Consumers Power

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DOCKET 50-255 - LICENSE DPR-20 - PALISADES PLANT -
ADDITIONAL INFORMATION ON SERVICE WATER SYSTEM TO SUPPORT TECHNICAL SPECIFICATIONS CHANGE REQUESTS

Consumers Power Company submitted Technical Specifications Change Requests on October 20, 1986, entitled "Removal of Containment Air Cooler Fan V4A," and December 2, 1986, entitled "Diesel Fire Pump Operability and Service Water Temperature." The earlier change was supplemented by letter dated November 21, 1986. Our letter of January 28, 1987, provided further information (in Attachment 5) on the service water system as part of the response to the NRC request for additional information dated December 23, 1986. In this latest letter, several service water system issues were left open pending further system flow testing and evaluation.

The service water system flow balance testing has been completed. The test results are provided in Table 1. The testing followed modifications to the service water pump impellers resulting in additional flow and modifications of system valves such that system flows can be balanced to ensure adequate flow to critical components during design basis accident (DBA) conditions. Along with providing adequate flow, determination of the maximum allowable service water temperature for the available service water flow condition was performed to ensure the design heat removal capacity of the components. The methodologies for determination of the allowable service water temperature, for the critical components, have been described in our earlier January 28, 1987, letter, Attachment 5, Item 1, except for the engineered safeguards room. No changes to the earlier evaluations are necessary. The results of the new flow balance testing for the critical components in Table 1 correspond to higher flows than obtained previously. The new testing was conducted with a different service water system configuration, with modified service water pumps and after flow orifices and test gauges were installed for the critical flow parameters. The previous testing of the service water system used installed plant instrumentation which did not have the required accuracy and was not calibrated before and after the test. Table 1 data was obtained using all applicable Quality Assurance requirements for test equipment and verifications.

Except for the engineered safeguards room, the results of the previous evaluations for the critical components justified operation at service water temperatures above the 53°F Technical Specification Change Request limit. Those

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results were 1) for the component cooling water heat exchangers 70.8°F based on 3130 gpm service water flow to the heat exchanger; 2) for the control room coolers 62°F based on a differential pressure of 8 psid across the coolers; 3) for the diesel generators 61°F based on inlet pressure of 15 psig; and 4) for the containment air coolers 75°F based on the 4875 gpm service water flow (no flow is required when operating with one service water pump). These values were based on the previous service water flow test results and are still valid, since the flow parameters from the latest testing have exceeded those from the previous test.

The calculation for determining the service water system required inlet temperature in the post-DBA condition for the engineered safeguards room is described in Attachment 1, Item 1. The results indicate that for the worst case flow, of 109 gpm, (Table 1) to the west engineered safeguards room cooler a service water temperature of less than 58°F is required to keep the room below its 135°F equipment qualification limit. Our intent is to operate with the service water containment outlet valve throttled and therefore, the minimum flow to the cooler will be 142 gpm. The calculation at the lower flow rate and the resultant 58°F provides additional margin to the 53°F Technical Specification Change Request service water temperature limit. This calculation is a complete revision of a previous calculation which had originally provided the basis for December 2, 1986, Technical Specifications Change Request. It should be noted that this new calculation contains several very conservative assumptions which were made to expedite the evaluation. Future calculations will contain more realistic assumptions.

The flow to the component cooling water (CCW) heat exchangers in Table 1 with one service water pump operating and the containment isolation valve closed is 3,130 gpm and 3,150 gpm. These values meet the previous cooling capacity acceptance criteria for 70.8°F service water temperature and are the basis for justification for operation of the CCW heat exchangers above the 53°F change request limit.

An inlet pressure of 15 psig for the diesel generator from previous testing corresponded to its previously evaluated 61°F service water temperature operating limit and was the basis for justification of operation of the diesel generators. During the latest balancing test, the pressure at the diesel was 22 psig when run in a similar configuration to the previous test. The inlet pressure to the diesel was above that for the previous test since the service water pump impellers were backfiled, which raised the pump head versus flow significantly, and the component cooling water heat exchanger temperature control valves were closed.

Since the increase in inlet pressure to the diesel generators is not directly related to increased flow, a temporary orifice to measure flow was installed for the latest tests. The flow through the 1-1 diesel generator was measured at 389 gpm and 383 gpm for the 1-2 diesel generator (Table 1). The diesel vendor was provided the flow through the diesel and has confirmed that the diesel is capable of operation in this configuration for 30 minutes at a corresponding inlet temperature of 80°F. For continuous operation at 80°F, a flow of 490 gpm is required according to the vendor. Twenty minutes is assumed as the operator action time to close the service water containment outlet valve. The vendor documentation provides further justification for operation of the diesel generators.

Previous service water flow balance testing of the control room coolers resulted in a differential pressure of 8 psid across the unit. For the control room cooler, a relation between differential pressure and service water temperature was derived as described in our January 28, 1987 letter Attachment 5, Item 1. This relationship was determined using a conservative linear correlation of flow vs temperature values of 110 gpm at 75°F and 11 gpm at 35°F obtained from Bechtel design documents. This same correlation would require 78 gpm for 62°F service water which was the temperature derived using the previously measured 8 psid which was the basis provided for justification for operation of the control room coolers. The measured differential pressure for the latest flow balancing test was 16 psid, which using the previous derived relationship corresponds to a temperature of 76°F which provides additional margin for justification for operation of the coolers. The flow alignment at the control room coolers was the same as the previous test.

