BaBar

Fire Hazards Analysis Addendum I

ADDENDUM

Fire Hazards Analysis
For the
BaBar Detector Project

September 16, 2001
(Final: December 19, 2001)

1.0 BACKGROUND

A fire hazards analysis (FHA) was completed for the BaBar Detector Project at the Stanford Linear Accelerator Center (SLAC) in December, 1996 [HAI, 1996]. The BaBar Detector Project is located in the PEP-II Research Hall at Interaction Region 2 (IR-2). IR-2 and all PEP-II facilities are located inside the SLAC Radiological Control Area.

The initial FHA provided a detailed assessment of the fire potential associated with the BaBar and its support equipment and facilities in relation to existing and planned fire protection features at that time. It was prepared in accordance with Department of Energy (DOE) orders and site procedures in place at that time, including DOE Order 5480.7A, Fire Protection [DOE, 1993], DOE Order 6430.1A, General Design Criteria [DOE, 1989]. The results of the FHA analyses were presented in terms of the potential fire hazards associated with BaBar and its support facilities, the potential extent of fire loss (Maximum Probable Fire Loss (MPFL) and Maximum Credible Fire Loss (MCFL)), the impact on employee and public safety, and the impact of the facilities' fire protection features.

The initial FHA was submitted prior to final design and installation of BaBar and its support facilities. In addition, initial operation of the Detector resulted in the need to consider several modifications to the facilities and the Detector in order to improve operational effectiveness.

2.0 SCOPE AND OBJECTIVES

Studies have been performed over the last 15 months in support of proposed changes to the BaBar Detector Project. Also included were studies of elements of the Detector installation that were completed after the original FHA was submitted. These studies included evaluation of the following factors:

- Potential impact on original estimates of fire development,
- Compliance with DOE 420.1 which has preempted DOE Order 5480.7A,
- Any effects on the original MPFL and MCFL results, and
- Life safety effects.

This report provides a summary of the results of the individual studies, and should be treated as an addendum to the initial FHA. Details associated with the design of BaBar and its associated equipment and facilities are contained in the FHA, and are not repeated here.

3.0 UPDATES/CANDIDATE CHANGES

Studies of completed BaBar Project elements (i.e., "updates") and potential changes under consideration by the BaBar Detector Project team included the following:

- Final Design/Installation of Gas Mixing Shack/Gas Storage,
- Adjustments to Drift Chamber HAD signal reporting protocol,
- Modifications to the North Alcove Shield Wall Installation,
- Smoke and Heat Leakage at top of Main Shield Wall,
- Effects on Fire Consequences of AC Installation on Roof of IR-2, and
- Modifications to proposed fire safety features at multiple locations.

Each of these issues were evaluated and recommendations provided to the BaBar Safety Officer at the time the individual issue was being considered. The following is a summary of the results of those evaluations, and documentation of the current status of these issues for the BaBar Detector Project. As indicated previously, analysis details for a number of these issues are documented in the FHA, and will only be referenced here.

3.1 Final Design/Installation of Gas Mixing Shack/Gas Storage

The design and installation of the Gas Mixing Shack (GMS) was one of the only components of the BaBar Detector Project not addressed in detail in the initial FHA. A detailed description of the Gas Mixing Shack (GMS) and storage pad are is included in the Safety Assessment Document – BaBar [SLAC, 1998].

Potential Fire Hazards:

The primary fire hazard associated with the operation of the GMS is a fire resulting from an explosion involving flammable gas. Other fire hazards exist due to electrical faults or human error during maintenance or other activities in the GMS.

Description:

The Gas Mixing Shack is located on the apron above the IR-2 hall. Flammable make-up gas (isobutene) is supplied to the GMS from gas storage tanks located outside of the GMS. The GMS is constructed with metal siding on a steel frame. A masonry fire wall separates the GMS from the flammable gas storage pad.

The design of the GMS meets applicable criteria in NFPA 497A, which primarily emphasizes ventilation as a means to prevent an explosion. The flammable gas storage area is a classified area and complies with NFPA 70, National Electrical Code. Isobutane tank heaters are utilized at the storage area. These heaters are Class I, Division I classified under NFPA 70.

The GMS primary safety system for control of isobutane leaks is ventilation. This ventilation system is interlocked to explosion proof dual redundant fail safe solenoid valves on the isobutane supply lines at the cylinders. If the ventilation system degrades or fails the solenoid valves close the isobutane is automatically shut off at the source. The airflow in the ventilation system is sensed at four locations in the HVAC ducting with Photohelic pressure gauges. The supply lines also have restrictors, which limit the maximum possible leak rate of isobutane into the GMS to 25% of the LEL, under worst case conditions, i.e., assuming that all four supply lines are severed simultaneously. A secondary safety system is the sensing of isobutane leaks utilizing infrared type Hazardous Atmosphere Detectors (HADs). Four HADs are located in the GMS, one at each of the four room exhaust grills. Three HADs are located outside in the flammable gas storage area. All of the HADs are also interlocked to the solenoid valves. The control system for the GMS safety system is based on the Summary Interlock and Alarm Modules (SIAM) in use at SLAC.

