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SAFETY EVALUATION FOR AN ULTIMATE HEAT SINK TEMPERATURE INCREASE TO 95^{O}F AT INDIAN POINT UNIT 3

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EXECUTIVE SUMMARY

This report describes the results of analyses used to support an increase in the design basis maximum temperature of the Indian Point 3 plant ultimate heat sink (Hudson River) to 95°F. The Service Water System (SWS) uses cooling water from the Hudson River to provide cooling to various plant equipment. SWS cooling is required to ensure equipment operability and adequate cooling performance to remove component and decay heat to support normal, safe plant operation, shutdown during abnormal conditions, and mitigation of postulated design basis accidents.

For this evaluation, normal, safe plant operation is defined as the ability to cool equipment whose sudden failure could cause a design basis transient analyzed in FSAR Chapter 14 or whose operability is required to ensure that initial conditions assumed in the accident analyses are not exceeded. This includes cooling the containment atmosphere via the reactor containment fan coolers and the various coolers required for turbine/generator operation. The SWS also provides cooling to the Component Cooling Water System (CCWS) which in turn cools the following equipment needed for normal, safe plant operations: the spent fuel pit heat exchanger, the reactor coolant pumps, the charging pumps, various sample coolers, the reactor vessel support cooling blocks, and various radiation monitors. In addition, cooling water from the Hudson River is used to cool the main condenser via the Circulating Water System. Adequate cooling of the condenser is required to maintain vacuum and thus prevent turbine trip on low vacuum.

The SWS and the CCWS provide the required cooling to support plant shutdown under abnormal condtions. The safe shutdown condition is hot shutdown. Cooling required under normal operations bounds the hot shutdown requirements. Following postulated plant fires, cooldown to cold shutdown via the RHR heat exchangers is needed to meet 10 CFR 50 Appendix R requirements.

The SWS provides cooling to the emergency diesel generators if offsite power is lost.

The SWS provides cooling to accident-required equipment following postulated design basis accidents, including the Reactor Containment Fan Coolers, the Emergency Diesel Generators, and the CCWS. The CCWS in turn cools the SI pumps, the Recirculation Pumps, the RHR Pumps, and the RHR Heat Exchangers. The effects of increased SWS temperature on the containment integrity analysis is addressed in WCAP-12269, "Containment Margin Improvement Analysis for Indian Point Unit 3", Revision 1.

The safety evaluation in this report addresses the functions discussed above.

CCWS cooling functions and operability are included in this report. To support this effort, a thermal-hydraulic computer model of the CCWS was developed to determine process conditions during various modes of operation. Each component was evaluated to ensure that supplied flow was adequate to support safety functions with an ultimate heat sink (UHS) temperature of 95^{O}F.

SWS cooling functions for non accident-required equipment were evaluated and required SW flow rates were determined to support equipment cooling. The evaluation of non accident-required components that are ultimately serviced by the Hudson River are not included in this report.

A licensing evaluation was then performed to ensure that the current licensed safety limits affected by UHS temperature are met. It is concluded that all equipment required for safe plant operations serviced by the 95^{O}F service water will operate acceptably. The current safety limits affected by SWS temperature will be met, and within the scope of this evaluation, this change does not involve a significant hazards consideration.

1.0 INTRODUCTION

The New York Power Authority (NYPA) Indian Point Unit 3 Service Water System (SWS) draws water from the Hudson River, and uses this water to cool various plant components. The warmed water is subsequently returned to the river. The design of the SWS is currently based on the inlet river water not exceeding 85°F. Because of the 1988 meteorological conditions, Westinghouse prepared a Justification for Continued Operation (JCO) for the Indian Point Unit 3 plant to operate the CCWS and the reactor containment fan coolers with a SWS inlet temperature up to 90°F. NYPA has determined that the ultimate heat sink temperature may be challenged during future summers. To address this issue in a systematic manner, NYPA contracted Westinghouse to perform the necessary analyses to increase the design basis temperature of the ultimate heat sink to as high as 95°F.

1.1 1988 JCO for Increased Service Water System Temperature

In 1988, Westinghouse prepared two JCOs for Indian Point Unit 3 based upon maximum SWS inlet temperatures of 87°F and 90°F. These safety assessments addressed the ability of the Component Cooling Water System (CCWS) to perform its normal and post-accident functions given the higher service water temperatures. They also addressed the containment analysis and reactor containment fan cooler motors. It was noted that additional confirmatory design calculations would be required to permanently increase the design temperature of the SWS.

To maintain adequate cooling at the elevated temperatures, specific recommendations regarding component cooling water (CCW) pump operating requirements were provided in the JCO. The limiting requirements were based upon ensuring that the CCW outlet temperature remained below 152°F. Recommendations were made to accomplish this.

Westinghouse recommended that interim emergency operating procedures be developed for implementation if CCW heat exchanger temperatures approached 150°F. The object was to maximize the CCW flow through the CCW heat exchangers and to reduce the CCW flow to the Residual Heat Removal (RHR) heat exchanger, as necessary, to maintain the CCW heat exchanger outlet temperatures at or below 150°F.

1.2 1989 PROGRAM TO INCREASE THE DESIGN BASIS OF THE SERVICE WATER TEMPERATURE TO 95 DEGREES F

This report contains the results of analyses performed to evaluate increasing the maximum allowable service water temperature. The conclusion of the analyses is that a river water temperature up to and including 95°F is acceptable providing operational changes are made. These changes are delineated in Section 6.0.

The analyses evaluated each accident-required component that is serviced to confirm acceptability of increased temperature and any corresponding flow or operating limits.

Section 2.0 contains a brief description of the SWS and the interfacing Auxiliary Coolant System (ACS). Sections 3.0 and 4.0 describe the analyses performed, including individual results and conclusions. Section 5.0 contains a summary of the containment integrity analysis performed using the higher SWS temperature, the results of the licensing evaluation that justifies a change in the ultimate heat sink design basis temperature to 95°F, and a brief discussion of the proposed Technical Specification changes required to allow operation of the plant with the higher ultimate heat sink temperature. Section 6.0 is a summary of conclusions and operating requirements associated with this design change. Appendix A defines the CCW pump minimum and maximum pump performance levels used to evaluate system performance.

The following areas are being addressed by NYPA in their assessment of the proposed Technical Specification change to increase the allowable ultimate heat sink temperature:

a. The effects of possible increase containment ambient temperatures, that may be associated with the increased service water temperature, on equipment operability or qualified life.

b. The basis of the SWS flow rates, as provided by NYPA, used to evaluate the increase in maximum service water temperature to 95^{o}F.

c. Possible effects of increased SWS and CCWS temperatures on piping stress analyses (e.g., increased thermal expansion due to higher process fluid temperatures).

d. The acceptability of increased SWS temperatures relative to environmental restrictions (i.e., releasing hotter water back to the Hudson River).

REFERENCES

1-1 Westinghouse letter to NYPA, INT-88-703, "JCO With a Service Water Temperature of 87 Degrees F," dated 8/4/88

1-2 Westinghouse letter to NYPA, INT-88-705, "JCO With a Service Water Temperature of 90 Degrees F," dated 8/5/88

2.0 SYSTEM DESCRIPTION

This section contains information on the current SWS and ACS. The system descriptions discuss aspects of the functions and operations that are affected by the SWS temperature change. They are not comprehensive descriptions of the systems. Modifications and recommendations required as a result of this evaluation are contained in subsequent sections.

2.1 SERVICE WATER SYSTEM

The SWS is designed to supply cooling water from the Hudson River to various heat loads in both the primary and secondary portions of the plant. The SWS also provides water required for cleaning the traveling screens and trash trough, provides seal and lubricating water to the main circulating water pumps, and supplies raw makeup water.

The SWS consists of six pumps, each having a capacity of 6000 gpm at 195 feet total design head. Three service water pumps are aligned to supply service water to an essential header and the other three service water pumps are aligned to supply service water to a nonessential header. The system loads can be supplied from either header, interchangeably, but the system is maintained and operated as a split system.

The essential header supplies those accidend-required and nonaccident-required loads that must have an immediate supply of cooling water in the event of a LOCA with a loss-of-offsite power (blackout). The nonessential header supplies the accident-required and nonaccident-required loads that do not require cooling immediately following an accident and are thus supplied with cooling water from the designated nonessential service water header by manually starting a service water pump, when required, following an accident.

Additionally, two backup service water pumps are valved to supply the Nuclear side header selected as the essential header. These backup service water pumps take their suction from the discharge canal common to both Indian Point units.

2.1.1 Normal Plant Operations

During normal operations, one set of three pumps is aligned to provide service water flow to the essential loads, and the other set is aligned to provide cooling to the nonessential loads. The Technical Specifications require that the reactor not be taken above a cold shutdown condition with less than three operable pumps aligned to the essential header or less than two operable pumps aligned to the nonessential header. The reactor must be shutdown if the above requirements cannot be met within twelve hours.

2.1.2 Post-Accident Operations

In the event of simultaneous loss-of-offsite power and an incident requiring safety injection, all SWS pumps are stripped from the electrical busses, but only the essential loads are automatically restored. During the switchover to the recirculation phase following a postulated design basis accident, one diesel generator and one control building air conditioning unit will be transferred to the nonessential header. This provides passive failure protection and ensures long-term cooling capability.

The cooling requirements for all five containment fan cooling units and the other essential loads can be supplied by any two of the three service water pumps on the header designated to supply the nuclear and essential secondary load supply lines. Any two of these three pumps can be powered by the emergency diesels. Either of the two sets of three pumps can be placed on the diesel starting logic.

The CCW heat exchangers are not needed during the injection phase, thus they are normally fed from the nonessential supply header. During switchover to the recirculation phase, one CCW heat exchanger is placed in service on the nonessential header, and the other CCW heat exchanger is placed in service on the essential header. The SWS provides cooling water to the tube-side of the component cooling water heat exchangers which in turn cools the RHR heat exchangers.

Two backup service water pumps are available to take suction from the discharge canal and provide cooling water for the containment ventilation cooling coils, the containment ventilation fan motor coolers, the instrument air compressors, and the diesel generator coolers in the unlikely event that a storm driven vessel damages the service water intake structure. However, the vessels that were docked in the Hudson River during the licensing of Indian Point Unit 3 are no longer docked there. Therefore, this event is improbable. The backup pumps are manually aligned to discharge to the header designated to supply the nuclear loads, and can be powered by the emergency diesels. (References 2-1, 2-2)

Provided below is a listing of the SWS loads on each header:

SWS Essential Header

- o Containment recirculation fan cooling coils
- o Containment recirculation fan motor cooler coils
- o Instrument air compressors closed cooling system
- o Main boiler feed pump lube oil coolers
- o Main Turbine oil coolers
- o Generator seal oil coolers
- o Diesel Generator cooling services
- o Control Room Air Conditioning Units

SWS Nonessential Header

- o Screen wash system
- o Circulating water pump seal water
- o Exciter air coolers

- Isolated phase bus coolers
- Hydrogen coolers
- Steam generator blowdown, recovery system non-regenerative heat exchanger
- Conventional plant closed cooling heat exchangers
- Component cooling heat exchangers

2.2 AUXILIARY COOLANT SYSTEMS

The ACSystem consist of the CCWS, the Residual Heat Removal System (RHRS), and the Spent Fuel Pit Cooling System (SFPCS). Each of these are cooled either directly or via the CCWS by the UHS.

2.2.1 Component Cooling Water System

The CCWS serves as an intermediate system between the Reactor Coolant System (RCS) and the SWS. This arrangement reduces the possibility of radioactive fluid leakage directly to the environment via the SWS.

The CCWS is designed to remove residual and sensible heat from the RCS via the RHR loop during plant shutdown and post-accident conditions, and to provide cooling to specific plant components during power operation.

The CCWS consists of three component cooling pumps, four auxiliary CCW pumps, two CCW heat exchangers, two component cooling surge tanks, cooling lines to the various components being cooled, and associated piping, valves, and instrumentation. The component cooling water flows from the CCW pumps, through the shell side of the CCW heat exchangers where heat is removed via the SWS, through the components being cooled, and is then returned to the pumps. The plant is provided with two headers with accident-related components serviced by both headers. Isolation valves are provided to separate the two headers in the event of a system leak.

Each CCW heat exchanger is designed to remove one-half of the heat load occurring at approximately 20 hours after plant shutdown. Each heat exchanger is also capable of removing one-half of the maximum heat removal load occurring when the RHR loop is first placed in operation during a plant cooldown operation. The heat removal load during normal full-power operation is normally transferred by two CCW heat exchangers. Operation with one heat exchanger is limited to 48 hours by plant Technical Specifications.

The surge tanks, which are connected to the suction side of the CCW pumps, accommodate surges resulting from component coolant thermal expansion and contraction and accommodate water which may leak into the system from components that are being cooled. The surge tanks also contain sufficient water to ensure a continuous component cooling water supply until a leaking cooling line can be isolated. Makeup water is normally taken from the Primary Makeup Water System as required, and delivered to the surge tanks.

2.2.1.1 Normal Plant Operations

During normal operation, the system is completely cross-connected. Only when a leak or other problem is indicated will the operator split the system to identify the source of leakage and ensure cooling to necessary equipment. During normal plant operation, the temperature of the cooling water supplied to CCWS components is approximately 95^{o}F (with a 95^{o}F ultimate heat sink, the CCWS will supply approximately 105^{o}F cooling water).

System operation depends upon the heat load. Two CCW pumps and two CCW heat exchangers are required to be operable by the Technical Specifications prior to going above a cold shutdown condition. The standby pump provides backup and starts automatically on low supply header pressure. CCWS water is normally supplied to all components except the RHR heat exchangers and the excess letdown heat exchanger.

2.2.1.2 Normal Plant Cooldown

Operation of three CCW pumps and both CCW heat exchangers are required for timely removal of residual and sensible heat during a normal plant cooldown. Failure of one of these components increases the time required for cooldown, but does not affect the safe operation of the plant.

The CCWS is designed to supply 120^{o}F cooling water to the components being cooled when the RHR loop is first placed in operation during plant cooldown, this being the maximum permissible temperature of the cooling water supply to the reactor coolant pumps.

2.2.1.3 Post-Accident Operations

The CCW pumps are not required immediately following a safety injection (SI) initiation signal. To reduce loading of the diesels during a blackout with SI, these pumps are not automatically started. However, for SI without blackout or blackout and unit trip without SI, the CCW pumps will be automatically started. If not running, the CCW pumps will be manually started during switchover to the the recirculation phase to provide cooling for the RHR heat exchangers and emergency core cooling pumps.

During the injection phase of SI, the CCW pumps are not operating. To protect the recirculation pump motors from the containment atmosphere, at least two of the four auxiliary CCW pumps are automatically started to circulate water to the recirculation pump motor coolers. A booster pump, driven by the SI pump motor shaft, supplies flow to each safety injection pump to cool the SI pump bearings. During this period, the thermal capacity of the CCW loop is used as the heat sink, since service water is not provided to the CCW heat exchangers.

As a result of the SI signal, the CCW flow to the RHR heat exchangers is automatically aligned. This is done in anticipation of recirculation later in the event.

The phase A isolation signal, which occurs as a result of the SI, isolates all CCW flow into containment except the headers supplying the RCPs, the RHR heat exchangers, and the recirculation pumps. If a phase B isolation signal occurs, the RCP supply and return headers are also isolated.

For the recirculation phase of SI, the CCW system will provide cooling water to the RHR heat exchangers. One CCW pump provides the minimum required flow. If all three emergency diesels are operating, a second CCW pump would be manually started. This provides the maximum long-term cooling capacity. (References 2-3, 2-4)

Provided below are the accident-required and nonaccident-required loads serviced by the CCWS.

<u>CCW Accident-Required Loads</u>

- Residual Heat Exchangers
- Residual Heat Removal Pumps
- Safety Injection Pumps
- Recirculation Pumps

<u>CCW NonAccident-Required Loads</u>

- RCP Thermal Barrier and Motor Coolers
- Nonregenerative Heat Exchanger
- Excess Letdown Heat Exchanger
- Seal Water Heat Exchanger
- Sample Heat Exchangers
- Spent Fuel Pit Heat Exchanger
- Charging Pump Gyrol and Bearing Coolers
- Waste Gas Compressors
- Reactor Vessel Supports Blocks
- Gross Failed Fuel Detector
- Auxiliary Condensate Radiation Monitor
- Steam Generator Blowdown Sample Radiation Monitor

2.2.2 Residual Heat Removal System

The primary function of the RHRS is to transfer heat energy from the reactor core and RCS during the second phase of plant cooldown. During the first phase of plant cooldown, the Main Steam System removes reactor core heat via the steam generators. The RHRS can also be used to transfer water between the refueling water storage tank (RWST) and the reactor cavity at the beginning and end of refueling operations. Additionally, the RHRS is used in conjunction with the SIS for emergency core cooling in the event of a loss-of-coolant accident (LOCA).

The RHR loop consists of two RHR heat exchangers, two motor-driven RHR pumps, piping, valves, and the instrumentation and control circuitry necessary for monitoring and operation.

The RHRS interfaces with the CCWS through the RHR heat exchanger and the RHR pumps. Cooling flow is provided to the shell-side of the RHR heat exchangers during plant cooldown operations and during the recirculation phase of SI. Cooling is also provided to the RHR pump mechanical seals.

2.2.2.1 Normal Plant Cooldown

Two RHR pumps and two RHR heat exchangers perform the decay heat cooling functions for the reactor core. After the RCS temperature and pressure have been reduced to approximately 350^{o}F and 450 psig, RHRS operation is initiated by aligning the pumps to take a suction from the hot leg of one reactor coolant loop and discharge through the RHR heat exchangers and back to the RCS cold legs. If only one RHR pump and one RHR heat exchanger are available, reduction of reactor coolant temperature is accomplished at a lower rate.

During plant shutdown, the cooldown rate of the reactor coolant is controlled by regulating the RCS flow through the tube side of the RHR heat exchangers. (References 2-3, 2-5)

2.2.2.2 Post-Accident Operations

The RHRS is designed to function during the recirculation phase of post-accident operations to remove long-term decay heat. This function is met by using the RHR heat exchangers to cool the recirculated sump fluid for both long-term core cooling and containment integrity.

2.2.3 Spent Fuel Pit Cooling System

The primary function of the SFPCS is to remove residual heat from spent fuel assemblies stored in the spent fuel pit. A secondary function of this system is to maintain water purity and clarity in the spent fuel pit and to purify the water of the RWST.

The cooling loop consists of two pumps, a heat exchanger, a filter, a demineralizer, piping and associated valves and instrumentation. One of the pumps draws water from the pit, circulates it through the heat exchanger and returns it to the pit. The second pump provides backup cooling capability. Component cooling is provided to the shell-side of the SFP heat exchanger.

When discharged nuclear fuel is stored in the pit, the pump and SFP heat exchanger were designed to handle the 1/3 core heat load (17E+06 Btu/hr) and maintain a pit water temperature at or below 128°F. The maximum full core discharge (26E+06 Btu/hr) is designed to be accommodated with the SFP temperature maintained at or below 153°F. (Reference 2-3)

REFERENCES

2-1 NYPA Document, Indian Point Unit 3 Updated FSAR, Section 9.6.1, "Service Water System"

2-2 NYPA Document, Indian Point Station Unit No. 3 System Description No. 34, "Service Water System"

2-3 NYPA Document, Indian Point Unit 3 Updated FSAR, Section 9.3, "Auxiliary Coolant System"

2-4 NYPA Document, Indian Point Station Unit No. 3 System Description No. 4.1, "Component Cooling Water System"

2-5 NYPA Document, Indian Point Station Unit No. 3 System Description No. 4.2, "Residual Heat Removal"

3.0 AUXILIARY COOLANT SYSTEM EVALUATION

As discussed in Section 2.2, the ACS is comprised of the three subsystems: CCW, RHR, and SFPCS. The impact of a maximum river water temperature of 95°F on these subsystems is discussed in this section.

3.1 COMPONENT COOLING WATER SYSTEM

The CCWS was evaluated to determine the impact of higher river water temperatures on system performance. A discussion of this evaluation is provided below

3.1.1 Thermal/Hydraulic Model

To assist in the evaluation, a thermal/hydraulic model of the Indian Point Unit 3 CCWS was developed to predict flow rates and temperatures supplied to each component during various system operating modes. An overview of the plant-specific model, analytical methodology, analysis assumptions, and calculated results are provided below.

3.1.1.1 PEGISYS Computer Code Description

The Westinghouse Computer Code PEGISYS was used to develop and analyze the thermal and hydraulic performance of the Indian Point Unit 3 CCWS. The PEGISYS code is a menu driven, interactive, fluid systems design program which provides a fully integrated component and piping database together with thermal and hydraulic analysis capabilities. Verification of the computer code has been performed in accordance with Westinghouse Quality Assurance Manual (Reference 3-1).

A unique feature of the code is its graphics capability which allows a user to interactively develop a schematic of the flow network being evaluated.

The PEGISYS database developed for the Indian Point Unit 3 CCWS contains both component and system level data. In general, detailed piping takeoffs of the main header and component supply and return lines were input into the code. PEGISYS utilizes piping data (pipe size, lengths, elbows, tees, etc.) to determine flow path resistances based on calculated operating conditions. Piping takeoffs of individual component branch lines containing throttle valves were not always performed when their resistances were to be determined by the system flow balance. For these component branch lines, PEGISYS calculates line resistances required to deliver the specific flow rates determined by the flow balance.

In addition to piping data, thermal and hydraulic design and operating data for system heat exchangers supplied with CCW were also input into the database to allow for thermal and hydraulic analyses. To model small equipment coolers (i.e., lube oil cooler), a component heat load was input into the flow path which contained that particular component.

In the analysis mode, the program performs steady-state hydraulic (isothermal) or thermal/hydraulic (non-isothermal) analysis of flow networks. In the hydraulic calculation, PEGISYS determines the set of steady state continuity equations and Bernoulli loop equations which apply to the network. These equations are solved iteratively to yield a flow and pressure distribution in accordance with the principles of conservation of mass and momentum. In the thermal calculation, enthalpy distributions within the network are determined in accordance with the principle of conservation of energy. If the network is analyzed as a non-isothermal case, the code iterates between the hydraulic and thermal portions of the code. The output of the code is the calculated pressure, temperature and flow distribution for the entire network.

As noted previously, the PEGISYS code utilizes an interactive graphics feature which provides an interface between the user and the PEGISYS database and analysis features. A graphical model of the CCWS has been developed to be consistent with the system flow diagrams (References 3-2 through 3-4).

All major system flow paths (excluding drains and vents) have been modeled except for the flash evaporator product cooler which has been retired from service with CCW physically isolated, and a HVAC modification package which is shown on the graphic model as isolated, since it is incomplete.

All system pumps and major water-to-water cooled heat exchangers are explicitly shown on the PEGISYS graphic model with conventional component symbols. Equipment coolers and small heat exchangers are shown on the graphic model as an equipment package (EP). Component branch lines are shown on the graphic model with at least one isolation valve. These valves allow a user to interactively isolate flow paths during the thermal/hydraulic analysis of the network. Check valves are also illustrated on the graphic model since they restrict back flow in their respective flow paths. Although not illustrated on the graphic model, other system valves have been included in the hydraulic database. Provided in Figure 3-1 is a simplified version of the PEGISYS graphic model of the Indian Point Unit 3 CCWS.

3.1.1.2 Modeling Methodology

As discussed earlier, the computer model of the CCWS is required to be initialized based on a flow balance test in order to establish branch line resistances. Since the actual performance level of all the pumps could vary throughout plant life, minimum and maximum balancing flows were established based on operation of only one CCW pump. The balancing flows were selected taking into account both equipment cooling requirements and pump performance acceptance criteria.

For this evaluation, the pump performance acceptance criteria used by NYPA to evaluate component operability (in accordance with ASME Section XI testing) was used. Provided in Appendix A is the pump performance criteria used in this project.

To account for the range of allowable balancing flows, two separate models of the CCWS were developed. One model was used to set the minimum branchline resistance for each component. This was accomplished by using the weakest CCW pump operating at its minimum acceptable pump performance level and all component flows were specified at their maximum allowable value. Based on layout considerations, the weakest pump was determined to be CCW pump 33. This model will be referred to as the "Minimum Resistance" model.

To set the maximum branchline resistances, the strongest pump was assumed to be operating at its maximum acceptable pump performance level and all component flows were specified at their minimum allowable value. Based on layout considerations, the strongest pump was determined to be CCW pump 31. This model will be referred to as the "Maximum Resistance" model. Provided in Figure 3-2 is an illustration of the approach utilized to predict minimum and maximum component flows.

The maximum resistance model, weakest pump, and a degraded pump performance curve defines minimum expected component flows (See Point A on Figure 3-2). In general, the calculated flows with this configuration are used as a basis for the evaluation of equipment performance at limiting temperatures and flows. The use of the minimum resistance model, strongest pump, and an enhanced pump performance curve defines maximum expected component flows (See Point D in Figure 3-2). The calculated flows with this configuration are used as a basis for maximum flow evaluations (i.e., vibration/erosion concerns). The intersection of the two models with the upper and lower pump performance criteria (See Points B and C in Figure 3-2) defined the balancing range developed for this project.

As long as the component flows as measured during the CCWS flow balance are within the established minimum and maximum balancing ranges, the analysis results would be bounded.

3.1.1.3 System Flow Balance

The Indian Point Unit 3 CCWS was flow balanced per Engineering Test Procedure ENG-366, Rev. 0. The flows defined in this procedure were based on the ranges defined as part of this project. As part of the test, pump performance data for CCW pump 33 was obtained.

The balancing flows were selected assuming a fully degraded and enhanced pump performance curve as presented in Appendix A. Evaluation of the pump test data showed that CCW pump 33 was approximately halfway between the minimum and maximum head limits. Based on the data obtained from the test, a third model was developed to determine the actual individual component branchline resistances. This "Test" model was then used to verify that the analysis models were conservative for both Power Operation and the post-LOCA modes. For Power Operation, minimum acceptable pump performance was assumed and a comparison of calculated to rated flowrate was performed.

The recommended flow rates to all components were met when considering the minimum acceptable pump performance curve and actual system resistances with the exception of the Reactor Coolant Pump (RCP) thermal barriers and upper motor bearings and the Safety Injection (SI) pump lube oil coolers.

Measured flows (25 to 30 gpm) to the RCP thermal barrier coolers were somewhat lower than recommended (42 gpm). The recommended flow was based on cooling requirements with a CCWS supply temperature of approximately 120^{o}F. The actual flows were limiting due to the cooler design. Section 4.2.2.5.1 discusses when a second CCW pump may be needed at elevated CCWS supply temperatures to ensure adequate cooling.

Measured flows (approximately 173 gpm) to the RCP upper bearing coolers were also somewhat lower than recommended (175 to 182 gpm). The recommended flow was selected based on maintaining less than maximum allowable flow with one enhanced CCW pump. Section 4.2.2.5.3 discusses when a second CCW pump may be needed at elevated CCWS supply temperatures to ensure adequate cooling.

Measured flows to two of the three SI pump lube oil coolers (4 to 5 gpm) were also lower than recommended (≥6 gpm). The lube oil cooler recommended CCWS flow was selected slightly higher than the rated flow (5 gpm) since this component was limiting for the 1988 temporary SWS temperature Technical Specification amendment. The actual flows are believed to be limiting due to the additional resistance of the SI circulating water pump which is attached to the shaft of the SI pump.

As tested, a CCW pump was required to deliver flow through the nonoperating SI circulating water pump. With the SI pump operational, the shaft-driven cooling water pump would also be operational. If the resistance of the nonoperating shaft-driven pump is high, the resistance of the cooler flow paths would be lower than currently modeled. This would result in higher flow to the coolers than measured via the flow balance and calculated with PEGISYS.

For the post-LOCA mode, the test model was used with the strongest CCW pump (31) operating at its maximum allowable head performance to verify that adequate runout protection was provided. Note that pump runout is approximately 5500 gpm. The results showed that the total pump flow would be less than 5400 gpm with the system aligned per the flow balance.

Although several component balancing flows fell outside of the defined flow balance range, it can be concluded that the flow balance alignment falls within the two analytical models (minimum and maximum resistance models) used to calculate "Worst-Case" system flows and temperatures.

For components other than those noted above, the worst-case component flows would also be bounding since small changes in total system flow would not cause system pressure to change significantly. With parallel flow paths, system pressure determines the flow distribution in individual branch lines.

3.1.1.4 Thermal Analysis Assumptions

To perform thermal (i.e., non-isothermal) analysis, PEGISYS has the capability to explicitly model the performance of water-to-water heat exchangers. To model other nonconventional heat exchangers, a point heat load can be specified in the component flow path. Provided in Table 3-1 is the thermal basis (heat exchanger or point heat load) used in this project. A discussion of the assumptions and data used for the thermal analysis is provided in this subsection.

3.1.1.4.1 Heat Exchangers

When a heat exchanger is explicitly modeled with the PEGISYS code, both design and operating data are required. In general, heat exchanger design data is based on information presented on the vendor specification sheet. Operating data (flows, pressures, and temperatures) are based on information from design basis documents. A key assumption in the evaluation of thermal performance is the heat transfer capability of system heat exchangers. Generally, a design fouled and clean heat transfer coefficient ("U") are provided on the vendor data sheet. In an effort to bound the maximum expected heat load rejected to the CCWS, a "U" greater than design (fouled) and the design surface area (i.e., no tube plugging) are used. For this project, the average of the clean and fouled "U" is used. For the CCW heat exchangers, the design (fouled) "U" and a five percent area reduction are used since they bound the minimum expected heat rejection capability of the system.

3.1.1.4.2 Heat Loads

As noted previously, the required input data for components not explicitly modeled as a heat exchanger is an expected heat load (Btu/hr). The heat loads used in this project are based on design basis documents. Provided in Table 3-2 is a summary of the heat loads specified for components modeled as point heat loads in Table 3-1.

3.1.1.4.3 RHR System Boundary Conditions

The RHR heat exchangers are the major heat loads on the CCWS during Plant Cooldown, Refueling, and post-LOCA operating modes. For Plant Cooldown, the heat rejection capability of the system is manually controlled to limit the rate of reactor coolant system (RCS) cooldown and to limit CCWS supply temperature. Since decay heat is a function of time since plant shutdown, the capability of the ACS to cooldown the plant is addressed in the evaluation of RHR system performance (see Section 3.2). To support the cooldown evaluation, the CCWS computer model is used to predict system flows during the cooldown alignment.

In the post-LOCA mode, the heat transfer rate of the RHR heat exchangers is not manually controlled. As such, the performance of the CCWS during the recirculation phase is specifically evaluated with PEGISYS. Since the RHR heat exchangers are explicitly modeled (see Table 3-1), a tube-side inlet temperature and flow rate are needed. Presented below are the basis for these parameters.

3.1.1.4.3.1 Containment Sump Temperature Post LOCA

During the recirculation mode of a LOCA, containment sump water is cooled by the ACS. Since the CCWS is used to cool Safety Injection (SI) pumps, the temperature of the sump water has a direct affect on the CCWS supply temperature to these essential components.

To assist in the evaluation of CCWS performance during post-LOCA, a containment sump temperature evaluation was performed to determine the "Worst-Case" sump temperature at the time the ACS is placed in service during the switchover to cold leg recirculation.

For this evaluation, several assumptions were made to conservatively envelope the sump temperature transient. The basic goal of these assumptions was to concentrate as much energy as possible in the containment sump so as to maximize sump temperature. Note, containment response analyses are based on assumptions which maximize energy release to the containment atmosphere.

Key assumptions used to maximize sump temperature are as follows:

- o Decay heat is added to the reactor vessel water instead of causing boiloff directly
- o Vessel thick metal energy is similarly added to the RCS water instead of causing boiloff directly
- o All safety injection and recirculation water available is assumed to enter the vessel with no spill
- o All water entering the reactor vessel is available for removing heat (maximizing spillage of hot water to the sump)

Of the preceding assumptions, the first two maximize heat available to the sump water and the last two maximize heat absorption of the sump. The result of these assumptions is a minimum steam phase heat inventory and a corresponding minimum heat removal by the fan coolers. The net result of these assumptions is a minimum containment pressure with a maximum sump water temperature.

To perform the subject evaluation, the Westinghouse Computer Code COCO (Reference 3-5) and the 1979 LOCA Mass and Energy Model (Reference 3-6) were used. The inputs for this evaluation are based on the standard minimum safeguards assumptions and are consistent with the results of the Containment Margin Program (Reference 3-7).

The mass and energy release rates for the double-ended pump suction break with minimum SI, discussed in detail in Reference 3-7 and adjusted per the previously mentioned assumptions, were found to be limiting for sump temperature calculations. The maximum sump temperature at the time of switchover to recirculation was found to be 256^{o}F. At approximately 37 hours into the event, the sump temperature has been reduced to approximately 200^{o}F. Provided in Table 3-3 is the calculated maximum sump temperature time history following a design basis LOCA.

3.1.1.4.3.2 RHR Heat Exchanger Tube-Side Flow Post-LOCA

The RHR pumps are used as low-head SI pumps during the injection phase of a LOCA. During the switchover to recirculation, the RHR pumps are shut down and SI recirculation pumps located inside containment are manually started. The use of the SI recirculation pumps in lieu of the RHR pumps maintains radioactive sump fluid internal to the containment building.

The alignment of the low-head recirculation is performed manually per plant Emergency Operating Procedures (EOPs). For the initial recirculation alignment, a minimum of 600 gpm in the lowest two out of four cold leg injection lines is needed. As such, the minimum expected sump recirculation flow through the RHR heat exchangers is approximately 1200 gpm (>600 + >600).

To estimate maximum heat input into the CCWS, a pump flow of 3100 gpm is used. This value is based on the design flow (3000 gpm) plus approximately 3% for conservatism. Note, the recirculation pump is limited due to NPSH concerns (Reference 3-8).

3.1.1.4.4 SWS System Boundary Conditions

As discussed in Section 2.1.2, cooling water is provided to the tube-side of the CCW heat exchangers by way of the SWS. Since these heat exchangers are explicitly modeled (eee Table 3-1), heat exchanger tube-side inlet temperature and flow are needed. Provided below are the bases of these parameters.

