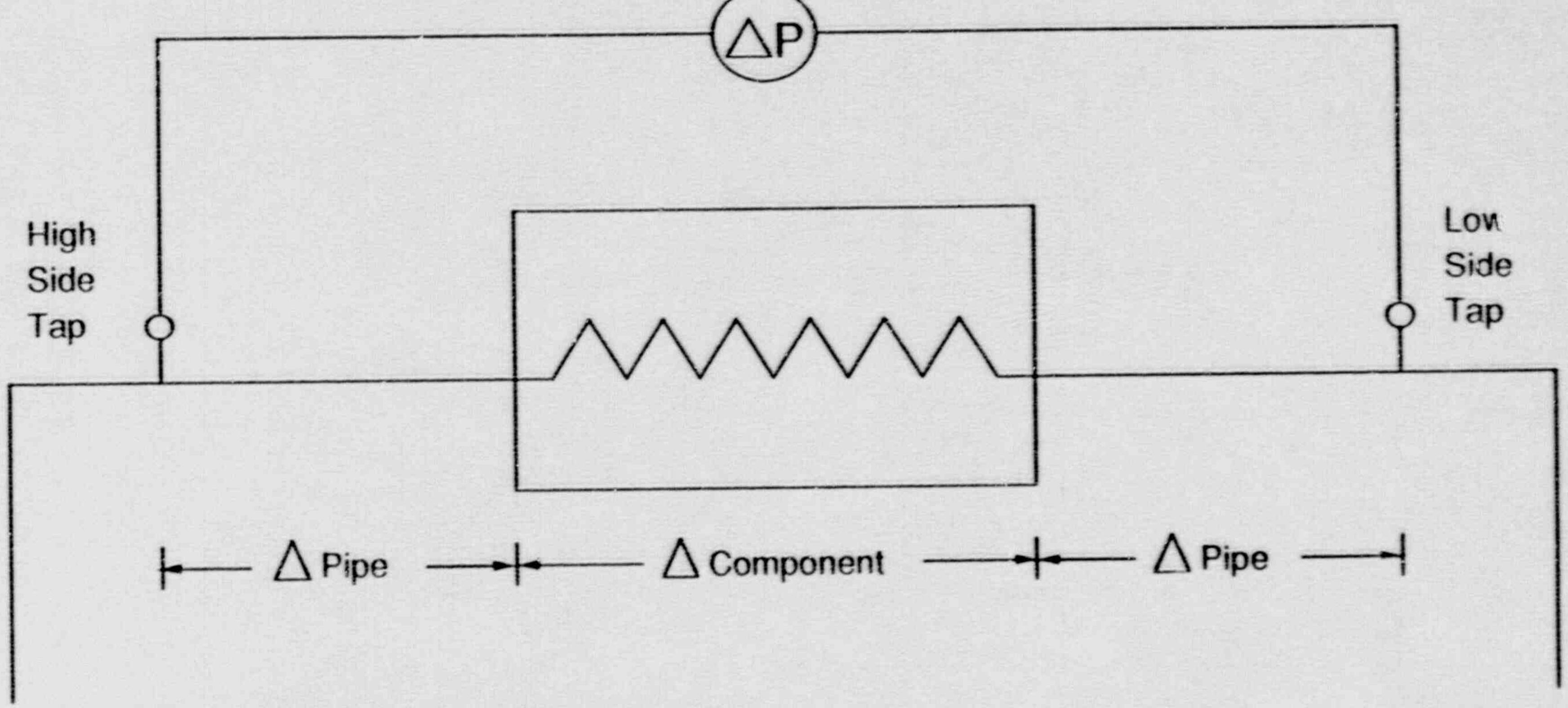

FIGURE 4. **Component Differential Pressure Drops**

ENCLOSURE 4

FIGURE 3. **Chilled Water Terminal Flow versus Heat Transfer**

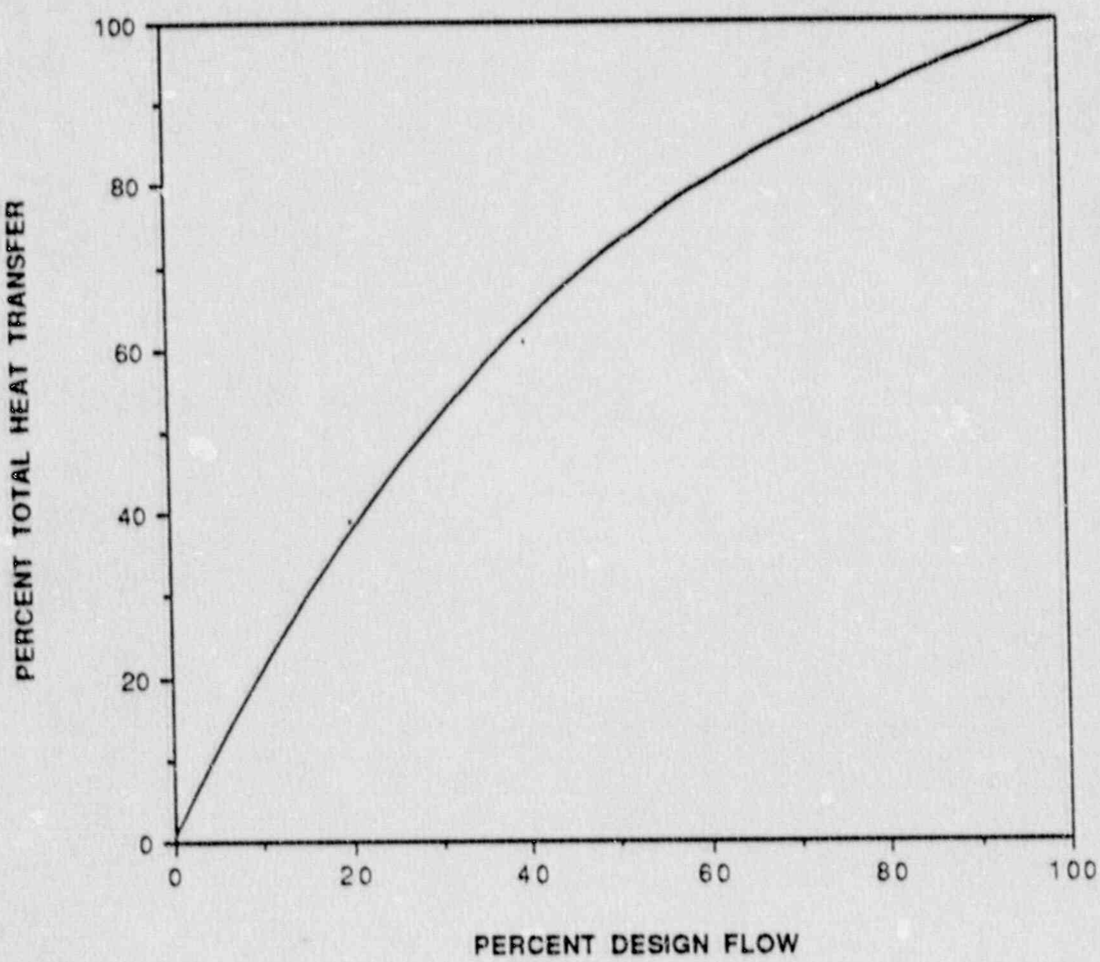

Table 1
Divisions 1 & 2 Shutdown Service Water (SX)
Pre- and Post-balance Component Flows

Division I

Equipment Designation	Component Flow Rate (GPM)	% of Design Flow
1VH07SA SX Pmp Room Flow:		
Design	82	100
As-Found	20.5	25
Minimum	16.0	19.5
As-Left	102	124
0VG05SA SBGT Room Flow:		
Design	90	100
As-Found	40.3	45
Minimum	31.4	35
As-Left	98.6	110
0VG07SA H_2 Recombiner Room Flow:		
Design	82	100
As-Found	50.8	62
Minimum	39.6	48
As-Left	92.6	113
1VY03S ECCS - RHR 1A HX Room Flow:		
Design	60	100
As-Found	23.0	38
Minimum	17.9	30
As-Left	70.9	118

Table 1 (cont'd)

Equipment Designation	Component Flow Rate (GPM)	% of Design Flow
1VX13SA <u>Inventer Room</u> Flow:		
Design	20	100
As-Found	15.7	79
Minimum	12.2	60
As-Left	23.7	118
1VY09S <u>MSIV Leakage Room</u> Flow:		
Design	60	100
As-Found	43.3	72
Minimum	33.7	56
As-Left	58	97
OVC13CA <u>Control Room HVAC Chiller</u> Flow:		
Design	800	100
As-Found	874	109
Minimum	804	100.5
As-Left	849	106
OPR13A <u>SGTS Exh Rad Monitor Cooler</u> Flow:		
Design	20	100
As-Found	13.8	69
Minimum	10.7	53
As-Left	19.3	96
1DG11AA/1DG12AA <u>EDG HX</u> Flow:		
Design	450/600*	100/100
As-Found	1139/1092	253/232
Minimum	1048/1005	233/167
As-Left	553/743	123/124

* Verified by Technical manual reference.

