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Requirements for an ES&H Assurance Program at the Working Levels of Organization

Martin S. Tierney, Andrew C. Ellingson

Sandia Laboratories

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Printed July 1979

**REQUIREMENTS FOR AN ES&H ASSURANCE PROGRAM
AT THE WORKING LEVELS OF ORGANIZATION**

M. S. Tierney
A. C. Ellingson
Special Projects Division 1418
Sandia Laboratories
Albuquerque, NM 87185

ABSTRACT

Some general requirements for an ES&H assurance program at the working level are identified and their feasibility of implementation is partially tested by application to an existing research division at Sandia Laboratories.

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REQUIREMENTS FOR AN ES&H ASSURANCE PROGRAM AT THE WORKING LEVELS OF ORGANIZATION

I. INTRODUCTION

Background

Sandia Laboratories, under contract to the Division of Operational and Environmental Safety of the Department of Energy (DOE) is investigating how the disciplines of quality assurance (QA), reliability (R), and human factors (HF) might be used to the advantage of Environment, Safety, and Health (ES&H) programs. As part of this effort, a generalized model assurance program, based on QA, R, and HF principles but specifically tailored to ES&H program needs, has recently been developed,¹ and certain aspects of the model program have been compared with the present practices of three existing institutional ES&H organizations at Sandia Laboratories, Albuquerque.^{2,3,4} The purpose of these comparative studies was to match the model assurance program with "reality" and to see which of its elements are practicable.

The present report begins to address this very important question: "Can the model assurance program be implemented at the working levels of organization?" It appears that the only way practicability at the working level can be determined is by the case study method. On a case-by-case basis, the requirements that are implicit in each of the model plan's elements must be matched with current practices of several organizations engaged in work that may have ES&H impacts. Then follows an estimation of overall costs, benefits, and levels of difficulty involved in changing the existing organizational practices to ones that produce an adequate level of assurance consistent with the model. Now it is possible to judge the potential value of the specific model assurance program. The present study represents a first step in the application of such a procedure. Here an attempt has been made to approach the question of practicability by first constructing a generic ES&H assurance plan for working-level organizations that is based upon

he more widely-applied model plan and studies mentioned earlier. Then the elements of this generic working-level plan were compared with the practices of an existing R&D organization at Sandia Laboratories, Albuquerque. Some of the necessary steps were taken to convert these practices to those required by the generic plan in order to gain a measure of the feasibility, cost, and some of the possible benefits of such a conversion. Thus, this report presents partial results of one case study and some generalizations that emerge regarding the structure of an idealized working-level ES&H plan. Though the results of this study are encouraging from the standpoint of implementing an assurance plan addressing ES&H concerns at the working levels of organization, further work is necessary before a generic plan can be derived that is suitable for the wide variety of working-level organizations engaged in DOE-sponsored activities.

The key terms used in this report are defined below. Certain definitions will have to be modified later, or liberally interpreted, if they are to have practical meaning for working-level (particularly R&D) organizations. Exceptions will be explained in each case.

Department	The generic "working-level" organization. An organizational unit of an institution devoted mainly to the practice of a single type of activity, containing a maximum of perhaps 100 persons.
Hazard	A potential source of harm to persons or damage to property or environment.
Risk	A compound measure expressing both the likelihood and severity of adverse effects of a hazard (Reference 5, pp. 70, 94).
Safety	The quality of being safe; a condition whose attendant risks are judged to be acceptable (Reference 5, p. 8).

In addition, the word "analysis" will always imply an effort toward viewing the phenomenon or concept being studied in terms of its component parts and their interrelationships. The effort may include quantification of the interrelationships and the "behavior" of the

component parts. The word "assessment" is more general; it may involve engineering judgment, expert opinion, or precedent, in addition to or in place of analysis.

II. ELEMENTS OF A GENERIC ES&H ASSURANCE PROGRAM AT THE DEPARTMENT LEVEL

A flow chart for the generalized model ES&H assurance program mentioned in the introduction is shown in Figure 1. As stated earlier, the model is intended for application at all levels of organization that are involved in ES&H assurance and is therefore a somewhat abstract representation of how an entire ES&H program based on assurance principles might be implemented. If all elements of the model are in place, there should ideally be assurance (in the technical sense) that ES&H requirements are being met. There are 37 elements requiring activities at one or more levels of the institution involved in assurance.

Of the 37 elements, 9 were selected as building blocks of a generic department program (these 9 are outlined by dashed lines in Figure 1). In a first approximation, the items of Figure 1 that are not outlined seem to fall in the category of activities required of higher-level management and institutional support organizations, although further study may reveal that some departmental participation is required. The motivation behind the choice of the nine outlined elements is explained below.

1. Facilities/Projects--List and Classify

Department management should know the facilities or projects for which it is responsible. Customarily, a department is responsible for all or parts of certain institutional facilities or projects, which may range from clerical support to experimental studies with special apparatus to the handling and storage of hazardous materials. A department is usually assigned working spaces to house the facility or project. The working space may be part of a single room in a building, or it may be a widely dispersed complex of field test areas serving a common purpose. In any case, the units of working space should be identifiable at any point in time. Each facility and project, and the working spaces assigned to them, are thus appropriately identified by the responsible department. Note that working spaces themselves are facilities from the viewpoint of a plant engineering department.

Figure 1. Generalized Model of an ES&H Assurance Program in which Elements Outlined by Dashed Lines May Apply at the Department Level (See Text for Explanation)

2. Identify Hazards

Department management is in a unique position to identify the hazards that reside in the facilities or projects for which it is responsible. Though certain hazards will ideally be identified in the design phase of a facility/project, the identification of operational hazards is appropriately accomplished at the working level (if necessary, with the assistance of experts) because department staff and management are often the only persons who are aware of (or may suspect) the existence of the hazard. The important question here concerns methods for hazard identification.

There appear to be no universally acceptable procedures for identifying hazards in operations. Lists of typical hazards, such as that shown in Appendix B of this report, may prove useful. However, it is strongly emphasized that such checklists must be supplemented with thoughtful observation. To identify hazards, the responsible parties in an operating department must (and usually do) rely on prior experience and knowledge, analogy with proven hazards, and advice from ES&H experts.

3. Prioritize Risk Assessments

In order to best use the necessarily limited time and resources allocated to ES&H activities, department management should prioritize efforts devoted to the assessment of the risks attending the set of hazards residing in department facilities or projects.

It is clearly the responsibility of department management to limit all risks attending departmental operations. How this is accomplished is not clear since circumstances vary among organizations. All organizations are, however, faced with the problem of optimally allocating the necessarily limited resources available for risk assessment prior to the realization of the information that those assessments would provide. In other words, how does the manager determine which hazards are "important" before devoting time to a study of their attendant risks? This problem is similar to that of hazard identification, in that there are no established procedures. The following suggestions are based on limited experience at Sandia.

Having identified the hazards (Item 2 preceding) residing in each departmental facility or project, the responsible party classifies them according to their status among the several categories of controllable risks which minimally include the following:

- (a) Hazards routinely encountered and accepted by the public (automobiles, certain home furnishings and appliances, region-wide natural hazards),
- (b) Occupational hazards routinely encountered and accepted by workers in construction and the "clean" industries (trucks, heavy equipment, power tools, scaffolding, etc.), and
- (c) All hazards not manifestly contained in categories (a) and (b) above, i.e., "unusual" hazards.

Items in the last category, (c), then receive first priority as candidates for further risk assessment, with categories (b) and (a) taking second and third priority, respectively. The reasons for this suggested ranking of hazard categories at the department level are three in number.

First, the unusual hazards residing in the department warrant special attention because (once again) department personnel are often the only persons aware of their existence and the possibly unique conditions under which they may be realized.

Second, departmental hazards falling in categories (a) and (b) are usually not unique to the department. The risks attending public hazards and frequently encountered occupational hazards are usually well-defined and documented. Mitigation and control actions for these classes of hazards are usually implemented at the institutional, or even interinstitutional, level.

Finally, with few exceptions, only "unusual" hazards are likely to be of concern for public safety and environmental protection. For these reasons, mitigation and control of hazards in categories (a) and (b) are best accomplished by relying on voluntary consensus standards and selective group training that draws upon the resources of the institutional ES&H organizations through the provision of lectures and training materials.

4. Assess Existing Risk

Department management is in a unique position to assess the risks of unusual hazards residing in departmental facilities or projects and to devise and require controls and procedures that minimize these risks. The unusual operational hazards identified in Item 3 preceding may realize harmful effects in several different ways, at different levels of effect, and with likelihoods that depend upon the conditions under which the hazard is encountered. Thus, department supervision and the technical staff are often the only persons capable of defining the realizable adverse effects of a hazard under the conditions of exposure that apply in departmental operations. Ideally, an assessment of the risks attending each hazard would follow the steps listed below (adopted from Reference 5, p. 18).

- (a) Identify all adverse effects,
- (b) Define conditions of exposure to each effect,
- (c) Relate effect/exposure combinations to the potential adverse health effects and property damage, and
- (d) Estimate overall risk.

The department management is clearly responsible for making risk assessments of unusual hazards that, at least, incorporate the spirit of the four steps, (a) through (d), outlined above.

The extent to which risk assessment extends beyond just the spirit of steps (a) through (d) depends upon many factors whose consideration would exceed the scope of this report: department resources to be devoted to ES&H activities, e.g., the nature of the particular hazard, and institutional policy. However, these problems are implied in setting a requirement for risk assessment: How far should the assessment be carried? What are the appropriate methodologies? Who pays the costs? Regarding costs, a formal risk analysis may prove to be necessary but can also be expensive. To ascertain typical analysis costs, the level of effort required to conduct and document two necessary studies of the risks of exposure to high concentrations of cold smoke and zinc chloride smoke was estimated.^{6,7} These studies, conducted by the staff of the Industrial Hygiene Division, Sandia Laboratories, Albuquerque, involved about 1.2 man-years total effort, or about 0.06 man-years effort per substantive page of report. The dollar costs are of the same order of magnitude (\$1000 per substantive page) as the

cost of writing the Environmental Impact Statements required by the National Environmental Policy Act (NEPA).⁸

A more significant (and feasible) activity at the department level is the provision of the controls and procedures to be employed in order to limit the risks attending an operational hazard, whatever the levels of risk may be. Though provision of hazard controls and mitigation procedures may not be a part of risk measurement per se, they are the logical end-product of any risk assessment, and it is clearly the department manager's responsibility to see that appropriate controls and procedures are applied. To this end, any desirable mitigation procedures or controls are considered to be a formal part of the ES&H Requirements shown in Figure 1. In many cases, the level of controls to be applied are mandated by Federal and state laws. In other cases, adherence to standards is required by DOE or other contracting agencies.

