Attachment 3
Control Room Heatup Analysis

R. E. GINNA
CONTROL BUILDING HEAT-UP
DURING STATION BLACKOUT

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ABSTRACT

The purpose of this report is to provide the methodology and results used to determine the thermal environment of the R.E. Ginna Nuclear Power Station Control Building during a four hour Station Blackout. The results provided predict the thermal environment during a complete loss of ventilation in the Control Building during and following a station blackout event. This report also documents testing which was performed to estimate actual area heat loads as used in the analysis.

SECTION 1 -- INTRODUCTION

The objective of this analysis is to determine the thermal environment in which safe shutdown components contained in the Control Building would be required to operate during an SBO event with no ventilation. For the purposes of this analysis, the Control Building was divided into the following four areas as shown in Figure 1:

(1) Control Room,
(2) Relay Room,
(3) Battery Room 1A, and
(4) Battery Room 1B.

Two additional areas in the Control Building that were not analyzed are the Air Handling Room and the Computer Room. The Air Handling Room was not analyzed since it only contains ventilation equipment which was assumed not to be operating, and, therefore, not required. The Computer Room was not analyzed since there is currently no safety-related equipment located in that area.

The remainder of this report is organized as follows:

Section 2 describes how the Control Building test was performed and the analytical approach, assumptions, and input that was used to construct the model.

Section 3 presents the results of the analysis.

Section 4 presents the conclusions of the analysis.

CONTROL BUILDING-GENERAL ARRANGEMENT
(Facing South)

