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CONVENTIONAL FIRE PROTECTION CONSIDERATIONS IN LMFBRs

(Report No. DOE/CL/98004-17)

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ABSTRACT

In Liquid Metal Fast Breeder Reactors (LMFBRs) the presence of liquid alkali metals such as sodium or NaK precludes the utilization of conventional fire fighting agents in areas containing liquid metals. Also because of fundamental differences between an LMFBR plant layout and that of a Light Water Reactor (LWR) plant, special LMFBR fire protection guidelines were established.

This report describes the design considerations for the Clinch River Breeder Reactor Plant (CRBRP) fire protection system.

The report concludes with a description of the CRBRP fire protection design features major differences from LWRs.

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1.0 INTRODUCTION

In Liquid Metal Fast Breeder Reactors (LMFBRs), liquid sodium is used as the coolant in both the primary and intermediate heat transport systems. In addition, liquid sodium and NaK (an alloy of sodium and potassium) is used in the auxiliary heat removal systems. Since these liquid metals react easily with oxygen, water and other compounds (e.g., concrete), water has been precluded as a fire fighting agent in areas containing liquid metals.

This report describes the fire protection design guidelines for the Clinch River Breeder Reactor Project (CRBRP). It contains a description of the fire detection and suppression features in the plant areas free of liquid metals and those areas containing liquid metals. The CRBRP fire hazards analysis methodology is also summarized in this report.

2.0 HISTORICAL DEVELOPMENT OF FIRE PROTECTION GUIDELINES FOR CRBRP

During the conceptual design phase of CRBRP, the Non-Sodium Fire Protection System (SDD-26B) (Reference 1) design criteria were based on existing Light Water Reactor (LWP) practices. The following publications were used as the basis for the design:

a. 10CFR Part 50, Appendix A "General Design Criteria for Nuclear Power Plants".

b. "The International Guidelines for the Fire Protection of Nuclear Power Plants" (IGL), 1974 Edition, published on behalf of the National Nuclear Risks Insurance Pools and Association, provided a step-by-step approach to assessing the fire risk in a nuclear power plant and described the protective measures to be taken as part of the fire protection of these plants.

c. "Specifications for Fire Protection of New Plants", prepared by the Nuclear Energy Liability and Property Insurance Association (NELPIA) gave general conditions and design criteria.

d. The Codes and Standards of the National Fire Protection Association (NFPA).

Following the fire at the Browns Ferry Nuclear Plant, the Nuclear Regulatory Commission (NRC) issued NUREG-0050 "Recommendations Related to Browns Ferry Fire" in February 1976 and subsequently, the Branch Technical Position BTP 9.5-1 "Guidelines for Fire Protection for Nuclear Power Plants" was issued. In addition, Appendix A to Branch Technical Position 9.5-1 "Guidelines for Fire Protection for Nuclear Power Plants Docketed prior to July 1, 1976", was issued. Since CRBRP was docketed with NRC prior to July 1, 1976, Appendix A to BTP 9.5-1 was adopted as the basis for the design for the Non-Sodium Fire Protection System.

In November of 1980 NRC issued Appendix R to 10CFR50 "Fire Protection Program for Nuclear Power Facilities Operating Prior to January 1, 1979" (Reference 2).

In July 1981, the NRC issued Revision 2 to BTP 9.5-1 (Reference 3) which included the requirement of Appendix A to BTP 9.5-1 and Appendix R to 10CFR50. In essence, Revision 2 to BTP 9.5-1 became a comprehensive, single source document which, to this date, presents the guidelines acceptable to NRC in the development of a fire protection program for nuclear power plants.

When the licensing process for CRBRP resumed in 1982, the NRC staff indicated to the Project that they would evaluate the design of the CRBRP Fire Protection System using the guidelines of Revision 2 to BTP 9.5-1. In order to expedite the licensing process, the Project informed the NRC that we would follow the guidelines of Revision 2 to BTP 9.5-1 in the design of the Non-Sodium Fire Protection System and proceeded accordingly until the termination of the project.

The Non-Sodium Fire Protection System (NSFPS) provides the plant with equipment, piping, valves, detectors, instrumentation and controls to prevent or mitigate the consequences of a non-sodium fire. The specific functions of the system are as follows:

1. Automatic detection of any abnormal condition of smoke or heat.
2. Generation and transmission of signals to annunciaters located on the local and/or control room fire protection panels.
3. Indication of fire location on local and remote fire protection panels.
4. Initiation and control of automatic fire extinguishing systems.
5. Initiate automatic signals for control of ventilation in plant buildings to mitigate the consequences of fire.
6. Activation of interlocking circuits of other systems which are required to change their operating mode during a fire.
7. Provide supervisory circuis to detect failure of detectors and interconnecting circuitry.
8. Distribution of fire extinguishing agents to areas having fire potential.

    (a) Distribution of water to yard hydrants, sprinklers, spray nozzles and standpipe system.
    (b) Distribution of Halon 1301, and dry chemical agent.
    (c) Provide portable fire extinguishers throughout the plant.

9. Control and monitoring of fire protection water supply system.
10. Review overall plant design and associated fire hazards in order to evaluate the adequacy of fire detection, annunciation and extinguishment systems.

3.0 FIRE PROTECTION DESIGN GUIDELINES

The fire protection program for a nuclear power plant consists of design features, personnel, equipment and procedures that provide protection of the plant staff and the public health and safety. The purpose of the program is to prevent significant fires, to ensure the capability to shutdown the reactor and maintain it in a safe shutdown condition and to minimize radioactive-releases to the environment in the event of a significant fire.

To achieve the required high degree of safety a concept called "defense-in-depth" is used in reaching an adequate balance in:

a) Preventing fires from starting

b) Detecting fires quickly, suppressing those fires that occur, putting them out quickly, and limiting their damage, and

c) Designing plant safety systems so that a fire that starts in spite of the fire prevention program and burns for a considerable time in spite of fire protection activities will not prevent essential safety functions from being performed.

No one of these echelons can be perfect or complete by itself. Each echelon should meet certain minimum requirements; strengthening any one can compensate in some measure for weakness, in the others.

3.1 Fire-Fighting Strategies

The common combustible materials found in nuclear power plants are fuels, chemicals, lubricants, electrical insulation and various transient combustibles. In addition, in LMFBRs the potential for sodium/NaK leaks exists. Experience with major electrical cable fires shows that water will promptly extinguish such fires. This is also true for fuel oils and lubricating oil fires. Since prompt extinguishing of the fire is vital to reactor safety, fire and water damage to safety systems is reduced by the more efficient application of water from fixed systems spraying directly on the fire rather than by manual application with fire hoses.

In those areas of the plant that contain sodium or NaK piping and equipment, passive catch pans with fire suppression decks and cell liners and inert atmospheres provide the essential functions for liquid metal fire suppression. The spread of fire and/or combustion products to spaces outside of the affected fire zone that contain redundant safety-related systems is prevented by housing redundant systems in separate fire areas with separate heating, ventilation and air conditioning (HVAC) systems. In those cases where combustion product aerosols can be discharged to the outside atmosphere, automatic actions are taken to isolate building exhaust paths to limit the quantity of aerosols released. Automatic actions are taken to isolate the HVAC air intakes to other plant areas to limit the quantity of ingested aerosols.

The designs of the systems that must function in the event of a significant sodium or NaK leak and fire are such that the capability to shutdown the reactor and maintain it in a safe shutdown condition is maintained, and radioactive and toxic releases are reduced to acceptable levels without operator intervention in the affected fire area. Planned responses to sodium or NaK leak/fire accidents are limited to those actions taken to eliminate the source of leakage and maintain and control the operation of essential plant equipment. These actions do not require entry into the affected fire area. Personnel entry into the fire area is required only if:

1) It is necessary in order to confirm the existence of a leak/fire or to determine the cause of a fire alarm; or

2) It is necessary in order to extinguish or suppress a non-liquid metal fire.

