Title

RULES AND PROCEDURES FOR THE DESIGN AND OPERATION OF HAZARDOUS RESEARCH EQUIPMENT

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Rules & Procedures for the Design & Operation of Hazardous Research Equipment

Lawrence Berkeley Laboratory
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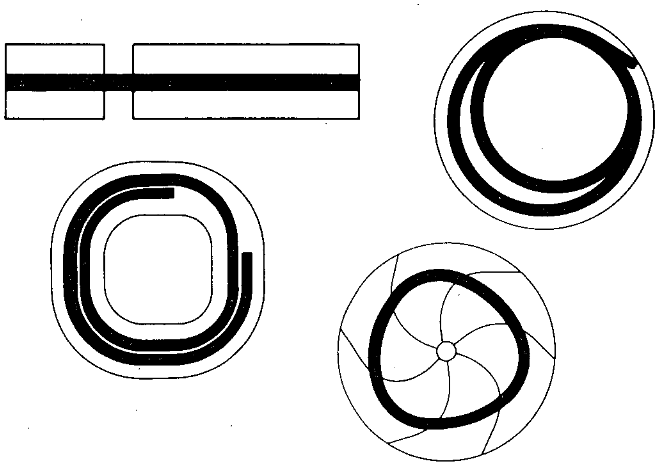

DISCLAIMER

Rules and Procedures for the Design and Operation of Hazardous Research Equipment

Pub-3001

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Revised February 1984

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RULES AND PROCEDURES FOR THE DESIGN AND OPERATION OF HAZARDOUS RESEARCH EQUIPMENT

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I.A INTRODUCTION

RULES AND PROCEDURES FOR THE DESIGN AND OPERATION OF HAZARDOUS RESEARCH EQUIPMENT AT THE LAWRENCE BERKELEY LABORATORY

Lawrence Berkeley Laboratory
University of California
Berkeley, California

November 1978

I. GENERAL INFORMATION

A. Introduction

This manual has been prepared for use by research personnel involved in experiments at the Lawrence Berkeley Laboratory. It contains rules and procedures for the design, test, installation, and operation of hazardous research equipment. Experimenters should be familiar with Section I (amounting to 16 pages). This section contains such information as responsibility of experimenters for safety, descriptions of the various Laboratory safety organizations, and enumeration of various services available to experimenters at the Laboratory. Section II describes specific rules for the setup and operation of experimental equipment at the Laboratory. Experimenters designing or operating experiments at accelerators must be familiar with the parts of Section II that apply to their particular experiment. Section III gives detailed design criteria and procedures for equipment frequently encountered in the high energy physics laboratory. Experimenters should consult the relevant subsections of Section III when designing equipment for use in their experiments.

The rules and procedures contained herein are in addition to the LBL Health and Safety Regulations (LBL-2077) set forth by the Environmental Health & Safety (EH&S) Department.

I.B STATEMENT OF POLICY

I. B. Statement of Policy

It is the policy of the Lawrence Berkeley Laboratory to provide a safe and healthful working environment for its employees, to protect its property from accidental damage or loss and to protect the health and safety of the general public from any harm that may arise from the Laboratory's activities. Because of the hazardous and unique nature of some experimental equipment, greater than usual attention and consideration must be given to the design, test and approval of such equipment, to the installation and operation of such experimental devices and setups, and to the supervision of experimental areas and activities. The possibility of serious accident is always present.

The safety attitudes and policies of the Laboratory are directed toward the elimination of hazardous conditions and the encouragement of safe work practices.

I.C STATEMENT OF RESPONSIBILITY

I. C. Statement of Responsibility

The primary responsibility for proper design, for the carrying out of required procedures, and the safe operation of equipment resides with the person in charge of the equipment or experiment. This generally will be the group leader, whether of a research group or one concerned with the operation of a Laboratory facility. The person in charge is responsible to the Laboratory Director. A secondary responsibility rests with the person in charge of a specific building or experimental area. Such persons have authority to prevent or stop operations considered unsafe, and may insist on standards above the minimum established in this document or by the engineering departments. The responsibility of the person in charge of the building is to be regarded as supplementing but not replacing the basic responsibility of the group leader concerned.

Supervisors at all levels should be responsible for the safety of their groups and should aggressively promote the safety program. Each individual, whether staff or user of the Laboratory facilities, should acquaint himself with the safety requirements and give full cooperation to the program.

The rules in this manual will be strictly enforced, and all group leaders are required to make certain that all members of their group really understand them and will follow them without "cheating." Particular attention is called to the rules regarding operation in the accelerator buildings. Willful violation of operating rules, or failure to understand thoroughly the operation of equipment, under both normal and emergency conditions, by persons in charge cannot be tolerated at any time; if necessary, disciplinary action will be taken. Such disciplinary action may be suspension of the privilege of operating equipment involving hazardous substances, or may involve application of the disciplinary measures covered in the Regulations and Procedures Manual (RPM), Section 2.03B.

I.D LABORATORY SAFETY ORGANIZATIONS

I. D. Laboratory Safety Organizations

The Laboratory and Accelerator Groups have established organizations and service groups to deal with the problems of safety in accelerator areas. The general responsibilities of these groups are: to formulate safety policy; to establish review procedures and standards; to coordinate and review safety activities; to assist experimenters in the design, construction, test, setup, and operation of hazardous equipment; and to examine requests for variance.

The following safety organizations and groups exist, and their membership and specific functions are as follows:

1. Safety Review Committee

Membership:

R. E. Muller, chairman
D. S. Andes, G. U. Behrsing, D. G. Eagling, R. J. Force, E. C. Hartwig, H. P. Hernandez, L. T. Kerth, R. M. Latimer, D. F. Lebeck, A. S. Newton, C. T. Schmidt, R. H. Thomas

Functions:

- To advise the Laboratory Director regarding safety policy and standards, with particular emphasis on hazardous experimental equipment.

- To review standards for the design and testing of hazardous research equipment.

- To act as an appeal committee and consider requests for variance from standard or established practice. It may prescribe special precautions or procedures in such cases.

The Safety Review Committee has formed several subcommittees to deal with specialized safety problems. These subcommittees are:

Electrical Safety Committee
E. C. Hartwig, chairman

Mechanical Safety Committee
H. P. Hernandez, chairman

Seismic Safety Committee
D. G. Eagling, chairman

Traffic Safety Committee
R. M. Latimer, chairman

2. Health and Safety Department

These groups are responsible for: providing laboratory management and supervision with advisory planning in areas of general industrial and laboratory safety, health physics programs and activities, and for monitoring of the laboratory environment to assure that safety is considered in working conditions and work practices at the Laboratory.

The following are in charge of the departments:

Environmental Health & Safety - R. M. Latimer

Medical Services - Dr. H. H. Stauffer

3. Building Managers

Building Managers ensure that work is performed safely within the areas under their jurisdiction. Building Managers, in their areas, have the authority to prevent or stop unsafe operations.

Building Managers and their phone extensions are listed according to building number (alternate in parenthesis):

B1	Fulton, Robert L.	5058
	(Moebus, Milton C).	6092
1	Long, Allen	5207
	(Whaley, G. Baird)	6033
3	Hayes, Paul M.	6131
	(Press, Michael J.)	6131
4	Latimer, Robert M.	5251
	(Haley, James T.)	5251
5	Pyle, Robert V.	5011
	(Berkner, Klaus H.)	5314
6	Kanstein, Leal L.	5467
	(Sylvia, Louis A.)	5291
7 (1st flr.)	Lanzit, Richard A.	5174
	(Medel, Richard)	5174

7 (2nd flr.)	Wilson, Gerald V.	5581
	(Wilkinson, Charles H.)	5581
9	Kanstein, Leal L.	5467
	(Sylvia, Louis A.)	5291
10	Kanstein, Leal L.	5467
	(Sylvia, Louis A.)	5291
12	Lanzit, Richard A.	5174
	(Medel, Richard)	5174
14	Thornton, Shelby A.	5477
	(Constantian, George A.)	5477
15	Silva, Elmer J.	6015
	(Haas, Harold R.)	6015
16	Pyle, Robert V.	5011
	(Berkner, Klaus H.)	5314
17	Nielsen, David V.	5151
	(Moitoza, Harry E.)	5303
19	Shugart, Howard A.	5034
	(Clarke, John)	7-23069
25	Bliss, Donald R.	5381
	(Worthington, Wm. L.)	5381
25A	Bliss, Donald R.	5381
	(Worthington, Wm. L.)	5381
26	Wales, Marcy	6266
	(Letchworth, William P.)	5829
27	Wilson, Gerald V.	5581
	(Wilkinson, Charles H.)	5581
29	Goulding, Frederick S.	5115
	(Kilian, George W.)	5115
37	Stewart, Robert L.	6011
	(Mathews, George E.)	6011
40	Thornton, Shelby A.	5477
	(Constantian, George A.)	5477
41	Thornton, Shelby A.	5477
	(Constantian, George A.)	5477

44	Hollowell, Craig D. (Traynor, Gregory W.)	5729 5729
45	Silva, Elmer J. (Haas, Harold R.)	6015 6015
46	Franck, Jack V. (Arthur, Allan A.)	5571 5571
46A, 46N	Rondeau, Donald J. (Reed, Eddie L.)	6411 6411
47	Chupp, Warren W. (Zelver, Judy A.)	6372 6372
50, 50A, 50B, B50A	Hinckley, Robert L. (Weber, P. Wes)	5511 5511
51	Force, Robert J. (Tekawa, Marsh M.)	5575 5575
52	Pyle, Robert V. (Honey, Vincent J.)	5011 5024
53	Newell, George A. (Morrison, Michael E.)	5831 6056
54	Serpa, Beverly C. (Hitchcock, Thomas P.)	5211 5211
55	Peters, Theresa C. (Long, Allan W.)	6325 6033
56	Force, Robert J. (Tekawa, Marsh M.)	5575 5575
57	Linfoot, John A. (Nakagawa, Jeanette S.)	6149 6141
58, 58A	Chupp, Warren W. (Lee, Wayne)	6372 6372
61	Stewart, Robert L. (Mathews, George E.)	6011 6011
62	Meschi, David J. (Pickus, Milton R.)	6077 5544
63, 63A, B63	Force, Robert J. (Tekawa, Marsh M.)	5575 5575

64	Force, Robert J. (Tekawa, Marsh M.)	5575 5575
65	Cone, Pearl B. (Jenkins, Carol L.)	6514 6514
69	Nielsen, David V. (Habe, Robert J.)	5151 5404
70	Escobales, Richard H.	6151
70A	Escobales, Richard H.	6151
71, 71A	Force, Robert J. (Stevenson, Robert R.)	5575 5846
72	Thomas, Ralph H. (Stephens, Lloyd D.)	5664 5656
73	Schmidt, Richard C. (Brendel, Henry A.)	5319 5319
74, 74B	Springsteen, Robert W. (Graham, Joan M.)	5107 5806
75	Latimer, Robert M. (Haley, James T.)	5251 5251
76	Stewart, Robert L. (Mathews, George E.)	6011 6011
77	Stallings, Donald W. (Kroll, Jack)	5901 5901
78	Lanzit, Richard A. (Medel, Richard)	5174 5174
79	Lanzit, Richard A. (Medel, Richard)	5174 5174
80	Kanstein, Leal L. (Sylvia, Louis A.)	5467 5291
81	Davey, James V. (Gachis, Gary A.)	5524 5481
88	Hendrie, David L. (Renkas, Mathew J.)	5088 5088
90	Eagling, Donald G. (Hopkins, Donald R.)	6366 5024

901	Nielsen, David V.	5151
	(Waterbury, John D.)	6121
930	Blake, Igor R.	6438
	(Hitchcock, Thomas P.)	5211
931	Amon, Elliott, W.	5557
	(Hirabayashi, Donald)	6585

1.E WHERE TO GET HELP

I. E. Where to Get Help

The services of a number of safety and support organizations are available to experimenters. Help may be obtained in the design, construction, installation, and operation of experimental equipment and setups. The Bevatron, SuperHILAC, 88-Inch Cyclotron, and 184-Inch Cyclotron Operations Groups, for example, assist in the design, layout and installation of experiments. They may, as required, coordinate the activities of various engineering, safety, and service organizations whose services may be needed. They also will advise on and enforce applicable safety rules and regulations.

Listed below are all the groups (including duties and personnel assignments related to this discussion) that may at one time or another be involved in design, review, or operation of hazardous equipment. It is not necessary, however, for experimenters to deal individually with these groups. As mentioned above, they may, if they wish, deal through the Accelerator Operations Group.

Bevatron Operations Group

Bevatron Building Manager	H. A. Grunder
Bevatron Operation Supervisor	H. A. Grunder R. J. Force
Supervision and coordination of experimental area activities, equipment, and setup review	W. W. Olson F. H. Lothrop R. S. Everett J. P. Brannigan
Safety control	W. W. Olson
Radiation control	W. L. Everette
Electrical safety	H. A. Wellemeyer

184-Inch Cyclotron Operations Group

Supervision and coordination of experimental area activities, equipment, and setup review	L. Kanstein
Coordination of experimental group activities and related work	L. Kanstein

Safety control	L. Kanstein
Radiation control	L. Stephens
Electrical safety	R. Sorensen

SuperHILAC Operations Group

SuperHILAC Building Manager	R. J. Force
Supervision and coordination of experimental area activities, equipment, and setup review	R. M. Diamond J. M. Nitschke M. S. Zisman F. B. Selph
Safety control	B. Shipley
Radiation control	L. Stephens
Electrical safety	R. W. Sorensen

88-Inch Cyclotron Operations Group

88-Inch Building Manager	D. K. Scott
88-Inch Operations Supervisor	R. A. Gough
Project Engineer	L. R. Glasgow
Supervision and coordination of experimental area activities, equipment, and setup review	D. K. Scott
Safety control	H. J. Harrington
Radiation control	L. D. Stephens
Electrical safety	R. S. Lam

Mechanical Engineering Department

Equipment and system design and review - Bevatron	A. Glicksman D. F. Rothfuss
Equipment and system design and review - 184-Inch Cyclotron	A. Glicksman D. F. Rothfuss

Equipment and system design and review - SuperHILAC	R. B. Yourd
Equipment and system design and review - 88-Inch Cyclotron	L. R. Glasgow

Electrical Engineering Department

Equipment and system design and review	E. C. Hartwig L. J. Wagner

Hydrogen Target Group

Target design, fabrication, test and installation	D. B. Hunt
Instruction in operation and emergency procedures having to do with hydrogen and deuterium target	D. B. Hunt R. Ellis

Safety Review Committee

See Section I.D.1

Environmental Health & Safety

R. M. Latimer

Operations Group (Radiation, safety, and emergency field services)	J. T. Haley

- Accelerators
- Radioactive materials
- X-ray machines
- Lasers
- Decontamination and waste disposal
- Transportation of hazardous materials
- Monitoring services
- Fire protection
- First aid response

Technology Group	J. Young
Radioisotope shielding, containers, enclosures Remote handling equipment Radiation instruments Traffic, shop, lab, office safety Safety education Environmental surveys, sampling, evaluations of: radioisotopes, hazardous substances, noise, lighting Film badge	
Radiation Physics Group	J. B. McCaslin
Special shielding design Special radiation surveys	

Mechanical Engineering Liaison Group

Responsible for ordering and scheduling deliveries of liquid hydrogen and liquid helium. Requests should be made to Gary Gachis, ext. 5676.	J. V. Davey G. A. Gachis

Mechanical Safety Committee

Chairman	Gerd Behrsing
All Chemistry, organic and inorganic, research equipment and installation. Buildings 62, 70 and 73 Areas. Hydrogen storage areas.	Rod Byrns Dick Wolgast
Bevatron, mechanical shops, Building 74, Biomedical and campus areas.	Gerd Behrsing Egon Hoyer
All Physics research equipment and installation, Heavy Ion Accelerator-Building 71, 184-Inch Cyclotron, and 88-Inch Cyclotron Areas.	William Pope Richard Warren
Lifting devices	Lee Glasgow

Vehicle safety devices	Al Ferrari
Earthquake and seismic hazards	Ted Scalise
Pressure vessels	Larry Beaulaurier

Electrical Safety Review Committee

Chairman	Ed Hartwig
Deputy Chairman	Don Rondeau
MFE	Bill Baker
Earth Sciences	Gene Binnall
Physics Instrumentation	Charlie Carr
Advanced Accelerators	Sandy Goss
MMRD	Joe Katz
Energy and Environment	Jeff Kessel
88-Inch Cyclotron	Bob Lam
TFTR	Don Morris
184-Inch Cyclotron/Hilac	Bob Sorensen
Donner Lab.	Frank Upham
Bevatron	Ferd Voelker
Environmental Health & Safety Liaison	Jack Izzo

I.F REVIEW AND VARIANCE PROCEDURES

I. F. Review and Variance Procedures

1. Early Review

Each experiment and the design of new experimental equipment shall be reviewed for possible hazards well in advance to insure that there will be compliance with Laboratory safety requirements.

The basic responsibility for seeing that reviews are made resides with the person in charge of the experiment or the equipment. In general, experimental setups and operational and emergency procedures will be reviewed at a special meeting called by the appropriate operation group. In attendance will be representatives of the Experimental Group, the EH&S Department, the Building Manager, the Engineering Groups, and the Hydrogen Target Group if the experiment involves the use of a liquid hydrogen or deuterium target or counter.

2. Design Review

Equipment design, fabrication, testing, and installation will be reviewed by the appropriate engineering department and by the Engineering Safety Committee. If the equipment is both new and being designed by an LBL engineering department, the review will be carried out in the natural course of events as part of established procedures. If, however, the equipment already exists or if the equipment is being brought here from outside the Laboratory, the design and status of the equipment must be subjected to a formal review. This review will be made by the appropriate Laboratory engineering department with the counsel and assistance of the experimenter. A member of the Engineering Safety Committee may be asked to attend if there are unusual problems to be considered.

3. Continuing Review

It is important that the various reviews be made early so that pressures of time will not result in substandard design or operations from the point of view of safety. It must also be considered that in all research activities the completed installation may differ in many respects from the initially conceived experiment or project. Therefore, it is important to conduct a comprehensive review just prior to operation. Also, modifications to equipment or procedures which occur during design, construction, or operation and which affect safety should be immediately evaluated. These reviews should be made by the same groups as were initially involved.

Some specific instructions for review and approval will be detailed in following sections of this manual, as is appropriate to the case.

4. Variance

Requests for variance from established criteria, rules, or procedures must be submitted to the Safety Review Committee in writing by the experimenter. See Section I.D.1.

The request for variance should include the following:

a. the necessity of performing the experiment in the proposed manner, from a physics point of view;

b. a written description sufficient to identify the experimental apparatus;

c. the variance being requested.

II.A PROCEDURAL REQUIRE-
MENTS FOR OPERATION
OF HAZARDOUS EQPT.

II. GENERAL RULES FOR SETUP AND OPERATION OF EXPERIMENTAL EQUIPMENT

A. Procedural Requirements for Operation of Hazardous Equipment

Greater than usual precautions must be taken at LBL to assure that experimental equipment is being set up and operated safely because of the unique and fluid character of experimental areas, and because of the unusual hazards associated with some experimental equipment. Experimental areas can be characterized as being highly congested; as containing a heterogeneous assemblage of experimental equipment in close association, some of which may be potentially and inherently hazardous; as having a high density of activities; and as being under diverse management. The status of experimental equipment may frequently change. Therefore, before hazardous experimental equipment may be filled, pressurized, or operated, the following procedural safety requirements must be satisfied:

1. Submission of Documents

Before equipment may be activated or operated for the first time, the following documents must be submitted to EH&S and the Building Manager (these documents will be kept on file during the course of the experiment and should be kept up to date. The person in charge of the experiment is responsible for seeing that new documents are submitted if changes have occurred):

a. Statement from the group leader giving the name of the person in charge of the equipment.

b. List of authorized operators. New personnel and those unfamiliar with the operation of the equipment must receive orientation and training. See Section II.B.

c. Copy of the operating procedures of the equipment, including emergency procedures.

d. Copy of the operation check list.

e. Certification of required engineering tests (a mechanical engineer must certify tests specified by the Engineering Safety Committee).

2. Review Prior to Initial Operation

Before equipment may be activated or operated for the first time a formal review of the entire experimental setup and operation will be made. This review should be made jointly by a member of the Engineering Safety Committee, a member of the Experimental

Group, and a member of EH&S. The review should examine compliance with Laboratory and local safety rules and policies, including those listed below. Deficiencies must be corrected before equipment may be operated.

a. The equipment and the setup must comply with Section II and Section III.

b. Hazard monitoring and warning devices must be in place and checked for proper operation.

c. Personnel traffic and access to and about the hazardous area must be controlled in a satisfactory manner.

d. Adequate egress must be provided.

e. Electrical equipment in and around block houses or equipment enclosures should be inspected and must meet Laboratory specifications.

f. Interlock systems must be tested and approved.

g. Block house or other enclosures containing flammable fluid devices must be properly ventilated.

h. Vent systems and associated connections shall be inspected and approved by appropriate Laboratory representatives (including systems for nonflammable fluids). Experience has indicated that this interface system between experimental group and accelerator group should be the concern of both.

i. Warning signs must be plainly visible from all approaches, including by crane. These signs, of course, should accurately represent the status of the equipment and should therefore differentiate between a safe and a potentially hazardous state of the equipment.

j. Personnel lists, phone numbers, schedules, and the names of the shift supervisor must be posted at the control area of the equipment. See Section II.B.

k. A copy of the schematic diagrams of the equipment, and a copy of operating and emergency procedures must be on file or posted at the control of the equipment. Emergency procedures should consider power failure, a building fire, apparatus fire, or failure of the equipment.

l. Emergency lights must be in place and tested.

m. The relationship, responsibilities and interface between the experimenter and the accelerator group must be established for normal and emergency conditions.

3. Notification of Intent to Activate Hazardous Equipment

a. Before equipment may be activated or operated (EACH TIME) the equipment operator must inform the EH&S Coordinator and the Building Manager and obtain approval.

b. If flammable liquefied gases are involved, permission must be obtained from the EH&S Coordinator and the Building Manager before the flammable fluids may be brought into the building or experimental area.

4. Requirements During Operation

The experimental group is responsible for insuring that safety standards are maintained during the entire period of operation of potentially hazardous equipment. This is particularly important for long runs during which equipment or procedures can deteriorate, and during which the equipment or the environment can change.

Periodic review or checks of the following should be made:

a. Equipment maintenance

b. Operating procedures

c. Emergency procedures

d. Training and competence of the operation staff

e. The state of the equipment and setup, taking into consideration recent changes to the equipment and to the experimental area

f. Suitability and operation of interlocks, monitoring, and surveillance equipment

g. Handling procedures for flammable or high-pressure fluids or gases

h. Storage of equipment. Particular attention should be given to minimizing the storage and accumulation of flammables

i. Adequacy of access and egress routes, including emergency escape routes

j. Adequacy and placement of emergency equipment--lights, fire extinguishers, etc.

The above reviews should be made jointly by a member of the Engineering Safety Committee, the EH&S Coordinator, the Building Manager, and a member of the Experimental Group.

5. Deactivation of Equipment

a. When equipment is deactivated, either temporarily or permanently, the EH&S Coordinator shall be advised and the status of the equipment reported to him.

b. Equipment that has been filled with flammable or toxic fluids must be purged before it may be left unattended.

c. Warning signs must be removed or changed to correctly indicate the status of the equipment.

II.B STAFFING: EQUIPMENT OPERATORS

II. B. Staffing: Equipment Operators

The importance of equipment operation and monitoring as provided by vigilant equipment operators cannot be overemphasized. Hence, a very important objective for equipment operators is that they have a strong interest in their job and a thorough knowledge of their equipment. They must be sufficiently trained to have confidence in their own ability to handle and cope with unusual and abnormal situations.

A great deal of faith and reliance must be placed upon the operator of a piece of hazardous equipment. The best-planned monitor and surveillance system can be circumvented by inept actions of a disinterested or untrained operator. It must be remembered that during emergency situations, monitoring and surveillance systems can function only to the extent planned in the original design. The well-trained operator has an advantage: he can think about the situation before taking the most appropriate action.

In areas where dependence must be placed upon the reliability of operators, it is extremely important that they be thoroughly trained in the intricacies of the equipment they are operating. The operators must understand and appreciate the interaction of their equipment with other devices and systems in the immediate area.

Supervisors for areas where hazardous equipment is located should always be alert to detect a casual and indifferent attitude that their operators may develop toward their responsibilities. A false sense of security may be brought about by continued safe and uneventful operation of a hazardous device.

General Requirements

1. Adequate numbers of trained supervisors and equipment operators must be on hand to assure safe operation of equipment during periods of operation and during the periods of standby (when the equipment is in a potentially hazardous condition but not in operation). At no time should only one person be involved in such operations. If, for instance, a person is working on electrical equipment (see electrical safety rules) another person may be required to be in the immediate area. For work associated with some other kinds of equipment--such as hydrogen targets, high pressure equipment, etc.--a second person must be within calling distance, but may be working on other equipment. As indicated in Section II.B.4, some equipment may be left unattended with the permission of the building supervisor.

2. Hazardous equipment may be operated only by trained persons certified for the operation of such equipment. They must be thoroughly familiar and practiced. They must recognize that they may be the only persons in the area technically qualified to handle emergencies involving their equipment.

3. The person in charge must ensure that all safety rules and any specific safety instructions, if established, are followed.

4. Operators should be on duty in the experimental area whenever hazardous equipment contains a flammable or high-pressure fluid (or both). Such equipment should not be left unattended except in the event of an emergency that requires evacuation of the area. However, with the knowledge and permission of the Building Manager, some hazardous equipment may be left unattended provided it is continuously monitored, suitably isolated, and interlocked. The Building Manager should be advised as to the status of the equipment and the hazards involved, and must accept the responsibility for carrying out the emergency procedures.

II.C HOUSEKEEPING

II. C. Housekeeping

Proper housekeeping is essential to the conduct of a safe experimental program. Experimental group management has the responsibility for assuring the development and continuance of proper attitudes and attention with respect to this kind of maintenance by members of their group.

The following objectives of a good housekeeping program should be considered:

- Minimization of the accumulation of flammable material.
- Minimization of congestion around experimental equipment.
- Provision and proper maintenance of aisles and of points and routes to emergency egress.

II.D DEFINITION OF "HAZARDOUS AREA"

II. D. Definition of the "Hazardous Area" Associated with Flammable-Fluid-Filled Research Equipment and Rules Governing the Installation and Operation of Electrical and Mechanical Equipment in Such Areas

1. Definition of Hazardous Area

A "hazardous area" is defined as an area in which no free flammable gas exists except in the event of an accident, and its physical limits are defined as a cylindrical volume extending 15 feet horizontally (radially) from a potential flammable gas source and extending vertically from the floor to the ceiling. In an open experimental area without a roof, the vertical height shall be 60 feet or greater.

2. Rules Governing Installation and Operation of Electrical Equipment in a Hazardous Area

a. Electrical equipment should be made explosion-proof if it is a permanent part of a device containing flammable fluid or if it will routinely be used in association with such devices.

b. Sparking devices are not permitted in the hazardous area unless they are either (a) sealed, or (b) enclosed and purged with a continuous flow of air passing through the enclosure. A sparking device is defined as any apparatus that sparks in normal operation more than once every 24 hours. Guidelines for purging may be found in NFPA 496, Purged Enclosures for Electrical Equipment, 1967.

c. All electrical equipment such as power supplies, motors, etc., must be grounded.

d. All flammable-fluid-filled equipment, including fill lines and vent lines, must be grounded.

NOTE: At the Bevatron or other areas with pulsed magnetic fields, a liquid hydrogen target system or other such hazardous system must be grounded at one point only. Accidental double grounding of equipment can allow very high ground currents, which might result in sparking at or near the target. A liquid hydrogen target is usually grounded through its vent line. An insulated section shall be installed in the vent line and a shunt connected across the insulated section so that the ground current may be monitored. In this manner excessive ground currents (representing accidental grounds) may be detected and alarmed. The insulated section must be designed for the service, taking into consideration possible temperatures and pressures.

e. Electrical wiring and equipment must be placed in such a way as to minimize the chance of accidental damage or accidental disconnecting. Electrical connections must be secure -- plug-in connections should be taped to prevent accidental breaking of connections.

f. All unused electrical equipment must be removed from the area. This includes drop cords, temporary lights, J-boxes, vacuum pumps, electrical tools, oscilloscopes, and other electronic test equipment.

g. Electrical equipment shall conform to the standards of the Electrical Engineering Department. See Section II.L.

3. Rules Governing the Installation and Operation of Mechanical Equipment in Hazardous Areas

a. The physical layout of the equipment, piping, wiring, etc., should be such that congestion is minimized, and access and egress routes are not blocked.

b. A properly functioning explosimeter is to be installed at a suitable location near the hazardous equipment. The controls and alarm should be located in the local control area. Proper functioning of the explosimeter should be checked daily.

c. Emergency lighting designed for the environment should be installed, and explosion-proof flashlights should be available at the local control area.

d. All pressure vessels and lines shall be pressure tested at pressures approved by the Engineering Safety Committee.

e. Nonsparking (beryllium copper) tools are recommended for working on or near equipment containing flammable fluids.

f. Emergency equipment such as portable gas detectors, fire extinguishers, flashlights, etc., shall be located in well-identified and accessible locations. It is good practice to have more than one station where such equipment may be found.

4. General Rules for Enclosed Hazardous Areas

a. Ventilation of known direction and flow rates must be provided in the hazardous areas to dissipate the flammable fluid if accidentally released. Particular attention must be paid to the direction of flow of the ventilating air when the gases are heavier than air.

b. For heavier-than-air flammable gases, floor drains and trenches shall be isolated from the hazardous equipment or shall be ventilated. Trenches must be monitored with an automatic gas detector, and a warning sign that describes the hazard must be posted.

c. The areas in which flammable gas may accumulate shall be minimized by segregation of work area, and ventilation utilized to maintain concentration below the flammable limit.

d. Where possible, flammable gases should be placed outside and piped directly to the apparatus. The amount of flammable gas in experimental areas should be minimized.

e. Appropriate flammable gas warning signs shall be posted inside the area and at entrances to the area when the equipment is filled with flammable fluid. The signs should be removed when the hazard no longer exists.

f. If a conducting floor is installed around hazardous equipment the floor should be electrically connected to the hazardous equipment.

g. At least two means of egress from the hazardous area, remote from each other, should be available, preferably located so that it will not be necessary to travel more than 75 feet from any point to reach the nearest exit.

h. Emergency lighting shall be provided.

i. Flammable material in the area shall be minimized.

j. All unnecessary cylinders shall be removed.

k. All gas cyclinders shall be secured and grounded.

II.E RADIATION SAFETY

II. E. Radiation Safety

The following discussion and rules are applicable to all persons working at the accelerators. They are included in this manual because it is essential that radiation safety be considered from inception in the design of experimental equipment and setups.

In addition, radiation safety must be a prime subject in a training and familiarization program for those who will be engaged in experimental area operations. As with all matters of safety, primary responsibility for the training of personnel and for compliance with safety rules resides with the group leader.

Radiation hazards and the possible consequences of exposure to high-intensity radiation fields or to high-intensity beams are generally unfamiliar subjects to persons who have not previously worked at accelerators. Special attention must be given to the familiarization and training of these people. Familiarity, however, may breed contempt. Supervisors at all levels therefore must be aware that individuals may develop a cavalier attitude toward or possibly an unconscious disregard of the dangers of radiation, and must be prepared to periodically point out the seriousness of the potential hazard and the obligation of all to follow safety policy.

Much thought and effort has been devoted to radiation shielding, to area isolation, and to personnel protection systems at the accelerators. However, in spite of all that has been done to safeguard personnel and to provide reliable and foolproof systems, INTERLOCK SYSTEMS CAN STILL FAIL. It is also conceivable that an unforeseen and unknown hazard can exist. This is particularly true in the experimental areas where beam and experimental arrangements frequently change.

A film badge must be carried or worn at all times by those working in the area. DO NOT leave the film badge hanging on the wall, in your desk, or lying about. Never place the film badge in a beam of particles. It is advisable to carry both a gamma-sensitive film and a neutron-sensitive film. The EH&S Film Badge Office will issue films to all who need them.

Access to areas around the accelerators or areas within the external proton beam shielding is restricted to those who are authorized to be in the area. Permission to enter these areas MUST be obtained from the Operations Crew prior to entry.

Neutron-detection devices are placed at strategic points in the experimental areas and give pulse-to-pulse information to the Operations Group concerning radiation levels. Some of these devices are vital elements of radiation interlock systems. DO NOT MOVE, ALTER, OR DISABLE any of these units.

The Bevatron Group reserves the right to place a scintillation counter to be used as an intensity monitor in all secondary-particle beams. The placement of such a counter, if needed, will be made with the advice of the experimenter. Such a monitor may NOT be moved, altered, or disabled without the permission of the Bevatron Radiation Safety Group.

REMEMBER - THESE SYSTEMS ARE PROTECTING YOU!

Questions regarding radiation safety at the accelerators can be answered by Accelerator Operations Group (Control Room) or the EH&S Department.

II. F. How to Report an Emergency

When reporting an emergency it is important to transmit as much pertinent information as you may have. Emergencies may be reported in the following ways:

1. ANY EMERGENCY situation can be reported by using the Laboratory phone system, DIAL 5333. It is important that you identify yourself, and that you be specific and accurate in your report with regard to:

   a. The nature of the emergency (gas leak, personal injury, fire, radioactive spill, etc.).

   b. The location of the emergency.

   c. The severity of the situation.

   d. The existence of contributing or potential hazards in the area.

2. FIRE may be reported by operating one of the many Fire Pull Boxes at the Laboratory. It is well to familiarize yourself with those in or about the area in which you work. If you turn in an alarm by this method, stay at the pull box and meet responding emergency personnel. Give them as much detail as you can. Of particular importance is a report of the status and location of hazardous equipment in the area and of any contributing hazards.

3. Emergency Reporting Systems at the Bevatron. In addition to the Laboratory phone system (Bell Telephone System) and the fire alarm boxes at the Bevatron, three other systems may be used for reporting emergencies. These systems are connected to the Bevatron Main Control Room and should be used only when Bevatron crews are on duty. It should be emphasized that the preferred methods, however, for reporting fire or personnel injury are those listed in items 1 and 2 above.

   a. Emergency Reporting Phones

   Emergency phones are located at a number of places in the Bevatron area. These phones are housed in white boxes, the covers of which are marked EMERGENCY PHONE. If one lifts the phone from the hook, an alarm automatically sounds in the Bevatron Building and an annunciator in the Main Control Room indicates the location of the phone. The phone is connected to a master phone in the control room and is answered by a member of the Bevatron Operations Group. If possible, wait for a response. Any emergency may be reported by using this system -- fire, gas leak, personal injury, etc. In this case the Bevatron Operator will relay the report to the proper authority.

b. PAX System

The PAX Phone System, a local phone system in the Building 51 and Building 64 areas, may be used for reporting emergencies to the Bevatron Main Control Room. Dial 00 or 20.

c. Intercom Systems

Most experimental group counting and experimental houses are outfitted with an Intercom System connected to the Bevatron Main Control Room. Be aware, however, if you use this system that after you buzz the Control Room you must wait for the channel to be selected before you may communicate.

II.G EMERGENCY PLANS AND PROCEDURES

II. G. Emergency Plans and Procedures

1. Objectives

The objectives of an emergency plan are to provide advance planning for actions to be taken in the event of an emergency. The principal goals are to safeguard personnel, to minimize damage to equipment and facilities, to limit the spread of an emergency situation, and to minimize programmatic interruptions. The importance of preplanning for emergency action cannot be stressed enough. Personnel must be familiar with Laboratory and Accelerator Area Procedures and know how to report an emergency. Emergency plans and procedures must be developed for each piece of hazardous equipment. Such plans must be consistent with Laboratory and Accelerator Area plans and procedures. Emergency plans are invaluable if they are up-to-date. An out-of-date plan is useless and can itself be a hazard.

2. Responsibility

a. Crew chief

The person in charge of accelerator area operations (crew chief) has overall responsibility for safety at the accelerator complex. It cannot be expected, however, that accelerator operations group personnel will be knowledgeable in the highly specialized fields of experimental equipment operations or related emergency procedures. Therefore the experimenter or equipment operator must keep the accelerator group informed and advised.

Assignments of specific responsibilities for members of the Accelerator Organization will be found in a later section.

In the event of an emergency, members of the Operating Group will carry out appropriate emergency procedures, including area evacuation if required.

b. Experimental or equipment operations group personnel

Each person who works in the experimental areas of the Laboratory is charged with the responsibility for knowing Laboratory and local emergency procedures, and for carrying out these procedures should an emergency arise. He must know how to properly report an emergency. (See Section II.F.)

The experimenter or person in charge of hazardous equipment is responsible for the development of emergency procedures for each piece of hazardous equipment in his charge and for the familiarization and training of personnel with regard to these procedures. In the event of an emergency, experimental group personnel are responsible for:

(i) Assessing the situation and instituting appropriate emergency procedures or remedial actions or both.

(ii) Maintaining liaison with members of the Accelerator Operations Group, keeping them informed and advised.

(iii) Cooperating with Laboratory or outside emergency agencies who may respond to an emergency call.