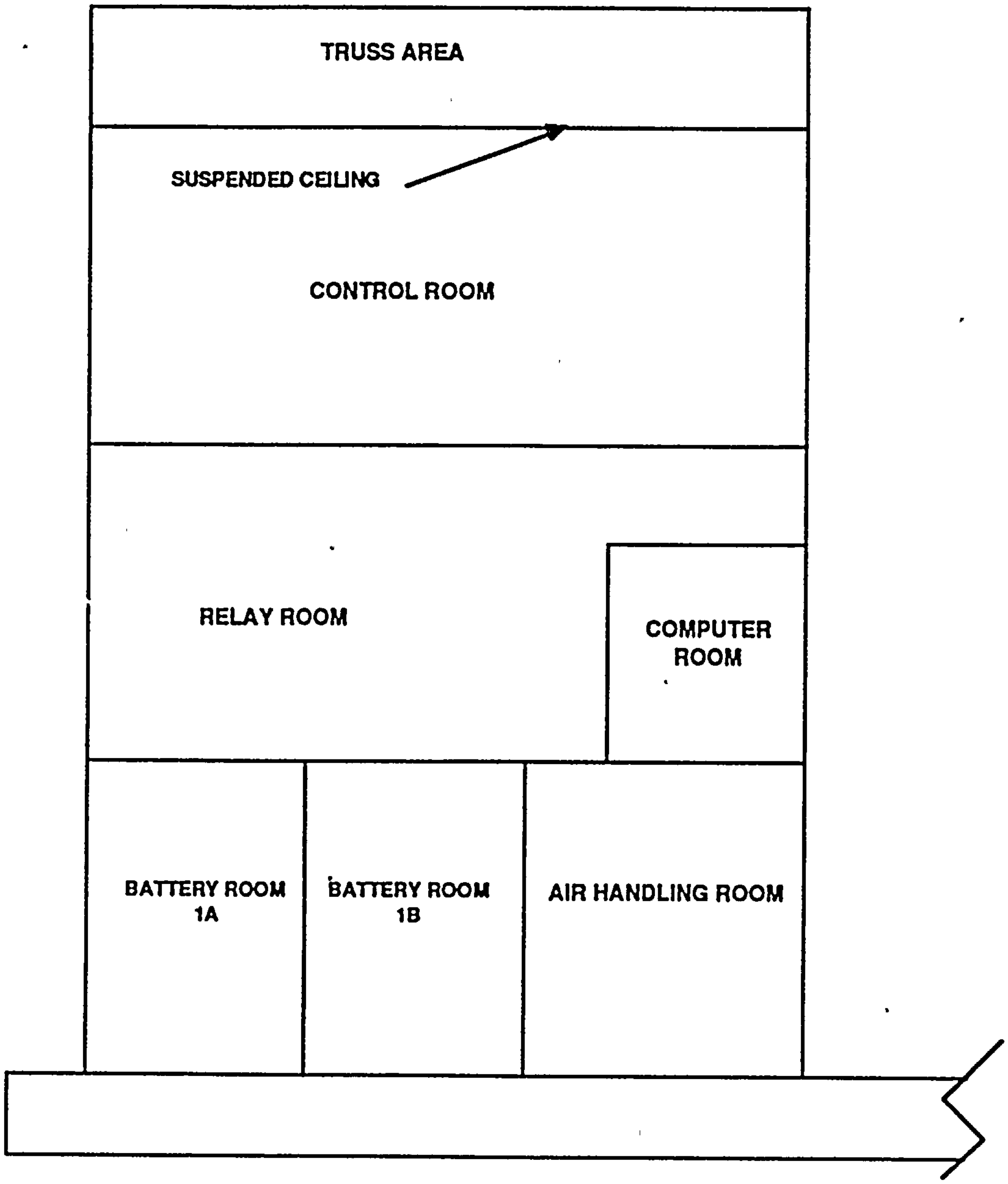

Figure 1

SECTION 2 -- ANALYSIS

2.0 Introduction

The analysis of the R. E. Ginna Control Building thermal environment was performed in three phases as follows:

Phase I	Collect air and wall temperatures within the various rooms comprising the R. E. Ginna Control Building
Phase II	Determine heat generation rates within the various rooms comprising the R. E. Ginna Control Building using the data from phase I.
Phase III	Determine the temperature rise in the various rooms comprising the R. E. Ginna Control Building using the heat generation rates obtained from phase II and the RHU computer code.

The following sections describe the process in more detail.

2.1 Data Collection (Phase I)

In order to accurately calculate the heat generation rate in the areas of interest in the Control Building, it was determined that a test should be performed to collect specific temperature profiles related to the Control Room, the Relay Room, and the two Battery Rooms. A test was considered necessary since an estimation of room heat loads would be extremely difficult due to the number and vintage of electrical components in the Control Building. In addition, any estimation of room heat loads would most likely be excessively conservative and not accurately representative of conditions expected during a loss of ventilation scenario. Consequently, a test was developed in order to measure specific room parameters under operating conditions.

As a means of controlling the test and to identify the data which would be collected and the associated instrumentation required, Ginna Station test procedure ST-89.02 entitled "Control Building Heat Generation Rate Testing" was developed. This procedure directed

the placement of various temperature elements at specified locations throughout the Control Building. The temperature elements were connected to multichannel temperature recorders and digital temperature readouts for data collection purposes. Procedure ST-89.02 also specified that the temperature recorders and digital readouts have a calibrated accuracy of $\pm$ 2% between 40 and 90°F and 0 and 100°F, respectively. The actual locations of the temperature elements (TEs) were photographed following their installation and are identified as follows:

Control Room

- 4 TEs each distributed evenly over the inside of the North, South, East, and West Walls;
- 3 TEs distributed evenly over the Floor;
- 2 TEs distributed on the return (exhaust) register on the West Wall;
- 1 TE placed outside the Control Room door on the Turbine deck area measuring air temperature;
- 1 TE in HVAC ductwork in the Air Handling Room measuring outside air temperature; and
- 1 TE in HVAC ductwork in the Air Handling Room measuring the temperature of the mixture of return air and outside air (i.e., Control Room supply register).

Relay Room

- 4 TEs each distributed evenly over the inside of the North, South, East, and West Walls;
- 4 TEs distributed evenly over the Floor;
- 4 TEs distributed evenly over the Ceiling;
- 1 TE placed on the air intake of each Relay Room air conditioning unit;
- 1 TE placed on the air outlet of each Relay Room air conditioning unit; and

- 1 TE placed outside the Relay Room door in the Turbine Building measuring air temperature.

Computer Room

- 3 TEs each distributed evenly over the inside of the North, South, East, and West Walls;
- 2 TEs distributed evenly over the Floor;
- 2 TEs distributed evenly over the Ceiling;
- 1 TE placed on the supply register for the Computer Room; and
- 1 TE placed on the return (exhaust) register for the Computer Room.