3.1.1.4.4.1 CCW heat Exchanger Tube-Side Flows

The design flow to each CCW heat exchanger as specified on the vendor specification sheet is approximately 9100 gpm. With both heat exchangers available, the design SWS flow would be approximately 18,200 gpm.

Based on Reference 3-9, the following combinations of SWS pumps and flow rates can be supplied to the CCW heat exchangers with the heat exchanger throttle valves set for runout protection:

Mode	Service Water Pump Combination	Flow to CCWS HX #31	Flow to CCWS HX #32
Power Operation	Three nonessential pumps	4503 gpm	4516 gpm
	- With One CCW heat exchanger Out-Of-Service (OOS)		5248 gpm
Power Operation	Two nonessential pumps	3641 gpm	3652 gpm
	- With One CCW heat exchanger Out-Of-Service (OOS)		4651 gpm
LOCA Recirculation	Two essential, one nonessential (Diesel Generator Failure)	3196 gpm	4405 gpm
LOCA Recirculation	Three essential, two nonessential (No Failure)	4137 gpm	5228 gpm
LOCA Recirculation	Three essential, two nonessemtial (Passive Failure - essential header)	4028 gpm	5226 gpm
LOCA Recirculation	Three essential, two nonessemtial (Passive Failure - nonessential header)	4134 gpm	5092 gpm

To account for potential pump wear, these flow rates were degraded by five percent when used to evaluate CCWS performance.

3.1.1.4.4.2 CCW heat Exchanger Tube-Side Inlet Temperature

For this project, a maximum SWS inlet temperature of 95°F is used to evaluate system performance.

3.1.1.5 Modes of Operation

The CCWS is required to operate during all modes including:

- o Startup
- o Power Operation
- o Blackout - Hot Standby
- o Plant Cooldown
- o Blackout - Cooldown
- o Refueling
- o Post-LOCA Injection
- o Post-LOCA Recirculation

A discussion of the CCWS alignment assumptions used to analyze these modes is provided below.

3.1.1.5.1 Startup/Power Operation/Blackout

During plant Startup, all CCWS flow paths were modeled open except for the RHR heat exchangers. For Power Operation, all system flow paths were modeled opened except for the excess letdown and RHR heat exchangers. During Startup, the excess letdown heat exchanger may be in service to assist in removing reactor coolant during primary plant heatup (i.e., thermal expansion). For both modes, the nonregenerative heat exchanger heat load was based on "maximum" letdown flow.

With the loss of offsite power (Blackout). all flow paths would remain opened since automatic isolation does not occur. With a Blackout, system heat loads would be less since power to several components would not be available. As such, CCWS flows and temperatures during a Blackout Mode is bounded by the Startup and Power Operation modes.

Provided in Table 3-4 are the system alignment cases analyzed for the Startup, Power Operation, and Blackout modes. Specifically, operation with one and two CCW heat exchangers and one and two CCW pumps was considered since these components are limited by Technical Specification 3.3.E.

Operation with three CCW pumps was not specifically evaluated in this project due to a concern of high component flows. Originally, the system design called for the use of three CCW pumps for plant cooldown since this would maximize flow to the RHR heat exchangers. Since the RHR heat exchanger throttle valves had to be set to prevent pump runout during the LOCA recirculation mode, component flows would be much higher than planned with all three CCW pumps operating. The use of minimum and maximum allowable pump performance limits for this project would also increase the range of flows delivered to CCWS users.

3.1.1.5.2 Plant Cooldown/Blackout

The plant Cooldown mode with and without offsite power is also identical since system flow paths do not automatically isolate on a Blackout signal. The heat loads imposed on the CCWS would be lower during a Blackout since power to several components would not be available.

To predict system thermal performance during the cooldown transient, the capability to model decay heat as a function of time is needed. Since the PEGISYS model is designed to calculate steady-state conditions, another computer code was used to evaluate system thermal performance. This evaluation is addressed in Section 3.2.1. To support this evaluation, the PEGISYS code was used to calculate system flow rates.

Key assumptions in the selection of cases analyzed are presented below:

- o Valve TCV-130, which controls CCWS flow to the nonregenerative heat exchanger, was modeled as full open or full closed
- o One CCW pump can be OOS for maintenance (three provided)
- o One CCW heat exchanger can be OOS for maintenance (two provided)

Provided in Table 3-5 are the various alignment cases considered for the plant Cooldown mode.

3.1.1.5.3 Refueling

Once plant cooldown to the Refueling mode is achieved, the system is more than capable of maintaining a refueling temperature since decay heat decreases with time. Since the PEGISYS model is designed to calculate steady-state conditions, only system flows were calculated. These flows are discussed in Section 3.3 in the evaluation of SFPCS performance.

Key assumptions in the selection of cases analyzed for the Refueling mode are presented below:

- o Only one RHR heat exchanger shell-side is needed for long-term heat removal
- o Flow to the RCPs and Reactor Vessel Nozzle Block (RVNB) coolers can be isolated to maximize flow to the SFP during a core unload operation (cooling water flow to the RCPs and the RVNB coolers would not be required)
- o One CCW pump can be OOS for maintenance (three provided)
- o One CCW heat exchanger can be OOS for maintenance (two provided)

Provided in Table 3-6 are the various alignment cases considered for the plant Refueling mode.

3.1.1.5.4 LOCA Injection

In the event of a Large-Break LOCA with Blackout, the CCW pumps would shut down since they are not loaded on to the emergency diesel generators. A CCW pump would not be restarted until the switchover to cold-leg recirculation (References 3-8 and 3-10). During the injection phase of the subject event, only the auxiliary component cooling (ACC) pumps and the SI circulating water pumps would be operational. With only these pumps operational, heat removal via the CCW heat exchangers is expected to be negligible due to low flow in the network and no SWS flow to the CCW heat exchangers (the nonessential SWS pumps are also not operating). Since several components are rejecting heat during this mode, CCWS temperature increases with time. The evaluation of this heatup transient is discussed in Section 3.1.2.5.

Due to the low flows in the network, the PEGISYS code and the results of the CCWS flow balance were used to calculate minimum and maximum component flows to the SI recirculation pump motor coolers and to the SI pump coolers. For the ACC pumps, operation with one and two pumps to one SI recirculation motor cooler is considered. These flows are used in Sections 4.2.2.1 and 4.2.2.2 to analyze component performance.

3.1.1.5.5 LOCA Recirculation

As discussed above, the CCW pumps are not started for a Large-Break LOCA with Blackout event until the switchover to sump recirculation. This event is considered limiting with respect to system operability since the heat transfer across the RHR heat exchangers is not manually controlled.

As discussed in Reference 3-8, there are two possible recirculation alignments for the ACS. The first alignment (initiated by recirculation switch two) establishes cooling water flow to the RHR heat exchangers. With this alignment, one CCW pump and one nonessential SWS pump is manually started. Once cooling is established, a SI recirculation pump would be started.

The second ACS alignment (initiated by recirculation switch seven) establishes additional cooling by the start of a second recirculation, CCW, and nonessential SWS pump. This alignment is nullified if only two out of three diesels are available. The start of the second CCW pump is conditional on the successful start of the second nonessential SWS pump. Likewise, the start of the second recirculation pump is conditional on the start of the second CCW pump.

In the thermal analysis of the CCWS, two constraints were identified for the system. The first constraint is high CCWS supply temperature. This temperature is limited by capability of equipment serviced by CCWS to remain functional at elevated supply temperatures. The second constraint is the shell-side outlet temperature of the RHR heat exchanger. Low RHR heat exchanger shell-side flows result in high shell-side outlet temperatures for a given heat exchanger duty. This temperature is limited by the structural integrity of the heat exchanger and downstream components.

With the initial ACS cooling alignment (recirculation switch two), CCWS supply temperature is maximized if recirculation flow is modeled through both RHR heat exchangers since the available heat transfer area is maximized. The isolation of cooling water flow paths also results in higher CCWS supply temperature since CCWS flow to the RHR heat exchangers is maximized. For this mode, the cooling water flow paths to the nonregenerative heat exchanger (assumed to be manually isolated - See Section 3.1.2.3), the excess letdown heat exchanger (automatically isolated on a containment phase A signal), and the RCPs and RVNB coolers (automatically isolated on a containment phase B signal) were isolated. This CCWS configuration is representative of a Large-Break LOCA design basis event.

For a Small-Break LOCA, a containment phase B signal may not occur. This would result in both lower component flows and lower CCWS supply temperatures. As such, the calculated Large-Break LOCA CCWS supply temperature would be bounding.

To maximize RHR heat exchanger shell-side outlet temperature, recirculation flow through the tube-side should be maximized and CCWS flow to the shell-side should be minimized. To maximize the RHR heat exchanger duty, only one RHR heat exchanger is considered operable. The RHR heat exchanger tube and shell sides are normally isolated. The power to these component isolation valves are provided by motor control centers (MCCs) 36A and 36B which receive power from the emergency diesel generators. As shown from Table 3-7, the failure of diesel generator 32 or 33 to start would leave one RHR heat exchanger isolated on both the tube and shell sides.

With one RHR heat exchanger isolated, the large-break LOCA CCWS alignment was considered (RCPs and RVNB coolers isolated on containment phase B signal). This case was analyzed with the nonregenerative heat exchanger flow path modeled opened since the CCWS control valve for this heat exchanger fails open on loss of instrument air. As discussed in Section 3.1.2.3, the CCWS flow path to the nonregenerative heat exchanger is required to be isolated prior to the start of a CCW pump post-LOCA. With the nonregenerative heat exchanger CCWS flow path opened, RHR heat exchanger shell-side outlet temperature would result in conservatively high CCWS supply temperatures since flow to all CCWS components would be lower.

For a small-break LOCA, the RCPs and RVNB coolers flow paths would stay open since a containment phase B isolation signal may not be generated. If this CCWS alignment was specifically analyzed, this configuration would result in higher RHR heat exchanger shell-side outlet temperatures. With the decision to isolate the nonregenerative heat exchanger prior to the start of a CCW pump, the maximum calculated CCWS supply temperature for the large-break LOCA case would be limiting.

For the additional ACS cooling alignment (recirculation switch seven), the same assumptions used to maximize CCWS supply temperature would apply. The one RHR heat exchanger case is not considered since operation of two CCW pumps would not result in limiting shell-side outlet temperatures.

Each of the three cases will be analyzed at both the initiation of sump recirculation (256°F sump temperature) and at approximately 37 hours (200°F sump temperature) into the event in order to support component evaluations performed in Sections 4.22.1 through 4.2.2.3. Provided in Table 3-8 are the CCWS alignment cases considered for this mode. Note that system performance was analyzed with one CCW heat exchanger aligned to the essential SWS header which is consistent with the plant FSAR (Reference 3-11).

3.1.1.6 Calculated Performance Results

The PEGISYS models described in Section 3.1.1.2 were used to evaluate system performance. As noted previously, the maximum resistance model is generally used to calculate minimum component flows. For this model, the weakest CCW pump operating at its degraded pump curve is used. To calculate maximum component flows, the minimum resistance model is used. With this model, the strongest CCW pump operating at its enhanced pump curve is typically used. Provided in the following sections are the calculated results for the limiting alignment cases defined in Section 3.1.1.5.

3.1.1.6.1 Plant Startup/Power Operation/Blackout

The plant Startup alignment (Table 3-4, Case A1) was found to be more limiting than the Power Operation alignment (Table 3-4, Case A2) with respect to minimum component flows and maximum CCWS supply temperature. This is true since with the excess letdown heat exchanger in service, component flows drop due to the decreasing head versus flow characteristic of the pump. The CCWS supply temperature is also higher since the excess letdown heat exchanger is rejecting heat to the CCWS.

With a 95°F SWS inlet temperature, two nonessential SWS pumps, and two CCW heat exchangers, the maximum CCWS supply temperature was calculated to be approximately 110°F with the excess letdown heat exchanger in service.

With the excess letdown flow path isolated, the CCWS supply temperature is conservatively calculated to be approximately 108°F. Both of these cases assumed a conservative SFP heat load based on a decay heat load 30 days after plant shutdown and maximum Chemical and Volume Control System (CVCS) letdown flow through the tube-side of the nonregenerative heat exchanger.

CCWS limiting temperatures were found to occur when a CCW heat exchanger is OOS. Note, this is a Limiting Condition of Operation per plant Technical Specification 3.3.E. With one CCW heat exchanger OOS, component flows are lower since the overall resistance of the network is increased. In this alignment and excess letdown isolated (Power Operation), the CCWS supply temperature was calculated to be approximately 118°F.

Comparison of the results of Cases A3 and A4 showed that component and system flows were limiting when CCW heat exchanger 32 is isolated. Provided in Table 3-9 are the calculated component and system performance data for the limiting cases presented in Table 3-4 (Cases A1 through A6).

In addition to the cases analyzed, the effect of reduced heat loads on the system was evaluated. The benefit of assuming a SFP decay heat load of 60 days post shutdown in lieu of 30 days on CCWS supply temperature was calculated to be less than one half degree.

If "normal" letdown was supplied to the tube-side of the nonregenerative heat exchanger in lieu of "maximum" letdown, the CCWS supply temperature with one CCW heat exchanger OOS was calculated to be approximately 113°F. A SWS flow of greater than 5700 gpm is required to maintain the CCWS temperature at 110°F. As shown in Section 3.1.1.4.4.1, this flow is greater than that which can be supplied with three nonessential SWS pumps. As such, the SWS throttle valve to the CCW heat exchanger may be required to be repositioned to maintain CCWS supply temperature at or below 110°F.

3.1.1.6.2 Plant Cooldown/Blackout

To simulate normal plant cooldown, the excess letdown heat exchanger was assumed to be isolated and the temperature control valve (TCV-130) which regulates flow to the nonregenerative heat exchanger was modeled as either full open or full closed. Two CCW pumps were assumed to be operating with either one or two CCW heat exchangers in service.

With TCV-130 closed, component flows increase but total system flow decreases. This occurs since isolation of the flow path increases the effective resistance of the network. This causes pump flow to decrease which increases pump discharge pressure. As such, flow to individual components increases due to the higher pump discharge pressure. Provided in Table 3-10 are calculated component and system flow data for the cases presented in Table 3-5 (Cases B1 through B4).

3.1.1.6.3 Refueling

To simulate the Refueling mode, one RHR heat exchanger was assumed to be isolated since decay heat levels are reduced. Note, the Cooldown mode addresses system flows with both RHR heat exchangers operating. During refueling, the nonregenerative and excess letdown heat exchangers were assumed to be isolated. Two CCW pumps and one or two CCW heat exchangers were assumed to be operating.

To maximize CCWS flow to the SFP heat exchanger during a core unload operation, the CCWS supply line to the RCPs and RVNB was modeled closed. As noted previously, isolation of component flow path results in higher component flows and lower total system flow.

Since decay heat levels are a function of time after plant shutdown and CCWS supply temperature is manually limited, the PEGISYS model is only used to determine system flows.

Provided in Table 3-11 are the component and system flow data for the cases described in Table 3-6 (Cases C1 through C4). These flows are used in Section 3.3 to evaluate SFPCS performance.

3.1.1.6.4 LOCA Injection Phase

For the injection phase of a LOCA with Blackout, only the ACC and SI circulating water pumps are operational. To support component evaluations performed in Sections 4.2.2.1 and 4.2.2.2, measured and calculated data were used to define minimum and maximum component flows to the SI pump coolers and the SI recirculation pump motor coolers.

For the SI pump coolers, the minimum and maximum CCWS flow is calculated to be approximately 4 gpm and 10 gpm, respectively. For the SI recirculation pump motor coolers, the minimum and maximum calculated CCWS flow is approximately 37 gpm and 50 gpm, respectively.

Since forced cooling is not provided, the system will gradually heat up with time. Provided in Section 3.1.2.5 are expected worst-case CCWS temperatures during this mode.

3.1.1.6.5 LOCA Recirculation Phase

To support component evaluations performed in Sections 4.2.2.1 through 4.2.2.3, measured and calculated data were used to define minimum and maximum component flows to the SI pump coolers and the SI recirculation pump motor coolers. For the SI pump coolers, the use of the minimum flow calculated for the injection phase would be conservative since the SI circulating water pump would be "boosted" by an operating CCW pump. As such, the minimum CCWS flow to the each coolers is calculated to be approximately 4 gpm. Considering CCW pump "boost", the maximum flow is calculated to be approximately 13 gpm.

If the ACC pumps are shutdown during the switchover to recirculation, the SI recirculation pump motor coolers would be supplied with cooling water via a CCW pump. In this alignment, the minimum CCWS flow to each cooler was measured to be approximately 25 gpm. If an ACC pump is left operating, at least nominal cooling water flow (40 gpm) would be provided.

Considering "boost" from two operating CCW pumps, the calculated maximum flow from two ACC pumps to each recirculation pump motor cooler is calculated to be less than 100 gpm.

With respect to thermal analysis, the minimum resistance model and the "strongest" CCW pump operating at its enhanced pump curve are used to maximize flow to the RHR heat exchangers. Cases E1, E2, E5 and E6 were run using this approach. Note, Cases E1 and E2 and E5 and E6 are identical except for the sump temperature boundary condition.

To maximize RHR heat exchanger shell-side outlet temperatures, the maximum resistance model and the weakest CCW pump operating at its degraded pump curve are used. Cases E3 and E4 which are identical except for the sump temperature boundary condition were run using this approach. The results of these six cases are presented in Table 3-12.

For the initial ACS alignment (recirculation switch two), the maximum calculated CCWS supply temperature at the initial switchover to sump recirculation post-LOCA is approximately 133^{O}F (Case E1). At approximately 37 hours after the event, the maximum calculated CCWS supply temperature would be at 121^{O}F (Case E2). The maximum calculated RHR heat exchanger shell-side outlet temperature at the initial switchover to sump recirculation post-LOCA is approximately 213^{O}F (Case E3). At approximately 37 hours after the event, the maximum calculated RHR heat exchanger shell-side outlet temperature would be at 172^{O}F (Case E4).

For the additional cooling ACS alignment (recirculation switch seven), the maximum calculated CCWS supply temperature at the initial switchover to sump recirculation post-LOCA is approximately 138^{o}F (Case E5). At approximately 37 hours after the event, the maximum calculated CCWS supply temperature would be approximately 124^{o}F (Case E6).

The above calculated temperatures assumed that one of the CCW heat exchangers would be serviced by the essential SWS header. Based on feedback from the plant, this realignment would not be performed until the end of the switchover to cold leg recirculation. It has been estimated that this realignment would be completed within one to two hours following the initiation of switchover. Note, SWS flow is not isolated during the realignment. Until the CCW heat exchangers are "split", both CCW heat exchangers would be serviced by the nonessential SWS header.

To evaluate the impact of this interim alignment on CCWS temperatures, Cases E1, E3, and E5 were rerun using revised SWS flow assumptions.

Based on Reference 3-13, the following SWS pump flow rates can be supplied to the CCW heat exchangers from the nonessential SWS header during this interim alignment:

- One nonessential SWS pump
  - CCW heat exchanger 31 - 2928 gpm
  - CCW heat exchanger 32 - 2939 gpm
- Two nonessential SWS pumps
  - CCW heat exchanger 31 - 4319 gpm
  - CCW heat exchanger 32 - 4334 gpm

To account for potential pump wear, these flow rates were degraded by five percent.

For the initial ACS alignment (recirculation switch two), the maximum calculated CCWS supply temperature increased from 133°F to 135.5°F. The maximum calculayed RHR heat exchanger shell-side outlet temperature increase from 213°F to 215°F. With the additional cooling ACS alignment (recirculation switch seven), the maximum calculated CCWS supply temperature increased from 138°F to 140.5°F.

Following completion of the SWS header realignment, the interim CCWS maximum calculated temperature is expected to drop to the final CCWS maximum calculated temperature within a hour.

If a passive failure (i.e., pipe crack) was postulated in either SWS header, the SWS flow to one of the two CCW heat exchangers could be approximately 100 to 150 gpm less. This flow reduction corresponds to an approximate 3 percent reduction in SWS flow. Due to conservatism used throughout the calculation of maximum CCWS temperatures, this small flow reduction is considered to have a negligible impact.

3.1.2 System Evaluation

The evaluation of the capability of CCWS equipment to operate at elevated river water temperatures is presented in this section. Components serviced by the CCWS are evaluated in Section 4.2.

3.1.2.1 Design Temperature

The design temperature of the CCWS is 200°F, except for portions of the system located downstream of the cooling water piping to the RCP thermal barriers, which were designed based on the RCS design temperature of 650°F. To evaluate the impact of a 95°F SWS temperature, the maximum expected system temperature for each mode is determined and compared to the system design temperature limitation. As long as the maximum calculated temperature is less than design, the system is evaluated to be acceptable.

In the Startup and Power Operation modes, the highest CCWS supply temperature occurs when one CCW heat exchanger is OOS. From Table 3-9 (Case A3), this temperature corresponds to approximately 118°F. For CCWS components (piping, valves, instruments, etc) located on the CCWS supply side, the maximum calculated temperature is significantly below design. For CCWS components located on the return side, a review of the PEGISYS calculated nodal temperatures was performed to define the highest calculated CCWS return temperature. With one CCW heat exchanger OOS, the highest CCWS return temperature occurred at the outlet of the nonregenerative heat exchanger. This temperature was conservatively calculated to be approximately 154°F and is based on a 120 gpm (maximum letdown) tube-side flow, an enhanced design heat transfer coefficient, and no automatic control function of TCV-130.

As noted in Sections 3.1.1.5.2 and 3.1.1.5.3, PEGISYS calculates steady-state conditions and cannot be used to calculate system thermal performance during the plant Cooldown and Refueling modes since decay heat varies with time after plant shutdown. Since CCWS supply temperature are manually controlled to ≤120°F, system temperatures would also be maintained below design.

The highest CCWS temperatures occur during the post-LOCA recirculation phase due to the following concerns:

- Sump temperatures are relatively high at the initial switchover to recirculation;
- RHR heat exchanger tube side flows are not manually controlled to limit heat transfer (during plant cooldown, the cooldown rate and the CCWS supply temperature are limited)

Provided in Table 3-12 are maximum calculated system temperatures during LOCA recirculation. As noted in Section 3.1.1.6.5, the highest CCWS temperature occurs at the outlet of the RHR heat exchanger at the initial switchover to sump recirculation. This maximum temperature was conservatively calculated to be as high as 215°F.

Although this maximum calculated temperature is higher than the design temperature of the CCWS, the elevated temperature is evaluated to be acceptable based on the following conclusions:

1) The post-LOCA mode is considered a faulted condition, and as such, does not constitute a revision to the design temperature of the RHR heat exchangers. As such, the major concern is to ensure th^ component structural integrity is maintained. The applicable ASME Code is Section VIII, Division 1. For carbon steel, the allowable stress is unchanged at the expected temperatures and pressures. Therefore, the vessels are considered adequate at the maximum calculated temperature.

2) The system pressure at the outlet of the RHR heat exchangers is calculated to be greater than the corresponding pressure at saturation temperature. As such, the fluid leaving the RHR heat exchangers would remain subcooled and flashing would not occur.

3) Sump temperature will decrease with time into the event as decay heat levels drop and ACS cooling is established.

4) CCWS flow leaving the RHR heat exchangers would mix with low-temperature return flows from other system users. This would cause the bulk temperature of the CCWS fluid to drop as it is returned to the suction of the CCW pumps. This mixing effect would maintain the fluid subcooled and would prevent flashing.

5) Since the mixed mean temperature at the pump suction (<180^{O}F from Table 3-12, Case E5) is less than the system design temperature, only components immediately downstream of the RHR heat exchangers are subject to elevated CCWS temperatures. These components are limited to piping, flanges, and valves. Fluid temperatures greater than 200^{O}F are acceptable with respect to the CCWS piping since the piping specification defines the design temperature of class 152 piping as 500^{O}F at the system design pressure (150 psig).

6) The design temperature of system valves and flanges are also higher than the maximum calculated RHR heat exchanger outlet temperature. System valves and flanges were built with a minimum USAS B16.5 class rating of 150 pounds. At a working pressure of 225 psig, the maximum allowable temperature for this class is 250^{O}F. Since the maximum calculated CCWS temperature (215^{O}F) is lower than the allowable maximum temperature (250^{O}F) for CCWS piping, valves, and flanges, structural integrity is ensured.

3.1.2.2 Component Cooling Water Heat Exchangers

The primary function of the CCW heat exchangers is to transfer waste heat from components serviced by component cooling to the SWS during all modes of plant operation. The heat exchangers are a shell and tube counter flow design with CCWS flow supplied on the shell-side. The design CCWS flow was selected based on an ACS optimization study of heat removal loads, raw water inlet temperature, and equipment costs. This flow corresponds to 2,660,000 lb/hr (approximately 5313 gpm). The design temperature and pressure of the CCW heat exchanger shell-side are 200^{o}F and 150 psig, respectively.

The highest CCW flow through the CCW heat exchanger shell-side occurs when two CCW pumps are operating, one CCW heat exchanger is OOS, and both RHR heat exchangers flow paths are opened. From Table 3-10 (Case B4), this maximum flow is calculated to be approximately 7500 gpm. Since this case results in flows in excess of design, a flow induced tube vibration analysis was performed. This analysis required the heat exchanger internal geometry to be reviewed to obtain flow velocities. These velocities were used with tube outside diameter and tube natural frequency to calculate the minimum value of the dimensionless quantity fd/V, which was then compared to allowable limits. Based on these results, the CCW heat exchanger should not be subject to excessive tube vibration at a maximum shell-side flow of 7500 gpm.

3.1.2.3 CCW Pumps

The design basis of the CCWS requires one CCW pump to be capable of operating in the post-LOCA mode with all system users available except for those automatically isolated on a design basis LOCA event. As noted in Section 3.1.1.5.5, the excess letdown heat exchanger is automatically isolated on a containment phase A signal. The RCPs and RVNB coolers are automatically isolated on a containment phase B signal. In this design basis post-LOCA alignment, CCW flow to the RHR heat exchangers is required to be throttled to prevent total CCW system flow rate from exceeding the maximum flow capability (i.e., runout) of one CCW pump.

For a small-break LOCA, a containment phase B isolation signal may not occur. In this alignment, a single CCW pump would runout beyond its current runout point (5400 gpm to 5500 gpm). To prevent pump runout during post-LOCA conditions, the cooling water flow path to the nonregenerative heat exchanger must be isolated prior to the manual start of the CCW pump during the switchover to recirculation.

The acceptability of operation within the maximum allowable pump runout flow is discussed below for both the pump and motor.

3.1.2.3.1 CCW Pump Capability

Operation at flow rates within the established pump operating range as defined in the vendor certified pump flow versus head performance curve is acceptable as long as adequate Net Positive Suction Head (NPSH) is available. NPSH required is defined by the pump vendor as a function of pump flow, and is usually included on the vendor certified pump performance curves. NPSH available is calculated based on plant piping and layout configuration and system operating temperatures.

At Indian Point Unit 3, the CCWS is provided with two surge tanks which are physically located approximately 30 feet above the suction of the CCW pumps. With this system configuration, the following equation can be used to calculate CCW pump NPSH available:

$NPSH_A$ = Surge Tank Pressure + Elevational Difference (tank water level - pump impellor centerline) - Piping Pressure Losses (surge line connection to pump suction) - Vapor Pressure of Pumped Fluid

The most limiting NPSH conditions occur during the LOCA recirculation alignment when pump flow can be near runout with both RHR heat exchanger shells opened and system temperatures maximized.

The original design basis NPSH calculation considered a pump flow of up to 6000 gpm. For a fluid temperature of 180°F, NPSH available was calculated to be approximately 46 feet with the water level of the surge tanks at approximately 50% and the tanks opened to atmospheric pressure. At this pump flow, NPSH required is approximately 36 feet.

The design basis NPSH calculation was revised to reflect higher expected system temperatures. With a CCWS temperature as high as 203°F and a CCW pump flow of 5500 gpm, the NPSH available was determined to be approximately 36 feet. At this flow, the NPSH required is approximately 29 feet.

In support of this project, CCW pump NPSH was revised based on the results of the thermal/hydraulic model and the CCWS flow balance test. Minimum NPSH available was found to be dependent on which CCW pump is operating due to layout effects. Note CCW pump 33 has the highest suction piping losses and the flow balance test was performed with this pump. To determine limiting NPSH, the highest suction temperature which would provide at least 10% margin between NPSH required and available was determined. This temperature was determined to be 197°F.

Table 3-12 (Case E5) defines the maximum calculated CCW return temperature to be less than 180°F. Since the system was flow balanced to limit CCW pump flow to less than or equal to 5500 gpm and maximum calculated pump suction temperature is less than 197°F, adequate NPSH would be available during the LOCA recirculation with a SWS temperature of 95°F.

3.1.2.3.2 CCW Pump Motor Capability

The capability of the CCW pump motor to drive a CCW pump at pump runout conditions was evaluated. Note, this evaluation is not impacted by the river water temperature increase, but is included for completeness. For this evaluation, the pump motor is considered adequate if pump required brake horsepower (bhp) as defined on the pump vendor performance curve is within the service factor rating of the pump motor.

The CCW pump motor nameplate output rating and service factor rating are 250 hp and 1.15, respectively. Therefore, the CCW pump motor is capable of driving the CCW pump up to a bhp of 287.5 hp. The maximum bhp, as defined on the vendor certified pump performance curve, occurs at pump runout condition and is approximately 285 hp. Since the pump motor capability exceeds the pump runout requirement, it can be concluded that the CCW pump motor can adequately support pump operation over expected operating conditions.

The design basis Emergency Diesel Generator load study is based on a power requirement of 285 bhp (Reference 3-12). Since this load is within the service factor of the motor, operation at pump runout conditions is acceptable.

3.1.2.4 CCWS Piping

As discussed in Section 2.2, two CCW pumps were originally required to operate during the Startup and Power Operation modes since the flow requirements of the various system users exceeded the flow capability of a single pump. With the removal of the boric acid and waste evaporators and the flash evaporator, the flow requirements of the system have been reduced.

As part of this project, component flow requirements were reviewed. In general, CCW flow was increased to components that were found to be limiting for the 1988 SWS temperature temporary technical specification amendment to counter the effect of higher CCW temperatures due to higher river water temperatures.

For the Plant Startup Alignment, the system flow requirement is less than 5000 gpm. For the Power Operation alignment, less than 4700 gpm is required. Both of these maximum flows are within the runout capacity of a single CCW pump.

In general, the carbon steel CCWS piping was sized to maintain fluid velocities at or below 15 feet per second. This velocity limit was selected to ensure that system piping would not be the limiting hydraulic resistance of the network. With this approach, component throttle valves could be used to established required system flows. The velocity limit was selected low enough to preclude piping erosion concerns.

Since pump and component flows were increasing, fluid velocities in CCWS piping were reviewed. Based on this review, four potential problem areas were identified. These are the following:

- o The 1 inch supply and return piping to the gross failed fuel detector unit
- o The 8 inch supply and return piping to the SFP heat exchanger
- o The 10 inch piping at the CCW pump discharge
- o The 14 inch inlet and outlet piping to the CCW heat exchangers

The maximum allowable flow which results in a 15 feet per second fluid velocity for the above four pipe sizes is calculated to be 40, 2341, 3691, and 6454 gpm, respectively. Flows greater than 40 gpm to the GFFD could occur when two CCW pumps are operating. Flows greater than 2341 gpm to the SFP heat exchanger could occur during refueling/core unload operations when maximum cooling is needed. Flows greater than 3691 gpm at the pump discharge piping could occur during Power Operation when only one CCW pump is in service as well a plant cooldown/refueling when two CCW pumps are operating. Flow greater than 6454 gpm to the CCW heat exchangers could occur whenever a CCW heat exchanger is OOS, at least one RHR heat exchanger flow path is opened, and two CCW pumps are operating.

The potential concern of higher fluid velocity is pipe erosion. Over the last five years, significant progress has been made in the area of pipe erosion technology and the ability to predict potential erosion locations. Since layout is also a critical parameter, a monitoring program on the above noted piping is required to be implemented to address potential thinning and erosion.

3.1.2.5 Heatup During LOCA Injection Phase

As noted in Section 3.1.1.5.4, the CCWS acts as a heat sink during the injection phase of a design basis LOCA with Blackout. The design basis calculation estimated the time to heat the CCWS from the normal operating temperature of 95^{o}F to 200^{o}F. The calculation also calculated the temperature of the CCWS at four hours into the event.

To perform this calculation, a conservative estimate of the CCWS volume was used. The heat loads used to calculate system heatup were based on heat addition from three SI pumps (10,000 Btu/hr each) and two SI recirculation pump motors (184,000 Btu/hr each). Note, a diesel generator failure was not taken. The heatup rate was calculated to be approximately 5^{o}F per hour.

Provided in the Indian Point Unit 3 Updated FSAR is the time required for the CCWS to heat up from 95^{o}F to 150^{o}F and 180^{o}F. These times were determined to be approximately 11 hours and 16 hours, respectively (Reference 3-10).

With a 95^{o}F SWS inlet temperature, the CCWS supply temperature will increase. From Section 3.1.1.6.1, the highest normal CCW supply temperature is calculated to be approximately 110^{o}F. Using the conservative heat loads provided in Table 3-2, the CCWS heatup rate is calculated to be approximately 7^{o}F per hour. The time required to reach 150^{o}F and 180^{o}F is calculated to be approximately 6 hours and 10 hours, respectively. The temperature of the CCW fluid at 4 hours is calculated to be approximately 138^{o}F.

For a design basis large-break LOCA, the duration of the injection phase is relatively short (approximately 30 to 45 minutes). As such, system temperatures would be relatively low (<120^{o}F) at the end of the injection phase. For smaller breaks, the time to switchover would increase.

The design basis calculation considered a four hour time interval. Within this time frame, it is reasonable to assume that operator action will be taken to implement forced cooling in the CCWS either via switchover to recirculation or by following post-LOCA cooldown procedures. Therefore, a 138^{o}F CCWS temperature is a conservative estimate of the maximum CCWS temperature prior to the initiation of forced cooling. Following initiation of forced cooling, the CCWS supply temperature would drop to the calculated steady-state recirculation maximum temperatures within one hour. The CCWS supply temperature would then decrease with time as discussed in Section 3.1.1.6.5.