(iv) Carrying out an orderly evacuation of the area if so instructed.

3. Emergency Plans and Procedures for Hazardous Equipment

Emergency plans and procedures must be developed for each piece of hazardous experimental equipment. The plans and procedures should take into account the logistics of the equipment and of the experimental area and should consider emergency situations arising from equipment failure; loss of power, water or other utilities; fire; failure of nearby equipment; injury to personnel; etc. See Section III for guidance in the development of procedures. Such procedures must be consistent with those already established for Laboratory buildings and described later in this section. Actions to be taken, of course, should fit the type and degree of emergency. They may range from corrective action not involving other operations or emergency personnel, to immediate abandonment of operation functions and the taking of measures for self-protection and survival. The broad spectrum of possibilities between these two extremes would consider the involvement of other Laboratory operations or emergency personnel and the desirability of calling in outside help.

Those responsible for the operation of hazardous equipment must recognize and accept their responsibility for the establishment and for the proper carrying out of emergency procedures for hazardous equipment. In the event of an emergency, either due to failure of their equipment or due to fire or failure of nearby equipment, they must assess the situation and institute appropriate emergency procedures. They must keep the Accelerator Operations Group informed and advised. Emergency procedures must make the best use of the specialized knowledge of the experimental operations group.

4. Recommended Procedures in the Event of an Emergency

a. Fire emergency

(i) Anyone who sees a fire or who detects a fire hazard that may suddenly develop into an actual fire should immediately turn in a fire alarm.

(ii) Fire-fighting action should be taken if this can be done with reasonable safety.

(iii) When a building fire alarm sounds, all persons should leave the building except those with specific fire-fighting or emergency assignments.

(iv) In case of fire involving a flammable-fluid-filled device (bubble chamber, liquid hydrogen target, Cerenkov counter, etc.), the equipment operators should immediately proceed with area evacuation procedures, turn in the alarm, and inform the Accelerator Operations Group. If possible, normal electric power to the area should be turned off. It is an important responsibility of the equipment operations group to ensure that ALL persons keep out of the area until the fire department arrives and assumes command.

(v) In the event of a fire in the building or area not directly involving flammable-fluid-filled devices, the equipment operators should immediately institute the established emergency procedures for that equipment. If possible and if safe, Dewars should be removed from the building.

b. Flammable-gas emergency

(i) Anyone who detects a flammable-gas leak should turn in a gas alarm. Dial 5333 and report the circumstances to the responding party. Next inform the Building Manager.

(ii) In many cases a flammable-gas leak will be detected automatically and an alarm sounded and transmitted to emergency units.

(iii) Equipment operators should immediately investigate and carry out established procedures. The person in charge must take command of the local situation. In most cases, remedial action will cure the problem.

(iv) At an accelerator, the Accelerator Operations Group must investigate immediately and assist the experimental group as advised. The person in charge of the Accelerator Operations Group will take charge of all building activities, as in the case of a fire, except those activities having to do with hazardous equipment as covered by the previous paragraph. He may order general evacuation of the building, in which case ALL persons will leave the area involved. It is advisable that those persons who are designated to assist in combatting such an emergency promptly report to the Main Control Room for instructions.

c. Personal injury

(i) Take first-aid measures immediately. If heavy bleeding is involved or if the victim's breathing or circulation has stopped, take immediate first-aid action. Bleeding must be arrested and/or circulation and breathing restored. Time should not be taken to report the emergency if it means a delay in these first-aid measures. A shout may bring other people to the scene who can report the emergency and call additional help.

(ii) Report the injury (to the fire department by dialing 5333) as soon as possible, giving details as to the nature of the injury and where the injured person is located.

(iii) Continue first-aid measures until professional help arrives.

d. Toxic materials

(i) The EH&S Department is prepared to advise experimenters and emergency squads as to emergency procedures to be instituted in the event of a spill or exposure of personnel. This will include recommendations regarding area isolation, clean-up procedures, and countermeasures. Preplanning in this area is important. If you expect to use toxic materials, inform the Accelerator Operations Group and the Laboratory Industrial Hygiene Section prior to their use.

(ii) In the event of a leak or a suspected leak of toxic gas, the building or area must be evacuated immediately and the emergency reported. ONLY trained and properly equipped emergency personnel may enter the area until it has been checked and cleared.

e. Personnel evacuation procedures and "head count"

In the event of an emergency requiring evacuation of accelerator buildings or experimental areas an important consideration is to assure that all operation group members, experimenters, and visitors have left the danger or emergency area. Efforts should be made to ensure that no one has been left in a hazardous situation because of injury and thus inability to leave, because of confusion as to egress routes, because of being trapped, or because he didn't get the word. If at all possible, accelerator group personnel will go through the accelerator complex in an organized and systematic way directing evacuation. If possible they will make sure no one is left behind. Experimenters and equipment operators must cooperate in this effort by following evacuation orders and assembling at a nearby designated location. A "head count" should be made and the Accelerator Operations Group or Fire Department informed of any missing persons and where they were last seen.

5. Emergency Procedures and Personnel Assignments

The intention of this outline is to assign duties and responsibilities to various people likely to be in buildings during periods of emergency.

An "emergency" for the sake of this outline is to be considered of the following nature:

- Fire anywhere in the building
- Fire in an area adjacent to the building
- Smoke or smoke odor
- Flammable-gas alarm
- Exposure to radiation
- Personnel injury
- Leaks of hazardous materials
- Flood or water damage
- Radioactive spills
- Earthquake
- Threat to the building or area
- Power failure
- Civil alert

In all cases of emergency, the Building Manager is in charge. If the Building Manager is not present, the most senior person available is to assume the duties of Building Manager. He should carry out the duties of Building Manager until relieved by the Building Manager or the person in charge of the group answering the emergency call--the Fire Chief or the person in charge of the Fire Department or the Laboratory Disaster Organization.

It is very important that the person who discovers an emergency situation inform the Building Manager immediately. This rule should be tempered as follows: In case of an obvious fire he should, of course, first telephone 5333 and report the fire; in the case of personnel injury involving loss of blood or stoppage of breathing, he should first render first aid.

II.H HANDLING OF FLAMMABLE AND HIGH-PRESSURE GASES OR LIQUIDS

II. H. Handling of Flammable and High-Pressure Gases or Liquids

1.0 Hazards of Flammable Fluids

1.1 Common Flammable Laboratory Gases: TABLE II.H.-1

	Explosive limits* (% by vol. in air) Lower	Upper	Auto-ignition* temp (°F)	Gas Specific Grav relative to air** (1 atm, 68°F)	Boiling point (°K)
Hydrogen	4.0	75	1085	0.0695	20.4
Deuterium	5.3	75	----	0.140	23.6
Methane	5.0	14.0	999	0.553	111.7
Acetylene	2.5	81.0	571	0.897	189.0
Ethylene	3.1	32.0	842	0.975	169.3
Ethane	3.0	12.5	959	1.049	184.8
Propylene	2.0	11.1	927	1.48	226.1
Propane	2.2	9.5	871	1.56	230.8

*NFPA Article 325M Flammable Liquids, Gases, and Volatile Solids.
**Density of air 0.07528 lb/ft^3 at 68°F.

1.2 Hazards

The dangers associated with the handling and use of flammable and high-pressure gases and liquids are:

1.2.1 Asphyxiation

1.2.2 Ignition or explosion of flammable gases, resulting in personnel injury or facility damage. Burns from the radiation produced by the high temperature of ignited gas, or from contact with burning materials.

1.2.3 Injuries caused by flying objects accelerated by an explosion or pressure release.

1.2.4 Secondary accidents such as falling, electrical shock, or accidents that may result in hearing loss.

1.2.5 Almost certain death, if a flammable mixture is inhaled and then is ignited.

1.3 Fire and Explosion Prevention

1.3.1 In general, for fire, three elements are required: fuel, oxygen, and ignition. To reduce risk of a fire, it is necessary to eliminate two of these elements whenever possible. Thus for flammable gases, (1) eliminate ignition and (2) prevent mixing or accumulation of fuel with air. Contain or vent fuel.

1.3.2 Prevent the entrapment of flammable gas in closed pockets by providing good ventilation and air dilution. If the gas is lighter than air--hydrogen, for example--provide overhead ventilation and dispersal. If denser than air, prevent the gas from entering trenches and manholes where it can collect.

1.3.3 Eliminate ignition sources in high-risk areas.

1.3.4 Oxygen in high concentrations can be an extreme fire hazard. Materials not normally considered combustible burn violently in high-oxygen concentrations.

2.0 High-Pressure Cylinders, Manifolds, and Regulators

2.1 Cylinders

2.1.1 Identification Code

High-pressure gases (over 100 psig) are usually stored in steel cylinders that are manufactured according to Department of Transportation (DOT) specifications. The handling of cylinders was administered by the ICC until about 1969, when the Department of Transportation was formed and took over this function. DOT regulations require the following markings on all cylinders:

a. Type of cylinder and pressure rating

b. Serial number

c. Inspection date

For example:

DOT 3AA2065
973487
6-70

DOT 3AA = A seamless steel cylinder of definite prescribed steel, not over 1000-lbs water capacity, with at least 150-psi service pressure.

2065 = service pressure at 70°F and maximum refill pressure.

973487 = Serial number of individual cylinder.

6-70 = Date of inspection and test.

Old cylinders (made before 1970) will have "ICC" in the markings, whereas those cylinders manufactured after 1970 will be marked "DOT." The rest of the identification markings are unchanged.

2.1.2 LBL Gas Cylinder Color Code

The Laboratory owns cylinders for most of the common gases and has its own color code for identification of the cylinder contents.

Since LBL uses some gases in non-Laboratory-owned cylinders, which will not necessarily have the LBL color code, it is recommended that the name of the gas that is painted on each cylinder, rather than the color code, be relied on for correct identification.

The Laboratory cylinder color code and some vendor color codes are shown in Table II.H.-2.

2.1.3 Mixed Gas Cylinders

2.1.3.1 The supplier will furnish mixed-gas cylinders with an adhesive label placed on the shoulder of the cylinder. The label will contain a RED diamond for flammable gas, or a GREEN diamond for nonflammable gas. The percentage of each gas component will be marked on the label. In addition, a circumferential white stripe will be painted near the shoulder of the cylinder as a visual indication of mixed gas.

TABLE II.H.-2

Compressed-Gas Cylinder Color Code

Gas (stenciled name)	Cylinder Owner	Color Code		
		Base	Center	Top
Acetylene	LBL	yellow	Red	Grey
Compressed air	LBL	Yellow	Grey	Grey
Ammonia	Vendor	Aluminum	---	---
Argon	LBL	Yellow	Brown	Brown
Carbon dioxide, Research	LBL	Yellow	Aluminum	Aluminum
Carbon dioxide, Fire	LBL	Red	Red	Red
Ethylene	Vendor	Aluminum with Blue & White top markings		
Freon 12	Vendor	White with decal (possible grey base)		
Freon 22	Vendor	Green with decal (possible grey base)		
Helium (extra pure)	LBL	Yellow	Orange	Brown
Helium (grade A)	LBL	Yellow	Orange	Orange
Hydrogen	LBL	Yellow	Red	Red
Methane	LBL	Yellow	Aluminum	Blue
Nitrogen	LBL	Yellow	Black	Black
Oxygen	LBL	Yellow	Green	Green
Magic Gas	Vendor	Lt. Blue	Lt. Blue	Lt. Blue

2.1.5 Cylinder Storage

2.1.5.1 All compressed-gas cylinders shall be stored on solid, level footings in well-ventilated areas. Cylinders shall be capped and properly secured to a wall or rack to prevent falling or mechanical damage.

2.1.3.2 When one component of the mixture has a higher mixture rating than all the others, that component shall determine the valve outlet connection. Percentages of mixture components do not determine the choice of valve outlet connections. Gas mixtures with a flammable component will have an outlet valve with left-handed threads (CGA 350) even though the gas mixture is nonflammable.

2.1.4 Cylinder Procurement

2.1.4.1 The Supply Department procures all gases used at LBL either on a blanket order for general use or on a special order from a User for a specific experiment. Most of the compressed-gas cylinders are kept in a designated storage area at Building 69. Some cylinders are also stored at the Accelerator buildings and project sites in designated areas for present experimental use.

2.1.4.2 When the cylinders are to be used in areas not previously established for such use, all gas-request forms for hazardous (flammable and/or toxic) gases must be sent to the EH&S Department for safety approval.

2.1.4.3 All compressed-gas cylinders must be free of defects that could cause a serious accident. Cylinders shall be considered defective and removed from sevice if they contain:

Dents

Cuts, gouges, or digs over 3-in. long.

Leaks (any leakage is cause for rejection)

Fire damage

Valve damage.

All defective cylinders (LBL or vendor-owned) shall be sent back to the respective manufacturer or vendor for repair and/or testing, or they must be replaced by new cylinders.

2.1.4.4 All standard high-pressure cylinders (~200 ft^3) that are used only at the LBL site, such as in fixed tube banks, shall be pressure tested to 5/3 of their service pressure every 6 years.

2.1.5.2 Cylinders shall be located well clear of traffic lanes.

2.1.5.3 Cylinders that are not actively being used inside of buildings shall be stored outside in approved areas.

2.1.5.4 Cylinders that are stored in the open shall be protected from continuous direct sunlight, extremes of weather, and rust caused by damp storage.

2.1.5.5 Cylinders shall not be stored near sources of intense heat such as furnaces, steamlines, or radiator. This is to avoid uncontrolled pressure increases within the cylinders.

2.1.5.6 Cylinders containing oxygen shall not be stored near highly combustible materials such as oil, grease, reserve acetylene supplies, or other flammable gases. Cryogenic and high-pressure-gas storage areas shall be separate.

2.1.6 <u>Cylinder Handling</u>

2.1.6.1 Compressed-gas cylinders are dangerous when handled incorrectly. Depending on the type of mishandling, they can release hazardous gas or cause severe physical injury.

2.1.6.2 Be very cautious in moving gas cylinders. Because of their shape, smooth surface, and weight, gas cylinders are difficult to move by hand. A truck or an approved cylinder-handcart shall be used when it is necessary to move a cylinder.

2.1.6.3 When a cylinder is not connected to a pressure regulator or a manifold, or is otherwise disconnected, the safety cap shall be kept in place.

2.1.6.4 Always assume that a cylinder is pressurized. Handle it carefully; avoid throwing, banging, tilting, or rolling. Cylinders shall not be dropped to the ground from a truck or any raised surface.

2.1.6.5 Do not upset gas cylinders or hit the valve or regulator. The safety cap shall be kept in place when moving or storing cylinders. Cylinders shall always be secured to a wall or rack when in use or in storage.

2.1.6.6 If it is necessary to lift a standard cylinder manually, at least two people shall do the lifting.

2.1.6.7 Oxygen-cylinders shall not be handled with greasy or oily hands or gloves. Note: The reaction between oxygen and hydrocarbons can be violent, even when minute quantities are involved. Prevent oxygen contact with oil or grase.

2.1.6.8 Cylinders shall be secured in metal cradles or skid boxes before raising them with cranes, forklift trucks, or hoists. Rope or chain slings alone shall not be used.

2.1.6.9 Gas cylinders shall never be used as rollers for moving materials or as work supports.

2.1.7 Inspection

2.1.7.1 Hoses, tubing, and manifolds shall be inspected frequently for pressure integrity. Hoses and fittings observed to appear worn shall be discarded and replaced before the equipment is put to further use. The Maintenance Technicians Shop (Building 76) may be contacted for replacement hose, tubing, and fittings.

2.1.7.2 If cylinder valves are stiff, or fittings leak, mark the cylinders and return them to the Stores Department (Building 7).

2.1.7.3 If a cylinder is found to be leaking a toxic, irritant, flammable, or unknown gas, the Fire Department shall be called immediately, and the area in the vicinity of the leak shall be evacuated until the emergency crew arrives.

2.1.8 Precautions

2.1.8.1 Open flames shall not be used to leak-check a cylinder; soapsuds or a leak-detection solution shall be used.

2.1.8.2 Talc powder and dust shall be blown from a new hose before it is connected.

2.1.8.3 Do not use white-lead, oil, grease, or any other nonapproved joint compound for sealing oxygen-system fittings. Fire or explosion could occur when oxygen contacts these materials. Threaded connections in oxygen piping shall be sealed with joint compounds approved for oxygen service. Litharge and water is recommended for service pressures above 2.0 MPa gauge (300 psig). Gaskets shall be composed of only noncombustible materials. For additional information, contact the Maintenance Technicians Shop or the Pressure Inspector.

2.1.8.4 Always identify gas cylinder contents correctly. Do not uses a cylinder if it is not clearly labeled.

2.1.8.5 Regulators and hose shall not be interchanged from one type of gas to another. Explosions can occur if flammable gases or other organic materials come into contact with oxygen under pressure.

2.1.8.6 Oxygen shall never be used to purge lines, to operate pneumatic tools, or to dust clothing, or as a substitute for compressed air.

2.1.8.7 Cylinders shall never be used for hat racks or as clothes hangers. Leaky fittings can accumulate large amounts of gas under the clothing. Clothes saturated with oxygen gas will burn explosively.

2.1.8.8 Gases shall not be mixed in commercial DOT cylinders, and gases shall not be transferred from one DOT cylinder to another. Commercial cylinder-gas mixtures are available through the LBL Supply Department.

2.1.8.9 Vendor-owned cylinders shall <u>not</u> be used other than as a source of gas. Only the owner is permitted to pressurize these cylinders.

2.1.8.10 Sparks, molten metal, or slag shall <u>never</u> be allowed to fall on cylinders, pressure apparatus, or hose.

2.1.8.11 Welding, torch-cutting, smoking, electrical arcing and arcing devices, lighting, electrostatic charge, pilot lights, and any other ignition sources shall be kept away from flammable gases at all times.

2.1.8.12 Liquid nitrogen or other refrigerants shall not be spilled on gas cylinders. Mild-steel gas cylinders may rupture due to thermal stress. Ferrous metals are extremely brittle at low temperatures.

2.1.8.13 High-pressure lines shall be secured to prevent whipping in the event of mechanical damage, breakage, or rupture.

2.1.8.14 Equipment shall not be disassembled while it is under pressure. Be aware that a valved-off line may still be under pressure and if not bled before disassembly, there may be enough pressure energy stored in trapped gas or in piping distortion to propel loose objects.

2.1.9 <u>Operation</u>

2.1.9.1 Gas-cylinder valves can be "cracked" before attaching regulators in order to blow dirt off the seats. Always be sure that the valve outlet points away from you. Be very careful with hydrogen because the gas may ignite due to static charge or friction heating, and it usually burns with an invisible flame. Closing the valve immediately stops the flame.

2.1.9.2 Before opening the cylinder valve, fully release (turn counter-clock-wise) the pressure-adjusting screw of the regulator.

2.1.9.3 Open high-pressure valves slowly; for gas cylinders, this gives compression heat a change to dissipate and prevents "bumping" the gauges. Never use a wrench on any cylinder valve that refuses to rotate when normal handforce is applied. Stand clear of pressure-regulator gauge-faces when opening cylinder valves. Defective cylinder valves shall be tagged, and the cylinder shall be returned to the Supply Department.

2.1.9.4 Keep removable keys or handles on valve spindles or stems while cylinders are in service.

2.1.9.5 Never leave pressure on a hose that is not being used. To shut down a system, close the cylinder valve and vent the pressure from the entire system.

2.1.9.6 When a cylinder containing flammable gas is used in a laboratory or confined space, the room shall be well-ventilated, or the cylinder shall be placed under a ventilated hood.

2.1.9.7 The number of active cylinders in an experimental area or room shall be kept to a minimum as approved by the Mechanical Safety Committee or the EH&S Department.

2.1.9.8 Gases mixed at LBL shall not be put into compressed-gas cylinders.

2.1.10 Empty Cylinders

2.1.10.1 About 0.2 MPa gauge (30 psig) of positive pressure shall be left in "empty" cylinders to prevent suckback of air into the cylinder; this would contaminate the cylinder and, in the case of hydrogen, be particularly dangerous.

2.1.10.2 Mark or tag empty cylinders with the letters "MT".

2.1.10.3 Store empty cylinders separate from full cylinders.

2.1.11 Manifolds

2.1.11.1 Before a job order for a manifold is written, the Requester shall arrange with the Industrial Gas Section of the Inventory Management Department for the established cylinder supply and storage requirements.

2.1.11.2 Manifolds shall be ordered from the Maintenance Technicians Shop (Building 76). Only maintenance Technicians Shop personnel are authorized to assemble compressed-gas-cylinder manifolds.

2.1.11.3 It is recommended that manifold pigtails not be left disconnected for more than a few minutes. Certain insects are attracted to pure gases and will clog these lines in a short time. Insects in oxygen pigtails can ignite spontaneously and cause sufficient heat and over-pressure to burst the pigtail, valve, or manifold.

2.2 Gas Pressure Regulators

2.2.1 General

The Laboratory stocks several models of cylinder-to-line regulators, each one designated for a particular gas as shown in Table II.H.-3.

Table II.H.-3

In-Stock Cylinder-to-Line Regulators for Compressed Gases

(Model) LBL Catalog No.	Type of Gas
6680-19991	CO_2
6680-19992	Acetylene
6680-19993	Explosive (hydrogen, methane, propane, etc.)
6680-19994	Nonexplosive, 0-150 psi delivery pressure (nitrogen, argon, helium, air, neon, etc.)
6680-19996	Oxygen
6680-19997	Nonexplosive, 0-1000 psi delivery pressure (nitrogen, argon, helium, air, neon, etc.)

Left-handed threads on regulator inlet connections can be identified by a groove on the hexagon nut.

Each regulator must be checked by the Regulator Shop in Building 76, Extension 5481, to ensure that it is correctly specified for the particular application and is in safe working condition.

2.2.2 Diaphragms

Diaphram failure permits the cylinder gas to escape to the surrounding atmosphere through holes in the regulator body. To reduce the probability of diaphragm failure, regulators used for gases listed in Table II.H.3 are purchased with stainless-steel diaphragms.

2.2.3 Operation

2.2.3.1 All new regulators are stocked and issued at Stores (Building 7). Before installation, all regulators shall be taken to the Regulator Shop (Building 76) for inspection, adjustment, and tagging.

2.2.3.2 When used regulators are temporarily stored, they shall be sealed in plastic bags to keep them clean.

2.2.3.3 Supervisors shall make periodic surveys of regulators on hand and shall send all surplus regulators to Stores for disposition. Stores shall send the regulators to the Regulator Shop for examination, cleaning, adjustment, and repair as required. The regulators shall then be tagged and returned to Stores for reissue.

2.2.3.4 Only the Regulator Shop is authorized to alter or repair regulators. All used regulators reapplied to oxygen service shall be degreased in the Regulator Shop.

2.2.3.5 Immediately upon removal of regulators from flammable, toxic, or radioactive systems, all hazardous gas shall be safely vented (and purged as required) from the entire regulator.

2.2.3.6 Use only regulators of the approved type and design for the specific gas-and-cylinder combination to be employed. Make sure that threads on regulators correspond to those on the cylinder-valve outlet. Never force connections that do not fit perfectly. Do not use regulators with green-face gauges for anything except oxygen service.

2.2.3.7 Damaged or defective regulators, or those that operate unreliably, shall be replaced immediately.

2.2.3.8 Line regulators shall not be used on gas cylinders; single-stage regulators are for use up to only 1.0 MPa (150 psig) and shall be used for in-line installation only.

2.2.3.9 Two-stage regulators for inert gas are equipped with two relief valves that protect the regulator diaphragms and gauges from excessive over-pressure. Relief valves on regulators for use with flammable, toxic, or radioactive gases shall be safely vented.

2.2.3.10 The Regulator Shop will adjust two-stage regulators so that the output pressure does not exceed 67% of the highest output-gauge reading; they also will set the low-side relief valve to open at not over the highest graduation of the low-side gauge.

2.2.3.11 Single-stage cylinder regulators (except acetylene regulators) are equipped with a single relief device that is set to relieve at not over the highest graduation on the low-side gauge. The Regulator Shop also adjusts these regulators to limit the output pressure to 67% of the highest graduation of the low-side gauge.

2.2.4 Relief Valves

Regulator valve seat failures permit high-pressure gas to enter the low-pressure side of the regulator. To protect against these failures, regulators are provided with safety relief valves. However, if the piping and associated apparatus that is connected to the regulator discharge is rated at a pressure lower than the pressure setting of the low-pressure relief valve on the regulator, a leak in the valve seat may cause damage to the connected apparatus. Under these circumstances a separate relief valve shall be installed in the experimental equipment to protect it from damage due to over-pressurization.

2.2.5 Vacuum Applications

When a regulator is used in a system in which piping on the high-pressure side of the regulator is to be evacuated through the regulator, the regulator shall be modified for vacuum service to prevent damage to the diaphragms and pressure gauges. The Regulator Shop will modify regulators for proper operation under vacuum. Regulators so modified shall be labeled to indicate the modification.

2.2.6 Flammable Gas

Whenever two or more cylinders containing flammable gas are used inside a laboratory or in a confined area, and are connected to a common mainfold, the regulator must be modified and connected so that the regulator relief valves vent outside the building. The existing relief valves on the regulator shall be replaced with two special relief valves which shall be connected to a metal vent line that terminates outside the building. The regulator modification shall be made by the Regulator Shop.

The above practice is also recommended for permanent single-cylinder applications, where it is important to reduce the probability of accidental gas leakage.

2.2.7 Toxic Gas

Use of toxic gases shall comply with the EH&S Department regulations and recommendations. If you are in doubt as to the hazards, toxicity, or safe-operating practices for any gases, please consult Industrial Hygiene, extension 5829.

2.3 Compressed Air

2.3.1 Safety Rules

2.3.1.1 Compressed air may be used to dry parts and to help accomplish many jobs in the shop or laboratory more efficiently, but in doing so the following safety rules shall be observed.

2.3.1.2 Compressed air shall not be used to clean-off clothing. The air jet tends to drive particles into the fabric where they can cause skin irritation and possibly serious infections. Use a clothes brush or wear protective clothing.

2.3.1.3 When compressed air is used to dry parts, be sure that nobody is in line with the air stream and wear goggles or a face shield to protect your eyes.

2.3.1.4 Air pressure shall not be used to transfer liquids from containers of unknown safe working pressure. If a standard 200-liter (55-gal) drum is pressurized to 100 kPa (14.5 psig), the force exerted on the head of the drum is about 25 kN (almost 3 tons). A siphon with a bulk aspirator or a pump shall be used instead.

2.3.1.5 The transfer pressure for LN Dewars shall be limited to 100 kPa (14.5 psig).

2.3.1.6 Never apply air pressure to the human body. Compressed air injected into the anus (posterior opening of the alimentary canal) can be fatal.

2.3.1.7 When a automatic shut-off coupling is not used, a short chain or equivalent shall be attached between the hose and the air-operated tool to prevent hose whipping in case the coupling separates from the hose or tool.

2.3.1.8 Whenever possible, the pressure shall be vented from the air line before the nozzles or fittings are changed.

2.3.1.9 Compressed air shall not be used for breathing in any building or confined space unless it has been specially installed for this purpose and approved by the Environmental Health and Safety Department.

2.3.1.10 Oxygen shall never be used instead of compressed air. A person wearing clothing saturated with oxygen will turn into a living torch if ignited.

2.3.1.11 Compressed air for general shop or Laboratory use shall be restricted to 207-kPa (30-psig) maximum pressure by restricting nozzles. Compressed air at up to full-line pressure of about 700 kPa (100 psig) may be used only as required to operate pneumatic tools and certain control instruments.

References

Compressed Gas Cylinder Valve Outlet and Inlet Connections, Compressed Gas Association, Pamphlet V-1.

Handbook of Compressed Gases, Compressed Gas Association, Reinhold Publishing Corporation (1966).

3.0 Liquid (Cryogenic) Gases, Flammable and Nonflammable: General

3.1 Liquid-gas vessels (Dewars) shall be safety-vented and protected against mechanical shock and damage.

3.2 The outside of glass Dewars shall be wrapped with fabric or fiber-glass tape to prevent flying glass in the event of breakage.

3.3 All liquid-gas Dewars shall be moved very carefully. Do not tilt, jar, bump, or roll the Dewar. Sloshing liquid into warmer regions of the container can cause sharp pressure rises. Before 150- and 165-liter industrial-type liquid-hydrogen Dewars are moved, the internal pressure shall be reduced to 5 psig or lower. The relief valve shall be set at not more than 10 psig.

3.4 Protect vents against icing and plugging. When all vents are closed the liquid can boil off enough gas to cause the vessel to explode. At LBL, liquid hydrogen is supplied only in dual-vent vessels. Liquid helium is supplied in both single- and double-vented vessels. The single-exit helium vessels have a special large-diameter neck and are issued on special request. All helium and hydrogen Dewars in use at LBL are checked by a member of the Mechanical Engineering Department Liaison Group (Building 81) at least once every 48 hours. A safety check record is maintained at Building 81.

3.5 On liquid-nitrogen-shielded laboratory-type hydrogen or helium Dewars, keep the rubber tube cap on the vent and fill lines of the nitrogen circuit at all times.

3.6 Operators should avoid physical contact with any liquified gases because "burns" can occur. Face masks and gloves should be worn while transferring and handling cryogenic liquids.

3.7 Liquid hydrogen and liquid helium shall be transferred only into approved closed systems by experienced personnel.

3.8 The proper transfer equipment shall be used when moving cryogenic liquids from one container to another. Liquid helium shall always be transferred through well-insulated, vacuum-jacketed lines. Flammable cryogenic liquids shall be transferred with controlled ventilation. The transfer of flammable cryogenic fluids within buildings or near ignition sources shall be avoided.

3.9 Only helium gas shall be used for pressurizing liquid-helium or hydrogen Dewars for liquid transfer.

3.10 When transferring from laboratory-type Dewars, insert a properly purged tube slowly.

3.11 When insufficient knowledge exists regarding potential hazards, evaluate hazards experimentally before proceeding to full-scale operations.

3.12 Plan for emergency conditions that may occur during operations by considering the possibility of malfunction, the consequences of malfunction, and all methods of preventing and minimizing their effects.

3.13 Cryogenic systems that require personnel and/or equipment protection shall be barricaded and isolated.

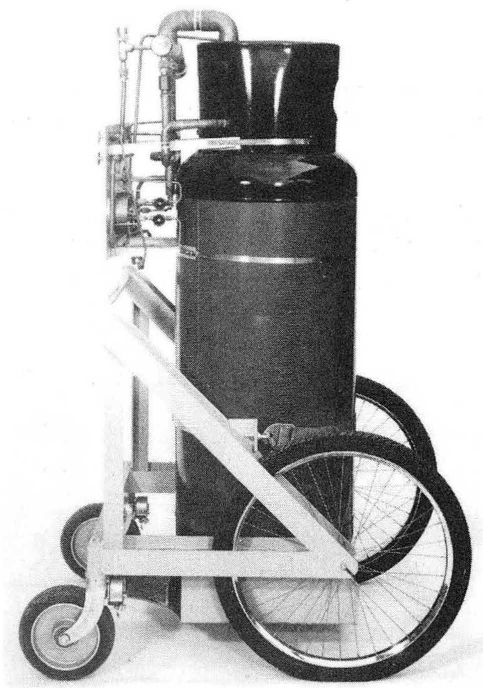
3.14 Shielding for glass apparatus in cryogenic systems shall be provided.

3.15 Adequate personnel exits shall be provided, and they shall never be blocked.

3.16 All cryogenic equipment shall be promptly and adequately maintained.

4.0 Liquid Hydrogen

4.1 The standard 150-liter industrial-type hydrogen Dewar with LBL modifications is shown in Figure II.H-1. Instructions for Dewar operations are available from the Cryogenic Group and from the Mechanical Engineering Liaison Group (Building 81).



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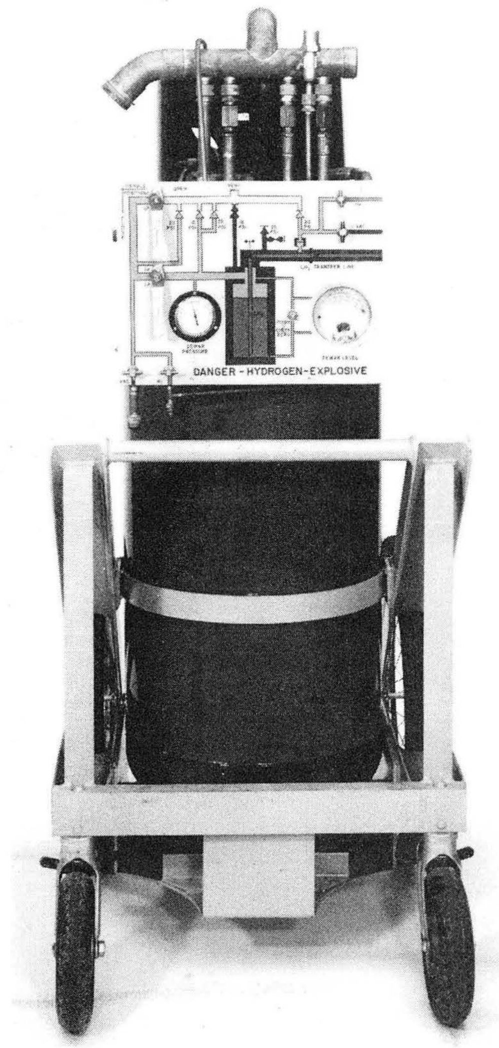


XBB 679-5646

Fig. II.H.-1. Two views of the 150-liter industrial-type liquid-hydrogen Dewar with LBL panel Attached.

4.2 Ice plugs rarely occur in hydrogen Dewars because of their closed-system fill and vent circuits and their warmups before every refilling. Air must be excluded from hydrogen-filled Dewars. Frozen oxygen has caused explosions in liquid hydrogen. Frozen nitrogen can plug valves.

4.3 Single-neck (single-opening) laboratory-type Dewars shall <u>not</u> be filled with liquid hydrogen.

4.4 Dewars filled with liquid hydrogen shall be stored outdoors in a controlled area, and shall be securely attached to the contact of a good electrical ground at all times to preclude build-up of a static charge which could ignite escaping gas.

4.5 The hydrogen Dewar cart shall be electrically grounded, and the hydrogen venting system shall be connected <u>before</u> filling or transferring takes place.

4.6 Mechanicl refrigerators with a 10-watt capacity and a 3-liter reservoir for liquid hydrogen are also used at LBL for liquid-hydrogen targets. Safety rules which shall be observed around targets are summarized as follows:

4.6.1 Efficient ventilation shall be provided around targets.

4.6.2 All equipment shall be electrically grounded.

4.6.3 No smoking or open flames near target.

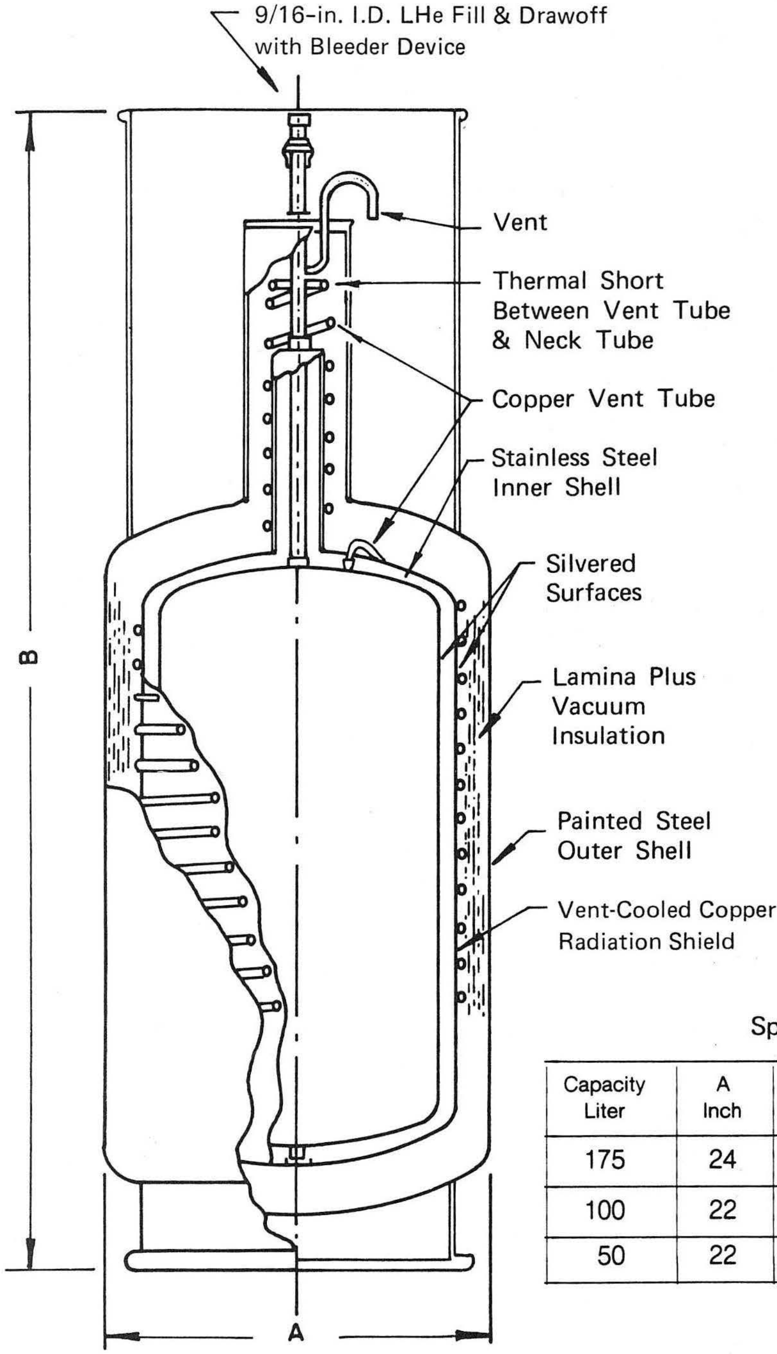
4.6.4 If possible, electrical equipment shall be kept remote from the target, or at least below the hydrogen level.