In the event of a fire detection alarm in a sodium or NaK fire area, the first responsibility of the plant operator is to confirm the existence of a leak and to take action to isolate the leak by utilization of valves or other means. Confirmation of a leak can be made by reference to leak detection alarms, radiation alarms, and liquid levels. If it is not possible to confirm the existing of a leak by these methods, it may be necessary to enter the fire area to determine the cause of the alarm. Such determination should be made without entering the alarmed fire zone if possible by looking for evidence of sodium or NaK smoke in adjacent fire zones within the fire area. If it is necessary to enter the alarmed fire zone to determined the cause of the alarm, personnel should be equipped with protective clothing and self-contained breathing apparatus. In no event should personnel attempt to enter a normally inerted cell unless the source of leakage has been eliminated and the cell has been deinerted. Emergency stations containing protective clothing, self-contained breathing apparatus, and portable fire extinguishers are located in proximity to accessible sodium and NaK fire areas.

In other areas of the plant that do not normally contain sodium or NaK piping systems or equipment, portable fire extinguishers are the primary means of mitigating the effects of fire due to a sodium spill accidents that may occur during sodium and NaK loading and unloading operations and during the handling and transport of sodium or NaK or sodium-or NaK-wetted components. leak (fire) accidents sufficiently large to cause significant plant damage or to pose a hazard to the operation of safety-related equipment are not expected to occur in these areas.

3.2 Building Design

CRBRP is designed such that safety-related systems are isolated from unacceptable fire hazards and redundant safety-related systems will be separated so that they are not subject to damage from a single fire hazard. See Section 2.0 of CRBRP Fire Hazard Analysis Report (Reference 4) for specific information on separation of safety-related systems.

The buildings and structures provide space, support, access, storage drainage and penetrations for the operation and maintenance of the Non-Sodium Fire Protection System. The design and installation of fire protection system facilities, which are permanently affixed to the buildings and structures, are in accordance with the requirements of National Fire Protection Association (NFPA) Codes (Reference 5).

Fire separation provisions are provided in the building design by walls, doors and stops with a three (3) hour fire resistance rating.

Access to each building is designed to permit multiple means of egress from any area for operating personnel and multiple means of access for fire-fighting personnel.

All stairwells, elevators and chases are enclosed in masonry towers with a fire rating consistent with the fire hazard in the adjacent area.

Fire doors will not be locked closed unless other considerations, such as plant security, dictate they be locked.

Self-closing devices are used on all exit doors. Panic hardware is used at major discharge points and at exits from designated hazardous areas. All fire doors are provided with self-closing devices and have a supervisory switch with a time delay relay. If a door remains open for more than two minutes the time delay relay will cause an alarm on the local Fire Protection Panel (FPP). The alarm will reset on closing of the door. A group alarm is transmitted to the Building FPP for that building, which in turn transmits a group alarm to the Non-Sodium FPP in the Control Room.

Fire stops are provided for electrical and piping penetrations through fire barrier walls and floors. The fire stop ratings will be the same as the wall or floor penetrations.

Penetration through three (3) hour fire rated construction includes fire dampers in ducts as well as seals around electric trays, cables and piping.

Because unprotected structural steel loses its strength at high temperatures, it is protected (insulated) from exposure to heat produced by building fires.

Interior finishes, insulating material, and absorbent material for Seismic Category I buildings are noncombustible and Underwriters' Laboratories (UL) listed (Reference 6) as having a rating of 25 or less for smoke contribution, fuel contribution, and flame spread. Halogenated plastics, such as PVC, are not used unless substitute non-combustible materials are not available or suitable.

Suspended ceilings and their supports are noncombustible construction as listed by Underwriters' Laboratories or Factor Mutual. Insulation for pipes and ducts and their adhesive are also non-combustible.

The concrete floors of buildings are pitched to a proper drainage facility. Safety-related equipment is installed on pedestals or provided with curbs as required to contain water and direct it to floor drains. Drains in areas containing combustible liquids are provided with provisions for preventing the spread of fire throughout the drain system. Drainage from areas which may contain radioactivity are routed to the Liquid Radwaste System. Tanks containing oil are enclosed with curbing or located in separate rooms to prevent spills from spreading into adjacent areas. Outdoor tanks containing oil are diked and will not expose safety-related equipment.

Drainage pits are provided under the transformers and oil circuit breakers. The pits will drain any oil spillage and water discharged from an operating deluge system into a holding tank. The water is drained from the holding tank, and oil is baffled to remain for separate removal.

3.3 Control of Combustibles

Safety related systems are isolated and separated from combustible materials. When this is not possible because of the nature of the safety system or the combustible material, then automatic fire suppression systems and/or fire rated construction is provided to prevent a fire from defeating the safety system function.

Emergency diesel generator fuel oil day tanks are located on separate enclosures with a minimum fire resistance rating of 3-hours and protected by an automatic fire suppression system.

Turbine-generator oil and hydraulic control fluid systems are protected by automatic fire protection systems.

Each of the three (3) primary heat Transfer and three (3) Intermediate Heat Transfer pump drive units are provided with a seismically qualified oil collection system. The systems provide oil line enclosures and detection capability to preclude escape of oil beyond the collection zone and reduces the fire hazard potential.

Bulk hydrogen gas storage is located outdoors on a concrete pad and container placed with long axis parallel to building walls, so that a fire or explosion will not adversely affect any safety-related buildings or equipment. Storage facilities are in accordance with NFPA 50A "Gaseous Hydrogen Systems".

Halogenated plastic such as polyvinylchloride (PVC) and neoprene is used only when a practical substitute is not available.

3.4 Electric Cable, Cable Trays and Cable Penetrations

Fire protection for electrical cable is provided by selection of material for insulation, the use of metal cable trays and metallic tubing for conduit, isolation of circuits, divisional separation of circuits and/or fire resistive barriers. Automatically actuated water pre-action fire protection systems are provided for the cable spreading areas of the Control Building and other high cable concentration areas. All electrical cabinets, raceways, and conduit are of noncombustible type.

Hose stations and portable extinguishers (selected for use against electrical fires) are provided as fire suppression systems for electrical cable fire protection. The UL or FM listed and approved extinguishing media selected for the hand extinguishers are compatible with known electrical equipment and wiring.

Where exposure to fire could affect safety-related cable trays from a single division, automatic pre-action water suppression systems are provided except at areas containing liquid metals or areas adjacent to liquid metal containing areas.

Cabling used at the CRBRP shall have fire retardant insulation and jackets and tested to meet IEEE 383-1974 requirements (Reference 7). To the maximum extent practicable, cable construction that does not give off corrosive gases while burning will be used. Approved fire stops shall be provided whenever cable raceways pass through fire barrier walls and floors.

Safe-shutdown can be accomplished from the Control Room or outside the Control Room by utilizing the remote shut-down panel rooms in the Steam Generator Building, Intermediate Bay and local equipment control panels. These areas are contained by three (3) hour rated fire walls.

3.5 Ventilation

The HVAC systems are designed to function as part of the fire protection systems of the station. The HVAC systems are designed to provide early indication of fires and/or products of combustion, to inhibit the spread of smoke from a fire zone to exit/access ways, to maintain fire integrity of the different compartments in the structures, and to provide a means for venting products of combustion from selected fire zones.

Ionization type smoke detectors are located in ductwork in accordance with NFPA 72E (Reference 8). These HVAC ionization air duct smoke detectors provide early indication of fires and their location.

