DETERMINATION OF THE WATTS BAR NUCLEAR PLANT DIESEL BUILDING VENTILATION SYSTEM REQUIREMENTS

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Abstract

The Watts Bar Nuclear Plant (WBN) diesel engines and their connected generators provide emergency power to the plant. As such, the diesels are considered as part of the most important safety equipment of the plant. The buildings that house the diesels are large concrete structures that provide protection from tornadoes, earthquakes, the environment. In order to provide an acceptable environment for the diesels, ventilation systems are provided to remove the large amounts of heat rejected to the building during engine operation.

The ventilation system was sized based on manufacturer's information and was initially tested in 1982. During that time frame, TVA was contacted by the diesel manufacturer and informed that the existing criteria for sizing the ventilation system was incorrect. This was confirmed independently by preoperational tests conducted at WBN. TVA conducted additional tests to determine the actual ventilation system requirement and modified the system to account for the true ventilation cooling loads.

In anticipation of maintenance requirements for the ventilation system WBN personnel, needed to establish ventilation system capabilities with reduced ventilation system capabilities. In establishing these requirements the existing system calculations proved inadequate for the necessary information. Testing was performed in the summer of 1997 to provide additional information. The information collected differed from previous information (both TVA and manufacturer) and showed higher cooling loads than previously calculated. The new information was used in calculations and resulted in more restrictive operation of the ventilation system. As there were differences between previous WBN test results, current test results, and manufacturer test results WBN planned and implemented a special test to resolve these differences and establish worst-case system operation.

To minimize the variables affecting the ventilation system operation, the special test on the system accounted for maximum diesel cooling water temperatures, minimum possible ventilation flows, minimum diesel cooling water flows, and maximum fouling of the DG heat exchanger. Data was collected and calculations were performed using the new data resulting in an increased operational range. The data and calculations also showed that the heat given up to the diesel room varied with ventilation airflow, diesel engine cooling water temperature, and entering air temperature. Consequently, new operating requirements were placed into the plant operating instructions.

Introduction

Diesel engines installed at nuclear power plants provide emergency power to the plant following an accident. The Watts Bar Nuclear Plant (WBN) diesel engines and their connected generators are considered as part of the most important safety equipment of the plant. The buildings that house the diesels are large concrete structures that provide the engines protection from tornado generated missiles, earthquakes, and the environment. Diesel engines/generators and all associated electrical equipment are designed to rigorous electrical requirements and typically include environmental consideration (this is called Class 1E). In order to provide an acceptable environment for the diesels and associated equipment, ventilation systems are provided to remove the large amounts of heat from the building during engine operation.

Once-through ventilation systems are typically used, rather than air conditioning or recirculation ventilation, due to the large amounts of heat released from the engines and generator. Once-through ventilation systems are commonly used as they are economical, simple, and can provide large amounts of cooling. The WBN ventilation system is a once-through system and was sized based on manufacturer's information. The diesel manufacturer provided a design cooling load value that referred to engine horse-power. During the time frame of the testing

TVA was contacted by the diesel manufacturer and was informed that the established criteria for sizing the ventilation system was incorrect. This was confirmed independently by preoperational tests conducted at WBN in 1982. TVA conducted additional tests to determine the actual ventilation system cooling requirement and modified the ventilation system to account for the true ventilation requirements such as cooling loads. The as-tested value was larger than the original manufacturer's value but smaller than the revised value.

Table 1
Various Tested
Diesel Engine* Heat Loads Used for
Ventilation System Design Values

Source	Value
Original Manufacturer Value (pre-1982)	1.37 btu/hp-min
Revised Manufacturer Value (1982)	3.82 btu/hp-min
As tested WBN Value (1982)	2.04 btu/hp-min
As tested WBN Value (Summer 1997)	2.70 btu/hp-min

*Same size engine

In 1984 WBN completed modifications to the ventilation system to account for increased heat loads. Note that the calculated values for the heat loads changed, not the actual heat as no new equipment was added. The modifications to the ventilation system were to have two ventilation exhaust fans run concurrent with diesel engine operation (previously only one fan ran concurrent with diesel engine operation) and to add a third fan providing direct ventilation air to the electrical generator air intake and to the control panels located in the engine room. The control panels and the generator are considered critical components requiring additional ventilation to maintain acceptable equipment temperatures and is based on an evaluation of equipment within the room.

Reestablishment of Heat Loads

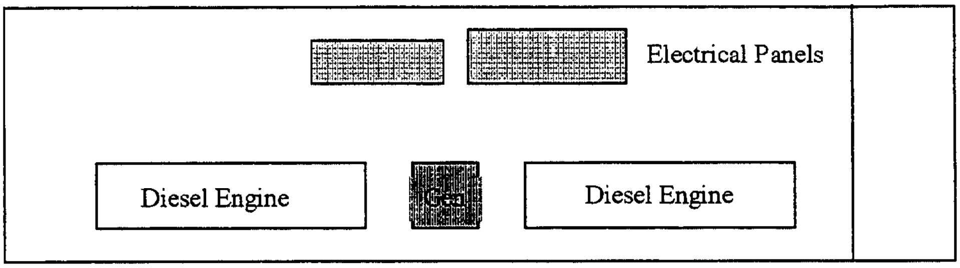
In anticipation of maintenance requirements for the ventilation system during plant full power operation, in 1997 WBN plant personnel needed to establish ventilation system capabilities with reduced fan capacities. In other words, when a fan is removed from service, what are the remaining capabilities of the system. Previous testing in 1982 established building cooling loads. This information was then used to establish fan requirements (via calculations) for varying outside air temperature. Three sets of fan combinations were considered. These are: 1) one DG room exhaust fan off, 2) the generator and electrical panels ventilation supply fan off, or 3) all fans running normally. A maximum outside temperature is associated with each set of fan combinations to allow removal of one of the three fans from service for maintenance during plant operation. This also establishes the maximum outside air temperature at which the ventilation system can maintain acceptable component and room temperatures. In establishing these requirements the previous system calculations (based on 1982-83 testing) proved inadequate in determining the acceptable room temperatures.