3.1.2.6 CCWS Radiation Monitors

The CCWS is monitored for radiation to detect a leak of reactor coolant from the RCS and/or RHRS into the ACS. The monitors employ a sodium-iodide scintillation detector which are placed in an in-line well in the CCWS piping. A separate monitor (R-17A and R-17B) is used to monitor each CCWS header at the outlet of the CCW heat exchangers. The monitors are physically located in the primary auxiliary building at the 41 foot elevation (Reference 3-17).

To protect the sodium-iodide crystal, fluid temperature must be maintained below the design temperature of the crystal which is typically 160^{o}F. Since these monitors are located at the outlet of the CCW heat exchangers, the CCWS fluid temperature would be much lower than 160^{o}F. As previously noted, the highest CCWS supply temperature occur during post-LOCA conditions. From Section 3.1.1.6.5, the maximum calculated CCWS supply temperature is calculated to be less than 141^{o}F. As such, the CCWS radiation monitors will remain functional with a 95^{o}F SWS inlet temperature.

3.2 RESIDUAL HEAT REMOVAL SYSTEM

The primary function of the Residual Heat Removal System (RHRS) is to transfer heat energy from the core and RCS during the second phase of plant cooldown. The RHRS was evaluated to determine the impact of higher river water temperatures on the ability of the system to cooldown the plant. In addition, the RHRS is used to support the emergency core cooling system by providing cooling to the recirculation sump fluid. The RHR heat exchangor ability to subcool the sump fluid is also evaluated. A discussion of these evaluations are provided below.

3.2.1 PLANT COOLDOWN

The cooldown analysis evaluates two separate plant cooldown scenarios. The first is a normal cooldown transient to both Cold Shutdown (RCS temperature $\leq$ 200^{O}F) and Refueling (RCS temperature $\leq$ 140^{O}F) with all cooling equipment available. The case of normal plant cooldown to a refueling mode is presented in Table 9.3-3 of the Indian Point Unit 3 Updated FSAR (Reference 3-10).

The second evaluation is an Appendix R cooldown to Cold Shutdown. For this evaluation, only equipment capable of being powered by the Indian Point Unit 3 Appendix R diesel generator are considered.

3.2.1.1 Background

During the initial phase of plant cooldown from operating temperatures, auxiliary feedwater is supplied to the steam generators. The steam is relieved through the steam dump or via the main steam power-operated relief valves. As temperatures decrease, the ability to remove heat by steaming becomes ineffective, so at approximately 350^{O}F and 450 psig the RHRS is aligned for operation.

Decay heat and sensible heat from the RCS is transferred to the CCWS via the RHR heat exchangers. RHR heat exchanger heat loads as well as auxiliary heat loads serviced by the CCWS are transferred to the SWS via the CCW heat exchangers. As SWS temperatures increase, the capability of the ACS to remove heat is decreased since the driving force (delta-T across the CCW heat exchangers) between the process and cooling fluids is decreased.

3.2.1.2 Methodology

To simulate the plant cooldown transient, the Westinghouse computer code RHRCOOL is used. The code simulates the heat transfer process of the RHR, CCW, and service water systems. The code requires various design and operating parameters as input which are used to determine heat transfer capability. Examples include reactor thermal power, RCP heat input, heat exchanger design and operating data, and auxiliary CCWS heat loads. The code uses the Westinghouse Decay Heat Standard to establish decay heat levels as a function of time into plant shutdown. In the case where operating flows are less than design, the heat transfer coefficient of the RHR heat exchangers is reduced from its design value. Verification of the computer code has been performed in accordance with Westinghouse Quality Assurance Manual (Reference 3-1).

The code was formulated to evaluate a design basis cooldown. As such, CCWS auxiliary heat loads and SWS inlet temperature are required to be supplied at both 4 hours after plant shutdown (start of RHRS cooling) and 20 hours (end of the transient). Interim values are calculated using a linear progression from the initial to final value.

A unique feature of the code is that RCS flow through the RHR tube-side heat exchangers will be "throttled" as necessary to ensure that one or both of the following limitations are satisfied:

- o RCS cooldown rate
- o Maximum CCWS supply temperature

The limits for the above two parameters can be specified.

The output of the code consists of RHR and CCW heat exchanger inlet and outlet temperatures, RCS flow, and decay heat levels and RHR heat exchanger duty as a function of time during the cooldown transient.

3.2.1.3 Assumptions

In general, conservative assumptions were used in the selection of system data used to analyze the cooldown transient. For example, CCW flows are based on the system data calculated by the PEGISYS CCWS model with the maximum resistance model and the weakest CCW pumps operating at their degraded pump curves (See Table 3-10). RHR pump flow is based on the design flow of approximately 3000 gpm. Service water flow capability is based on a hydraulic analysis performed by United Engineers and Constructors (Reference 3-9). These flows were reduced by 5% to allow for pump degradation. In the determination of minimum RHR heat exchanger heat transfer capability, the design (fouled) "U" and a five percent area reduction are considered for both the RHR and CCW heat exchangers.

For the normal plant Cooldown case, all three SWS pumps on the nonessential header are assumed to be operating. As noted in Section 3.1.1.4.4.1, the SWS flow to CCW heat exchanger 31 and 32 are calculated to be 4503 gpm and 4516 gpm, respectively.

The lower of the two calculated flows was reduced by 5 percent (to account for pump wear) and was used for both CCW heat exchangers. For an Appendix R Cooldown, only one SWS pump is available. For this alignment, a SWS flow of 2500 gpm per CCW heat exchanger was assumed. This flow is conservative since it it well within the capacity of a single SWS pump (Reference 3-11).

For the cooldown evaluations, SWS inlet temperatures of 32, 50, 65, 75, 85, 90, and 95^{O}F were considered. Specific assumptions and results for each of the cooldown scenarios are provided in the following sections.

3.2.1.4 Results

Provided below are the calculated cooldown times for both a normal and Appendix R cooldown.

3.2.1.4.1 Normal Plant Cooldown

The original design basis of the RHR and CCW heat exchangers called for a CCW flow of approximately 5000 gpm per RHR heat exchanger (assuming 3 CCW pumps operating) and 9200 gpm SWS flow to each CCW heat exchanger (assuming 3 SWS pumps operating). At these flows and a SWS temperature of 75^{O}F, the CCW heat exchangers were sized to cool the plant from 350^{O}F to 140^{O}F in approximately 16 hours. A decay heat load based on a core thermal rating of 3083 MWt was considered. (Note: the subject design basis calculation was performed for Indian Point Unit 2 at its stretch power level. The calculation is applicable to Indian Point Unit 3 since ACS equipment parameters are identical.)

As part of this project, the FSAR basis normal cooldown time was recalculated with a SWS inlet temperature of 75^{O}F, 85^{O}F, and 95^{O}F. At a core power level of 3025 MWt, RHR and CCW heat exchanger design conditions, no auxiliary heat loads, and a maximum CCWS supply temperature of 115^{O}F, the RCS cooldown time from a temperature of 350^{O}F to 140^{O}F was calculated to be 19, 32, and 59 hours. The slightly longer time as compared to the design basis is primarily due to changes in decay heat assumptions.

Based on the calculated CCWS flows provided in Table 3-10, the throttle valves used to control flow to the RHR heat exchangers (820 A and B) will be repositioned, as required, to allow for an adequate plant cooldown rate.

3.2.1.4.2 Appendix R Cooldown

To meet 10CFR50 Appendix R "Fire Protection Program for Nuclear Power Facilities Operating Prior to January 1, 1979" requirements, Indian Point Unit 3 has an Appendix R diesel generator with which an alternate power supply can be provided to vital components. The following equipment, within the scope of this analysis, can be supplied with power:

- o 1 RHR pump
- o 1 CCW pump
- o 1 Charging pump (requires CCW cooling)
- o 1 backup SWS pump aligned to the nonessential header

The RHRS was evaluated to determine if the Appendix R cooldown requirement could be satisfied with both the flow capacity of a single CCW pump and the manual adjustment of CCW flow to one RHR heat exchanger. For this evaluation, both CCW heat exchangers were considered since the SWS pump could deliver to both heat exchangers. Although two RHR heat exchangers could be manually placed in service, only one was considered since system flow must be controlled to within the runout capacity of a single CCW pump. Provided in Table 3-13 are the CCWS auxiliary heat loads considered for the Appendix R Cooldown following plant shutdown. From this table, note that station blackout is assumed to occur which would trip the RCPs (no heat load).

Based on the analysis, the plant can achieve Cold Shutdown within the 72 hours requirement provided that 1) total CCWS flow is greater than or equal to 4500 gpm, 2) CCWS flow greater than or equal to 3500 gpm is directed to the one operable RHR heat exchanger, and 3) the RHRS is cut in at approximately 29 hours after plant shutdown. For this analysis, the CCWS supply temperature was allowed to increase to 125°F.

As noted in Reference 3-11, the backup SWS pumps take suction from the Indian Point Unit 2 discharge canal. With Indian Point Unit 2 operating at full power with a SWS inlet temperature of 95°F (Reference 3-15), the Unit 2 discharge canal temperature could reach 110°F. As instructed by NYPA, the Appendix R analysis was performed with a 95°F SWS temperature. If the backup SWS pump is used, Indian Point Unit 2 would have to reduce power as necessary in order to limit discharge temperature. A memo of understanding is available between Indian Point Unit 2 and 3 which would cover this subject (Reference 3-16). An alternative is to power one of the nonessential SWS header pumps from the Appendix R emergency diesel generator.

3.2.2 Post-LOCA Performance

The RHR heat exchangers are used during the recirculation phase of a LOCA to provide cooling to the recirculation sump fluid. In order to provide adequate cooling, the recirculation sump fluid must be subcooled to prevent flashing in the reactor vessel.

To determine the minimum amount of subcooling, RHR heat exchanger heat transfer capability was minimized. This included the use of the RHR heat exchanger fouled heat transfer coefficient and a five percent surface area reduction. Component cooling water conditions at the initiation of recirculation were used. Based on this analysis, the maximum RHR heat exchanger tube-side outlet temperature is calculated to be approximately 225°F. Since the pressure and inside the reactor vessel is greater than or equal to containment pressure, at least 30 degrees of subcooling is available to the recirculation sump fluid.

3.3 SPENT FUEL PIT COOLING SYSTEM

Component cooling is provided to the shell-side of the SFP heat exchanger in order to remove decay heat generated by spent fuel assemblies in storage. Typically, approximately one third of the fuel assemblies contained in the reactor vessel are added to the SFP each refueling. The SFP heat exchanger tube-side inlet temperature is a key parameter in that it represents the bulk temperature of the SFP.

Provided in this section is the calculated SFP bulk temperatures for both Power Operation and Refueling conditions. For both of these modes, the following design data is available for the SFP heat exchanger:

- General Data
  - Design Area - 2,000 ft^2
  - Design U - 310 Btu/lb-ft^2-^oF
  - Clean U - 468 Btu/lb-ft^2-^oF
  - Design Duty - 7.96E+06 Btu/hr
  - Tube Fouling Factor - 0.0005 hr-ft^2-^oF/Btu
  - Shell Fouling Factor - 0.0005 hr-ft^2-^oF/Btu
- Tube-Side Conditions
  - Design Flow - 1.1E+06 lb/hr
  - Design Inlet Temperature - 120^oF
- Shell-Side Conditions (CCWS)
  - Design Flow - 1.4E+06 lb/hr
  - Design Inlet Temperature - 100^oF

To minimize heat transfer capability, the fouled heat transfer coefficient and a 5% reduction in the design surface area was considered. For this evaluation, the heat exchanger transfer rate, tube area, and overall heat transfer coefficient at design flows were defined as 310 Btu/hr-ft^2-^oF, 1900 ft^2, and 0.589E+06 Btu/hr-^oF, respectively. In addition, tube-side design flows are used to calculated SFP temperatures.

Provided below are the calculated SFP temperatures for both Power Operation and Refueling conditions.

3.3.1 Power Operation

During Power Operation, the CCWS was evaluated with a SFP heat load based on a 1/3 core discharge with 30 days decay and previous discharges (8.79 mBtu/hr per Table 3-2). With one degraded CCW pump, two CCW heat exchangers in service and 95^{O}F SWS temperature, the minimum calculated CCW flow to the SFP heat exchanger is 1487 gpm and the maximum calculated CCWS supply temperature is 110^{O}F (See Table 3-9, Case A1). At these conditions, the maximum SFP temperature is calculated to be 138^{O}F.

With one CCW heat exchanger OOS, the minimum calculated CCW flow to the SFP heat exchanger is 1462 gpm and the maximum calculated CCWS supply temperature is 118^{O}F (See Table 3-9, Case A3). At these conditions, the maximum SFP temperature is calculated to be 147^{O}F.

These temperatures are evaluated to be acceptable since they are below the concrete design temperature (150^{O}F).

3.3.2 Refueling

The highest SFP temperatures occurs during the initial discharge of spent fuel to the SFP during plant refueling. Provided in the FSAR is the evaluation of a one-third and full core discharge to the SFP. The maximum SFP temperature with a one-third and full core discharge is calculated to be 128^{O}F and 153^{O}F, respectively (Reference 3-10). The FSAR analysis considered a CCWS design flow rate of 1.4E+06 lb/hr (approximately 2800 gpm).

During refueling conditions, many CCWS users do not require cooling since they are OOS. In the analysis of the refueling alignment, the PEGISYS model was run with the flow paths to the RCPs, RVNB, and nonregenerative heat exchanger isolated. From Table 3-11 (Case C4), the minimum calculated flow to the SFP heat exchanger in this alignment would be 1844 gpm.

Based on the calculated system flows with CCWS throttle valves left as is, the design CCW flow can not be delivered to the SFP heat exchanger. To satisfy the cooling requirements of the SFP heat exchanger, CCW flow to other system users (which are not operating) should be isolated and/or the CCWS throttle valve to the SFP heat exchanger (valve 803) should be manually repositioned.

With a 95°F SWS inlet temperature, the CCWS supply temperature is calculated to be approximately 101°F. This temperature considers both CCW heat exchangers to be in service at design flows. With design CCW flow to the SFP heat exchanger, the one-third and full core discharge SFP temperatures are calculated to be 145°F and 168°F, respectively. Since the revised SFP temperatures with a 95°F SWS inlet temperature are higher than the present basis, an update to the FSAR is required.

The licensing basis for the SFPCS was revised in 1987 when an amendment was approved for a 162 hour decay period for a full core discharge. The thermal/hydraulic assumption was that the SFP temperature would be maintained below the design temperature of the SFPCS (200°F) with a full core discharge to the SFP. NYPA has recently submitted a rerack amendment to the NRC for the use of high density racks in the SFP. For this analysis, a one region and full core discharge were considered (Reference 3-14).

The impact of a 95°F SWS inlet temperature on these analyses were reviewed. Based on the assumption for heat exchanger performance defined in 3.2, the SFP maximum calculated temperatures with a 95°F SWS inlet temperature were found to be within the conservative rerack maximum calculated SFP temperatures.

REFERENCES

3-1 "NATD Quality Assurance Program", Westinghouse Electric Corporation, WCAP-9565.

3-2 NYPA Drawing, "Flow Diagram Auxiliary Coolant System PAB & FSB Sheet No. 1," No. 9321-F-27513-1.

3-3 NYPA Drawing, "Flow Diagram Auxiliary Coolant System PAB & FSB Sheet No. 2," No. 9321-F-27513, Revision 21.

3-4 NYPA Drawing, "Flow Diagram Auxiliary Coolant System Inside Containment," No. 9321-F-27203-16.

3-5 Westinghouse WCAP-8326, "Containment Pressure Analysis Code (COCO)," July, 1974.

3-6 Westinghouse WCAP-10325-A, "Westinghouse LOCA Mass & Energy Model for Containment Design - March 1979 Version," May, 1983

3-7 Westinghouse WCAP-12269, Revision 1, "Containment Margin Improvement Analysis for Indian Point Unit 3," May, 1989.

3-8 Indian Point Unit 3 Updated FSAR, Section 6.2.

3-9 UE&C Letter IUP-8265, "Service Water System Flows to the Component Cooling Water HXs", December 1, 1988.

3-10 Indian Point Unit 3 Updated FSAR, Section 9.3.

3-11 Indian Point Unit 3 Updated FSAR, Section 9.6.

3-12 Indian Point Unit 3 Updated FSAR, Section 8.2.

3-13 UE&C Letter IUP-8404, "Additional Service Water System Model Cases", July 21, 1989.

3-14 NYPA Letter, IPN-99-018, J. C. Brons to USNRC, "Indian Point 3 Power Plant, Docket 50-286, Proposed Technical Specifications Requirement Spent Fuel Pit Storage Capability Expansion," May 9, 1988.

3-15 Westinghouse WCAP-12312, "Safety Evaluation For An Ultimate Heat Sink Temperature increase To 95°F At Indian Point Unit 2", July, 1989.

3-16 NYPA Memorandum of Understanding, "Rules Govering the Implementation of the Emergency Plan at the Indian Point Site", No. 28, Revision 1, March 18, 1983.

3-17 Indian Point Unit No. 3 System Description, "Radiation Monitoring System", No. 12.0, Revision 0.

TABLE 3-1
CCWS THERMAL MODEL BASIS

Component	Model Basis
RHR and CCW Heat Exchangers	Heat Exchanger
SG Blowdown, Reactor Coolant, and Pressurizer Sample Heat Exchangers	Point Source
Spent Fuel Pit Heat Exchanger[1]	Point Source
Seal Water, Nonregen.[2], and Excess Letdown Heat Exchangers	Heat Exchanger
Reactor Coolant Pumps (RCPs)	Point Source
RHR, Safety Injection (SI), Charging Pumps, and Recirculation Pumps	Point Source
Reactor Vessel Supports	Point Source
Waste Gas Compressors	Point Source
CCW Pumps[3]	Point Source
Gross Failed Fuel Detector	Point Source
Rad. Monitor Sample Cooler	Point Source

[1] This component was specifically modelled as a point source since a heat load is easily calculated.

[2] The temperature control capability of valve TCV-130 could not be modelled. The valve was modelled in its maximum allowable open position since PEGISYS does not model temperature control valves..

[3] Heat addition due to pump inefficiency is considered.

TABLE 3-2
SUMMARY OF CCWS POINT HEAT LOADS

Component	Heat Load (Btu/hr x 10^6)
SG Blowdown, Reactor Coolant, and Pressurizer Sample Heat Exchangers	0.2 / Cooler
Reactor Coolant Pumps	1.2 / Pump
Safety Injection Pumps	0.075 / Pump
Charging Pumps	0.45 / Pump
Recirculation/RHR Pumps	0.15 / Pump
Reactor Vessel Supports	0.2
CCW Pumps (Heat Addition)	0.3 / Pump
Waste Gas Compressors	0.14 / Unit
SFP heat exchanger	
- 30 Days After Shutdown	8.79
60 Days After Shutdown	7.41
Radiation Monitor Sample Heat Exchanger	0.07
Gross Failed Fuel Detector	0.30

TABLE 3-3
SUMP TEMPERATURE TIME HISTORY FOR THE LOCA EVENT

Time (Sec)	Temperature (^oF)	Time (Sec)	Temperature (^oF)
0	130.0	2400	255.5
5	230.0	3000	253.7
20	251.5	3999	250.7
40	252.0	4999	247.9
60	253.8	5999	245.2
80	254.0	6999	242.6
100	254.9	7999	240.2
150	256.7	8999	237.9
199	258.0	9999	235.8
399	261.0	19999	221.1
599	262.3	29999	214.0
799	263.0	49999	207.5
999	263.2	69999	204.5
1199	262.0	89999	202.2
1499	261.3	99999	200.9
2000	258.2	299999	195.5
2100	257.5	399999	194.7
2200	256.8	599999	191.9
2300	256.2	799999	189.6
2325	256.0		
2351*	255.8		
2360	255.7		
2370	255.7		

*Approximate time of switchover

TABLE 3-4
CCWS ALIGNMENT FOR STARTUP/POWER OPERATION/BLACKOUT MODES

Component	Cases Considered				
	A1	A2	A3	A4	A5
CCWS USERS IN SERVICE[1]					
Seal Water HX	Y/1	Y/1	Y/1	Y/1	Y/1
Waste Gas Comp. (Coolers)	Y/2	Y/2	Y/2	Y/2	Y/2
RC Sample HXs	Y/1	Y/1	Y/1	Y/1	Y/1
Nonregenerative HX	Y/1	Y/1	Y/1	Y/1	Y/1
RHR Pumps (Coolers)	Y/0	Y/0	Y/0	Y/0	Y/0
Presurizer Sample HXs	Y/2	Y/2	Y/2	Y/2	Y/2
SFP HX	Y/1	Y/1	Y/1	Y/1	Y/1
RV Nozzle Blocks	Y/4	Y/4	Y/4	Y/4	Y/4
Excess Letdown HX	Y/1	N	N	N	Y/1
SG Blowdown HXs	Y/4	Y/4	Y/4	Y/4	Y/4
RCPs (Coolers)	Y/4	Y/4	Y/4	Y/4	Y/4
Recir. Pumps (Coolers)	Y/0	Y/0	Y/0	Y/0	Y/0
Charging Pumps (Coolers)	Y/2	Y/2	Y/2	Y/2	Y/2
SI Pumps (Coolers)	Y/0	Y/0	Y/0	Y/0	Y/0
Rad. Monitor Sample Cooler	Y/1	Y/1	Y/1	Y/1	Y/1
Gross Failed Fuel Detector	Y/1	Y/1	Y/1	Y/1	Y/1
RHR HX 31	N	N	N	N	N
RHR HX 32	N	N	N	N	N
CCWS EQUIPMENT IN SERVICE					
CCW Pumps On	1	1	1	1	2
AC Coolant Pumps On	0	0	0	0	0
SI Circ. Water Pumps On	0	0	0	0	0
CCW HXs In Service	2	2	1(31)	1(32)	2
SWS BOUNDARY CONDITIONS					
SWS Pumps On	2	2	2	2	2
SWS Temperature - ^{o}F	95	95	95	95	95
SWS Flow CCW HX 31 - gpm	3460	3460	4418	0	3460
SWS Flow CCW HX 32 - gpm	3469	3469	0	4418	3469
RHR SYSTEM BOUNDARY CONDITIONS					
RHR/Recirc. Pumps on	0	0	0	0	0
RHR HX Inlet Temp. - ^{o}F	N/A	N/A	N/A	N/A	N/A
RHR Flow Per RHR HX - gpm	0	0	0	0	0

[1] Y/N refers to whether or not CCW flow is supplied to User; Digit refers to number of components rejecting heat to CCWS.

TABLE 3-5
CCWS ALIGNMENT FOR PLANT COOLDOWN/BLACKOUT MODE

Component	Cases Considered B1	B2	B3	B4
CCWS USERS IN SERVICE[1]				
Seal Water HX	Y	Y	Y	Y
Waste Gas Comp. (Coolers)	Y	Y	Y	Y
RC Sample HXs	Y	Y	Y	Y
Nonregenerative HX	Y	N	Y	N
RHR Pumps (Coolers)	Y	Y	Y	Y
Presurizer Sample HXs	Y	Y	Y	Y
SFP HX	Y	Y	Y	Y
RV Nozzle Blocks	Y	Y	Y	Y
Excess Letdown HX	N	N	N	N
SG Blowdown HXs	Y	Y	Y	Y
RCPs (Coolers)	Y	Y	Y	Y
Recir. Pumps (Coolers)	Y	Y	Y	Y
Charging Pumps (Coolers)	Y	Y	Y	Y
SI Pumps (Coolers)	Y	Y	Y	Y
Rad. Monitor Sample Cooler	Y	Y	Y	Y
Gross Failed Fuel Detector	Y	Y	Y	Y
RHR HX 31	Y	Y	Y	Y
RHR HX 32	Y	Y	Y	Y
CCWS EQUIPMENT IN SERVICE				
CCW Pumps On	2	2	2	2
AC Coolant Pumps On	0	0	0	0
SI Circ. Water Pumps On	0	0	0	0
CCW HXs In Service	2	2	1 (31)	1 (31)
SWS BOUNDARY CONDITIONS				
SWS Pumps On	N/A	N/A	N/A	N/A
SWS Temperature - °F	N/A	N/A	N/A	N/A
SWS Flow Per CCW HX - gpm	N/A	N/A	N/A	N/A
RHR SYSTEM BOUNDARY CONDITIONS				
RHR/Recirc. Pumps on	N/A	N/A	N/A	N/A
RHR HX Inlet Temp. - °F	N/A	N/A	N/A	N/A
RHR Flow Per RHR HX - gpm	N/A	N/A	N/A	N/A

[1]Y/N refers to whether or not CCW flow is supplied to User; All cases based on isothermal conditions.

TABLE 3-6
CCWS ALIGNMENT FOR REFUELING MODE

Component	Cases Considered C1	C2	C3	C4
CCWS USERS IN SERVICE[1]				
Seal Water HX	Y	Y	Y	Y
Waste Gas Comp. (Coolers)	Y	Y	Y	Y
RC Sample HXs	Y	Y	Y	Y
Nonregenerative HX	N	N	N	N
RHR Pumps (Coolers)	Y	Y	Y	Y
Presurizer Sample HXs	Y	Y	Y	Y
SFP HX	Y	Y	Y	Y
RV Nozzle Blocks	Y	Y	N	N
Excess Letdown HX	N	N	N	N
SG Blowdown HXs	Y	Y	Y	Y
RCPs (Coolers)	Y	Y	N	N
Recir. Pumps (Coolers)	Y	Y	Y	Y
Charging Pumps (Coolers)	Y	Y	Y	Y
SI Pumps (Coolers)	Y	Y	Y	Y
Rad. Monitor Sample Coolers	Y	Y	Y	Y
Gross Failed Fuel Detector	Y	Y	Y	Y
RHR HX 31	Y	Y	Y	Y
RHR HX 32	N	N	N	N
CCWS EQUIPMENT IN SERVICE				
CCW Pumps On	2	2	2	2
AC Coolant Pumps On	0	0	0	0
SI Circ. Water Pumps On	0	0	0	0
CCW HXs In Service	2	1(31)	2	1(31)
SWS BOUNDARY CONDITIONS				
SWS Pumps On	N/A	N/A	N/A	N/A
SWS Temperature - ^{o}F	N/A	N/A	N/A	N/A
SWS Flow Per CCW HX - gpm	N/A	N/A	N/A	N/A
RHR SYSTEM BOUNDARY CONDITIONS				
RHR/Recirc. Pumps on	N/A	N/A	N/A	N/A
RHR HX Inlet Temp. - ^{o}F	N/A	N/A	N/A	N/A
RHR Flow Per RHR HX - gpm	N/A	N/A	N/A	N/A

[1]Y/N refers to whether or not CCW flow is supplied to User; All cases based on isothermal conditions.

TABLE 3-7
480 V BUS ESSENTIAL LOADING SUMMARY

Description	Bus 5A DG #31	Bus 2A/3A DG #32	Bus 6A DG #33
SI Pumps	32	33	31
Cont. Spray Pumps		32	31
RHR Pumps	31	32	
Aux. FW Pumps	31	33	32
Cont. Fans	32/34	35	31/33
Recirc. Pumps	31		32
Service Water Pumps	32/35	33/36	31/34
CCW Pumps	32	33	31
MCCs	36C	36B	36A

TABLE 3-8
CCWS ALIGNMENT FOR LOCA RECIRCULATION MODE

Component	Cases Considered E1	E2	E3	E4	E5	E6
CCWS USERS IN SERVICE[1]						
Seal Water HX	Y/0	Y/0	Y/0	Y/0	Y/0	Y/0
Waste Gas Comp. (Coolers)	Y/0	Y/0	Y/0	Y/0	Y/0	Y/0
RC Sample HXs	Y/0	Y/0	Y/0	Y/0	Y/0	Y/0
Nonregenerative HX	N	N	Y/0	Y/0	N	N
RHR Pumps (Coolers)	Y/0	Y/0	Y/0	Y/0	Y/0	Y/0
Presurizer Sample HXs	Y/0	Y/0	Y/0	Y/0	Y/0	Y/0
SFP HX	Y/1	Y/1	Y/1	Y/1	Y/1	Y/1
RV Nozzle Blocks	N	N	N	N	N	N
Excess Letdown HX	N	N	N	N	N	N
SG Blowdown HX	Y/0	Y/0	Y/0	Y/0	Y/0	Y/0
RCPs (Coolers)	N	N	N	N	N	N
Recir. Pumps (Coolers)	Y/2	Y/2	Y/2	Y/2	Y/2	Y/2
Charging Pumps (Coolers)	Y/0	Y/0	Y/0	Y/0	Y/0	Y/0
SI Pumps (Coolers)	Y/3	Y/3	Y/3	Y/3	Y/3	Y/3
Rad. Monitor Sample Cooler	Y/0	Y/0	Y/0	Y/0	Y/0	Y/0
Gross Failed Fuel Detector	Y/0	Y/0	Y/0	Y/0	Y/0	Y/0
RHR HX 31	Y	Y	Y	Y	Y	Y
RHR HX 32	Y	Y	N	N	Y	Y
CCWS EQUIPMENT IN SERVICE						
CCW Pumps On	1	1	1	1	2	2
ACC Pumps On	0	0	0	0	0	0
SI Circ. Water Pumps On	0	0	0	0	0	0
CCW HXs In Service	2	2	2	2	2	2
SWS BOUNDARY CONDITIONS						
Essential SWS Pumps On	2	2	2	2	3	3
Nonessential SWS Pumps On	1	1	1	1	2	2
SWS Temperature - ^{o}F	95	95	95	95	95	95
SWS Flow CCW HX 31 gpm	3036	3036	3036	3036	3930	3930
SWS Flow CCW HX 32 gpm	4185	4185	4185	4185	4967	4967
RHR SYSTEM BOUNDARY CONDITIONS						
RHR/Recirc. Pumps on	1	1	1	1	2	2
RHR HX Inlet Temp. - ^{o}F	256	200	256	200	256	200
Sump Flow Per RHR HX - gpm	1550	1550	3100	3100	3100	3100

---

[1]Y/N refers to whether or not CCW flow is supplied to User; Digit refers to number of components rejecting heat to CCWS.

TABLE 3-9
CCWS PERFORMANCE FOR STARTUP/POWER OPERATION/BLACKOUT MODES

Equipment	Case A1 Minimum Flow (gpm)	Case A2 Maximum Flow (gpm)
Seal Water HX	98	122
Waste Gas Comp.[1]	33	41
Sample HXs[1]	13	16
Rad. Monitor Sample Cooler	3	5
Gross Failed Fuel Detector	28	37
Nonregenerative HX	869	987[2]
RHR Pumps[1]		
- Seal Cooler	6	8
- Jacket Cooler	6	8
SFP HX	1487	1815
RV Nozzle Blocks[1]	9	11
Excess Letdown HX	192 222[3]	0
RCPs[1]		
- Upper Bearing Cooler	163	197
- Lower Bearing Cooler	6	7
- Thermal Barrier Cooler	39	48
Recirculation Pumps[1]	37	46
Charging Pumps[1]		
- Gyrol Cooler	84	101
- Oil Cooler	6	9
SI Pumps (Total flow per pump)	19	24
RHR HXs	0	0
CCW HX 31	2000	2477
CCW HX 32	2184	2342
CCW HXs Outlet Temp. (^{o}F)	110	108

[1]All flows are on a per component basis.

[2]TCV-130 would limit flow to this value.

[3]Case A1 with enhanced pump curve.

TABLE 3-9 (cont)
CCWS PERFORMANCE FOR STARTUP/POWER OPERATION/BLACKOUT MODES

Equipment	Case A3 Minimum Flow (gpm)	Case A3 Maximum Flow (gpm)
Seal Water HX	96	117
Waste Gas Comp.[1]	32	39
Sample HXs[1]	13	15
Rad. Monitor Sample Cooler	3	5
Gross Failed Fuel Detector	27	36
Nonregenerative HX	852	979
RHR Pumps[1]		
- Seal Cooler	5	7
- Jacket Cooler	5	7
SFP HX	1462	1754
RV Nozzle Blocks[1]	9	10
Excess Letdown HX	0	0
RCPs[1]		
- Upper Bearing Cooler	160	189
- Lower Bearing Cooler	6	7
- Thermal Barrier Cooler	38	46
Recirculation Pumps[1]	37	44
Charging Pumps[1]		
- Gyrol Cooler	82	97
- Oil Cooler	6	8
SI Pumps (Total flow per pump)	18	23
RHR HXs	0	0
CCW HX 31	3921	4643
CCW HX Outlet Temp. (^{o}F)	118	118

[1]All flows are on a per component basis.

TABLE 3-9 (cont)
CCWS PERFORMANCE FOR STARTUP/POWER OPERATION/BLACKOUT MODES

Equipment	Case A5 Minimum Flow (gpm)	Case A5 Maximum Flow (gpm)
Seal Water HX	118	156
Waste Gas Comp.[1]	40	52
Sample HXs[1]	16	20
Rad. Monitor Sample Cooler	3	7
Gross Failed Fuel Detector	34	47
Nonregenerative HX[2]	1048	1300
RHR Pumps[1]		
- Seal Cooler	7	10
- Jacket Cooler	7	10
SFP HX	1793	2311
RV Nozzle Blocks[1]	11	13
Excess Letdown HX	232	292
RCPs[1]		
- Upper Bearing Cooler	197	252
- Lower Bearing Cooler	7	10
- Thermal Barrier Cooler	47	61
Recirculation Pumps[1]	45	57
Charging Pumps[1]		
- Gyrol Cooler	101	129
- Oil Cooler	8	11
SI Pumps (Total flow per pump)	22	30
RHR HXs	0	0
CCW HX 31	2466	3262
CCW HX 32	2583	3178
CCWS Supply Temp.[3] (^{o}F)	107/113	108/113

[1]All flows are on a per component basis.

[2]With control valve TCV-130 modelled at its maximum allowable open position.

[3]At outlet of CCW HX 31 and 32, respectively.