Smoke and/or fire dampers are installed in the ductwork in accordance with NFPA 90A (Reference 9) and NFPA 91 (Reference 10) to provide smoke and/or fire barriers and pressure differentials that will inhibit the spread of smoke from the fire zone. Fire dampers, fire doors, and fire-rated duct enclosures are utilized to maintain the fire integrity of the unit structures.

Certain HVAC systems or portions of systems are utilized to vent heat and smoke from fire zones. Safety-related areas with large amounts of combustibles and/or combustibles which, if ignited, give off large amounts of smoke are provided with smoke and heat venting. Separate smoke venting is provided from specific areas where potential exists for heavy smoke conditions. Smoke and gases containing radioactive materials are monitored to determine if release to the environment is within the permissible limits of the plant Technical Specifications. Any ventilation system designed to exhaust smoke or corrosive gases are evaluated to ensure that inadvertant operation or single failures will not violate the controlled areas of the plant design.

Power supply and controls for smoke venting systems are outside the fire area served by the system. For the total flooding extinguishing systems, the ventilation damper control satisfies NFPA 12A (Reference 11).

Fresh air supply intakes are located remote from exhaust air outlets and smoke vents of other fire areas to minimize the possibility of contaminating the intake air with the products of combustion.

Fire suppression systems that are to protect charcoal filters will be in accordance with Regulatory Guide 1.52, "Design Testing and Maintenance Criteria for Atmospheric Cleanup Air Filtration." (Reference 12).

Pressurization systems are provided for stairwells to minimize smoke infiltration during a fire.

3.6 Lighting and Communications

The Lighting and Communication systems provide adequate illumination and two-way voice communication following accident conditions, such as fires. These features are vital to safe shutdown and emergency response. The CRBRP design incorporates the following provisions:

Fixed self-contained lighting units with individual eight (8) hour rated battery power supply for all manned safe-shutdown areas and access and egress routes to and from all fire areas.

Sealed-beam battery-powered portable hand lights for emergency use by the fire brigade and other operations personnel required to achieve safe plant shutdown.

Fixed emergency communications between the control room and the building fire panels, independent of the normal plant communication system are provided at the building fire panels.

Portable radio communications system for emergency use by the fire brigade and other operations personnel required to achieve safe plant shutdown. The fixed repeaters for the portable radio communication system is protected from exposure fire damage.

4.0 FIRE HAZARDS ANALYSIS

A fire hazards analysis should be performed for each nuclear power plant to demonstrate that the plant will maintain the ability to perform safe shutdown functions nd minimize radioactive releases to the environment in the event of a fire, as required by Branch Technical Position 9.5-1 (Reference 3). The following is a summary of the steps taken to perform the CRBRP fire hazards analysis (Reference 4):

4.1 Assumptions

In order to conduct the CRBRP fire hazards analysis certain assumptions were made with the regard to the combustible materials as follows:

a. Electrical cable insulation has been considered as a combustible material in the evaluation of a Design Basis Fire (DBF). This is conservative as all cables are fire retardant and fabricated in accordance with IEEE 383 (Reference 7). A representative fire loading of 190,000 BTU/Lineal foot of (power) cable tray and 140,000 BTU/lineal foot of (control) cable tray was estimated based on manufacturer's values and the maximum cable loading of a standard 24-inch tray (40% full). Lineal feet of the trays in each fire area were totaled and the BTU contribution to the total combustible loading ascertained.

b. It is assumed that any cabling system which is enclosed in conduit, which also passes through a DBF area, will not provide any combustible load to the DBF. Any cable enclosed in conduit passing through a DBF area is assumed to fail.

c. Pipe and its insulation is not considered combustible. The following was taken into consideration:

   1. If the pipe is all welded construction and filled with water, fuel or lubrication oil, there would be no consequences due to fire.

2. If the pipe has gasketed or flanged connection in the vicinity of the fire, the piping will fail and the fluid would be released.

d. The combustible fire loadings used in the analysis are shown in Table 1.

The weight of the material as found throughout the plant times the BTU/LB or gallon value for each type of material determines the BTU loading for each combustible. The final figure represents the total BTU loading existing in each fire area.

4.2 Methodology

The first step of the fire hazards analysis was to designate fire areas* and fire zones**. The division of the plant into fire areas follows logical boundaries which enclose fire hazards of interest. These boundaries, to the maximum extent practicable, follow existing building walls and floors. Redundant trains of engineered safeguards systems are evaluated for separation at this step.

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*Fire area--that portion of a building or plant that is separated from other areas by fire barriers (i.e., walls, floors, ceilings, roofs, penetration seals or closures, fire doors and fire dampers) that are rated by approval laboratories in hours of resistance to fire and are used to prevent the spread of fire.

**Fire zone--subdivisions of fire areas in which fire detection and/or suppression systems are designed to combat particular types of fires.

Table-1

Combustible Materials Fire Loading

Material	BTU Per Pound of Material	BTU Per Gal. or Cu. Ft. of Material
Oil	---	152,000/Gal
Hydraulic Fluid	---	147,000/Gal
Grease	20,000	---
Sodium (Na)	4,500	34,000/Gal
Sodium-Potassium (NaK)	---	23,000/Gal
Solvent	---	144,000/Gal
Paint	---	18,000/Gal
Plastic	15,000	---
Wood	9,500	---
Paper	7,000	---
Heat Transfer Fluid "Dowtherm"	17,800	7.25 lb/gal @ 25°C
CPVC Piping	8,000	---
Rubber	17,000	---
Rags	7,100	---
Wiring Insulation	15,000	---
Filter Media	15,000	---
Filter Carbon	13,480	---
Fiberglass Insulation	3,000	---
Textiles (Carpet)	10,000	---

The types and quantities of combustibles contained within each fire area were realistically estimated and a fire loading determined.

Next, design basis fires which are considered to cause the most damage were hypothesized for each area (not simultaneously). The design basis fire assumes:

a. No manual, automatic, or other fire fighting action has been initiated.

b. The fire has passed flashover (i.e., the temperature at which auto-ignition of other combustibles in the area will occur).

c. The fire has reached its peak burning rate.

The design basis fire was then evaluated to determine the impact on station safety, such as damaged or destroyed equipment or fire spread to other areas. Fire severity was determined and then compared to the rating of the fire walls that form the respective fire area boundaries. It should be noted many concrete floors and walls, due to structural or shielding requirements, are thicker than required for fire protection.

If postulated fires result in safety-related losses, appropriate protection against the hazards involved are proposed and evaluated for effectiveness. Possible solutions consisted of choosing a particular fire suppression system, redefining the fire areas by selecting new fire barriers, or rearranging equipment to provide spatial separation. Solutions were selected which limit the consequences of the design basis fire. Factors such as fire suppression and containment effectiveness were considered. The solution to problems reflect requirements, criteria, and guidelines of regulatory agencies, National Fire Codes, nuclear liability insurance pools, industry practice, and sound engineering practice.

The final step of the fire hazards analysis was to evaluate the effects of a fire in the fire area with fire protection systems operating. The evaluation demonstrates that the plant will be safely protected from the consequences of a fire in that area and that the fire will be effectively controlled and extinguished.

Inadvertent operation or malfunction of the fire system was evaluated at this point. Drainage systems have been sized to remove expected water flow without flooding safety-related equipment; and all systems are supervised to alarm during trouble or operation, alerting Control Room personnel.

Table 2 of this report is typical of tables developed for the fire hazards analysis listing fire areas, cells within the fire areas, safety-related equipment, combustible materials, type, quantity, heat of combustion and fire loading.

