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Time of the July 5, 1965 Accident and Fire

By: R. D. Biron

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Experiments and Target-Gas Storage at the CEA at the

Time of the July 5, 1965 Accident and Fire*

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I. Introduction

This paper is concerned with the experimental systems and the materials which contributed to the explosion and fire of July 5, 1965¹ at the Cambridge Electron Accelerator (CEA).

The CEA is a 6-BeV electron synchrotron² located at Harvard University and is managed jointly by M.I.T. and Harvard. Used by scientists from several universities, it has been operating since 1961. Most of the particle detection apparatus and related equipment for experiments is located in a main experimental hall, 100 ft x 300 ft in plan dimensions, which can accommodate six electron-photon beams.

Figure 1 shows the various experiments in the hall at the time of the accident. Most experiments are located along beam paths and are separated from each other by eight-foot high concrete radiation walls. Normally, the accelerator operates on a continuous basis with periodic shut-downs for repairs. The support facilities, such as the machine shop, electronics, and cryogenics are located adjacent to the experimental hall.

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Experiments being carried out at this facility used liquid hydrogen for beam targets and hydrocarbon gases for particle analysis equipment. Other inflammables, such as oxy-acetylene, oil, and liquified petroleum gas used in support equipment were located in the hall. The fuel sources in the hall that contributed significantly to the fire included: 500 liters of liquid hydrogen from a bubble chamber; 300 pounds of propane gas stored in gas cylinders for use in Cerenkov counters; 20 pounds of propane from a Cerenkov counter; two 100-pound LPG cylinders for an emergency power generator; and two oxy-acetylene setups. Several other fuels that were present including gaseous hydrogen, butane, and ethylene, did not burn.

II. Discussion

A. Experimental Setups

Several experiments were in various stages of completion at the time of the accident. A brief description of each follows.

1. Photo-production of Mesons (Beam 4)

This experiment was in the process of being assembled at the time of the fire. The equipment located in the area consisted of a one-liter liquid hydrogen target facility, a 1500-psi carbon dioxide Cerenkov counter, scintillation counters, beam transport magnets, and several CO₂ cylinders to be used in the counter. The hydrogen target and Cerenkov counter were empty, but a 200 SCF hydrogen bottle was located at the control console.

2. Photo-production of Mesons (Beam 6-1/2)

Equipment in this area included a hydrogen target facility, two 150 cu-ft propane Cerenkov counters, one 30 cu-ft ethylene

Cerenkov counter, the beam transport system, six propane cylinders, and four ethylene cylinders.

The propane counters were steel cylinders 5 ft. long 5 ft. dia, with a 12-in flanged opening at one end that was sealed with three layers of 14 mil mylar clamped between metal flanges. One of the two counters was active and it contained 20 pounds of propane.

The ethylene counter consisted of a 5 ft long 8-in dia flanged pipe sealed by two thin stainless-steel diaphragms clamped at each end.

The hydrogen target had been removed prior to the fire but the control console located just outside the area had a 200 SCF hydrogen cylinder secured to it.

3. Spark Chamber (Beam 6-1/2)

This group was located in the same area as the above-mentioned experiment. The equipment included a small spark chamber and the electronic equipment which was in operation at the time of the accident.

4. Bubble Chamber Equipment

The bubble chamber experimental complex which included the chamber and magnet assembly, hydrogen purification equipment, refrigerator, film processor, auxilliary power generator, and associated support equipment was located behind beams 4-1/2 and 6-1/2. The chamber was being filled with hydrogen for the first time. Approximately 500 liters of liquid hydrogen had been condensed in it.

5. Scattering Experiment

An electron-proton scattering experiment including a hydrogen target facility, butane gas Cerenkov counter, beam transport and one cylinder of butane was inactive at the time of the fire.

6. Photo-production Mesons (Beam 10)

This experiment was the prime beam user and was active at the time of the fire. Equipment included a full one-liter target facility, freon-gas cerenkov counter, beamport transport system, and analysis equipment.

B. Arrangements for Flammable Gases

1. Storage

All commercial gas bottles used at the CEA were normally stored in the hall. However, the hydrogen-gas supply trailer for the bubble chamber was located outside the hall in a fenced-off area. Since the bulk of the inflammable hydrocarbons were used by experimenters, these cylinders were normally stored within the confines of the respective experiment. The cylinders were secured to special stands provided by the laboratory. Experimenters were responsible for the control of these gases. Each target facility required one 200 SCF hydrogen cylinder for operation which normally was secured to the target control console.

2. Experimental Equipment

Special consideration was given for designing experimental equipment containing inflammable gases. The major design effort was in the equipment containing liquid hydrogen; the emphasis was

to reduce the quantity of hydrogen to a minimum. The laboratory designed and constructed a closed-cycle helium refrigerator for the bubble chamber system, a helium liquefier, and several hydrogen target facilities that were intended to use the liquid helium from the aforementioned liquefier as a source of refrigeration. Target systems at other laboratories use liquid hydrogen as a source of refrigeration. These design considerations not only make it possible to reduce the overall inventory of liquid but eliminated the problems associated with liquid transfer and continuous venting of hydrogen. The maximum quantity of hydrogen tolerated in target systems never exceeded 2 liters; the maximum quantity of hydrogen associated with hydrogen refrigerated 2-liter targets is approximately 45 liters.

