EXECUTIVE SUMMARY
ANALYSIS OF EQUIPMENT FUNCTIONALITY
WITH
ESSENTIAL CHILLER SYSTEM INOPERABLE

The E.C. system consists of two 100% capacity, redundant, chilled water trains rated at 235 tons refrigeration each. It provides chilled water to the essential HVAC systems in the ESF equipment and main control rooms. With both chillers inoperable due to isolation of the flow transmitter by root valves (LER 1-88-017-00), Engineering's analysis determined that:

i. All equipment would perform their intended function with the E.C. system inoperable for 415 minutes (Reference Study 13-MS-A15, Revision 0).

ii. Equipment qualified life is shortened, but the decrease is not significant (Reference Calculation 13-EC-EC-200, Revision 1).

Based on an accident scenario of LOCA concurrent with LOP, a transient temperature calculation model was developed and temperatures were calculated for each room. To verify the temperature rise calculated for the control room by the model, a heat-up test was conducted inside the control room. This test provided a more realistic temperature rise and total heat load. The test data was incorporated into a separate calculation to modify the model and then recalculate the final room temperatures.

Based on the maximum evaluated temperature for individual rooms, all safety related equipment was analyzed for functionality and loss of E.Q. life. This analysis included, but is not limited to, bearing temperatures, lubricants, charcoal filter efficiencies, and tripping characteristics of electrical devices. The equipment operating temperatures were obtained from project specifications, existing vendor data, E.Q. reports and direct vendor contact.

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PURPOSE

THIS PRESENTATION IS TO OUTLINE THE ENGINEERING METHODOLOGY, LOGIC, ASSUMPTIONS AND END RESULTS IN THE ANALYSIS OF THE EC CHILLER INOPERABILITY.

THIS INFORMATION IS TO PROVIDE THE INTERFACE BETWEEN THE LER AND THE DETAILED EVALUATIONS PERFORMED BY ENGINEERING.

Scope of The Evaluation

Engineering conducted an evaluation of the recent Essential Chiller inoperability to determine the safety significance and functionality of the equipment in rooms whose HVAC equipment is supplied by the essential chilled water system. The evaluation looked at the following:

1. Determine all the safety related equipment within the affected rooms.
2. Perform transient temperature calculations for the affected rooms to establish an ANPP Model.
3. Perform a control room test to determine actual heat load and actual heat rate rise to be used to refine the ANPP model.
4. Determine the functionality of the equipment at the refined maximum evaluated temperature calculated for each effected room.
5. Determine the loss of qualified life as a result of the refined maximum evaluated temperatures calculated for each effected room.
6. Determine the confidence level of the operator response time.

- Mechanical, Electrical and Instrumentation & Controls Evaluations
  - Functionality review
- Equipment Qualification Evaluation
  - Loss of EQ life
- PRA Evaluation
  - Analysis of operator response time
- EED Evaluation
  - Control room heat-up test
  - Chiller start scenario

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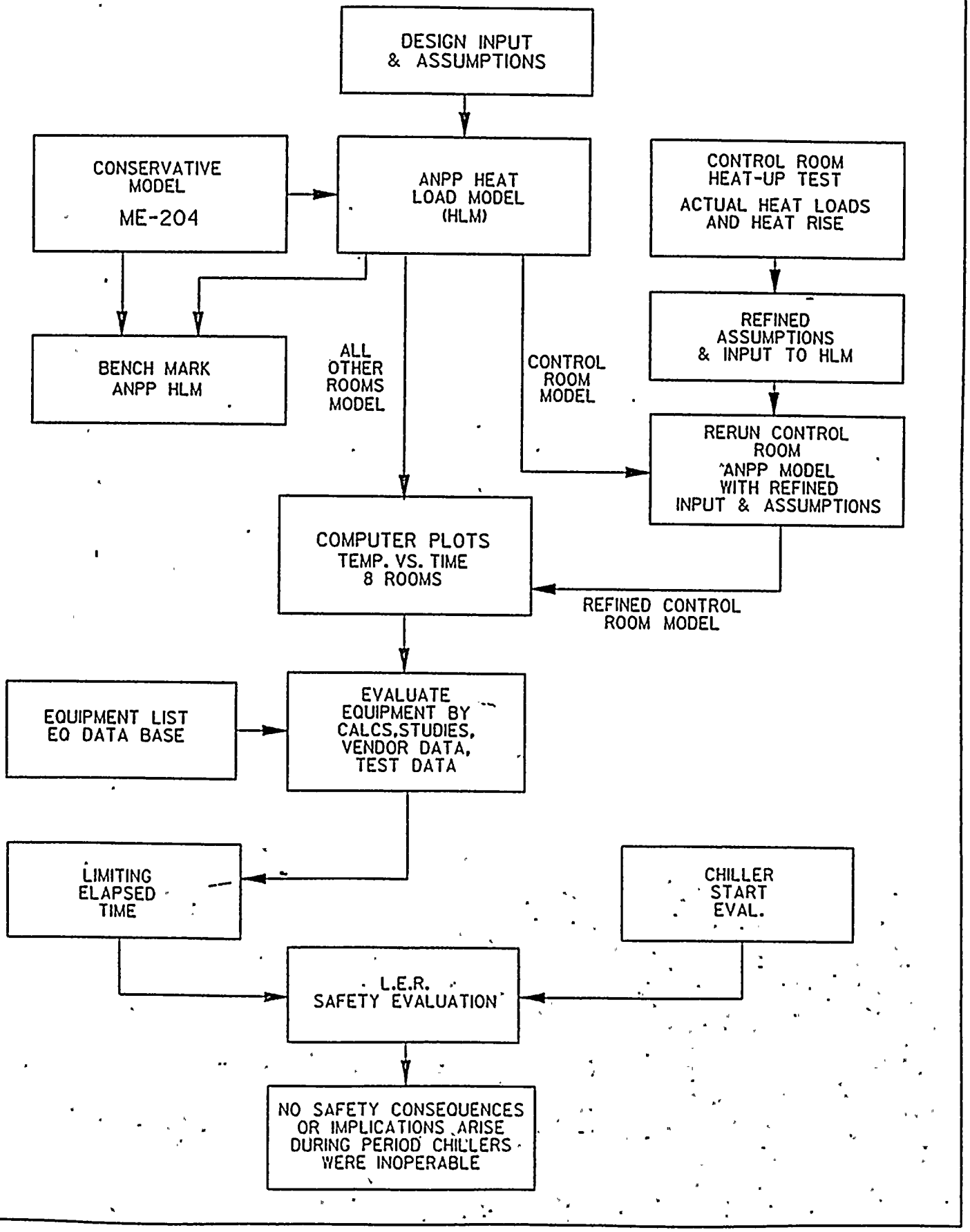
ENGINEERING EVALUATION LOGIC TREE