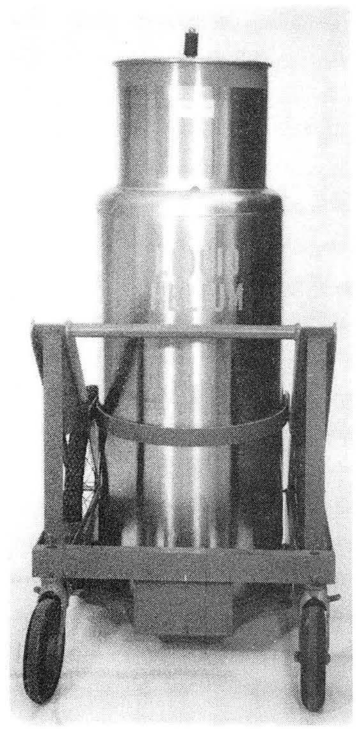
4.6.5 If it is necessary that electrical equipment be located close to the target, the equipment shall be explosion proof.

4.6.6 All vessels and piping shall be properly purged before introduction of liquid hydrogen. Great caution shall be used to prevent air from entering into hydrogen spaces during a run and forming an explosive mixture.

5.0 <u>Liquid Helium</u>

5.1 Liquid helium is supplied in the gas-shielded 50-, 100-, 250- and 500-liter Dewars (Fig. II.H.-2) and 10-, 25- and 50-liter nitrogen-shielded Dewars (as shown in Fig. II.H.-3).





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Specifications

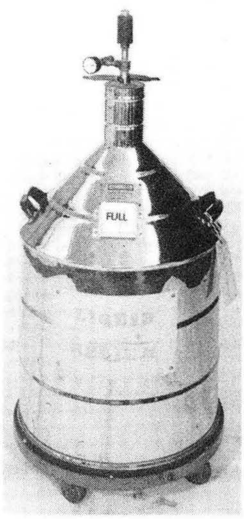
Capacity Liter	A Inch	B Inch	Est. Wt. pounds	Boiloff %/Day
175	24	62½	325	1.0
100	22	62½	275	1.5
50	22	48	175	2.5

XBL 7810-6585

Fig. II.H.-2. A 100-liter industrial-type liquid-helium Dewar having gas shielding.

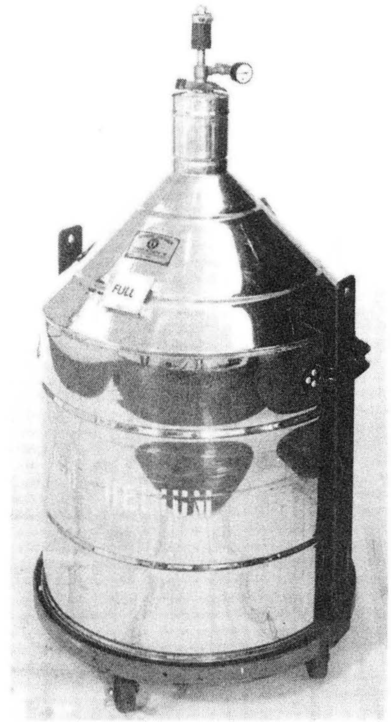
XBB 679-6039

10-liter, single-neck.
(1.5 inch i.d.)



XBB 679-5647

25-liter dual-safety neck.



XBB 679-5648

50-liter dual-safety neck.

Fig. II.H.-3. Laboratory-type liquid-hydrogen/-helium Dewars with liquid-nitrogen shield and vacuum insulation.

5.2 Filled liquid-helium Dewars shall be inspected daily by the User to assure that the Dewar is not plugged.

5.3 Helium Dewars commonly develop ice plugs because of their extreme low temperatures and the tendency for air to be wiped into the neck when the fill-tube is inserted. Air must be excluded from the Dewar. Air and other impurities can freeze solid and interfere with operation and may eventually become a safety hazard.

5.4 An ice plug in a single-vented helium Dewar may cause the Dewar to explode.

5.5 Detecting a plugged Dewar

To distinguish an unplugged Dewar from a plugged Dewar, first see if helium boil-off gas is comming out of the vent-cap check valve. This may be detected by lifting the valve cap slightly. You will feel the gas flowing if the Dewar is not plugged. If you wish to test that helium gas is flowing out, use a wooden dip stick and, keeping your face away, remove the vent-cap and dip the stick into the Dewar. A cloud of cold helium gas will come out if liquid helium is in the Dewar and the Dewar is not plugged. The stick will enter more than 24 inches into a 25-liter Dewar. Replace the cap quickly to keep out air. If you use a metal rod as a dip stick, be careful not to plunge it through the bottom of the Dewar.

5.6 What to do with plugged Dewar

5.6.1 The dip stick will not go in, if the Dewar is plugged.

5.6.2 Immediately notify the Building Manager and call the Mechanical Liaison Group:

Day shift: Ext. 5524

Night Shift and Weekends: Maintenance Technician, Ext. 5481

5.6.3 Always keep your face and body away from the top of the Dewar. The pressure in the Dewar depends on the heat-leak rate, how the Dewar has been handled, and how long the Dewar has been plugged. The pressure in a 25-liter helium Dewar in good condition rises about 3 psi per hour. A Dewar in poor condition will have a faster pressure rise. Also the pressure will rise faster when a plugged Dewar is transported and the liquid helium is allowed to slosh against the warmer parts of the Dewar.

5.6.4 Find out when the Dewar was last observed unplugged.

5.6.5 Do not attempt to unplug a Dewar when it has been more than 72 hours since the Dewar was last observed open. Immediately evacuate all personnel from the area.

5.6.6 "Emergency Deicing Kits" containing equipment to open an ice plug are located in the Liquid Hydrogen and Liquid Helium Storage Building (81), and also in Building 62, Room 135, and Building 70A, Room 1151.

5.7 To remove an ice plug from a helium Dewar or LN_2-shielded LH_2 Dewar

5.7.1 Be aware of the possibility of high pressure in the Dewar. Always keep your face and body away from the top of the Dewar. Attempt this operation only if judgment, previous experience, or knowledge leads you to believe that the Dewar will not blow up while you are working on it. If you are in doubt, leave the Dewar; it is expendable. Keep other people away. If the Dewar is in an experimental area, advise the Building Manager or Crew Chief.

5.7.2 Spend a minimum amount of time near the Dewar.

5.7.3 A face shield and lose-fitting protective gloves shall be used. Warp a turpaulin around the Dewar to help absorb energy in case the Dewar explodes.

5.7.4 Procedure:

5.7.4.1 Obtain a solid copper rod from the "Emergency Deicing Kit." (The rod should have a rubber stopper installed on its upper end to prevent it from striking the bottom of the Dewar when the ice plug is melted and the rod drops in.) Insert the copper rod into the neck of Dewar, allowing its weight to rest on the ice plug. The heat of conduction down the copper rod is usually sufficient to melt-in the ice plug.

5.7.4.2 For severe plugs, take the copper tube from the "Emergency De-icing Kit" and connect it to a compressed helium bottle. Be certain that you use helium and not nitrogen. The helium bottle should be located out of the line of sight of the Dewar.

5.7.4.3 Start helium gas flowing through the tube from the bottle regulator and insert the tube into the helium Dewar. Helium gas will melt the ice plug.

5.8 Purge Procedure

5.8.1 At LBL, the purging of hydrogen and helium Dewars is the responsibility of the Mechanical Engineering Department Liaison Group. The Dewars shall be purged at least every 30 days. This procedure applies to LN_2-shielded Dewars for either liquid helium or liquid hydrogen and is as given below.

5.8.2 First: Remove liquid nitrogen from the jacket

Attach the rubber hose from the nitrogen gas cylinder on the vent side of the Dewar's liquid-nitrogen circuit. Set the regulator to 10 psi and force liquid nitrogen out of the fill side until the liquid-nitrogen circuit is empty. Do not spill liquid nitrogen on the N_2 gas cylinder or any ferrous metal. A cold gas-cylinder is brittle and can explode from its own internal pressure. Normal procedure is to transfer liquid into an LN_2 dewar.

5.8.3 Second: Purge the helium or hydrogen circuit

Connect a rigid tube to 10 psi of helium gas. Insert the tube slowly into the helium or hydrogen circuit of the Dewar. Be careful that the tube does not "freeze" in the Dewar neck. Purge a Dewar that has been filled with liquid helium until the Dewar is warm. Purge a Dewar that has been filled with hydrogen until it is free of hydrogen gas; use a gas detector.

II.J VENTING

II. J. Venting

1. Equipment-Venting Guidelines

a. Every vessel connected to research apparatus and containing flammable gas or flammable liquefied gas shall be connected to a building fixed-vent system. Exceptions to permit small sized research apparatus to vent flammable gas into a ventilated hood or forced ventilated room requires the approval of the Mechanical Safety Committee.

b. Only one flammable fluid device shall be connected to a piped vent.

c. Vent lines, associated equipment, and experimental apparatus attached to the vent line shall be designed so that they do not fail when subjected to thermal changes.

d. All vessels, piping, or other closed circuits shall have positive relief devices connected to the building fixed-vent system.

e. Mechanical vacuum pumps which by design or accident can pump flammable gas mixtures or oil vapors shall be connected to a separate metal exhaust line that vents to the outside of the building.

f. Venting of toxic gases must comply with the EH&S Department regulations and recommendations. If you are in doubt as to the hazards, toxicity, or safe operating practices of toxic gases, please consult EH&S, Ext. 5251.

2. Building Fixed-Vent-System Guidelines

a. All flammable gas vent lines or exhaust systems, including those for normal boil-off, emergency dump, and relief valve and rupture-disk venting, shall lead directly outside the building without the possibility of discharging into the building interior.

b. The vent system shall terminate outside the building in such a manner as not to release flammable gases near the intakes of the building airhandling system or other openings in the building. The vent system termination outside of the building shall not terminate directly above or below any other opening.

c. The vent line shall be unobstructed and made of metal. The vent line shall have a design rating of 150 psig. Valves or other methods of blocking the vent, except approved full-size check valves, shall not be installed between the relief device and the discharge end of the vent line.

d. Seals and gasketing in the vent line shall be designed to be tight under vacuum test, proof pressure, and temperature. The vent system shall be designed to remain tight under fire or under temperatures and pressures that may be experienced during emergency conditions. Quick-opening rubber gasket couplings are permitted in vent lines for research apparatus containing less than three liquid liters of flammable liquefied gas; these coverings shall not be used within the "hazardous area."

e. The vent line shall have sufficient mechanical strength and suitable anchoring, and shall be protected or so located as to reduce the probability of damage. The vent line, where exposed in the building, shall be insulated if it is made of low-melting-point metal such as aluminum when the research apparatus contains more than three liquid liters of flammable liquefied gas. Soft-solder joints shall not be used.

f. Vent systems shall be inspected prior to any use and at monthly intervals.

g. Vent systems shall be designed so that they can be vacuum- and pressure-checked conveniently from the experimental area. Each vent system shall have suitable identification, and the user shall follow a written procedure to insure that the vent system is both open to the atmosphere and gas tight.

3. Block House or Enclosure Vents

Block houses, rooms, or other enclosures housing flammable-gas or flammable liquefied gas-filled equipment must be vented to the outdoors.

II.K PREVENTION OF OVERTURNING: EQUIPMENT-HANDLING CONSIDERATIONS

II. K. Rules for Prevention of Equipment-Overturning; Seismic Considerations; Equipment-Handling Considerations

1. General

a. Seismic Safety Committee Functions

The seismic-safety codes have been in a state of rapid evolutionary change in recent years. Therefore, it is important to recognize this rapid evolution and its impact on the LBL seismic-safety policy.

The Seismic Safety Committee is a subcommittee of the LBL Safety Review Committee. It provides guidance to program personnel by conducting Seismic Design Review meetings for structures and special LBL equipment involving state-of-the-art seismic design problems, or for those cases where the codes may not apply directly. These meetings are convened at the request of the person in charge of the equipment or experiment. This person has the primary responsibility for the proper design and the carrying out of required procedures for the safe operation of equipment (as defined in this manual, LBL Pub. 3001, Sec. I.C.).

In the Seismic Design Review meetings, the Seismic Safety Committee determines whether dynamic-structural analyses are required or whether a static-structural analysis is sufficient. The Committee provides a Design-Basis Earthquake (with time-history and spectral-response data) if dynamic analyses are required. The Committee is responsible for keeping updated on state-of-the-art development in the seismic response of structures and for utilizing this knowledge in the performance of its functions.

The statutory seismic codes are changed as seismic knowledge is developed and codified. However, current codes necessarily lag the state-of-the-art developments and are considered a minimum LBL standard. Accordingly, all structures and equipment at LBL, as a minimum requirement, shall be designed and constructed to be in accordance with the latest editions of the following: (1) "Uniform Building Code" and all other applicable seismic safety codes; (2) LBL Pub. 3001, Rules & Procedures for the Design & Operation of Hazardous Research Equipment, Section II.K. and (3) LBL Pub. 3000, Health & Safety Manual, Chapter 23, "Seismic Safety."

b. General Seismic Design Requirements

Note: This section is excerpted from LBL Pub. 3000, Chapter 23, and is repeated here for convenient reference.

All critical items, or equipment associated with critical areas of radioactive containment, and special-hazards assemblies shall be designed to withstand base-shear-static lateral forces, depending on the type of structural bracing system used.

Bracing systems, including their connections, that are constructed of structural materials that fail in a brittle manner (are susceptible to sudden failure and do not exhibit ample reserve strain-energy capacity resulting from inelastic non-linear behavior, e.g. non-ductile reinforced concrete) are considered non-ductile bracing systems. For non-ductile bracing systems, the design shall be based on the following:

(i) Base shear = 0.70 W
W = Total dead load of structure and equipment

(ii) Maximum allowable stress in structural elements shall not exceed:

- o 75% of the ultimate compressive strength for concrete in bearing or compression
- o 50% of the ultimate strength for welds
- o 75% of the manufacturer's recommended ultimate load values for anchor bolts or proprietary expansion anchors which depend on the concrete for their ultimate load capacities
- o 75% of the ultimate strength for other structural elements.

Bracing systems, including their connections, that are constructed of structural materials which exhibit ductile-inelastic (non-linear) behavior at stresses beyond their yield points (and have ample reserve strain energy capacity beyond their yield points, e.g., structural steel), are considered ductile bracing systems. For ductile bracing systems, the design shall be based on the following:

(iii) Base shear = 0.50 W

(iv) Maximum allowable stress in ductile structural elements shall not exceed their yield strengths.

Massive structures, such as concrete-shielding-block assemblies associated with critical areas, shall be designed where practical, to meet the above criteria. If this is impractical, then the seismic-bracing design must incorporate alternate methods to protect the containment box, such as use of ductile structural steel, energy-absorbing frames, or other structural systems exhibiting ductile behavior beyond the yield points of the materials used.

Seismic criteria for critical items (as defined in Chapter 23 of LBL Pub. 3000) requiring dynamic analysis are developed on a case-by-case basis by the design engineer and reviewed by a special LBL earthquake engineering consultant. Ground spectra guidelines are 0.7g peak acceleration at frequencies less than 10 Hz, based upon a magnitude 7.0 earthquake on the Hayward Fault. Seismic design for critical items are reviewed and approved by the LBL Seismic Safety Review Committee and the Environmental Health and Safety Department.

2. Prevention of Overturning

a. Lateral Restraint of Heavy Objects

(i) General

If loss of life and/or injury to personnel can arise (through being struck, or being entrapped and crushed or through having an escape route obstructed) due to the lateral movement or upset of any heavy object from any cause (such as self-excitation in a machine tool with an eccentric work piece, seismic disturbance, wind gust loads, being struck by a moving vehicle, etc.), then such heavy object shall be restrained from movement or upset without reliance on friction when subjected to a horizontal acceleration of 70% of gravity. If the object is provided with adjustments, it must resist 70% of gravity when the adjustments are in the most unfavorable positions. In this context "heavy object" shall mean any objects (such as cabinets or benches, machine tools or surface plates, laboratory apparatus, platforms, etc.) which if put in motion cannot be easily intercepted and their motion arrested by the effort of one man.

The maximum allowable stress in the seismic restraining system shall not exceed that specified in Section 1.b.(ii) above.

In certain instances it may be undesirable to solidly secure objects to a floor, since normal settlement may cause unacceptable warpage or misalignment of sensitive elements. It is acceptable to supply the requisite restraint without initial hard contact by allowing a small movement before motion-stops become effective.

In other instances when it is not clear if the floor under a "heavy object" can withstand the horizontal earthquake force, it may be desirable to decouple the "heavy object" from the floor and allow an acceptable but limited horizontal motion. This decision can be made by the Project Engineer or with the assistance of the Mechanical Safety Committee. The motion must not permit the "heavy object" to cause personnel injury or obstruct an escape route and should be limited to a few inches. In all cases, upset (toppling, falling over) must be prevented.

Seismic protection shall be provided as soon as possible after installation and as much as possible during major maintenance or reassembly.

(ii) Heavy Magnets or Heavy Equipment Mounted on Stands

For heavy magnets or heavy equipment mounted on stands, the dynamic load during an earthquake may greatly exceed the maximum ground acceleration due to amplification. The responsibility for providing a structural design of sufficient strength and ductility to withstand dynamic loads rests with the project leader or his designee. When any doubt exists, the natural frequency of the structure shall be computed and the maximum stress determined from the Design-Basis Earthquake specified by B. Bolt in his report dated July 10, 1979 entitled "Strong Seismic Motion for Design Purposes at the Lawrence Berkeley Laboratory," LBL-17377.

Many good references on response spectrums are available; see, for example, "Response of Simple Structures to Earthquake Motions," Section 16.2, by N. M. Newmark in Earthquake Engineering, Robert L. Weigel, editor, Prentice-Hall (1970), in the LBL Engineering Library.

In certain cases, the project leader may request the Seismic Safety Committee to review the dynamic analysis made by his group. In such cases the review procedure will be similar to that described in Section 2.c. below.

b. Research Apparatus Mounted on Wheels or Casters

This Section 2.b. covers apparatus mounted on wheels or casters during the time it is being intentionally moved. When this apparatus is stationary, Section 2.a. applies.

(i) For research apparatus, the center of gravity has to rise at least 3 inches before overturning, with the casters in any position. The center of gravity can effectively rise 3 inches when the casters strike an obstruction at a speed of 4 ft/sec and abruptly stop.

(ii) If swivel casters are used, vertical stops must be provided to limit the amount of tipping and to avoid overturning in the event that a caster breaks. When stops are used, the 3-inch rise of the center of gravity is required after a caster has broken and the stop is supporting the equipment.

c. Specific Seismic Design Criteria for Shielding

The following requirements and guidelines shall apply to all LBL accelerator concrete-shielding blockhouses, particle-beam shielding, or other structures consisting of large blocks.

(i) Guideline--In view of the developing nature of seismic-design philosophy for concrete shielding structures and as a result of the seismic-shake-table experiments, it is recommended that each concrete-shielding structure to be modified, moved, or constructed shall be reviewed by the Seismic Safety Committee in a seismic Design Review Meeting, convened as provided in Section 1.a. above. The review committee shall consist of members of the Seismic Safety Committee and include at least the following:

- The seismic representative of the LBL Mechanical Safety Committee to act as Chairman;
- An engineer from the LBL Plant Engineering Department;

- o A professional member of the project's staff;
- o A member of the EH&S Department;
- o And, in complex cases, an external seismic engineering consultant.

(ii) Requirement--All shielding structures shall be designed to resist static lateral loads applied to the center of gravity from any horizontal direction. The horizontal acceleration shall be 0.7g where "g" is the acceleration of gravity. Unless otherwise specified by the Seismic Safety Committee, when calculating moments resisting upset of a structure, vertical loads shall be taken as the dead weight of parts. The intended system of restraint shall be described in an engineering note, which shall also contain the supporting calculations.

The maximum allowable stress in the seismic restraining system shall not exceed that specified in Section 1.b.(ii) above.

(iii) Requirement--Elements of a shielding structure shall be prevented from moving in any lateral direction with respect to one another by a positive physical interference, such as integral keys, metal plates with end stops, or equal. This requirement does not include the shielding-to-floor interface.

The capacity of the floor to carry lateral loads shall be ascertained. When it is not clear if the floor under a structure can withstand the horizontal earthquake force, it may be desirable to decouple the structure from the floor and allow an acceptable but limited horizontal motion. This decision shall be made by the Person-in-Charge and the Seismic Safety Committee. In all cases, upset (toppling, falling over) must be prevented. Engineering studies and shake-table tests are underway to determine optimal methods of absorbing the lateral load energy of concrete-shielding structures.

(iv) Requirement--When limited horizontal motion of the structure with respect to the floor is permitted during a seismic disturbance, the structure shall be constructed such that the personnel escape routes will remain open.

(v) Requirement--Moment arms for resistance against upset may be calculated from the edge of a block when the corner is formed by a metal angle adequately anchored to the concrete. When the corner is only concrete, or when the block rests on a substantial thickness of resilient material such as timber, the load line shall be inset 5 inches from the edge of the block.

(vi) Requirement--The structural integrity of buildings and the continuity of plant services are Plant Engineering responsibilities. If shielding is in contact with building elements or is sufficiently close that contact is likely during a seismic disturbance, or if shielding is supported, restrained or braced from the building structure, then Plant Engineering must participate in, and approve of, any design for the lateral restraint of the shielding. Buildings and shielding can be expected to have different motions in response to a seismic disturbance, and should be made structurally independent whenever possible.

(vii) Requirement--Whenever dispersible residual radiation must be contained, for example, the material used in a radioactive-chemistry experiment, more stringent safeguards are necessary and the EH&S Department must be consulted for appropriate requirements, including seismic stability of shielding.

(viii) Guideline--The best seismic defense for shielding is to unify an assemblage of blocks into a single integral structure by use of keys, strap-plates, tie rods or chain, etc.

(ix) Guideline--The requirements establish minimum criteria. In many cases lateral restraint can be significantly increased at very small increase in cost (1-2%) or loss in functional flexibility. Increasing the strength of restraints is to be encouraged and is left to the engineering judgment and resourcefulness of the individual engineer.

3. Design and Use of Handling Equipment

a. The burden of verifying the strength and safety of a piece of handling equipment rests upon the person in charge of the project in which the equipment is being used. For equipment designed at LBL, it is the responsibility of the designer or engineer to provide the user with information required to utilize the handling equipment safely.

It is the responsibility of the supervisor to assure himself that the user knows how to use the handling equipment safely. If there are questions regarding safety, the supervisor is responsible for obtaining satisfactory answers before using the equipment. The supervisor may obtain answers from the designer, the engineer in charge, or from the appropriate person on the Mechanical Safety Committee.

b. The design stress for handling equipment shall not exceed one-fifth (1/5) the ultimate strength of the material being used at the temperature of operation. If welded fabrication is utilized, then the design stress must take into consideration any weakening effects due to welding, such as those that occur in aluminum alloys.

c. It is preferable, if practical, to avoid the use of welding in the design and fabrication of handling equipment; however, if welding technology is utilized, design and fabrication must be done according to the latest standards of the American Welding Society (AWS) D1.1. Careful, thoughtful design and follow-up is required. The following rules shall apply when designing welded units:

(i) There must be no possibility of subjecting welds to tearing loads. Stresses in welds should be substantially uniform.

(ii) Where possible, design handling equipment so that the main loads are carried only by structural members or plates rather than by welds. Examine this possibility carefully.

(iii) Welded fabrications shall be proof tested to twice the maximum rated load and then magnafluxed.

d. Eye bolts without shoulders shall not be used for lifting. Eye bolts with shoulders are permitted for lifts perpendicular to plate or shoulder.

Single-bolt pickup devices, such as "Safety Hoist Rings" or equivalent carefully designed and maintained in-house units, are convenient and satisfactory handling systems when used properly. It is recommended that these devices be used in place of standard eye bolts with shoulders in handling and lifting applications.

Screws used for "in-house" single-bolt pickup devices shall be tested to two (2) times the rated load and then given a magnaflux test to insure soundness. It is desirable to keep a supply of tested bolts on hand in case one is lost.

Once a fixture is in the hands of the user, it is his responsibility to see that it is used correctly, that the screw is the proper one, that it is screwed into the proper depth, that it is torqued correctly, and that it is maintained properly.

The appropriate screw-thread engagement required for conservative development of the full strength of a screw depends upon the materials involved. If the material of which the screw is made and the material in which the hole is tapped are identical, such as a mild-steel screw in a mild-steel hole, then an engagement of 1-1/2 diameters is sufficient. A hex-socket cap screw (Allen screw) in mild steel requires 2 diameters' engagement. Other material combinations should be checked.

e. Although the use of standard eyebolts with shoulders is discouraged, there may be cases where old designs will not permit substituting a Safety Hoist Ring. If it is necessary to use a standard eye bolt with shoulders, then the following rules apply:

(i) Load must be in line with the axis of the eye bolt.

(ii) <u>No side pull forces are permitted</u>.

(iii) Average stress on the root area of the thread must not exceed 5000 psi.

(iv) Thread engagement must be at least two diameters.

f. All handling equipment designed at LBL shall be proof-tested to twice the maximum rate load before placing it in service. The capacity shall be stenciled on the equipment in 3-inch high letters.

4. Commercial Handling Equipment

   a. All commercial handling equipment shall be proof-tested to twice the maximum rated load before putting it into service. The capacity shall be stenciled on the equipment in 3-inch high letters.

   b. The person in charge of the project is responsible for insuring that such proof testing is done and that adequate records of the tests are kept.

II.L ELECTRICAL SAFETY RULES

II. L. LAWRENCE BERKELEY LABORATORY

SAFETY REQUIREMENTS FOR

CONSTRUCTING ELECTRICAL EQUIPMENT

AND

WORKING ON ENERGIZED ELECTRICAL EQUIPMENT

(This section has been taken <u>in toto</u> from publication UCID-3937, by E. C. Hartwig of the Electrical Safety Review Committee.)

SAFETY REQUIREMENTS FOR CONSTRUCTING ELECTRICAL EQUIPMENT AND WORKING ON ENERGIZED ELECTRICAL EQUIPMENT

Introduction

This document contains safety requirements for constructing electrical equipment and working on energized electrical equipment. Special emphasis is placed upon problems associated with personnel working on hazardous electrical equipment in an energized condition. This is permissible only after extensive effort is made to perform the necessary tasks with the equipment in a securely de-energized condition, or with the equipment so enclosed and protected that contact with hazardous voltages is essentially impossible.

As used in this document, shall denotes a requirement, should a recommendation, and may means only permission. This document supersedes "Electrical Safety Practices LRL Berkeley" date April 24, 1970, and "Safety Requirements for Working on Energized Electrical Equipment" dated March 1, 1974.

Safety procedures for high-line and standard electrical power substations are well established and are not considered in this document.

This document is in effect at LBL as of this date, 8/1/77.

Electrical Safety Review Committee
E. C. Hartwig, Chairman

DEGREE OF ELECTRICAL HAZARD

Recognition of the hazards associated with various types of electrical equipment in research activities is of paramount importance in developing and applying safety guidelines for working on energized equipment. Two classes of electrical hazards have evolved.

Class A

A "Class A" electrical hazard exists when all of the following conditions prevail:

1. The primary ac potential does not exceed 130 volts.

2. The available primary ac current is limited to 30 amperes.

3. The stored energy available in a capacitor or inductor is less than 5 joules.

4. The dc or secondary ac potentials are less than 30 volts to ground or have a power limit of 150 volt-amperes.

Although the voltages and currents may be considered nominal, a "Class A" electrical hazard is potentially lethal and must be regarded as such. This class is particularly dangerous because of everyday familiarity, an assumed ability to cope with it, and its common occurrence in less guarded exposures.

Class B

Class B electrical hazard classification prevails for all situations when one or more of the limitations set in Class A are exceeded.

Working on Energized Electrical Equipment

MODES OF OPERATION

The attitudes and habits of personnel and the precautions they routinely take when working on energized equipment are extremely important. The three modes of working on electrical equipment are identified as follows:

1. Mode 1

All operations are to be conducted with the equipment in a "positively" de-energized state. All external sources of electrical energy must be disconnected by some positive action (e.g., locked-out breaker) and with all internal energy sources rendered safe.

"Mode 1" is a minimal hazard situation which requires little or no supervision of the worker(s) after the initial protective steps are taken.

2. Mode 2

All manipulative operations (such as making connections or alterations to normally energized components or in close proximity to normally energized components) are to be conducted with the equipment in a "positively" de-energized state. Measurements and observations of equipment functions may then be conducted with the equipment energized and with normal protective barriers removed. In this case, another knowledgeable person may be involved (see Personnel Requirement Chart).

"Mode 2" is a moderate-to-severe hazard situation, depending on the operating voltages and energy capabilities of the equipment.

3. Mode 3

Manipulative, measurement, and observational operations are to be conducted with the equipment fully energized and with the normal protective barriers removed.

"Mode 3" is a severe hazard situation which should be permitted only when fully justified and should be conducted under the closest supervision and control. One knowledgeable person is involved in addition to the worker(s). Written permission may be required (see Personnel Requirement Chart).

These specific safety considerations which are dependent on the degree of electrical hazard and the mode of working on equipment are classified in the following Personnel Requirement Chart, and listed on the next page.

PERSONNEL REQUIREMENT CHART

Degree of Hazard	MODE OF WORKING		
	Mode 1	Mode 2	Mode 3
Class A	Personnel can work alone.	Personnel can work alone with general supervision and implied approval.	Companion required, plus general supervision and implied approval.
Class B	Two workers to start, w/general supervision and implied approval.	At least two knowledgeable persons at all times, plus verbal approval by supervisor.	At least two knowledgeable persons (one as a safety watch) with written approval by 2nd level of technical supervision.

1. When working on Class A equipment in Modes 2 and 3 in confined spaces, or in conditions involving massive grounds, at least two knowledgeable (including the worker) people shall be present and in position for continuous sight and sound communication.

2. In the case of Class A-3 conditions, a worker shall have either a co-worker or a companion who occasionally checks on his safety.

3. In the case of Class B-1 conditions, at least two knowledgeable people shall be on hand until the positively de-energized state is clearly verified.

4. When working on equipment having a Class B hazard, instructions to prevent accidents and guidelines for use in case of emergencies should be posted conspicuously.

5. On Class B equipment the use of personal protection devices such as face shields, safety glasses, insulating mats, body protection, etc., should be promoted.

6. In the case of Class B-2 conditions, the verbal approval of the worker's supervisor shall be obtained for the work contemplated and risks to be taken.

7. In the case of Class B-3 conditions, the written approval of the second level of technical supervision above the workers exposed to the hazard shall be required. Said approval to be valid for 24 hours or the duration of the particular job, whichever is the least time.

8. In the case of Class B-3 conditions, one person in addition to the worker(s) shall be identified as "safety watch". His attention shall not be substantially distracted from this assignment.

9. In the case of Class B-2 and B-3 conditions, at least two knowledgeable people (including the worker) shall be in position for continuous sight and sound communication.

CONSTRUCTION PRACTICES

a. Philosophy

Design and construction shall provide protection for persons not familiar with equipment and for the occasional forgetful person. First line and backup protection should be provided to prevent personnel access to energized circuits. Periodic tests should be established to verify that these protective systems are operative.

b. Safety practices

Adequate lighting shall be provided for easy visual inspection.

Isolation. All sources of dangerous voltage and current shall be isolated by covers and enclosures. Access to lethal circuits shall be only via screw-on panels or interlocked doors. The frame or chassis of the enclosure shall be connected to a good earth ground with a conductor capable of handling any fault current.

Safety grounding. Suitable, fully visible manual grounding devices shall be provided to short out dangerous equipment while work is performed.

Automatic discharge. Automatic devices for discharge shall be used on stored-energy equipment.

Overload protection. Overload protection and well-marked disconnects shall be provided. Local "off" controls shall be provided on remote-controlled equipment.

All disconnects and breakers should be clearly labeled as to the loads they control.

Fire control. The use of flammable material shall be kept to a minimum. When flammable fluid-filled components are used, a catch basin shall be provided to prevent the spread of potential fuel.

Rating. All conductors, switches, resistors, etc., shall be operated within their design capabilities. Pulsed equipment shall not exceed either the average or the peak rating of components. When equipment is derated, adequate allowance must be made for environment and the use of components.

Emergency Lighting. There shall be an emergency lighting system that goes on when normal power fails in Class B-2 and B-3 conditions.

3. Safety Considerations for Enclosures

The following check list shall be used as a guide for circuits operating at 130 V or more or storing more than 5 joules. (An enclosure may be a room, a barricaded area, or an equipment cabinet.)

a. Isolation. The enclosure shall physically prevent contact with live circuits.

b. Grounding. The enclosure should be constructed of conductive material all electrically interconnected, and connected to a good earth ground. These connections shall be adequate to carry possible fault currents.

c. Access. Easily opened doors, panels, etc., shall be interlocked so that the act of opening de-energizes the circuit. Automatic discharge of stored energy devices shall be provided. Doors should be locked, with the required key used also in the control circuit interlock chain.

d. Visibility. The enclosure should allow observation of equipment and of men working inside.

There should be conspicuous visual indication of both ON and OFF conditions of each separately operable piece of hazardous equipment. This indication should be readily visible from any point where a person may make a hazardous contact.

Heat. Heat-generating components such as resistors shall be mounted so that heat is safely dissipated and does not affect adjacent components.

e. Strength. Enclosures shall be strong enough to contain flying debris due to component failure.

f. Ventilation. Ventilation shall be adequate to prevent overheating of equipment and to purge toxic fumes produced by a fault.

Warning. Signs stating the nature and location of the hazard shall be posted. When practical, disconnect and safety instructions shall be included. A warning light to indicate when equipment is energized shall be installed.

g. Temporary enclosure. Temporary enclosures not conforming to the normal requirements shall be considered Class B-2.

4. Power Supplies

Such a wide range of power supplies is used in the Laboratory that no one set of considerations can be applied to all cases. Table I and the following classification scheme may be helpful in assessing hazards with power supplies:

a. Power supplies of 30 V or less with high current capability are considered a negligible shock hazard and are frequently "worked hot." The primary hazard in this situation is severe burns caused by high currents passing through tools, metal watch bands, wedding rings, etc.

b. Power supplies in the range of 30 to 400 V with lethal current capability present the greatest potential hazard. Although these voltages are capable of producing fatal shocks, they are not considered "high voltage," and as a result are frequently not treated with proper respect. To the obvious shock and burn hazards must be added the likelihood of injury in getting away from the source of a shock. Severe and sometimes fatal falls, or at least cuts or bruises, have been the result of otherwise insignificant shocks.

c. Power supplies of 400 V or more, with lethal current capability, have the same hazards to an even greater degree. As supplies in this category are considered "high voltage," they are usually treated with more respect.

d. High voltage supplies that do not have dangerous current capabilities are not serious shock or burn hazards in themselves and are therefore often treated in an offhand manner. However, they are frequently used adjacent to low-voltage lethal circuits, and a minor shock could cause a rebound into such a circuit. Also, an involuntary reaction to a minor shock could cause a serious fall (as from a ladder or from experimental apparatus.)

e. Additional safety consideration for power supplies

Primary disconnect. A means of positively disconnecting the input shall be provided. This disconnect shall be clearly marked and located where the workmen can see it while servicing the supply. Remotely controlled supplies and those with remote loads shall be equipped with a disconnect that may be "locked out." A permanently affixed lock that does not lock the switch or allow the key to be removed except in the "off" position should be provided.

Overload protection. Overload protection shall be provided on the input and should be provided on the output.

5. Capacitors

Only those capacitors are covered that have more than 5 joules stored or operate at 130 V or more.

a. Hazards

Capacitors may store hazardous energy even after the equipment has been de-energized, and may build up a dangerous residual charge without an external source. "Grounding" capacitors in series may transfer rather than discharge the stored energy. Capacitors may be subjected to high currents, which may cause heating and explosion.

Capacitors may be used to store large amounts of energy. An internal failure frequently results in explosion. All other capacitors in a bank may then discharge into the fault. Approximately 10^4 joules is the threshold energy for explosive failure.

High-voltage cables have capacitance and thus can store energy; they should be treated as though they were capacitors.