As was noted above, the service water system flow balance testing followed modifications to several components. These modifications were described in our January 28, 1987, letter, Attachment 5, Item 11. They include 1) a modification to the service water air operated temperature control valve on the component cooling water (CCW) heat exchanger to close on a recirculation actuation signal (RAS); 2) backfiling impellers for the three service water pumps to the original design, to provide additional flow; and 3) adding nitrogen backup supplies to the service water control valves to containment to ensure valve operability during a transient. These valves are remotely operated from the control room. The effect of these modifications is that operation of the service water system in the post-DBA condition with loss of offsite power and 1-2 diesel generator failure will be different from that described in our previous correspondence. Instead of requiring that the diesel fire pumps be aligned to the service water system, we will now require operator action to close the service water containment outlet valve. Service water to the containment air coolers is not required if the 1-2 diesel generator is lost. A revision to the previous Technical Specification Change Request is not necessary to incorporate requirements for the service water containment outlet valve operability as the present Technical Specification, Section 3.4.4, applies to the valves directly associated with the service water pumps and requires they meet the same requirements as the service water pumps. Also, since the portion of Technical Specification Change Request requiring diesel fire pump operability is not now required for plant operation with service water at or below 53°F, we request withdrawal of our December 2, 1986, commitment to operate the plant by incorporating the diesel fire pump operability proposed change request as an administrative control. We will, in the near future, evaluate the tested service water system flow rates to critical components to justify operation at a higher service water temperature. At that time, we will determine whether the additional flow provided by a diesel fire pump is required to ensure the DBA heat load requirements for the service water system are met for the higher service water temperatures.

Attachment 1 to this letter provides information that Consumers Power had committed to providing in our January 28, 1986, letter to support the October 20, 1986, and December 2, 1986, Technical Specifications Change Requests.

Attachment 2 provides a summary of the operability of the VHX-4 containment air cooler following removal of one of its seven cooling coils and is pertinent to a commitment made in our October 20, 1986, Technical Specification Change Request to maintain the cooler operable.

Consumers Power also formally withdraws our request to have our November 24, 1980, Technical Specifications Change Request approved at this time. We had asked for approval along with our December 2, 1986 change request since this change also impacted the same section of the Technical Specification. It is understood that additional information is required to support this change request.

Clarifications to the December 2, 1986, Technical Specification Change are requested. In that submittal, we requested existing Section 3.4.1c be deleted and a new 3.4.1c be added. Our discussion of the removal of the old Section 3.4.1c was that it was "..an editorial revision. The same requirements are included in Section 3.4.4." The discussion should have also referenced Sections 3.3.1e and 3.3.1g. In addition, this final paragraph of the Basis, Section 3.4, Page 3-36, should be revised to reference the CCW and shutdown heat exchangers operability as follows:

> Operability of the component cooling and shutdown heat exchangers is specified by Technical Specification 3.3.1e. Limitations have been imposed on the Service Water System inlet temperature. These limitations are required to ensure adequate heat removal occurs for critical service water loads when only one diesel generator is operating.

James L Kuemin

James L Kuemin
Staff Licensing Engineer

CC Administrator, Region III, NRC
NRC Resident Inspector - Palisades

Attachments

TABLE 1

Consumers Power Company
Palisades Plant
Docket 50-255

Additional Information of SWS
To Support Technical Specifications
Change Requests

Results of Service Water Flow Verification
Test No T-216 Completed February 3, 1987

TABLE 1

FLOWS IN GPM

	1 SWP CONT VLV ISOLATED	1 SWP CONT VLV OPEN	1 SWP CONT VLV THROTTLED	1 SWP, 1FP CONT VLV ISOLATED	1 SWP, 1FP CONT VLV OPEN	2 SWP CONT VLV THROTTLED	3 SWP CONT VLV OPEN
Control Room Coolers							
VC-10	91	49	49	108	68	100	119
VC-11	91	59	38	101	68	98	114
ES Room Coolers							
East Room VHX-27A	166	96	117	203	135	196	223
West Room VHX-27B	214	109	142	250	160	243	269
Diesel Generators Coolers							
DG 1-1	601	366	389	>699*	486	>699*	>699*
DG 1-2	621	356	383	>699*	471	>699*	>699*
CCW Heat Exchangers							
E-54A	3,150	2,360	2,400	3,520	2,720	3,520	3,800
E-54B	3,130	2,040	2,100	3,700	2,500	3,560	4,040
Containment Air Coolers							
VHX-4	0	0	0	0	0	0	0
VHX-1,2,3	0	3,862	3,609	0	4,626	5,578	6,234

*699 = Limit of Instrument Range

Pump Discharge Press (psig)	P7B:52	P7B:33	P7B:34	P7B:65 P9B:64	P7B:42 P9B:38	P7A:64.5 P7C:65	P7A:74.5 P7B:75 P7C:76
Cumulative Flows	8,064	9,297	9,227	>9,280	11,234	>14,695	>16,199

ATTACHMENT 1

Consumers Power Company
Palisades Plant
Docket 50-255

Additional Information on SWS
To Support Technical Specifications
Change Requests

Update to Items 1, 2, 3, 8, 10 and 11
Of Consumers Power Company's
January 28, 1987 Letter, Attachment 5

February 25, 1987

5 Pages

OC0287-0014C-NL04

ATTACHMENT 1

<u>Additional Information for Item 1</u>

Consumers Power committed to providing the following information:

- ° The revised calculation for determining the required inlet temperature to the engineered safeguards room coolers in the post-DBA condition.