In summary, the activity "assess existing risk" means, for a department, a conscious effort applied to the identification of the risks attending each unusual operational hazard; an awareness of the standards that apply for hazard control; and, most important, the provision of adequate controls and procedures that mitigate adverse health effects and property damage. Thus, an assurance approach to ES&H compliance at the working level might allow considerable flexibility in the methodology of risk assessment and the specific techniques applied to hazard control, but such an approach would require that controls and procedures exist, be used, and be adequate to meet mandatory or, possibly, voluntary standards.

5. Store Information, Hazards/Risks per Facility/Project

To assist in relating department activities connected with the assurance model to institutional assurance activities, the department should maintain up-to-date records of the facilities or projects under its authority, the hazards associated with each facility or project, and the controls and procedures applied to the mitigation of each hazard, including, as appropriate, the risk assessments on which such procedures and controls are based.

The activity indicated here is simply one of recording the information obtained and the actions taken in the preceding four activity

items. As stated, the records should at least show the facilities/projects for which the department is currently responsible, the hazards residing in each facility/project, and a statement of controls and procedures applied. A format for such records is suggested in Section III without intending to limit flexibility. However, the requirements for audits and reviews of adequacy (to be discussed later) may dictate that different categories of information be easily identified and therefore result in constraints upon the level and ordering of information to be included in the records.

6. Monitor Factors (Known Hazards)

The day-to-day monitoring of the factors that contribute to the realization of known hazards (particularly the unusual hazards) is clearly the responsibility of department management. Management verifies the existence and use of the appropriate controls and procedures, but they must also be aware of changes in the factors that determine the levels and likelihoods at which a hazard is realized. Unnecessary changes in factors influencing risk would in general be undesirable. Those changes found necessary for programmatic reasons should be reviewed in the same manner as new hazards are reviewed (see Items 3 and 4 preceding and Item 9 following).

There should also be provision for a periodic, in-depth, review of department risk factors by an independent party, perhaps the institutional ES&H organizations. During such reviews, some departmental assistance would obviously be required, but the burden of the independent review would fall upon the auditors.

7. Monitor Methods (Controls) and Procedures

The day-to-day monitoring of the actual use of existing controls and procedures for hazard mitigation is a clear responsibility of department management, a responsibility that is carried in parallel with the requirement for maintaining awareness of potential changes in risk factors. The comments made in Item 6 preceding also apply here. In particular, there should be periodic, in-depth, reviews of hazard controls and mitigation procedures by an independent party emphasizing the adequacy of the controls and procedures. Since the independent review might require special knowledge of risk factors, health physics, industrial safety, and certain legal or voluntary standards, the review or auditing activity will draw upon resources of the institutional

ES&H organizations which will provide either the necessary specialists or training of an appointed auditing group.

8. Monitor for New Hazards

This item is similar to Items 6 and 7, previously discussed, and the comments made for those items also apply. The inspection of departmental facilities/projects for new hazards is a logical followup to Item 2 (Identify Hazards) and is an activity of which the department staff is uniquely capable. The activity implies a commitment of staff to a periodic inspection of work spaces and projects and to some education in the process of hazard identification.

9. Monitor Facilities/Projects Changes

The status of the department's current facilities or projects may change, thereby changing the nature of the hazards, the risk factors involved, or the kinds of controls applied to hazard mitigation. It is the responsibility of department management to be aware of any significant changes and to assess their effects upon safety goals. Thus, the activity mentioned here is part of a parallel activity involving the periodic reevaluation of risk factors (Item 6), controls and procedures (Item 7), and inspection for new hazards in existing projects (Item 8).

Though they are still somewhat vague in relation to a department-level program directed towards ES&H compliance and assurance, the nine elements just discussed may form the basis for such a program and the plan that guides it. The next section presents the outline of a generic ES&H Assurance Plan incorporating the nine elements/activities and other elements that are needed to tie working-level activities to the institutional and agency assurance program.

III. PLANNING FOR ES&H ASSURANCE AT THE LEVEL OF DEPARTMENTS

The activities appropriate to working-level organizations in an ES&H assurance program were sketched in the previous section, based on the set of activities set out in the model assurance program.¹ Following is the structure of a plan to guide the program at the level of a department. Planning for an ES&H assurance program at the working levels of organization may, in general, proceed along various paths and utilize different proportions of the "pure" planning strategies indicated below.

The Strict "Quality" Assurance Approach

An approach to planning that adheres strictly to quality assurance (QA) principles might incorporate all 18 of the general elements of QA used by the Nuclear Regulatory Commission (NRC),⁹ for example, by interpreting "quality" (or fitness for use) as compliance with ES&H regulations and standards. There is no question that compliance is an essential part of an ES&H assurance program. There are, however, drawbacks to the sole reliance on QA principles in formulating an ES&H assurance plan. First, a review of the 18 QA elements⁹ shows that most of them are intended to apply to hardware-oriented programs, i.e., programs assuring the quality of engineered devices or products, and that the meaning of some QA elements in relation to ES&H compliance is not clear. Second, a crisp definition of "quality" in terms of degrees of compliance with a specific set of regulations and standards is neither feasible nor desirable at present, owing to the diversity of ES&H regulations/standards that may apply. Existing ES&H regulations and formal standards are far from being uniform in application and unambiguous in content.

On the other hand, certain QA elements are sufficiently general to benefit the formulations of any plan: the elements that enjoin

- A policy,
- A program plan,
- An organization (to implement program),

- Records,
- Inspections (or reviews),
- Audits, and
- Corrective actions

all seem to be necessary for an assurance program. A clear statement of organization for ES&H assurance (who is responsible for each activity) is essential, as are records and the review and audit functions.

Military and Industrial Systems Safety Approach

Many useful elements of an ES&H program can be taken directly from the military standard outlining requirements for a systems safety program.¹⁰ Like quality assurance, the systems safety approach is inherently hardware-oriented, but the standard, which sets program requirements, includes other activities in addition to those elements it shares with QA standards. For instance, the needs for risk assessment (hazard identification and analyses) and historical systems safety data are spelled out, and rankings for hazard probability and hazard severity are suggested. Similar activities and elements are also stressed in texts or handbooks on systems and product safety.¹¹ In addition to emphasis on identification and analyses of the objects of concern (hazards), modern systems and product safety programs place emphasis on the need for active participation of management in the program. It is felt by some that the level of managerial concern for ES&H compliance is the major determining factor in achieving program success. The limited evidence available (mostly from the construction industry) suggests that managerial concern is a necessary, if not sufficient, element for an effective program.¹²⁻¹⁴

The Safety Professional's Approach

The mention of the construction industry prompts the consideration of yet another point of view concerning elements that should be included in ES&H program planning: the point of view of the professional in occupational safety. This approach recognizes many of the elements that were outlined under the QA and systems safety approaches just mentioned. In fact, occupational safety programs may be effectively organized around the following seven elements (Reference 15, p. 50):

1. Management Leaderships (assumption of responsibility and declaration of policy),

2. Assignment of Responsibility (to operating officials, safety directors, supervisors, committees),
3. Maintenance of Safe Working Conditions (inspectors, engineering revisions, purchasing, supervisors),
4. Establishment of Safety Training (for supervisors and workers)
5. Accident Record System (accident analysis, reports on injuries, measurements of results),
6. Medical and First Aid Systems (self-explanatory), and
7. Acceptance of Personal Responsibility by Employees (self-explanatory).

It is also evident that the safety professional's viewpoint incorporates elements that are much nearer to the "nuts and bolts" of working-level ES&H programs. The one drawback of this viewpoint, relating to ES&H assurance, is the partial emphasis on records and remedies that are after the fact of a realization of hazards (accident records versus hazard identification, medical and first aid versus prior prevention measures). The safety professional is, of course, deeply concerned with prevention and would certainly endorse strongly any program elements that really increase hazard awareness.

Though there are many elements common to each of them, these three approaches roughly specify the options available for planning strategies and provide specific ideas for incorporation in a plan for ES&H assurance at working levels. By combining some of these ideas with the nine activities described in Part II, the following, self-contained section presents an outline for a generic plan for working-level ES&H assurance. The outline is theoretical in nature, as in the model assurance program from which it was partly derived, and should not be considered a final product.

Annotated Outline of a Generic ES&H Assurance
Plan for Departments

1. Policy

1.1 Statement of Institutional ES&H Policy

1.2 Statement of Department ES&H Policy

Comments -- Departmental operations policy is specified by the department manager within the limits allowed and specified by higher levels of management.

2. ES&H Responsibilities

2.1 Of Department Management

The department manager and his delegated supervisors are responsible for implementing all functions and activities identified in the department's assurance plan.

Comments -- Normally, the department management delegates the tasks of implementation to a group of selected staff members and superiors (hereinafter called the department safety committee) who actually review operations, rules, and procedures, and maintain the required records.

2.1.1 Appointment of a Department Safety Committee

A department safety committee (DSC) shall be appointed to assist management in the implementation of certain ES&H functions to be specified in the department's ES&H assurance plan. The department manager shall also designate a chairman of the DSC from among the committee members.

Comments -- A DSC of at least one member is required. Though needs of each working organization vary and allowance for these needs should be made by building flexible plan requirements, a typical DSC member is appointed for a 1-year term. Appointments could be made on a semiannual basis so that there would be an overlap of 6 months between the terms of successive committees in order to provide continuity of purpose. It is also suggested that, prior to assuming office, each new member of the DSC complete a

short course in hazard identification and general safety conducted by institutional ES&H organizations or, if such organizations are not present at the institution, by an outside firm or agency designated by management.

2.2 Of the Department Safety Committee

The DSC is delegated the responsibility for completing specific tasks to be described in the section of the department's assurance plan that deals with compliance and assurance functions. Management may assign other ES&H-related responsibilities to the DSC.

Comments -- The chairman of the DSC is responsible for the scheduling of committee meetings and the conduct of business at meetings, the equitable division of the DSC's work load among its members, routine liaison between the committee and management, and the compilation of department safety records and reports. The DSC chairman might also schedule and conduct general safety meetings for the department.

2.3 Of Department Personnel in General

All department personnel are responsible for performing their work in a manner that is safe with respect to themselves, to their co-workers, and to the public. Personnel should be thoroughly familiar with any hazard controls and mitigation procedures involved in each of their tasks, and they should be alert for unanticipated hazards that may appear in the course of operations. All new hazards and unusual circumstances that might lead to unsafe conditions should be reported to supervision or to a member of the DSC.

Comments -- Apart from a general exhortation such as the one given above, other more specialized responsibilities of certain department personnel are stated in this section. These specialized responsibilities, for example, might derive from operations that are peculiar to the department's role (high-risk operations which, for example, might imply the need for special education in industrial safety or health physics) or from the statements of institutional and departmental policy.

