Title
GUIDE TO SAFETY IN ACCELERATOR LABORATORIES

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Publication Date
1967-09-13

University of California

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An invited talk for presentation at the
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UCRL-17815
Preprint

UNIVERSITY OF CALIFORNIA

Lawrence Radiation Laboratory
Berkeley, California

AEC Contract No. W-7405-eng-48

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Abstract

The AEC established a National Committee in April 1966 to propose broad safety guidelines for high-energy accelerators. The guidelines have been written and are about to be published.

The guidelines aid the director in the organization and review of his safety program and provide a checklist to consider when assembling a safety manual. It allows each laboratory to establish its own safety program to fit its own needs.

The intent of the Committee and some of the problems they faced are discussed.

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Introduction

Background

The introduction that I will use is taken directly from the "Safety Guidelines for High Energy Accelerator facilities." Since so much effort went into the writing of these sentences, I doubt if I could improve the ideas any by rewriting them.

> On July 5, 1965, a major fire and explosion occurred at an AEC High Energy Physics installation. As part of its effort to minimize the possibility of another such occurrence, the AEC established a national committee to prepare Safety Guidelines for High Energy Accelerator Facilities. The committee was composed of representatives of major AEC research facilities and AEC Headquarters and field office staffs.

The committee worked under the chairmanship of J. Allentuck of the New York AEC Office, and personnel was chosen from the AEC offices in New York, Chicago, Brookhaven, and San Francisco, and the Washington Headquarters; and from the Argonne National Laboratory, the Brookhaven National Laboratory, the Cambridge Electron Accelerator, the Lawrence Radiation Laboratory, the Massachusetts Institute of Technology, the Princeton-Penn Accelerator, and the Stanford Linear Accelerator.

Charter

The New York Operations Office was given the task of writing the guideline. The committee's charter as specified by W. M. Johnson, NYAEC, on 7 April 1966 is as follows:

> To establish an Accelerator Safety Committee to prepare broad safety guidelines of general applicability for both experimental use of accelerators and accelerator operations at AEC facilities. The charter of this Committee is such as to specifically exclude radiation safety.

History

Four major subcommittees were established to develop guidelines in the areas of

I Management Procedures

II Buildings and Facilities

III Experimental Equipment

IV Operating Procedures

The first general meeting was held at Argonne on 18-19 May 1966; members were appointed to the subcommittees and the form for the guidelines was established. During the period from May to October 1966, each subcommittee prepared initial drafts of its guidelines. At meetings from October 25 to 28, 1966, the entire committee met at Brookhaven to review the prepared drafts, and (after some disagreement) agreed on areas requiring further subcommittee effort.

On January 3, 1967, an editorial subcommittee was established to prepare a composite document. A draft was edited and completed on March 7, 1967, and distributed to committee members for comment; later it went to the directors of accelerator laboratories and to AEC field offices for their comments. The comments are now being incorporated into the guidelines at the AEC Headquarters in Washington, and the guidelines are expected to be published in the last quarter of this year.

Description of the Guidelines

Preface to the guidelines

The purpose of these guidelines (as stated in the guidelines) is

> . . . . to provide a guide for the organization and review of safety programs in accelerator laboratories. The various laboratories differ significantly in size, location, and scope of their activities. Therefore, safety at each installation can best be served by the individual laboratory developing its own detailed safety-program standards, procedures, and specifications. This document presents guidelines that may be considered by management for development of its policies and standards.

In other words, this document guides the director in setting up

(a) laboratory safety organization to formulate, advise on, and implement safety policy;

(b) asks that local safety rules be written by the laboratory;

(c) provides a checklist of guidelines that should be considered in the assembling of the local safety manual.

The importance of the guideline approach is that each laboratory is required to establish its own safety program to fit its own needs. It was the committee's intent to emphasize that each laboratory is different and has its own style of operation. Keep in mind also that these guidelines are directed to specific facilities--namely <u>high energy accelerator facilities</u> only. They are not directed to or tested for their applicability to other areas such as chemistry laboratories, nor do they consider the design and operation of the accelerator itself. Radiation and electrical safety are treated only in a peripheral manner; other documents treat these subjects in greater detail.

Parallel with this effort the AEC has in preparation guidelines for electrical safety.

<u>Introduction to the guidelines</u>

The introduction of the guidelines recognizes that

> The laboratory in its mission of supporting High Energy Physics is involved continuously in the operation of accelerators and experimental devices; in the design and construction of buildings, facilities and experimental equipment; in the installation and removal of experimental setups and beam transport arrays; and, in the assembly and disassembly of experiments.