Figure 1 is a typical drawing showing fire areas and fire zones, fire walls and doors, general arrangement of major safety-related and non safety-related equipment, fixed automatic extinguishing equipment, manual fire extinguishing equipment (hose stations and portable extinguishers) and fire detection system.

Appendix A of this report is a detailed analysis of a typical CRBRP fire area. Included is a detailed description of the sources of combustion, design fire loadings, detection and extinguishing capabilities, safety-related equipment and cabling, and a description of the design basis fire and expected consequences.

TABLE 2

COMBUSTIBLE MATERIALS LISTING

SGB		FIRE AREAS			COMBUSTIBLES						
Area Designation	Elev.	Cells Comprising Fire Area	Safety Related Equipment Located Within	Fire Rating in Hours	Material	Total Amount (Lb)(Gal)	Heat of Combustion (Btu/Lb) Btu/Gal	Total Heat of Combustion (Btu)	Floor Area (Ft^2)	Fire Load (Btu/Ft^2)	Remarks
IB-7	794'-0	251	Sys 51 Component Piping	3	Sodium	20,200 gals.			504		Sodium
IB-11	794'-0	252	Sys 51 Component Piping	3	Sodium	19,800 gals.			540		Sodium
IB-10-1	794'-0	253	Sys 12 PNL & MCC	3	Cables Ins		7.52x10^6				
					Elec Compt. (96)	See Sys 96	0.0996325x10^6		782	9,740	
IB-6-1	816'-0	262	Sys 12 PNL & MCC		Cable Ins			1.260x10^6			
					Cables Ins			299.54x10^6			
			Sys 25 HVAC		INS (RDATS)	50#	20,000/#	1.0x10^6			
			Equipment	3	Filter	228#	15,000/#	3.42x10^6	10000	30,760	Intermediate Bay
			Div 2 Remote		Motor Ins	2.3#	15,000/#	.0345x10^6			
			Air Intake P/G/I		Elect Comp.(96)	See Sys 96	See Sys. 96	1.957718x10^6			
					Vacuum Pump Oil	3 gal	144,600/gal	.434x10^6			
IB-6-2	816'-0	263		3					875		Protected Corridor
IB-4-1	816'-0	264			Cables Ins			54.88x10^6			
					Ref Oil	24G(200#)	20,400/#	4.08x10^6	2700	21,840	Chillers

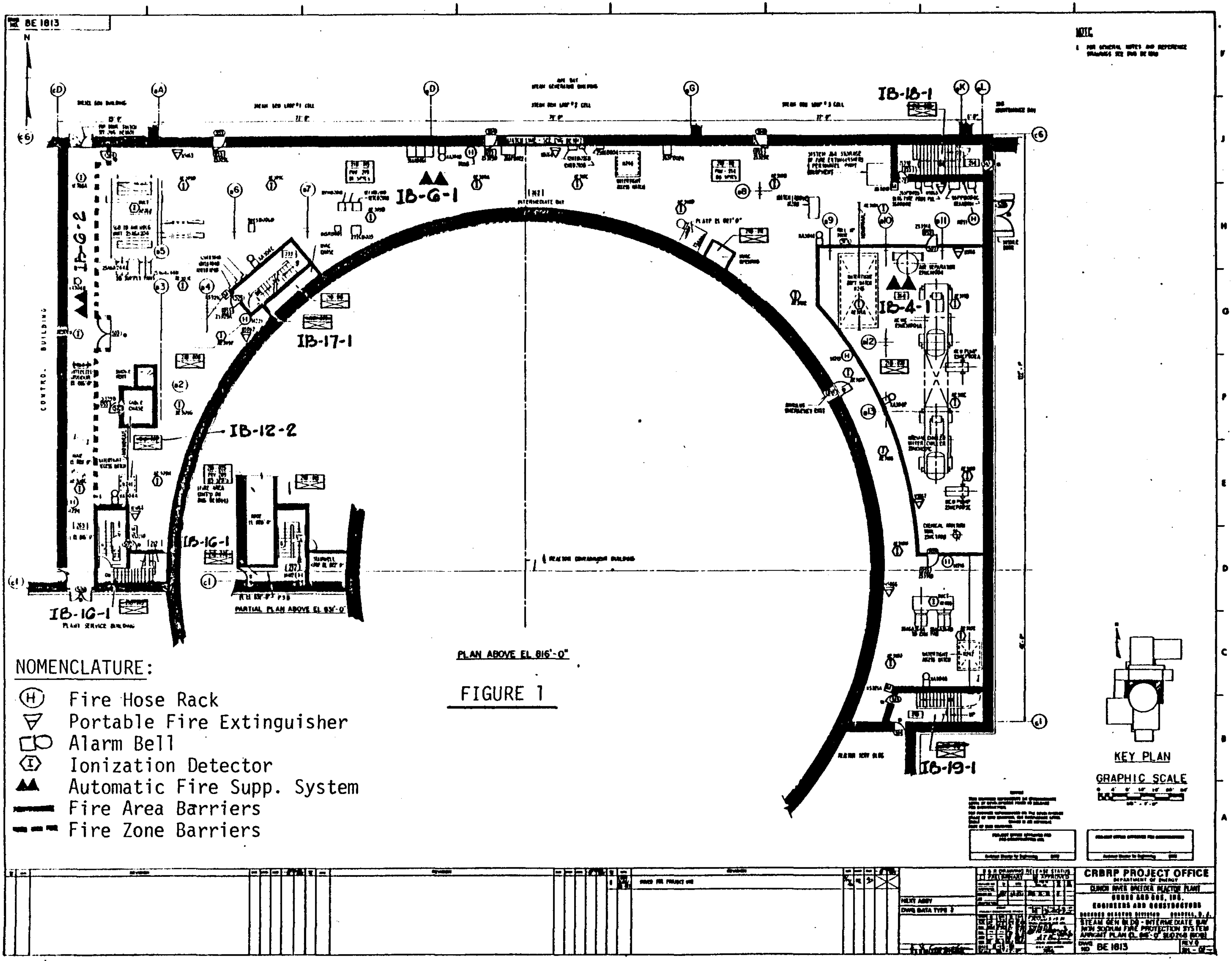

BE 1813
N
IB-18-1
IB-G-1
IB-G-2
IB-17-1
IB-4-1
IB-12-2
IB-16-1
IB-16-1
IB-19-1
PARTIAL PLAN ABOVE EL 83'-0"
PLAN ABOVE EL 816'-0"
KEY PLAN
GRAPHIC SCALE
CONTROL BUILDING
NOMENCLATURE:
Fire Hose Rack
Portable Fire Extinguisher
Alarm Bell
Ionization Detector
Automatic Fire Supp. System
Fire Area Barriers
Fire Zone Barriers
CRBRP PROJECT OFFICE
BE 1813

FIGURE 1

5.0 FIRE PROTECTION SYSTEM DESIGN FEATURES

The CRBRP fire protection features are designed as such to protect the plant from the consequences of both a liquid metal fire and a conventional fire. The following is a brief description of these design features.

5.1 Conventional Fire Suppression Systems

These fire suppression systems are provided for the plant areas free of liquid metals and consist of the following:

5.1.1 Fire Protection Water and Supply Systems

The plant buildings are encircled by a 12 inch diameter underground yard main piping loop which supplies water to the Sprinkler and Spray System, the Standpipe System and the yard hydrants as shown in Figures 2 and 3.

Each Nuclear Island Building is served by two branch connections from yard main piping loop, one for the Sprinkler and Spray System and one for the Standpipe System, the latter of which is seismically qualified.

Post indicator valves are provided to isolate portions of the main for maintenance or repair without shutting off the supply to primary and backup fire suppression systems.

