Safety Note 15

Brief Summary of the January 6, 1987 Draft Report on the A-3 Beamline Fire at the Alternating Gradient Synchrotron at Brookhaven National Laboratory

Don Cossairt, Chairperson
Fermilab Fire Safety Subcommittee

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In this brief note I attempt to summarize the conclusions of the Fire Safety Subcommittee on drawn from a review of the subject report and a telephone conversation with the chairman of the BNL investigation committee. The emphasis here will be on the lessons learned from this incident which may be directly applicable to the operation of Fermilab, particularly those applicable to physics experiments which are likely to be quite similar in character to that involved in this incident. First the incident will be summarized. Second, the results of some flammability tests done by the Brookhaven investigators will be described. Finally some of the conclusions of general interest reached both by the very capable Brookhaven investigators and by the Fermilab Fire Safety Subcommittee will be discussed.

The Incident:

In the fall of 1986, an experiment at the AGS was being constructed in anticipation of its operation. The apparatus consisted of the usual array of scintillators, drift chambers, a lead glass array, and a Cerenkov counter. The drift chamber frames consisted of fiber glass impregnated with polyester reson (Pultrusion) clamped in aluminum and would normally be filled by 79% argon, 15% isobutane, and 6 % methylal but at the time of the fire were filled with argon. Nearby (in parallel planes each within one to two inches of its neighbor) were the plastic scintillation (polyvinyltolune) hodoscopes mounted in a 3/4 in plywood sheet supported by an aluminum channel frame, the lead glass array, and the Cerenkov counter. The latter, which during operations would be filled with approximately 260 ft^3 of hydrogen gas at 0.2 in positive pressure, was filled with nitrogen at the time of the fire. This device had mylar entrance and exit windows. A fire detection system based upon 197^{o}F fixed temperature/rate of rise heat detectors each covering large areas (750-2500 ft^2) located within 12 in of the ceiling which ranges between 40 to 70 feet above the floor in the area of concern. A small number of additional heat detectors were installed near this experiment, the closest being about 25 ft from the fire approximately 2 ft below the ceiling. Several safety reviews had been made of various facets of this experiment including a hydrogen safety review of the

Cerenkov and various fire protection reviews recommending the minimization of the mass of combustibles present and placement of additional fire detectors. The detectors had been added prior to the fire.

Late on a Friday evening (emphasis mine) members of the experiment who were testing electronics associated with the scintillation counters left for the day. On the following Saturday morning, the two "watch" technicians (who cover such areas "on shift") were working elsewhere in the building when they noticed smoke at the ceiling level. The manual fire alarm box was pulled and the AGS Main Control room was notified by telephone as these two technicians searched for the fire. The technicians activated roof vent fans to remove some of the smoke which was sufficiently thick to impede the search. One of these people entered the cave containing the apparatus (at this time filled with thick smoke) alone and without SCBA and discharged a CO_2 fire extinguisher. The fire was extinguished by the Fire/Rescue Group who arrived soon thereafter. The resulting damage to the experiment was considerable (~ $77,000). The scintillation hodoscope and most of its light pipes were consumed, their aluminum frame was melted and the plywood burned. The lead glass blocks were damaged by smoke and soot and its photomultiplier tubes damaged. A drift chamber was totally destroyed. The mirrors and windows of the Cerenkov were destroyed by the fire. Extensive damage to cabling was apparent.

The investigators of this incident, through detailed analysis, were able to reduce the number of probable ignition sources to two; the photomultiplier tube bases and the preamp printed circuit cards to the drift chamber. The mechanism for the former suspect source would be for a 1000 ohm 1/4 watt resistor to fail toward short circuit. The particular resistor was used as a "fuse" in the hope that an overcurrent through it would result in an "open" circuit. It is well known that, instead, such resistors when subjected to high voltage stress fail toward short circuit. This type of resistor failure could have caused the base to draw a maximum of 80 watts instead of the designed 6 watts. These photomultiplier bases were almost certainly "on" at the time of the fire and it was concluded later that this some of the resistors had degraded to lower values. However, the burn pattern observed would tend to rule, with considerable uncertainty, toward the latter indicated source. Also, experience at Brookhaven with photomultiplier tube base failures indicates that the usual failure is that of an "open" circuit as the final situation.

The more probable source, the preamp cards, normally are powered by 6 volts. Four power supplies, each rated at 8 A, power large numbers of these cards. They do not trip off on overcurrent but instead go into a current limiting mode. An ordinary resistor was used on the individual cards to protect against overcurrent in lieu of actual fuses. Thus the same possible failure mode exists as described above for the photomultiplier tube bases. Hence, a short in one card could cause it to draw essentially all the 8 amps at 6 volts. This event would cause overheating over a period of time and would probably evolve sufficient flammable gases from the epoxy materials (see summary of fire tests below) in them to eventually ignite in this dense array of detectors. Although some doubt exists, the evidence led the investigators to conclude that these cards were "on" at the time of the incident. After ignition, it was a short path via the plywood panel to the scintillators, the major fuel of the fire.

Flammability Studies:

As a part of their investigation, the Brookhaven committee performed a number of fire tests. First, samples were supported in a position similar to the beam line array and were conducted outdoors in a 2-3 mph wind. A road flare was used to represent a severe ignition source. The following is a summary of the results and may be useful due to its general applicability to components of Fermilab experiments.