TABLE 3-10
CCWS PERFORMANCE FOR PLANT COOLDOWN/BLACKOUT MODES

Equipment	Case B1 Minimum Flow (gpm)	Case B2 Maximum Flow (gpm)
Seal Water HX	107	144
Waste Gas Comp.[1]	35	47
Sample HXs[1]	14	19
Rad. Monitor Sample Cooler	3	6
Gross Failed Fuel Detector	30	43
Nonregenerative HX	946	0
RHR Pumps[1]		
- Seal Cooler	6	9
- Jacket Cooler	6	9
SFP HX	1610	2080
RV Nozzle Blocks[1]	10	12
Excess Letdown HX	0	0
RCPs[1]		
- Upper Bearing Cooler	177	226
- Lower Bearing Cooler	6	8
- Thermal Barrier Cooler	43	55
Recirculation Pumps[1]	41	53
Charging Pumps[1]		
- Gyrol Cooler	92	119
- Oil Cooler	7	10
SI Pumps	20	27
(Total flow per pump)		
RHR HXs[1]	1298	1726
CCW HXs 31	3382	3959[3]
	3058[2]	4263[3]
CCW HXs 32	3536	3845
	3195[2]	4145[3]

[1]All flows are on a per component basis.

[2]With flowpath to the Non-Regenerative HX closed.

[3]With flowpath to the Non-Regenerative HX opened.

TABLE 3-10 (cont)
CCWS PERFORMANCE FOR PLANT COOLDOWN/BLACKOUT MODES

Equipment	Case B3 Minimum Flow (gpm)	Case B4 Maximum Flow (gpm)
Seal Water HX	96	130
Waste Gas Comp.[1]	32	42.5
Sample HXs[1]	13	17
Rad. Monitor Sample Cooler	3	6
Gross Failed Fuel Detector	27	38.5
Nonregenerative HX	852	0
RHR Pumps[1]		
- Seal Cooler	6	8
- Jacket Cooler	6	8
SFP HX	1461	1887
RV Nozzle Blocks[1]	9	11
Excess Letdown HX	0	0
RCPs[1]		
- Upper Bearing Cooler	159	203
- Lower Bearing Cooler	6	8
- Thermal Barrier Cooler	38	50
Recirculation Pumps[1]	36	47
Charging Pumps[1]		
- Gyrol Cooler	82	107
- Oil Cooler	6	9
SI Pumps (Total flow per pump)	18	25
RHR HXs[1]	1169	1565
CCW HX 31	6250 5743[2]	7052 7495[3]
CCW HX 32	OOS	OOS

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[1]All flows are on a per component basis.

[2]With flowpath to Non-Regenerative HX closed.

[3]With flowpath to Non-Regenerative HX opened.

TABLE 3-11
CCWS PERFORMANCE FOR PLANT REFUELING MODE

Equipment	Case C2 Minimum Flow (gpm)	Case C1 Maximum Flow (gpm)
Seal Water HX	112	157
Waste Gas Comp.[1]	37	51
Sample HXs[1]	15	20
Rad. Monitor Sample Cooler	3	7
Gross Failed Fuel Detector	31	46
Nonregenerative HX	0	0
RHR Pumps[1]		
- Seal Cooler	6	10
- Jacket Cooler	6	10
SFP HX	1686 1788[2]	2290
RV Nozzle Blocks[1]	11	13
Excess Letdown HX	0	0
RCPs[1]		
- Upper Bearing Cooler	183	246
- Lower Bearing Cooler	6	9
- Thermal Barrier Cooler	44	60
Recirculation Pumps[1]	43	57
Charging Pumps[1]		
- Gyrol Cooler	96	129
- Oil Cooler	8	11
SI Pumps (Total flow per pump)	21	30
RHR HX 31	OOS	OOS
RHR HX 32	1344	1832
CCW HX 31	4860 2523[2]	3361 6136[3]
CCW HX 32	OOS 2647[2]	3278 OOS[3]

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[1]All flows are on a per component basis.

[2]Case C1 flows with both CCW HXs available.

[3]Case C2 flows with one CCW HX available.

TABLE 3-11 (cont)
CCWS PERFORMANCE FOR PLANT REFUELING MODE

Equipment	Case C4 Minimum Flow (gpm)	Case C3 Maximum Flow (gpm)
Seal Water HX	118	165
Waste Gas Comp.[1]	39	54
Sample HXs[1]	16	22
Rad. Monitor Sample Cooler	3	7
Gross Failed Fuel Detector	33	49
Nonregenerative HX	0	0
RHR Pumps[1]		
- Seal Cooler	7	10
- Jacket Cooler	7	10
SFP HX	1769, 1844[2]	2407
RV Nozzle Blocks[1]	0	0
Excess Letdown HX	0	0
RCPs[1]		
- Upper Bearing Cooler	0	0
- Lower Bearing Cooler	0	0
- Thermal Barrier Cooler	0	0
Recirculation Pumps[1]	44	61
Charging Pumps[1]		
- Gyrol Cooler	101	136
- Oil Cooler	8	12
SI Pumps (Total flow per pump)	22	31
RHR HX 31	OOS	OOS
RHR HX 32	1424, 1488[2]	1986
CCW HX 31	4090, 2086[2]	2858, 5320[3]
CCW HX 32	OOS, 2182[2]	2776, OOS[3]

[1]All flows are on a per component basis.

[2]With Two CCW HXs available.

[3]With one CCW HX available.

TABLE 3-12
CCWS PERFORMANCE DATA FOR LOCA RECIRCULATION MODE

Component	Case Results		
	E1/E2	E3/E4	E5/E6
COMPONENT FLOWS (gpm)			
Seal Water HX	111	96	152
Waste Gas Comp.[1]	36	32	49
Sample HXs[1]	14	13	20
Nonregenerative HX	0	853	0
RHR Pumps[1]			
- Seal Cooler	7	5	9
- Jacket Cooler	7	5	9
SFP HX	1599	1462	2196
RV Nozzle Blocks	0	0	0
Excess Letdown HX	0	0	0
Gross Failed Fuel Detector	33	27	46
Radiation Sample Cooler	5	3	7
RCPs			
- Upper Bearing Cooler	0	0	0
- Lower Bearing Cooler	0	0	0
- Thermal Barrier Cooler	0	0	0
Charging Pumps[1]			
- Gyrol Cooler	91	82	126
- Seal Cooler	8	6	11
RHR HX 31	1330	OOS	1829
RHR HX 32	1336	1186	1841
CCW HX 31	2629	2032	3568
CCW HX 32	2478	2219	3458

[1]Flow is on a per component basis.

TABLE 3-12 (cont)
CCWS PERFORMANCE DATA FOR LOCA RECIRCULATION MODE

Component	Case Results E1/E2	E3/E4	E5/E6
SYSTEM TEMPERATURES (^oF)			
RHR HX 31 Outlet	200	OOS	206
RHR HX 31 Outlet[1]	164	OOS	168
RHR HX 32 Outlet	192	213	200
RHR HX 32 Outlet[1]	159	172	163
CCW HXs Inlet	169	149	177
CCW HXs Inlet[1]	145	133	149
CCW HX 31 Outlet	133	119	138
CCW HX 31 Outlet[1]	121	112	124
CCW HX 32 Outlet	128	117	137
CCW HX 32 Outlet[1]	117	110	123

[1]With a 200^oF sump fluid.

TABLE 3-13
CCWS AUXILIARY HEAT LOADS - APPENDIX R COOLDOWN

Component	Heat Loads (Btu/hr x 10^6)
Spent Fuel Pit HX (at 30 days)	8.79
Seal Water HX	0.33
Nonregenerative HX	----
S/G Blowdown HXs (0)	----
Pressurizer Sample HXs (0)	----
Reactor Coolant Sample HXs (0)	----
Reactor Coolant Pump (0)	----
RHR Pump Coolers (1)	0.08
SI Pump Coolers (0)	----
Charging Pump Coolers (1)	0.45
Recirculation Pump Motor Coolers (0)	----
Waste Gas Compressors	----
Excess Letdown HX	----
Reactor Vessel Supports	----
CCW Pump Heat Input (1)	0.29
TOTAL AUXILIARY HEAT LOAD	10

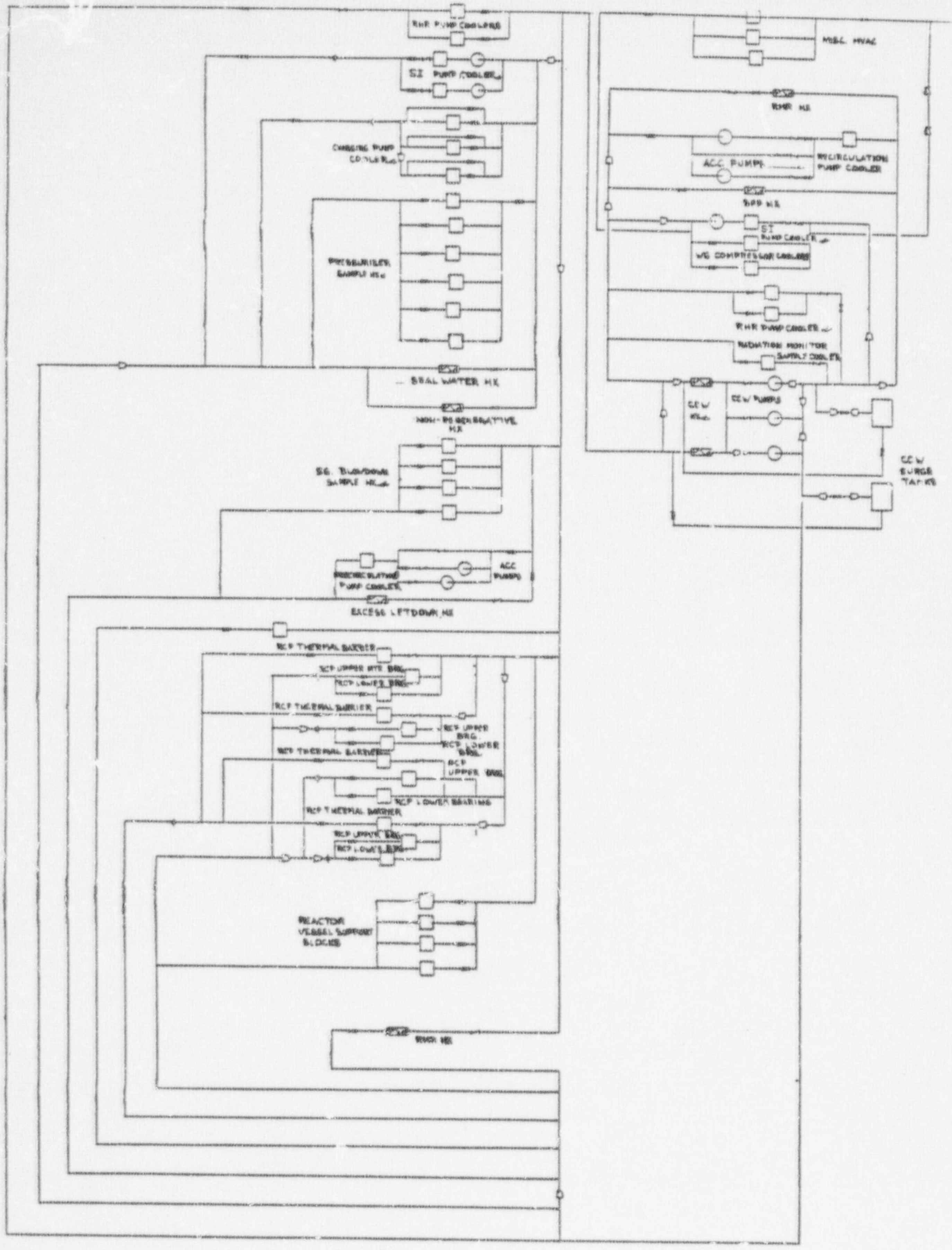

Figure B-1 Schematic of The Indian Point 3 CCWS Thermal/Hydraulic Model

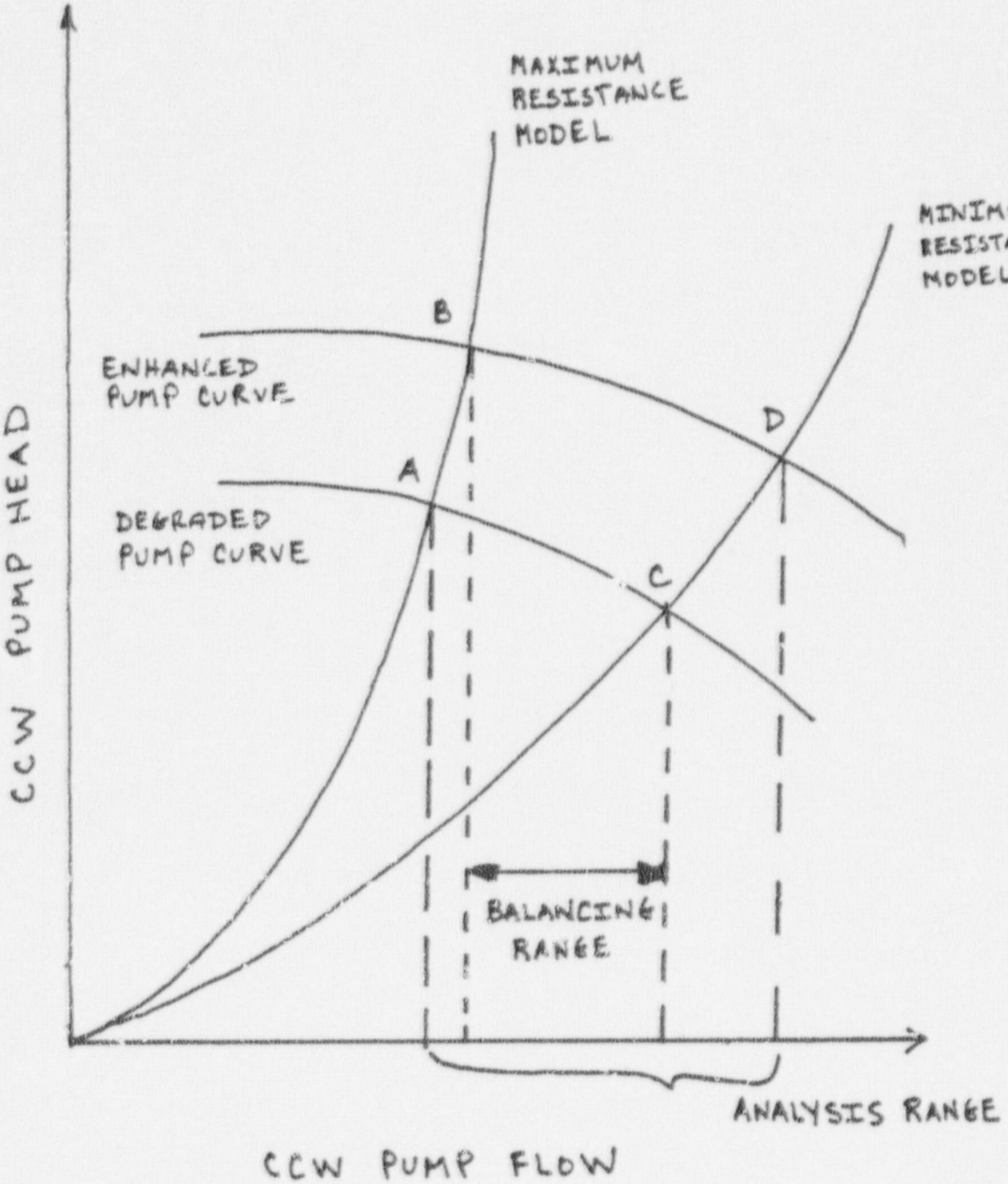

FIGURE 3-2 CCWS MODELING METHODOLOGY

4.0 COMPONENT EVALUATIONS

Table 4-1 lists the accident-required components serviced by the SWS. An evaluation of the increased service water temperature from 85^{O}F to 95^{O}F was conducted for each of the components listed in this table. The component studies consisted of analyses and engineering evaluations sufficient to justify that the SWS process conditions are acceptable, subject in some cases to corresponding flow or operating limits.

The SWS also cools the CCWS. The CCWS in turn, cools the equipment listed in Table 4-2. This equipment was also evaluated to justify that adequate SWS, and thus CCWS, cooling is provided to support safe plant operation.

All engineering analyses required for accident-required component evaluations have been performed by Westinghouse in accordance with the applicable requirements of WCAP-9565 (NATD QA Program). Analyses and data obtained from the original component manufacturers have been utilized as reference information.

Various aspects of the unit were included in the evaluation with regard to the function of the components in the system. The evaluation considered both the mechanical aspects of maximum cooling flow rates for tube vibration and erosion, as well as the thermal aspects of sufficient cooling. Where an absolute determination that design limits could be met was not possible, one or more of the following considerations was discussed:

- o Impact on equipment performance
- o Required service water flow at evaluated temperatures (i.e., flow at 95^{O}F versus flow at 85^{O}F)
- o Valve position for process flow to achieve desired temperature

This section includes a summary of the evaluations performed for each component. Each item will be covered on an individual basis with a portion of that section devoted to concluding the impact of service water temperature changes. The result will be the impact of the temperature effect and justification that the SWS process conditions are acceptable as a permanent design basis.

Included in each section will be a discussion of the component function as-well-as the evaluation assumptions and results.

The overall conclusion following evaluation of the accident-required components serviced by the SWS and the CCWS is that equipment currently installed will function and perform within the confines of the system restrictions, as delineated in Section 6.0, with 95^{O}F service water temperature (a 95^{O}F Ultimate Heat Si).

4.1 ACCIDENT-REQUIRED EQUIPMENT COOLED BY THE SWS

4.1.1 Reactor Containment Fan Coolers

Description/Function

The Reactor Containment Fan Cooler (RCFC) Units provide for cooling and filtering of recirculated containment building air to:

1) Maintain containment building temperatures during normal plant operation.
2) Reduce containment building temperatures and remove radioactive iodine and methyl iodide from the steam-air during incident conditions.

The RCFC unit is an engineered safeguard system. There are five RCFC units in the containment building. Each unit consists of a series of filters for removal of entrained moisture, particles, and radioactive iodine and methyl iodide, two banks of cooling coils, a fan assembly, a motor assembly including an enclosed heat exchanger, an enclosure assembly, and four dampers. During normal operation, air is drawn from the containment building through the normal flow inlet dampers, through the cooling coils, and discharged by the fan into a common distribution header. During the post-LOCA operating mode, a portion of the air-steam flow is passed through the filtration train, then mixed with unfiltered air before passing through the cooling coils.

The two banks of cooling coils in each unit include eight Westinghouse Sturtevant continuous water tube cooling coils stacked four high to each bank. Each coil consists of plate copper fins spaced 8-1/2 fins per inch of tube length and 5/8 inch O.D. AL6X tubes. The coils have eight rows of tubes through their depth with 4 pass flow circuiting. Cooling water is provided by the SWS.

Method of Analysis

The performance of the cooling coils was determined for both the normal and post-accident conditions using a 95^{o}F inlet service water temperature. Table 4-3 provides the data used in the evaluations. All of the data provided in Table 4-3 was taken from the "Westinghouse Reactor Containment Fan Cooler System Technical Manual," PE-1275, May, 1982, except as noted below.

1) Service Water Inlet Temperature - The coils were evaluated for an inlet water temperature of 95^{o}F.

2) Fouling Factor and Tube Pluggage - These values were provided by NYPA as documented by NYPA letter REC: 89-003, January 4, 1989.

3) Service Water Flow Rates - The service water flow rates were provided by NYPA and reference UEC Report 6604.266 S-M-2 Rev. 4. For normal operation, the coils were evaluated for a range of flow rates from 500 gpm to 2000 gpm per unit. The minimum required flow for an accident condition is 1400 gpm per unit.

4) Containment Atmosphere Temperature - Normal Condition - The fan cooler performance was evaluated for containment temperatures of 120^{o}F and 130^{o}F at the request of NYPA.

For the normal condition, heat removal rates were determined for cooling water flow rates ranging from 500 gpm to 2000 gpm. The calculations conservatively assume no heat removal via condensation. The heat removal rates (Q) were determined from the following relationship:

$$Q = (U)(A)(LMTD)$$

where U is the overall heat transfer coefficient as provided for these coils by the vendor, A is the face area of the coils and LMTD is the logarithmic mean temperature difference.

As noted above, heat removal rates were calculated for containment temperatures of 120°F and 130°F and are plotted in Figure 4-1. Outlet water temperatures are provided in Table 4-4.

A computer evaluation using the Westinghouse computer code HECO was performed to determine the heat removal rates for the accident condition. The HECO program computes heat transfer rates for plate-fin coils from air-steam mixtures where the steam is saturated and at high pressure. The code has been validated against test data. The heat removal rates were calculated for containment temperatures ranging from 130°F to 300°F and are provided in Figure 4-2. Table 4-5 provides the resulting outlet water temperatures for each coil bank.

Impact and Conclusion

Plant operating data was obtained from NYPA which included SWS inlet and outlet temperatures and flow rates for two of the five RCFC units (Reference 4-14).

This data was used to estimate an expected summertime heat load in the containment building of 2.6×10^6 Btu/hr. This number is greater than the calculated heat removal rates provided in Figure 4-1 to maintain a containment temperature of 130°F. It is expected, however, that significant conservatisms in determining heat transfer capability and heat generation will result in containment temperature remaining below 130°F. However, actual containment temperature must be monitored to insure that the maximum allowed ambient temperature is not exceeded.

For the post-accident condition, the heat removal rates shown in Figure 4-2 were provided for the evaluation of the containment integrity, which is documented in WCAP-12269, Revision 1.

4.1.2 RCFC Fan Motor Heat Exchanger

Description/Function

The RCFC Fan Motor Heat Exchanger is a component of the motor/motor base assembly which is designed to absorb heat due to motor assembly heat losses and external effects under all operating conditions and limit the maximum thermal environment consistent with the motor design. The motor and motor base assembly serve as an enclosure to isolate the major functional elements of the motor from the containment environment which would exist in the post-accident condition. Air exiting the motor passes through the heat exchanger and is directed by the ductwork in the enclosure back through the motor. A relief valve mounted on the enclosure allows the pressure inside the enclosure to equalize with the pressure outside in the post accident condition. In this case, moisture is condensed from the air by the heat exchanger to protect the motor.

The motor heat exchanger is a Marlo continuous water tube cooling coil manufactured by Nuclear Cooling Inc. The coil is a plate copper fin coil with 5/8 inch O.D. AL6X tubes. Cooling water is provided by the SWS.

Method of Analysis

A motor life expectancy calculation was completed which evaluates the performance of the cooling coil with a 95^{O}F inlet water temperature against conservatively calculated heat loads for the normal and post-accident conditions. Motor losses for the normal and post-accident conditions as well as heat addition through the surface area of the enclosure during the post-accident condition were included in the heat loads. Table 4-6 provides the data used in the evaluation of the coils. The sources of this data are as follows:

- o The number of motor cooler assemblies and coils, containment atmosphere pressure and maximum fan brake horsepower were taken from Reference 4-1.

- All other coil data as specified in Table 4-6 with the exception of the fouling factor was taken from Marlo Coil drawing #7071C001 Rev. 1 which was provided by NYPA. The evaluation was completed assuming tube pluggage of 10% since this is the margin specified on this drawing.

- A fouling factor of 0.004 ft^2-hr-^oF/Btu was provided by NYPA for use on the evaluation of the main RCFC cooling coils. This value was also used for the motor heat exchanger evaluation.

- The Service Water flow rate was provided by NYPA via Reference 4-2.

The heat exchanger was evaluated by determining the maximum motor winding temperatures permitted to provide an expected motor life of 40 years of normal operation plus one year of post-accident operation. The heat exchanger was then evaluated to determine if it could remove the calculated heat load to maintain these temperatures. The following conservative assumptions were made:

- The coil was evaluated assuming a year round water inlet temperature of 95^{o}F.

- The calculated heat load for the post accident condition is based on a containment temperature of 271^{o}F for the entire year.

The maximum permitted motor winding temperatures were established from the relationship of motor winding life to insulation temperature, per References 4-3 and 4-4.

The heat removal capacity of the heat exchanger was then calculated for the normal and post-accident conditions from the following relationship:

$$Q = (U)(A)(LMTD)$$

where U is the overall heat transfer coefficient for a plate fin coil of this type, A is the face area of the coil, and LMTD is the logarithmic mean temperature difference. The resulting heat removal rates were then compared to the calculated heat loads for the normal and post-accident conditions to verify the adequacy of the heat exchanger performance.

Impact and Conclusion

It was concluded from the calculations described above that the heat exchanger performance with 95^{o}F inlet cooling water is adequate to maintain motor winding temperatures below a level which will provide for the required motor life. Therefore, an increase in the SWS temperature to 95^{o}F will not impact the life expectancy of the RCFC motors of 40 years of normal operation plus one year of post-accident operation.

4.1.3 RCFC Service Water Return Radiation Monitor

Description/Function

RCFC Service Water Return Radiation Monitors serve to detect radiation leakage from the containment into the service water return lines from the containment fan coolers and motor coolers. A portion of the return flow from each of the fan coolers, as-well-as from a common header from the motor coolers, is directed through a mixing nozzle where it is mixed with service water taken from the supply header. The flow then goes to two redundant radiation monitors which are mounted in series. The mixing nozzle acts as an eductor and it serves to cool the process stream for the radiation detectors. The redundancy of these monitors is necessary due to the continuous flow of service water with no other monitoring provided for this flow. The maximum temperature of the water for the monitor to function properly is 160^{o}F. An alarm is provided to warn the operator when the temperature exceeds 130^{o}F. Temperature is reduced by increasing flow through the nozzle.

Method of Analysis

Information on the monitors was taken from the Indian Point Station Unit No. 3 System Description No. 24, Service Water System. Flowrates, data sheets, and detail sketches or drawings for the mixing nozzle are not available. From the evaluation of the containment fan coolers, the temperature of the service water exiting the fan coolers is 165^{o}F for a post-accident containment temperature of 271^{o}F. It is estimated that in order to maintain the water temperature into the radiation monitor below 130°F at this maximum containment temperature and when the inlet service water temperature is 95°F, 1 gpm of supply service water into the mixing nozzle is required for every 1 gpm of return service water. To maintain the flow into the radiation monitors below 160°F, a minimum of 1 gpm of supply service water is required for every 13 gpm of service water from the return side of the cooling coils.

Impact and/or Conclusion

Due to the relatively low temperatures, (approximately 100°F) of the return service water during the normal condition there is no impact to the radiation monitors of raising the inlet service water temperature to 95°F. In a post-accident condition, the ratio of supply-side service water flow to return-side service water flow into the mixing nozzle will need to be regulated to protect the radiation monitors from excessive service water temperatures. It is estimated that the return side flow to supply side flow ratios required are 1:1 to maintain the temperature below the alarm setpoint of 130°F and 13:1 to maintain the temperature below the monitor limit of 160°F.

4.1.4 Diesel Generators

Description/Function

The function of the emergency diesels is to provide a reliable source of backup power to the essential equipment receiving power from the 480 volt buses. This includes equipment required for a safe shutdown of the reactor following a loss of the normal power supply and the safeguards equipment specifically required to limit the consequences of a loss-of-coolant accident.

Three emergency diesel generators are installed to provide a high degree of reliability and independence from outside power to the engineered safeguards system components requiring electrical power. Two of the three diesel generators can supply sufficient power to meet the minimum safeguard requirements.

This evaluation addresses the three emergency diesel generators installed at Indian Point Unit 3. These units are Alco Power 2450 HP sixteen cylinder turbo-supercharged engines of the four-stroke cycle type, designed with open combustion chambers and a solid-state fuel injection system. The evaluation covers those items of the diesel generators which receive cooling from service water (considered to be 95^{O}F for this evaluation). These include the diesel generator jacket water cooler and the lube oil cooler.

The jacket water system removes the unused heat of combustion imparted to the cylinder's walls and thereby keeps the engine metal within design temperature conditions (Refer to Figure 4-3, Engine Jacket Water System). Heat removed from the engine jacket is subsequently transferred to the service water through the jacket water cooler.

The oil used in the engine lubricates and cools bearings and friction parts of the engine. The oil must also be maintained within a specified temperature range, otherwise it breaks down and loses its lubricating qualities. The heat of the oil is transferred to the SWS through the lube oil cooler (refer to Figure 4-4, Diesel Engine Lube Oil System).

Method of Analysis

A review of the performance of the emergency diesel generator jacket water and lube oil coolers at 95^{O}F SWS temperature was done for the IP3 Technical Services Department. This review was done by United Engineers & Constructors and is documented in References 4-5 and 4-6. The results of this work are included as the basis for the equipment evaluation. Results of the UE&C review provided the following justification for operation of the coolers. The summary provided by UE&C for the limiting case analyzed is provided below.

The limiting cooling water condition for the diesel generator is the case of a passive (piping) failure in its 10 inch SWS supply line. The size of the passive failure was selected to be in accordance with the NRC Standard Review Plan Criteria 3.6.2, which was recently approved for use on the

Indian Point Unit 3 SWS. For this case, a minimum service water flow of 357 gpm was calculated. At this flow, a 95°F SWS inlet temperature, the diesels operating at their maximum two (2) hour rating of 2650 HP (1950 KW) and with 12 lube oil cooler tubes plugged, the calculated cooler temperatures are shown below:

- o JW Temp. (°F) = 180
- o LO Temp. (°F) = 182

The evaluation is based on design fouling of both the jacket water and lube oil coolers. In addition, adjustments for pump and/or system degradation were not considered.

The diesel manufacturer, Alco Engines, has provided the following as guidelines for jacket water and lube oil temperatures:

	Jacket Water	Lube Oil
Maximum Recommended Operating Temperature (°F)	190	210
Normal Operating Temp (°F)	170	180 - 195

For the limiting case, the lube oil and jacket water temperatures were found to be within the normal and maximum recommended temperatures provided by the manufacturer. The JW temperature will increase approximately 12°F beyond the normal range but will still be within the maximum recommended operating temperature.

Impact and Conclusions

The diesel generator jacket water coolers and lube oil coolers are capable of providing the necessary cooling with service water temperatures up to 95°F. This cooling will not be detrimental to the diesel generator and resulting oil temperatures will be within safe limits, as provided by the equipment vendor, Alco Engines.

4.1.5.. Instrument Air System

Description/Function

The primary function of the Instrument Air System is to provide clean, oil and moisture free compressed air to the instruments, controls and other required services in the plant.

Ambient air is supplied to two motor driven 225 SCFM single stage horizontal compressors, tag numbers 31 IAC and 32 IAC. The compressed air exits to an aftercooler (heat exchanger) and then to a series of moisture separators, dryers, and filters. After the refrigerant dryers, the header splits, supplying compressed air to the conventional plant building instrument air system. A restriction orifice designed to pass 225 SCFM (the capacity of one compressor) is contained in this line. In the event of a line rupture in the secondary plant, one compressor will supply the primary plant while the second compressor will supply the line break until isolation can be accomplished. Included in each line between the compressor and aftercooler are individual temperature controllers TC-1104S and TC-1105S. Each controller will trip its associated compressor on high discharge air temperature of 375°F (Reference 4-8).

The aftercooler and compressor cylinder jackets are cooled by the Instrument Air closed cooling water system. This system consists of two 20 gpm pumps, two heat exchangers, expansion/replenishment tank and a chemical feed system. Normally, one pump is in service while the other is in standby in case of problems with the first. From the pump, flow proceeds to the heat exchanger at a temperature of about 120°F. The temperature of the water exiting the heat exchanger is maintained at about 95°F by TC-1113 modulating service water valve TCV-1113 (Reference 4-7).

The design basis service water flow rate to each heat exchanger is 72 gpm. After leaving the heat exchanger, flow proceeds to the aftercooler and then to the compressor jacket. Before entering the compressor jacket, the flow splits, with one line continuing to the compressor jacket, and the other line bypassing the compressor. A manual valve in the bypass line allows regulation of the temperature of the cooling water as it exits the compressor and returns to the circulating pump. On the discharge from each compressor is a temperature controller (TC-1106S, No. 31 and TC-1107S, No. 32) which measures cooling water return temperature and at 150°F will shutdown its respective compressor (References 4-7 and 4-8).

Method of Analysis

The instrument air closed cooling system shows that there is a margin of about 30°F between the normal operating temperature of the compressor cooling water (120°F) and the high temperature trip setpoint (150°F). Considering this margin, it can be assumed that a 10°F increase in service water temperature will not cause a 30°F increase in closed cooling water temperature.

Since heat exchangers are typically selected with conservative performance margins, it is not expected that excessively high compressor cooling water outlet temperatures will be experienced with 95°F service water, as long as normal operating temperatures are indeed in agreement with the values stated above.

Although the air compressors and aftercoolers for Indian Point Units 2 and 3 have been supplied by different vendors, review of the various flow diagrams, vendor manuals, systems descriptions, etc. for both plants indicates that the instrument air systems for both units were most likely designed to the same specifications. Heat transfer calculations performed for Indian Point 2 using the original heat exchanger specifications with 95°F service water predicted a closed cooling water temperature increase of about 10°F above original design levels with 85°F service water. These results add credibility and confidence to the prediction that Indian Point 3 instrument air closed cooling water temperatures will remain within acceptable limits with service water design temperature increased to 95°F.

One certain result of having a service water temperature of 95°F is that TC-1113 will obviously not be able to maintain the closed cooling water temperature of 95^{o}F exiting the heat exchanger, as currently designed. This is not viewed as a problem since valve TCV-1113 will simply remain fully opened during periods of elevated service water temperature.

Impact and Conclusions

Based upon the information provided by NYPA (References 4-7 through 4-11) and on evaluations performed by Westinghouse on similar equipment, it can be concluded that the Indian Point Unit 3 instrument air system will function as designed and within original design temperature limits with a revised service water temperature of 95^{o}F.

However, since confirmation is currently unavailable to show that the system is actually operated at the temperatures stated above (i.e. 120^{o}F compressor cooling water outlet temperature) with 85^{o}F service water, it is recommended that a surveillance program be initiated to support the stated conclusion. The surveillance program would record temperatures at various locations in the closed cooling system using existing temperature indicators, and compare them to normal and alarm point levels as defined above and in the appropriate systems descriptions (References 4-7 and 4-8).

4.1.6 Control Room Air Conditioners

Description/Function:

The purpose of the control room air conditioning system is to maintain a room temperature of 75^{o}F for personal comfort and equipment operation.