Problems with the previous information included unverified assumptions for acceptable maximum component temperatures, equipment added since 1984 was not considered, uses Sequoyah Nuclear Plant (SQN) test data (temperature limits were based on testing at SQN which was not performed at WBN and assumes the ventilation systems, cooling loads, and temperature gradients are similar between the two plants, as both plants have the same basic design), and essential raw cooling water (ERCW) temperature during the tests at WBN that were not discussed and have an indeterminate affect on the room cooling loads and temperature. These assumptions are not backed up with sufficient documentation to support their validity.

Testing was performed in the summer of 1997 to provide additional information. Information collected differed from previous information (both WBN and manufacturer) and showed higher heat loads than previously known (see Table 1). Data was collected using the same methodology as used in previous tests. This methodology consisted of measuring mass flow (airflow) through the room and the temperature change of the air. This information was used in calculations and resulted in more restrictive operation of the ventilation system. There were inconsistencies in test results between vendor, TVA test in 1982 time frame, and TVA test in 1997. This was puzzling as the test methodologies used were the same in all three instances and should have resulted in the same results (see Table 1). As there were differences between previous WBN test results, current WBN test results, and manufacturer test results; WBN planned a special test to resolve these differences and establish worst-case system operational limits.

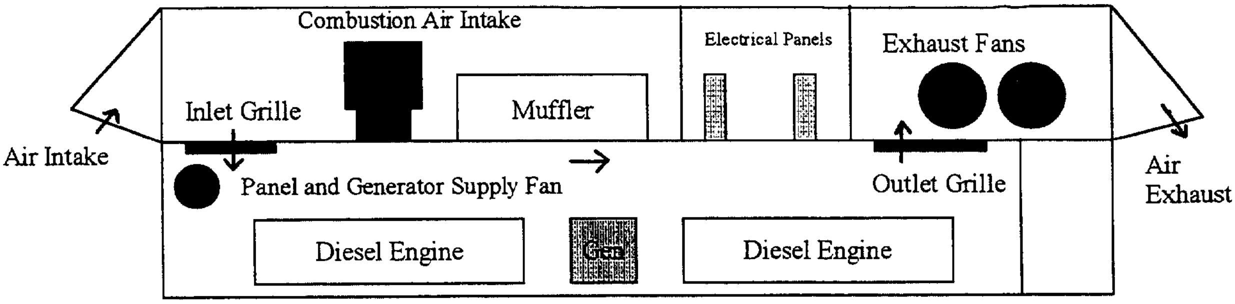
Discussion of Special Test

Air flow through each diesel engine/generator (DG) room is induced by two exhaust fans which draw outside air into the air intake room, through the DG room and into the air exhaust room (see Figures 1 and 2). The generator and electrical panels ventilation supply fan draws air from the air intake opening (in the DG room) and ducts this air directly to both DG electrical panels and near the generator air intakes. In doing so, it provides location specific (spot) cooling to critical components within the DG room. There are four DG rooms within the diesel building and all are identical in arrangement.