Refer to Appendix A of this Attachment.

<u>Additional Information for Item 2</u>

Consumers Power committed to providing the following information:

- ° Service water pump data to ensure (when operating a single service water pump) the pump is operating within its capacity.
- ° Determine flow contribution of the diesel fire pumps.
- ° Diesel fire pump discharge pressure and flows for justifying sustained operation in the postulated conditions.
- ° Results of the additional service water system flow tests.

The service water pump was run beyond its design flow (8000 gpm) for approximately 50 minutes during the flow balance testing of the service water system. The pump motor showed no signs of stress as the amperage readings were normal. The pump showed no signs of cavitation, ie, no vibration or noise or loss of head, during the flow balancing test. The highest flow during the test was approximately 9300 gpm. With the service water system operation such that isolation of containment will be operator initiated following the DBA and loss of diesel generator 1-2, the pump will be required to operate at the higher flow rate for only 20 minutes. Twenty minutes is assumed for operator action time to recognize the low service water flow condition and actuate valve closure from the control room. Subsequent to the flow balance testing, the pump head vs flow values have been obtained. These values plotted as a head curve correlate with the head curve taken prior to conducting the flow balancing. This substantiates that the pump was not degraded when operating at the higher flow.

The contribution of the diesel fire pumps with 53°F service water is not necessary. Our intent is to not require the fire pumps be aligned to the service water system as they are not required to attain the flow necessary to provide adequate cooling to the required heat loads. Therefore, no requirements will be placed in the diesel fire pump to operate in a condition which is beyond their design capacity.

The results of the additional service water flow testing are provided in Table 1 and described in the body of this letter.

Additional Information For Item 3

Consumers Power committed to the following information:

- Verify the diesel fire pump setpoint is above the service water discharge pressure.

Again, the fire pumps will not be required to operate in this condition to justify operation with 53°F service water.

Additional Information For Item 8

Consumers Power committed to the following information:

- If diesel generator 1-2 fails during the recirculation phase of the post-LOCA response, describe the corrective actions required and the time restraints involved to prevent elevated temperatures in the engineered safeguards room from damaging essential equipment. No response was provided in our January 28, 1987, letter.

This comment assumes that the previously proposed alignment of the diesel fire pumps to the service water system was necessary to maintain the west engineered safeguards room below 135°F, the equipment design operating temperature limit. However, the modification of service water pump impellers have, along with the modified system operating configuration, resulted in enough flow to the engineered safeguards room cooler from a single service water pump using the revised methodology for calculating the room heat loads, to justify operating with a service water temperature below 58°F (see Item 1). Therefore, it is of no consequence to the safeguards room equipment if failure of the 1-2 diesel generator occurs because the room temperature will be maintained below 135°F with one service water pump operating.

Additional Information For Item 10

Consumers Power committed to the following:

- Determine the cause of the apparent inconsistencies for measured pressure changes across parallel components (0 - 17 psi).

- Determine the cause of the apparent inconsistency in flow measured to the containment air coolers (1222 gpm vs 300 gpm).

The previous service water flow test results showed some apparent inconsistencies in the flow data. As a result, additional instrumentation was added for the most recent testing. The inconsistency in the containment air cooler data was not borne out in the latest test. We conclude the diesel generator pressure difference was due to the pressure drop in the "A" and "B" service water headers. The same system configuration was not tested because of the modifications made to the service water components and the dependence upon closure of the service water containment outlet valve instead of the diesel fire pump alignment. However, we believe the inconsistency noted by the Staff to have resulted from a data recording error in the case of the 1222 gpm listed flow difference for the containment air coolers. The 0-17 psi pressure difference between the pressures at the two diesel generators correlates with the 8-22 psi pressure difference obtained in the latest test using calibrated instruments, with the modified service water pump impellers and modified system operating configuration.

The pressure difference in the headers is due to the flow differences in the "A" and "B" service water headers. The "A" header with the component cooling water heat exchanger and the 1-2 diesel generator consistently has had higher flow rates and lower pressure at the 1-2 diesel generator than the "B" header with the 1-1 diesel generator. Therefore, although the "A" and "B" service water headers are connected upstream of the piping branches to the diesel generators, the flow rates and the pressure head in the headers are not the same. Because of the system configuration, these components should not be considered to be parallel components.

We have reviewed the results of the service water tests and also the component cooling water flow balancing and noted another apparent inconsistency. Differences exist between the old and new service water test data for the engineered safeguards room coolers. In the original testing, the flow data to the east room cooler, VHX-27A, was consistently higher than the west room cooler, VHX-27B, data. Just the opposite is true for the latest test data. For comparable service water pump discharge pressures during both tests, the flow data for the east room cooler is very similar. However, for the west room, the new data consistently exceeds the old data. A repeat test of the west safeguards room cooler produced comparable results in the new system configuration. We are very confident of these latest test results. The new test data, as identified earlier, was taken with calibrated test instruments across installed flow orifices. The original tests used installed plant instrumentation which, in this case, were neither pre-test nor post-test calibrated.

<u>Additional Information For Item 11</u>

Consumers Power committed to the following:

- Provide update on completion of modifications and future plans and schedules.