The following assumptions were made in the evaluation to determine whether the control room A/C system will function as designed with a 95^{o}F SWS temperature.

- The design Outside Air (O.A.) temperature is 104^{o}F Dry Bulb (D.B.) and 78^{o}F Wet Bulb (W.B.). Based upon data from Reference 4-12, these temperatures are conservative.

- 25% O.A. will be used for make up for leaks and pressurization.

Figure 4-7 contains a flow diagram of the service water system portion of the control room air conditioning system, taken from Reference 4-14. Figure 4-8 contains a flow diagram of the air conditioning system itself.

The control room air conditioning system consists of the following equipment:

- Westinghouse A/C Unit Model UF 180W; 15 Ton, 6000 cfm capacity
- Water Cooled Condenser (two required):
  - Parallel flow
  - Plate fin
  - 3 Rows of tubes
  - 16.65 ft^2 face area
- Compressor (two required):
  - 60 Hz
  - 81,100 BTU/Hr
  - 45^{o}F Sat. suction temperature
  - 130^{o}F Sat. discharge temperature
  - 115^{o}F Liquid temperature
  - 95^{o}F Return gas temperature
  - Refrigerant R-22 @ 11 lbs.
- Fan Section (two required)
  - Two 12 inch Centrifugal Fans
  - 6000 cfm (total)

<u>Evaluation</u>:

This analysis was done by two different methods:

- Extrapolation of the vendor data
- By using the psychrometric chart

The use of two separate methods provides increased confidence in the analysis results.

Initially, the analysis was to be done by blocking off up to 10% of the condenser tubes. However, since there are only three tubes (coils), a fouling factor of .001, conservative for the water in this area, was used instead.

Applicable vendor data has been compiled in Figure 4-5 and is represented by the boxed-in area. The data in each column was compared and extrapolated to compile the balance of the table, including: Total Heat Removed, Total Sensible Heat Removed and the Coil Leaving Temperature (both W.B. and D.B.).

The basis for the design Control Room temperature is for human comfort and for safe operation of the equipment. At the time of the original design of the plant human comfort design temperature was 72^{O}F. The energy crisis has since caused the design temperature to be increased to 75^{O}F, as it is today.

Impact and Conclusions:

Comparison of results between the two different methods of analysis revealed a difference of only 0.3%, which is insignificant. The results based on both methods show that there will be a 1^{O}F rise in room temperature. This would increase the room temperature from 72^{O}F to 73^{O}F, which is still under the allowable temperature of 75^{O}F.

After factoring in the a fouling factor of .001, the required cooling water flow rate changed from 45.8 gpm to 70 gpm, per unit, to maintain the same level of cooling. This is less than the available service water flow rate measured in Reference 4-10 (142 gpm to both units), and is therefore acceptable.

Therefore, based upon the evaluation results presented above, it can be concluded that the CCR air conditioning system will function as designed, with no impact on the performance of the unit or on room comfort level as a result of the increase in inlet service water temperature from 85^{O}F to 95^{O}F.

4.1.7 Component Cooling Heat Exchangers

The primary function of the CCW heat exchangers is to transfer waste heat from components serviced by component cooling during all modes of plant operation. The heat exchangers are a shell and tube counter flow design with SW flow supplied on the tube-side. The design SW flow was selected based on an ACS optimization study of heat removal loads, raw water inlet temperature, and equipment costs. This flow corresponds to 4,550,000 lb/hr (approximately 9100 gpm). The design temperature and pressure of the CCW heat exchanger tube-side are 200°F and 150 psig, respectively.

The highest SWS temperatures would occur during the post-LOCA conditions when CCW temperatures are maximized. As shown in Section 3.1, the highest CCW return temperature is less than 180°F. At CCWS operating conditions and at a 95°F inlet temperature, the maximum SW outlet temperature is calculated to be less than 140°F. Since this calculated maximum temperature is less than the design temperature (200°F), the CCW heat exchangers are capable of performing their required functions at a river water temperature of 95°F.

4.2 EQUIPMENT COOLED BY THE CCWS

As a result of the CCWS evaluations which are discussed in Section 3.1, revised CCW flow rates and temperatures have been defined for various components. Flow rate and temperature revisions for plant startup, power operation, station blackout hot standby, plant cooldown, station blackout plant cooldown, refueling, and post-LOCA injection and recirculation modes of operation have been evaluated. The nature of these evaluations depends upon the type of component being evaluated.

The equipment cooled by the CCWS is evaluated for (1) mechanical integrity and (2) thermal performance.

Mechanical Integrity

The mechanical integrity of the various coolers and heat exchangers must be assured to prevent cooler failure and subsequent leakage from the CCWS. This structural integrity is based on, (1) maximum flow rates through the coolers and heat exchangers remaining below acceptable limits that are based on tube vibration and tube erosion criteria, and (2) CCW temperatures remaining below design temperature limits that are based on stress criteria.

To ensure the structural integrity of the various heat exchangers and coolers, the maximum flow rates determined for all operating modes will be compared to acceptable flow limits. In addition, the maximum temperature determined for all modes of operation will be compared to the maximum design temperature limits.

Thermal Performance

The CCWS provides cooling to interfacing Auxiliary Coolant System heat exchangers, process coolers, and to various mechanical equipment coolers. As such, acceptable CCWS thermal performance is based on (1) supporting RHR and SFPCS functions, (2) supporting process cooling functions, and (3) supporting mechanical equipment operability.

As the thermal performance required to support the above functions varies between operating modes, the thermal performance evaluation is based on supporting various functions that differ in each operating mode.

4.2.1 Mechanical Integrity Evaluation

The mechanical evaluation of the the equipment cooled by the CCWS consisted of first comparing the maximum flow rate and temperature seen for each component (as determined in Section 3.1.2), to the design flow and temperatures given on the manufacturer's specification sheet. For those heat exchangers whose maximum flow and temperature is less than or equal to their design flow and temperature, no further work was necessary. If the maximum flow or temperature exceeded the design value, new calculations were performed to determine if the maximum flow would cause unacceptable vibration of the heat exchanger tubes or if the maximum temperature would result in unacceptable stresses. However, before any meaningful evaluations could be performed, maximum design flow limits had to be generated for each of the coolers for which no design limits were available.

Maximum Flow Rate Limits

Most of the coolers and heat exchangers are of the tube and shell design. Typically, tube side flow is limited by erosion of the tubes, which is a function of the flow velocity and tube material. Maximum shell side flow is typically limited by flow induced tube vibration limits. The pump and heat exchanger vendors were contacted and provided the information necessary for Westinghouse to calculate the maximum allowable tube side flow rates for the coolers where design limits were not already available.

The two mechanical seal jacket coolers are not heat exchangers in the traditional sense but are simply cavities in the pump casing which to some extent surround the stuffing box area. Since there are no erosion or vibration concerns with this design, there are no specified maximum flow limits for these coolers.

The results of the comparison of maximum actual versus allowable design flow limits is shown in Table 4-7.

Examination of the information given in Table 4-7 reveals that the CCW heat exchangers and the excess letdown heat exchanger will experience flows in excess of their design flows. For both of these heat exchangers, CCW flow is on the shell side of the heat exchanger. In any shell and tube heat exchanger, excessive shell side flow can lead to high tube vibrations and eventual failure.

To determine the acceptability of the maximum flows, heat exchanger internal geometry was examined to obtain the flow velocities associated with the maximum flow rates. These velocities were used with tube outside diameter and tube natural frequency to calculate the minimum value of the dimensionless quantity fd/V, which was then compared to allowable limits. Based upon these results, neither the CCW heat exchangers nor the excess-letdown heat exchanger are subject to excessive tube vibration when exposed to the maximum flows given in Table 4-7.

Maximum Temperature Limits

The maximum CCW supply temperature for all modes of operation, were determined in Section 3.0. These maximum temperatures were then compared to the maximum allowable design temperature for the various equipment.

The comparison of maximum versus design temperatures is given in Table 4-8. As the table shows, with the exception of the RHR heat exchanger, none of the maximum temperatures evaluated herein exceed the design temperatures of the tabulated equipment. The acceptability of temperatures greater than design are addressed in Section 3.1.2.

In conclusion, the equipment listed in Tables 4-7 and 4-8 has been shown to be adequate in terms of mechanical integrity for all modes of operation, plant cooldown, and refueling.

4.2.2 Thermal Evaluation of CCW Cooled Equipment

This section provides the results of the evaluation of adequate component cooling for the equipment cooled by the CCWS. Since the thermal equipment function as integral parts of the ACS, the effects of the ultimate heat sink temperature increase to 95^{o}F on the performance of these heat exchangers and the interfacing systems have been evaluated as part of the CCWS, RHRS and SFPCS evaluations documented in Section 3.1, 3.2, and 3.3, respectively.

The evaluation of adequate CCW cooling to the non-ACS interfacing components is provided below. This evaluation determines whether the CCW supplied to each component is adequate to perform the required cooling function The evaluation is performed for various operating modes, as the cooling function, the CCW supply flow and the CCW temperature vary for different operating modes.

4.2.2.1 SI Recirculation Pump Motors

The SI recirculation pumps need to operate only during LOCAs. As such, the thermal evaluation only covers CCW cooling capability during the post-LOCA injection and recirculation phases.

The SI recirculation pump motors are totally enclosed water to air cooled motors. The motor exhaust air is cooled by heat exchangers and recirculated to the motor air intakes in an enclosed system.

The maximum actual CCW flow rate to the motor air cooler is $\leq$100 gpm, which is through the tube side of the cooler. This is within the design allowable flow limit of 102 gpm and is therefore acceptable.

From Section 3.1.1.6.5, with the ACC pumps shut down, the motor air cooler would only receive about 25 gpm of CCW flow, which is unacceptable. Since the nominal cooling water flow rate of 40 gpm would be maintained with one ACC pump operating, at least one ACC pump should be kept on line.

The increased component cooling water temperature will result in increased stator winding and bearing temperatures. These motors were originally qualified by WCAP-7829 for a containment ambient temperature of 324^{O}F. Actual containment temperatures for Indian Point Unit 3 will not exceed 324^{O}F, per WCAP-12269, Revision 1. This qualification demonstrated that the stator winding and bearing temperatures were well within acceptable limits with the ambient temperature of 324^{O}F and various component cooling water temperatures.

Based on the results of WCAP-7829, the stator winding temperature with maximum cooling water temperature of 155^{O}F is expected to remain within the maximum allowable temperature limit for Class F insulation systems. Thus no abnormal insulation degradation is expected to occur and there will be no reduction of the motor qualified life. The motor bearing temperatures are predominantly dependent on the ambient temperature and not the component cooling water temperature.

The test results for the ambient temperature of 324^{O}F are bounding for the actual ambient temperature in conjuntion with the increased component cooling water temperature. Therefore, the recirculation pump motors will remain operable for the component cooling water temperatures experienced during the post-LOCA recirculation phase.

4.2.2.2 Safety Injection Pumps

The safety injection pumps operate during the injection and recirculation phases following a LOCA. During the injection phase, the SI pumps take suction from the RWST and inject this coolant into the RCS cold legs.

During the injection phase, the CCW pumps are not running, but auxiliary component cooling pumps driven off the SI pump shafts, circulate CCW through the SI pump coolers. Because the SI fluid pumped during injection is cool water from the RWST, the cooling requirements during the injection phase are not as severe as during the recirculation phase. A minimum of 4 gpm of CCW flow should provide adequate cooling to the SI pump coolers during ECCS injection. The CCW temperature slowly increases during the injection phase since no CCW heat is rejected to the SWS during this mode (the CCW pumps are not operating).

During the ECCS recirculation phase, the SI pumps pump recirculated core coolant provided by the recirculation pumps and cooled by the RHR heat exchangers.

The high head safety injection (HHSI) pumps each contain two mechanical seal coolers, two mechanical seal jacket coolers and a lube oil cooler which are serviced by component cooling water through a common header. The mechanical seal coolers are intended to maintain temperatures in the mechanical seal chambers within limits that will prevent abnormal seal wear. The lube oil cooler is required to maintain the oil temperature at a level which will provide adequate lubrication to the bearings and prevent accelerated viscosity breakdown.

The HHSI pumps were originally provided with John Crane mechanical seals, which are qualified for operation at temperatures up to 300^{o}F. The mechanical seals are cooled by component cooling water which flows through the pump seal coolers. Seal chamber fluid is pumped by a pumping ring through the mechanical seal coolers and returned to the seal chambers. Mechanical seals are installed on both ends of the pump shaft and each seal has its own mechanical seal cooler.

The maximum calculated cooling water temperature to the seal coolers was determined to be 140.5^{o}F at the initial switchover to recirculation, decaying to 124^{o}F within 40 hours. The seal chamber temperature is influenced by the pump suction temperature due to migration of the pumped fluid into the seal chamber. Therefore, it was considered that the pump suction temperature will correspond to the discharge temperature from the RHR heat exchanger at the beginning of the LOCA (approximately 256^{o}F), and decrease over time.

The effect of elevated temperatures on the seal would be an increase in seal wear and a reduction in seal life. Tests performed by the seal manufacturer (John Crane) with 300^{o}F seal cavity temperatures and no seal cooling resulted in only minor wear to the seals. The seal temperature conditions posed here are much less severe, considering that there will be cooling of the seal cavity from the seal coolers.

Consequently, it was determined that the post-LOCA recirculation conditions will have little effect on mechanical seal life expectancy, compared to operation at 85^{o}F SWS temperature. Finally, both of these seals are furnished with a safety bushing which, in the event of catastrophic failure to the primary seal, will limit leakage from the seal to maintain the operability of the HHSI pump.

The safety injection pumps utilize a pressurized lubrication system which provides oil to the two shaft journal bearings and a thrust bearing. The hot oil leaving the bearings is drained into a 3-gallon reservoir. This reservoir is the source of oil for the lube oil pump which supplies oil through the lube oil cooler to the pump bearings. The oil recommended by the vendor for use in these pumps has a nominal viscosity rating of 150 SSU at 100^{o}F.

An increased CCW temperature will result in increased lube oil temperatures at both the inlet and outlet of the pump bearings. Excessive increases in lube oil temperature can lead to breakdown of the oil and subsequent loss of lubricating qualities.

Thermal evaluations of the lube oil system have been performed by the pump vendor for the CCW temperatures discussed in Sections 3.1.1.6.5 and 3.1.2.5. At the initiation of the event, the CCWS temperature would be 110^{o}F. The CCWS would heatup by 7^{o}F per hour. At four hours, the CCWS temperature would be 138^{o}F. Following switchover to recirculation, the CCWS supply temperature would increase to 140.5^{o}F. Within three hours, the temperature would be back to 138^{o}F. The CCWS supply temperature would reduce to 124^{o} within 36 hours after switchover.

From Sections 3.1.1.6.4 and 3.1.1.6.5, the minimum CCW flow rate is 4.0 gpm to each lube oil cooler. The results of the vendor evaluation of this transient are that adequate cooling would be provided to support long term operation of the SI pumps.

4.2.2.3 Residual Heat Removal Pumps

The RHR pumps operate during the second phase of plant cooldowns. The RHR pump mechanical seal coolers are cooled by CCW shell side flow. In addition, the RHR pumps provide a backup to the recirculation pumps during post-LOCA ECCS recirculation.

The RHR pump is equipped with a shell and tube mechanical seal cooler, in addition to a jacket cooler similar to that used on the HHSI pump, which are serviced by component cooling water. The mechanical seal coolers are intended to maintain temperature in the mechanical seal chamber within limits that will prevent abnormal seal wear.

During any mode of operation, the maximum CCW flow rate into the mechanical seal cooler (shell side) is 10 gpm, which is consistent with the vendor limit of 10 gpm and is therefore acceptable. As with the HHSI pump, there is no maximum flow limit specified for the jacket coolers.

The mechanical seals originally specified for use in the RHR pumps are manufactured by John Crane and are very similar in design to the HHSI pump mechanical seals. The RHR pump mechanical seals will be subjected to a peak pump suction temperature of 256°F, reducing with time, and a peak CCW temperature of 140.5°F, also reducing with time. Thus the manufacturer test which qualified the seal for 300°F seal chamber temperatures with no seal cooling bounds the RHR pump mechanical seal operating conditions.

Therefore, it is concluded that the CCW cooling water temperature during post-LOCA recirculation will have an insignificant effect on the mechanical seal life.

4.2.2.4 Charging Pumps

The charging pumps provide makeup and RCP seal injection during non-accident operations. In addition, the charging pumps provide RCP seal injection during plant cooldown following postulated plant fires. The charging pumps use CCW for both the Gyrol drive oil cooler and the pump lube oil cooler. An adequate cooling water supply is needed to prevent the oil temperatures in the Gyrol drive and pump power frame from increasing to the point of oil breakdown and subsequent bearing failure.

CCW flow to both the Gyrol drive and lube oil coolers is through the tube side of each cooler. During its most limiting normal mode of operation, the Gyrol cooler is supplied with cooling water at a minimum flow rate of 82 gpm and a temperature of 118°F. This compares very well with the normally recommended cooling flow of 85 gpm at 125°F.

Since minor variations in cooling water flow rate do not significantly affect the temperature of the oil being cooled, adequate cooling will clearly be provided to the Gyrol during this mode of operation. Since the minimum available cooling flow to the Gyrol cooler is within acceptable limits, the Gyrol oil will be adequately cooled during all normal modes of operation.

The expected limiting abnormal mode of operation for the Gyrol cooler is the Appendix R cooldown. From Section 3.2.1.4.2, the maximum CCWS supply temperature would be 125°F. To ensure adequate cooling at this temperature, CCW flow to the Gyrol cooler should be maintained at or above 85 gpm. This minimum cooling flow requirement should also be maintained during normal plant cooldown if the CCWS throttle valves to the RHR heat exchangers are manually repositioned. It should be noted that the maximum recommended operating temperature of the Gyrol oil is 180°F, which could be monitored by plant maintenance personnel.

The vendor recommended limit for the power frame lube oil is 6.0 gpm at 130°F. For Power Operation, adequate cooling would be provided. As with the Gyrol cooler, the minimum cooling flow for the power frame lube oil cooler should be maintained during the cooldown transient if the CCWS throttle valves to the RHR heat exchangers are manually repositioned.

4.2.2.5 Reactor Coolant Pumps

Cooling water is provided to three separate components of the RCPs. These are the pump thermal barrier cooler and the motor upper and lower bearing cooler. As part of this project, cooling requirements and recommendations were obtained from the pump vendor. In the case of the motor bearing coolers, the cooler vendor was contacted to obtain cooling data. Provided below is a discussion of the cooling requirements for the three RCP coolers.

4.2.2.5.1 Thermal Barrier Cooler

The design basis cooling water requirement as a function of CCW supply temperature was obtained. Thermal barrier cooling provides a redundant backup to seal injection. In the event of a loss of seal cooling, thermal barrier cooling provides cooling to RCS fluid which would leak through the No. 1 seal. Cooling flows up to 75 gpm are acceptable.

The design basis cooling water requirement as a function of CCW supply temperature was obtained from the pump vendor. Provided below are the minimum cooling water flow as a function of CCW supply temperature:

CCW Supply Temp. (F)	Minimum Flow (gpm)
70	13
80	16
90	19
100	23
110	29
120	45

Measured flows during the flow balance test range from 24 gpm to 29 gpm with the permanently installed flow instruments (Rotometer). With temporary ultrasonic flow instrumentation, the measured flows were always higher and ranged from 29.5 gpm to 40 gpm. Note, these flows are based on all system users opened including the excess letdown heat exchanger With the excess letdown heat exchanger closed (Power Operation), the component flows will be some what higher.

Based on the measured flows and the cooling water requirements, adequate cooling water would be provided for CCW supply temperatures up to 105°F with the flows measured with the permanent instrumentation. With the flows measured with the temporary instrumentation, CCW supply temperatures up to 110°F would be acceptable.

Based on the measured data, operation with CCW supply temperatures $\leq 105^{o}F$ is acceptable. To ensure adequate cooling to the coolers when CCW supply temperature is greater than $105^{o}F$, a second CCW pump should be started. Cooler flows calculated with two CCW pumps are within the maximum recommended flow limit.

4.2.2.5.2 Motor Lower Bearing Cooler

Cooling water to the RCP motor lower bearing cooler is provided to maintain the lower bearing temperature within design limits. Oil is used to transfer heat from the bearing to the CCW fluid. For CCW supply temperatures between 70 and $105^{o}F$, the recommended flow range is 5 gpm to 8 gpm. For inlet water temperatures higher than $105^{o}F$, but less than $120^{o}F$, the recommended flow range is 7 gpm to 8 gpm. Inlet cooling temperatures greater than $120^{o}F$ are not recommended.

Based on the calculated flows and the cooling water requirements, operation with CCWS supply temperature $\leq 105^{o}F$ is acceptable. To ensure adequate cooling to the coolers when CCW supply temperature is greater than $105^{o}F$, a second CCW pump should be started. A potential problem with two CCW pumps in operation is that the flow to the lower bearing cooler can be greater than the maximum allowable limit (See Table 3-9, Case A5). With two CCW pumps operating, CCW flow to the lower bearing coolers should be maintained below this maximum limit.

If the flow limit is exceeded, one or two CCW flow paths to the shell-side of the RHR heat exchangers (MOV 822 A/B) should be opened as necessary to maintain the CCW flow to each lower bearing cooler to $\leq$ 8 gpm.

4.2.2.5.3 Motor Upper Bearing Cooler

Cooling water to the RCP motor upper bearing is provided via a cooler to maintain the upper bearing temperature within design limits. Oil is used to transfer heat from the bearing to the CCW fluid. For CCW supply temperatures between $70^{o}F$ and $105^{o}F$, the recommended flow range is 150 gpm to 219 gpm.

For inlet water temperatures higher than 105°F, but less than 110°F, the recommended flow range is 200 gpm to 219 gpm. Inlet cooling temperatures greater than 110°F are not recommended for continuous service. Fouling on the oil-side of the cooler may occur at temperatures greater than 110°F. A RCP upper bearing alarm is provided in the central control room to alert of inadequate cooling to the upper bearing.

Based on the calculated flows and the cooling water requirements, operation with CCW supply temperatures $\leq$ 105°F is acceptable. If the CCW supply temperature exceeds 105°F or a RCP upper bearing high temperature alarm is signalled, a second CCW pump should be started to ensure adequate cooling. A potential problem with two CCW pumps in operation is that the flow to the upper bearing cooler can be greater than the maximum allowable limit when two enhanced pump curves are considered (See Table 3-9, Case A5). With two CCW pump operating, CCW flow to the upper bearing coolers should be maintained below this maximum limit. If the flow limit is exceeded, one or two CCW flow paths to the shell-side of the RHR heat exchangers (MOV 822A/B) should be opened as necessary to maintain the CCW flow to each upper bearing cooler to $\leq$ 219 gpm.

4.2.2.6 Reactor Vessel Support Cooling Blocks

The reactor vessel has supports located at alternate nozzles. These supports are cooled by CCW flowing through the support cooling blocks. This cooling prevents the structural concrete from exceeding temperature limits during normal operations.

The RVNF coolers are cooled by component cooling water to prevent the supporting concrete from overheating. The design basis calculation ensured that sufficient CCW flow to each support was provided to keep the concrete temperature (underneath the support block) at or below 150°F. The initial design basis calculation used a CCW supply temperature of 91°F and a RCS hot leg temperature of 596°F. Based on the results, three gpm was determined as the required cooling water flow.

In support of this project, a calculation was performed to determine the minimum CCW flow required with a maximum CCW supply temperature of 120°F and maximum RCS hot leg temperature of 611.7^{o}F. Using the same methodology, approximately five gpm was calculated to achieve the required cooling.

Based on the calculated flows for the Startup/Power Operation and Cooldown modes (Tables 3-9 and 3-10), the minimum delivered flow is 9 gpm. Since the minimum calculated flow is exceeded, it can be concluded that sufficient flow is provided to the RVNB coolers to ensure adequate cooling of the supporting concrete with a SWS temperature of 95^{o}F.

The CCW supply and return lines to the support block cooler are 3/4 inch in diameter. The design basis piping calculation considered a flow rate of 12.5 gpm to each nozzle block. At this flow rate, the velocity through the individual supply and return lines is 7.5 feet per second (fps). The tubes embedded in the cooling plate are 1/2 inch diameter. At the 12.5 gpm flow rate, the velocity through the cooling tubes is 13.2 fps. Based on the calculated flows for the Startup/Power Operation and Cooldown modes (See Tables 3-9 and 3-10), the maximum delivered flow rate is 13 gpm. At these flows, the fluid velocities in the CCWS piping and cooling tubes are within the design basis piping sizing flow limit of 15 fps.

4.2.2.7 Sample Heat Exchanger Cooling

The CCWS provides cooling to the following sample heat exchangers:

- Pressurizer Liquid and Vapor sample coolers
- Reactor Coolant sample cooler
- Steam Generator Blowdown sample coolers

These samples are high-pressure, high-temperature samples that are cooled to minimize the generation of radioactive aerosols. The samples are cooled as they pass through the tube side of the coolers while CCW flows through the shell side.

Sampling capability is required during normal and post-accident operations. Sampling during post-LOCA operation, however, will be performed from the ECCS recirculation flow path, which does not require cooling. Therefore, CCWS sample cooling is only required during normal and abnormal modes of operation.

In general, higher CCW supply temperatures will result in higher sample outlet temperatures with all other parameters held constant. For the supplied heat exchangers, sampling fluid flows through the tube-side and CCW flows through the shell-side. The heat exchanger design shell-side flow is 14 gpm; design inlet and outlet temperatures are 105°F and 125°F, respectively.

Tube-side design conditions are based on approximately 0.5 gpm sample flow and an inlet and outlet temperature of 653°F and 127°F, respectively. The tube-side inlet temperature is based on the saturation temperature of the pressurizer fluid at a pressure of 2250 psia. This temperature is very conservative for all sample coolers except for the pressurizer sample heat exchangers. The tube-side outlet temperature is based on the normal operating temperature of the volume control tank (VCT) and coolant discharge to the Waste Disposal System. The design shell-side temperature is 350°F (Reference 4-17).

As discussed in Section 4.2.2.5, a second CCW pump is required to be started if the CCWS supply temperature reaches 105°F. With one CCW pump in operation and CCWS supply temperature less than or equal to 105°F, the minimum calculated cooling water flow to the sample heat exchangers is approximately 13 gpm (See Table 3-9, Case A1). Since this calculated flow is very close to the design flow, adequate cooling should be provided to the sample heat exchangers. Tube-side sample heat exchanger outlet temperatures, however, could be a few degrees higher than design. Since the RCS samples would be typically returned to the VCT during plant operation, a 5°F to 10°F higher tube outlet temperature is evaluated to be acceptable. This is true since individual sample flow rates are very small (< 1 gpm) compared to the normal flow through the VCT with a charging pump inservice (75 gpm).

With two CCW pumps operational, the sample heat exchanger flow will be in the 15 gpm to 16 gpm range (See Table 3-9, Case A5 and Table 3-11, Case C2). At CCW supply temperatures up to 110^{o}F, adequate cooling should be provided since the CCW flow to the sample heat exchangers is greater than design.

4.2.2.8 Waste Gas Compressors

The waste gas compressor does not perform any post-accident safety-related functions. Only operability during normal operations is evaluated.

The waste gas compressor uses CCW to cool seal water which provides cooling of the mechanical seal and acts as a liquid compressant in the compressor. The waste gas compressor, by design, requires a nominal cooling water flow of 42.5 gpm at 105^{o}F. In addition, the vendor has stated that minimum cooling requirements can be met with a flow rate of 25 gpm at 105^{o}F.

The 105^{o}F temperature limit is exceeded for several operating modes. The worst-case flow conditions are 32 gpm to 54 gpm at temperatures up to 118^{o}F. However, due to reactor coolant pump limits, the maximum CCW temperature for Power Operation is limited to 110^{o}F.

The mechanical seal is a John Crane Type 9 seal which can operate with normal temperatures as high as 175^{o}F. The normal operating temperature range of the compressor seal water is 70^{o}F to 130^{o}F. Since the maximum seal water temperature will clearly not increase by 45^{o}F, the higher CCW temperature will have no effect on the mechanical seal operation.

The seal water which is injected into the compressor acts as the liquid compressant which forces the waste gas through the compressor discharge nozzle. The seal water at higher temperatures becomes more compressible and, therefore, is less capable of forcing the waste gas out of the compressor. This will result in decreased performance of the compressor, but the increased seal water temperature will have no detrimental mechanical effect on the compressor unit. Thus, the waste gas compressor will operate satisfactorily, with slightly reduced performance, when supplied with 110°F CCW. The reduction in compressor performance due to the increased cooling water temperatures may actually be offset to some extent by the increased cooling water flow rates, which are all higher than the minimum recommended flow rate and in several cases are higher than the nominal flow rate. Therefore, any reduction in compressor performance is expected to be minor.

4.2.2.9 Nonregenerative Heat Exchanger

The CVCS nonregenerative heat exchanger is used to cool reactor coolant to approximately 130°F prior to purification through the CVCS demineralizers. Following purification, the reactor coolant is normally returned to the VCT where it is pumped back to the RCS via a charging pump.

The CVCS process fluid flows through the tube-side and CCW flows through the shell-side. The design shell and tube flows of the nonregenerative heat exchanger are 494,000 lb/hr (approximately 987 gpm) and 59,280 lb/hr (approximately 120 gpm). The design CCW inlet temperature is 105°F and the design CVCS outlet temperature is 127°F (Reference 4-18).

CCW flow to the nonregenerative heat exchanger is automatically controlled via TCV-130 to maintain the tube outlet temperature at approximately 127°F. When the nonregenerative heat exchanger outlet temperature is at 130°F or higher, a control room alarm would be provided via control loop TIA-129. If the letdown temperature reaches 145°F, letdown flow would be diverted to the VCT via control loop TIC-149 (Reference 4-19). This flow diversion automatically occurs to prevent high-temperature fluid from being delivered to the CVCS demineralizers.

The calculated minimum flow to the nonregenerative heat exchanger is approximately 869 gpm (See Table 3-9, Case A1). At this minimum CCW flow and design conditions, the CVCS process outlet temperature is calculated to be as high as 134°F. With higher CCW supply temperatures or reduced heat exchanger performance (fouling, tube plugging, etc.), letdown temperatures will increase. Component cooling flow to the nonregenerative heat exchanger is not recommended to be increased to counter the effect of higher CCW supply temperatures since flows greater than design could result in vibration and/or erosion concerns and have not been evaluated as part of this project.

At the "Normal" letdown flow (75 gpm), the letdown heat exchanger should be capable of maintaining the nonregenerative heat exchanger outlet temperature to below the 127°F alarm setpoint for the maximum calculated CCW supply temperature of 119°F.

In order to protect the demineralizer beds from potential damage at elevated river water temperatures, Westinghouse recommends that maximum letdown be discontinued if a high letdown temperature alarm occurs on control loop TIC-129.

4.2.2.10 Excess Letdown Heat Exchanger

The CVCS excess letdown heat exchanger is provided as a backup letdown flowpath in the event the normal letdown flowpath (via the regenerative and nonregenerative heat exchangers) is not available. The heat exchanger can also be used during plant startup to remove RCS fluid due to thermal expansion. Tube-side flow is directed to the VCT via the seal water heat exchanger.

The CVCS process fluid flows through the tube-side of the heat exchanger and CCW flows through the shell-side. The design shell and tube flows of the excess letdown heat exchanger are 119,000 (approximately 238 gpm) and 12,400 lb/hr (approximately 25 gpm), respectively.

The design CCW inlet temperature is 95°F; the design CVCS inlet and outlet temperatures are 555°F and 195°F, respectively (Reference 4-18). When the excess letdown heat exchanger outlet temperature is at $200^{o}F$ or higher, a control room alarm would be provided via control loop TIA-122 (Reference 4-19).

The calculated minimum flow to the excess letdown heat exchanger is approximately 192 gpm (see Table 3-9, Case A1). At this minimum CCW flow and elevated CCW supply temperatures, the CVCS outlet temperature would be higher than $200^{o}F$. Component cooling flow to the excess letdown heat exchanger was not increased for the CCWS flow balance in order to keep the CCW flow with one CCW pump operating at or below heat exchanger design flow.

Westinghouse recommends that reactor coolant flow through the excess letdown heat exchanger be manually reduced, as required, to limit tube-side outlet temperature to below $200^{o}F$. If, under this scenario, the delivered flow is inadequate to meet plant operation requirements, a second CCW pump could be started to increase CCW flow to the heat exchanger.

4.2.2.11 Seal Water Heat Exchanger

The CVCS charging pumps deliver seal water injection to each RCP at a rate of approximately 8 gpm per pump. Of the 8 gpm, 5 gpm are normally injected into the RCS. The remaining 3 gpm flows past the pump radial bearing and the No. 1 seal and out the No. 1 seal leakoff line. RCP seal leakoffs are directed to the VCT via the seal water heat exchanger. Note, the excess letdown heat exchanger process flow is also directed through the seal water heat exchanger.

The design shell and tube flows of the seal water heat exchanger are 108,541 lb/hr (approximately 217 gpm) and 126,756 lb/hr (approximately 270 gpm), respectively. The design CCW inlet temperature is $105^{o}F$; the design CVCS inlet and outlet temperatures are $144^{o}F$ and $127^{o}F$, respectively (Reference 4-18). Note, a seal water heat exchanger outlet high temperature alarm is not provided. A high temperature alarm is provided for the VCT at $145^{o}F$ via control loop TIA-140 (Reference 4-19).

The maximum tube-side flow is based on the excess letdown heat exchanger design flow plus the maximum design leakage from the RCP shaft seals. Since the design tube-side flow was very conservative for normal plant operation, the CCW flow to the seal water heat exchanger was reduced. The balancing flow was specified as approximately 110 gpm.

The calculated minimum flow to the seal water heat exchanger is approximately 98 gpm (See Table 3-9, Case A1). At this minimum CCW flow, reduced tube-side flow, and a 105^{O}F CCW supply temperature, the seal water heat exchanger outlet temperature is calculated to be less than 124^{O}F. At a CCW supply temperature of 110^{O}F, the tube outlet temperature is calculated to be 128^{O}F. At the maximum CCW supply temperature of 118^{O}F and only one CCW pump operating, the tube outlet temperature is calculated to be 134^{O}F. If the second CCW pump is started, the temperature would be approximately 132^{O}F.