These guidelines go on to recognize the problems of

(a) The simultaneous use of many pieces of hazardous equipment.

(b) The consequences to the surroundings of the failure of a piece of equipment.

(c) The diverse activities and interests of those present.

(d) How to maximize the use of equipment while minimizing the hazard.

The Guidelines

Each of the subcommittees wrote one of the four major sections shown on this abbreviated table of contents.

SAFETY GUIDELINES FOR HIGH ENERGY ACCELERATOR FACILITIES

Problems

Format

The titles of the four sections could be grouped easily into Management and Buildings, then Equipment and Operation, as this is the way most laboratories are organized. Choosing the forms of the Equipment Section and of the Operations Section was more difficult, as there are many groups of words (or matrices) which can be put together in many ways and which have a large number of combinations. For example, in the Equipment Section, the following partial lists yield 3888 combinations--each had to be considered.

General Categories

Flammable	Cryogenic	Mechanical
Nonflammable	Noncryogenic	Electrical

Systems	Components	Functions
Bubble chambers	Vessels	Design
Cryogenic targets	Vacuum tanks	Fabrication
Spark chambers	Reservoirs	Inspection
Gas counters	Piping	Reports
Superconducting magnets	Controls	Safety devices
Auxiliary storage	Instrumentation	Testing
Fluid handling		Installation
Thin windows		Maintenance
Others		Standard codes

Which would you choose for the primary headings? In these guidelines the first two groups were combined to give four of the major headings of Section III of the Guidelines, as shown on the table of contents. And, of course, there are always a few headings that do not seem to fit anywhere.

Scope and Detail

The committee limited the scope of its work to hazards associated with research at high energy accelerators. For example, in the experimental equipment section, we did not describe how an accelerator is designed. An accelerator, we agreed, is designed under standard codes such as AEC 6300, NFPA, etc., and we did not see the need for any unusual rules that would be required other than radiation precautions, which were not a part of the committee's charter. On the other hand, some areas that have not received specific attention but perhaps should are

- Hydrogen liquefiers and purifiers,
- Liquid oxygen,
- Liquid helium,
- On-site transport of flammable fluids.

The detail of the report varies mainly because of the nature of each section. Section I, Management is the least detailed, and the amount of detail increases to its greatest in Section IV, Operating Procedures. There is also variation in subject, coverage, and style, which is a consequence of having many authors.

Another item was to review the guidelines to see that they did not recommend the preparation of too many reports.

Audience

Identifying the audience was one of the first problems; this affected all the different subcommittees and was interlocked with the question of guidelines vs rules. The guidelines are directed to the laboratory management, who can use them as a starting point for specific instructions to engineering and scientific groups. The audience probably consists principally of the safety committees of the various laboratories, although the overall report may reach several other groups. For example, the Management Subcommittee directed its work to managers, and the Equipment Subcommittee to technical personnel.

Guidelines vs Code

The most difficult question the committee faced was whether the report should be mandatory or nonmandatory--i.e., guidelines or minimum acceptable standards. The problem became apparent when the first drafts were brought together for the first time at the Brookhaven meeting. The sections varied greatly, but in general the mandatory nature increased from Section I to Section IV. Section I, Management, was always in the nature of guidelines, as it is directed to the whole laboratory. Section III, Equipment, becomes more mandatory; the first arrangement included a statement of the problem followed by an example written as a rule. This approach was too wordy. The section was rewritten and the draft taken to Brookhaven was written in the form of minimum acceptable standards.

Even where there was mutual agreement, the idea of minimum acceptable standards was not approved. Many people sincerely believe, and I concur, that providing standards eliminates the necessary thought on and discussion of safety at the laboratories, and that directives and manuals can introduce a false sense of security. There was also great concern over the probability that any mandatory sentence would in future generations become a rule. This question was discussed vigorously, and in the end guidelines won out.

Technical Problems

There are still unsolved technical problems but only a few can be discussed in this short paper.

Building forced-air emergency ventilation: Does it do any good? At CEA and Saclay it didn't help. Perhaps forced-air ventilation in buildings need only be sufficient to prevent flammable gas mixtures from accumulating. Looking specifically at liquid hydrogen, it now seems clear that we should assume that any sudden release of large amounts of hydrogen into the air would ignite spontaneously. Consequently it is even more important to emphasize the design philosophy of containment and put less emphasis on emergency ventilation.