The liquid dielectric or its combustion products may be toxic in many capacitors.

b. Additional safety considerations for capacitors

Automatic discharge. Permanently connected bleeder resistors should be used when practical. Capacitors in series should have separate bleeders. Automatic shorting devices that operate when the equipment is de-energized or the enclosure is opened should be used. The time required for a capacitor to discharge to safe voltage (50 V or less) shall be not greater than the time needed for personnel to gain access to the voltage terminals. In no case shall it be longer than 5 minutes.

In case of Class-B equipment, where there is stored energy in excess of 5 joules, an automatic mechanical discharging device shall be provided which functions when normal access ports are opened. This device should be in plain view of the person breaking the protective barrier so that he can verify its proper functioning. Protection against the hazard of the discharge itself shall be provided.

Safety grounding. Fully visible manual grounding devices shall be provided to render the capacitors safe while they are being worked on. Grounding points should be clearly marked, and caution must be used to prevent transferring charges to other capacitors. On high energy systems the grounding device shall contain resistors to limit the discharge current to a safe level.

All grounds hooks shall: (a) have conductors crimped and soldered, (b) be less than 0.1 ohms impedance, (c) have the cable conductor clearly visible through its insulation, (d) have a cable conductor size of at least #2 extra flexible, (3) be in sufficient number to conveniently and adequately ground all low impedance points, (f) be draped across the normal entry way when stored to make certain they are used.

In Class B equipment, where there is stored energy in excess of 5 joules, discharge point with an impedance capable of limiting the current to 500 amperes or less should be provided. A grounding hook may first be connected to the discharge point, and then to a grounding point having low impedance (less than 0.1 ohm). The hooks shall be left on all of these low impedance points during the time of safe access. The low impedance points shall be provided, whether or not the current limiting points are provided.

Fusing. When capacitors are used in parallel they should be individually fused to prevent the stored energy from all dumping into a faulted capacitor when possible. Special knowledge is required for High Voltage and High Energy fusing.

Storage. Unused capacitors should have the terminals shorted.

6. Inductors and Magnets

Only those inductors and magnets are covered that have more than 5 joules stored energy or operate at 130 V or more.

a. Types of hazards. Some hazards peculiar to inductors and magnets are:

-- the ability of an inductor to release stored energy at a much higher voltage than that used to charge it;

-- stray magnetic fields, which attract magnetic materials;

-- varying stray fields, which induce eddy currents in conductive material and thereby cause heating and mechanical stress.

b. Additional safety considerations for inductive circuits

Automatic discharge. Free-wheeling diodes, thyrites, or other automatic shorting devices should be used to provide a current path when excitation is interrupted.

Eddy Currents. Units with pulsed or varying fields should have a minimum of eddy-current circuits. Where large eddy-current circuits are unavoidable they should be mechanically secure and able to dissipate any heat produced.

Connections. Particular attention should be given connections in the current path of inductive circuits. Poor connections may cause destructive arcing.

Cooling. Many inductors and magnets are liquid-cooled. The unit should be protected by thermal interlocks on the outlet of each parallel coolant path, and a flow interlock should be included.

Grounding. The frames and cores of magnets and inductors should be grounded.

7. Control and Instrumentation

Philosophy is applicable to most control applications. The following check list should be used as a guide:

Fail-safe. All control circuits shall be "fail-safe." Starting with a breaker or fuse, the circuit should go through all the interlocks in series to momentary on-off switches which energize and "seal in" a control relay. Any open circuit or short-circuit will turn off the control and lock it off.

Visual indicators. Lights should be used to monitor the status of the circuit: green to indicate "ready" or safe" and red to indicate "on."

Isolation. Control power shall be isolated from higher-power circuits by transformers, contactors, etc. Control power should be not more than 120 V, ac or dc. All circuits should use the same phase or polarity so that no additive voltages are present between control circuits.

Lockout. A keyed switch should be used in interlock chains to provide positive control of circuit use. To assure power removal before anyone enters the enclosure this same key should also be used to gain access to the controlled equipment.

Checkout. Interlock chains shall be checked for proper operation after installation, after any modification, and on periodic routine testing.

Bypass. A systematic procedure for temporarily bypassing interlocks shall be established. Follow-up procedure should be included to assure removal of the bypass as soon as possible. When many control circuit points are available at one location the bypassing should be done through the normally open contacts of relays provided for this purpose. In emergency these relays can be opened from a remote control area.

Overvoltage protection. Control and instrumentation circuits used with high voltage equipment shall have provision for shorting fault-induced high voltages to ground. High voltage fuses with a high-current, low-voltage spark gap downstream from the high voltage source are recommended.

Voltage dividers. The output of voltage dividers used with high voltages shall be protected from overvoltage to ground within the high voltage area by spark gaps, neon bulbs, etc.

Current monitors. Currents should be measured with a shunt that has one side grounded or with a current transformer. Current transformers shall be either loaded or shorted at all times.

Accuracy. Instrumentation should be checked on a routine basis for function and calibration.

8. Radiation Hazards

This covers radiation hazards that may be encountered in working with electrical equipment. The following check list should be used as a guide. Consult with EH&S for more details. See Table II.

Warning. Signs stating the location and nature of the hazard, with specific safety instructions, shall be prominently posted. Warning lights shall be used to indicate when the equipment is energized.

Monitoring. When equipment is used that is capable of generating a radiation hazard, monitoring shall be provided to detect and measure radiation. When personnel may be exposed, this monitoring equipment should be arranged to de-energize the generating equipment at a preset level.

Isolation. X-ray-producing equipment (hv vacuum tubes operating at greater than 15,000 volts), or any equipment that under fault conditions could produce x-rays (spectrometers, etc.), shall be isolated from personnel. This isolation may be by distance or by lead shielding, for example. For any questions, check with EH&S at extension 5251.

Hazardous electromagnetic radiation shall be isolated in shielded enclosures. Transmission paths of microwave energy shall be enclosed or barricaded and well marked. Care shall be taken to avoid reflecting energy out of this path. Suitable goggles shall be worn where exposure is possible. Dose rates shall not exceed that shown in Table II. Check with Electronics Special Problems Engineering for testing of equipment.

High-power sources of ultraviolet, infrared, and visible light shall be isolated by barriers that are opaque to the radiation. When a beam of this radiation is projected out of an enclosure, the beam path shall be barricaded and well marked. Care shall be taken to eliminate reflective surfaces along the beam path. Suitable goggles shall be worn where exposure is possible. See Table II.

Ventilation. Radiation fields that may produce ozone shall be confined to areas that are well ventilated. Consult with EH&S for more details.

MEASURES FOR PREVENTING ACCIDENTS

1. The supervisory chain shall be identified for normal operation and development, servicing, or testing of hazardous equipment.

2. An up-to-date set of instructions for operation, maintenance, testing, and safety should be provided and made readily available to anyone working on hazardous equipment.

3. On any type of electrical equipment as many tests as practicable should be made in the unenergized condition, or at most, energized with reduced hazard.

4. Removal of covering, clothing, and jewelry, which might cause hazardous involvement, should be required.

5. Adequate and workable lockout/tag-out procedures shall be employed.

6. A person in a hazardous position who appears to be fatigued, ill, under the influence of alcohol and/or drugs (medicinal, or other kinds) or emotionally disturbed shall be replaced by a competent back-up man, or the hazardous work shall be terminated.

7. Supervisors and workers should be encouraged to take the conservative choice when they are in doubt about a situation regarding safety.

8. Training sessions and drills shall be conducted periodically to help prevent accidents and train personnel to cope with them, should they occur. Cardiopulmonary resuscitation instruction shall be included.

9. A generally immobilizing Emergency-OFF switch, clearly identified and within easy reach of all high-hazard equipment, should be provided. Also, this switch may be used to initiate a call for help. Resetting an Emergency-OFF switch must <u>not</u> be automatic, but shall require an easily understandable overt act.

10. Automatic safety interlocks shall be provided for all access to high-hazard equipment. Any bypass of such an interlock should have an automatic reset, display conspicuously the condition of the interlocks, and be such that barriers cannot be closed without resetting the interlock.

11. There should be convenient, comfortable, and dry access to all equipment.

12. Communication equipment for use in emergencies (e.g., fire alarm box, telephone) should be provided near any hazardous equipment and marked with its location, to ensure that proper instruction can be given so that people responding to a call for help can find the site quickly.

13. Any component which in its common use is nonhazardous, but in its actual use may be hazardous, shall be distinctively colored and/or labeled. (An example might be a copper pipe carrying high voltage or high current.)

14. Periodic tests of interlocks to assure operability shall be performed at least yearly.

Table I. Quantitative effects of electrical current on man.

(C. F. Dalziel, "Deleterious Effects of Electrical Shock," Geneva, 1961)

	Milliamperes					
	Direct Current		Alternating Current			
			60-Cycle		10,000 Cycles	
	Men	Women	Men	Women	Men	Women
Slight sensation on hand	1	0.6	0.4	0.3	7	5
Perception threshold, median	5.2	3.5	1.1	0.7	12	8
Shock - not painful and muscular control not lost	9	6	1.8	1.2	17	11
Painful shock - muscular control lost by 1/2 percent	62	41	9	6	55	37
Painful shock - let-go threshold, median	76	51	16	10.5	75	50
Painful and severe shock-breathing difficult, muscular control lost by 99 1/2 percent	90	60	23	15	94	63
Possible ventricular fibrillation						
Three-second shocks	500	500	100	100		
Short shocks (T in seconds)			$165/\sqrt{T}$	$165/\sqrt{T}$		
High voltage surges	50*	50*	13.6*	13.6*		

*energy in watt-seconds.

Table II. Electromagnetic radiation information on levels.

Visible light - discomfort level	50 percent at 900 foot lamberts 18 percent at 600 foot lamberts 6 percent at 400 foot lamberts
Ultra-violet (below 3100 A)	0.5 $\mu W/cm^2$ for 7-hour exposure 0.1 $\mu W/cm^2$ for continuous exposure
Infra-red	0.1 cal/cm^2 delivered in 0.15 sec gives minimal eye burn. 2 cal/cm^2 will give skin burns. 5 cal/cm^2 will give ignition on most flammable household materials. 0.032 cal/cm^2 sec is solar radiation above atmosphere (estimated).
Radio Frequency*	For normal environmental conditions and for incident electromagnetic energy of frequencies from 10 MHz to 100 GHz, the radiation protection guide is 10 mW/cm^2 (milliwatt per square centimeter) as averaged over any possible 0.1-hour period. This means the following: <u>Power Density</u>: 10 mW/cm^2 for periods of 0.1 hour or more. <u>Energy Density</u>: 1 mWh/cm^2 (milliwatt hour per square centimeter) during any 0.1-hour period. This guide applies whether the radiation is continuous or intermittent.

*USA Standard C95.1-1966.

5. ELECTRICAL SAFETY REVIEW COMMITTEE

November 20, 1978

Chairman	Ed Hartwig	
Deputy Chairman	Don Rondeau	
	Bill Baker	MFE
	Gene Binnall	Earth Sciences
	Charlie Carr	Physics Instrumentation
	Sandy Goss	Advanced Accelerators
	Joe Katz	MMRD
	Jeff Kessel	Energy and Environment
	Bob Lam	88-Inch Cyclotron
	Don Morris	TFTR
	Bob Sorensen	184-Inch Cyclotron/Hilac
	Frank Upham	Donner Lab.
	Ferd Voelker	Bevatron
	Jack Izzo	Environmental Health & Safety Liaison

III.A GENERAL GUIDELINES
FOR EQUIPMENT

III. EXPERIMENTAL EQUIPMENT: DESIGN, FABRICATION, TEST OPERATION, AND EMERGENCY PROCEDURES

A. General Guidelines for Equipment

The following general guidelines apply to all hazardous research experimental equipment covered in Section III. These rules do not cover high-pressure equipment that is a part of permanent plant or buildings, or the ordinary use of natural gas.

1. General

a. Equipment and its installation should be subject to early safety review. Consider possible interactions between different equipment components. Consider also possible interactions between the equipment installation and the surrounding areas--and the converse.

b. Equipment and all associated components and instruments must be designed to operate safely under both normal and emergency conditions. Consideration must be given to the effects of environment, working fluid, vacuum, pressure, temperature, and magnetic fields.

c. When new materials and techniques are used, a continuing review of the related technologies should be made. Such materials and techniques can be used only when sufficient information is available to determine a predictable safety factor or when adequate measures are taken to eliminate any hazard arising from failure of components fabricated from these materials or by these techniques.

d. It is strongly recommended that piping control panels be schematic. The control panel should contain the interconnecting piping, valves, and instruments. The function indicated by each readout must be clearly shown.

e. All equipment and controls must be designed so that the safety of the system is not jeopardized by failure of controls and utilities (electrical power, water, air, etc.).

f. All electrical apparatus must be designed and constructed in compliance with the National Electrical Standards and requirements of the Electrical Engineering Department.

g. For pressure vessels not within the scope of the ASME codes, the design stresses and the test procedure shall comply with the ASME Boiler and Pressure Vessel Code: Section VIII, Pressure Vessels; or Section III, Power Plant Components.

2. Inspection and Reports

a. Design calculations, test reports, material reports, or equipment drawings may be required by the Engineering Safety Committee.

b. Where test, operation, or emergency procedures are required, the operating personnel must be trained in their use. Procedures must be reviewed periodically. Where systems drawings are required they must be available and should be kept up to date. A copy of the current procedures and systems drawings should be available at the installation.

c. Equipment systems and components must be inspected to insure that design specifications are met.

3. Installation

a. A manned control panel or piping manifold required for operating any hazardous equipment must be physically isolated from the equipment as far as practicable.

b. Adequate alarm systems to warn operating personnel of impending hazardous situations must be installed. These systems must be fail-safe and must be checked and tested periodically to insure that they are functioning correctly.

c. Adequate measures to prevent asphyxiation of personnel must be provided in and around all vessels, containers, and other areas where people work under normal and emergency conditions.

d. Personnel must be able to leave the area of an installation rapidly. Uncluttered access from the installation to at least two building exits must be maintained and must be clearly marked.

e. Emergency equipment must be provided and its location must be clearly indicated.

f. Potentially hazardous activities may be carried out only by trained personnel.

g. Storage and use of combustibles must be minimized.

4. Poisonous Nature of Beryllium

Beryllium metal and all its compounds may be poisonous to some persons. Beryllium compounds likely to be used include beryllium copper, beryllium oxide ceramics (beryllia), and fluorescent coatings.

All drawings of parts made of beryllium or beryllium compounds or alloys, including beryllium copper, shall include the note:

> Beryllium alloy (or metal, oxide, etc.) used in this part (or assembly) is poisonous and must be handled with proper precaution.

5. Pressure Definitions

Pressures as used in Section III are defined in Table I.

6. Review

a. General

A mechanical engineer from the Lawrence Berkeley Laboratory shall review the design, fabrication, test, installation, and operation of all high-pressure research equipment piping and pressure-relief devices and all large vacuum vessels.

b. Hazardous Research Equipment

The Mechanical Safety Committee (MSC) shall review the design, fabrication, test, installation, and operation of all research equipment such as:

Section III. B, Flammable-Fluid Cryogenic Targets and Counters

Section III. C, Noncryogenic Pressure Vessels, Counters, and Piping

Section III. D, Pressure Vessels for Nonflammable Fluids

A representative from Environmental Health & Safety shall be invited to any major Committee Review Meeting called by an MSC member. In cases where a change in plant facilities is expected, the MSC member shall also invite a representative from Plant Engineering.

c. Plant Engineering Facilities

All safety matters relating to plant facilities, buildings, outside structures, earthwork or any changes affecting LBL buildings or site, are to be referred to Plant Engineering.

Table 1. Definition of pressure as called for in ASME Boiler and Pressure Vessel Code Section VIII, Pressure Vessels - Division 1 and this report.

3000 psig

MAXIMUM PRESSURE FOR WHICH CODE RULES CONSIDERED ADEQUATE

BURSTING PROOF TEST PRESSURE, UG-101

For most materials: MAWP x 5 x Correction Factors for Variations in Material Properties, for Joint Efficiency, for Casting Quality Factors and for Temperature.

YIELDING PROOF TEST PRESSURE, UG-101

MAWP x 2 x Correction Factors for Variations in Material Properties and for Temperature,

or

MAWP x 2.5 x Correction Factor for Temperature.

STD. HYDROSTATIC TEST, UG-99

MAWP x 1.5 x Correction Factor for Temperature.

PNEUMATIC TEST, UG-100

MAWP x 1.25 x Correction Factor for Temperature.

PRESSURE AT MAX. FLOW THRU PRESSURE

10% of MAWP max. (except 20% for pressure due to fire).

MAXIMUM ALLOWABLE WORKING PRESSURE, UG-98, UA-60(a) (MAWP)

MAWP may be established at higher than original Design Pressure if excess material provided. Usually design pressure = maximum allowable working pressure.

Any desired fraction of MAWP but never higher than MAWP (except devices to protect against fire).

DESIGN PRESSURE, UG-21 & UA-60(b)

The pressure used in the design of a vessel for determining the minimum thickness of physical characteristics of the parts.

PRESSURE SETTING OF PRESSURE RELIEF DEVICE, UG-133

Enough below set pressure to prevent frequent opening or leakage of valves (usually 10% min.) or short fatigue life of rupture discs (usually 33% min.).

OPERATING PRESSURE, UA-60(f)

For targets, counters and pressure vessels: the pressure at which it normally operates. For bubble chambers: The highest instantaneous pressure that can be reached during any normal expansion and recompression of the chamber.

PREVIOUS FOR EXTERNAL PRESSURE SAME AS FOR INTERNAL PRESSURE

III.B FLAMMABLE-FLUID CRYOGENIC TARGETS AND COUNTERS

III. B. Flammable-Fluid Cryogenic Targets and Counters

The liquid hydrogen target operating at 1 atm is the principal research apparatus covered by the rules of this section; however, these rules apply also to other cryogenic flammable-fluid low-pressure containers and storage Dewars.

1. General

a. The low-temperature properties of materials to be used for cryogenic systems should be carefully considered. For example, the effect of differential contraction, embrittlement, phase transition in metal, and fatigue failures on equipment and associated piping during normal emergency conditions must be recognized. Reduce stress concentration and avoid brittle materials.

b. Hoses and seals that can embrittle at cryogenic temperatures shall not be used in pressurized systems.

c. Procedures for pumping and purging must be followed to eliminate impurities and eliminate the possibility of blockage due to freezing of impurities.

d. All valves in contact with cryogenic liquid shall be designed to remain in operation at the expected temperature conditions.

e. Vessels normally at low pressure -- such as vacuum tanks, heat exchangers, or switch housing -- that enclose vessels or piping carrying high-pressure or liquefied gases shall be protected from inadvertent pressure rise.

f. Liquid helium containers shall have two independent and accessible means of venting.

g. An engineering note shall be written and filed with the Mechanical Engineering Department recording the pressure tests. The note shall include the design stresses, material strengths, vessel drawing numbers or description, and the name of the design engineer. The note shall also include the test description, test fluid, pressure, temperature, date, and the name of the engineer certifying the tests. Material tests may be required by the Mechanical Safety Committee.

2. Target Flask

a. Flasks shall be pressure-tested three times to a minimum of twice maximum allowable working pressure, but not less than 40 psi total differential pressure. The first test shall be made at room temperature, the second test at liquid nitrogen temperature or colder, and the third test at room temperature.

There must be no noticable permanent deformation resulting from these tests.

b. The maximum allowable working pressure for new developments in non-metallic flasks can be established as follows:

(i) At least two full-size samples shall be thermally cycled from room temperature to liquid nitrogen temperature or colder and back to room temperature five times. Each time the flask is cold and each time it is warm, it shall be pressure-tested to twice the maximum allowable operating differential pressure but not less than 40 psi differential. Succeeding models of the same materials, design, and construction shall be tested according to the procedure described above in item a.

(ii) At least one of the full-size samples shall be pressurized to destruction at near operating temperature.

(iii) When the data obtained from the rupture test agree with the expected results, the remaining parts may be used.

c. Previously tested reassembled flasks shall be pressure-tested to a minimum of 1.5 times the maximum allowable working pressure at liquid nitrogen temperature or colder.

d. The target flask shall have two independent and accessible means of venting with a relief valve on each vent. The relief devices shall comply with the section (III.C.4) on relief devices. Consideration should be given to making the two fittings such that they cannot be easily interchanged.

3. Vacuum System

a. Vacuum vessels for cryogenic systems containing more than three liquid liters of flammable liquid. Vacuum vessels together with all cover plates, viewing ports and beam windows shall be designed and tested to an internal pressure of 150 psig and shall be designed to withstand a differential external pressure of 30 psig without collapsing. Permanent deformation that is noncontinuous at the maximum pressure is allowed.

Whenever low-temperature fluids can come in contact with the vacuum vessel, normally or accidentally, the vessel shall have a test rating of 150 psig at the fluid temperature.

b. Vacuum vessels for cryogenic systems that are operated by mechanical refrigerators and that contain less than three liquid liters of flammable fluid. Vacuum vessels together with all cover plates, viewing ports and beam windows shall be designed and tested to an internal pressure of 75 psig and shall be designed to withstand a differential external pressure of 22 psi without collapsing. Permanent deformation that is noncontinuous at the maximum pressure is allowed.

Whenever low-temperature fluids can come in contact with the vacuum vessel, normally or accidentally, the vessel shall have a test rating of 75 psig at the fluid temperature.

c. Whenever low-temperature fluids can come in contact with a vacuum vessel optical window normally or accidentally, the window and window gaskets shall be designed and tested for these low-temperature conditions.

d. Beryllium or other brittle materials shall not be used as the material for vacuum system beam windows.

e. Deterioration of beam windows due to radiation or other environmental conditions shall be considered.

f. Insulating vacuum systems for cryogenic fluids shall have a pressure-relief device.

g. Vacuum piping systems shall be designed and pressure tested at 150 psig. Only one sample of each model of vacuum pump need be tested.

h. Vacuum pump systems shall be designed to isolate themselves from the vacuum system, and annunciate an alarm, whenever the pressure rises above 150 microns.

i. A major interlock system that will activate an alarm and remove power from all equipment in the hazardous area shall be provided when the vacuum tank pressure exceeds 1 psig.

j. Glass vacuum ion gages shall not be used.

4. Liquid Nitrogen Vessels

A liquid nitrogen vessel in a cryogenic flammable-fluid system shall be tested at twice the operating internal pressure, or 30 psi differential, whichever is greater. The vessel shall be tested to an external pressure of 1 atmosphere differential.

5. Cryogenic Flammable-Fluid Reservoir

Cryogenic flammable-fluid reservoirs must be tested at 77°K in a vacuum to an internal pressure of 50 psi differential, or twice the operating pressure, whichever is the higher, without permanent deformation. The vessel shall be designed to withstand an external differential pressure of 2 atmospheres. All cryogenic flammable-fluid reservoirs shall have two connecting pipes leading from the liquid compartment to the outside of the vacuum vessel. The pipes shall not join inside the vacuum system.

6. Piping

   a. Piping to be used for flammable fluids shall be pressure tested to 2.0 times the maximum allowable operating pressure or 150 psig, whichever is greater.

   b. Piping to be used for non-flammable fluids shall be tested to 1.5 times the maximum allowable operating pressure or 150 psig, whichever is greater.

   c. Piping shall be of metal suitable for use at cryogenic temperatures.

   d. Acceptable methods of joining piping are welding, silver-brazed socket joints, or approved-type tube fittings.

   e. Soft solder is acceptable only to seal screwed threads.

   f. National pipe thread is not recommended, except for instrument, bottle, or valve connections. Where possible, permanent thread connections should be soft-soldered.

   g. Flexible metal hose reinforced with metal braid may be used for short jumpers when flexibility is required; jumpers should be located so that they are protected from mechanical damage.

   h. Rubber, plastic, or other combustible hose, piping, or tubing shall not be used for flammable gas.

   i. Quick-disconnect fittings shall not be used for flammable gas or on sensitive secondary circuits such as insulating vacuums, critical instruments, or safety devices.

   j. The pressure in any part of a high-pressure system shall be indicated on a pressure gage.

   k. Gages, switches, and other instruments shall be calibrated or tested or both through their full range, which shall be 120 percent or more of the relief-valve setting.

   l. Instruments shall be capable of withstanding the temperature and pressure rating of the system.

   m. Glass vacuum ion gages shall not be used.

7. Relief Devices

a. All systems, system components, and piping subject to accidental overpressures shall be equipped with relief devices. Particular attention should be paid to parts of a system where cryogenic fluids can be isolated or where gases can be liquefied.

b. Insulating vacuum systems for cryogenic fluids shall have relief devices.

c. Shutoff valves shall not be installed in series with a relief device.

d. All valves that could isolate a part of a high-pressure system and thereby create a hazard shall be bypassed with a relief valve.

e. Relief devices shall have sufficient capacity and be set to limit the pressure to 10 percent or less above the maximum allowable working pressure for any emergency condition.

f. All safety valves shall be tested a minimum of three times. Rupture-disk assemblies shall be tested by rupturing three disks selected at random from disks made from the same sheet. Permanent test records shall be kept.

g. Relief devices shall be set, locked, and tagged with the date and set pressure.

h. The operation of primary relief valves shall be assured before each use or setup of the equipment.

i. Relief devices for atmospheric pressure targets shall be set at not more than 10 psig.

j. Relief devices and lines shall be sized to handle emergency flow conditions without excessive over-pressures.

8. Instruments

a. Components or vacuum pressure gages exposed to the vacuum in flammable-gas systems shall not have temperatures exceeding 80 percent of the ignition temperature of the flammable gas unless interlocked to remove power wherever the pressure rises above 10 microns.

b. Electrical liquid-level indicators located in flammable fluids must be intrinsically safe (i.e., the amount of energy that can be released by the indicator must be less than the energy required to ignite the most sensitive mixture).

c. Flow meters having plastic bodies for use with flammable gas shall operate at ambient temperature, at less than 2 atm differential pressure, and at less than 15 scfh. The flow meters shall have a safety factor of not less than 8 to rupture and be tested to 2.5 times the operating pressure. The flow meter shall be protected with a relief valve set at no higher than 1.25 times the operating pressure. The flow meter shall be mounted so that exposure to mechanical damage and strains caused by the connected meter tubing are minimized.

III.C NONCRYOGENIC PRESSURE VESSELS, COUNTERS, AND PIPING

III. C. Noncryogenic Pressure Vessels, Counters, and Piping

The Cerenkov counter is the principal research apparatus covered by the rules of this section. Design stress values for pressure vessels may be found in ASME Pressure Vessel Codes.

Rules for pressurized flammable-fluid counters, pressure vessels, piping and relief valves are described in this section.

1. Noncryogenic Flammable-Fluid Pressure Vessels and Counters

a. If the flammable-fluid counters and pressure vessels are made of known materials, and where engineering information is adequate for proper design:

(i) Areas of the counter or vessel other than the beam-entrance windows, etc., shall be designed according to the ASME Boiler and Pressure Vessel Code, Section III-Nuclear Power Plant Components or Section VIII-Pressure Vessels. When possible, beam-entrance windows, etc., should also be made to adhere to the same design requirements. The counter or vessel shall be pressure-tested to twice the maximum allowable working pressure (MAWP) at room temperature and at the operating temperature.

(ii) Calculated stresses in ductile metal beam windows shall be less than 45% of the yield stress at the maximum allowable working pressure. The windows shall be pressure-tested to twice the MAWP and that pressure held for 6 hours at the operating temperature. The pressure shall then be cycled between 1.8 and 2.0 times the MAWP four times and held at 2.0 for 1 hour. Pressure deformation measurements should be made.

b. If the flammable-fluid counters and pressure vessels are made of unknown new material, or when engineering information is inadequate for proper design:

The maximum allowable working pressure shall be determined from prototype tests. At least two of the parts shall be made. One of the prototype vessels shall be pressure-tested to destruction or tested to at least 10 times the MAWP at the operating temperature. When the data obtained from the rupture test agrees with the expected or acceptable results, the remaining part may be used. The MAWP shall be 1/4 the rupture pressure or less. Pressure-deformation measurements should be made. The part to be used shall be pressure-tested to twice the MAWP and the pressure held for 6 hours at the operating temperature. The pressure shall then be cycled between 1.8 and 2.0 times the MAWP four times and held at 2.0 for 1 hour.

c. General design requirements include the following:

(i) Materials shall be suitable to environment, working fluid, pressure, and temperature. Radiation damage, corrosion, diffusion (H_2), and alloying shall be considered where necessary. Minimize the use of brittle materials.

(ii) Any pressurized system shall have two independent and accessible means of venting.

(iii) Pulsating pressure systems shall be designed to withstand vibration and fatigue.

(iv) Any line or part of a pressurized system that may be isolated by valves shall have a pressure gage indicating the pressure in that part of the system.

(v) Optical windows shall be designed according to the guidelines of Section III.H, Glass Windows.

(vi) An engineering note shall be written and filed with the Mechanical Engineering Department recording the design calculations and pressure tests. The note shall include the design stresses, material strengths, vessel drawing numbers or description, and the name of the design engineer. The note shall also include the test description, test fluid, pressure, temperature, date, and the name of the engineer certifying the tests. Material tests may be requested by the Mechanical Safety Committee.

d. Equipment shall be installed according to the following requirements:

(i) High-pressure counters or vessels assembled and ready for use shall be pressure-tested to 1.5 times the maximum allowable working pressure at the operating temperature before being filled with flammable fluid. A pressure test to at least 1.1 times the MAWP shall be performed prior to filling each time the counter is reassembled with the same previously assembled and tested parts or when the assembly is reactivated after 1 year or more of inactivity. The relief valve shall be set at 1.1 times the MAWP or lower.

(ii) Vessels containing liquefied gases shall be connected to a relief system before being heated.

(iii) High-pressure gas equipment shall be secured against recoil forces in the event of a failure. Lines shall be secured against whipping in the event of a failure.

(iv) The equipment shall be protected from possible damage by external occurrences.

(v) Windows must be protected from accidental mechanical impact.

(vi) Precautions shall be taken to protect personnel against hazards resulting from the rupture of thin or brittle windows in vacuum and pressure vessels.

2. Noncryogenic Nonflammable-Fluid Pressure Vessels and Counters

Noncryogenic nonflammable-fluid pressure vessels and counters shall comply with the rules for noncryogenic flammable-fluid pressure vessels and counters except that the pressure test may be reduced to 1.5 times the maximum allowable working pressure.

3. Pressurized Flammable-Fluid Piping

Flammable-fluid piping as used around pressurized equipment shall comply with the following rules (additional guidelines for piping for flammable-fluid service can be found in the American Standards Association Code for High Pressure Piping, Petroleum Refinery Piping ASA B31.1 and B31.3):

a. Flammable-fluid piping shall be designed for the pressure and temperature at which it is to operate, and shall be tested at 2 times the maximum allowable working pressure or 150 psig, whichever is greater.

b. Stainless steel welded piping is preferred (high melting point).

c. Silver-brazed socket type joints are permitted.

d. Approved tube fittings are acceptable.

e. Soft-solder should not be used for general service. Soft-solder is acceptable to seal screwed threads for instruments. Soft-solder is permitted for noncritical and nonflammable-fluid piping of 1 atmosphere or less.

f. National pipe thread is not recommended, except for instrument, bottle, or valve connections. Where possible, permanent thread connections should be soft-soldered.

g. Flexible metal hose reinforced with metal braid may be used for short jumpers when flexibility is required, and should be located so that it is protected from mechanical damage.

h. Rubber or other combustible hose piping or tubing shall not be used for flammable gas.

i. Quick-disconnect fitting shall not be used for flammable gas or on sensitive secondary circuits such as insulating vacuums, critical instruments, or safety devices.

j. Instruments shall be capable of withstanding the temperature and pressure rating of the system.

k. The pressure in any part of a high-pressure system shall be indicated on a pressure gage.

l. Gages, switches, and other instruments shall be calibrated or tested or both through their full range, which shall be 120 percent or more of the relief-valve setting.

m. Manifolded flammable gas cylinders for use with research apparatus and located in an enclosed area shall have their regulator and/or manifold relief valves relieve into a vent system that discharges the flammable gas outside the building.

n. Manifolded propane gas cylinders shall have check valves installed between the cylinder valve and the manifold to prevent gas flow into a cylinder. The check valve prevents air from entering the cylinder to form a combustible mixture should the manifold be let up to air before closing the cylinder valve when the propane cylinder is below atmospheric pressure.

4. Relief Valves

a. All systems, system components, and piping subject to accidental overpressures shall be equipped with relief devices.

b. Relief devices shall not be set higher than the maximum allowable working pressure.

c. Relief devices shall have sufficient capacity, and be set to limit the pressure to 10 percent or less above the maximum allowable working pressure for any emergency condition.

d. Relief devices and lines shall be sized to handle emergency flow conditions.

e. Relief devices shall be set, locked, and tagged with the date and set pressure.

f. All safety valves shall be tested a minimum of three times. Rupture-disk assemblies shall be tested by rupturing three disks selected at random from disks made from the same sheet. Permanent test records shall be kept.

g. The operation of primary relief valves shall be assured before each use or setup of the equipment.

h. Shutoff valves shall not be installed in series with a relief device. Particular attention should be given to liquid-gas systems.

i. All valves that can isolate a part of a high-pressure system and thereby create a hazard shall be bypassed with a relief valve.

III.D PRESSURE VESSELS FOR NONFLAMMABLE FLUIDS

III. D. Pressure Vessels for Nonflammable Fluids

1. Design

   a. Pressure vessels within the scope of the ASME codes (over 6 in. diam, and 15 to 3000 psi for unfired pressure vessels) shall comply with the requirements of those codes.

   b. Pressure vessels and systems made of commercial pipe or pipe fittings or both shall not be used above their rated ASA working pressure. Such vessels and systems shall comply with all the rules herein. The design stresses and test procedures shall be as specified in the ASME Boiler and Pressure Vessel Code; Section VIII - Pressure Vessels, or Section III - Nuclear Power Plant Components.

   c. Welding should be avoided for longitudinal joints of pipes or shells or pressure vessels under 6 in. in diameter.

   d. Welded vessels should be stress-relieved.

   e. Stress concentrations shall be minimized in pressure vessels for use at temperatures below -20°F.

2. Inspection and Testing

   a. The engineer in charge shall inspect the completed pressure vessel to insure that it is free from manufacturing defects that might affect its performance or intended use.

   b. The vessel shall be pressure tested to 1.5 times the operating pressure. Any special conditions of temperature or temperature cycles to which the vessel is to be subjected in use shall be reproduced as closely as possible while the test pressure is applied. Temperature effects on test fluids shall be allowed for.

   c. Reactivated equipment shall be inspected, evaluated, and tested according to the rules herein.

   d. An engineering note shall be written and filed with the Mechanical Engineering Department recording the test. The note shall include the design stresses, material strengths, and vessel drawing numbers or description, and the name of the design engineer. The note shall also include the test description, test fluid, pressure, temperature, and date, and the name of the engineer certifying the tests.

3. Installation and Operation

   a. Changes made in equipment or its assembly, for use only at pressure below that for which the equipment was originally designed (reduction in the number of bolts in flanged joints, for example), shall be approved by the engineer in charge. All safety requirements for the lower pressure shall be met. When fewer than the originally intended number of bolts or other supports are used, the number required and the reduced working pressure shall be clearly marked on the equipment.

b. If special or high-strength bolts are required, this shall be clearly marked near the holes on the equipment.

c. Instructions stating the precautions to be observed when operating the equipment shall be formulated, and copies sent to all persons concerned. One copy is to be filed in the Mechanical Engineering note file.

d. A list of the persons authorized to operate the equipment, and the name of the engineer in charge, shall be attached to the equipment.

e. All instructions and lists of authorized persons shall be signed by the engineer in charge.

f. Installations of experimental high-pressure gas equipment working at pressures greater than 500 psig shall include a sign, "DANGER, HIGH-PRESSURE EQUIPMENT." All high-pressure experimental equipment shall have the pressure clearly marked.

g. Use of steel barriers and wearing of earplugs may be advisable when working with equipment at very high pressures. (Refer to EN 4610-02 M2).

h. All pressure vessels for experimental apparatus containing high-pressure gas shall be painted yellow.

i. When a system contains a poisonous gas at any pressure, a sign shall state the name of the gas and indicate that it is poisonous, as for example,"DANGER -- HIGH-PRESSURE BORON TRIFLUORIDE GAS--POISONOUS."

4. <u>Relief Devices</u>

a. All systems, system components, and piping subject to accidental overpressures shall be equipped with relief devices. In liquid-gas systems particular attention should be given to those areas where cryogenic fluid can be isolated.

b. Relief devices shall be set higher than the maximum allowable working pressure.

c. Relief devices shall have sufficient capacity and be set to limit the pressure to 10 percent or less above the maximum allowable working pressure for any emergency condition.

d. Relief devices and lines shall be sized to handle emergency flow conditions.

e. All safety valves shall be tested a minimum of three times. Rupture-disk assemblies shall be tested by rupturing three disks selected at random from disks made from the same sheet. Permanent test records shall be kept.

f. Relief devices shall be set, locked, and tagged with the date and set pressure.

g. The operation of primary relief valves shall be assured before each use or setup of the equipment.

h. Shutoff valves shall not be installed in series with a relief device.

i. All valves that could isolate a part of a high-pressure system and thereby create a hazard shall be bypassed with a relief valve.

