CONSUMERS POWER COMPANY

MIDLAND NUCLEAR PLANT

FIRE ANALYSIS AND EVALUATION

FOR C31 CONTROL PANELS

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

MIDLAND NUCLEAR POWER PLANT

MAIN CONTROL ROOM

FIRE ANALYSIS AND EVALUATION

FOR

C31 CONTROL PANELS

MIDLAND PROJECT POSITION ON C31 CONTROL PANELS

I. INTRODUCTION

In the Midland Safety Evaluation Report, NUREG-0793, issued May 1982, the NRC indicated that additional information was required on the alternate shutdown capability to complete the NRC safety review. Subsequent meetings with the NRC have addressed this issue in depth, including concerns related to control room panels.

In a recent meeting on October 26, 1983, Consumers Power Company, Midland Project (CPCo) presented their position on control room fires and how redundant safe shutdown systems will be protected against fire induced electrical circuit faults. This presentation included acknowledgement of the possibility of shorts to grounds, open circuits, and hot shorts occurring as the result of a postulated fire. Hot shorts are of concern due to their potential for spurious activation of safe shutdown or associated components.

The presentation identified single cabinet fire scenarios. Fires were considered by CPCo to affect all circuits in any cabinet and all bays of the walk-through panels. This presentation characterized the C31 control panel as two separate cabinets. CPCo indicated that because of the 1C31 (2C31) panel location, design and construction, manning of the control room, low probability of a control room fire, and the small number of operator actions required, that no more than one cabinet (C31-A or C31-B) could be affected by a

fire before operator actions will be taken to mitigate the possible fire effects. Emphasis was also placed on control room/cabinet fire detectors and availability of hand-held fire extinguishers.

In the October meeting with the NRC, the staff expressed their concerns over the consequences of fires involving the C31 control cabinets, and suggested that a further evaluation be performed. The staff also suggested that as part of this further evaluation, the installation of Halon in the cabinets and fire dampers for the cabinet vents should be evaluated.

This submittal presents CPCo's evaluation and position on the protection of the 1C31 (2C31) control panel through design changes and providing an alternate control point external to the control room. The information presented in this report applies equally to both Units 1 and 2 of the Midland Nuclear Plant and either panel 1C31 or 2C31 may be referred to as C31.

II. EXECUTIVE SUMMARY

This evaluation considers existing design, design modifications, operator actions, and the low probability of a damaging control room fire and concludes that safe shutdown can be achieved.

For fires which would occur in the control room of the Midland Plant, all control panels and/or cabinets are protected such that a fire in any single cabinet will not affect the capability to safely shut down the plant from outside the control room. For the C31 control panel the two redundant trains are located in separate cabinets of that panel. This study demonstrates through computer analyses that for the C31 control panel, **there is no reasonable fire which could affect both redundant trains and hinder CPCo's ability to safely shut down the plant.**

For any fire which could occur in the control room, certain manual actions must be completed in a timely manner to mitigate fire effects on the C31 control panel. These manual actions affect the following components; 1) Decay Heat Removal (DHR) Dropline Bypass Valve 2) Power Operated Relief Vent (PORV) and Block Valves.

These components will be secured in the switchgear rooms, placing them in a safe configuration for post-fire shutdown. The detailed analysis contained in this submittal identify that fires will not affect the internal functions of both cabinets within the time required to perform the necessary actions.

The time available to perform these actions is based on completing certain design changes outlined as follows:

- Fire dampers on selected C31 panel ventilation louvers.
- An insulation barrier on the common wall between C31 cabinet Sections A and B.
- Insulation with a radiant shield to mitigate external fire effects.
- Isolation switches at the applicable MCC to provide reliable local control of valve operators without depending on "repairs."
- Electrical interlock of POAV valve operators to prevent spurious valve operation.
- Fire detection within the C31 control panel.

CPCo will implement control room housekeeping procedures that will prohibit the accumulation of combustibles in the gross quantities assumed in this report near any control room panel.

III. NRC REQUIREMENTS AND POSITION

Branch Technical Position BTP-CMEB 9.5-1 presents guidelines for implementing General Design Criterion 3. In particular, Sections C5b and C7b are of concern to the NRC for the Midland Plant. Section C5b addresses Safe Shutdown Capability and Section C7b addresses the Control Room Complex. These two sections require that one train of systems necessary to achieve and maintain hot shutdown conditions from either the control room or auxiliary areas be free of fire damage, including redundant safe shutdown equipment located in the same control room cabinet.

On October 26, 1983, a meeting was held with CPCo to discuss safe shutdown capability in the event of a control room fire pursuant to BTP-CMEB 9.5-1 Section C5b. In this meeting, CPCo presented their evaluation of control room panels for all types of circuit faults and concluded that C31 was a panel of concern. For control panel C31, CPCo identified that without operator action potential circuit faults could occur and affect a high/low pressure interface in the decay heat removal (DHR) system or steam generator power operated atmospheric vent (POAV) valves. In addition to the internal fires, it was postulated that a fire could occur external to the cabinets affecting both redundant trains A and B through hot shorts, thus leading to spurious operation. As a result of this concern, the staff suggested that CPCo evaluate both a halon suppression system and ventilation fire dampers for the C31 control panels.

IV. MIDLAND PROJECT EVALUATION

Based upon the analysis contained in this submittal, it has been determined that the C31 control panels do not require halon fire suppression and with minor modifications the design will meet the requirements of BTP-CMEB 9.5-1, Sections C5b and C7b. CPCo has concluded that only "hot shorts" can cause spurious operation of either the PORV, POAV, or DHR Dropline Bypass Valve controlled from the C31 control panel. Further, CPCo has concluded that an external exposure fire of sufficient size to precipitate "hot shorts" will not affect these circuits of concern within the panel before necessary manual actions can be performed.

CPCo maintains that should a fire external to the cabinet occur, it would (1) be readily detected by both control room personnel and fire detectors and (2) would be easily extinguished by control room personnel prior to any control circuit damage. However, in the unlikely event an external fire would go visually undetected, there is sufficient time following alarm initiation to secure critical safe shutdown components. Also, in the very unlikely event of an internal fire, which would be immediately alarmed and affects only one cabinet, there also exists sufficient time to secure critical safe shutdown components. These operator actions are identified in Section VI.F of this report, and include operator actions taken outside of the control room.

All types of circuit failures are evaluated in this analysis. Any number of open circuits and shorts to ground are assumed possible. Multiple hot shorts are evaluated as follows:

1. For each safe shutdown system, the effects of the first hot short will be mitigated before the next hot short will occur on either redundant train.

2. For high/low pressure interfaces no more than three hot shorts could occur simultaneously.

   This position on circuit failures was presented by CPCo at the October 26, 1983 meeting and was accepted by the NRC staff. CPCo's position is reinforced by the inherent protection in the design of the C31 cabinets as described in Section V and as analyzed in Section VI.

V. DESIGN AND CONFIGURATION

A. EXISTING DESIGN

The C31 control panel in the Main Control Room contains Post-Accident Monitoring Instrumentation and selected controls involved in reactor shutdown.

These panels, 1C31 and 2C31, are shown on Figure 1 (Reference Dwg. J-725, Rev. 12) which depicts the general arrangement of panels within the main control room. Each control panel labeled C31 (ore for each unit) consists of two cabinets. Each cabinet is formed from 10 gauge (0.1345 inches) sheet steel on all sides. These cabinets are placed side-by-side and mechanically fastened together with bolts. Fastening the two cabinets together form a composite wall consisting of two sheets of 10 gauge steel. For this report, this composite wall will be referred to as the "common wall". The left cabinet (C31-A) contains only Load Group I (channels A and C) devices while the right cabinet (C31-B) contains only Load Group II (channels B and D) devices. Refer to Figure 2 (Reference Dwg. J-955, Rev. 7) for front panel arrangement. Cabinet ventilation is by natural convection using louvers in the front and back as shown in Figures 3 and 5.

Besides post-accident monitoring instrumentation which is not required for safe shutdown, the following controls are provided on C31:

- PORV (Power Operated Relief Valve) for the Pressurizer
- PORV Block Valves

- POAV's (Power Operated Atmospheric Vent Valves) for the Secondary Steam

- DHR (Decay Heat Removal) Dropline Bypass Valves

- Pressurizer Auxiliary Spray Valves

- Pressurizer Gas Vent Valves

- Core Flood Tank Vent Valves

- Reactor Coolant Hot Leg Piping Vent Valves

- Service Water Isolation Valves to Auxiliary Feedwater System Suction Supply

The critical safe shutdown and high/low pressure interface circuits included in the above listing are the PORV, redundant PORV block valves, POAV and DHR dropline bypass valves. These circuits need to be protected from the effects of fire in the C31 panel such that:

- Any loss of coolant accident via spurious operation of the PORV and disabling of the redundant PORV block valves is prevented.

- Any loss of coolant accident via spurious operation of both redundant DHR dropline bypass valves is prevented.

- The spurious operation of a POAV valve is prevented.

Other circuits and instrumentation in the C31 panel can be damaged without consequence to the ability to safely shutdown the Midland Plant.

The two cabinets are identical in construction and arrangement. The controls and instrumentation are redundant to each other except for the following items:

- PORV, which has control circuitry in cabinet C31-A.
- Pressurizer Gas Vent Valves, with controls on cabinet C31-B.
- Annunciator, located on cabinet C31-B with horn on the C31-A.

The redundant switches, indicators, and wiring in cabinet C31-A are located similarly in cabinet C31-B. This means, as a minimum, redundant devices are separated by the width of the cabinet (4 feet). Figures 2 and 3 show the arrangement of the devices in question.

Field wiring between the valves, MCC, and main control room enters the C31 control panel via lower and upper cable spreading rooms. The Load Group I cables enter cabinet C31-A through the floor from the lower cable spreading room. The Load Group II cables enter the top of cabinet C31-B through the main control room ceiling from the upper cable spreading room. Figure 4 illustrates the cable routing from the redundant switchgear rooms through the cable spreading rooms and termination within the C31 control panel.

B. FIRE DETECTION

Fire detection within the main control room is accomplished by ionization detectors. Ionization detectors alarm at the presence of combustion products during the incipient stage of fire (i.e., before open flame). Placement and spacing of the ionization detectors within the control room are based on consideration of the area design, configuration and draft condition due to natural and mechanical ventilation.

The ionization detectors and alarm system within the main control room includes a supervisory circuit which indicates the failure of individual detectors and circuit trouble. These alarm signals annunciate in the main control room.

C. MODIFICATIONS

Consumers Power Company will implement several modifications to the present design. Modifications applied to the C31 control panel improve fire detection, reduce the rate of heat transfer from the analyzed fires to the critical components, and preclude the need to utilize repair procedures for attaining safe shutdown.

To assure rapid detection of a fire within the C31 control panel, an ionization detector will be mounted directly within each cabinet with a remote indicating lamp mounted on the outside of the cabinet.

The reduction in heat transfer is accomplished by applying insulation within the C31 control panel and heat actuated fire dampers to the lower louvered openings in the back door sections (refer to Figure 5).

The application of insulation with an equivalent R value of 1 (0.5 inches of mineral wool at 500°F) to the common wall within cabinet C31-A limits the amount of heat transfer between cabinet C31-A and cabinet C31-B in the event of an internal fire.

The application of insulation with an equivalent R value of 2 (1.0 inch of mineral wool at 500°F) with a radiant heat shield having an emissivity of 0.4 to the back wall of both cabinets C31-A and C31-B and the installation of heat activated fire dampers, limits the amount of heat transfer into each cabinet in the event of an external fire.

In addition to the above heat transfer reduction features, electrical modifications will be made to prevent spurious operation of the POAV valves and which allow repositioning the PORV block and POAV valves from their respective motor control center within the switchgear rooms without requiring repairs to their control circuits.

The electrical modifications at the Motor Control Centers include isolation switches on control circuits for both PORV Block Valves and all POAVs. These switches enable the operator to position the valves from the local built-in MCC pushbuttons and indicating lights with the controls completely isolated from the control room circuits. Addition of pushbuttons and indicating lights at the MCCs for the POAVs is part of the modification. PORV block valves have existing local controls. Remotely operated power lock-out contactors will be mounted in the MCC in series with the existing POAV motor operator starters to prevent spurious valve operation by fire induced hot shorts. The valve operator power will be "locked out" during normal operation using switches to be mounted on the C15 panel (electrical distribution control panel). Refer to Figure 1 for panel C15 location.

In order to experience a high/low pressure interface problem on the DHR dropline bypass valves, both valves must spuriously operate. There is adequate operator action time to isolate at least one of these valves. These components are only needed for cold shutdown and, as such, there is time to manually align these valves to achieve cold shutdown.

VI. FIRE ANALYSIS

A. INTRODUCTION

The C31 control panel, as previously described, is made up of two cabinets bolted together. Redundant trains of several shutdown related circuits are located in the separate cabinets of the panel providing separation between the two channels. Physical layout of the cabinets as shown in Figure 2 provides an effective separation of 4' (cabinet width) and two thicknesses of 10 gauge steel forming the common wall. Even with this separation, however, there was concern that certain potential fires could affect both channels of the circuits noted above. In order to demonstrate the adequacy of design, a fire analysis was conducted as described in this Section.

Two fire scenarios were considered, an internal fire and an external fire. The effects of these fires were determined utilizing standard heat transfer relationships and calculating the temperature rise at selected locations within the panel.

Some combination of hot shorts, shorts to ground, or open circuits is assumed to occur during the progress of the fire. The time at which these failures occur, however, is a function of the temperature of the wires and components within the cabinets and is assumed in accordance with the restrictions as stated in Section IV.

Failures are assumed to occur as the temperature of a component reaches a defined "critical temperature" for that item. The "critical temperatures" for each component were very conservatively chosen based on existing test data. Where specific failure data was not available, information on elevated

temperature testing was utilized. This is a highly conservative assumption in that the high temperature tests indicate that the item will continue to operate without failure at the critical temperature.

The fires and cabinets were reduced to a mathematical model and time-temperature histories were developed utilizing a computer simulation. Several configurations were assumed in considering the specific model. As noted earlier, two fire scenarios, internal and external, were modeled assuming the cabinets are unmodified, except for a fire damper located at the bottom rear of each cabinet. In a second model for each fire scenario, insulation was strategically located to reduce the heat flux entering the cabinets, thereby, extending the allowable response time. In conjunction with these analyses, time-motion studies were conducted to provide assurance that the required activities could be completed within the allowed times.

