FIRE HAZARD ANALYSIS 1006
(STAR)

September 1998

Fire Protection Assessment / Fire Hazard Analysis
Building 1006, 1006A, 1006C, STAR Experimental Complex
Brookhaven National Laboratory

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Project Concurrence: 9/4/98
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Purpose/Scope

The purpose of this assessment is to comprehensively and qualitatively assess the risk from fire within the STAR Complex at Buildings 1006, 1006A, and 1006C, and to ensure that DOE fire safety objectives are met. The assessment includes the risks from fire and related hazards (direct flame impingement, hot gases, smoke migration, fire-fighting water damage, etc.). DOE fire protection criteria are outlined in DOE Order 420.1[1], Chapter 4. The Fire Hazard Analysis required for the Safety Analysis Document for this facility is incorporated into this assessment.

Summary

The current and proposed uses of 1006, 1006A, and 1006C for the STAR physics experiment is described under "Occupancy and Associated Fire Hazards," listed below. These descriptions are based on field surveys, a review of the planned and completed installations, and discussions with STAR Project staff. This FHA describes the achievement of a reasonable and equivalent level of fire safety to meet DOE 's "Improved Risk" objectives.

Recommendations:

1) The labyrinth between the WAH and the Control Room needs to be a one-hour fire rated division to segregate the two areas of high valued equipment. Likewise, the two HVAC openings from the WAH to the Support Bldg. need to be sealed to prevent passage of smoke and heat between the high valued areas.

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[1]US Department of Energy Order No. 420.1, Facility Safety, 11/16/95

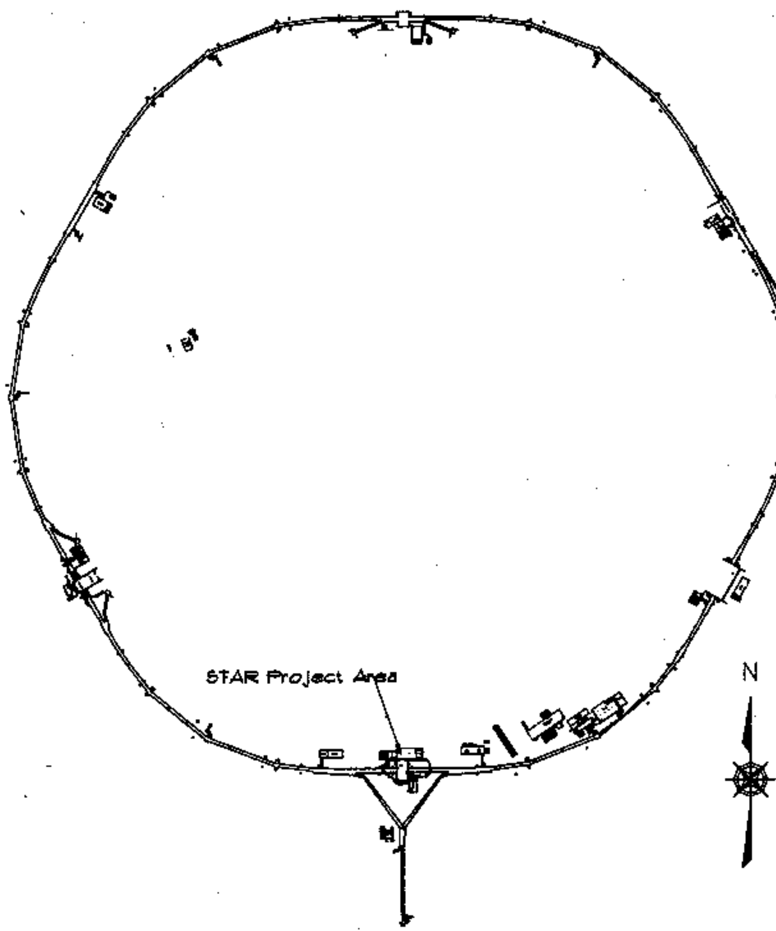
Analysis

1. Scope

This review includes the experimental facilities and support structures for the STAR Experiment at the Relativistic Heavy Ion Collider (RHIC), located at Brookhaven National Laboratory (BNL). The buildings associated with STAR are Bldg. 1006 (Assembly Hall and Intersecting Region) and Bldg. 1006A (Control Room, Technical Support Building).

1.1 Construction

The STAR Complex is located in the northern region of Brookhaven National Laboratory (BNL). BNL is a 5,000 acre site owned by the Department of Energy and operated by Brookhaven Science Associates. BNL is located in Upton, New York.



KEY PLAN
NOT TO SCALE

1.1.2 <u>Building 1006</u>

Building 1006 is a one story, 15,390 sq. ft. building. The building is divided into two halves. The south portion of the building is the Wide Angle Hall (WAH) built in 1981 with an approximate square footage of 5,600 sq. ft. The WAH is 40 ft. high, with reinforced concrete roof, walls and floor. To the east and west, two 900 sq. ft. openings are provided from the RHIC Tunnel. A 30 ft high shield wall fills the opening in the heavy concrete shield wall that separates the WAH from the Assembly Hall (AH) to the north. The facility is windowless and covered by several feet of earth for radiation shielding.

The AH is 60 ft. by 130 ft., built in 1997. The roof is a Class I insulated steel deck roof by Factory Mutual standards. Walls are fiberglass insulated metal panels. The floor is reenforced concrete. Within the AH a 60 ft. by 30 ft. mezzanine is located on the east side. The mezzanine is concrete poured over a metal deck and supported by a steel frame. The wall partitions are non-combustible. An insulated metal door and roll-up door is present. The partition is not fire rated. First floor rooms, under the mezzanine, have 8 inch concrete block walls.

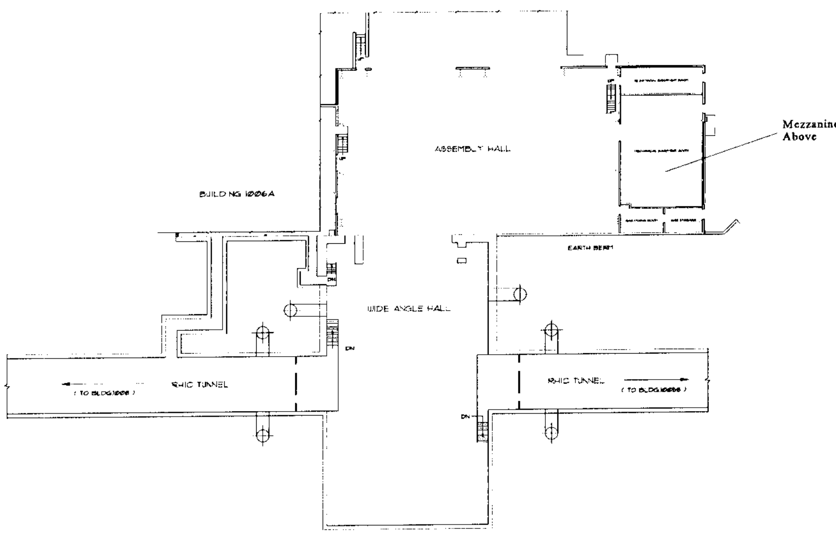
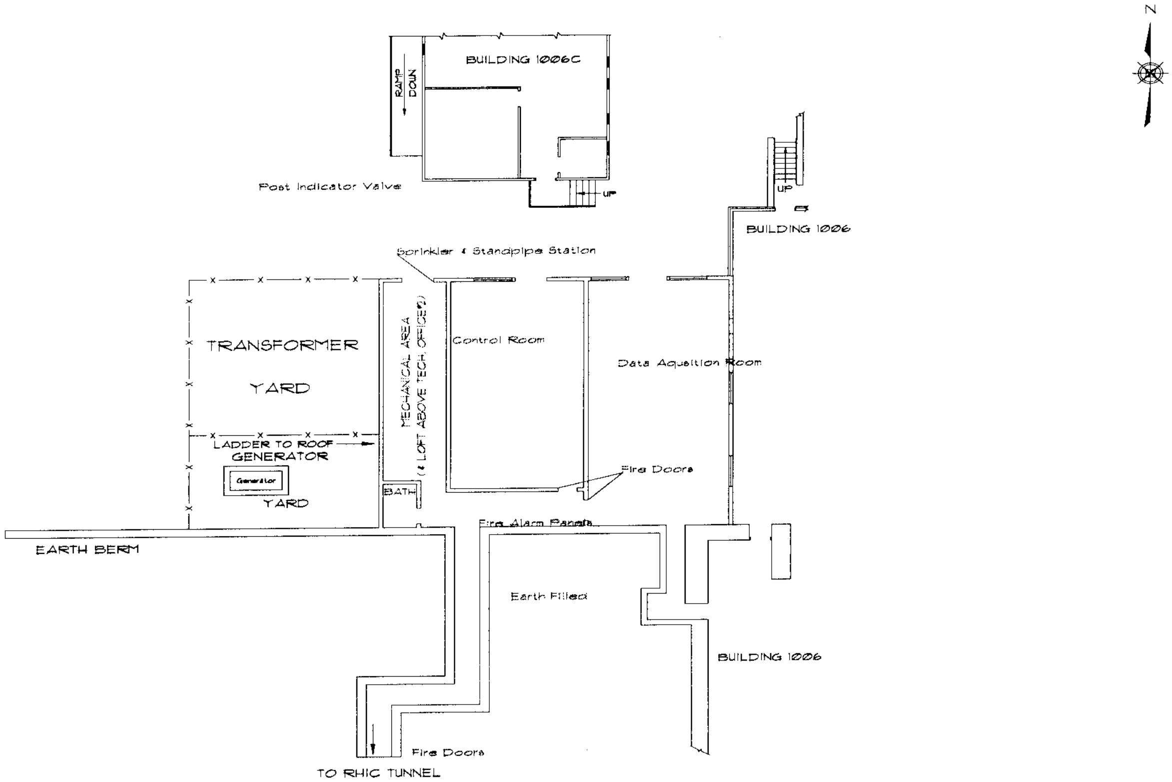


Figure 2 Plan view of Bldg. 1006

Figure 3 Looking south toward north face of Bldg 1006. On the right is the north mechanical platform of STAR, standing outside the West roll up door.

1.1.3 Building 1006A

Built in 1981 with the WAH, the Support Building is a one story fiberglass insulated metal panel building of 2,800 sq. ft. The steel deck roof is rated as Class I by Factory Mutual Standards. Interior walls are 8 inch concrete block. The floor is reinforced concrete. A labyrinth connects Bldg 1006A to the RHIC Tunnel.



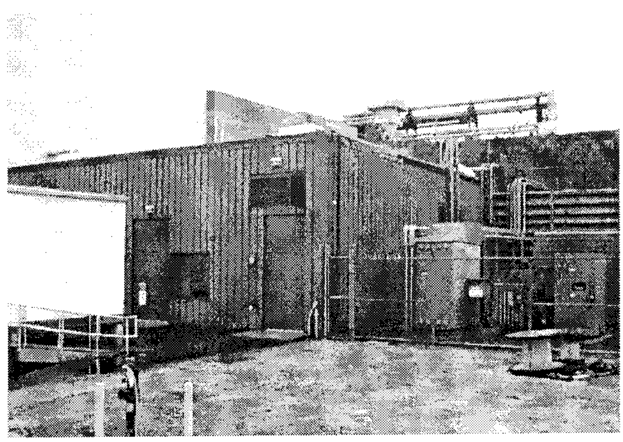


Figure 4 View of Bldg. 1006A looking to the south

1.2 <u>Fire Barrier Integrity</u>
The majority of the dollar value for the facility is in the STAR Detector (>$60 million design and construction costs; replacement cost of $30 million). The Detector primary location is the WAH. The Detector is transferred to the AH for servicing (a few times per year). The RHIC Tunnel opens to the WAH to allow the Beam Transport System (a string of magnets) to enter the WAH. Normally, a fire rated barrier would be installed to segregate the high value accelerator from the WAH. A fire rated barrier was not installed. The following is a list of mitigating features:

1) Low combustibility of RHIC Tunnel and contents (See RHIC SAD).
2) Spot smoke detection in tunnel, on alternating zones for reliability and with separate redundant rate of rise/fixed temperature heat detection units at each detector location.
3) Automatic smoke removal system (in the tunnel and WAH).
4) Highly sensitive smoke detection in the WAH.
5) Highly sensitive smoke detection in the Detector.
6) Low combustible contents and construction of the detector.
7) Ceiling mounted wet pipe sprinkler system in the WAH.
8) Vapor barrier for the oxygen deficiency hazard posed by Helium will also act as a smoke barrier between tunnel and WAH on both sides (Hercullte fabric on metal frame).

This arrangement deviates from DOE's requirement to isolate high value equipment with fire rated construction. By way of this document, an exemption request is being processed

The first floor south, under the mezzanine, contains the gas mixing equipment. Original design has changed and while the room was constructed with a 2 hour fire rating, the bulk gas systems are now outside (see gas system section). The room no longer requires a fire rating, nor the explosion protection for electrical equipment. Solid piping passes through this area into the gas mixing equipment. There are no relief valves nor are there frequently made or broken connections. Therefore this area is not exposed to combustible gases. Fire dampers in the communicating wall to the AH have been removed from the west wall and the room is no longer fire rated.

1.3 <u>Windstorm Damage Potential</u>
Bldg. 1006 and 1006A steel deck roofs are in good repair and are expected to withstand local windstorms.

Portions of the STAR Detector have fragile gas chambers. Rapid fluctuations in atmospheric pressure can cause damage. While hurricanes have the highest wind speeds, the most severe pressure drop in 40 years at BNL has occurred during the "Northeaster". Pressure dropped ½ inch of water column within ½ hour. This was used as the design basis for chamber design. See RHIC Experimental Safety Review Committee for details.