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ANPP Heat Load Model (HLM)

Inputs

- Actual initial air and wall temperatures with normal HVAC operating.
- Heat loads from equipment, lighting and personnel were taken from the design calculations.
- Room volumes and surface areas.
- Chilled water system characteristics.

Assumptions

- Accident scenario - large break LOCA, concurrent with LOP was chosen to model the most safety related equipment in operation.
- Although LOP was assumed, some normal operating equipment heat loads such as cabinet area, communications area were assumed.
- Miscellaneous metal fixtures, e.g., structural steel, platforms, desks, were not included as heat sinks.
- Constant conservative thermal properties were assumed.
- 100% of essential equipment heat loads were included at time = 0.

Model

- Model results in a system of 17 first order ordinary differential equations which were integrated numerically by computer.
- Model was benchmarked against the ME204 Design Program, the conservative design model used at Palo Verde. The ANPP model was found to be 98% accurate as compared to the ME204 Program.
- Chilled water heat transfer was set to zero during the benchmark to be consistent with the ME204 Program.

Results

- Conservative values of room temperatures.
- Found the limiting room, based on conservative room temperatures, to be the control room.
- Conservative temperatures for all other rooms except control room are used to evaluate the safety related equipment functionality.

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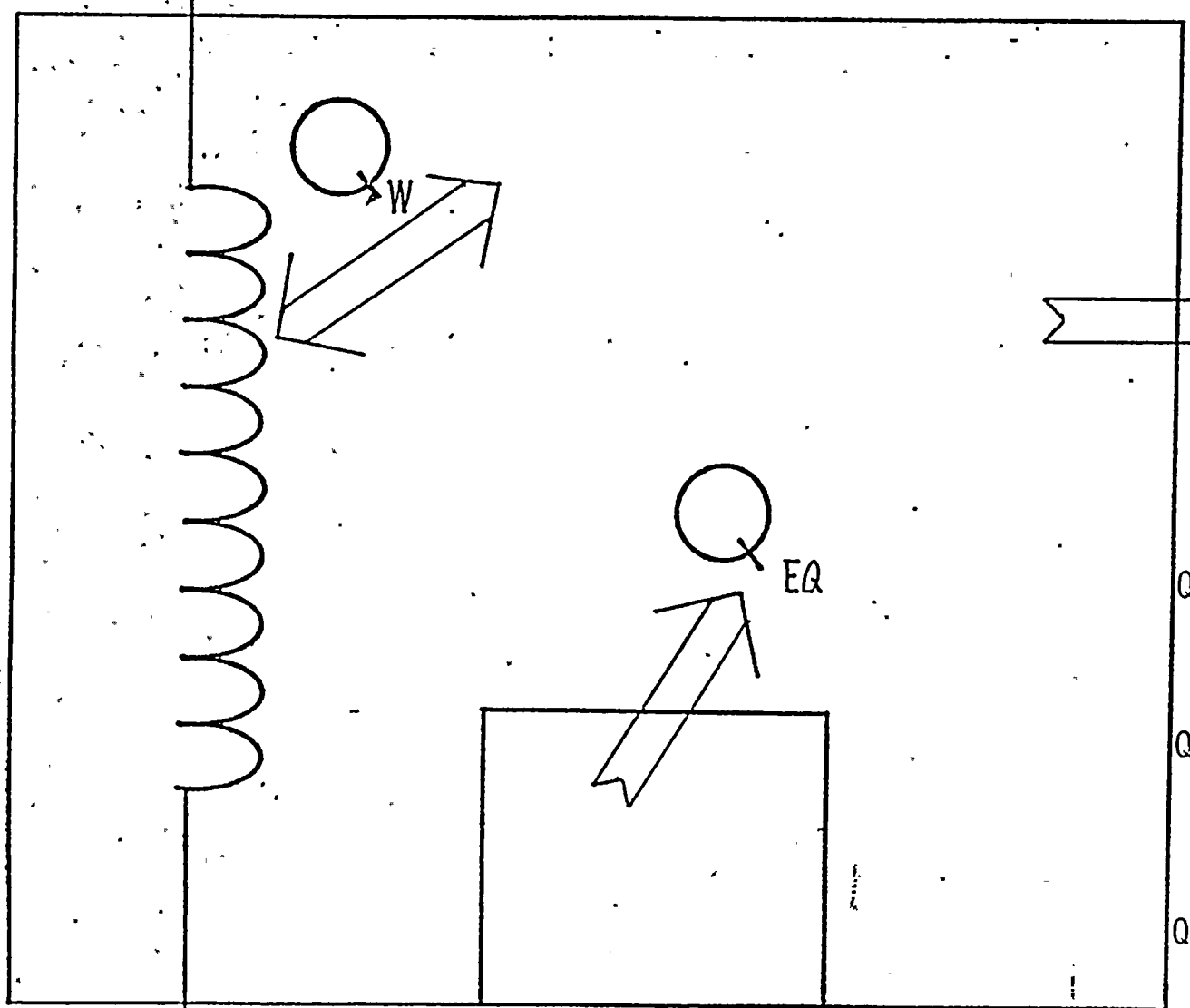
ANPP HEAT LOAD MODEL