B. FIRE LOCATION

1. Internal Fire

As noted in Section V the critical contents of the two cabinets are identical, except the PORV control circuit is located only in cabinet C31-A. The wiring harnesses come off the controls and are routed along the outside wall of cabinet C31-A and the common wall within cabinet C31-B to terminal blocks mounted off these walls. For cabinet C31-B wiring configuration refer to Figure 10. Because of the location of the PORV control circuit and the wire bundle within cabinet C31-B, the worst case internal fire was postulated to occur within cabinet C31-A

affecting cabinet C31-B. With the internal fire, it is assumed that circuits in that cabinet would be affected immediately following the onset (open flame) of the fire. For Unit 1, this results in the PORV, 1SV-0102 and the DHR dropline bypass valve, 1MO-1058 stroking open due to hot shorts. The corresponding Unit 2 valves would be 2SV-0202 and 2MO-1158. The analysis applies equally to either unit. In addition, the PORV block valve circuit for 1MO-0111 is assumed to open, failing the valve in the open condition. The "B" channel circuits, located near the common wall and subjected to the maximum heat flux, are then assumed to fail as their temperature exceeds the maximum allowable temperature for that component or wire bundle. The critical "B" channel circuit is the second DHR letdown valve, 1MO-1059. If this valve were to stroke open, given that 1MO-1058 is open and the RCS is at pressure, the potential exists for an outside-of-containment LOCA. Section VI.D details the analytical model and Section VI.E presents the results of the analysis.

2. <u>External Fire</u>

The limiting external fire is a transient fire adjacent to the C31 control panel of sufficient severity to eventually damage the components or wiring within the C31 control panel. The external fire directly affects the C31 control panel through radiant and convective heat transfer. The radiant and convective heat transfer effects are directly related to the location and size of the fire.

Four possible locations exist where the transient fire could occur. These locations are:

a. in front of the C31 control panel immediately behind the operator's console, (OC01 on Figure 1)

b. at the left end of the C31 control panel (i.e., cabinet C31-A),

c. at the right end of the C31 control panel (i.e., cabinet C31-B), or

d. in back of and centered on the common wall of the C31 control panel.

The transient fire was evaluated at the above locations to determine what effects the fire would have on components and wires within the C31 control panel.

The area in front of the C31 control panel is directly behind the operator's console and is in constant view of the manned control room. The amount of combustibles which could accumulate in this area would be insufficient to develop into a sustained fire which would adversely affect both the C31-A cabinet and the C31-B cabinet. These two factors offset the close proximity of internal switchboard wiring and switches to the front of the C31 control panel. Administrative procedures are in place which minimize the accumulation of combustible materials. A fire in front of the C31 control panel would be detected and suppressed by control room personnel using hand-held extinguishers before radiant and convective energy from the fire can damage the components within the C31 control panel.

The left and right ends of the C31 control panel are the least sensitive to a transient fire because a single fire will not affect both cabinets simultaneously. Based on the control room general arrangement, both ends of the C31 control panel are in view of the control room personnel. This type of scenario is bounded by the internal fire scenario and therefore no further evaluation was considered necessary.

Of the four possible locations for the external fire scenario, the most likely and most serious location is centered in back of the C31 control panel. A fire in this location would directly affect the wiring within both cabinets C31-A and C31-B, simultaneously (refer to Figures 5, 6, and 7). Because this location is not in full view of the operator's console or other areas of the control room, the greatest potential for undetected combustible material buildup is present. Also for this external fire location, the potential exists to bypass an interlock on both of the redundant DHR dropline valves causing their spurious operation. This potential does not exist for any other fire location, internal or external. Therefore, based on circuit sensitivity and the potential buildup of combustible materials, the back of the C31 control panel was selected as the location for the external fire scenario.

C. FIRE SCENARIO

For the purpose of analyzing the effects of fire on the C31 control panels, two fire scenarios were considered. The first fire scenario is a fire within the C31-A control cabinet and the second is an external fire adjacent to the back of the C31 control panel.

1. Internal Fire

The internal fire scenario which assumes the combustion of components and wiring within cabinet C31-A is more severe than any fire which might occur because it is assumed there is no time delay between open flame and circuit damage. The combustion of components and wiring assumes that a transient ignition source is introduced within cabinet C31-A and that the transient ignition source has sufficient energy to ignite and support the combustion of IEEE 383-74[1] qualified cables and phenolic components.

An analytical approach was taken to determine the mass of combustibles within one half of the C31 control panel. The analysis indicates each cabinet C31-A and C31-B contains approximately 107 lbs of combustible material. Further analysis indicated that 71 lbs of the total combustibles consisted of plastic relay cases and cable jacket and insulation material. The remaining 36 lbs of combustible material are contained within metal-cased instruments. Since the instrument cases are tight construction, it is assumed that the contained combustibles will not contribute tc the total fire loading.

To develop the internal fire load, a conservative assumption has been made. The internal switchboard and field wiring within each cabinet, C31-A and C31-B, are qualified to IEEE 383-74. For the jacketing and insulation material to contribute to the internal fire, it must be heated by a 200,000 Btu ignition source as described in the IEEE 383-74 test. Based on the limited combustibility of the IEEE 383-74 qualified wires, a large margin of

conservatism is introduced if 10,000 Btu/lb is assumed as the heat of combustion for the 71 lbs of combustibles within each cabinet, C31-A and C31-B. Each cabinet is approximately 4' wide and 3' deep. With an assumed heat of combustion of 10,000 Btu/lb, this equates to a fire loading of 59,166 Btu/sq ft of cabinet floor area.

The 15th Edition of NFPA Handbook[2] addresses guidelines developed by the General Services Administration which reads, "Ordinary combustibles enclosed on five sides by steel, ... are derated to 75 percent of their weight." To use this derating factor, the heat of combustion for plastic can be converted to ordinary combustibles having a value of 8,000 Btu/lb by the appropriate proportion factor (10,000/8,000 = 1.25). This means 71 lbs of plastic can be derated and converted to 66.5 lbs of equivalent ordinary combustibles. Using the 12 sq ft floor area of each cabinet, the 66.5 lbs of equivalent combustibles can be expressed as 5.54 lb/sq ft fire loading.

With the combustible material converted to an equivalent fire loading of ordinary combustibles, a comparison can be made to the ASTM E-119[3] Standard Fire Exposure Curve. Figure 5-9E of the NFPA Handbook shows the relationship between the ASTM E-119 standard fire exposure curve and four other temperatures curves, based on the fire severity expected by occupancy described in Table 5-9D of the NFPA Handbook. Based on the occupancies described in Table 5-9D, Temperature Curve A (slight) or B (moderate) would correspond to the expected fire severity. To add an extra margin of conservatism to the internal fire scenario, Temperature Curve C (moderately severe) has been selected for input to the fire model.

Using Figure 5-9E from the NFPA Handbook, the expected fire duration can be determined based on the fire load (5.54 lb/sq ft) and the temperature curve selected. The fire durations assume complete combustion and no fire suppression activities performed.

Fire Load (5.54 lb/sq ft)	Fire Duration (Minutes)
Temperature Curve C	50 minutes
Std. Time-Temp. (ASTM-E119)	35 minutes

The NFPA Handbook addresses the subject of equivalent fire severity. The NFPA Handbook states:

> "Two fires with differing temperature histories are considered to have an equivalent severity when the area under their time temperature curves is the same. This concept permits comparison of any fire test data to the standard time-temperature curve by relating the area under the test curve to that under the standard curve as illustrated in Figure 5-9C."

The following is a summary of the area under Temperature Curve C and the Standard Time-Temperature Curve (ASTM E-119) expressed in °F minute.

Fire Duration (Minutes)	Fire Severity (°F -Minute)
Temperature Curve C at 50 min.	45,750
Std Time Temp. (ASTM E-119) at 35 min.	42,860

These two curves bound essentially equal areas, therefore, their severities are approximately equal.

2. External Fire

The external fire scenario assumes a buildup of combustible materials behind the C31 control panel, then the combustibles are ignited by a transient ignition source. As previously mentioned, the heat transfer effects of the external fire are directly affected by its size, type of combustible, and location. To establish the size and severity of any external fire, two items must be addressed:

a. The composition of the transient combustible and the heat of combustion of each component.

b. The quantity of transient combustible, identified by type.

The NRC's generic letter 83-33[4], referring to "design basis transient combustibles," indicates that no industry standard exists for validating these items. For this reason the main control room at CPCo's Palisades Nuclear facility was surveyed to establish a reference base for the above items. This report recognizes that the combustibles survey was taken on a single day and that the main control room was for a single unit facility, however, the combustible inventory described below establishes a point of reference for estimating the size and severity of the external fire.

Based on conversations with the Palisades' operating personnel and a visual inspection of it's control room area, the following is a summary of combustibles which may be present at the Midland operator's console or in close proximity to the C31 control panel during plant operations:

Type of Combustibles	Quantity
Ordinary @ 8,000 Btu/lb (Books, paper, etc.)	50 lbs
Plastic Products @ 17,600 Btu/lb (Trash bags, cups, etc.)	5 lbs
Flammable Liquid @ 93,216 Btu/gal (isopropyl alcohol-contact cleaner was not observed but is conservatively assumed to be brought into the MCR during plant outage)	1 pint

The heat of combustion for each of the identified combustibles can be obtained from standard references. The total heat of combustion presented below assumes complete combustion and that no operator action or fire brigade activity is initiated to suppress the transient combustible.

Type of Combustible	Heat of Combustion
Ordinary	400,000 Btu
Plastic Products	88,000 Btu
Flammable Liquid	11,600 Btu

TOTAL: 499,600 Btu

Based on an even distribution of the identified control room combustibles over two desks (30" x 60" each), the calculated fire loading was 19,984 Btu/sq ft (approximately 2.5 lb/sq ft of equivalent 8,000 Btu/lb combustible).

A second reference basis for determining the type and quantity of transient combustibles was NUREG/CR 3192[5]. The composition of combustibles described in NUREG/CR 3192 provides data on several different fires which might be expected throughout the entire plant. NUREG/CR 3192 describes five fires having an approximate heat of combustion ranging from 116,600 Btu (123 MJ) to 581,124 Btu (613 MJ). This range is equivalent to 1 to 5 gallons of heptane.

Since the Palisades' data base for the control room combustible inventory was a single sample, a more severe transient fire was extracted from NUREG/CR 3192. The transient fire was selected for the greatest heat of combustion and the greatest likelihood of composition. The fuel source titled "Simulated Plant Trash" was selected and consisted of the following:

Type of Combustible	Quantity
Rags	25 lbs
Paper Towels	17 lbs
Plastic Products	13 lbs
Methyl Alcohol	2 gallons

Total: 581,124 Btu (613 MJ)

To compare the identified control room fire loading with that of the simulated trash, the floor area which the simulated trash occupies must be assumed. As described in NUREG/CR 3192, the simulated trash was evenly mixed and placed in two plastic trash bags (approximately 40 gallon size). Each 40 gallon trash bag is approxi-

mately 18" in diameter and 36" long. Since the trash bag is longer than it is wide, it can be assumed that the bag will lay on its side occupying an area of 4.5 sq ft (18" x 36"). For two trash bags the assumed floor area is 9 sq ft. Based on this assumption, the calculated fire loading is 64,569 Btu/sq ft (approximately 8.1 lb/sq ft of equivalent 8,000 Btu/lb combustible).

This indicates that the fire loading described in NUREG/CR 3192 is 3.2 times greater than the combustible inventory identified by the main control room survey of combustible. Applying the NUREG/CR 3192 fire loading to the fire duration curves in Figure 5-9E of the NFPA Handbook, it can be shown that a fire following Temperature Curve C has a 65 minute duration compared to a 45 minute duration following the Standard Time-Temperature Curve.

As previously described, the severity of two fires with differing temperature histories are considered equal when the area under the temperature curves is the same.

Fire Load (8.1 lb/sq ft)	Fire Duration (Minutes)	Severity °F-Minute
Temperature Curve C	65 minutes	69,500
Std. Time-Temp. (ASTM E-119)	45 minutes	58,300

Based on the fire duration times described above, it can be concluded that the severity of both fires are approximately equal.

3. Summary

In summary, both the internal and external exposure fires have been compared with the Standard Fire Endurance Test of ASTM E-119 and experimental data presented in NUREG/CR 3192. It can be concluded that a reference fire following Temperature Curve C described in the NFPA Handbook will have a severity greater than, or equal to, the ASTM E-119 or NUREG/CR 3192 fires.

D. MODELS

1. Computer Model

An analytical approach was taken to study the effects of each fire scenario on the C31 control panel. This approach modeled the fire and each cabinet as a system equating the various modes of heat transfer. The heat transfer calculations were performed using a Continuous System Modeling Program[6] (CSMP). CSMP is a software package developed by IBM Corporation specifically designed for simulation of time dependent physical systems. An advanced version called CSMP III is utilized for this analysis. The package, which is written such that standard FORTRAN programming techniques and functions can be used, has built-in capabilities for solving large systems of simultaneous differential or integral equations. Since these functions are a part of the software package, the user need only set up the expressions and terms needed to define the time dependent equations to be solved, then invoke the proper function for their solution.

For this study the time dependent equations that were developed took the form of a differential expression for temperature. A differential expression was written for each component for which temperature was calculated. The general form of these expressions was:

$$\frac{DT}{Dt} = \frac{1}{mc_p} \sum q$$

where $\sum q$ represents the summation of all heat in or out of the component by conduction, convection, and radiation, m is the mass of the component and c_p is the heat capacity. Since the heat transferred between any two objects is a function of temperature, the expressions for each component are interrelated. The solution to the temperatures is obtained by simultaneously integrating the differential expressions for each component.

2. <u>Model Geometry</u>

The mathematical model simulated the actual physical configuration of the C31 panel. For the internal fire located in cabinet C31-A, it was assumed that the fire resulted in immediate damage to the cabinet C31-A components. Therefore only cabinet C31-B was modeled. For the external fire, located on the panel centerline, only one cabinet needed to be modeled because of symmetry. Therefore, only cabinet C31-B was modeled. As illustrated on Figures 8, 9, and 10, the critical components were located within the cabinet and these locations became reference points for the heat transfer calculations.

The cabinet wall, near the assumed flame, was divided into sections to account for the differences in radiant flux due to distance from the flame. The heat was then conducted through the wall (insulated or uninsulated) and then transferred to the cabinet internals by radiation and convection. As the outer walls of the cabinet heat up, the heat is rejected into the control room by natural convection off the panel surfaces.

Natural convection through the vent openings at the top and bottom of the panels provides a cooling influence to the cabinet internals. At fire initiation, vents at the front and rear bottom and rear top are open and provide free airflow through the cabinet. As the bulk air temperature in the cabinet exceeds 135°F, a fire damper at the lower back opening is closed, reducing the convective airflow. The vents at the bottom front and top rear remain open.

Specific items modeled include a switch mounted on the panel front and items on the common wall including terminal blocks and the wire bundle as shown on Figures 8, 9, and 10. The wire bundle was assumed to be layered having one layer exposed directly to the hot surfaces and a second layer receiving heat by conduction from the first layer. A composite bundle was also modeled which considered the mass of the whole bundle as a unit to obtain an average wire bundle temperature.

