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Safety

13.1 Introduction

This chapter provides a description of identified and potential hazards, their relative significance, and the proposed design controls needed to eliminate or reduce the associated risk to acceptable levels.

This chapter does not assess the risk for those identified hazards in terms of severity or probability. This will be accomplished in the Safety Assessment Document (SAD), which will further identify, evaluate, track, and resolve safety issues. The *BaBar* Detector will also be reviewed by SLAC safety committees such as the Hazardous Experimental Equipment Committee (HEEC), the Radiation Safety Committee, the Pressure Safety Committee, and the Earthquake Safety Committee.

The purpose of performing this analysis and the committee reviews is to make sure that safety is designed into systems, subsystems, equipment, facilities, and their interfaces, consistent with the objective of the detector. The policy of management is to design for minimum risk.

13.2 Detector Safety Overview

BaBar will be housed in the existing PEP Research Hall at Interaction Region 2 (IR-2). The detector weighs approximately 800 metric tonne. The floor of IR-2 is constructed of two-foot-thick reinforced concrete. Estimated dimensions of *BaBar* are 6.7 m in height, 9.5 m in width, and 8.3 m in length from the outer edge of the forward door to the outer edge of the DIRC water tank. The design of the Research Hall incorporates a concrete shield wall, which will contain penetrations for cableways and cryogenics. The fast electronics will be located in a counting house just outside the wall. The existing control room area in IR-2 will be utilized. The cryogenic plant will be located on an existing pad outside the southern wall of IR-2, and cryogenic storage tanks will be located on another pad on the hill at the western end of the building.

BaBar is similar to detectors operating at SLAC and other physics laboratories, therefore the hazards contained in *BaBar* are similar to previous examples.

Hazards contained in *BaBar* which are currently under assessment are:

- Gases—flammable, asphyxiant, toxic—possibly utilized in the drift chamber and RPCs;
- Electrical hazards in the various high voltage systems (the drift chamber, the RPCs, and the DIRC photomultiplier tubes), the electronics, the power supplies, the high current and stored energy associated with the magnet, and support equipment in the counting house and control room area;
- Radiation due to operation of the machine and possibly from a calibration system for the calorimeter;
- Cryogenics for the superconducting coil and possibly the Q1 magnets;
- Magnetic forces during operation of the magnet;
- Pressure/vacuum in the beam pipe, the drift chamber, the cryostat, and the associated supply systems; and
- Toxic materials such as beryllium, thallium-iodide, and cesium-iodide.

Generic hazards currently under assessment are

- Earthquake,
- Radiation,
- Fire,
- Occupational (Oxygen Deficiency and Confined Space), and
- Environmental.

13.3 Beam Pipe and Support Barrel

The Q1 magnets, the B1 magnets, the IP beam pipe, and the vertex detector are assembled into a single rigid support barrel. The beam pipe at the interaction point is a double-wall structure made of beryllium. The inner tube is 50 mm in diameter with a separation of

2 mm from the outer tube. Helium gas flows between the tubes to remove the beam-induced heating.

The health hazard of the beryllium is minimal in the form used. The particulate created as a result of machining, grinding, corrosion, *etc.*, is toxic if ingested. A coating will be applied which should control corrosion, and all machining will take place at an outside vendor under appropriate safety conditions. If the beryllium needs to be worked at SLAC, special procedures to control the particulate will be developed.

The thin wall beryllium tubes are easily damaged, and special handling requirements to reduce this potential will be developed.

13.4 Vertex Detector

The vertex detector consists of double-sided silicon microstrip detectors and readout hybrid circuits assembled into mechanical modules. These modules are glued to lightweight support structures. At each end of the module, beryllium oxide or aluminum blocks provide the required mechanical precision and act as a heat sink for the electronics.

