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HEALTH AND SAFETY

REPORT ON GLOVE BOXES AND CONTAINMENT ENCLOSURES

Edited by
Nelson B. Garden

June 20, 1962

Ad Hoc Committee

UNITED STATES ATOMIC ENERGY COMMISSION • DIVISION OF TECHNICAL INFORMATION

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FOREWORD

This report, covering glove box construction materials, auxiliary components, safety, fire protection, and operational problems, was approved by the General Manager on June 18, 1962, for use as a guide in the design and operation of glove boxes, pending the establishment of formalized design criteria.

The preparation of design criteria will be initiated upon completion of the comparative evaluations and tests of various glove box materials and components, as recommended in the report. Approved design criteria will be issued as a chapter of Section 6300 of the AEC Manual.

John A. Derry

John A. Derry, Director
Division of Construction
June 20, 1962

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REPORT ON

GLOVE BOXES AND CONTAINMENT ENCLOSURES

Nelson B. Garden, Editor

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SUMMARY

This report has been prepared by an ad hoc Committee, established by memorandum from the General Manager dated August 27, 1959, for the purpose of establishing guide lines for the design of efficient, safe, and economical glove boxes.

Comprehensive discussions of glove box materials and components, safety and fire prevention methods, health physics problems, operational considerations, and brief descriptions of AEC installations, are included.

The Committee recommends that the report be utilized as a design guide, pending the establishment of formalized criteria; that the AEC support projects for testing the application of existing products and components to glove box operations and the development of improved components where necessary; that the AEC establish communication channels to encourage the exchange of information between installations, covering experiences and developments in the design and operation of enclosures.

REPORT ON
GLOVE BOXES AND CONTAINMENT ENCLOSURES

AUTHORITY AND PURPOSE

As a result of various studies into the fire and safety conditions prevailing in AEC glove box facilities, the General Manager, by memorandum dated August 27, 1959, established an ad hoc committee to formulate criteria and guide lines for the design, construction, and operation of safe, economical, and efficient glove boxes and associated facilities based upon present conditions and anticipated changes. In order to provide complete coverage of the many facets of the problem four subcommittees were appointed as follows:

(1) Glove Box Construction Materials and Components

(2) Glove Box Operations

(3) Safety and Fire Protection

(4) Health Physics

The subcommittees developed a comprehensive questionnaire which was submitted to all Operations Offices having extensive experience with glove boxes and other type enclosures. The responses to this questionnaire have been supplemented and consolidated with information obtained through personal visits to various offices, discussions with operating personnel, and review of available publications. Reporting offices are listed in Table I.

DEFINITION OF GLOVE BOX

For the purpose of this report, a glove box or enclosure and associated facilities, is defined as: a compartment, box or hood used to enclose an operation or process to contain and separate hazardous materials from operating personnel or unfavorable environmental conditions. This definition does not include "Hot Cells". The terms "glove boxes" and "enclosures" are used synonymously herein, and include boxes equipped for semi-remote operations, but principally those equipped with gloves. Enclosures are used extensively throughout AEC in both laboratory and fabrication operations.

APPLICATION OF GLOVE BOXES AND ENCLOSURES

Reasons for employing enclosures may be either necessity or simply an advantage. The "necessity" is to keep workers or material separated from hazardous situations with toxic, pyrophoric or radioactive substances. The "advantage" is in keeping workers or materials separated from detrimental situations involving moisture, fumes, dust, oxygen, etc., so as to effect economy or improve product.

In the early stages of dealing with these situations an attempt was made to accomplish the separation of worker and hazard by enclosing the worker with such awkward devices as masks, shoe covers, respirators, special suits, etc. This approach to the problem has many disadvantages which have been discussed in various reports. Discussions of protective clothing are contained in AEC report, ORNL-3070 by C. J. Barton, and in the publication, "Glove Boxes and Shielded Cells", edited by G. N. Walton.

Later on, means were found to enclose the work instead of the worker. The first enclosures left much to be desired. Over the years, however, materials and techniques have improved so that today it should be possible to provide a good box for almost any situation. What is a good box? Simply one that adequately yet economically encloses an operation.

Information on enclosures as used in many different applications is important to anyone who wishes to adopt or expand their use. This report presents such information. Emphasis is upon glove boxes - a special class of enclosure that satisfy a large portion of the problems - but the principles apply to all enclosures.

When laboratories began to deal with radioactive materials, it became necessary to find means of safely handling these hazardous substances. Although this problem is relatively new, great progress has been made and is continuing. Techniques and equipment have been developed whereby control can be established and maintained within relatively small volumes of space in enclosures - particularly glove boxes. Thus the potentially hazardous operation is isolated and contained, and by concentration of the controls within a small area it is possible to carry on highly specialized work in a laboratory that is otherwise normal and in which the workers themselves are not hampered by cumbersome protective devices.

This concept of the enclosure within which to incorporate the specific controls needed to carry out specialized work is not necessarily limited to the handling of radioactive materials. Originally devised as a means of controlling a hazard, enclosures can be used effectively as a convenient and economical means for quality control and can be applied to practically any operation for which it is necessary to establish certain conditions of environment or of confinement, whether of solids, liquids, or gases, or of radiation.

ADVANCE PLANNING

The decision to use, or not use enclosures, automatically determines the philosophy of operations. This decision should be made very early in the planning stage as the choice may have profound effects upon building requirements, equipment selection, budget estimates, etc. After analyzing the basic operation and its possible separation into phases for convenient enclosure application, it is possible to evaluate the personnel problems and building and operation costs. The heating, ventilation, insurance, safety, and other factors of operating a plant are influenced by the use of enclosures. The importance of pre-planning is stressed at nearly every site employing enclosures.

COMMERCIAL BOXES

In recent years various manufacturers have entered the field of glove box fabrication. Standard design boxes are available from a few sources, but a relatively large number of firms fabricate enclosures to conform with the customers' specific requirements and specifications. Since the procurement of a ready-made box may result in substantial economies, the application or adaptability of such boxes should be investigated before a decision is reached to design and procure a custom made box. The names and addresses of manufacturers of glove boxes, equipment and components are listed in the annual "buyers guide" issue of "Nucleonics".

DISCUSSION

It is expected that future technical developments will result in modifications in established design, fabrication and operation of enclosure facilities. Owing to the rapid changes in design and operation of enclosures, periodic reappraisal is in order. Management must be able to anticipate trends to the extent permitted by practicality, ingenuity, and economy in order to assure effective operation in the future.

The use of enclosures, including glove boxes, comes into increasing favor as their advantages are recognized. Applications may be in chemistry, biology, medicine, engineering, electronic manufacturing, pharmaceutics, etc., and the advantages of an enclosure are not restricted to safety aspects; economy, efficiency, or production quality may frequently be enhanced regardless of whether or not there are any questions of safety involved.

Since the possibility of accidents must not be overlooked, the protective measures being employed in any enclosure, or system, wherein radioactive materials are being handled, should be supplemented by an active and effective health physics program.

If the general development and application of enclosures seems slow, it may be for these three reasons:

1. Unfamiliarity -- People called upon to specify and design installations, having established certain thought patterns, are reluctant to depart from the designs and techniques with which they are familiar and in which they have confidence.

2. Specificity -- Those forced by circumstances (handling plutonium, bacteria, etc.), to employ enclosures, consider their own specific requirements but have no great interest in the broad aspect of "general" design.

3. Inexperience -- Few have the background of experience and ingenuity necessary to advance into the front line of development. Knowledge of, and experience with enclosures, are necessary if one is to design an efficient and economical unit to meet the requirements for any particular job.

A consolidation of opinions, techniques, and equipment design is provided herein. It is hoped that this report will serve:

Management: in demonstrating that enclosures can be of vital concern to their field of responsibility;

Engineers and Architects: in emphasizing the value of anticipating certain features of building design, in stimulating their interest and ingenuity in this area, and providing knowledge of existing installations;

Scientists and Researchers: in acquainting them with certain information that may be of help in planning their equipment and processes;

Operating Technicians: in assisting in their understanding of any complexities of enclosure operation;

Safety Specialists: in appreciating the value of enclosures in safety programs and the need for safety and fire prevention devices in glove boxes.

If some progress can be made in more frequent standardization and in closer cooperation on direct and related problems of enclosures in the many applicable fields, this report will have served a useful purpose.

ENCLOSURE DESIGN

The design of glove boxes or enclosures requires careful consideration of construction materials, air flow patterns, ventilating equipment, filters, atmospheric control, lighting, glove and bag port sizes, alarm devices, fire extinguishing equipment, explosion suppression or containment features, window size and construction and many other items. The design is effected by the types of materials to be handled, operating procedures, safety requirements, and health physics considerations. It is more economical, as well as more convenient, to limit to the smallest possible volume the space to which the controls - of pressure, temperature, humidity, atmosphere, or isolation-must be applied.

Detailed discussions of glove box construction materials and components are contained in Appendix I; of operational considerations in Appendix II; of safety and fire protection in Appendix III; and of health physics factors in Appendix IV. Appendix V contains brief descriptions of various AEC installations. A bibliography is contained in Appendix VI.

The variety in design and construction of glove boxes seems to be as extensive as the number and ingenuity of designers. To accomplish greater economy and efficiency in the design of enclosures, information collected by the committee has been analyzed to determine whether any items could be standardized for a substantial number of boxes. From this analysis it appears that the following guides could be applicable to a majority of box installations:

a. Ventilation of enclosures should generally be designed to provide a supply rate of 1 to 2 volume changes per minute, at a negative pressure of about 1/2 inch of water.

b. Recirculation of the ventilating medium should be considered where use of inert gases or conditioned atmosphere is necessary, or economic advantages accrue.

c. The advantages of "close capture" systems should be investigated where dust or fumes having explosive, pyrophoric, or toxic properties are generated in hazardous quantities.

d. Standby equipment should be installed to assure continuity of ventilation in hazardous operations.

e. Dual incombustible (AEC type high efficiency) filters, designed to permit alternate use, should be provided where hazardous operations are conducted.

f. Viewing windows should be of sufficient size to permit the operator, when in an operating position, to observe the entire interior of the enclosure. Window material should be of a type which will resist abrasion, fragmentation, heat or fire, and discoloration from radiation.

g. Circular glove ports, generally 8" in diameter, should be used, with provision for smaller and larger ports as needed, and located to permit the operator to reach all parts of the interior of the enclosure.

h. Bag ports should be limited to the following sizes: 4", 8", 12", 16", and 24" diameter.

i. Removal of contaminated equipment and materials from enclosures through use of sealed plastic bags, results in more effective contamination control than through use of air locks;

j. Enclosures should be designed to permit replacement of gloves and transfer bags without violating the integrity of the physical barrier;

k. Explosion venting or suppression devices should be provided in enclosures subject to explosion hazards.

l. Emergency controls for equipment enclosed in glove boxes should be located both inside and outside of the enclosure.

m. Recognized fire protection and detection practices and the latest engineering developments in the fire protection field should be incorporated in the design.

n. Auxiliary equipment should be located outside the enclosure to the maximum practicable extent.

CONCLUSIONS

From the information gathered it is concluded that:

1. the establishment of criteria, for use as guides in the design of glove boxes and enclosures should result in more uniform, safe and economical facilities. The information presented in this report fulfills the Committee's assignment by providing an interim guide for the design of enclosures and should prove helpful in the subsequent development of formal criteria;

2. a certain amount of standardization of glove box components would be beneficial and could result in substantial economies;

3. a continuing program should be initiated to distribute notices and communications to all AEC installations as pertinent techniques, designs, and materials develop;

4. a forum should be established for periodic factual discussions of the technical, safety, and economic developments which can and have been successfully applied in the use of glove boxes and enclosures;

5. operator training programs should be emphasized at all AEC installations to insure operator familiarity with good housekeeping practices, precautionary and emergency procedures, and operating techniques;

6. certain research and development projects should be undertaken to determine relative advantages of various materials and enclosure components and the properties and effects of various ventilating media. In this program, care should be exercised to avoid duplication of tests, evaluation and development. Investigational projects have been suggested by various subcommittees and are detailed in the appendices.

RECOMMENDATIONS

The Committee recommends that the AEC:

1. Adopt this report as an interim guide for the design of glove box facilities and undertake the development and distribution of formal design criteria;

2. Support necessary research and development projects to determine relative advantages of various materials and enclosure components;

3. Encourage better communications between various sites regarding pertinent techniques, designs and materials development in the glove box field.

TABLE I
REPORTING OFFICES

SYMBOL	OFFICE AND LOCATION
AGN	AEROJET GENERAL NUCLEONICS San Ramon, Calif.
AMES	AMES LABORATORY Ames, Iowa
ANL	ARGONNE NATIONAL LABORATORY Argonne, Ill.
AI	ATOMICS INTERNATIONAL Canoga Park, Calif.
BW	NUCLEAR FACILITIES PLANT BABCOCK & WILCOX Lynchburg, Va.
BMI	BATTELLE MEMORIAL INSTITUTE Columbus, Ohio
BNL	BROOKHAVEN NATIONAL LABORATORY Upton, Long Island, N. Y.
HAPO	HANFORD ATOMIC PRODUCTS CO. General Electric Co. Richland, Wash.
ICPP	IDAHO CHEM. PROCESSING PLANT PHILLIPS PETROLEUM CO. Idaho Falls, Idaho
KAPL	KNOLLS ATOMIC POWER LABORATORY General Electric Co. Schenectady, N. Y.
LRL	LAWRENCE RADIATION LABORATORY (A) Berkeley, (B) Livermore Calif.
LAR	LOCKLAND AIRCRAFT REACTORS G.E. - ANP - Cincinnati, Ohio
LASL	LOS ALAMOS SCIENTIFIC LABORATORY Los Alamos, N. M.
MAL	MALLINCKRODT CHEMICAL WORKS Weldon Springs, Mo.
MND	MOUND LABORATORY Monsanto Chem. Co., Miamisburg, O.
NBL	NEW BRUNSWICK LABORATORY New Brunswick, N. J.
ORNL	OAK RIDGE NATIONAL LABORATORY (A) X-10, (B) Y-12 Oak Ridge, Tenn.
PW	PRATT AND WHITNEY Middletown, Conn.
RFP	ROCKY FLATS PLANT Dow Chemical Co., Boulder, Colo.
SRP	SAVANNAH RIVER PLANT duPont, Aiken, So. Carolina

GLOVE BOX CONSTRUCTION MATERIALS AND COMPONENTS

Sub-Committee Members:

LeRoy Kelman, ANL, Chicago, Chairman (Aug. '59 to Oct. '60)
P. J. Peterson, LASL, Los Alamos, Chairman (Oct. '60 to completion)
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GLOVE BOX CONSTRUCTION MATERIALS AND COMPONENTS

A. GENERAL DISCUSSION

1. Materials of Box Construction

Enclosures have been constructed of plywood, carbon steel, stainless steel, aluminum, and various plastic materials. A tabulation summarizing materials used in glove box construction at various AEC installations is shown on page I-13. A comprehensive presentation of this subject is contained in the report by Barton[1].

Supports for enclosures are usually fabricated of commercially available steel angles or welded pipe frames. In the case of plywood boxes, the supporting frames are constructed of wood or steel.

Boxes constructed of carbon steel or plywood and all supporting frames are usually coated with corrosion resistant paint, vinyl paint or thin plastic sheeting.

2. Ventilation, Filtration and Atmosphere Control.

In designing an enclosure one of the most important items is ventilation. Ventilation covers the supply and exhaust of the proper volume of the required type of air or gas to the glove box or enclosure. The success of ventilation control in a glove box or enclosure obviously can determine the success of the installation, since by our original concept - for our purposes - an enclosure is a volume of space wherein atmospheric conditions are maintained under control. An unexpected leak anywhere - through a gasket, glove, or cracked window - indirectly constitutes a failure in the ventilation system.

There are so many inter-related factors in designing and operating a satisfactory ventilation system that a simple description is not possible. In general, the various ventilation systems can be divided into the following basic types:

(1) A minimum of air or gas flow.
(2) A maximum of air or gas flow.
(3) No air or gas flow (only adjustment for make-up leakage volume to maintain specified pressure).

Types (2) and (3) are special cases and need individual consideration.

1/ ORNL-3070, "A Review of Glove Box Construction and Experimentation", by C. J. Barton

Type (1) "a minimum of air flow" is recognized as the basis for the majority of operations. Even the various opinions as to the minimum volume requirements would fall within a fairly narrow range of values as adopted by the different users. Exact volumes in a number of cases are given under the discussion for a particular site.

Combined with general ventilation are special auxiliaries - close capture (see page I-4), scrubbers, recirculating gas, internal condensers, or heat exchangers, - all are usually considered components of ventilation, internal to an enclosure system. The enclosure system is intact except at the inlet and outlet filters and the filters form the boundaries of the enclosure.

Operation of the ventilation system begins with the blower which, in the case of enclosures, should be located beyond the exhaust filter and as near the exhaust point as can be arranged. This maintains a negative pressure within the duct system, and hence an accident or filter failure would not spread activity into a building or area, should there be openings in a duct. With a properly operating exhaust filter the blower itself should remain clean and present no difficulties for maintenance.

At the enclosure exhaust it is customary to control the negative pressure with dampers. The amount of this negative pressure must account for the pressure drop of the entering air through the inlet filter plus the pressure drop through the exhaust filter and leave the box operating at the desired negative pressure. This is a rather universal basic premise and is achieved by various combinations of blowers, duct pressures and ventilation balancing an inlet filter and the outside face of an outlet filter where the exhaust goes to a duct and to the atmosphere.

The negative pressure is expected to insure that leaks of any kind - accidental or operational - have a minimum probability of permitting contamination to escape. The approximate range used in most cases is between 1/4" and 1" negative water pressure with respect to the atmosphere surrounding the glove box. When a water pressure of less than minus 3/4" is used, the gloves extend quite rigidly into the glove box and, in some cases, this can interfere with operations. Some sites feel that at least minus 1/2" water pressure is required to insure against escape of contamination at even a small opening.

Thus the characteristics and size of the inlet filters are largely determined by the air volume and the negative pressure desired. Nearly all installations recognize that the incoming air should be cleaned by a building filter system. The enclosure inlet filter serves the dual function of providing additional cleaning thus prolonging the life of the exhaust filter, and preventing activity in the box from escaping upstream. The location of the inlet filter and the provisions for changing filter elements are features which must receive attention in designing an enclosure.

An enclosure usually is adjusted to operate between 1/2 volume change per minute and 3 volume changes per minute. The smaller the volume that can be used with safety, the lesser the power demand, filter capacity, and duct sizes required, and the greater the cost savings that will result.

Numerous systems have been devised for measuring and controlling the negative pressure. Manometers can be employed, but at present magnohelic gauge controllers are in wide use at the various sites. Combined with these are arrangements to provide alarm and control in case of fire or accident.

The air leaving the clean side of the enclosure system exhaust filter is presumed to be almost, if not entirely, free of the contaminating elements in the box. To achieve this result, special design of filters, scrubbers, condensers, etc., has been required in many cases. Complicated procedures are frequently involved in changing these filters and, in some instances, dual exhaust filters are designed into the system so that when one is plugged or fails it can be removed from service and the second filter put into service without interruption of work while the filter is changed.

To make the changing of filters as infrequent as possible, special equipment is introduced to prevent acid fumes from destroying the filter, dust from clogging it, or moisture from causing troublesome condensation in the ducts or filter media. Facilities for these purposes will be reported under the individual installations.

Filter units are the most standardized component of the enclosures. High efficiency filters are available in several sizes and several thicknesses from commercial sources. Improved filters with greater fire resistance are being installed at practically every site. The efficiency rating has become widely accepted as the D O P test, and the shipping, handling, storage and installation techniques are also somewhat routine[1/]. To offer protection to high

1/ See U.S.A.E.C.Publication TID-7023- Issued Aug. 1961- "High Efficiency Particulate Air Filter Units" - Available from the Office of Technical Services, Dept. of Commerce, Washington 25, D. C., - Price $0.75.

efficiency filters it is common practice to install some fibre glass media ahead of the high efficiency unit. The prefilter installation is either incorporated in the enclosure in such a way that the filter change is carried out within the box, or is installed in a short run of duct beyond the box. Some of the old large filter banks at the end of long large contaminated ducts are still in use, but they are seldom considered in new construction.

3. Recirculating Ventilation

There are numerous instances where it is advantageous to recirculate all or a portion of the ventilating gas being used for an enclosure. Where an inert gas is required, such as argon or helium, an economic factor may easily justify a recirculating system. Also an extra dry atmosphere may be costly and difficult to obtain, and this can be recirculated economically. Recirculation is sometimes necessary where the cleaning techniques are not sufficiently good to permit exhausting the air to the atmosphere. Heat generated within the box is often removed through the ventilation system. A greater volume of air must be used and frequently it is an advantage to cool the air through heat exchangers, and recycle rather than provide filtration for this extra volume of air.

Many systems have been considered for recirculating the gas, and a number of them tried out - some successfully - while others were abandoned without overcoming the difficulties. Many pertinent points are covered in various reports.[1]

4. Close Capture

The close capture technique has proved very valuable in a number of installations. Wherever dust or fumes are produced in troublesome quantities within limited areas it is an advantage to collect these without letting them become dispersed throughout the entire box or enclosure. This is accomplished by having a special blower installed to gather air at high velocities through a "snout" and placing the snout in a strategic position over the source point. The exhaust dusts or fumes are filtered or scrubbed within the same box, or transferred to another enclosure for processing.

Because of the explosive nature of many dusts, the pyrophoricity of numerous materials, and the toxic properties of various materials, great care must be observed in designing a close capture system into an enclosure.

1/ U.S.R.L-3635, "Off-Gas Treatment in Berkeley Enclosures: by Thaxtor,M.D., Cantelow, H.P., and Burk, C.
ANL-5509,"The Safe Handling of Radioactive-Pyrophoric Materials" by Kelman, L.R., Wilkinson,W.D., Sheck,A.B., and Goertz, R.C.
Proceedings of 8th Hot Lab. Conference, Dec. 1960, Coleman,L.F., et al. "Atmosphere Handling and Control for a Glove Box Facility".

5. Scrubbers - Absorbers - Dryers.

Scrubbers used in connection with box operations function in their normal manner but require that some special features be added. Pressure control must insure that the proper box pressure is maintained. Usually each specific application imposes a special set of conditions.

Absorbers are called upon to remove gases, and the most common type is activated carbon. This is used extensively, and where it will not remove sufficient gas by itself, it is cooled with liquid nitrogen. The use of liquid nitrogen cooled traps must be avoided where air is the ventilating medium since oxygen will liquify in the trap at the temperatures of liquid nitrogen. A mixture of liquid oxygen and activated carbon is potentially explosive.

The dryers in use are all commercial units supplemented, when necessary, with special chemical or freezing trap to obtain very low moisture content. Performance under these extreme demands is influenced by gloves, and will be discussed under that topic.

Descriptions of special auxiliary units designed for use with enclosure facilities are contained in several publications.1/

6. Air Pattern within Enclosure - Down Draft

The air pattern within an enclosure must be considered in the box design. Ventilating air may be introduced in a pattern to prevent condensate from accumulating on the window. Smoke tests will indicate where adjustments should be made. Several sites have adopted a "down draft" design, taking the exhaust out at the floor of the box, but no great advantage for this draft pattern has been demonstrated.

7. Zoning

Zoning of ventilation must be tied in, to a certain extent, with the subdivision or zoning of processes being carried out. Zoning of enclosure operations generally depends upon the contamination release potential of the activity. Fresh air is introduced about every 10 feet into long enclosures. The exhaust filters are placed to maximum advantage, depending upon the operation. It is certainly advisable to break down the exhaust system into zones somewhat comparable to the supply zones.

Under certain conditions individual exhaust blowers for each box have an advantage, but grouping the boxes in one room for an exhaust

1/ See ORNL-3070, "A Review of Glove Box Construction and Experimentation" by D. J. Barton; Publication "Glove Boxes and Shielded Cells" edited by G. N. Walton, Butterworths, London (1958); Proceedings of the Eighth Conference on Hot Laboratories and Equipment, Book 2, available from Office of Technical Services, Dept. of Commerce, Washington 25, D. C.

to the roof is considered most satisfactory[1].

8. Standby Facilities

The maintenance of a negative pressure in many enclosures is a critical function. If the failure of the ventilation system may result in serious consequences, blowers may require the installation of standby power generators, or separate prime movers to assure operation. Dual systems or interconnections between boxes should be arranged in hazardous installations.

9. Windows and Viewing

The window, as a potential weak spot in the final glove box assembly, has received a great deal of attention at all sites. The primary purpose of a window is to give the worker or operator an adequate view of the process area in the enclosure. There exists a wide difference of opinion as to what constitutes an "adequate" view. If all other factors could be disregarded, it seems universally agreed that a completely transparent enclosure is ideal. Many glove boxes are made of lucite or transparent plastic and achieve this at the expense of other factors. There are strength considerations, cost figures, safety aspects, fire hazards, and many details that usually make it advisable to restrict the window to some suitable size. If improvement in plastics continues, it may well be that an all-purpose material will become available for the fabrication of a transparent box, eliminating the window as now employed.

Some enclosures have larger window areas than are necessary. Only one or two sites have studied what viewing is needed before selecting the size and number and location of windows. It is important to be able to see all the interior of a box, but not while standing some distance away.

The choice of material for the window may be forced upon the design because of the proposed use of the enclosure. For performance characteristics the window must

(1) Transmit adequate light (wave lengths considered in some cases);
(2) Provide view from operating position (employing gloves or manipulator);
(3) Continue to give clear vision (including no condensate);
(4) Be at an angle - or be arranged to give no troublesome reflection.

1/ The Report on "Laboratory Ventilation" by R. J. Hale, of Savannah River Laboratory, presented at the Sixth Hot Laboratory Conference (1958) is an excellent reference in regard to Ventilation.

It is desirable that window materials meet the following mechanical and safety requirements:

(1) Be Shock resistant;
(2) Withstand some mechanical abrasion - not scratch;
(3) Offer fire resistance;
(4) Facilitate sealing or gasketing;
(5) Be chemically resistant and sometimes radiation resistant;
(6) Remain tight with frequent temperature and pressure changes;
(7) Fabricate with ease.

These are the major considerations which have led those in the field to choose materials as listed in the tabulation on page I-14. In addition to the lucite, plexiglass, homolyte, safety glass, there are instances where quartz is used for special light transmission or temperature shielding and heavy plate glass 1" or more for unusual conditions.

There has been a great amount of individual site research[1/] conducted in an effort to choose the proper window material, and numerous reports have been written on this subject, but the general opinion is that much valuable information could come from further research regarding window materials.

If a group were to be selected to adopt half-a-dozen standard sizes for windows, these could be commercially available and stocked, influencing the designer and contributing to safety, economy and convenience. This would in no way prevent the use of whatever size conditions demanded, but it could be helpful.

The lighting for the box interior is usually provided from an external source through a window. This permits changing or giving any required attention without introducing or removing items from the enclosure. Windows for lighting are at the top or sides, and the lighting itself may be incandescent, fluorescent or mercury vapor. Occasionally spot lights within an enclosure are very valuable.

The generation of heat by lights or other equipment within an enclosure may prove detrimental to the operation. In such cases, it is necessary to locate the heat generating equipment outside the enclosure.

1/ The characteristics of these materials are discussed and reference to the reports is given in ORNL-3070 "A Review of Glove Box Construction and Experimentation", by C. J. Barton.

In the early days, whenever direct observation was not possible, due to radiation, or for some other reason, mirrors were used, but these were quite unsatisfactory. The mirrors gave way to periscopes, and now closed circuit television is playing an important role in some applications. Stereoscopic television is at the consideration stage, and may ultimately be of great value in certain situations.

Where high levels of penetrating radiation are involved, special shielding windows are necessary, but these should not be an integral part of an enclosure. Such shielding may involve several feet of water, zinc bromide solution, dense lead glass and special non-browning glass.

10. Glove Ports and Gloves

One component of the Glove Box that should be easy to discuss is the Glove Port, since its function seems simple and clean cut. It should secure a work glove in such a manner that the contaminating elements inside do not get out of - or contaminating elements outside do not get into - the enclosure. Also its design should make it easy to change to a new glove whenever this is necessary without losing the integrity of the enclosure.

The service to which a glove port is to be put will influence the choice of size and material. The more important characteristics are:

(1) Size - Diameter
(2) Attaching - Welded - bolted and gasket - bonded - threaded
(3) Material - Aluminum - stainless steel - plastic
(4) Glove securing - External banding
- O-ring
- Grooves - plain - double - shaped
- External and Internal banding
(5) Glove changing
(6) Cost - Port itself - port installed
(7) Atmosphere control ports - where they must be sealed to withstand atmosphere pressure.

The size is influenced by the type of service and the space limitations when crowding of equipment occurs. There may be simple operations involved or chemical processes or heavy mechanical operations. The survey shows sizes 4", 5", 6", 8", 10", 11" and 12" diameters as listed in table on page I-16. Many of these are made in several styles. In discussing this item with various users nearly all agreed that an 8" size should adequately meet most requirements, with the provision that one smaller - say 5" or 6" - and one larger - 10" - should be available when required. Elliptical or oval ports have been tried but have not found favor as they are expensive and make it more difficult to maintain a tight glove seal.

The method of attaching is influenced by the enclosure material the port passes through - whether glass, plastic, metal, etc. Some styles and variations in attaching techniques are shown in the glove port illustrations on Sheets I-23 and 24. The choice of port material is largely limited to aluminum, stainless steel and plastic, with various users claiming advantages for each. The method to be employed for securing the gloves naturally influences the design of the port. Also it is expected that some ports can be sealed to permit increasing the negative pressure within the box. This is essential in some inert atmosphere or moisture control boxes.

The cost of a port is frequently an argument in favor of some particular design. A proper evaluation is to determine the cost installed. Savings through the purchase of a cheap port can be more than lost in extra installation costs.

From the survey it is evident that many designs have been developed to do the job adequately under every type of service. It will be unfortunate if sizes, materials and designs continue to expand over the years because of personal preferance or interest of an engineer to make his own "custom job" when there is no technical advantage.