2.4 Of Institutional Organizations toward the Department

The service organizations devoted to the disciplines of industrial safety, fire protection, environmental health, and occupational medicine are responsible for the provision of expert advice or training aids relating to their areas of concern upon request of department management. The service organizations are also responsible for the provision and interpretation of mandatory requirements, applicable voluntary consensus standards, and such approvals as specified in Section 3. If such service organizations are not present in the institutional structure, it is the responsibility of line management above the department level to obtain equivalent services and expertise, by contract if necessary, from firms or agencies outside the institution.

Comments -- The last requirement (for ES&H services and expertise independent of the working level) is an essential one in that an independent agent is needed to "couple" the department-level program to the assurance program at higher levels of organization by means of reviews for adequacy of procedures, audits for existence and use of procedures and controls, and also as a source of up-to-date information from which remedies for observed deficiencies can be constructed (the "helping hand" aspect of ES&H Assurance).

3. Department ES&H Functions

3.1 Identification of Department Facilities/Projects

The DSC shall identify the nature and location of all facilities, projects and field operations under departmental control or requiring the planned presence of department personnel.

3.2 Identification of Hazards

The DSC shall identify hazards that reside in the facilities, projects, and field operations under departmental control or requiring the planned presence of department personnel (see Section 3.1).

The methods used to identify hazards shall be approved by the appropriate institutional service organizations in the environment, safety, and health disciplines. If such service organizations are absent, management at the next level above department shall approve a method for hazard identification.

3.3 Safety Assessments

The DSC shall make, or cause to be made, appropriate safety assessments of the hazards identified during the activities of Section 3.2. The methods used to decide upon the kind of safety assessment to be employed for different classes of hazard and the methodologies for safety assessment of each class of hazard shall be approved by appropriate institutional service organizations in the environment, safety, and health disciplines. In the absence of such service organizations, management at the next level above department shall approve methods for selecting and implementing safety assessments.

3.4 Hazard Controls and Mitigation Procedures

The department safety committee shall periodically review the adequacy of all methods and physical controls applied to the elimination or mitigation of the hazards identified during the activities of Section 3.2. In reviewing methods and controls, the following points should be given priority in order of their mention:

- a. Specific guidance from institutional ES&H organizations concerning the adequacy of hazard controls and mitigation procedures,
- b. Consistency with recommendations (if any) of the individual safety assessments provided by the activities mentioned under Section 3.3,
- c. Consistency with the spirit of the individual safety assessments provided by the activities of Section 3.3, and
- d. The apparent costs of the specific hazard controls and mitigation procedures.

3.5 Department Safety Notes

The DSC shall maintain records of the information obtained during the activities required in Sections 3.1-3.4 and 3.6. These records shall, at minimum, consist of the following items:

- a. The location of, and a brief description of the nature of, all facilities, projects, and field operations that require the planned presence of department personnel;
- b. The hazards that reside in each of the facilities, projects, and field operations listed in item (a) above;

- c. Brief summaries of the methods and physical controls that are applied to eliminate or mitigate the hazards listed in item (b) above and the safety assessments to which they are related;
- d. A list of current members of the DSC;
- e. Brief descriptions of topics and the dates of departmental training and orientation meetings concerning environment, safety, and health compliance; and
- f. Review and inspection records (Sections 3.4 and 3.6) and records of any corrective actions.

Comments -- For lack of a better name, we shall hereafter refer to the incorporated department safety records as "Department Safety Notes" (DSNs). Such records could be conveniently organized and stored in an easily amendable loose-leaf notebook. Though no special format is (or should be) required, the required contents of the DSNs are such that material organization would logically start with a list of department facilities and projects, followed by lists of hazards and statements of hazard controls that are keyed to each item in the facility project list. One way of organizing the proposed DSNs is illustrated in Appendix A and given further discussion in Part IV.

The DSNs would provide strong evidence that the department is meeting its mandate for ES&H compliance. In addition, the records are a necessary "baseline" from which those institutional groups involved in audits and reviews can begin their independent assessment of the department's performance. Finally, and of perhaps the greatest potential benefit to the department itself, such records could be used as part of a data base for an institution-wide (or even paninstitutional) information retrieval system for hazard identification and control, and for compliance laws and standards, affording relatively easy access to the best technology currently available.

3.6 Safety Inspections and Reviews

The department safety committee shall conduct inspections of all working spaces devoted to department facilities or projects. Such inspections will be conducted as necessary but at least once annually. Deficiencies will be recorded. Supervision within the department is responsible for accomplishing and documenting corrective actions.

Following inspections or reviews of hazard control procedures, the chairman of the DSC shall revise the DSNs if such changes are warranted by the results of the inspections or reviews.

Comments -- No mention has been made of requirements for inspections and reviews of department field operations, i.e., operations requiring the presence of department personnel at a location where direct institutional support is impossible or very limited. The spirit of the proposed plan would, under such circumstances, at least be met by appointing and training one member of the field staff to act as a temporary member of the DSC. The department manager, supervision within the department, and the DSC would be responsible for the intelligent anticipation of the hazards to be encountered by personnel during field operations.

3.7 Assistance during Audits and Reviews

Upon receiving a request by auditing and review groups designated by the institution, the DSC shall provide a copy of current department safety notes to the audit/review group leader and designate one of the DSC members to serve as a guide to department facilities or projects or, as necessary, to otherwise serve the purpose of the audit/review.

Comments -- We anticipate that audits and review of departmental ES&H compliance will be conducted on a random basis in terms of both the frequency of audits/reviews and their depth-of-concern, although the records of deficiencies found in previous inspections might dictate the average frequency of independent audits/reviews to which the department is subjected. Thus, the amount and kinds of assistance to be provided by the DSC to auditors will be variable.

Guidelines for Auditing

For the auditing of departmental assurance programs, the institution must have access to the services of individuals who are familiar with the types of operation, equipment, and hazards involved in a subject department yet who are not directly involved with the subject department's interests. These individuals, brought together for the purpose of an independent audit or review of a department, will be called the Audit Group (AG). The practical problems concerning the

constitution and composition of an AG are not addressed here since it is only assumed that an AG exists.

Following are some guidelines for the AG that complement the generic ES&H assurance plan for departments that was described earlier. The guidelines are in the nature of suggestions and are appropriate for audits of general use of the ES&H assurance plan at the department level.

Facility/Project Listing

Verify that department's facility/project list is accurate and up-to-date, using

- a. Observations of listed working spaces,
- b. DSC inspection notes or reports,
- c. Supervisory instructions, and
- d. Occupancy data for working spaces (if those exist).

Departmental Hazards

Verify that the list of hazards specified to reside in departmental working spaces is accurate and up-to-date by

- a. Observations of listed working spaces,
- b. Review of DSC inspection notes or reports, and
- c. Review of recommendations by supervision and institutional ES&H support organizations.

Safety Assessment

Verify that safety assessments have been performed, as specified in the department's safety plan, by review of the DSNs.

Verify that approved methods have been used for the safety assessments.

Hazard Controls and Mitigation Procedures

Verify that hazard controls and mitigation procedures, as stated in the DSNs, are in place and are being used.

Review the adequacy of hazard controls and mitigation procedures, based on

- a. Recommendations of the institutional ES&H organizations or line management,
- b. Specific recommendations made in the hazard-specific safety assessment, and
- c. The consistency of such controls and procedures with the spirit of the hazard-specific safety assessments.

Department Safety Committee

Verify the membership and training of the DSC.

Verify that DSC inspections were conducted as specified in the department's safety plan (see Item 3.6 of the plan outline).

Verify that any corrective actions recommended by the DSC have been or are being taken.

Department ES&H Functions in General

Review the use by the department of expertise from the environmental safety and health disciplines.

Verify that department personnel are qualified and trained to perform their tasks from a safety point-of-view and are familiar with the policy set forth in the department's safety plan.

Upon completion of a study of the department's operations based upon these guidelines, the AG will prepare a short report evaluating the operations and noting any deficiencies that were found during the audit. A copy of this report will be sent to the department supervisor who may then mandate action by the DSC, if necessary. Copies of all AG reports are to be integrated into the DSNs.

The guidelines proposed above are by no means exhaustive: they do not cover procedures for reviews of the adequacy of methods used to control hazards or methods of safety assessment. Procedures for in-depth audits of certain department operations are also not recommended here because of the variability possible among different departments.

IV. TESTING THE IDEALIZED ES&H ASSURANCE PROGRAM AT SANDIA LABORATORIES

The ideas for an ES&H Assurance Program proposed in this report have been partially tested for practicability by attempts to apply some of them to an existing, working-level organization at Sandia Laboratories, Albuquerque. Prior to a discussion of the results, information is here provided on the context in which this experiment was made: the existing ES&H compliance structure for a typical Sandia department.

The working-level organization at Sandia is called a division and is typically comprised of 4 to 25 members (staff, technicians, and clerical aides). The day-to-day concerns for occupational health and safety begin at the division. A large division at Sandia meets the definition of a "department," (as used in this document) but, more often, two to five divisions are integrated by a commonality of their technical disciplines or tasks into a formal organizational unit called a department. Department managers and their division supervisors share the tasks of complying with institutional policy, rules, and procedures, although the responsibility for compliance is vested primarily with the supervisory personnel in each department. Depending upon the ES&H responsibilities of a department, an informal safety committee may be periodically formed from among department personnel.

Formal rules and procedures for safe operations are promulgated at Sandia in three ways: (1) Sandia Laboratories' Instructions (SLIs), having the force of institutional policy; (2) Safe Operating Procedures (SOPs), having the approval of institutional service organizations in the environmental, safety, and health disciplines; and (3) directives from the department manager and division supervisors. In addition, general guidance for safe operations is provided in special Sandia manuals¹⁶ and by the institutional service organizations: Safety Standards and Engineering Department; Environmental Health Department; and the Fire Protection Organization.

The major record of safe operating procedures is the SOP; and the integrated SOPs of a department in effect presently constitute its "safety plan." The SOPs are prepared for all operations involving "unusual" hazards and are reviewed annually by the appropriate institutional service organizations. In addition, the safe conditions of work spaces are monitored by informal DSCs and are reported in an area inspection report at least once a year. Documented department safety meetings are required at least once a year.

A formal inspection of department operations is periodically conducted by the Facility Safety Appraisal Committee (FSAC), a director-level safety committee appointed within each of the Sandia Laboratories' vice presidencies. A department may also be subject to reviews and audits by the Laboratories' sponsoring agency, the Department of Energy, through established requirements for DOE overview of contractors' operations regarding operational safety and compliance with environmental standards. Inspections of a given department by the FSAC may occur as often as every 18 months, whereas the chances of a DOE audit are small unless the department is having "problems" with compliance.