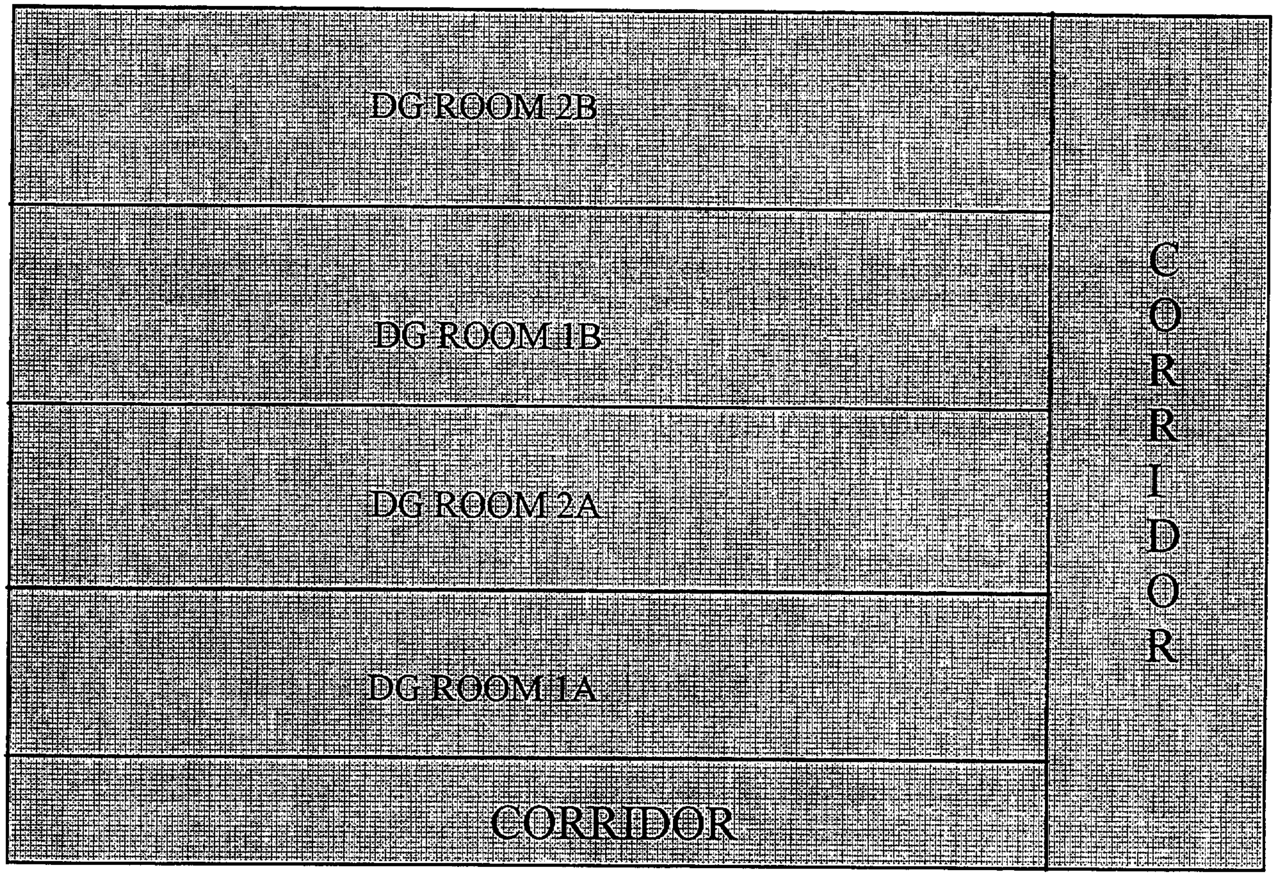
Diesel Building Plan View

→ Airflow Direction Through Room



Diesel Building Section View

Figure 1 - WBN Typical DG Room



WBN SIMPLIFIED DIESEL BUILDING ROOM ARRANGEMENT
FIRST FLOOR

Figure 2
(Plan View)

DG room air temperatures, both the bulk air temperature and temperatures at specific locations within the room, are a function of the heat loads present, the mass flow rate of air passing through the room, and the entering air temperature. Major sources of heat within each DG room are the diesel engines and electrical generator. The generator heat load contribution is a function of how it is loaded electrically and is controlled throughout each test. The diesel engine heat load contribution to the room air is a function of its surface temperature, surface area and convective heat transfer coefficient. Surface temperature is controlled by the jacket water cooling system, while the heat transfer coefficient, in simplified form, is a function of the air velocity and surface geometry. Jacket water cooling system performance is affected by ERCW entering temperature, ERCW flow rate, and the degree of fouling present within the jacket water heat exchanger. In consideration of all of these variables, it is not practical to calculate location specific temperatures within the room, or bulk air temperatures for postulated worst case accident conditions (reduced ERCW flow rate, maximum heat exchanger fouling factor, changing heat transfer coefficients, etc.). The most accurate method for eliminating these unknowns is to manually increase the diesel engine jacket water temperature to near its high temperature alarm limit (187°F), de-energize one DG room exhaust fan, or the generator and electrical panels ventilation supply fan and directly measure temperatures at specific locations within the DG room. Therefore, to minimize the variables affecting the ventilation system operation, the Special Test on the system accounted for maximum diesel cooling water temperatures, minimum possible ventilation flows, and minimum diesel cooling water flows.

Thus, the purpose for the Special Test was to simulate worst-case conditions with 1) one DG room exhaust fan off, 2) the generator and electrical panels ventilation supply fan off, or 3) with all fans running normally. The outside air temperature recorded during the test can be extrapolated by a subsequent design calculation to establish accurate limiting outside air temperature values for each fan out-of-service condition.

The following additional items were also considered in performance of the Special Test:

- Technical Specifications: The test was performed during a refueling outage. This required two diesel generators (DGs) either train A or train B capable of supplying one train of onsite Class 1E AC electrical power. This was adhered to as only one of the four diesels was being tested concurrent with its required 24 hour endurance run.
- Compensatory Measure: Compensatory measures required re-establishing full ventilation and (or) ERCW flow if temperature limits for DG jacket water, generator stator winding, generator bearing, electrical panels internal, and DG room exhaust weighted air average were exceeded.
- Design Basis Document: The maximum electrical panels internal temperatures and air temperature supplied to the generator was monitored. Documentation provided by DG vendor allows for the electrical panels internal temperature to reach 120°F during periods when the DG is operating (130 °F was allowed by the vendor). Generator stator winding and bearing temperatures were monitored throughout the test to assure that maximum values of 248°F (120°C for stator) and 185°F (85°C for bearings) were not reached.
- Electrical Loads: The only electrical load changes associated with the test were due to de-energizing either the generator and electrical panels ventilation supply fan, or one DG room exhaust fan. The effects of these changes were monitored during the test by measuring temperatures at specific locations.
- Equipment Failure Modes: No new failure modes were created since temperatures, both at specific locations within the room and average room exiting air temperature were maintained below allowable maximum values.
- Instrument Setpoints: Instrument Setpoints associated with the engine for high jacket water temperature of 187°F +/-3°F for high diesel water temperature were monitored. This value is below the HI temperature shutdown limit of 205°F and does not result in damage to the engines. Guidance was provided in the test instruction to plant Operations that these alarms may initiate during the test, and that jacket water was to be continuously monitored. Actions were taken during the test to maintain jacket water temperature at 185°F +/-2°F. A caution in the test instruction required full ERCW flow to be re-established if jacket water reached 190°F.
- System Design Parameters: Temperatures at critical locations were monitored during the test to assure that design values were not exceeded. These included the bulk room air as measured at the DG room exhaust grille, diesel jacket water entering the heat exchangers, generator stator winding and bearing, and electrical panels internal temperature. Cautions were in place within the test instruction to re-establish full ERCW flow and/or ventilation if maximum design acceptable temperatures were reached.
- Valve Alignment Changes: Valve alignment changes were not made during the test, however, ERCW valves to the diesel engine heat exchangers were throttled toward the closed position from their balanced position to increase the diesel jacket water temperature. Continuous monitoring of this temperature was performed during the test to assure that 190°F was not reached. Each throttle valve was then returned to its original balanced position prior to exiting the test.
- Neutral Grounding Resistor: Resistance was used by the diesel generator as a substitute load. Located in the diesel building air intake room this resistor, when operating, increases the room air intake temperature by less than 1°F. The value 1°F is conservatively used in calculations to account for the effects of the grounding resistor.