11. Bagging and Sphincter Valve

Preplanning is stressed at nearly every site and, if this is carried out properly, requirements for a process within an enclosure can be anticipated. Cold runs (test operations without use of contaminating elements) usually establish any unforeseen difficulty and, hence, a final set-up should not develop foreseeable troubles. This should provide for rapid and safe transfers into or out of an enclosure. Provision is made for occasional tools, repair parts, samples, etc., which may have to be introduced; and certainly waste and some miscellaneous pieces will need to be removed.

The air-lock was the first attempt to transfer between the enclosure interior and the outside without releasing contamination. Air-locks are still used where it is necessary to transfer large equipment or materials into and out of enclosures. It is a component which can be built as part of the box or attached to it.

As plastics became suitable for the purpose, the bagging technique was developed. This is best understood from the illustration on Page I-25. The bag port is closely allied to the glove port, and in some cases the same ring type and size is used for both purposes.

The bag port has been developed in several styles, and at present there are many sizes. From the survey it would appear that 4", 8", 12", 16" and 24" would meet all situations.

The bagging material and sealing methods must be considered together. In some cases twisting the bag, sealing with tape and cutting, is adequate. Heat sealing with polyethylene material is successful with proper controls of time and temperature for the sealing step. A set-up to control these automatically is essential. Polyvinyl material is used for bagging with high frequency electronic sealing. There are commercial units available that do this successfully, but they become quite large when designed to handle the large diameter bags.

The Sphincter Valve (see sketch - page I-26) is a popular method of introducing items into an enclosure. It is simple and fast, but operates in one direction only, and has limitations as to how large it can be made. Neoprene gaskets are cut with a hole slightly smaller than the can which has been selected for use. A can is forced into the series of gaskets and remains there to form a seal. To introduce an item, it is placed in the can and another can is pushed into the gasket array so as to force the first can into the box and at the same time maintain the seal to await an occasion when some other item is to be put into the box. Three or four inches in diameter are the usual sizes of sphincter valves used.

B. CONCLUSIONS

1. The field reports show wide spread interest in the applications and developments of glove boxes and enclosures for present and future use.

2. A continuing program for dissemination of information on techniques, designs, materials, and developments in these areas, could be of great assistance and earn the support of the field. It could be of value technically and monetarily and contribute to safety.

3. Personal discussion disclosed hesitant concurrence in the possibility of some standardization. Carried too far standardization could stifle initiative and encroach on the privilege of choice. Standardization of various components should not be objectionable and the establishment of criteria or guides for the design and fabrication of enclosures should certainly be helpful. As an example of the need for criteria, over fifty varieties and combinations of glove ports are in current use and result from the different sizes, materials, designs for glove attachment, method of fastening to the box, etc. It appears probable that glove port design could be restricted to about three materials and two ways of

attaching, so that the resulting combinations would satisfy the majority of situations and make it seldom necessary to design a special port. With fewer port sizes a valuable secondary advantage would result. A smaller number of different glove diameters would have to be manufactured and stocked.

4. A continuing - perhaps annual - revision of the information would be desirable and could be accomplished without imposing the extensive and time-consuming reporting as was required with the original questionnaire. As a suggested method, the process might be somewhat reversed. The present questionnaire asked brief leading questions requiring long write-ups by many people at many sites, and the answers were in a form not easily compared. If the narrative data could be prepared once and sent out as the questionnaire, employing tables to some extent, those in the field need only use check marks. Returned forms of this type would require a minimum of editing, if any, before incorporation in the up-dated report.

C. TABLES AND ILLUSTRATIONS

The Tables are compiled largely from the answers to the Committee's questionnaire and are intended only to indicate trends and provide a quick general reference. The characteristics of the individual materials have not been discussed, as this has been well covered in Barton's report.[1/]

The illustrations show several typical applications of glove boxes and details of various glove box components.

1/ ORNL-3070, "A Review of Glove Box Construction and Experimentation", by C. J. Barton.

PROPERTIES OF WINDOW MATERIALS (RELATIVE)

MATERIAL	CLARITY (TRANSPA-RENCY)	EASE OF FABRICATION	RESISTANCE TO							
			FIRE	HEAT	IMPACT	ACIDS	SOLVENT	EDGE CRACK	DISCOLOR	SCRATCH
Laminated Safety Glass	Excellent	Fair	Excellent	Very Good	Good	Good 1/	Good	Poor	Good	Good
Plexi-glass 5009 (Flame-res.)	Very Good	Good	Very Good	Poor (125°F)	Good	Good	Good	Good	Good	Good
Homalite CR-101	Very Good	Fair	Good	Good	Good	Good	Good	Fair	Good	Good
Homalite CR-39	Very Good	Fair	Poor	Good (200°F)	Good	Very Good	Good	Fair	Good	Good
Plexi-glass (flammable)	Very Good	Excellent	Poor	Good (200°F)	Very Good	Good	Good	Excellent	Fair	Fair
Lucite	Very Good	Excellent	Poor	Good (200°F)	Good	Good	Good	Excellent	Fair	Fair
Poly-vinyl-chloride	Poor	Very Good	Good	Poor (140°F)	Good	Very Good	Very Good	Very Good	Good	Good

1/ Adversely affected by hydrofluoric acid.

BOX MATERIAL

SYMBOL	Lucite	Hetron 92	Plexi-glass 5009	P V C	Poly ester	Stainless Steel	Mild Carbon Steel	Aluminum	Plywood
	PLASTIC					METAL			WOOD
1 AGN	X					X			Formica Coated
2 AMES									Formica Coated
3 ANL		X				X	X	X	
4 AI			X			X	X		
5 BW						X		X	X
6 BMI							X		
7 BNL	X				X	X			
8 HAPO						(X)	X		X
9 ICPP									See Reference Page V-14
10 KAPL						(X)			
11 LRL	X								(X) Asbestos Covered
12 LAR	X					X			
13 LASL	X					(X)	Plasite Coated	X	X
14 MAL						Commercial Boxes			
15 MND	X					X	X		X
16 NBL						X			
17 ORNL			X			(X)	Coated Phenoline LiquidTile		
18 PW						X			
19 RFP						(X)	Plasite Coated		
20 SRP	X			X	X	X			Micarta Covered

Where one style predominates it is marked (X) but the absence of an X does not mean that the particular items are not or have not been used at the site.

WINDOW MATERIALS

SYMBOL	PLASTICS					GLASS
	Lucite	Plexiglass 5009	Homolite CR-39	Homolite CR-101		
1 AGN	X					1/4" Safety
2 AMES		x				
3 ANL			X			3/8" Lam. Safety
4 AI		X				Safety Glass
5 BW						Safety Glass
6 BMI		X				3/8" Lam. Safety
7 BNL	X					Tempered Glass
8 HAPO	X	X	X			
9 ICPP						Safety Plate
10 KAPL						Lam. Safety
11 LRL	X					Safety
12 LAR	X	X				Safety
13 LASL		X	X	X		Lam. Safety
14 MAL						1/4" Safety
15 MND		X		X		Lam. Safety
16 NBL						2 Ply Safety
17 ORNL	X					1/4" & 3/8" Safety
18 PW		X				Safety
19 RFP		X -B				Safety
20 SRP		X	X			

Special Windows have used: Pyrex, Tempered Plexiglass, NonUVA and Plexiglass 5009B

WINDOW SEALS

	SYMBOL	Neoprene	
1	AGN	Sheet	
2	AMES	Sheet	
3	ANL		Extruded Zipper (page I-27)
4	AI	O-Ring	
5	BW	Sheet	
6	BMI	3/8" D- O-ring	Extruded Zipper
7	BNL	Sheet	
8	HAPO	Soft	
9	ICPP	Sheet	
10	KAPL	O-Ring or Flat	
11	LRL	Soft Sponge	
12	LAR		
13	LASL	Sheet	Extruded Zipper
14	MAL	Sheet	
15	MND	Channel or Bound	
16	NBL	Sheet	
17	ORNL	Sheet	Extruded Zipper
18	PW	Sheet	
19	RFP		Molded Closed Cellular Rubber Sponge
20	SRP	Sheet	

	Symbol	GLOVE PORTS (INCHES) 4	5	6	8	10	11	12	Port Center to Center	BAG PORTS (INCHES) 4	6	8	11	12	14	16	22	24	Sphincter
1	AGN			Some	X														
2	AMES			X					18"										
3	ANL				X				18"			X					X		X
4	AI			X	X				18"			X							
5	BW																		
6	BMI				X				16"		X	X			X			X	X
7	BNL			X	X														
8	HAPO				X				16" 18"				X					X	X
9	ICPP			X															
10	KAPL				X		X												
11	LRL		X		X				17½" 19"				X					X	
12	LAR																		
13	LASL				X					X		X		X		X		X	
14	MAL			X															
15	MND				X				18"			X		X		X	X		
16	NBL																		
17	ORNL				X	X						X							
18	PW																		
19	RFP				X							X							
20	SRP	X			X			X		X		X		X		X			X

(Oval Glove Ports have largely been discarded)

GLOVES

	SYMBOL	Fastening to Ring	Material: Secondary Surgeons	Material: Neo Prene	Material: Butyl	Material: PVC	Length: 27"	Length: 30"	Length: 32"	Length: 36"	Thickness: Hand	Thickness: Glove	Sizes: 8½	Sizes: 9	Sizes: 9½	Sizes: 10	Special
1	AGN	"O" Ring	X	X				X						X			40 mg. per sq. cm.
2	AMES	"O" Ring	X	X			X										
3	ANL	"O"Ring Clamp	X 1/	X				X	X			25 30		X			
4	AI	"O" Ring Clamp		X				X									Few Pb. Impregnated
5	BW			X													
6	BMI	"O" Ring		X					X								Pb. Impregnated
7	BNL	"O" Ring		X		X											
8	HAPO	"O" Ring		X				X								10½	
9	ICPP	"O" Ring	X	X													
10	KAPL			X						X		20 30					
11	LRL	"O" Ring		X			X				6 8	15	X	X	X	X	
12	LAR	Metal Straps	X														
13	LASL	Internal External		X	X	X		X				15 30			X		
14	MAL	"O" Ring		X													
15	MND	"O" Ring		X				X				30			X		Embroidery Hoops
16	NBL		X	X													
17	ORNL	Clamp & "O"Ring	X	X				X				20			X		Embroidery Hoops
18	PW	"O" Ring		X													
19	RFP	Clamp	X	X								15 30			X		50 mil. Pb. Impreg.
20	SRP *	Double "O"Ring	X	X		X		X			10	15 25			X		

*Hypalon rings are replacing Neoprene rings

1/ Normal practice at ANL requires secondary surgeon's glove under regular box glove.

DUCT MATERIAL

	SYMBOL	Stainless Steel	Other Metal	Plastic	
1	AGN				2" Flexible Tubing
2	AMES				Wire Reinforced Rubber Tubing
3	ANL	Type 304	Some Aluminum		
4	AI	When needed			
5	BW				Flexible Fireproof
6	BMI		Galvanized Iron with Amercoat Lining		
7	BNL				
8	HAPO	X	Aluminum. Galvanized Iron with acid resistant Amercoat lining.		
9	ICPP	2" Flexible			
10	KAPL	X			
11	LRL		4" Seamless Tube Baked Resin Finish		
12	LAR				Corrugated flexible rubber
13	LASL	X		polyvinyl-chloride	
14	MAL			Flexible Fiber-glass Resin Coated	
15	MND	In small diameters	Black Iron coated with #55 Amercoat	Vinylite	
16	NBL	X		Polyvinyl-chloride	
17	ORNL	Where necessary	Coated		
18	PW	X			
19	RFP	On exhaust			
20	SRP	X		Flexible Neoprene Coated Fabric Hose	

FILTERS AND SCRUBBERS

	SYMBOL	INLET	EXHAUST IN BOX	EXHAUST IN DUCT	EXHAUST BANK	SCRUBBER
1	AGN	PF-105		CWS		
2	AMES	PF-105		CWS- Metal Case		
3	ANL	Fiberglass C W S	High Effic.	CWS		X
4	AI	PF-105		CWS		Caustic to Remove Acid
5	BW	Wool		CWS		
6	BMI	Fiberglass		CWS		
7	BNL	PF-105		CWS		X
8	HAPO	Fiberglass		CWS		Caustic
9	ICPP			CWS		
10	KAPL	Fiberglass		Fiberglass CWS		
11	LRL	PF-105		CWS		X
12	LAR			CWS		
13	LASL	CWS	CWS		X	Wet Filtration (See LAMS-2128)
14	MAL	Fiberglass		CWS		
15	MND			CWS		For Recovery and Reduce Corrosion
16	NBL					
17	ORNL	Fiberglass		Bag Filters	Filters	X
18	PW			CWS	X	X
19	RFP	High Efficiency		CWS	1000 24" x 24" x 12"	To Remove HNO_3 1000 cfm.
20	SRP	Dustop of P-F Pipe Insulation		CWS		Scrubbers in Box

CWS - Army Chemical Corps filters (chemical, biological, radiological)
PF-105 - Commercial prefilter

PROTECTIVE COATINGS

	SYMBOL	AIR DRIED	BAKED	LINING	STRIPPABLE
1	AGN	Amercoat on Purchased Boxes			
2	AMES		Enamel		
3	ANL	Permalume Liquid Tile Acti-Thane			
4	AI	Amercoat Phenoline Krylon			Some
5	BW				
6	BMI	Amercoat			
7	BNL	Amercoat Epoxy			
8	HAPO	Amercoat #33 Phenoline			
9	ICPP		Enamel on Floor Pan		
10	KAPL				Strip Coat in Hoods
11	LRL	Amercoat	Phenolic Epoxy on Metals	Polyethylene	
12	LAR				
13	LASL	Plasite-7122		Poly-vinyl Chloride	
14	MAL	Chem. Resist. Paint			
15	MND	Amercoat Seal-N-Peel			Seal-N-Peel
16	NBL	Amercoat			
17	ORNL	Amercoat Phenoline Liquid Tile			
18	PW			Plastic Film	
19	RFP	Placite			
20	SRP	Perma-Skin	Enamels on Floor Pan		Butvar-D1000 Liquid Envelope

MATERIAL AND SEALING
FOR
BAG OR POUCH

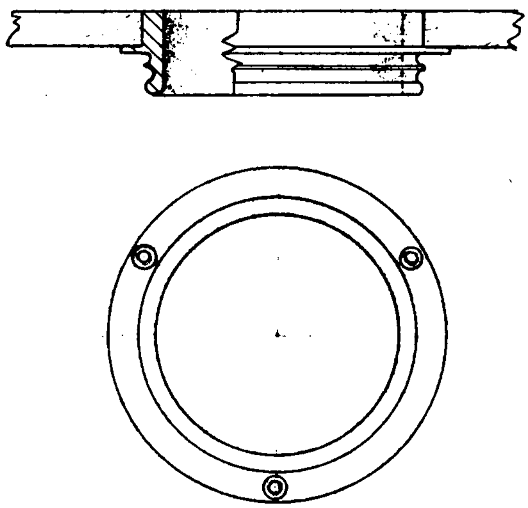
	SYMBOL	PVC	Polyethylene	Sealing	Explosion Venting
1	AGN	--	--	150 Watt Dobeckman In Box	No
2	AMES	--	--	--	No
3	ANL	12 - 20 mil.		Dielectric	No
4	AI		X	Twist and Tape	--
5	BW	--	--	--	No
6	BMI	X			No
7	BNL	10 mil.		Dielectric	Diaphragm
8	HAPO	X			No
9	ICPP	--	--	--	No
10	KAPL	--	--	--	No
11	LRL	X	X	Heat	No
12		LAR	X		No
13	LASL	12 mil			No
14	MAL	--	--	--	No
15	MND	X			Disc
16	NBL		X		No
17	ORNL		6 mil		--
18	PW	--	--	--	--
19	RFP	12 mil.		Twist and Tape	--
20	SRP	12 - 20 mil.	X		No

ALLOWABLE SURFACE CONTAMINATION

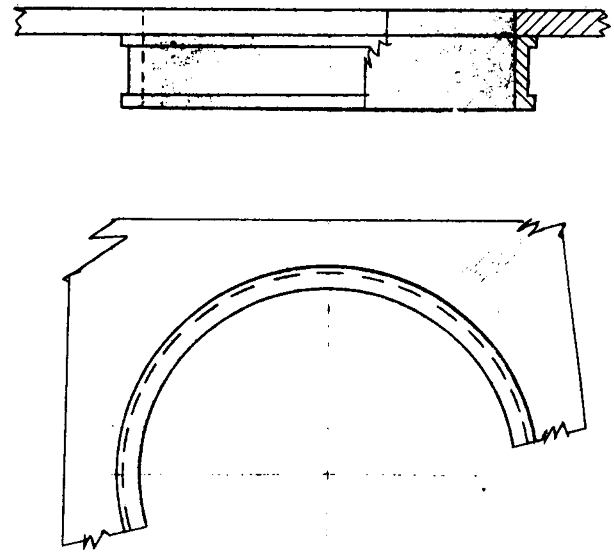
	SYMBOL	Method of Detection	Approximate Numerical Values
1	AGN		2000 Alpha/100 sq. cm. Swipe Negative. .2 mr./hr. Swipe Negative
2	AMES	From levels of Swipe Tests	
3	ANL	No Contamination Within Limits of Survey Inst.	Limit of Beta-Gamma Survey - .1 mr at 1". Limit of Alpha Survey - 500 d/m per 100 sq. cm.
4	AI		1000 - 2000 Counts U on Hands
5	BW	X	
6	BMI		Fixed 1 d/m/sq. cm. In Lab. - Fixed 10 d/m/sq/cm. Transfer .2 d/m/sq. cm. In Lab. - Transfer 1 d/m/sq.cm.
7	BNL		1000 c/m/100 sq. cm. Fixed Alpha. 1 mrad. at 2 cm.
8	HAPO		500 d/m Alpha 100 c/m Beta-Gamma (See Manual HW-25457
9	ICPP		20 d/m/100 sq. cm. Alpha Smears
10	KAPL		200 d/m/sq. ft. Alpha 200 c/m/sq. ft. for Beta-Gamma Smear
11	LRL	Action if Detectable Contamination	
12	LAR	X	
13	LASL		500 c/m/55 sq. cm. (See CMB-11-Health & Safety Booklet)
14	MAL	X	
15	MND		500 d/m/40 sq. cm. for Po 20 d/m/40 sq. cm. for Pu
16	NBL		500 d/m/100 sq. cm.
17	ORNL		500 d/m/100 sq. cm. Alpha for 100 sq. cm. swipe
18	PW	X	
19	RFP		500 d/m/70 sq. cm. Alpha
20	SRP	Action if Detectable Contamination	

X - No report

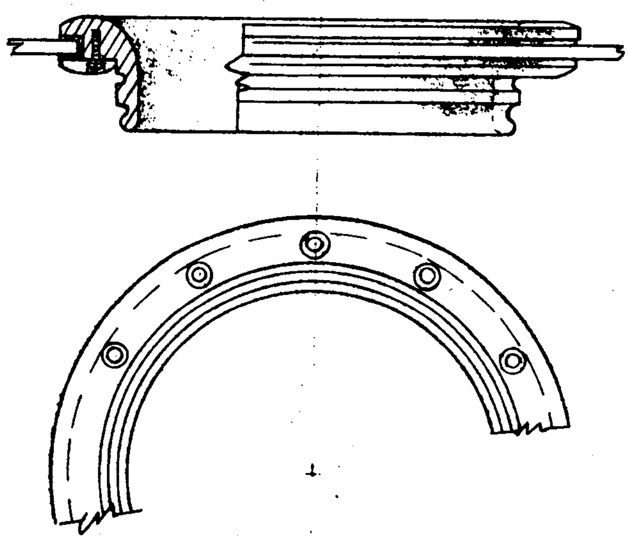
STANDARD GLOVE PORTS



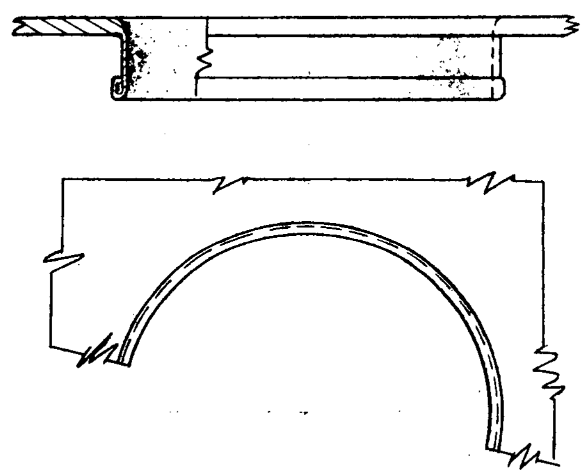
PORT #1



PORT #2



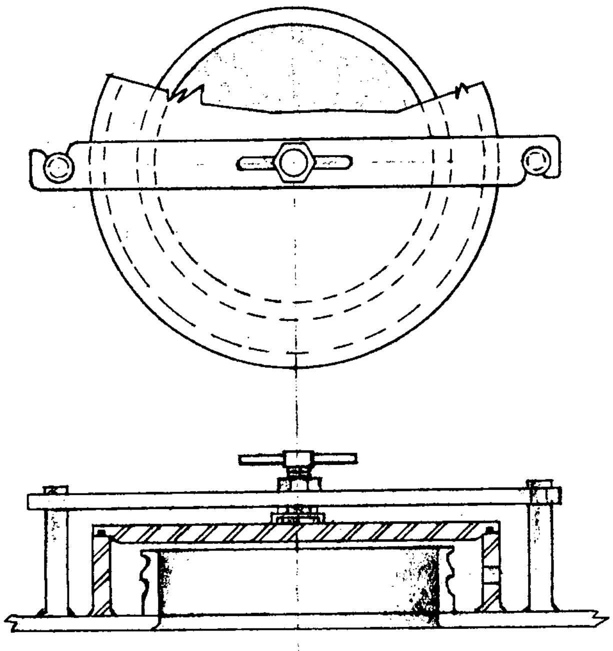
PORT #3



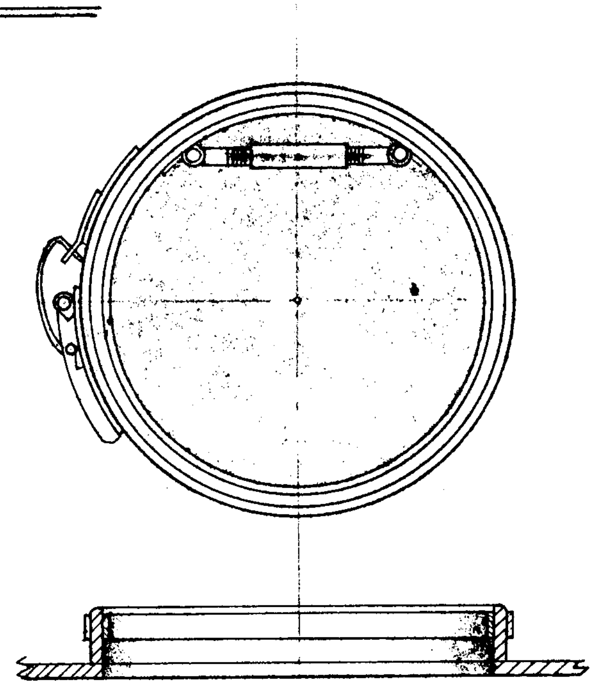
PORT #4

GLOVE PORT No.	SIZE	MATERIAL	ORIGIN	REMARKS
1	5-1/8" I.D.	AL. ALLOY	LRL. BERKELEY	1 PIECE
2	8 I.D.	AL ALLOY	ROCKY FLATS	1 PIECE
3	8 I.D.	BAKELITE	ARGONNE	2 PIECE
4	8 I.D.	16 GA.. S.S.	OAK RIDGE	WELDED TO PANEL

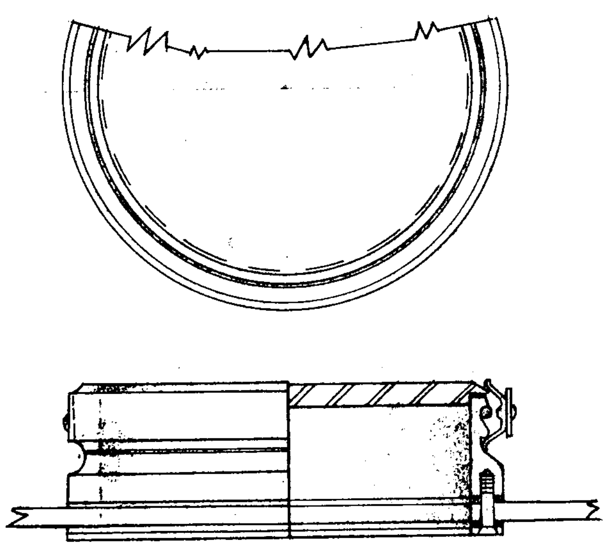
GLOVE PORTS



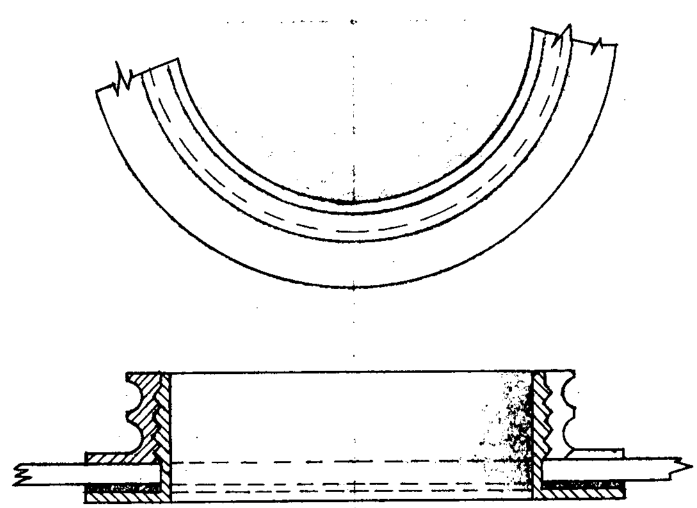
MOUND LAB. MODEL
WITH COVER FOR VAC. DRYBOX



OAK RIDGE
DOUBLE-CLAMP MOD.

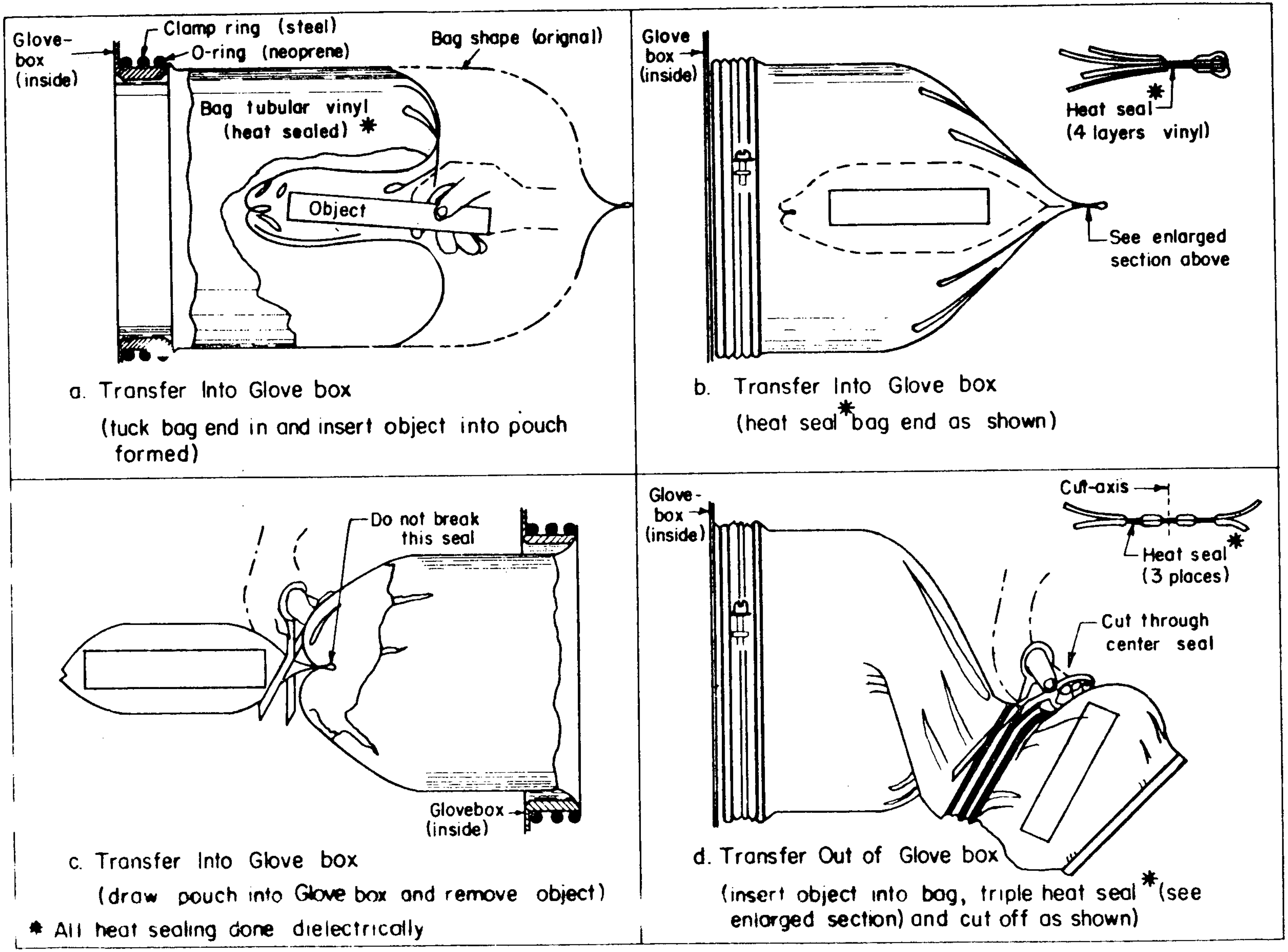


HANFORD MODEL
WITH COVER.