Q_C = HEAT ABSORBED BY CONCRETE (FROM ME 204)

Q_{EQ} = HEAT LOAD GENERATED BY EQUIPMENT (FROM ME 204 OR HEAT-UP TEST)

Q_W = HEAT LOAD ABSORBED OR RELEASED BY EC SYSTEM (VENDOR DATA)

RATE OF ENERGY ABSORBED BY AIR $= Q_{EQ} - Q_C \pm Q_W$

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ANPP HEAT LOAD MODEL BENCHMARK

Comparison with ME204 at 90 Minutes

Room	ANPP HLM AVG Δ °F/Δ TIME	ME204 AVG Δ °F/Δ TIME	Variance %
Auxiliary Feed Pump	1.374	1.391	1.24
Containment Spray Pump	1.684	1.720	2.14
Control	1.409	1.416	0.50
Electrical Penetration	.349	.343	(1.72)
EW Pump	1.513	1.546	2.18
HPSI	1.863	1.758	(5.64)
LPSI	1.684	1.720	2.14
Switchgear	.835	.826	(1.08)

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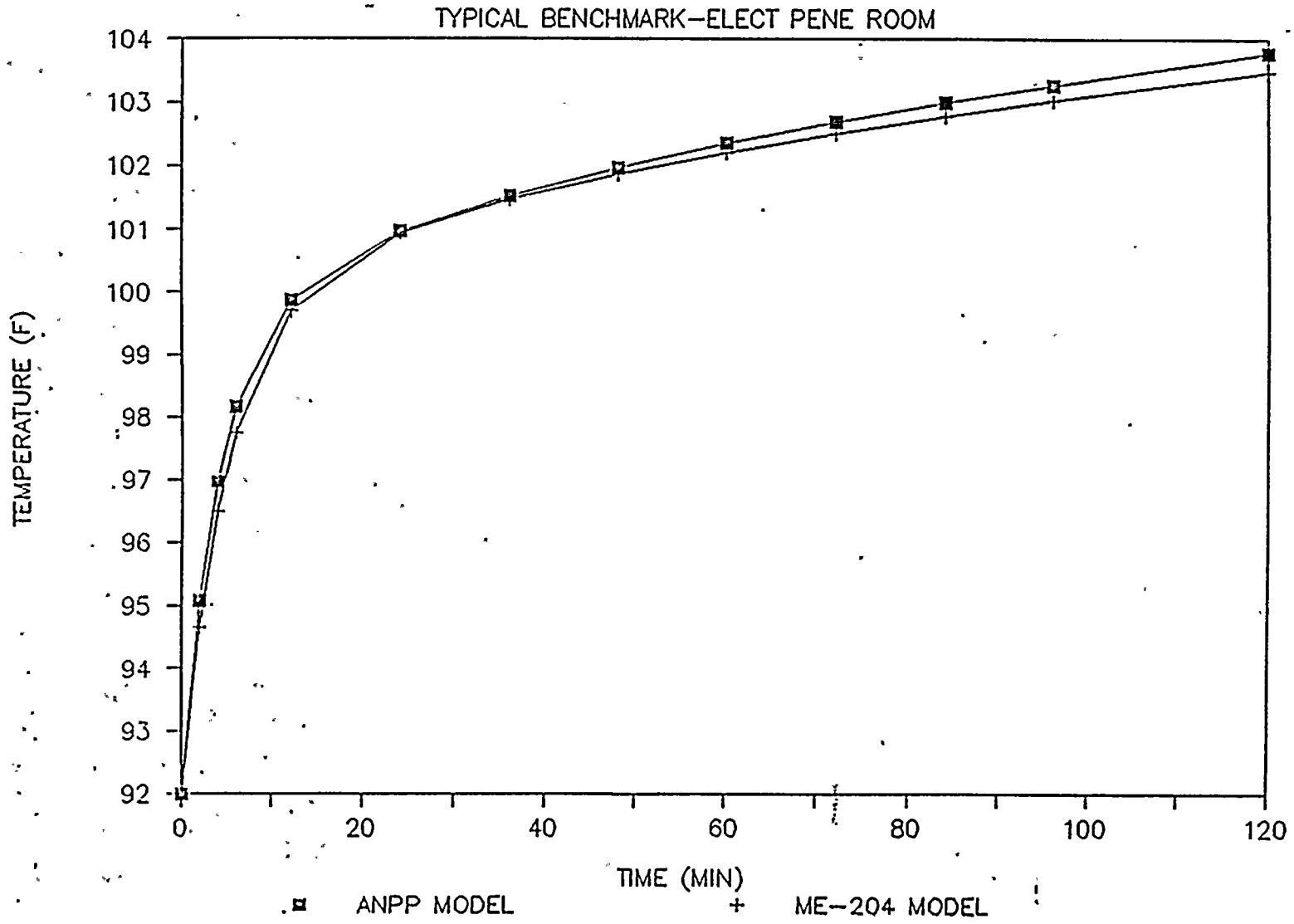
ANPP/ME-204 MODEL COMPARISON



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Control Room Heat-Up Test

Purpose

The test purpose was to determine the actual rate of temperature increase over time for the control room to compare with the rate of increase calculated by the ANPP Heat Load Model.