In addition to gas leak detection, fail safe shutdown and ventilation the GMS is protected by a smoke detection system which is connected directly to the site alarm system, and an automatic sprinkler system, with flow alarm connected directly to the site alarm system.

Fire Development:

Incidental fires in the GMS are expected to be detected during incipient burning. The fire department is expected to respond within 3.5 to 4 minutes of incident detection. Fires that develop beyond incipient burning will be controlled by the automatic sprinkler system. In the event of sprinkler system operational failure, the fire department will still be able to control and extinguish the fire.

In the event that the ventilation controls and the gas detection systems all fail, the potential for an explosion in the GMS will exist. Although the probability of the loss of all of these systems simultaneously is small, it could result in an explosion that would destroy the GMS and secondary deflagrations at the storage pad.

Compliance:

The design of the GMS and the safety systems are in compliance with applicable NFPA standards and DOE 420.1.

MPFL/MCFL Impact:

The loss of the GMS due to an explosion will not effect the results of the MPFL and MCFL calculations presented in the initial FHA.

Life Safety:

Based on requirements in the NFPA 101 Life Safety Code for Special Purpose Industrial occupancies, the GMS has adequate provisions for egress, including travel distances, number and location of exits, avoidance of dead-end travel paths, and lighted/marked exits.

Recommendations:

None.

3.2 BaBar Drift Chamber HAD Reporting Protocol

Potential Fire Hazards:

The flammable gas in the drift chamber poses a hazard if the gas leaks out of the chamber. There is also a hazard within the chamber if air enters the chamber and mixes with the flammable gas while the high voltage is on and a spark ignition occurs.

Description:

A detailed description of the Drift Chamber can be found in the Safety Assessment Document – BaBar [SLAC, 1998]. The Drift Chamber contains 5000 liters of flammable gas mixture (80% helium and 20% isobutane). The chamber operates at 2000 volts and at a pressure of 5 mbar, slightly above atmospheric. The gas mixing/control system in the GMS maintains a flow of approximately 10 liters/minute of gas through the chamber. The gas in the chamber exits through the forward endplate and returns to the GMS. At the GMS, the gas is either recirculated or vented to the atmosphere. Racks, which provide bubblers, pressure transducers, gas analyzers, HADs and valves associated with the chamber are located above the Detector in the IR-Hall. Essential components of the Drift Chamber safety system include: (1) piping/fitting leak prevention, (2) hardware interlocks that shut down the flammable mixture supply, and (3) gas monitoring and detection, including for both oxygen and isobutane.

The primary means of controlling the hazard of leaking gas in the bulkhead area is by maintaining a nitrogen atmosphere in the bulkhead. The secondary safety system is to monitor for isobutane here with HADs. These HADs monitor the bulkhead nitrogen flush lines. The threshold for an alarm is 10% of the LEL for isobutane in air. An alarm state shuts down detector operations until trained personnel are located and the problem is resolved.

There has been a number of failures of HAD sensors resulting in trouble states. These failures of the sensors are not an indication of a hazardous condition. It is typically the sensor going out of calibration or contamination on the mirror. Originally, this caused an alarm state that resulted in shutting down the detector and a significant loss of data. A change has been implemented in the protocol such that a "trouble" state will result in audio and visual signals on the BaBar operating console, and an automatic paging of a cryogenics technician. Investigation of the "trouble" state occurs at the next scheduled access to the radiation area.

Equipment monitoring over the last 15 months indicates that the isobutane mixtures have remained below 4% LEL (air) for both bulkheads.

Fire Development:

No changes in fire development are expected due to this change in the HAD signal interpretation.

Compliance:

Since the primary safety systems are in full compliance with applicable standards and DOE 420.1, modification in the HAD signal interpretation does not represent a significant compromise in fire safety. The HADs were not required or recommended in the initial FHA.

MPFL/MCFL Impact:

No changes in the MPFL or MCFL analyses presented in the initial FHA occur as a result of this modification.

Life Safety:

No changes in the life safety analysis presented in the initial FHA occur as a result of this modification.

Recommendations:

None.

3.3 Installation of North Alcove Shield Wall

Potential Fire Hazard:

An important effect of restricting the opening into the north tunnel would be to speed up the rate of accumulation of a hot smoke layer in the IR-Hall due to a fire in the BaBar area. This could directly affect (reduce) the estimated time to exposure of the Detector and support equipment to the fire.

Description:

A shield wall has been constructed at the north alcove (reference SLAC DWGS # SA-363-770-01 and SA-343-720-02). The design of the shield wall resulted in reduction in the clear opening into the north tunnel.

Fire Development:

This modification could potentially affect the development of the hot smoke layer in IR-2 as well as its rate of decent. The results of upper gas layer temperature modeling performed in the initial FHA were used to estimate the potential impact of inclusion of this shield wall. The modeling used the computer based fire simulation model CFAST [Peacock et al., 1993]. Originally, significant advantage in slowing down the development of a hot smoke layer and exposure of the equipment to the hot layer was attributed to the open beam tunnels [HAI, 1996, Appendix B].