2.0 Occupancy and Associate Fire Hazards

2.1 STAR Detector

The STAR Detector main structures consists of the Main Magnet, North Platform and South Platform. The Main Magnet is a 5.6 meters by 6.2 meters long solenoid magnet made from aluminum coils and 1,200 tons of steel. Various subsystems are used to detect interaction events from the intersecting heavy ion beams which cross at the center of STAR. A beryllium beam pipe is used to transport the beam through the magnet. The Detector has an array of subsystems. In the center is the Silicon Vertex Tracking (SVT) Detector. It is an assembly of low mass circuit boards and wafers on a beryllium frame. The combustible metal is of sufficient thickness not to pose an easily ignited combustible material, even if the RHIC beam impinges on it (maximum calculated temperature rise of 1 degree C with impingement). During the design of STAR's various detector subsystems, materials were selected to be low combustibility (FR4 printed circuit boards, fire rated cables).

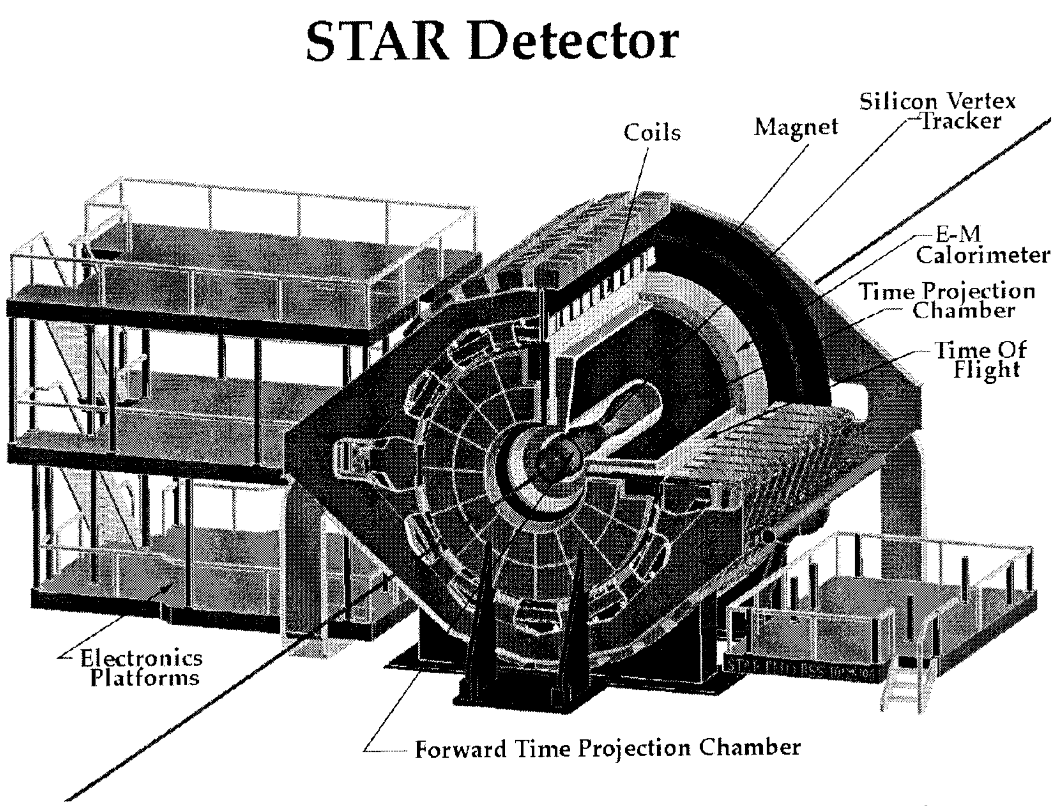


Figure 6 A sectional view of the Detector with the two top most north platform removed (north is to the right).

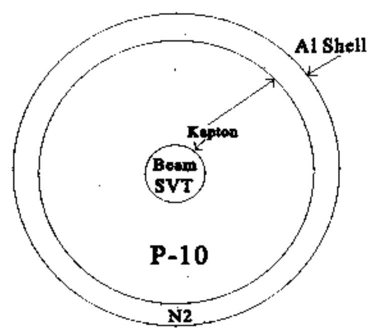
The ignition sources were limited by Overcurrent protection to the board level. During RHIC Experimental Safety Committee Reviews a 80 watts maximum over current load was established. Most designers of sub systems choose polyfuses for over current protection. Polyfuses are semi conductor devices that shutdown at twice their rated operating currents. Polyfuses remain "off" until all power is removed from them, thereby allowing remote resetting while latching under fault conditions. The intent was to limit maximum power dissipation, provide a highly sensitive detection system on the magnet to turn off power, and to have materials that self extinguish when small initiating power is terminated.

2.1.1 STAR TPC

One of the subsystems at STAR, the Time Projection Chamber (TPC), has an inventory of 50,000 cubic liters P-10. P-10 is a blend of 10% methane in 90% argon. Therefore the TPC has a potential inventory of 5 m^3 of methane, although it is diluted with an inert gas. While this blended gas is classified as a non-flammable gas by the Department of Transportation, it does support combustion (mainly by methane diffusion from the blend [2]). Therefore, STAR has approached this situation by treating the P-10 as a flammable gas to ensure sensitive equipment is not severely damaged.

The TPC is cylindrical in shape. The 1 meter diameter middle opening is for the beam pipe and the SVT. The next concentric opening is the Inner Field Cage, which is a cylinder of two layer of aluminum coated Kapton on a honey comb Nomex structure. The next cylindrical volume is a blanket of P-10 gas. The Outer Field Cage is the next cylindrical boundary, which is Kapton coated with copper. A Nitrogen blanket is in the next cylindrical volume followed by the aluminum shell. The shell is aluminum honeycomb on both sides of a 2 mm aluminum skin. 30 kV potential is applied across the cages. The inner system systems operate at 5 milibars of pressure, while the external shell can withstand 5 psi.

The two faces of the TPC are two part solid aluminum frame work. A honeycomb of oblong openings in the frame allow the passage of electrical signals. FR4 boards were to seal the openings (under 10% are G-10).



Process controls will measure moisture and oxygen content. These will be interlocked to shutoff power and start a purge unacceptable conditions occur. The TPC will purge the P-10 with nitrogen at the rate of 450 liters per minute, taking approximately an hour and one half to displace one volume. Since any dilution by an inert gas of P-10 moves it out of it's explosive range, this is acceptable.

Figure 7 Simple Cross Section of TPC

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2 Department of the Interior, US Bureau of Mines, Bulletin 627, Characteristic of Flammable Gases and Vapors, 1965

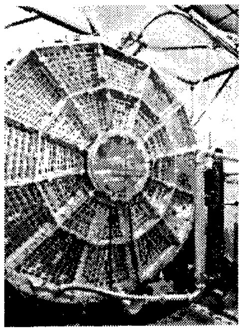


Figure 8 View of TPC aluminum end frame.

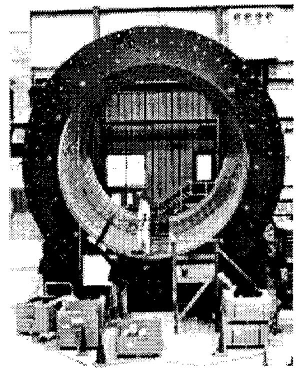


Figure 9 A view of the Magnet Coils during construction, representing almost 1,200 tons of steel. TPC slides inside of the coil.

STAR will blend their own mixture of P-10. Strict controls and redundant systems are used to monitor the proportions of Argon to Methane for operational and safety reasons. Gas is monitored as it is mixed and recirculated within the TPC. The bulk supply of gas is stored to the east of Bldg. 1006 in an outdoor location. It is delivered into the building through metal piping, protected from mechanical damage. Mixing occurs through controllers in the Gas Mixing Room.

For the purpose of classifying this facility for Fire Code applications, the occupancy is an ordinary hazard industrial facility.

The North Platform of STAR contains mainly mechanical services, monitoring systems for the magnet, water pumps, and some water cooled electrical buss. There is no unusual fire hazards associated with this use.

The first two levels of the South Platform has the majority of electronics and is the most vital. The highest value is located on the first level, row "A". These are the trigger electronics with a value of $250k per each of two double width rack enclosures. The electronics and power supplies do not pose an unusual fire hazard. Metal cabinets house the majority of the equipment. Metal dividers aid in the segregation of equipment. The electronics were designed using less combustible materials for printed circuit boards (FR4) and cabling. The protection of the electronics is under electronic data processing section of this report. Several power conduits were constructed of PVC plastic due to the need for electrical isolation and experimental signal quality. These run under the magnet and do not expose the Platforms.

2.2 Assembly Hall

The AH has the same hazards as the WAH. P-10 will not be present in the Detector when it is moved form the WAH to the AH. P-10 may be present in the AH during servicing.

Two small hydraulic systems are used for moving the Detector. Reservoir on both systems are under 50 gallons and develop several thousand psi. Factory Mutual less flammable liquids are used. The hydraulic systems are connected to the Detector only during movement. The systems are manual and operations are constantly supervised as per an Operating Procedure.

Located on the mezzanine of the AH are main magnet power supplies, water systems for the magnet, MCWS, Power Supply/Buss, and the cooling tower. Water systems include pumps, filters, and resin beds. This equipment is considered common industrial hazards. The water cooled power supplies are not oil insulated. This area is an ordinary industrial occupancy.

The first floor, north area, under the mezzanine in the AH houses dry type power transformers for normal building support services. This is fully sprinklered and not fire rated. The first floor also contains electrical control centers and water systems (pumps, chillers, water treatment equipment).

2.3 Bldg. 1006A
Bldg. 1006A DAQ Room will house data acquisition equipment, control and monitoring systems. Data storage will only consist of a buffer set of information in case the mass storage link is unavailable. Mass storage will be provided at the Brookhaven Computer Facility's RHIC Computer Facility subsystem which is located several miles away (subject of separate reviews). In the Control Room, process and safety control systems will reside. These areas are low hazard occupancies, from a fire hazard standpoint.

3.1 Critical Process Equipment

The STAR Detector is divided into several sub-systems, some of which are not needed for the entire experiment to operate. However, without the full compliment of systems, the quality of physics will suffer. The following is a matrix of subsystems, total construction costs (including engineering, design), and a replacement value for as-is systems.

System	Total Cost	Estimated Replacement Cost
Conventional Systems	$1.5 million	$1.0 million
Magnet	$11.4 million	$4 million
Time Projection Chamber	$11 million	$5 million
Forward TPC	$2.4 million	$1.5 million
Electro Magnetic Cal	$11 million	$7 million
Front End Electronics	$4 million	$1.5 million
Silicon Vertex Tracker	$7 million	$4 million
Computing (DAQ, Processing)	$5 million	$3 million

The Support Systems (such as Magnets, cooling water, electrical power) are required for STAR operations. The majority of components in these systems are common and easily deliverable. Custom parts in other sub systems do have limited spares. The major exceptions are the large structural elements, such as the Main Magnet, and TPC. It is impractical to have spares for these massive devices. Concurrently, it is unlikely that an event will inflict significant damage to these devices.

3.2 Special Occupancies

Special occupancies include electronic data processing and vital/important records. The special occupancies of STAR and Bldg. 1006 are expanded upon in Sections 3.2.1 and 3.2.2, below.

3.2.1 Electronic Data Processing
The data acquisition equipment (DAQ) associated with the operation of STAR is located in a DAQ Room in Bldg. 1006A. Dollar values for control equipment exceed $1 million, but are under $10 million. The facility is a non-combustible construction, segregated from other occupancies by one hour fire walls (except for the division between the AH and the DAQ Room, see below), provided with smoke detection, and protected by a wet pipe sprinkler system. The labrinyth to the WAH from the DAQ Room is not fire rated. This labyrinth needs to be sealed (see Recommendation #1).

The separating wall between the DAQ Room and the AH is also not fire rated. The insulated metal wall has sprinkler protection on both sides. In addition, HSSD early warning smoke detection is provided on the AH side. The occupancies are similar and do not warrant an increased level of segregation. The overall arrangement poses an acceptable risk when recommendation #1 is completed.

The Control Room is adjacent to the DAQ Room. The area contains workstations and terminals. Dollar value is low. The room is segregated from the DAQ and adjacent mechanical spaces by 8 inch concrete block walls. The non-fire rated separations are adequate for the risk.

3.2.2 Vital and Important Records Storage

Vital records are those records which are essential to the mission of an important program and which, if lost, could not be reproduced or obtained elsewhere. Important records are those records possessing a high value to the mission of an important program but which, if lost, could be reproduced or reconstructed with difficulty or extra expense.

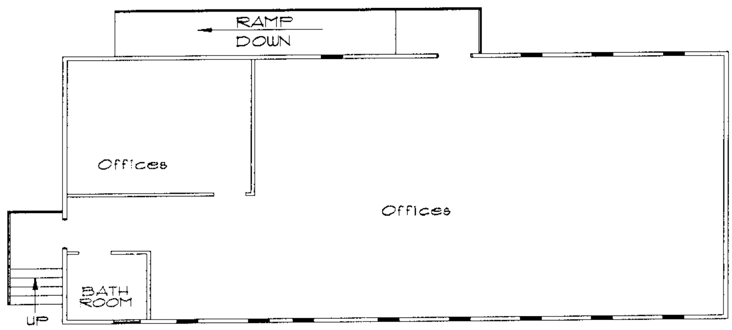
Based on the above definition, the data collected from the experiment is vital. This information is collected by the facility and transported to the RHIC Computing Facility in Bldg. 515, Brookhaven Computing Facility (separate facility several miles away, connected by computer network). Except for a minimally sized buffer arrangement, on-site storage of data in not done. The petabytes of data are the subject of another analysis for the RHIC Computing Facility, located several miles away.

3.3 Unique Fire Hazards

Unique fire hazards include; modular buildings, trailers, cooling towers, flammable liquid and gas storage, cable trays, housekeeping in vital areas, and highly combustible building materials. The unique fire hazards at the STAR Complex are expanded upon in sections 3.3.1 through 3.3.7, below.

3.3.1 <u>Modular Buildings</u>

Bldg. 1006C was built in 1992. The facility was formerly Bldg. 831. It was relocated in 1996 to the south side of Bldg. 1006, and renamed Bldg. 1006C. The facility is constructed from three prefabricated modular units, with a total floor are of 1,700 sq. ft. The assembly is one story with a framed roof. Fiberglass insulation, metal studs, and metal framing were used throughout. The floor deck is plywood, covered carpet (Class I rating by Radiant Panel Test).