This brief review of the existing structure for ES&H compliance at Sandia Laboratories shows that the system is flexible and informal. It relies upon the technical foresight of the division supervisors, a high-quality staff, and conscientious oversight by small but experienced ES&H service organizations to promote health and safety and limit loss of Federal property through accidents. Informal as it is, the present structure has been effective. Sandia's safety and health record is exemplary. If it were not for the increasing national concern for public and occupational safety and health, for environmental protection, and for the fact that the Laboratories' tasks are now extended beyond the traditional ones of weapons development, there would be little justification for changing the ways by which Sandia effects safe and environmentally sound operations. The formation of the DOE has, however, changed many of the "ground rules" under which Sandia and other multipurpose laboratories must operate. The legal requirements for assurance^{*} in

^{*}"Assurance" means the ability of management to demonstrate that regulations, codes, and voluntary standards are being observed. The demonstration is through the existence of structured plans, written procedures, and records of audits or reviews. Assurance may also involve judgment of adequacy of plans and procedures, though there must also be "standards" against which a judgment of adequacy is made.

the areas of the environment and public and occupational safety have been stressed (see Reference 1 for a discussion of this point), and there is an urgent need for uniform and economical approaches to developing assurance at all levels of organization.

The generic program proposed earlier in this report is only one of many possible approaches to ES&H assurance at the working levels of organization, subject to a verification of the program's practicability and the acceptability of its costs.

The present ES&H program structure of a typical Sandia department requires four major changes to meet the needs of the proposed assurance program. These changes can be accomplished by

1. The constitution of formal, trained DSCs to perform those functions described in the generic plan;
2. The initiation and maintenance of written records of
 - a) Department facilities/projects and
 - b) "Unusual" hazards residing in each facility/project;
3. More explicit description within SOPs of the reasons for the particular mitigation controls and procedures that are applied;
4. Requiring
 - a) Somewhat more formal inspections by the DSC,
 - b) Structured audits and reviews by an independent audit group (AG),
 - c) Organization and operation of department safety meetings by the DSC, and
 - d) A unified record keeping system.

It is seen that the most radical departures from present departmental procedures are the requirements for structured records (DSNs), structured audits of the department's programs, and the delegation of many of the department's ES&H functions to a formally constituted and trained DSC.

Application to a Sandia Division

To begin to see whether these proposed changes are feasible and economical, their application has been partially tested in the context of a large division (22 individuals) devoted to research in laser

physics at Sandia Laboratories, Albuquerque. This division, Laser Physics Research, is presently supervised by Dr. R. A. Gerber, who has kindly permitted this intrusion.

The first test has been the writing of a set of "prototype" department safety notes, using the division's safe operating procedures and advice from its staff.* The resulting DSNs are shown in Appendix A of this report and are organized in terms of the

- I. Facility/Project List (p. 47)
- II. Hazard Classification List
 - A. List of Hazards (pp. 48 through 50)
 - B. Hazard Analysis and Mitigation (pp. 51 through 79)

The sample Facility/Project List includes a brief, descriptive title of the project activity, the location of working spaces in which each activity takes place, and the last date on which the project was active (actually, the last date mentioned on the review SOPs). Note that presumed "low risk" working spaces, such as staff offices and meeting rooms, are included. The sample Facility/Project List also provides a basis for indexing the Hazard Classification List that follows it. In Part A of the hazard classification, departmental hazards are listed item by item (but in no special order), and for each identified hazard a brief statement of its potential adverse effects is attached. Using the Facility/Project List as a key, each hazard is identified as residing in one or more of the division's projects (middle column of List of Hazards). Finally, the right-hand column of the List of Hazards contains an index to sections that describe analysis and mitigation procedures for each hazard. This index directs the reader to the appropriate section describing the hazard analysis and mitigation employed in each project. Note that procedures used to effect health and safety with respect to a given, generic hazard may necessarily be different for various projects or facilities. For example, the controls applied to the use of fluorine (F_2) and hydrogen fluoride (HF) may be less stringent for operations in an isolated laboratory than those controls applied in congested areas.

The descriptions of hazards analyses and mitigation procedures given in Part B of the Hazard Classification List are extracted from

*Particular thanks to R. A. Klein for his assistance.

existing SOPs of the Laser Physics Research Division with only slight amplification or amendment. The level of detail to which safety procedures should be spelled out is not specified. This is the prerogative of the working staff and the ES&H support organizations. The level of detail presented in written safety procedures and hazards analyses will vary considerably, depending upon familiarity with the particular hazard. The SOPs of the Laser Physics Research Division emphasize laser safety and procedures for handling highly reactive and corrosive gasses. The use of standard procedures for the safe handling of HV power supplies and ordinary gas bottles is implicit but not emphasized. In effect, a "prioritization" of risks is already made with the writing of the SOPs.

Remarks on Advantages and Disadvantages

1. Of the DSCs

The partial test of the generic ES&H assurance plan did not extend to the simulation of a formal DSC. The division used as a test subject does have an informal safety committee that operates on an "as needed" basis and is comprised of staff members who are called on because of their special knowledge of the immediate problem of concern. Because the day-to-day problems of operating safety are an almost indistinguishable part of the programmatic work, there is no easy way to extract total ES&H costs. However, it is likely that the Laser Physics Research Division spends less than one man-month per year (about 0.4 percent of total effort) on the assurance aspects of its ES&H responsibilities (record keeping, report writing, and nonroutine safety inspections). Estimates of the level-of-effort required to meet the assurance aspects of the proposed plan suggest that about 1 percent of the total department effort would be sufficient: if the DSC for a department of 50 were composed of 5 individuals who were active about 1 day out of every 2 weeks, then the time devoted to DSC functions would come to about 130 man-days per year or 1 percent of the total annual effort of that department. This estimate is crude and should be taken as an average value. Some organizations would need to invest more, and some less, time relative to ES&H assurance. However, based on work with the proposed plan, the estimated level-of-effort of the DSC was independently arrived at by two individuals who used different methods of estimation.

Thus, the major disadvantage of a formal DSC is the diversion of a department's effort and key staff away from programmatic tasks, albeit on a temporary basis. The advantages of formal DSCs are at present not proven, but possible advantages at the working level include

- Provision of a formal focal point for ES&H activities at the department level,
- Organization of ES&H data and reports to assist the department manager and supervision in meeting their responsibility,
- Provision of a stable assurance overview of department ES&H activities,
- Training of committee members, which because of rotation, leads to a trained staff, and
- Continuity and better organization of safety meetings which can then be meaningfully focussed upon DSC findings and those aspects of safety related to other than "unusual hazards."

It is believed that the advantages of a formal DSC will ultimately exceed in value the small increment in costs required to achieve them.

2. Of the DSNs

The effort involved in converting the Laser Physics Research Division's SOPs into the suggested format for DSNs was minimal. The task was accomplished in about 5 man-days by individuals who were not familiar with the division's operations. Experienced personnel should be able to make the conversion of the same number of SOPs (here treated as a measure of a department's ES&H responsibilities) in roughly half the time. For situations where SOPs do not exist, the bulk of the work falls on the DSC through the identification of hazards and the summarizing of controls used to eliminate or mitigate hazards. It appears that the effort would be no greater than that required to construct the mandated SOPs and possibly less effort, depending on the nature of the hazards. Thus, the two kinds of efforts are comparable if the initial, "front-loading" costs of conversion are ignored. Some readers may question the fact that certain items recommended in the generic plan (Section 3.5, Department Safety Records) are missing from the prototype notes of Appendix A. These items, (d) membership in the DSC, (e) records of department safety meetings and training sessions, and (f) review or inspection records and records of corrective action, are of a routine nature, and their cost is negligible.

One possible disadvantage of the DSN approach to record keeping not connected with costs lies in an increased potential for confusion (and, therefore, error) on the part of working personnel, owing to a dilution of the force of the department's project-oriented safe operating procedures. In actual practice, such confusion could be avoided by maintaining separate integrated SOPs extracted from the DSNs. The extra effort needed to accomplish this could be minimized by carefully scheduling preparation of DSNs to coincide with the required SOP reviews during the term of transition between present and proposed ES&H programs. After this front-loading effort is completed, the work required to simultaneously maintain SOPs and DSNs should be a very small part of overall ES&H efforts. As mentioned earlier, the bulk of the work falls on the DSC, which would be responsible for the observations and data-gathering that form the basis for the DSNs.

Advantages of the DSN approach to record keeping (as opposed to the present exclusive use of integrated SOPs) are seen to lie with the emphasis placed upon hazards and their controls, the provision of records facilitating independent audit, and the possibility of using the structured DSN data as input to institutional or agency safety information systems. A well-designed institutional information system for safety and compliance data will, in the long term, decrease the cost of ES&H programs by facilitating the rapid exchange of experience and new solutions to ES&H problems among the working-level organizations. As far as is known, no such information systems presently exist.

3. Of the Audit Requirements

A structured audit of the subject division's activities, using the guidelines for auditing proposed in this report, has not been conducted, and little can be said about the benefits or costs of this requirement. However, it is hard to believe that the results of structured audits based on the generic plan and audit guidelines proposed here would be less meaningful than the relatively unstructured audits in current use. The costs of the recommended audits do not appear to be excessive or even beyond the present level of funding for such activities at Sandia. The effort required to conduct an independent audit of the Laser Physics Research Division based on the prototype safety notes of Appendix A has been roughly estimated to be 12 to 20 man-days. A recent audit by the FSAC of laser facilities, which are largely under control of the Laser Physics Research Division, involved 8 persons, not

including division staff, for a term of about 2 days. The overall cost of the audit requirement would, of course, depend upon the degree of an organization's ES&H involvement, the number of organizations subject to the requirement, and the frequency of audits.

V. SUMMARY AND TENTATIVE CONCLUSIONS

This study represents one facet of an examination of the feasibility and cost-effectivity of a model ES&H assurance program plan.¹ One requirement of the model is for an ES&H staff, independent of line organizations. The feasibility of the model relative to ES&H staff functions has been previously examined^{2,3,4} and the potential benefits of the model's approach examined generically.¹⁷

This study represents a first step toward determining the feasibility and cost-effectivity of the model ES&H assurance program plan in the context of a "working-level" organization. The practicability of any approach to ES&H programs at the "working level" is a crucial issue for two reasons. First, it is at the working level that most hazards are encountered and controlled. Thus, whatever happens relative to ES&H at the working level determines whether injury, illness, or damage to property and environment really occur. Second, the traditional orientation of line organizations is "to get the job done." At times this attitude causes conflict between ES&H programs, which directs resources away from programmatic activities, and the programmatic works of the line organizations. Such conflict may lead to the neglect of valid ES&H factors or, at the other extreme, the suppression of initiative and productivity at the working level. Sympathy for each side of the problem has influenced the approach to the determination of feasibility and cost-effectivity.