Battery Rooms 1A and 1B

(the information below reflects instrumentation of one battery room; the other is identical)

- 3 TEs each distributed evenly over the inside of the North, South, East, and West Walls;
- 2 TEs distributed evenly over the Floor;
- 2 TEs distributed evenly over the Ceiling;
- 1 TE placed on the air inlet (southwest corner) for the Battery Room;
- 1 TE placed on the air exhaust (northeast corner) for the Battery Room;
- 1 TE placed outside the Battery Room door in the Turbine Building measuring air temperature; and
- 4 TE's suspended evenly throughout the Battery Room measuring air temperature.

In placing the temperature elements as described above, care was taken to ensure that they were located a sufficient distance from adjacent localized heat sources so as to not affect the temperature readings. In addition, at the completion of the test, the data was screened to determine if in fact any heat sources adversely affected the temperature readings of the elements.

The TEs placed in the Turbine Building were used to verify that the room being tested was at a lower temperature than the Turbine building. Consequently, the opening of doors to the Turbine Building data collection created a heat source instead of a potential heat sink. This is conservative since the effect of opening doors was not included with respect to calculating room heat heat generation rates (see Section 2.2). In addition, the air temperature in the Truss Area above the Control Room ceiling (see Figure 1) was assumed to be the same as the Room Supply register. This is due to the fact that the supply register for the Control Room empties into the open Truss Area. This cooler air then falls through holes in the Control Room ceiling.

The test was performed separately for each room and temperature data was collected for a minimum of 24 hours. The procedure included a provision to ensure at least once per shift, the temperature recording equipment was functioning properly and the integrity of the temperature leads had been maintained.

2.2 Determination of Electrical Heat Generation Rate (Phase II)

Following the completion of the Control Building test, the data obtained was used to determine room heat generation rates. The methodology used to determine these rates is outlined in the following sections.

2.2.1 Performance of an Energy Balance

The quantity of heat that is removed or added to a particular volume of air can be determined by performing an energy balance over time as shown below:

$$\Sigma Q' = \rho c_p V dT/dt \qquad \text{Eqn 1}$$

The left hand side of the equation represents the summation of the various heat rates that are imposed on the air volume of concern. The right hand side of the equation represents the change in temperature of a specific volume of air over time.

If equation 1 is evaluated at any point in time, the right hand side of the equation is equal to zero and the equation can then be presented as:

$$\Sigma Q' = 0$$

or

$$\Sigma Q' = Q'_{e} + Q'_{floor} + Q'_{wall} + Q'_{ceiling} + Q'_{hvac} + Q'_{solar} \quad \text{Eqn 2}$$

where:

Q'_{e} = the electrical heat generation rate;
Q'_{floor} = the rate of heat transferred from the floor to the air;
Q'_{wall} = the rate of heat transferred from the wall to the air;
$Q'_{ceiling}$ = the rate of heat transferred from the ceiling to the air;
Q'_{hvac} = the rate of heat added to the air by the ventilation system; and
Q'_{solar} = the rate of heat added to the air by solar effects.

A sign convention was selected as follows:

If heat is being removed from the air, such as heat removed by the ventilation system, then a negative sign (-) will be applied. If heat is being added to the air, as in the case of a wall or ceiling which is warmer than the ambient air, then a positive sign (+) will be applied.

Once the heat generation rates are determined for Q'_{solar}, Q'_{floor}, Q'_{wall}, $Q'_{ceiling}$, and Q'_{hvac} this steady state relation (Eqn 2) can be used to determine the heat emitted by electrical equipment since the ventilation system attempts to maintain a constant room temperature. Consequently, any increase in room heat load (equipment, solar, etc) is matched by a corresponding increase in heat removed by the ventilation system and heat transfer to the walls.

Q_{floor}, Q_{wall}, and $Q_{ceiling}$ were calculated using data taken during the Control Building test as follows:

For each surface (wall, ceiling, or floor), a mean surface temperature was calculated from the temperature reading output. This arithmetic average was calculated by selecting the temperature readings at various points in time from each of the TEs on these surfaces. Since the variations of wall temperature were minimal over the duration of the test, eight readings were selected. The readings were taken so as to represent an even distribution throughout the test. An average surface temperature was then determined for each point in time based on the TE readings. In addition to these eight temperatures, the highest single temperature recorded and the lowest single temperature recorded by any of the TEs on the subject surface were included. An "analysis value" was then determined based on the mean

of the 10 defined points; i.e., the mean of each of the eight points, the highest single reading, and the lowest single reading. Air temperatures were treated in a similar manner.