3. <u>Flame Model</u>

The flames were modeled as having a flame temperature which rose from 80°F to 1,800°F in 2 minutes and remained

constant at 1,800°F for the next 58 minutes. The flame emissivity was conservatively assumed to be 1.0. The size and shape of the flame was dependent on the assumed fire source. For the internal fire, the flame was assumed to be restricted to the terminal strip at the back corner of cabinet C31-A nearest cabinet C31-B. The flame dimensions were therefore equal to the length of the terminal strip and stood out 2" from terminal strip toward the front of the cabinet. The external fire dimensions were modeled as 5' wide and 90" high, centered about the panel centerline. Heat transfer from the flame to the cabinet was due entirely by radiation. In addition, the air temperature between the cabinet and the flame was assumed to be Fire Curve C as described in Section VI.C. The heat transfer between the air and the cabinet wall was assumed to be governed by free convection.

For the list of modeling assumptions and additional details refer to Table 1.

E. ANALYSIS

Having addressed the size, location, and severity of both an internal and external reference fire, the results of the fire models can be discussed. As previously addressed, the temperature at various points within each C31 cabinet is time dependent. Figures 11-14 show the time-temperature plots at selected locations within the cabinets. The critical components within each C31 cabinet were identified as the switchboard wire, field wire, and control switches.

In order to correlate the operator action with the time available to mitigate the consequences of a modeled fire, a critical

temperature for each component must be identified. The internal switchboard wiring, field wiring, and switches have been exposed to elevated temperatures for thermal aging or to withstand a simulated LOCA condition. The critical temperature of each component is defined as the maximum temperature used for these thermal aging tests or used during the LOCA qualification tests since data from tests performed to component failure are not available. This critical temperature is highly conservative compared with the actual wire insulation and switch failure temperature.

Component	LOCA or Thermal Aging Temperature (^{o}F)	Location within C31 Cabinets
Selector Switches (General Electric)	268^{o}F	Front of Each Cabinet (Figures 3 & 10)
Internal Switchboard Wiring (Anaconda-NSIS Wire)	385^{o}F	Back, Common, and Front Wall (Figures 6, 7, 8, 9, 10)
Field Wiring (Rockbestos Firewall III Wire)	340^{o}F	Back and Common Wall (Figures 6, 7, 8, 10)

Because test temperature data for the terminal blocks is not available, it was conservatively assumed that these components failed at the critical temperature of connected wires.

The components listed above are shown on Figures 8, 9, and 10. These photographs also show the temperature locations evaluated in the mathematical model described in Section VI.D. The time-temperature graphs shown in Figures 11-14 each graphically

illustrate the relationship between time and temperature for the following locations:

1. Front of cabinet temperature (i.e., selector switch temperature).

2. Air temperature within the analyzed cabinet.

3. Terminal block temperature.

4. Surface temperature of the wire bundle.

Using Figures 8-10 in conjunction with Figures 11-14, the elapsed time before components reach their critical temperature can be determined.

For a fire within the uninsulated cabinet C31-A, the surface temperature of the wire bundle within C31-B, shown on Figure 9, reaches its critical temperature (385^{o}F) within 36 minutes of open flame as shown on Figure 11. To extend the time elapsed before components reach their critical temperature, the equivalent of 0.5 inches of mineral wool insulation was applied to the common wall within cabinet C31-A. This modification was subsequently modeled and the resulting time-temperature relationship is shown on Figure 12. This figure shows that none of the identified components reach their critical temperature before 60 minutes. As previously shown in Section VI.C, the internal fire has a calculated duration of 50 minutes and, therefore, CPCo expects no consequential damage to the redundant cabinet.

For an external fire centered in back of the C31 control panel, the surface temperature of the wire bundle, shown on Figure 8,

reaches its critical temperature (385°F) whthin 4 minutes of open flame as shown on Figure 13. To extend the time elapsed before components reach their critical temperature, the equivalent of 1.0 inch of mineral wool insulation with a radiant heat shield was assumed to be applied to the back wall of both cabinets C31-A and C31-B. This modification was subsequently modeled and the resulting time-temperature relationship is shown on Figure 14. This figure shows that the elapsed time before the surface temperature of the wire bundle reaches its critical temperature (385°F), has been extended from 4 minutes to 20 minutes.

F. OPERATOR ACTIONS

The fire described in the internal fire scenario has a calculated duration of 50 minutes. This assumes that no action is taken by control room personnel or the fire brigade to suppress or extinguish the fire. To establish the required operator action, it is assumed that fire-induced failures occur within the affected cabinet simultaneously with open flame as shown in Figure 15. It is further assumed that the fire-induced failures cause spurious operation of the DHR dropline bypass valves and PORV. The POAV cannot operate because the power to the valve operator is normally "locked out" by the remote power switch.

The simulated plant trash fire described in the external fire scenario has a calculated duration of 65 minutes. This assumes that no action is taken by control room personnel or the fire brigade to suppress or extinguish the fire. Figure 16 shows that fire induced failures are assumed to occur 20 minutes after open flame occurs. As previously discussed, 20 minutes is the time required for the external fire to heat the internal

components to their critical temperature. Spurious operation of the DHR dropline bypass valves and PORV can occur through fire-induced shorts.

1. Priority Actions for Control Room Operators

Operator actions for safe shutdown must prevent any loss of primary coolant by way of the PORV or high/low pressure interfaces by assuring that the redundant isolation valves for these paths close and remain closed.

2. Response Time

The effects of spurious valve operation can be mitigated by operator action using redundant controls located in their respective motor control centers. The following assumptions are made in determining the operator response time:

a. A complete breakdown of the fire detection within the C31 control panel and main control room has occurred.

b. Detection of a fire by control room personnel occurs when the fire develops into the flaming stage (time = 0).

c. The operating personnel response and travel time is conservatively chosen based on plant layout (time = 11 minutes). This includes operating both PORV block valve controls at the C31 control panel to the "valve closed" position.

d. For actions in the switchgear room, all of the components on a single train are secured before any actions are taken to secure components on the redundant train.

e. The following activities are performed for any fire scenario affecting the C31 control panel:

- Remove power to the DHR isolation valves at their Motor Control Center. One DHR valve may be open, however, this will not violate the high/low pressure interface.

- Electrically isolate the PORV block valve circuits from the C31 control panel at the MCC and assure at least one PORV block valve is closed using its controls at the MCC.

The time required to perform the identified operator actions is illustrated on Figure 17. As shown on this figure, the necessary operator actions can be completed in the allotted amount of time.

The installation of the interlock circuit on the POAV motor operator circuits, as described above in Section IV-C, negates the need for operator actions to secure the POAV's in the event of a C31 panel fire. An additional modification to the POAV control circuit to isolate the C31 cabinet portions of the control circuit are only necessary for local operator control of these valves for cold shutdown of the plant.

VII. CONCLUSIONS

This evaluation concludes that safe shutdown can be achieved from either the control room or the redundant switchgear rooms, considering either internal or external fires in/near the C31 control panel. With the combination of existing design, modifications, operator actions, and administrative procedures, the guidelines stated in BTP-CMEB 9.5-1 are met without the addition of a halon suppression system.

Safe shutdown can easily be accomplished, in part, due to the licensee's commitment to:

- modify the existing cabinet design by the installation of internal insulation and addition of ventilation fire dampers.

- ensure administrative procedures which preclude the buildup of external combustibles.

- modify the POAV circuits with an interlock circuit in the C15 panel to "lock-out" power to the valve operators during normal plant operation.

- modify MCC circuitry for PORV block valves and POAVs allowing nonrepair type operator actions to quickly secure the effected components in the unlikely event of a control room fire affecting the C31 control panel.

This conclusion has been reached even with very conservative modeling parameters that assume, among other things:

- unrealistic accumulation of combustibles,

- visual fire detection does not occur,

- fire propagation reaches a peak temperature and stabilizes without allowing for natural decay as combustibles are consumed,

- cabinet component failures are attained at conservative temperatures, and

- the fire burns without extinguishment by CPCo personnel.

Plant walkdowns confirm that all necessary operator actions can be performed within the times specified in Section VI.E of this report to achieve safe shutdown considering all of the above conservative assumptions.

VIII. REFERENCES

1. IEEE-383, Class 1E Electric Cables, Field Splices, and Connections for Nuclear Power Generating Stations, Standard for Type Test of; 1974.

2. Fire Protection Handbook, Fifteenth Edition, Section 5 Chapter 9, pp 5-88 through 5-93, National Fire Protection Association, Quincy MA, 1981.

3. ASTM E119; Fire Tests of Building Construction and Materials; 1983.

4. "NRC Positions on Certain Requirements of Appendix R to 10CFR50," Generic Letter 83-33, USNRC, October 1983.

5. "Investigation of Twenty-Foot Separation Distance as a Fire Protection Method as Specified in 10CFR50, Appendix R," NUREG/CR-3192, October 1983.

6. "System/360 Continuous System Modeling Program (360A-CX-16X) System Manual," IBM publication GY20-0111-0.

TABLE 1

MODELING ASSUMPTIONS

1. All heat transfer from solid surfaces to air is by natural (or free) convection.

2. Surfaces in contact with each other transfer heat by conduction.

3. Radiation heat transfer between any two surfaces where neither of the surfaces is the "Hot" wall is negligible. This is conservative since the wire heats up more rapidly than the surroundings.

4. Control room air remains constant at 80°F.

5. Air temperature at location of the fire is obtained from fire curves, Figure 5-9E of the NFPA Handbook.

6. Internal components not specifically defined have a negligible effect on the other components.

7. Flame temperature increases linearly from time 0 to a maximum of 1,800°F at 2 minutes. The flame temperature holds at this value through the remainder of the program to give a worst case condition. Actual tests indicate that the flame temperature peaks then tapers off to a lower value.

8. For internal fire cases, the flame is situated at the terminal block next to the back corner of the common wall.

9. For the external fire cases, the flame is the result of the contents of two large trash bags burning next to the back wall of the cabinet. The flame is assumed to completely engulf the trash bags and to reach a height equal to the height of the cabinets.

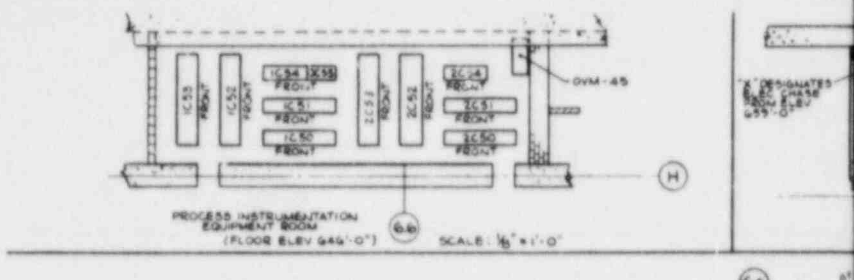
10. For external fire cases, the model is symmetrical about the center of the panel.

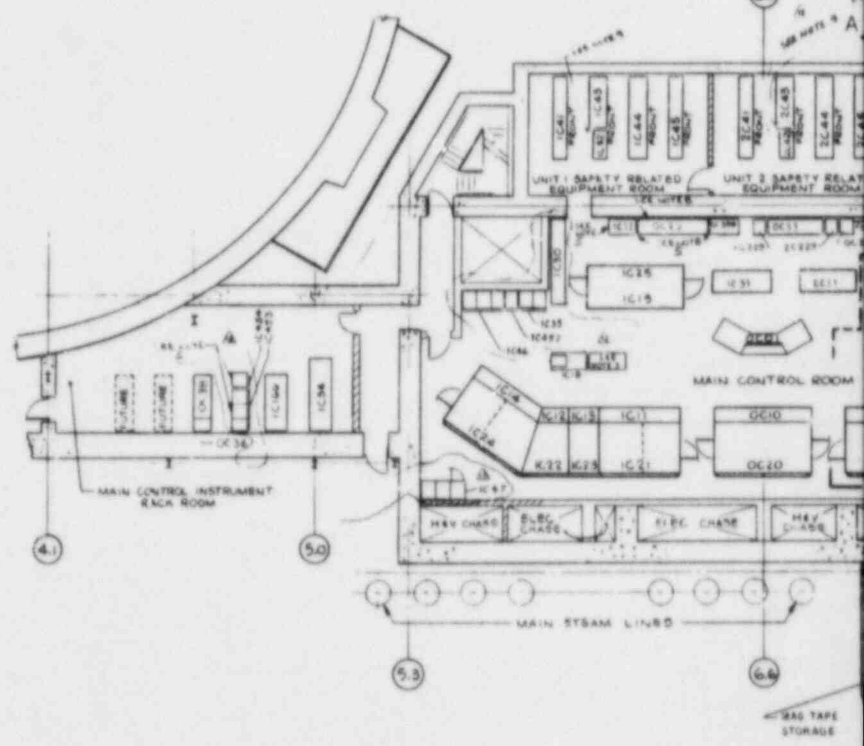
11. The floor area of the panels are omitted in the heat transfer calculated because this area is partially shielded by equipment. Omission of this heat sink is conservative.

12. For the internal fire, the cables are assumed ignited to open flame at time = 0.

13. Emissivity of the foil radiation shield is assumed to be 0.4, which is 2 to 3 times greater than typical values. Therefore, the radiant heat transfer is over estimated.

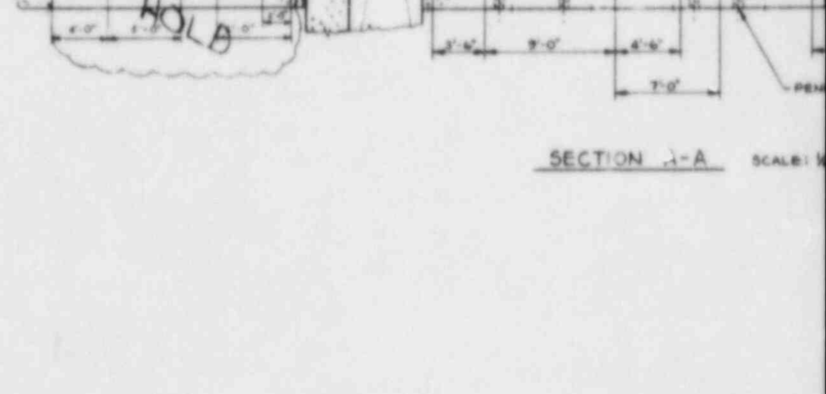
14. Radiation shape factors are based on flat plates with the same projected area. This gives higher values than would be used otherwise, resulting in more radiation heat transfer.