Noted earlier in this letter were the three modifications to service water system components that were described previously in our January 28, 1987 letter. They are 1) modification to the service water air operated temperature control valves on the component cooling water heat exchangers; 2) backfiling the service water pump impellers; and 3) adding nitrogen backup to the service water containment isolation valves. These were the short term actions to attain a higher service water system operating temperature. Additional information on our long term plans and schedules for both the service water and component cooling water systems did not contain any specific actions. There remain no proposals which have been completely scoped, cost estimated, approved and scheduled, however, several alternatives are being pursued. These are 1) insulating piping in the engineered safeguards rooms; 2) increasing the engineered safeguards room cooler fan capacity; 3) automatic isolation of the service water containment outlet valve; 4) replacing the containment air cooling coils; and 5) addition of a third component cooling water heat exchanger. As specified in our January 28, 1987, letter, we will keep the staff informed of our plans and schedules as they are finalized.

APPENDIX A

Engineered Safeguards Room Coolers
Maximum Allowable Service Water System Inlet Temperature
Revision 1

15 Pages

APPENDIX A

Introduction

A previous calculation (Revision 0) completed in November and used as support for the December 2, 1986, Technical Specifications Change Request determined that the 110 gpm service water flow to the west engineered safeguards room cooler (VHX-27B) provided for 55°F maximum allowable service water temperature. The calculation was based on:

1. Flow of 110 gpm obtained from data from Special Test Procedure T-216, Revision 0.

2. Previous calculations (References 2 and 3) of convective and radiative heat transfer.

3. Safety injection system piping temperature of 241°F and 200°F assumed in heat transfer calculations.

4. Total west engineered safeguards room post-recirculation heat load of 998,085 Btu/hr.

This calculation (Revision 1) is based on different inputs and determines that a 109 gpm service water flow to VHX-27B provides for a 58°F maximum allowable service water temperature. This calculation was based on:

1. Flow of 109 gpm obtained from Special Test Procedure T-216, Revision 2.

2. New methodology for calculating piping radiative heat transfer.

3. Inclusion of CCW piping leaving the shutdown heat exchangers E-60A and B.

4. Piping temperatures of 223°F, 147°F, and 144°F assumed in heat transfer calculations.

5. Total west engineered safeguards room post-recirculation heat load of 955,754 Btu/hr.

The major differences in the two analyses is in the method of calculating convective and radiative heat transfer. The convective heat transfer calculated in Revision 1 differs from the previous calculation in the following specific areas.

1. Safety injection system water enters E-50A and B at 223°F vs 241°F. Reference 9 provides the basis of the revised value while 241°F had been from the heat exchanger data sheet and is not based on the analyzed value.

2. Safety injection system water leaves E-50A and B at 144°F (per Reference 9) vs 200°F conservatively assumed in the previous calculation.

3. The component cooling water piping leaves E-50A and B at 147°F (per Reference 9). This piping was previously neglected.

4. The average west engineered safeguards room air temperature of 100°F assumed except air surrounding piping in direct path of the cooler fan discharge is assumed to be at 70°F. The previous calculation assumed 100°F and 84°F per the cooler specification which was based on 75°F service water temperature. The reduction of the temperature from 84°F to 70°F is conservative because it increases the calculated heat load.

The radiative heat transfer differences are:

1. The concrete surface is heated to 135°F and all pipe radiative heat transfer to concrete is transmitted to the air. Previously for wall heat-up (in Reference 3) in ten hours, the temperature was calculated to be less than 135°F and after this time, the total radiative heat transfer was assumed as 184,917 Btu/hr. Thus, for the first ten hours, radiative heat load was neglected.

2. A stainless steel emissivity value of 0.85 vs 1.0 is assumed.

3. Air absorptivity of 0.2 and concrete absorptivity values of 0.8 assumed. Previously, these were not considered.

PURPOSE

Determine Palisades Engineering Safeguards room air cooler maximum allowable Service Water inlet temperature to prevent room air temperature from exceeding 135F.

BACKGROUND

The equipment in the ESG rooms is qualified for an air temperature of 135F. The temperature in each room is maintained by air coolers, VHX-27A for the east room and VHX-27B for the west room. The coolers are controlled by wall mounted thermostats.

The greatest demand placed on the ESG room air coolers is in response to a LOCA. The largest heat load for this accident is during the recirculation phase (post-RAS) when SIS piping circulates hot containment sump water through the rooms.

Each room cooler consists of two fan/motor assemblies operating in parallel to draw air through the cooler coils. One fan in each room is powered by Diesel Generator (D/G) 1-1 and the other by 1-2, therefore if one D/G fails, one fan in each room is required to maintain room air temperature at or below 135F.

SCOPE

The heat load in the ESG rooms includes pump motor, lighting, fan motor, and piping heat. The heat load in the west room has been determined to be much greater than that of the east room due to the Shutdown Cooling Heat Exchangers, larger amount of SIS piping and additional number of pumps operating[2,3]. Therefore, this room presents the limiting heat load for VHX-27A or VHX-27B. The worst single failure for this analysis is loss of D/G 1-2, leaving only one SWS pump (P-7B) operable. SWS flow testing[6] has determined the west room post-RAS one pump flows to be 109 gpm (containment open) and 214 gpm (containment isolated). No credit will be taken for room heat sinks, room air exchange, or manual action of opening cross-ties between SWS and two diesel driven fire water pumps.

Consequently, this analysis will focus on a hypothetical LOCA concurrent with LOOP and failure of D/G 1-2 with post-RAS heat load to the west room. D/G 1-1 loads include P-7B, P-54B/C, P-67B (automatically deactivated on RAS), P-66B, and P-8C (formerly P-66C). All except P-7B are located in the west ESG room. This presents the bounding case for heat load demand placed on either VHX-27A or VHX-27B.