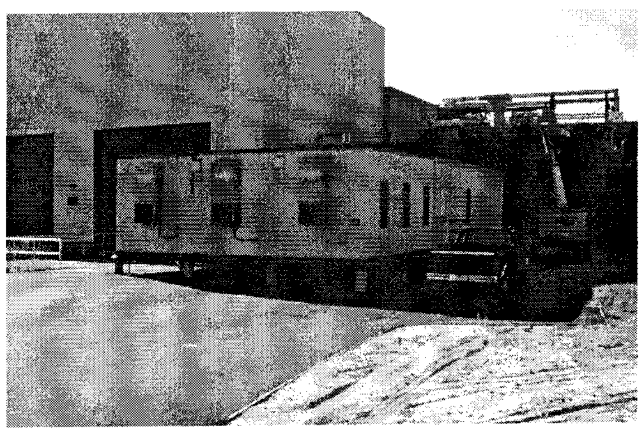


Figure 11 View of Bldg. 1006C looking toward the south.

3.3.2 <u>Trailers</u>

Currently there are no funded plans for additional buildings around STAR. If facilities are provided, they will comply with DOE Orders on separations, construction, and protection.

3.3.3 <u>Cooling Towers</u>

The experiment has a water based heat removal system. One cooling tower is located to the east of Bldg. 1006. The unit is metal, prefabricated, and serves the STAR Magnet, MCWS, and Power Supply/Buss cooling systems. There is no fire exposure concern.

3.3.4 Flammable Liquid/Gas Use and Storage

The TPC at STAR uses P-10 as a detector gas. It is a blend of 10% methane and 90% argon. It is considered non-flammable by the Department of Transportation. However, studies by the US Bureau of Mines show that the gas can ignite and burn (mainly from defusion of methane). The studies also indicate that any minimal amounts of ventilation will dilute the gas below the Lower Explosive limits for Methane. The STAR project is treating the gas as flammable gases. The inventory is large, 50,000 liters. A study was performed to analyze the potential for damage (Design Basis Accident, see STAR SAD). The events postulated show that the damage does not involve areas beyond the WAH and gas mixing room.

The RHIC Experimental Review Committee has examined the design and installed configurations of the Detector and its sub systems.

Release of gases into the WAH have been addressed as follows:

1) Limits to on-line supplies for flammable gas systems,
2) Solid metal piping from the supply to the Detector's distribution systems,
3) Requirements for leak checking of piping systems following modifications & repairs,
4) Detector chambers are designed to ensure integrity (burst safety factor)
5) Pressure tests that assure chamber construction meet design boundary limits,
5) Designs that "fail-safe" with loss of power (i.e., purge of flammables with inert gases),
6) Combustible gas detection in the regions where gas could be released and could collect,
7) Highly sensitive smoke detection to promptly indicate off normal conditions,
8) Interlocks to shut off all power to the Detector in the event of certain fire alarm conditions (and starts purge/vent),
9) Over current protection of power distribution system on printed circuit boards within the STAR Detector to limit maximum power dissipation potential under 80 watts on one board,
10) Normal ventilation in the WAH to dissipate combustible gases ("normal leakage"),
11) High rate purge, activated with interlocks, in the WAH to dilute and remove released gases,
12) Monitoring of oxygen content of detector gas at gas mixing and in the recirculation stream.

Gas releases into the AH have similar protective measures, except the AH has a higher natural air exchange rate provided by the type of construction. The AH's steel deck construction and numerous external openings provide better ventilation of methane than the WAH's sealed concrete structure. The AH does not have an emergency exhaust system. The RHIC Experimental Safety Review Committee reviews and establishes the required controls of the P-10 use in the AH. This is expected to be an infrequent event, occurring during servicing.

3.3.5 Cable Trays

High voltage, low voltage, control, and signaling cables are segregated in accordance with NEC requirements throughout the STAR Complex. The cabling is located in conduits, raceways and cable trays. In most instances, the cables provided in the cable trays meet the RHIC flammability test criteria (IEEE 383, VW-1, NEC rated wire for cable trays). Automatic sprinkler protection is provided in the Bldg. 1006, WAH, AH, DAQ Room, and Control Room.

3.3.6 Housekeeping in Vital Areas

For this high value facility, good housekeeping and control of combustibles will be essential. Internal self inspection will be routine and an aid in evaluating the effectiveness of the program.

3.3.7 Highly Combustible Building Materials

No significant amounts of exposed polystyrene insulation or other highly combustible building materials are used in the construction or operations at the STAR Complex.

The North and South Platforms are constructed of metal frames. Resin particle board, with a Resin Decking finished, has been installed on the platforms to provide a walking/working surface. This decking was chosen for its ridigity and comparative low weight. Resin Decking does not have a significant flame spread concern due to the open nature of the platforms. To provide structural ridigity, aluminum sheet metal was attached directly to the underside of the decking. The metal will prevent ignition in the event of a cable tray fire (trays are run below the decking; cable are low flammability and easily accessed).

To provide electrical isolation between the North and South Platforms, PVC electrical conduits were installed. These are short run, beneath the heavy steel of the magnet and do not expose the detector to damage.

4.1 Fire Protection/Suppression Features

4.1 Infrastructure Support

4.1.1 Site Water System
BNL has a combination domestic and fire protection water supply system. The system is supplied by several deep wells and is stabilized by two elevated water storage tanks (one 1 million gallon and 350,000 gallon capacity). The wells have electric primary drivers and a limited number have backup internal combustion drivers. The system can sustain three days of domestic supply and a maximum fire demand (4000 g.p.m. for 4 hours) for BNL with two of the system's largest pumps out and one storage tank unavailable. The piping distribution network is well gridded. Water supplies around the RHIC Ring Road are fed from two well separated connections to the BNL system. Ample valves provide isolation in case of a main break. Static water pressure to the STAR complex is typically 70 psi. Water supplies to Bldg. 1006 and 1006A are capable of supplying 1,700 g.p.m. with 60 psi residual pressure.

Fire hydrants are provided within 300 ft. of each facility. Frost proof hydrants are needed since the frost line extends to 4 feet below the surface in the winter. BNL and the local Suffolk County Fire Departments use National Standard Thread couplings.

BNL's Plant Engineering Division maintains the water supply system. BNL's Fire/Rescue Group conducts valve inspections on the distribution system to ensure reliability of firefighting water supplies.

4.2.1 BNL Fire/Rescue Group
The BNL Fire/Rescue Group is a full time, paid department. Minimum staffing is five firefighters and one officer per shift (Fire/Rescue Staff & Organization). The firefighters are trained to meet Firefighter Level III by International Fire Service Training Association standard , National Fire Protection Association (NFPA) Fire Fighter Level II standard, and (NFPA) Hazardous Material Technician Level and they are Suffolk County Certified Confined Space Rescuers.

The BNL Fire/Rescue Group also provides emergency medical services to an on-site population of 3200 people. A minimum of two members per shift hold New York State "Emergency Medical Technician - D" certifications ("D" is for defibrillation). Normally all five firefighters have EMT status. The Group operates a New York State Certified Basic Life Support Ambulance (a 1988 Wheeled Coach Type I on a Type III Chassis). Medivac services are available to BNL via the Suffolk County Police Department (a training session).

Additionally the Group has two 1500 g.p.m. "Class A" Pumpers, one Rescue Vehicle for initial hazardous material incident response and heavy rescue operation, one Command Post Vehicle, and one 5 ton military chassis converted to a Long Island Style Brush Truck.

The single Fire Station is on the west side of the BNL's property. Response time to the most remote section of the BNL is less than eight minutes (if not out of quarters on another emergency response call). RHIC represent one of the most remote areas. Future plans may reduce this response time to less than 4 minutes with the addition of an access road from Upton Road to Ring Road.

BNL participates in the Suffolk County Mutual Aid Agreement. This allows the resources from over 130 departments to assist BNL. BNL is also a member of the Town of Brookhaven Foam Bank and Town of Brookhaven Hazardous Material Mutual Aid Agreement.

4.1.3 Site Fire Alarm System
Brookhaven National Laboratory provides central fire alarm station coverage by an Underwriter Laboratory listed multiplexed Site Fire Alarm System. The system is a Wormald System 1000, installed in 1987 (Wormald is now know as Grinnel Fire System). The system complies with the requirements of NFPA 72 for a Style 7D System.

The system uses the existing site telephone cable plant. RS232 signals are sent via full duplex line drivers. Each fire alarm panel has two channels connected to the Central Station. The panels are divided into 7 communication "loops." The system can monitor more than 20,000 points. It is currently monitoring 3,800. Response time from alarm at the panel to alarm indication at the Central Station is less than 10 seconds, which is well within the 90 seconds allowed by NFPA 72.

The main console is at the Firehouse, Bldg. 599. This station monitors all fire alarm signals, trouble and communication status alarms. A satellite station is provided at Safeguards and Security, Bldg. 50, and receives only the fire alarm signals. If the Firehouse does not acknowledge an alarm within 90 seconds, the satellite station at Bldg. 50 will receive an audible indication to handle the alarm. A second satellite station is provided at AGS Main Control Room, Bldg. 911, and receives only the fire alarm signals from the RHIC/AGS accelerator buildings. A team of operators and Health Physics Support personnel respond during accelerator operating times.

4.1.4 Fire Extinguishers
Fire extinguishers have been installed throughout the facilities in accordance with NFPA 10. Clean agent units are installed in the WAH, AH, and Control Room. Multipurpose units are installed in the other conventional areas. Although the distribution of these units meet NFPA 10, the access to burning materials within STAR will be difficult, if not impossible, with hand held units (height of equipment, depth and density of equipment). Attempts to acquire streaming type Wheeled Clean Agent units have not been successful.

4.2 STAR WAH

4.2.1 Highly Sensitive Smoke Detection System (HSSD)

To provide early warning in both the WAH and the Assembly Hall, the High Bay area are provided with a Highly Sensitive Smoke Detection System (HSSD). The ceiling heights in excess of 50 ft. prompted the need for a detection system with greater sensitivity than the standard spot type of detectors. The air aspirating type of detection has a ceiling mounted network of pipe. The sampling ports have been designed in accordance with the manufacturer's Underwriter's Listing. The ceiling piping has been labeled with orange pressure sensitive "Fire Alarm" labels. Sampling ports have been marked with blue tape. The system has been tested to verify conformance with design response time. Twenty four hour battery backup and emergency generator power has been supplied.

The HSSD system provides three levels of alarm. All three alarms report back to the BNL on-site Fire Department via the Site Fire Alarm System. The first level alarm is a local alarm (intended for the control operators). Second level alarms also sound locally, but require an investigation by Fire/Rescue. Third level alarms require full response by Fire/Rescue. Third level alarms from the WAH also activate building audible/visual devices, STAR Detector experimental power off, emergency Detector vent/purge, and building emergency exhaust fans. The HSSD system complies with NFPA 72 and the UL listing. Building fire alarms have battery backup (24 hour capacity) and emergency generator power (24 hour capacity). This system, combined with the on-site Fire/Rescue Group, satisfies the DOE requirement for a redundant fire suppression system for loss potentials over $50 million.

4.2.2 STAR Detector Electronics Cabinets

On the STAR Detector, electronics will be housed in enclosed racks on the North and South Platforms. The most significant racks are on the two lower levels of the South Platform. Given the high value of the equipment, smoke detection has been installed at the first and second levels (third level is directly under the ceiling HSSD). On the first level, one segment of racks has been provided with Inergen due to its value. The detection and release system travels with the Detector and is tied into the building fire alarm system (except during actual movement when everything is powered off and P-10 gas is removed). Building fire alarms and the Rack Fire Alarm Panel have battery backup (24 hour capacity) and emergency generator power (24 hour capacity).

4.2.3 HSSD on the Detector

Within the STAR Detector, an HSSD System will be installed. The detection system will monitor the volumes around the interior electronics. Similar to the WAH HSSD, the units will have three levels of alarm. First level alarms will require STAR Detector operator attention. Second level alarms will involve the operator and the Fire/Rescue Group for investigation. A third level alarm will evoke electrical shutdown, flammable gas detector purge/vent sequences, and building emergency exhaust ventilation for the WAH.

This application of HSSD technology does not fit standard installation rules. Best engineering judgement has been used for detector port placement. Factors influencing placement included normal air flow, collection points for smoke, location of ignition sources (electronic printed circuit cards, power devices as opposed to signal circuits). Detector ports have been spaced at 400 sq. ft. spacings. The HSSD Control Panel is tied into the building fire alarm system and will activate building wide audible/visual devices upon third level alarm. Building fire alarms and the HSSD system have battery backup (24 hour capacity) and emergency generator power (24 hour capacity).

4.2.4 Combustible Gas Detection on the Detector
Within the STAR Detector, an air sampling system combustible gas detection system will be installed for experimental operations using flammable gases. The air sampling system consists of a network of tubes that connect to a selector valve system. The selector valves and detection assembly will be located outside of the WAH. Sample points will be located on and around the detector based on potential leak points, potential collection points, normal air flow patterns, and the detector's construction. There is no installation standard for this type of application. The "off the shelf" flame ionization system uses a selector valve system to cycle through the sampling tubes and monitor combustible gas levels. Detection cycles and lengths of sampling points will ensure response to a leak within 90 seconds. Individual channel values are displayed and programmed for alarm and output functions. There will be warning levels in the ppm range, in which operators will investigate and monitor the situation. Higher reading will force action levels at 25 % of the Lower Explosive Limit, which will entail notification of Fire/Rescue, electrical shutdowns, activation of building emergency ventilation systems, vent and purge of detector chambers. The system will be on emergency power to provide continued operations during power outages.