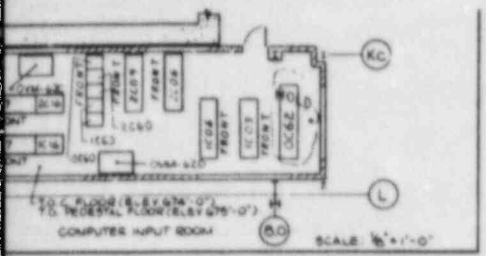


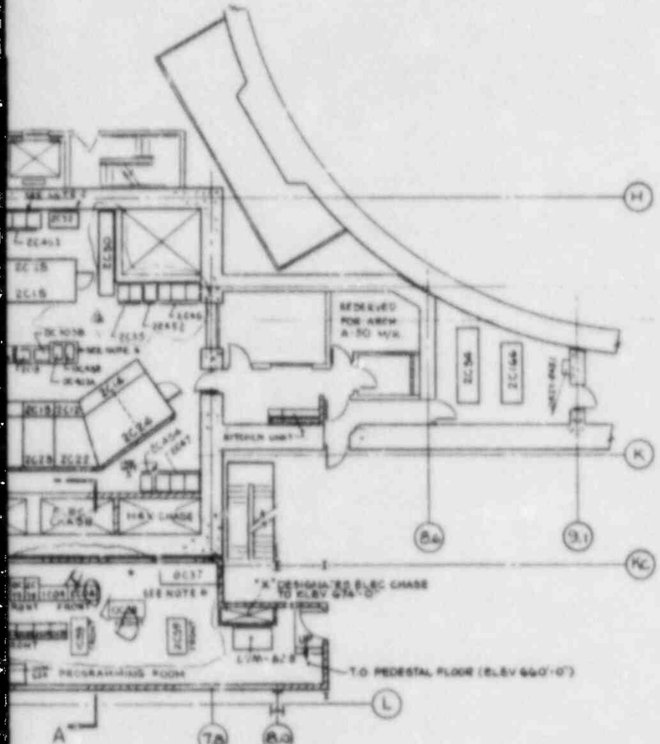
MAIN CONTROL ROOM ARRANG

SCALE



SECTION A-A SCALE:





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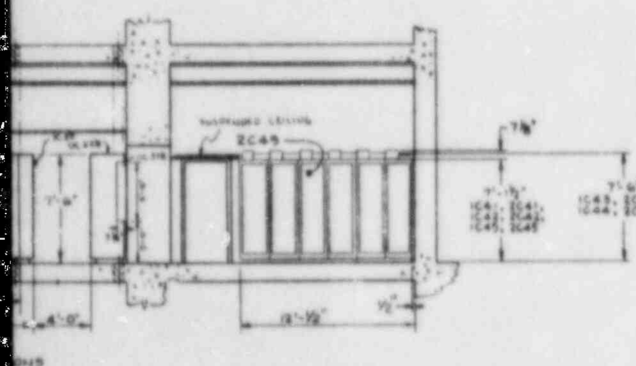
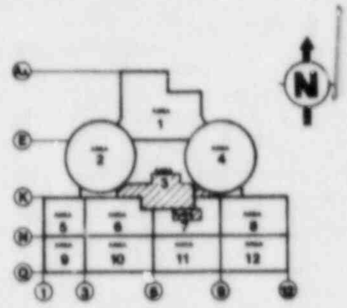




NOTES:

1. CONTROL PANEL DESCRIPTION:

Q-LISTED ITEMS	CONTROL PANEL (ARRANGEMENT DWG)			DESCRIPTION
	UNIT NO. 1	UNIT NO. 2	COMMON	
			0C01(J-748)	NUMBER ONE OPERATOR'S DESK
	1C59	2C59 *	0C59 *	PROGRAMMING FACILITY
			0C39	AYDIN DISPLAY GENERATORS SEE NOTE 6
	1C04	2C04		LINE PRINTER
	1C57	2C57 *	0C57 *	CENTRAL PROCESSING UNIT * SEE NOTE 6
	1C06	2C06		ANALOG INPUT PERIPHERAL TERMINATION CABINET (4 BAYS)
	1C07	2C07		COMPUTER INPUT MULTIPLEXER CABINET (6 BAYS)
	1C60	2C60	0C60	COMPUTER INPUT MULTIPLEXER CABINET (2 BAYS TOTAL)
		2C09		LOGIC INPUT/OUTPUT PERIPHERAL TERMINATION CABINET (4 BAYS)
Q			0C10(J-726)	EVAPORATOR & COMMON AUXILIARY CONTROL BENCHBOARD
Q	1C11(J-727)	2C11(J-731)		TURBINE-GENERATOR AND FEEDWATER CONTROL BENCHBOARD
Q	1C12(J-729)	2C12(J-733)		REACTOR COOLANT CONTROL BENCHBOARD
Q	1C13(J-728)	2C13(J-732)		CONTROL ROD DRIVE AND COMPUTER CONTROL BENCHBOARD
Q	1C14(J-730)	2C14(J-734)		ENGINEERED SAFETY FEATURES CONTROL BENCHBOARD
Q	1C15(J-744)	2C15(J-746)		ELECTRICAL VERTICAL PANEL
	1C16	2C16		COMPUTER INPUT MULTIPLEXER CABINET (2 BAYS)
	1C58	2C58	*	MAGNETIC TAPE UNIT AND PERIPHERAL CONTROLLERS
	1C18	2C18		CONTROL OPERATOR'S DESK AND ALARM TYPER
	1C19	2C19	0C19 *	MOVING HEAD DISC UNIT
Q			0C20(J-735)	COMMON AUXILIARY VERTICAL PANEL
Q	1C21(J-736)	2C21(J-740)		TURBINE SUPERVISORY INSTRUMENTATION & TURBINE-GEN AUXILIARIES VERT PNL
Q	1C22(J-738)	2C22(J-742)		BALANCE OF REACTOR COOLANT AND REACTOR AUXILIARIES VERTICAL PANEL
Q	1C23(J-728)	2C23(J-732)		BALANCE OF REACTOR MONITORING VERTICAL PANEL
Q	1C24(J-739)	2C24(J-743)		POST ACCIDENT MONITORING & BALANCE OF ENGINEERED SAFETY FEATURES VERT PNL
Q	1C25(J-745)	2C25(J-747)		ELECTRICAL PROTECTIVE RELAYS VERTICAL PANEL
Q			0C29	REACTOR BUILDING RADIATION SAMPLE AND HYDROGEN MONITORING CONTROL PANEL
Q	1C30	2C30		SAFETY RELATED AUXILIARY RELAY CABINET
Q	1C31	2C31		SAFETY PARAMETER DISPLAY CONSOLE
Q	1C32	2C32		RADIATION MONITORING SYSTEM VERTICAL PANEL
			0C33	ELECTRICAL SYSTEM STATUS DISPLAY PANEL
	1C34	2C34		ANNUNCIATOR TERMINATION CABINET
Q	1C35	2C35		ECCAS CONDITIONING CABINET (ACTUATION CHANNELS A&B) (2 BAYS)
			0C36	MEPCC DATA ACQUISITION REMOTE STATION (CONITEL)
			0C37	ENGINEERS CONSOLE * SEE NOTE 6
			0C38	SWITCHYARD TELEMETRY AND CONTROL CABINETS
Q	1C41	2C41		NUCLEAR INSTRUMENTATION AND REACTOR PROTECTION SYSTEM CABINET (SAFETY CHANNELS A, B AND C) (6 BAYS)
Q	1C42	2C42		NUCLEAR INSTRUMENTATION AND REACTOR PROTECTION SYSTEM CABINET (SAFETY CHANNEL D) (2 BAYS)
Q	1C43	2C43		B.O.P. ENGINEERED SAFETY FEATURES CABINET (ANALOG SENSOR CHANNELS 1, 2, 3 & 4) (4 BAYS)
Q	1C44	2C44		B.O.P. ENGINEERED SAFETY FEATURES CABINET (ACTUATION CHANNELS A & B) (6 BAYS)
Q	1C45	2C45		EMERGENCY CORE COOLING ACTUATION SYSTEM CABINET (6 BAYS)
Q	1C46	2C46		ESIS ANALOG CABINET (2 BAYS)
Q	1C47	2C47		ESIS DIGITAL CABINET (1 BAY)
	1C50	2C50		INTEGRATED CONTROL SYSTEM CABINET (5 BAYS)
	1C51	2C51		NON-NUCLEAR INSTRUMENTATION X CABINET (8 BAYS)
	1C52	2C52		AUXILIARY RELAY CABINET (6 BAYS)
	1C53	2C53		PROCESS INSTRUMENTATION EQUIPMENT CABINET (6 BAYS)
	1C54	2C54		NON-NUCLEAR INSTRUMENTATION Y CABINET (3 BAYS)
			0C55	EVAPORATOR STEAM DEVELOPMENT SYSTEM CABINET (2 BAYS)
			OVM-45	PROCESS INSTRUMENTATION EQUIPMENT ROOM UNIT COOLER
			OVM-63A&B	PROGRAMMING ROOM AIR HANDLING UNIT
			OVM-63C&D	COMPUTER INPUT ROOM AIR HANDLING UNIT
Q	1C166	2C166		B.O.P. SAFETY RELATED INSTRUMENTATION CABINET (4 BAYS)
			0C67	FRONT END PROCESSORS * SEE NOTE 6
			0C118	SEISMIC MONITORING PANEL
	1C219	2C219		LOOSE PARTS MONITORING PANEL
			0C315	MAIN CONTROL ROOM FIRE/SMOKE DETECTION PANEL
Q			0C388	HAZARDOUS GAS MONITORING PANEL
			0C403A	RADIATION MONITORING PANEL CRT
			0C403C	RADIATION MONITORING PANEL PRINTER
			ORTY 8462	AREA RADIATION MONITOR LOCAL CONTROL UNIT
Q	1C452	2C452		ESIS ANALOG CABINET (1 BAY)
Q	1C453	2C453		ESIS DIGITAL CABINET (1 BAY)
Q	1C454	2C454		ESIS ANALOG CABINET (1 BAY)
			0C458	PROCESS STEAM RADIATION MONITORING CRT AND KEYBOARD