The first step was to identify those functions of the model assurance program plan¹ which are appropriately performed at the working level of line organizations. Of 37 elements of the model plan, 9 were so categorized. As stated in the description of the model plan, these functions or elements are very general in character, and it was necessary to devise an operational scheme for implementing the nine that were chosen in a working-level setting. The scheme chosen is by no means unique but it does use some of the proven principles encountered in both quality assurance and systems safety. By building directly on traditional ES&H efforts, the scheme also reflects concern for the

possible ES&H as opposed to "get-the-job-done" conflicts. At the same time, the scheme deviates significantly in one respect from traditional organization: it creates working-level safety committees that assume responsibility for a large part of the ES&H activities required by the model plan. This is illustrated in Figure 2, which is drawn in the context of Sandia Laboratories' management structure. The figure also shows the general ES&H functions to be performed and identifies the persons responsible for their performance in the context of the generic, working-level ES&H assurance plan developed in this report.

The next step was to compare the idealized scheme of Figure 2 with an actual working-level program at Sandia Laboratories. Nearly all of the functions shown in the figure are now typically a part of working-level operations at Sandia Laboratories. Only the degree of formality and some assignments of responsibility differ. The major differences are found in the following areas:

1. The nature of ES&H "plans." Currently, there are no formal organizational plans. Each hazardous operation requires a safe operating procedure (SOP). The integrated set of SOPs is the current version of a plan.
2. There are currently no formal ES&H status reports to department managers.
3. Current department safety committees have an ad hoc character and exist only to perform operational inspections and make recommendations for corrective actions to department management. Other functions of the DSC shown in Figure 2 are currently the responsibility of the division supervisor.
4. There are currently no training requirements for either existing audit groups or members of DSCs.
5. Independent audits are typically informal and are not based on department ES&H plans.

In this study, it was assumed (fairly, it is believed) that a DSC could perform the functions identified in Figure 2. Under these circumstances, the feasibility and cost-effectivity of the model's approach to ES&H reduced to understanding

1. The effort required to prepare, and the possible benefits derived from, the department ES&H plans in comparison with effort and benefits of SOPs,

Figure 2. ES&H Functions in Generic Working-Level Assurance Program Plan

2. The effort required in structured audits by an independent audit group, and
3. The costs and benefits that might accrue from a centralized, trained DSC.

To understand these items, the Laser Physics Research Division at Sandia Laboratories was used as a real organization against which ideas could be tested. This division was chosen because of its large size and its involvement with a wide spectrum of hazards (fire, corrosive gasses, laser radiation). The SOPs of this division were converted into a plan form which would meet requirements of the model ES&H assurance program plan. The effort involved in this conversion was minimal. It was judged to be comparable to the effort involved in updating the integrated set of division SOPs. Significantly, the resulting (partial) plan involved fewer pages than the integrated set of division SOPs, which suggests that some economy may be achieved through the model approach.

In a similar way, using the Laser Physics Research Division as a test subject, estimates were made of the effort involved in audits structured around the ES&H plan that had been prepared, and these estimates were compared with current audit efforts. The two levels of effort were found to be comparable.

Finally, estimates of the total effort required to implement the ES&H assurance functions of Figure 2 were compared with highly subjective estimates of current assurance efforts. The proposed approach could involve as much as 1 percent of the organization's total staff time, while current efforts involve about 0.4 percent of the staff time. Thus, it appears there may be a net increase in costs for the addition of the formality indicated in Figure 2.

The potential benefits of the model approach being investigated were balanced against the costs mentioned above. Potential benefits were felt to be the following:

1. Provision of a stable assurance overview of ES&H activities (as is now mandated for DOE by its enabling law),
2. Provision of a formal focal point for ES&H activities at the working level,

3. Organization of ES&H data and reports to assist management in meeting its ES&H responsibilities,
4. Training of committee members, which leads (through rotation of membership) to a better trained staff,
5. Continuity and better organization of safety meetings which can focus meaningfully on safety concerns of employees, and
6. Better overall institutional ES&H information that can form the basis for an information system containing up-to-date hazards and mitigation data facilitating future hazard identification and control actions.

Whether these anticipated benefits outweigh possible costs is still a subject question that must be resolved by individual decision. Based on the present and previous studies,^{2-4,17} it is tentatively concluded that an ES&H assurance program, following the requirements outlined in Reference 1, is feasible and can be cost-effective, provided that a certain degree of flexibility is allowed to account for the different structures and needs of various organizations. This judgment is based heavily upon experience at Sandia Laboratories, and further study is needed to determine whether it applies in other contexts.

APPENDIX A
Department Safety Notes*

I. Facility/Project List

1. High-Pressure Electron Beam Initiated H_2-F_2 Laser Experiment
Date: 2 November 1977.
Location: SLA, Building 893, Room 91.
2. Electron-Beam Initiated H_2-F_2 Laser Experiment
Date: 9 November 1977.
Location: SLA, Area III, Building 9927, Northeast Room.
3. H_2-F_2 Explosion Limit Experiment
Date: 13 January 1978.
Location: SLA, Area II, Building 9927, Test Room.
4. Sandia Glass Laser Experiments
Date: 6 March 1975.
Locations: SLA, Area I, Building 893.
Thin-film experiments in Rooms 240, 250, and 43.
X-ray laser experiments in Rooms 51b, 250 and 43.
High-power laser experiments in Rooms 43, 51, 53, and 250.
5. Staff Offices
Date: 13 September 1978.
Locations: SLA, Area I, Buildings M071 (7), M033 (1), and 893 (3).

*An example of department safety notes (based upon SOPs of the Laser Physics Research Division, Sandia Laboratories, Albuquerque).

II. Hazard Classification List

A. List of Hazards

<u>Hazard</u>	<u>Project/Facility*</u>	<u>Analysis and Mitigation</u>
1. Fluorine (F ₂) and Hydrogen Fluoride (HF)		
(a) <u>Corrosive Substances:</u> Gases are highly irritating when inhaled or in contact with skin.	1, 2, 3	51, 1.1** 60, 1.2 63, 1.2.1
(b) <u>Explosive Substances:</u> Fluorine may react exothermically with hydrogen (H ₂) and other substances.	1, 2, 3	57, 1.1.1 63, 1.2.1
2. Hydrogen (H ₂)		
(a) <u>Flammable Substance:</u> Hydrogen may burn in the presence of oxygen (O ₂) or air.	1, 2, 3	67, 2.1
(b) <u>Explosive Substance:</u> Hydrogen may react explosively with fluorine (F ₂).		68, 2.2
3. Pulserad 110A (PiPi) Electron Beam Accelerator		
(a) <u>X-rays (Bremsstrahlung):</u> Operation of electron beam accelerator may result in production of stray keV X-rays.	1	68, 3
4. Febetron 706 Pulsed Electron Beam Accelerator		
(a) <u>X-rays (Bremsstrahlung):</u> Operation of electron beam accelerator may result in production of stray keV X-rays.	1, 2	72, 4

* Keyed to items on Facility/Project List.

** Page and section where mitigation measures are described.

<u>Hazard</u>	<u>Project/Facility</u>	<u>Analysis and Mitigation</u>
5. Maxwell Labs. 20kV-50kJ Capacitor Bank		
(a) <u>Electrical Discharge:</u> Capacitor case may have a high potential with respect to ground.	1	72, 5.1
(b) <u>Explosions:</u> Electrically induced stress may lead to explosion of capacitor.	1	73, 5.2
6. Marx Generator - 4 MV		
(a) <u>High Pressure:</u> Interface between Marx tank and electron beam apparatus sustains 180 psi pressures.	1	74, 6.1
(d) <u>Flammable Substance:</u> Marx tank contains 9700 gallons of mineral oil.	1	74, 6.2
7. Laser Cell (H_2-F_2 Laser)		
(a) <u>Explosions:</u> Fluorine mixed with H_2 , O_2 , SF_6 may explode spontaneously and rupture laser cell.	1, 2	74, 7.1 75, 7.3
(b) <u>Laser Radiation:</u> Intense laser radiation (300-1000 joules at 2.5-3.5 μm) may cause eye damage or burns.	1, 2	74, 7.2 75, 7.3
8. Explosion Cell		
(a) <u>Explosions:</u> F_2-H_2 mixture may explode spontaneously and rupture cell.	3	75, 8.1
9. Source and Alignment Lasers		
(a) <u>Laser Radiation:</u> Laser radiation at 1.06 μm or 0.63 μm may cause eye damage	4	76, 9.1

<u>Hazard</u>	<u>Project/Facility</u>	<u>Analysis and Mitigation</u>
Burns may result from pulsed lasers or 5 watts CW alignment lasers.	4	78, 9.2
(b) <u>Kinetic Energy (Projectiles)</u> : Flying particles from an exploded flashlamp in laser amplifiers.	4	79, 9.3
(c) <u>Electrical Discharge</u> : High voltage on laser amplifier flashlamps and power supplies.	4	79, 9.4
10. Gas Bottles		
(a) <u>High Pressure</u>	1, 2, 3, 4	79, 10
(b) <u>Kinetic Energy (Projectiles)</u> : Rupture or sheared valve may cause gas bottle to act as projectile.		

II. Hazard Classification List (Continued)

B. Hazard Analysis and Mitigation

1. Fluorine (F_2) and Hydrogen Fluoride (HF)

1.1 Apparatus in Building 893

One of the main health concerns of this project is the use of fluorine in a highly populated area (Building 893). Other similar H_2-F_2 projects have been conducted in remote areas (in Area V or at Building 9927), where a possible vent of fluorine would be dissipated before it spread to a highly populated area. Therefore, in this project, precautions are being taken to react the fluorine with carbon if such a vent occurs. In addition, the fluorine supply system is housed in a manner that would offer the greatest safety to personnel if a vent or fire occurs.

A building approximately the size shown in Figure A-1 has been constructed on the east side of Building 893. The building is made of high-density concrete blocks. A charcoal filter with an explosion-proof fan is attached to this supply building. The exhaust stack extends above equipment already on the roof of Building 893. The size of the exhaust fan will give a change of air in about 30 seconds at a $4000\text{-ft}^3/\text{min}$ flow rate. The size of the charcoal filter is 60 by 27 by 32 inches thick (30 ft^3). A filter this size will allow the disposal of 22 pounds of F_2 per minute. The maximum fluorine that will be in the supply building will be approximately 10 pounds. Therefore, a full vent, should it occur, will be reacted in 30 seconds. The F_2 reacts with carbon to produce CF_4 which is less toxic than carbon tetrachloride. The reaction $2F_2 + CF_4$ is exothermic by 221 kcal per mole; therefore, the charcoal will heat up. For a filter of 30 ft^3 , the temperature rise should be less than 300°C . Since there will be hot spots, some of the charcoal may burn. The filter thus has a damper on both the inlet and the outlet so that if a charcoal fire starts, it can be smothered. A means to inject either N_2 or CO_2 also ensures that a smoldering charcoal fire will be put out. The design of the charcoal trap is based on the design given in report NASA SP-3037 (1967). The building has explosion-proof lights and an intercom system to the control room of the e-beam. The supply

Figure A-1. Barrier Building

building is to be kept locked. Signs reading "Fluorine Gas--Poisonous--Keep Away" are placed around the building, and flashing red lights operate when experiments using fluorine are being conducted.