ANALYSIS

The west ESG room heat loads were determined to be:

Q_{HPSI} = Q(P-66B,P-8C) = 88,570 Btu/hr[2]
Q_{CSP} = Q(54B/C) = 55,230 Btu/hr[2]
Q_{lights} = 6,800 Btu/hr[2]
Q_{pipe} = 379,438[a] + 222,106[b]
= 601,544 Btu/hr
Q_{fan} = 59,810 Btu/hr[3]

After RAS, P-66B, P-8C, P-54B/C, lights, and 1 fan (loss of D/G 1-2) are operating plus piping heat gives

$$Q_{total} = 2Q_{HPSI} + 2Q_{CSP} + Q_{light} + 1Q_{fan} + Q_{pipe}$$
$$= 2(88,570) + 2(55,230) + 6,800 + 59,810 + 601,544$$
$$= \underline{955,754 \text{ Btu/hr}}$$

The methodology of Reference 1 will be used to solve for the maximum allowable VHX-27B inlet water temperature. As described in Reference 1 Section 6.2, the overall heat transfer coefficient can be modified to account for Reference 6 SWS flows by the following relationships

eqn 1a $\quad U_2 = [1/U_1 + (A_f/A_i)(1/h_{i2} - 1/h_{i1})]^{-1}$

eqn 1b $\quad U_3 = [1/U_1 + (A_f/A_i)(1/h_{i3} - 1/h_{i1})]^{-1}$

where

U = Overall heat transfer coefficient

A_f = Total face area
= 30 ft^2 (Ref 5)

A_i = Total internal coil space
= 331 ft^2 (Ref 1)

h_i = Internal film coefficient

Subscripts 1, 2, and 3 represent SWS flows of 175gpm(Ref 1), 214 gpm, and 109 gpm, respectively.

(a) Pipe convective heat transfer (see Table 1). Air heat-up was calculated assuming the air is at 100F or less, and the piping is at 223F (SIS entering E-60A/B), 147F (CCW leaving E-60A/B), and 144F (SIS leaving E-60A/B).
(b) Pipe radiative heat transfer (see Table 2). Air heat-up was calculated assuming air and piping temperatures as for convective heat transfer and the concrete is at 135F. All the radiative heat is assumed to be absorbed by the air.

The Dittus-Boelter relation for turbulent flow in smooth tubes with moderate temperature differences between wall and fluid conditions is

eqn 2 $h_i = (K_w/d)(0.023 \times Re^{0.8} \times Pr^{0.4})$

where

K_w = Conductivity of water

Pr = Prandtl number for water
= $C_{pw}u/K_w$

C_{pw} = Heat capacity of water

u = Viscosity of water

Re = Renolds number
= $\rho vd/u$

ρ = Density of water

d = Tube inside diameter
= 0.0439 ft (Ref 1)

v = Velocity of water, ft/sec
= (GPM/48 circuits)(1/60 sec)(0.1337ft^3/gal)(1/0.00151ft^2)
= 0.0307(GPM)

GPM = SWS flow in gpm

48 circuits = (2coils)(12tubes/row/coil)(10rows deep)x
(1circuit/5tube passes) (Ref 1)

Properties for h_{i1} will be evaluated at 80F, where

K_w = 0.353 Btu/hrxftxF

u = 5.78E-4 lbm/ftxsec

C_{pw} = 0.998 Btu/lbmxF

Pr = 0.998x5.78E-4x3600/0.353 = 5.88

ρ = 62.2 lbm/ft^3

v_1 = 0.0307(175) = 5.380 ft/sec

Re_1 = 62.2x0.0439x5.380/5.78E-4 = 25,417

Eqn 2 gives

h_{i1} = $(0.353 \times 0.023/0.0439)(25{,}417)^{0.8}(5.88)^{0.4}$
= <u>1255 Btu/hrxft^{2}xF</u>

Properties for h_{i2} and h_{i3} will be evaluated at 65F, where

K_w = 0.343 Btu/hrxftxF

u = 7.1E-4 lbm/ftxsec

C_{pw} = 0.998 Btu/lbmxF

Pr = 0.998x7.1E-4x3600/0.343 = 7.44

ρ = 62.3 lbm/ft^3

v_2 = 0.0307(214) = 6.570 ft/sec

v_3 = 0.0307(109) = 3.346 ft/sec

Re_2 = 62.3x0.0439x6.570/7.1E-4 = 25,308

Re_3 = 62.3x0.0439x3.684/7.1E-4 = 12,890

Eqn 2 gives

h_{i2} = (0.343x0.023/0.0439)(25,308)$^{0.8}$(7.44)$^{0.4}$
= 1,335 Btu/hrxft^{2}xF

h_{i3} = (0.343x0.023/0.0439)(12,890)$^{0.8}$(7.44)$^{0.4}$
= 778.0 Btu/hrxft^{2}xF

A BASIC program has been developed to solve for heat transfer through a heat exchanger based on solving the following three eqns.