2. ALL BAYS WITHIN CABINETS ARE NUMBERED FROM LEFT TO RIGHT AS VIEWED FROM THE FRONT.

3. THIS SPACE IS RESERVED FOR THE SHIFT SUPERVISOR'S DESK. NO EQUIPMENT IS TO BE LOCATED IN THIS RESERVED AREA.

4. DESK MAY BE OFFSET TO IMPROVE VISIBILITY OF THE MAIN CONTROL BOARD.

5. A MINIMUM SEPARATION OF 3" REQUIRED BETWEEN THE PANELS. A MINIMUM SEPARATION OF 1" REQUIRED BETWEEN PANELS AND WALLS.

6. ON "HOLD" PENDING INCORPORATION OF ECN

7. DELETED

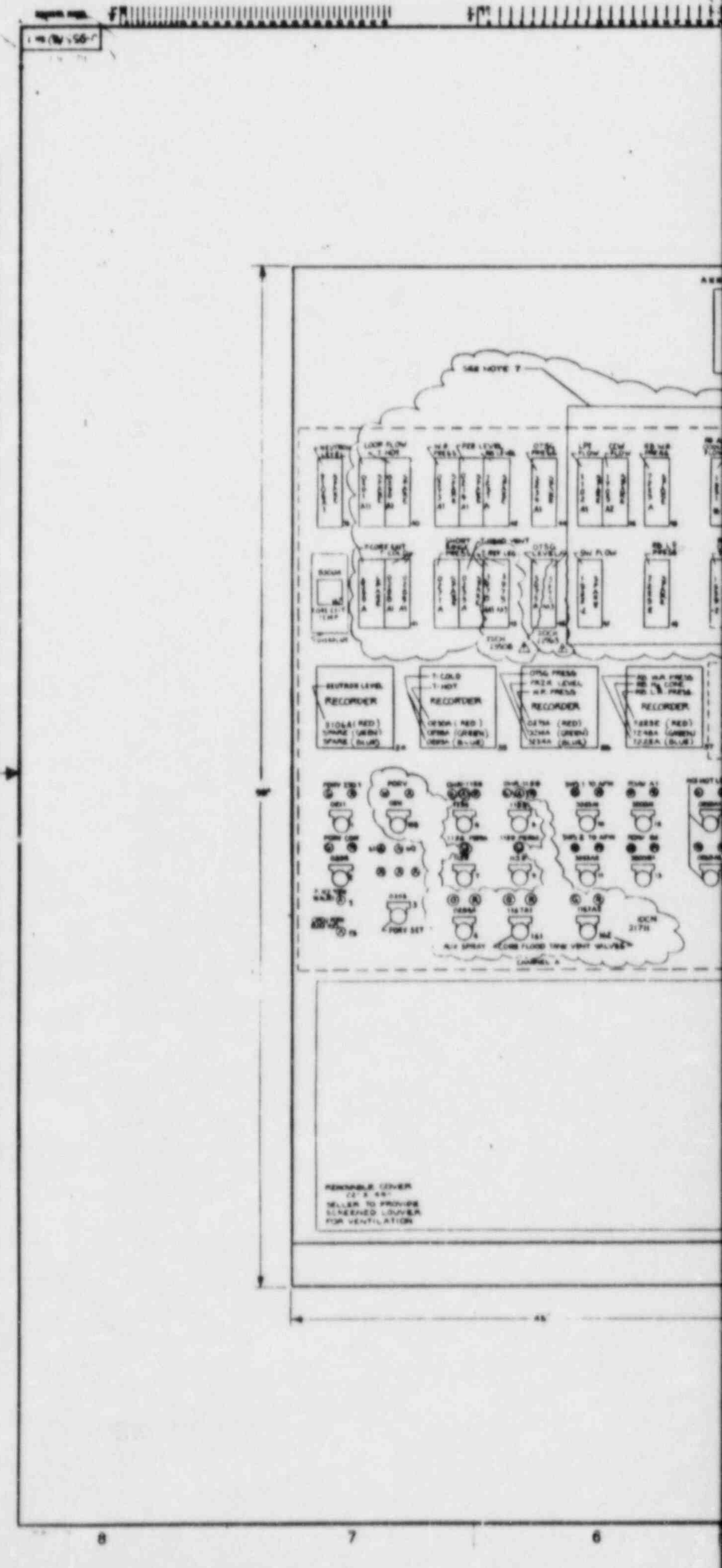
8. PANEL 0C29 IS SET AT 1½" OUT FROM SOUTH SIDE OF K WALL'S FACE

9. PANEL 1C43 IS SEPARATED FROM PANEL 1C43 BY A DISTANCE OF [illegible]

Also Available On Aperture Card

MCR GENERAL ARRANGEMENT
FIGURE 1

8405150132-01


SEE NOTE 7
RECORDER
RECORDER
RECORDER
RECORDER
T-COLD
T-HOT
PORV
PORV SET
REMOVABLE COVER
SELLER TO PROVIDE
SCREENED LOUVER
FOR VENTILATION
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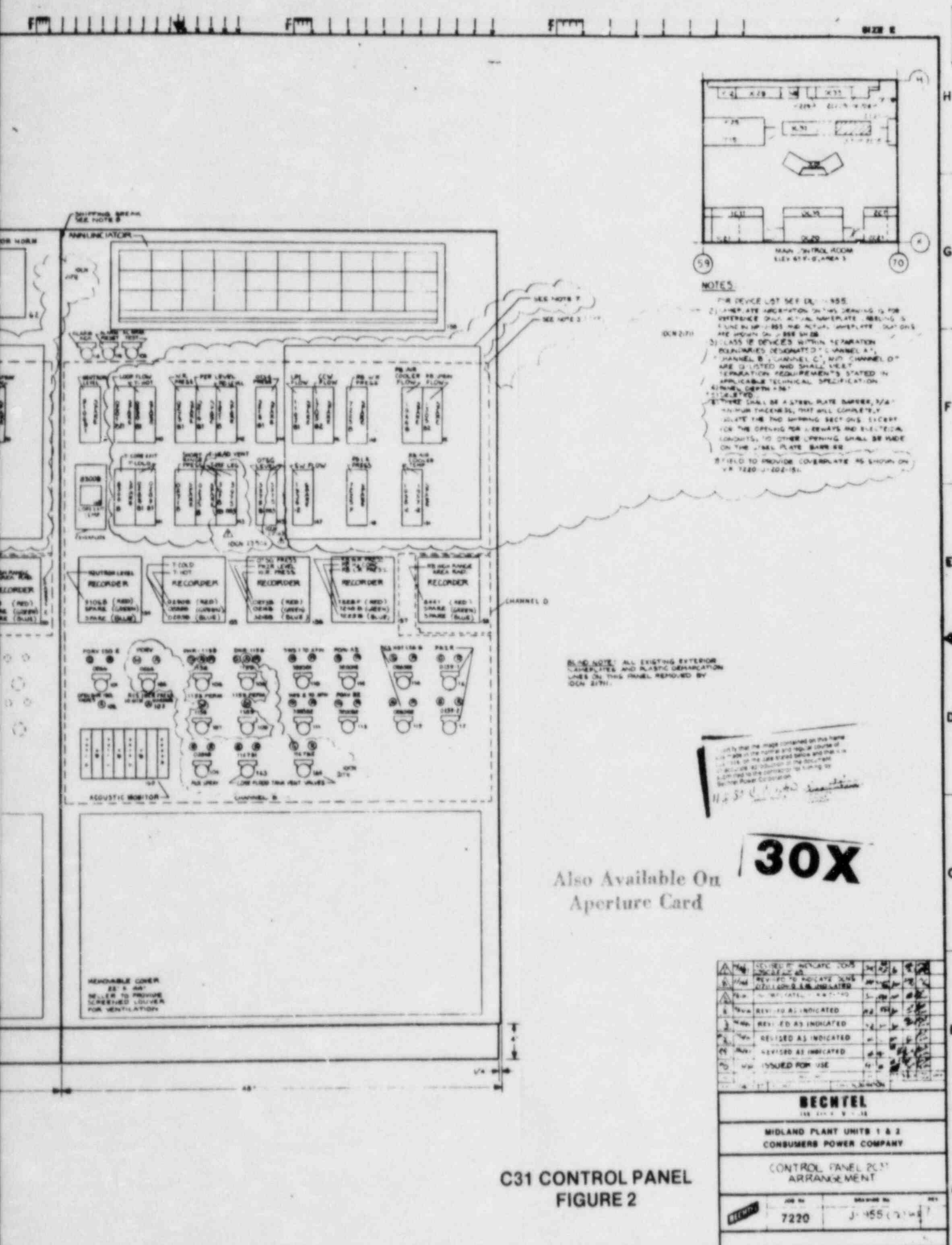

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30X

C31 CONTROL PANEL
FIGURE 2

8405150132 -02

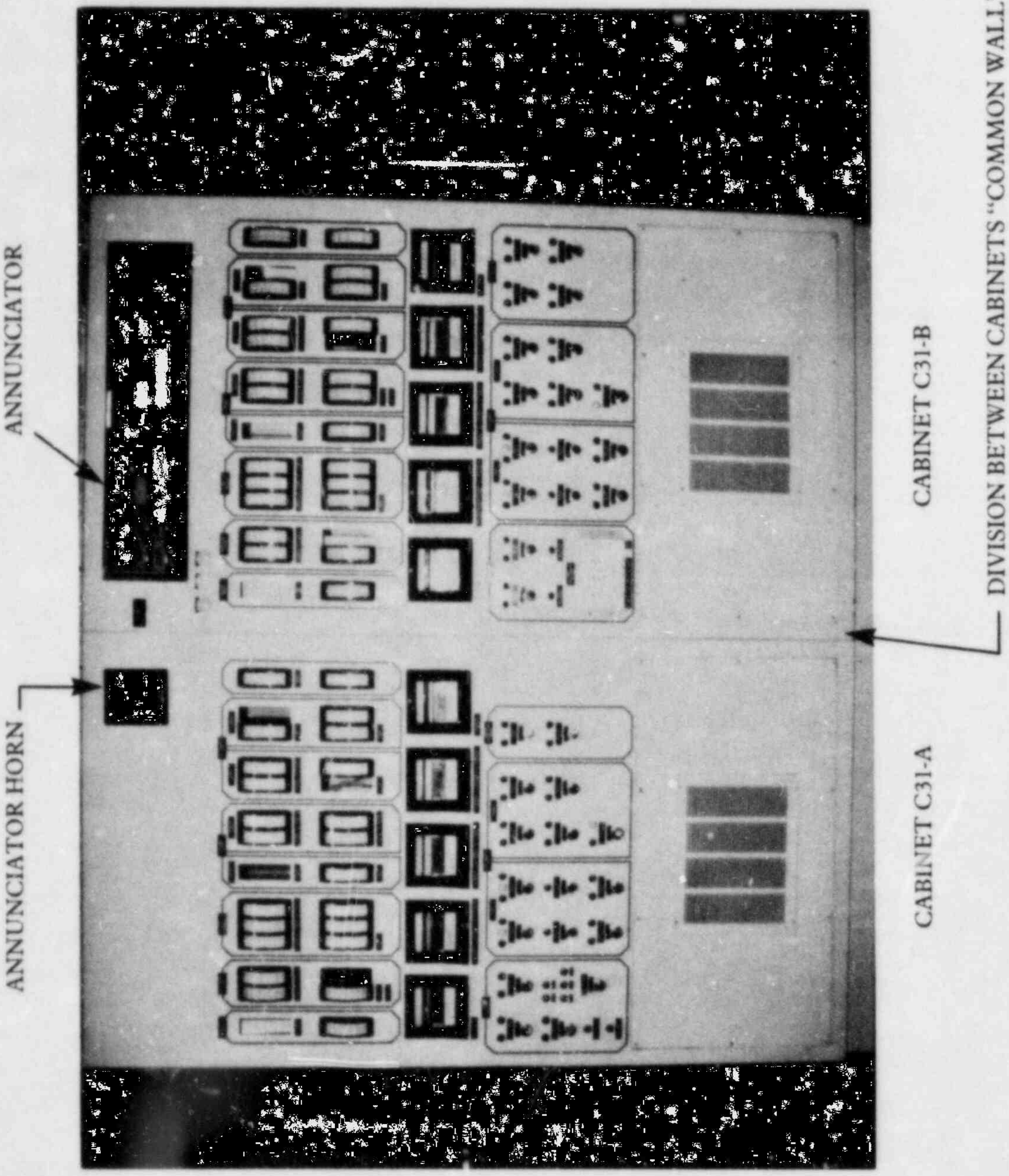
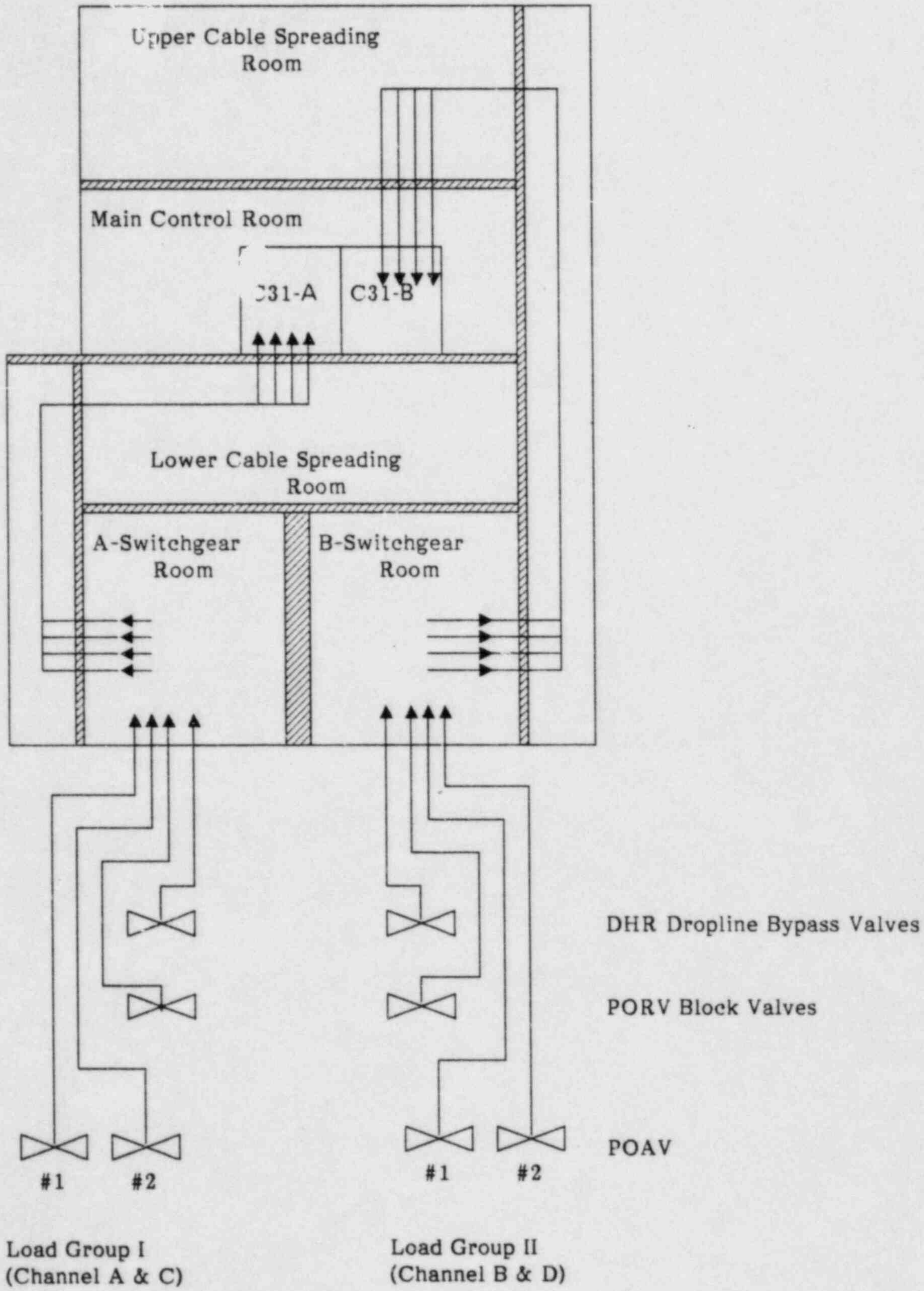


FIGURE 3. C31 CONTROL PANEL.



CIRCUITRY ARRANGEMENT

FIGURE 4

Scpm/C31-Fig. 04

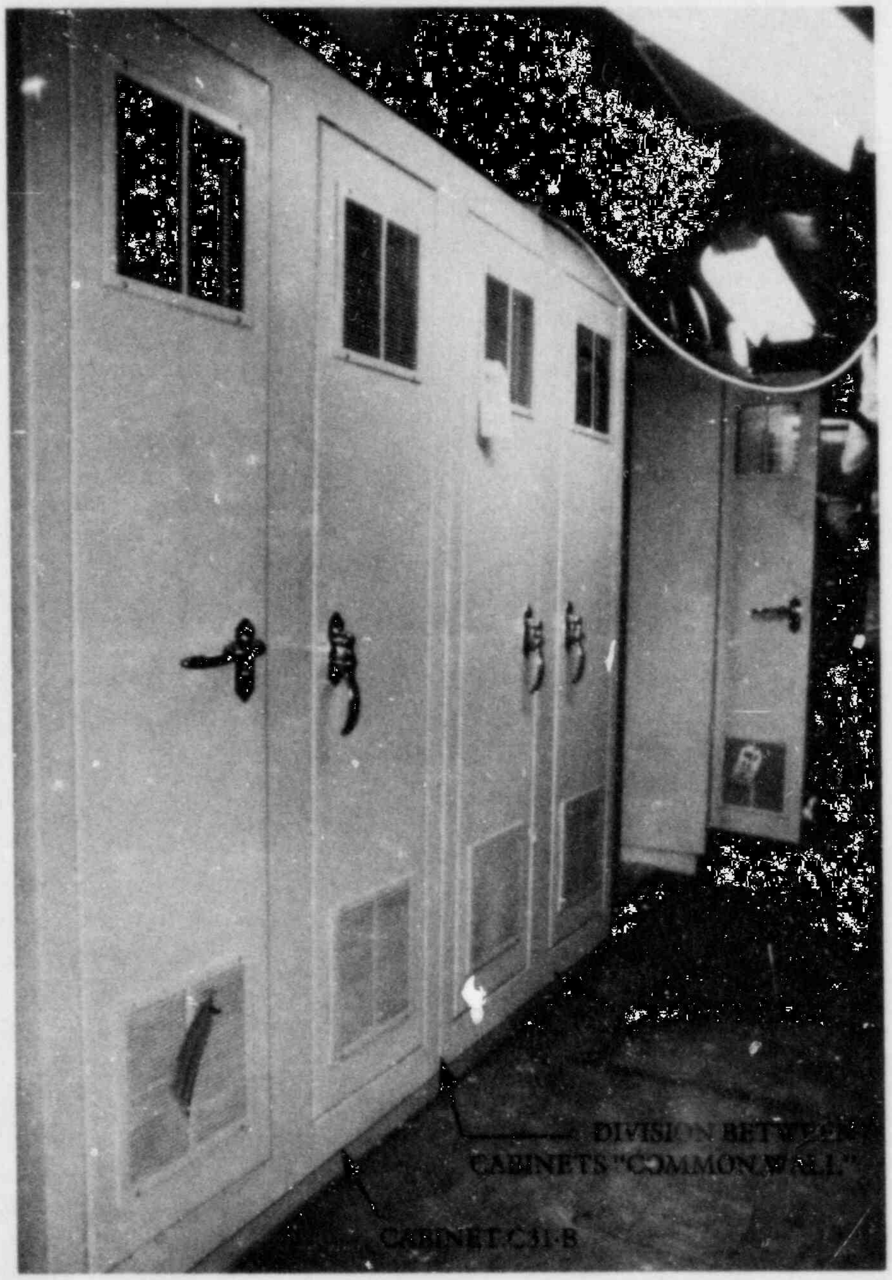


FIGURE 5. BACK VIEW CONTROL PANEL C31.