4.2.5 Special Consideration for Electrical Isolation of Power

The Detector requires that the power and signal circuits be isolated from general building ground. Inadvertent grounds will create an electrical noise and mask signals form the Detector. To accommodate the need for isolation, the fire alarm system required several unique arrangements. A sub panel was installed on the platform. The output for alarm and trouble signals required isolation from the building fire alarm panels. This was accomplished by using a supervised output from the subpanel to a relay at a ground isolation terminal strip in Bldg. 1006. The fire alarm panel monitored the contact closures from this relay via a supervised circuit. This maintains alarm, trouble and ground fault supervision of all parts of the sub panel alarm circuit. The general trouble condition from the subpanel is connect to the ground isolation terminal strip by a normally power relay from the general trouble relay in the subpanel. A supervisory circuit monitors the relay at the isolation terminal strip. This has a fail safe trouble condition for indication of subpanel trouble. It does not have ground fault supervision from the subpanel to the isolation terminal strip.

The power for the subpanel is supplied from the clean power provided to the platform. Since a gas alarm or fire alarm condition will remove all power from the Detector, the subpanel will loose normal AC power. The 24 hour battery back up will carry the panel during this abnormal condition.

4.3 AH and Bldg. 1006A

4.3.1 Wet Sprinkler System
To provide suppression of a disastrous level fire in the WAH and the AH, a wet sprinkler system has been installed. Installation of the sprinkler system complies with NFPA 13. The system protecting the WAH has been designed to provide a .17 g.p.m. per sq. ft. density over 3,000 sq. Ft. with 250 g.p.m. for hose streams (NFPA 13 Standard). The AH system is supplied by the same riser station as the WAH. The AH system was installed as a Pipe Schedule System. Waterflow alarms are tied into the building fire alarm. Sprinkler valve supervision report through the Site Fire Alarm System as supervisory devices.

Standpipes are provided to the WAH and AH via the wet pipe standpipe system serving the RHIC Accelerator Tunnel.

4.3.2 DAQ and Control Room
Automatic sprinkler protection has been provided in the DAQ and Control Room. Both areas have been provided with ceiling mounted smoke detection. The DAQ has a raised, computer type floor, under which spot smoke detection has been installed. The DAQ Room has an Intergen system installed, protecting the high value electronic racks. Smoke Detection is provided within the racks. These provide an alarm only signal. Release of the Intergen is by rate compensated fire detectors located within the rack. Any fire alarm signal from the rack will cause the power to be disconnected from the rack. All fire alarm signals and supervision go to the Site Fire Alarm System.

4.4 STAR Counting House

The STAR Counting House is a separate structure (Bldg. 1006C). It is provided with smoke detection and manual fire alarm stations. Local audible/visual devices are provided to alert the building occupants. Building fire alarms have battery backup (24 hour capacity) and emergency generator power (24 hour capacity).

The fire protection/suppression features of vital programs, high valued property, and essential safety class systems at the STAR Complex are expanded upon in Sections 5.1 through 5.3, below.

5.1 Fire Protection of Vital Programs

The operation associated with this facility is not considered to be a DOE "vital program." Therefore, no special fire protection precautions, beyond those that are generically described above, are required for this facility.

5.2 Fire Protection of High Value Property

The majority of the dollar value is concentrated in the WAH and the DAQ Room. During periods of maintenance, the STAR Detector is relocated to the AH. With over $30 million (replacement value) concentrated in the WAH, multiple fire systems have been installed.

The HSSD detection system on the STAR Detector, combined with the on-site Fire/Rescue Group, is considered the primary response system. This system will summon aid at the earliest practical stages (local alarms and signals to Fire/Rescue) and initiate protective actions (power off, vent/purge flammable gases, activate emergency ventilation in the WAH). Smoke detectors have been placed above the platform racks and initiate the same actions as the HSSD. Great effort was made during the design stages to keep the amount of combustibles low as reasonably achievable. To this end, printed circuit boards were FR4 (self extinguishing). Wires, cables, and materials were also specified as self extinguishing (see Section 3.3.5). The intent was to have materials that would self extinguish upon removal of power.

The most likely source of ignition on the STAR Detector is the power for electronics. To minimize the Detector loss potentials, a HSSD system was installed on the detector. The equipment is Underwriter's Laboratory Listed. Sampling ports and tubes were located to monitor electronics. Standard installation rules cannot be applied to a piece of equipment. Detection ports were placed based on air flow and ignition source location.

Response to the three level of alarms will be:
1) first level is local to The STAR Control room,
2) Second level alarms at The control room and at Fire/Rescue for an investigative response,

3) third level alarms are fire alarms, ringing building bells, sending signals to control room and Fire/Rescue, and initiating interlocks (shutoff electrical power to STAR WAH, vent/purge of detector, building emergency ventilation system).

Control and set points of the HSSD system are administered through the Site Fire Alarm System configuration control procedures.

A secondary level of protection is provided by the building's ceiling level HSSD system. It will detect a fire in the WAH/AH and start the same protective actions as the HSSD on the Detector.

A third level of protection will be provided by the Building's wet pipe sprinkler system. It is anticipated that this will only activate when a sustained fire occurs in the Detectors and all other controls have failed.

The primary and third level protective systems, described above, are installed to meet DOE's requirements for redundant fire system in high value areas.

The Data Acquisition Room has over $1 million worth of equipment. This room is protected by ceiling level smoke detectors. A wet pipe sprinkler system is also present. Due to the high value of several racks, additional fire suppression systems are provided. DAQ Room Rack Row "A" will have an Inergen system. The system will have smoke detection internal to the rack for early warning. Addressable fixed temp programmable detectors will also be mounted in each rack for clean agent release. Smoke detectors are programmed as "dual level" smokes. The first level provides a local audible alarm and notifies the Fire/Rescue Group of a low level alarm. The second level will shut down power in addition to setting off the building alarm system and notifying the Fire/Rescue Group of a second stage alarm. Rate compensated fixed temperature heat detectors release Inergen into the rack where detection has activated.

5.3 <u>Protection of Essential Safety Class Systems</u>

There are no essential safety class systems associated with this non-nuclear facility.

6. <u>Fire Loss Potentials</u>

Fire loss potentials are classified into three major categories; the maximum credible fire loss, the maximum possible fire loss, and the recovery potential. The loss potentials for the STAR Complex are expanded upon in sections 4.1 through 4.3, below.

6.1 <u>Maximum Possible Fire Loss (MPFL)</u>

The Maximum Possible Fire Loss (MPFL) for STAR is estimated to be $30 million (replacement costs). The event would include a fire in the Detector that burns and involves the Detector's central region. The steel for the magnet would not be damaged (insufficient heat release to damage 1,200 tons of steel). Coils would be damaged, and the two Field Cages would be lost. The fire is not likely to spread from the central region and onto the platforms. However the electronics on the platforms will experience some smoke damage.

6.2 Maximum Credible Fire Loss (MCFL)

A worst case, normal fire will result in the loss of a Detector sub system. Sustained burning of a portion of a system will result in upwards of $1 million in damage. The fragile nature of the SVT makes it the most vulnerable to complete damage, although it does not have the power nor the combustible mass. The recovery time for STAR damage would take several months. Portions of the STAR could be operated without certain subsystems. This would degrade the quality of the physics. STAR could be extracted from the WAH to allow resumption of other RHIC experiments.

6.3 Recovery

Recovery time from the MPFL would be several years.

Recovery time from the MCFL would be many months.

STAR could be extracted from the WAH, a beampipe installed, shield blocks replaced, and RHIC would be able to run. This operation would take a month or more.

7. Security Considerations Related to Fire Protection

There are no security considerations which relate to fire protection at this facility. Radiation Security barriers comply with the Life Safety Code for egress.

7.1 Exposure Fire Potential

The STAR Gas mixing operation and gas storage pads meet the National Fire Protection Association and Factory Mutual Loss Prevention Data sheets separation guidelines. They are not considered exposures of concerns to the main facility.

The electrical sub station to the north of Bldg. 1006A for experimental power and the "house" power from the sub station to the west meet the Factory Mutual Loss Prevention Data Sheet on electrical transformer yard separation. The emergency generator is separated by a two hour fire wall from the "house" transformer yard. These are not exposures of concern to Bldg. 1006.

Bldg. 1006C has a low combustible loading and the separation is sufficient to avoid damage to Bldg. 1006A.

The STAR Complex is located in the middle of the Pine Barrens. Pine trees and shrubs do pose a potential exposure to the insulated metal structures. Although the frequency of occurrences are very low, wildland fires are a possibility. While the roof systems will not ignite from burning brands produced in a brush fire, the metal walls will not provide a significant fire barrier. Distance is the key element for protection. A minimum 50 ft. distance (100 ft. for upward slopes) is required to protect the structure. The conditions are acceptable now. Efforts will be needed to maintain theses

8. Environmental Impact due to a Fire (Including Water Runoff)

Toxic, biological, and radiation incidents resulting from a fire, including water runoff, are analyzed in sections 8.1 through 8.3, below.

8.1 Toxic Incident

There are no known materials in the STAR Detector that, if involved in a fire, would result in a significant quantity of toxic material being created and released.

8.2 Biological Incident

Due to the lack of biological matter at this facility, an incident of this type is unforeseeable.

8.3 Radiation Incident

By the nature of the operations of the accelerator, various pieces of equipment can be expected to become activated. This activation is not expected to pose a significant environmental impact in the event of a fire since the material will not be easily disbursed.

For calibration of instruments, several small sealed calibration sources will be present. These sources do not have the curie content nor the physical state to be disbursed and contaminate large areas.

No other radioactive materials are used or stored in the STAR Complex.

9. Prefire and Emergency Planning

The BNL Fire Department maintains an adequate prefire plan book for this facility. "Hold Points" are defined so that the Fire/Rescue Group will wait until conditions are safe prior to approaching the facility.

A Local Emergency Plan is maintained by the Facility. It includes Control Room actions to take with various alarms.

9.1 Fire Apparatus Accessibility

Fire apparatus accessibility is adequate for the main facility. Current parking lot configurations allow access by apparatus in the event of an emergency.

10. Life Safety Considerations

Major life safety considerations for this industrial facility include the following components; means of egress components and capacity, number and arrangement of the means of egress, travel distances to exits, discharge from the exits, and emergency lighting and marking of the means of egress.

The likelihood of a fast spreading fire is remote, given the nature of P-10. No other substance poses a high fire hazard. Hence the facility is an "ordinary hazard special purpose industrial occupancy" by the Life Safety Code. The anticipated occupancy load is less than 25 people for the WAH. The WAH has three means of egress. Two exits are available through the two labyrinths.

A third exit is available through the east tunnel. The tunnel exit is required due to the Life Safety Code requirement for remoteness of exits. The tunnel exit has a radiation security gate that is crashable into the tunnel. The gate can be opened by pushing a hand through a clear panel and turning a knob. Personnel in the area are trained in the use of these standard gates and can easily operate them. While this arrangement is not clearly defined in the Life Safety Code, it meets the intent of an easily operated mechanism. The exit widths are sufficient to accommodate the occupant load.

The AH has two means of egress, one from the east side and one from the north west. Occupancy of this area is more routine and more populated. Maximum occupancy is not expected to exceed 100. Exit widths are sufficient to accommodate the occupant load.

The Mezzanine in the AH is a restricted area. A maximum of five people is expected at any one time. Only authorized personnel are permitted. This area has two exits due to the common path of travel requirement. The east exit discharges onto a platform. From the platform, a ladder brings the people to grade. The Life Safety Code allows ladders for use by three or less people. The ladder conforms to ANSI requirement.

Lighting for all areas is on the Bldg. 1006A's emergency generator.

FIRE HAZARD ANALYSIS 1008
(PHENIX)

September 1998

Fire Protection Assessment / Fire Hazard Analysis
Building 1008, 1008A, PHENIX Experimental Complex
Brookhaven National Laboratory

Prepared by: J. Levesque

Reviewed by: J. A. Eckroth

Project Concurrence: M. Marx

Date of Survey: Various to September 4, 1998

Date of Report: September 4, 1998

Conferred with: Michael Marx, PHENIX Deputy Project Director
William Mc Gahern, PHENIX Safety Coordinator

Purpose/Scope

The purpose of this assessment is to comprehensively and qualitatively assess the risk from fire within the PHENIX Complex at Buildings 1008, 1008A, 1008B, and 1008C, to ensure DOE fire safety objectives are met. The assessment includes the risks from fire and related hazards (direct flame impingement, hot gases, smoke migration, fire-fighting water damage, etc.). DOE fire protection criteria are outlined in DOE Order 420.1[1], Chapter 4. The Fire Hazard Analysis, required for the Safety Analysis Document for this facility, is incorporated into this assessment.

Summary

The current and proposed uses of Buildings 1008 and 1008A for the PHENIX Physics Experiment have been analyzed. These descriptions are based on field surveys, a review of the planned and completed installations, and discussions with PHENIX Project staff. This FHA describes the achievement of a reasonable and equivalent level of fire safety to meet DOE 's "Improved Risk" objectives.

Recommendations:

1) The EM Calorimeters and ToF regions should be provided with a clean agent fire suppression systems prior to use of flammable gases in the Detector. An alternative would be to inert the enclosures. These units contain photo multiplier tubes (an ignition source), significant combustibles that are not self extinguishing (cables, scintillating plastics, plastic PMT Hoods), and the Detector configuration can burn without the ability to manually mitigate a fire (enclosed, mounted off the floor). While several hundreds of thousands of dollars of damage can occur in a fire, this situation can lead to flammable gas involvement and an ensuing explosion.

2) The regions below the Detector should be examined and methods developed to ensure heavier than air flammable gas do not accumulate.

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[1] US Department of Energy Order No. 420.1, Facility Safety, 11/16/95

3) The PEH ceiling area should be studied to determine if methane can accumulate from the P-10 and form an explosive mixture. If so, methods to vent the accumulations should be developed prior to use of lighter than air gases.

4) With the normal lighting being one of the system de-energized upon detection of flammable gas, and personnel being allowed into the PEH with flammable gas in the detector, Class I Division II lighting should be installed to provide safe egress for occupants upon gas alarms prior to use of combustible gases.

5) The $10 million of equipment in the Rack Room should be evaluated for a clean agent fire suppression system.

6) The blue stone road up to Bldg. 1008D and 1008C should be made more substantial to allow fire apparatus to respond during inclement weather.