Special Test Scope

The Special Test was conducted with a 24-hour endurance load test surveillance instruction in September 1997, during a refueling outage. During the initial two hours of the test (Phase I), while the DG was fully loaded, the DG was allowed to stabilize thermally in an as-found condition. Air inlet and outlet dry bulb temperatures as well as barometric pressure, inlet wet bulb temperature and surrounding room temperatures were measured and recorded.

Phase II After the initial two hours and once generator stator winding temperatures have stabilized, the generator and electrical panels ventilation supply fan was de-energized simulating an out-of-service condition for this fan. ERCW valves associated with diesel engine heat exchangers were throttled from their balanced position until diesel water jacket temperatures of 185°F +/- 2°F were obtained, simulating reduced ERCW flow, maximum fouling condition, and maximum ERCW temperature; which could exist during worst case accident conditions. Jacket water return temperature to each heat exchanger was recorded and monitored throughout the test. Enough data was collected to demonstrate thermal equilibrium was achieved. Air inlet and outlet dry bulb temperatures for the DG room as well as barometric pressure, inlet wet bulb temperature and surrounding room temperatures were measured and recorded. Air inlet temperatures and velocities to the six generator air intakes and the internal temperatures of the DG electrical panels were recorded and monitored throughout the test. Maximum acceptable temperature limits for the generator stator winding, generator bearings, and within each electrical panel were not exceeded. DG room bulk air temperature were determined based on a weighted average of the exhaust air temperature from the DG room. This temperature was not allowed to exceed the abnormal maximum value of 120°F. Diesel jacket water cooler performance data was also collected concurrently to determine the total heat load removed by each heat exchanger and to record jacket water temperatures. At the end of this portion of the test, the generator and electrical panels ventilation supply fan was restarted.

Phase III The next phase of the test required one of the two DG room exhaust fans to be de-energized, simulating an out-of-service condition for the exhaust fan with the greatest flow rate. ERCW valves remained in a throttled position such that jacket water temperature remained at 185°F +/-2°F. Data was then collected to demonstrate thermal equilibrium has been achieved. The same data was then collected as described previously. At the end of this portion of the test, the DG room exhaust fan was restarted.

Phase IV The final phase of data collection was performed with all fans, both DG room exhaust fans and the generator and electrical panels ventilation supply fan, running normally. Again, data was collected demonstrating that thermal equilibrium has been achieved. ERCW flow to each heat exchanger remained throttled to maintain DG jacket water temperature at 185°F +/-2°F. The same critical temperatures were monitored and recorded as discussed above. At the end of this final phase, ERCW throttling valves were returned to their original balanced position and the 24-hour load test continued as normal.

Evaluation of Data

The diesel engines and electrical generator are the major contributors of heat in each DG room. The heat contribution from each engine is a function of its surface temperature which is controlled by jacket water heat exchangers cooled by ERCW. Forcing each engine's jacket water temperature to approach 190°F during the Special Test by throttling ERCW flow to each heat exchanger was representative of worst-case accident conditions.

During Phase III of the Special Test the exhaust fan with the greatest flow rate was de-energized simulating an out-of-service condition while de-energized. This exhaust fan was then observed rotating backwards while de-energized resulting in a reduced total flow rate through the DG room. Air velocity data was obtained from each air intake opening of the stopped fan at equal areas in order to establish the total flow rate passing back through the fan. Back flow was calculated through the fan and a conservative correction factor of 0.78 was applied based on guidance provided in Table 9-5 of the Industrial Ventilation Manual, 19th Edition since the openings were covered by a grille and data was collected against the grille.

Several sets of data were recorded in order to establish a relatively stable (steady state) cooling load value. Total room cooling load for each set was calculated as follows:

1. DG room air inlet temperatures were recorded by a resistance temperature device (RTD) digital thermometer.
2. Wet bulb and dry bulb temperatures were used to determine the specific volume (v) of the entering air from the psychometric chart [recall that air density (ρ) = $1/v$].