Three-way hydrants controlled by individual curb box valves are provided on the yard main at approximately 250-foot intervals. Curb valves are key operated (tee wrench). Hose threads and valve nuts compatible with those used by area fire departments are provided on hydrants.

Fully equipped hose houses are located adjacent to each hydrant.

Water for the Fire Protection System is supplied from the Potable Water System and is stored in two separate 100 percent capacity fire protection storage tanks. Each tank contains a minimum of 360,000 gallons of water allocated to fire protection. The tanks are interconnected such that fire pumps can take suction from either or both. The piping arrangement is designed such that a leak in one tank or its piping will not cause both tanks to drain.

Fire protection water is supplied to the yard main from the fire protection water storage tanks by three 50 percent capacity fire pumps. One pump is electric motor driven; the other two are diesel engine driven. Each pump is capable of taking suction from either fire protection storage tank. Alarms indicating pump running, driver availability, or failure to start are provided in the control room. The fire pumps are located in a pumphouse and separated by three hour firewalls.

A jockey pump is provided to maintain yard main line pressure, thus preventing frequent starting and stopping of the main fire pumps. The jockey pump operates continuously.

The three fire pumps are arranged for automatic operation. When the system pressure falls, the electric driven fire pump is arranged to start first, while one of the two diesel engine driven fire pumps will start next if water demand of the system is not met. The second diesel engine fire pump starts when system pressure drops further.

5.1.2 Water Sprinklers and Hose Standpipe Systems

Sprinkler systems (preaction sprinklers, wet pipe sprinklers and automatic deluge) and wet standpipes have independent connections to the outside, underground yard main as shown in Figure 3. Isolation valves will be provided such that no single failure can impair both the sprinkler systems and the standpipe systems. Safety-related equipment that does not itself require sprinkler protection, but is subject to unacceptable damage if wetted by sprinkler water discharge, is protected by water shields or baffles.

FIGURE 2

FIRE PROTECTION WATER SUPPLY

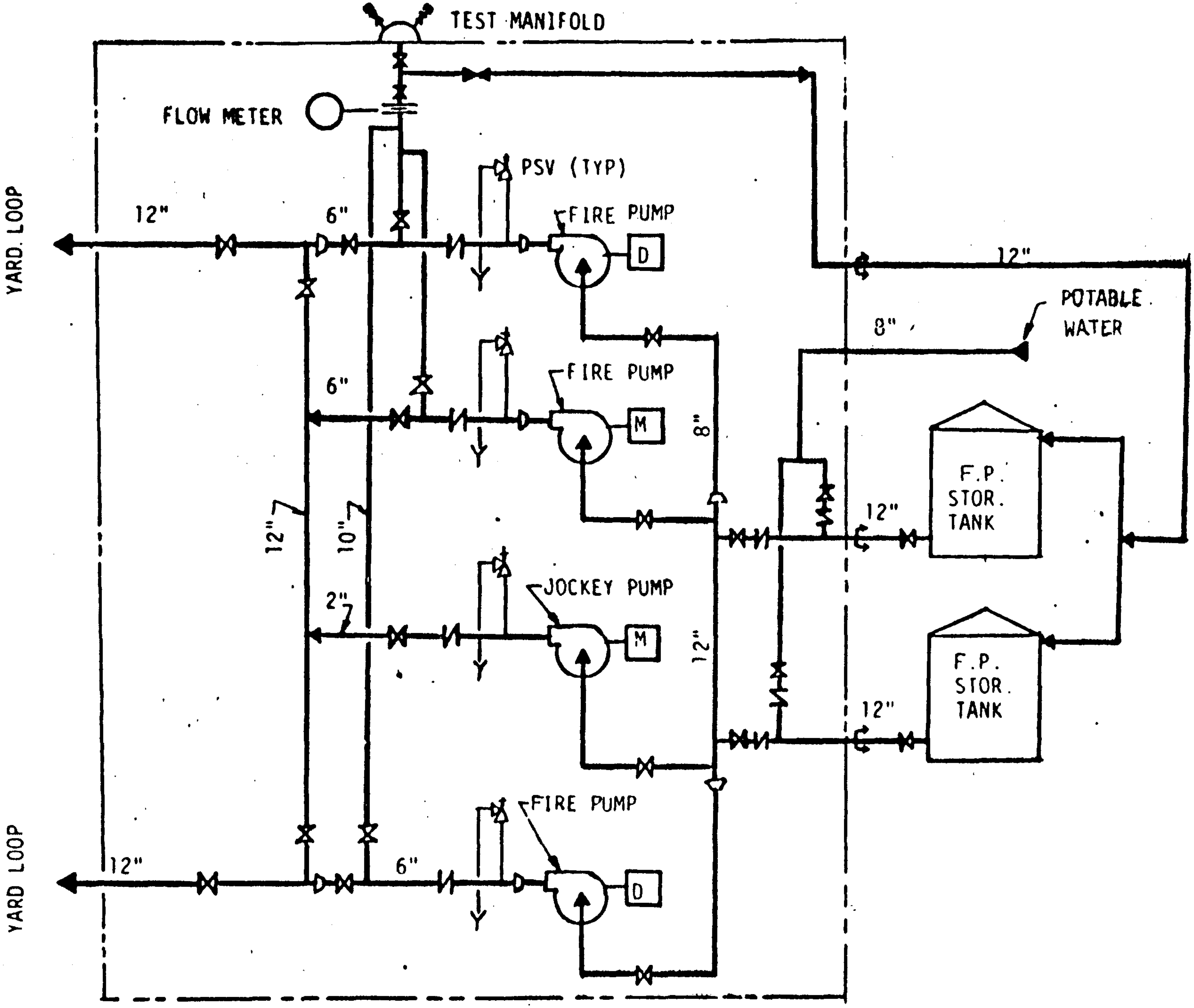
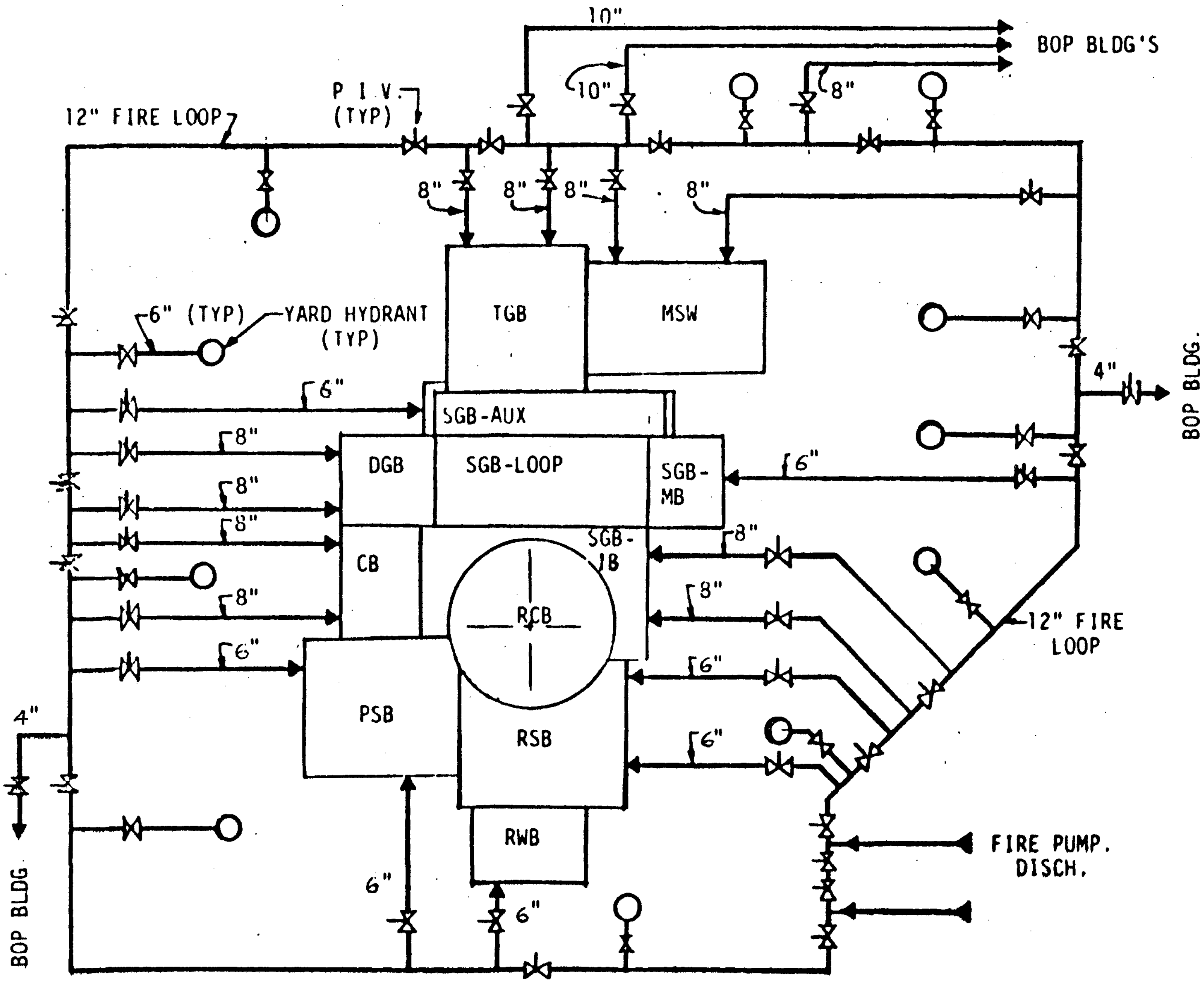