A schematic of the F_2 piping in the supply building is shown in Figure A-2. The building has provisions for one 1/2-pound bottle and one 5-pound bottle. Spare F_2 bottles are to be located either by Building 9927 or at Building 895. The double valves connecting the F_2 bottles with the rest of the system are Matheson-passivated F_2 valves. The F_2 bottle pressure is less than 400 psi. The F_2 - O_2 mix tank is made from a new N_2 bottle. The purpose of this tank is to reduce the F_2 pressure and allow a container to premix oxygen with the fluorine. If the 5-pound bottle is dumped into the mix tank, the pressure is reduced to about 200 psi. The specifications of the valves shown in Figure A-2 are given in Table A-I. They are all of the stainless steel bellows type. The emergency shutoff valves are remotely operated from the control room and are used if there is a fluorine vent, a fire, or a rupture in the laser cell.

Outside the supply building, bottle racks with shades will be provided for H_2 , O_2 , and N_2 gas bottles. There are facilities to allow opening the 5-pound F_2 bottle from outside the building. All gas lines running from the supply building to inside Building 893 are 3/8-inch copper or stainless steel and are securely fastened. The construction of the building, the associated exhaust system, the warning lights, and the intercom are covered under Plant Engineering Order No. 521-75-53.

Figure A-2. Schematic of the F₂ Piping in the Supply Building

TABLE A-I
Equipment List

ITEM	NUMBER	MATERIAL	WORKING PRESSURE
<u>VALVES</u>			
NUPRO Air Operated Bellows Valve			
1/2-inch Swagelok SS8VW-NC-STE	1	316 S.S.	2500 psi at 650° F
3/8-inch Swagelok SS6VW-NC-STE			
1/4-inch Swagelok SS4VW-NC-STE			
NUPRO Manual Bellows Valve			
1/2-inch Swagelok SS-8BG	3	316 S.S.	1000 psi at 70° F
3/8-inch Swagelok SS-6BG			
1/4-inch Swagelok SS-4BG			
NUPRO Manual Bellows Metering			
1/4-inch Swagelok SS-4BMG	6	316 S.S.	psi at 70° F
Varian Bakeable Vacuum			
1-1/2-inch R. Angle 951-5027	5	304 S.S.	N.C.
<u>FITTINGS</u>			
Swagelok All Sizes		Brass, S.S.	Same as tubing of same material
<u>TUBING</u>			
1/4-inch dia x .035 wall		Copper	1890 psi
1/4-inch dia x .049 wall		S.S.	8700 psi
3/8-inch dia x .035 wall		Copper	1206 psi
1/2-inch dia x .035 wall		S.S.	2775 psi
1/2-inch dia x .065 wall		S.S.	5437 psi

TABLE A-I (Continued)

<u>ITEM</u>	<u>NUMBER</u>	<u>MATERIAL</u>	<u>WORKING PRESSURE</u>
<u>FILTERS</u>			
NUPRO All Sizes			
1/2-inch Swagelok SS-8F-7	4		2500 psi at 70° F
3/8-inch Swagelok SS-6F-7			2500 psi at 70° F
1/4-inch Swagelok SS-4F-7			3000 psi at 70° F
<u>PRESSURE SENSING</u>			
Validyne Differential Pressure Transducer	2	S.S.	Line Pressure 3000 psi max
<u>PRESSURE RELIEF TANK</u>			
30 inches OD x 7 Feet x 10 Inches Long A/G Propane Tank	7	Steel SA-285-C	250 psi max
<u>REGULATORS</u>			
O ₂ and N ₂		Brass	3000 psi
H ₂ - High Purity Reg. From Matheson Gas Products		S.S.	3000 psi
F ₂ - Three-Way Valve System From Matheson Gas Products		Brass	≈2000 psi
<u>GAUGES</u>			
For F ₂ : Prepassivated 0-400 psi Matheson 63-5542	8	Brass	
Sandia Stock No. 709924 0-100 psi	9	Brass	

Provisions have been made to install F_2 and H_2 systems in Rooms 91, 150, 172, and 192. The current F_2 and H_2 system is installed only in Room 91. Each room will be provided with a hood such as that shown in Figure A-3. This hood has a charcoal filter to react to the F_2 if a vent occurs. The maximum amount of F_2 to be reacted in the hood filter would be about 2.5 pounds. For a filter of about 4 ft³ (100 pounds of charcoal), the maximum temperature rise should be about 300° C. Here again, if hot spots develop, a damper can be used to extinguish a charcoal fire if it develops. The air outlet of each room has provisions so that it can be closed quickly in case of an F_2 vent. This apparatus to close vents is also covered by Plant Engineering Order No. 521-75-53.

A schematic of the gas handling system placed near the laser cell is shown in Figure A-4. This system is similar to that used on previous REBA experiments in Area V. This system is remotely operated from the area from which the electron beam is operated. The area is separated from the experiment region by the Marx tank and concrete walls. Because of the higher pressure to be used there, all remotely operated valves have metal seats and have a working pressure up to 2500 psi. All fluorine used for passivation, as well as the products produced during the e-beam initiation, are pumped out through soda-lime or charcoal traps to react to the fluorine. The gasses other than F_2 and H_2 shown in Figure A-4 are located near the gas handling system.

The gas control system is on a movable cart with provisions to lock the wheels to prevent movement. It also has an exhaust fan with a charcoal filter. There is a master shutoff to close all valves in an emergency. The control panel is located near a door so that, in an emergency, personnel can exit easily.

1.1.1 Passivating Fluorine Supply System

1. Before fluorine is admitted into Building 893, the fluorine supply system shown in Figures A-2 and A-4 must be properly passivated to minimize the possibility of a fluorine "burn-through" and fire. Before the initial passivation of the plumbing shown in Figures A-2 and A-4, all lines, mix tanks, etc., will be evacuated by means of

Figure A-3. Exhaust Fan

vacuum pumps. For the initial passivation, a nearly empty (30 to 50 psi) 1/2-pound fluorine bottle will be used. Initially, the fluorine will be diluted with nitrogen or a dry inert gas so that all the metal will initially be exposed only to low pressure F_2 (≈ 1 psi). The concentration will be increased in steps until the entire system is exposed to pure F_2 . Each mixture will be left in the system for a 1/2- to 1-hour period.

2. After the F_2 system is passivated, the lines into Building 893 and the gas handling system will be passivated as in step 1.
3. The tube will then be initially passivated in the same manner as in step 1.
4. Before each laser experiment, the laser cell will be evacuated, passivated, evacuated, and then filled with mixtures of F_2 , O_2 , H_2 , and sometimes other gasses, like SF_6 , He, and so forth.

Figure A-4. Schematic of the Gas Handling System Placed near the Laser Cell

5. After each shot, the system will be visually checked and diaphragms replaced before step 4 is repeated.

1.1.2 General Safety Procedures

1. The buddy system will be used when passivating, valving fluorine, or running an actual test.
2. Full face respirators with acid gas filters will be in hand and/or immediately available to the individuals operating the F_2 supply cylinder valves.
3. Rubber gloves will be worn in repairing or working on any surface which might have been exposed to F_2 or HF unless completely neutralized prior to handling.
4. All personnel in Room 91 will be out of the experiment area (e-beam cell area) when F_2 is being introduced into the laser cell. A limited number of personnel will be allowed in e-beam cell during the passivation process after the F_2 is admitted.
5. Warning lights will be on at the F_2 building whenever F_2 is being used.
6. During nonoperational hours and at such times that fluorine is not being used, the door of the F_2 supply building will be locked.
7. The exhaust fan in the F_2 supply building will be turned on whenever an F_2 bottle is open or when experiments are in progress.

1.2 Apparatus in Building 9927

A venting of fluorine from Building 9927 would not be as critical as from Building 893. Released material would react and be diluted before reaching highly populated areas.

A schematic of the gas-handling system is shown in Figure A-5 and the general layout of the experiment is shown in Figure A-6. The fluorine barrier will accommodate a 1/2-pound F_2 bottle at a maximum pressure of 400 psi. The purpose of the mix bottle (about one-third the volume of the F_2 cylinder) is to keep the working supply of F_2 low and to allow premixing of the F_2 with other, nonreactive, gasses. All gas lines are stainless steel with working pressures of 1800 psi or greater. Valves are hi-vacuum bellows valves with minimum working pressures of 2500 psi at 650° F.

Figure A-5. Schematic of the Gas Handling System

Figure A-6. General Layout of the Experiment

The following general safety procedures will be employed in handling fluorine at this location:

- a. The buddy system will be used when passivating, valving fluorine, or running an actual test.
- b. Full face respirators with acid gas filters will be in hand and/or immediately available to the individuals operating the F_2 supply cylinder valves.
- c. Rubber gloves will be worn in repairing or working on any surface which might have been exposed to F_2 or HF unless completely neutralized prior to handling.
- d. When exchanging F_2 cylinders in the system, full face shields shall be worn by those individuals involved.
- e. All personnel in the 9927 area will be in the control room during a test involving reactive gasses and the steel door between the control room and the cell room will be shut. However, during a test, periodic inspection will be made outside the building to insure that persons have not inadvertently entered the area of 9927.
- f. The ventilation system will be on in the test cell room when fluorine or hydrogen is introduced into the cell.
- g. Warning lights will be on, the access control gate will be down, and a tape recording warning of danger in the area of 9927 will be in operation just prior to and during a test.
- h. An additional audible alarm will be placed in the control room and will be activated in the event of a fluorine vent or other personnel hazard.
- i. During nonoperational hours, the extension handle on "T" handle on the F_2 supply tank valve will be disconnected.

1.2.1 Explosion Limit Experiments

The block diagrams of the apparatus are shown in Figures A-7 and A-8. The reaction cell is located within a test room inside Building 9927 and is separated from the control room by a reinforced concrete wall about 1 foot thick. The cell room is ventilated with a blower which changes the air in the cell room about once every 3 minutes. The system is designed so that there is an under-pressure in the cell room. Thus, any air leakage between the control room and the cell room is such that air will flow from the control room to the cell room.

Figure A-7. Block Diagram of the Apparatus

Figure A-8. Block Diagram of the Apparatus

Once the gas bottles (Figure A-7) are valved open manually, operation of all valves necessary to carry out a complete set of experiments is done remotely from the control room. It is not necessary to enter the fluorine or hydrogen mix building or cell room during an actual explosion limit experiment or at any time fluorine is present in the explosion cell. In addition to the automatic valves shown in Figure A-8, a number of flow-limiting valves are also in the system which are not adjusted during a run or during the time fluorine is in the system.