3. Since the values of specific volume listed on the psychometric chart correspond to a barometric pressure of 29.921 inches of Hg, the density used in the evaluation was adjusted for the lower pressures measured during each test. Since air behaves as an ideal gas, $P = \rho RT$ and $P_1/\rho_1 R_1 T_1 = P_2/\rho_2 R_2 T_2$. Since R is a constant and T_1 is considered the same as T_2, the relationship becomes $P_1/\rho_1 = P_2/\rho_2$, or $\rho_2 = \rho_1 P_2/P_1$.
4. The density factor is simply the product of (density) * (specific heat) * (60 min/hr)
5. Total air flow rate used is based on the flow balance data contained from plant startup tests for either: 1) both DG room exhaust fans running or 2) one fan de-energized.
6. The weighted average exhaust air temperature was calculated based on the summation of the temperature measured at a particular location times its associated velocity divided by the summation of the measured velocities. A weighted average temperature is important since the measured temperatures vary significantly across the DG room exhaust grille area.
7. The heat load removed by the ventilation air flow is based on the equation q = (density factor) * (cfm) * (exit temperature - entering temperature).
8. Heat removed or gained by transmission through the floor, walls and ceiling was calculated based on the overall heat transfer coefficients. The summation of the transmission losses were added to the ventilation cooling load in order to establish the total room cooling load. The percent of the total load associated with transmission was also calculated and determined to be only a few percent of the total maximum.

The following figures and tables show how the heat loads varied for each phase of the Special Test.

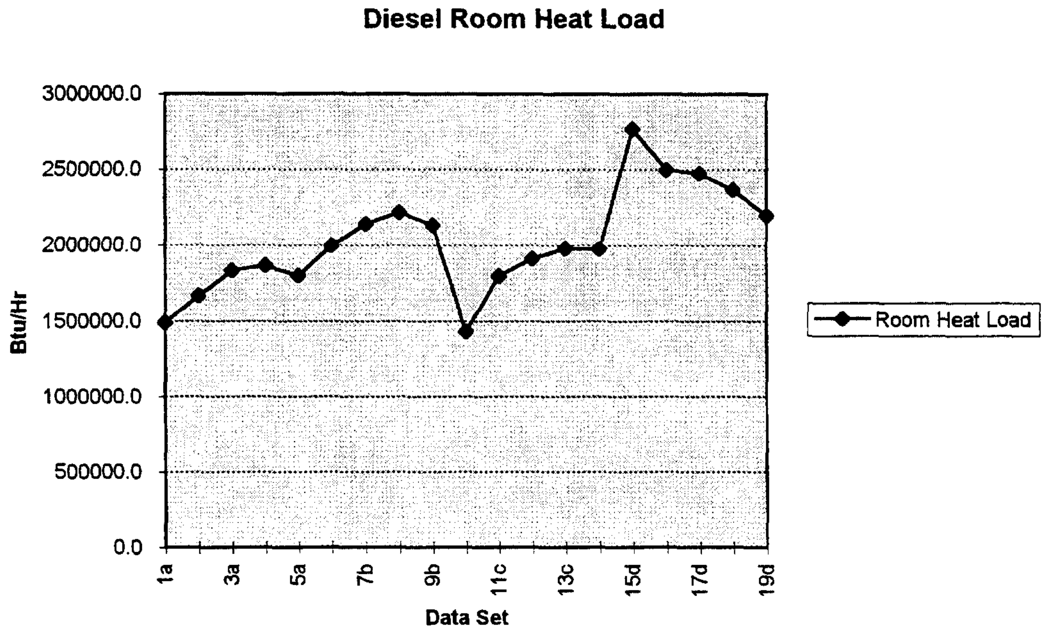


Figure 3

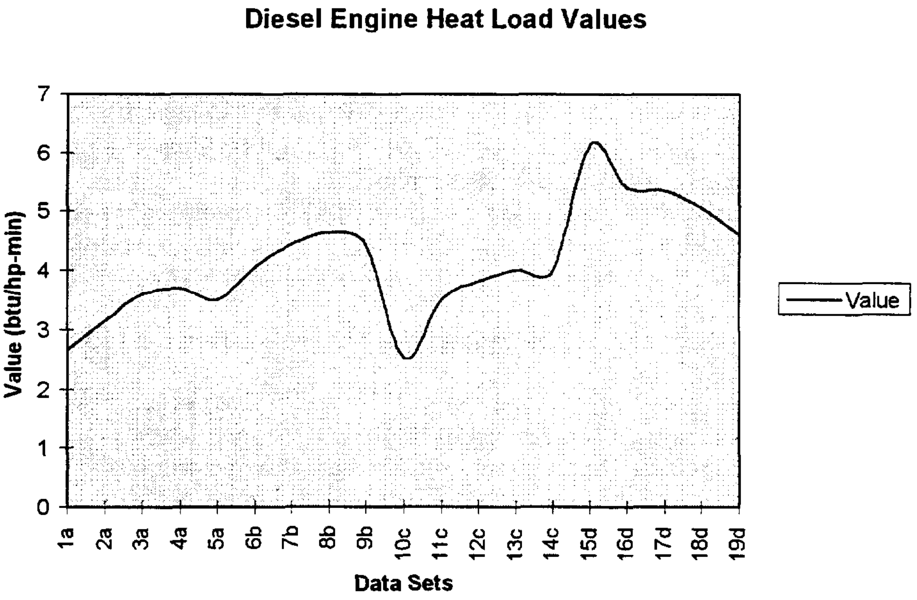


Figure 4

Table 2
WBN Diesel Engine Heat Loads
Special Test

Special Test Phase	Value (btu/hp-min)
Initial Two Hours (data sets 1-5) Phase I	3.7
Generator and Panel Fan Off (data sets 6-9) Phase II	4.65
One Exhaust Fan Off (data sets 10-14) Phase III	4.01
All Fans Running (data sets 15-19) Phase IV	5.06

Note: for data sets 6-19 the diesel engine jacket water temperature was artificially raised to its maximum acceptable value (185°F +/- 2°F)

Thus, it was shown that engine heat load to the room varies with different conditions. Using the heat load data from the Special Test to calculate room temperatures at various points in the rooms and for the various components in the room proved to be complex and led to the following way to evaluate the data.