Based on the calculated temperatures, the seal water heat exchanger is capable of maintaining the CVCS process fluid within recommended limits.

4.2.2.12 Gross Failed Fuel Detector Cooler

The GFFD system is used to continously monitor the delayed neutron activity in a continuous fluid sample drawn from the RCS. The delayed neutron activity provides a rapid indication of gross amounts of fission products contained in the RCS resulting from possible fuel defects.

Component cooling is supplied to the GFFD unit to cool the primary RCS sample temperature from approximately 650^{O}F to not more than 135^{O}F prior to its monitoring for radiation. The nominal cooling water flow requirement is 14 gpm at a maximum temperature of 105^{O}F (Reference 4-20).

From Table 3-9, the limiting cooling condition for the GFFD cooler is 27 gpm at 118^{O}F. Since the CCWS supply temperature is limited to 110^{O}F due to the RCPs, 27 gpm to the GFFD cooler would provide adequate cooling to the GFFD coolers to ensure component operability during normal plant operation.

The maximum allowable flow limit has not been defined for this cooler. From Table 3-9, CCW flows as high as 47 gpm are calculated. To ensure long-term operation and structural integrity of the cooler, the maximum flow limit of the cooler is required. Depending on the limit, cooling water to the cooler may be required to be throttled.

4.2.2.13 Steam Generator Blowdown Radiation Monitor Cooler

The steam generator blowdown fluid is continuously monitored for radioactivity by radiation monitor R-19. Component cooling is provided to a sample cooler which cools the process fluid prior to it being monitored for radiation. To reduce the process temperature to satisfy chemistry sampling requirements, two additional coolers were added downstream. These coolers are cooled by city water. At the outlet of the last cooler, a temperature control valve is provided to maintain sample temperature to approximately $77^{o}F$.

A temperature alarm (TCA-1110S) is provided at the outlet of the third cooler to monitor for high temperature (Reference 4-21). With the cooler design configuration, adequate cooling should be provided to the sample fluid to ensure the operability of the R-19 monitor.

The maximum allowable flow limit has not been defined for this cooler. The CCWS flow to this cooler was measured during the CCWS flow balance. In the Startup alignment, approximately 23 gpm was measured with one CCW pump in operation (Reference 4-22). To address long-term operation and structural integrity of the cooler, the maximum flow limit of the cooler is required to be defined. Depending on the limit, cooling water to the cooler may be required to be throttled.

4.2.2.14 Auxiliary Condensate Radiation Monitor Cooler

The auxiliary condensate fluid is continously monitored for radioactivity by radiation monitor R-37. Component cooling is provided to a sample cooler which cools the process fluid prior to it being monitored for radiation. The nominal cooling water flow requirement is 3 gpm (Reference 4-23). From Table 3-9, the CCW minimum flow is calculated to be 3 gpm.

Although detailed thermal performance data for the cooler was not available, the radiation monitor should remain operable during plant operation since a high temperature alarm is provided (Reference 4-22). The alarm would alert plant operators if cooling water to the radiation monitor approached maximum limits.

The maximum allowable flow limit has not been defined for this cooler. Based on Table 3-9, a maximum flow of 7 gpm was calculated. To address long-term operation and structural integrity of the cooler, the maximum flow limit of the cooler is required to be defined. Depending on the limit, cooling water to the cooler may be required to be throttled.

REFERENCES

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4-2 UE&C Report 6504, 266 S-M-2, Rev. 4.

4-3 "Steady State Performance of Fan Motor Cooling Systems Following a Reactor Incident," Westinghouse Research Report 69-1E9-TABLD-R1, December 22, 1969.

4-4 "Temperature Rise and Insulation," <u>Machine Design - Electric Motors Reference Issue</u>, March 19, 1964.

4-5 UE&C Letter IUP-8360, "Replacement Service Water Pump - Diesel Generator Jacket Water/Lube Oil Cooler Performances with Tube Plugging," May 12, 1989.

4-6 UE&C Letter IUP-84[illegible], "Diesel Generator Jacket Water/Lube Oil Cooler Performance - Post [illegible] Recirculation," May 21, 1989.

4-7 Indian Point Station Unit No. 3 System Description No. 24.0, "Service Water System," Rev. 0, October, 1988.

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4-9 Chicago Pneumatic Instruction Book 728-A, Ninth Edition, 9-60, "Instructions for Installing and Operating Chicago Pneumatic Type 'T' Air Compressors."

4-10 NYPA Service Water System Alignment, Balance and Acceptance Test, ENG-281, August 12, 1987.

4-11 Chicago Pneumatic Tool Co. dwg. 019119 Rev. B, November 25, 1970, "Schematic Air & Water Flow Diagram."

4-12 Weather Data Handbook

4-13 Not used.

4-14 NYPA letter 89-035, from G. M. Canavan (NYPA) to A. Ball (W), February 15, 1989, including attached IP3 "Historical Data Log Report."

4-15 Westinghouse Commercial Packaged Cooling, Model UF 180W, Performance Data Sheet UF-B5, December, 1969.

4-16 Westinghouse Sealed Hermetic Compressor, Data Sheet CD-072, June, 1969.

4-17 Westinghouse Document, "Sampling System Description," Indian Point Unit 3 Plant Manual, Volume 1.

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4-18 Westinghouse Document, "Chemical and Volume Control System Description," Indian Point Unit 3 Plant Manual, Volume 1.

4-19 Westinghouse Document, "Precautions, Limitations, Setpoint," Indian Point Unit 3 Plant Manual, Volume 6.

4-20 Technical Manual, "Gross Failed Fuel Detector System", Volumes I and II.

4-21 Indian Point Station Unit No. 3 System Description No. 7, "Steam Generator Blowdown System", September, 1985.

4-22 NYPA Component Cooling Water Flow Balance, ENG-366, Revision 0, April 7, 1989.

4-23 NYPA Acceptance Test, "Installation Of Auxiliary Condensate Radiation Monitor", ENG-19, Revision 2, March 17, 1983.

TABLE 4-1

ACCIDENT-REQUIRED EQUIPMENT COOLED BY THE SERVICE WATER SYSTEM

- Reactor Containment Fan Coolers (RCFCs)
- RCFC Fan Motor Coolers
- RCFC Service Water Return Radiation Monitor
- Instrument Air Compressors Closed Cooling System
- Diesel Generator Cooling Services
- Component Cooling Heat Exchangers
- CCR Air Conditioners

TABLE 4-2
EQUIPMENT COOLED BY THE CCWS

<u>Accident-Required Loads</u>

- Residual Heat Exchangers
- Residual Heat Removal Pumps
- Safety Injection Pumps
- Recirculation Pumps

<u>Accident Non-Required Loads</u>

- RCP Thermal Barriers
- RCP Cooler Header
- Letdown Heat Exchanger
- Excess Letdown Heat Exchanger
- Seal Water Heat Exchanger
- Sample Heat Exchangers
- Spent Fuel Pit Heat Exchanger
- Charging Pump Gyrol Coolers
- Charging Pumps Bearing Coolers
- Waste Gas Compressors
- Reactor Vessel Supports Blocks

TABLE 4-3
INDIAN POINT UNIT 3 REACTOR CONTAINMENT FAN COOLER COOLING COIL
INFORMATION USED FOR 95^{o}F SERVICE WATER EVALUATION

Coil Data

Number of Coil Assemblies	5
Number of Banks/Assembly	2
Number of Coils/Bank	4
Coil Type	W Sturtevant WC36114
Fin Material	Copper
Tube Material	AL6X
Fins per Inch Tube Length	8.5
Tube Wall Thickness (in)	0.028
Fin Thickness (in)	0.008
Tube Nominal O.D. (in)	5/8
Tube Length (in)	114
Fouling Factor (ft^{2}-hr-^{o}F/BTU)	0.004
Percent Tubes Plugged	4
Tube Rows/Coil	8
No. of Passes	4

Conditions

	Normal	Post-Accident
Service Water Flow Rate (gpm)	500 to 2000	1400
Service Water Temperature (^{o}F)	95	95
Containment Atmosphere Temperature (^{o}F)	120/130	271 Design
Containment Atmosphere Pressure (psig)	0 - 2.5	47 Design
Containment Atmosphere Density (lb/ft^{3})	0.069	0.175
Fan Capacity (cfm)	69,500	34,000

TABLE 4-4
INDIAN POINT UNIT 3 REACTOR CONTAINMENT FAN COOLER OUTLET WATER TEMPERATURE - NORMAL OPERATION - 95^{o}F INLET WATER TEMPERATURE

Flow Rate (gpm)	Outlet Water Temp. Cntmnt Temp. = 120^{o}F (^{o}F)	Outlet Water Temp. Cntmnt Temp. = 130^{o}F (^{o}F)
500	101.3	103.8
750	99.3	101.0
1000	98.3	99.6
1250	97.6	98.7
1500	97.2	98.1
1750	96.9	97.7
2000	96.7	97.3

TABLE 4-5

INDIAN POINT UNIT 3 REACTOR CONTAINMENT FAN COOLER OUTLET

WATER TEMPERATURE - POST ACCIDENT OPERATION - 95°F INLET WATER TEMPERATURE

Containment Air Temp (°F)	Outlet Water Temp	
	Coil Bank 1 (°F)	Coil Bank 2 (°F)
130	105.3	102.6
140	108.4	105.5
160	115.0	112.2
180	121.7	119.3
200	128.3	126.5
220	137.3	134.3
240	149.5	147.2
260	160.2	158.6
280	170.4	169.2
300	179.5	178.8

TABLE 4-6
INDIAN POINT UNIT 3 REACTOR CONTAINMENT FAN MOTOR COOLER INFORMATION
USED FOR 95^{O}F SERVICE WATER EVALUATION

Coil Data

Number of Motor Cooler Assemblies	5
Number of Coils/Assembly	1
Coil Type	Marlo Coil 6Q16-30.0-5608.5T
Fin Material	Copper
Tube Material	AL6X
Fins per Inch Tube Length	8.5
Tube Rows/Coil	6
Number of Passes	2
Tube Wall Thickness (in)	0.035
Fin Thickness (in)	0.01
Tube Nominal O.D. (in)	5/8
Tube Length (in)	30
Fouling Factor (ft^2-hr-^{O}F/BTU)	0.004
Percent Tubes Plugged	10

Conditions

	Normal	Post-Accident
Service Water Flow Rate (gpm)	50	50
Service Water Temperature (^{O}F)	95	95
Containment Atmosphere Pressure (psig)	0 - 2.5	47
Maximum Fan Brake Horsepower	87.4	219

TABLE 4-7
EQUIPMENT COOLED BY THE CCWS
MAXIMUM ACTUAL FLOW VERSUS ALLOWABLE DESIGN FLOW LIMITS

EQUIPMENT NAME	MAX FLOW (gpm)	DESIGN FLOW (gpm)
RHR Heat Exchanger	1986	4920
CCW Heat Exchanger	7500	5313
Spent Fuel Pit Heat Exchanger	2407	2796
Seal Water Heat Exchanger	165	217
Letdown Heat Exchanger	987	987
Excess Letdown Heat Exchanger	292	238
Sample Heat Exchanger	21	40
RV Support Cooling Blocks	13	14
Reactor Coolant Pump		
Thermal Barrier	61	75
Lower Bearing Cooler	≤8	8
Upper bearing Cooler	≤219	219
Charging Pump		
Gyrol Drive Cooler	136	209
Lube Oil Cooler	12	39
Safety Injection Pump		
Lube Oil Cooler	≤13	13
Seal Cooler	≤20	20
Jacket Cooler	≤20	N/A
Recirculation Pump		
Motor Cooler	≤100	102
RHR Pump		
Seal Cooler	10	10
Jacket Cooler	10	N/A
WG Compressor Seal Cooler	54	95

TABLE 4-8
EQUIPMENT COOLED BY THE CCWS
MAXIMUM TEMPERATURE VERSUS DESIGN TEMPERATURE

EQUIPMENT NAME	MAX TEMP (°F)	DESIGN TEMP (°F)
RHR Heat Exchanger	215	200
CCW Heat Exchanger	<180	200
Spent Fuel Pit Heat Exchanger	<200	200
Seal Water Heat Exchanger	<200	250
Letdown Heat Exchanger	<200	250
Excess Letdown Heat Exchanger	<200	250
Sample Heat Exchanger	<200	350
RV Support Cooling Blocks	<200	200
Reactor Coolant Pump		
Thermal Barrier	<200	200
Lower Bearing Cooler	<200	200
Upper Bearing Cooler	<200	200
Charging Pump		
Gyrol Drive Cooler	<200	300
Lube Oil Cooler	<200	300
Safety Injection Pump		
Lube Oil Cooler	<200	300
Seal Cooler	<200	550
Jacket Cooler	<200	350
Recirculation Pump		
Motor Cooler	<200	200
RHR Pump		
Seal Cooler	<200	350
Jacket Cooler	<200	400
WG Compressor Seal Cooler	<200	300

FIGURE 4-1
INDIAN POINT 3 – RCFC
HEAT REMOVAL RATE FOR NORMAL OPERATION

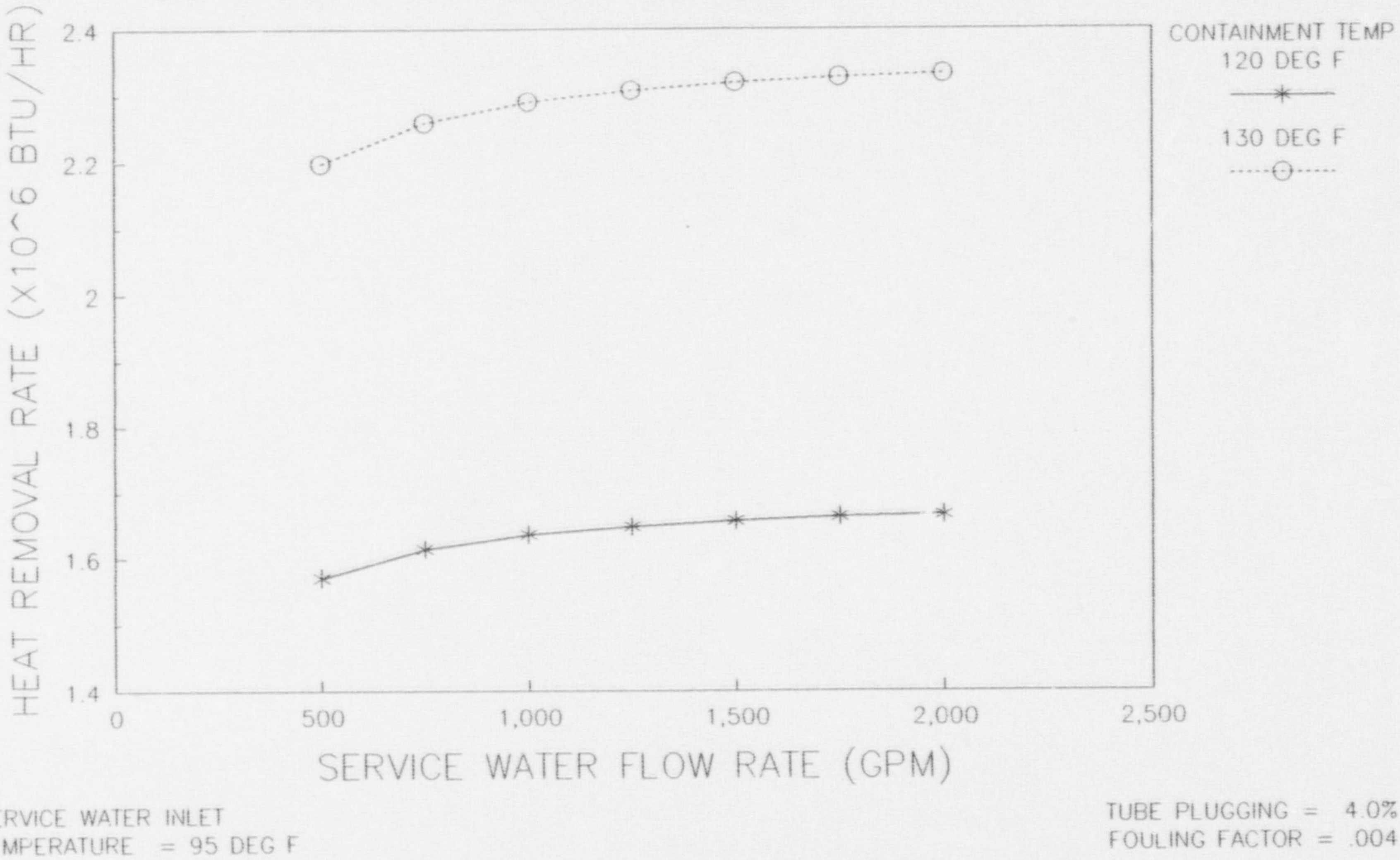


FIGURE 4-2

INT RCFC ACCIDENT HEAT REMOVAL

FOR SERVICE WATER AT 95 DEG. F, 4% PLUGGED, FF=.004

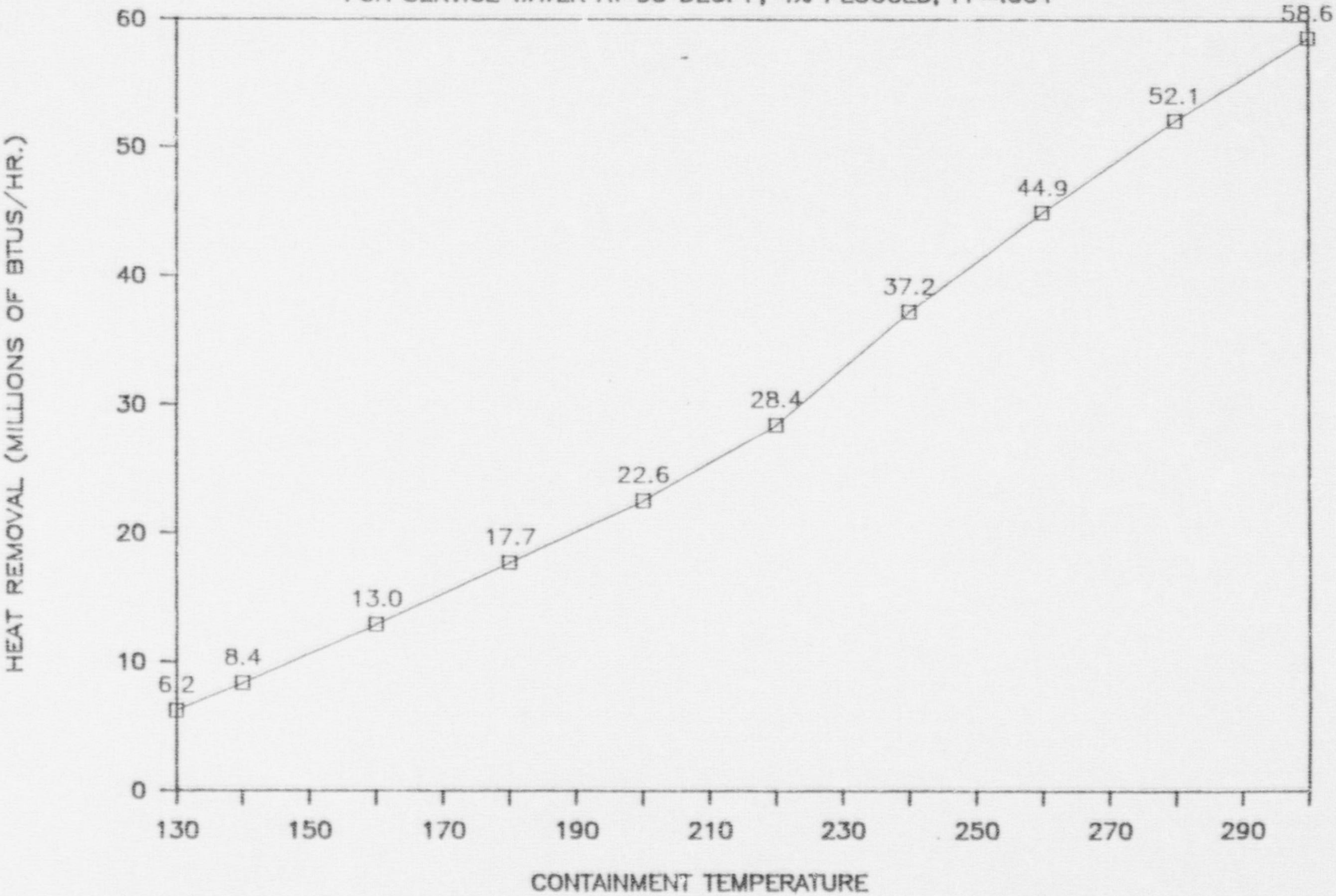
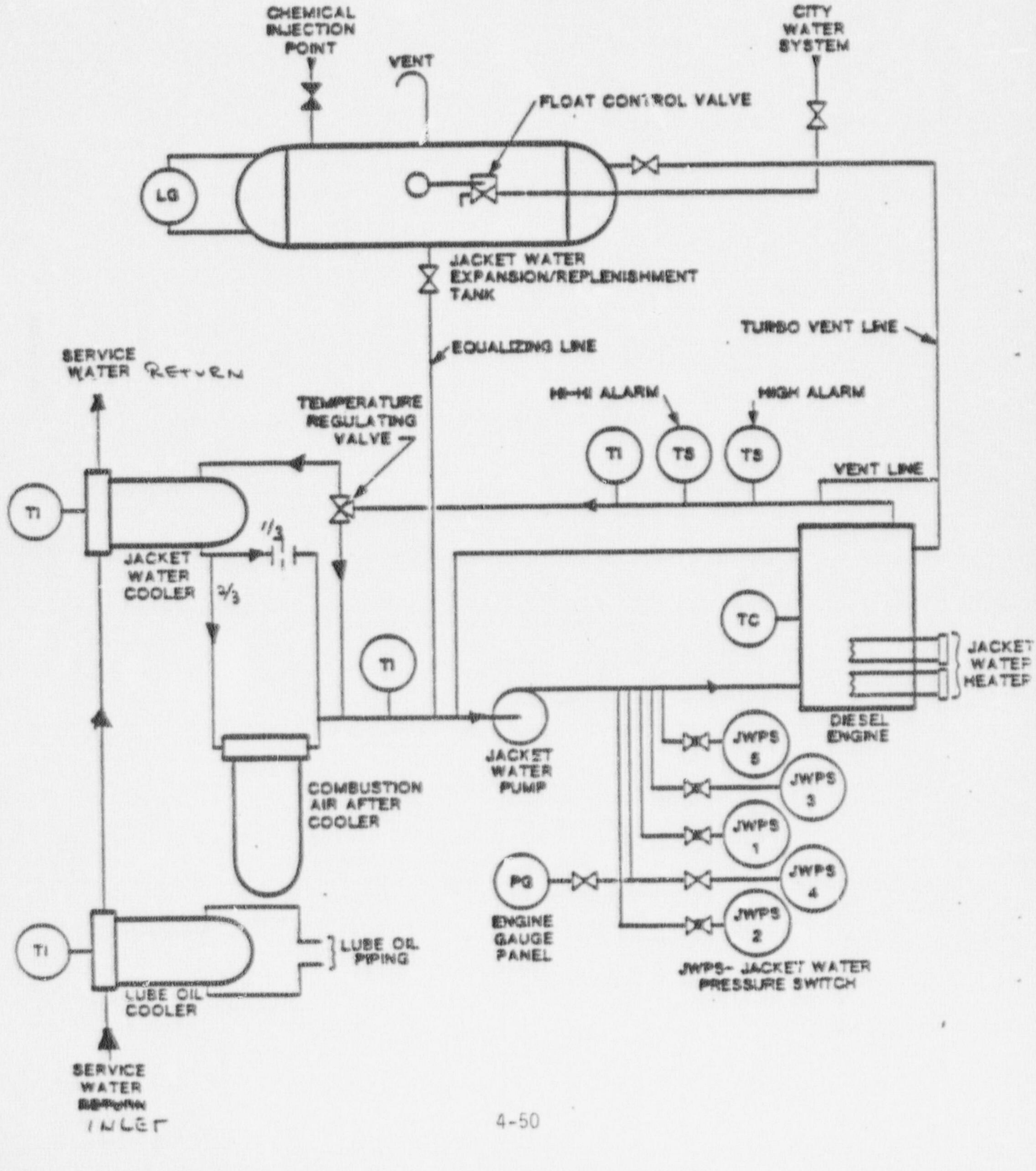


FIGURE 4-3

DIESEL ENGINE JACKET WATER SYSTEM



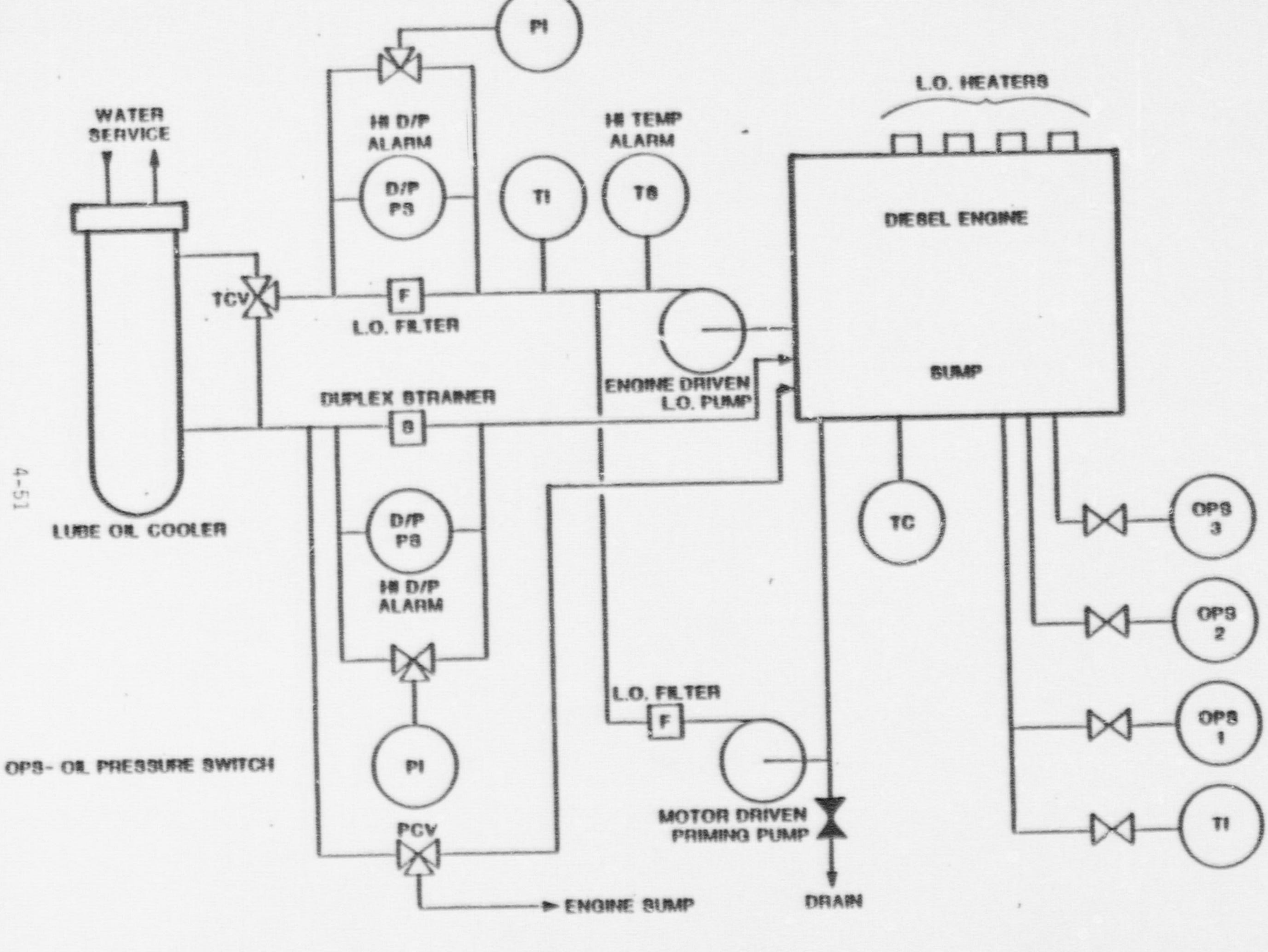


FIGURE 4-4 - DIESEL ENGINE LUBE OIL SYSTEM

FIGURE 4-5

INDIAN POINT 3
CONTROL ROOM A/C

ITEM	EVAPORATOR (Mixed Air Conditions): ENTER. W.B. (F) (1)	EVAPORATOR: COOLING CAPACITY SENS @ 80F (BTUHx1000) (2)	EVAPORATOR: TOTAL HEAT (BTUHx1000) (3)	COMPRESSOR: HEAT OF COMPRESSION: COMP. INPUT (KW) (4)	COMPRESSOR: HEAT OF COMPRESSION (BTUH) (5)	CONDENSER: TOTAL HEAT (BTUH) (6)	CONDENSER: WATER TEMP. ENT. (F) (7)	CONDENSER: WATER TEMP. LEAV. (F) (8)	CONDENSER: FLOW RATE (GPM) (9)	CONDENSER: PRESS. DROP (FT) (10)	COIL: D.B. DELTA T (SENS) (F) (11)	COIL: D.B. LEAV TEMP (F) (12)	COIL: HEAT REMOVED (BTU/Lb) (13)	COIL: W.B. HEAT CONTENT (BTU/Lb) (14)	COIL: LEAV TEMP (F) (15)
1	67	130.2	194.4	14.27	48,718	243,118	70	80	48.623[illegible]		20	60	9.00	22.62	54.0
2	67	129.6	190.4	14.6	49,844	240,244	75	85	48.04888	16.4	20	60	8.90	22.72	54.2
3	67	115.7	186.4	14.9	50,869	237,269	80	90	47.45372	17.5	18	62	8.79	22.83	54.4
4	67	125.7	182	15.34	52,371	234,371	85	95	46.87415	16.1	19	61	8.68	22.94	54.5
5	67	124.5	178	15.7	53,600	231,6[illegible]	90	100	46.31996	7.1	19	61	8.58	23.04	54.7
6	67	116.6	174	16.06	54,829	228,829	95	105	45.76576		18	62	8.48	23.14	54.9
7	67	113.9	170	16.43	56,092	226,092	100	110	45.21840		17	63	8.37	23.25	55.1
8	67	111.2	166	16.81	57,389	223,389	105	115	44.67786		17	63	8.27	23.35	55.2

NOTES:
1. Boxed in data has been taken from Ref. 4-15, 16.
2. Item 4 data represents the existing design conditions.
3. Item 6 represents the new design conditions with 95 F S.W.
4. The remaining items are used to provide a more complete profile of the A/C unit