FIGURE 3

FIRE PROTECTION WATER YARD LOOP



The sprinkler systems isolation valves and the standpipe isolation valves are supervised by a taper switch which activates alarms when the valves are not fully open.

All valves in the fire water system should be routinely inspected to ensure that they are properly positioned. Supervision of valves will be in accordance with NFPA 26 (Reference 13).

Hose standpipe systems are provided in all buildings such that all areas to be protected are within 30 feet of a nozzle attached to not more than 100 feet of hose.

All building standpipe systems except the Reactor Containment Building are supplied water from their individual branch line which is connected in the yard loop.

Each building equipped with both a sprinkler and a standpipe system has separate supplies from the yard main. The supplies are cross-connected and controlled by a normally closed isolation valve. This provides redundant supplies for the standpipe system. In addition, a separate seismically qualified water supply is connected to each nuclear island standpipe system. Check valves are provided and arranged on all supplies to prevent back flow.

The proper type of hose nozzles is supplied to each area depending on the type of fire hazards. For example, fog type nozzles are provided where high-voltage shock hazards exist. The usual combination spray/straight-stream nozzle may cause unacceptable mechanical damage and will not be used in areas containing delicate equipment such as in the control room.

The seismically qualified portion of the water supply system consists of two (2) 150 GPM electric motor driven pumps, piping, valves, instrumentation and controls.

Each of the seismically qualified fire pumps, located in the Electrical Equipment Building, is arranged to take suction from each of the loops of the Emergency Plant Service Water System and is rated to supply 100% of the system capacity, i.e., 150 gpm. Standpipes located in the Reactor Containment Building, Reactor Service Building, Steam Generator Building, Electrical Equipment Building and Control Building are connected to the seismically qualified water supply system.

5.1.3 Halon Suppression System

A Halon 1301 Suppression System is used in the Computer Room. It is designed in accordance with NFPA 12A (Reference 11) to provide Halon 1301 at 7% concentration by volume in 10 seconds or less.

The system employs a total flooding principle, that is, a fixed amount of Halon 1301 is discharged into the computer room including the room under floor area to enable the required Halon concentration to be built up and maintained to ensure complete extinguishment. It consists of Halon storage tanks, piping, valves, discharge nozzles, and controls.

The Halon system employs a double circuit or "cross zoned" fire detection system. Halon will not be released unless a detector from each zone is activated. When the first detector is activated, a hazard alarm will continuously sound in the computer room and the control room.

If a fire is not discovered and the second smoke detector is activated, dampers located in ducts for the computer room including the room underfloor area will shut and seal these areas. A delay switch will activate the Halon System solenoid valves.

The Halon may be manually released using the remote manual switch located adjacent to the computer room in the event of a malfunction of the automatic control systems.

5.1.4 Portable Fire Extinguisher System

The Portable Fire Extinguisher System consists of the necessary portable fire fighting equipment located throughout the plant facilities for the purpose of manual fire fighting in accordance with NFPA-10 (Reference 14).

Portable fire extinguishers are maintained in a fully charged and operable condition, and kept in their designated places at all times when not in use and are conspicuously located where they will be readily accessible and immediately available in the event of fire. They are divided into six basic types to extinguish four classes of fire. The basic six types of extinguishers are multipurpose dry chemical, regular dry chemical, foam, Halon, CO_2 and pressurized water. The four classes of fires are Class A, B, C and D.

Class A fires are wood, paper and cloth fires. The most efficient extinguishers for this type of fire are foam, pressurized water, multipurpose (ABC) dry chemical, or Halon. CO_2 or regular dry chemical is not recommended.

Class B fires are gasoline, oils, paints or other flammable liquid fires. The extinguishers that best extinguish this type of fire are foam, regular dry chemical, Halon 1211, Co_2 or multi-purpose dry chemical. Water is not recommended because it will spread this type of fire.

Class C fires, which are electrical in origin, should use extinguishers that contain a non-conducting extinguishing agent. The type of extinguishers that can be used are the multi-purpose dry chemical, CO, regular dry chemical and Halon 1211.

Class D fires are those that support and ignite combustible materials such as magnesium, titanium, sodium, etc. The types of extinguishers required to extinguish such fires are the sodium carbonate-based dry powder extinguishers.

5.2 Sodium Fire Suppression

5.2.1 Inert Atmosphere Cells

Those cells of the plant that normally contain radioactive sodium piping and components are equipped with steel liners and inert (N_2) atmospheres (2% oxygen). These cells contain the reactor vessel, the piping and components of the primary heat transfer sysetm, those portions of the auxiliary liquid metal system and the impurity monitoring and analysis system that contain primary system sodium and the sodium piping and components of the ex-vessel fuel storage system. Portions of the NaK containing piping and components of the auxiliary liquid metal system and the intermediate heat transport system piping at the inlets and outlets of the intermediate heat exchangers are also included. The fuel handling cell is equipped with a steel liner and an argon atmosphere.

The cell liner system utilizes a continuous steel plate liner welded to stud anchors (in the walls and ceilings) and embedded steel structural sections (in the floors). Additional features of the cell liners include an integral insulating concrete panel to protect the structural concrete from severe thermal loading and an integral vent system to relieve the behind-the-liner steam buildup under sodium/NaK leak accident conditions.

In the event of a sodium or NaK leak, the quantity of liquid that can be burned is fixed by the availability of oxygen. The cell liner contains the spilled liquid in a leak-tight manner and prevents contact with the concrete. The liner also controls the spread of combustion products, and the temperatures imposed on the structural concrete are limited by the insulating panels. The liquid pool is allowed to cool to a temperature at which a fire is unlikely even if exposed to an ambient air atmosphere. The liners and the concrete structures are designed to withstand the thermal and pressure loadings associated with design bases leak accidents.