During the summer 1997 testing, the ERCW flow to each jacket water heat exchanger was balanced and all test conditions were the same. This information is important as it establishes a second data point at a considerably higher DG room entering air temperature than was recorded during the Special Test. This is used to define the cooling load relationship at varying entering air conditions for the DG room. Resulting total cooling loads for the DG room with all fans operating and balanced ERCW flow to each jacket water heat exchanger are as follows:

Table 3
Comparison of DG Room Heat Loads
for Differing Entering Air Temperatures

Test	Heat Load	Entering Air Temperature
Special Test	2.108E+6 Btu/hr	58.58°F
Summer 1997	1.303E+6 Btu/hr	87.83°F

These results substantiate that the DG room cooling load varies significantly with changing entering air temperatures and its affect on air density and mass flow rate. Since fans are constant volume devices the total flow rate through the room remain constant.

These two points were plotted to establish the projected cooling load curve for entering air temperatures reaching a maximum of 108°F. A temperature of 108°F was chosen since it is the extreme maximum temperature for the 0.99 probability level (100 year return period) as defined in NUREG / CR-1390, "Probability Estimates of Temperature Extremes for the Contiguous United States".

The equations for each straight line segment are developed below. Recalling from analytical geometry the slope of a line through two points P1 and P2 is given by:

$$m = (y_2 - y_1)/(x_2 - x_1) \qquad \text{(equation 1)}$$

The two point form of the equation for a line is

$$y - y_1 = m(x - x_1) \qquad \text{(equation 2)}$$

solving for y,

$$y = m(x - x_1) + y_1 \qquad \text{(equation 3)}$$

or

$$y = mx + b$$

which is the slope intercept form of an equation for line.

Using equations 1 and 3 above, an equation for the line defining the DG room total cooling load as a function of entering air temperature under balanced ERCW and full ventilation flow conditions is as follows:

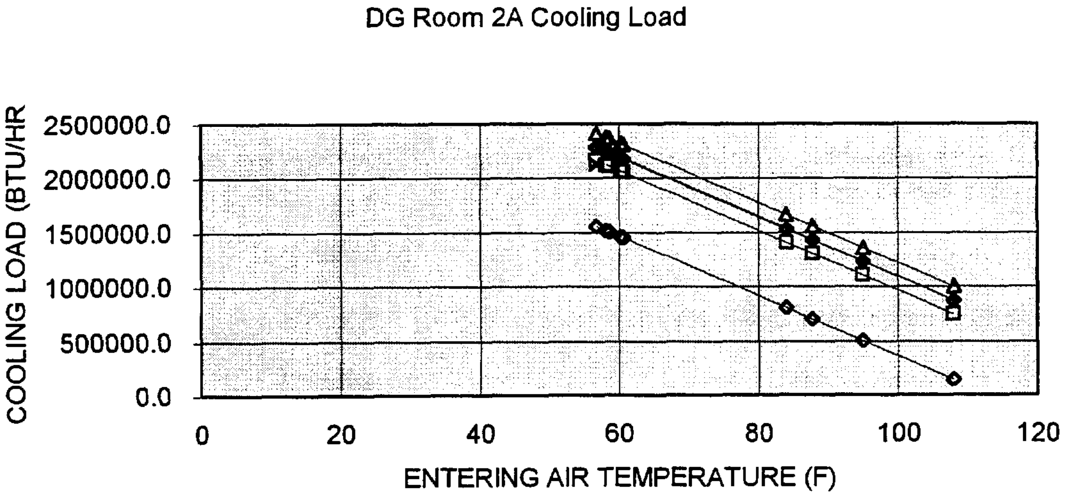
$$m = (y_2 - y_1)/(x_2 - x_1) = (1303433.9 - 2108383.1) / (87.83 - 58.58) = -27519.63$$

$$y = -27519.63\ (x - 58.58) + 2108383.1$$

$$y = -27519.63\ (x) + 3720483.03 \qquad \text{(equation 4)}$$

Equation 4 was programmed into a spreadsheet to define projected total cooling loads for the DG room at entering air temperatures ranging from 56.75°F to 108°F.

The amount of heat removed from a DG room is directly proportional to the mass flow rate of air passing through the room. Since the internal geometry of each DG room is the same and each diesel engine/generator is sized equally, the total room cooling load measured for the room with the greatest air flow rate is bounding for the remaining DG rooms. Based on air balance tests, the DG room which experiences the greatest air flow rate (91,440 cfm) should, therefore, remove the greatest amount of heat. In other words, the maximum measurable cooling load for any of the DG rooms is bounded by the room with the greatest air flow. Based on the results of data collected during summer 1997 and using the above relationship (equation 4) a total cooling load curve can be plotted. The slope of this cooling load line cannot be explicitly defined since additional data at different entering air temperatures does not presently exist for the DG room with the greatest air flow. However, due to the physical similarities between each diesel room, a change in mass flow rate from one room to the next (due to different air flow rates) would produce cooling load versus entering air temperature curves which are parallel to each other. Therefore, an equation was developed for this room (DG 2B) based on the summer 1997 data and used the slope calculated in equation 4 for the tested room above (DG 2A, which is the room tested under the Special Test).