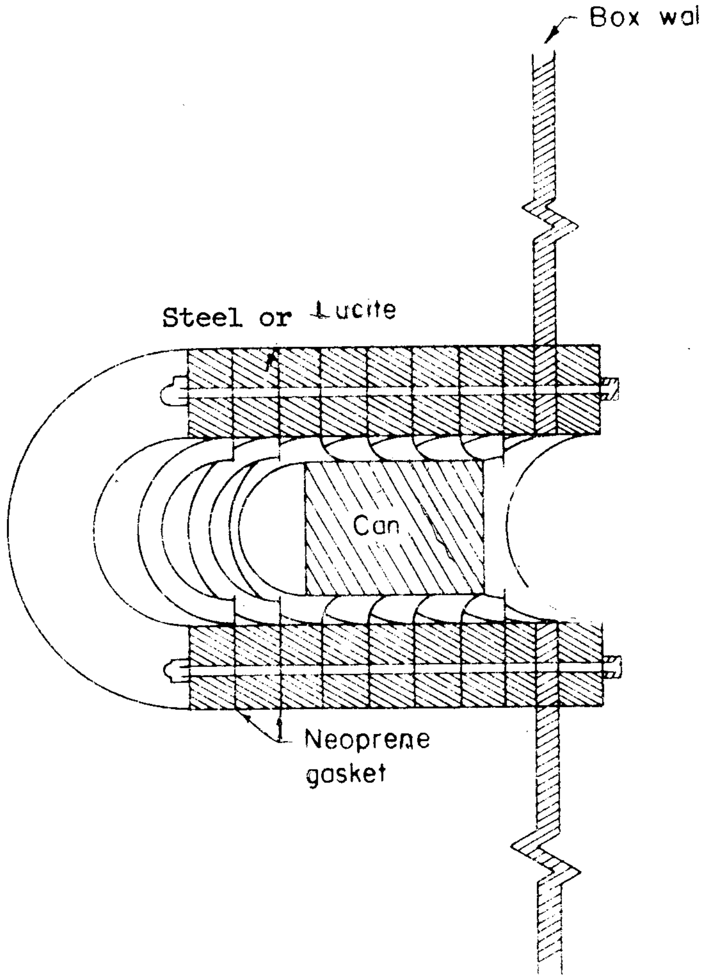


THREAD 2 PIECE MOD.

COMMERCIAL
(Used at several installations)

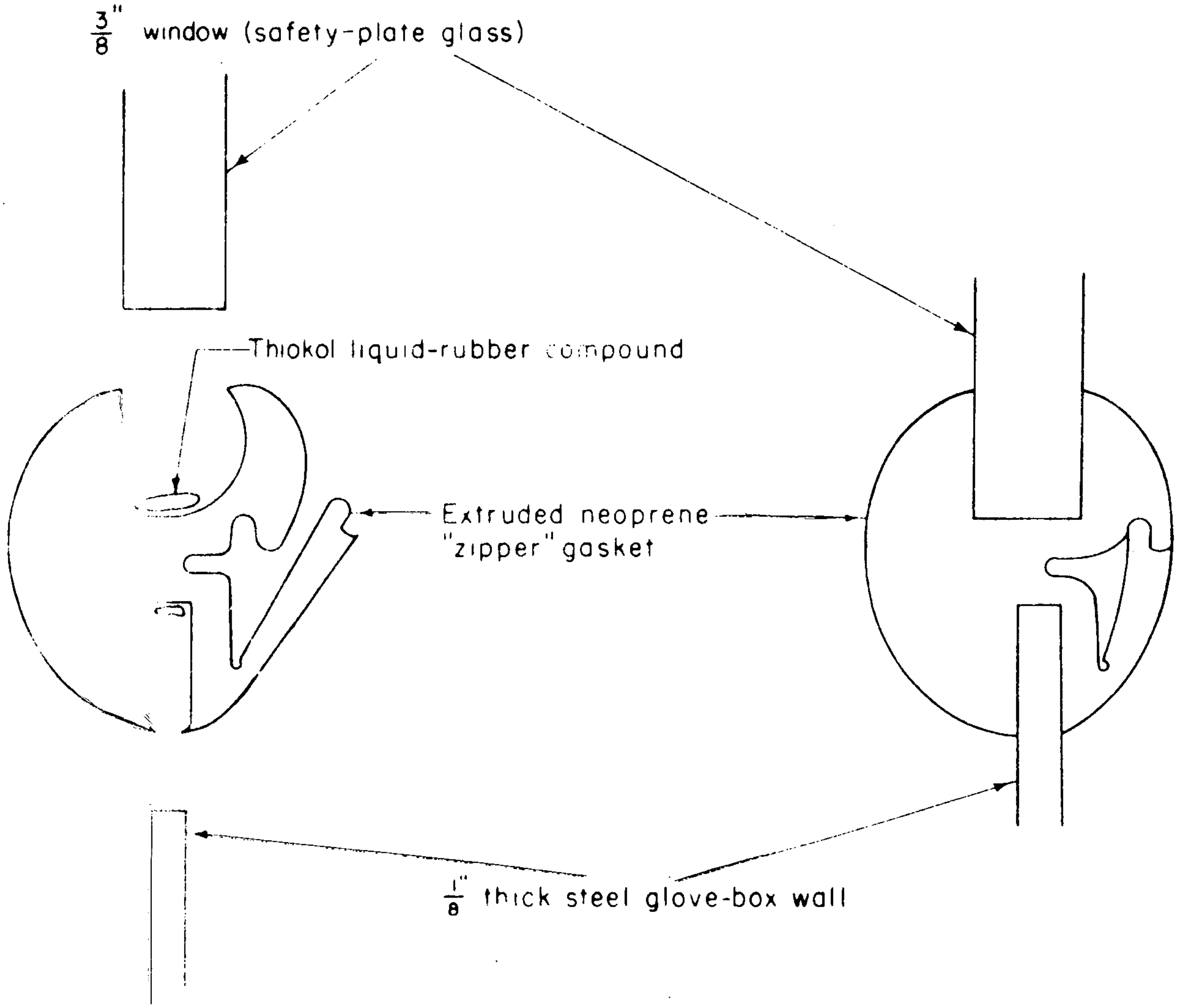


BAG TRANSFER PROCEDURE



SKETCH OF SPHINCTER VALVE CROSS SECTION

I-26

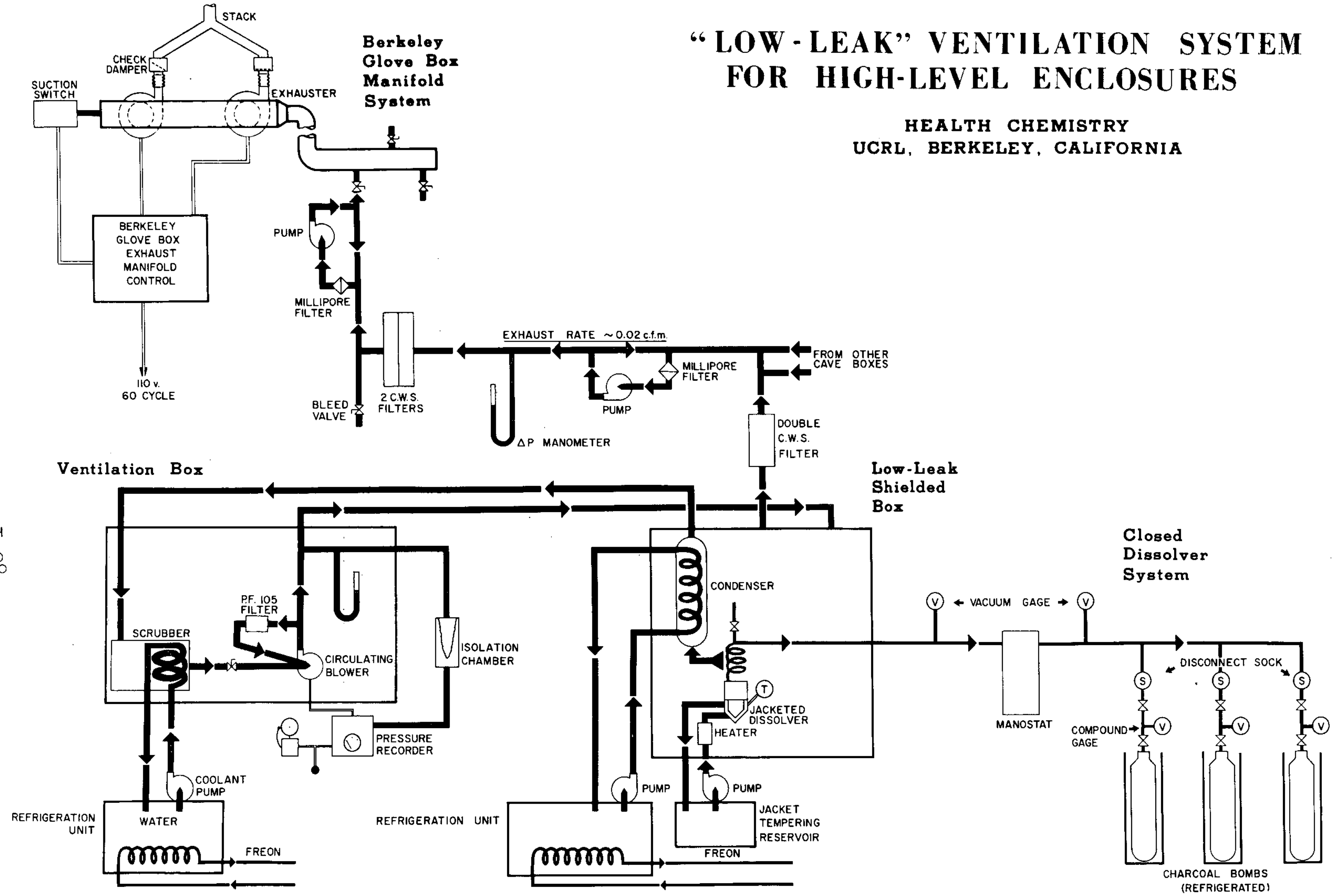


"Zipper" Closure

GLOVE BOX WINDOW-MOUNTING SYSTEM

"LOW-LEAK" VENTILATION SYSTEM FOR HIGH-LEVEL ENCLOSURES

HEALTH CHEMISTRY
UCRL, BERKELEY, CALIFORNIA



VENTILATION FOR LOW-LEAK SYSTEM

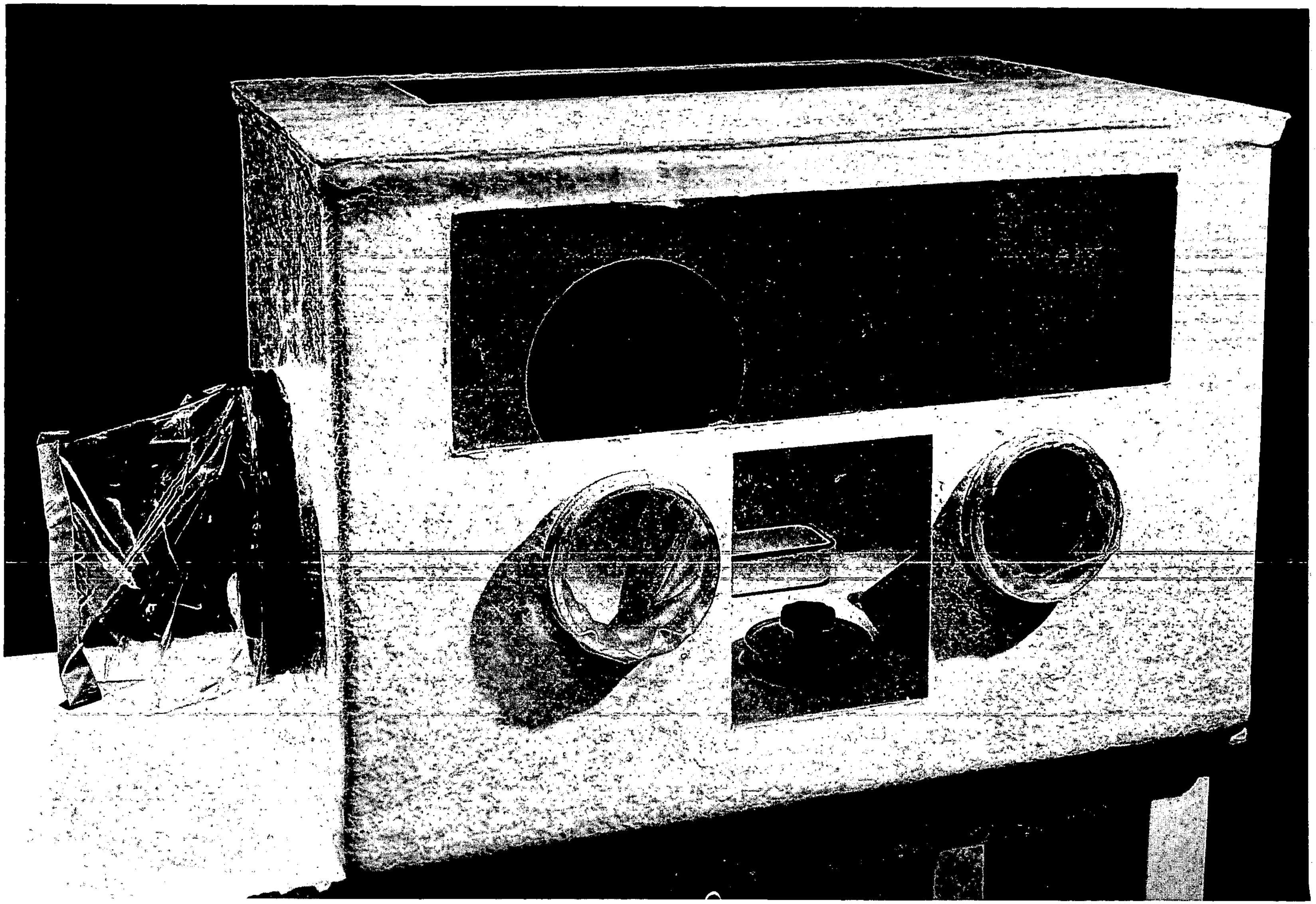
LOW-LEAK VENTILATION SYSTEMS ARE USED FOR HIGH-LEVEL SHIELDED ENCLOSURES BECAUSE FILTRATION EFFICIENCY IS GREATER WHEN FACE VELOCITIES THROUGH THE FILTER ARE LOW.

EACH ENCLOSURE IS EQUIPPED WITH AN INDIVIDUAL SCRUBBER UNIT FOR REMOVING CHEMICAL FUMES (PRODUCED IN MANY OF THE PROCESSING STEPS IN THE ENCLOSURE) AND EXCESS MOISTURE. THE AIR FROM THE ENCLOSURE CIRCULATES REPEATEDLY THROUGH A BUFFERED SCRUBBER SOLUTION (FOR REMOVING BOTH ACIDIC AND BASIC FUMES).

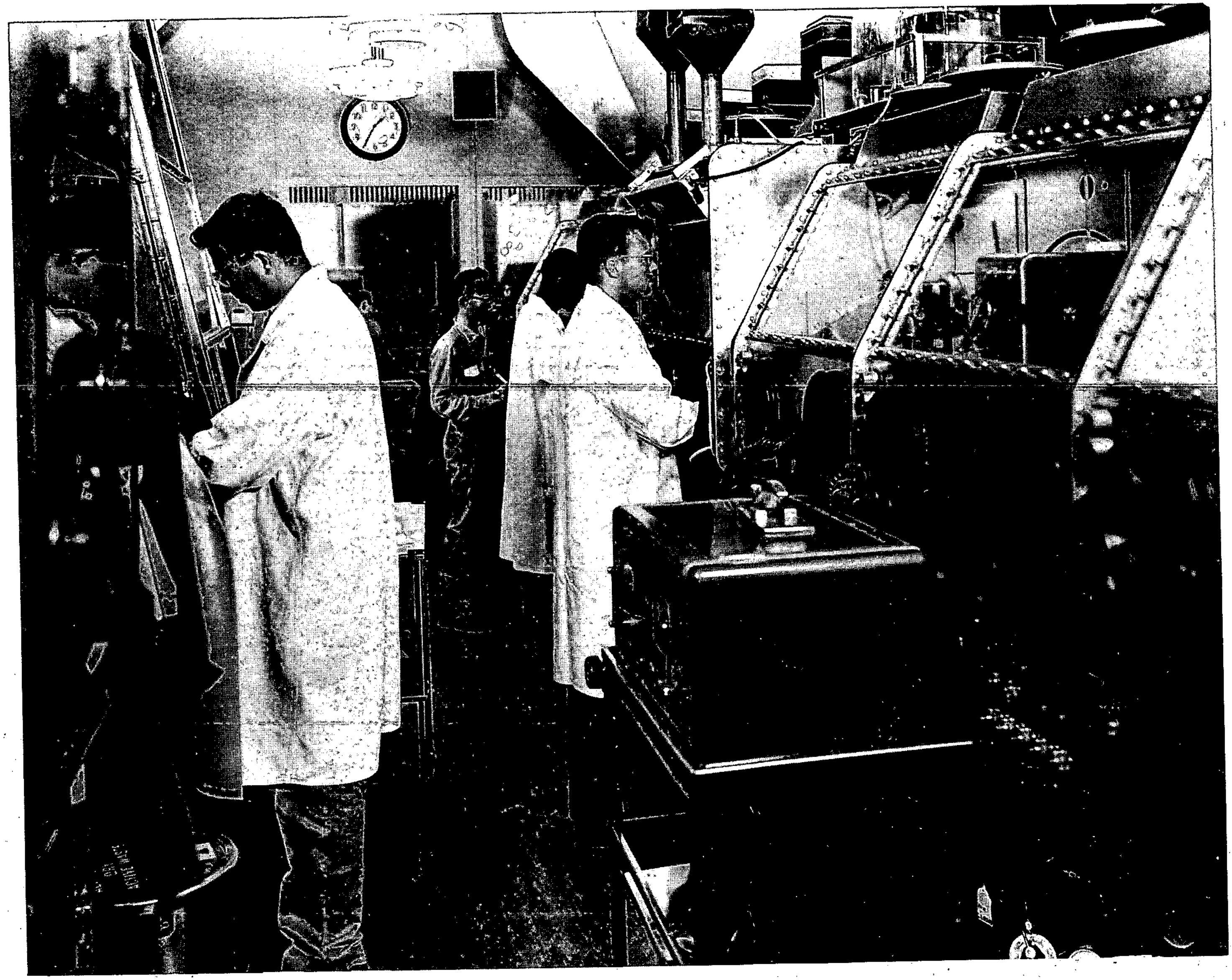
AT THE SAME TIME, AN EXHAUST SYSTEM TO WHICH ALL THE ENCLOSURES ARE CONNECTED MAINTAINS A SLIGHT VACUUM SO THAT AIR LEAKS GRADUALLY INTO THE ENCLOSURE FROM THE SURROUNDINGS. THE EXHAUST IS TAKEN FROM THE ENCLOSURE THROUGH A CWS FILTER, THEN THROUGH A LOOP (WITH ITS OWN PUMP) WHICH PASSES IT REPEATEDLY THROUGH A MEMBRANE FILTER AT 0.6 CFM; A FINAL BLOWER MOVES THE EXHAUST THROUGH A LARGE DOUBLE CWS FILTER INTO THE ATMOSPHERE AT A RATE OF ABOUT 0.02 CFM.

CLOSED DISSOLVER SYSTEM

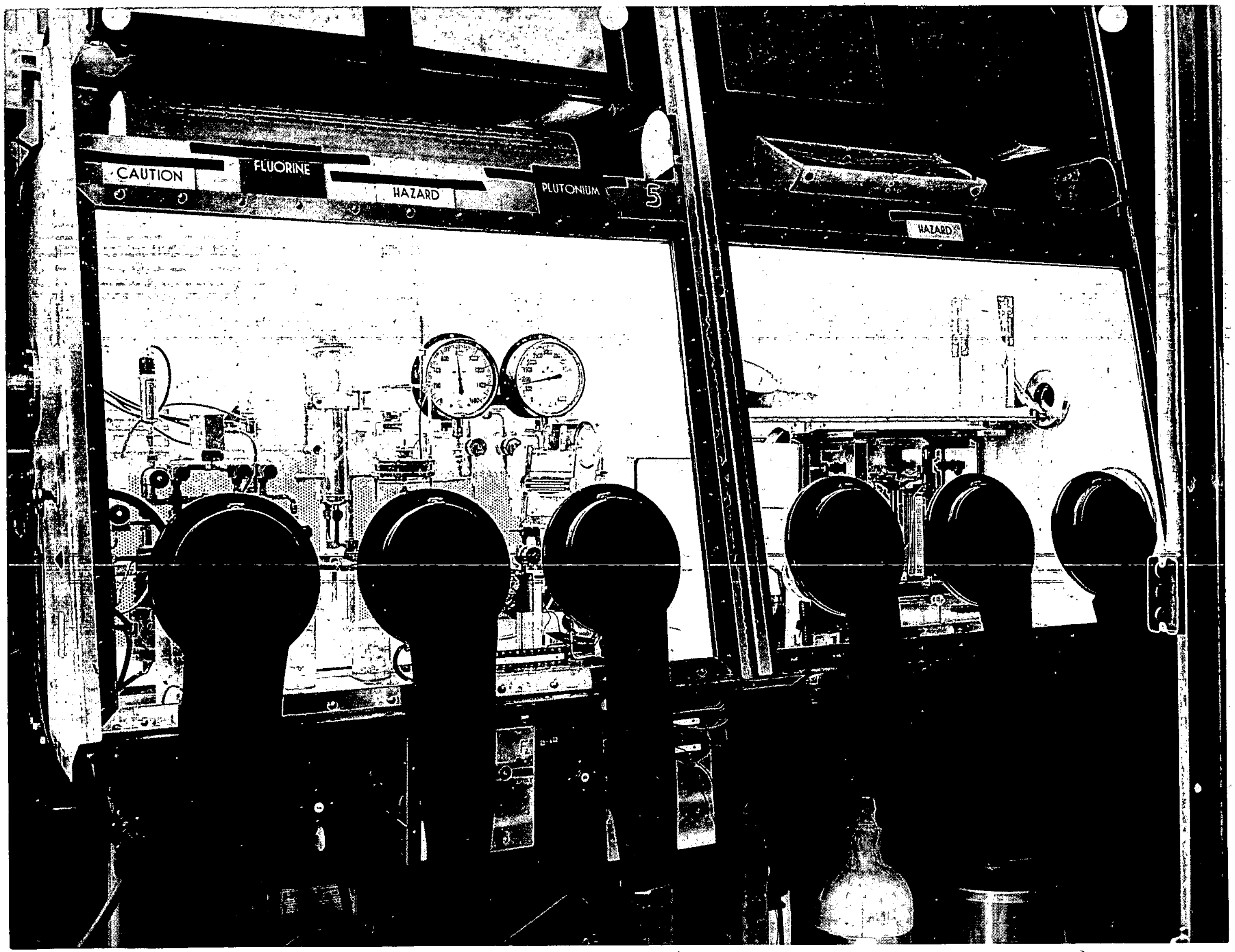
THE RADIOACTIVE GASES AND OTHER BY-PRODUCTS LIBERATED OR PRODUCED DURING THE DISSOLVING OF A PILE-IRRADIATED SLUG ARE COMPLETELY CAPTURED BY A BOMB CONTAINING 170 G ACTIVATED CHARCOAL. THE BOMB IS REFRIGERATED BY A MIXTURE OF BUTANOL AND SOLID CO_2, WHICH PRODUCES A TEMPERATURE OF -77° C. AT THIS TEMPERATURE THE VOLUME OF GAS THE BOMB CAN ABSORB IS 40 TO 45 TIMES ITS OWN VOLUME. SUCTION IN THE CLOSED DISSOLVER IS MAINTAINED AT 5 INCHES OF HG BY A MANOSTAT. THE CHARCOAL BOMB ITSELF IS EVACUATED TO 30 INCHES OF HG BEFOREHAND. UPON COMPLETION OF THE DISSOLVING STEP, THE BOMB AND ITS CONTENTS ARE TREATED AS SOLID RADIOACTIVE WASTE.



Polyester and Fiberglass Enclosure



Section of Plutonium Analytical Facility Chemical Engineering Div., ANL



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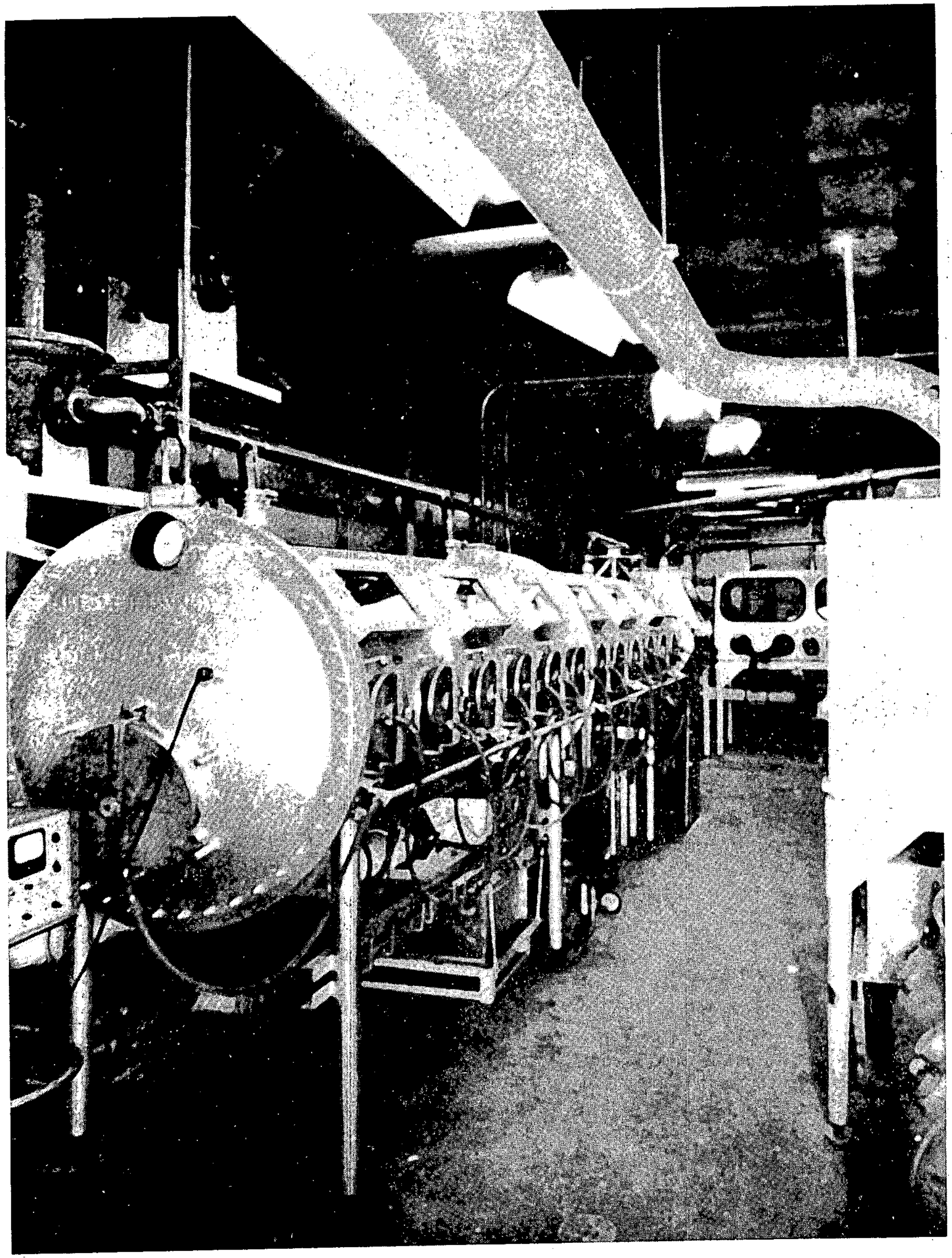

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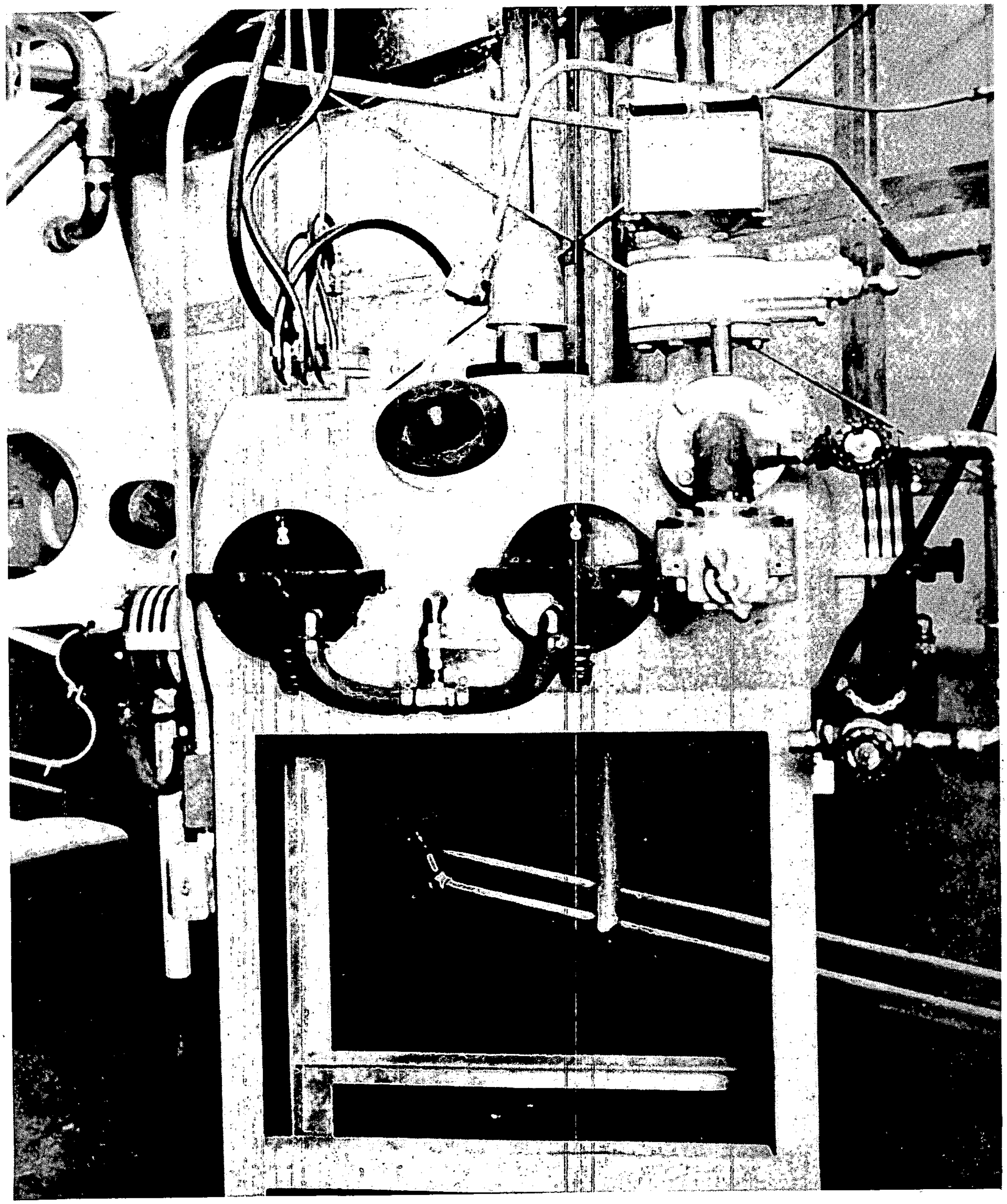