Table 1 (cont'd)

Equipment Designation	Component Flow Rate (GPM)	% of Design Flow
1E12B001A RHR HX Flow:		
Design	5800	100
As-Found	4466	77
Minimum	4243	73
As-Left	5671	98
1VX06CA Div. 1 Switchgear HX Flow:		
Design	160	100
As-Found	231	144
Minimum	203.3	127
As-Left	207.5	130
1VY02S ECCS RHR 1A Pump Room Flow:		
Design	60	100
As-Found	52	87
Minimum	40.5	67
As-Left	88.1	147
1E12C002A RHR Pump Seal Cooler Flow:		
Design	20	100
As-Found	22	110
Minimum	17.1	85
As-Left	22	110
1VY01S ECCS LPCS Pump Room Flow:		
Design	90	100
As-Found	57.5	64
Minimum	44.8	50
As-Left	106.8	119

Table 1 (cont'd)

Equipment Designation	Component Flow Rate (GPM)	% of Design Flow
1VY04S ECCS RCIC Pump Room Flow:		
Design	18	100
As-Found	10.1	56
Minimum	7.9	44
As-Left	17.5	97
1VR09S CGCS Room Flow:		
Design	36	100
As-Found	7.1	20
Minimum	5.5	15
As-Left	27.4	76
1VP14CA Drywell Chiller Flow:		
Design	2000	100
As-Found	2140	107
Minimum	2033	102
As-Left	2058	103
1FC01AA Fuel Pool Cooling HX Flow:		
Design	4143	100
As-Found	3376	81
Minimum		78
As-Left	3898	94
1VH07SB SX Pump Room Flow:		
Design	82	100
As-Found	38	46
Minimum	29.6	36
As-Left	99.5	121

Table 1 (cont'd)

Equipment Designation	Component Flow Rate (GPM)	% of Design Flow
	DIVISION 2	
0VG05SB SBGT Room 1B Flow:		
Design	90	100
As-Found	40.3	45
Minimum	31.4	35
As-Left	114.3	127
0VG07SB H_2 Recombiner Rm Flow:		
Design	90	100
As-Found	20.9	23
Minimum	16.3	18
As-Left	72	80
1VY05S ECCS RHR HX Room Flow:		
Design	60	100
As-Found	26	43
Minimum	20.2	34
As-Left	76.5	127
1VX13SB Inverter Rm 1B Flow:		
Design	20	100
As-Found	15.4	77
Minimum	12	60
As-Left	20.9	105
1VY10A MSIV Leak Otbd Room Flow:		
Design	10	100
As-Found	12	120
Minimum	9.4	94
As-Left	11	110

Table 1 (cont'd)

Equipment Designation	Component Flow Rate (GPM)	% of Design Flow
1VX14S Div 4 Inverter Room Flow:		
Design	60	100
As-Found	28.4	47
Minimum	22.1	37
As-Left	66.5	111
0VC13CB Control Room HVAC Chiller Flow:		
Design	800	100
As-Found	905.6	113
Minimum	833	104
As-Left	872	109
1DG11AB/1DG12AB EDG HX Flow:		
Design	450/600	100/100
As-Found	1326/1362	295/227
Minimum	1220/1253	271/209
As-Left	625/751	139/125
1E12B001B RHR HX 1B Flow:		
Design	5800	100
As-Found	5643	97
Minimum	5360	92
As-Left	6342	109
1VX06CB Div 2 Switchgear HX Condenser Flow:		
Design	160	100
As-Found	74.9	47
Minimum	65.9	41
As-Left	178.8	112

Table 1 (cont'd)

Equipment Designation	Component Flow Rate (GPM)	% of Design Flow
1VY06S/1VY07S ECC RHR Pump Room Flow:		
Design	60 ea.	100
As-Found	34.7/35.8	58/60
Minimum	27/27.9	45/47
As-Left	75.4/64.2	126/107
1E12C002B&C RHR Pump Seal Cooler Flow:		
Design	20 ea.	100
As-Found	12.9/11.6	64/58
Minimum	10.0/9.0	50/45
As-Left	21.1/18.2	105/91
1VR12S CGCS Room Flow:		
Design	36	100
As-Found	9.2	26
Minimum	7.2	20
As-Left	20.3	56
1VP04CB Drywell Chiller 1B Flow:		
Design	2000	100
As-Found	2301	115
Minimum	2186	109
As-Left	2230	111
1FC01CB Fuel Pool Cooling HX Flow:		
Design	4143	100
As-Found	4847	117
Minimum	4677	113
As-Left	3607	87