Initial Conditions

- Test was performed in the Unit 1 control room during an unscheduled outage to measure the actual temperature increase and verify heat loads.
- Test was performed without chilled water flow and with one control room essential fan operating.
- Control room temperature was lowered to 62.5°F so a 15°F rise could be experienced without exceeding the design maximum ambient room temperature of 80°F.
- Control room was maintained at approximately 60°F for a 70 hour stabilization period prior to the test.

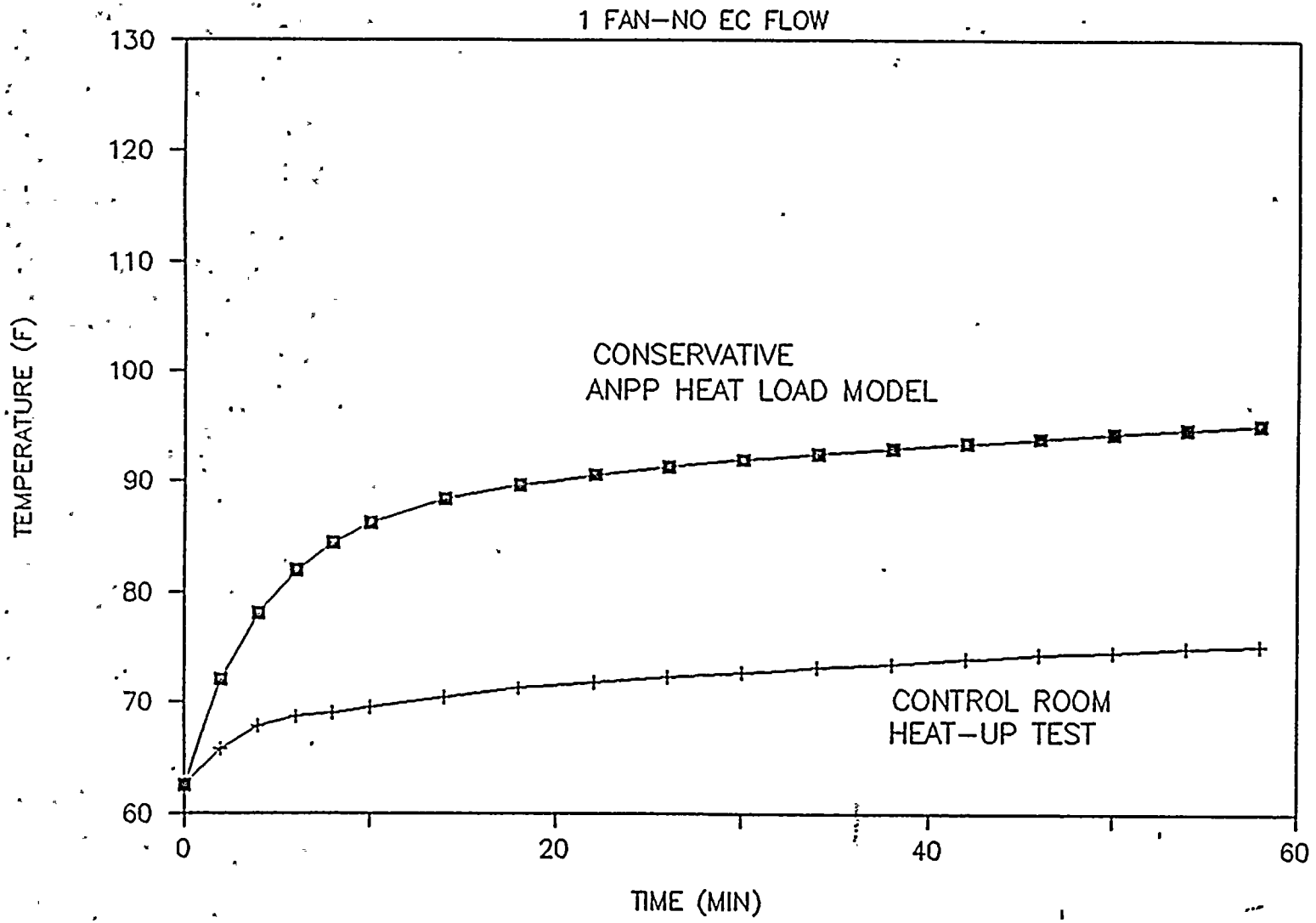
Tested Parameters

- Temperatures were taken at 10 equipment locations over a 58 minute time period.
- Steady state heat balance analysis was performed to verify control room equipment heat load.

Results

- Control Room temperature actually increased by 12.5°F in 58 minutes versus the calculated rise of 32.5°F in 58 minutes for the same operating conditions.
- The ANPP HLM is conservative versus the actual control room temperature test.

CONTROL ROOM TEMPERATURE



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Refined Control Room HLM

Inputs

- Actual initial room air and wall temperatures with normal HVAC operating.
- Heat loads from equipment, lighting and personnel were reduced from the design values to the actual test heat load data.
- Room volumes and surface areas.
- Chilled Water System characteristics.