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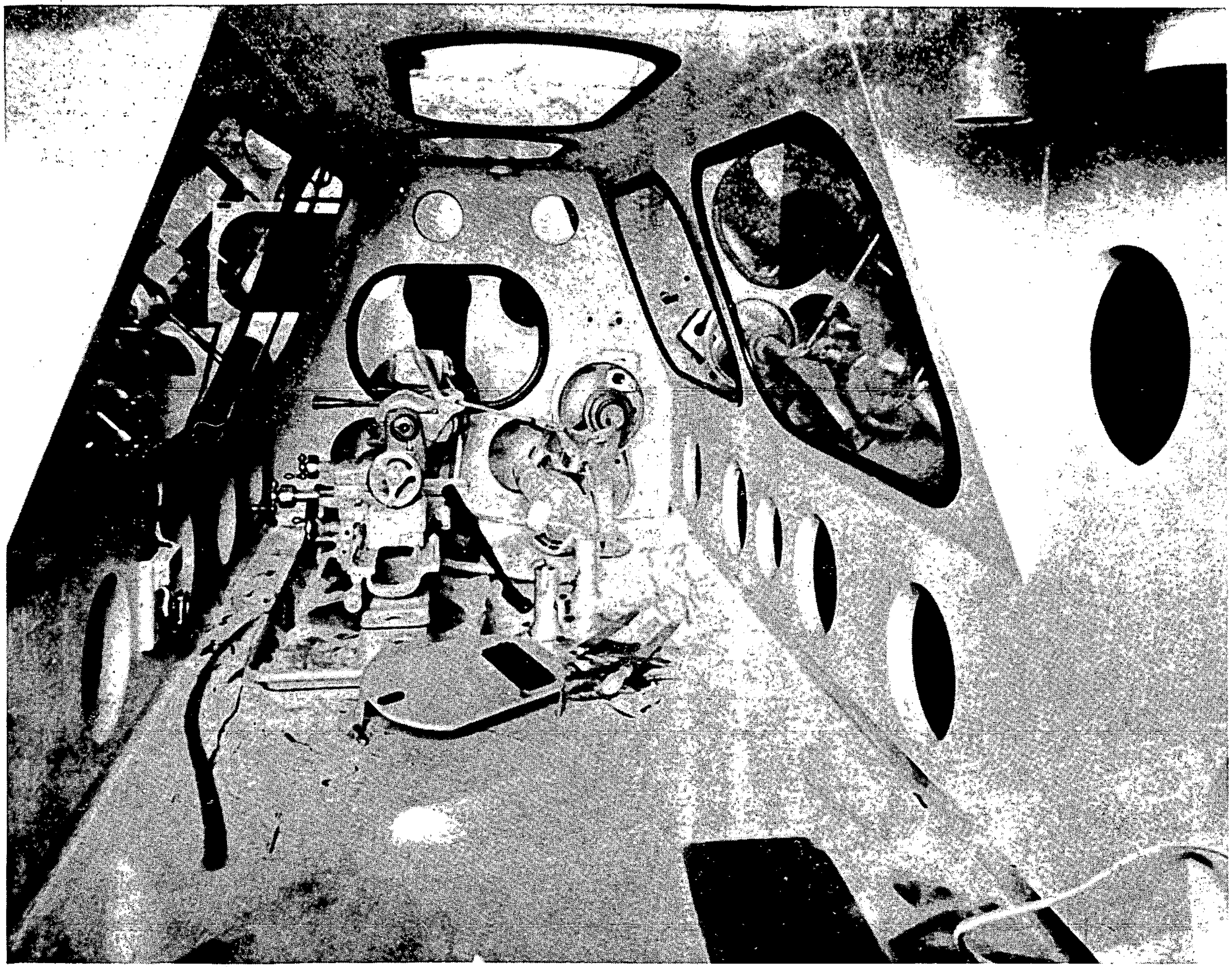
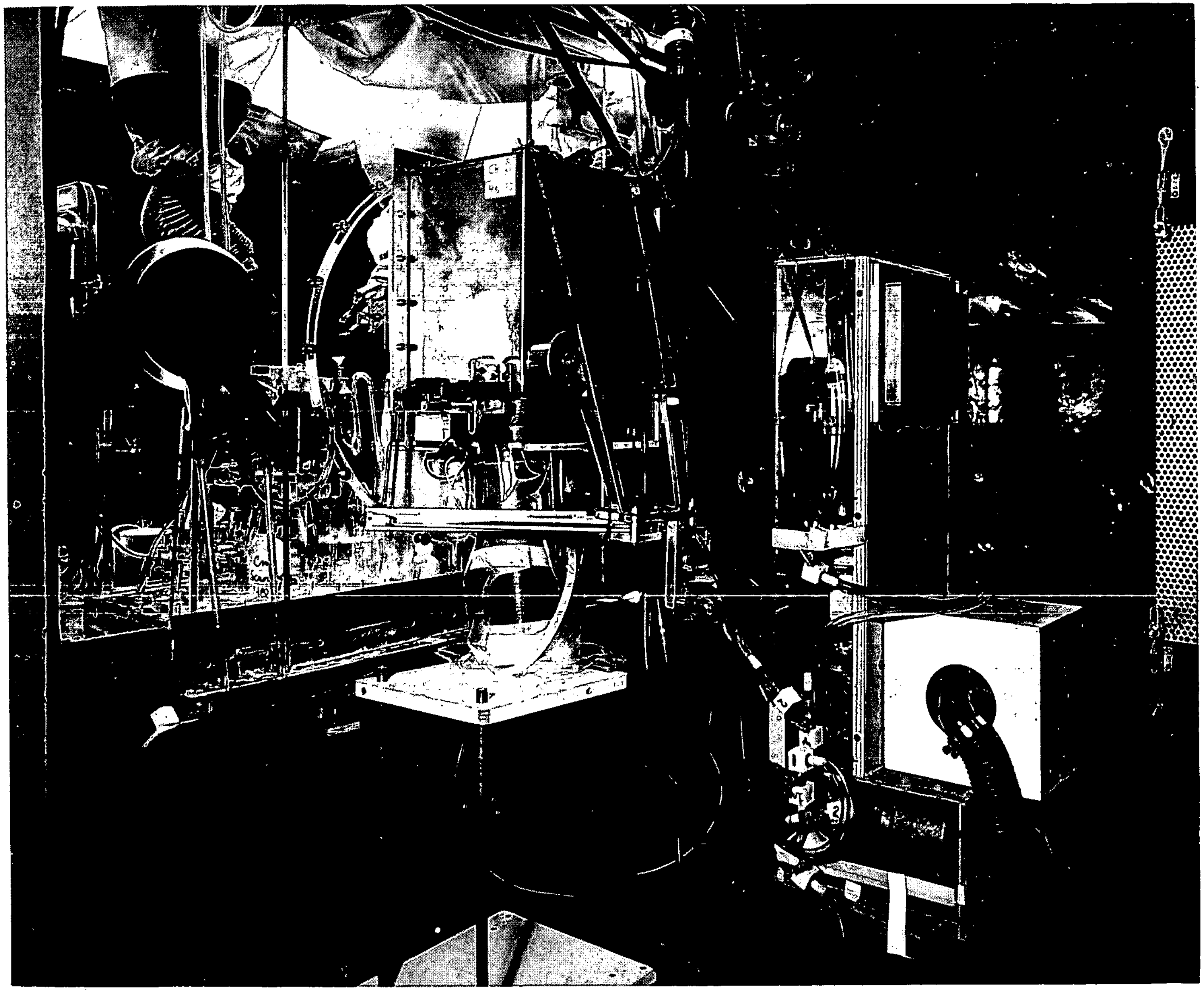
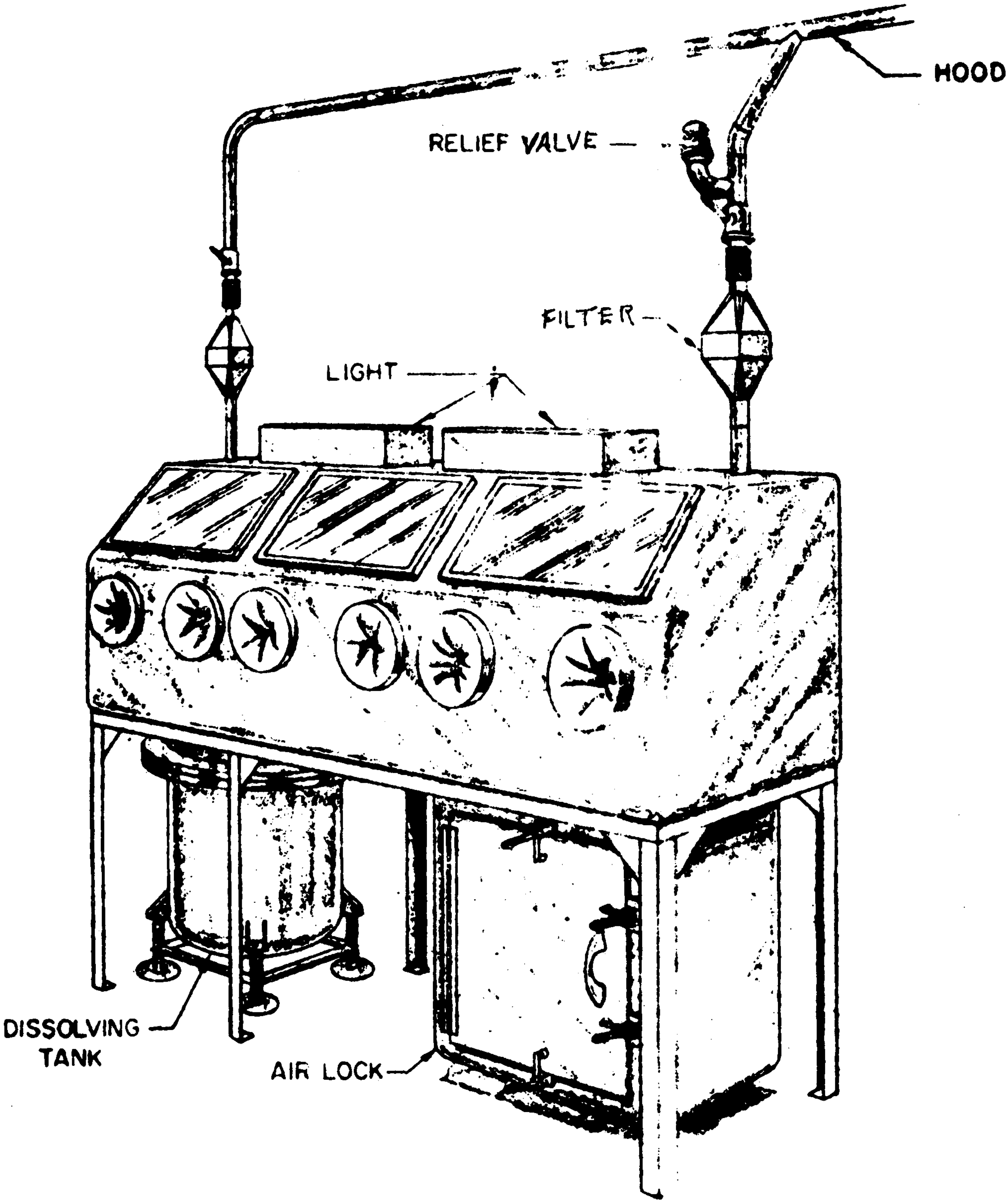


Glove Box with Lathe



Auxiliary Equipment Outside Glove Box



Beryllium Pilot Plant Dry Box

APPENDIX II

OPERATIONAL CONSIDERATIONS

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OPERATIONAL CONSIDERATIONS

1. Functional Design

As evidenced in Appendix V and as discussed in the report, glove boxes have been designed and used for a large variety of purposes. The design of glove boxes is closely related to the operation to be performed within the enclosure and to the material being handled. The layout of laboratories is also important in this respect and criteria covering such layouts are contained in AEC Manual Chapter 6301 Appendix Handbook. All factors concerning the safety of personnel and protection of the physical facility should be considered in the overall design. These factors are discussed in detail under Appendices III and IV.

The characteristics of the material to be handled within the enclosure (either toxic, radioactive, pyrophoric, etc.) dictate certain aspects of design, enclosure components, and characteristics of ventilation media. The design, however, should provide for the adaptation of the enclosure to the accommodation of other materials if such change in function appears probable.

It is important to recognize that limitations and restrictions will be placed upon the operations performed within the enclosure, in direct relation to the restrictions imposed upon the operator by the enclosure. A discussion of operator restrictions as related to safety aspects is contained in Appendix III.

Glove boxes can be designed as either free-standing or wall-mounted. Free standing glove boxes have certain functional advantages in the ease with which they may be moved from one area to another or changed from individual use to interconnecting or multiple arrangements. Auxiliary components (drives, controls, shafts, lighting, etc.) should be located outside the enclosure to permit unhampered servicing, maintenance, and repair. Enclosure designs should also provide for mechanized operations performed through remote controls, provided there is a possibility of such operations. The economy of fabricating boxes designed for the immediate purpose as opposed to incorporating facilities to cover a wide range of future operations should be considered in the light of the safety and economy with which changes can be made.

2. Services and Auxiliary Equipment

Overhead service connections have been found to be advantageous in providing flexibility for servicing free standing glove boxes. Overhead services have the additional advantage of being less likely to become contaminated in the event of accidental spills. Gas tight O-ring seals, compression fittings, and gasket closures have been used extensively where services pass through enclosure walls. Auxiliary equipment is generally located under the enclosure. Check valves installed in service connections will prevent the escape of radioactive contaminants through these openings. Standby equipment, to assure uninterrupted operation of ventilating equipment, is generally installed in facilities handling highly toxic or radioactive materials.

3. Atmosphere Control

The control of the atmosphere within the enclosure is often necessary to provide conditions that will not support combustion or to protect against the introduction of moisture and contaminating elements. Where an inert gas or conditioned air is utilized gas-tight glove boxes are required to maintain an inert atmosphere economically and protect against contamination leakage. Of the inert gases used in enclosures (helium, argon, nitrogen, and carbon dioxide), nitrogen is usually the most economical. The installation of alarm devices to detect and indicate undesirable concentrations of unwanted constituents is frequently advantageous.

A dry atmosphere will reduce the loss of material by oxidation and is usually employed in operations involving plutonium. Temperature control is necessary in some applications. For a further discussion of atmosphere control, refer to sections 2, 3, and 4 of Appendix I.

4. Ventilation Systems

Good design will provide for slightly negative pressure in laboratories, with respect to other parts of the building, to establish an air flow pattern from the offices and corridors to the laboratories (or areas of least contamination risk to areas of greater contamination risk). Criteria covering ventilation systems for laboratories are presented in AEC Manual Chapter 6301, Appendix Handbook.

Where a recirculating ventilation system is employed in an enclosure, it may be necessary to decontaminate or dry the ventilating medium. An economic evaluation should be made to determine the relative cost of a recirculating system compared to a "once through" system. Enclosures should be maintained at a negative pressure of about 1/2" of water and positive pressure boxes should not be used for operations involving radioactive or toxic materials. The regulation of pressure is accomplished through automatic or manual controls. Where hazardous materials are being handled a standby blower should be installed to operate automatically in case of failure of the primary blower. An automatic emergency electric supply, powered by a standby diesel generator, should also be provided in such cases. Consideration should be given to the installation of a dumping feature, that will automatically maintain negative pressure in case of a broken window or glove, in hazardous operations. The enclosure ventilation systems should be equipped with alarms to register pressure surges beyond predetermined limits. Ventilation system ducts are usually fabricated of metal, plastics, or fire retardant fibreglass. Duct materials in use at various facilities are tabulated on page I-18 of Appendix I. Ventilation system auxiliaries (scrubbers, absorbers, and driers) are described in Appendix I of this report. Exhaust air from enclosures handling radioactive materials should be filtered through AEC-type high efficiency filters, preceded by an incombustible commercial pre-filter.

5. Pyrophoric materials.

Where pyrophoric materials are present within glove boxes a dry, inert atmosphere must be maintained. A discussion of five prevention and control is contained in Appendix III. Pyrophoric materials and alkaline metals should not be allowed to accumulate. Such waste materials should be properly packaged and promptly transferred to designated storage areas or disposal.

Pyrophoric material in production boxes should be isolated from all other flammable materials and should not be left unattended.

6. Waste Disposal.

Dry radioactive waste is usually removed from glove boxes in containers sealed in plastic pouches, through bag ports or air locks. Ultimate disposal of bagged solids is by burial, reclamation or dumping at sea.

Liquid waste is removed from boxes by (1) piping leading to waste storage containers, (2) in bottles or cartons, and (3) by evaporation or absorption and then handled as dry waste. Pyrophoric wastes are often oxidized within the enclosure before removal for disposal. Pre-planning of waste disposal operations is imperative to assure the prompt, safe, and effective removal of hazardous materials.

7. Introduction and Removal of Materials.

Small items are often introduced into enclosures through sphincter, or push-through, entry ports, using aluminum or other metal cans. Larger items are introduced through bag ports, using the pouch technique, or through the use of air locks. Removal of materials, tools, or equipment is normally effected through bag ports or air locks. The danger of release of contaminants through the use of air locks requires the utmost caution in their use. The construction of sphincter valves, bag ports, and air locks is described in Appendix I.

8. Additional Shielding

Normal glove box operations do not present serious shielding problems. However, several factors have contributed towards increasing radiation exposure over the past several years. Problems of handling materials undergoing spontaneous fission have now introduced the requirement of shielding against neutrons. Such a requirement for additional shielding should be expected where the enclosure operation involves irradiated plutonium, americium, curium, and similar radioisotopes.

For a time the use of ordinary materials such as safety glass provided sufficient shielding to be effective in reducing exposure. More recently, X-ray glass has been used and high density lead glass is planned for future equipment. A water wall has been utilized where this technique was practical. Other material, such as metallic lead, in block or sheet form, and masonite, have been used where visibility is not a factor. Lead enclosure of the contaminated vessel or equipment inside the box has also been employed. Lead glass has been used over the window to increase its shielding properties.

For the protection of the hands, 30 and 50 mil lead impregnated neoprene gloves have been used. Shielded tongs, forceps and other devices have also been used, but it must be recognized that such tools have practical limits in the confines of an enclosure. Dexterity of operations is also seriously limited by the use of mechanical devices.

Operator education in radioactive hazards, in proper working habits, and improvement in operation techniques are essential where neutron emission or high level gamma radiation is present.

9. Conclusions

(a) A survey of the various unit operations carried out in glove boxes, together with the details of the equipment, should be assembled. The resulting compendium would serve as a handbook for those unfamiliar with the use of glove boxes but with both a need for enclosures as well as a definite program to be accomplished.

(b) A description of special techniques in chemistry, engineering, biology, production, etc., used in glove boxes should be assembled. Such a report would serve as a guide for an audience engaged in the use of glove boxes, having limited experience but a need for, special techniques.

APPENDIX III

REPORT ON GLOVE BOX SAFETY AND FIRE PROTECTION

BY

SAFETY AND FIRE PROTECTION SUBCOMMITTEE

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I. SAFETY

A. Summary of Safety Factors in Glove Box Operations

In this summary, where the word "safety" is used, it means conventional or industrial safety and not radiation safety, which is covered in Appendix IV.

1. Principles.

Broadly speaking, the same safety principles and practices which apply to work outside of glove boxes also apply to work inside of glove boxes. With glove box operations, however, the safety problem is more complicated (as compared with work in an open shop for example). Consequently, it needs more attention, because the glove box work imposes restrictions which are not present in work outside of glove boxes. For example, a machine should have guards installed to prevent injury to the operator when it is located in an open shop area. However, due to added restrictions to operator movement and reduced tactile sense, adherence to approved safety practices and the guarding of equipment in glove boxes is even more important.

2. Limitations.

Glove boxes place restrictions on the operator and hence on the operations. Speed of operations are considerably reduced from that possible in the absence of the enclosure. Glove boxes restrict the operator's vision and movement and they control his position. The gloves limit the operator's sense of touch and add to his fatigue. Large or rapidly moving equipment must often be of special design for use in glove boxes. Glove boxes are frequently used to contain highly hazardous materials; thus, the consequences in an accident may be unusually severe.

3. Special Materials Hazards.

Certain glove box operations involve handling volatile flammable liquids and flammable gases. The possibility of forming an explosive mixture due to flammable liquids or flammable gas in the glove box atmosphere are greater than in an open area because of the limited air volume of the enclosure. This possibility is strong in a glove box with a near static air atmosphere. Explosions have caused injuries by flying window material and by the spread of radioactive contamination.

4. Maintenance.

When equipment must be removed from glove boxes for maintenance or replacement, extra care is needed to avoid injury and the spread of radioactive contamination outside the glove box.

5. Training.

Proper instructions and training, designed to promote safe operations, are important in glove box work. They should include measures to avoid fires, accidents and injuries. These incidents can be quite serious due to radioactive contamination aspects.

6. Emergency Instructions.

Adequate emergency instructions and procedures are also important. They should include measures to minimize the effects of fires, accidents and injuries. An error on the part of an operator during glove box work or in an emergency could have very serious consequences. It could result in the spread of fire or radioactive contamination, or possibly a criticality incident.

B. General Problems Affecting Safety

1. Visual Restrictions.

Vision of the operator is generally reduced in glove box work. This factor should be considered in design, so that the window area will provide adequate vision and yet not seriously conflict with other essential glove box requirements. In the interest of good vision, a window material which will remain "clear" and resist abrasion, discoloration and shattering should be used. Glove box windows are subject to reflected glare from room lighting. This should be avoided by properly locating room lighting with respect to the glove boxes. Lighting is often required within glove boxes. This lighting should also be arranged to avoid subjecting the operator to glare. Dark or neutral shade clothing helps to reduce reflections from glove box windows.

2. Restrictions to Movement and Position.

A glove box operator works under more strain because his freedom of movement is restricted. He must work through gloves from fixed positions and his vision is limited; consequently, he is more subject to fatigue and injury from working and lifting in an unnatural position. He is in an awkward position for lifting or moving heavy objects, and hoists or transfer devices are needed in these cases. To reduce the fatigue factor, it is advisable that glove box operators work at a slower pace and avoid prolonged continuous work where possible. Platforms may be needed in some cases for operators who are less than average height.

3. Problems Imposed by Gloves

A glove box operator must, of necessity, work through gloves, and in some cases, heavy shielding gloves are used. Consequently, his sense of touch is reduced, depending upon the thickness and flexibility of the gloves. His response to heat may be considerably changed by the use of gloves.

Certain glove box operations involve handling highly hazardous and toxic materials, such as plutonium. A puncture wound (through a glove) is much more serious than a similar wound with non-hazardous materials. Because of reduced sensitivity and bulkiness, gloves are susceptible to being punctured or torn, and the operator may not be immediately aware of this. Sharp edges should be eliminated from glove boxes and equipment to reduce the possibility of glove perforations.

Gloves must fit operators with large hands; therefore, they fit the operator with small hands and short fingers very loosely. This excess finger length can add to the hazard of working in a glove box.

When wet operations are performed, certain types of gloves become slippery and present a hazard in the manipulation of equipment or products. Perspiration from operator's hands adds to his discomfort and may impair his ability to handle objects. In certain instances, operators may experience allergic reactions to glove material. The use of tight-fitting cotton gloves within rubber gloves will help to reduce perspiration and allergy effects.

Since 22 to 24 inches is the limit of reach radius from glove ports, considerable modification of equipment and careful preplanning is often necessary to bring the operations within comfortable and safe working distance of the glove ports.

4. Mechanical Safeguards.

In the design of glove boxes, space requirements should be anticipated so that needed mechanical safeguards can be installed on equipment. Where rapidly rotating equipment is used, care must be taken to prevent entanglement of the gloves. Guards are even more important on glove box equipment than would be the case in normal operations. Emergency shutoffs for glove box equipment should be located both inside and outside of the glove boxes, even though accessory equipment may be located outside the glove boxes. Such shutoffs should be installed in a convenient location to permit as quick an emergency shutoff as possible.

5. Requirements for Special Equipment.

Large equipment must often be of special design for operation within a glove box. Because of the restricted movements of the operator, remote control of the equipment and mechanized changing of heavy parts is sometimes required for safe operations.

C. Special Hazards Controlled by Glove Boxes

Since a principle purpose of a glove box is to confine hazardous materials, maintenance of the glove box integrity during the periods of normal use or in the event of accidents must be emphasized. The hazards involved include: (1) radioactivity, (2) pyrophoricity, (3) chemical and toxic, and (4) explosion. They are briefly discussed in the following.

1. Radioactivity. While radiation safety is discussed in detail in Appendix IV, it is important to recognize the problems associated with potential dispersion of radioactivity by such incidents as fires or explosions. The latter are discussed briefly below, but in more detail in Section II, FIRE PROTECTION, of this appendix. Glove box integrity, to assure proper containment, should be periodically checked. Devices are available to detect radioactivity and, where necessary, to sound alarms for abnormal conditions.

2. Pyrophoricity. The control of pyrophoric materials is included in Section II, FIRE PROTECTION, of this appendix. Safety considerations dictate that proper controls be in effect to prevent a fire from burning through glove box materials and violating the integrity of the box. The selection of proper glove box construction materials is an important factor in preventing penetration by burning materials. Systems are available to detect and report abnormal heat (fire) conditions.

3. Chemical and Toxic. Chemical reactions are of concern, in part, because of corrosion effects (for example, on gasketing material, deterioration of rubber gloves and discoloration of window material). Also, some chemical reactions may generate gases at a more rapid rate than can be relieved by the ventilating system.

   Effects of dangerous chemical irritants and toxic materials often contained in glove boxes, should be considered in developing operating and emergency procedures. Secondary containment within the glove box can sometimes be provided for additional safety. Consideration should also be given to a "close capture" system as described on page I-4 of Appendix I.

4. Explosion. Explosions within glove boxes are of three types:

   a. explosion of experimental equipment creating missile hazards,

b. explosion of flammable gases or combustible dusts, and

c. pressure buildup and explosion caused by malfunctioning of high pressure manifold equipment.

The explosion potential can be reduced by providing proper controls on equipment and by proper operating procedures. Provisions can be made for possible loss of pressure control. Gauges are available to indicate that glove box ventilating systems are operating within proper limits. Excessive negative pressure within a glove box may cause an implosion. Proper controls, including design features, should be provided to minimize the possibility and dampen the effects of such incidents.

D. Operating Procedures

1. Preplanning. Proper written instructions designed to promote safe operations, including experimental procedures, should be detailed. These instructions should be originated by the person responsible for the operation and they should be reviewed by supervisory and appropriate hazard control groups for all phases of safety. They should include measures to: avoid fires, accidents and injuries; properly handle hazardous and flammable materials; avoid puncture wounds; prevent the ingestion or inhalation of toxic materials; and provide for repairs and disposal.

2. Organization and Training. Qualified operators should be employed and trained. Instructions must be thoroughly understood by the operators and provisions made to insure enforcement of approved operating procedures. Operating instructions should be kept current.

E. Emergency Procedures

1. Preplanning. Emergency procedures, including evacuation requirements, should be pre-planned and employees instructed and trained in their application. The instructions should be coordinated with operating procedures and kept current. Further, emergency procedures for glove box working areas should be carefully coordinated with similar procedures in effect throughout the rest of the site.

2. Organization and Training. Responsibility should be specifically assigned for carrying out the emergency instructions. The emergency organization should include fire fighting, rescue, health physics and criticality control individuals or groups, and they should be properly trained in their functions. Plans should be made to deal with emergencies which could spread beyond the confines of the facility and which could involve possible public relations aspects.

II FIRE PROTECTION

A. Summary of Fire Protection Factors in Glove Box Operations

Fire protection factors are of major concern in the design of glove boxes and glove box facilities. They are also very important with respect to the work done in glove boxes, and in the preparation of operating and emergency procedures.

Fire protection methods are strongly influenced by the need for assuring containment under normal and emergency conditions. Certain basic fire protection practices, such as providing fire dampers in ventilation ducts, are generally not applicable. Fires have the potential for causing considerable damage and health hazard by promoting spread of radioactive contamination and causing serious interruption to important work programs. Proper emergency procedures can help minimize the effects of fires and explosions.

B. General Problems Affecting Fire Protection

Broadly speaking, fire protection problems associated with glove box work can be treated under (a) construction, (b) materials handled in glove boxes, (c) equipment used in glove boxes, (d) ventilation, (e) facilities for assuring containment under emergency conditions, and (f) type of building or area in which the glove boxes are located.

1. Glove Box Construction Materials.

Construction materials in current use are non-combustible (metal), or combustible (plywood, rubber and plastics). Some of the plastics have flame inhibitors in their composition to make them "self-extinguishing". However, such plastics will burn and they may soften or deform under heat and cause loss of glove box integrity even though not actually burning. The same may be said of some gasketing materials. Flammable surface coatings, used on the interior of glove boxes and their ventilation systems, may in themselves constitute a serious fire problem, and their use should be minimized. Useful information on fire-retardant coatings is detailed in UCRL-6697.