Analysis

1. Scope

This review includes the experimental facilities and support structures for the PHENIX Experiment at the Relativistic Heavy Ion Collider (RHIC), located at Brookhaven National Laboratory (BNL). The buildings associated with PHENIX are Bldg. 1008 (Assembly Hall and Experimental Hall), Bldg. 1008A (Control Room, Technical Support Building), Bldg. 1008B (Mezzanine only) and Bldg. 1008C (Pump Room). Excluded are the RHIC Accelerator systems (Tunnels, Cold Box in Bldg. 1008B).

1.1 <u>Construction</u>

The PHENIX Complex is located in the northern region of Brookhaven National Laboratory (BNL), in the RHIC Collider site. BNL is a 5,000 acre site owned by the Department of Energy and operated by Brookhaven Science Associates. BNL is located in Upton, New York.

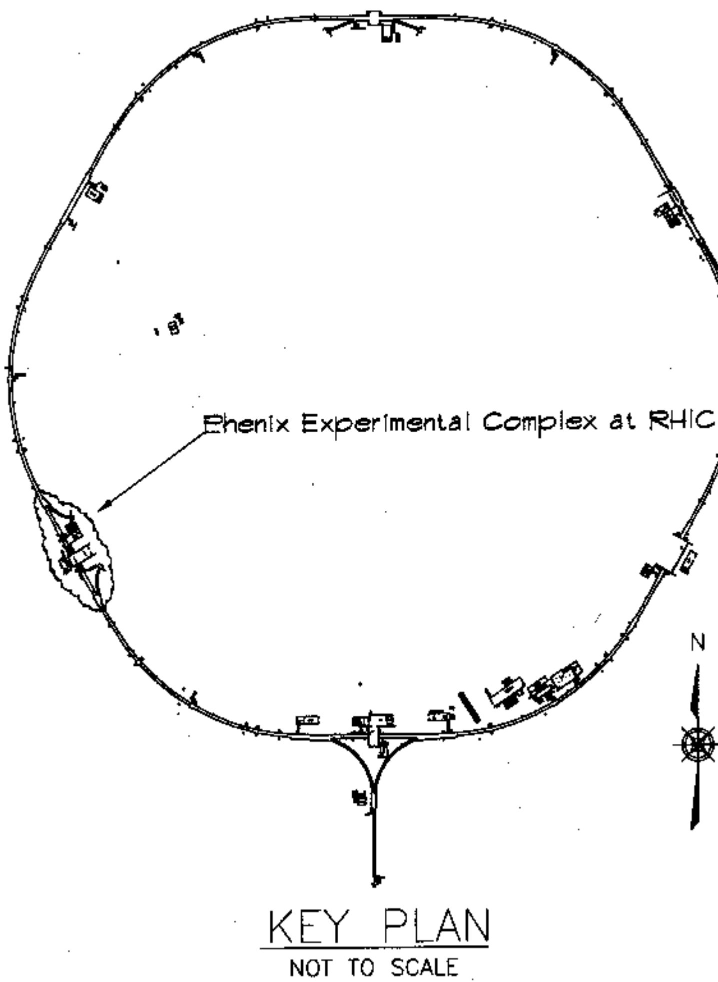

Figure 1 Location of PHENIX Experiment at RHIC

1.1.1 <u>Bldg. 1008 PHENIX Experimental Hall (PEH, See Figure 2, 3, 4)</u>
Building 1008 is a one-story, 11,400 sq. ft. building, built in 1981. The facility is set astride the RHIC accelerator tunnel, facing Ring Road on the interior of the RHIC Ring. Bldg. 1008 has two parts, the Interaction Region (IR) is 50 ft. high, and the Assembly Hall (AH) which is 60 ft. high. The IR is the western portion of the facility and is set back into the earth. Floors, walls, and ceiling are made of reinforced concrete. A fifty foot high, 5 ft. thick shielding block wall separates the IR from the AH. The shield wall has one emergency exit. One normal exit is provided by a removable plug door. The north and south walls both have one 900 sq. ft. (approximate) opening that communicate to the RHIC Accelerator Tunnel. In front of these openings are five metal plates, each several inches thick, and each exceeding the opening's area in size (35 ft. by 43 ft.). They are part of a Detector sub system called Muon ID. A 10 inch air gap is provided around the opening to the vertically mounted Muon ID Plates. Through the center of the five plates, approximately a 5 ft. by 5 ft. opening is present. A cryogenic magnet and beam pipe brings the Heavy Ions into the experimental hall via these openings.

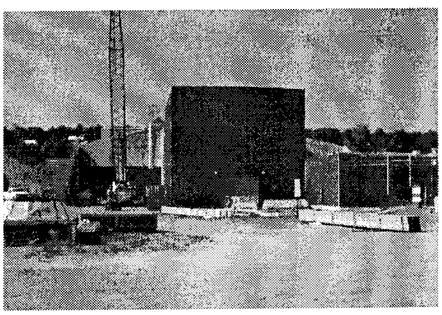

FIGURE 2 View of Bldg. 1008 looking from the east.

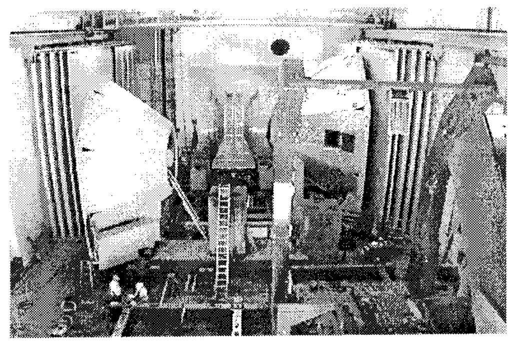

Figure 3 Interior of IR during detector construction. Muon ID Plates are to left and right.

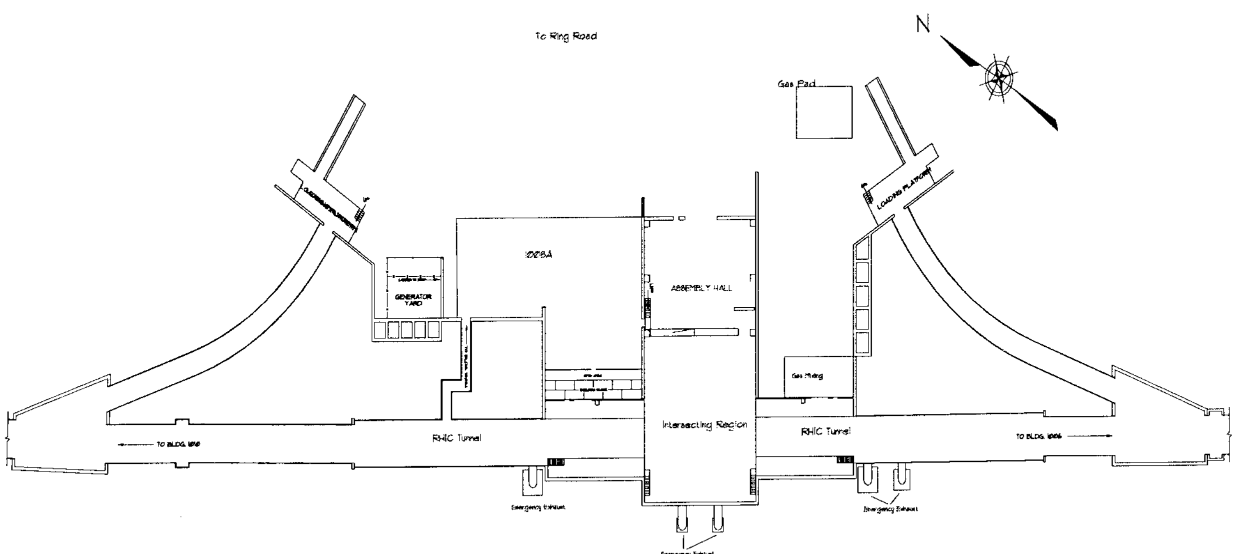

FIGURE 4 Layout of PHENIX Complex (1008B and 1008C not shown, they are south west of the tunnel).

The AH is in the eastern portion of the facility. It is used as a staging area for equipment entering the IR. The walls are made of fiberglass insulated metal sandwich panels. Roof construction is Class I by Factory Mutual Standards. The floor is reinforced concrete.

1.1.2 <u>1008A</u>
Adjacent to the north side of Bldg. 1008 is Bldg. 1008A. Building 1008A is a one-story metal framed and sided building with a standing seam metal roof. Roof construction is Class I by Factory Mutual Standards. Total floor area is approximately 7,600 sq. ft. There are two portions of the facility. The Counting House is the newly constructed southern half (5,700 sq. ft. built in 1997). The Support Building is the original northern half (2,800 sq. ft. built in 1981). The original part of 1008A resides on the north side. The newer portion of Bldg. 1008A fills the 107 by 52 ft. area between the 1008 and the original 1008A. The interior of Bldg. 1008A Counting House has a steel framed gypsum wall. Fire rated sheetrock was used on the interior side.

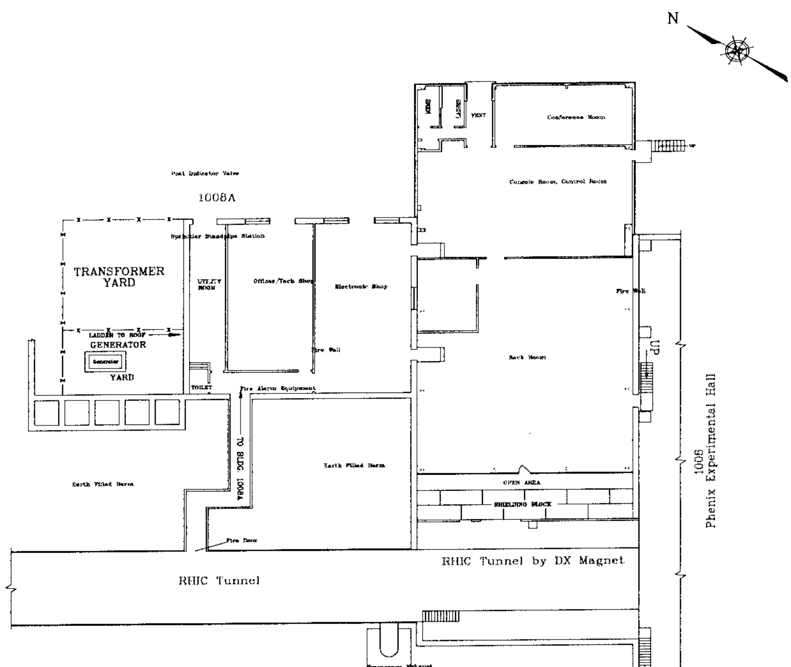

Figure 5 Bldg. 1008A and adjacent area.

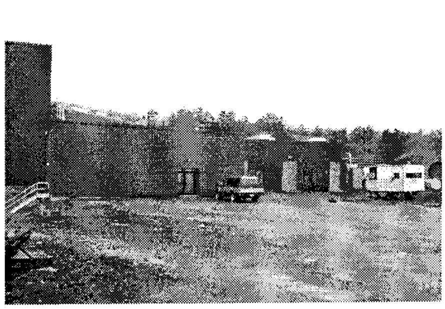

Figure 6 Exterior view of Bldg 1008A looking from the east. Bldg. 1008 PEH is on the left side.

1.1.3 Bldg. 1008B
Bldg. 1008B is a 3,200 sq. ft. free standing structure on the outside of the RHIC Ring at the eight o'clock sextant. The structure is one story, 20 ft. high, prefabricated insulated metal building, built in 1995. A metal framed mezzanine has been installed, on which PHENIX magnet power supplies reside. An interior one-hour fire rated room has been constructed to house pump controllers, vacuum controllers, and similar instrumentation. Roof construction is Class I by Factory Mutual Standards. Interior finish has a Class A flame spread rating.

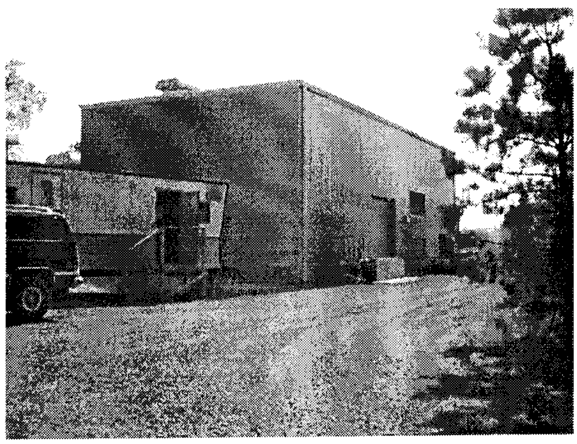

Figure 7 Exterior view of Bldg. 1008B looking from the north west.

1.1.4 Bldg. 1008C
Bldg. 1008C is a 1,125 sq. ft. free standing structure on the outside of the RHIC Ring at the 8 o'clock sextant, just south of Bldg. 1008B. The structure is a one story, prefabricated insulated metal building, built in 1997. The floor is reinforced concrete. The facility houses water treatment, water circulating pumps, and cooling tower controls for PHENIX. An induced draft, prefabricated, metal cooling tower is located south of this structure.

1.1.5 PHENIX Gas Mixing House and Gas Pad
The Gas Mixing House is a prefabricated, 2 hour fire rated, storage facility. It is approximately 500 sq. ft. The unit is typical of a "Haz Store" structure. To the east of the Shed, PHENIX has an open air pad for gas cylinder storage. Cylinders are stored and connected to manifolds on a concrete pad. Metal racks are provided for securement of cylinders.

1.2 Fire Barrier Integrity

Bldg. 1008A is separated from the RHIC Tunnel by a two hour fire rated assembly. The labyrinth is made of reinforced concrete, covered by 15 ft. of earth, and has a rated fire door where it enters Bldg. 1008A. Cable penetrations are sealed. This barrier is required by the Life Safety Code (horizontal exit requirements associated with the RHIC Tunnel travel distance). Also this barrier isolates the high value tunnel equipment from the control room and tech shop areas.

The IR houses the majority of high valued equipment (greater than $50 Million in value). The RHIC Tunnel opens to the IR on the north and south sides. Several tons of steel are in front of this opening, but it does not provide a barrier (see section 1, Bldg. 1008 PEH).