The health hazard for beryllium is minimal in the form used (Section 13.3). The operating voltage is less than 50 V, with currents less than 100 mA. Dry nitrogen or air will be used to control the atmosphere. If nitrogen is used, the hazard of asphyxiation may exist depending on the quantity. Water may be used for cooling. This detector system appears to have minimal overall risk for causing injury to personnel or damage to equipment.

13.5 Drift Chamber

The drift chamber consists of a carbon-fiber shell, a helium-based gas which may be flammable, and a large number of wires with high voltage. Significant effort is under way to find an acceptable gas mixture that is nonflammable. The drift chamber may operate at constant gas pressure resulting in a pressure differential (as much as 30–40 mbar) between the chamber and the atmosphere. On both ends of the chamber, rf-shields will contain an inert gas (probably N_2) that is circulated and will provide humidity control. The gas will be monitored for helium content, which will allow detection of leaks from the chamber.

The drift chamber gas is an asphyxiant and may be flammable; it is probably not toxic. The storage, transport, mixing, use, and disposal must be adequately controlled. The following are the proposed controls:

- Development of a safety system to sense leaks and/or oxygen deficiency, and to automatically bring the system to a safe state. This will require the shut-off of the flammable gas at its source, the interruption of electrical energy to potential ignition sources, the purging of the system with inert gas, the operation of a ventilation system to dilute any leaking gas, and the sounding of appropriate alarms to warn personnel;
- Isolation of the bulk storage and the mixing operations in separate areas outside the experimental hall;
- Utilization of flow restrictors at the storage area;
- Transportation and distribution of the gas in metal pipes to prevent leaks;
- Comparison of chamber supply and return flow rates to aid in the detection of leaks; and
- Utilization of an appropriate fire suppression system.

Control of the high voltage will be accomplished by conventional means. Design controls will include short-circuit protection; isolation by insulating, enclosing, or covering; and grounding. Equipment will be designed to meet appropriate codes and standards. Procedural controls will include utilization of properly trained personnel and adherence to established safe work practices and procedures.

Pressure is a concern in terms of damage to the chamber. The design must have features that will prevent overpressurization which could result in subsequent damage to the chamber and possibly other systems.

Accessibility to the chamber for assembly, maintenance or repairs (broken wire removal), may pose a threat to personnel due to the confined space and to the presence of hazardous gas. Reviews of the various scenarios to assure safe access will be accomplished in the SAD.

13.6 Particle Identification

13.6.1 DIRC

The DIRC system will consist of quartz radiator bars, a support structure, a standoff box containing a reservoir filled with water, and conventional photomultiplier tubes.

The hazards associated with the DIRC include high voltage at the photomultiplier tubes, water leakage from the standoff box reservoir, and the possible degradation of the tubes due to long-term exposure to helium. Control of high voltage is discussed in Section 13.5.

A water leak could damage electronics, short circuit electrical equipment, and cause corrosion in other detector systems. The presence of water near the calorimeter may degrade the calorimeter crystals. The interface between the standoff reservoir and the window frame/flange must provide a positive water seal. Flexing of the door due to the magnetic and seismic loads will need to be considered. In addition, features to control leaking water should be fairly simple to incorporate due to the location of the reservoir outside the backward door.

13.6.2 Aerogel

The second part of the particle identification system is constructed of silica aerogel. Silica aerogel is a glass-like structure which consists of amorphous SiO_2.

When aerogel is unprotected, it is very fragile and pieces easily break off at edges and corners. Cracks may develop inside during handling due to the low tensile strength. Aerogel also is damaged by most gases and liquids, including water. For these reasons, the aerogel blocks will be wrapped for protection. Aluminum, Teflon, and paper are under consideration. Photomultiplier tubes will be utilized and the issues addressed in the previous section pertaining to high voltage and He gas are applicable.

In the form used in the detector, aerogel appears to present minimal risk. The very fine dust of SiO_2 generated as a result of machining requires the use of respiratory protection. No such machining of aerogel is planned at SLAC.