Low melting alloys, such as the iron-plutonium eutectic may be formed with the glove box structural material during a fire. These eutectics are often more pyrophoric and have a lower melting point than the materials from which they are made. This hazard may be minimized by use of glove box floors which form higher melting, less pyrophoric materials. In addition, if high conductivity materials with sufficient mass to dissipate the heat are selected for the glove box structure, the fire risk may be reduced.

From a fire protection viewpoint, the most fire resistive materials available, which will meet requirements, should be used for construction materials.

2. Materials Handled in Glove Boxes.

A number of combustible or toxic materials are sometimes handled in glove boxes. Ordinary combustibles include paper tissue, cardboard containers, combustible metals (e.g. sodium and sodium-potassium), pyrophoric metals (e.g. uranium and plutonium), oils (e.g. machine oil, vacuum pump oil and heat treating oil), volatile solvents (e.g. alcohol and acetone), and flammable gases.

Where flammable liquids are used in combustible (i.e., plastic) or glass containers in glove box work, secondary metal containers should be provided to confine the liquid in case of rupture of containers. The quantity of flammable liquids permitted in the glove box should be rigidly controlled. The provision of a metal pan to impound and confine flammable liquids in event of equipment rupture or spill is another method of confining a fire to a pre-determined location.

Relatively small quantities of certain volatile solvents, such as acetone and ether, form explosive mixtures with air. Such mixtures will be more quickly formed in a glove box with near static air atmosphere.

Ordinary combustibles within glove boxes should be limited to the minimum required for the work.

3. Equipment Used in Glove Boxes

Certain equipment utilized in glove boxes furnishes an electrical source of heat for a possible fire or explosion. Such equipment includes ovens, furnaces, heating units, hot plates, soldering irons, motors, lights, wiring and sometimes, plastic bag sealers. Under certain conditions, static electricity also may be a potential hazard.

Other possible sources of ignition are hand and power tools, bunsen burners, torches, and cutting, sawing, machining and centrifuging operations involving pyrophoric metals.

Explosions are possible from the ignition of flammable gases or flammable liquid vapors, from chemical reactions, combustible metallic dust and from compressed fluids. The use of flammable gases within glove boxes should be avoided where possible. Implosions of glove boxes may occur from the use of vacuum systems.

Self-initiating fires are possible from chemical reactions and pyrophoric metals. Spontaneous ignition of chemically saturated waste is another source of fire.

Since there are many sources of ignition, proper instructions for operators in the use of materials and equipment, and proper operating procedures are very important to prevent the occurrence of fires and explosions, and to minimize their effects.

4. Ventilation Systems.

To avoid fire spread through ductwork, normal fire protection practice would be to shut down ventilation systems in event of fire. Also, automatic fire dampers would be installed in these systems. However, contamination control usually dictates that there be no fire dampers, and that ventilation be maintained. The latter requirement introduces the possibility of fire spread through the ductwork, and the possibility of an explosion in the ductwork from partially burned gases. This can extend the fire and spread contamination to other areas even outside the building. This problem could be further aggravated by combustible ductwork or duct lining.

Smoke and soot from burning materials within glove boxes or from combustible glove box and ventilation duct materials can clog pre-filters and high efficiency filters in the exhaust system. This would result in a positive pressure buildup in the system and spread of contamination to the work area and building. This problem may be further aggravated if manifolded ventilating systems are used.

Prompt detection and control of fires is necessary to prevent filter clogging by smoke and soot. Wire mesh pre-filters in the form of fire screens can be used to reduce the possibility of fire spread. Installed with a glove box exhaust filter, the wire mesh filter will act as a fire stop between the glove box and ductwork. Installed ahead of the final high efficiency exhaust filter, it will act as a fire stop to a fire which would normally involve the filter. Fire resistive type high efficiency filters are available and should be used. However, the exhaust filter system is still a weak point in event of fire. Currently available high efficiency filters are susceptible to damage at a temperature above 500°F. Also, the accumulation of combustible dusts may cause loss of integrity of the filter if involved in fire.

Where exhaust gases are such as to cause damage to filters, suitable scrubbing systems should be installed ahead of the filters.

5. <u>Containment Under Emergency Conditions.</u>

A fire or explosion, either outside or inside the glove box, may destroy the integrity of the enclosure. The fire protection in areas external to glove boxes should, in general, be so designed as to protect exterior portions of the box from damage from fires occurring outside the glove box. Automatic sprinklers are commonly used for conventional exposure protection, fire control and extinguishment. Fires within glove boxes may warp or destroy construction materials or components of the enclosure and generate smoke which may clog exhaust filters and impair the ventilation system as discussed in Section 4.

Explosions originating within a glove box generate increased pressures which should be relieved in a pre-determined path to a safe area. It is particularly important that the boxes be so designed as to preclude relief of pressure in the direction occupied by employees.

Relatively high property damage may be experienced from fires or explosions which cause loss of glove box integrity and widespread dispersion of airborne contamination. Fire protection external to the glove box should be premised on the need for reducing a three dimensional airborne contamination dispersion problem to a two dimensional problem as rapidly as possible. It is paramount that under the worse credible conditions, fire protection be such as to preclude airborne contamination spread beyond the confines of the room or building in which it originates.

6. <u>Glove Box Rooms or Areas.</u>

The construction and protection of rooms or areas in which glove boxes are located is important because a fire in such a room or area may involve the glove box. This is discussed in more detail under Section D in this appendix.

C. <u>Fire Prevention, Detection, Control and Extinguishment for Glove Boxes</u>

1. <u>Fire Prevention.</u>

Fires may be prevented in hazardous glove box work by means of a dry inert atmosphere of argon, helium or nitrogen. In some cases dry air is used. Dryness of the air or inert atmosphere helps prevent the formation of combustible and sensitive metal hydrides. Control of moisture in the glove box atmosphere is also very important in preventing pyrophoric metal fires.

Where inert gas systems are installed, controls should be provided to avoid pressurizing the glove box system by the gas used. Use of devices to detect and provide warning of excessive concentrations of hazardous vapors is sometimes warranted.

Other fire prevention measures include avoiding combustibles or reducing them to a minimum, good housekeeping, control of flammable liquids, etc., and inspections by operating and plant protection personnel. Inspections by the latter during non-working periods (nights, weekends, etc.) requires precaution because the glove box areas are potentially hazardous from a radioactive contamination aspect. Where, for any reason, inspection access is limited, it becomes more important that automatic fire detection and control systems be seriously considered. Also, in such cases, a responsible operator should be designated to check the glove box area at the close of the working period and, where practicable, a window should be provided for plant protection patrols to view the glove box area during the non-working hours. In general, plant protection patrols should conduct inspections in glove box areas when boxes are unattended by operating personnel.

2. Fire Detection.

Fires may be detected in glove box operations by automatic heat (fire) detection systems and smoke detection systems. 1/ A wide variety of heat and smoke detection devices are currently available, some of which are adaptable to specialized application. They are prompt, reliable, rugged and self-restoring after operation. Detection systems in use in glove boxes at present include the rate-of-rise tubing type, eutectic salt tubing type and "spot" fixed-temperature thermostat type. The thermostat type is available, mounted in a magnet, for direct application to any ferrous equipment where overheating may occur. For high efficiency filter banks, a test conducted at an AEC contractor facility (Rocky Flats) indicated that the eutectic salt tubing type was the most effective heat (fire) detection system.

Means are available to detect incipient explosions and fires and automatically surpress them in less than a second.* This recently developed approach has been applied to specialized commercial explosion problems.

3. Fire Control and Extinguishment.

Since the types of fires within glove boxes can be anticipated, it is possible, with proper preplanning, to provide the extinguishing agent or agents needed for fire control.

1/ See Underwriters Laboratories publications titled, "Approved Devices".

* Details may be obtained from AEC Headquarters' Division of Operational Safety.

Currently, various manual extinguishing agents, mostly dry types, are used to control or extinguish pyrophoric metal fires. They include magnesium oxide, MET-L-X powder, G-1 powder, sand and a eutectic salt mixture. The eutectic salt mixture ($NaCl$, KCl, $BaCl_2$) is a recent development and appears to be very effective.1/ Metal blocks may be used to conduct heat away from burning chips. Also, pyrophoric metal fires are sometimes permitted to safely burn to the oxide under controlled conditions. A glove box floor material which will effectively conduct heat, also assists in the control of metal fires.

In specialized cases of the machining of metals using high-flash point oil coolants, the coolant may be used to douse and extinguish incipient fires in burning chips. Also, the burning metal may be immersed in the coolant for extinguishment.

Carbon dioxide type fire extinguishers are effective on flammable liquid and electrical fires, but when used in glove boxes, care must be taken to avoid over-pressurizing the glove box and spreading radioactive contamination. Tests at an AEC contractor facility (Hanford) indicate that the dry chemical type extinguisher will not over-pressurize a glove box.2/ The powder, of course, would have to be cleaned up, usually by vacuuming. The new "all purpose" powder extinguisher is probably similar to the dry chemical extinguisher in these respects. The "all purpose" extinguisher is approved for fires in ordinary combustibles and flammable liquids and for electrical fires.

Quick connect couplings may be installed on glove boxes to facilitate discharging the contents of a portable extinguisher into the box. Piercing nozzles are sometimes installed on pressure-operated extinguishers, (such as dry chemical and MET-L-X units), to pierce a glove and combat a fire when other manual methods fail. The use of a piercing nozzle presents the problem of violating the integrity of the box. When used, it should be designed so that the glove will effectively seal on the nozzle.

1/ Holliday, J., "The Extinguishment of Uranium and Plutonium Fires", TGR Report 86 (D), UKAEA, 1962.

2/ Tests conducted at Hanford were described by R. R. King, "The Prevention and Control of Fire in Glove Boxes Containing Plutonium:, presented at the ANS Meeting in Chicago, Nov. 7-10, 1961.

Water type extinguishers should be avoided for glove box fires where liquid metals or pyrophoric metals are present because of the possible violent nature of the reaction. Water should also be avoided where criticality is a consideration. However, the use of water should not be definitely ruled out in glove box areas even where these problems may exist. A situation may arise where water may be the only means of preventing uncontrolled spread of a fire and release of radioactive contamination to areas outside of the area of fire origin. In other words, the risk of not using water may be greater than the risk of using it. For this reason, building fire hose systems with "fog" nozzles should be available for use if needed. These comments should not be construed as minimizing the importance of automatic sprinkler systems for protecting glove box exteriors.

Automatic fire extinguishing systems of the CO_2 type are installed in glove boxes in a few cases at present. An automatic extinguishing system is particularly appropriate where hazardous materials within the glove box could be dispersed outside the box. Spreading of radioactive or toxic materials could lead to costly clean up or even catastrophic consequences. Automatic systems are also appropriate to glove boxes containing fire risks, including combustible construction materials, located in areas which are not under constant surveillance.

In view of the vulnerability of glove boxes to fire damage, time is very important in fire control. Experience to date indicates that considerable delay may occur from the time a fire is discovered until the time of arrival of fire crews. The use of automatic fire detection and control systems minimizes delay and the risk of personnel exposure. For certain applications, where water may be acceptable, pressurized water tanks could be used to supply a pre-determined quantity of water to "fog" type sprinkler heads within a glove box. In this case, provisions would have to be made to handle water run-off.

A new high expansion foam system, recently developed, uses relatively little water. 1/ It shows encouraging potential for rapidly controlling fires which may occur within glove boxes or within glove box rooms.

Where there are large banks of high efficiency filters, automatic water spray protection is advisable, particularly if the filters are the combustible type. This protection is advisable for the fire resistive type also, where they are subject to

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1/ Commercial development described and demonstrated at the AEC Fire Protection Engineers' Conference held at SRO, Jan. 1962.

combustible loading. Tests at an AEC contractor facility (Rocky Flats) indicate that the automatic water spray protection should be installed on both the upstream and downstream sides of combustible high-efficiency filters. It is only required on the up-stream side of the fire resistive type high efficiency filters. Automatic water spray protection may also be needed to protect the main blowers and ductwork of large installations subject to damage from the high temperatures of a fire.

4. Operating Procedures.

Comments concerning written operating instructions, covered in Section I (SAFETY) of this appendix, also apply to the prevention of fires and explosions in glove box work.

5. Emergency Procedures.

Comments concerning emergency procedures, covered in Section I (SAFETY) of this appendix, also apply to emergencies involving fires or explosions.

In the case of pre-planning for fire emergencies proper liaison between operating groups, fire emergency crews and health physics groups is very important. This includes: (a) informing emergency crews in advance of the problems involved and the precautions which should be taken in fighting a fire in a glove box facility, (b) proper instruction and drilling of emergency crews, and (c) pre-planning of procedures to be following in fire emergencies during working hours and during non-working hours. The latter includes an understanding of who will be in charge, protective clothing or equipment to be worn, access of the emergency crew to the glove box area and extent to which emergency crews engage in fire fighting activities during non-working hours.

Where warranted by the hazard, health physics personnel should be available at all times, so that action by fire emergency crews will not be delayed. If this procedure is not feasible, fire emergency crews should be trained in the health physics aspects to operate unassisted during an emergency.

D. Fire Prevention, Detection and Control for Glove Box Rooms or Areas

Rooms or areas in which glove boxes are located should be fire resistive or non-combustible in construction and separated from other areas of the building by fire resistive walls or partitions.

Portable fire extinguishers for the area should be a type required for the fires which may occur. The new "all purpose" type powder[1] extinguisher is available for fires in ordinary combustibles and flammable liquids and also for electrical fires. The CO_2 type is preferred for electrical fires where avoiding the cleanup of powder is important, such as in delicate electrical equipment. Other special materials which may be present (liquid metals, pyrophoric metals, etc.) would require additional special purpose type extinguishers. Standpipe hose stations with "fog" nozzles should be available for "backup" protection and their use restricted to those who are properly trained and familiar with the problems involved in using water.

Where the area is of combustible construction, or contains other extensive combustibles, automatic sprinklers will, in general, provide the most effective and most economical protection. Where the area is fire resistive, but the glove boxes are of combustible construction, sprinklers over the glove boxes would be one means of protecting them from a fire originating in the room or area. In event that a fire destroyed the integrity of a glove box, automatic sprinklers in the room or area would be effective in promptly converting a three dimensional contamination problem to two dimensional proportions, that is, the water spray from the sprinkler system would tend to accumulate smoke and soot on the floor or low point of the area and prevent the airborne spread of radioactive contamination to areas outside of the room or building in which the fire originated. The new high-expansion foam development may also be an effective solution to this problem.[2]

Where sprinklers are installed, measures should be taken to confine the flow of water by curbs, hot drains or holding tanks as needed. Where there is concern for water run-off spreading contamination, consideration should be given to means of collecting the water and recirculating it (i.e., by means of a catch basin and pump) where this is feasible.

Heat (fire) and smoke detection systems are available for glove box rooms or areas where detection alone is considered adequate protection.

E. Illustrations.

Various AEC "Serious Accidents Bulletins" contain illustrations of enclosures involved in different type accidents. The following may be of interest:

1/ Manufacturers are named in Underwriters Laboratories' Lists of Approved Devices.
2/ See page III-12.

1. USAEC Serious Accidents Bulletin No. 129, Oct. 28, 1957, (Flammable vapors, ignited by an electrical source, resulted in an explosion which blew out rubber gloves and cracked safety glass windows.)

2. USAEC Serious Accidents Bulletin No. 148, Oct. 8, 1959. (An explosion, resulting from a chemical reaction in a glove box, ruptured the rubber gloves, cracked and bulged the safety glass window and blew open an explosion suppression door at rear of box.)

3. USAEC Serious Accidents Bulletin No. 152, Oct. 29, 1959. (Fire, originating in plastic tubing, spread to a plastic "walk-in" type hood in a high vacuum laboratory. An automatic sprinkler head operated to control the fire and confine loss to approximately $350.)

4. USAEC Serious Accidents Bulletin No. 175, April 5, 1961. (A fire, originating in a caveroom drybox designed for working with high levels of radioactivity, spread to external areas within the cave, where it was fed by combustion of flammable surface coatings, plastic components and the underside of a plywood ceiling.)

III CONCLUSIONS

Based upon a study of successful glove box practices and from lessons provided by various accidents, fires and explosions which have been experienced at AEC facilities, it is concluded that:

1. Non-combustible materials should be used to the maximum practical extent in the fabricating of glove boxes. Combustibles permitted within glove boxes should be kept to a minimum;

2. Proper design of glove boxes and equipment will contribute to the reduction of injury and fire hazards. Proper operating instructions will help to avoid accidents, injuries, fires and explosions; consequently it is important that adequate written operating and emergency instructions be prepared and maintained up-to-date for glove box facilities;

3. Safety and fire protection engineers should be consulted for advice and assistance in the design of glove box facilities and in the preparation of operating and emergency procedures;

4. All fire detection and extinguishing equipment and materials used should be of a type approved by Underwriters Laboratories or the Factory Mutual Engineering Division Laboratories except where modifications are necessary to comply with operating requirements.

5. Current information and new developments in the glove box field should be periodically compiled and distributed to field offices and other interested parties;

6. Emergency shutoffs for equipment within glove boxes should be conveniently located both inside and outside the glove box to permit quick use in an emergency;

7. Sharp edges should not be permitted in glove boxes and on equipment to reduce the possibility of puncturing or tearing gloves. Guards should be provided for all moving parts of equipment which may injure operators or damage the gloves or glove box;

8. The window material should be a type which will remain "clear" and which will resist abrasion, heat, discoloration and shattering;

9. Provision should be made for secondary containers to confine spills of flammable or hazardous materials and prevent them from spreading within the glove box;

10. Where hydraulic equipment is needed in glove box work, approved fire resistive hydraulic fluids should be used;

11. An alarm should be provided to indicate overpressure of a glove box or glove box system;

12. The use of air-operated motors and tools should be considered where electrical equipment would cause a serious fire hazard;

13. Means should be provided by use of internal covers, "bungs", or other devices to keep gloves out of glove boxes when the glove boxes are not in use (i.e., to avoid a fire in the glove box burning through a glove and destroying the integrity of the glove box), and non-combustible glove port covers should be used to protect the gloves from a fire external to the glove box;

14. Unless the glove box is to have an inert atmosphere, space and facilities should be provided within the glove box for the storage of manual fire extinguishing agents, such as the eutectic salt mixture for uranium and plutonium fires. Storage in plastic bags and application to the fire in plastic bags is suggested for this type extinguishing agent. The British use this method with success;

15. Consideration should be given to providing quick couplings on glove boxes for the application of fire extinguishing agents (i.e., dry powder types and CO_2) to fires within the glove boxes;

16. Means should be provided for fire breaks or fire cutoffs between glove boxes where it is possible for a fire to spread from one glove box to another;

17. Where feasible, a wire mesh-pre filter should be installed with the glove box exhaust filter to provide a fire stop between the glove box and ductwork. Where feasible, this type pre-filter should also be installed ahead of the final high efficiency filter. Where this is not feasible, the physical separation of final pre-filters and high-efficiency filters should be considered;

18. In the design of glove box facilities large filter banks should preferably be avoided;

19. The number of service entrances to glove boxes should be limited and gas service should be excluded;

20. Further research and testing is desirable in the following fields:

    a. to develop glove box structural materials and surface coatings to better satisfy both fire protection and operating requirements;

    b. to determine if suitable fire resistive coolants are available for machining operations;

    c. to determine effective explosion venting provisions for glove box systems, means to prevent filter clogging by smoke and soot, and further improvements in high efficiency filter installations to resist fires and explosions;

    d. to test filter efficiencies using combustion products of various materials handled within boxes;

    e. on various extinguishing agents for pyrophoric metal fires to determine the most effective type;

    f. to determine the most effective automatic fire extinguishing systems for glove box application, both inside glove boxes and in glove box rooms. Special analyses of available types of automatic sprinkler protection should be included to determine conditions under which sprinklers would be appropriate in glove box rooms. Situations in which reactive metals may be present (in the quantities normally used), and situations in which criticality is a consideration, should be included;

g. available smoke and fire detection devices should be further tested to determine the most effective types for glove box systems. Explosion suppression systems should be investigated for possible glove box application, and available explosive atmosphere detection systems should be checked to determine the most effective type for glove box application.

REPORT ON HEALTH PHYSICS

by

Health Physics Subcommittee
of the Glove Box Committee

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CONTENTS

I. INTRODUCTION

Prevention of personnel exposures to radioactive or other harmful material, limiting the spread of contamination to uncontrolled areas, and provision of controlled atmospheric conditions for processed materials are the basic purposes of the glove box. A combination of specialized equipment, development of procedures and extensive personnel training is often required to accomplish effective results. The atomic energy industry finds it necessary to perform many processes on materials that would be harmful to the individual if introduced into the body even in very minute amounts. It is therefore important that essentially total exclusion of certain materials from the human environment be accomplished. The glove box offers unique features in the control of environmental hazards.

This appendix is primarily concerned with the control of personnel exposure to ionizing radiation, through use of the glove box. Desirable design features, operational techniques, precautionary measures and solutions to some past problems are presented from the standpoint of protecting the individual worker from quantities of radioactivity and/or external radiation that may be detrimental to his health and well being. Radiation exposure limits and radiation protection guides are pointed out. While nuclear safety is extremely important, it is outside the scope of heath physics and therefore is not included. It is recognized, however, that a glove box operation which experiences a nuclear accident will result in a heavy responsibility for health physics personnel.

Nuclear safety of operations carried out in glove boxes usually relies upon a safe mass of fissionable material for control. This safe mass is determined by the moderation available within the glove box. Good neutron moderators include beryllium, graphite, H_2O, D_2O, and other hydrogenous materials. Therefore glove boxes should be designed to prevent the fissionable materials involved from coming into contact with the above moderators. Air ducts from glove boxes should be constructed in a manner which will not allow rain water to find its way into the system. Water pipes should be kept away from glove boxes and shielding devices employing hydrogenous material in liquid form should be avoided.

It is true that only so much safety can be built into any equipment or facilities for processing inherently hazardous material. An active and effective health physics program must augment any radiation protection devices. However, the role of the glove box in health protection is large, and by effective use of properly designed glove boxes protection of the individual from harmful amounts of radioactivity is greatly enhanced.

II. INTERNAL RADIATION

General

Radioactive material that is taken into the human body produces constant radiation exposure until it is eliminated. Natural excretion and radioactive decay are normally the only methods of elimination and these are often slow processes. Usually, there is little than can be done to reduce or control exposure once radioactive material is inside the body. However, promising results in accelerating elimination rates have recently been obtained through the use of chelating and sequestering agents.1/ Nevertheless, internal exposure must be controlled by preventing the entry of radioactive materials. Unique features of the glove box make it particularly useful for this purpose.

Entry of radioactive materials into the body may be gained by inhalation, ingestion, injection or in some instances by absorption through the skin. A radiation accident might possibly subject an individual to internal exposure by more than one of the above means, depending upon the nature of the accident and safety measures taken prior to the accident. For example, an explosion involving plutonium solution in a glass container might cause internal exposure from wounds made by contaminated glass and from breathing the contaminated vapors.

Of the four modes of entry listed above, inhalation and injection are most important. However, the glove box is primarily designed to control the inhalation of materials. Techniques for treatment of contaminated wounds are beyond the scope of this report. Yet they are very important and should be given careful consideration by those in charge of glove box operation.

Contamination control through the use of glove boxes has proven to be a very effective method of limiting both internal and external personnel exposures to acceptable levels. Many processes may be safely performed on radioactive materials, by the use of glove boxes, that otherwise would be very hazardous. Containment of the inevitable contamination which accompanies the processing of elements such as plutonium, polonium, etc., is enhanced in a properly constructed glove box. This reduces the potential for contamination of the entire operating area and lessens the requirement for very restrictive health protection measures. It should be recognized that the inside surfaces of a glove box may become grossly contaminated and procedures taking this into account must be followed.

Maximum Permissible Limits

The United States Atomic Energy Commission Manual Chapter 0524, "Permissible Levels of Radiation Exposure", establishes rules governing the AEC and AEC contractors with respect to levels of radiation exposure to be used as the maximum permissible occupational exposure for their personnel and other

1/ Norwood, W. Dagget, M.D.: "Treatment of Plutonium Deposition in Humans with DTPA", Richland, Wash., (Paper read before 13th International Congress on Occupational Health, New York City, July 1960).

persons who may be exposed to radiation originating from AEC operations. AEC regulation 10 CFR, Part 20, "Standards for Protection Against Radiation", establishes standards for the protection of licensees, their employees and the public against radiation hazards arising out of the possession or use of special nuclear, source, or by-product material under license issued by the AEC. The regulation establishes standards which must be followed in handling radioactive materials which are subject to the licensing authority of the Commission and provides procedures whereby deviations from such standards may be authorized on a case-to-case basis. The regulation prescribes limits which govern exposure of personnel to radiation, concentrations of radioactive material which may be discharged into air and water, and disposal of radioactive wastes. It also establishes certain precautionary procedures and administrative controls.

In establishing the above standards the Commission has substantially adopted the recommendations of the National Committee on Radiation Protection and Measurement (NCRP). These standards also conform with the basic recommendations, concerning permissible radiation exposure, of the International Commission on Radiological Protection (ICRP). The NCRP report on permissible internal dose from occupational exposure is published in National Bureau of Standards Handbook 69, "Maximum Permissible Body Burdens and Maximum Permissible Concentrations of Radionuclides in Air and in Water for Occupational Exposure". This report of the NCRP is an abridgment of the ICRP Internal Radiation Report.

The Federal Radiation Council was formed in 1959 (Public Law 86-373) to provide a Federal policy pertaining to radiation exposure. This council issued a Staff Report and made seven recommendations to the President of the United States. These recommendations were approved by the President on May 13, 1960, for the guidance of all Federal agencies. The Radiation Protection Guides as recommended by the Federal Radiation Council and approved by the President do not differ substantially from recommendations of the NCRP and ICRP. Further regulations may be imposed by some state or municipal governments. However these are usually patterned after the NCRP or ICRP recommendations.

It should be noted that the maximum permissible limits and radiation protection guides referred to above are not intended to apply to radiation exposure from natural background or the purposeful exposure of patients by practitioners of the healing arts. Furthermore, they may not be appropriate under unusual circumstances, but are intended to apply to normal peacetime industrial operations. There is no single permissible or acceptable level of exposure without regard to the reasons for permitting the exposure. Every reasonable effort should be made to keep exposures to the lowest levels compatible with practicality. However, the MPLs and Guides have been established at what is believed to be the best estimate of appropriate limits available in the light of present knowledge.

Conditions That Lead to Internal Exposure

Acute internal exposure is generally caused by an accident or incident resulting in loss of contamination control. Such an accident may in turn be caused by equipment failure or by an error in judgment. For example, a small hole or tear in a hood glove can allow significant quantities of airborne contamination to escape from the enclosure even if negative pressure is maintained and the fault is promptly discovered and corrected. If use of the damaged glove is continued and repair neglected serious internal personnel exposure may result. Regardless of basic causes, however, the impact of an accident and the resultant undesirable consequences may be greatly reduced by adequate and proper preplanning. Preplanning includes preparation of procedures to be followed in case of unusual circumstances as well as normal operations. It includes the determination of what material and equipment may be needed in the event of an incident and the availability of this equipment. It also includes the training and indoctrination of personnel. An adequate procedure, together with prompt and judicious action can often convert a potentially serious accident into a minor incident.

The more insidious chronic internal exposure is likely to be caused by a failure to recognize that a hazard exists and failure to realize that corrective action is necessary. Chronic exposure also can often be minimized by good standard operating procedures. However, in handling or processing radioactive materials nothing can substitute for constant vigilance by well trained personnel with adequate radiation detection means. Also close administrative control is necessary over all processes and personnel to see that safe procedures are followed and that careless habits do not develop. Standards of safe operation must be carefully formulated and then put into practice through careful indoctrination of operating personnel. The standards must not be allowed to deteriorate through lack of supervision or discipline.

When processing is to be done on the more hazardous alpha emitters such as plutonium, prompt detection of significant concentrations or atmospheric contamination becomes very important. The National Committee on Radiation Protection has established a maximum permissible limit of 2.0×10^{-12} microcuries of plutonium per milliliter of air. Expressed in units enabling comparison with several nonradioactive air pollutants the maximum allowable concentration of Pu^{239} in air is 3.2×10^{-8} mg/m^3 or 32 billionths of a milligram in a cubic meter of air. This may be contrasted with the maximum allowable concentrations in air of 5 mg/m^3 for cyanide; 0.5 mg/m^3 for arsenic; 0.15 mg/m^3 for lead; and 0.002 mg/m^3 for beryllium. From this very low maximum permissible limit of plutonium in air it is evident that constant vigilance and good instrumentation are both needed. The biological fate of plutonium in the body also is a factor pointing up the requirement for effective confinement.1/

1/ W. Langham (Health Physics 2, 172 (1959))

Plutonium which enters the blood stream through routes such as inhalation, injury to the skin or absorption from the gastrointestinal tract is deposited primarily in the skeleton, where it apparently becomes well fixed. Plutonium contamination in a skin injury is largely localized and the fraction absorbed from the gastrointestinal tract is extremely small and generally considered to be unimportant. The small amount of plutonium which is excreted is contained principally in the urine. The excretion rate is so low that one half year after an exposure, about 96 per cent of the original deposition is still deposited in the body. At five years, about 91 per cent still remains.

In ordinary air, plutonium tends to form a finely divided, loosely held oxide which will disperse into the air and remain airborne. Because of the above fundamental characteristics, it is necessary to completely separate the atmosphere exposed to plutonium from the air breathed by personnel processing it. This is commonly done by enclosing the work spaces and equipment in glove box enclosures. Because the inside of these enclosures becomes very highly contaminated it is necessary when designing a glove box to achieve a high degree of integrity. The associated duct work, piping, electrical lines and process equipment which penetrate the walls of the enclosures must be made gas tight to the outside. It is also customary to maintain the inside of a glove box at a negative pressure with respect to the room atmosphere. About 3/4" negative water gauge is the maximum differential pressure recommended because with a greater differential the gloves tend to inflate on the hands of operators, making manipulation very clumsy. In addition to the heavy synthetic rubber gloves that are an integral part of the glove box, an operator usually wears thin surgical gloves on his hands to afford secondary protection in case the heavy gloves become snagged or cut. Care should be taken to prevent penetration of the gloves by sharp or hot objects. To prevent contamination of the room, techniques have been devised for changing gloves and filters and for moving items into and out of the glove boxes without opening them directly to the room air.