Normally a fire barrier would be expected to segregate the high value magnet strings in the tunnel from the PHENIX Experiment. Due to the configuration of the beam transport system and the IR, a fire rated barrier was not installed. Mitigating features to allowing this condition are as follows:

1) low combustibility of the contents and structure in the RHIC Accelerator Tunnel (see RHIC SAD),
2) spot smoke detection in the tunnel,
3) redundant spot heat detection in the tunnel,
4) heat detection and preaction sprinkler system in the IR (area of some combustibles),
5) HSSD smoke detection in the IR at the ceiling level,
6) low pressure of flammable gases in the IR (no significant flame impingement from a leak),
7) limited volume of gas in the IR (limited burn time),
8) shielding effect of the Muon Steel Plates from the PHENIX gas systems
9) a vapor barrier for the liquid helium oxygen defiency hazard, acts as a smoke barrier, segregating the tunnel sections from the IR on both sides
10) the RHIC tunnel has a emergency smoke ventilation system, activated by tunnel smoke detectors,
11) the IR has an emergency ventilation system independent from the RHIC tunnel system.

This is a deviation from the DOE requirement to isolate high value equipment with fire rated construction. By way of this document, an exemption request is being processed.

The PHENIX Control Room is located in Bldg. 1008A. The wall between the AH and the Counting Room is a fiberglass insulated metal panel with framed fire rated gypsum board walls on the Counting House side (IR has reinforced concrete walls). This construction does not meet the standard one hour fire rated construction required by DOE's Standard on Fire Protection for Electronic Data Processing Systems. However the assembly is equivalent, given the insulative qualities of the metal panels and the existence of sprinkler protection on both sides of the wall.

Bldg. 1008B has a one hour fire enclosure in the first floor's South West corner. There are no deficiencies with this barrier.

1.3 Windstorm Damage Potential

The portions of Bldg 1008 and the seamed steel metal built up roofs of Bldg. 1008A, 1008B, and 1008C are in good repair. The roof for the new Counting House meets Factory Mutual I-90 rating from windstorm resistance.

Portions of the PHENIX Experiment have gas filled chambers. These chambers have thin windows, typically 5 mil Kapton (the TEC is 1 mil). These chambers operate at pressures slightly over atmospheric pressures. The gas system design is capable of accommodating rapid pressure drops due to storms. For large chambers, buffer volumes are provided to provide prompt supplies. Although hurricanes posses the highest wind speeds, the "Northeaster" storms have demonstrated that they produce the quickest pressure drops. The worst storm in BNL's 40 year history produced a ½ inch water column drop in ½ hour. This was used as the design basis. Details are provided in the RHIC Experimental Review Committee files.

2.0 Occupancy and Associated Fire Hazards

2.1 The IR
The IR will house the PHENIX Detector. This detector is a physics experiment. Two heavy ion beams from RHIC will collide in the middle of the hall. The detector, and its multiple systems, will monitor the events that develop. Various systems are used to track these interactions. Six of the eleven systems at PHENIX that have gases mixtures with flammable components. The largest being the RICH Detector, with two chambers containing 40 m^3 of pure ethane each. These large quantities of flammable gases are housed in thin windowed pressure vessels. Typically the windows on these vessels are Kapton, with a thickness of 5 mils. Maximum operating pressures are ½ inch water column. Based on these hazards, the area is considered a "high hazard industrial occupancy" (by the Life Safety Code) due to the likelihood of a quick developing fire (Note: the quantity and pressures are low, an event will stay local and is not expected to be of a long duration). Based on this Life Safety Code classification, two exits are required with no dead end distance. The placement of the doors is sufficiently separated (i.e., ½ D) to qualify for remote exits. By using the removalable plug door for all access, the project will ensure that two exits are available when ever the IR is entered.

The electronics on the PHENIX Detector is the main potential source of ignition. The cabinets on the Carriages will be pressurized with air to prevent infiltration of combustible gases.

During the design of the sub systems, efforts were made to reduce the combustible ratings of the equipment. The electronics and cable within the PHENIX Detector have been selected to be low combustibility and self extinguishing (FR4 printed circuit boards, IEEE 383 rated cables, Underwriter's Laboratory listed cables for National Electric Code plenum/riser/general use applications, IEC 332-2/UL1581 VW-1 ratings; see RHIC Cable SEAPPM and RHIC Experimental Safety Review Committee meeting notes for details). Removal of electrical power has a high probability of resulting in self extinguishment (early detection and early power off).

Electronic circuit boards that are in the racks attached to the Detector's Carriages are housed in cabinets pressurized with fresh air from outside the PEH to prevent the infiltration of flammable gases (compliant with the National Electrical Code for flammable gas ignition prevention). The pressurization of the cabinets by air for the purging will be monitored and interlocked to the cabinet power. Although the contents of the each rack will be less than $100k, smoke detection is being provided within each enclosure. Smoke detection will be interlocked with the individuals rack's power. This will minimize the size of an event on the Carriages, which are closely located to the Detector and its flammable gases. There is a possibility that the Project may arrange the cabinet pressurization system to supply nitrogen when the cabinet fire alarm systems activate. This is optional and may provide a benefit if the cabinet can be flooded with 30 to 50% nitrogen within a reasonable time.

Electronics around the RICH windows (the largest flammable gas source) and Pad Chambers will be purged with nitrogen for cooling and inerting. Other electronics in the Detector will be within a region potentially exposed to flammable gases during an accident. Combustible gas detection will sample areas in the expected leak path from subsystems containing flammable gases. In the event of a detected leak in the range of 25% of the lower explosive limit, power will be shutdown to the Detector and a purge/vent protection action will be started (power off to the detector, turn on IR emergency exhaust system, purge chambers with inert gases, vent combustibles gases to exterior through the High Capacity Vent Stack).

Ceiling Level and Floor Level gas detection will be provided in the PEH. These two systems are intended to detect accumulations of flammable gases minute leaks. Minute leaks may not active the Detector flammable gas detection systems, but the gases may accumulate at collection points, to levels above the explosive limits. At 25% of the Lower Explosive Limit the PEH flammable gas detectors will initiate the PEH's emergency exhaust fan system and remove power from all non-explosion proof devices in the PEH.

This protective arrangement within the PEH is considered equivalent to the Class I Division II electrical equipment rating required for occasional exposure to combustible gases. The specially fabricated electronics cannot be rated for Class I Division II environment due to the experimental physics requirements and impractical nature of fabricating explosion proof detector electronics. Time and cost of the testing by nationally recognized testing laboratory is prohibitive.

The design intent for the HSSD system within the detector senses a board fault as it develops smoke. The ignition source is limited by over current protection. Most designers selected Polyfuses, a semiconductor device that stops current flow at twice the rate value. It requires all power to be removed before it will reset. Board level fusing limits fault conditions to a maximum of 80 watts (a number developed during the RHIC Experimental Safety Review Committee meetings).

The notable exceptions to the flammability control policy were the EM Cal arrays (Lead Scintillator and Lead Glass) and Time of Flight (ToF). The high density plastic scintillator (polymethyl methacrylate) in the Lead Glass EM Cal is in the form of 4.4 inch squares, .2 inches thick. Each square is sandwiched between lead plates of the same size. The square are stacked to approximately 20 inches deep and wrapped in a thin stainless steel housing. This reduces the plastic's likelihood of being the first material ignited. Since plastic melts and then burns, the Lead Glass plastic will contribute fuel to a established fire.

The Lead Glass Array reused existing equipment that contained plastic hoods and unrated cables. These detector sub systems are on the exterior of the east and west carriage arms and are contained in large metal boxes. The hoods and cables represent significant quantities of flammable materials. The ToF, located directly in front of the Lead Glass, contains Photo Multiplier Tubes mounted directly to plastic scintillator. This arrangement provides a potential ignition source directly connected to a significant fuel source. These are ideal application for a clean agent suppression systems (see recommendation 1).

Emergency exhaust ventilation is provided for the IR via one 54 inch exhaust duct is located high on the back (west) wall (visible in Figure 5) as a 37,000 cfm supply source. A second 54 inch exhaust duct is located low on the back wall and is an exhaust. Both have non-sparking fan blades and motor out of the air stream. When the emergency exhaust system is activated, dampers close off an HVAC system that uses the duct work and activate supply and exhaust fans. The flow will provide one air change every three minutes. The design using low exhaust is suitable for equal or heavier than air gases. It is not ideal for smoke removal, but it is adequate. The quantities of lighter than air gases are limited and generally involve methane (from P-10). P-10 (10% methane, 90% argon) is a non-flammable gas by Department of Transportation classifications. It requires the slightest dilution in air to become locally non-flammable (Department of the Interior, US Bureau of Mines Bulletin 627, Flammability Characteristics of Combustible Gases and Vapors, 1965). The methane in P-10 can diffuse out and collect in the well sealed IR. A method of dissipating methane is being examined. It will be presented to the RHIC Experimental Review Committee and approved prior to using lighter than air flammable gases (see recommendation 3).

The emergency exhaust duct discharge discharges above the IR, on top of the radiation shelding berm. Ignition sources have been excluded from an volume 5 ft. in all directions from the vent. Ignition sources have also been excluded for the region 36 inches above the grade.

The emergency exhaust system provides one air change evey six minutes. This exchange rate will exhaust smoke and combustible gases (fans are non-sparking; motor is out of the air stream). The liquid/gaseous helium hazards from the tunnel are segregated by a vapor barriers in both tunnels adjacent to the Muon ID Plates. The RHIC Personnel Access Safety System (PASS)[2] is used to activate the ventilation system. PASS receives alarm signals and outputs interlock commands. Since the emergency power generator cannot sustain the start up current draw when all fans active at the same time, fan start up in staggered.

Normal IR ventilation utilizes the emergency ducts to reach the air handlers above the roof berm. Dampers "fail-safe" to purge configurations. The normal ventilation system will be provided with fresh makeup air at the rate of 1500 cfm. Methods will be developed to ensure circulation of air past any potential collection points below the Detector (see recommendation 2).

Duct smoke detectors have not been installed in the normal air handling system. The HSSD area smoke detection system is interlocked to shut down normal air systems and initiate emergency ventilation systems. This complies with National Fire Codes NFPA 90A, Chapter 4. However, due to the complexity of the air handler system logic and control in the IR, interlocks are handled through several control systems, and are not in strict compliance with National Fire Code 72 supervisory requirements regarding fan shutdown circuits. Periodic testing of the circuits will be conducted as part of the normal Fire Protection System Inspection Test and Maintenance Program.

2.2 <u>The AH</u>
The Assembly Hall is used for staging and as an assembly area for the various PHENIX Detector sub systems (sub systems assembled and check elsewhere, construction of sub system arrays done in AH). The AH has not been provided with the protective systems that would enable sub assemblies to run will full inventories of combustible gases. The AH's fire hazards include all elements present in the IR, except for the use of flammable gases. Small quanitities of flammable gas mixtures maybe allowed with the review and approval of the RHIC Experimental Safety Review Committee.

2.3 <u>Bldg. 1008A</u>
Bldg. 1008A is used as a control facility and houses the support services (Data Acquisition, control electronics, laser calibration, control room, console room). The Rack Room will be occasionally occupied. The Control/Console room will have operators and support staff on a frequent basis. The primary fire hazards associated with these operations are high value/critical electronic equipment. Approximately $10 million of equipment will be housed in the Rack Room. Control consoles are valued at less $300,000. The Rack Room and Control Room occupancy is considered an ordinary industrial facility by the various fire codes.

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[2] PASS is a PLC based control system used for all personnel safety functions, including radiation safety and oxygen deficiency safety. See the RHIC SAD for details on this safety system.

2.4 Bldg.1008B

An interior one-hour fire rated room has been constructed to house pump controllers, vacuum controllers, and similar instrumentation (valued at less than $500k). PHENIX has several power supplies on the a metal frame, metal deck mezzanine. There are three supplies (potentially a fourth in the future), valued at approximately $100k each. They are similar to the RHIC Accelerator Supplies (dry transformers, electronics). These supplies are "off the shelf", custom configured for voltage and amperage delivery. The remainder of the facility is a RHIC "Cold Box." This is the power supply transition point from warm to cryogenic buss for the RHIC Accelerator Magnets in the RHIC Tunnel. The facility is a low hazard, industrial facility.

2.5 Bldg. 1008C

Bldg 1008C is used for a pump house and water system supporting PHENIX. Circulating pumps and deionizes for the cooling water systems are present. A prefabricated metal cooling tower is present to the South. This is a low hazard, industrial occupancy. No high value equipment is located in this structure.

2.2 Critical Process Equipment

The PHENIX Detector is divided into 11 Detector sub-systems, which are not all required for the experiment to produce useful data. The Beam-Beam Counter supplies timing information for several other systems. It is also one of the least expensive and easily replaced sub systems. The remaining systems are needed in different combinations to support various aspects of physics investigation. Except for MVD and ToF, each subsystem consists of at least two components located on opposite sides of the Detector. Typically these separated portions can support the physics experiment without all units on-line (i.e., the West carriage EM Cal can support the program without the East carriage EM Cal). Each Detector subsystem has spares for electronic readout components, but in no case are their sufficient spares to replace the entire subsystem.

The Support Systems (such as Magnets, cooling water, electrical power, gas supply, gas vent) are required for PHENIX operations. The majority of components in these systems are common and easily deliverable. Custom parts do have spares. The major exceptions are the large Central, North, and South Magnets, including their coils. It is impractical to have spares for these massive devices. Concurrently, it is unlikely that an event will inflict significant damage to these devices.

2.2.1 Special Occupancies

Special occupancies include electronic data processing and vital/important records. The special occupancies of PHENIX and Bldg. 1008 are expanded upon in sections 2.2.1 and 2.2.2, below.

2.2.1 Electronic Data Processing

The control equipment associated with the operation of PHENIX is located in a control room in Bldg. 1008A. Dollar values for control equipment and data acquisition equipment in the rack room approach $10 Million. The facility is a non-combustible construction, segregated from other occupancies by one hour fire walls, provided with smoke detection, and protected by a preaction sprinkler system. This arrangement poses an acceptable risk.