FIGURE 4-6

TRANE

PSYCHROMETRIC CHART

Barometric Pressure 29.921 Inches of Mercury

$Q_{TOTAL} = 4.5 \times \Delta h \times CFM$

$Q_{TOTAL} = (4.5)(8.5)(6000)$

$Q_{TOTAL} = 229{,}500\ BTUH$

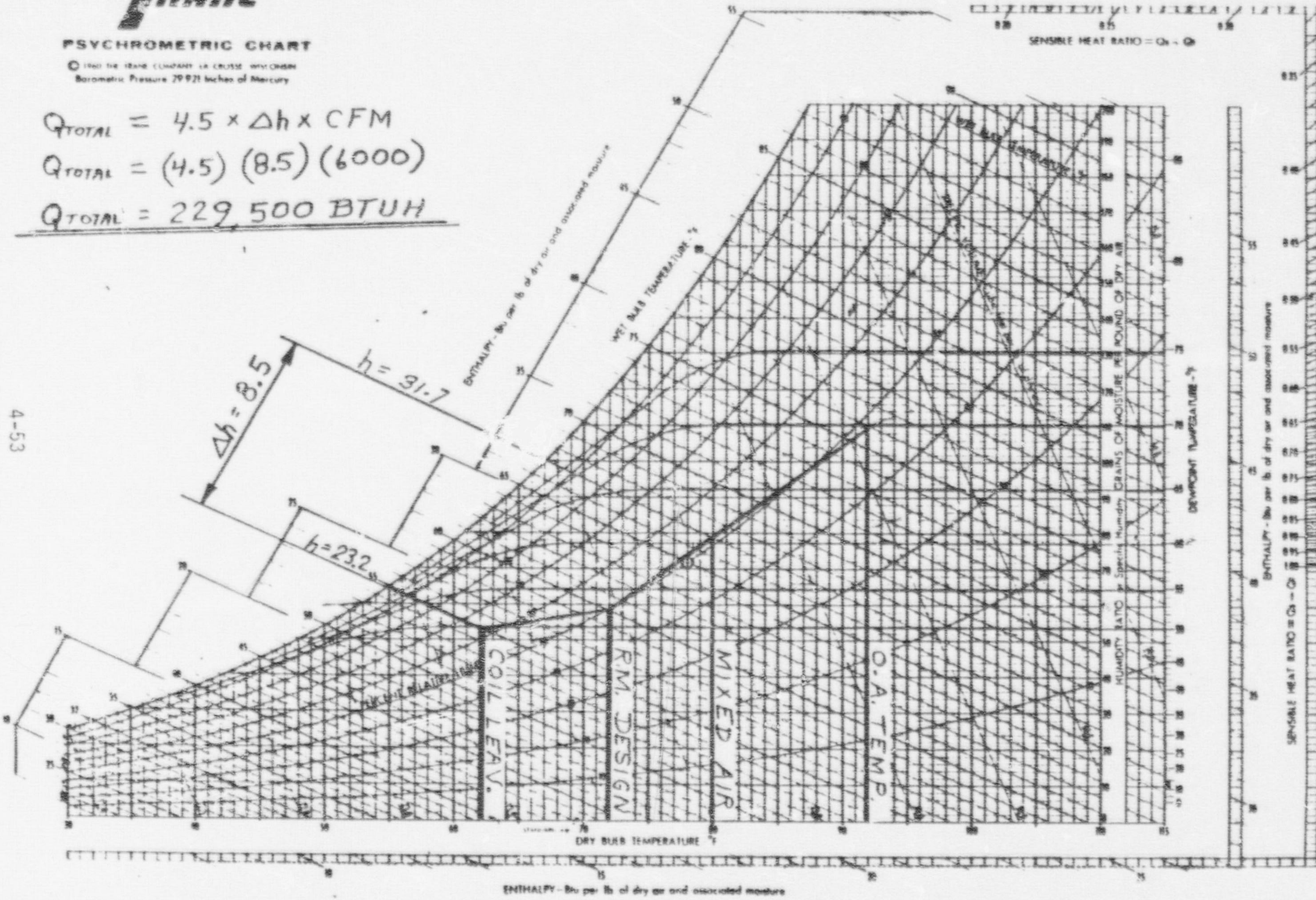
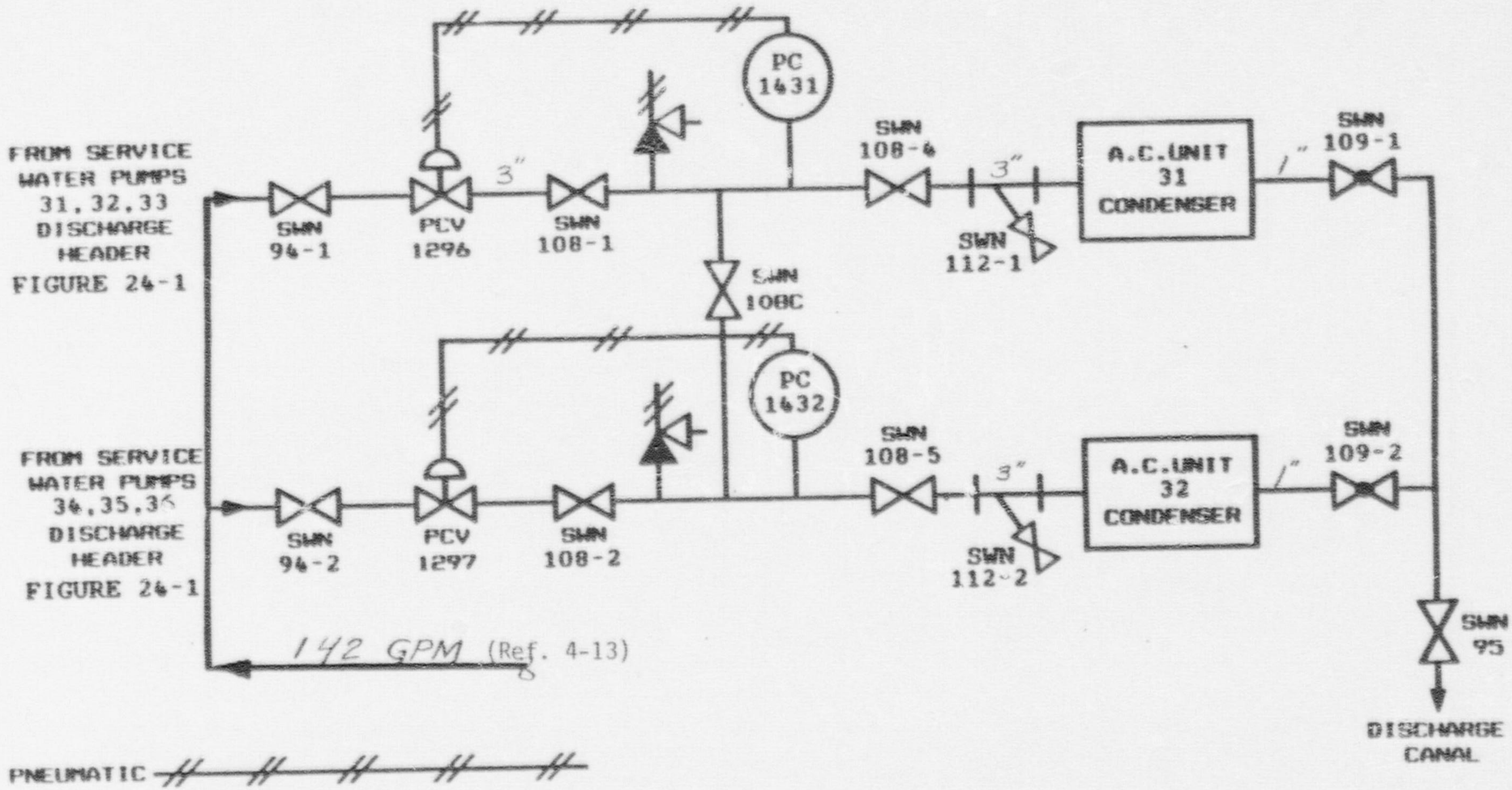


FIGURE 4-7

ESSENTIAL SERVICE WATER TO CONTROL ROOM AIR CONDITIONING UNITS



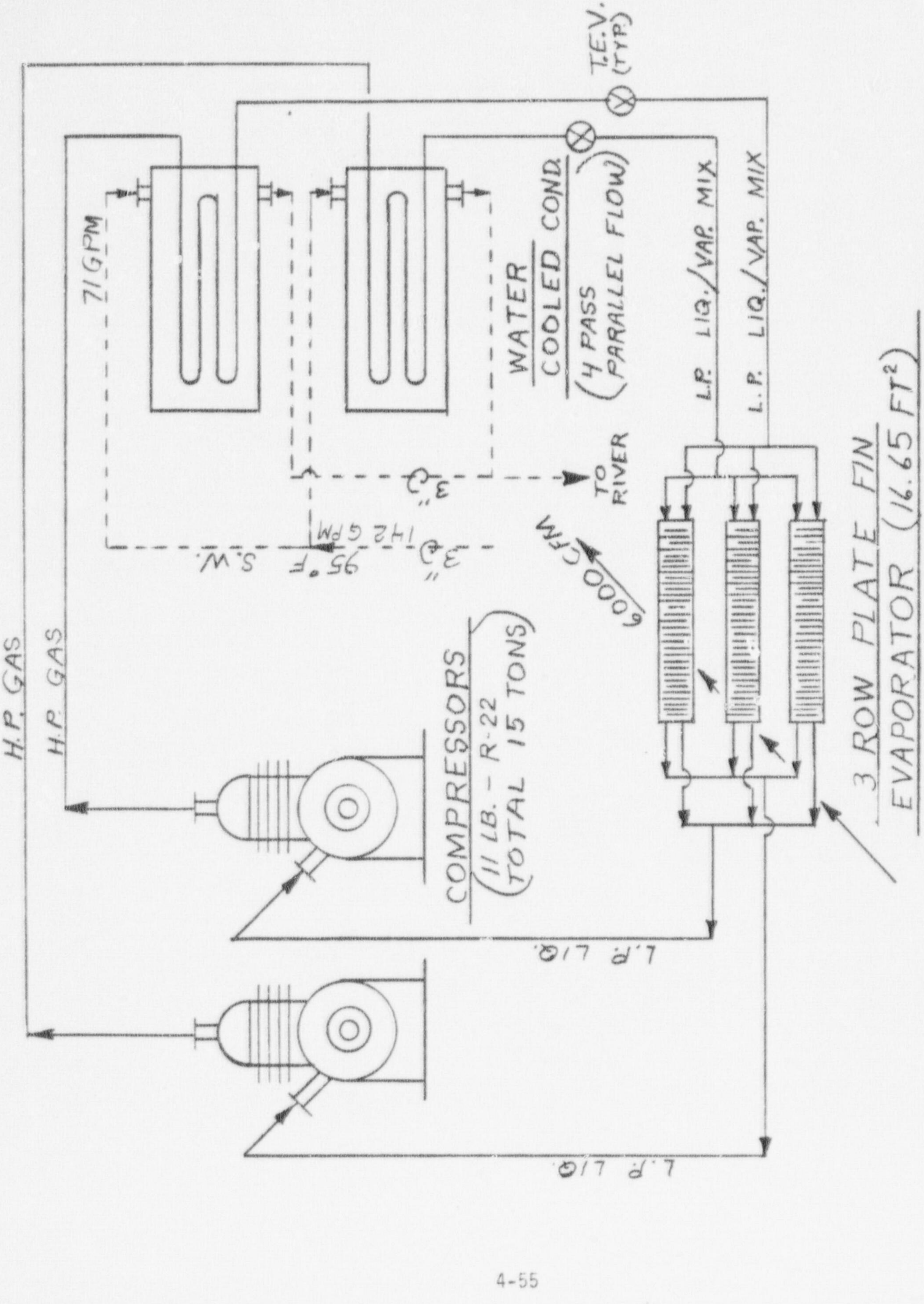

H.P. GAS
H.P. GAS
COMPRESSORS
(11 LB. - R-22
TOTAL 15 TONS)
L.P. LIQ.
L.P. LIQ.
71 GPM
95 °F S.W.
3" Ø 142 GPM
3" Ø
TO RIVER
WATER
COOLED COND.
(4 PASS
PARALLEL FLOW)
T.E.V.
(TYP)
L.P. LIQ./VAP. MIX
L.P. LIQ./VAP. MIX
6000 CFM
3 ROW PLATE FIN
EVAPORATOR (16.65 FT²)

FIGURE 4-8

5.0 LICENSING EVALUATION

5.1 DISCUSSION

The SWS is designed to supply cooling water from the ultimate heat sink (Hudson River) to various heat loads in both the primary and secondary portions of the plant. Provision is made to ensure a continuous flow of cooling water to those systems and components necessary for plant safety during normal operation, or under abnormal and accident conditions.

Sufficient service water cooling must be provided to accident-required plant equipment to ensure equipment operability and adequate cooling performance to remove component and decay heat to support safe plant operation, shutdown, and mitigation of postulated design basis accidents.

Normal, safe plant operation is defined for this evaluation to be the ability to cool equipment whose sudden failure could cause a design basis transient analyzed in FSAR Chapter 14 or whose operability is required to ensure that initial conditions assumed in the accident analyses are not exceeded. This includes cooling the containment atmosphere via the reactor containment fan coolers, cooling the instrument air compressors, cooling the main boiler feed pump lube oil coolers, and various coolers required for turbine/generator operation. In addition, the SWS provides cooling to the CCWS which in turn cools the following equipment needed for normal, safe plant operations: the spent fuel pit heat exchanger, the reactor coolant pumps, the charging pumps, various sample coolers, radiation monitors, and the reactor vessel support cooling blocks. In addition, cooling water from the Hudson River is used to cool the main condenser via the Circulation Water System (CWS). Condenser vacuum must be maintained to prevent turbine trips on low vacuum.

The SWS and the CCWS provide the required cooling to support plant cooldown via the RHR heat exchangers.

The SWS provides cooling to the emergency diesel generators if offsite power is lost.

The SWS and the CCWS provide cooling to accident-required equipment following postulated design basis accidents.

The following report addresses the functions described above.

5.1.1 Normal Operations

The cooling functions required for safe, normal plant operations are discussed below.

5.1.1.1 Reactor Containment Fan Cooling Units

The SWS provides cooling for the reactor containment fan cooling units which provide cooling to maintain the containment temperature during normal operations. They also provide cooling during post-LOCA conditions. There are five RCFC units in the containment building. Each unit consists of a series of filters for removal of entrained moisture, particles, and radioactive iodine and methyl iodide, two banks of cooling coils, a fan assembly, a motor assembly including an enclosed heat exchanger, an enclosure assembly, and four dampers. During normal operation, air is drawn from the containment building through the normal flow inlet dampers, through the cooling coils, and discharged by the fan into a common distribution header.

As discussed in Section 4.1.1, a conservative evaluation of the containment heat loads verses the heat removal capability of the fan coolers, supplied with 95^{o}F service water, indicates that it may not be possible to maintain the containment temperature below 130^{o}F. However, because significant conservatism was used in determining the heat removal capability and the heat loads, it is expected that the containment temperature will actually remaining below 130^{o}F.

Containment temperature is an initial condition assumed in the containment integrity and post-accident EQ profile analyses. The containment integrity analysis assumed an initial containment temperature of 130^{o}F. For the equipment located inside containment, normal containment temperature is considered in determining equipment operability and qualified life. As addressed in Section 1.2, evaluating the effect of higher containment temperatures on equipment qualification was not addressed as part of this effort. Therefore, it is recommended that containment temperature be monitored, and if the fan coolers cannot maintain temperature within the allowable limit of 130^{o}F, action be taken to either increase the heat removal rate by starting additional service water pumps or to reduce the heat load.

As containment temperature will be monitored and adjusted to remain within limits, increasing the service water temperature limit to 95^{o}F, will not impact plant safety in this area.

5.1.1.2 RCFC Fan Motors

The RCFC fan motors are cooled by the SWS and are required to operate during normal plant operations and following design basis accidents to provide air flow over the RCFC cooling coils. The RCFC fan motor heat exchanger is a component of the motor/motor base assembly which is designed to absorb heat due to motor heat losses and external effects under all operating conditions and limit the maximum thermal environment consistent with the motor design.

As discussed in Section 4.1.2, a motor life expectancy calculation was completed which evaluates the performance of the motor cooling coil against conservatively calculated heat loads for the normal and post accident conditions. It was concluded from the calculations that the heat exchanger performance is adequate to maintain motor winding temperatures below a level which will provide for the required motor life. Therefore, an increase in the service water temperature to a maximum of 95^{o}F will not impact the life expectancy of the RCFC motors.

5.1.1.3 RCFC Service Water Return Radiation Monitor

The RCFC service water return radiation monitors serve to detect radiation leakage from the containment into the SWS. Upon detection of radiation in the effluent, each cooler discharge line would be monitored individually and the defective line isolated to prevent the release of the radioactivity to the environment.

As discussed in Section 4.1.3, during normal operations, the monitored flow will remain below temperature limits if the ratio of supply side service water flow to return side service water flow is about 1:1. As temperatures can be maintained below the monitor limits of 160^{o}F, a service water temperature of 95^{o}F will not adversely affect the radiation monitors ability to perform their safety functions.

5.1.1.4 Instrument Air Compressor Cooling

The primary function of the Instrument Air System is to provide clean, oil free and moisture free compressed air to the instruments, controls and other required services in the nuclear plant. The Instrument Air System is designed such that instrument air is available under all operating conditions; all essential systems requiring air during or after an accident are self supporting; all controls fail to a safe position on loss of power; and, after an accident, the air system can be re-established.

To support this design criteria, duplicate compressors, dryers and filters are installed throughout the system. In addition, a backup supply can be taken from the station air system. Those items required for safe operation and safe cooldown are provided with air reserves or gas bottles. These supplies allow the equipment to function in a safe manner until the air supply is reestablished.

As discussed in Section 4.1.5, there is a margin of about 30^{o}F between the normal operating temperature of the compressor cooling water (120^{o}F) and the high temperature trip setpoint (150^{o}F). Considering this margin, adequate cooling to the instrument air compressors will be provided by 95^{o}F service water, provided that the Instrument Air System operating temperatures are monitored as discussed in Section 4.1.5.

5.1.1.5 Main Feed Water Lube Oil Coolers

Two half-size steam-driven main feedwater pumps are provided to increase the pressure of the condensate for delivery through the final stage of feedwater heating and then through the feedwater regulating valves to the steam generators.

Bearing lubrication for the pumps and their turbine drives is provided by an integral lubricating oil system. Cooling of this lubricating oil system is provided by lube oil coolers that are cooled by the essential header of the service water system.

The main feedwater pumps do not perform an accident-required function. Following most postulated accidents, main feedwater flow is isolated and the steam generator inventory is maintained by the auxiliary feedwater system. The loss of normal (main) feedwater, however, is a design basis transient analyzed in FSAR Chapter 14 (FSAR Section 14.1.9.1). The loss of normal feedwater can be initiated by the failure of piping, valves, or pumps. Thus, adequate lube oil cooling should be provided to support main feedwater operation and prevent sudden pump failure during power operation.

If insufficient cooling is provided when service water is above 85^{o}F, service water flow rate to the coolers can be increased, as required, to provide adequate pump cooling. In addition, lube oil temperature is monitored in the control room and alarmed on high oil temperature. Thus, the operators will be aware of a high oil temperature condition, and action to decrease oil temperature can be taken or the plant can be shutdown before pump failure could occur (Reference 5-1).

5.1.1.6 Turbine/Generator Cooling

Service water cooling is provided to several components that are required to support operation of the turbine/generator. The sudden failure of the turbine/generator could lead to a loss of external electrical load transient. The loss of external electrical load transient is analyzed in FSAR Chapter 14.1.8.

SW cooling is supplied to the following equipment which are required to support safe turbine/generator operation:

- o Main turbine oil coolers
- o Generator hydrogen coolers
- o Generator seal oil coolers

Since important turbine/generator parameters are normally monitored during operations at high service water temperatures, and actions can be taken to increase service water flow to the various coolers if required, operation with 95^0F service water is not expected to increase the probability of a loss of load transient (Reference 5-2).

5.1.1.7 CCW Heat Exchanger Cooling

The SWS nonessential header cools the CCWS via the tube-side of the CCW heat exchangers. The CCWS in turn cools other plant equipment required for safe plant operations including the spent fuel pit heat exchangers, reactor coolant pumps, charging pumps, sample coolers, radiation monitors, and the reactor vessel support cooling blocks. The various aspects of safe CCWS operation are addressed below. The cooling provided by the CCWS to the equipment considered essential to safe plant operation is also addressed below.

Safe CCWS operation is defined, for this evaluation, to be the ability to maintain CCWS structural integrity (i.e., system temperatures below design limits and system flow rates below maximum limits), to support CCWS pump operability (i.e., CCW pump operation within NPSH and runout limits), and to provide adequate cooling to system users to support cooled equipment operation as required for safe plant operations.

5.1.1.7.1 CCWS Structural Integrity

CCWS structural integrity is based on maintaining CCW temperatures below acceptable limits, and maintaining CCW flow rates below acceptable maximum limits.

The design temperature of the CCWS is 200^{o}F, except for portions of the system located downstream of the cooling water piping to the RCP thermal barriers which were designed based on the RCS design temperature of 650^{o}F. This is well above the CCW temperatures that must be maintained to support system cooling functions. As such, structural integrity will not be jeopardized, during normal operations, due to CCW temperature.

To compensate for the higher SWS temperature, component flows were generally increased to ensure adequate equipment cooling. As component flows are increased, the fluid velocity of the cooling water in the system piping also increases. Maximum flow rates were evaluated to determine the effect on piping erosion and flow induced tube vibration in the heat exchangers and coolers.

In general, the carbon steel CCWS piping was sized to maintain fluid velocities at or below 15 feet per second. This velocity limit was selected so that system piping would not be the limiting hydraulic resistance of the network. With this approach, component throttle valves could be used to established required system flows. The velocity limit combined with the material selection ensures adequate erosion protection.

A review of the piping design identified four areas where fluid velocities could potentially exceed 15 feet per second. The results of this review are presented in Section 3.1.2.4. CCWS structural integrity will be maintained provided the requirement for monitoring, as defined in Section 6.1, is met.

The mechanical integrity of the various coolers and heat exchangers must be assured to prevent cooler failure and subsequent leakage from the CCWS. This structural integrity is based on (1) maximum flow rates through the coolers and heat exchangers remaining below acceptable limits that are based on tube vibration and tube erosion criteria, and (2) CCW temperatures remaining below design temperature limits that are based on stress criteria.

Most of the coolers and heat exchangers are of the shell and tube design. Typically, tube side flow is limited by erosion of the tubes, which is a function of the flow velocity and tube material. Section 4.2.1 addresses flow induced tube vibration limits. Two heat exchangers were identified as exceeding the original design flows. Additional evaluations were performed and showed that the higher maximum flow rates would not cause excessive tube vibration. As stated in Sections 4.2.2.12 through 4.2.2.14, three coolers were not be evaluated for this report. Provided that these three coolers are evaluated and found to be acceptable, as required in Section 6, CCWS structural integrity will be maintained.

Structural integrity of the CCWS is not jeopardized due to 95^{O}F SWS inlet temperature, since system temperatures are well below design temperatures.

5.1.1.7.2 CCW Pump Operability

CCW pump operability is based on maintaining pump flow rate below runout and providing adequate NPSH. The most limiting condition for pump operation will be during post-LOCA recirculation, since CCW temperatures are maximized and only one CCW pump may be operable. As shown in Section 3.1.1.2, adequate runout protection and NPSH is available during this limiting condition. Since power operations are not as limiting, adequate protection is available.

5.1.1.7.3 Spent Fuel Pit Cooling

CCW cooling is provided to the SFP heat exchanger to remove decay heat generated by spent fuel assemblies in storage. Normally, approximately one-third of the fuel assemblies from the previous core are placed in the SFP during each refueling. The SFP temperature is dependent on the CCW flow to the SFP heat exchanger, the heat rejection capability of the system, and the amount of heat generated by the spent fuel assemblies. The SFP decay heat load decreases with time due to radioactive decay. The design temperature of the SFP cooling system is 200^{O}F.

Section 3.3.1 calculates maximum SFP temperatures with 30 days decay and previous fuel discharges. The maximum calculated temperatures are evaluated to be acceptable, since they are below the concrete design temperature of 150^{O}F.

5.1.1.7.4 Reactor Coolant Pump Cooling

The CCW provides cooling to the RCP thermal barriers and the motor upper and lower bearing lube oil coolers.

The loss of reactor coolant flow is analyzed in FSAR Chapter 14.1.6. Loss of reactor coolant flow may result from a mechanical or electrical failure in one or more RCPs. In addition, the sudden seizure of a reactor coolant pump rotor is analyzed in FSAR Chapter 14.1.6.5.

The RCP thermal barriers cool the controlled seal leakage to prevent the seals from exceeding design temperatures. The thermal barriers provide backup to seal injection, provided by the charging pumps, which is the normal means of cooling the seals. Section 4.2.2.5.1 states that adequate cooling to the thermal barriers is provided to maintain seal integrity if seal injection is lost up to a 105^{O}F CCWS supply temperature. As discussed in Section 6.1, two CCW pumps are required to be in operation when CCWS supply temperature reaches 105^{O}F. With this action, adequate cooling will be provided to the RCP thermal barriers.

Cooling water to the RCP motor upper and lower bearings is provided to maintain the bearing temperatures within their design limits. As discussed in FSAR Chapter 4.2.2, a complete loss of bearing lubrication will not cause a sudden seizure of the reactor coolant pump. Therefore, increasing the service water temperature to 95°F is not expected to increase the probability of a loss of reactor coolant flow transient.

As addressed in Sections 4.2.2.5.2 and 4.2.2.3, adequate cooling is provided to the motor upper and lower bearings with a CCWS supply temperature up to 105°F. Section 6.1 states the requirement that two CCW pumps be in operation when CCWS supply temperature reaches 105°F. With this action, adequate cooling will be provided to the RCP motor upper and lower bearings.

A potential problem with two CCW pumps in operation is exceeding the maximum recommended flowrates to either the upper or lower bearings. As addressed in Sections 4.2.2.5.2 and 4.2.2.5.3, if the flow limit is exceeded, actions can be taken to open one or two flow paths to the shell side of the RHR heat exchanger to decrease flow to the bearings.

5.1.1.7.5 Charging Pump Cooling

The positive displacement charging pumps are not used to mitigate design basis accidents but are used during plant operations to provide CVCS charging functions. These include providing seal injection to the RCPs, controlling reactor coolant chemistry, inventory, and boron concentration.

CCW cooling is provided to the charging pump Gyrol drive cooler and lube oil cooler. An adequate cooling water supply is needed to prevent the oil temperatures in the Gyrol drive and pump power frame from increasing to the point of oil breakdown and subsequent bearing failure.

As discussed in Section 4.2.2.4, adequate cooling water is provided to the charging pumps, and increasing the service water temperature to 95°F will not have an adverse effect on the safe operation of the charging pumps.

5.1.1.7.6 Sample Coolers

A sampling system is provided for the analysis of liquid and gaseous samples obtained during normal and post-accident conditions according to the requirements of NUREG-0737, Item II.B.3. Sample coolers are provided where required to cool the sample to acceptable temperatures for processing. The CCWS provides cooling to the pressurizer steam space and liquid space sample coolers, the reactor coolant sample coolers, and the steam generator blowdown sample coolers.

Sampling capability is required during normal and post-accident operations. Sampling during post-LOCA operation, however, will be performed from the ECCS recirculation flow path, which does not require cooling. Therefore, CCWS sample cooling is only required during normal and abnormal modes of operation.

As discussed in Section 4.2.2.7, adequate cooling is provided to these coolers to support their functions. Thus, increasing the service water temperature to 95^{O}F will not adversely affect the ability to sample primary and secondary coolant systems.

5.1.1.7.7 Reactor Vessel Support Cooling Blocks

The reactor vessel support cooling blocks cool the concrete which supports the reactor vessel. This prevents the concrete temperature from increasing beyond design limits due to the conduction of heat from the reactor vessel nozzles.

As discussed in Section 4.2.2.6, adequate cooling is provided during normal operations to maintain concrete temperatures within limits. Thus, a service water temperature of 95^{O}F will not have an adverse effect on the safe operation of the reactor vessel support cooling blocks.

5.1.1.7.8 Radiation Monitors

The CCWS provides cooling to radiation monitors. These monitors are important as operational tools that allow the detection of potential loss of fission product barriers. The following radiation monitors are cooled by the CCWS:

- o CCWS radiation monitors, which detect leakage from the RCS or RHRS into the CCWS
- o Gross failed fuel detector, which monitors the delayed neutron activity in the RCS to detect failed fuel
- o Steam generator blowdown radiation monitor, which detects primary to secondary leakage through the steam generator tubes
- o Auxiliary condensate radiation monitor

As addressed in Sections 3.1.2.6 and 4.2.2.12 through 4.2.2.14, the cooling requirements for these monitors are met with the 95^{o}F service water.

5.1.1.8 Main Condenser Cooling via the CWS

Cooling water from the UHS cools the main condenser via the Circulating Water System (CWS). Increasing the cooling water temperature to the condenser coolers could decrease condenser vacuum. The turbine/generator is automatically tripped on low condenser vacuum. Turbine trip will cause a loss of external electrical load transient which is analyzed in FSAR Chapter 14.1.8.

Condenser vacuum may be affected by increasing UHS temperatures, so it is monitored, and appropriate actions can be taken to maintain acceptable levels (References 5-2 and 5-3). With actions taken to maintain condenser vacuum, the probability of a turbine trip/loss of load transient is not expected to be increased.

5.1.1.9 RHR Performance During Plant Cooldown

The primary function of the RHRS is to transfer heat energy from and the RCS to the CCWS via the RHR heat exchangers during the second phase of plant cooldown. As discussed in Section 3.2.1, the RHRS was evaluated to determine the impact of higher river water temperatures on the ability of the system to cooldown the plant.

Evaluations to determine the RHRS normal plant cooldown capability showed that with the valves in their current positions, CCWS flow to the RHR heat exchangers is inadequate to achieve required cooldown rates. As addressed in Section 3.2.1.4.1, the CCW flow control valves, 820A and 820B, can be repositioned to allow for an adequate plant cooldown rate. Therefore, by increasing CCWS flow through the RHR heat exchangers, normal plant cooldown capability can be achieved with the 95^{O}F service water temperature.

5.1.2 Cooling Performance During Abnormal Conditions

SWS and CCW cooling is required to support safe plant shutdown under abnormal plant conditions including loss-of-offsite power and following postulated plant fires.

5.1.2.1 Loss-of-Offsite Power

The loss of all AC power to the station auxiliaries is analyzed in FSAR Chapter 14.1.12. This event is mitigated by starting the emergency diesel generators and restoring component cooling water flow to the RCP thermal barriers. Thus, the service water system must supply adequate cooling to the emergency diesel generators to support their continued operations, and also to the CCWS to provide adequate cooling to the RCP thermal barriers (lube oil cooling is not required as the RCPs will not be running).
As discussed in Section 4.1.4, adequate service water cooling is provided to the diesel generator heat exchangers to support diesel generator operation following a loss-of-offsite power for SWS temperatures up to 95^{O}F. In addition, CCW cooling flow to the RCP thermal barriers is

adequate to ensure pump seal integrity. Therefore, safe plant shutdown following a loss-of-offsite power is supported with a service water temperature of 95°F.

5.1.2.2 Safe Shutdown Following Postulated Plant Fires

The safe shutdown capability following postulated plant fires is discussed in Section 3.2.1.4.2. For this evaluation, only equipment capable of being powered by the diesel generator are considered. Based on the analysis, the plant can achieve cold shutdown within the 72 hour requirement provided the following conditions exist:

- Total CCWS flow is greater than or equal to 4500 gpm
- CCWS flow greater than or equal to 3500 gpm is directed to the one operable RHR heat exchanger
- RHRS cooling is initiated at approximately 29 hours after plant shutdown

Therefore, the Appendix R cooldown requirements can be met with 95°F service water.

5.1.3 Cooling Following Design Basis Accidents

The SWS and CCWS are required to provide cooling to accident-required equipment following design basis accidents. In particular, the SWS provides cooling to the RCFCs and the RCFC motor coolers, the instrument air compressors, the diesel generators, and the CCWS heat exchangers. The CCWS, in turn, provides cooling to the SI recirculation pumps, the SI pumps, the RHR heat exchangers, and the RHR pumps (if required as a backup to the recirculation pumps).

5.1.3.1 Reactor Containment Fan Coolers

The RCFCs transfer the heat discharged from the RCS into the containment to the SWS and therefore the ultimate heat sink. This containment heat removal is required to limit post-accident pressure and temperature within containment design limits and thus maintain containment integrity. During the post-LOCA operating mode, the RCFCs also provide filtration functions by passing a portion of the air-steam flow through the filtration train, then mixing it with unfiltered air before it passes through the cooling coils.

As discussed in Section 4.1.1, the RCFCs will operate satisfactorily with 95°F service water. The Containment Margin Improvement Analysis for Indian Point Unit 3 (Reference 5-6) notes that the heat removal capability of the containment cooling systems is sufficient to absorb the energy discharges and still keep the maximum calculated pressure below the design pressure.

5.1.3.2 RCFC Fan Motors

The RCFC fan motors are cooled by the SWS and are required to operate following design basis accidents to provide air flow over the RCFC cooling coils. The RCFC fan motor heat exchanger is a component of the motor/motor base assembly which is designed to absorb heat due to motor heat losses and external effects under all operating conditions and limit the maximum thermal environment consistent with the motor design.

As discussed in Section 4.1.2, a motor life expectancy calculation was completed which evaluates the performance of the motor cooling coil against conservatively calculated heat loads for the normal and post accident conditions. It was concluded from the calculations that the heat exchanger performance is adequate to maintain motor winding temperatures below a level which will provide for the required motor life. Therefore, an increase in the service water temperature to a maximum of 95°F will not significantly impact the life expectancy of the RCFC motors.

5.1.3.3 RCFC Service Water Return Radiation Monitor

The RCFC service water return radiation monitors serve to detect radiation leakage from the containment into the SWS. Upon detection of radiation in the effluent, each cooler discharge line would be monitored individually and the defective line isolated to prevent the release of the radioactivity to the environment.

As discussed in Section 4.1.3, the monitored flow will remain below temperature limits if the ratio of supply side service water flow to return side service water flow is about 13:1. As temperatures can be maintained below the monitor limits of 160°F, a service water temperature of 95°F will not adversely affect the radiation monitors ability to perform their safety functions.

5.1.3.4 Instrument Air Compressors

The instrument air compressors are restarted after cooling water and electrical power are established following an accident. The cooling water requirements to support instrument air compressor operation following an accident are similar to those needed during normal operations. As discussed in Section 4.1.5, adequate service water cooling is provided to support air compressor operation following a design basis accident. Thus, a service water temperature of 95°F will not prevent the Instrument Air System from performing its post-accident functions.

5.1.3.5 CCWS Cooling

The thermal capacity of the CCWS provides a heat sink for the SI, RHR and recirculation pumps during ECCS injection. During this mode, the auxiliary cooling pumps circulate CCW through the SI pump coolers and the recirculation pump motor coolers to provide cooling. The CCW pumps, however, are not started following a loss-of-offsite power, and would not be running following the early stages of the design basis LOCA. Therefore, the CCWS will absorb the heat and slowly heatup until a CCW pump is started during the recirculation phase.

The SWS provides cooling to the CCWS during the recirculation phase following a design basis LOCA. The CCWS in turn, cools the recirculation pumps, the safety injection pumps, the RHR pumps (if required as a backup to the recirculation pumps), and the RHR heat exchangers.

5.1.3.5.1 CCWS Performance

CCWS operability during post-LOCA recirculation is affected by the system flow rates and temperatures. CCW temperature is based on the heat being input into the system, primarily from the containment sump water via the RHR heat exchangers, and the heat that can be rejected to the SWS via the CCW heat exchangers.

The CCWS recirculation evaluation presented in Section 3.1.2.1, indicates that CCW temperature exiting the RHR heat exchangers may exceed the 200^{o}F system design temperature. Although this maximum calculated temperature is higher than the design temperature of the RHR heat exchanger shell-side and the system, the temperature is evaluated to be acceptable.

As discussed in Section 3.1.2.3, CCW pump NPSH and runout are acceptable and pump motor performance is adequate.

The evaluation discussed in Section 3.1.2.4 indicates that CCW flows at the CCW pump discharge may exceed the maximum limits based on erosion concerns. The potential for pipe erosion is not considered to be a significant concern during post-LOCA operation since CCW flow rates can be reduced after the initial phase of operation and CCW pump duty can be switched between pumps during long-term operations.

The ability of the CCWS to provide adequate cooling to safety-related equipment is addressed below.

5.1.3.5.2 SI Recirculation Pump Cooling

The SI recirculation pump motors are totally enclosed water to air cooled motors. The motor exhaust air is cooled by heat exchangers and recirculated to the motor air intakes in an enclosed system.

As discussed in Section 4.2.2.1, increased CCW supply temperature will result in increased stator winding and bearing temperatures. These motors were originally qualified for a containment ambient temperature of 324°F. This qualification demonstrated that the stator winding and bearing temperatures were well within acceptable limits with the ambient temperature of 324°F and various component cooling water temperatures. Maximum predicted containment temperature for Indian Point Unit 3 is less than 324°F and is therefore acceptable for this component.