The use of plastic bag ports for transfers has been found to be generally more effective in contamination control, although not always as initially convenient. This technique employs the use of plastic tubing access ports where items to be transferred into and out of the glove box are dielectrically sealed into a plastic tube or bag. This permits insertion or withdrawal of objects into or out of the box without violating the integrity of the physical barrier wall.

In the use of a glove box there is a tendency to accumulate and store contaminated material and equipment in the box. At times such storage is necessary, but every reasonable effort should be made to keep the inside working area in a well-arranged orderly condition and as free of contamination as practicable.

III. EXTERNAL RADIATION

In designing a glove box for handling alpha emitters,[1] one may have to consider the external radiation exposure potential along with the problem of internal exposure potential. This consideration is not only dependent upon the material and quantity to be handled, but is also dependent upon such things as the physical state and shape of the material, the chemical form of the material, the history and age of the material, the possibility of radioactive impurities and the required time to do the job.

A very high degree of containment for such materials as Pu, Am and Po is necessary even for very small quantities -- quantities that yield very low levels of X, gamma and neutron radiation. For such small quantities the normal design for containment may be sufficient. As quantities are increased one may eventually reach the point at which shielding or exposure time limitations will be required to maintain external exposures below the recommended levels.

From the standpoint of self-absorption and the concept of a point source vs. a distributed source, the shape and physical state of the material or in the case of solutions, the shape of the container will have some effect on the X and gamma field. This is especially important when considering hand exposure.

When alpha emitters become intimate with certain light elements as compounds or mixtures, production of neutrons by the α-n nuclear reaction takes place. Consequently, the chemical form or process needs to be considered.

The growth of radioactive daughter products in the material under consideration may change the external radiation potential with time. For example, the growth of gamma-emitting daughters from U^{232} which exists in minute quantities when working with U^{233} is such that handling becomes more restrictive in a matter of weeks after chemical separation.

Reactor made alpha emitters such as Pu^{239} and U^{233} will contain isotopes of themselves and may also contain small quantities of fission product impurities. In this case a knowledge of the isotopic content and the extent of fission product impurities that may exist in the material is important.[2]

1/ ANL-6540, "Radiation Problems Associated with the Handling of Actinide Elements", M. J. Steindler.

2/ E. D. Arnold, Proceedings of the Second United Nations International Conference on the Peaceful Uses of Atomic Energy; Geneva, 13, 241 (1958), and ORNL-CF-59-6-39 (1959); J. J. DeVanry, "Radiation Intensity from Spheres of U^{233} Contaminated with U^{232}", LAMS-1892 (1955).

Exposure Limits

Recommendations for external exposure limits have been set down by the NCRP and ICRP in their various publications. At present the design and operation of glove boxes should be such as to prevent an individual from being exposed to greater than 30 rem/year to the skin, 5 rem/year penetrating radiation, 5 rem/year to the lenses of the eyes and 75 rem/year to the extremities. In many glove box operations all four of these will have to be considered and any one may be controlling depending on the nature of the operations. RBE's for neutrons are covered extensively in NBS Handbook No. 63.

External Radiations from some Common Materials Handled in Glove Boxes

Po^{210} is an alpha-emitter and has a half-life of 138 days. Its specific activity is 4.5×10^3 curie/gram. A gamma ray of 800 Kev energy is associated with 1.2×10^{-5} of the alpha decays. The gamma exposure levels encountered with less than curie amounts are low and present no problem. The gamma field encountered in handling larger quantities may be significant. For example, a point source calculation for a one-gram (4.5×10^3 c) source would yield a dose rate of 260 mr/hr at one foot. Po^{210}, because of its high specific activity, is frequently used for the manufacture of neutron sources. Neutron yields for mixtures of alpha emitters and light elements are given in Table I. Additional data on polonium may be found in TID-5221.

U^{233} is an alpha-emitter and has a half-life of 1.62×10^5 years. Its specific activity is 9.51×10^{-3} c/g. Because of its low specific activity and low abundance of gammas associated with its decay, the external radiation from it alone is negligible. However, in the production of U^{233} some U^{232} is also formed to an extent depending on reactor parameters. U^{232} has a half-life of 74 years and decays to Th^{228} by alpha emission. The growth of all the daughters of U^{232} is controlled by the 1.9-year half-life of Th^{228}. This chain of daughters is extremely gamma active. Although elimination of a large part of the gamma activity may be accomplished through chemical separation, regrowth is such that operations would have to be completed in a matter of weeks and preferably days if done under ordinary glove box conditions. Lawrence[1] has reported calculated dose rates from a 0.635 cm thick by 5.08 cm diameter

1/ Lawrence, H.N.P., "Aspects of Handling Uranium-233 Feed Material", Second United Nations International Conference on the Peaceful Uses of Atomic Energy, Vol. 23, pp 330-333

U^{233} disk containing 20 ppm of U^{232} as follows:

TABLE I

Time after Separation	Dose Rates (r/hr at 1 cm)	
	U^{233} + daughters	U^{232} + daughters
1 day	0.0029	0.19
4 weeks	0.0032	0.37
32 weeks	0.011	3.2
10 years	0.15	14.

Energies of the significant gammas vary from 0.04 Mev to 2.8 Mev. Approximately half of the dose rate is from the Tl^{208}, 22.6 Mev gamma. A discussion of the problems encountered in the handling of U^{233} may be found in the paper by Arnold. (2nd Geneva Conference 13, 241(1958))

Pu^{239} has a half-life of about 24,000 years. Its specific activity is 0.062 c/g. The X and gamma rays associated with the decay of Pu^{239} when handled in production quantities will yield doses to personnel that should be measured and documented. If massive quantities are handled through gloves, limitations on handling may need to be imposed. In general, however, ordinary glove box material will be sufficient to reduce the X and gamma radiation to tolerable levels.

Unfortunately, in handling plutonium, one will have to concern himself also with other isotopes of plutonium, daughter products of the isotopes and possible fission product impurities. The isotopic content of plutonium is a function of reactor parameters during its production from U^{238} and the magnitude of fission product impurities is a function of chemical separation efficiency and age of the material. Roesch[1/] has made calculations for surface dose rates from plutonium. Pu^{239} by itself in a semi-infinite thick piece of metal yields a calculated surface dose rate of 610 mrad/hr from the X-rays (average energy of 17 Kev) and 56 mrad/hr from the harder components of energies 39, 53, 100, 124, and 384 Kev.

Pu^{238} is an alpha emitter and has a half-life of 89.6 years. Its specific activity is 16.8 c/g. From a semi-infinite piece of metal, Roesch[1/] calculated a surface dose rate of 980 rad/hr from X-rays of about 17 Kev average energy and 2 rad/hr from gammas which are primarily of 45 Kev energy. Pu^{238} spontaneously fissions with release of neutrons at a rate of 3420 n/gm-sec.

Pu^{240} is an alpha emitter and has a half-life of 6600 years. Its specific activity is 0.227 c/g. From a semi-infinite thick piece of metal, Roesch[1/] calculated a surface dose rate of 14 rad/hr from

1/ Roesch, W. C. Surface Dose from Plutonium. HW-51317, July 10, 1957, and Geneva paper (2nd Geneval Conference 23, 339 (1958))

X-rays and 370 mrad/hr from harder components (average of 1 Mev) associated with spontaneous fission and 270 mrad/hr of 1 Mev average energy associated with the formed fission products at equilibrium. The neutron release from spontaneous fission is at the rate of 1380 n/gm-sec.

Pu^{241} has a half-life of 13.2 years. Over 99% of its decays are by beta to Am^{241}, about 4.4×10^{-5} of its decays are by alpha to U^{237}.[1/] Its specific activity is 113 c/g. Its equivalent alpha specific activity is about 0.005 c/g. The maximum beta energy is about 20 Kev and presents no external radiation problem. Since a number of gammas are associated with both Am^{241} and U^{237}, the growth of these two isotopes in time will yield significant gamma radiation. Roesch[1/] gives formulas for calculating the dose rate for a semi-infinite piece of Pu^{241} metal. These are as follows:

X-rays (17 Kev) from Am^{241}

$$237\ (4.28 \times 10^{-4} t)\ \text{rad/hr.}$$

Hard components (primarily 60 Kev)

$$221\ (4.28 \times 10^{-4} t)\ \text{rad/hr.}$$

U^{237} (several energies 59 Kev to 334 Kev)

$$23\ (1 - e^{-0.102\, t})\ \text{rad/hr.}$$

The above formulas are good for times much less than 14 years and t is in days. For further discussion see Seaborg, et.al. (Rev. Mod. Phys. 30, 585 (1958) and Hyde (UCRL-9458).

Consideration of Pu as a Mixture of Isotopes

A typical mixture of plutonium would be Pu^{239}, 94.5%; Pu^{240}, 5%; and Pu^{241}, 0.5%. Immediately after chemical separation, the surface dose rate contribution would be composed of the following: 610 mrad/hr x 0.945 or 578 mrad/hr X-ray contribution from Pu^{239}, 56 mrad/hr x 0.945 or 53 mrad/hr hard component from Pu^{239}, 14,000 x 0.05, or 700 mrad/hr X-ray contribution from Pu^{240} and 370 mrad/hr x 0.05 or 18.5 mrad/hr hard component contribution from Pu^{240}. This totals to 1278 mrad/hr X-rays and 71.5 mrad/hr hard radiation. The spontaneous fission neutron yield would be 69 n/gm-sec. At fission product equilibrium which will exist in a matter of a day or so, an additional 13.5 mrad/hr will be contributed to the hard components. The growth of Am^{241} and U^{237} will yield additional contributions to both the soft and hard components as time goes on. For example, at 30 days Am^{241} contributes $237\ (4.28 \times 10^{-4} \times 30) \times 5 \times 10^{-3}$ or 15.2 mrad/hr to the X-ray surface dose rate and about 142 mrad/hr to the harder components. U^{237} activity grows in to the extent of about 50% of equilibrium in one week and 95% in 30 days. Therefore, at 30 days the U^{237} contribution to the hard components surface will be $23 \times 0.95 \times 5 \times 10^{-3}$ or 107 mrad/hr. The contributions from Am^{241} and U^{237} growth are therefore significant and

1/ See reference, previous page

for higher percentages of Pu^{241} in a mixture of plutonium, the growth of the two materials becomes the major consideration from the external radiation standpoint. The neutron yield of a plutonium mixture will be for practical purposes proportional to the Pu^{240} content.

In addition to the above consideration experience has shown that depending on chemical separation efficiency, fission products such as Zr^{95}-Nb^{95} and Ru^{103}-Rh^{103} may exist to the extent of contributing considerably to the hard gamma components. The former contributes gamma of about 750 Kev and the latter about 500 Kev.

Am^{241} has a half-life of 462 years. Its specific activity is 3.22 c/g. Its radiation properties were considered under the plutonium discussion. The radiation from curie amounts of Am^{241} would prohibit its handling to very small exposure times if handled in an ordinary glove box of standard construction. Since the radiations are relatively soft, added on shielding materials will in most cases reduce the radiation field to tolerable levels.1/

Production of Neutrons by α -n.

The yield of spontaneous fission neutrons from Pu^{238} and Pu^{240} has been discussed. The average energy of the fission spectrum will be about 1. The production of neutrons from the α-n reaction with light elements can present a serious exposure problem. Perhaps the greatest one of concern in chemical work is the α -n reaction with fluorine. If one can assume the energy spectrum and yield to be about equivalent to that known for Po^{210} α F1/, the average energy is 1.4 Mev and the yield is 4×10^5 n/sec/c. There are also some significant gammas associated with the α -n reaction which add to the total gamma field. These gammas have energies of about 1.27 Mev and 2.1 Mev.2/

Shielding Considerations

Usual glove box construction from the material standpoint consists of windows of 1/4-inch glass, 1/4-inch plastic or 1/2-inch plastic. The remainder of the box will probably be 1/8-inch steel with 15 to 30 mil thick gauntlet gloves. These materials are somewhat effective in shielding the softer electromagnetic and beta radiation but do not offer much in the way of shielding for the harder gammas or neutrons. Replacement or "added on" materials such as X- ray glass, lead sheet or leaded gloves may be used. In many cases such additions will reduce the radiation field to tolerable levels with versatility of operation remaining. Data is presented in the appendix for shielding effectiveness of various typical glove box materials and "added on" materials. One is cautioned to keep in mind that these data should

1/ Moyer, Harvey V., "Polonium", TID-5221, July 1956

2/ Moulthrop, H.A., Z Plant Radiation Study, Interim Report No. 5-Part II, Data on Gamma Shielding of Special Plutonium Samples, HW-61755 Pt. 2, October 22, 1959, and Steindler, M. J., ANL-6287, pg. 143.

be used only as guides since the many parameters which exist in practical situations obviously could not be accounted for.

It is generally accepted that shielding should be used as close to the radiation source as possible. This concept can be used to a degree in glove box design. For example, many chemical apparatus can be jacketed with lead sheet very easily within the glove box. On the other hand, it may be more practical to shield the entire box to maintain versatility within the box. Also, the problem of radiation due to spills and general accumulation of radioactive material over the inside surfaces of glove boxes and on equipment can be handled better if the entire box is shielded.

The physical and chemical properties of a good neutron shield do not allow shielding of glove boxes to be done in a similar manner as described for gamma radiation. Basically a good neutron shield is one whose chemical composition is high in hydrogen. Materials such as water, paraffin, masonite and plexiglass have been used. Paraffin, although a good neutron shield, is not well received because of its flammability and need for structural support. Water also needs to be contained. A combination of plexiglass and water has the advantage of transparency and can be constructed so the water can be drained in the event the shield must be moved. Neutron removal cross sections for a number of materials and elements are given in NBS Handbook 63.

Reduction in neutron exposure to the hands by shielding is impractical. Consequently, operations such as those involving large quantities of alpha emitter fluoride mixtures should be done by remote control such that distance and/or shielding may be imposed between operator and operation. Roesch[1/] gives a value of 0.115 mrem/hr per neutron/cm^2-sec to tissue at the surface of Pu metal. He also shows that the neutron flux at the surface of a sphere is 1/2 na where n is the neutrons emanated per unit volume per second and a is the radius of the sphere. Therefore, for a 2 cm diameter sphere of Pu with composition such that the neutron yield is 80 neutrons/gm-sec, the dose rate to tissue in contact with the sphere is 88 mrem/hr from the neutrons alone.

In addition to shielding, operation methods and procedures should be considered in the light of increasing operator distance from the source of radiation and reducing time of exposure. Placement of controls at maximum distances or behind barriers and utilization of tongs where possible will reduce exposure.

1/ See reference, page IV-8

Housekeeping Practices

Good housekeeping practices are very important for the minimizing of radiation exposure. This fact is well recognized by experienced personnel and most successful operators assign a high priority to good housekeeping. Spillage of active material should be cleaned immediately and all interior surfaces of the enclosure should be cleaned frequently. Chips, filings, powder, and other solid waste should be promptly removed or placed in shielded containers. A glove box should not be allowed to become a contaminated waste storage area.

Minimum material inventories should be maintained, volatile solvents and combustible material should be kept to as small a quantity as possible and pyrophoric material should be segregated. Specifically, the glove box should be maintained in a high level of cleanliness and should contain only essential materials and equipment. Perhaps one of the most important methods of minimizing exposure is a good educational program designed to make the operator aware of those principles or practices which he may use to reduce his own exposure.

For a more thorough discussion on the merits of good housekeeping see references 1/ and 2/.

1/ Barton, C. J., "A Review of Glove Box Construction and Experiments". ORNL 3070

2/ Miles, G. L., UKAEA - AERE-C/R - 958

TABLE II

Yields of (α, n) neutrons from Polonium sources

Target	Roberts*	Neutrons/10^6 Alphas Breen and Hertz*	Hess**
Li	2.6	1.0	2.5
Be	80	59	58
B	24	15	24
C	0.11	-	-
N_2	0.01	-	-
O_2	0.07	-	-
CaF_2	-	2.8	-
BF_3	-	-	15.4
F_2	12	-	-
N_2	1.5	1.1	-
M_g	1.4	0.80	-
A_l	0.74	0.53	-
S_i	0.16	-	-
Cl_2	0.11		
A	0.38		

* J. B. Marion and J. L. Fowler, Editors, Fast Neutron Physics Interscience Publishers, Inc., New York, 1960, Chapter 1A

** Wilmot N. Hess, Neutrons from (α n) Sources, UCRL-3839, July, 1957

TABLE III

Radioactive Properties of Some Isotopes

Isotope	Sp. Act.(1) c/g	Type(1) Emitter	γ Energy Mev	Gamma per Disintegration	Spontaneous fission yield
Po^{210}	4.5×10^{3}	a, γ	.08	1.2×10^{-5} (2)	
U^{233}	9.5×10^{-3}	a, γ			
U^{232} daughters		a, b, γ	.04 to 2.8	-----	
Pu^{238}	16.8	a, γ, n	0.017 0.045	9.6×10^{-1} 3.4×10^{-4} (3)	3420(4)
Pu^{239}	6.17×10^{-2}	a, n	0.017 (avg) 0.039 0.053 0.100 0.124 0.380	2.9×10^{-1} 2×10^{-5} 7×10^{-5} 5.5×10^{-5} (3) 2.5×10^{-5} 1.5×10^{-5}	
Pu^{240}	0.227	a, γ, n	0.017 1 (avg-fission 1 (avg-fission product)	9.6×10^{-1} 7.5 per fission (3) 5 per fission	1380(4)
Pu^{241}	113	a, b			

TABLE III (Cont'd.)

Isotope	Sp. Act.[1] c/g	Type[1] Emitter	Energy Mev	Gamma per Disintegration		Spontaneous fission yield
Pu^{242}	3.91×10^{-3}	a	Fission gammas probably similar to Pu^{240}	gammas/fission probably similar to Pu^{240}		2500[4]
Am^{241}	3.22	a,	0.017	3.7×10^{-1}		
			0.260	2.7×10^{-2}		
			0.430	6×10^{-4}		
			0.590	3.7×10^{-1}	(3)	
			0.099	2×10^{-4}		
U^{237}	8.4×10^{4}	b,	0.0261			
			0.0332			
			0.0435			
			0.0596	3.6×10^{-1}		
			0.0648	2.3×10^{-2}		
			0.1139			
			0.1646	3.6×10^{-2}		
			0.2079	2.4×10^{-1}	(2)	
			0.2342			
			0.2675	8.6×10^{-3}		
			0.3323	1.4×10^{-2}		
			0.3353	2×10^{-3}		
			0.3685			
			0.3710			

(1) J. E. Dummer, Jr., Editor, Los Alamos Handbook of Radiation Monitoring, LA-1835 (3rd Ed.)Nov. 1958

(2) Reviews of Modern Physics, 30, No. 2, Part II, April 1958

(3) W. C. Roesch, Surface Dose from Plutonium, HW-51317, July 10, 1957

(4) Calculated from data in Reviews of Modern Physics, 30, No. 2, Part II, April 1958

TABLE IV

% Transmission of Gammas through Several Materials

Energy Mev	Pb Gloves * 30-Ga	Pb Gloves * 50-Ga	Pb Glass 4.8 Sp.Gr.(1) ¼"	Pb Glass ½"	Pb Glass 3/4"	Pb Glass 1"	Safety Glass(1) ¼"	Safety Glass ½"	Safety Glass 3/4"	Safety Glass 1"	Plexiglass(1) ½"	Plexiglass 1"	Lead(1) 1/16"	Lead 1/8"	Lead ¼"	Steel(1) 1/8"	Steel ¼"	Steel ½"
.017	1	0	1.3	0.0			13				40	15	0.0			0		
.060	85	45	1.5	0.0			75	55	42	32	81	68	0.0			0		
.100	78	29	5.4	0.0			84	70	58	49	82	71	35.0	10.0	1.0	45	20	3.5
.200	96	82	33	14.0	5.4	2.2	88	76	67	60	87	76	47.0	25.0	5.0	82	67	45.0
.380	99	96	69	47.0	31.0	21.0	90	84	75	68	90	86	70.0	56.0	30.0	82	68	47.0
.510	~100	97	75	60.0	45	35							80.0	70.0	50.0			
.750	~100	98	81	66	52	45	94	87	80	75	90	86	85.0	78.0	62.0	85	74	56.0
1.27	~100	~100	87	74	61	52							88	85	72	90	79	61.0
2.1	~100	~100	90	80	73	64							92	87	76	90	80	64.0

(1) H. A. Moulthrop, Z Plant Radiation Study, Interim Report #5 - Part II, Data on Gamma Shielding of Special Plutonium Samples, HW-61755, Part 2, October 22, 1959.

* 30-Gauge gloves ~.04 mm Pb equivalent

50-Gauge gloves ~.20 mm Pb equivalent

IV. CONTAMINATION CONTROL

The Objective of Contamination Control is to Limit the Spread of Spilled Contamination to as Small an Area as Possible

To the uninitiated, it might appear that utilization of a glove box system would obviate the need for further contamination control measures. This would indeed be true if the integrity of the glove box system and its associated operations were absolute. Experience has shown, however, that such systems do not have absolute integrity. Spills occur due to leakage, glove failure, and inadvertent acts of the technicians operating the boxes.

It is necessary, therefore, to set up secondary controls if contamination is to be confined to the controlled area. These secondary controls include zoning, air flow patterns, control lines, surface contamination monitoring, air monitoring, bioassay, protective clothing and good personal hygiene on the part of the technicians.

Contamination Control Aspects of Area Design

The objective of area design is to lay out the area in a manner that is compatible with contamination control measures and operating efficiency. The design or layout of an area has a major effect on the efficiency of contamination control measures. It is important that these factors be considered in the initial design of the area.

Proper zoning of the area consists of segregating sub-operations within the total operation according to contamination release potential and placing them in the area in a manner compatible with contamination control and operating efficiency. The size, shape and location of these zones can increase or diminish the effect of subsequent contamination control measures.

In general, the best approach to proper zoning depends on an analysis of the total operation relative to the contamination release potential. Evaluation of the release potential of an operation is highly qualitative and depends on the experience and knowledge of the analyst. It is obvious that an open hood has more potential for spills than a glove box and that a glove box handling powder has more release potential than one handling solids. Glove boxes requiring frequent decontamination present more release potential than those requiring less frequent decontamination.

Many other factors beyond the scope of this report must be considered in evaluating the release potential. Some of the more important of these factors are: (1) the quantity of pyrophoric and combustible material that will be present; (2) the use of tools and the presence of other objects capable of perforating gloves and plastic bags; (3) corrosive characteristics of material to be handled; (4) the possibility for violent chemical reactions or explosions; and (5) the possibility of a nuclear excursion. Careful thought along these lines in the design stages will be beneficial in subsequent operation of the area.

After the release potential of the sub-operations has been evaluated, they should be segregated into two or more categories, e.g., none, low, medium or high release potential. Provided that overall operational efficiency is not seriously impeded, efforts should be made to locate those sub-operations with high release potential in the most remote location in the area, i.e., away from the main entrance or high traffic areas. Operations falling in the lower release potential categories are placed in the less remote areas. It is realized that optimum layout of the area may be impractical in the case where an existing area is being altered for a new operation. The approach, however, should be followed as closely as possible.

Air Flow Pattern. The air flow pattern should be designed so that airborne contamination will be limited to as small an area as possible and rapidly exhausted in case of a release. Proper design of air flow is highly effective in control of contamination spread due to airborne contaminants. Air flow patterns should ideally be designed to provide clean air from a corridor into each contamination release zone discussed above, and exhausted through filters from these zones. Again, this is not always feasible. An effective, and in general, attainable arrangement, is to design the ventilation system to cause clean air to flow from zones of low contamination release potential to zones of high release potential with the exhaust located in the latter. Thus, if contamination is released from the zone of high potential for release, contamination will not be spread into other zones, and, by definition, the most probable sources for such a release are in the zone of higher potential release.

Contamination Control Lines. The contamination control lines should be set up to prevent physical transfer (tracking or transfer of contaminated objects) of contamination from controlled to uncontrolled areas. Ideally, the contamination control line should be a buffer zone, such as a wash room located at the primary entrance to the area. This buffer zone should be equipped with monitoring and decontamination facilities. Secondary contamination control lines should be set up at "limited use entrances" and will normally consist of a line of demarcation painted or taped on the floor. In some cases, it may be desirable to set up a secondary contamination control line at the entrance to areas with high potential for contamination release. In general, monitoring devices alone are sufficient at secondary contamination control lines. The minimal requirements for a contamination control line is a line of demarcation and monitoring equipment. Types and applicability of the various monitoring instruments will be discussed later.

The effectiveness of contamination control lines is directly dependent on the cooperation of personnel working in the area. Police power is usually ineffectual unless a person can be assigned to the control line for enforcement of regulations, a measure that few plants can afford and one that is usually unnecessary. In general, if operating personnel can be made to understand the necessity for contamination control lines, the implementation of control lines can be effected through cooperative action. In extreme cases wherein a person refuses to follow the contamination control line procedures, disciplinary action should be taken on the second offense. Continued infraction of the procedures by one or two persons can quickly spread to other personnel, rendering the control line ineffective. In all cases, regulations pertaining to maintenance of control lines should be written and posted at the control line. Typical instructions might be as follows:

No Smoking or Eating within area.
Before leaving area:
- Monitor Hands and Feet
- Monitor all outgoing equipment
- Wash Hands
- Remove Shoe Covers and Lab Coats

Contamination Control at the Local Level

The objective of contamination control measures at the local level is to detect and correct equipment or operator failure that cause or might cause release of contamination. The glove box facility is normally designed to completely contain all radioactive material during normal operations. The effectiveness of the design will depend upon many factors, such as operating procedure, quality of construction and the ability of the designer to foresee potential failures. It is necessary, therefore, to analyze the complete system under operating conditions, and maintain a check on the efficiency of containment during continuing operations.

Many potential sources of leakage can be detected and corrected during the initial operation of the system through observation of operating techniques, measurement of air pressure differentials, smoke checks, air monitoring at likely sources of contamination, and other evaluation techniques. In general, a full evaluation of the complete operation to determine potential sources of contamination should be made during the initial operation. Correction made at this time will usually be simpler and require less work loss than corrections at a later time when contamination levels are high and work schedules are pressing.

The most insidious and frustrating problems encountered in a glove box facility are due to small, but continuing contamination leaks. These leaks may be due to minute glove punctures, eddy currents in hoods, etc. This type of leakage is inconspicuous and results in rising air and surface contamination. Most plants find that routine inspection and monitoring is the most feasible method of detecting this type of problem. Smear survey and general room air sampling on a routine basis are performed in most plants. Some plants, handling plutonium, require hand monitoring each time the hands are removed from the glove box in order to detect glove failure immediately. Other plants require daily, weekly or bi-weekly glove inspections to detect breaks or require frequent contamination checks by the operators.

Other mechanisms by which contamination may be released in large quantities are more obvious, usually occurring during operations where containment is purposely broken, e.g., glove box maintenance, transfers to and from box and filter changing. General precautions that should be taken during operations wherein the contamination barrier is broken include rough decontamination to minimize loose contamination, protective clothing and respiratory equipment for the operator, placement of "blotter paper" on the floor of the immediate area, and setting of contamination control lines around the area to limit the spread of contamination. The extent to which the above precautions are exercised will depend on the degree of residual contamination in the box, the nature of the operation to be performed and the knowledge gained from similar operations in the past.

Ingenious methods have been developed to prevent contamination release during glove changes and removal of materials from the glove box. Glove changing techniques in boxes are similar in most plants. Material transfer procedure, by use of a plastic bag, is illustrated on page I-25.

Other methods of material transfer utilize sphincter ports, evacuated isolation air locks, air locks, ice cream cartons, paint cans, or other containers. The sphincter port is an excellent method of getting small items into the box and is illustrated on page I-26. Another more elaborate, but highly successful method utilized a portable transfer glove box to effect transfers between boxes. One plant is discouraging the use of air locks since it has been their experience that this method is relatively unsuccessful in preventing contamination spread. Interconnecting air locks between glove boxes, where operations permit, are widely used.

The preferred technique of changing filters depends on the filter location. If the filter plenum is located within the glove box enclosure, the changing operation is completely contained. If the filter is located outside the glove box, the changing operation should employ the same techniques and precautions used for maintenance operations when the box must be disassembled.

Air Monitoring

Air is monitored for the presence of radioactive material to accomplish one or more of the following objectives:

1. To detect the presence of air contamination due to continuous leakage from the containment system.

2. To detect the presence of air contamination due to short term, intermediate level leakage from the containment system as rapidly as possible.

3. Alarm operating personnel when hazardous conditions exist.

4. Provide a historical record of activity in air that can be compared to maximum permissible concentrations (MPC's).

Air monitoring techniques used at the various facilities are as follows:

1. Eight hour continuous air samples are taken, using an air pump and filter paper. At the end of the sampling period, the samples are removed, the natural occurring activity allowed to decay, and the samples counted on laboratory type counters.

2. Twenty-four hour continuous air samples are taken using an air pump and filter paper. At the end of the sampling periods, the samples are removed, the naturally occurring activity allowed to decay and the samples are counted on laboratory type counters.

3. Spot air samples are taken, using high volume air samplers, electrostatic air samplers, or other pump-filter systems. The naturally occurring activity is allowed to decay and the sample counted on laboratory type counters. These samples may be taken in breathing zone, general room air, or at the point of highest expected concentration.

4. Continuous air monitoring, using fixed or moving filter media. Detecting devices utilize a count rate meter and/or the newer ratio detector. Most of these devices are equipped with alarm circuits.

The eight hour sample accomplishes above objectives numbered 4 and 1. Short term leakage may or may not be detected due to the dilution effect of the long sampling period. The twenty-four sample accomplishes objective 1, provided the long term leakage is unaffected by operations, but since the historical record should be based on a 40-hour work week, does not adequately accomplish objective No. 4. Spot sampling, in conjunction with thorough evaluation of the operation, can accomplish objectives Nos. 1, 3 and 4. It is generally argued that spot sampling, although more sensitive, may miss short term leakage events. Counter arguments contend that operations that might lead to short term leakage events will be detected in the operation evaluation and that samples in the breathing zone of the operator should be taken when those operations are performed. In addition, the counter argument contends that smear sampling is as adequate for detection of short term leakage events as continuous sampling, and that once the event has taken place, urinalysis is the most dependable means of evaluating the effect of the event.