2.2.2 Vital and Important Records Storage

Vital records are those records which are essential to the mission of an important program and which, if lost, could not be reproduced or obtained elsewhere. Important records are those records possessing a high value to the mission of an important program but which, if lost, could be reproduced or reconstructed with difficulty or extra expense.

Based on the above definition, the data collected from the experiment is vital. This information is collected by the facility and transmitted to the RHIC Computing Facility in Bldg. 515, Brookhaven Computing Facility (separate facility several miles away, connected by computer network). This is no on-site storage of data. The petabytes of data are the subject of another analysis.

2.3 Unique Fire Hazards

Unique fire hazards include; modular buildings, trailers, cooling towers, flammable liquid and gas storage, cable trays, housekeeping in vital areas, and highly combustible building materials. The unique fire hazards at the PHENIX Complex are expanded upon in sections 2.3.1 through 2.3.7, below.

2.3.1 Modular Buildings

Currently there are no funded plans for additional buildings around PHENIX. If facilities are provided, they will comply with DOE Orders on separations, construction, and protection.

2.3.2 Trailers

See 2.3.1.

2.3.3 Cooling Towers

The experiment has a water based heat removal system. One cooling tower is located to the south of Bldg. 1008C. The unit is metal, prefabricated, and serves the PHENIX Magnet Systems. There is no fire exposure concern.

2.3.4 Flammable Liquid/Gas Use and Storage

Six of the Sub Systems at PHENIX use gas mixtures containing flammable gases. Their inventory represent significant hazards. A study was performed to analyze the potential for damage (Design Basis Accident[3]). The Analysis assumes the release of the full inventory of all gas systems (unlikely due to the separation of gas systems and their low pressures) and forms a homogenous cloud prior to ignition. The events postulated do show that the damage does not involve areas outside of the normally unoccupied PEH area and only minimally affects in the AH. Refer to the PHENIX SAD for details.

3 Explosion Analysis for the RHIC PHENIX Detector, July 1998, RHIC/DET Note 27, PHENIX/Tech Note 354, by Dr. G. Ciccarelli

The following is an inventory of flammable gases used:

Detector	Gases Used	Total Detector Volume (m^3)
Drift Chamber (DC)	Ar/C_2H_6 (50%/50%)	5.6
Pad Chambers (PC)	Ar/C_2H_6 (50%/50%)	1.12
Time Expansion Chamber (TEC)	Ar/CH_4 (90%/10%)	11.5
Ring Imaging Cherenkov Counter (RICH)	C_2H_6 (100%)	80
Muon Tracker (Mu Tr)	CF_4/C_4H_{10} (50%/50%)	2.92
Muon Identifier (Mu ID)	CO_2/C_4H_{10} (91%/9%)	59

The RHIC Experimental Safety Review Committee has examined the design and installed configurations of the Detector and its sub systems.

Release of gases into the IR have be addressed by:
1) flow limiters in supply lines and limitations on quantities for flammable gas systems,
2) solid metal piping from the supply to the Detector's distribution systems (with the exception being at the base of both carriages and the Muon Magnet System where a flexible pipe is used),
3) requirements for leak checking of piping systems,
4) Detector chambers are designed to ensure window integrity (burst safety factor)
5) pressure tests that assure chamber construction meets design boundary limits,
5) designs that "fail-safe" with loss of power (i.e., purge of flammables with inert gases),
6) combustible gas detection in the regions where gas could be released and could collect,
7) highly sensitive smoke detection to promptly indicate off normal conditions,
8) interlocks to shut off all power to the Detector in the event of fire alarm conditions from within the Detector (Detector purge/vent is also started),
9) fusing of power distribution system on printed circuit boards within the PHENIX Detector to limit max front end power dissipation potential (normally under 80 watts),
10) mechanical protection for chamber windows that may expand during over pressurization and contact electronics,
11) continuous purging of the interstitial space between Pad Chambers, Front End Electronics and RICH windows with an inert gas,
12) continuous purging of electronic racks and AC power distribution panels with fresh air to prevent flammable gas contacting non-rated electrical equipment,
13) normal ventilation in the IR to dissipate combustible gases ("normal leakage"),
14) high rate purge, activated with interlocks, in the IR to dilute and remove released gases,
15) monitoring of oxygen content of flammable detector gas in the detector system,
16) for all new equipment brought into the interior of the IR, Class I, Division II criteria was imposed for classification of electrical devices (existing circuits were not retrofitted, but dilution over the travel distance from the devices to the source makes these devices unlikely ignition sources).

The quantitly of flammable gas is of particular concern. The PHENIX Project study on the explosion potential from the flammable gas used (See PHENIX SAD) looked at several cases of accident. Under "ideal" conditions severe damage could occur to the entire contents of the IR.

The vent/purge time of the Detector's larger flammable gas chamber is complicated by the window chamber relief pressure of 3/4 inches of water column, the distance and height of the vent stack through the radiation shielding, and the density of the gas.

Normal venting of excess Detector gas occurs through a system called the Low Capacity Vent Stack (LCVS). Gas lines terminate within a exhaust duct, located in the soil, on the outside back wall of the IR. A ventilation fan forces a draft up the vent stack from the bottom. The fan is monitored for flow. The fan's cfm dilutes the gases below their lower explosive limits by at least a factor of four (assuming maximum flow from the vent lines). The LCVS vents above the radiation shielding, above the roof.

Emergency venting of the Detector gasses occurs through a second system called the High Capacity Vent Stack (HCVS). The Detector is connected to a 4 ½ inch O.D. header and then to a 30 inch stack which travels in the soil up the outer wall of the IR to above the roof's berm. The system has a fan mounted on the top of the vent to induce a flow by aspiration. This arrangement requires 3 to 4 hours in order to effect several air changes and ensure concentrations less than the lower explosive limit in the detector. Studies have been done to model the Detector/Vent system. This is the fastest and safest flow achievable without rupturing the Detector's fragile Kapton windows.

The Gas Mixing House will contain flammable gas cylinders, connected to supply manifolds. Connects are made here often, therefore the room has been classified as a Class I Division II area for electrical equipment.

2.3.5 Cable Trays

High voltage, low voltage, control, and signaling cables are segregated in accordance with NEC requirements throughout the PHENIX Complex. The cabling is located in conduits, raceways and cable trays. In most instances, the cables provided in the cable trays meet the RHIC flammability test criteria (IEEE 383, VW-1, NEC rated wire for cable trays). Automatic sprinkler protection is provided in the PEH, Rack Room and control room.

2.3.6 Housekeeping in Vital Areas

For this high value facility, good housekeeping and control of combustibles will be essential. Internal self inspection will be routine and an aid in evaluating the effectiveness of the program.

2.3.7 Highly Combustible Building Materials

No significant amounts of exposed polystyrene insulation or other highly combustible building materials are used in the construction or operations at the PHENIX Complex.

3. Fire Protection/Suppression Features

3.1 BNL Infrastructure Fire Safety Support Systems

3.1.1 Site Water System

BNL has a combination domestic and fire protection water supply system. The system is supplied by several deep wells and is stabilized by two elevated water storage tanks (one 1 million gallon and one 350,000 gallon capacity). The wells have electric primary drivers and a limited number have backup internal combustion drivers. The system can sustain three days of domestic supply and a maximum fire demand (4000 g.p.m. for 4 hours) for BNL with two of the system's largest pumps out and one storage tank unavailable. The piping distribution network is well gridded. Water supplies around the RHIC Ring Road are fed from two well separated connections to the BNL system. Ample valves provide isolation in case of a main break. Static water pressure to the PHENIX complex is typically 70 psi. Water supplies to Bldg. 1008 and 1008A are capable of suppling 1,700 g.p.m. with 60 psi residual pressure. Supplies to 1008C are similar.

Fire hydrants are provided within 300 ft. of each facility. Frost proof hydrants are needed since the frost line extends to 4 feet below the surface in the winter. BNL and the local Suffolk County Fire Departments use National Standard Thread couplings.

BNL's Plant Engineering Division maintains the water supply system. BNL's Fire/Rescue Group conducts valve inspections on the distribution system to ensure reliability of firefighting water supplies.

3.1.2 BNL Fire/Rescue Group

The BNL Fire/Rescue Group is a full time, paid department. Minimum staffing is five firefighters and one officer per shift (Fire/Rescue Staff & Organization). The firefighters are trained to meet Firefighter Level III by International Fire Service Training Association standard , National Fire Protection Association (NFPA) Fire Fighter Level II standard, and (NFPA) Hazardous Material Technician Level and they are Suffolk County Certified Confined Space Rescuers.

The BNL Fire/Rescue Group also provides emergency medical services to an on-site population of 3200 people. A minimum of two members per shift hold New York State "Emergency Medical Technician - D" certifications ("D" is for defibrillation). Normally all five firefighters have EMT status. The Group operates a New York State Certified Basic Life Support ambulance (a 1988 Wheeled Coach Type I on a Type III Chassis). Medivac services are available to BNL via the Suffolk County Police Department (a training session).

Additionally the Group has two 1500 g.p.m. "Class A" Pumpers, one Rescue Vehicle for initial hazardous material incident response and heavy rescue operation, one Command Post Vehicle, one 5 ton military chassis converted to a Long Island Style Brush Truck.

The single Fire Station is on the west side of the Site. Response time to the most remote section of the Site is less than eight minutes (assuming the Fire/Rescue Group is not on another emergency call). RHIC represent one of the most remote areas. Future plans may reduce this response time to less than 4 minutes with the addition of an access road from Upton Road to Ring Road.

BNL participates in the Suffolk County Mutual Aid Agreement. This allows the resources from over 130 departments to assist BNL. BNL is also a member of the Town of Brookhaven Foam Bank and Town of Brookhaven Hazardous Material Mutual Aid Agreement.

3.1.3 Site Fire Alarm System
Brookhaven National Laboratory provides central fire alarm station coverage by an Underwriter Laboratory listed multiplexed Site Fire Alarm System. The system is a Wormald System 1000, installed in 1987 (Wormald is now know as Grinnel Fire System). The system complies with the requirements of NFPA 72 for a Style 7D System.

The system uses the existing site telephone cable plant. RS232 signals are sent via full duplex line drivers. Each fire alarm panel has two channels connected to the Central Station. The panels are divided into 7 communication "loops." The system can monitor more than 20,000 points. It is currently monitoring 3,800. Response time from alarm at the panel to alarm indication at the Central Station is less than 10 seconds, which is well within the 90 seconds allowed by NFPA 72.

The main console is at the Firehouse, Bldg. 599. This station monitors all fire alarm signals, trouble and communication status alarms. A satellite station is provided at Safeguards and Security, Bldg. 50, and receives only the fire alarm signals. If the Firehouse does not acknowledge an alarm within 90 seconds, the satellite station at Bldg. 50 will receive an audible indication to handle the alarm. A second satellite station is provided at AGS Main Control Room, Bldg. 911, and receives only the fire alarm signals from the RHIC/AGS accelerators buildings. A team of operators and Health Physics Support personnel respond during accelerator operating times.

3.1.4 Fire Extinguishers
Fire extinguishers have been installed throughout the facilities in accordance with NFPA 10. Clean agent units are installed in the IR, AH, and Rack Room. Multipurpose units are installed in the other conventional areas. Although the distribution of these units meet NFPA 10, the access to burning materials within PHENIX will be difficult, if not impossible, with hand held units (height of equipment, depth and density of equipment). Attempts to acquire streaming type Wheeled Clean Agent units have not been successful.

3.2 PHENIX Experimental Hall

3.2.1 Highly Sensitive Smoke Detection System (HSSD)
To provide early warning in both the Intersecting Region and the Assembly Hall, the PHENIX PEH is provided with a Highly Sensitive Smoke Detection System (HSSD). The ceiling heights in excess of 50 ft. prompted the need for a detection system with greater sensitivity than the standard spot type of detectors. The air aspirating type of detection has a ceiling mounted network of pipes. The sampling ports have been designed in accordance with the manufacturer's Underwriter's Listing. The ceiling piping has been labeled with orange pressure sensitive "Fire Alarm" labels. Sampling ports have been marked with blue tape. The system has been tested to verify conformance with design response time. Twenty four hour battery backup and emergency generator power has been supplied.

The HSSD system provides three level of alarms. All three alarms report back to the BNL on-site Fire Department via the Site Fire Alarm System. The first level alarm is a local alarm (intended for the control operators). Second level alarms also sound locally, but requires an investigation by Fire/Rescue. Third level alarms require full response by Fire/Rescue. Third level alarms also activate building audible/visual devices, PHENIX Detector power off, emergency Detector vent/purge, and building emergency exhaust fans. The system complies with NFPA 72 and the UL listing. Building fire alarms have battery backup (24 hour capacity) and emergency generator power (24 hour capacity). This system, combined with the on-site Fire/Rescue Group, satisfies the DOE requirement for a redundant fire suppression system for loss potentials over $50 Million.

3.2.2 Preaction Sprinkler System & Standpipe System
To provide suppression of a disastrous level fire in the Experimental Hall and the Assembly Hall, a preaction sprinkler system has been installed. Installation of the sprinkler system complies with NFPA 13. The system protecting the experimental area has been designed to provide a .17 g.p.m. per sq. ft. density over 3000 sq. Ft. with 250 g.p.m. for hose streams. The heat detection has been installed in accordance with NFPA 72, to activate the preaction system.

The Counting House and support areas has been designed to provide a .15 g.p.m. per sq. ft. density over the entire facility with 250 g.p.m. for hose streams. The heat detection and smoke detection has been installed in accordance with NFPA 72, to activate the preaction system.

Waterflow and detection is tied into the building fire alarm system and will activate building wide audible/visual devices upon third level alarm. Air pressure and valve supervision report through the site fire alarm system as supervisory devices.

Standpipe are provided to the IR and AH via the wet pipe standpipe system serving the RHIC Accelerator Tunnel. This is a wet system, provided with hose connections for Fire/Rescue use (no hose at the station).

