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Assessment of Coping Capability on Room Cooling under Loss of Ultimate Heat Sink

Byung Sun Kim [a*], Kag Su Jang[a], Han Cheol Kim[b], Jong Hwan Joo[b], Ki Tack Kim[c]
[a]*KEPCO E&C, Nuclear Technology Research Dept.*, [b]*Mechanical & Plant Design Engineering Dept.,*
[c]*Nuclear Engineering Dept., 269 Hyeoksin-ro, Gimcheon-si, 39660*
[*]*Corresponding author: bskim@kepco-enc.com*

1. Introduction

The loss of ultimate heat sink (LOUHS) can lead to loss of cooling water supply to forced ventilation system (HVAC). The LOUHS therefore will often result in a long-term challenge to particular location (i.e., equipment rooms) in the plant. The locations of most concern will generally be those rooms containing the plant's safety related equipment needed for and supporting safe shutdown. The use of that equipment (e.g., Charging Pump (CP), Main Control Room (MCR), etc.) will result in a more rapid local heat-up than for other rooms where equipment is not being utilized. The continued room heat-up may result in automatic or manual equipment trips, and/or equipment degradation.

This paper presents analysis results of coping capability for room cooling of Hanul Unit 3&4 under the LOUHS classified as one of multiple failure accidents by regulatory guide of Korean accident management [1]. Also it is to provide alternate room cooling strategies to ensure that the functionality of the equipment is maintained for the duration of the event.

2. Methods

This section provides information about the analyses performed to provide a basis for the LOUHS coping strategy, including computer code and methods, key assumptions, and the results of the analyses.

2.1 Analysis Methods

The GOTHIC (Generation of Thermal-Hydraulic Information for Containments) computer code [2] was used to evaluate the heatup of rooms following a loss of all forced cooling resulting from the LOUHS event. Each room was modeled as a single node (control volume), considering the heat sink, comprised of concrete. The nodes were assumed to have a homogenous temperature and evaluated individually with heat transfer to adjacent regions being considered. The concrete surface, as well as the free volume of air, served as heat sinks. The heat load was modeled as a heater within each node if any regarding level.

2.1.1 Key Assumptions

The GOTHIC analysis of heatup of the specified rooms was performed using the following key assumptions and inputs:

- Each room is assumed to constitute a single, homogenous, free volume with concrete walls, ceiling and floor by level.
- As the initial room temperature, the maximum normal temperature specified as design value [3] is applied. The relative humidity used the median value of the normal condition.
- Doors are opened at 60 minutes after event initiation.
- Operator action for load shedding is assumed to take 35 minutes.
- The heat load during normal operation for electrical equipment is assumed to be 64% of design load except electrical lighting.
- Shedding heat load for electrical equipment during normal operation is assumed to be 5% of design load for the lighting and 25% for the others.
- The free volume of the room is conservatively assumed to be 70% of total volume with considering the volume of equipment occupied.
- Ambient pressure in the room is assumed as atmospheric pressure (14.7 psia)
- Forced cooling of rooms is assumed to be lost simultaneously with initiating event and to be restored after seventy two (72) hours.

The assessment on the effects of loss of HVAC following the LOUHS event is performed using the GOTHIC and criteria of NUMARC 87-00 [4]. The functionality of equipment which could be used to bring a plant to hot shutdown following the LOUHS event can be guaranteed when the room temperature remains below the limit specified in the NUMARC 87-00 as shown in Table I.

Table I: Maximum Allowable Temperature

Room	Temperature (NUMARC 87-00)
Main Control Room	110 ^{o}F for habitability
Mechanical equip. room	150 ^{o}F
Electrical and I&C room	120 ^{o}F

2.1.2 Heatup Evaluation Process

The heatup evaluation process for rooms being considered is as follows:

A. Perform the heatup evaluation on rooms using normal operation load with their doors closed and no operator actions such as opening door.
B. Compare the evaluated temperatures of rooms for 72 hours with the maximum allowable temperature Table 1.
C. 1) If the heatup temperature of each room is lower than the maximum allowable temperature, no additional cooling is required.
2) If it exceeds the maximum allowable temperature, the further heatup evaluation is performed with room doors opened and/or load shedding.
D. 1) The second resultant temperatures by C.2) are considered as the maximum temperatures of rooms during 72 hours assuming a loss of HVAC system, and if secondary temperature doesn't exceed the maximum allowable temperature, additional cooling is not required as long as operators open the doors and/or load shedding.
2) If the maximum temperature that are derived with the room doors opened and/or load shedding still exceed the maximum allowable temperatures of the rooms, additional cooling shall be considered.

2.2 GOTHIC Model

GOTHIC model for heatup calculation is developed by each level of Auxiliary Building in order to implement the interaction with adjacent rooms which contain the safety and non-safety related component such as 321, 322, 323 and 325 level as shown in Fig. 1.

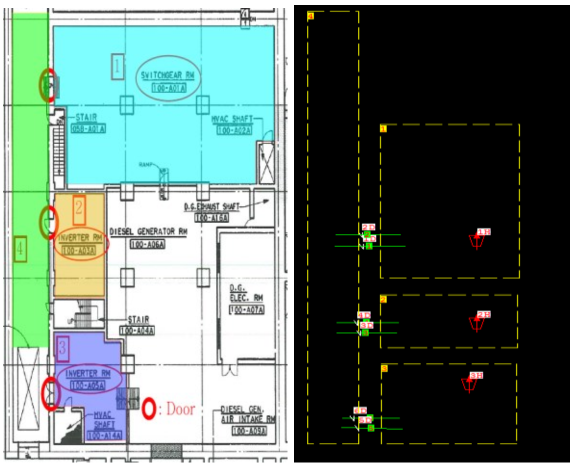

Fig. 1. Room location and GOTHIC model for 323 Level

3. Results

3.1 Room Cooling Capability

The results of the analysis indicate that the temperature profile for the rooms with their doors closed, except for the HVAC equipment room exceed the maximum allowable temperatures as shown in Table II. The HVAC equipment room was expected to remain less 120ºF for 72 hours. The rooms except HVAC equipment room are required alternate cooling via local manual actions (e.g., open doors, load shedding of non-essential loads).