Additional cases have now been modeled in which the same fire exposure scenarios located on the west side of the main shield wall have been evaluated under restricted opening conditions into the north tunnel. For purposes of this analysis, the restrictions were varied from 0% to 25% of the opening. This represents a safety factor in that no credit has been taken for the fan operated ventilation shafts located at each tunnel entrance which go to the surface.

The results of this analysis indicate that the vertical cable tray fire (i.e., the MPFL fire scenario) will result in a somewhat more rapid decent of the hot layer than for the case where both tunnels are open. However, results also indicate that the layer decent will not reach the top level of the Detector, even at a 25% reduction in the north tunnel opening.

Compliance:

The design of this shield wall is in compliance with NFPA standards as well as applicable DOE Orders.

MPFL/MCFL Impact:

This modification does not result in significant changes to the results of the MPFL and MCFL scenarios evaluated in the initial FHA.

Life Safety:

The shield wall will not affect the life safety analysis provided in the initial FHA. A significant amount of excess egress capacity exists in the IR-2 Hall, and the shield wall does not represent a barrier.

Recommendations:

None.

3.4 Smoke and Heat Leakage at Top of Main Shield Wall

Potential Fire Hazards:

The primary hazard associated with the shield wall not being sealed at the ceiling of the IR-2 Hall is leakage of hot gases and smoke from one side of the shield wall to the other. This could potentially extend the damage to both sides of the shield wall somewhat quicker, reducing the time available for fire fighting and related activities.

Description:

When in place, the main shield wall does not extend completely to the ceiling. A six inch nominal gap extends the length of the wall between the top of the wall and the ceiling.

Fire Development:

The gap at the ceiling, depending on its size, could result in a significant impact on fire development. However, even for the MPFL fire involving vertical cable bundles (representing a high fuel load) the present gap in the wall does not represent a significant change in the fire development. Several of the more challenging fire scenarios modeled in the initial FHA were repeated, again using the CFAST fire development computer model. The results indicate that for fires which start on the Detector side of the shield wall, the layer decent to the top of the Detector is slowed down marginally. For fires which start on the east side of the shield wall, e.g., storage crates, drums, or the Electronics House, the fires are not large enough to cause exposure of the Detector or its support equipment on the west side of the shield wall.

Compliance:

There are no compliance issues associated with this design.

MPFL/MCFL Impact:

No changes in The MPFL and MCFL scenarios occur as a result of this design.

Life Safety:

No changes to the life safety analysis provided in the initial FHA are necessary as a result of this design.

Recommendations:

None.

3.5 Installation of Forced Ventilation on Roof of IR-2 Hall

Potential Fire Hazards:

While there are no fire hazards associated directly with installation of forced ventilation at the roof, considerable effects on air movement during a fire can result. The potential effects include delayed or no detection from detector devices located in the immediate proximity to the vent. And, the rate of the smoke layer formation and decent may be effected. The reliance on the available natural ventilation at the roof to slow down the decent of the smoke layer may be negated.

Recommendations:

In discussions with BaBar staff, it was agreed that installation of forced ventilation at the roof of the IR-2 Hall requires considerable additional fire impact analysis. This was based on initial calculations and modeling which demonstrated the potential for adverse effects on smoke detector performance. Therefore, it was recommended that no further action be taken on this proposed design change without a complete evaluation of the potential impact.

4.0 SUPPLEMENTAL CHANGES IN BABAR FIRE PROTECTION

Additional modifications to some of the fire protection features outlined in the initial FHA are documented here. Based on technical reviews performed when the changes were initially considered, it is concluded that none of these changes qualitatively change the life safety analysis or the MPFL/MCFL analyses in the FHA. The changes are outlined here for documentation purposes:

4.1 Main IR Hall:

- The proposed installation of High Sensitivity Smoke Detection Systems (HSSD) at the ceiling on the east side of the main shield wall (i.e., service area) was changed to ceiling spot type photoelectric smoke detectors. The smoke detectors are connected to the BaBar control panel and the site Fire Alarm System.

- On the west side of the shield wall, HSSD was installed only at the ceiling; the proposed intermediate level installation was deleted.

4.2 Electronics House:

- The existing wet pipe automatic sprinkler system was not converted to a pre-action sprinkler system.

- The underfloor cable plenum is protected by an HSSD detection system.

- FM 200 is used as a suppression gas in lieu of carbon dioxide.

4.3 Counting House:

- The existing wet pipe automatic sprinkler system was not converted to a pre-action sprinkler system.

4.4 PEP Magnet Power Supply Building (624):

- The spaces are protected by an HSSD detection system.

None of these changes in BaBar fire protection qualitatively impact the compliance of the BaBar facility with applicable DOE and nationally recognized engineering standards. In addition, no changes in the MPFL/MCFL estimates presented in the FHA [HAI, 1996] occurred as a result of these changes.