The normal fill and test procedures, including the passivation of the fluorine supply system, are indicated below:

1. Before tests are conducted, the fluorine gas handling and mixing system and explosion cell must be properly passivated to minimize the possibility of a fluorine "burn-through" and fire. Every modification of the system requires passivation. This procedure will generally involve purging the cleaned system with dry, inert gas and then slowly displacing the inert gas with fluorine. For higher pressure studies, it may be necessary to passivate the system with fluorine at pressures greater than 1 atmosphere.
2. The test cell and mixing systems are then evacuated.
3. Proper amounts of fluorine and hydrogen are introduced into their respective mixing tanks located outside mix buildings along with appropriate amounts of other gasses (e.g., oxygen in the fluorine).
4. After an appropriate mixing time has lapsed, preparation is made to conduct an actual run in the explosion cell. Before fluorine is introduced into the explosion cell, all personnel must leave the cell room and enter the control room. Before fluorine is introduced into the cell, the steel door between the cell room and the control room is to be shut. The cell room blower system is then turned on. The outside door to 9927 is also to be closed.
5. Using the remotely controlled valves and pressure indicators, the cell is filled with the desired amount of gas from the fluorine mix and hydrogen mix tanks.
6. After termination of the test (whether or not an explosion within the cell takes place), the contents of the explosion

cell are exhausted into the surge tank by actuating the hydraulic valve (remotely controlled from the control room).

7. The hydraulic valve is then closed, and the cell is opened to a roughing line, which reduces the cell pressure in the millitorr range.
8. The roughing line is closed off, and the cell is then opened to the liquid nitrogen trap and diffusion pump.
9. All remote pressure sensors in the control room are to be checked to verify the condition of the cell and mixing systems.
10. After a period of about 20 minutes from the time the hydraulic valve was opened to allow dumping the contents of the cell into the surge tank, the ventilating system for the cell room may be turned off.
11. Once this ventilator is turned off, the steel door between the control room and the cell room may be opened. Also personnel may then leave the building. If a fluorine, HF, or hydrogen vent occurs during filling of the cell or during an explosion in the cell, such a vent should be detected by abnormal pressure gauge readings as seen in the control room. If an indication exists that a malfunction has occurred, all remote valves should be placed in the OFF position. This can be accomplished by turning off a single master control switch in the control room. The hydraulic valve connecting the cell to the surge tank should be opened in case the vent occurred at the explosion cell.

General safety procedures are given in Section 1.2, Items (a)-(i). In item (f), read "explosion cell room" for "test cell room."

2. Hydrogen (H₂)

2.1 Hydrogen Fires

Hydrogen fires are prevented by taking standard and specific precautions in the use of compressed hydrogen and in the design of hydrogen supply systems. These precautions and criteria are listed in Reference 16, pages 2-87 through 2-100a and, specifically, pages 2-96 through 2-98.

2.2 H₂-F₂ Explosive Reactions

To avoid the uncontrolled mixing of hydrogen with fluorine, separate supply systems are used in each experiment. Mixing of these gasses will always be done in laser or explosion cells that are designed to contain explosions or vent reaction products through a burst diaphragm to a dump tank. Additional precautions are described in Section 1.1.1 and 1.2.1.

3. Pulserad 110A (PiPi) Electron Beam Accelerator

To avoid unnecessary exposure of personnel, electron beam accelerators are operated within radiation cells, enclosures of shielding material that prevent stray X-rays from reaching areas occupied by humans.

The Pulserad 110A is an electron accelerator that produces an electron beam with voltage up to 1.5 MeV and currents up to 35 kA. These parameters will not be exceeded without prior notification to Health Physics personnel (4-5943).

This electron accelerator will be operated at two different locations in Building 893. Initially, the machine will be checked out in the modified-existing KrF laser facility located along the north-east wall of the hi-bay area. The location of the various components is shown in Figure A-9. The first cell is located in the hi-bay adjacent to Room 150. The shielding, utilities, and so forth are to be found on Plant Engineering Order Nos. 521-76-25 and 521-76-32. A general layout of this facility is shown in Figure A-10. This cell has provision for H₂-F₂ gas handling. Upon completion of the radiation cell, the existing KrF laser cell will be dismantled. The completion of this cell is expected in August or September, 1976.

The final location in which the accelerator will be used is in the existing MiMi radiation cell (Room 91, Building 893). For these series of experiments, both electron accelerators will be used simultaneously. Both machines, as well as the capacitor bank, will be interlocked at the cell door.

1 FT. SCALE

NOTES:

1. HEIGHT OF E-BEAM IS 4.0 FEET.
2. HEIGHT OF CELL IS 8.0 FEET.

N →

Figure A-9. Location of Various Components

Figure A-10. General Layout of the Facility

General Procedures

- A. This accelerator and capacitor bank will be operated only by those designated or authorized as qualified operators who have been instructed in the proper operation of the machine and are aware of the hazards to personnel which can exist during its operations.
- B. The operator and other appropriate personnel of the facility are responsible for maintaining adequate radiation safeguards at and about the machine, including the following:
 - 1. Keeping occupational exposure to radiation as low as practicable,
 - 2. Wearing personnel radiation dosimeters (TLD badges) in the prescribed manner,
 - 3. Following radiation safety rules and regulations,
 - 4. Reporting radiation accidents, incidents, and unsafe working conditions, and
 - 5. Informing Health Physics personnel when unusual setups are to be used.
- C. The radiation cell will be interlocked so that the machine and capacitor bank cannot be charged when the cell door is open. The enclosed capacitor bank is interlocked so that charging is impossible if any of the panels are removed.
- D. Health Physics safety devices, i.e., interlocks and shutter systems, flashing lights, remote radiation monitors, and so forth will be checked weekly for proper operation. A record of these checks is to be kept in an appropriate logbook for audit by Health Physics personnel and DOE inspectors.
- E. If the routine operating procedures, interlocks, or safety systems are to be altered in any way, Health Physics Division, Ext. 5943 or 5236, must be notified first.
- F. Potentially hazardous experiments will be reviewed by the supervisor, Laser Physics Research Division, Industrial Hygiene Division, the Health Physics Division, the Safety Standards and Engineering Department, and the Vice-Presidential Safety Committee.

Operating Procedures

- A. The audible warning and warning light shall be on any time the console power is on.

- B. The vicinity of the Pulserad 110A and control area shall be restricted to personnel required for actual operation of either the machine or the experiment in progress.
- C. No personnel will be allowed to enter cell without permission of the operator.
- D. Any deviation from the foregoing instructions must have the written approval of the Health Physics Division and of the supervisor of the Laser Physics Research Division.
- E. Prior to operation of the Pulserad 110A, the operator shall ensure that
 - 1. The radiation cell is clear of personnel,
 - 2. There are no personnel above floor level where a line-of-sight to the diode is possible, and
 - 3. The audible personnel warning system and warning light are functioning properly.
- F. After firing, the operator shall shut down the control console and remove the console key. The capacitor bank will be dumped at that time. The door to the cell is interlocked so that both the machine and capacitor bank are dumped when the door is open.

4. Febetron 706 Pulsed Electron Beam Accelerator

Refer to Section 3, specifically first paragraph and guidelines listed under General Procedures and Operating Procedures.

5. Maxwell Labs. 20kV-50kJ Capacitor Bank

5.1 Electrical Safety (General Procedures)

- A. The capacitor bank will be located on the hi-bay side of the east wall of Room 172 (north) and will be surrounded by walls of high-density concrete blocks in order to contain the debris in the event of a capacitor exploding. The cover will consist of 3/4-inch plywood. Access panels will be interlocked such that the capacitor bank cannot be charged while these panels are open.
- B. The Febetron (see Section 4) and capacitor bank system will be operated only by authorized personnel who have been instructed in the proper operation and are aware of the potential hazards which may exist during operation.
- C. The capacitor bank shorting relay will be visually inspected before access to the bank is attempted.

- D. A warning light will be displayed adjacent to the bank and will be operational during each shot.
- E. Before work begins on the bank itself, the capacitors will be manually shorted to ground with a flexible ground strap attached to a 3-foot insulating handle. The capacitors will then be permanently grounded with a clip lead.

Operating Procedures

- A. Prior to operation of the Febetron 706 and pulsed magnetic field, the operator in Room 172 (north) shall ensure that
 - 1. All personnel are cleared from the immediate vicinity of the laser cell and from the vicinity of the capacitor bank,
 - 2. The warning light near the bank is operational,
 - 3. The Febetron and capacitor bank are charged and fixed, and
 - 4. After firing, the operator ensures that both charging systems are disabled by removing their respective interlock keys.

Maintenance Procedures

Normal high-voltage safety procedures will be followed whenever maintenance is performed on the accelerator or capacitor bank. Although the capacitor cases are normally maintained at ground potential, the combination of a shorted capacitor section and a disconnected resistor (or open circuit) would cause a capacitor case to have a high potential with respect to ground. All cases will be shorted to ground with a shorting bar that has a metal rod, a flexible conductive strap that can be attached to ground, and at least a 3-foot-long plastic handle. This same shorting bar will be used to short each capacitor terminal with respect to its case. A clip lead will be installed across the capacitor to prevent it from being recharged by adjacent capacitors or from developing a residual dielectric polarization.

5.2 Explosion Protection

(See Item A, Section 5.1)

6. Marx Generator - 4 MV

6.1 High Pressure

The lucite interface between the Marx tank and electron beam line may sustain a static pressure of about 180 psi, owing to the oil in the tank. However, under normal conditions, the pressure on the tank side is balanced by hydrostatic pressure from the oil-water mixture on the line side of the interface.

6.2 Flammable Substance

The mineral oil used in the Marx tank is classified ULC 10-20 and is consequently a low-fire hazard. The tank is periodically checked for leakage, and all oil spills incurred during maintenance are promptly cleaned up. Equipment for the handling of Class B fires is present in the laboratory.

7. Laser Cell (H_2 - F_2 Laser)

7.1 Explosion Controls

- A. The laser cell is designed to sustain pressures up to 20 atmospheres. During normal operation, gas mixtures are first introduced to give a pressure of 2 atmospheres: an explosion increases cell pressure by a factor of 10. However, near 20 atmospheres, burst diaphragms will break and allow explosion products to vent into a closed pressure relief tank (see Figure A-4, Section 1). Burst diaphragms are replaced after each shot, independent of the occurrence of an explosion.
- B. All personnel are out of experiment area (e-beam/cell area) during a shot.

7.2 Radiation Controls

- A. The majority of the laser energy (up to 10 kJ) is stopped by a laser calorimeter. The rest is intercepted by the walls of the e-beam cell.
A small portion of the laser beam may be relayed to detectors outside the e-beam cell for diagnostic purposes.
- B. All personnel are out of experiment area (e-beam/cell area) during a shot.