FIGURE 6. COMMON WALL CABINET C31-A.

FIGURE 7. COMMON WALL CABINET C21-B.

FIGURE 8. CABLE ENTRY & TERMINAL BLOCKS TOP BACK CABINET C31-B.

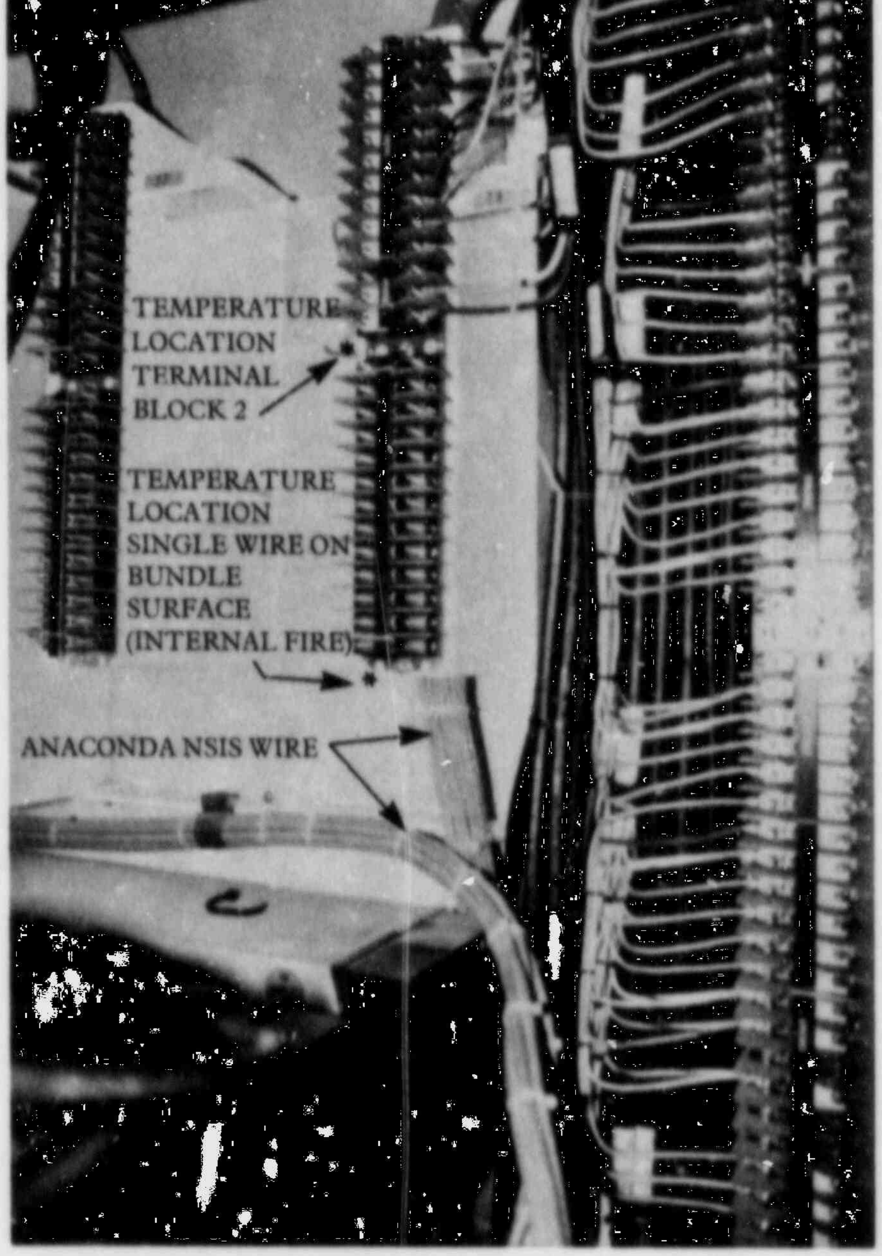


FIGURE 9. TERMINAL BLOCKS WITHIN CABINET C31-B TOP THIRD.

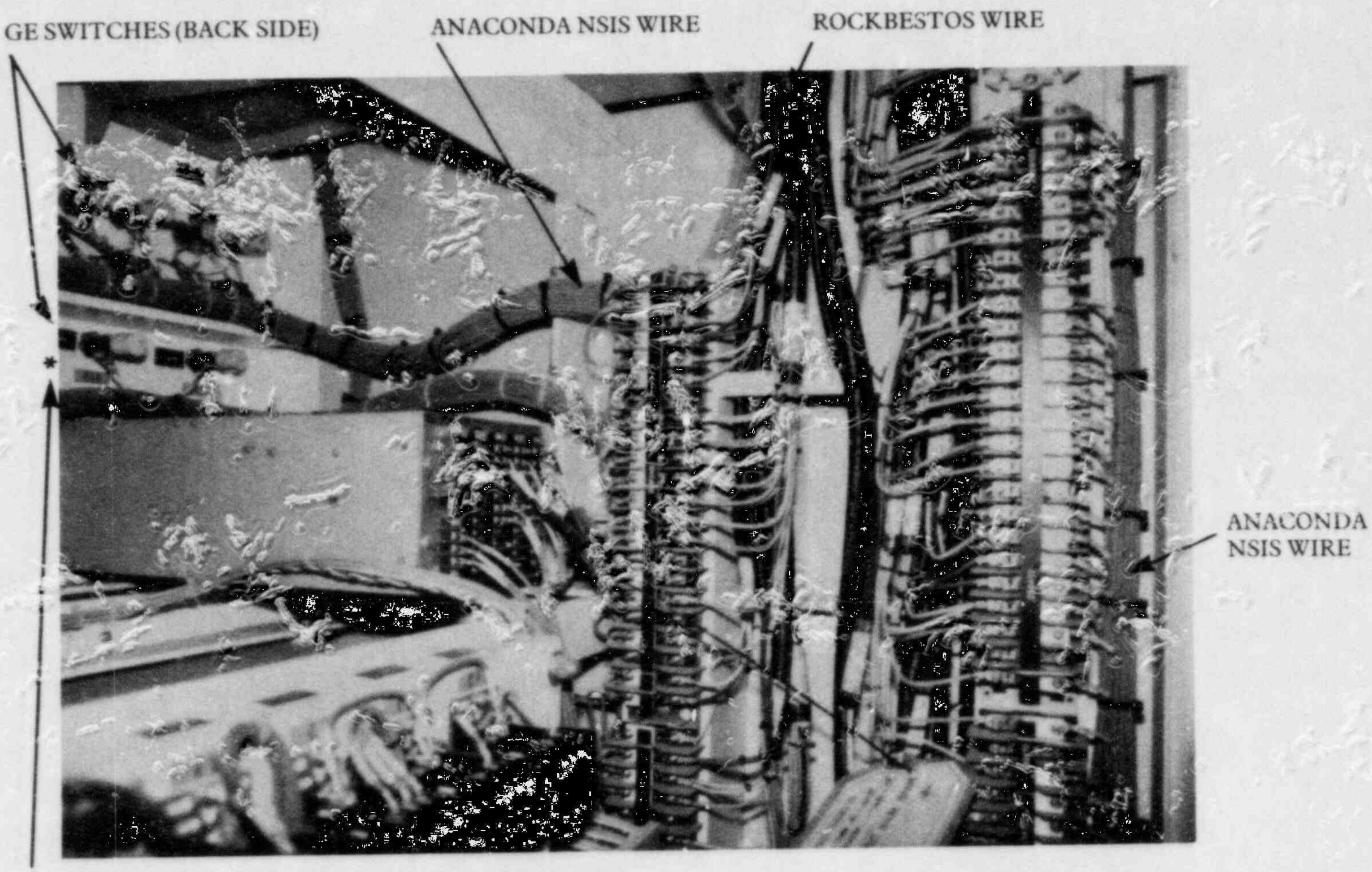
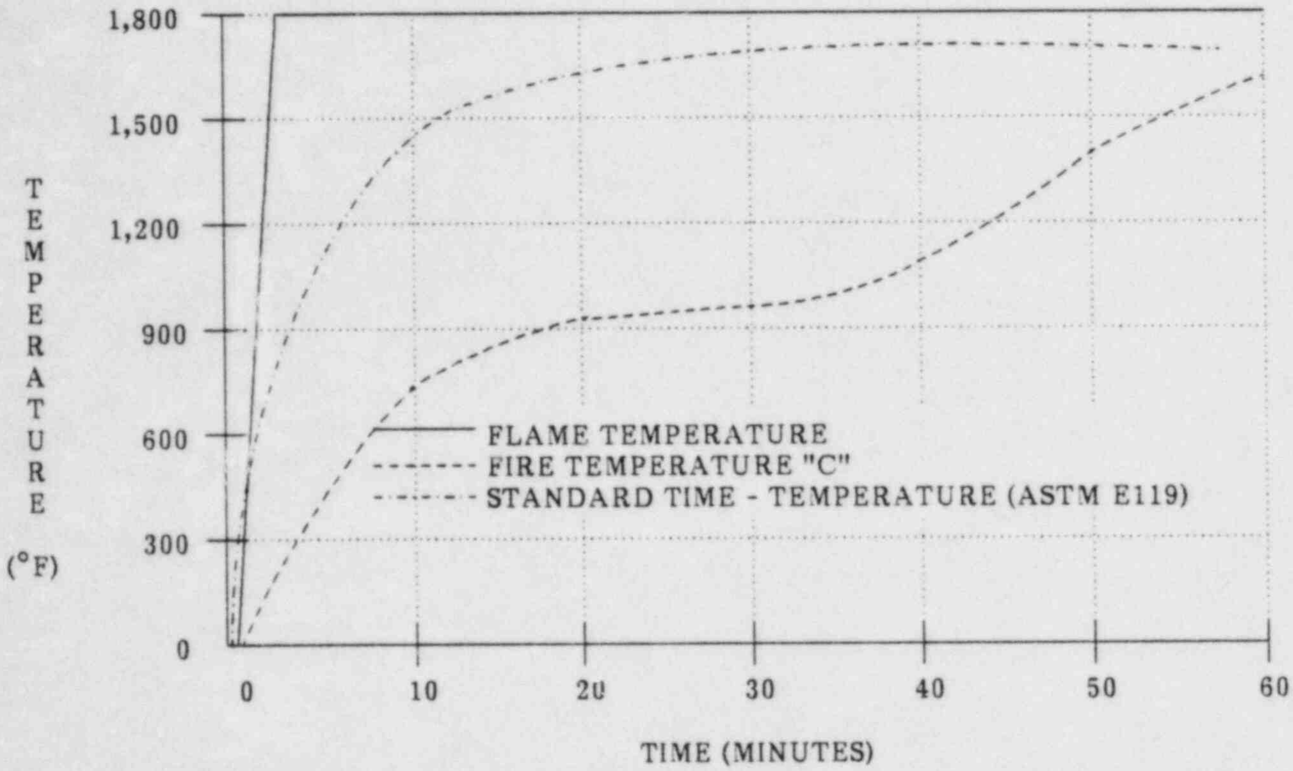
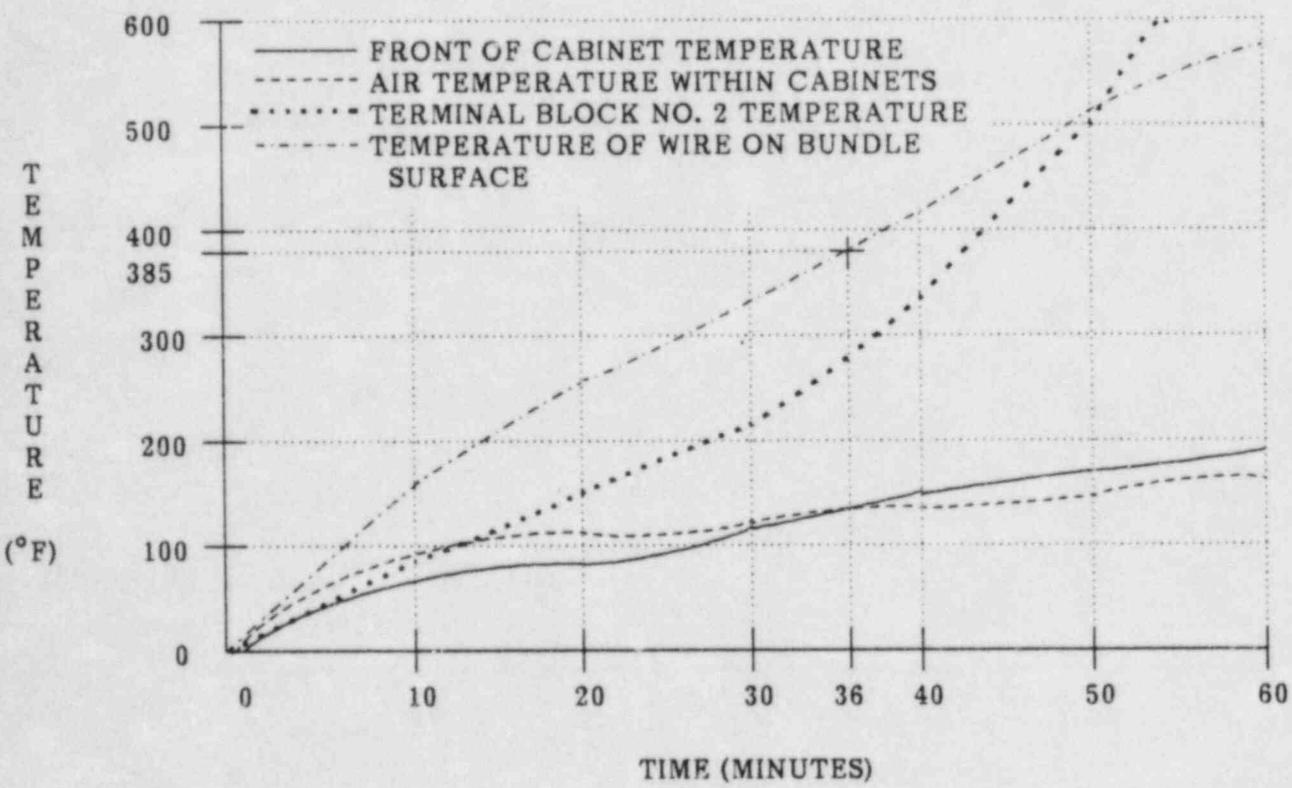


FIGURE 10. CENTER THIRD OF CABINET C31-B.