Total heat transfer through a heat exchanger

eqn 3 $\quad Q = U \times A_f \times \Delta T_m$

Air side heat transfer

eqn 4 $\quad Q = SCFM(C_{pa} + C_{pg}W)(T_{ai} - T_{ao})$

Water side heat transfer

eqn 5 $\quad Q = GPM(C_{pw})(T_{wo} - T_{wi})$

where

SCFM = Cooler entering air flow, corrected to 0.075 lbm/ft^3

$\Delta T_m = [(T_{ai} - T_{wo}) - (T_{ao} - T_{wi})]/\ln[(T_{ai} - T_{wo})/(T_{ao} - T_{wi})]$

C_{pa} = Heat capacity of air

C_{pg} = Heat capacity of water vapor

W = Humidity ratio
  = 0.165 (15% RH at 135F)

C_{pw} = Heat capacity of water

Subscript a,w,i, and o represent air, water, in, and out, respectively.

U_1 will be determined from eqn 3 using Reference 1 Section 7.2 temperatures, Q, and A_f.

$$\Delta T_m = [(135 - 84) - (83.4 - 75)/\ln(135 - 84)/(83.4 - 75)] = 23.62F$$

eqn 3A

$$U_1 = Q/A_f \times \Delta T_m = 780{,}000/30 \times 23.62 = \underline{1100\ Btu/hr \times ft^2 \times F}$$

Substituting values into eqn 1a and 1b gives

$$U_2 = [1/1100 + (30/331)(1/1355 - 1/1255)]^{-1} = \underline{1106\ Btu/hr \times ft^2 \times F}$$

$$U_3 = [1/1100 + (30/331)(1/778 - 1/1255)]^{-1} = \underline{1048\ Btu/hr \times ft^2 \times F}$$

Let

$$C_{pa} = C_{pa} + C_{pg}W \text{ , evaluated at 100F} = 0.240 + 0.489 \times 0.0165 = 0.248\ Btu/lbm \times F$$

$$C_{pw} = C_{pw} \text{ , evaluated at 65F} = 0.998\ Btu/lbm \times F$$

converting units gives

$$C_{pa} = 0.248 \times 60 min/hr \times 0.075 lbm/ft^3 = 1.116\ Btu \times min/hr \times ft^3 \times F$$

$$C_{pw} = 0.998 \times 0.1337 ft^3/gal \times 60 min/hr \times 62.3 lbm/ft^3 = 498.8\ Btu \times min/gal \times hr \times F$$

Now input U_2, C_{pa}, C_{pw}, Q_{total}, and VHX-27B SWS flow and air flow (Reference 1 Section 7.2) into the BASIC program to solve for T_{wi2} and T_{wi3}

$$T_{wi2} = \underline{62.2F} \quad \text{(Attachment A)}$$

$$T_{wi3} = \underline{58.8F} \quad \text{(Attachment B)}$$

CONCLUSION

For a hypothetical LOCA with LOOP and failure of D/G 1-2, the maximum allowable SWS inlet water temperature to the ESG room coolers is 58.8F with 109 gpm SWS flow to VHX-27B (containment open) or 62.2F with 214 gpm to VHX-27B (containment isolated).

Rev 01

REFERENCES

(1) Keith Canazzi, "Performance Analysis of Engineered Safeguard Cooler Units for Consumers Power Company Palisades Plant", Keith Canazzi, Report ER-1074, Buffalo Forge Co., March 31, 1983.

(2) CPCo Internal Report, WGBrigger, Analysis for E-PAL-83-30, March 3, 1983.

(3) CPCo Internal Report, WGBrigger, Additional Information for Analysis for E-PAL-83-30, February 28, 1984.

(4) Deleted

(5) "Cooling Coil Thermal and Structural Capacity Evaluation for the Palisades Plant of Consumers Power Company", Report RS-1003, American Air Filter Co, November 2, 1967.

(6) Palisades SWS Special Test T-216, Rev. 02, February 1987.

(7) Deleted

(8) W.H.McAdams, "Heat Transfer", 1954.

(9) CE Report,"Final Report Rev 02 to CPCo for Phase 1 Analysis to Determine the Palisades Plant Containment Response to LOCAs and SDC System Performance", Task 601634, November 26, 1986, JOB = AL2QVTZ, JSN = AVPC.

Table 1 - Sheet 1
Post-RAS Pipe Convective Heat Load for One Fan Operation

Drawing number (a)	A - 6	A - 6	A - 5	A - 6	A - 6	A - 5	A - 5	A - 7	A - 7
Pipe OD, ft (b)	0.719	0.896	1.17	0.719	0.896	1.17	2	0.719	0.896
Pipe Length, ft (b)	31.3	11.4	46.1	27.5	64.6	88.7	44.5	19.1	51.5
Pipe Area, ft**2 (b)	70.70076	32.08955	169.4484	62.11728	181.8408	326.0321	279.6024	43.14327	144.9659
Air Speed, fpm (c)	1300	1300	1300	150	150	150	150	150	150
Reynolds number (d)	86074.83	107264.3	140066.1	9931.712	12376.65	16161.47	27626.45	9931.712	12376.65
HTC - n (e)	0.805	0.805	0.805	0.618	0.618	0.618	0.618	0.618	0.618
HTC - B (e)	0.0239	0.0239	0.0239	0.174	0.174	0.174	0.174	0.174	0.174
HTC, Btu/hrxft**2xF (f)	5.149064	4.932764	4.682676	1.178868	1.083812	0.978788	0.797521	1.178868	1.083812
Air Temperature, F (g)	70	70	70	100	100	100	100	100	100
Pipe Temperature, F (h)	223	223	223	223	223	223	223	144	144
Heat Transfer, Btu/hr (i)	55698.54	24218.40	121401.2	9007.054	24240.99	39251.30	27427.62	2237.850	6913.099

