Title	REACTOR BUILDING COOLING UNIT AVAILABILITY DURING ILRT
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A.1 EC Folder Contents

ED template 7/05/05

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EC FOLDER UTILITIES (Rev 4)	
Open selected doc files from the folder	Administrative Review Report
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Save all EC Folder doc files as read-only	Allow change to all EC Folder doc files
Select an open doc and insert an 11x8.5 page following its current page	Select an open doc and insert a 17x11 page following its current page

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A.2 List of Hard Copy Only Pages

N/A

A.3 Revision Summary

This is the original version.

A.4 Problem Statement

An RB fan is required to be available during AI-504 Shutdown Condition 4, which is when the ILRT will be performed in 14R. Since air is denser than steam at a given pressure, it is desired to know how much the RB will need to be depressurized to allow an RB fan to operate if a loss of decay heat is experienced. This evaluation will determine the maximum RB pressure to operate the fans with no change to the current configuration (baffles, overloads), as well as for larger overloads without baffles. These values will be compared to the estimated time to boil for the RCS and a recommendation will be made regarding configuration during 14R.

This EC-ED will also evaluate the ability to depressurize the RB at 15 psi/hr.

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A.5 Solution Statement

The pressure at which the density of air equals the post-accident containment steam/air density of 0.19 lb_m/ft^3 is approximately 24 psig. If the RB fan motor overloads are replaced with 129 amp overloads, the allowable pressure can be increased to approximately 29 psig. This means the RB fans would not be considered "available" above these pressures. If decay heat removal was lost while the ILRT was in progress and at the maximum potential pressure of 55 psig, it would take approximately 2 hours to depressurize at 15 psi/hr, plus the time required to perform the necessary valve and equipment manipulations. The entire evolution would need to be completed prior to reaching the time to boil (estimated at approximately 3 hours).

The alternative to depressurizing the RB is to install baffles and change the fan motor overloads, similar to previous ILRTs. This would result in the fan being available during the entire duration of the ILRT. **This is the recommended option.** The baffles are stored in the oil tank warehouse (CATID 52700753). Details regarding their installation are included on drawing 311-725.

The installed ILRT depressurization line and two 8" temporary lines have adequate capacity to initially depressurize containment at 15 psi per hour. The containment pressure will eventually decrease to the point that there is insufficient ΔP to continue at 15 psi/hr and a slower rate will result.

A.6 Evaluation

During previous performances of the containment integrated leak rate tests (ILRT), the RB fans operated while the RB was pressurized. Since air is denser than steam at a given pressure, baffles were installed in the intake plenums of the fans and the motor overloads were replaced with overloads with higher ratings to prevent the fans from tripping. During 14R, the RB fans will not be operating during the ILRT. One fan, however, must still be available per AI-504, Enclosure 4. This ED will evaluate how much RB pressure would need to be reduced to allow the fans to operate, and also determine if a 15 psi/hr depressurization rate is feasible.

The following items will be included in this evaluation:

1. Determine the RB pressure that will allow a RB fan to operate in low speed if the ILRT baffles are not installed and the motor overloads are not changed.
2. Determine the RB pressure that will allow a RB fan to operate in low speed if the ILRT baffles are not installed and the motor overloads are changed
3. Determine the time to boil for the RCS during the ILRT.
4. Determine if the RB can be depressurized at a rate of 15 psi/hr.

Design Inputs:

Design Accident Ratings for AHF-1A/B/C [References 1 and 4]

Volumetric Flow Rate = Q = 50,000 ft^3/min

Density = ρ_{RB} = 0.19 lb_m/ft^3

Full Load Motor Current = FLA = 114 A

Volume of Containment is 2,060,000 ft^3 [Reference 10]

Assumptions:

1. The average air temperature inside containment during the ILRT is 90°F (the average air temperature during the ILRT in 6R was ~89°F with mixing/cooling [Ref. 3]. This is conservative because air temperature is expected to be higher without mixing/cooling (higher temperature = lower density).
2. Pressure drop in the suction ductwork is neglected (low velocity).