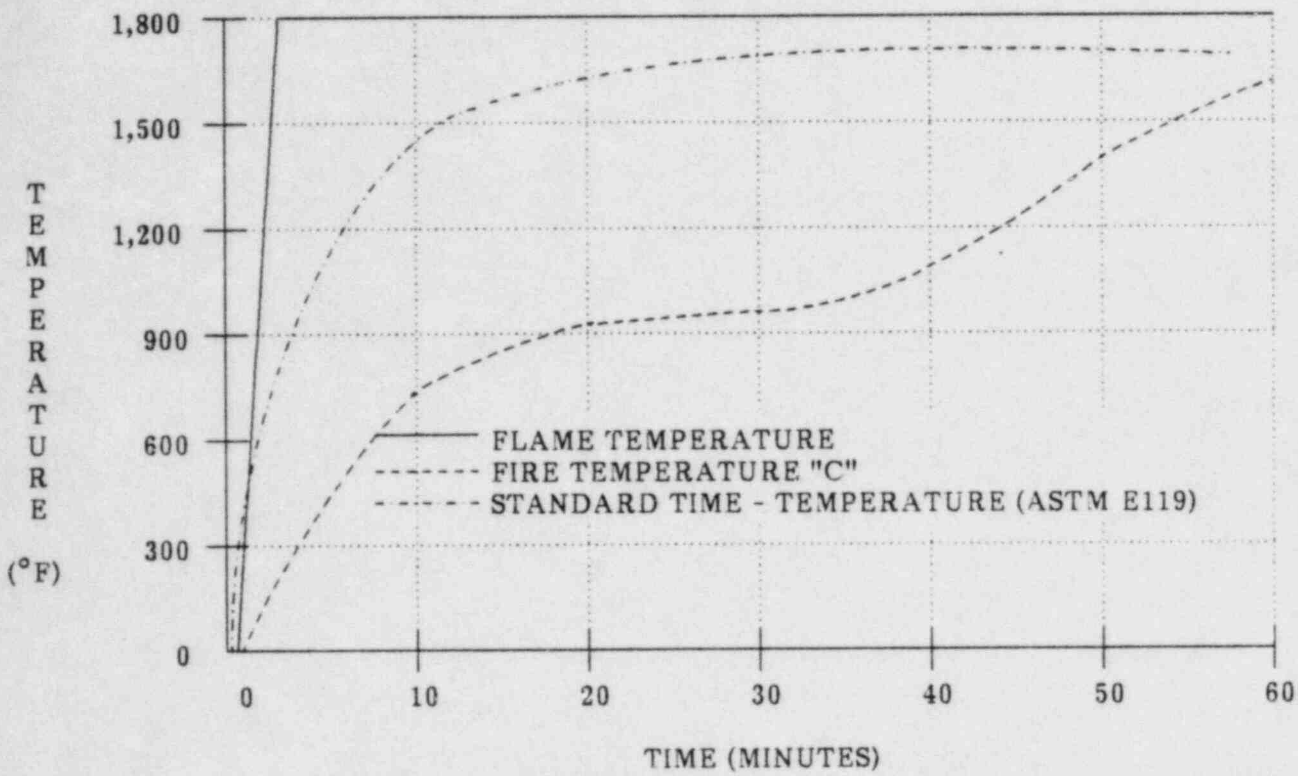


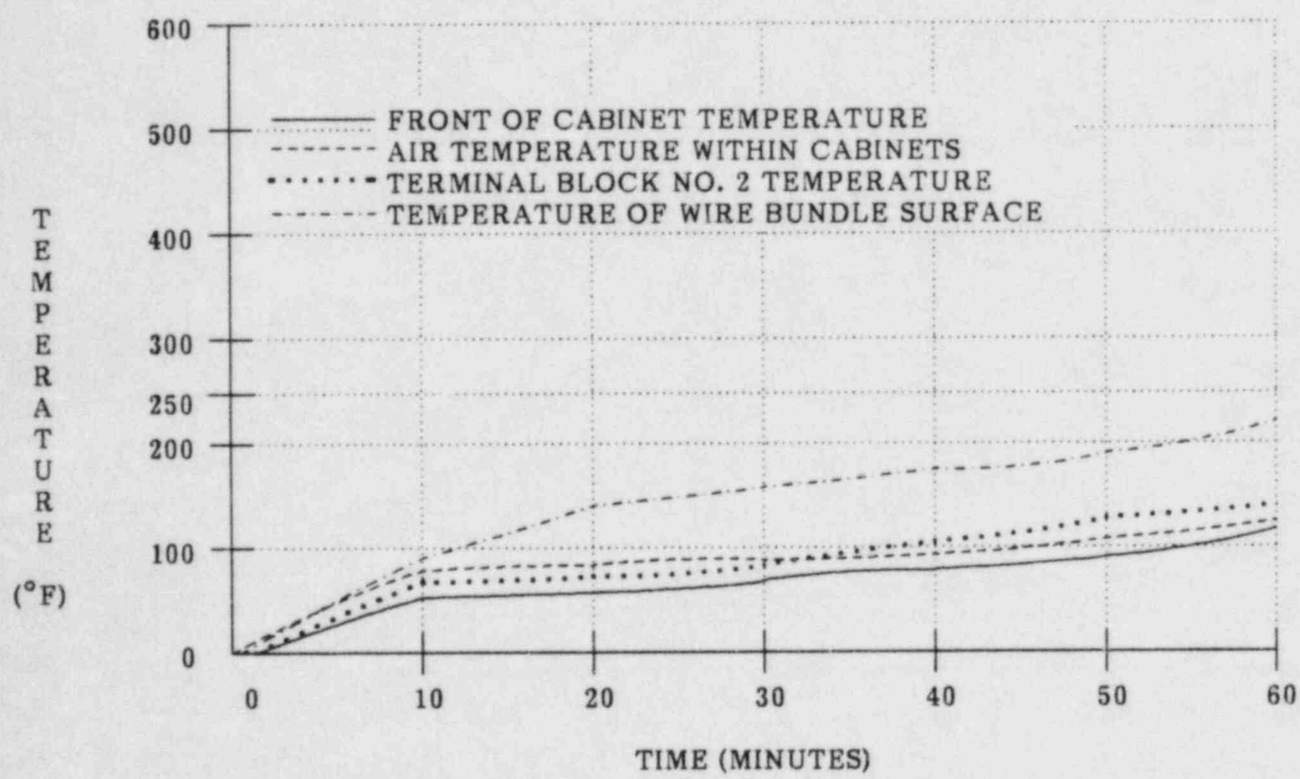


C31-B TIME-TEMPERATURE GRAPHS FOR
FIRE IN CABINET C31-A (UNINSULATED)

FIGURE 11

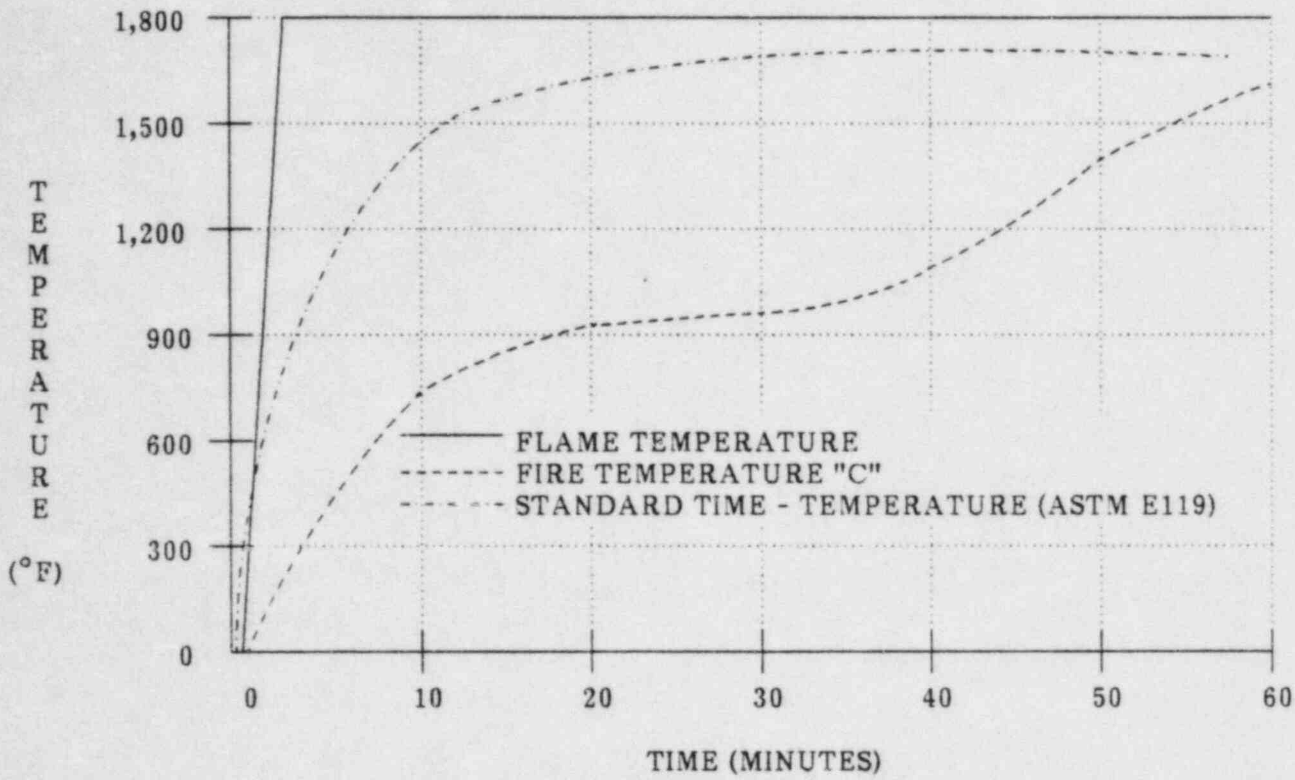
Scpm/FP-Gphs-3

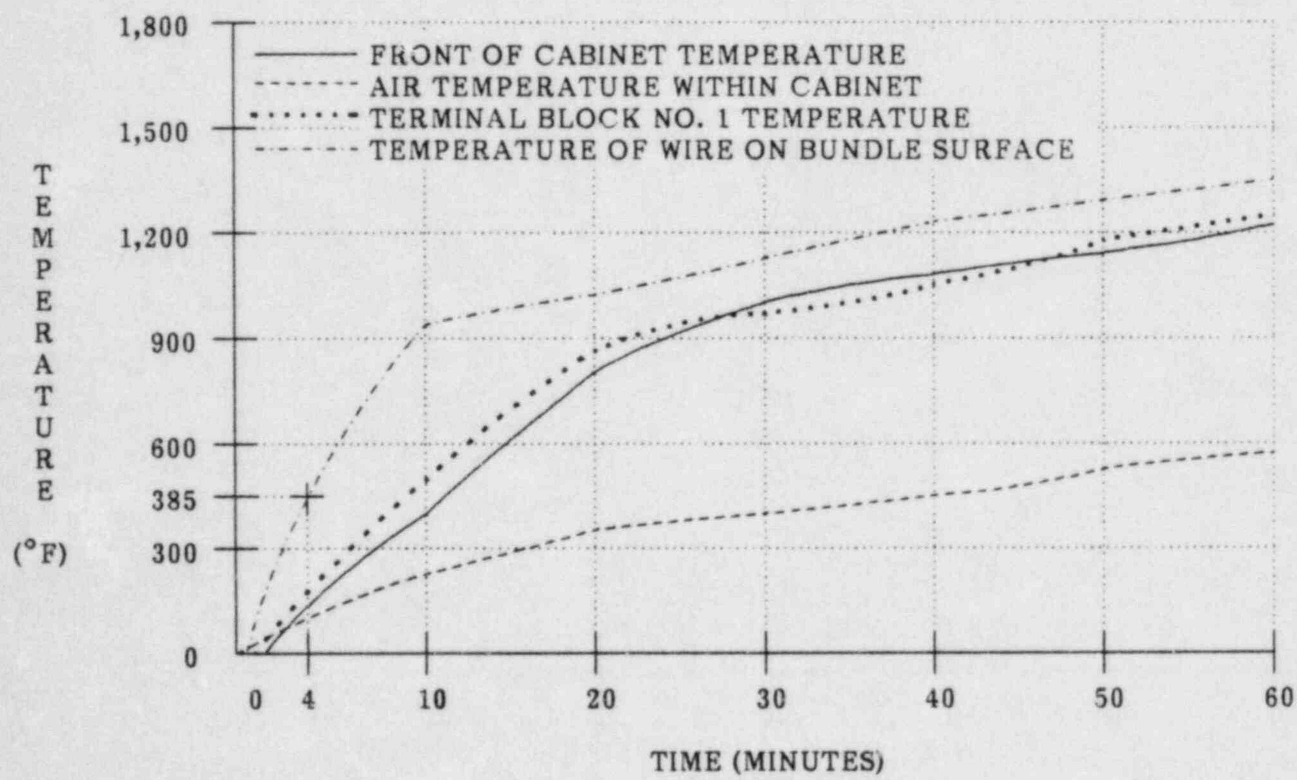




C31-B TIME-TEMPERATURE GRAPHS FOR
FIRE IN CABINET C31-A (INSULATED)