Assumptions

- Accident scenario-large break LOCA, concurrent with LOP, was chosen to model the most safety related equipment in operation.
- Although LOP was assumed some normal operating equipment heat load such as cabinet area, communications area were included in the test and included in the model.
- Additional heat sinks were modeled, such as structural steel, platforms, etc.
- Constant but realistic thermal properties were assumed.
- 100% of equipment heat loads included at time = 0.
- Heat loss by radiation was modeled.
- Chilled water heat transfer was set to zero to be consistent with the actual test data.

Results

This results in a realistic best estimate model producing temperatures approximately 8°F greater than the heat-up test; which removed the conservative inputs and assumptions.

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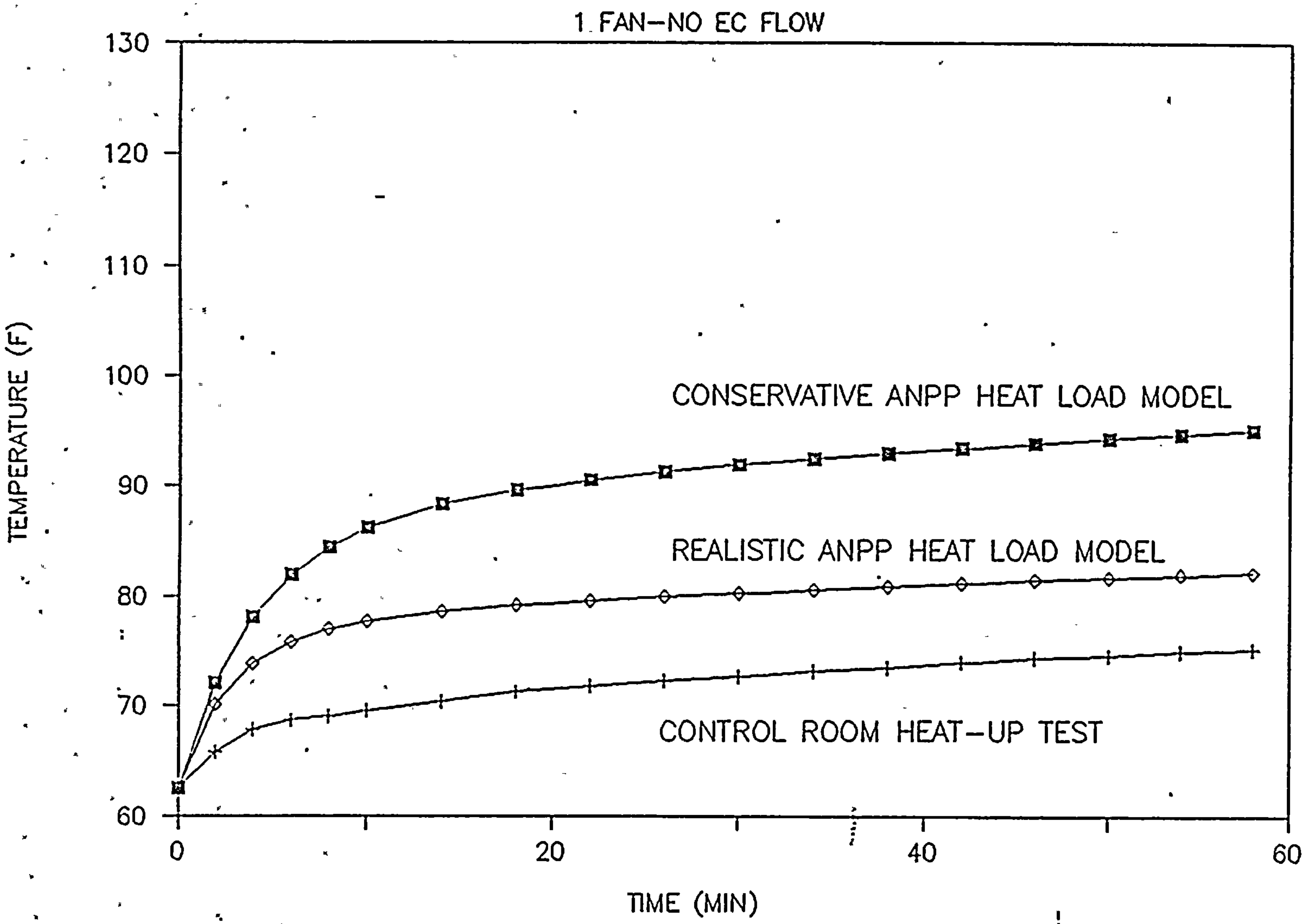
CONTROL ROOM TEMPERATURE



Final Program Modeling For the Control Room Heat Load

- Control Room Refined HLM was run with 75.5°F initial temperature.
- Two Control Room fans were running vs. the one fan in the heat-up test.
- EC chilled water was modeled into all rooms by a heat balance method to simulate actual condition from the event.