(a) A - # from Reference 2, CCW from CPCo Drawing 950W1-M101-sh2842-0, and E-60A/B from CE Drawing CO-15080.
(b) Area = 3.1416xODxLength
(c) Reference 2
(d) Re = DensityxAirSpeedxOD/Viscosity, Density = 0.071 lbm/ft*3(100F), Viscosity = 1.285E-5 lbm/ftxsec(100F)
(e) Reference 8 Table 10-3, Air flow normal to cylinder

Re	n	B
40 - 4,000	0.466	0.615
4,000 - 40,000	0.618	0.174
40,000 - 250,000	0.805	0.0239

(f) HTC = (ThermalConductivityxB/OD)[(Re)**n], ThermalConductivity = 0.0165 Btu/hrxftxF(135F)
Reference 8 Eqr 10-2
(g) Conservatively assumed all SIS piping in direct path of cooler discharge (Ref 2 Fig A.1) transfers heat to 70F air. All other air at 100F.
(h) Conservatively assumed all SIS piping is at a constant 223F except for piping leaving E-60A/B which is at 144F. CCW piping leaving E-60A/B at 147F. All pipe temperatures from Reference 9.
(i) Heat Transfer = HTCxAreax(Pipe temp - Air temp)

Table 1 - Sheet 2
Post-RAS Pipe Convective Heat Load for One Fan Operation

Drawing number (a)	A - 8	A - 8	A - 9	A - 9	A - 8	CCW	CCW	E-60A/B
Pipe OD, ft (b)	0.552	0.719	0.292	0.375	0.719	1.5	1	3.75
Pipe Length, ft (b)	31.7	27.1	35.3	42.3	25.9	23.77	39	46.9375
Pipe Area, ft**2 (b)	54.97297	61.21376	32.38235	49.83363	58.50318	112.0137	122.53	552.9706
Air Speed, fpm (c)	150	150	150	150	150	150	150	150
Reynolds number (d)	7624.902	9931.712	4033.463	5179.961	9931.712	20719.84	13813.22	51799.61
HTC - n (e)	0.618	0.618	0.618	0.618	0.618	0.618	0.618	0.618
HTC - B (e)	0.174	0.174	0.174	0.174	0.174	0.174	0.174	0.174
HTC, Btu/hrxft**2xF (f)	1.304112	1.178868	1.663257	1.511665	1.178868	0.890161	1.039287	0.627271
Air Temperature, F (g)	100	100	100	100	100	100	100	100
Pipe Temperature, F (h)	223	223	223	223	223	147	147	147
Heat Transfer, Btu/hr (i)	8817.982	8876.042	6624.802	9265.808	8483.007	4686.385	5985.162	16302.55

TOTAL HEAT TRANSFER = 379437.9 BTU/HR

(a) A - # from Reference 2, CCW from CPCo Drawing 950W1-M101-sh2842-0, and E-60A/B from CE Drawing CO-15080.
(b) Area = 3.1416xODxLength
(c) Reference 2
(d) Re = DensityxAirSpeedxOD/Viscosity, Density = 0.071 lbm/ft*3(100F), Viscosity = 1.285E-5 lbm/ftxsec(100F)
(e) Reference 8 Table 10-3, Air flow normal to cylinder

Re	n	B
40 - 4,000	0.466	0.615
4,000 - 40,000	0.618	0.174
40,000 - 250,000	0.805	0.0239

(f) HTC = (ThermalConductivityxB/OD)[(Re)**n], ThermalConductivity = 0.0165 Btu/hrxftxF(135F)
Reference 8 Eqn 10-2
(g) Conservatively assumed all SIS piping in direct path of cooler discharge (Ref 2 Fig A.1) transfers heat to 70F air. All other air at 100F.
(h) Conservatively assumed all SIS piping is at a constant 223F except for piping leaving E-60A/B which is at 144F. CCW piping leaving E-60A/B at 147F. All pipe temperatures from Reference 9.
(i) Heat Transfer = HTCxAreax(Pipe temp - Air temp)

Consumers Power Company

NUCLEAR OPERATIONS DEPARTMENT
Engineering Analysis Work Sheet

EA – ______
Sheet ______ of ______

Table 2

Title Radiative Heat Transfer

Performed by SPForte Date 2/3/87

References Table 1 Temperatures and Areas

Review Method by:
- [ ] Alternate Calculations
- [ ] Detailed Review
- [ ] Qualification Test

Technical Review by ______ Date ______

T_{pipe} (°F)	T_{air} (°F)	$T_{concrete}$ (°F)	Area (ft^2)	Heat Transfer[a] (Btu/hr)
223	70		273	11,006
223		135	273	29,290
223	100		1107	38,375
223		135	1107	118,769
144	100		190	1,919
144		135	190	1,714
147	100		915	9,948
147		135	915	11,085
			2485	61,248 Air
				160,858 Concrete
				222,106 Total

(a) $Q = \sigma \alpha \epsilon A (T_p^4 - T_{a,w}^4)$

$\sigma = 0.1713 \times 10^{-8}$ Btu/hr·R^4·Ft^2

α = absorptivity, Air = 0.2, concrete/Paint = 0.8

ϵ = emissivity, stainless steel = 0.85

A = pipe area

T(R) = 459.7 + T(F)