5. <u>Pressurized Nonflammable-Fluid Piping</u>

a. <u>Pressurized fluid piping</u>

Pressurized fluid piping used to connect pressurized cryogenic or noncryogenic equipment shall comply with the following rules (additional guidelines for pressurized fluid piping can be found in the American Standards Association Code for High Pressure Piping, Petroleum Refinery Piping ASA B31.1 and B31.3):

(i) Piping to be used for nonflammable fluid shall be designed for the pressure and temperature at which it is to operate, and shall be tested at 1.5 times the maximum allowable working pressure or 150 psig, whichever is greater.

(ii) Soft-solder should not be used for general service. Soft-solder is acceptable to seal screwed threads for instruments. Soft-solder is permitted for noncritical and nonflammable-fluid piping operated at 1 atmosphere gage pressure or less.

(iii) The pressure in any part of a high-pressure system shall be indicated on a pressure gage.

(iv) Instruments shall be capable of withstanding the temperature and pressure rating of the system.

(v) Gages, switches, and other instruments shall be calibrated or tested or both through their full range, which shall be 120 percent or more of the relief-valve setting.

III.E BEAM SEPARATORS

III. E. Beam Separators

Beam separators used at the Bevatron generally employ very high voltages across rather small gaps; 400 to 600 kV across a 2- to 4-inch gap are typical values. The electrical hazard associated with such equipment (high-voltage power supply, cables, connectors, and separator) must be considered by all who work with separators. The subject of electrical safety is covered in Section II.L of this manual. Another hazard, that of x-rays, is not quite so obvious, and may be overlooked by the uninitiated or may be forgotten by many unless they are frequently reminded.

Separators can be sources of very high x-ray fields, particularly if they are sparking. Separators are generally shielded with walls of concrete, lead, or other heavy material. The entrance to the separator areas is interlocked with the high voltage power supplies, but it is possible to deliberately or inadvertently "beat the system." Therefore BE AWARE of the possibility of high radiation exposure should you be around an operating separator, and take appropriate precautions. Bill Everette of the Bevatron Radiation Control Group, and the Laboratory Health Physics Group are at your service and will advise you and supply you with proper instrumentation.

III.F HAZARDS ASSOCIATED WITH MAGNETS AND MAGNETIC FIELDS

III. F. Hazards Associated with Magnets and Magnetic Fields

1. The Hazards Associated with Magnetic Fields

a. Equipment to be located in or near magnetic fields must be designed with magnetic field environment in mind. Objects made of magnetic material must be securely and adequately fastened down. Objects made of nonmagnetic but electrically conducting material and located in changing magnetic fields can have large forces exerted on them and should likewise be fastened down.

b. Working in or about magnetic fields may be hazardous if you are handling objects of magnetic material--equipment or tools, for example. Therefore, when you have to work in or near magnets, turn off the magnet power supply and keep the interlock key until you are finished.

c. Respect barricades or caution signs around magnets being tested or operated.

d. Specific rules for operating magnets having large stray fields:

(i) A warning shall be fixed to any magnetic research apparatus that is designed to be moved during the experiment and is located in a magnetic field. The warning shall state, "SECURE AGAINST MAGNETIC FORCE", written in 1/2 inch letters or larger.

(ii) Remove unneeded magnetic materials from the area.

(iii) Install warning signs or lights on magnets having large stray fields.

(iv) A magnet search for loose magnetic material shall be made before turning on the magnet and before increasing the field to a higher level. The search shall be made also at the beginning of each shift during the period of magnet operation.

2. High-Field Pulsed Magnets

The design of high-field pulsed magnets and associated power equipment and the experimental arrangements using such magnets must be reviewed by the Mechanical and Electrical Engineering Departments prior to setup of such equipment.

III.G EVACUATED BEAM PIPES OR LARGE VACUUM VESSELS

III. G. Evacuated Beam Pipes or Large Vacuum Vessels

1. The allowable differential internal pressure shall not exceed 15 psi for vessels not designed according to the ASME Pressure Vessel Code.

2. Vacuum vessels that are subjected to a few pounds internal pressure during testing or purging shall have the design internal pressure marked on the vessel as follows: "Max pressure ______ psig."

3. A relief device shall be provided on vacuum vessels in which there is a possibility of overpressure. The relief device shall comply with Section III.C. 4 on Relief Valves.

4. Deterioration of beam windows due to radiation or other experimental conditions must be considered.

5. Thin metal windows having diameters greater than 6 inches shall be externally pressure-tested to 2 atmospheres differential pressure. Nonmetallic windows that could be damaged by the 2 atm external pressure test can be proven by testing duplicated parts of destruction. The parts must be designed to withstand an external pressure of 2 atm.

6. Protection for thin windows against mechanical damage should be considered, especially when personnel injury can result and also when the vacuum system is directly connected to a bubble chamber, an accelerator, or other critical vacuum systems.

7. Thin windows easily damaged should be protected when not in use by cover plates or be designed to fit into recesses.

III.H GLASS WINDOWS

III. H. Glass Windows

Glass does not have a plastic range, and whenever a strain is imposed on the glass there is a corresponding stress, as determined by Young's modulus. When the glass is strained too far the rupture stress is exceeded and the glass breaks. Glass fails only in tension. Any load, any compressive load that stretches the glass surface causes tension, which can lead to failure. The rupture stress for glass depends upon surface flaws (sometimes upon internal flaws) and many of the following parameters:

- The size, thickness, surface finish, and type of glass.
- The environment, temperature, and pressure.
- The mounting design, gasketing, and assembly procedure.
- The thermal and stress history.

1. Guidelines Listed Below Apply to Glass Windows

a. Minimize the tension stresses.

b. The mounting for the glass should be such that bending moments are not introduced into the glass from the mount whenever the mount or glass is strained.

c. The glass shape should be simple, avoiding sharp corners, point loads, stress concentrations, and sudden changes in section.

d. The materials in contact with the glass should have a low modulus of elasticity relative to the glass.

e. The glass and flanges should be parallel to each other and remain parallel. Bolting loads should not distort the flange or cause bending moments in the glass.

f. Differential expansion between the glass and mounting must be considered.

g. Careful analysis should be made of thermal stresses caused by temperature gradients within the glass during transient temperature conditions.

h. All edges should be radiused or beveled.

i. All nonoptical surfaces should be fine-ground and etched.

j. Fiducials should be etched only on the compression side of the glass. The number of fiducials on the glass should be minimized.

k. The mechanical strength of the glass should be known for the environmental conditions and at the operating temperature. The principal design stress in the glass is usually one-tenth to one-fifth the ultimate strength. The choice depends on how well the stress and properties of the glass are known.

l. The window should be pressure-tested at about one-fifth the ultimate strength. The glass should be pressure-tested to prove the system, but the test pressure should be limited to avoid initiating cracks in the glass. A single test at high pressure proves the basic design, but the uncertainty in the use of large glass windows is in the mounting and thermal stress history. With simple shapes and conservative design the principal stress in the glass is not in doubt. Glass is clear and can be examined for cracks before installation. Each assembly has its own risk, and inspection after assembly is difficult.

III.J SPARK CHAMBERS

III. J. Spark Chambers

The hazard connected with spark chambers is an electrical one. This section is applicable to only the ordinary spark chambers, i.e., those operating at atmospheric pressure and with noble gases. Designs for chambers involving cryogenic fluids or abnormal pressures should be referred to the Engineering Safety Committee for comments. The general electrical safety rules of Section II.L should be followed wherever applicable. Several additional guidelines should be kept in mind.

1. Cables connecting power supplies with capacitors must either be permanently connected at each end or be such that both male and female parts are safe when disconnected.

2. In the design of an experiment using spark chambers some concern must be given to the flow of ground currents. Because of the very large instantaneous currents involved in spark chambers a considerable potential drop may develop between various parts of the apparatus normally considered at ground. This can constitute a hazard both to personnel and to equipment. When spark chambers are used with targets or counters containing flammable fluids, additional rules must be observed.

a. All high voltage electrical cables and other equipment must be securely fastened.

b. When a spark chamber is used very close to a liquid hydrogen target the target frame must not carry any of the ground current to the spark chamber. An electrical shield should be placed between the spark chamber and the target. The shield is grounded to the spark chamber supply but does not carry the spark chamber ground current.

c. Where possible all high-voltage dc power supplies and any large storage capacitors should be placed outside the hazardous area.

d. Spark chamber capacitors and spark gap assemblies that must be in the hazardous area are classified as sparking devices and therefore must be either sealed or purged (see Section II.D.2). When air-purged the suction must be placed low and at a safe distance from any possible sources of flammable gases. (See NFPA No. 496, 1967.)

e. The spark chamber trigger, clearing field, and high voltages must be interlocked with the 1-psi interlock of the hydrogen target.

f. All capacitors used in a spark chamber setup must have bleeder resistors that will provide a discharge path for the capacitors with a time constant no longer than 1 second.

III.K LASERS

III. K. LAWRENCE BERKELEY LABORATORY

LASER SAFETY REGULATIONS

FOR THE SAFE USE OF LASERS

(This section has been taken from publication UCID-3986 by Samuel B. Thomas, Laser Safety Officer.)

INTRODUCTION

These regulations provide reasonable standards for the safe use of lasers that emit electromagnetic radiation with wavelengths between 200 nm and 1 mm. It establishes general and mandatory requirements for the operation of lasers and laser systems in areas controlled by the Lawrence Berkeley Laboratory, and defines control measures applicable to each of four laser classifications. After a laser or laser system is classified by the Laser Safety Officer, this standard can be used to implement control measures without the need of carrying out tedious calculations or measurements in order to determine hazardous conditions. However, technical information on measurements, calculations and biological effects are provided in the ANSI-Z136.1 standard for the safe use of lasers. Specific requirements for all laser classifications are based on the ANSI-Z136.1 standard, the LBL Health and Safety Regulations (LBL-2077), and appropriate sections of the Federal Register, Vol. 40, No. 148. (These documents can be obtained by calling the Laser Safety Officer, Environmental Health and Safety Department, LBL.)

DEFINITIONS

accessible radiation. If it is possible for the human eye or skin to be exposed to laser radiation in normal usage, then it is considered to be accessible.

attenuation. The decrease in the radiant flux as it passes through an absorbing or scattering medium.

beam diameter. The distance between diametrically opposed points in that cross section of a beam where the power per unit area is 1/e times that of the peak power per unit area.

beam divergence, ϕ. The full angle of the beam spread between diametrically opposed 1/e-irradiance points; usually measured in milliradians (one milliradian $\approx$ 3.4 minutes of arc).

continuous wave (cw). The output of a laser which is operated in a continuous rather than pulsed mode. In this standard, a laser operating with a continuous output for a period greater than 0.25 second is regarded as a cw laser.

controlled area. An area where the occupancy and activity of those within the area is subject to control and supervision for the purpose of protection from radiation hazards.

electromagnetic radiation. The flow of energy consisting of orthogonally vibrating electric and magnetic fields lying transverse to the direction of propagation. X-rays, ultraviolet, visible, infrared, and radio waves occupy various portions of the electromagnetic spectrum and differ only in frequency and wavelength.

infrared radiation. Electromagnetic radiation with wavelengths which lie within the range 0.7 μm to 1 mm.

intrabeam viewing. The viewing condition whereby the eye is exposed to all or part of a laser beam.

lambertian surface. An ideal surface whose emitted or reflected radiance is independent of the viewing angle.

laser. A device which produces an intense, coherent, directional beam of light by stimulating electronic or molecular transitions to lower energy levels. Also, an acronym for Light Amplification by Stimulated Emission of Radiation.

laser safety officer. A designated individual who is knowledgeable in the evaluation and control of laser hazards and has authority for supervision of the control of laser hazards.

laser system. An assembly of electrical, mechanical, and optical components which includes a laser.

laser system supervisor. The person having administrative control over a laser or laser system and is so designated in the Operational Safety Procedure for his laser(s) or laser system(s).

MPE. Maximum permissible exposure.

optical density. Logarithm to the base ten of the reciprocal of the transmittance: $OD = -\log_{10} \tau$, where τ is transmittance.

$P_{excempt}$. That output power (Q_{exempt} that output energy per pulse) of a laser such that no applicable MPE for exposure of the eye may be exceeded, with or without optical instruments.

power, Φ. The time rate at which energy is emitted, transferred, or reviewed; usually expressed in watts (or in joules per second).

pulsed laser. A laser which delivers its energy in the form of a single pulse or a train of pulses. In this standard, the duration of a pulse $\leq$0.25 s.

shall. The word "shall" is understood to mean mandatory.

should. The word "should" is understood to mean that which is advisable.

specular reflection. A mirrorlike reflection.

transmittance, τ. The ratio of total transmitted radiant power to total incident radiant power.

ultraviolet radiation. Electromagnetic radiation with wavelengths smaller than those for visible radiation. For the purposes of this standard, 0.2-0.4 μm.

visible radiation (light). Electromagnetic radiation which can be detected by the human eye. It is commonly used to describe wavelengths which lie in the range between 0.4 μm and 0.7 μm.

RESPONSIBILITIES

A. Laser Safety Officer

The Laser Safety Officer is responsible for the control of laser hazards. Such authority is to include the following:

1. Provide consultation on laser hazard evaluation and control and provide appropriate safety training for laser system supervisors. The Laser Safety Officer is available for making calculations or beam power measurements for selecting the proper eye protection, laser classification, and in writing the operational safety procedure.

2. Establish and maintain adequate regulations for the control of laser hazards.

3. To suspend, restrict, or terminate the operation of a laser system, if he deems that laser hazard controls are inadequate.

4. Maintain the necessary records required by applicable governmental regulations.

5. Provide an adequate stock of laser safety eyewear and warning signs for LBL laser users. He must assure that the installation of warning systems and signs are in appropriate locations.

6. Maintain appropriate records showing that scheduled medical examinations have been performed.

7. Survey all areas using laser equipment as frequently as deemed necessary, but not less than annually.

8. When notified, he shall review the planned installation or modification of laser equipment relative to laser hazards and their control, approving of the installation or modification only if he is satisfied that laser hazards controls are adequate.

9. He shall approve a laser system for operation, only if he is satisfied that laser hazard controls are adequate. This approval will be so designated on the last sheet of all completed Operational Safety Procedures.

10. On notification of a real or suspected accident resulting from laser operation, he is to investigate said accident and initiate appropriate action. (As specified in DOE Manual Chapter 0502.)

B. Laser System Supervisor

The Laser System Supervisor is responsible for all safety management within areas over which he has administrative control. His responsibility is to include but is not necessarily limited to the following:

1. The supervisor shall provide appropriate instructions on laser hazards and their control to all personnel scheduled to work with lasers under his supervision. This instruction shall include making personnel familiar with Laboratory safety policy, the relevant sections of appropriate ANSI standards, and the contents of the operational safety procedures for each laser system to be used.

2. He shall prepare an Operational Safety Procedure and shall make it available for review by placing it alongside the laser.

3. Except for class I and class II lasers, he shall submit (as part of the Operational Safety Procedure write-up) the names of persons scheduled to work with lasers to the Laser Safety Officer and the Medical Department for laser eye examination scheduling.

4. He shall not permit the initial operation of a laser system which is under his supervision without prior approval by the Laser Safety Officer.

5. He shall notify the Laser Safety Officer of plans for the modification of a laser system which may result in additional laser hazards. These plans are to be submitted to the Laser Safety Officer for approval.

6. At no time will he permit the operation of a laser unless there is adequate control of hazards to employees, visitors, and the general public.

7. When a supervisor knows of or suspects an accident resulting from a laser operated under his supervision, he shall discontinue the laser operation--making sure that the laser is off, notify immediately the Laser Safety Officer, and he shall assist in obtaining appropriate medical attention for the employee involved. He shall also preserve the scene of the accident.

C. Employees Working With or Near Lasers

1. An employee shall not energize or work with or near a laser unless he has been trained and authorized to do so by the supervisor of the laser.

2. Before any person is authorized to use any laser system, he shall be instructed in and comply with all applicable safety regulations of LBL laser safety standards and the Operational Safety Procedures for that laser system operated.

3. When an employee suspects that a laser accident has occurred, he shall immediately inform the supervisor of the laser, or the Laser Safety Officer if the supervisor is not available.

D. Acquisition and Use of Lasers

From LBL's Administrative Policy and Procedure Memo, March 19, 1975, Vol. 1, No. 9.

"It is the responsibility of the user to notify the LBL Laser Safety Officer whenever the decision is made to fabricate, purchase or otherwise acquire a laser. This will facilitate the proper functioning of the Laboratory's laser safety program and afford the user the opportunity to be informed about the safety considerations appropriate to the laser he is acquiring, prior to its actual use. To help ensure that oversights do not occur, Purchasing has been asked to refer each requisition for a laser to the Laser Safety Officer to initial before an order is placed."

E. Operational Safety Procedures

Each laser or laser system shall have an Operational Safety Procedure (OSP) located near the unit. It shall contain at least:

1. Name of person responsible for the unit (system supervisor).
2. List of authorized users.
3. Emergency or problem call list.
4. Description of safety features (prepared by the Laser System Supervisor).
5. Specific operating procedures (submitted by the Laser System Supervisor for approval by the Laser Safety Officer).
6. Specific alignment procedures as applicable (submitted and approved as 5 above).
7. Emergency instructions.
8. Copy of appropriate standards and policies.

These Operational Safety Procedures will be prepared from the latest OSP preparation guide, filled out initially by the Laser Safety Officer and the Laser System Supervisor, and sent at least annually to the Laser System supervisor for review and, if necessary, revision.

LASER HAZARD CLASSIFICATIONS

1. The laser or laser system's capability of injuring personnel is the basis of the following hazard classification scheme.

- A class I laser (P or Q-exempt) is one considered to be incapable of producing damaging radiation levels and is, therefore, exempt from any control measures. As a matter of good practice, any needless direct exposure of the eye by a class I laser should be avoided.

- A class II laser (low-power visible lasers) emits accessible radiation at levels where damage from chronic exposure is possible. Class II lasers must have a cautionary label affixed to the external surface of the device.

- A class III laser (medium-power laser system) requires control measures to prevent viewing of the direct beam since biological damage to human tissue is possible from acute direct exposure. Class III lasers are subdivided into two classes, class IIIa and class IIIb. (See under "Control Measures" for specifics.)

- A class IV laser (high-power laser system) requires the use of controls which prevent exposure of the eye and skin to the direct and diffusely reflected beams. Whenever possible, the entire beam shall be controlled.

2. The following tables give a summary of laser power/energy levels for continuous wave (Table 1) and for single-pulsed lasers (Table 2) to be used for checking the classification of laser systems with output wavelengths between 200 nm and 1 mm. All laser systems shall be classified in accordance with its accessible radiation. Since the classification is the basis for determining the extent of safety control measures, the final judgment as to the class of a laser is the assignment of the Laser Safety Officer.

Table 1
Summary of Levels of Power Emissions for Continuous-Wave* Laser and Laser System Classification

Wavelength Range (µm)	MPE Limiting Aperture (mm)	Emission Duration (s)	Class I†	Class II	Class III	Class IV
Ultraviolet 0.2-0.4	1	3×10^4	$\leq 0.8 \times 10^{-9}$W to $\leq 8 \times 10^{-6}$W depending on wavelength	--	>Class I but $\leq$0.5 W depending on wavelength	>0.5 W
Visible 0.4-0.55	7	3×10^4	$\leq 0.4 \times 10^{-6}$W	>Class I but $\leq 1 \times 10^{-3}$W	>Class II but $\leq$0.5 W	>0.5 W
Visible and Near-Infrared 0.55-1.06	7	3×10^4	$\leq 0.4 \times 10^{-6}$W to $\leq 200 \times 10^{-6}$W depending on wavelength	--	>Class I but $\leq$0.5 W depending on wavelength	>0.5 W
Near-Infrared 1.06-1.4	7	3×10^4	$\leq 200 \times 10^{-6}$W	--	>Class I but $\leq$0.5 W	>0.5 W
Far-Infrared 1.4-10^2	1	>10	$\leq 0.8 \times 10^{-3}$W	--	>Class I but $\leq$0.5 W	>0.5 W
Submillimeter 10^2-10^3	11	>10	$\leq$0.1W	--	>Class I but $\leq$0.5 W	>0.5 W

*Emission duration $\geq$0.25 second.
†When the design of the laser or laser system assures personnel exposures of less than 10^4 seconds in any 24-hour period, the limiting exposure duration may establish a higher exempt power level (P_{exempt}).

Table 2
Summary of Levels (Energy and Radiant Exposure Emissions)
for Single-Pulsed Laser and Laser System Classification*

Wavelength Range (µm)	MPE Limiting Aperture (mm)	Emission Duration (s)	Class I	Class III	Class IV
Ultraviolet† 0.2-0.4	1	$>10^2$	$\leq 24 \times 10^{-6}$ J to 7.9×10^{-3}J	$>$Class I but ≤ 10 J·cm^{-2}	>10 J·cm^{-2}
Visible 0.4-0.7	7	10^{-9} to 0.25	$\leq 0.2 \times 10^{-6}$J	$>$Class I but $\leq 31 \times 10^{-3}$J·cm^{-2}	$>31 \times 10^{-3}$J·cm^{-2}
			$\leq 0.25 \times 10^{-3}$J	$>$Class I but ≤ 10 J·cm^{-2}	>10 J·cm^{-2}
Near-Infrared†† 0.7-1.06	7	10^{-9} to 0.25	$\leq 0.2 \times 10^{-6}$ to 2×10^{-6}J	$>$Class I but $\leq 31 \times 10^{-3}$J·cm^{-2}	$>31 \times 10^{-3}$J·cm^{-2}
			$\leq 0.25 \times 10^{-3}$ to 1.25×10^{-3}J	$>$Class I but ≤ 10 J·cm^{-2}	>10 J·cm^{-2}
1.06-1.4	7	10^{-9} to 0.25	$\leq 2 \times 10^{-6}$J	$>$Class I but $\leq 31 \times 10^{-3}$J·cm^{-2}	$>31 \times 10^{-3}$J·cm^{-2}
			$\leq 1.25 \times 10^{-3}$J	$>$Class I but ≤ 10 J·cm^{-2}	>10 J·cm^{-2}
Far-Infrared 1.4-10^2	1	10^{-9} to 0.25	$\leq 80 \times 10^{-6}$J	$>$Class I but ≤ 10 J·cm^{-2}	>10 J·cm^{-2}
			$\leq 3.2 \times 10^{-3}$J	$>$Class I but ≤ 10 J·cm^{-2}	>10 J·cm^{-2}
Submillimeter 10^2-10^3	11	10^{-9} to 0.25	$\leq 10 \times 10^{-3}$J	$>$Class I but ≤ 10 J·cm^{-2}	>10 J·cm^{-2}
			≤ 0.4J	$>$Class I but ≤ 10 J.cm^{-2}	>10 J·cm^{-2}

*There are no Class II single-pulsed lasers.
†Wavelength dependent.
††Diffuse reflection criteria apply from 10^{-9} to 33×10^{-3}s for Class III. For $>33 \times 10^{-3}$s exposure, the maximum radiant exposure is 10 J·cm^{-2}. Class I and III values are wavelength dependent.

CONTROL MEASURES

Application of control measures shall commence after the Laser Safety Officer has classified the laser. Control measures are broken into four types. These include:

1. Physical (enclosures, interlocks, beamstops, etc.)
2. Personnel protection (goggles, clothing, etc.)
3. Warning devices (signs, lights, labels, etc.)
4. Procedures

Maximum emphasis should be placed on physical control measures.

Class I (exempt lasers)

There are no control measures or warning labels required for Class I lasers, but needless exposure of the eye should be avoided as a matter of good practice.

Class II (low-power visible lasers)

An appropriate "Caution" label shall be affixed to a conspicuous place on the laser housing and an appropriate "Caution" sign should also be affixed at the entrance of the laser area. (See Fig. 1.) The caution sign should include the precautionary statement "DO NOT STARE INTO BEAM."

Class III (medium-power lasers)

Class III lasers are divided into two groups, class IIIa and class IIIb. Class IIIa lasers are visible (0.4-0.7 μm) cw lasers whose output power is in the range of 1 to 5 mW and whose beam irradiance is < 2.5 mW/cm^2. Class IIIa laser signs and labels shall have the signal word "CAUTION" and shall contain the following precautionary words: "DO NOT VIEW LASER BEAM WITH OPTICAL INSTRUMENTS." All other provisions listed under class III lasers are considered advisory rather than mandatory for the Class IIIa lasers. Class IIIb lasers require the following mandatory control measures.

a. Training: All persons using a class III laser shall be duly informed about the potential hazards of laser operations.

b. Engineering controls: Priority shall be given to the incorporation of appropriate safety mechanisms (i.e., shutters, interlocks, enclosures, beam stops, beam enlarging systems, etc.) as an integral part of the laser system.

c. <u>Laser controlled area</u>: Only authorized personnel shall operate laser systems. Spectators shall not be permitted into the laser controlled area unless appropriate supervisory approval has been obtained and protective measures taken. If the laser beam is not enclosed, special emphasis shall be placed on control of the path of the laser beam.

d. <u>Alignment procedures</u>: Alignment of a class III laser beam shall be performed in such a manner that the primary beam or a specular reflection of a primary beam does not expose the eye to a radiation level above the MPE.

e. <u>Optical viewing aids</u>: Special care shall be taken using optical systems such as lenses, telescopes and microscopes. Filters or interlocks shall be provided when using telescopes or microscopes to prevent ocular exposure above the MPE.

f. <u>Equipment labeling</u>: Class III lasers shall have warning labels with the appropriate cautionary statement affixed to a conspicuous place on the laser housing.

g. <u>Key-switch master interlock</u>: Class III lasers shall be provided with an operative keyed master interlock or switching device. The key shall be removable and the laser shall not be operable when the key is removed.

h. <u>Eye protection</u>: Eye-protection devices which are specifically designed for protection against radiation from the class III laser should be used when engineering and procedural controls are inadequate.

<u>Class IV (high-power lasers)</u>

High-power lasers require more rigid control measures not only because of the obvious risk of injury from the direct beam or specular reflections, but because there is a greater risk of injury from hazardous diffuse reflections. The entire beam path capable of producing hazardous diffuse reflections shall be controlled. Controls shall rely primarily on more positive engineering safeguards, and secondarily on procedural safety.

In addition to the control measures outlined under class III lasers of this standard, the following class IV control measures shall be applied.

a. <u>Laser controlled area</u>. Class IV laser devices shall be isolated in an area solely designed for laser operation and access to such an area shall require appropriate authorization.

b. <u>Interlocks</u>: Safety latches or interlocks shall be used to prevent unexpected entry into laser controlled areas. The design of interlocks shall be such as to allow both rapid egress by the laser personnel and admittance under emergency conditions. A control-disconnect switch ("panic button") shall be available for deactivating the laser. The person in charge of the laser controlled area shall be permitted to momentarily override the safety interlocks when continuous operation is necessary, but specification for the momentary override shall have the approval of the Laser Safety Officer. Interlocks shall not allow automatic reenergizing of the power supply, but shall be designed so that the power supply or shutter must be reset manually.

ENCLOSED LASERS

The protective housing on any class II, class III or class IV laser system shall limit the maximum accessible laser radiation to that level which defines the classification desired. The control measures appropriate to the classification shall apply when the laser is in normal operation.

Each enclosed laser system shall be provided with a minimum of two operative safety interlocks (one must be concealed) for any portion of the protective housing, which, by design, can be removed or displaced during normal operation. Failure of any single mechanical or electrical component in the redundant interlock system shall not prevent the total interlock system from functioning.

Viewing windows incorporated into an enclosed laser shall be of a suitable filter material which attenuates the laser radiation to levels below MPE.

SPECIAL CONTROL MEASURES FOR INVISIBLE RADIATION

Since infrared and ultraviolet radiation is invisible, particular care shall be taken when using these laser systems. Thus, in addition to the control measures which apply to the laser hazard classification, the following controls shall also apply.

a. <u>Infrared lasers</u>: The beam from a class III infrared laser should be terminated by a highly absorbant backstop. Class IV laser beams should be terminated by a fire resistant material. (Note: Many surfaces which appear "dull" can act visually as reflectors of infrared radiation.)

b. <u>Ultraviolet lasers</u>: Exposure to ultraviolet radiation shall be minimized by using shield material which attenuates the radiation to levels below MPE for the specific U.V. wavelength. Special attention shall be given to the possibility of producing hazardous byproducts, such as ozone, and the formation of skin sensitizing agents.

c. When invisible radiation is accessible from a class III or class IV laser system, a warning sign and light should be displayed in a conspicuous location, warning those in the area when the laser is being operated.

LASER PROTECTIVE EYEWARE

All laser protective eyeware shall be clearly labeled with the optical density values and wavelengths which the particular eyewear affords. Adequate optical density at the laser wavelength of interest shall be weighted with the need for adequate visible transmission. Periodic inspection shall be made of protective eyewear to ensure that pitting, cracking, etc. will not endanger the wearer. The frame of the protective eyewear should also be inspected for mechanical integrity and light leaks.

WARNING SIGNS

All signs and labels shall be conspicuously displayed in locations which serve to warn onlookers.

Figures 1 and 2 show samples of class II and class IIa (Caution) signs, and class III and class IV (Danger) signs. Appropriate space above the tail on the sunburst shall allow the inclusion of the type of laser. Space below the tail on the sunburst shall be used for the inclusion of special precautionary instructions.

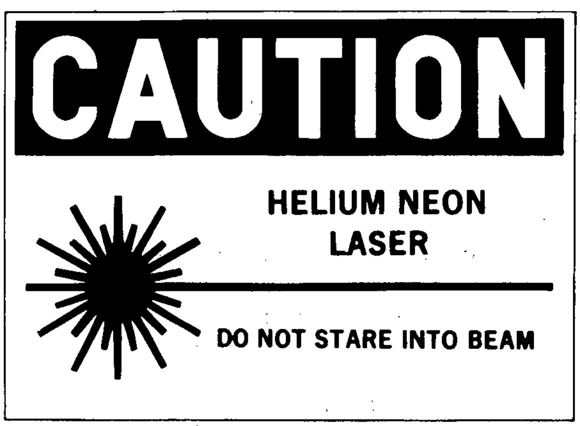


Fig. 1

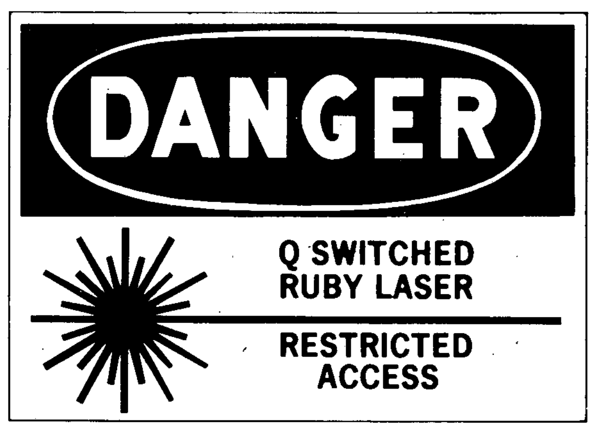


Fig. 2

MEDICAL SURVEILLANCE

All users of class III and class IV lasers shall have special eye examinations prior to participating in laser work, each year, when discharged from the laser work, and immediately after suspected laser eye exposure.

Names of employees needing special laser eye examinations are submitted to the Medical Services Department by memorandum from the Laser Safety Officer.

Upon request of the Laser Safety Officer, Medical Services schedules each laser user for an examination by a board-certified opthalmologist. The users are rescheduled for eye examinations at yearly intervals and again upon terminating use. The opthalmologist's reports are filed in the individual employee's medical records. The Laser Safety Officer is notified by memorandum that the examination has been completed. If contraindication to use of lasers is found, the Laser Safety Officer will be notified immediately by telephone, followed by a memorandum.

ASSOCIATED LASER HAZARDS

A. Industrial hygiene and associated laser hazards shall be evaluated and appropriate control measures shall be taken. Each building at LBL has a safety coordinator whose job is to evaluate industrial hygiene problems such as: compressed gas, cryogenic material, toxic material, and ionizing radiation, etc. To find out the name and location of your safety coordinator, contact the Department of Environmental Health and Safety.

B. Electrical Hazards

1. Various surveys of accidents associated with lasers have revealed that electrical accidents occurred more frequently than eye or skin injuries from laser radiation. Therefore, all electrical equipment shall be installed as outlined in LBL Safety Requirements for Constructing Electrical Equipment and Working on Energized Electrical Equipment (UCID-3937). Special consideration shall be given to grounding all accessible, non-current carrying metallic parts of laser equipment.

2. Electrical fire hazards shall be evaluated and power supply circuit wiring shall be completely enclosed in non-combustible material.

III.L SUPERCONDUCTING MAGNETS

III. L. Superconducting Magnets

Superconducting materials being used in the fabrication of magnets at present are known to become superconducting only in the temperature range below 18°K. In most cases, the appropriate coolant in this temperature range is helium, although a flammable refrigerant such as hydrogen may be used in the cool-down process.

One characteristic of the superconducting materials being used in magnet technology is the rapidity of the transition from the superconducting to the normal or resistive state when certain thermal or electromagnetic instabilities occur. Excessive values of the electric current, the magnetic field intensity, or the temperature at the superconductor may also cause a transition from the superconducting to the normal state. A normal or resistive region, once initiated, may propagate quickly throughout the magnet. In the design of a superconducting magnet system, there should be recognition of the hazards that may arise from release of the magnetic field energy if the superconductor goes into the normal state. These hazards and the measures used to guard against them are directly related to the amount of energy stored in the magnetic field, and hence depend on the size of the magnet and the intensity of the field.

The development of various configurations of superconducting conductor has made feasible the construction of magnets capable of generating high magnetic field intensities over large volumes.

These technological advances carry with them additional problems resulting from the interaction of the magnetic field with associated and nearby equipment, instrumentation, and structures. There should be concern also for possible effects of the magnetic fields and magnetic field gradients on personnel, since this is an area where both information and experience are limited.

Some Guidelines for Superconducting Magnets

a. Provide adequate means of protecting the system from the release of magnet energy in the event the coil goes normal. Consideration should be given to the possibility of induced high voltage and gas overpressures resulting from the dissipation of some magnetic field energy in the magnet and its cryostat. Large amounts of stored energy should be dissipated in external circuits.

b. All components of the system, including the magnet conductor, should be designed to withstand the thermal and electromagnetic forces that occur under abnormal as well as normal conditions.

III.M ORDERING AND HANDLING OF DEPLETED URANIUM

III. M. Ordering and Handling of Depleted Uranium

The use of uranium, including procuring, assembly, transportation, and processing (machining), must be accompanied by pre-notification to the Environmental Health & Safety Department. The EH&S Roving Monitor has the assignment of evaluating the operation and providing necessary technical services.

All uranium stock is stored by the Environmental Health & Safety Department except for small quantities in use for accelerator targets or high density shielding.

All machining and cutting operations performed on uranium at LBL shall be done at the Main Machine Shop, Building 77.

For monitor, service, or for movement of uranium within the Laboratory, phone extension 5251, EH&S.

References: Operational Safety Procedures - Procedure 321
October 2, 1972, Lawrence Livermore Laboratory
Phone: 8-8347

Materials Management, Vol. 1, Section 1.11
February 15, 1968, Lawrence Livermore Laboratory
Phone: 8-8531

III.N MULTIWIRE PROPORTIONAL COUNTERS CONTAINING FLAMMABLE GAS

III. N. Multiwire Proportional Counters Containing Flammable Gas

1. Introduction

These rules apply to proportional counters operating with flammable gas mixtures such as "Magic Mix II" currently used at LBL. This particular mixture is denser than air and is composed of:

Isobutane	23.52 percent
Methylal (dimethoxy-methane)	4.00 percent nominal
Freon 13-B1	0.48 percent
Argon	72.00 percent

The gas is purchased premixed in cylinders pressurized to nominally 35 psig. The liquid capacity of the Matheson 1F (Fat Boy) cylinder is 3.87 ft^3, its pressure rating is 300 psig, and at 35 psig it holds 13.2 ft^3 STP of gas of which 9.3 ft^3 STP, the amount normally stored above atmospheric pressure, is used. The flammable gas content in the cylinder is 3.63 ft^3 STP total of which 2.56 ft^3 STP is used unless the remainder is removed by evacuation.

The magic gas cylinders do not contain a large quantity of thermal or PV energy since the cylinder pressure must be low (nominally 35 psig) to prevent the gas from liquefying. If the valve on the cylinder breaks off, there is little danger that the cylinder will jet out as a rocket, as is the case with cylinders having gas pressures in the range of 2000 psig.

The internal energy content of a 1F-size magic gas cylinder charged to 35 psig with 28 percent isobutane (methylal is assumed to have the same specific heat energy as isobutane) and the remainder inert gas is 13 megajoules internal energy and 0.04 megajoule PV energy. The enthalpy of a hydrogen cylinder is about 0.6 megajoule as PV energy and 79.0 megajoules internal energy. The energy equivalent of 20 magic gas bottles is equivalent to about 3 high pressure hydrogen gas cylinders or about one tenth of a 1F butane cylinder.