2. Venting

There were three basic venting systems used at the CEA for inflammables used with experiments. The main laboratory ventilation system, local exhaust systems associated with experiments, and a bubble chamber venting system. The general philosophy was to provide maximum protection at all times. Eleven ceiling fans located on a platform along the inside wall of the experimental hall provided continuously 215,000 CFM of air into the one million ft³ building. The flow of air from these fans is across the floor and upward to a continuous vent along the entire ceiling outer periphery. Some air was directed across the ceiling to eliminate pocketing of the lighter-than-air inflammables. All service areas in direct communication with the experimental hall were kept

under positive pressure and provide additional air into the building.

Venting of inflammables from targets and Cerenkov counters was through several stacks to the outside. Exhaust fans connected to each vent provided a continuous flow of diluent to maintain the concentration below the flammable limits during normal and abnormal venting conditions. Collection manifolds (envelopes) around the lower areas of Cerenkov counters, containing heavy hydrocarbons, exhausted small leaks. Vent stacks were normally extended several feet above the roof and were provided with special diffusers.

Several means of venting the bubble chamber system were provided, as shown in Figure 2. All dump and vent valves were either connected to a normal vent or an emergency vent. The normal vent line extended directly to the out-of-doors, and the emergency dump line was connected to an emergency dump tank. This vessel contained several tons of copper shot that would provide sufficient heat capacity and heat transfer surface to warm the hydrogen prior to being dumped outside. The exhausting hydrogen was of sufficiently low density to insure rapid diffusion in the air. A hydrogen detection system monitored conditions in the bubble chamber area.

4. Ignition Source Controls

As a general rule most of the electrical equipment in the hall was not of an explosion-proof design. Continuous ventilation was provided to dilute any leakage of inflammables below the flammable limit. A four minute air change by the building

ventilation system and local exhaust fans were the main line of ignition prevention. Some of the electrical equipment in the bubble chamber complex, however, was explosion proof.

C. Probable Sequence of Events in the Accident

1. Cause of Accident

The Bubble Chamber complex consists of a chamber, refrigeration system, magnet, vacuum system, emergency vent system, and the control system. Figure 3 shows an exploded view of the chamber body, safety box, main viewing window, vacuum box, main distance piece, and hydrogen condensers, all of which are suspended from and sealed to the main support plate. The chamber body and vacuum box were equipped with beamport windows made of beryllium. The AEC investigation¹ indicated the most probable cause of the accident to be the failure of first the inner and then the outer of these beryllium beamports, which sealed liquid hydrogen from the bubble chamber insulating vacuum and the vacuum from the atmosphere, respectively.

The most reasonable explanation for failure of the inner window is that it fractured in a brittle mode due to biaxial stresses induced by differential thermal contraction forces as well as internal pressure.³ Although calculations would indicate that stresses in the beamport were substantially below the normal failure levels, it has been suggested that surface imperfections from machine-tool fabrication operations produced stress-raisers of sufficient intensity to cause ultimate failure.

The failure of the outer beryllium window then was concluded

to be a consequence of the impact of the inner window fragments and the sudden temperature shock from the hydrogen.

Under these circumstances, it was postulated that release of fracture energy from the outer beryllium window was the most probable source of ignition.

2. Sequence of Events After Ignition

It is believed that the initial fire from hydrogen in the chamber was of short duration; that secondary fires were minor at first; and that it was not until several minutes had elapsed that a release of LPG from two 100-lb cylinders caused a second explosion. This accelerated burning of roofing materials throughout the area--the mylar window on the propane Cerenkov counter, weakened by heat from burning roofing, failed. About 20 minutes after the second explosion, the intense heat in the hall caused a pressure rise and subsequent failure of the relief valves of the six propane cylinders in the Beam 6-1/2 area. Ignition of this gas caused an intense fire that persisted for a long time. The final stages of the fire involved the burning of large quantities of flammable roofing tar and insulation.

III. Conclusions

It is believed that a different system for storing flammable gases used in the Experimental Hall would have resulted in considerably less physical damage due to the accident. The bubble chamber, named as the site of the most probable cause, contained only about 15% by weight of all the gaseous fuels consumed in the fire; as pointed out earlier, this initial fire was thought to be of short duration.

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2. CEAL 1000, Cambridge Electron Accelerator, Cambridge, Mass.
3. NYO-10742, Investigation of Beryllium Windows from CEA Bubble Chamber.

Conscientious efforts were made by each group of experimenters to minimize the hazards associated with their equipment arrangements, and by the CEA to accomodate each group on the basis of its safety requirements. But to a considerable extent, experiments were set up without concern for the hazards they might be subject to due to the presence of neighboring experiments. This shows a clear need for integrated planning of equipment arrangements for all experiments sharing the floor of laboratories of this type.

More emphasis on the isolation of the Bubble Chamber-Magnet Assembly might have prevented the spread of fire. Isolation by totally enclosing the assembly in a structure of standard shield blocks, as is now done at some other laboratories, was not possible because of insufficient clearance under the building's overhead crane.

Fig. 2

BUBBLE CHAMBER DUMPING AND VENTING SYSTEMS

Note : For detailed assembly dwg., see
M.I.T. - LNS Dwg. S-4224-A)

Fig. 3

GENERAL EXPANDED VIEW OF 40" BUBBLE CHAMBER SHOWING
ORDER OF ASSEMBLY OF MAJOR COMPONENTS EXCLUSIVE OF
EXPANSION SYSTEM