Form 3119 3-83

Attachment A

```
LIST
10   'PROGRAM NAME - ESG.BAS'
15 PRINT
25 PRINT
30 PRINT
35 INPUT   " ESTIMATED SW INLET TEMPERATURE = ",T2
40 PRINT
45 PRINT
50 MSW=214!
60 MAF=13590!
70  U=1106!
75 A=30!
80 T3=135!
85 CPSW=498.8
90 CPAF=1.116
95 Q= 955754!
100 NN=0
105 PRINT MSW,MAF,U,A,Q
110  PRINT
115 T4=T3-Q/MAF/CPAF
125 T1=Q/MSW/CPSW+T2
130 TM=(T3-T1-T4+T2)/LOG((T3-T1)/(T4-T2))
135 QP=U*A*TM
140 DIF=1!-QP/Q
145 IF ABS(DIF)<.0001 THEN END
150 T2=T2-DIF*5
155 NN=NN+1
160 PRINT NN,T1,T2,T3,T4,TM,DIF
165 IF NN<10 GOTO 125
170 END
O
RUN


 ESTIMATED SW INLET TEMPERATURE = 62.2

 214           13590         1106          30            955754

 1             71.15377      62.20262      135           71.98231
 28.82023     -5.245209E-04
 2             71.15639      62.20464      135           71.98231
 28.81675     -4.036427E-04
 3             71.15841      62.20619      135           71.98231
 28.81407     -3.103018E-04
 4             71.15996      62.20739      135           71.98231
 28.812       -2.38657E-04
 5             71.16116      62.20831      135           71.98231
 28.81041     -1.835823E-04
 6             71.16208      62.20901      135           71.98231
 28.80919     -1.410246E-04
 7             71.16278      62.20956      135           71.98231
 28.80825     -1.084805E-04
O
```

Attachment B

```
LIST
10    'PROGRAM NAME - ESG.BAS'
15 PRINT
25 PRINT
30 PRINT
35 INPUT   " ESTIMATED SW INLET TEMPERATURE = ",T2
40 PRINT
45 PRINT
50 MSW=109!
60 MAF=13590!
70  U=1048!
75 A=30!
80 T3=135!
85 CPSW=498.8
90 CPAF=1.116
95 Q= 955754!
100 NN=0
105 PRINT MSW,MAF,U,A,Q
110  PRINT
115 T4=T3-Q/MAF/CPAF
125 T1=Q/MSW/CPSW+T2
130 TM=(T3-T1-T4+T2)/LOG((T3-T1)/(T4-T2))
135 QP=U*A*TM
140 DIF=1!-QP/Q
145 IF ABS(DIF)<.0001 THEN END
150 T2=T2-DIF*5
155 NN=NN+1
160 PRINT NN,T1,T2,T3,T4,TM,DIF
165 IF NN<10 GOTO 125
170 END
O
RUN


 ESTIMATED SW INLET TEMPERATURE = 58.83

 109           13590          1048          30            955754

 1              76.40896       58.8325       135           71.98231
 30.41446      -4.987717E-04
 2              76.41146       58.8345       135           71.98231
 30.41147      -4.003048E-04
 3              76.41346       58.83611      135           71.98231
 30.40907      -3.21269E-04
 4              76.41506       58.8374       135           71.98231
 30.40714      -2.578497E-04
 5              76.41635       58.83843      135           71.98231
 30.40559      -2.069473E-04
 6              76.41739       58.83926      135           71.98231
 30.40435      -1.660585E-04
 7              76.41822       58.83993      135           71.98231
 30.40335      -1.331568E-04
 8              76.41888       58.84046      135           71.98231
 30.40255      -1.068115E-04
O
```

ATTACHMENT 2

Consumers Power Company
Palisades Plant
Docket 50-255

INFORMATION ON VHX-4 CONTAINMENT AIR COOLER

February 25, 1987

2 Pages

OC0287-0014D-NL04

Attachment 2

In our October 20, 1986, Technical Specification Change Request, Consumers Power stated our intention to maintain the environmental qualification of VHX-4 Containment Air Cooler and keep the unit in an operational condition, even though the operability of this cooler was not considered in any accident analysis. Pursuant to this objective, we have contracted Westinghouse to determine the heat removal capacity of the cooler, based upon actual operating parameters and with one of the eight sets of cooling coils removed due to excessive leakage. A comparison of the original bases and the current analytical model follows:

	FSAR	WESTINGHOUSE ANALYSIS	WESTINGHOUSE CORRECTED ANALYSIS*
Containment Air Flow (CFM)	30,000	38,125	38,125
Number of Cooling Coils	8	7	7
Service Water Flow (GPM)	1,625	1,422	1,422
Heat Removal (E + 06 Btu/hr)	76.6	73.4	76.0

*The vendor's analysis was compared to the heat removal calculated by Westinghouse for 8 coils and found to differ by 3.6%. This percentage was applied to Westinghouse's calculated heat removal rate for 7 coils to arrive at 76.04 E + 06 Btu/hr. These values are viewed as sufficiently close not to warrant any system or equipment changes to claim unit operability.

The Westinghouse analysis used a larger air flow than the FSAR value. The larger value is based on recent testing of the cooling fans. The service water flow of 1422 gpm is based on removal of one-eighth of the coils resulting in a direct loss of one-eighth of the flow.

A cooling coil was removed for metallurgical analysis to help determine the cause of leakage. The leakage was attributed to the joint configuration and age of the cooling units. The coolers have all been repaired and all the repairs have met the leakage acceptance criteria.

Procurement and replacement of all the VHX-4 coils is presently being planned for the next refueling outage. However, as noted in Attachment 1, Item 11, this replacement has not been approved.