The presence of helium near the forward aerogel PID photomultiplier tubes could degrade the performance of the tubes. The drift chamber, the cryostat, and various cooling systems will use helium. It may be appropriate to direct the air/N_2 flow of the ventilation system so that any possible helium present will be drawn away from the sensitive components.

Aerogel is an excellent insulator and the heat created by the tubes will need to be removed. Nitrogen gas is being considered for cooling.

13.7 Electromagnetic Calorimeter

The calorimeter consists of cesium-iodide crystals wrapped in PTFE Teflon or Tyvek, a support structure, photodiodes, and associated power supplies and regulators. The photodiodes will operate at approximately 75 V. Cooling will be required and freon is currently under consideration.

The principal hazard is the thallium iodide contained in the cesium iodide. The concentration of thallium iodide is approximately one part per thousand. The federal OSHA permissible exposure level (PEL) is 0.1 mg/m^3 for airborne thallium particles [CFR93]. The thallium iodide is contained in the crystal structure of the cesium iodide. Machining operations and handling of the uncoated crystal will require special precautions.

The possible presence of a mutagen in the fluorescent flux concentrator will also be evaluated. This is a laser dye that will be dispersed in solid plastic.

The effect of moisture on the crystals is detrimental, therefore the calorimeter will be contained in a closed, shielded environment, where the humidity will be strictly controlled to a level of approximately 3%.

One of the calibration systems under consideration contains a radiation hazard. This system would utilize polonium beryllium (Section 7.5.3) as a source of fast neutrons to activate freon. The freon would then be piped across the face of the crystals. The neutron source and the pipe carrying the pressurized, activated freon liquid through the detector would be located inside the IR concrete curtain wall. An alternative calibration scheme entails placing low-level sources on each crystal. Both schemes will be evaluated for radiation hazard in the SAD.

13.8 Muon and Neutral Hadron Detector

The system under consideration utilizes Resistive Plate Chambers (RPCs). These chambers consist of large-area parallel-plate electrodes held apart at a distance of 2 mm with spacer buttons and filled with a gas mixture. Approximately 3000 m^2 will be covered by these RPCs.

The hazards associated with the chambers are related to electrical safety, flammability of material used in chamber construction, and the possible use of a flammable gas.

Electrical hazards are associated with the use of high voltage in the operation of the chambers. High voltage will be controlled through the use of appropriate cables and connectors, short circuit protection, isolation by insulating or enclosing, and grounding. High voltage supplies will not deliver currents in excess of 1 mA and will be interlocked with hazardous gas and fire alarms.

The RPCs are constructed of materials (bakelite) which are combustible only when exposed to an intense flame or arc. As the chambers are confined to narrow gaps between steel plates, there is a very limited supply of oxygen available and any combustion initiated at an exposed edge will be self-extinguishing. Smoke and heat-sensitive alarms will be located at strategic locations around the detector.

Proposed controls for the use of a flammable gas mixture are listed in Section 13.5. Due to the large number of RPCs and the large surface area covered, attention must be paid to the issue of leaks. Appropriate pressure testing before and after installation will be necessary.

Because the use of a nonflammable gas mixture is highly desirable, active R&D in this direction is currently being performed.

13.9 Magnet Coil and Flux Return

The magnet system consists of the superconducting solenoid, the flux return, and supporting systems including cryogenics. The superconducting solenoid consists of the coil in a cryostat; the vacuum system to provide thermal insulation; the power supply; the quench detection and protection system; and the control system. The flux return is composed of a barrel and endcaps, support/translation/alignment systems for each movable section and restraints to provide structural stability. The endcap doors are designed to split on a vertical line for access.

The principal hazards associated with the magnet are: cryogenic, electrical, magnetic, and the control of energy during a quench.