Once all of the aforementioned temperatures were derived, Q, the rate of heat transfer was calculated using flat plate free convection heat transfer correlations. The correlations for dimensionless constants such as Ra and Nu are based on physical properties of air at 80°F (300°K). The equations applied are as follows (see Reference 1):

$$Q = h\ A\ (Ts - T_\infty) \qquad \text{Eqn 3}$$

where:

h = heat transfer coefficient — Eqn 4
A = area of the surface being considered
T_S = temperature of the surface being considered
T_∞ = temperature of the air surrounding the surface being considered

In addition, the following relations are used (see Reference 1):

$$h = (Nu*k)/L$$

where:

$$Nu\ \alpha\ Ra \qquad \text{Eqn 5}$$
$$Ra = \{gB\ (Ts - T_\infty)\ L^3\}/\ \alpha\ v \qquad \text{Eqn 6}$$

for a vertical plate (wall) (see Reference 1):

L = height

$$Nu = \{\ 0.825 + [0.387\ Ra^{1/6}]\ /\ [1 + (0.492/Pr)^{9/16}]^{8/27}\} \qquad \text{Eqn 7}$$

for a horizontal plate (wall or ceiling) (see Reference 1):

L = Surface Area / Perimeter

Nu for the Upper Surface of a Heated Plate or the Lower Surface of a Cooled Plate is (see Reference 1):

$$Nu = 0.54\ Ra^{1/4} \qquad \text{Eqn 8}$$

Nu for the Lower Surface of a Heated Plate or the Upper Surface of a Cooled Plate is (see Reference 1):

$$Nu = 0.27\ Ra^{1/4} \qquad \text{Eqn 9}$$

Physical properties of air such as k, α, ν, and Pr have been taken from Table A.4 of *Introduction to Heat Transfer* by Incropera and DeWitt (Reference 1). The wall, ceiling and floor surface areas were calculated based on Reference 3.

Qhvac has been calculated using the following relationship:

$$Q_{hvac} = \rho c_p V' dT \qquad \text{Eqn 10}$$

where:

dT = the change in air temperature at each time step

V' = the volumetric flow rate of the ventilation system.

For the Control Room, a volumetric flow rate V' of 4826 cfm was determined from the 1987 Control Room Habitability Survey performed by Nuclear Consulting Services, Inc (Reference 2). It was assumed that the system flow rate was unchanged since the 1987 test since no modifications have been performed to the system and the damper positions essentially remain constant as confirmed verbally with Results and Tests personnel.

In the case of the Relay Room, it was necessary to account for the on/off operation of the individual air conditioners. Therefore, air temperatures for the inlet and outlet of both units were recorded and their associated Q was calculated at each time step using equation 10. The total Q was then calculated over the entire test period and transferred to an average rate for the test. The Qe values were then obtained for each room based on the above calculated values and equation 1. The resultant Q_e values are provided in Table 1.

TABLE 1
INITIAL CONDITIONS

ROOM	SURFACE AREA (SQ. FT.)	INITIAL AIR TEMP (°F)	HEAT SOURCES	HEAT INPUT (BTU/HR)
CONTROL ROOM	5674.6	77	INSTR. PANELS INSTR. CABINETS LIGHTING PERSONNEL	48609.7
RELAY ROOM	6358.9	77	INSTR. CABINETS LIGHTING ACU FAN MOTORS	33703.2
BATTERY ROOM A	2475.8	85	CLASS 1E INVERTER A LIGHTING	15998.7
BATTERY ROOM B	2525.3	85	CLASS 1E INVERTER B LIGHTING	15998.7

2.3 Determination of Temperature Rise (Phase III)

The temperature rise in the R.E. Ginna Control Building following a loss of all ventilation was determined by applying the RHU computer code. The following sections describe the RHU computer code and the inputs used.

2.3.1 Methodology and Analytical Approach

Devonrue's RHU computer model was used to analyze the Control Building Thermal Environment during a loss of ventilation (see Reference 8). RHU is a one-dimensional lumped-parameter heat transfer model. A variety of parameters which represent the physical characteristics of the building being analyzed are input to the model. These parameters include, surface area of heat sinks, heat transfer properties of the materials, and heat generation rates. More detail on the required inputs are found in the following subsections.