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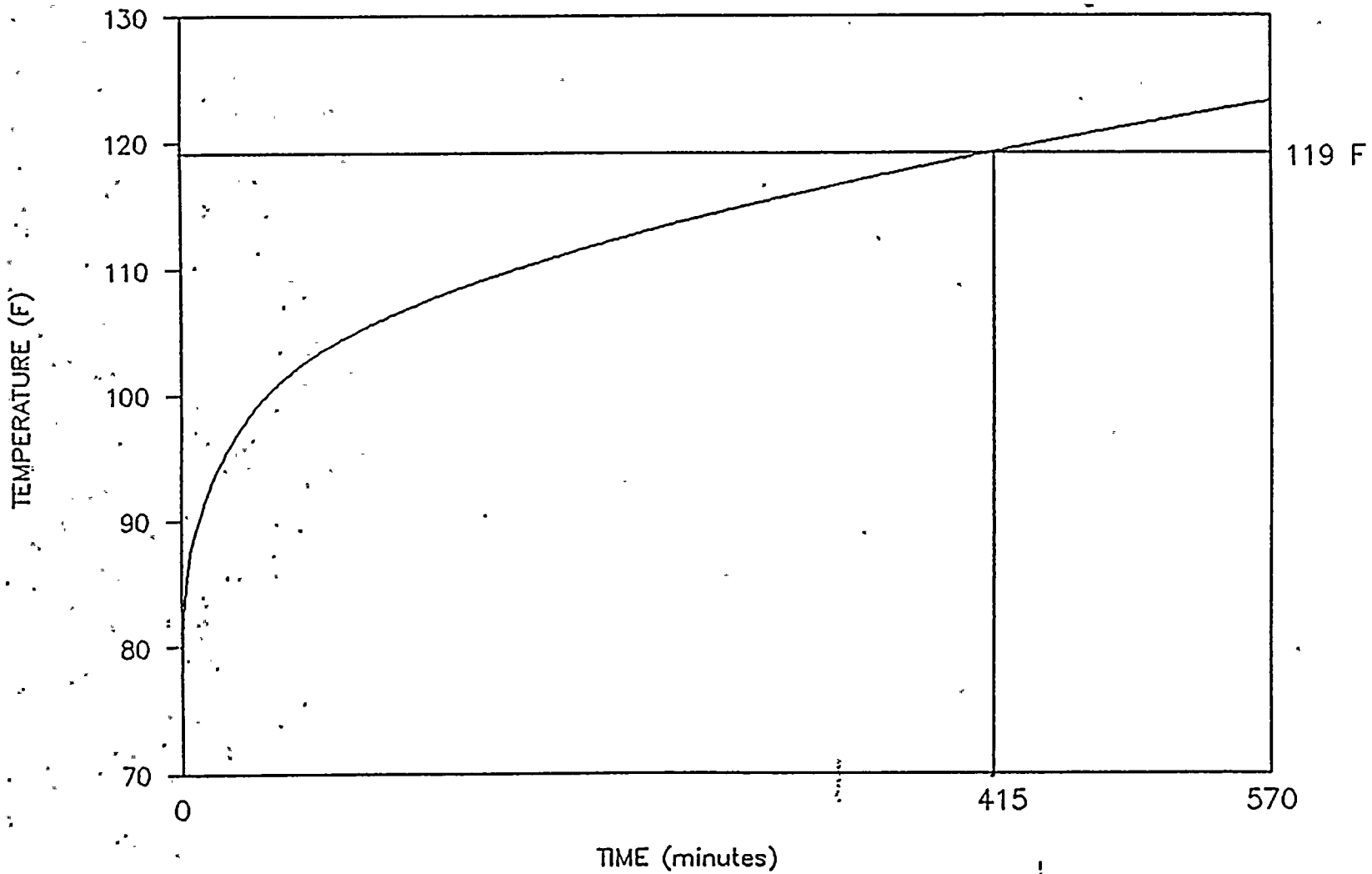
CONTROL ROOM TEMPERATURE



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Equipment Evaluated for Functionality

- Reviewed all Qualified Equipment
- Types of equipment evaluated
  - Pumps
  - Fans
  - Electrical Switchgear
  - I&C Cabinets and Local Instruments
  - Transformers
  - Motors
  - Dampers
- Equipment Evaluation Based on Calculated Maximum Evaluated Room Temperature to Determine Functionality
  - Equipment Bearing Temperatures
  - Equipment Lubricants
  - Effects on Charcoal Filters
  - Tripping Characteristics of Electrical Devices
  - Vendor Data on all Equipment
  - Reduction in EQ Life for all Equipment
- Operating temperatures of equipment were obtained from:
  - Project Specifications
  - Vendor Data
  - Equipment Qualification Reports
  - Direct Vendor Technical Contact

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LIMITING ELAPSED TIME TO REACH POSTULATED FUNCTIONALITY LIMIT

Room	Temp. of Other Rooms When Control Room Reaches Postulated Functionality Limit (°F/6 Hr:55 Min) (c)	Room Temperature Limit For Postulated Functionality Limit Temp. Limit (°F)	Total Time To Reach Limiting Component Temperature (HR:MIN) (c)
Aux. Feed	134.4	140.0 (a)	10:35
Cntmt. Spray	133.2	135.8 (b)	8:17
Control	119.0	119 (a)	6:55
Elec. Pen.	109.1	131 (b)	>24:00
EW Pump	131.0	164.3 (b)	>24:00
HPSI	136.2	159.8 (b)	>24:00
LPSI	135.8	135.8 (b)	6:55
Swgr	119.2	122 (b)	8:37

All times from accident at time = 0

Reference:

a. 13-JS-A05
b. 13-EC-EC-200
c. 13-MC-EC-253

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Conclusions

Engineering's evaluation of equipment functionality of 415 minutes following the postulated accident scenario described concludes that:

1. With the EC system inoperable as described, the operating electrical and mechanical equipment in all areas served by essential chilled water will not significantly degrade at the elevated room temperatures and will perform their functions.