The flammable limits of pure isobutane in air are 1.8 to 8.4 percent by volume. The addition of the other gases listed above will reduce the flammable limits to about 1.8 to 7 percent in air (Engineering Note M4579A, "Multiwire Proportional Counter Chambers Estimated Combustible Limits of Magic Mix," Paul Hernandez, 23 Jan 73. Engineering Note M4931B, "Estimated Combustible Limits of Methane Gas Mixtures, Gerd Behrsing, 11 Mar 76.). The flammability of the gas has been demonstrated. The gas was burned at the end of a 1/4-inch i.d. tube at a line pressure of about 5 inches of water and gave a flame about 14 inches long. Methylal $CH_2(OCH_3)_2$ is a colorless liquid having an ambient temperature density of 0.866 gm/cc and a boiling point of 42°C at 1 atm. (Chemical Engineering Handbook by Perry, McGraw-Hill, 2nd Ed., pp. 143, 216, 226.)

2. <u>Rules for Operation with Flammable Fluid</u>

a. LBL Rules for High Pressure Cylinders, Engineering Note M3954, page 29, Section 2, shall apply.

b. At the time of the safety review, an understanding and agreement shall be reached as to how the magic gas cylinders will be stored and how the deliveries will be made at the accelerator or experimental area.

c. Magic gas cylinders shall be color-coded light blue and may be stored with other flammable gas but not with oxygen.

b. Not more than two flammable magic gas 1F cylinders shall be stored in any enclosed experimental area. Not more than twenty filled flammable magic gas cylinders shall be stored at any accelerator or research site. Magic gas in excess of twenty cylinders shall be stored by the LBL Supply Services Department.

e. The supply cylinders for the Magic Mix shall not contain more than 5 SCF of flammable gas. Only one such cylinder at a time may be opened to the system. One additional cylinder may be on manifold standby.

f. If the first stage pressure gage of the cylinder regulator is changed to a lower rating, a relief valve shall be installed between the cylinder and the cylinder regulator and shall be set no higher than the maximum reading on the pressure gage. The relief valve capacity shall be greater than the cylinder valve capacity.

g. Any modified regulator mounted on the Magic Mix gas cylinder shall be marked on the dial under the glass or on a metal tag attached securely to the regulator with the following statement: "REGULATOR MODIFIED FOR USE WITH MAGIC MIX. DO NOT USE ON OTHER CYLINDERS."

h. To ensure that a gas regulator is correctly specified for your particular application and is in safe working condition, it should be checked by the Regulator Shop in Building 76, extension 5481.

i. Regulators should be mounted in a manner that will protect them from damage.

j. The output pressure of the last stage of regulation shall not exceed 5 inches of water.

k. Piping or tubing containing flammable gas shall be metal up to the flow control point to reduce the probability of accidental damage, unless this piping and the gas supply cylinder are in a protected area and within a few feet of each other.

l. Plastic tubing may be used beyond the flow control point and shall be arranged to minimize the amount of combustible plastic tubing. The plastic tubing shall be securely fastened at each end.

m. The exhaust gas flow shall be monitored with a bubbler to indicate an open line or a leaking counter. The bubbler is a flow indicator but also functions as a relief valve for the counter.

III.0 ROLL-OVER PROTECTION

III. O. Roll-over Protective Structure (ROPS)

Requirement for LBL Vehicles

These standards shall be applied to the design and acceptance of ROPS Systems. However, because destructive testing and extensive analytical computer modeling are not practical for the relatively few and varied Lab vehicles involved, the final criterion for acceptance of designs and installations must be the judgment of the Mechanical Safety Committee. Structural calculations and other evidence may be required to assist in this process. The final design and installation must be reviewed and approved by the Department of Environmental Health & Safety.

Part I. Criteria for ROPS Requirement

1. Any vehicle not equipped with an integral cab or ROPS as original equipment must be provided with a ROPS meeting the criteria set forth in Part II.

2. Any vehicle with a cab or ROPS which is not believed to be adequate for its service application by the Safety Committee must be provided with a cab/ROPS System that will meet the criteria set forth in Part II and/or such criteria deemed necessary for that vehicle by the Safety Committee.

Part II. Criteria for Design and Acceptance of ROPS Systems (as installed condition)

1. Static design loads: (see Figure 1)

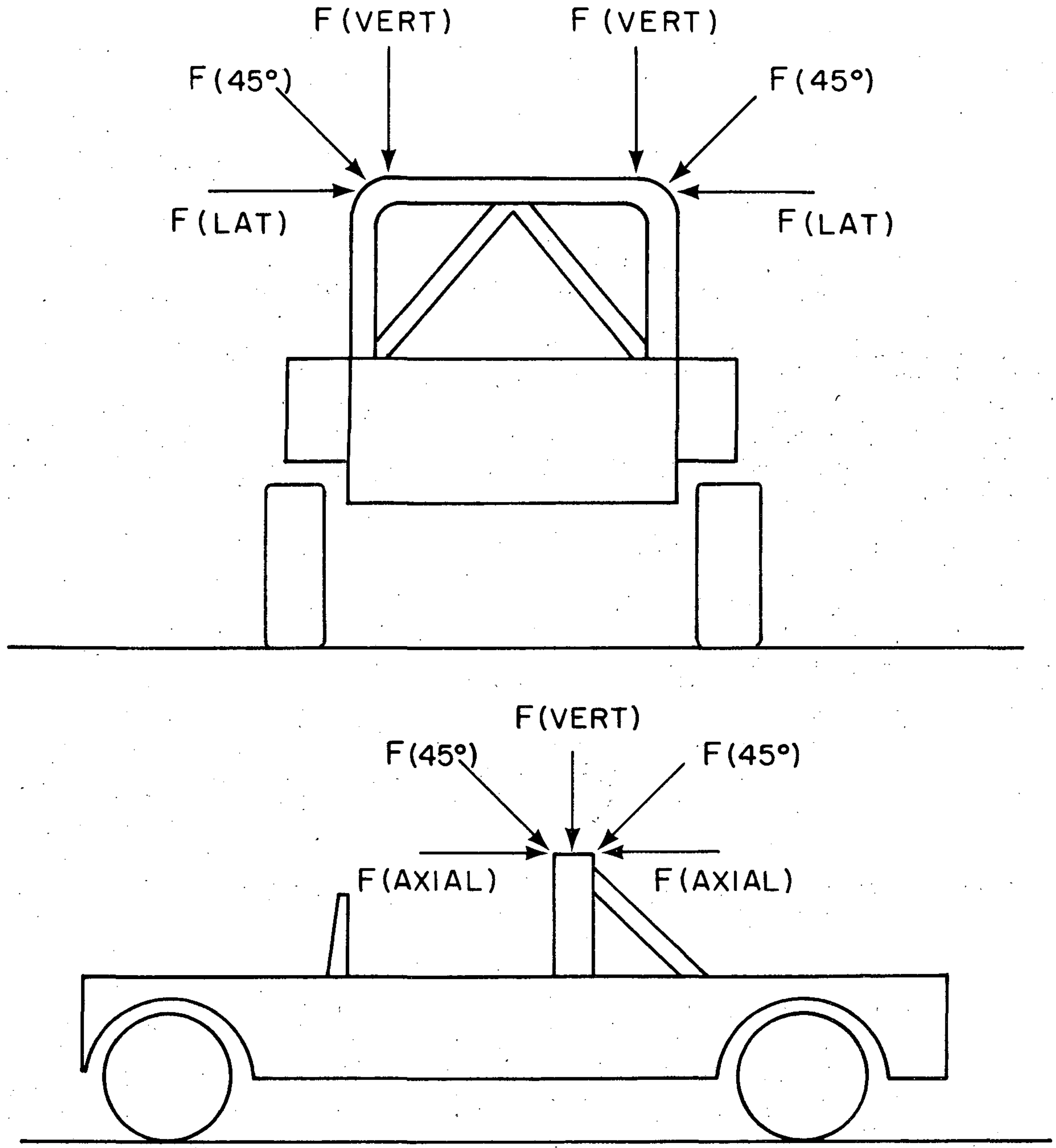
   a. Vertical: F = 2 (GVW, Gross Vehicle Weight) applied uniformly along each edge over occupant space.

   b. 45^o to vertical - axial and lateral; F = 2 (GVW) applied uniformly along each edge over occupant space.

   c. Horizontal - axial; F = 2 (GVW). Applied uniformly at the forward-most and rear-most edges of ROPS over occupant space.

   d. Horizontal - lateral; F = 1.5 (GVW) applied uniformly along the lateral edge near occupant space.

   The design should be such that the sequential application of these loads will not cause local yielding or damage to any portion of the ROPS System (i.e., ROPS, mounting and vehicle). Accordingly, only elastic design methods and assumptions should be necessary for the analysis of stress and deflection due to these loads. However, should plastic deformation occur due to the above loads, it must not be so extensive as to constitute premature failure of the ROPS System.



LOAD APPLICATION - GENERAL

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Fig. 1.

2. Deflection and energy absorption:

   a. Deflection due to the above static loads shall not cause intrusion into the occupant space by any portion of the ROPS System or vehicle body.

   b. The ROPS geometry should be resistant to premature collapse as plastic deformation begins. Accordingly, the design should be such that progressively increasing loads are required to induce relatively large energy absorbing plastic deformations before ultimate collapse occurs. Plastic design methods and assumptions at load and stress levels greater than the static loading outline in Part II, 1.a through d, are appropriate for analysis in the plastic range.

   c. ROPS mounting to the vehicle shall be capable of transmitting loads equal to or greater than those experienced by the ROPS without contributing deformation to an extent that constitutes failure of the ROPS System prematurely.

   d. 3/4" thick minimum energy absorbing (high density/closed cell) padding such as Dow Etha-foam must be provided over any part of a ROPS that might contact an occupant's head.

   e. Lap belts shall be provided on all Lab vehicles. Shoulder belts should be provided unless clearly counterproductive in a particular vehicle. Good practice and good sense should be exercised in mounting safety belts. Applicable S.A.E. and D.O.T recommendations must be observed when installing seat belts.

   f. Sharp corners and other hazards are to be avoided in the vicinity of the occupants. Padded head restraint may be required if occupant's head is in proximity of hazardous objects.

3. Materials:

   a. Main structural members shall be of a material and section size meeting the following requirements:

      i. Yield strength (σ_y) $\geq$ 30,000 psi.

      ii. Ultimate strength (σ_u) $\geq$ 45,000 psi.

      iii. Elongation (ε) $\geq$ 0.10 in/in (in 2 inches).

iv. $$\frac{\sigma_y + \sigma_u}{2} A \varepsilon \geq 8{,}000 \frac{\text{in.-lb}}{\text{in.}}$$

(A = cross sectional area of member)

v. The material shall be covered by a suitable ASTM spec insuring uniformity of composition, strength, dimensions and quality.

iv. The materials used shall have suitable impact properties. Low temperature service requires special consideration. See SAE J1119 on this subject.

b. Mounting plates shall be 3/16-inch thick minimum.

c. Mounting bolts shall be 3/8-inch diameter SAE Grade 5 minimum.

4. Fabrication and installation:

a. The design and execution of all structural welds shall comply with the standards and requirements of the American Welding Society (AWS) Structural Welding Code.

b. Welded joint strength should be designed to equal or exceed that of the joined members.

c. Welds to be made on vehicle shall be located for accessibility.

d. Tubing bends should be mandrel-formed with maximum practical radius over 6-inch minimum.

e. Avoid welding to any member subject to fatigue loading. Bolted connections should be used in such cases. Connections to the frame may require special treatment if fatigue is possible.

References:

Code of Federal Regulations, Title 49. Transportation, Chapter V. National Highway Traffic Safety Administration, Department of Transportation.

CAL-OSHA, Title 8. Division of Industrial Safety, Construction Safety Orders. Part 1596. Roll-Over Protective Structures (ROPS).

Society of Automotive Engineers Recommended Practice, J1040a, J1042, J394a, J397a, J833a, J857a, J996, J374a, J208b, J885a, J140a, J141, J117, J383, J384, J385, J114, J128, J1119 SAE Handbook.

Sports Car Club of America 1977 Rules Book.

Roll-Over Protective Structures for Farm and Construction Tractors - a 50 Year Review. James F. Arndt Deer and Co. SAE Paper No. 710508, April, 1971.

The Design and Evaluation of a Protective Canopy for Agricultural Tractors. D. H. Bucher. Society of Agricultural Engineers Paper No. 66-625. December, 1966.

Analytical Prediction of ROPS Static Elastic-Plastic Behavior by Rollen G. Easter, Journal of Experimental Mechanics, February, 1977.

Blodgett, O. W., Design of Welded Structures, the James F. Lincoln Arc Welding Foundation, Cleveland, Ohio. May, 1972.

American Welding Society Structural Welding Code.

III.P PRESSURE-VESSEL AND SYSTEM DESIGN

III.P. PRESSURE-VESSEL AND SYSTEM DESIGN

DEFINITIONS

Low Pressure	Gas or Liquid pressure less than 1 MPa gauge (150 psig).
Intermediate Pressure	Gas pressure from 1 to 20 MPa gauge (150 to 3000 psig) and liquid pressure from 1 to 35 MPa gauge (150 to 5000 psig).
High Pressure	Gas pressure greater than 20 MPa gauge (3000 psig) and liquid pressure greater than 35 MPa gauge (5000 psig).
Low-Hazard Pressure Equipment	Pressure equipment for use where the hazard is low enough that approval of design criteria and operational controls by a Department Head or equivalent level of Laboratory management is not required. See paragraph 1.1.1 of this Section for pressure/energy limits.
High-Hazard Pressure Equipment	Pressure equipment for use where the hazard is high enough to require approval of design criteria and operational controls by a Department Head of equivalent level of Laboratory management. See paragraph 1.1.2 of this Section for pressure/energy limits.
Maximum Allowable Working Pressure (MAWP)	The maximum differential pressure at which a vessel is designed to operate safely. It is the basis for the pressure setting of the pressure-relieving devices protecting the vessel and/or system.
Operating Pressure (OP)	The pressure at which a vessel is normally operated. OP shall never exceed the MAWP of the vessel and is normally kept sufficiently below the settings of relief devices to prevent their frequent opening.
Pressure Test	Testing pressure vessels in accordance with this Manual, LBL Pub. 3001, to assure that vessels will not fail or permanently deform, or that pressure systems will operate reliably at the test pressure.
Proof Test	Pressurizing prototypes of a pressure component or vessel to determine the actual yield or

burst pressure. This pressure is then used to calculate the MAWP of the vessel or component. See the ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, paragraph UC-101, for acceptable proof test procedures.

Safety Factor — The ratio of the calculated failure-pressure (or actual failure-pressure when known) to the MAWP. A safety factor relative to other than failure pressure should be identified with an appropriate subscript, i.e., SF_y for safety factor based on the yield strength of the material and SF_u for safety factor based on ultimate strength.

Leak Test or Leak Check — A pressure or vacuum test to determine the existence, rate, and/or location of a leak.

Pressure Vessel — A relatively high-volume pressure component (such as a spherical or cylindrical container that has a cross section larger than the associated pipe or tubing, or a coil (three or more full turns) of pipe or tubing.

Any operating pressure above or below atmospheric pressure qualifies the vessel as a pressure vessel. A vacuum vessel is a special case of pressure (external) vessel.

Ductile Vessel — A pressure vessel fabricated from materials that yield extensively before failure when overstressed at any temperature within the specified working temperature range of the vessel. Materials that exhibit greater than 5% plastic strain to rupture are generally considered ductile. Some of these materials are listed in the ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, Subsection C.

Brittle Vessel — A pressure vessel fabricated from materials that do not yield extensively before failure, when overstressed at any temperature within the specified working-temperature range of the vessel. Materials that exhibit less than 5% plastic strain to rupture are generally considered brittle.

Pressure System	Any mechanical system, containing vessels, manifolds, or piping, which operates above or below atmospheric pressure. A vacuum system is an external pressure system.
Manned-Area Vessel	A pressure vessel or pressure system that has been approved for operation (within specified limits) with personnel present.
Remote-Area Vessel	A pressure vessel or pressure system that contains a high risk of personal injury. Remote-area vessels must be installed in test cells or behind certified barricades (concrete blocks, steel plates, etc.), or be operated from a safe location.
Inert Fluid	A liquid or gas which is nonflammable, nontoxic, and has a low-chemical-reaction-hazard potential.
Reactive Fluid	A liquid or gas which is flammable, toxic, radioactive, or a strong oxidizer and has a radiation- or high-chemical-reaction-hazard potential.
SI (Metric) Pressure Units	Pa, Pascal, the basic SI pressure unit, equal to 0.000145 psi. Kpa, Kilopascal, 1000 Pa, equal to 0.145 psi. Notice that 100 KPa absolute is equal to 14.5 psia, or MPa, Megapascal, 1 000 000 Pa, is equal to 145 psi.

See LBL Health and Safety Manual, Pub. 3000, Chapter 20, for additional definitions of pressure terms and pressure documentation.

1.0 INTRODUCTION

1.1 General

All pressure (see Fig. III.P.-1) vessels and pressure systems designed or operated by Lawrence Berkeley Laboratory personnel are within the scope of these rules. For convenience in describing the required controls, pressure vessels and pressure systems have been divided into two hazard categories:

- Low-hazard pressure equipment--low hazard level, or is satisfactorily covered by existing regulatory standards.
- High-hazard pressure equipment--where operational risk is high and special approvals and controls are necessary.

1.1.1 Low-Hazard Pressure Equipment

The following systems are either of relatively low hazard or are adequately controlled so they do not require an Operational Safety Procedure (OSP).

1.1.1.1 Air and inert-gas systems for working pressures up to 1 MPa gauge (150 psig) and inert-liquid systems for working pressures up to 10 MPa gauge (1500 psig), provided that the contained isentropic energy does not exceed 100 kJ (75,000 ft-lb).

1.1.1.2 Utility systems for maximum allowable working pressures up to 2.0 MPa gauge (300 psig), including cold-water, hot-water, low-conductivity-water, compressed-gas, natural-gas, butane and propane (LPG), and steam systems that strictly comply with applicable Plant Engineering standards and are inspected and maintained by the Plant Engineering Department.

1.1.1.3 Compressed-gas cylinder manifolds assembled with compound-thread fittings by the Plant Maintenance Technicians Shop in compliance with Section II.H. of this Manual, Pub. 3001.

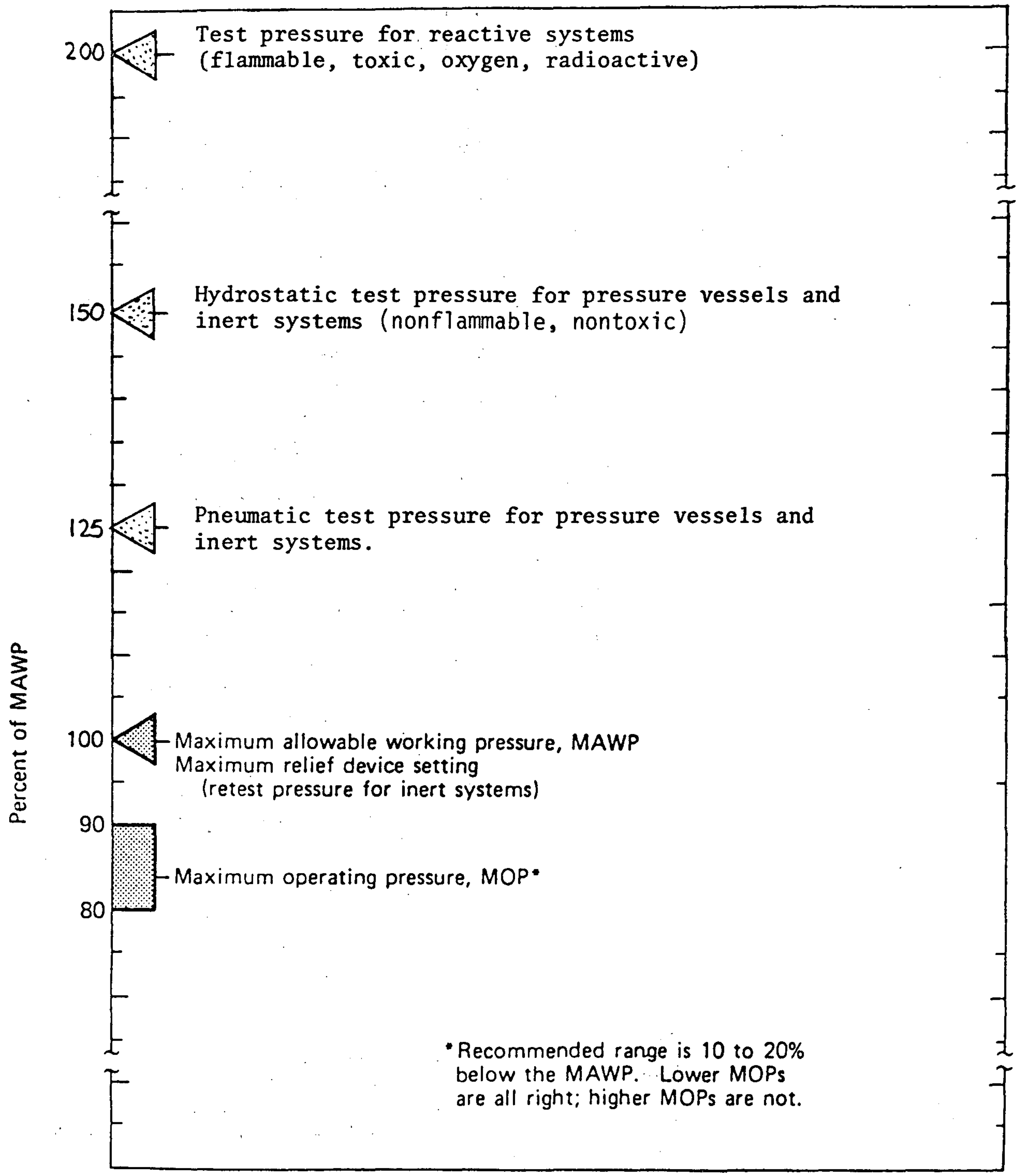


Fig.III.P.-1 Relationships of defined pressure terms.

1.1.1.4 Manifolds on tubebanks and tubetrailers that consist of components rated at 20 MPa gauge (3000 psig) or higher and are periodically retested at 27.6 MPa gauge (4000 psig) and labeled by the Plant Engineering Department.

1.1.1.5 Unmodified pressure vessels designed in accordance with the ASME Boiler and Pressure Vessel Code and ASME-code stamped. If the contained fluid exceeds 1 MPa gauge (150 psig) gas pressure, 10 MPa gauge (1500 psig) liquid pressure, or 100 kJ (75,000 ft-lb) isentropic energy, it must be inspected and labeled by the Pressure Inspector prior to pressurization and every 3 years thereafter, unless it is inspected periodically by the State of California.

1.1.1.6 Refrigeration systems that comply with the ASME Boiler and Pressure Vessel Code and applicable Air-Conditioning and Refrigeration codes.

1.1.1.7 Pressure vessels stamped with a Department of Transportation (DOT) rating, used to supply and transport fluids. These vessels are subject to retesting requirements of the Code of Federal Regulations, CFR 49, Transportation, Parts 100-199 (current issue).

1.1.1.8 Air-pressure tanks, liquefield-petroleum-gas tanks, anhydrous-ammonia tanks, and fired-steam boilers inspected periodically in accordance with the "Unfired Pressure Vessel Safety Orders" or the "Boiler and Fired Pressure Vessel Safety Orders" of the State of California. The Designer must notify the Plant Maintenance Technicians whenever he installs such a vessel.

1.1.1.9 Unmodified, commercially manufactured hydraulic systems for working pressures to 35 MPa (5075 psi) on hydraulic presses, motorized vehicles, and matching tools that are periodically inspected and maintained by the using Department.

1.1.2 High-Hazard Pressure Equipment

Pressure vessels and systems used for manned-area operation and containing hazardous materials or employing high pressures involve relatively high levels of hazard. For the applications itemized below, it is required that the Designer prepare an Engineering Safety Note (ESN), or a Safety Note Equivalent, and that the User prepare an Operational Safety Procedure (OSP). (See ESN example in 12.0 of this Section, and in the LBL Health and Safety Manual, Pub. 3000, Ch. 20.)

1.1.2.1 All vessels and systems that contain irritant, toxic, or radioactive fluids at any pressure and operate in manned areas.

1.1.2.2 All flammable-gas vessels and systems operating in manned areas.

1.1.2.3 All vessels and systems used for operation in manned areas at gas pressures over 1 MPa gauge (150 psig), or liquid pressures over 10 MPa guage (1500 psig), or that contain over 100 kJ (75,000 ft-lb) of isentropic energy, including ASME-coded vessels that have been structurally modified.

Caution

If an ASME-Coded vessel is modified, the Code stamping shall be obliterated and the LBL Engineering Coordinator shall be so notified.

2.0 PRESSURE-VESSEL DESIGN

2.1 Design Criteria

The following criteria apply to the design of liquid-pressure or gas-pressure vessels for manned-area operation. For remote operation, the extent to which these criteria apply depends upon the functional reliability required.

2.1.1 Apply a safety factor of 4 to the ultimate strength when designing for normal manned-area operation. Use a higher factor if operation involves detrimental conditions, such as vibration, corrosion, shock, or thermal cycling. Never use a safety factor of less than 4 when designing a vessel for manned-area operation unless the design conforms to the ASME Code (Ref. 2). Any manned-area vessel design based on a safety factor of less than 4 requires approval by the Mechanical Safety Committee.

2.2 Material Selection

2.2.1 Materials that remain ductile throughout the working temperature range of the vessel shall be selected. If use of a brittle material for the body of a manned-area pressure vessel cannot be avoided, the ESN shall be approved by the Mechanical Safety Committee.

2.2.2 Materials that are physically and chemically compatible with the fluid(s) to be contained in the vessel shall be selected.

2.2.3 Beware of hydrogen embrittlement. High pressure hydrogen gas drastically degrades the ductility of highly stressed, high-strength, pressure-vessel materials. This problem can be avoided as follows:

1. Use lower-strength vessel-materials such as type 304, 316, 321, 347, or 21-6-9 stainless steel; 2024 or 6061 aluminum alloy; oxygen-free copper; phosphor bronze; or beryllium copper (or other materials recommended by the Mechanical Engineering Department).

2. Include an inner liner (or bladder vessel) of one of these hydrogen-resistant materials. When designing such a liner, ensure that it will withstand the working and testing stresses, and that it is positively vented so that any hydrogen that

penetrates this liner cannot subject the high-strength vessel body to high-pressure hydrogen. Also, provide means for periodically verifying that this vent-path is open to the atmosphere.

2.2.4 Consider the creep characteristics of the material. This is an important consideration when pressure is to be contained for extended periods at elevated temperatures.

2.2.5 Make sure that vessel material meets the appropriate ASME Code and is of acceptable fracture toughness throughout its working temperature range. Be aware that all materials have flaws and that all flaws will grow as the vessel is pressure cycled. Know the duty cycle and the number of pressure cycles expected. The object is to determine how many pressure cycles can be permitted between inspections.

Charpy impact values less than 30 J (22 ft-lb) and $K1_C$ values less than 100 are usually considered unacceptable for the manned-area pressure vessels. For pressure vessels of wall thickness over 50 mm (2 in.) and working pressures over 100 MPa (15,000 psi), consider specifying impact-testing of vessel matrial specimens at the lowest vessel-working-temperature or -7°C (+20°F), whichever is lower.

2.2.6 Confirm material identity by verifying it through certification to be of a particular specification, or by chemical analysis, metallography, or sample testing, as required.

2.2.7 Materials listed in Subsection C of Ref. 2, and the alloys listed in Table 1, are normally satisfactory for pressure-vessel fabrication. The strength values listed in Table 1 apply between -30°C (-20°F) and +95°C (+200°F). At working temperatures below -30°C, the possibility of brittle behavior must be considered; at temperatures over +95°C, reduction in strength usually becomes significant. The tabulated information is from Refs. 3 thru 6.

2.3 Design Considerations

2.3.1 Specify that all purchase-fabrication welding be performed per approved ASME procedures by ASME-certified welders.

2.3.2 Avoid longitudinal welds in vessels less than 0.15 m (6 in.) in diameter. Seamless tubing or pipe, or bar-stock, is usually available in these smaller diameters.

2.3.3 Avoid stress concentrations. This is most critical when vessel-material elongation and toughness are relatively low.

2.3.4 Adjust the design and the allowable stresses to compensate for such environmental conditions as vibration, temperature fluctuation, shock, corrosion, and extreme thermal operating conditions.

2.3.5 Specify inspection by appropriate nondestructive detection methods (such as radiographic, ultrasonic, dye-penetrant, or magnetic-particle inspection) when designing a high-strength, high-pressure vessel. Specify appropriate ultrasonic inspection of all manned-area pressure vessels of wall thickness over 50 mm (2 in.). Maximum permissible defects should be based upon the capability of the vessel material to resist crack growth under the specified operating conditions. Contact the Materials Test and Evaluation Section of the Materials Engineering Division at LLNL for guidance in determining the allowable-defect-size, and the Nondestructive Testing Section of the same Division for assistance in properly specifying ultrasonic inspection.

2.3.6 Prepare a Fracture Control Plan for all gas-pressure vessels of wall thickness over 50 mm (2 in.) that are to be operated in a manned area. Such vessels should be periodically (or possibly continuously) monitored by appropriate acoustic-emission equipment to assure that previously undetectable, undetected, and detected cracks are not approaching critical size. Contact the Materials Test and Evaluation Section at LLNL for assistance. Such a plan should be prepared for vessels of even thinner wall thickness wherever radioactive, toxic, explosive, or flammable materials are involved.

2.3.7 When specifying welding of pressure-vessel components, consider the following:

1. A weld might be brittle, and welding might embrittle the materials in the heat-affected zone. Check a weld cross-section for toughness.

2. Weld penetration might not be to the full thickness of the parent materials so include realistic joint efficiencies in your calculations (see Ref. 2, Table UW-12, p. 89).

3. Welding normally anneals the material in the heat-affected zone, so consider the reduced properties of this zone when calculating the overall strength of the vessel.

4. Welding reduces resistance to hydrogen embrittlement of some materials, so consult the Mechanical Engineering Department when planning to weld a vessel that is to contain a high-pressure hydrogen gas.

2.3.8 Use a realistic MAWP as basis for design calculations. A MAWP that is 10 to 20% above the highest anticipated operating pressure is recommended. This permits proper relief protection against overpressure without degrading the dependable, leak-tight functioning of the vessel at its operating pressure. The MAWP shall be stated on all pressure-vessel drawings.

2.3.9 A relief valve(s) or rupture disc(s) of sufficient capacity and set at a pressure not exceeding the MAWP of the vessel shall be provided.

2.4 Calculation Guide (for ductile vessels)

Equations (1), (2), (3), and (4) below are based on maximum allowable circumferential or hoop stress, and not on the true combined-stress condition of the vessel. The actual stress near a weld joint or in any area of stress concentration will be considerably higher than the "average" stress that results from applying these equations. However, proper application of these equations will result in a vessel of ASME-Code-equivalent safety.

The following notations apply to all of the equations listed in this section.

d = diameter exposed to pressure, in m (in.)

E = joint efficiency (usually 1, except for welded vessels)

h_G = radial difference between bolt circle and pressure-seal circle on a bolted end closure, in m (in.)

p = maximum allowable working pressure, in Pa (psi)

σ_a = allowable stress, in Pa (psi)

σ_y = yield strength, in Pa (psi)

σ_u = ultimate strength, in Pa (psi)

SF = safety factor, based on elastic/plastic failure (see Eq. 6)

SF_u = safety factor, based on ultimate strength (see Eq. 5)

t = wall thickness, in m (in.)

r_i = inner radius, in m (in.)

r_o = outer radius, in m (in.)

r_m = mean radius, $\frac{r_i + r_o}{2}$, in m (in.)

U = energy in Joules (ft-lb)

v = volume in m^3 (in^3)

W = pressure force plus required gasket-sealing force in N (lb)

C = attachment coefficient

γ = ratio of specific heats, c_p/c_v

2.4.1 For thin-wall vessels, where $R = r_o/r_i$ is less than 1.1, use Equations (1), (2), (3), (4), or (5) below to calculate p, the MAWP (Ref. 6, Ch. 12).

For Cylinders

$$p = \frac{\sigma_a E\ t}{r_m} \quad \text{or} \quad p = \frac{\sigma_u E\ t}{r_m SF_u} \tag{1}$$

For Spheres

$$p = \frac{2\sigma_a E\ t}{r_m} \quad \text{or} \quad p = \frac{2\sigma_u E\ t}{r_m SF_u} \tag{2}$$

2.4.2 For medium-wall vessels, where $R = r_o/r_i$ is between 1.1 and 1.5, use Equations (3) through (8) below to calculate the MAWP (Ref. 1, par. UG-27).

For Cylinders

$$p = \frac{\sigma_a E\ t}{r_i + 0.6t} \quad \text{or} \quad \frac{\sigma_u E\ t}{SF_u(r_i + 0.6t)} \tag{3}$$

For Spheres

$$p = \frac{2\sigma_a E\ t}{r_i + 0.2t} \quad \text{or} \quad \frac{2\sigma_u E\ t}{SF_u(r_i + 0.2t)} \tag{4}$$

2.4.3 For thick-wall vessels, where $R = r_o/r_i$ is over 1.5, use Equation (5), (6), (7), or (8) below to calculate the MAWP.

For Cylinders

Ref. 9, Ch. 12, and Ref. 1, par. UA-2:

$$p = \sigma_a \frac{\left(r_o^2 - r_i^2\right)}{\left(r_o^2 + r_i^2\right)} \quad \text{or} \quad p = \frac{\left(\sigma_u\ r_o^2 - r_i^2\right)}{\left(SF_u\ r_o^2 + r_i^2\right)} \tag{5}$$

Ref. 10, page 429, Equation 6.370:

$$p = \frac{2\sigma_y}{\sqrt{3}\ SF}\left(2 - \frac{\sigma_y}{\sigma_u}\right) \ln R \tag{6}$$

For Spheres

Ref. 9, Ch. 12 and Ref. 1, par. UA-3:

$$p = 2\sigma_a \frac{\left(r_o^3 - r_i^3\right)}{\left(r_o^3 + 2r_i^3\right)} \quad \text{or} \quad p = \frac{2\sigma_u\left(r_o^3 - r_i^3\right)}{SF_u\left(r_o^3 + 2r_i^3\right)} \tag{7}$$

Ref. 10, page 424, Equation 6.333:

$$p = \frac{2\sigma_y}{SF}\left(2 - \frac{\sigma_y}{\sigma_u}\right) \ln R \tag{8}$$

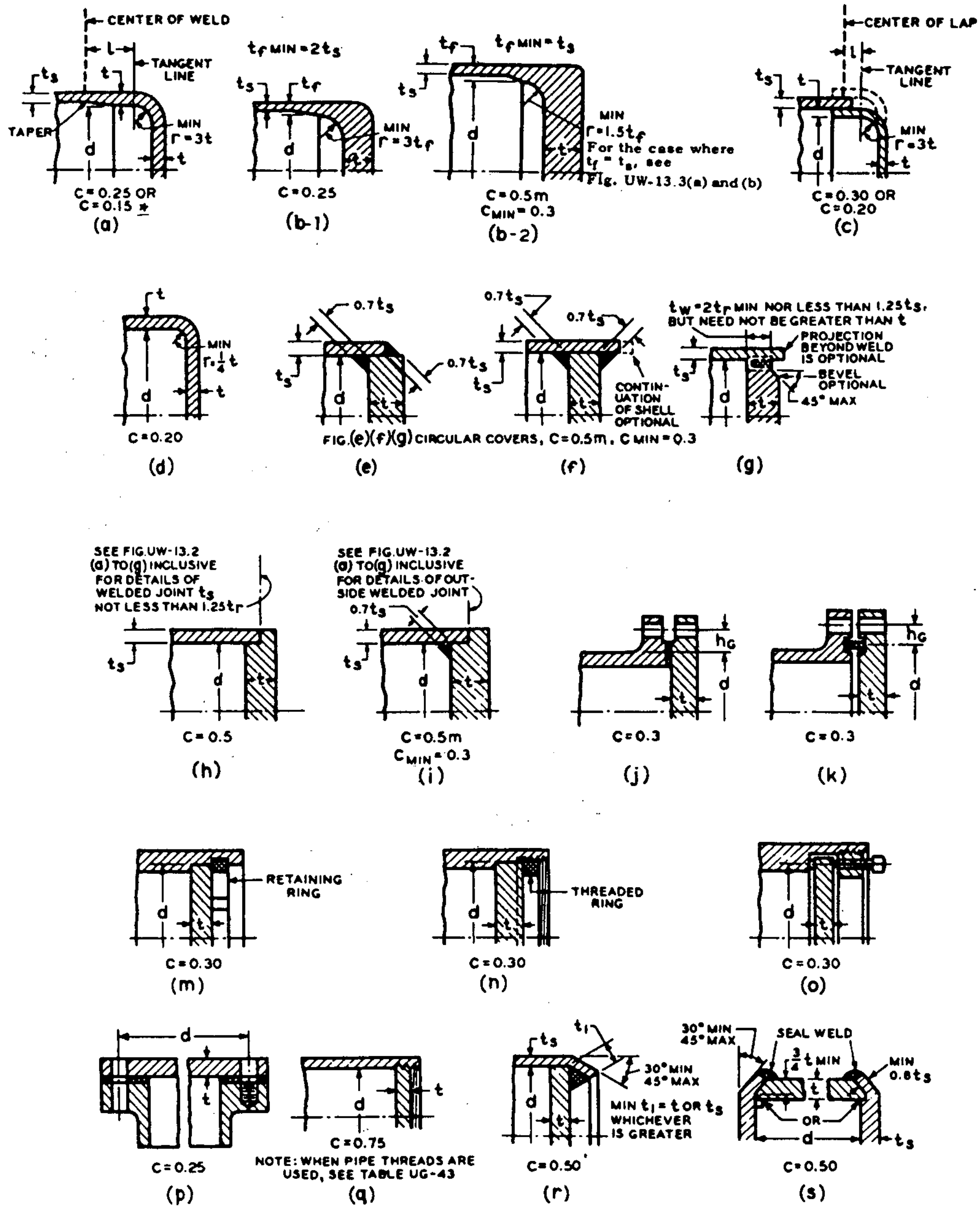
2.4.4 Medium- and thick-wall vessels of certain materials may also be designed in accordance with the rules of the ASME Boiler and Pressure Vessel Code, Section VIII--Division 2 (Ref. 2), and with Appendix C. For flat circular end-closures, use Equations IV-9 or IV-10 below to calculate the required thickness. See the ASME Boiler and Pressure Vessel Code (Ref. 1, par. UG-34) for design details; Fig. UG-34 of this code is reproduced in Fig. III.P.-2 for your reference. If no bending moment is imposed on the end-closure when securing it [welded, integral, ring-retained, or other method, see Fig. UG-34 (a) through (i) and (m) through (s)], use

$$t = \sqrt{d\,\frac{C\,p}{\sigma_a}} \quad \text{or} \quad t = d\sqrt{\frac{C\,SF_u p}{\sigma_u}} \qquad (9)$$

If a bending moment is imposed on the end-closure when securing it (bolted, i.e., Fig. UG-34 (j) and (k)) use

$$t = d\sqrt{\frac{C\,p}{\sigma_a} + \frac{1.78\,W\,h_G}{\sigma_a d^3}} \quad \text{or}$$

$$t = d\sqrt{\frac{C\,SF_u p}{\sigma_u} + \frac{1.78\,W\,h_G\,SF_u}{\sigma_u d^3}} \qquad (10)$$



This figure was reproduced from Fig. UC-34 of Ref. 1 with the permission of the American Society of Mechanical Engineers. Minor portions of the printed material have been deleted.