In order to accurately represent the physical occurrences during a loss of ventilation scenario, the Control Building was divided into the four areas as described previously. This was done since thorough mixing of the ambient air could be assumed for these areas.

The temperature of each area of concern was determined by performing an energy balance on the area. This energy balance is represented by the equation:

$$\rho C_p V dT/dt = Q'_{total} \qquad \text{Eqn 11}$$

where:

ρ is the density of the room air at a particular time

C_p is the specific heat of the air at a particular time

V is the volume of air within the room

dT/dt is the change in room air at a particular time

Q'_{total} is the sum of the heat rates generated by sources and absorbed by heat sinks

Many factors need to be considered in order to accurately represent the quantity Q'_{total}. Q'_{total} consists of heat from motors, lights, hot pipes, personnel, solar effects and in some cases the heat through openings from adjacent rooms (doors) as well as the heat lost through concrete walls, and heat loss through openings in the room. More accurately the above equation can be represented as:

$$\rho C_p V dT/dt = Q'_{electric} + Q'_{wall} + Q'_{solar} + Q'_{openings} \qquad \text{Eqn 12}$$

The quantity of heat that is imparted to the room as well as the heat removed by heat sinks is dependent on the temperature difference between the air within the room and the surface temperature of these sources and sinks. For the purposes of this analysis, heat generated by electrical equipment is considered to be constant. This temperature difference will account for a sign change in the above quantities for surfaces that are cooler than the room air indicating that heat is being removed from the room. In general, the quantity of heat generated or absorbed by a particular object or structure can be represented as:

$$Q = H_t A_s (T_{surface} - T_{air}) \qquad \text{Eqn 13}$$

where:

Q is the heat transferred from the surface to the air

H_t is the natural convective heat transfer coefficient

A_s is the surface area of the object
T_{air} is the temperature of the air within the room
$T_{surface}$ is temperature of the object

As is readily apparent, the direction of heat transfer is dependent on the sign of the temperature difference between $T_{surface}$ and T_{air}.

The major difference between analyzing natural and forced convection is that for forced convection the air velocity is constant. Since the convective heat transfer coefficient is dependent on the velocity of the air, it follows that the heat transfer coefficient is also constant for forced convection. However, since the air velocity for natural convection is dependent on the difference in temperature between the surface and the air, it is readily apparent that the convective heat transfer coefficient is affected by this temperature difference. Therefore, as the air temperature changes, so must the convective heat transfer coefficient. This change in heat transfer coefficients can be determined by a variety of correlations depending on the geometry of the object being considered.

The models used for this analysis incorporate the latest numerical techniques to accurately represent the temperature rise within the rooms considered. The models which were used require inputs that represent the physical parameters of the rooms as well as various heat inputs. The inputs required for each room to be analyzed by the model are as follows:

QEL:	The heat input due to electrical equipment within the room (W)
AREA:	The surface area of walls, floors, and ceilings that can be readily considered as heat sinks (m^2)
VOLUME:	The free air volume in the room (m^3)
TAIR:	The initial air temperature of the room (°K)
TW:	The initial temperature of the walls and ceiling (°K)
AND:	The number of openings in the room
WIDTH:	The width of any openings (m)
HEIGHT:	The height of any openings (m), or length in the case of openings in the floor or ceilings

Several of these inputs were determined in Section 2.2 of this report with the remaining inputs being calculated as necessary. Assumptions which were used are discussed below.

2.3.2 Input Data and Assumptions

The input data for the RHU computer code contains various underlying assumptions as described in the following sections.

2.3.2.1 Initial Conditions

The R.E. Ginna Nuclear Power Plant was assumed to be operating at full power when a station blackout (SBO) event occurs. At that time, all ventilation is lost to the Control Building including the individual AC units in the Relay Room. It should be noted that no credit was taken for the single DC powered fan between the Air Handling Room and Battery Room 1B. The basis for this is that the supply air for this fan is taken directly from the Air Handling Room. There is a nominal temperature increase for this room during the station blackout due to conduction of heat through the walls from Battery Room 1B and the Turbine Building. Since the DC powered fan has no cooling function, providing warm air to the Battery Rooms would be of limited benefit. In addition, the exhaust fans for each Battery Room are AC powered and would not operate during a station blackout. Consequently, the effect of the DC powered fan would be negligible.