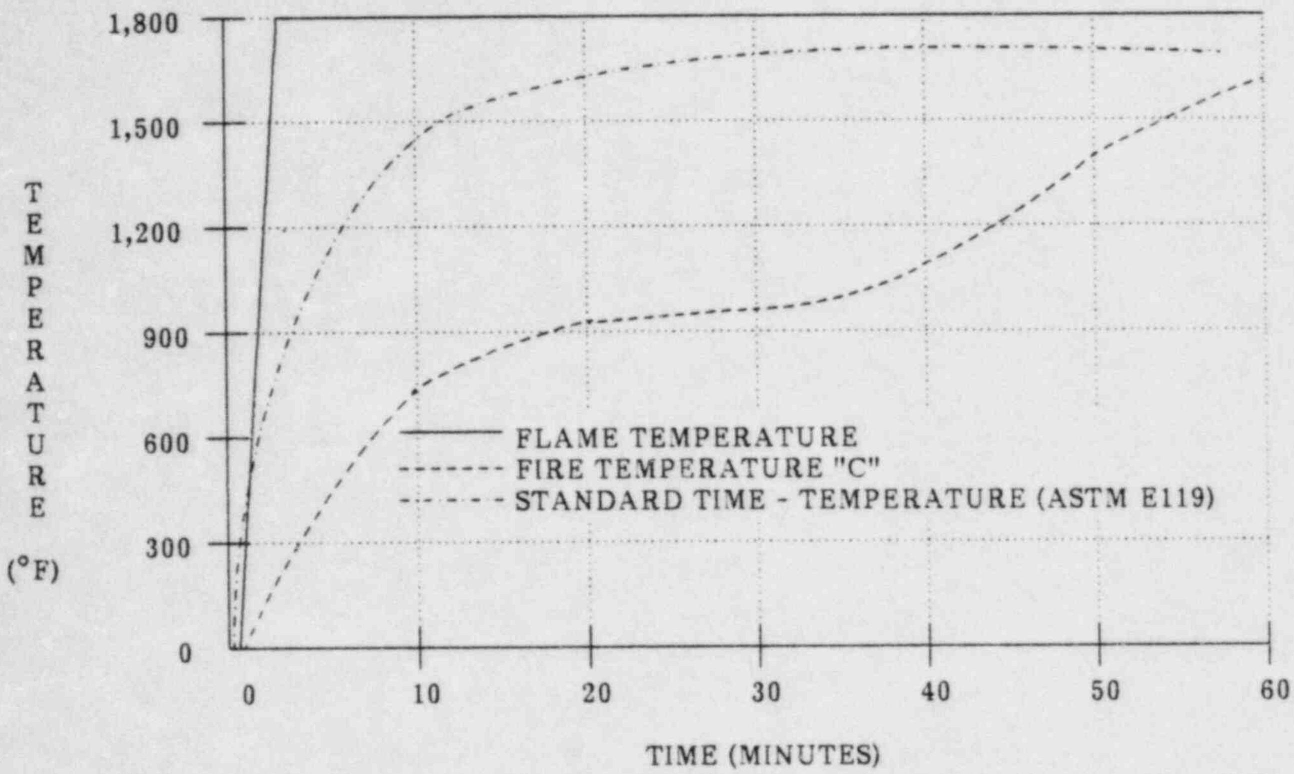
FIGURE 12

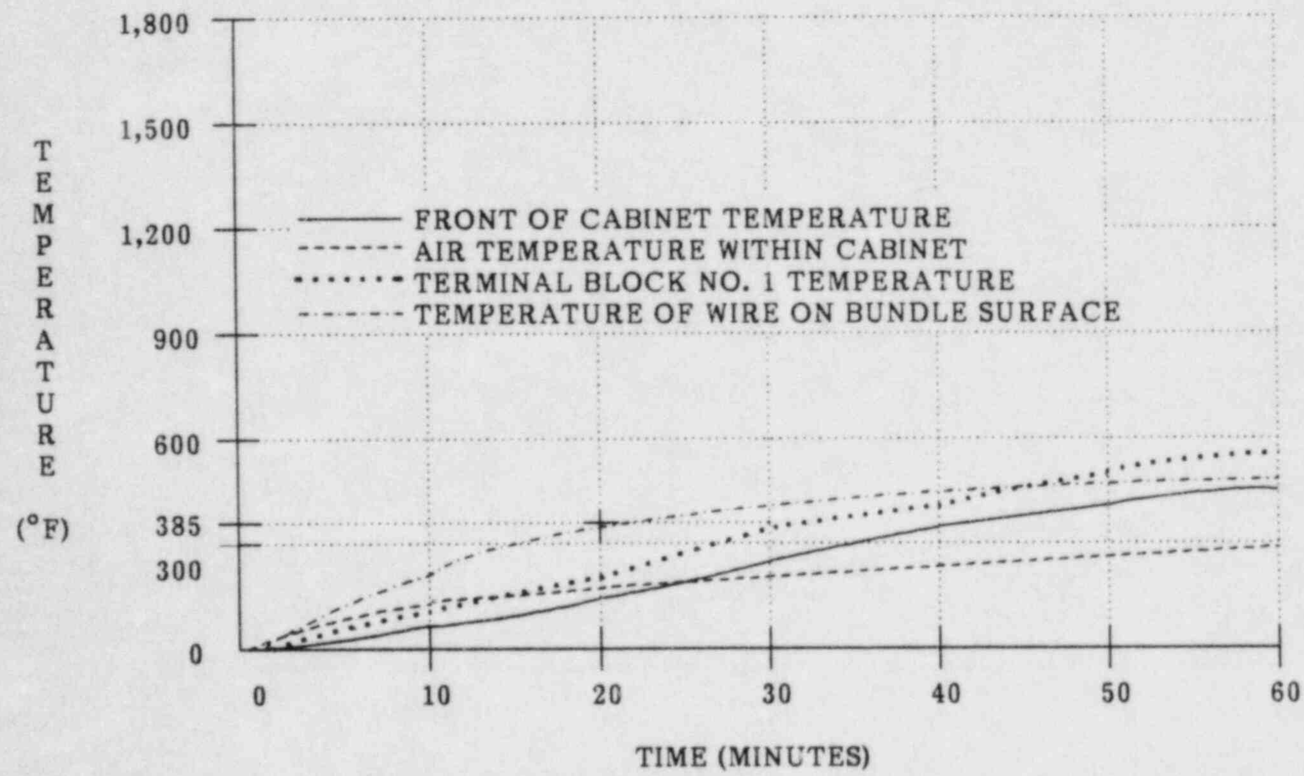




TIME-TEMPERATURE GRAPHS
CABINETS C31-A, C31-B EXTERNAL FIRE (UNINSULATED)

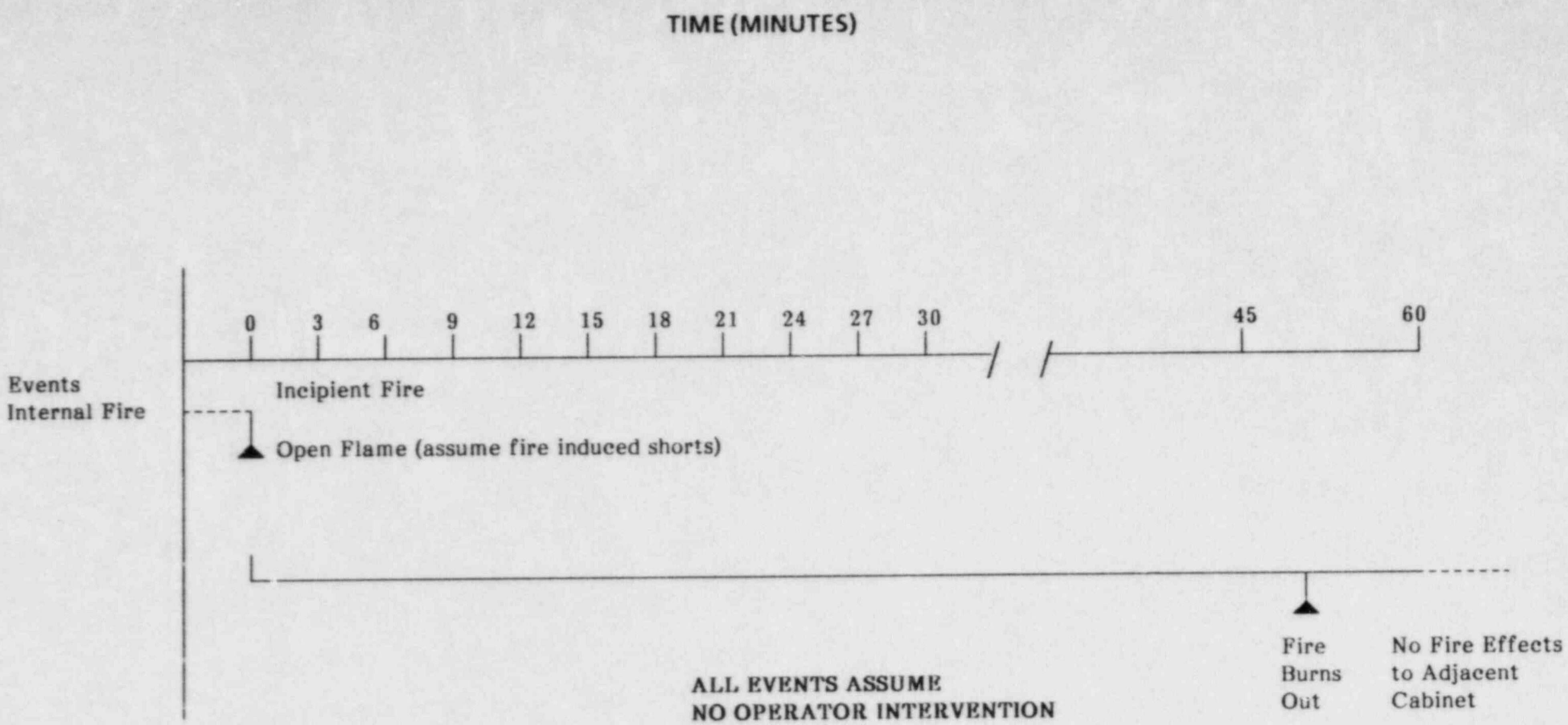
FIGURE 13





TIME-TEMPERATURE GRAPHS
CABINETS C31-A, C31-B EXTERNAL FIRE (INSULATED)

FIGURE 14

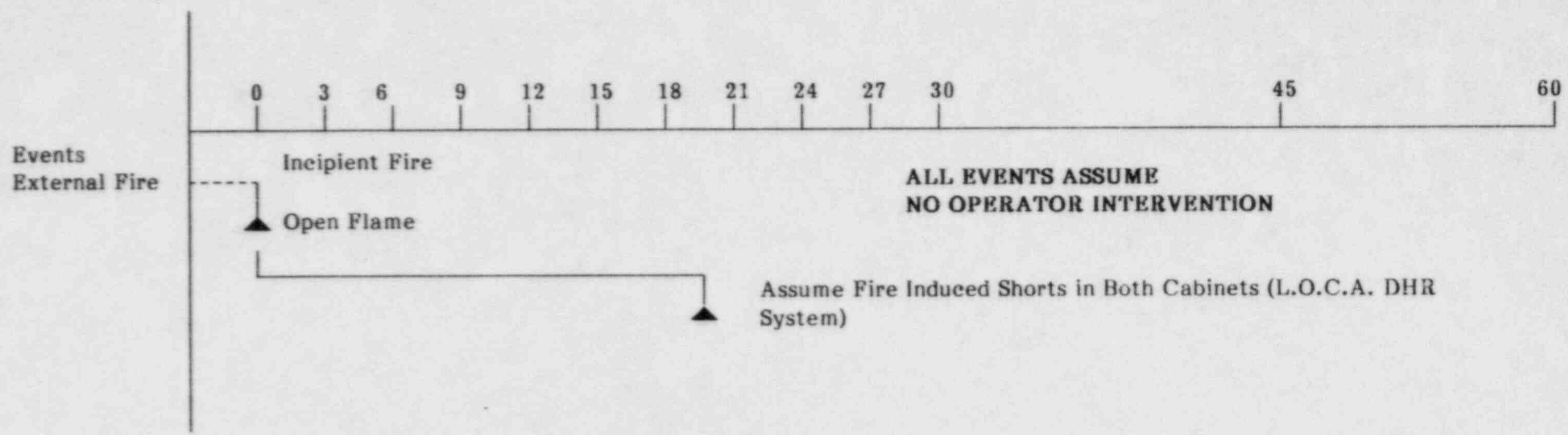


TIME-LINE
EFFECTS OF INTERNAL CABINET FIRE

FIGURE 15

Scpm/C31C-Fig.15

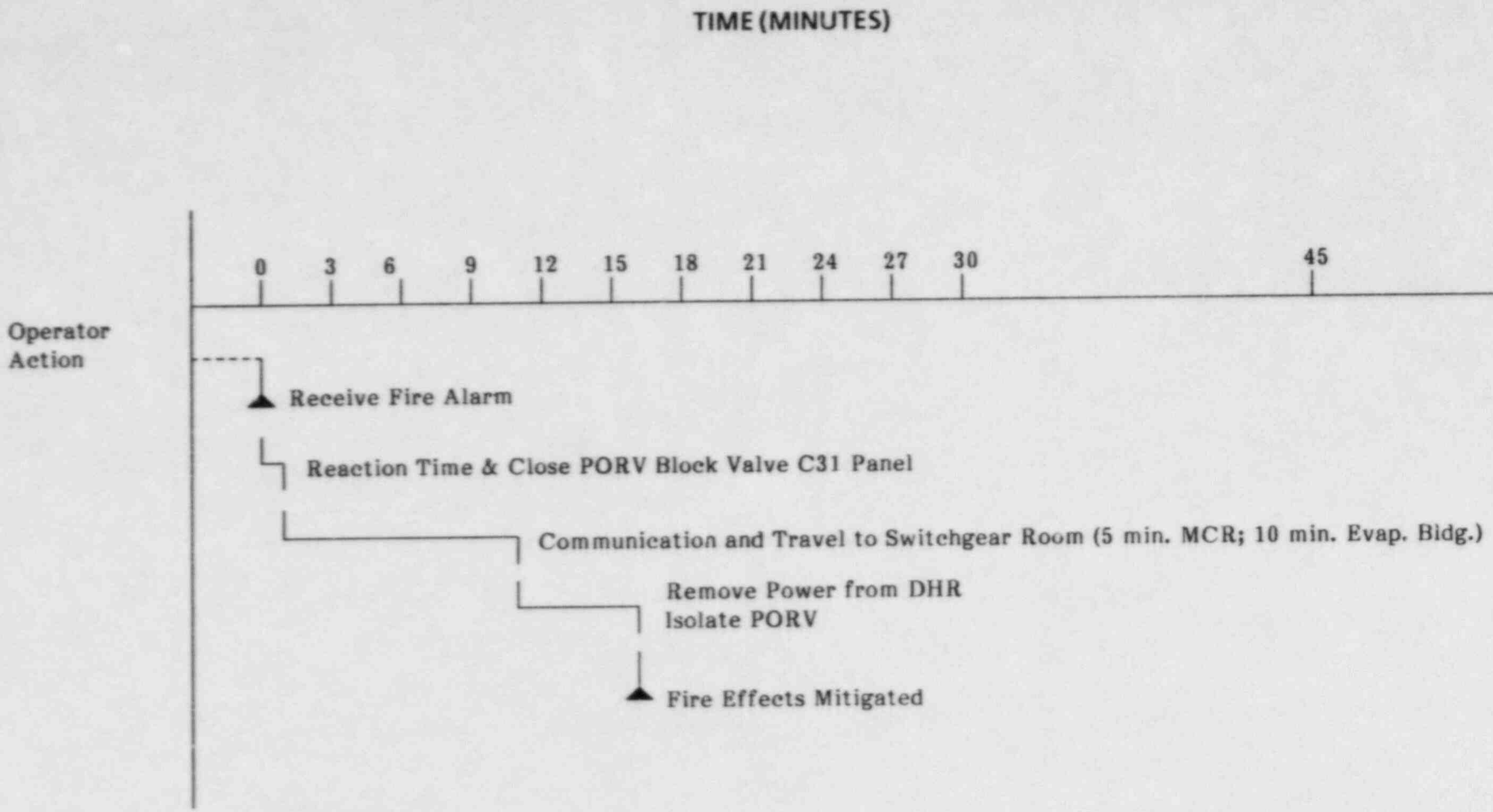
TIME (MINUTES)



TIME-LINE
EFFECTS OF EXTERNAL CABINET FIRE

FIGURE 16

Scpm/C31C-Fig.16



TIME-LINE
OPERATOR ACTIONS

FIGURE 17

Scpm/C31C-Fig 17