2. Equipment qualified life is shortened during the time period the room temperature is above design basis. However, this decrease in qualified life is negligible and not significant (Reference 13-EC-EC-200, Revision 1).

3. Reliable operation of plant solid state instrumentation and control (I&C) equipment is considered to be the limiting factor based on external cabinet temperature. However, all ANPP cabinets (CAB) or the solid state I&C components which they contain and that are required to function during the assumed postulated accident scenario have been qualified in excess of the external cabinet temperature.

Therefore based upon ANPP's engineering evaluation, the safety consequences and implications arising from the event described in the LER are considered to be minimal.

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ESSENTIAL CHILLED WATER SYSTEM (EC)

EC System Consists Of:

- Two, 100 percent-capacity, redundant, chilled water trains.
- Chillers are self-contained, packaged refrigeration type with centrifugal compressors.
- Each chiller has a rated capacity of 235 tons refrigeration.

The essential chilled water (EC) system supplies chilled water to the essential heating, ventilating, and air-conditioning (HVAC) systems for control building, auxiliary building, and main steam support structure.

Room	Design Room/Air Temp-°F
ESF Switchgear	104
Control	80
Auxiliary Feedwater Pump	120
EW Pump	104
Electrical Penetration	104
LPSI Pump	104
HPSI Pump	104
CS Pump	104
DC Equipment	104

Design room air temperatures from project Design Criteria Manual.

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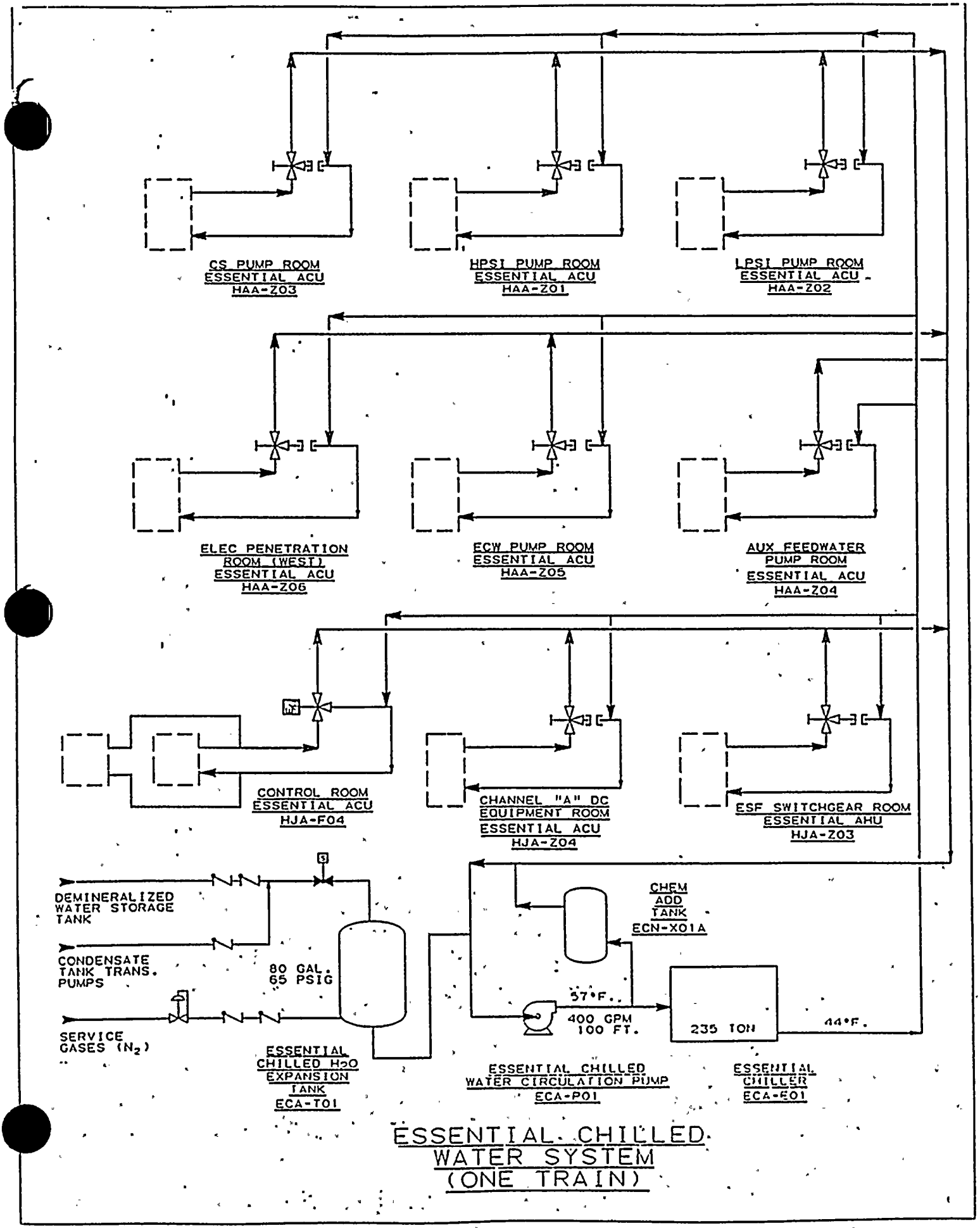

ESSENTIAL CHILLED WATER SYSTEM (ONE TRAIN)

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Engineering Evaluation

Mechanical Evaluation

- ANPP Heat Load Model - Calculation 13-MC-EC-253, Rev. 4.