The four hour station blackout-induced loss of ventilation event was assumed to take place at noon on a day with maximum design basis outside temperatures. This assumption allows for additional conservatism in that the maximum heat input experienced to the Control Building areas occur during the time of day when the air temperature is greatest. This is due to the fact that because of thermal lag time, it takes several hours for the concrete walls and roof to heat up and effect the room thermal environment. The outside air temperature profile as determined from Reference 4 was used for this analysis. In addition, the maximum outside temperatures were assumed to exist throughout the four hour scenario.

The solar heat loads were calculated using the following relationship (see Reference 4):

$$q = U \times A \times CLTD \qquad \text{Eqn 14}$$

where:

U = the overall heat thermal resistance
A = the surface area of the wall
CLTD = Cooling Load Temperature Difference

2.3.2.2 Initial Wall Temperatures

The initial wall temperatures are internally initialized by the RHU computer code. The code performs a heat balance across the wall based on the initial temperatures of the surroundings on each side of the wall. For those surfaces located beneath ground level, a temperature of 75° F was used for the initial temperature of the exterior surroundings. This temperature was determined by the following relationship:

$$T_S = T'_a - A \qquad \text{Eqn 15}$$

where:

T_S is the temperature of the surroundings

T'_a is the mean air temperature

A is constant based on geographical location (see Ref. 4)

T'_a was conservatively assumed to be the maximum design basis outside air temperature. This forced the surrounding temperature to be a reasonable maximum, thereby minimizing the capability of these surfaces to act as a heat sink.

2.3.2.3 Heat Sinks

The heat sinks credited during this analysis consisted of the structural boundaries of the various rooms analyzed. As inside room temperatures rises, the solar contribution diminishes and the outside environment also becomes a heat sink.

SECTION 3 -- RESULTS

3.0 Introduction

This section of the report presents the results of the RHU computer runs for the R.E. Ginna Control Building. Each area is evaluated for a four hour period consistent with the Ginna SBO coping duration.

3.1 Control Room

Figure 2 presents the results over a four hour period for SBO purposes. As can be seen, the four hour temperature for the Control Room are 123.8 °F with the door closed and 115.9 °F with the door opened. Since the temperature calculated during the four hour period is less than 120 °F with the doors open, reasonable assurance of equipment operability is provided in accordance with NUMARC 87-00 and its supplemental guidance. However, Ginna procedures will have to be revised to require operators to remove ceiling tiles and open the door to the Turbine Deck.

There appear to be several factors contributing to these elevated temperatures. First, the addition of the "super wall" between the Control Room wall and the Turbine Deck created an air space of approximately two feet. This air space acts as an insulator and prevents rejection of heat to the Turbine Deck. Second, a significant amount of the remaining three walls and roof of the Control Room are exposed to significant gain effects. Finally, the calculated temperature in the Relay Room below inhibits the Control Room floor's capability to act as a heat sink and actually contributes as an additional minor heat source.

CONTROL ROOM TEMPERATURE PROFILE
(4 hours)