Liquid helium (LHe) will be utilized to cool the solenoid. Issues of concern are leakage, pressurization/vacuum, rupture, oxygen deficiency, and cryogenic burns. The helium plant will be located outside the hall. It will contain a $4000\,\ell$ dewar. The total volume of LHe in the experimental hall including the Q1 magnets and the solenoid is expected to be less than $250\,\ell$.

Leakage of the LHe will be controlled in the distribution system by the use of coaxial lines with pressure switches interlocked to the supply valves. If vacuum in the line is lost (any leak will degrade the vacuum shield), the supply of LHe will be automatically interrupted at the source. Overpressurization of the aluminum restraining hoop cooling tubes and the cryostat will be controlled by pressure release valves and burst discs. The worst case release of LHe would require a catastrophic rupture of the dewar (such as a fork lift tine puncture). Barriers will be strategically positioned to prevent this kind of accident. If the dewar were opened in this way, the LHe would immediately evaporate and dissipate. Asphyxiation will be a hazard in enclosed areas. One liter of LHe vaporizes to approximately $750\,\ell$ of gaseous He at 20°C and atmospheric pressure.

The solenoid current will be 7000–8000 A. Appropriate protection for the power supplies, cabling, and connectors will be required.

Whenever the magnet is energized, it poses a hazard due to the damage that may be caused by objects, such as tools, being sucked into it. Procedural controls will be established to control the use of equipment during this time period.

A quench detection and energy extraction system will protect the coil in the event of a quench. The system to detect a quench will include the sensing of a voltage imbalance or an increase of pressure. The energy extraction system will utilize external dump resistors. Peak voltage across the magnet terminals during a quench will be less than 500 V.

13.10 Generic Hazards

The following is a brief discussion of the more general hazards:

Earthquake. The earthquake design requirements for the detector structure are defined in the SLAC Seismic Design Manual (this is more stringent than the Uniform Building Code). The Earthquake Safety Committee will review and approve the design based on compliance with the Seismic Design Manual [SDM91].

Radiation. Established radiation protections systems at SLAC include the Beam Containment System (BCS), the Personnel Protection System (PPS), the Beam Shut-Off Ion Chambers (BSOIC), shielding systems, and a radiological training program. For *BaBar*, the design of the BCS and shielding, implementation of the PPS, placement of the BSOICs, and development of operational requirements and procedures will be reviewed by the Radiation Safety Committee.

Fire. An evaluation of the fire prevention and fire protection systems will be performed. Life safety provisions will be provided for the facility in accordance with the NFPA Life Safety Code. Noncombustible materials will be utilized where possible.

Occupational. The SLAC safety standards for Environmental Safety and Health are contained in the SLAC ES&H Manual. During assembly, commissioning, operation, maintenance, and repair, the safety rules and regulations contained in this manual are applicable to SLAC personnel, collaboration personnel, subcontractors, and users.

Hazards to personnel during maintenance and repair of components inside the detector are under evaluation. The forward and backward end doors are designed in two halves, which allows retraction on rails for access to the aerogel, forward end of the drift chamber, and calorimeter. Access to the backward components of the drift chamber will be possible through the DIRC strong tube. A rail system allows the endcap iron plug to be retracted back to a point where the crane could be used to set it aside. The rail system may then be used to support a cart to carry personnel. A full-size mock-up will be used to develop and simulate emergency evacuation procedures. The hazard of entrapment and the potential for hazardous atmospheres, may classify the inside of the detector as a permit-required confined space.

The hazards associated with elevated work will be considered in the design. Platforms, railings, barriers, stairways, and ladders will be designed in accordance with the Life Safety Code.

Environmental. Consideration of environmental issues such as the generation of hazardous waste, the uses of freon, the release of gas mixtures, and environmental reporting requirements will be addressed.

References

[CFR93] Code of Federal Regulations, Title 29, 1910.1000 (1993).

[SDM91] Earthquake Safety Committee, "Seismic Design Manual—Mechanical R1 Draft 2," (1991).