Support Calculations	Description
13-MC-HA-252, Rev. 0	Electric Penetration Room Transient Temperature Study
13-MC-HA-253, Rev. 0	EW Pump Room Transient Temperature Study
13-MC-HA-A02, Rev. 0	HPSI Pump Room Transient Temperature Study
13-MC-HA-A03, Rev. 0	Aux. Feed Pump B Room Transient Temperature Study
13-MC-HA-A05, Rev. 0	Containment Spray Pump Room Transient Temperature Study
13-MC-HJ-253, Rev. 0	Main Control Room Transient Temperature Study
13-MC-HJ-254, Rev. 0	ESF Switchgear Room Transient Temperature Study
13-MC-HJ-255, Rev. 0	Control Room Heat Load Calculation

- Mechanical Equipment Evaluations - Study 13-MS-A13, Rev. 0, Mechanical Equipment Operability Review with EC System Unavailable for 415 minutes and Calculation 13-MC-ZZ-202, Rev. 0, Bearing Temperature Calculation for AFA-P01 and SIA/B-P01 Motors, including CCN No. 1.
  - Bearing Temperatures for pumps, fans, motors and dampers
  - Lubricants
  - Charcoal Filters
  - Dampers
- ESF room design basis temp restoration - Calculation 13-MC-ZZ-201, Rev. 0
- Conclusions
  - Continued bearing operations for rotating mechanical equipment is highly dependent upon the operating temperature limits of the grease. Grease temperature limits for this safety equipment range from 275°F to 450°F. Calculated maximum temperature for the equipment without HVAC, ranges from 198°F to 335°F, well within the capabilities of the grease.
  - Dampers operation during accident conditions requires only one time movement. Mechanical components can adequately accomplish this short time function without being compromised.
  - Fire dampers activate at 160°F. All room temperatures are below this activation temperature.
  - Charcoal filters were tested for their design efficiency to 176°F (80 C) and will perform their intended function.

Engineering Evaluation

Instrumentation & Controls Evaluation

- Instrumentation & Controls Equipment - Study 13-JS-A0[illegible]5
  - I&C Equipment
  - I&C Panels/Cabinets
- Implementing Documents/Sources
  - EQ Engineering Revelation Database
  - Control room heat-up evaluation - Letter 167-02653-MFH/HWR and Calculation No. 13-MC-EC-253 to include Calculation Change Notices No. 1 and 2
- Conclusions
  - All individual I&C equipment/components that are located in the subject rooms which were impacted by the loss of essential chillers were determined to have no impact to functionality or safety significance as all components were either specified or qualified to temperatures equal to or in excess of the ambient temperatures postulated post accident (T_{ppa} at 415 minutes).
  - All I&C panels/cabinets in the same aforementioned rooms were also looked at. Only those panels/cabinets that were necessary to mitigate, and/or monitor the accident or perform safe shutdown of the plant were considered. All of the panels/cabinets reside in the control room. It was also determined that there was no functionality or safety significance as all panels were qualified to ambient temperatures equal to or in excess of the T_{ppa}.

Engineering Evaluation

Electrical Evaluation.

- Tripping characteristics of elec. devices based on T_{peak}
- Max. ambient temp on electrical equipment basis
- Vendor data review based on T_{peak} at 415 min

- References
  - Calculations: 13-EC-EC-200
    13-EC-MC-Q53 ⇐ ?
    2
  - Equipment Qualification Reports
  - Vendor Product Literature

- Conclusion

There are no functionality/operability difficulties for the equipment investigated during the transition from To - o to T_f - 415 minutes. If functionality is preserved in the safety related equipment, then it follows that there can be no safety significance to the occurrence, provided that the essential chilled system is restored at 415 minutes.

The postulated ambient room temperatures will not cause premature tripping of breakers or increased clearing time on fuses in circuits operating normally.

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Risk and Reliability Evaluation

Operator Response Evaluations

- Operations Response for isolation of EC Flow Transmitters Calculation - 13-NC-EC-200, Rev. 0
- Maintenance Response for manual restart of EC Chiller Calculation - 13-NC-EC-201, Rev. 0

Conclusions

- Operations response to diagnose and restore the EC Chiller following isolation of its flow transmitter is estimated to occur within 130 minutes (95% response time)
- Maintenance response to diagnose EC Chiller fail to start and perform a manual chiller restart is estimated to occur within 320 minutes (95% response time)

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SUMMARY ANALYSIS
TECHNICIAN EXPOSURE

SEQUENCE	TASK/DESCRIPTION	LOCATION	DURATION (MIN)	WHOLE BODY DOSE (REM)	THYROID DOSE (REM)
#1	EVACUATION	AUX	15	7.5	+
#2	EVACUATION	YARD	10	1.25	33.3
#3	ACCOUNTABILITY	ANNEX	20	0.33	27.8
#4	RETURN TO UNIT	ANNEX TO SERVICE	5	0.63	16.65
#5	REPORTING TO OSC	SERVICE TO AUX	5	0.63	16.65
#6 (A)	RESPIRATOR ISSUE	AUX BLDG	15	0.05	
(B)	TRANSIENT TO CONTROL BLDG	CONTROL BLDG	95	7.88	*10
(C)	BACK TO EOF BLDG	TO ANNEX	10	1.25	
#7	CLOSE OUT PAPER WORK & OTHERS	EOF	60	0.05	2
TOTAL DOSE				20	106
CRITERIA FOR EMERGENCY CORRECTION ACTION (EPIP 18)				25	125

* Respirator
\+ Dose not calculated, release to AUX Building is minimal.

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