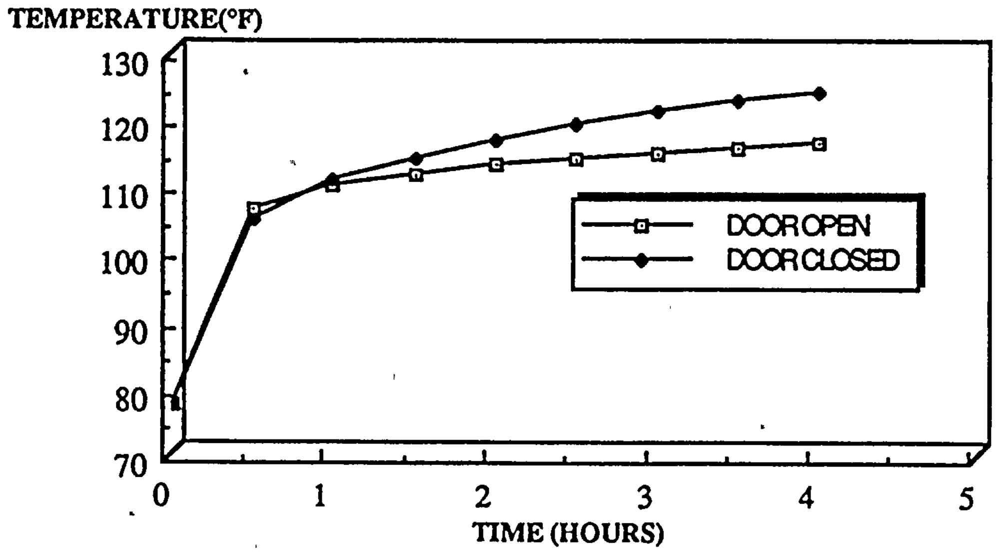

Figure 2

3.2 Relay Room

Figure 3 presents the four hour temperatures for the Relay Room. As can be seen, room temperatures are not expected to exceed 99 °F with the door open and 103 °F with the door closed. Consequently, since both cases produce temperatures less than 120 °F, reasonable assurance of equipment operability is provided in accordance with NUMARC 87-00 and its supplemental guidance. Therefore, no operator intervention is required for SBO purposes.

RELAY ROOM TEMPERATURE PROFILE
(4 hours)

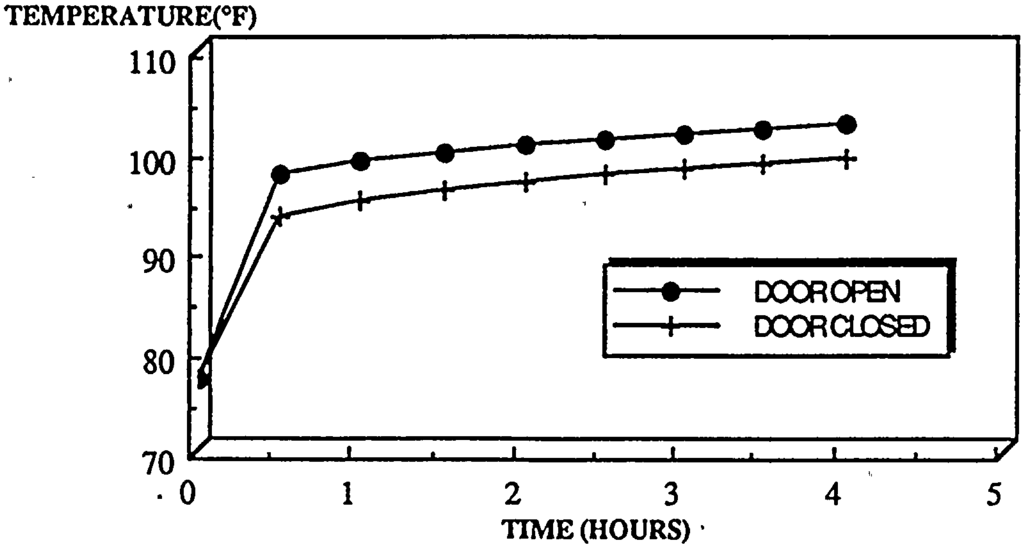

Figure 3

3.3 Battery Room 1A

Figure 4 presents the four hour temperatures for Battery Room 1A. Room temperatures are not expected to exceed 107 °F with the door closed and 106.4 °F with the door open. Since both cases produce temperatures less than 120 °F, reasonable assurance of equipment operability is provided in accordance with NUMARC 87-00 and its supplemental guidance. Therefore, no operator intervention is required during a SBO event.

BATTERY ROOM 1A TEMPERATURE PROFILE
(4 hours)