5.2.2 Air-Filled Cells

Those cells of the plant containing non-radioactive sodium and NaK piping and components are normally air-filled. These cells contain the bulk of the Intermediate Heat Transport System (IHTS) piping and components, those portions of the auxiliary liquid metal and the impurity monitoring and analysis system associated with the IHTS, and portions of the NaK containing piping and components of the auxiliary liquid metal system. Also included in this category are the cells containing the ex-containment primary sodium storage tanks and associated piping of the auxiliary liquid metal system, although the cells are inerted (N_2) whenever primary or ex-vessel storage system sodium is present in the tanks. In air-filled cells, the basic fire suppression feature is a covered catch pan located in the floor of the cell.

5.2.2.1 Open Catch Pans

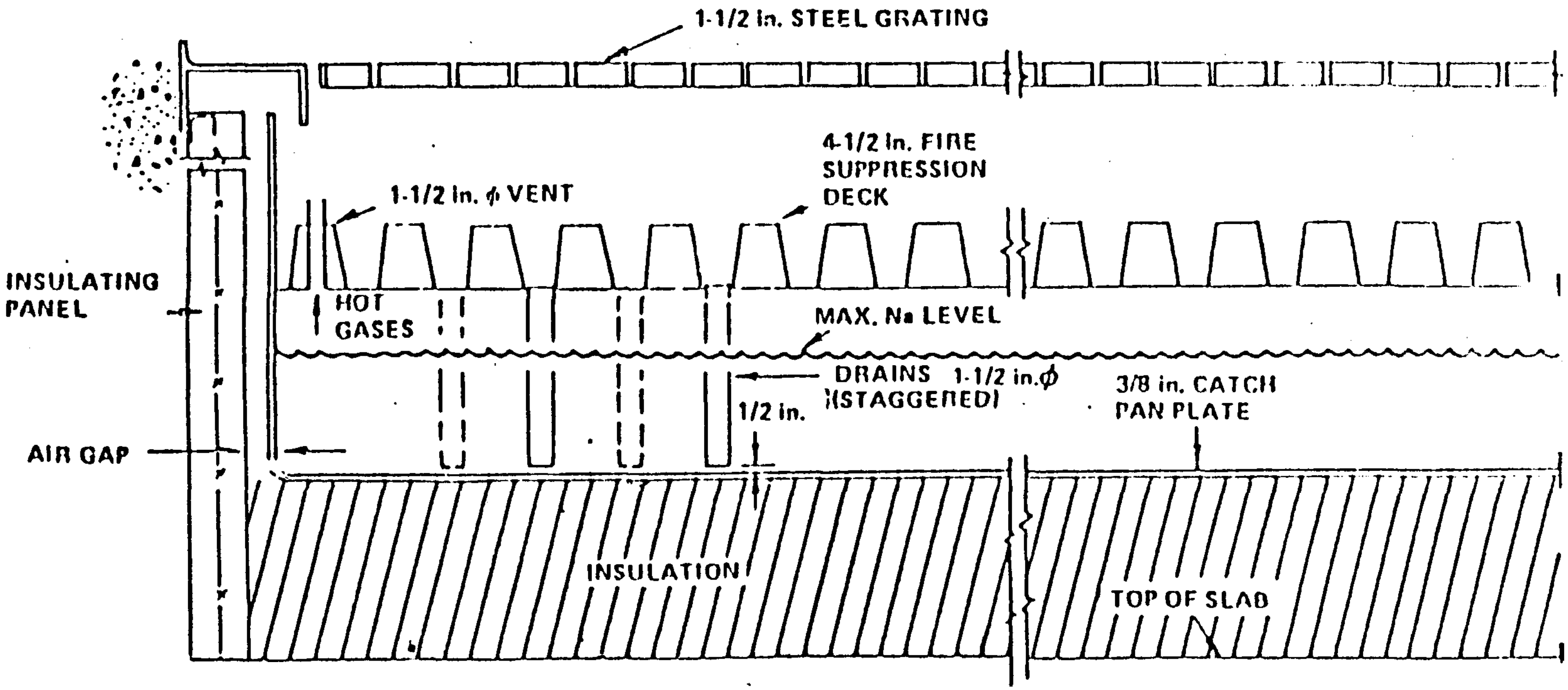
The catch pan consists of a carbon steel plate assembly which covers the entire floor surface of the cell and extends vertically up the wall to a height sufficient to prevent spilled liquid metal from flowing over the edge of the plate into the area between the plate and the wall. A continuous lip plate is provided at the top of the catch pan sidewall to prevent liquid metal from running down the cell walls into the region behind the catch pan plate sidewalls. The catch pan is free floating and is supported above the concrete floor of the cell by a continuous layer of insulating material (MgO aggregate). Thermal insulation is provided behind the wall sections of the catch pans. An air gap between the insulation and the vertical catch pan plate sidewall allows for relative movement between the concrete and the catch pan plate, and allows for the venting of hot gases from behind the catch pan plate to the cell atmosphere.

In the event of a sodium or NaK leak accident, the catch pan contains the spilled liquid in a leak-tight manner and prevents contact with the concrete structure. In those cells where the design basis spill volumes are small and open pool burning does not result in unacceptable concrete temperatures, the spilled liquid is allowed to burn until the fire is either self-extinguished or the entire mass of spilled liquid is consumed.

5.2.2.2 Catch Pans with Fire Suppression Decks

In cells where the spill volumes are large and open pool burning poses a challenge to the structural integrity of the building and/or to safety-related equipment, the catch pans are provided with a steel fire suppression cover (deck). The deck covers the entire open area of the catch pan and is supported by a structural steel framework. The deck is connected to the support framing with metal-to-metal contact around all edges to form a barrier against air in-leakage into the interior of the catch pan. Carbon steel drain pipes (downcomers) are welded to the deck and extend downward to a point 1/2 inch above the bottom of the catch pan. The pipes are distributed over the entire floor area. Vent pipes are welded to the fire suppression deck to vent hot gases from the region below the deck in the cell atmosphere to prevent pressure buildup underneath the deck. Figure 4 is a schematic of the catch pan fire suppression deck arrangement.

In the event of a liquid metal spill, the liquid metal flows from the surface of the fire suppression deck through the drain pipes into the catch pan. As the liquid metal drains into the catch pans, the drain pipes become partially filled, and the effective burning surface of the resulting liquid metal pool is limited to the cross-sectional area of the drain pipes. The design is such that this area is approximately 1/250 of that of an open pool. Burning is effectively terminated as the pipes become plugged with combustion products and the liquid metal is cooled to a temperature at which reignition is unlikely even if exposed to an ambient air atmosphere.



Typical Catch Pan Fire Suppression Deck Arrangement

FIGURE 4

5.2.2.3 Open Catch Pans with Drains

In certain cells where the postulated spill volumes are large compared to the floor area of the cell such that consideration of cell penetrations and building structural loading make it impractical to contain the entire spill volume, open catch pans with drains are provided. The drains are in the form of carbon steel pipes passing through the structural concrete of the cell. Horizontal pipes interconnect cells on the same level; vertical pipes interconnect cells on different levels.

In the event of a liquid metal spill, the catch pan prevents contact between the liquid metal pool and the structural concrete. The liquid metal is drained into a cell that has the capability for fire suppression (catch pan with fire suppression deck). This concept has been extended to include draining large upper level cells into lower elevation cells such as in the Steam Generator Building.