1. Plastic (PVT) Scintillator--A single piece of scintillator material was difficult to ignite initially. As the buring end of the PVT melted, portions of the material dropped and formed pools of buring materials. Burning continued for several minutes after the ignition source was removed.

2. Lucite Light Pipe--This material ignited more easily than the PVT scintillator. It burned in a similar fashion. Burning was self-perpetuating.

3. Printed Circuit Cards--When exposed to the severe ignition source, the resins in the fiber-glass cards baked off quickly. A single PC card did not continue to burn after the ignition sourcewas removed. However, when the escaping gas from the resins were confined by other cards, the evolving smoke appeared to burn. There was continuous buring of several cards in a stack after the ignition source was removed.

4. 3/4 in Marine Grade Plywood--The plywood was difficult to ignite. It was easily blown out by the slight wind present during our testing. (Since this was a flat sheet in an open environment, the road flare did not readily ignite a self-perpetuating fire. This material is a known combustible and provides a scale by which the plastics can be measured.) In the fire, the wood

almost certainly provided a propagation pathway.

5. Photomultiplier Tube Base--The base contained printed circuit cards in the interior and has a micarta exterior. While the assembly would burn, it was difficult to ignite and easily extinguished.

6. PVC Signal Cable--A single strand of cable melted and shrank away from the road flare. Pairs of cables acted similarly. Neither propagated the fire away from the ignition source. (In fire protection technology, twelve or more cables of this type are considered a potential path for fire spread. This amount of cable was not tested by the BNL investigators).

7. Polyethylene Twisted Pair Ribbon Cable--Burning was similar to the signal cable, except there was apparent ignition of materials by the ignition source.

8. Aluminized Mylar--Despite prolonged exposure to the ignition source, the material in the region beyond the impingement of the direct flame was not damaged. The mylar in direct contact with the flame melted but did not sustain a flame.

A second series of tests were conducted on 8" X 8" sections of various plastic sheets. These tests were conducted in a Laboratory hood (low wind factor). A match was used as the ignition source. The ignited match was held at the edge of a folded sheet. The match was moved to maintain flame impingement on the sheet.

9. Black Polythylene (used as a "light-tight" shield for the scintillators)--This material readily ignited, melted rapidly, and formed burning pools from dripping liquid. The material continued to burn for a short while after the flame was removed.

10. Mylar Sheets (0.001" and 0.002" thickness)--The material melted quickly away from the flame, but burned only slightly and was not self-sustaining.

11. Mylar sheet (0.003" thickness)--This material melted and ignited rapidly. It continued to burn after the match was removed.

12. Aluminized Mylar--This material melted and burned rapidly in spurts. In between the bursts of burning, it would simply melt away from the flame. The BNL investigators remarked that this result contrasts with that obtained using the highway flare and points out the limited nature of these tests.

Findings Causally Related to the Incident-BNL Investigators (paraphrased by me for their general applicability to Fermilab):

1. Many of the materials commonly used in experiments are combustible and can contribute to a fire if ignited. Many of these materials are <u>essential</u> to the experiments and substitutes are <u>not</u> readily available.

2. High currents or high voltages required by electronics represent sufficient power to provide ignition sources.

3. Nonessential combustibles were present and the use of plywood for support and polystyrene spacers in the apparatus contributed to the size and spread of the fire.

4. Safety reviews did not identify the vulnerability of the apparatus to the development of fire without prompt fire detection or the unnecessary combustibles.

5. An adequate local detection system would have provided prompt automatic detection.

6. The "watch" technician should not have entered the smoke-filled room alone and without SCBA equipment.

7. Entry of emergency response personnel to areas potentially containing flammable gases may not have been adequately defined.

8. It was not clear that geographic locations used by firefighters were equivalent to those used by operations personnel. This may have caused unnecessary confusion during the event.

9. Specific procedures are needed to define the situations requiring SCBA use and to prevent people from fighting fires alone.

10. Use of appropriate current-limiting devices on electronic devices needs to be reviewed.

Conclusions-Fermilab Fire Safety Subcommittee (in addition to the above with which we concur):

1. The BNL recommendation 10 in the above list should be heeded by Fermilab. It is clear that the failure mode of ordinary resistors is not as well-known as it should be. The use of resistors as fuses is not appropriate or reliable. Devices such as preamp cards should have individual fuses. It was the observation of two physicist members of the subcommittee that many such cards used at Fermilab do have such fuses. There also may be some that do not. This should be given serious consideration by the designers and users of such components.

2. In this case humans detected the fire. At Fermilab, we conventionally do not have the equivalent of "watch" technicians on duty during nonoperational periods. It is not clear that the temperature/rate of rise detectors would have ever seen a smoky, electrical fire. Fermilab experiments typically do not have any appropriate smoke detectors (photoelectric or ionization). Building sprinklers would serve only to save the building, not the experiment in a typical experimental hall. The subcommittee suggests that the Laboratory investigate improved means of fire detection near experiments to reduce this vulnerability. Some work in this area has been done for CDF, this should be pursued further. In our view in this incident, the absence of flammable gases which would have been present in actual operation, was of significant benefit in reducing the potential consequences of this fire.

3. The subcommittee believes that emergency response personnel should have a better defined approach to dealing with suspected fires in experimental halls which have combustible items (apparently always) and flammable gases (usually). Procedures should be clearly stated to prevent an isolated individual from fighting such a fire alone and without SCBA.

4. The importance if minimizing the combustibles present near experiments cannot be

overemphasized.

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