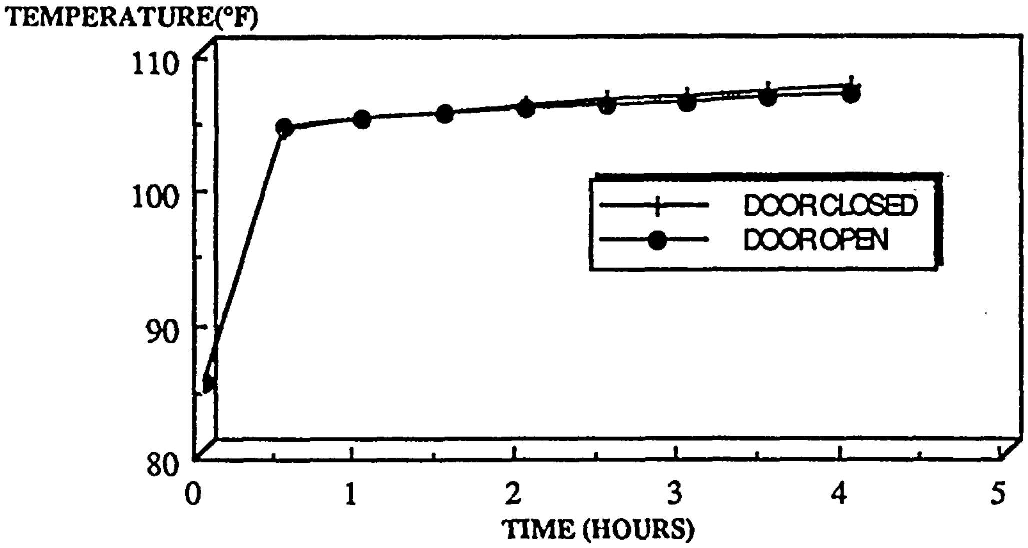

Figure 4

3.4 Battery Room 1B

Figure 5 shows that the four hour temperatures for Battery Room 1B is not expected to exceed 106.2 °F with the door closed and 105.8 °F with the door open. Since both cases produce temperatures less than 120 °F, reasonable assurance of equipment operability is provided in accordance with NUMARC 87-00 and its supplemental guidance. Therefore, no operator intervention is required during a SBO event.

It should be noted that the resultant temperatures are slightly lower than Battery Room 1A. The likely explanation for this is that Battery Room 1B abuts the Air Handling Room. The wall between Battery Room 1B and the Air Handling Room is thinner than the exterior wall for Battery Room 1A. The thinner wall promotes better heat transfer out of the area, in the short term, accounting for the slight difference in temperature.

BATTERY ROOM 1B TEMPERATURE PROFILE
(4 hours)

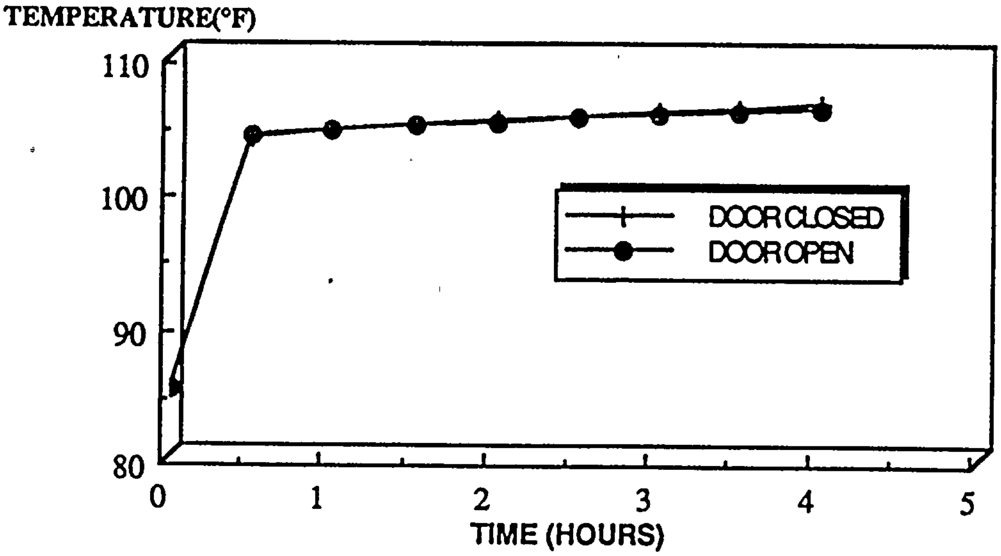

Figure 5

SECTION 4 -- CONCLUSION

4.0 Uncertainties

The expected uncertainty in the calculated results can be considered counterbalanced by the conservatism employed in the analysis. In addition to those conservatisms incorporated in the RHU Computer Code, these include:

(1) assuming equipment heat loads remain constant and that power is not lost to any of those loads, and

(2) assuming that no heat was added to the room due to solar effects during the Control Building test.

Consequently, the calculated peak temperatures can be considered bounding.

4.1 Summary

The scenarios analyzed in this report represent the worst possible heat load combinations for the R.E. Ginna Control Building. The Control Room is the only area requiring operator intervention over a four hour SBO event.

SECTION 5 -- REFERENCES

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