3.3 PHENIX Detector

3.3.1 Electronics Cabinets
On the PHENIX Detector, electronics will be housed in enclosed racks. Since these racks are purged with air, the ceiling level detection will not be effective. Given the high value of the equipment, smoke detection has been installed in the racks. Each rack is provided with a spot type smoke detector. These standard detectors will provide ample sensitivity given the fact the racks are less than 8 ft. tall, 4 ft. wide and 4 ft. deep. The detectors in the racks will be grouped to allow interlocks to shut down power to specific racks upon alarm. Future plans may have the normal purge air replaced with nitrogen when the system goes into alarm. The rack system is tied into the building fire alarm system and will activate building wide audible/visual devices. Building fire alarms have battery backup (24 hour capacity) and emergency generator power (24 hour capacity).

3.3.2 HSSD on the Detector
Within the PHENIX Detector, an HSSD System will be installed. The detection system will monitor the volumes around the interior electronics. Similar to the IR HSSD, the units will have three levels of alarm. First, will require PHENIX Detector operator attention. Second, will involve the operator and the Fire/Rescue Group for investigation. A third level alarm will evoke electrical shutdown, flammable gas detector purge/vent sequences, and building emergency exhaust ventilation for the IR, as appropiate.

This application of HSSD technology does not fit standard installation rules. Best engineering judgement has been used for detector port placement. Factors influencing placement included normal air flow, collection points for smoke, location of ignition sources (electronic printed circuit cards, power devices as opposed to signal circuits). Detector ports have been spaced at 400 sq. ft. spacings. The HSSD Control Panel is tied into the building fire alarm system and will activate building wide audible/visual devices upon third level alarm. Building fire alarms and the HSSD system have battery backup (24 hour capacity) and emergency generator power (24 hour capacity).

3.3.3 Combustible Gas Detection on the Detector
Within the PHENIX Detector, an air sampling system combustible gas detection system will be installed for experimental operations using flammable gases. The air sampling system consists of a network of tubes that connect to a selector valve system. The selector valves and detection assembly will be located outside of the IR. Sample points will be located on and around the detector based on potential leak points, potential collection points, normal air flow patterns, and the detector's construction. There is no installation standard for this type of application. The "off the shelf" flame ionization system uses a selector valve system to cycle through the sampling tubes and monitor combustible gas levels. Detection cycles and lengths of sampling points will ensure response to a leak within 90 seconds. Individual channel values are displayed and programmed for alarm and output functions. There will be warning levels in the ppm range, in which operators will investigate and monitor the situation. Higher reading will force action levels at 25 % of the Lower Explosive Limit, which will entail notification of Fire/Rescue, electrical power shutdowns, activation of the IR emergency ventilation system, vent and purge of detector chambers, as appropiate. The system will be on emergency power to provide continued operations during power outages.

3.4 PHENIX Counting House

The PHENIX Counting House is protected by a preaction sprinkler system in the Counting House and the mechanical equipment spaces of 1008A (tech lab and offices have smoke detection). Sprinkler system design and installation complies with NFPA 13. The Counting House and support areas have been designed to provide a .15 g.p.m. per sq. ft. density over 2500 sq. ft. with 250 g.p.m. for hose streams. Smoke detectors have been provided at 400 sq. ft. spacings in areas where high value electronics are present. Heat detection at 400 sq. ft. spacings are present in other areas. Manual fire alarm boxes have been provided at the exits. Local audible/visual devices are provided to alert the building occupants. Building fire alarms have battery backup (24 hour capacity) and emergency generator power (24 hour capacity).

The PHENIX Counting House has been isolated from the adjacent mechanical spaces and tech shops by a one hour fire wall with 3/4 hour rated doors.

3.5 PHENIX Gas Mixing House & Gas Storage Pad

The PHENIX Gas Mixing House is provided with NEC Class I Division II flammable atmosphere rated fire detection. Detection is spaced at less than 400 sq. ft. per detector. Manual fire alarm boxes are provided outside of the building. The service complies with NFPA 72 and is connected into the building system. Local audible/visual devices are provided to alert the building occupants.

3.6 Bldg. 1008C
Smoke detection has been provided at the ceiling level to protect the low valued electronics. Manual fire alarm pull boxes are located by the exits. Combination bell and strobe lights have been installed for local notification. An independent fire alarm panel has been installed to provide

coverage for this facility. All fire alarm and supervisory devices have been tied back to the BNL Fire/Rescue Group via the Site Fire Alarm System.

The fire protection/suppression features of vital programs, high valued property, and essential safety class systems at the PHENIX Complex are expanded upon in Sections 3.1 through 3.3, below.

4.1 Fire Protection of Vital Programs

The operation associated with this facility is not considered to be a DOE "vital program." Therefore, no special fire protection precautions, beyond those that are generically described above, are required for this facility. In the event PHENIX is damaged, it would take several weeks to replace PHENIX with a beam pipe and resume operations at RHIC.

4.2 Fire Protection of High Value Property

The majority of the dollar value is concentrated in the IR and the Control Room. During extended periods of maintenance, the PHENIX Detector is relocated to the AH, as a whole or in pieces. With over $60 Million concentrated in the IR, multiple fire systems have been installed. The following matrix lists the experimental subsystem, the associated costs (including engineering and design), and an estimated replacement value (costs less engineering and salvageable materials such as the large steel carriages).

System	Total Construction Cost	Replacement Costs	Funding Source
Ring Imaging Cherenkov (RHIC)Counter	6.8M	6.3M	KEK Japan
Time Expansion Chamber (TEC)	5.4M	2.9M	DOE
Drift Chamber (DC)	2.2M	1.8M	DOE
Central Magnet	2.5M	1.8M	DOE/KEK Japan
Muon Magnet North	8.8M	5.9M	DOE
Muon Magnet South	6.6M	5.6M	RIKEN Japan
Electro Magnetic Calorimeter (EM Cal) (Lead Scintillator)	4.7M	3.7M	DOE
Electro Magnetic Calorimeter (EM Cal) (Lead Glass)	6M	5.6M	CERN/DOE
Time of Flight (ToF)	2M	1.6M	KEK Japan
Muon ID North	4.8M	3.5M	DOE
Muon ID South	3.6M	3.3M	RIKEN Japan
Beam-Beam Counter	.9M	.7M	KEK Japan
Pad Chambers (PC)	4.3M	2.8M	DOE & LUND

The HSSD detection system on the PHENIX Detector, combined with the on-site Fire/Rescue Group, is considered the primary response system. This system will summon aid at the earliest practical stages (local alarms and signals to Fire/Rescue) and initiate protective actions (power off, vent/purge flammable gases, activate emergency vent in IR, as appropiate).

The most likely source of ignition on the PHENIX Detector is the power for electronics. To minimize the Detector loss potentials, a HSSD system will be installed on the detector. The equipment is Underwriter's Laboratory Listed. Sampling ports and tubes located to monitor electronics. Standard installation rules cannot be applied to a piece of equipment. Detection ports were placed based on air flow and ignition source location. Response to The three level of alarms will be: 1) first level is local to The PHENIX Control room, 2) Second level alarms at The control room and at Fire/Rescue for an investigative response, 3) third level alarms are fire alarms, ringing building bells, sending signals to control room and Fire/Rescue, and initiating interlocks (shutoff electrical power to PHENIX IR, vent/purge of detector, building emergency ventilation system). Control and Set points of HSSD system are administered through the Site Fire Alarm System configuration control procedures.

A secondary level of protection is provided by the building's ceiling level HSSD system. It will detect a fire in the IR/AH and start the same protective actions as The HSSD on The Detector.

For enclosed electronic racks on the Detector, smoke detectors will be placed inside of the racks They will initiate the alarms, power shutdown to the rack effected. PHENIX is considering an option to flow nitrogen in place of air into the racks upon alarm.

Great effort was made during the design stages to keep the amount of combustibles low as reasonably achievable. To this end, printed circuit boards were FR4 (self extinguishing). Wires, cables, and materials were also specified as self extinguishing (see Section 2.3.5). The intent was to have materials that would self extinguish upon removal of power.

In areas with significant combustibles could not be controlled (EM Cal), and removal of power will not ensure self extinguishment, local application suppression systems are being recommended to mitigate burning materials after removal of power (see Recommendations).

A third level of protection will be provided by the Building's preaction sprinkler system. This ceiling level system is activated by heat detection. It is anticipated that this will only activate when a sustained fire occurs in the Detectors and all other controls have failed.

The primary and third level protective systems, described above, are installed to meet DOE's requirements for redundant fire system in high value areas.

The Control Room has over $1 Million worth of equipment. This area is protected by smoke detectors that actuate a preaction sprinkler system.

4.3 Protection of Essential Safety Class Systems

There are no essential safety class systems associated with this non-nuclear facility.

5.0 Fire Loss Potentials

Fire loss potentials are classified into three major categories; the maximum credible fire loss, the maximum possible fire loss, and the recovery potential. The loss potentials for the PHENIX Complex are expanded upon in sections 4.1 through 4.3, below.

5.1 Maximum Credible Fire Loss (MCFL)
A Maximum Credible Fire Loss (MCFL; worst case, normal fire) assumes that the installed fire protection systems function. For PHENIX, the definition of "fire protection systems" include a portion of the systems that protect property. The Highly Sensitive Smoke Detection System in the detector is interlocked with the electrical supplies. Combined with the power fusing at board level and use of non-prorogating materials, detection of a fire and self extinguishment is likely. However a worst case scenario could result in the loss of an entire region in a sub system if Overcurrent devices fail or a drastic faults occur. In the unlikely event that sustained burning occurs, damage to a portion of a subsystem will result in upwards of $1 Million in damage. Most systems can run independent of other systems (although the quality of the physics is decreased). Therefore the overall program interruption will not be severe.

5.2 Maximum Possible Fire Loss (MPFL)
The Maximum Credible Fire Loss (MCFL; assumes failure of all active fire systems) for PHENIX is estimated to be over $43 Million. The event would include a fire in the detector that burns and involves the flammable gas systems. The destruction would include total loss of all electronics and chambers. The electronics racks and the South/North/Central Magnets would be heavily damaged. The facility would be minimally damaged, with most impact to fixtures as opposed to the reinforced structure. PHENIX could be extracted from the IR to allow resumption of other RHIC experiments. The recovery of PHENIX would take over 2 years due to the unique construction features.

6.0 Security Considerations Related to Fire Protection

There are no security considerations which relate to fire protection at this facility. Radiation Security barriers comply with the Life Safety Code for egress.

7.0 Exposure Fire Potential

The PHENIX Gas mixing shed and gas storage pads meet the National Fire Protection Association and Factory Mutual Loss Prevention Data sheets separation guidelines. They are not considered exposures of concerns to the PEH.

The electrical sub station to the north of Bldg. 1008A meets the Factory Mutual Loss Prevention Data Sheet on electrical transformer yard separation. The emergency generator is separated by a two hour fire wall from the transformer yard. These are not exposures of concern to Bldg. 1008.

The PHENIX Complex is located in the middle of the pine barrens. Pine trees and shrubs do pose a potential exposure to the insulated metal structures. While the roof systems will not ignite from burning brand produced in a brush fire, the metal walls will not provide a significant fire barrier. Distance is the key element. A minimum 50 ft. distance (100 ft. for upward slopes) is required to protect the structure. The conditions are acceptable now. Efforts will be needed to maintain theses separations.

8.0 Environmental Impact due to a Fire (Including Water Runoff)

Toxic, biological, and radiation incidents resulting from a fire, including water runoff, are analyzed in sections 7.1 through 7.3, below.

8.1 Toxic Incident

There are no known materials in the PHENIX Detector that, if involved in a fire, would result in a significant quantity of toxic material being created and released.

8.2 Biological Incident

Due to the lack of biological matter at this facility, an incident of this type is unforeseeable.

8.3 Radiation Incident

By the nature of the operations of the accelerator, various pieces of equipment can be expected to become activated. This activation is not expected to pose a significant environmental impact in the event of a fire since the material will not be easily disbursed.

For the calibration of instrumentation, there will be several small sealed sources. These sources do not have the physical configuration nor the curie content to pose are radiological concern in the event they are involved in a fire.

No other radioactive materials are used or stored in the PHENIX Complex.

9.0 Prefire and Emergency Planning

The BNL Fire Department maintains an adequate Prefire plan book for this facility. "Hold Points" are defined so that the Fire/Rescue Group will wait until conditions are safe prior to approaching The facility. These hold points would be used during the two hour duration of venting/purge of flammable gas.

A Local Emergency Plan is maintained by the Facility. It includes Control Room actions to take with various alarms.

9.1 Fire Apparatus Accessibility

Fire apparatus accessibility is adequate for the main facility. Bldgs. 1008B and 1008C has a stone dust road which will be difficult to negotiate with heavy fire trucks in the winter and during periods of heavy rain (see Recommendations).

10.0 Life Safety Considerations

Major life safety considerations for this industrial facility includes the following components; means of egress components and capacity, number and arrangement of the means of egress, travel distances to exits, discharge from the exits, and emergency lighting and marking of the means of egress.

With the routine use of the personel plug door, the PHENIX IR will have two well marked exits available to occupants at all times. The exits meet the remote criteria of ½ D as required by the Life Safety Code for "high hazard" industrial occupancies. Travel distances to an exit is within industrial occupancy standards of the Life Safety Code. Discharges from exits are to exterior grade and are provided with exterior lighting (around the clock occupancy is expected). There are no exit paths into the RHIC tunnel due to the presence of the Muon ID Plates.

Typical to an experimental area, beampipes and other services in the IR may create unavoidable intrusions into the head room clearance in exit paths. These are point restrictions and occur only in isolated areas. They are clearly marked on the floor with yellow/black tape and allow for people to "duck under" (at least 54 inches above the finished floor).

The AH has two well marked and remote exits and in complete compliance with NFPA 101-97. Large quantities of flammable gases will not be present in the AH, therefore it is not a high hazard area as defined by the Life Safety Code. The RHIC Experimental Safety Committee will review all quantity limits.

Bldg. 1008 and 1008A are similarly in compliance with NFPA 101-97 for industrial occupancies.

All areas are provided with emergency lighting via the emergency generator set at Bldg. 1008A.