Air monitoring for alarm purposes has not been in wide use in glove box facilities until recently because satisfactory instrumentation that would detect alpha radiation had not been developed. Most of the trouble with previous instruments was due to the presence of naturally occurring alpha emitters. Instruments based on the alpha and beta-gamma ratio have become commercially available and are sufficiently sensitive to serve as alarm type air monitors. Developments at Argonne National Laboratory have further increased the sensitivity of these instruments. In general, these instruments are expensive and can be justified only when high toxicity materials, such as plutonium, are used or where very high release potential exists. Properly calibrated, the records generated by these instruments should prove to be excellent for historical purposes.

Surface Contamination

Surface contamination limits are probably the most widely divergent semi-standard in the Atomic Energy Industry. Answers by various facilities using glove box systems range from qualitative statements to definite limits for various types of surfaces. It is apparent, however, that the majority of the facilities answering the AEC questionnaire are following the general philosophy that surface contamination is held to the lowest practical limit in working areas and to non-detectable limits in uncontrolled areas.

The point at which surface contamination can be detected is dependent upon the instrument or technique used for detection. Portable alpha survey meters will detect activity in the order of 500 disintegrations per minute (dpm) per window area (usually between 50 and 100 cm^2). Internal gas flow counting of an alpha smear sample (filter paper rubbed over surfaces) for a one minute period will detect activity in the order of 20 dpm per smear. An attempt is usually made to cover 100 cm^2 or 1 square foot with the smear; therefore, the smear results are reported in dpm per 100 cm^2 or dpm per square foot.

Surface contamination limits within working areas should be based on experience and the effect on air sample and/or urinalysis results. It can be generally stated that surface contamination in working areas is of concern only because it can be ingested, transferred to uncontrolled areas, or technically affect operations. Theoretically, if surface contamination in a working area is contained within the area, is not being ingested by personnel and does not affect the sensitivity of measuring or monitoring devices, decontamination efforts are not justified. In practice, the working surface contamination limit is normally a compromise between monitoring sensitivity and operating efficiency. Many facilities have found it convenient to set plant-wide limits for various types of surfaces and will allow deviation from this limit if necessary. Others set specific limits, based on monitoring sensitivity, for surfaces in uncontrolled areas only. The limits, as stated, refer to a specific monitoring technique and since techniques differ from plant to plant, have resulted in an apparent discrepancy in surface contamination limits.

Instrument Monitoring for Surface Contamination. Portable or semi-portable survey meters are widely used to check for the presence of radioactive contamination on surfaces that might be contaminated. Semi-portable instruments are normally used at contamination control lines for checking tools and equipment leaving the area, in addition to personnel contamination monitoring.

Beta detecting instruments used for this purpose are generally the Geiger tube type, although in some cases scintillation type instruments are used. Portable alpha survey instruments commercially available include the air chamber proportional counter, gas flow proportional counter, scintillation counter, and the "samson" ionization type survey meter. The "samson" type instrument is sensitive to beta-gamma as well as alpha and, therefore, has a higher background than the other instruments. The air chamber proportional counter has been used successfully in areas where the humidity is closely controlled, but has generally proved unsatisfactory under high humidity conditions. The gas flow and the scintillation type counters have proved effective under most operating conditions. The lower limit of detectibility on these instruments is in the order of 500 dpm.

Alpha monitoring is accomplished by placing the window of the probe within about 1/4 inch of the surface to be monitored. If the surface is much farther away, erroneous readings will result due to air and probe window absorption of the alpha particles.

Interpretation of the results of portable survey meters should be made in light of the qualitative nature of the results obtained under normal working conditions. In general, the instrument survey will indicate the presence of significant contamination and provide a relative order of magnitude for contamination levels.

Smear Monitoring for Surface Contamination. The "smear survey" monitoring technique is widely used throughout the industry for detection of transferable contamination. The technique consists of wiping a filter paper tab across the surface suspected of being contaminated. The smear is then counted in a laboratory counter for approximately one minute to determine the radioactive contamination picked up by the smear.

Results of the smear technique are highly qualitative since they are dependent on the area covered, the nature of the contaminant, and the pressure exerted on the smear. Most facilities have attempted to make the method more quantitative by specifying the area to be covered by a smear. In spite of the qualitative results, experience indicates that the smear technique is highly effective in detection of transferable activity. Since the major problem associated with surface contamination is due to the removable or transferable contamination, the smear technique is adequate for routine monitoring of uncontrolled areas or other areas where contamination is not expected and, in addition, is one of the least expensive monitoring techniques.

Personnel Contamination Monitoring

The objective of personnel contamination monitoring is to detect the presence of contamination on the skin or clothing of persons so that it can be removed or shown to be non-ingestable and/or non-hazardous. TID 3535, USAEC, Radioactive Decontamination, available from Technical Information Service, Department of Commerce, Washington, D. C., is a bibliography of publications dealing with decontamination of surfaces of various materials, metals, equipment, buildings, clothing, skin, earth, etc. The primary problem connected with personnel contamination is based on the presumption that the contamination will (a) be transferred to the internal organs of the body; (b) fall off in uncontrolled areas; (c) deliver excessive radiation dose to the skin; or (d) affect future contamination monitoring. In the situation where the contaminant is a beta-gamma emitter, all four factors must be considered in the decision relative to the significance of residual contamination. For alpha emitting contaminants, only the first three factors are considered. For example, if the hand of a person is found to be contaminated with plutonium to the extent of 1000 dpm after repeated decontamination efforts have been attempted without success, and if further efforts might damage the skin tissue, the contamination may be considered insignificant. This decision would be based on the fact that further decontamination must occur due to sloughing of the skin, which will be a slow process that would probably not result in ingestion and would result in insignificant contamination of uncontrolled areas. Future monitoring might be affected, but this effect is unavoidable and is of little consequence since the presence of the contamination is known.

Instruments available for personnel monitoring include portable and semi-portable survey meters for both alpha and beta-gamma radiation, hand and foot counter for beta-gamma radiation and, to a limited extent, alpha radiation, and portal monitors for beta-gamma radiation.

Beta-gamma monitoring can be accomplished with many commercially available instruments which usually utilize Geiger tube detectors. It is important that these instruments be as sensitive as possible so that contamination can be easily detected. The sensitivity of the portable or semi-portable instruments can be increased by a factor of 10 through use of a probe utilizing four Geiger tubes wired in parallel. The increased sensitivity makes it possible to quickly scan a person for contamination. Use of a portal monitor with an alarm circuit is effective in preventing grossly contaminated persons from leaving a controlled area. Hand and foot counters are available to monitor the hands and feet, which are the most likely points of contamination.

Alpha monitoring is more difficult due to the properties of alpha radiation. The penetration power of the alpha particle demands a very thin window in the probe resulting in frequent failure, especially when scintillation detectors are used. Portable or semi-portable instruments using air chamber, gas flow proportional or scintillation detectors are commecially available. The scintillation and gas flow proportional type counters appear to be the most dependable, although both, if improperly adjusted may be sensitive to beta-gamma and/or neutron radiation. Hand and foot counters utilizing alpha sensitive scintillation detectors have been used with moderate success, although maintenance is difficult due to window breakage. Although alpha monitoring equipment has many faults, it is capable of detecting significant amounts of contamination if carefully used.

V. PERSONNEL MONITORING

The numerous measures and procedures discussed above would seem to provide adequate protection for personnel working at or around glove boxes. Various appropriate shielding techniques, careful administrative control, constant monitoring outside the boxes, exhaust monitoring, pre-estimations of the amount and hazard of exposure for each individual operation performed in the box, protective clothing, glove changing techniques and inspections, swipe procedures, and many other measures, cover all the avenues of possible contamination of the individual. And yet, there are accidents and unforeseen happenings that make it necessary and desirable to take even further steps to protect the health of the workers.

External Radiation

Film badges are worn generally by all personnel who may be exposed to industrial radiation. While there is some variation in the styling of these badges, they all indicate beta and gamma exposure, and some are modified to read neutron exposure. Usually, these badges are read at one week to three month intervals. Some facilities require the additional use of pocket dosimeters which can be read each day. If the operation warrants it, film rings or wrist badges may also be worn. At the present time, there is unsufficient data available to make a general correlation of the ring or wrist badge readings with whole body exposure. However, these readings may be valuable as an index of relative exposure. Hand and foot counters, and alpha probes are routinely used in most installations. The permissible levels are set locally, depending on the operation, however, all levels are equal to or below those set by AEC Manual Chapters or AEC Regulation 10, CFR Part 20.

Internal Radiation

There is also a wide variation in bio-assay techniques used by the various facilities in the Atomic Energy Industry. For example, the frequency of urine or feces examination depends to a large extent upon the type of work being done, and varies from weekly to annual or bi-annual examination. Usually, a gross beta-gamma scan is done that can be followed up by search for any specific isotopes that may actually be involved. It is realized that this gives only an inferred measurement of the actual body burden of internal deposition.

At the present time, there are no methods for accurate estimation of internal deposition of radioisotopes that lend themselves as feasible routine control measures, to be generally used throughout the industry. Use of biopsy or the whole body counter for more accurate estimation is not feasible except in isolated cases of known or strongly suspected contamination. Routine blood studies for radiation effects of small doses would fail to give conclusive results. Special procedures such as slit lamp examination for early radiation cataract require the services of a well-trained ophthalmologist, and hence could not be used as a routine control measure. It will be seen that, at the present time, internal radiation can best be calculated from results of environmental measurements and reports of the bio-assay of periodic urine and feces specimens.

VI CONCLUSIONS

Engineering and operational requirements must be coordinated with Health and Safety requirements if an efficient, safe operation is to result. A review of successfully operated gloveboxes reveals several important, common features of facilities, equipment, handling methods, and administrative methods necessary for the control of materials requiring a high degree of confinement. The items listed below are those directly affecting Health and Safety requirements:

1. The area should be laid out to minimize contamination spread through air borne or physically transferred radioactive material.

2. Ideally, the worker should be able to reach all areas of the interior of the glove box through the use of glove ports. This will facilitate cleaning and removal of waste material. Inaccessible areas tend to accumulate contaminated dust, and if liquids are splashed on surfaces that cannot be reached, clean-up is most difficult.

3. The enclosure should be constructed with high integrity, a high degree of leak tightness, provisions for external radiation protection based on the nuclear properties of the material and a reasonable anticipation of future usage.

4. The floor of the enclosure should be without seams, corrosion resistant, and capable of being cleaned and decontaminated.

5. Corrosive effects on gloves, plastic transfer ports, plastic or glass panels and viewing windows, and other components of the enclosure must be considered relative to potential for leakage.

6. The probability of accidents such as spills, unexpected chemical reactions, small fires or explosions should be considered. Insofar as possible, provisions to minimize the effects of these incidents should be made.

7. Complete separation of glove box and external atmospheres is essential. Negative pressure within the glove box should not be considered as an absolute barrier in case of a containment break.

8. Transfers of materials and equipment into and out of the glove box are made through the use of plastic bag ports or air locks. Everything removed from the glove box will usually be grossly contaminated. This assumption is made until survey measurements show otherwise. The sealing technique used with plastic bag transfers is usually a more effective contamination control barrier than the use of air locks.

9. Effective means of replacing defective gloves without violating the integrity of the physical barrier should be provided. Similar techniques are required for preserving the physical barrier at plastic bag ports.

10. Operator training and strict compliance with well conceived procedures are essential.

11. Film badges should be worn by personel who may be exposed to industrial radiation. In addition, pocket dosimeters, film rings, and/or wrist badges may be worn during operations in which higher external radiation exposure potential is involved.

12. Hand and foot counters and alpha probes may be used to detect external contamination and control spread of radioactivity.

13. Routine bioassay procedures should be performed. The frequency and specific type of examination to be accomplished should be regulated by the specific radio-isotopes involved in the operation.

14. Estimation of internal deposition of radioactive material should be based on results of environmental measurement and reports of bioassay examination. Other procedures, such as use of whole body counters, may be used if such facilities are available.

15. While the above are important for protection of personnel, they cannot be used as a substitute for evaluation, routine inspection and monitoring, good housekeeping practices within and outside the enclosure, operator training and other conventional health physics principles.

In summary, the glove box can be a very helpful tool in controlling exposure of personnel to radioactive material. Its usefulness is in direct proportion to adequacy of design, effective preplanning, and processing methods used. Radioactive materials for which the human body has an extremely low tolerance may be processed in a properly designed glove box with comparative safety. However, this does not eliminate the need for informed and vigilant personnel, and an effective health physics program.

GLOVE BOX INSTALLATIONS

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GLOVE BOX INSTALLATIONS

The following is a summary of data and description of facilities extracted from the field reports, combined with information obtained in personal visits to the principal AEC glove box installations:

AEROJET GENERAL NUCLEONICS

The San Ramon plant has been concerned with fuel development and fabrication and the extensive related technical areas. The materials handled include Beryllium, Uranium, and a limited quantity of Plutonium. There are also small amounts of other radioactive materials. Examples of operations set up in glove boxes involve weighing, blending, sieving, granulating, drying, pelleting, a centerless grinder, pressing, etc.

Construction Materials:

About 20 boxes are installed - one-quarter are plywood; one-quarter are lucite; and the remainder are stainless steel. These have been largely obtained from outside commercial suppliers. Specifications for the stainless steel box (Technical Procurement Specification No. 44 AGN-G1) were drawn up to obtain versatility, ease of decontamination and fire safety. Six boxes can be used for inert atmosphere.

The windows are of ordinary safety plate glass or, in some cases, 3/4" lucite. Sealing is accomplished with neoprene gaskets. The glove ports are commercially supplied 8" diameter aluminum, and the gloves neoprene, with Size 9 standard. Any other size requested is a special order.

Ventilation Systems:

About one-half the boxes have their own blowers and the others are on manifolds.

An inlet prefilter is provided on each box and an absolute type with a prefilter is installed on the outlet.

The ventilation exhaust ducts are elephant trunk 2" diameter flexible tubing.

Waste Disposal

Waste is disposed of by placing in ice cream containers with a secondary polyethylene bag surrounding the container. Material is removed from the glove box through the access port only after packaging as described above. Equipment is removed from these glove boxes after decontamination by removing the cover plate.

AMES LABORATORY

Ames Laboratory has been conducting pyrometallurgical research with Uranium-plutonium alloys. This has necessitated some glove boxes, the principal features of which follow:

Box frames:	Mild steel angles.
Floors:	Formica covered plywood (easily decontaminated).
Supports:	Mild steel angles.
Windows:	Plexiglas (easily fabricated and economical).
Window seals:	Sheet neoprene.
Window fasteners:	Cold rolled, mild steel, straps are located around the periphery of the windows. Machine bolts pass through the straps, windows, gaskets and threaded holes in the box frames.
Gloves:	"Berkeley Box" Combination Gloves (Style NLR527) and Neoprene gauntlet gloves.
Glove rings:	Neoprene "O" rings.
Gloveport covers:	Polyethylene bags secured with neoprene "O" rings.
Ventilation ducts:	Inlet ducts are copper pipes slit down the side to produce a ribbon of air. Outlet ducts are spring wire reinforced, rubber tubes.
Protective coatings:	Enamel.
Filters:	Inlet prefilter - Fiber glass. Outlet filter - Chemical Warfare Service (CWS) made of mineral fiber with aluminum separators and metal case.
Tent Materials:	Polyethylene.

Atmosphere Control.

An aneroid type pressure regulator automatically controls a diaphram exhaust valve positioned in the exhaust line of the outlet filter and a solenoid operated gate valve in the intake of the inlet filter box. The pressure in the system is maintained slightly below atmospheric. In the event a glove is accidentally removed or a fire starts, etc., the inlet valve automatically closes and the exhaust valve opens wide to maintain the proper direction of air flow.

Ventilation.

The air passes through a fiber glass filter into the plenum then through copper pipes to each box. Individual exhaust lines from the boxes lead to the plenum of the exhaust filter box where the air is pulled through a fire resistant, mineral fiber, absolute filter and exhausted into the general hot canyon filtering system.

Waste Disposal

A two-inch thick layer of concrete is poured in a polyethylene bag lining a two-gallon, wax-coated, fiber-pak drum and allowed to harden. A quantity of cement powder is added and the solution and dry wastes are mixed with the powder then enough water is added to make a suitable concrete. The top of the polyethylene bag is folded over the concrete and a quantity of uncontaminated concrete contained in another plastic bag is poured over the waste. The drum is closed, placed in a clean polyethylene bag and removed from the facility for disposal.

ARGONNE NATIONAL LABORATORY

Research Facilities.

The new Fuels Technology Center at ANL (Bldg. 212) is designed to handle all aspects of plutonium and non-plutonium metallurgical research, with emphasis on nuclear fuel applications. The wing housing the plutonium research area consists of two stories besides a service tunnel and a fan loft. Part of the ground floor and all of the second floor are devoted to laboratory functions. The balance of the ground floor, the tunnel, and the fan loft are devoted to building functions.

Two rows of laboratory rooms separated by an auxiliary equipment and instrument service corridor are located in the center of the wing. On both sides are located auxiliary laboratories and office rooms. These are separated from the main laboratories by a personnel corridor. The arrangement of laboratory and non-laboratory space is such as to permit convenient control of personnel traffic and to separate areas of different degrees of potential contamination.

The auxiliary equipment and instrument corridor frees space in the laboratory and minimizes replacement of instruments in case of an inadvertent spill. The corridor also serves for moving equipment and gloveboxes to and from the laboratories thus minimizing potential hazards in the personnel corridors.

The main functional advantage of the new free-standing glove boxes is the ease with which plutonium facilities can be set up in non-plutonium areas. Glove boxes can be moved from one area to another, or new glove boxes can be set up, with a minimum of effort. They can be used individually or connected in trains. Services to the glove box can be easily adapted to the needs of the individual scientist.

Services are brought into the glove box through gas-tight O-ring seals in the glove box walls or base. Auxiliary equipment is usually under the glove box. Some is in the auxiliary equipment and instrument service corridor. Heavy pieces of auxiliary equipment such as motor generators are on the ground floor level under the laboratories. The main utility headers are brought into the rooms overhead, above a false ceiling, and connected to the glove boxes. One of the reasons for bringing services in overhead is the flexibility it gives for connecting free-standing glove boxes. Another is that overhead services are less likely to be contaminated from a possible spill. The floor of the laboratory is constructed on a waffle-iron grid pattern. Where necessary, services may be brought up directly through the floor.

Atmosphere Control

Where an inert atmosphere is required nitrogen is supplied to the glove boxes by evaporation of liquid nitrogen in a central storage dewar. The pressure in the glove boxes is maintained at -0.5" water column by a differential pressure controller on the exhaust header common to all glove boxes. The atmosphere in the glove boxes is maintained by passing nitrogen "once-through" the glove boxes at a rate of 0.2 CFM for a 100 cubic foot box. Because of the tightness of the glove boxes it has been possible to maintain the oxygen level at around 200 ppm with this low flow rate. The moisture level normally stays around 300 ppm at this flow rate but climbs rapidly when wet solutions are used in the glove box. A small recirculating dryer is being developed for use on glove boxes where the moisture level is a problem.

Much effort was originally expended in developing a recirculating nitrogen purification system. The system used catalytic combination of hydrogen with oxygen to form water, and the water was removed by absorption drying. The system looked very promising as regards to cost, but was easily poisoned by various solvents used in the glove boxes. When it was found that it was possible to maintain the atmosphere with a flow rate of 0.2 CFM instead of 2 to 5 CFM per glove box, the recirculating system was abandoned in favor of the much simpler "once-through" system now used.

Ventilation System

Supply air for the plutonium wing of Bldg. 212 is heated or cooled in a central equipment room and distributed to the offices, corridors, and laboratories of the wing through a dual-duct high-velocity air system. The hot and cold air ducts, located in the personnel corridors, supply the conditioned air to air attenuators or mixing boxes where it is admitted at constant volume to the rooms in accordance with the temperature demands of the control instrument location in the rooms. Pressure in the laboratories will be slightly negative (-0.01 W.C.) with reference to other parts of the wing. This is done to provide an air flow pattern from the offices and corridors to the laboratories, or from areas of least contamination risk to areas of greater contamination risk. The air supplied to the offices and corridors flows to the laboratories through the grills and openings in the floors. Air is also supplied to the laboratories through a duct extending over the perforated ceiling through which the air is allowed to diffuse into the laboratory room.

Because of the heat load an average of twenty air changes per hour in the laboratories is required for human comfort. The air is exhausted from the laboratories on each side of the equipment corridor, by separate fans located in the fan loft on a modular basis and corresponding to the air attenuators located in the personnel corridors. One of these typical exhaust systems is shown on the drawing. Before leaving the room, the air is filtered first through a fiberglass pre-filter and then through the usual AEC type high efficiency filters used throughout the Lab. The filters are located in the laboratory areas and are there only as insurance in case of a contaminated incident. In the event of a contamination incident, provision is being made to reduce the air flow through the contaminated room by by-passing all supply air to the personnel corridor, and exhausting through the laboratory only the amount of air required to maintain the laboratory at a slight negative pressure with respect to both offices and other laboratory rooms. As the grilled openings and other inlets to the contaminated room are sealed, the air flow through the room can be manually reduced until the minimum amount of air needed to maintain the reduced pressure is reached. Flanged openings are provided in the laboratory wall adjacent to the auxiliary equipment corridor to permit the connection of a recirculating air cleanup system. This recirculating cleanup system will be used to remove air borne contamination before cleanup crews enter the room.

Waste Disposal.

All dry active waste (DAW) is removed from the glove-boxes in plastic pouches, put into cardboard cartons, and stored in large steel containers. Whenever possible liquid active waste (LAW) is evaporated to dryness and handled as DAW. Very low level LAW is absorbed in vermiculite and handled as DAW. When neither of these techniques is possible, the LAW is removed from the system in polyethylene bottles and transferred to the Reclamation Department for disposal. Pyrophoric wastes must be oxidized by the originator before being acceptable for disposal. Facilities for treating all pyrophoric solids are being provided.

Storage.

All pyrophoric materials are kept in the glove boxes in an inert atmosphere. Where they must be stored outside of a glove box, the material is sealed in a polyvinyl chloride pouch under an inert atmosphere. The pouch is then contained inside a gas-tight steel container. We prefer to get rid of all pyrophoric materials as soon as possible and not store them outside of glove boxes. All pyrophoric waste is first oxidized before storage or shipment.

Access.

Introduction of small items into the glove boxes is made through a sphincter, or push-through, entry port, using a 4" diameter aluminum can. Larger items are introduced by a pouch technique. All material is removed from glove boxes by putting it into a polyvinyl chloride pouch attached to the glove box. Three seals are then made across the pouch dielectrically, and the pouched material is removed by cutting down the middle seal. The sealed plastic very effectively contains the contamination. Apparently the contaminated surface flows to the side of the seal. Where pieces of equipment must be removed that are too large to go into a pouch, we plan in our new glove boxes to remove them by taking off a window. A special housing will be attached to the glove box to accommodate the window and equipment, as well as to re-install the window. There are no air locks used in our facility as we prefer to use a completely closed approach and avoid the contamination dragout that normally occurs with air locks.

Shielding.

There has been no general need for extra shielding in our plutonium research laboratories. In a few instances lead bricks have been placed around a particular operation because of (α,n) reactions. The gamma emission of the plutonium that we are using is low enough so that extra shielding is not needed. The present glove boxes have no special provision for extra shielding in case future plutonium should require it.

CHEMICAL ENGINEERING DIVISION (ANL)

A-133 Facility.

The A-133 glove boxes consist of 15 "boxes". The primary function of the facility is to provide wet chemical analytical services and analytical development in plutonium chemistry for the Chemical Engineering Division.

G-102 Facility

Nine glove boxes are arranged so that three-module boxes are connected to 3 two-module boxes by means of transfer locks. Two four-module boxes will be used, one for metallographic preparations, the other for any "machine shop" operations that might be needed. The remaining box, of a two-module configuration, is to be used for specimen storage. One of the four, and one of the three-module boxes are 1-1/2 modules high (60 inches inside height) for use where more head room is needed.

G-117 Facility.

Two three-module boxes are used for the chemical research required in connection with direct fluorination of spent reactor fuels. No fission product work is planned for this facility and therefore no arrangements for beta-gamma shielding have been made. Equipment included in the boxes is constructed of metal (Primarily nickel and Monel) and consists of a metal vacuum line (pumping system housed underneath the boxes in a separate enclosure) with attached furnace tubes, cold traps, vertical bed reactors, gas circulating pumps and associated instrumentation. Both plutonium compounds and fluorine are handled in these systems.

Atmosphere Control.

A-133 Facility.

Once through filtered room air as furnished by building air condition system.

G-102 Facility.

The primary box atmosphere is to be recirculating dry air (2% relative humidity at 60 F) with the possibility of changing to nitrogen or argon upon the addition of an oxygen removal unit and minor changes in duct work.

If some other atmosphere is needed by an experimentor, a box can be set up to bypass the main system and the required atmosphere introduced through appropriate valving arrangement.

The boxes are maintained at -.5" W. G. This is achieved by means of valves and orifices arranged so that air is discharged from the system until the required negative condition is reached, after which the valves must be opened only to discharge in-leakage. This is done automatically through the use of differential pressure switches and solenoid valves.

The gas is circulated through each glove box at 33 cubic feet per minute. This high flowrate gives greater stability to the system because it minimizes the effect of sudden glove movements. (It is almost impossible to pressurize the glove box by rapid "pumping of the gloves). It also facilitates heat removal from the boxes.

G-117 Facility.

Laboratory air is on a "once through" basis. In the summer laboratory air is conditioned and cooled.

Ventilation System.

A-133 Facility.

Air exhausts from each box into a common plenum, discharged through two AEC filters in series to an outdoor stack. Blowers are automatically switched to emergency power in the event of an electrical power failure.

G-117 Facility.

The building ventilation system consists of ductwork from the laboratory area to the fan loft. In the fan loft filter banks (24 x 24) using AEC filters are used and the filtered air is discharged to the atmosphere through 4 ft. stacks. The boxes also contain a set of filters in the outlet side and therefore the air is filtered twice before discharge. Filters in the boxes ("prefilters") are 12" x 12" x 6" high efficiency filters made by the Cambridge Filter Co. and are rated at 500 cfm/1" wg. Other makes of filters are also used. The box ventilation systems are equipped with standard alarms which register (bell and Lights) over pressure surges. These are set for -o.5" wg. and the alarm sounds when this pressure is exceeded. In addition, manual damper controls are available to double the air flow through the boxes in the event of an incident such as loss of glove, etc. A normal 50 cfm is maintained during routine work.

Waste Disposal.

A-133 and G-117 Facilities.

Solids bagged out as DAW for disposal by reclamation (burial). High level LAW (liquid active waste) bagged out in gallon quantities for return to Special Materials. Low level LAW is accumulated in six gallon polyethylene containers, neutralized with a caustic solution, immobilized in vermiculite and disposed as DAW.

Removal of Material.

A-133 Facility.

Standard bagging procedures needed. In addition the transfer of material to a clean secondary container (ice cream craton) is used for short distance movements.

G-117 Facility.

Material is moved into and out of the boxes by the standard bagging techniques using dielectric sealing of pvc bags. Two sizes of ports are available. A standard 8-inch glove ring and a 22-1/2 in. bagout port are available on one of the end plates.

FUEL FABRICATION FACILITY (ANL)

The glove boxes, process equipment, facility floor plans, services, and auxiliary equipment are described in detail in Report ANL-5499 "The Process Equipment and Protective Enclosures Designed for the Fuel Fabrication Facility, Facility 350", by A. B. Shuck and R. M. Mayfield.

Services penetrate the glove boxes through double compression seals in aluminum service panels at the top of the boxes. Auxiliary equipment is located below the glove boxes and is enclosed and ventilated at a pressure below that of the operating zones by means of controlled flow of air.

Ventilation Systems.

The glove box atmospheres are (1) purified recirculated helium gas or (2) once through air ventilation. The helium gas ventilation is sued for the main interconnected hood system and is employed where work is done on unclad plutonium alloys. The helium atmosphere contains between 100 parts per million and 1% oxygen with normally less than 100 parts per million of H_2O. Air ventilation is used in the aqueous solution lines, and where work on clad materials only will be performed. The glove boxes are sealed to a maximum in-leakage rate of 0.02 cubic ft. per hour at -2" pressure differential. In addition, all boxes are positively pressurized with helium and the mass spectrometer helium leak detector was utilized to test for leakage.

Waste Disposal.

The facility does not include waste reclamation facilities. Fine plutonium turnings and chips will be oxidized in a special combustion furnace which is now under construction. Wastes are posted from the system by the sealed vinyl pouch technique and are transferred to reclamation or disposal facilities.

The storage of pyrophoric materials in the glove boxes does not constitute a problem as long as a dry inert atmosphere is maintained. Normally the plutonium will be stored within this atmosphere in a sealed food can or in a friction lid can.

All materials will be removed from the glove boxes and sealed in unlined tinned food cans. The sealing machines are in a hood line in a helium atmosphere. A small container of dessicant is sealed into cans containing plutonium metal. This material is posted from the hood in dielectrically sealed vinyl pouches and placed in one gallon friction lid cans for storage in vaults or in bird cage containers for shipment.

Shielding.

The need for Shielding is a recognized problem when the higher isotopes of plutonium build up. The facility will require major modification to operate with increased quantities of Pu-240 or uranium-233.

ANALYTICAL FACILITIES

The glove box now in use is small and inadequate for analytical chemistry operations. Several styles and sizes of boxes have been made of fiberglass reinforced polyester. Limited experience with these different boxes would indicate that the optimum size for the box is 3-1/2' wide x 3-1/2' high x 4' depth. A box that size would be free standing with two sides utilized as working faces with the two ends equipped with 1' x 1' doors. The same box could be split in the middle and used as a wall type box. The window frames are designed to facilitate rapid change.

The services entering the box will have valves on both sides of the glove box wall. The inside valve will be plastic whenever that is practical. The electrical lines will be brought into the box so that the cord will be locked into the wall and can only be removed by pulling it into the box.