Legend for Curve:
□ = DG room 2A, balanced ERCW, full ventilation flow
+ = DG room 2B, balanced ERCW, full ventilation flow
◊ = DG room 2A, throttled ERCW, full ventilation flow
– = DG room 2B, throttled ERCW, full ventilation flow (projected)
x = DG room 2A, throttled ERCW, generator and panel supply fan off
⊗ = DG room 2A, throttled ERCW, exhaust fan off

Figure 5

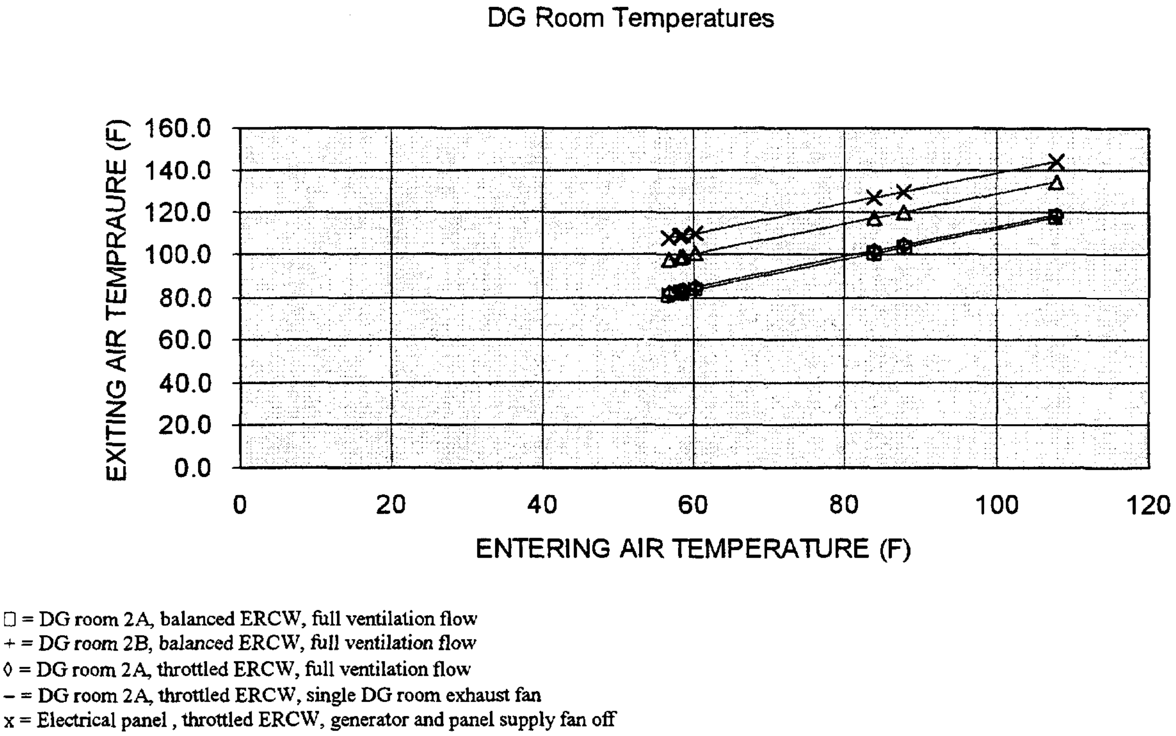


Figure 6

The difference between the cooling load curves for rooms 2A and 2B during balanced ERCW conditions was added to the room 2A throttled ERCW case to establish an anticipated room 2B cooling load curve during throttled ERCW conditions. This becomes the worst-case bounding cooling load curve for any diesel room during post accident conditions.

An equation of total cooling load versus entering air temperature for room 2A can also be developed for the data point representing single DG room exhaust fan operation and for the generator and electrical panel supply fan de-energized case. Again, considering the same slope since only the mass flow rate through the room has changed.

Extrapolated results of the Special Test and summer 1997 test indicate that the original design cooling load associated with 95°F entering air (all fans operating) of approximately 2.0E+6 Btu/hr and revised value used of 1.6E+06 Btu/hr for single exhaust fan operation are both very conservative values. Rather than trying to predict maximum acceptable outside air temperatures by iterating back through heat balance equations with the new cooling load values; limiting entering air temperatures for cases when all fans are operating, one DG room exhaust is fan operating, or the generator and electrical panels supply fan is out-of-service will be based on temperatures recorded at specific component and room locations relative to the maximum acceptable temperature at that location. This will be consistent with the methodology described previously.

The difference between the cooling load curves for rooms 2A and 2B during balanced ERCW conditions was added to the room 2A throttled ERCW case to establish a projected worst-case room 2B temperature difference curve during throttled ERCW conditions and the difference was 0.03°F (negligible). Therefore, the DG room 2A line is considered representative of both rooms 2A and 2B. Also, due to the physical similarities between all diesel rooms and in consideration that total flow rates for rooms 1A and 1B are within (+/-10%) of room 2A, the room 2A line is considered representative of all four DG rooms. It can be seen from the extrapolated data that an entering air temperature of 108°F would result in an exiting diesel room mixed air exhaust temperature of approximately 119°F. This bounds all accident conditions with the exception of the loss of offsite power with neutral grounding resistor load present in the air intake room. Simulating the neutral grounding resistor cooling load during the Special Test was not practical. However, its affect on the entering air temperature to each diesel room has been documented in WBN design calculations. The difference between air intake room temperatures during loss of offsite power conditions with and without the neutral grounding resistor load is approximately 1°F. Therefore, an entering air temperature of 108°F during loss of offsite power conditions while the neutral grounding resistor load is present coupled with: a) maximum ERCW temperature of 85°F, b) reduced ERCW flow of 650 gpm, and c) maximum jacket water heat exchanger fouling would result in a diesel room exiting air temperature of approximately 119°F + 1°F = 120°F. Calculations document that only a 0.3°F temperature rise occurs through the air exhaust room which is considered insignificant. Therefore, continued operation with all fans running and a maximum outside entering air temperature of 108°F is considered acceptable from a DG room temperature standpoint.