***See Ref. 1, par. UG-34.**
The symbol "m" here is the ratio t_r/t_s, where t_r is the required shell thickness and t_s is the actual shell thickness, exclusive of corrosion allowance.

Fig. III.P.-2 Some acceptable types of unstayed flat heads and covers.

2.4.5 For other vessels such as multiwall cylinders and other end-closure designs, refer to the references at the end of this Section. Where imposed stresses in a large high-pressure vessel appear to be complex and possibly excessive, contact the Applied Mechanics Group of the Nuclear Explosives Engineering Division at LLNL for assistance in performing a finite element analysis.

2.4.6 Calculate the energy contained in the fully pressurized vessel; include in the ESN. Compare this value with the 4.63 x 10^6 Joules (3.42 x 10^6 ft-lb) potential energy of 1 kg (2.2 lb) of TNT.

$$U = \frac{P_1 V_1}{\gamma - 1}\left[1 - \left(\frac{P_2}{P_1}\right)^{\frac{\gamma - 1}{\gamma}}\right]$$

Example: Using the above equation (Ref. 9, page 4-23), a fully charged, standard Size 1 cylinder of nitrogen gas contains energy equivalent to about 0.25 kg (0.5 lb) of TNT. This calculation is based upon reversible adiabatic (isentropic) expansion of the confined gas.

Use Reference 10 for calculating the MAWP of LBL-owned DOT cylinders that are to be used in stationary installation.

3.0 GAS PRESSURE-CONTAINMENT VESSELS

3.1 Scope

This section is essentially identical to Reference 12 and covers equipment used for protective enclosure of gas-pressurized vessels, including those that contain toxic, radioactive, and/or flammable materials. Such equipment must be designed to protect personnel from the pressure-vessel-failure hazards of blast pressure and flying fragments; if hazardous materials could escape from the contained vessel (in case of pressure media leakage), the containment vessel must also be designed to prevent subsequent leakage to the atmosphere.

3.2 Special Shipping Requirements

Only containers approved by the Department of Transportation (DOT) or by the Department of Energy (DOE) shall be used for off-site shipment of pressure vessels containing radioactive materials. See Reference 13 for current DOT shipping regulations and contact Environmental Health and Safety for DOE shipping requirements. See Reference 14 for pertinent details regarding DOE shipping requirements and Reference 15 for information about gas-sampling cylinders, where only small quantities of radioactive materials are involved in a shipment.

3.3 Design Safety Factors

If the contained-pressure-vessel is of ductile material and has been LBL approved for a manned-area Maximum Allowable Working Pressure (MAWP) of at least the maximum pressure to which it could be subjected inside of the containment vessel, the containment vessel shall be designed to an ultimate or burst safety factor of at least 4.

If the contained-pressure-vessel has not been LBL approved for a manned-area MAWP of at least the maximum pressure to which it is to be subject inside of the containment vessel, the containment vessel shall be designed to an ultimate or burst safety factor of at least 8 for manned-area operations.

3.4 General Design Requirements

The following requirements apply to all gas-pressure containment vessels, including those that are to contain toxic, radioactive, and/or flammable materials, that are designed, specified, or used by Lawrence Berkeley Laboratory personnel.

3.4.1 Design the containment vessel using the appropriate safety factor specified in paragraph 3.3. Base the design upon the maximum equilibration pressure subsequently heated to the highest temperature expected within the containment vessel, or to 55°C (130°F), whichever is higher.

3.4.2 In selecting materials of satisfactory fracture toughness, assume a minimum operating temperature of -40°C (-40°F), unless a lower temperature is required and specified.

3.4.3 If off-site transportation is to be permitted, design the containment vessel to withstand the normal conditions of transport as listed in References 13 and 14. This includes heat, cold, pressure, vibration, water spray, free drop, corner drop, penetration, and compression. It is also required (in Annex 1) that the contained vessel be mounted securely inside the containment vessel.

3.4.4 Include a compound pressure/vacuum gauge for periodically monitoring the internal pressure of the containment vessel. This gauge shall be graduated to at least 120° but not over 200° of the highest credible room-temperature equilibration pressure.

3.4.5 Include two separate valve entries for safely introducing and exhausting (and monitoring) flushing gases through separate lines.

3.4.6 Include suitable covers and shields to protect all valves and gauges from damage. Cap or plug all terminal valve-ports. Provide accommodations for locking or wiring valve handles closed, or have valve handles removed during shipment, to prevent unauthorized operation or tampering.

3.4.7 If the contained vessel has not been LBL approved for a manned-area MAWP of at least the maximum pressure to which it could be subjected inside the containment vessel, show that the containment vessel would not be penetrated by any credible flying fragments if the contained vessel failed catastrophically.

3.5 Testing and Labeling

3.5.1 Pressure test the containment vessel at 1.50 times the maximum possible equilibration pressure. To determine the maximum equilibration pressure, assume that the most energetic contained vessel specified equilibrates into the containment vessel, which is then heated to 55°C (113°F) unless a higher temperature is specified. No detectable plastic strain is permitted, as determined by measurements made to within 0.025 mm (0.001-inch), both before and after testing.

3.5.2 Leak-check the containment vessel at its maximum possible equilibration pressure with a leak detector capable of detecting leakage of 1×10^{-8} atm cm^3/sec. No detectable leakage is permitted.

3.5.3 The Designer should specify contained-vessel-rupture-testing of the containment vessel if he deems it advisable.

3.5.4 After successful testing, the LBL Pressure Inspector will label the containment vessel with the working-pressure value that was the basis for the design calculations and tests, and will also label it for a working-temperature range of -40 to +55°C (-40 to +130°F) unless a wider temperature range is required and specified.

4.0 PRESSURE-SYSTEM DESIGN

4.1 Precautions

4.1.1 The MAWP shall be stated on all pressure-system assembly drawings.

4.1.2 Observe the following precautions when you design, install, or operate a pressure system (or vessel):

4.2 Prevent Overpressurizing a System

4.2.1 Pressure Sources. Limit pressure sources to the MAWP of the lowest-rated system component. Do not consider a pressure regulator by itself as satisfactory overpressure protection.

4.2.2 Pressure-Relief Devices. When pressure sources cannot be limited to less than the MAWP of every system component, include pressure-relief devices (relief valves or rupture-disc assemblies) to protect those components that are rated at less than the system-supply pressure. All pressure vessels must be protected by a relief device that is set at a pressure not exceeding the MAWP of the vessel.

4.3 Relief Valves

4.3.1 Never place a valve between a relief device and the component it is installed to protect.

4.3.2 Never set a relief device above the MAWP of the lowest-rated system component(s) it is installed to protect.

4.3.3 Locate and orient relief devices so that their discharge is not hazardous to personnel.

4.3.4 Install relief devices of adequate total flow capacity. When all supply ports are open, the pressure must never exceed 100° of the MAWP.

4.3.5 Do not reset relief devices unless you are specifically authorized to do so. No LBL personnel are permitted to set, seal, and stamp relief devices on utility water boilers, steam boilers, and compressed-air receivers that are under the jurisdiction of the State of California. Only authorized personnel in Building 76 (Plant Maintenance Technicians) are permitted to set and seal relief devices on non-coded pressure vessels and systems.

4.3.6 Use ASME code-approved or LBL-stocked relief devices whenever possible. The use of any other non-ASME-pressure-relief device on high-hazard pressure equipment must be specifically approved by the Mechanical Safety Committee.

4.3.7 Have all component relief devices rechecked before the end of the contract guarantee period if the pressure equipment was installed by an outside contractor.

4.4 Pipe and Tubing

4.4.1 Use metal pipe and tubing rated at or above the MAWP. If you plan to use pipe or tubing at pressures above those indicated in the references listed, include calculations in the Safety Note to justify your selection.

1. Use the American National Standard Code for Pressure Piping, ANSI-B31.1, or refer to the LBL Stock Catalog to determine the MAWP for intermediate and low-pressure pipe and tubing.

2. Use LLNL Standard Specification MEL 681, or MEL 71-001150, to determine the acceptable MAWP for high-pressure tubing.

4.5 Flexible Hose

Use flexible hose only where it is impractical to use metal tubing or pipe.

4.5.1 Do no use hose at a pressure over one-fourth of its rated minimum burst pressure as stated by the hose manufacturer.

4.5.2 Keep hose lengths as short as possible.

4.5.3 Anchor hose ends to prevent whipping in case of a hose or hose/fitting failure.

4.5.4 Avoid sharp hose bends. Do not bend hoses more sharply then recommended by the hose manufacturer.

4.5.5 Replace or prepair any hose showing leaks, burns, wear, or other detrimental defects.

4.5.6 Do not use hose on flammable, toxic, or radioactive gas systems. Gases tend to permeate through flexible hose.

4.6 Valves and Fittings

4.6.1 Use proper valves and fittings. Use valves and fittings that are rated at or above the MAWP and are compatible with the system fluid. On liquefied-gas systems, make sure that all terminal-block valves (valves where users could attach to the system) are rated above 38°C (100°F) vapor pressure of the liquefied gas, or that a properly set relief valve is permanently installed on the outlet side of each such valve.

4.6.2 Make sure that all valve-stem packing nuts are kept properly adjusted and locked.

4.6.3 Make sure that there is no oil or other organic material in valves or fittings that are used on gas (especially oxygen) systems.

4.6.4 Open all internal-system valves when pressure-testing a system.

4.7 System Components

4.7.1 Secure all components of pressure system.

1. Use adequate machine screws (or bolts) and nuts to secure all components. Wood screws are not considered adequate.

2. Support and secure hose and tubing at least every 2 m (7 ft) in manned area. Support and secure pipe according to Table III.P.-1 in manned areas. Locate supports so that you limit strain on fittings and minimize overhang at bends. Consider that pipe and tubing expand and elongate when heated and contract when cooled. Use additional supports for heavy-system components.

3. All systems must be adequately secured against seismic forces. See Section II.K of this Manual, LBL Pub. 3001.

Table III.P.-1. Maximum span for various pipe sizes

Nominal pipe size (inches)	Maximum unsecured span (meters)	(feet)
1	2.0	7
1-1/2	2.7	9
2	3.0	10
2-1/2	3.4	11
3	3.6	12
3-1/2	4.0	13
4	4.3	14
5	4.9	16
6	5.2	17
8	5.8	19
10	6.7	22
12	7.0	23

4.8 Gas Pressure Gauges

4.8.1 Use gauges graduated to about twice the MAWP of the system; never use gauges graduated to less than 1.2 times the MAWP. (This also applies to liquid-pressure gauges.)

4.8.2 Be sure that gauge materials are compatible with the system fluid. (This also applies to liquid-pressure gauges.)

4.8.3 Use safety-type gauges (with shatterproof faces, solid fronts and blow-out backs) or protect operators with a tested, LBL-approved-gauge-safety shield. This applies to all gas-pressure gauges over 100 mm diameter graduated to over 35 MPa (5000 psi) and to all liquid-pressure gauges over 100 mm diameter that are graduated to over 140 MPa (20,000 psi).

4.8.4 Protect a gauge that is subject to pressure surges or cyclic pulses by installing a throttling device such as pulsation-dampener (preferred), a pressure snubber, a gauge-saver, or a restricting orifice, or use a gauge equipped with a throttle screw in the tube socket.

4.8.5 Make sure that there is no oil in gauges used on gas systems. This is most important on oxygen systems since hydrocarbons and oxygen can combine explosively.

4.8.6 Protect the gauge with a relief device as required to prevent the static pressure from exceeding the full-scale pressure of the gauge.

4.9 Flash Arresters and Check Valves

4.9.1 Equip every flammable-gas drop or regulator/hose connection with a flash arrester or a check valve. If the flammable gas is to be (or could be) cross-connected with oxygen or compressed air, a flash arrester must be installed in the flammable-gas line and a check valve in the oxygen- or compressed-air line.

4.9.2 Equip all oxygen drops with a check valve such as Victor No. 50-R. This applies to all single and multiple-station installations and portable equipment.

4.10. Pressure Components Procurements

4.10.1 Low- and intermediate-pressure fittings, valves, gauges, pipe, and tubing may be obtained from LBL Stores. High-pressure components are not stocked at LBL Stores and must be purchased from outside vendors. All purchase requisitions for high-pressure equipment must be approved by the Designer prior to placements of order.

4.10.2 All used pressure equipment which had been deactivated or which is being converted from some other prior use, shall be inspected and approved by the Designer before being used in a pressure system.

5.0 PRESSURE-SYSTEM INSTALLATION

Refer to the LBL Health and Safety Manual, Pub. 3000, Chapter 20, for information on the installation procedures of pressure vessels and systems.

6.0 PRESSURE-SYSTEM TESTING

Refer to Section III.Q. in this Manual, Pub. 3001, for information on testing procedures for pressure vessels and systems.

7.0 PRESSURE-SYSTEM OPERATION

7.1 Authorized Personnel

Refer to the LBL Health and Safety Manual, Pub. 3000, Chapter 20, for information on personnel authorized to operate pressure equipment.

7.1 Operation

The User shall confirm his responsiblity for operation of the high-hazard pressure equipment in an Operational Safety Procedure (OSP). The User may also authorize any technically competent person to operate low-hazard pressure equipment. The User shall assure himself that the following safety precautions are observed:

7.2.1 A system or vessel shall not be operated until the operator has read and completely understands all applicable Safety Notes, Operational Safety Notes, Operational Safety Procedures and all other related procedures.

7.2.2 Neither flammable, radioactive, irritant, or toxic gases or fluids, nor oxygen, shall be used in systems that are not specifically designed for the use of a specific hazardous gas or fluid.

7.2.3 Flammable gas shall not be used in combination with oxygen or compressed air unless there is a flash arrestor in the flammable-gas line and a check valve in the oxygen, or air line. Oxygen, and air because of its oxygen content, can combine explosively with organic materials and flammable gases. Acetylene and hydrogen have especially wide flammable ranges (explosive if confined and ignited) in air and oxygen.

7.2.4 Acetylene-gas pressure shall be limited to 15 psig. Acetylene is unstable and will explode spontaneously around 30 psig at room temperature. Acetylene gas is used for welding and is stored at pressures around 250 psig in cylinders containing about 350 ft^3 of acetylene. The cylinders contain a porous, cement-like material, and acetone which dissolves 300 times its volume of acetylene.

7.2.5 Before connecting a pressure source, such as a compressed-gas cylinder to a pressure system, the source valve should be gently cracked to expel any foreign material. For pressure sources that are toxic or flammable (including oxygen), carefully vent the hazardous purging gas to a safe location, or use vacuum to clean the valve port.

7.2.6 The pressure source shall be limited to the MAWP of the pressure system, or a properly set pressure-relief device of sufficient flow capacity shall be installed between the source and the system. Refer to Section III.D in this Manual, Pub. 3001, for detailed relief device requirements.

7.2.7 When letting evacuated vacuum vessels up to atmospheric pressure with a pressurized-gas source, a relief device shall be installed between the gas source and vacuum system to prevent overpressure.

7.2.8 Pressure-relief devices shall be set or reset only by authorized personnel of the Plant Maintenance Technicians Group (Building 76).

7.2.9 No work shall be performed on pressurized components unless the method has been approved in an Operational Safety Procedure, or is specifically authorized by the Experiment Group Leader or his designated alternate.

7.3 Remote Operation

Remote-area vessels do not qualify for manned-area operation because of the high risk of personal injury. They may be pressure vessels which operate above the MAWP under a variance, or they may contain highly toxic or radioactive fluids.

All remote-area vessels shall be reviewed for safety on an individual basis. Conspicuous warning signs bearing operational restrictions and safety guidelines shall be posted at such vessels. A member of the Mechanical Safety Committee or the Engineering Coordinator will inspect the installation prior to operation.

8.0 PRESSURE-SYSTEM MAINTENANCE

8.1 The User shall make sure that pressure equipment under his control is maintained in safe functional condition.

For both low-hazard and high-hazard equipment, this requires that:

8.1.1 The User instruct operating personnel in operational and servicing requirements and see that these instructions are carefully followed.

8.1.2 Pressure-relief devices shall be operational and labeled. The label shall include the set pressure, the date, and the tester's name. Any relief device that is activated by other than the Pressure Inspector shall be immediately checked and/or reset by by authorized personnel of the Plant Maintenance Technicians Group.

For high-hazard pressure equipment, this also requires that:

8.1.3 Worn or defective components are repaired or replaced only by a Pressure Installer and inspected by the Pressure Inspector or the Engineering Coordinator.

8.1.4 If the equipment is modified (any change other than repair or replacement with identical or equal components) the Engineering Safety Note shall be revised to reflect the modification and the system shall be retested by the assembly shop or the maintenance technicians and observed by the Pressure Inspector.

8.1.5 The equipment shall be reinspected in accordance with Section III.Q.

9.0 STORAGE AND DISPOSITION OF PRESSURE EQUIPMENT

Whenever practical, a system or vessel that is not being used shall be depressurized. When a vessel or system is stored under pressure, the pressure and fluid shall be clearly identified on the exterior of the vessel. When the User no longer has use for a pressure vessel or system, he shall contact the Safety Coordinator to determine the disposition of the pressure equipment. If the vessel or system bears an "LBL Pressure-Tested" label, the User shall notify the Engineering Coordinator of his intention to store or dispose of the labeled pressure equipment. The User shall also notify the Mechanical Safety Committee whenever a high-hazard pressure vessel or system is sent to salvage, destroyed, or is permanently dissassembled, so that the related ESN or ESNE can be inactivated in the permanent files.

10.0 PLANT-FACILITY PRESSURE SYSTEMS

10.1 General

In addition to the safety requirements previously defined in this Section, Plant-Facility utility pressure vessels and systems are also covered by the State of California Administrative Codes.

10.2 Unfired Pressure Vessels

10.2.1 Reference: State of California Administrative Code
Title 8. Industrial Relations
Part 1. Department of Industrial Relations
Chapter 4. Division of Industrial Safety
Subchapter 1. Unfired Pressure Vessel Safety Orders.

10.2.2 Minimum Standards

These Safety Orders establish minimum standards for:

1. The design and construction of all unfired-pressure vessels for Plant-Facility pressure systems.

2. The installation of, and the use, inspection, repair, and issuance of permits to operate air-pressure tanks and liquefied-petroleum-gas tanks.

3. The installation, use and repair of anhydrous-ammonia tanks.

4. The design and construction of pressure vessels for the storage and dispensing of natural gas for motor fuel and for motor-fuel tanks installed on vehicles which are not licensed to travel on high-ways.

5. The installation, use and repair of natural-gas vessels and systems that are not a part of Hazardous Research equipment.

6. The design and construction of storage tanks for the storage of liquefied-natural gas at 15 psi or less and for the repair and alteration of such tanks.

10.2.3 Exceptions

These Safety Orders are not applicable to the following:

1. Pressure vessels that are under the jurisdiction and inspection of the United States Government and that are specifically exempted by the Labor Code.

2. Pressure vessels, except for liquefied-natural-gas tanks, subject to an internal or external pressure of not more than 15 psi, with no limitation on size, and vessels having an inside diameter not exceeding 6 inches with no limitation on pressure. However, vessels excluded in this section shall be designed and constructed in accordance with recognized standards when applicable, or in accordance with good engineering practices concerning pressure-vessel design with a factor of safety of at least 4, and shall be fitted with necessary controls and safety divices to permit safe operation.

3. Natural-gas vessels and installations subject to the jurisdiction and inspection of the Public Utilities Commission, the Department of Transportation, or the Highway Patrol; air-brake tanks installed on units of transportation, including trucks, buses, railroads, and streetcars, which units of transportation are operated by any person, firm, or corporation subject to the jurisdiction and inspection of the Public Utilities Commission, the Department of Transportation or the Highway Patrol.

4. Hazardous Research equipment covered in LBL Pub. 3000, Health and Safety Manual, and this Manual, Pub. 3001.

10.2.4 Code Stamp

The following vessels shall be constructed, inspected, and stamped in accordance with the ASME Boiler and Pressure Vessel Codes:

1. Air-pressure tanks

2. Liquefied-petroleum-gas tanks.

3. Anhydrous-ammonia tanks.

4. All Plant-Facility pressure vessels other than liquefied-natural-gas tanks, air-pressure tanks, LP-gas tanks, and anhydrous-ammonia tanks.

10.2.5 Liquefied Natural Gas Tanks for low-temperature storage at 15 psi or less shall be designed, constructed, inspected, and certified in accordance with API (American Petroleum Institute) Standard 620.

10.2.6 LP Gas Vaporizers having a volumetric capacity greater than one U.S. gallon shall be constructed in accordance with the Boiler and Fired Pressure Vessel Safety Orders (Title 8, Subchapter 2).

10.2.7 Permits to Operate

State of California "Permits to Operate" are required for:

1. Air tanks larger than 1.5 cubic feet and with relief valves set to open above 150 psi.

2. Liquefied-petroleum gas tanks.

10.3. Boiler and Fired Pressure Vessels

10.3.1 Reference: State of California Administrative Code
Title 8. Industrial Relations
Part 1. Department of Industrial Relations
Chapter 4. Division of Industrial Safety
Sub-Chapter 2. Boiler and Fired Pressure Vessel Safety Orders.

10.3.2 Minimum Standards

These Safety Orders establish minimum standards for:

1. The design, construction, installation, inspection, operation, and repair of all power boilers and nuclear boilers in California not specifically exempted from these Orders.

2. The design, construction, installation, operation, and repair of all low-pressure boilers and high-temperature-water boilers in California not specifically exempted from these Orders.

3. The design and construction of fired-pressure vessels in California not specifically exempted from these orders.

10.3.3 Exceptions

These Safety Orders are not applicable for the following:

1. Boilers and fired-pressure vessels under the jurisdiction or inspection of the United States Government.

2. Boilers and fired-pressure vessels used in household service.

3. Automobile boilers and boilers used exclusively to operate highway vehicles.

4. Hazardous Research equipment.

10.3.4 Design and Construction

10.3.4.1 Power Boilers and High Temperature Water Boilers.

All new power boilers and high-temperature water boilers shall be constructed, inspected, and stamped in full compliance with the ASME Boiler and Pressure Vessel Code, unless the design and construction of the boiler are accepted by the Engineering and Technical Services Division as equivalent to Code.

10.3.4.2 Fired-Pressure Vessels

All fired-pressure vessels shall be constructed, inspected and stamped in accordance with the ASME Code insofar as applicable. Those vessels not included in the scope of the ASME Code shall be designed and constructed in accordance with good engineering practice regarding pressure-vessel design for the pressure and temperature to be expected in service, with a factor of safety of at least four.

Good engineering practice as used in this article shall be construed to require details of design and construction which will be as safe as otherwise provided by the rules in the ASME Code, including shop inspection.

10.3.4.3 Low-Pressure Boilers.

All new low-pressure boilers shall be constructed, inspected, and stamped in accordance with the Code, unless the design and construction are accepted by the Engineering and Technical Services Division as equivalent to Code.

10.3.5 Permits to Operate

State of California "permits to operate" are required on all boilers and fired pressure vessels except:

1. Low-pressure boilers
2. Miniature boilers
3. High-temperature-water boilers
4. Boilers, including forced-circulation boilers, in which none of the following is exceeded:
    a. One hundred square feet (100 sq. ft.) of heating surface.
    b. Steam drum does not exceed 16-inch inside diameter.
    c. Maximum allowable working pressure does not exceed 100 psi.
    d. Water Capacity does not exceed 35 gallons when filled to normal operating level.
    e. The power input to the burners does not exceed 400,000 Btu/hr.

10.3.6 Code Definitions

1. Code: The ASME Boiler and Pressure Vessel Code and of the ANSI Standards.

2. Low-Pressure Boiler--A boiler which does not:

   a. Operate at steam pressure or with steam-safety valve settings exceeding 15 psi (low-pressure boiler), or

   b. Operate at water pressures exceeding 160 psi or water temperatures exceeding 250°F (hot-water-heating boiler).

This definition is not intended to include domestic-type water heaters, provided all of the following are complied with;

   a. The heater does not have more than 120-gallon water capacity.

   b. The heater is used only for heating service water.

3. Miniature Boiler--A boiler which does not exceed any of the following limits:

   a. 16-inch inside diameter of shell.

   b. 5 cubic feet gross volume, exclusive of casing and insulation. (This volume includes the total volume of the steam- and water-containing parts of the boiler plus the volume of the combustion space and gas passages up to the point of attachment of the smokestack or chimney breeching.)

4. High-Temperature Water Boiler: A fired- or unfired-pressure vessel used to heat water to temperatures above 212°F at pressures exceeding 160 psi, or to temperatures exceeding 250°F regardless of pressure.

5. Power Boiler: Steam boiler operated at pressures exceeding 15 psi.

11.0 REFERENCES

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14. DOE Order 5480.1 Chapter III, Safety Standards for the Packaging of Fissile and Other Radioactive Materials, Department of Energy, DOE Manual.

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ASME Boiler and Pressure Vessel Code, Section X, "Fiberglass-Reinforced Plastic Pressure Vessels" (current issue).

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12.0 MECHANICAL-ENGINEERING-SAFETY-NOTE EXAMPLE

An example of a Mechanical Engineering Safety Note covering the design of an 83 MPa (12,000 psi) manned-area, gas-pressure vessel is shown.

Even though the design criteria for pressure vessels and systems have been complied with, an Engineering Safety Note is required as indicated in the LBL Health and Safety Manual, Pub. 3000, Chapter 20.

The calculation shows that the test pressure should be limited to 110 MPa (16,000 psi) which is 1.33 rather than 1.5 times the MAWP, because the maximum Energy of Distortion Theory predicts yielding due to combined stresses when this vessel is pressurized to 124 MPa (18,000 psi).

The Engineering Safety Note should be used as a guide for the calculations and testing only.

LAWRENCE LIVERMORE LABORATORY · UNIVERSITY OF CALIFORNIA ENGINEERING NOTE		FILE NO. ENW 78-999	PAGE 1 OF 4
SUBJECT MECHANICAL ENGINEERING SAFETY NOTE		NAME (RESPONSIBLE DESIGNER)	
PROGRAM 11.2 PRESSURE VESSELS		DATE OCTOBER 10, 1978	

A. DESCRIPTION FOR THE NEXT 3 YEARS I WILL BE THE RESPONSIBLE USER IN CHARGE OF OPERATING 2 TYPE 304 STAINLESS STEEL PRESSURE VESSELS, SERIAL NUMBERS AAA 78-10772-0A-001 & -002, IN BUILDING 231, ROOM 1002, FOR PROGRAM 11.2.

B. HAZARDS THE MAXIMUM OPERATING PRESSURE (MOP) OF THESE 50 CM^3 VESSELS WILL BE 70 MPa GAUGE (10,150 PSIG) OF HELIUM GAS AT ROOM TEMPERATURE UNDER MANNED-AREA OPERATING CONDITIONS. THE MAWP IS 83 MPa GAUGE (12,035 PSIG).

THE ENERGY OF THE PRESSURIZED VESSEL, ASSUMING REVERSIBLE ADIABATIC (ISENTROPIC) EXPANSION OF THE COMPRESSED HELIUM GAS, PER MARKS' HANDBOOK, 1958, PAGE 4-23, IS:

$$U = \frac{P_1 V_1}{(\gamma-1)}\left[1-\left(\frac{P_2}{P_1}\right)^{\frac{(\gamma-1)}{\gamma}}\right]$$

WHERE: $\gamma = \frac{C_p}{C_v}$ FOR $H_e = 1.63$

$P_1 = 83.1$ MPa ABSOLUTE

$P_2 = 0.1$ MPa ABSOLUTE

$V_1 = 50\ CM^3$

$$U = \frac{83.1 \times 50}{(1.63-1)}\left[1-\left(\frac{0.1}{83.1}\right)^{\frac{(1.63-1)}{1.63}}\right] = 6105 \text{ JOULES } (4503 \text{ FT-LB})$$

WHICH IS EQUIVALENT TO $\frac{4503 \times 454}{1.55 \times 10^6} \simeq$ 1.3 GRAMS OF TNT

THESE VESSELS WILL BE RIGIDLY MOUNTED TO THE CONCRETE FLOOR WITH 1/8-INCH THICK BY 1-INCH WIDE STEEL BRACKETS AND ANCHORED 3/8-16 MACHINE SCREWS. THEY WILL BE CONNECTED TO THE PROGRAM 11.2 SYSTEM WITH SUPPORTED 1/4-INCH O.D. X 0.125-INCH I.D., 138 MPa MAWP STAINLESS STEEL TUBING PER LLL STANDARD SPECIFICATION MEL 681, USING HIGH PRESSURE CONED/THREADED FITTINGS RATED AT 207 MPa. AN 82 MPa RUPTURE DISC IN EACH VESSEL LINE PROVIDES REQUIRED OVERPRESSURE PROTECTION.

New Section

LAWRENCE LIVERMORE LABORATORY · UNIVERSITY OF CALIFORNIA ENGINEERING NOTE		FILE NO. ENW 78-989	PAGE 2 OF 4
SUBJECT MECHANICAL ENGINEERING SAFETY NOTE		NAME (RESPONSIBLE DESIGNER)	
PROGRAM 11.2 PRESSURE VESSELS		DATE OCTOBER 10, 1978	

C. CALCULATIONS VESSEL MATERIAL AND VOLUME WERE SPECIFIED, SO A 25.4 mm (1.0-IN.) I.D. WAS SELECTED AND ALL OTHER DIMENSIONS WERE CALCULATED:

1. INSIDE LENGTH, ℓ

$$V = \frac{\pi d^2 \ell}{4} \text{ OR } \ell = \frac{4V}{\pi d^2} = \frac{4 \times 50}{\pi (25.4)^2} = \underline{\underline{98.68\,mm}}$$

2. OUTSIDE DIAMETER, O.D.

$$p = \frac{\sigma_u (r_o^2 - r_i^2)}{4 (r_o^2 + r_i^2)} \quad \ldots \text{[M.E. SAFETY MANUAL EQ III-5]}$$

$$\text{OR } \frac{(r_o^2 + r_i^2)}{(r_o^2 - r_i^2)} = \frac{\sigma_u}{4p} \quad \text{WHERE: } \begin{cases} r_i^2 = (25.4/2)^2 = 161.29\,mm^2 \\ \sigma_u = 517.24\,MPa, \text{ FOR 304SS} \\ p = 83\,MPa, \text{ MAWP} \end{cases}$$

$$\text{OR } \frac{(r_o^2 + 161.29)}{(r_o^2 - 161.29)} = \frac{517.24}{4 \times 83} = 1.558$$

$$\text{OR } r_o = \sqrt{739.39} = 27.19\,mm$$

$$O.D. = 2 r_o = 2 \times 27.19 = 54.38\,mm \text{ MINIMUM}$$

$\therefore$ LET O.D. = 57 mm

3. THICKNESS OF END PLUGS, t

$$t = d\sqrt{\frac{Cp}{\sigma_a}} \ldots \text{[MESM EQ IV-9]}$$

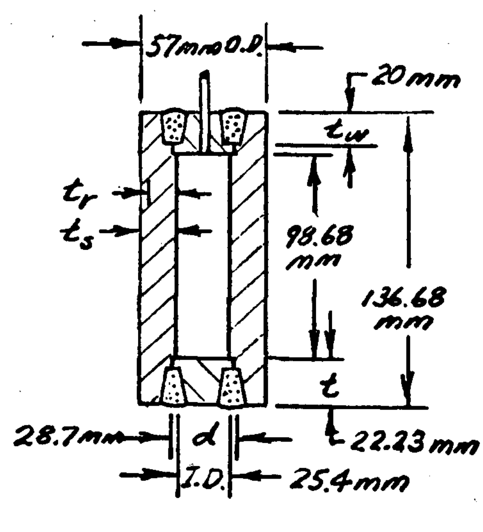
WHERE: $C = 0.5$, $p = 83\,MPa$,

$$\& \; \sigma_a = \frac{\sigma_u}{SF} = \frac{517.24}{4} = 129.3\,MPa$$

$$t = 28.7\sqrt{\frac{0.5 \times 83}{129.3}} = 16.26\,mm \text{ MINIMUM}$$

$\therefore$ LET t = 22.23 mm (7/8" STOCK)

SKETCH



t_r = REQUIRED SHELL (WALL) THICKNESS, 14.49 mm

t_s = ACTUAL SHELL THICKNESS, 15.8 mm

New Section

C. CALCULATIONS (CONTINUED)

4. WELD DEPTH, t_w, PER ASME CODE SEC VIII DIV 1, EQ UG 34(g)

$t_w = 2t_r$ MIN. NOR LESS THAN $1.25\, t_s$, BUT NEED NOT EXCEED t

OR $t_w = 2\,\dfrac{54.38-25.4}{2} = 29\text{ mm}$ NOR $1.25\,\dfrac{57.00-25.4}{2} = 19.75\text{ mm}$,

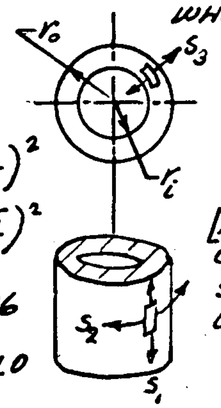
BUT NEED NOT EXCEED $t = 22.23$, SO LET $t_w = 20.00\text{ mm}$ TO PROVIDE A 2.23 mm SHOULDER FOR POSITIONING PLUG.

D. PRESSURE TESTING VESSELS TO BE TESTED AT 110 MPa, WHICH IS ABOUT 130% OF THE 83 MPa MAWP. AS SHOWN BY THE FOLLOWING CALCULATION, THEY WOULD YIELD AT 150% OF THE MAWP (N = 0.9 AT 124 MPa). THIS "MAXIMUM ENERGY OF DISTORTION ENERGY" ANALYSIS SHOWS 110 MPa IS THE HIGHEST ALLOWABLE TEST PRESSURE.

$$N = \sigma_e \Big/ \sqrt{\tfrac{1}{2}\left[(\sigma_1-\sigma_2)^2+(\sigma_2-\sigma_3)^2+(\sigma_3-\sigma_1)^2\right]} \ldots$$

[SEELY & SMITH ADVCD MECHANICS OF MATLS PG. 90 EQ. (85)]

OR $$N = \sigma_y \Big/ \sqrt{\tfrac{1}{2}\left[(S_1-S_2)^2+(S_2-S_3)^2+(S_3-S_1)^2\right]}$$



WHERE: N = FACTOR OF SAFETY BASED ON YIELD STRENGTH. MUST BE AT LEAST 1.0

σ_y = YIELD STRENGTH = 241.38 MPa

$Z = \left(\dfrac{r_o}{r_i}\right)^2 = \left(\dfrac{28.5}{12.7}\right)^2 = 5.036$

E = EFF = 1.0

[ASME CODE SECTION UA-2]

$S_1 = \dfrac{P}{E(Z-1)} = \dfrac{110}{1(5.036-1)} = 27.25\text{ MPa}$

$S_2 = \dfrac{P}{E}\dfrac{(Z+1)}{(Z-1)} = \dfrac{110}{1}\dfrac{(5.036+1)}{(5.036-1)} = 164.51\text{ MPa}$

$S_3 = -P = -110.00\text{ MPa}$

$$N = 241.38 \Big/ \sqrt{\tfrac{1}{2}\left[(27.25-164.51)^2+(164.51+110.00)^2+(-110.00-27.25)^2\right]}$$

$$N = 241.38 \Big/ \sqrt{\tfrac{1}{2}[113034]} = 241.38 / 237.73 = 1.02,$$

WHICH IS SLIGHTLY GREATER THAN 1.0, SO THEY WILL NOT QUITE YIELD AT 1.3 x 83 ≃ 110 MPa TEST PRESSURE.