1. Determine the RB pressure that will allow a RB fan to operate in low speed if the ILRT baffles are not installed and the motor overloads <u>are not</u> changed

Per the RB fan vendor manual [Ref. 1], the design density of the air/steam mixture inside containment during accident conditions is 0.19 lb_m/ft^3. The pressure of air that corresponds to this density can be approximated from the following equation (ignores humidity and losses):

$$P = [\rho * R * (t + 460)/144] - 14.7$$

where $R = 53.3$ $ft\text{-}lb_f/lb_m{}^\circ R$ for air and $t = {}^\circ F$

For $\rho = 0.19$ lb_m/ft^3 and $t = 90°F$,

$$P = [0.19 * 53.3 * (90 + 460)/144] - 14.7$$

$$\mathbf{P_{max} \approx 24\ psig}$$

2. Determine the RB pressure that will allow a RB fan to operate in low speed if the ILRT baffles are not installed and the motor overloads <u>are</u> changed

Fans are constant volume devices, i.e., the volume of gas being transferred does not significantly change as temperature and pressure are varied. What does change is the mass flow rate, which is equal to the volumetric flow rate times the density. The change in mass flow rate has a direct impact on the motor current. The relationship of power input (H) and air density (ρ) can be approximated by the following equation [Reference 2]:

$$H_1 / H_2 = \rho_1 / \rho_2$$

If the motor overloads are replaced with higher-rated overloads, as was done during the previous ILRTs, the fans will be able to operate at higher containment pressure (density). The density of air that will result in the higher overload current rating of 129 amps is

$$\rho_2 = \rho_1 * (H_2 / H_1)$$

$$= 0.19\ lb_m/ft^3 * (129/114)$$

$$= 0.215\ lb_m/ft^3$$

The corresponding RB pressure is

$$P = [0.215 * 53.3 * (90 + 460)/144] - 14.7$$

$$\mathbf{P_{max} \approx 29\ psig}$$

3. Determine the time to boil for the RCS during the ILRT for the containment pressures determined above

The spreadsheet included in Attachment 1 calculates time to boil for CR-3's core configuration in 14R at 20 days after shutdown with a RB pressure of 24 psig. The time to boil varies with RCS level and initial temperature, but will be approximately 3 hours if the RCS is above 141 feet and initially controlled at 120°F. The time can be extended about 12 minutes if RB pressure is 29 psig. *Note: this is an unverified spreadsheet, but the results are considered reasonable based on comparison to previous time to boil calculations.*

4. Determine if the RB can be depressurized at a rate of 15 psi/hr

The depressurization of the RB will be performed utilizing the ILRT depressurization line as well as two 8" temporary lines that will also be used for pressurization.

Assuming a maximum RB pressure of 55 psig, the mass of air in the containment building is

$$M = PV/RT$$

$$= (55\ lb_f/in^2 + 14.7\ lb_f/in^2)(144\ in^2/ft^2)(2{,}060{,}000\ ft^3)/(53.3\ ft\text{-}lb_f/lb_m{}^\circ R)(90 + 460^\circ R)$$

$$\approx 705{,}300\ lb_m$$

Similarly, the mass of air in containment at 40 psig is

$$= (40\ lb_f/in^2 + 14.7\ lb_f/in^2)(144\ in^2/ft^2)(2{,}060{,}000\ ft^3)/(53.3\ ft\text{-}lb_f/lb_m{}^\circ R)(90 + 460^\circ R)$$

$$\approx 553{,}500\ lb_m$$

Therefore, the mass flow required to reduce RB pressure 15 psi/hr at 55 psig is

$$705{,}300\ lb_m - 553{,}500\ lb_m = 151{,}800\ lb_m/hr$$

The volumetric flow rate, in terms of standard cubic feet per minute (scfm),would be