7.3 Apparatus in Building 9927

Explosion controls and radiation controls for the apparatus in Building 9927 are similar to the ones indicated in Sections 7.1 and 7.2 above except for the following:

- a. A laser beam of energy up to 10 joules is produced. The beam is then guided to various diagnostics within the cell.
- b. The burst diaphragm separating the laser mixture from the dump tank breaks, and the gas is pumped through an HF trap outside the building.
- c. During this period a high-volume exhaust fan ventilates the test cell room. Any leaks or ruptures will be detected by inspection of the remote sensors connected to the laser cell and dump tank.

8. Explosion Cell (H_2-F_2 Explosion Limit Experiment)

8.1 Explosion Controls

- A. The design of the explosion cell is similar to the laser cell in the H_2-F_2 experiments (see Section 7.1) in that pressure relief diaphragms are used to vent possible explosion products to a surge tank.
- B. The ideal operation of the devices is as follows:
 1. Fluorine and other gasses mixed with fluorine are introduced into the explosion cell.
 2. Hydrogen (possibly mixed with inert gasses) is then added to the cell through separate fill lines to a predetermined pressure.
 3. The maximum fill pressure for equal amounts of fluorine and hydrogen are such that no more than 5 atmospheres of fluorine and 5 atmospheres of hydrogen are able to react in the cell for any given shot. (This amounts to the formation of about two moles of HF.) The maximum fill pressure may exceed 10 atmospheres through addition of excess gasses which do not lead to additional HF formation.
 4. The mixture will then heat up slightly (i.e., from 1° to 50° C above ambient temperature) and will then either suddenly explode or will not explode, depending upon the pressure-temperature regime existing in the cell at the time of the experiment.

5. After it has been determined that an explosion has occurred in the cell (or, after waiting a sufficient length of time, it is determined that an explosion will not take place), the gas in the cell will be exhausted through the appropriate valving system. The gas will then enter the surge tank and soda lime chemical trap where it will be disposed of by chemical reaction. The contents of the soda lime trap are to be disposed of at the chemical dump when calculations indicate a 10 to 20 percent deterioration of the soda lime.

9. Source and Alignment Lasers (Glass Laser Experiments)

Apparatus

Figure A-11 illustrates the geometry of the experiments with associated lasers. There are four separate laser paths for the several experiments, designated as Legs A, B, C, and D in Figure A-11. Legs B and D constitute the Sandia glass laser system. Leg A is the pulsed X-ray laser amplifier system. Leg C is the frequency-doubled 0.53- μm pulsed holographic laser plasma diagnostic.

9.1 Protective Measure Against Eye Burn

Lasers operating at 0.63 μm or 1.05 μm may cause eye damage.

Measures for eye protection during the use of the CW YAG are as follows:

1. A flashing red light located in Rooms
51, 51b, 51d, 240, 250 (Leg A)
51, 240, 250 (Leg C)
51, 51b, 240, 250 (Legs B and D)
will be activated when either of the CW lasers are un-
tional. An explanatory warning sign will be located nearby.
2. All access doors to the laser area will be closed and/or
locked during CW YAG operation.
3. All authorized personnel in the laser area(s) where the
beams are propagating will wear 1.06- μm safety eye protec-
tion during CW YAG operation.

Figure A-11. Geometry of the Experiments with Associated Lasers

9.2 Pulsed Operation (Skin Burns)

9.2.1 Quantel Glass Laser System (Leg A)

The Quantel laser will be operated remotely from Room 51.

When the laser is fired, the following will be done:

1. All personnel will be made to leave Rooms 51b, 51d, 250 and 240 (screen room excluded).
2. Warning lights, access control gates, and capacitor bank interlocks will be activated during experimental test shots. Emergency manual override of the interlock system is possible at all doors in the laser area for possible trapped personnel.
3. Visual check and audio check for trapped personnel will be conducted before each test via closed circuit television and intercom system.

9.2.2 Sandia Glass Laser (Legs B and D)

The amplifier system will be remotely operated from the control room (Room 51).

When the laser is fired, the following will be done:

1. All personnel are to be removed from all areas where the laser pulsed beam is propagating.
2. Warning lights, access control gates, and capacitor bank interlocks will be activated during experimental test shots. Emergency manual override of interlock system is possible at all doors in the laser area for possible trapped personnel.
3. Visual check and audio check for trapped personnel will be conducted before each test via closed circuit television and intercom system.

9.2.3 Sandia Diagnostic Laser (Leg C)

The amplifier system will be remotely operated from the control room (Room 51). During pulsed operation

1. All personnel are removed from Rooms 240 and 250, but the screen room in Room 240 is considered a safe area.

2. Warning lights, access control gates, and capacitor bank interlocks will be activated during experimental test shots where appropriate. Emergency manual override of interlock system is possible at all doors in the laser area for possible trapped personnel.
3. Visual check and audio check for trapped personnel will be conducted before each test via closed circuit television and intercom system.

9.3 Exploded Flashlamp

Personnel are excluded from oscillator room (Room 43) when lasers are operating.

9.4 High-Voltage

All high-voltage power supplies and circuits are maintained and operated according to the manufacturer's safety recommendations or according to standard codes.

The safety philosophy used for equipment not covered by standard codes is set out in Reference 16, pages 2-39 through 2-46.

10. Gas Bottles

Standard procedures are used in the storage and handling of high-pressure gas bottles (or cylinders). These procedures are set forth in the section on "Pressure Safety" in Reference 16, pages 2-8 through 2-100a. See, specifically, pages 2-87 through 2-91.

APPENDIX B
Typical Hazards*

1. Acoustical Radiation

- (a) Detonation noise
- (b) Equipment noise
- (c) Ultrasonic cleaners
- (d) Other (specify)

2. Corrosive Substances (specify)

- (a) Acids
- (b) Caustics
- (c) Gasses
- (d) Other (specify)

3. Electrical Discharges

- (a) Battery banks
- (b) Cable runs
- (c) Capacitor banks
- (d) Diesel generators
- (e) Heaters (electric)
- (f) High-voltage power lines
- (g) High-voltage power supplies
- (h) Marx generators
- (i) Motors (electric)
- (j) Outlets (electric)
- (k) Power tools (electric)
- (l) Pumps (electric)
- (m) Transformers
- (n) Wiring
- (o) Other (specify)

*Adopted from Appendix II, Occupancy-Use Readiness Manual Safety Considerations, ERDA-76-45-1, SSDC-1, September 1975.

4. Explosions

- (a) Caps
- (b) Dust
- (c) Dynamite
- (d) Gasses (specify)
- (e) High explosives (specify)
- (f) Other (specify)

5. Fires

- (a) Gasses (specify)
- (b) Hydrocarbons (specify)
- (c) Metals (specify)
- (d) Solvents (specify)
- (e) Wood
- (f) Other (specify)

6. Gravitational Energy

- (a) Cranes
- (b) Elevators
- (c) Excavations
- (d) Hoists
- (e) Human effort
- (f) Inclines
- (g) Jacks
- (h) Ladders
- (i) Scaffolds
- (j) Stairs
- (k) Other (specify)

7. Heat (Thermal Energy)

- (a) Electrical wiring and equipment
- (b) Fire boxes
- (c) Furnaces
- (d) Heaters
- (e) Molten metals (specify)
- (f) Steam
- (g) Welds
- (h) Other (specify)

8. Kinetic Energy - Linear
- (a) Automobiles (incl. buses and trucks)
 - (b) Carts
 - (c) Crane loads in motion
 - (d) Dollies
 - (e) Fork lifts
 - (f) Obstructions (to motion)
 - (g) Projectiles
 - (h) Railroads
 - (i) Other
9. Kinetic Energy - Rotational
- (a) Centrifuges
 - (b) Fans/propellers
 - (c) Pumps (rotary)
 - (d) Motors
 - (e) Turbines
 - (f) Other (specify)
10. Natural Hazards - Biologic (specify)
- (a) Bacteria (pathogens only)
 - (b) Parasites
 - (c) Poisonous flora
 - (d) Venomous fauna
 - (e) Viruses
 - (f) Other
11. Natural Hazards - Climatic
- (a) Floods
 - (b) Fog
 - (c) High temperatures
 - (d) High winds
 - (e) Hurricanes
 - (f) Ice
 - (g) Lightning
 - (h) Low temperatures
 - (i) Snow
 - (j) Tornadoes

- (k) Water (drowning)
- (l) Other (specify)

12. Natural Hazards - Geologic

- (a) Caving (of excavations)
- (b) Earthquakes
- (c) Landslides
- (d) Rockfalls
- (e) Seiches/tsunamis
- (f) Subsidence (of excavations)
- (g) Vulcanism/magma flows
- (h) Other (specify)

13. Pressure - Volume/K - Constant - Distance

- (a) Autoclaves
- (b) Boilers
- (c) Coiled springs
- (d) Gas bottles
- (e) Gas receivers
- (f) Pressure lines
- (g) Pressure vessels
- (h) Stressed materials
- (i) Other (specify)

14. Radiation - Electromagnetic

X-rays:

- (a) Bremsstrahlung (specify source)
- (b) Medical X-rays
- (c) Radiography equipment

UV-Visible:

- (d) Blacklight (e.g., magniflux)
- (e) Electric arc
- (f) Electric furnace
- (g) Lasers
- (h) Sunlight (concentrated)
- (i) Welding
- (j) UV lamps

IR - Microwave:

- (k) Boilers
- (l) Furnaces
- (m) Heaters (radiant)
- (n) IR lamps
- (o) Lasers
- (p) Microwave equipment
- (q) Radars
- (r) Steam lines
- (s) Solar collectors
- (t) Other (specify)

15. Radiation - Particulate

- (a) Accelerator beams
- (b) Other (specify)

16. Radiation - Nuclear* (specify particulars)

- (a) Casks
- (b) Critical facilities
- (c) Contaminated Equipment
- (d) Contaminated wastes
- (e) Enrichment facilities
- (f) Laboratory isotopes/sources
- (g) Medical isotopes/sources
- (h) Nuclear power supplies
- (i) Nuclear reactors
- (j) Neutron-activated materials
- (k) Radiographic sources
- (l) Radon/Radon daughters
- (m) Reprocessing facilities
- (n) Subcritical facilities
- (o) Waste disposal facilities
- (p) Well-logging sources
- (q) Other

* Not completed

17. Toxic Substances (Non-Nuclear)*

- (a) Acetone
- (b) Ammonia and compounds
- (c) Asbestos
- (d) Beryllium and compounds
- (e) Cadmium and compounds
- (f) Chlorine and compounds
- (g) Carbon monoxide
- (h) Decon solutions
- (i) Dusts and particulates (smoke)
- (j) Fluorine and fluorides
- (k) Lead
- (l) Pesticides - herbicides - insecticides
- (m) Sandblast
- (n) Trichloroethylene
- (o) Other (specify)

* Not completed

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