New Section

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D. PRESSURE TESTING (CONTINUED) TEST PRESSURE WILL BE HELD FOR 30 MINUTES. MEASUREMENTS OF DIAMETER BEFORE AND AFTER TESTING WILL BE RECORDED ON THE TEST REPORT FORM BY THE PRESSURE INSPECTOR.

E. LABELING THE PRESSURE INSPECTOR WILL CERTIFY EACH VESSEL BY LABELING AS FOLLOWS:

ASSY (DWG/SERIAL NUMBER)
SAFETY NOTE ENW 78-999
MAWP 83 MPa (12 KSI)
FLUID INERT GAS
TEMP. 0 TO 100 °C
REMARKS TEST AT 110 MPa MAX.

F. ASSOCIATED PROCEDURES

- M.E. SAFETY NOTE ENW 78-998 COVERS DESIGN OF THE PROGRAM 11.2 SYSTEM.
- OPERATIONAL SAFETY PROCEDURE, OSP 231, HAS BEEN REVISED TO NAME ME AS RESPONSIBLE USER FOR THESE VESSELS (& SYSTEM)

DISTRIBUTION

(DEPARTMENT HEAD)
(DIVISION LEADER)
(AUTHORIZED INDIVIDUAL)
(SECTION, GROUP, OR PROJECT LEADER)
LLL PRESSURE INSPECTOR, L384, OR H.C. INDUSTRIAL SAFETY
(RESPONSIBLE USER)
(RESPONSIBLE DESIGNER)
(OTHERS CONCERNED, INCLUDING BUILDING COORDINATOR)

PREPARED BY: S/________
RESPONSIBLE DESIGNER

REVIEWED BY: S/________
AUTHORIZED INDIVIDUAL

APPROVED BY: S/________
DIVISION LEADER

New Section

III.Q PRESSURE TESTING

1.0 GENERAL

1.1 This Section covers the pressure testing of research equipment, pressure vessels, and systems. Whenever practical, pressure vessels and systems shall be sent to the Assembly Shop or the area Maintenance Technician Shops for pressure testing. When this is not practical, the vessel or system shall be tested in accordance with Procedure 2 or 3 of this Section. All pressure tests shall be conducted remotely by a Plant Maintenance Technician, a Physical Plant Mechanic or a Machinist in the Assembly Shop and shall be observed (or conducted) and certified by a member of the Mechanical Safety Committee and the Pressure Inspector.

1.2 The Mechanical Safety Committee member who observes or conducts the test shall send the completed "Pressure Test Record" form (suggested format in Fig. III.Q-1) to the LBL Engineering Coordinator who shall then attach or authorize to have attached an "LBL Pressure Tested" label (Fig. III.Q-2) to the successfully tested vessel or system.

1.3 For definitions of pressure terms used in this Section, refer to Chapter 20 in the LBL Health and Safety Manual, Pub. 3000, and Section III.P in this Manual, LBL Pub. 3001.

1.3.1 Pressure Vessels

Manned-area and remote-operation vessels shall be tested in accordance with the rules in this Section, using an inert fluid (temperature-correction factors shall be applied to the test pressure employed).

Pressure vessels for inert systems containing non-flammable, non-toxic fluids require a hydrostatic (preferred) test of 1.5 times the MAWP, or a pneumatic test of 1.25 times the MAWP (where electrical equipment or research requirements do not permit a hydrostatic test). This result must then be multiplied by the lowest ratio of the vessel-material stress value, S_1 (at vessel-test temperature), to the corresponding design-temperature stress value, S_2 (see ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, UG-99, 100).

LAWRENCE BERKELEY LABORATORY

PRESSURE TEST RECORD

Date: ____________

Location of vessel (or system): Bldg. ______ Rm. __________

Description: ______________________________

____

____

Pressure Vessel ☐ Pressure System ☐ (check box)

"Pressure-Tested" Label attached ☐

TEST INFORMATION:

1. Test Pressure _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ ____________ Pa (________ ksi)
2. Testing fluid (oil, He, etc.) _ _ _ _ _ _ _ _ _ _ _ _ _ _ ____________
3. Test temperature _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ ____________ °C (________ °F)
4. Design temperature _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ ____________ °C (________ °F)
5. Safety Case _ _ _ _ _ _ _ _ _ _ _ _ _ _ ____________
6. Responsible Designer _ _ _ _ _ _ _ _ _ _ _ _ _ Name: ____________
7. Responsible User _ _ _ _ _ _ _ _ _ _ _ _ _ _ Name: ____________

   Dept.: ____________

   Divn.: ____________

8. Diameter measurements (for pressure vessel tests only)

Location (marked)	Before testing	After testing	Difference (+ or −)

Remarks: ______________________________

Test by: ______________________________

C & M, Mech. Shop

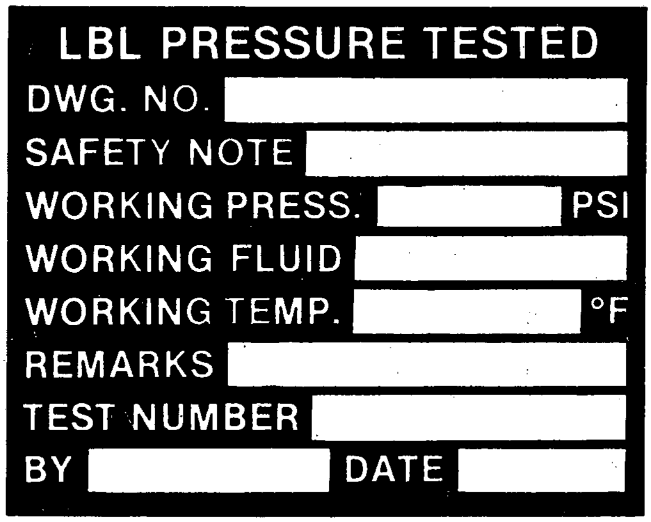
Send this completed form to the LBL Engineering Coordinator, Environmental Health and Safety Department

Witness: ______________________________

RL-6546

Fig. III.Q.-1

New Section 2/84



LBL PRESSURE TESTED
DWG. NO.
SAFETY NOTE
WORKING PRESS. PSI
WORKING FLUID
WORKING TEMP. °F
REMARKS
TEST NUMBER
BY DATE

Fig. III.Q.-2 "LBL Pressure Tested" label.

Pressure vessels for reactive systems containing oxygen, or flammable, toxic, or radioactive fluids must be tested to 2.0 times the MAWP with an inert liquid (preferred) or gas. This result must then be multiplied by the lowest ratio of the vessel-material stress value, S_1 (at vessel-test temperature), to the corresponding design-temperature stress value, S_2 (see ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, UG-99, 100).

When testing pressure vessels close to the yield strengths of their construction materials, strain-gauge measurements shall be made at high-stress locations. Diameter measurements shall also be taken which are accurate to within 0.025 mm (0.001 inch), both before and after testing, to show whether detectable plastic yielding has occurred during pressurization.

In cases where the strength of the vessel is questionable (old or unknown design), strain-gauge measurements shall be made during testing, and diameter measurements shall be taken before and after testing. The Maximum Allowable Working Pressure (MAWP) for ASME Pressure Vessels, Section VIII, Division 1, made of the acceptable ductile materials listed, shall not exceed 0.4 times the test pressure and shall comply with UG-101.

1.3.2 Pressure Systems

Inert-substance pressure systems which will operate with non-hazardous liquids, inert gases, or compressed air shall be tested hydrostatically (preferred) at 1.5 times the MAWP or pneumatically at 1.25 times the MAWP using an inert fluid. This result must then be multiplied by the lowest ratio of the vessel-material stress value, S_1 (at vessel-test temperature), to the corresponding design-temperature stress value, S_2 (see ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, UG-99, 100).

Reactive-substance pressure systems which will operate with oxygen or with flammable, toxic, or radioative fluids shall be tested at 2.0 times the MAWP using an inert liquid (preferred) or gas. This result must then be multiplied by the lowest ratio of the vessel-material stress value, S_1 (at vessel-test temperature), to the corresponding design-temperature stress value, S_2 (see ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, UG-99, 100).

See Chapter III.P, Pressure Vessel and System Design, Fig. III.P.-1 for relationships of test pressures to Maximum-Allowable Working Pressure (MAWP) and Maximum Operating Pressure (MOP).

1.3.3 Leak Testing or Leak Checking

Pressure vessels and systems shall be leak-checked at their MAWP after successful pressure testing. Gross leakage can be detected by observing the drop in pressure on the test gauge during pressure testing, and can be pinpointed with leak-detection fluid. Small leaks can be located with commercial leak detectors.

Caution:

Open flames shall not be used for peak-checking.

Remote-operation vessels and systems shall be remotely leak-checked.

Manned-area leak-checking of pressure-tested, remote-operation vessels and systems shall be limited to a maximum of 20% of the test pressure.

1.3.4 Repairs

If a leak is detected during pressure testing of a manned-area vessel or system, and it is decided to repair the leak before completing the test, the pressure shall be reduced to not over one-half the immediately preceding test pressure while locating the leak.

Caution:

For safety reasons, a system or vessel shall not be repaired while it is pressurized, unless specifically authorized by an Operational Safety Procedure or by the Mechnical Safety Committee.

1.3.5 Modifications

Any modification to the vessel or system, other than repair or duplicate replacement of existing components, shall be recorded in a revision to the applicable ESN or ESNE.

1.3.6 Inspection and Retesting

All high-hazard pressure vessels and systems shall be inspected at least every three years, and retested remotely at least every six years, unless otherwise specified on the ESN or ESME.

Low-hazard pressure equipment, unless otherwise required, need not be periodically inspected and retested.

1.3.6.1 Inspection

Pressure inspection is performed by the Pressure Inspector and is recorded on a "Pressure Inspection Record" form (Fig. III.Q.-3). After an inspection has been completed, this form shall be signed by the User and returned to the Engineering Coordinator for filing as a permanent record.

Any modification other than repair or duplicate replacement of existing components, shall be reflected by a revision of the applicable ESN or ESME. If a vessel or system has been modified, it shall be retested before further operation.

LAWRENCE BERKELEY LABORATORY

PRESSURE INSPECTION RECORD

Date: ______________________

Location of vessel or system: Bldg. ______, Rm. ______

If vessel or system still in use? Yes ______ No ______

If not in use, refer to the LBL Engineering Coordinator for disposition, (Environmental Health and Safety Dept.)

Pressure Vessel ☐ Pressure System ☐ (check box)

INSPECTION INFORMATION:

Inspect the following and check (√) appropriate column, explaining as required. (Enter "N/A" under Remarks if item is not applicable)

Item	Satis-factory	Unsatis-factory	Remarks
1. General appearance of system (or vessel)			
2. Relief devices are: a. Property set (have checked; reset as required)			
b. Properly sealed			
c. Pointed in safe direction or safely vented			
3. All fittings are tight			
4. Replaced or added fittings, gauges, valves, (and piping*) are properly rated			
5. All system components are adequately secured			
6. Valve packing nuts are tight, and locked (if locking type)			
7. Oil is not apparent on or in* gas (especially oxygen) systems			
8. The outside surface of the vessel shows no evidence of strain, damage, or corrosion			
9. The inside surface of the vessel shows no evidence of strain, damage, or corrosion			
10. Lined vessel vent path is unobstructed: Check with helium			
11. Vessel or system seals are leak-tight. Have replaced as required.			
12. In my opinion, the vessel or system is safe for continuing operation.			
13. Vessel or system was pressure tested within the last 6 years, or as required by the safety note. (If not, and certified for manned-area operation, retest it and submit a Pressure Test Record in place of this Pressure Inspection Record).			

Inspected by: ______________________________

C & M, Mech. Engrg., EH&S

CERTIFICATION:

As the professional person responsible for safe operation of this system (or vessel), I certify that, to the best of my knowledge, since last tested at LBL this vessel (or system) has not been critically modified, has not been subjected to temperature or pressure cycling in excess of its design imitations, has not been subjected to temperatures or pressures in excess of those for which it is rated, that all applicable listed conditions are satisfactory, and that I consider this vessel or system safe for operation in a ______________________________ (manned or remote) area within the limitations of the Pressure Test for ______________________ (three or less) more years as required by the safety note for this vessel or system.

____

RESPONSIBLE USER

Send this completed form to the LBL Engineering Coordinator
Environmental Health and
Safety Department

RL-6547

New Section 2/84

Fig. III.Q.-3

1.3.6.2 Retesting

Pressure vessels shall be retested at the same pressure as the initial test, unless otherwise specified in the ESN or ESNE.

Inert-substance pressure systems that operate with non-hazardous liquids, inert gases, or compressed air shall be retested at 1.5 times the MAWP with an inert liquid (preferred) or at 1.25 times the MAWP with an inert gas.

Reactive-substance pressure systems that operate with oxygen or with flammable, toxic or radioactive fluids shall be retested at 2.0 times the MAWP with an inert liquid (preferred) or gas.

The result of the retest shall be recorded on the "Pressure Test Record" form (Fig. III.Q.-1) and sent to the Engineering Coordinator who shall then update the "LBL Pressure Tested" label on the vessel or system.

1.3.7 In-Place Pressure Testing

1.3.7.1 Responsibilities

The Designer shall prepare the required test procedure, direct the testing personnel, and witness in-place pressure testing of vessels and systems for which he is responsible.

The User shall be similarly responsible for in-place retesting of pressure equipment for which he is responsible.

1.3.7.1 Responsibilities (cont)

Although other individuals may be designated to observe and direct testing or retesting, the responsibility for safe conduct of the test and safe functioning of tested pressure equipment cannot be delegated.

1.3.7.2 Test Procedure

A written test procedure is required for every high-hazard pressure test conducted in the field. If only a safety manifold or equivalent (see Figs. III.Q.-4 and III.Q.-5) is employed, use the applicable standard procedure, specified in paragraphs 2 and 3, for pressure testing in-place.

Because the condition requiring that testing be conducted in-place is usually apparent to the Designer, the test procedure should normally be included in (or appended to) the ESN or ESNE.

1.3.7.3 Test-Procedure Approval

Procedures for in-place testing of high-hazard vessels and systems shall be approved by the Mechanical Safety Committee which maintains a complete file of all in-place testing procedures that it approves.

The Environmental Health and Safety Department shall be notified if toxic or radioactive material is involved.

The Building Manager or area Supervisor shall be advised of pressure tests planned to occur in his facility.

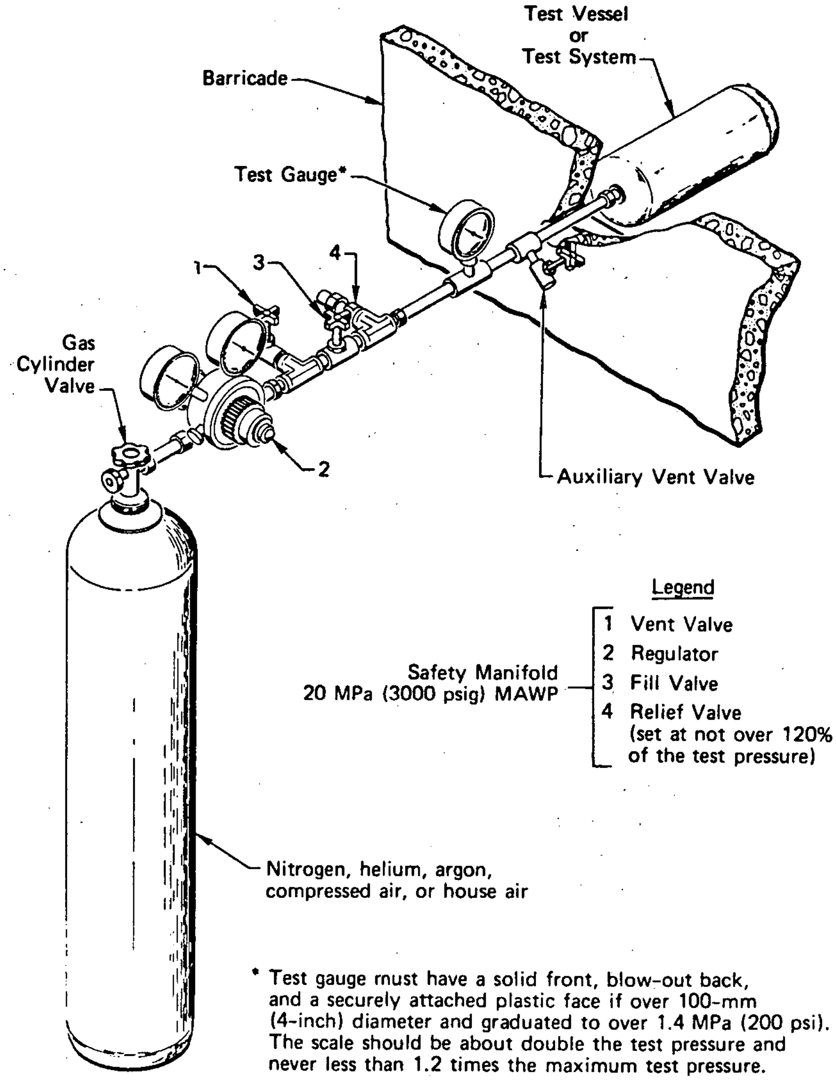


Fig. III.Q.-4 Setup for pressure-testing with gas.

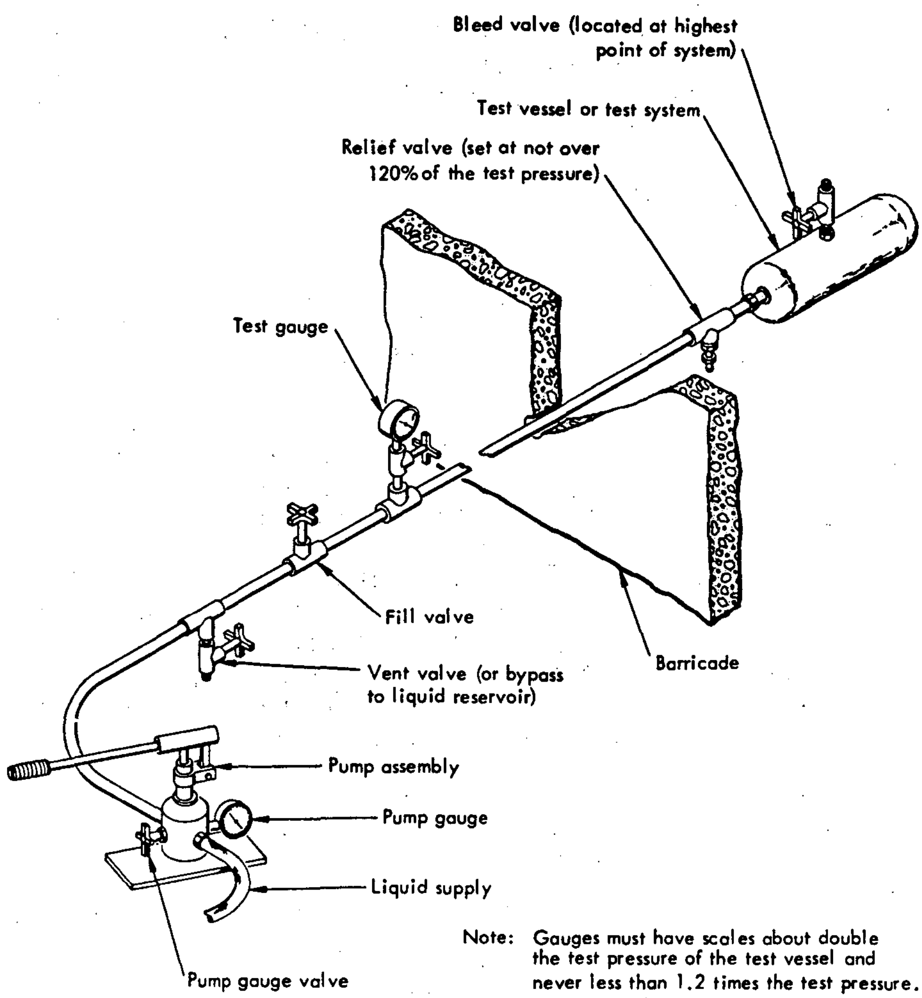


Fig. III.Q.-5 Setup for hydrostatic pressure tests.

1.3.8 Test Personnel

All pressure tests shall be conducted remotely by a Pressure Inspector who is a Plant Maintenance Technician, a Physical Plant Mechanic, or a Machinist in the Assembly Shop and shall be observed (or conducted) and certified by a member of the Mechanical Safety Committee.

1.3.9 Precautions

1.3.9.1 Pressure testing with a gas is more dangerous than testing with a liquid. Therefore tests shall be conducted with liquids whenever practical.

1.3.9.2 If practical, fill the test vessel with solids such as balls or rods. Filling the vessel with solids reduces the available energy in case of violent vessel failure.

1.3.9.3 The equipment being tested shall be barricaded, the controls and operators shall be shielded, and all unauthorized personnel shall be evacuated. Selective shielding against possible projectiles, fragments, and liquid jets should be considered.

1.3.9.4 Signs reading "Danger--High-Pressure Test in Progress--Keep Out" shall be borrowed from EH S, B78B, and shall be posted at all approaches to the test area.

1.3.9.5 For in-place testing with liquids, all air shall be removed from both the testing system and the equipment to be tested. Compressed air will expand violently in case of vessel failure. Spongy action of pumping equipment usually indicates the presence of trapped air.

2.0 STANDARD PROCEDURE FOR PRESSURE TESTING IN-PLACE WITH GAS

2.1 Applicability

This standard may be used for conducting low- and intermediate-pressure, in-place gas tests with safety manifolds, for gas testing at up to 20 MPa gauge (3000 psig), are available from the Plant Maintenance Technicans Shop in Building 76. Warning signs may be borrowed from the same building.

2.2 Pretest Procedure

2.2.1 The following actions shall be taken before actual pressure testing is started (refer to Fig. III.Q.-4).

2.2.2 The Maintenance personnel (Bldg. 76) shall issue the appropriate safety manifold and required warning signs, in accordance with the approved test procedure.

2.2.3 Barricade the test vessel or system, or install personnel shielding.

2.2.4 Attach the safety manifold to the test vessel or system with adapters and tubing rated at or above the testing pressure.

2.2.5 Signs reading "Danger--High Pressure Test in Progress--Keep Out" shall be posted at all approaches to the test area.

2.2.6 Back-off the Regulator Adjusting Screw (counter-clockwise), open Vent Valve (1) close Fill Valve (3) and connect the regulator to the supported compressed-gas cylinder.

2.2.7 The test system shall be checked by a member of the Mechanical-Safety Committee who is authorized to prohibit testing if, in his opinion, the test setup is unsafe, the system has not been properly identified, or all precautions in this procedure have not been observed.

2.3 Test Procedure

2.3.1 Persons not directly involved in the test shall leave the area. A member of the Mechanical-Safety Committee (or his designated alternate) shall witness the test, which shall consist of the following steps:

1) Measure and record test-vessel dimensions as indicated on the test procedure. (Omit this step and Step 13 below when only a system is being tested.)

2) With Fill Valve (3) closed, Vent Valve (1) open, and Regulator Adjusting Screw (2) backed-off (counter-clockwise), slowly open Gas-Cylinder Valve.

3) Close Vent Valve (1).

4) Turn Regulator Adjusting Screw (2) until about 110% of the test pressure is indicated on the regulator low-side pressure gauge.

5) Open and close Vent Valve (1) to confirm accurate regulator setting; then close Vent Valve (1).

6) Close Gas-Cylinder Valve, open Fill Valve (3) and confirm by the low-side regulator gauge reading that the flow path is open to the test vessel or system. Then close Fill Valve (3) and slowly open Gas-Cylinder Valve.

7) Slowly open Fill Valve (3).

8) When test vessel or system has reached and specified test pressure, close Fill Valve (3) and Gas-Cylinder Valve, and open Vent Valve (1).

9) Periodically check Test Gauge for signs of vessel- or system-leakage during the 30-minute (or otherwise specified) pressure-hold time.

2.3 Test Procedure (cont)

10) If unacceptable leakage is observed, open Auxiliary Vent Valve to drop the system to the lowest-possible pressure for locating the leak. This leak-test pressure must never exceed one-half the immediately preceding pressure applied to the system. Locate the leak, drop the pressure to zero, repair the leak, and repeat Steps 1-9.

Caution:

This vessel or system has not yet been proven safe for manned-area operation. If leakage is minor, complete the pressure test remotely and leak-test later (after Step 13) at a pressure (not exceeding the MAWP) that you have by then established as safe. Reduce the pressure to zero before repairing any leaks.

If a leak is detected past a seal of a test vessel, as distinguished from a minor fitting peak, repair as required and repeat the entire pressure test.

11) If the leak rate is acceptable, hold the test pressure for the required time, then release the pressure by opening Fill Valve (3) or the Auxiliary Vent-Valve.

12) Verify that the Gas-Cylinder Valve is closed and that both regulator gauges read zero.

13) After 30 minutes, remeasure and record diameters to confirm that the vessel has not permanently expanded.

2.4 Leak Checking

After pressure testing, leak-check (as required by the ESN or ESNE) the manned-area gas vessel or system at its MAWP.

2.5 Labeling

If the vessel or system successfully passes the pressure test, the Pressure Inspector shall label (Fig. III.Q.-2) the tested equipment. The Engineering Coordinator shall sign the Pressure-Test Record and file it.

3.0 STANDARD PROCEDURE FOR PRESSURE TESTING IN-PLACE WITH LIQUID

3.1 This procedure may be used for conducting in-place hydrostatic pressure tests.

3.2 Pretest Procedure

3.2.1 The following actions shall be taken before actual testing is started (refer to Fig. III.Q.-5).

3.2.2 Signs reading "Danger--High Pressure Test in Progress--Keep Out" shall be posted at all approaches to the test area.

3.2.3 Fill Pump Gauge and Test Gauge with testing liquid, close Pump Gauge Valve, close Test-Gauge Valve and assemble as shown in Fig. III.Q.-5 using components rated at or above the test pressure.

3.2.4 Remove, or fill with liquid, any test-system gauges, and plug openings as required. Caution: If gas pressure is required to operate any test-system valves or components, the Designer (or User) shall include instructions for their operation in the pretest- or test-procedure and shall be present whenever such valves or components are operated. These valves or components shall be tagged with their rated MAWP before being operated.

3.2.5 Close Vent Valve, open Fill Valve, open Bleed Valve, and fill the system with liquid using (or through) the pump.

3.2.6 Close Bleed Valve, open Pump-Gauge Valve, open Test-Gauge Valve, and and close Fill Valve.

3.3 Test Procedure

3.3.1 Persons not directly involved in the test shall leave the area. A member of the Mechanical-Safety Committee (or his designated alternate) shall witness the test, which shall consist of the following steps:

1) Measure and record diameters at mid-point and quarter-points of cylindrical test vessels (at pole and waist of spherical vessels). (Omit this step, and Step 7 below, when only a system is being tested.)

2) Open Fill Valve and slowly pump to the test pressure.

3) Close Fill Valve.

4) Periodically check test-gauge for signs of vessel leakage during the 30-minute (or otherwise specified) pressure-hold time.

5) If unacceptable leakage is observed, open Vent Valve and Fill Valve to drop system pressure to zero, then locate and repair the leak. Remove all air from the system, close Vent Valve, then slowly pump again to the test pressure, and hold for the required time.

6) If the leak rate is acceptable, hold test pressure for the required time by opening Fill Valve, pumping as required and then closing Fill Valve. Then open Vent Valve, Fill Valve, and Bleed Valve to release pressure and drain the liquid from the system.

7) After 30 minutes remeasure and record diameters to confirm that the vessel has not permanently expanded.

3.4 Leak Checking

After pressure testing, leak-check (as required by the ENS or SNE) manned-area systems which operate with gas at their MAWP. Leak-check vessels and systems which operate with liquids to the extent necessary to assure the functional reliability required, as specified on the ESN or ESNE.

3.5 Labeling

If the vessel or system successfuly passes the pressure test, the Pressure Inspector shall label (Fig. III.Q.-2) the tested vessel or system. The Engineering coordinator shall sign the Pressure Test Record and file it.

III.R HYDROGEN FURNACES

III.R. HYDROGEN FURNACES

In addition to the general flammable-gas safety rules shown in Sections II.D, II.H, II.J, and III.C, the following special guidelines shall be observed for operation of hydrogen furnaces:

A. CONSTRUCTION

1. All hydrogen furnaces shall be constructed of material resistant to impact and heat shock and not subject to hydrogen embrittlement.

2. The furnace and associated equipment shall be micro-range vacuum-tight at all operating temperatures. It shall be checked for leaks with helium or nitrogen gas before first-use, at both room- and operating-temperatures.

3. Personnel shields shall be placed around all hot-outside surfaces on the furnace to prevent people from touching them and getting burned. Shields shall also be installed as a shrapnel barrier when the explosion risk is high, as determined by the Mechanical-Safety Committee.

4. All electrical equipment and wiring on and within 10 feet of the furnace and hydrogen supply system shall be explosion proof or intrinsically safe, Class I, group B, Division I (NFPA 70-NEC). All equipment and wiring within 25 ft of the furnace shall be suitable for Division 2 installations.

5. When hydrogen furnaces are located in large rooms, existing nonexplosion-proof electrical equipment shall not be operated, even though it is outside the boundaries defined in Item 4 above, if it is more than 5 ft above the floor, or above the level at which hydrogen may evolve.

6. In lieu of explosion-proof equipment all electrical devices (switches, relays etc.) shall be totally enclosed and purged with nitrogen at a positive pressure of not less than 0.1 inch of water when power is on. Other requirements regarding purge-gas flow-rate, alarms, and other items, as stated in NFPA 496, Type Z Purging, shall be incorporated.

7. A solenoid valve shall be installed in the high-pressure section of the hydrogen-supply line and shall be interlocked with the room combustible-gas detectors to shut off the hydrogen flow in case of an alarm or power failure.

   After a power failure, both the solenoid valve in the hydrogen supply line and the furnace shall be manually reactivated.

8. A solenoid valve shall be located in the inert-gas supply line and shall be interlocked with the combustible-gas detectors to flood and purge the furnace with helium or nitrogen in case of an alarm.

   The inert-gas supply cylinder should be located outside the laboratory room to permit manual activation of the inert-gas flow from the outside.

9. All safety devices on the furnace and associated equipment shall be checked at least every 6 months by the user. The user shall notify the EH S safety coordinator, in writing, of said check. The safety coordinator shall ensure that these periodic safety checks are made.

10. The furnace room shall be heated by steam, hot water, or any other indirect means. Exposed-ignition sources shall not be used.

B. INSTALLATION

1. Hydrogen furnaces shall be installed and operated only in rooms having automatic-sprinkler protection.

2. Installation of flash arresters in hydrogen-gas supply lines for hydrogen furnaces is recommended. The Rego 869 Series Water-Seal Flash Arrester is suitable for this purpose. The Matheson Series 6103 dry-type flash arrestor shall not be used.

3. Installation of a check valve in the inert-gas supply line is recommended.

4. The furnace and associated equipment shall be electrically grounded and bonded to minimize voltage- capacitive- , and electrostatic-spark hazards.

5. Flammable-gas detectors shall be mounted above the furnace and also above the hydrogen-supply cylinder if the cylinder is located inside the building (cylinder-location outside the building is preferred). The gas detectors shall be set to give an alarm at 10% of the Lower Explosive Limit (LEL) for hydrogen.

6. Forced-air systems with exhaust near the ceiling shall be used in all laboratory rooms having hydrogen furnaces in operation. In large laboratory rooms which do not have the recommended air ventilation, a hood-and-blower unit discharging to the outisde of the building shall be provided above the furnace and the hydrogen cylinder to remove any escaping gas.

The capacity (cfm) of the exhaust blower must be calculated to insure that the maximum concentration of H_2 does not exceed 10% of the LEL based on the maximum expected leak rate of H_2 over a time period of 8 hours. In most cases this is calculated through the formula:

$$\log_{10}\left(1 - \frac{QC}{G}\right) = -\frac{Qt}{2.3P},$$

where

C = concentration of H_2 expressed as a fraction at any time, t

P = room volume (ft^3)

G = rate of generation of addition of H_2 (ft^3/min)

Q = ventilation rate (ft^3/min).

Consideration must be given to deviations from the ideal conditions for the location of air inlets and outlets, room baffling, location of hoods, and any other factors affecting exhaust efficiency.

7. The exhaust fan should be explosion proof.

8. Proper fire extinguishers shall be located at points of free access, within a few feet of the furnace.

9. Tubing used for supplying hydrogen to the furnace area shall be protected from physical damage.

C. OPERATION

1. An Operational Safety Procedure (OSP) must be prepared by the owner or person in charge of the furnace. Guidelines for writing the OSP can be found in the LBL Health and Safety Manual, Pub. 3000, Chapter 1, Appendix E. The objective of the OSP is to prepare a safety proceudre, not a detailed operation manual.

2. The furnace shall be flushed with an inert gas to remove all traces of air before introduction of hydrogen.

3. A positive hydrogen pressure shall be maintained in the furnace at all times to prevent leakage of air into the system (auto-ignition-temperature for hydrogen in air is 585°C).

4. Other flammable gases shall not be used unconfined in the laboratory room while the furnace is in operation, since its hot surfaces could act as an ignition source for these gases.

5. At the end of each experiment the heater shall be turned off, the hydrogen flow shut off, and the furnace flushed with inert gas.

6. The user shall make sure that hydrogen-furnace-use proposals are reviewed by a member of the Mechanical-Safety Committee and the EH S Department.

7. Only trained personnel thoroughly familiar with the hydrogen furnace shall be authorized to operate it. A list of qualified and authorized operators, including their phone numbers, shall be posted at the hydrogen furnace.

8. A schematic diagram of the furnace system and an OSP shall be filed with the Mechanical Safety Committee and the EH&S Department, and also posted at the furnace.

9. The hydrogen-furnace system and the OSP shall be reviewed by a member of the Mechanical Safety Committee and the EH&S Department before approval for operation is given.

10. A listing of all hydrogen furnaces at LBL shall be maintained by the EH&S Department and the status of the furnaces shall be checked periodically during the normal safety inspection program.

11. Any modification to an existing hydrogen-furnace system requires new safety reviews by a member of the Mechanical Safety Committee and the EH&S Department.

D. REFERENCES

1. Health and Safety Manual, LBL Pub. 3000, Chapter 13.

2. NFPA 50A, 70, and 496.

3. NBS Safety Guide No. CM-4.

4. "Protection of Laboratories and Buildings from Hydrogen Explosion," Hazards-Control Progress Report No. 26, UCRL 50007-66-2.

III.Z BIBLIOGRAPHY OF STANDARD CODES

III. Z. Bibliography of Standard Codes

General guidelines for equipment can be found in the following codes:

1. ASME Boiler and Pressure Vessel Code, Section III, Nuclear Power Plant Components.

2. ASME Boiler and Pressure Vessel Code, Section VIII, Pressure Vessels.

3. American Standard Code for Pressure Piping, ASA B31.1 and ASA B31.3.

4. Interstate Commerce Commission Regulations, Tariff No. 19.

5. Safe Handling of Compressed Gases, Pamphlet P-1, Compressed Gas Association.

6. Compressed Gases, Safe Practices Pamphlet No. 95, National Safety Council.

7. National Fire Protection Association, Vol. 1, Flammable Liquids, Vol. 2, Gases.

8. National Fire Protection Association National Electrical Code, Article 500, Hazardous Locations.

9. American Petroleum Institute, API RP-500. API recommended practice for classification of areas for electrical installations in petroleum refineries.

10. Instrument Society of America RP-12.1. Electrical instruments in hazardous atmospheres.

11. Instrument Society of America RP-12.2. Intrinsically safe and non-incendiary electrical instruments.

12. Instrument Society of America RP-12.1. Instrument purging for reduction of hazardous area classifications.

13. National Fire Protection Association Technical Committee Report 1967 NFPA No. 496, Purged Enclosures for Electrical Equipment, 1967.

    NFPA No. 493-PT, Intrinsically Safe Process Control Equipment for Use in Hazardous Locations.

    NFPA No. 50B-T, Liquefied Hydrogen Systems at Consumer Sites.

    NFPA No. 68, Guide for Explosive Venting

14. Handbook of Compressed Gases, Compressed Gas Association, Reinhold Publishing Corporation, New York (1966).

15. Handbook of Hydrogen Handling Equipment (PB 16 183 5), U.S. Dept. of Commerce, Office of Technical Services, Washington, D.C.

16. Fire Protection of AEC Electronic Data Processing System, Safety and Fire Protection Technical Bulletin 12, 1968.