The design and pressure testing of bubble chambers: How should the pulsed stressing of a bubble chamber be considered? How much detail should be included in the guidelines? In the ASME Nuclear Boiler Code no less than ten kinds of stresses are described. In general, existing codes, such as the ASME Pressure Vessel Codes and the NFPA National Electrical Code, were used as points of departure in developing the Equipment Guidelines. These codes provided a checklist of items to consider, and indicated the importance of test procedures. However, these codes were not written generally to include bubble chambers, high pressure counters, and the like.

Hazardous research equipment in general operates at relatively low pressures (less than 1000 psi) and temperature ranges (less than 600°K). In this respect the design problems are not difficult, and there are many good materials. The important problem is that the working fluid is flammable, and brittle materials such as glass may be used for optical windows, or plastic for thin beam windows, operating at very low temperature. Once we are sure of the integrity of the parts of the system that do not affect the experiment, and the weakest points of the system such as the optical or beam windows are identified, then it suffices to focus and maintain attention on only those few points (the exception principle). The relief devices protecting these weakest points must be adequate to assure that the windows themselves do not become the "rupture discs."

A possible cause of explosions in hydrogen liquefiers and purifiers: The cause of explosions in hydrogen liquefiers and purifiers, to my knowledge, has not been satisfactorily explained. It could be as described below. We know, from studies of gas-stream Van de Graff generators, that a high-velocity gas stream can produce an electrical charge. If there is an insulator to accumulate charge, such as a layer of frozen oxygen, then when the voltage across the insulator is sufficient to break down the insulator a spark discharge can occur. The spark can be the ignition source, the hydrogen exists, and the oxygen can enter the system as impurity in the hydrogen. In liquid hydrogen bubble chambers, for example, the impurity is seen as fine powder on the bottom of the chamber which is easily moved around. All the requirements for an explosion are satisfied.

The spark discharge required to ignite a hydrogen-oxygen mixture must satisfy two requirements: (a) The spark must contain sufficient energy to ignite the mixture, and (b) the layer of insulation must be thick enough to hold the required voltage before discharging. The minimum energy required to ignite an H_2-O_2 mixture is about 0.02 millijoule. What voltage is necessary? Consider a 1-in.-long section in a stream of hydrogen gas 0.3 in. in diameter and flowing parallel to an insulated plane (layer of oxygen) and 0.5 in. above it. The capacitance of such a hydrogen stream to the oxygen layer is about 0.75 $\mu\mu$F. From $W = 1/2\, CV^2$, where W is the stored energy in joules, C is the capacitance in farads, and V is the voltage, one sees that only 7000 V would be required. If the ignition energy is considered at H_2-O_2 mixtures of 10 or 55% H_2, then the energy needed is about 2 mJ, which requires 70 000 V. Evidence of voltages in this range have been seen as dendritic trails in insulators, made by sparks. Such trails were made in the SLAC 40-inch-diameter liquid hydrogen bubble chamber, and were observed as carbonized paths left in the epoxy base of the Scotchlite light reflector. To make similar trails in Lucite-type plastics has required voltages of about 100 000 volts.

At this time, the mechanism described above is unproven, and experimental evidence is needed to establish its correctness. However, the petroleum industry solved a problem involving a similar mechanism several decades ago. The suggested mechanism makes clear the importance of keeping oxygen out of hydrogen systems by careful attention to hydrogen purity and procedures.

In the meantime, liquefiers and purifiers might be considered as high-voltage electrical apparatus, with thought given to such items as voltage gradients, arrangements that will drain electric charge rapidly, and hydrogen stream velocities.

Review

The guidelines were reviewed by six accelerator laboratories and five AEC Field Offices. Two laboratories and two AEC Field Offices replied without comment. Two people even commended the committee for its effort.

Several laboratories stated that they were glad that the guideline approach was chosen rather than a mandatory approach. One laboratory thought that the report was too detailed and unbalanced, and overemphasized the CEA factors. This is probably true, since the CEA report was the basis of these guidelines; perhaps those who are farther from the project can better evaluate this comment. Corrections and improvements, I believe, will be made in time. Perhaps these guidelines should be reviewed about every three years.

I would caution against too much emphasis toward formal certification and a checkoff approach to safety. An attempt to include all problems, many of which are of no consequence, can lead to a serious decrease in safety effort on major problems. Certification and safety reviews must be made, but they must not be so formal that cooperation and communication between the equipment users and the safety personnel are suppressed or cut off. Maintaining this communication, I believe, is one of the most important and difficult tasks facing safety personnel today.