3.2 Coping Strategy for Room Cooling

Room cooling strategies to be implemented when normal cooling functions have been lost typically fall into one or all of two categories of A and B below.

A. Alternate Room Cooling Via Operator Actions

1) Opening the room door

This strategy is to promote natural air circulation cooling from adjacent rooms and/or the outdoors. The results of the analysis for rooms with doors opened are shown in Table III. The temperatures of the most rooms except for MCR, electrical and I&C rooms, remain below the temperature limit. For example, the temperature for CP room shows that if the door to the CP room is opened within 1 hour, the room temperature will remain below the maximum allowable temperature so that CP will continue to perform its function. The HVAC room still remains below the allowable temperature but is higher than with the door closed. Heat is flowed into that from nearby rooms, including the inverter (A) room. Therefore, it is concluded that, to maintain temperature in the room during the event below the limit value, doors to the rooms including CP room will need to be opened. However, for the rooms exceeded the allowable temperature are still required an additional actions to cope with.

2) Load shedding with opening the doors

This strategy is to reduce the heat generated by electrical devices such as cable tray, lighting, and panels, etc. The results of the analysis shown in Table IV indicate that the room temperatures, except Inverter (A) room and MCR, are maintained less than the maximum allowable temperature. The rooms exceeding the temperature limit are required to place an alternate room cooling.

B. Alternate room cooling via portable fan

This strategy is to provide additional forced air circulation when room cooling via operator actions is not sufficient to maintain temperature limits. The results of analysis show that the Inverter (A) room and MCR cannot be maintained below the temperature limit of

120 ºF and 110 ºF by operator actions with opening the doors and reducing the unnecessary loads. Therefore, these rooms are required to use a portable fan as an additional room cooling. The minimum capacity of the portable fan to cool down the MCR is conservatively set to 140,261 BTU/hr. The portable fan of 2,500 cfm should be placed in service within twenty-four (24) hours after the LOUHS initiating event.

Table II: Rooms Temperature with Closed Door

Room (RM) No.	RM Description	Allow. Temp. (˚F)	Room Temperature (˚F)			
			0 hr	8 hr	24 hr	72 hr
058-A06A	CP	150	104	146.7	156.9	176.5
077-A01A	Inverter (A)	120	104	145.5	155.3	171.9
077-A04A	HVAC	120	104	110.8	112.2	115.6
077-A07A	MCC (A)	120	104	118.2	121.0	126.4
077-A14A	TDAFWP*	150	104	145.7	154.7	170.1
100-A01A	Switchgear	120	104	126.6	131.2	138.8
100-A03A	Inverter (B)	120	104	137.2	144.6	157.4
100-A05A	Inverter (C)	120	104	129.9	135.2	143.7
144-A01	MCR	110	77	123.3	133.1	151.6
144-A02A	Electrical.	120	77	104.3	109.4	119.3

* TDAFWP: Turbine Driven Auxiliary Feedwater Pump

Table III: Rooms Temperature with Opened Door

Room (RM) No.	RM Description	Allow. Temp. (˚F)	Room Temperature (˚F)			
			0 hr	8 hr	24 hr	72 hr
058-A06A	CP	150	104	134.2	138.2	145.0
077-A01A	Inverter (A)	120	104	132.7	136.6	143.0
077-A04A	HVAC	120	104	112.6	114.5	118.4
077-A07A	MCC (A)	120	104	114.0	115.5	118.7
077-A14A	TDAFWP	150	104	137.0	141.8	139.7
100-A01A	Switchgear	120	104	123.3	126.7	132.3
100-A03A	Inverter (B)	120	104	127.4	131.0	137.2
100-A05A	Inverter (C)	120	104	122.8	125.8	131.0
144-A01	MCR	110	77	112.5	118.6	129.9
144-A02A	Electrical.	120	77	103.9	108.8	118.0

Table IV: Rooms Temperature with Opened Door and Load Shedding

Room (RM) No.	RM Description	Allow. Temp. (˚F)	Room Temperature (˚F)			
			0 hr	8 hr	24 hr	72 hr
058-A06A*	CP	150	N/A			
077-A01A	Inverter (A)	120	104	117.4	119.0	122.1
077-A04A*	HVAC	120	N/A			
077-A07A*	MCC (A)	120	N/A			
077-A14A	TDAFWP	150	104	135.2	139.7	137.1
100-A01A	Switchgear	120	104	112.2	113.4	115.6
100-A03A	Inverter (B)	120	104	115.2	116.7	119.2
100-A05A	Inverter (C)	120	104	113.5	114.7	116.9
144-A01	MCR	110	77	105.5	110.3	119.7
144-A02A*	Electrical.	120	N/A			

* Note: These rooms are excluded from the application of this strategy because it is possible to maintain the temperature below allowable limit by opening door

4. Conclusions

The evaluation on heatup of the rooms containing the plant's safety equipment needed for safe shutdown following a loss of all forced ventilation caused by the LOUHS event is performed for Hanul 3&4 Units to assess the coping capability for long-term operability. The evaluation results show that most of the rooms are able to maintain the temperature below the allowable limit by the operator actions such as opening the doors and/or the load shedding. For MCR and Inverter (A) room, it is required to deploy a portable fan by operators to maintain temperature in the room below acceptable limit during the event.

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