$$Q = m/\rho$$

$$= (151{,}800\ lb_m/hr)(1\ hr/60\ min)/0.0764\ lb_m/ft^3$$

$$Q \approx 33{,}115\ scfm$$

The installed ILRT depressurization line (from Penetrations 305 and 306 through LRV-122 to RB Purge Exhaust ductwork [Ref. 7]) has been analyzed to pass 12,000 scfm (55,008 lb_m/hr) at an RB pressure of 60 psig [References 5 and 6]. Although the flow rate will be slightly less when considering 55 psig vs 60 psig RB pressure, there is sufficient pressure drop across the control valve (LRV-122) in the calculation (35 psi) to increase the flow rate by opening the valve further.

If 12,000 scfm passes through the ILRT depressurization line, the remaining 21,115 scfm will need to exhaust through the two temporary 8" lines. These lines are a combination of carbon steel pipe and flexible hose, and are approximately 225' long each from the RB penetration to the exhaust muffler. The exact configuration is not presently known, as they will be field-run during the outage, but the general arrangement is shown on Attachment 2. Conservatively assuming each line is 1000' long to account for bends, fittings and valves, and using 11,000 scfm per line, the pressure drop is [Reference 8]:

$$\Delta P = \Delta P_{100\text{ psig, }60°F} * [(100 + 14.7)/(P + 14.7)] * [(460 + t)/520] * L \text{ ft}$$

$$\Delta P = 0.633 \text{ psi}/100 \text{ ft} * [(114.7)/(55 + 14.7)] * [550/520] * 1000 \text{ ft}$$

$$\Delta P = 11 \text{ psi}$$

As long as the flow is not limited due to the velocity becoming sonic, the 8" lines (in conjunction with the ILRT depressurization line) will pass sufficient air flow to reduce RB pressure at 15 psi/hr. From Reference 9 Equation 9-23, the critical pressure (where velocity becomes sonic) is 52.8% of initial pressure. For a starting pressure of 55 psig (69.7 psia), the flow will become sonic if pressure drops below 22 psig. Therefore, since 55 psig – 11 psi = 44 psig (> 22 psig), sonic flow is not reached in the pipe line, and **15 psi/hr is achievable.**

From a structural standpoint, depressurizing (or pressurizing) the RB at 15 psi/hr is not challenging, as accident conditions are much more severe. The concern with the ILRT pressure change rates is with the impact on insulation, paint, electrical boxes, etc. There is no analysis that evaluates the 15 psi/hr. However, industry experience has demonstrated its acceptability. Brunswick Nuclear Plant currently uses this limit in BNP Procedure 0PT-20.5, and the ILRT vendor contracted for 14R provided a listing of plants that had previously depressurized at this rate (Attachment 3). One station did experience some insulation being displaced from a penetration, but this is considered minor and unusual. Containment inspections after the ILRT will identify any damage and evaluations or corrective actions will be performed as necessary.

A.7 References

1. Vendor Manual 0002, Reactor Containment Fan Cooler, Rev. 11
2. Marks' Standard Handbook for Mechanical Engineers, Ninth Edition
3. SP-178, Rev. 10 (completed 1987, Refuel Outage 6)
4. EDBD 8/11, Reactor Building Air Handling System, Rev 13
5. Calculation M92-0056, H2 Purge Pressure Loss Calculation, Rev. 0
6. MAR 91-05-03-01, Hydrogen Purge Redundancy Restoration
7. Drawing 302-723, Post-Accident Venting System, Rev. 15
8. Crane Technical Paper No. 410, Flow of Fluids Through Valves, Fittings, and Pipes, 1969
9. Essentials of Engineering Fluid Mechanics, Second Edition
10. Calculation M98-0010, Containment Free Volume, Rev. 0
11. Drawing 311-725, Reactor Building Plan at Floor Elev. 95'-0", Rev. 9