The remainder of this evaluation focused on temperatures measured at critical component locations including the generator bearings, windings, and within the electrical control panels. Temperatures were recorded at these locations throughout each phase of the Special Test. The same methodology as described previously was used to evaluate this data.

Temperatures were measured inside each of the electrical panels near the exhaust grille located at the top of each cabinet door. Temperatures were recorded at this location since cooler air entering the bottom of the cabinet will flow up through the panel and exit through the upper grille by natural convection when the panel supply fan is off (Phase II of Special Test). This data was recorded using a data acquisition system (DAS) portion of the 24 hour endurance run which was conducted concurrently during the Special Test. The electrical generator stator winding and bearing temperatures are also directly affected by the generator and electrical panel supply fan. The generator bearing and stator temperatures are rated as 85°C (185°F) and 120°C (248°F) respectively.

Summary of Results

The analysis shows how the total diesel generator room cooling load changes significantly with varying entering air temperatures. The original design cooling load of approximately 2.0E+6 Btu/hr at an entering air temperature of 95°F is very conservative and could be reduced to approximately 1.3E+06 Btu/hr based on test results. Additionally, maximum acceptable temperatures are not exceeded for either the DG room air, or critical components within, if the following outside entering air temperatures are not exceeded for a particular fan out-of-service condition. This criteria is summarized below.

- All fans running (both DG room exhaust fans and the generator and panels supply fan) = 108°F maximum outside entering air temperature

- One DG room exhaust fan and the generator and electrical panels supply fan running (one DG room exhaust fan out-of-service) = 86°F maximum outside entering air temperature

- Generator and Electrical Panels Ventilation Supply Fan out-of-service (both DG room exhaust fans running) = 86°F maximum outside entering air temperature

These temperatures consider worst-case design basis conditions which include the effects of full load on the generator, maximum design ERCW temperature, jacket water heat exchanger tube fouling, reduced ERCW flow rate, and neutral grounding resistor cooling load.

Discussion of Instrument Errors

Air Velocity Meter: The post test calibration report for the air velocity meter indicated the instrument did not meet its required accuracy of +/-5%. Error values are presented in the report over the range of velocities measured during the Special Test. In order to account for the additional error in any velocity data used, the error was plotted as a function of the measured value. The error was approximated by linear equations connecting each known error/velocity data point given in the calibration report. The equations for each straight line segment were programmed into the spreadsheet tables to correct for errors in the velocity readings.

RTD Thermometer: The post test calibration report indicated an error of approximately 0.09°F (69.97 - 69.88 = 0.09) which is near the values measured during the Special Test. This error was added to each entering air temperature value. Similarly, the calibration report for the RTD digital thermometer used to obtain entering air temperature data during the summer 1997 tests was indicating approximately +0.2°F. As appropriate measurements were reduced by this amount.

Barometer: The post test calibration report for the barometer indicated an error of +0.061inches of Hg for a standard value near 29.0 inches of Hg. Therefore, 0.061 was subtracted from the recorded values listed in the spreadsheet tables.

Exhaust grille air flow and temperature: The velocities recorded in the Special Test were increased to account for the error discussed above. Exhaust air temperatures recorded during the Special Test were measured using a digital thermometer. The post test calibration report indicated the instrument was reading 1°F greater than standard values. Therefore, the values recorded in the test were adjusted in the calculations. The calibration report for the RTD digital thermometer, used to measure the exhaust grille temperatures, indicated an error of approximately 0.08°F. The values used in the calculations were adjusted accordingly.

Room temperature measurements for heat transfer: A RTD digital thermometer was used to record surrounding room temperatures during the Special Test. The post test calibration report indicated the values were approximately 0.03°F below standard values. Since these values erred on the low side, a conservative estimate of heat loss was calculated within the spreadsheet tables were not corrected.

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5. Calculation EPM-AMP-081789 (B26 970728 300), Cooling Load, Static Pressure and Equipment Performance Analysis for the DG Room.
6. NCR WBNNEB8212 (NEB 820524 854) WBN Diesel Room Heat Loads.
7. NUREG / CR-1390, “Probability Estimates of Temperature Extremes for the Contiguous United States”.
8. Preoperational Test TVA-14C, Test Deficiency Report PT-88 (dated 4/16/1982), Failure to Meet Acceptance Criteria for Room Temperature.
9. Engineering Change Notice (ECN) 3898 (WBP 830728 510), Diesel Generator Ventilation Cooling.
10. System Description N3-30DB-4002, Revision 6 (RIMS T29 940712 888) .
11. Calculation EPM-CES-082989, Revision 6 “DGB Ventilation, Static Pressure & Equipment Performance for Electrical Panel Fan” (RIMS B26 970728 301).
12. Calculation EPM-JJL-070789, Revision 4 “HVAC Cooling Load DGB Electrical Board Rooms Elevation 760.5” (RIMS B26 970728 302).
13. STI-97-01, “Diesel Generator Room 2B-B And 480 Volt Board Room 2B Ventilation Systems Heat Balance Test.