The stator winding temperature is expected to remain within the maximum allowable temperature limit for Class F insulation systems. Thus no abnormal insulation degradation is expected to occur and there will be no reduction of the motor qualified life. The motor bearing temperatures are predominantly dependent upon the ambient temperature and not the component cooling water temperature.

The test results for the ambient temperature of 324°F are bounding for the actual ambient temperature in conjunction with the increased component cooling water temperature. Therefore, the recirculation pump motors will remain operable for the component cooling water temperatures experienced during the post-LOCA recirculation phase. Thus, 95°F service water does not have an adverse effect on the ability of the recirculation pumps to perform their safety function.

5.1.3.5.3 Safety Injection Pump Cooling

The SI pumps each contain two mechanical seal coolers, two mechanical seal jacket coolers and a lube oil cooler which are serviced by CCW through a common header. The mechanical seals originally provided are qualified for operation at temperatures up to 300°F. The mechanical seal coolers are intended to maintain temperatures in the mechanical seal chambers within limits that will prevent abnormal seal wear. The lube oil cooler is required to maintain the oil temperature at a level which will provide adequate lubrication to the bearings and prevent accelerated viscosity breakdown.

As discussed in Section 4.2.2.2, the effect of elevated temperatures on the seal would be an increase in seal wear and a reduction in seal life. Tests performed by the seal manufacturer with 300^{0}F seal cavity temperatures and no seal cooling resulted in only minor wear to the seals. The seal temperature conditions posed here are much less severe, especially since there will be cooling of the seal cavity from the seal coolers. Consequently, it was determined that the post-LOCA recirculation conditions will have little effect in reducing seal life expectancy, compared to operation with 85^{0}F SWS temperature.

The safety injection pumps utilize a pressurized lubrication system which provides oil to the two shaft journal bearings and a thrust bearing. The hot oil leaving the bearings is drained to a 3 gallon reservoir. This reservoir is the source of oil for the lube oil pump which supplies oil through the lube oil cooler to the pump bearings.

Increased CCW temperature will result in increased oil temperatures at both the inlet and outlet of the pump bearings. From Section 3.1.1.6.5, the maximum CCW supply temperature to the SI pump coolers occurs at the initial switchover to recirculation. This temperature decreases as decay heat levels decrease with time. Based upon the results of a thermal evaluation of the lube oil system, it has been determined that the high peak temperatures are acceptable for this limited period of operation.

5.1.3.5.4 RHR Pump Cooling

The RHR pumps operate during the LOCA injection phase. In addition, the RHR pumps provide a backup to the recirculation pumps during post-LOCA ECCS recirculation.

The RHR pump is equipped with a shell and tube mechanical seal cooler as well as a jacket cooler, similar to that used on the HHSI pump, which are serviced by CCW. The mechanical seal coolers are intended to maintain temperature in the mechanical seal chamber within limits that will prevent abnormal seal wear.

As addressed in Section 4.2.2.3, the RHR pump mechanical seals will be subjected to a peak post-LOCA pump suction temperature that is reduced with time, and a peak CCW temperature that is also reduced with time. These peak temperatures are bounded by the manufacturer's test which qualified the seal for 300^{O}F seal chamber temperatures.

Therefore, it is concluded that the CCW cooling water temperatures during post-LOCA injection and recirculation will have an insignificant effect on the mechanical seal life.

5.1.3.5.5 RHR Heat Exchanger Cooling

During post-LOCA recirculation, the RHR heat exchangers are used to cool the recirculated sump fluid before it is returned to the RCS. As discussed in Section 3.2.2, sufficient CCW cooling is provided to maintain the recirculated emergency core coolant subcooled.

In addition, cooling provided by the RHR heat exchangers, removes heat from the containment via the containment spray system and from the containment sump. As discussed in Reference 5-6, the cooling provided by the RHR heat exchanger, in conjunction with the cooling provided by the RCFCs, will prevent the containment pressure from exceeding design limits due to core boiloff during recirculation. Further, the combined heat removal capability of the RHR heat exchangers and the RCFCs will maintain containment temperature below the acceptable equipment qualification (EQ) envelope even with a service water temperature of 95^{O}F.

5.2 CONTAINMENT INTEGRITY ANALYSIS

Westinghouse recently re-evaluated the containment integrity analyses in support of the Indian Point Unit 3 effort to determine the impact of increasing the SWS maximum inlet temperature to 95°F (Reference 5-6).

During the recirculation mode of safety injection, the containment recirculation sump water is cooled by the RHR system. Since cooling for the RHRS comes ultimately from the SWS, through the CCWS, the increased SWS temperature impacts the results of the containment integrity analyses.

The purpose of the containment integrity LOCA analyses is to demonstrate the acceptability of the containment safeguards systems to mitigate the consequences of a hypothetical rupture of the main RCS pipe. The impact of LOCA mass and energy discharges on containment pressure was addressed to ensure that the containment pressure remains below its design pressure of 47 psig and to assure that the pressure is rapidly reduced to 50% of the peak in a period of 24 hours. Due to the extended mass and energy discharges associated with a large break LOCA, the containment must also be capable of maintaining the long-term temperature response of the containment to values that are less than the long-term equipment qualification temperature envelope.

The Indian Point Unit 3 containment structure has a design pressure of 47 psig. The limiting design basis LOCA for containment design is a RCS double-ended rupture; this accident results in the highest containment pressure after a LOCA. The results of the analysis show that the maximum calculated containment pressure for the double-ended pump suction minimum safeguards case is 39.8 psig and 40.3 psig for the double-ended hot leg break case. A core power level of 3025 MWt was used.

Operation of minimum ECCS equipment and failure of one diesel generator was assumed which resulted in minimum containment safeguards of three fan coolers and one containment spray pump operating. The containment model also included an initial containment temperature of 130°F and a 95°F SWS temperature.

The purpose of the containment integrity MSLB analysis is to demonstrate the acceptability of the containment safeguards systems to mitigate the consequences of a hypothetical rupture of a main steam line pipe. The impact of steam line break mass and energy discharges on containment pressure was addressed to ensure the containment pressure remains below its design pressure of 47 psig. The worst case secondary system pipe rupture has also been analyzed to determine containment integrity. The calculated containment pressure for the MSLB event is 42.42 psig.

The calculated pressure for both design basis events is below the 47 psig design value. Reference 5-4 discusses the containment integrity analysis for Indian Point Unit 3. The model discussed in Reference 5-5 was used for the mass and energy release calculation. The COCO computer program, Reference 5-6, was used for the containment response.

REFERENCES

5-1 NYPA Procedure ARP-6, "Alarm Response Procedure for Panel SCF, Condensate & Boiler Feed"

5-2 NYPA Procedure ARP-8, "Alarm Response Procedure for Panel SEF, Turbine Startup Panel"

5-3 NYPA Procedure ARP-7, "Alarm Response Procedure for Panel SDF, Turbine Recorder"

5-4 Westinghouse topical report, WCAP-12269, "Containment Margin Improvement Analysis for Indian Point Unit 3," May 1989

5-5 Westinghouse topical report, WCAP-10325-A, "Westinghouse LOCA Mass and Energy Release Model for containment Design - March 1979 Version," May 1983

5-6 Westinghouse topical report, WCAP-8326, "Containment Pressure Analysis Code (COCO)," July 1974

6.0 CONCLUSIONS

Provided below are conclusions and recommendations that have been developed as part of this project. This information is presented below on a subject basis.

6.1 ACS PERFORMANCE

Provided below are specific requirements for the ACS:

1. To be consistent with the methodology used to evaluate system performance (Section 3.1.1.2), the CCWS system operating procedure should be updated to reflect the throttle valve positions defined in ENG-366, Revision 0. This procedure will ensure that the CCWS throttle valves are properly aligned.

2. As discussed in Section 3.1.1.5.1, system operation should be limited to no more than two CCW pumps during power operation. Operation with all three CCW pumps should be avoided due to component vibration and erosion concerns. System operating procedures should be revised to reflect this concern.

3. As discussed in Section 3.1.2.3, the cooling water flow path to the nonregenerative heat exchanger is required to be isolated prior to the start of a CCW pump during the switchover to recirculation. This change is needed to ensure adequate CCW pump runout protection and NPSH with a small-break LOCA.

4. To be consistent with the initial assumptions used to evaluate the heatup of the CCWS during the injection phase of a LOCA with Blackout (See Section 3.1.2.5), the CCWS supply temperature is required to be limited to less than or equal to 110^{o}F during plant Startup and Power Operation.

5. As noted in Section 3.1.2.4, operation with one or two CCW pumps can result in fluid velocities which are greater than the maximum specified in the original piping design basis (15 feet per second). Velocities greater than this maximum have the potential for long-term erosion and/or pipe wall thinning. To address this concern, a monitoring program is required to be instituted for the following piping:

- The 1 inch supply and return piping to the gross failed fuel detector unit
- The 8 inch supply and return piping to the SFP heat exchanger
- The 10 inch piping at the CCW pump discharge
- The 14 inch inlet and outlet piping to the CCW heat exchangers

6. As discussed in Sections 3.1.1.6.5 and 4.2.2.1, at least one ACC pump on each CCWS header should be left operating during the recirculation phase of a LOCA to ensure adequate cooling to the SI recirculation pump motor coolers.

7. As discussed in Section 4.2.2.5, a second CCW pump is required to be started when CCW heat exchanger outlet temperature reaches 105 °F. This is needed to ensure adequate cooling to the RCPs. Following pump start, total cooling flow to each RCP motor bearing coolers should be checked to ensure that flow is less than or equal to 225 gpm. This limit is to prevent long-term erosion. If the flow is greater than 225 gpm, steps must be taken to reduce system flow. This can be accomplished by restoring cooling water flow to isolated users or opening a flow path to a RHR heat exchanger.

8. As discussed in Sections 4.2.2.12 through 4.2.2.14, the gross failed fuel detector cooler, steam generator blowdown sample radiation monitor cooler, and the auxiliary condensate radiation monitor cooler have not been reviewed for maximum flow concerns. The maximum allowable flow to each cooler is required to be reviewed to address long-term operation and mechanical integrity.

6.2 COMPONENT PERFORMANCE

Specific recommendations for components in the CCWS and the SWS are provided below.

6.2.1 SWS Components

The components evaluated in this program are capable of performing their required functions provided the minimum cooling water flows as defined in Section 4.0 can be supplied and the requirements discussed below are addressed.

6.2.1.1 RCFC Service Water Return Radiation Monitor

In a post-accident condition, the ratio of supply-side service water flow versus return-side service water flow into the mixing nozzle will need to be regulated to protect the radiation monitors from excessive service water temperatures. Therefore, NYPA is required to demonstrate that the ratio of return-side flow to supply-side flow is set less than 13:1. This will ensure that the sample temperature is maintained at or below design limits for the radiation monitor.

6.2.1.2 Diesel Generators

EDG jacket water and lube oil temperatures for some modes of operation and various levels of heat exchanger tube plugging are predicted to exceed normal operating temperatures, and may therefore exceed current high temperature alarm setpoints. Therefore, resetting of alarm setpoints, consistent with the maximum recommended operating temperatures of 190^{O}F for the jacket water and 210^{O}F for the lube oil, per References 4-5 and 4-6, should be considered.

6.2.2 CCWS Components

As part of this project, maximum CCW flow have been evaluated to ensure that mechanical integrity is maintained. During plant cooldown when the CCWS throttle valves can be repositioned, cooling water flow to CCWS components should be maintained at or below the maximum allowable flows defined in Table 4-7.

Specific recommendations on a component by component basis are provided below.

6.2.2.1 Charging Pumps

During plant cooldown when the CCWS throttle valves to the RHR heat exchangers may be repositioned, cooling water flow to the Gyrol and lube oil coolers should be maintained at a minimum flow of 85 gpm and 6 gpm, respectively.

6.2.2.2 RCPs

Operation with CCW heat exchanger outlet temperatures greater than 110^{o}F are not recommended for continuous operation. At elevated CCW temperatures, the cooler vendor has indicated that reduced heat transfer on the oil-side of the cooler could occur which would results in elevated bearing temperatures. A high bearing temperature alarm would sound in the CCR to alert of elevated oil temperatures. If CCW inlet temperature to the RCPs exceeds 110^{o}F, the pump vendor recommends that the cooler be inspected during the next refueling outage.

APPENDIX A

CCW PUMP MINIMUM/MAXIMUM PERFORMANCE DATA

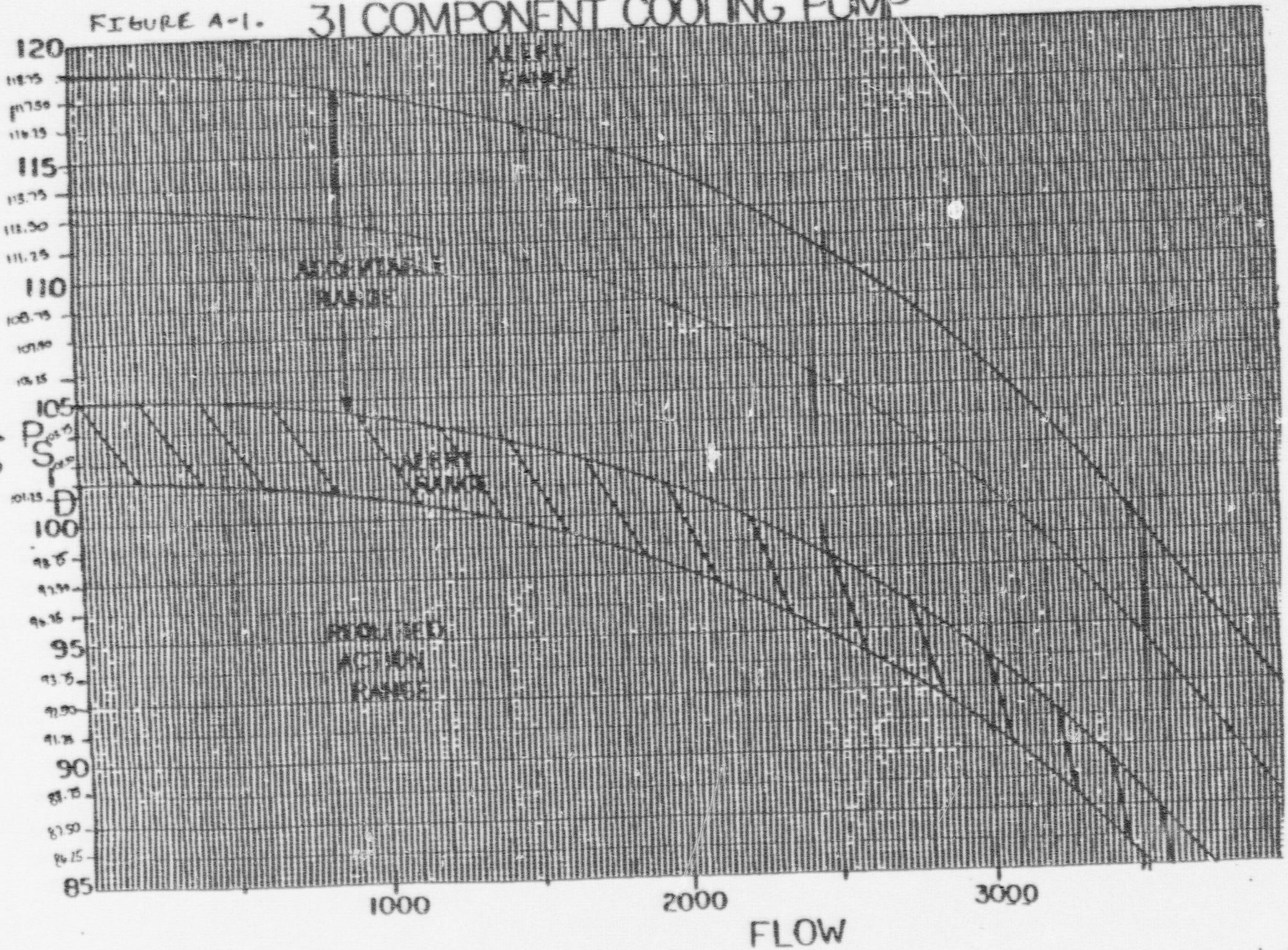
Provided in this appendix is the minimum and maximum pump performance data used in this project for the following sets of pumps:

- o Component Cooling Water
- o Auxiliary Component Cooling Water
- o Safety Injection Circulating Water

For the CCW pumps, the present plant performance acceptance criteria was used to determine the range of allowable pump performance. This data is shown in Figures A-1 through A-3. Since the current range of limits did not extend up to pump runout (5500 gpm), the maximum difference between the pump operability limit and the vendor pump curve was determined over the range presented. This maximum difference was then uniformily applied over the entire vendor pump curve. Provided in Table A-1 is the model assumptions for the CCW pumps.

For the ACC and SI circulating water pumps, seven percent reduction and a 3 percent increase was uniformily applied to the vendor performance curves. Provided in Tables A-2 and A-3 are the model assumptions for these pumps.

FIGURE A-1. 31 COMPONENT COOLING PUMP



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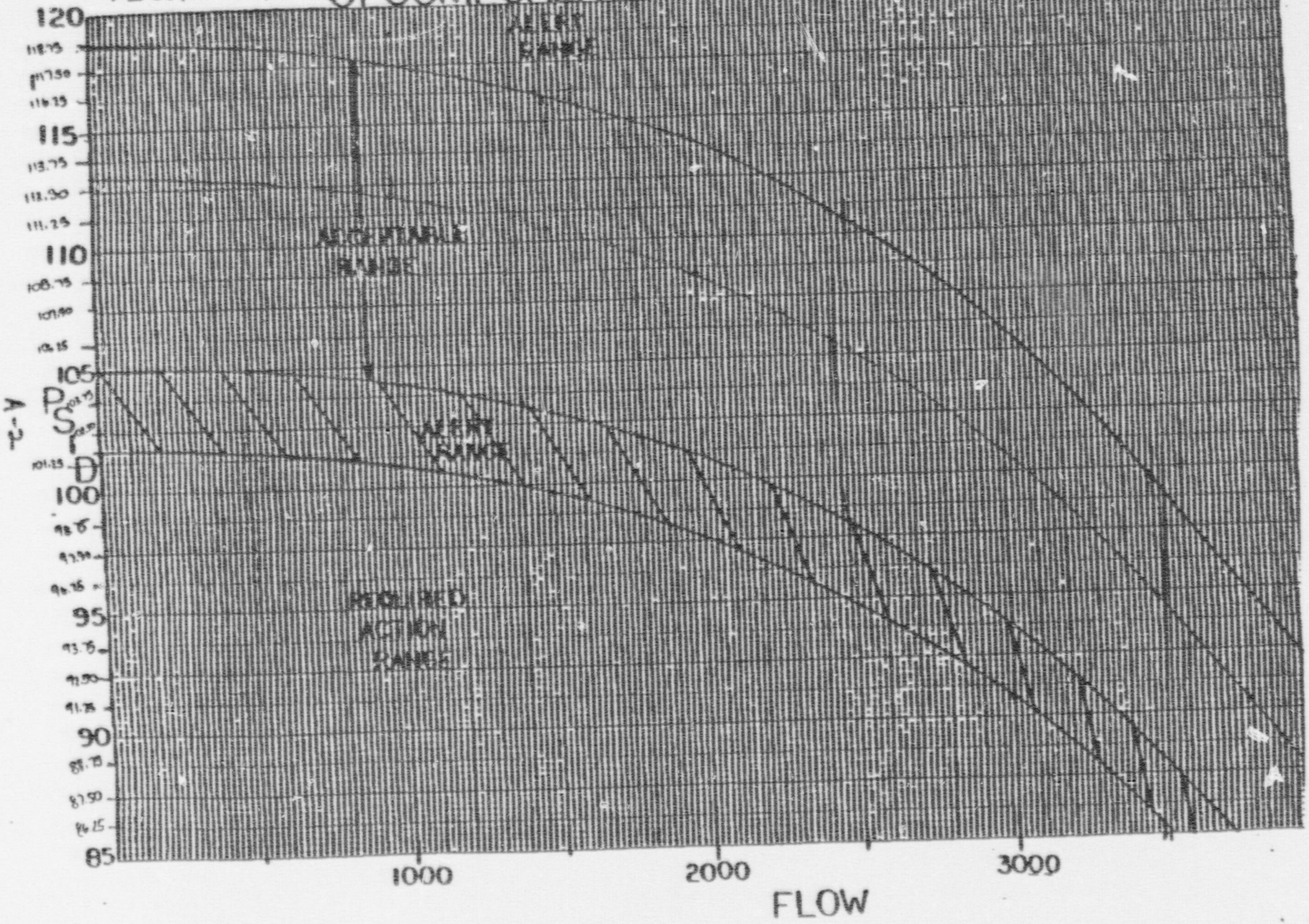

FIGURE A-2.

32 COMPONENT COOLING PUMP

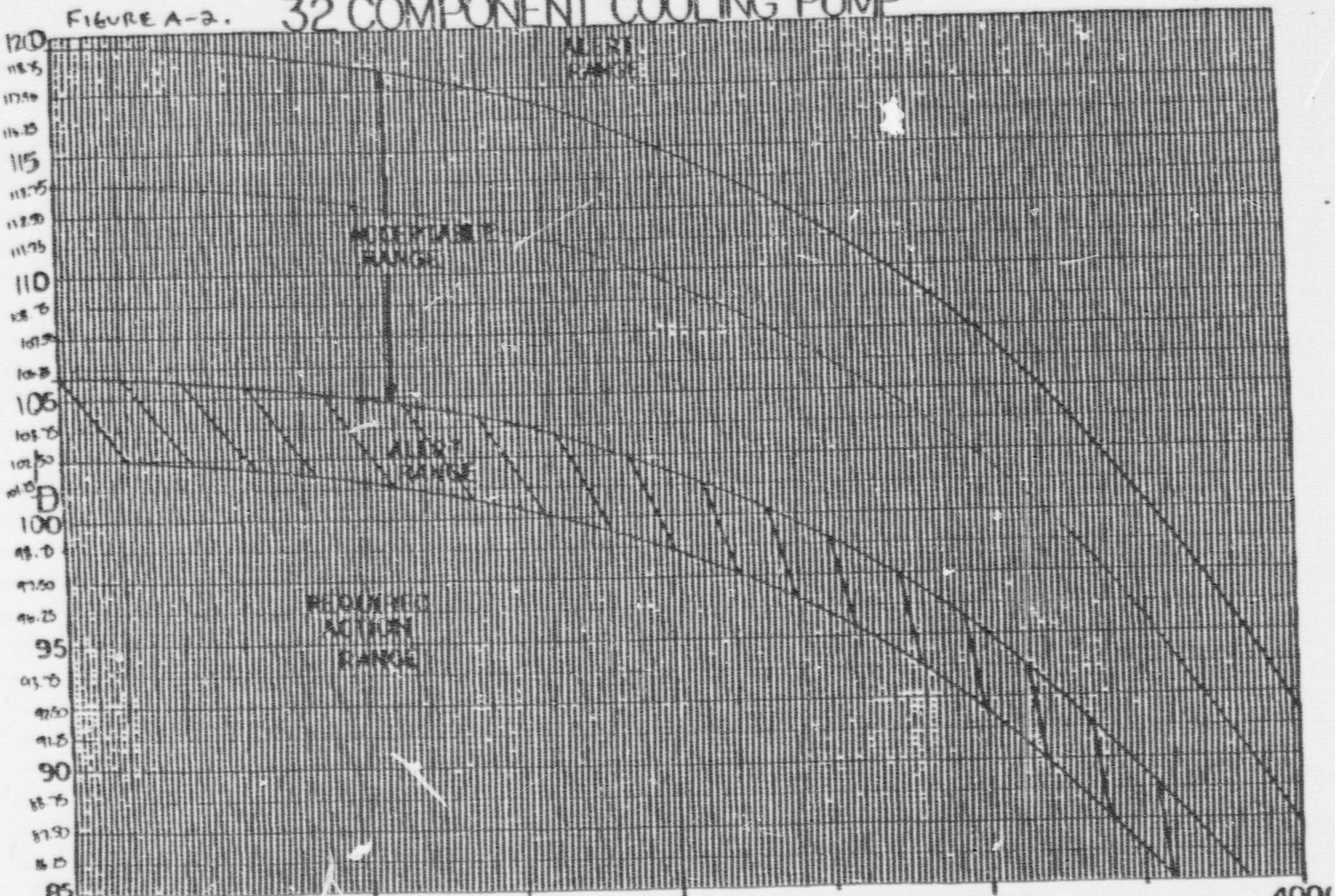

FIGURE A-3. 33 COMPONENT COOLING PUMP

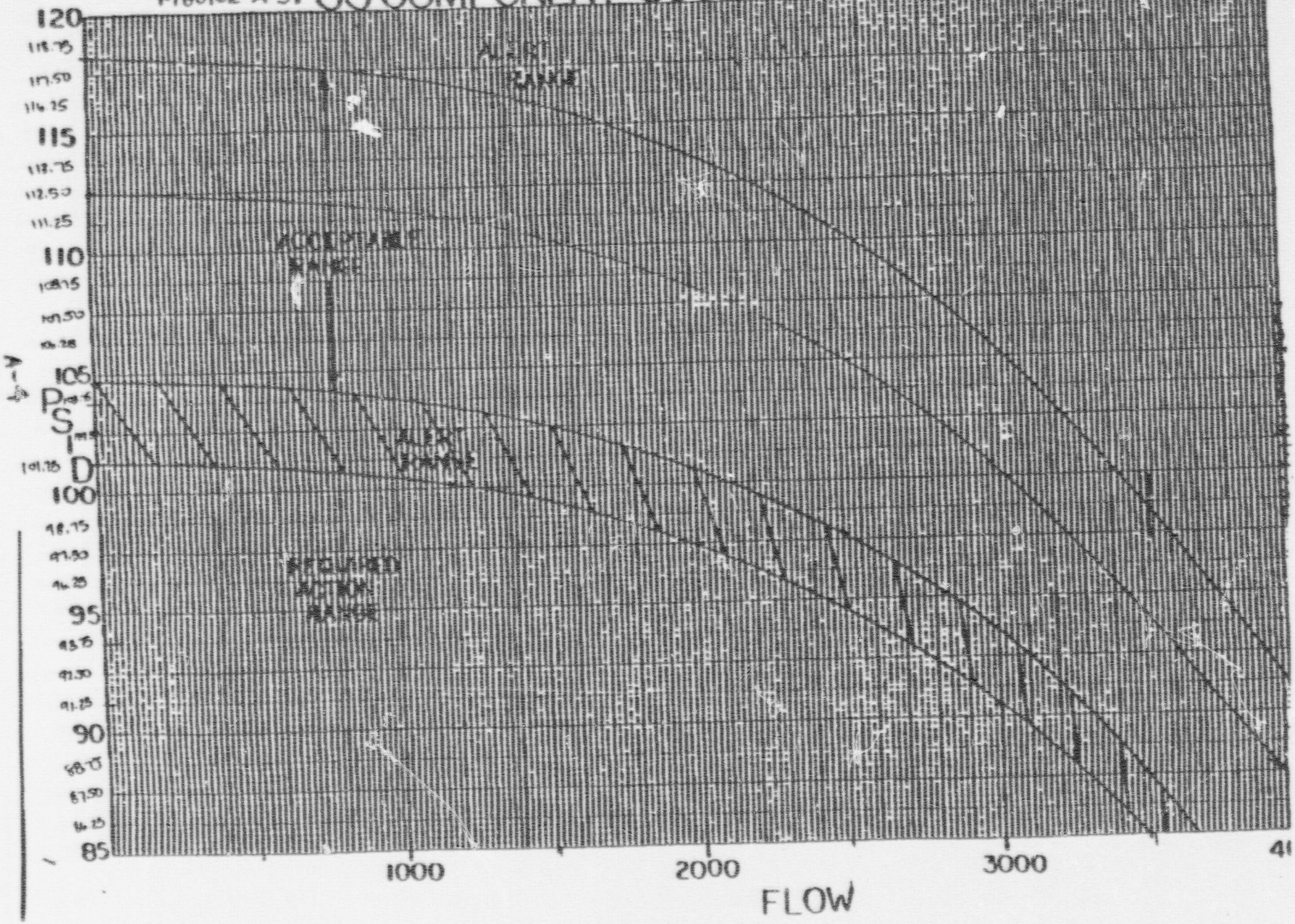

TABLE A-1

INT CCW PUMP CURVE DATA FOR USE IN UHS PROJECT

PUMP 31 PERFORMANCE DATA

VENDOR FLOW (GPM)	VENDOR HEAD (FT)	TEST UP PSID	TEST UP HEAD (FT)	TEST UP PERCENT	TEST LOW PSID	TEST LOW HEAD (FT)	TEST LOW PERCENT	MODEL ASSUMPTION ENHANCED HEAD (FT)	MODEL ASSUMPTION DEGRADED HEAD (FT)
0.0	270.0	118.8	274.3	1.6	105.0	242.6	-10.2	275.4	239.5
1000.0	269.0	117.5	271.4	0.9	104.3	240.8	-10.5	274.4	238.6
1500.0	267.0	116.0	268.0	0.4	103.0	237.9	-10.9	272.3	236.8
2000.0	263.0	114.0	263.3	0.1	101.0	233.3	-11.3	268.3	233.3
2500.0	253.0	111.0	256.4	1.3	98.0	226.4	-10.5	258.1	224.4
3000.0	240.0	106.0	244.9	2.0	93.8	216.6	-9.8	244.8	212.9
3500.0	227.0	99.0	228.7	0.7	88.0	203.3	-10.4	231.5	201.3
4000.0	208.0							212.8	184.5
4500.0	184.0							187.7	163.2
5000.0	153.0							156.1	135.7
5400.0	121.0							123.4	107.9

+2% -11.3%

PUMP 32 PERFORMANCE DATA

VENDOR FLOW (GPM)	VENDOR HEAD (FT)	TEST UP PSID	TEST UP HEAD (FT)	TEST UP PERCENT	TEST LOW PSID	TEST LOW HEAD (FT)	TEST LOW PERCENT	MODEL ASSUMPTION ENHANCED HEAD (FT)	MODEL ASSUMPTION DEGRADED HEAD (FT)
0.0	270.0	119.5	276.0	2.2	106.0	244.9	-9.3	279.5	244.9
1000.0	267.0	118.5	273.7	2.5	105.0	242.6	-9.2	276.3	242.2
1500.0	263.0	116.8	269.7	2.5	103.8	239.7	-8.9	272.2	238.5
2000.0	257.0	115.0	265.7	3.4	102.0	235.6	-8.3	266.0	233.1
2500.0	250.0	111.5	257.6	3.0	99.0	228.7	-8.5	258.8	226.8
3000.0	240.0	107.5	248.3	3.5	95.0	219.5	-8.6	248.4	217.7
3500.0	225.0	100.0	231.0	2.7	89.0	205.6	-8.6	232.9	204.1
4000.0	207.0							214.2	187.7
4500.0	182.0							188.4	165.1
5000.0	150.0							155.3	136.1
5400.0	119.6							123.8	108.5

+3.5% -9.3%

PUMP 33 PERFORMANCE DATA

VENDOR FLOW (GPM)	VENDOR HEAD (FT)	TEST UP PSID	TEST UP HEAD (FT)	TEST UP PERCENT	TEST LOW PSID	TEST LOW HEAD (FT)	TEST LOW PERCENT	MODEL ASSUMPTION ENHANCED HEAD (FT)	MODEL ASSUMPTION DEGRADED HEAD (FT)
0.0	270.0	118.3	273.2	1.2	104.8	242.0	-10.4	275.9	241.9
1000.0	265.0	117.3	270.8	2.2	103.3	238.5	-10.0	270.8	237.4
1500.0	263.0	116.0	268.0	1.9	102.5	236.8	-10.0	268.8	235.6
2000.0	258.0	113.8	262.8	1.8	100.5	232.2	-10.0	263.7	231.2
2500.0	250.0	110.5	255.3	2.1	97.8	225.8	-9.7	255.5	224.0
3000.0	240.0	105.5	243.7	1.5	93.5	216.0	-10.0	245.3	215.0
3500.0	225.0	98.8	228.1	1.4	87.5	202.1	-10.2	230.0	201.6
4000.0	207.0							211.6	185.5
4500.0	184.0							188.0	164.9
5000.0	155.0							158.4	138.9
5400.0	122.2							124.9	109.5

+2.2% -10.4%

TABLE A-2

ACC PUMP PERFORMANCE DATA

Flow (gpm)	Nominal Head (ft)	Max. Head (ft.)	Min. Head (ft.)
		PUMP 31	
0	115	118.45	106.95
20	114	117.42	106
40	113	116.4	105.1
60	108	111.2	100.44
80	100	103.0	93
100	91	93.7	84.6
120	77	79.3	71.6
140	55	56.65	51.15
		PUMP 32	
0	111	114.3	103.2
20	110.5	113.8	102.8
40	110	113.3	102.8
60	108	111.2	100.4
80	101	104	93.9
100	91	93.7	84.6
120	77	79.3	71.6
125	73	75.2	67.9

TABLE A-2 (cont)

ACC PUMP PERFORMANCE DATA

Flow (gpm)	Nominal Head (ft)	Max. Head (ft.)	Min. Head (ft.)
PUMP 33			
0	113	116.4	105.1
20	112	115.4	104.2
40	110	113.3	102.3
60	107	110.2	99.5
80	101	104	93.9
100	90	92.7	83.7
120	76	78.3	70.7
140	69	71.1	64.2
PUMP 34			
0	114	117.42	106
20	113.9	117.32	105.9
40	113	116.4	105.1
60	109	112.3	101.4
80	102	105.1	94.9
100	93	95.8	86.5
120	81	83.4	75.3
140	54	55.6	50.2

TABLE A-3

SI CIRCULATING WATER PUMP PERFORMANCE DATA

Flow (gpm)	Nominal Head (ft)	Max. Head (ft.)	Min. Head (ft.)
0	119	110.7	122.6
10	118	109.7	121.5
20	114	106.0	117.4
30	110	102.3	113.3
40	102	94.9	105.1
50	88	81.8	90.6