5.3 Fire Detection (Conventional and Sodium Fires).

The Fire Detection and Alarm System is designed to detect smoke and/or fire in non-inerted sodium and non-sodium areas of the plant and provide visual and audible alarm in the area where a fire occurred and in the control room to alert personnel of the existence of fire. In addition the system provides the supervision and/or automatic actuation of the Sprinkler Systems, the Gas Blanketing System and the Stand Pipe System of the Non-Sodium Fire Protection System, transmits signals and provides control and indication for stairwell pressurization and smoke vent fans, operates motor operated fire dampers to isolate smoke filled areas, monitors critical Heating, Ventilation and Air Conditioning (HVAC) equipment for fire or smoke, and monitors those fire doors not monitored by Plant Security System. For the inerted sodium areas the sodium leak detection system provides detection and alarm functions in the control room for sodium/NaK fires.

Alarm and trouble signals received by the Local Fire Protection Panels (in each building) are grouped by signal types and transmitted to the Building Fire Protection Panel. There is one Building Fire Protection Panel per building. Alarm and trouble signal received by the Building Fire Protection Panel are again grouped by signal types and transmitted to the Fire Protection Panel (in the Control Room) where they are annunciated on the panel annunciator and permanently recorded by the Sequence of Events Recorder.

All circuits in the Fire and Detection and Alarm Systems are designated to perform Class A service. A Class A circuit detects and initiates a trouble signal for any single break or single ground fault in the detection circuit. Any single break or single ground fault in the detection circuit will not prevent initiation or transmission of an alarm signal.

The Fire Detection and Alarm System is designed in accordance with NFPA Codes 72A (Reference 15) and 72D (Reference 16). Ionization type detectors and thermal combination type detectors are located in accordance with NFPA 72E (Reference 8).

All redundant safety-related cable trays are provided with continuous line-type heat detectors.

The HVAC Air Duct Detectors and HVAC Temperature Switches are located in the return air ducts exhausting from the building or being returned to the supply units, and at a suitable location in the main supply duct on the downstream side of the air filters.

Manual Pull Stations are located at easily accessible locations, usually as close to the door as possible.

6.0 DIFFERENCES FROM LWRs

Since the principal fire hazard associated with sodium is its rapid reaction with water, water has been excluded as a fire fighting agent in the CRBRP areas when a hazard involving metal coolant fires exist. Instead, passive design features such as the use of inerted atmosphere and catch pans were used to mitigate the consequences resulting from a liquid metal spill as described in Section 5.2 of this report.

As an added precaution to prevent sodium water reaction, dry standpipes are used for manual extinguishment of non-sodium fires in the plant areas adjacent to those containing liquid metal piping and components. These standpipes are normally free of water and are connected to the Nuclear Island Standpipe System using normally closed valves. These valves will be opened only after it is judged by the plant supervisor that a non-sodium fire is out of control with the use of portable extinguishers, and that no liquid metal is likely to react with the standpipe water.

7.0 CONCLUSION

The presence of liquid metals such as sodium and NaK in CRBRP precluded the utilization of conventional fire fighting agents such as water, in areas containing liquid metals. The passive design features described herein to mitigate the consequences of sodium fires and the formulation of the conventional fire protection system design provides useful guidelines for the use of future LMFBRs.

References

1. SDD-26B, "Non-Sodium Fire Protection System", Revision 27.

2. Appendix R to 10CFR50 "Fire Protection Program for Nuclear Power Facilities Operating Prior to January 1, 1979".

3. Branch Technical Position BTP CMEB 9.5-1 "Guidelines for Fire Protection For Nuclear Power Plants', Revision 2, July 1981.

4. CRBRP Fire Hazard Analysis Report, Draft "C".

5. National Fire Codes of the National Fire Protection Association.

6. Underwriters Laboratories, Inc. (U.L.), "Approved Directories and Equipment Lists".

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

8. NFPA-72E, "Automatic Fire Detectors".

9. NFPA-90A, "Air Conditioning and Ventilation Systems".

10. NFPA-91, "Blower and Exhaust Systems".

11. NFPA-12A, "Halon 1301 Systems".

12. NRC Regulatory Guide 1.52 "Design, Testing and Maintenance Criteria for Engineered Safety Feature Atmosphere Cleanup System Air Filtration and Adsorption Units of Light-Water-Cooled Nuclear Power Plants."

13. NFPA-26, Supervision of Valves.

14. NFPA-10, Portable Fire Extinguishers.

15. NFPA-72A, Local Protection Signaling Systems.

16. NFPA-72D, Proprietary Signaling Systems.

APPENDIX A

FIRE AREA ANALYSIS

BUILDING: STEAM GENERATOR BUILDING - INTERMEDIATE BAY

Fire Area SGB-IB-6   Zone No. 1   Cell No. 262

Description of Fire Area

Fire area consists of general floor area, elevation 816'-0", of the Steam Generator Building - Intermediate Bay.

Safety-Related Equipment in the Area

I&C Cabinets, Division 2
Power Panels
Lighting Panels
Transformer
SGB Air Handling Unit
Exhaust Fans
Cables, Division 2
Division 2 Remote Air Intake

Radioactive Material Contained in Area

a. Equipment/Piping - None.

b. Airborne - None.

Fire Hazards

Type and Quantity of Combustible Material in the Area

a. Cable Insulation - 307.2 x 10^6 BTU

b. Oil/Grease - 3 Gal x 144,600 BTU/GAL = .43 x 10^6 BTU

c. Other - (transient 55 gal drum) 55x152,000 BTU/gal = 8.4 x 10^6 BTU

Fire Loading Which Represents Combustibles

a. Floor Area - 10,000 sq. ft.
b. Fire Loading - 31,600 BTU/FT^2

Fire Area Construction

a. Walls - Concrete walls with three (3) hour fire rating.

b. Floor - Concrete floor slab on steel framing. Steel framing is fire coated for an equivalent three (3) hour fire rating.

c. Ceiling- Concrete floor slab on steel framing. Steel framing is fire coated for an equivalent three (3)hour fire rating.

d. Doors - Doors to other fire areas are three (3) hour fire rated.

e. Penetrations - Penetrations are sealed for an equivalent three (3) hour fire rating.

f. There are three (3) watertight access hatches in the floor.

Heating, Ventilating and Air-Conditioning

Smoke Removed through:

a. Smoke Removal System

Drainage - Water from fire suppression system would be removed through:

a. Floor Drains

Electrical - All cables are routed in tray and conduit.

Fire Protection

Consequences of Design basis Fire for Area

Loss of Equipment listed on Page A-1.

Effect of Fire Protection System Operation

a. A fire would activate the smoke detectors which would alarm in the control room. An onsite brigade would be dispatched which would take appropriate action in accordance with pre-fire plans and emergency response procedures. Manual hoses and portable extinguishers are available. Other fire stations offsite will be alerted.

b. A high heat condition would cause the preaction valve to open and fill the piping system with water.

c. A further heat build-up would fuse the individual heads of the sprinkler system thus initiating extinguishment.

d. Loss of electrical panels and cabinets due to sprinkler system operation.

Extinguishing, Detection and Alarm Capabilities in the Area

a. The entire plant is protected by a preaction sprinkler system.

b. Five (5) standpipe hoses are available.

c. Six (6) portable extinguishers (dry chemical).

d. Eighteen (18) area and two (2) duct mounted ionization detectors.

e. Four (4) manual pull box and alarm bells are in the area.

Safe-Shutdown Capability

Safe-shutdown capability is not lost due to a fire in this area.

a. Inadvertent operation of the manual fire suppression system in this area is not considered credible due to trained personnel.

b. Rupture of a preaction system pipe would not cause any flow of water, but would sound an alarm in the control room.