Ventilation System.

Atmosphere control on boxes will be manual by damper and/or the sizing of the filters.

The ventilation system will be constructed of fiberglass reinforced polyester (FRP-self extinguishing resin). These will be two 8" x 8" x 4" filters with the air to be brought across each window at the top through a small duct. The air will pass through slots at a high velocity across the inside face of the window, moving to the floor and across the bottom. The air flow at the floor level is fast enough to remove fumes as heavy as those from H_2SO_4. The exhaust is centered at the top as a 6" diameter hole or as a 4" x 12" slot. This size will take enough air to allow the box to be used as a glove box or as a fume hood. The box duct system will have available a 4" to 8" water negative pressure differential.

Pyrophoric materials will be processed (storage, sampling, weighing and initial dissolving) in a nitrogen atmosphere.

Waste Disposal

The dry active waste disposal will be handled by pouching the material out through the bottom of the box via a carton inside the pouching material.

The liquid active waste will be stored in bottles stationed under the box. The liquid will be transferred into the bottles by gravity. Both disposal units will be contained in a metal housing.

Removal of materials from the glove boxes will be handled by a vinyl pouching process. The boxes can be made into trains with the available ability of transporting from box to box or from box to hood without using the pouching procedure.

ATOMICS INTERNATIONAL

Atomics International was set up to do development work and pilot plant production work involving radioactivity, toxic, and pyrophoric materials - Uranium, Beryllium, Zirconium, etc. These projects usually are limited in time covering about two or three years. Thus equipment planning is influenced by this fact since these problems are of diverse nature, and equipment should be versatile.

Glove boxes in use include those made of metal with a plastic facing for viewing operations. In some cases, where non-flammable materials are used, the entire glove box construction is of 3/8" plexiglas material and a steel or plywood encased in steel bottom. Originally all glove boxes constructed at this Facility used plexiglas for viewing windows. The departments concerned have been advised to use the newer plexiglas 5009 for future construction of glove boxes.

BATTELLE MEMORIAL INSTITUTE

The use of glove boxes and enclosures at Battelle at present is restricted to the Plutonium Facility. In this area there is a well coordinated arrangement of boxes, some of mild steel and some of stainless steel. About 12 individually designed enclosures are arranged to care for most processes involving atmosphere control and alpha containment. This includes welding in a helium atmosphere vacuum furnace operation, machining, chemistry, rolling mill, metallography, etc. These are interconnected wherever this presented an advantage in going from one step to the next. The windows are 3/8" safety plate glass in the majority of boxes, with four enclosures using plexiglas. The pressure failure of one safety glass was replaced with plexiglas.

The windows are sealed in place with extruded neoprene zipper gasket (see Illustration p.I-30, App. I). The glove ports are 8" diameter aluminum with aluminum port covers where evacuation of a box is required. The gloves are 32" length lead impregnated neoprene.

Pass-out openings are 6", 8" and 14" and, where possible, material is introduced through a 3" or 4" Sphincter valve. The 4" is preferred, but the 3" diameter is the standard can available and hence is used more often.

The rolling mill is arranged so that most of the auxiliary equipment, motor reduction gears, etc., are outside the box, and only the drive shaft goes through the box wall with a laboratory developed seal which has proven satisfactory.

BROOKHAVEN NATIONAL LABORATORY

Brookhaven National Laboratory devotes its efforts to various fields of research, many of which require enclosures for atmosphere or moisture control, or protection from radioactive or toxic material.

In an effort to take advantage of the developments in the field of plastics special enclosures have been designed and fabricated from polyester reinforced with 20 to 25% fiberglass. The walls are 3/16" thick and lucite windows are used in the enclosure bonded with polyester resin. This is shown in illustration - page I-29, App. I.

Requirements for enclosures have increased greatly, and extensive development work has been carried out, especially in the field of low moisture boxes. These now operate at 1 - 2 parts per million moisture as determined by a thermocouple calibration from known moisture content. The determination is made as a thermocouple reading when dew forms on a polished surface cooled with liquid nitrogen.

HANFORD ATOMIC PRODUCTS CO.

Hanford was established specifically as a facility to produce Plutonium. Separate divisions were created for the various portions of the production process. The difference in the processes has resulted in different requirements for enclosures and glove boxes and much attention has been given to increasing their value and efficiency.

The report, HW-64888 - April, 1960, "Human Engineering Considerations for Glove Box Design", presents some conclusions for a specific facility that may well be applied elsewhere. The studies recommend a distance of 16 inches between glove ports. This is closer than usually found in most installations. The distance varied from site to site, and for different conditions, between 16 and 19 inches with the majority between 17 and 18 inches.

The height of the center line of the glove port was selected as 56 inches for a man to stand and work. Mound Laboratory reports the height of their glove ports as 46 inches above the floor. Other sites vary the height of the ports between these values. The proper selection of the height and distance between glove ports can improve efficiency.

Another "Glove Box Design Study" - HW-68442 - February, 1961, for a specific application, recommends 48 inches as the height from the floor, and 16 and 18 inches as the spacing between glove ports for different conditions.

Auxiliary Equipment.

Services and auxiliary equipment are kept out of glove boxes proper, wherever possible. For example, with a high vacuum furnace everything would be located outside the hood except the part of the heating chamber where material is introduced or removed. The philosophy of keeping as much equipment outside of hoods as possible was developed because experience has shown that it is easier to maintain equipment when it is more accessible. The diagnosis of trouble areas is also greatly simplified.

Ventilation Media.

Several types of atmospheres are employed depending on operating conditions and type of material being handled. The three general types that are employed are ordinary room air, which is drawn into the hoods through filters, dry air and inert gas. A variety of inert gases can be and are used, and these are Helium, Argon, Nitrogen, and Carbon Dioxide. An inert atmosphere is always used when work is being conducted on plutonium metal. Nitrogen is favored where it can be used due to the lower cost. Hoods where inert atmospheres are used are outfitted with indicating and recording analyzers. Dry air is used in cases where it is desired to reduce the corrosion or deterioration of plutonium, such as in a storage hood or conveyor hood. This type of atmosphere reduces the loss of material by oxidation. Ordinary moist air or room air is employed in glove boxes where wet chemical operations are conducted. Temperature control is necessary for some applications.

Ventilation Systems.

The ventilation system for a plutonium plant is naturally quite complicated. Dust control is related closely to contamination control. Therefore, elaborate means of achieving the elimination of dust are provided and include such things as dry air filtration, wet cell washing, and temperature adjustments. Exhaust air from the glove boxes is filtered at least twice through high efficiency filters before discharging to the atmosphere. Glass mat pre-filters are used wherever possible at the entry point to the exhaust system to reduce lint from collecting in the duct work. This technique has proved to be very effective.

Waste Disposal.

The basic policy which has been adopted is that no waste will be discharged without first being properly processed through some sort of recovery step. Dry waste is currently stored waiting completion of equipment for processing this material. Regular process waste such as skulls, metal dust sweepings, slag and crucibles, is packaged and transferred to recovery where the material is dissolved and recovered in a solvent extraction process. Pickling wastes or other liquid wastes are piped directly to recovery. These techniques have resulted in the recovery of all but residual amounts of plutonium. The residual amounts are discarded to underground caverns or cribs.

Pyrophoric Materials

Gross quantities of plutonium are handled and stored as mentioned earlier in the report. Dry air atmosphere is employed for the storage hoods which are connected to the main conveyor system. Storage hoods are arranged in such a manner as to take into account the pyrophoric nature of plutonium. Whatever plutonium is stored outside of the hoods in vaults, for example, it is enclosed first in plastic and then in tin cans. Experience has shown that if the material is removed under dry conditions, that is, a dew point of less than 10^{o} F., no tendency to fire is apparent. Where extremely clean surfaces are important, such as in finished weapons, an inert gas such as Argon is used when placing the material in shipping containers. In this particular case, the container is generally of an intricate design which takes into account the physical characteristics of the weapon.

Access

The standard plastic bag technique is used for the removal of any and all material from glove boxes. The air lock technique was used several years ago and it served rather effectively. However, with the development of the new plastics which are quite easy to handle, this system has long been replaced. Air locks are used today where it is not possible to avoid them.

Shielding.

A tendency toward increasing radiation exposure to employees has been evident for several years. The increase has been due to several factors most important of which are a processing of greater quantities of material and a basic change in the material due to higher exposure in the piles. The first technique used to control exposure was concerned with the establishment of guide rules for the workers when they were informed of the radiation levels and encouraged to use proper working habits in order to minimize exposure. For a time the use of an ordinary material such as safety glass proved to be quite effective in reducing exposure. More recently X-ray glass has been used and high density lead glass is planned for newer equipment. A water wall has been set in place where it was practical to use this technique. Other material such as metallic lead and masonite have been used where visability is not a factor.

IDAHO CHEMICAL PROCESSING PLANT

The Idaho Chemical Processing Plant report covers the characteristics and work with commercial boxes made of plywood covered with a Formica overlay. These were chosen for economical reasons.

Their enclosure operation for remotely controlled processes is an outstanding example of this type of installation. A report, "Facilities and Techniques for the Analysis of Highly Radioactive Samples" by

Ralph C. Shank, James E. Rein, George A. Huff, and Fred W. Dykes, was published in June 1957, describing this installation.

Boxes are not located in a fixed position but by means of mobile under-carriages are moved from lab to lab as required.

Auxiliary Equipment

Standard, commercially available, auxiliary equipment is utilized, e.g., centrifuges, reagent racks, trays, etc.

Ventilation Systems

Intake air from lab. enters via filters. Exhaust is via two CWS packaged filters in series on each box. These are supplied with box. All boxes operate at a vacuum of 3 to 4 inches of water. All boxes exhaust through a spray type caustic scrubber to remove any acidic vapors and particulate matter. The exhaust then travels to the MTR stack where particulate and gaseous monitors are installed.

Waste Disposal

Solid wastes - usually alpha contamination only - are collected in polyethylene bags, sealed and rebagged and sent to burial. Liquid radioactive wastes are bottle and sent to ICPP for disposal.

Access

Materials are removed via interchange compartments with added covering added as materials emerge from box and then from compartment. Samples removed are usually canned or packaged and outside washed with acid,etc., before removal from box.

KNOLLS ATOMIC POWER LABORATORY

Glove boxes are designed for laboratory research currently involving powder metallurgy of zirconium and niobium alloys and fuel materials, and the fabrication processes involving these alloys. The chief purpose in utilizing glove boxes has been to control the atmosphere to prevent contamination with oxygen and nitrogen from the air which effects the corrosion resistance and mechanical properties of these alloys. The atmosphere is either helium or argon of high purity, or evacuation in welding boxes. Glove boxes also have been utilized in the past in connection with research on plutonium and the assembly of radioactive materials (for example, the encapsulation of neutron sources).

Auxiliary Equipment

Services and auxiliary equipment on powder metallurgy boxes include a circulation system, evacuation transfer ports, gas recovery and addition system, with associated pumps, thermocouple vacuum guages, temperature controllers, titanium "getter towers", surge tank, etc. Welding boxes include an evacuation system with filters, and a thymotrol motor system.

Atmosphere Control

Atmosphere control in powder boxes is maintained by evacuation and backfill with helium (used currently), or argon after passing through the recovery system. Welding boxes are evacuated.

Waste Disposal

Radioactive waste disposal is provided by one qt. ice cream cartons or one gal. paint cans. Non-radioactive pyrophoric wastes are burned immediately (same day) after removal from boxes by the Knolls Atomic Power Lab. firemen.

Pyrophoric Materials

Pyrophoric materials are generally stored under argon atmosphere in an outdoor shed in amounts up to one Kg. The amount of zirconium allowed in the lab. is not more than five lbs. in a glove box. Polystyrene bottles have been used in the past for storage; however, adapted commercial pressure cookers are currently being utilized. Consideration is also being given to the possibility of canning stored zirconium in cans.

Access

Polyethylene bags are used for the removal or transfer of material from glove boxes.

Shielding

Additional shielding is provided by lead sheets or bricks, as required. Up to 18 in. of paraffin were used during a special job of encapsulating neutron sources.

LAWRENCE RADIATION LABORATORY, (Berkeley and Livermore)

The materials handled in glove boxes and enclosures cover the entire list of isotopes, in quantities up to the kilocurie amounts. The same containment equipment has been extended to handle beryllium and other toxic materials. About 800 glove boxes and enclosures have been put into service over the past fifteen years, and included in these are many to accommodate a variety of processes and procedures, both mechanical and chemical.

With a few exceptions the boxes and enclosures have been fabricated in the laboratory shops. Plywood has been successfully employed over the years for most of the usual enclosure problems. Although several small fires have occurred within boxes, no plywood box itself ever burned. Nevertheless, the present practice is to cover the plywood with an asbestos board, and tests have shown this to be fire resistant.1/ Special enclosures have been built of stainless steel, mild steel and plastics, as required by conditions of a particular problem. Standard procedure is to line enclosures with .005 in. polyethylene and place a metal tray, coated with a baked vinyl, in the bottom.

The window material used in the Berkeley boxes is either lucite or laminated safety glass. Other plastic window materials have been tried, but tests showed that the advantage of fire resistance can be offset by softening at a lower temperature and the integrity of the box is lost sooner. Windows are sealed with a soft sponge neoprene strip.

The Glove Port has gone through many transitions over the years. Any port is necessarily a compromise since an increase in diameter cuts down the useable window area in the box. The 5-inch inside diameter has been satisfactory for many years and some operators still like it. There is being offered a modified box with an 8-inch port for those who desire it. The 5-inch ports are cast aluminum coated with baked vinyl resin, and they have proved most satisfactory as to wear, ease of decontamination, and cost.

Gloves are fastened onto the port with O-Rings and are usually 27 inches long. Longer gloves are seldom needed and they are more expensive and more troublesome to get into. Rough operations are not so prevalent at Lawrence Radiation Laboratory, so most gloves are .015 inches thick with hand thicknesses between .006" and .008", obtained either in the manufacture of the glove or by welding a thin glove at the wrist. Pairs of gloves are stocked in sizes from 7 to $9\frac{1}{2}$.

Ventilation Ducts

Ventilation ducts constitute an integral part of the box ventilation system and their size, material, design, etc., are dictated by the overall requirements and their contribution to the economy of filtering, building heating, flexibility, etc.

The ventilation ducts are based upon having preplanned enclosures or boxes employed in modules or zones. This means that no duct need be designed for a very large ventilation air volume.

1/ Fire tests are described in LRL-10180

Duct work (to which Berkeley boxes are connected) is fabricated of 4" O.D. seamless steel tubing with flanged ends for bolting. Each component is coated with a baked resin finish to provide a corrosion resistance. Forty inches is the minimum unit length to permit adequate coating, to facilitate monitoring on the inside and when the need arises permits decontamination or easy burial. Neoprene gaskets 1/8" thick are used in assembly. At intervals along the duct run within the operating room are components bearing four 2" O.D. nipples for affixing the flexible exhaust hose downstream of the box exhaust filters. Each nipple has an adjustable butterfly valve. This same size duct runs to the roof where the blowers are roof-mounted, 1 operating and 1 standby in parallel, at the end of each duct. A self-checking electrical circuit energizes the standby blower in the event of failure of the primary unit. The assembly operates within the range of 1-2½" water gauge reduced pressure. A manometer is mounted visibly in the operating room.

The usual ventilation pattern for the glove boxes is for the incoming air to pass through a filter pad of fiberglass on the back of the box. Two ducts with tapered slots located inside the box on either side bring in the dust-free air and distribute it evenly across the box floor. This incoming air sweeps through the box and is taken out through a nipple located high in the center of the back panel. The incoming air ducts are made of 1" thin wall Bakelite tubing and the outlet nipple is of 2" brass tubing coated with a baked phenolic epoxy paint. Outside of the box is a flexible length of Airtron duct leads to one or more box air filters. The same material is used on the output side of the filters to lead to the exhaust duct.

Protective Coatings

The polyethylene film on the walls of the enclosure is a satisfactory coating. Plastic equipment is used as much as possible and metal in the box is coated with a baked phenolic-epoxy. Amercoat chemical resistant paint is used under some conditions.

Shielding

Additional shielding for gammas has been achieved by substituting Heavimet or uranium for lead. Problems of handling materials undergoing spontaneous fission have now introduced the requirement of shielding against neutrons. This has been receiving much attention at LRL and merits much more investigation.

Waste Disposal

Each enclosure is provided with one of the following waste handling systems, selected to maximize economy and safety:

System 1. Where small volumes, in the order of a liter, of high levels involving curies of waste can be quickly solidified in the box;

System 2. Where volumes can be transferred to larger connected waste containers, 20 gal. capacity for solids or liquids with shielding when necessary.

System 3. Volumes of lower levels discharged to 5 gal. containers for transfer of container to waste packaging area.

LOCKLAND AIRCRAFT REACTORS, OHIO

A glove box system is designed on the basis of flow diagrams of the operations to be performed. Air locks are provided for inter-box transfers. In the past, the glove box system was arranged to cover a wide range of operations, resulting in a generalized system of relatively high cost. Currently, the immediate use of the glove box system is considered to be the predominant factor and will result in a more economical and efficient system, but may require more alteration for conversion to other operations.

Atmosphere Control

Atmosphere requirements range from negative air pressure relative to room air to vacuum boxes and inert atmosphere.

In the boxes requiring negative air pressure, a slight pressure differential is maintained via a slotted valve in the pressure manifold.

The vacuum box is an autoclave type box with the vacuum pump exhaust vented to the main filter bank.

The inert atmosphere is obtained by evacuation and gas filling with subsequent gas flow. An inert gas flush system without evacuation is in experimental use.

Waste Disposal

Waste disposal from dry boxes during operations make use of plastic film bags. The waste material is bagged in the glove box and the bag placed inside a clean bag in the air lock. The double-bagged waste is then placed in storage or the waste disposal system.

Shielding

Shielding is added by use of plastic wrapped lead brick inside the glove box. External lead sheet can be used but to date has not been necessary.

Pyrophoric Materials

Storage of pyrophoric materials in glove boxes is not prohibited but is dissuaded. If the efficiency of the operation is enhanced, such material may be stored, within limits, with adequate precautions.

LOS ALAMOS SCIENTIFIC LABORATORY

Los Alamos is a facility with assigned responsibility primarily in the area of research in every aspect of Pu, with an occasional problem that could be considered a small production job. This means that every type of chemical, mechanical, metallurgical, analytical handling of Pu must be done, and it is a rare exception when an enclosure is not required to control the Pu contamination.

There are four styles of boxes that make up numerous enclosure systems, some enclosing conveyors. There are five or six areas with somewhat different interests and they have developed boxes independently, so there is little standardization. Some areas do have a common contact through utilization of the same engineering group. About 2000 boxes, most stainless steel 12 or 16 gauge No. 316 or 347, are in use. Some boxes have been made of mild steel and coated with placite. Others are made of plexiglass.

In the Chemical Analysis area there are two box designs. These are fabricated from mild steel and coated with placite. Numerous boxes are interconnected and communication between them is through an opening fitted with guillotine doors. These operate remotely by means of a hydraulic cylinder and perform their function very well, but they are an expensive installation.

Los Alamos continued to use the old proven method of testing enclosures for leaks, - seal the box tightly, apply a positive pressure inside and test with soap solution.

Ventilation Systems

Ventilation systems on glove box trains at LASL are all of the single pass type. Filtered air is supplied to the work area and passed into the glove box through high efficiency filters. It is then exhausted through high efficiency filters to the atmosphere. Air from glove boxes is usually filtered at least twice before being discharged. Some special glove box trains are supplied with air that has been treated by drying equipment. Filter changes are carried out inside the box. Ducts then lead to a filter bank before discharge to the atmosphere.

In the system requiring dry air there are two 1500 cfm electro dryers - steam regenerated - giving 2500 cfm at -18° F. dew point. The high efficiency filters are DOP[1] tested at Hanford and shipped to Los Alamos. There is a desire to test the filters in place but a satisfactory system is not available. Los Alamos has employed the "down draft" system in their box exhausts more than any other site.

(1) DOP is an abbreviation for the dioctylphthalate test for filter efficiency utilizing a particle size of 0.3 microns.

Auxiliary Equipment

Services required for glove box operation are the usual ones found in almost any chemical or metallurgical laboratory. They are, in some cases, modified for adaptation to glove box use. For instance, where circulating water is required inside glove boxes the water is sometimes sucked through the system rather than being pushed through as in the usual manner. This eliminates the possibility of glove boxes being flooded by a broken hose connection or the like. One service that is found in some laboratories, but is prohibited in glove boxes at LASL, is open flame heating.

Waste Disposal

Disposal of radioactive trash from glove box systems at Los Alamos takes place in three ways: (1) dry land burial; (2) precipitation of contaminant, encapsulation in steel drums and dry land burial of the drums; (3) encapsulation of americium residues in concrete blocks and disposal at sea.

Pyrophoric Materials

As soon as residues that may be pyrophoric are created, it is the policy of most groups to process them to a non-pyrophoric compound. This ideal, of course, cannot always be met and where storage is necessary for a period of time, metal containers are used. It is preferable that these containers be made of aluminum. The reason for this is that the eutectic melting point for plutonium-aluminum alloys is much higher than for plutonium-iron alloys. Further, the higher conductivity of the aluminum dissipates heat more readily and helps prevent the generation of excessive temperatures if the pyrophoric material does ignite.

Access

The most generally used method of removing material from glove boxes is the plastic bag technique. This is in such common use that no description of the technique will be offered. Double lidded transfer mechanisms are also in common use. Another course that some people use for removal of material from glove boxes is the air lock. Contaminated material is carefully placed in a cold container in the air lock and the container capped. This method requires great care in its usage and routine monitoring and clean up of the air lock is a necessity.

Shielding

Present radiation exposure levels for operating personnel are not dangerously close to the maximum permissible limits. Those people who are receiving approximately 1/2 the permitted exposure are usually workers in the plutonium recovery operation. This exposure is primarily due to processing solutions high in americium. Since the main function of LASL is a research and development lab., it is not anticipated that increased radiation dosage from plutonium generated by higher reactor power exposure (in terms of MWD/Tonne) will become an important factor. It is, however, anticipated that additional shielding for glove boxes will be required for working with americium, curium and radio-isotopes of this nature. It is further anticipated that more work with irradiated plutonium will be done in the future, requiring shielding equivalent to hot cells.

MOUND LABORATORY

Mound Laboratory has been processing materials requiring enclosures largely because of high levels of Alpha. There are also problems with pyrophoric, toxic materials, along with nickel carbonyl, beryllium and dust, all of which have compelled the use of boxes.

In the early years wooden boxes were installed and have continued to give good service. About forty of these are now considered obsolete, and will be replaced with stainless steel boxes.

Some provision has been made to care for explosions within an enclosure, since some work introduces this as a hazard. Dry boxes are primarily used to contain radioactive or toxic materials. This laboratory prefers criteria providing:

(1) interchangeable boxes,
(2) spacing between glove ports 18" center to center,
(3) glove ports 46" above floor,
(4) working box floor 36" above floor, and
(5) front to back 30" maximum.

Auxiliary Equipment

Service lines include vacuum, air, hot and cold water, ventilation (including inert atmospheres), various gases, reagents, and low pressure steam. Other services are drains, 110 and variable voltage lines, thermocouple lines, lectrodryer, diffusion pumps and other remote and auxiliary service and process equipment.

Atmosphere Control

The atmosphere is controlled by the ventilation supply and exhaust systems with differential pressure control; inert gases are also used with or without lectrodryer, and further controlled by use of Foxborough D/P controllers which operate the valving of the inert gas.

Ventilation Systems

In some process lines a once-through parallel air flow is used. A pressure differential from the clean area to radioactive or contaminated area is automatically maintained. For recirculation of gases, this lab. has used commercial equipment. All exhausts are ultimately stacked.

Waste Disposal

Waste disposal is accomplished by use of plastic trash bags and a drum for solid materials. A processing system for the recovery of waste materials is usually included and designed for each specific project.

Pyrophoric Materials

Pyrophoric materials at this laboratory are usually small in quantity and are stored under inert liquids and/or gases, or sealed in appropriate containers under an inert atmosphere.

Access

Plastic bagging techniques are used to remove materials from hoods. The materials are put into proper containers prior to removal from the hoods.

Shielding

Additional shielding occasionally is required for protection from gamma radiation. This is provided or designed for each specific installation as required.

NEW BRUNSWICK LABORATORY

The number of glove boxes, the arrangement, and the utilization of the boxes were designed to provide maximum space utilization. The work involves the study of the wet chemistry of plutonium and includes the emission spectrographic analysis for impurities. Further, the preparation and the study of the behavior of plutonium compounds is necessary in the development of plutonium standards using wet chemical procedures. All work requiring glove box facilities is done in the glove boxes, whereas support activities not requiring glove boxes is done in the main laboratory.

Services

Power is supplied from the primary distribution system of the main laboratory. Hot and cold water is also supplied from the main laboratory; the hot water is softened in the main laboratory building whereas the cold water is softened by a Zeolite softener in the foyer of the plutonium facility. Distilled water is supplied to glove boxes requiring this service from individual containers through hoses. Steam for space heating is supplied from the main laboratory to steam chests in the plutonium facility air-system. Compressors are provided to supply air to the pneumatic cylinders operating doors between boxes and to the pneumatic control system of the laboratory air system. The facility also has been provided with its own vacuum system.

Waste Disposal

The waste from the laboratory is handled separately and is not mixed with the main laboratory waste until it is declared safe. A laundry has been installed in the facility so that the protective clothing used in the facility could be washed without the involvement of off-site interests.

Atmosphere Control

Control is maintained to establish differential pressures between the various area and is controlled by dampers in the air inlet and outlet systems and between the different rooms. Entry of personnel into the various area is through weatherstripped doors, so that the individual integrity of the air in each room can be maintained when the doors are closed.

Ventilation System

The system integrates the air flow on a once through basis first through the plutonium facility and then through the glove boxes. Air flow through the facility is essentially maintained by an exhaust fan. A fan is also used at the outside air inlet to help in the control of the flow of the laboratory air. The air entering into the facility is first filtered through "Aerosolve" filters, then heated to the required temperatures by passage through a steam coil whose operation is controlled by a thermostat in the plutonium laboratory, then humidified by a steam injector whose operation is also controlled by a humidistat in the plutonium laboratory and finally distributed to the different room through ducting and diffusers. The flow rates to the various rooms are adjusted by means of the diffusers. The air from the various rooms is exhausted into the plutonium laboratory, and then it is exhausted through the glove boxes. The exhausted air is filtered through fireproof absolute filters at the glove boxes and then again filtered through a pair of filters before passing through the exhaust fan. This final filter set consists of a fiber glass prefilter and a fireproof absolute filter. The air is finally ejected from the building through a 35 ft. stack. The transfer vents between the various rooms also contain metal-wool type filters.

The diffusers and the vanes in the exhaust and inlet ducts are adjusted so that the facility is under reduced pressures. The plutonium laboratory is at the lowest pressure. The air flow through the glove boxes is adjusted so that the closed port boxes are at a half inch of water pressure below the static plutonium laboratory air pressure and the air flow through the open ports into the open port boxes is at a linear rate of 150 ft. per second.

For safety the exhaust fans are provided in a duplicate set-up to provide flexibility in operation. The system is automatically controlled to permit alteration of the fans on a weekly basis and to permit a switch to the stand-by fan in case of malfunction of the on-stream fan. A selector is provided for selection of either automatic or manual fan operation.

During periods of high humidity in the summer, some difficulty has been experienced with sweating in the facility. The laboratory has a tendency to cool off during the cool nights and then to sweat due to the condensation of the moisture of very humid air. Provisions are currently being made to incorporate an air conditioner in the laboratory air system to eliminate this difficulty.

Waste Disposal

Laboratory wastes from the glove box sinks, laundry, shower in the change room and the lavatory and change room sinks is accumulated in one of two 500 gal. stainless steel underground tanks. The accumulated waste is periodically monitored for contamination and if found safe it is dumped into the main laboratory waste system. During the operations of the past year it has been possible to dispose this waste without any further treatment. In case it becomes necessary to treat this waste to reduce contamination to permit disposal to the main laboratory waste system, one of two methods will be used. A choice will be made of either decontamination by a carrier precipitation or by an ion exchange treatment. The organic wastes from the water closet in the lavatory are dumped directly into the main laboratory waste stream. The main laboratory wastes are dumped directly into the municipal sewage lines.

OAK RIDGE NATIONAL LABORATORY

Many glove boxes are in use at the Oak Ridge National Laboratory for a wide range of research and production purposes. Glove boxes are used in welding and brazing laboratories to provide a controlled atmosphere. They are used in the Metallurgy laboratories for the preparation of reactor fuels and for many other metallurgical operations requiring high purity atmospheres. They are used by the Analytical Chemistry Division, the Chemical Technology Division and the Chemistry Division to perform chemical operations on the transuranic elements and other radioactive materials which require either containment of the material and/or a controlled atmosphere. The Special Separations Department of the Isotopes Division uses glove boxes for equipment servicing and washing and chemistry processing. Other groups use one or more glove boxes whenever it is necessary to work in a controlled atmosphere or confine the material.

The design, construction and arrangement of the glove boxes at Oak Ridge National Laboratory differ widely; there are all kinds, shapes and sizes. Some of the glove boxes were made for temporary use, from sketches. Some have been well engineered for specific purposes with complete drawings. In other cases, the glove boxes have been obtained from commercial manufacturers. Some are constructed of wood, finished with a protective coating and are fitted with plastic windows. Some are ordinary carbon steel, suitably painted and may have either glass or plastic windows. Some are fiberglas with plastic windows; some are all plastic; and some are stainless steel, polished to facilitate cleaning and decontamination, with rounded corners, and have safety glass windows.

Ventilation Systems

The off-gas system for the glove boxes in the High Level Alpha Analytical Laboratory and the Chemical Development Isolation Laboratory is connected to the plant off-gas system by means of an 8-inch stainless steel header. Near the junction of the 8-inch header and the main header a pressure regulating valve reduces the 20-inch water negative pressure of the main plant system to .35-inch water negative pressure in the 8-inch manifold. Two filters are used in the exhaust from the box -- a Fiberglas roughing filter followed by a 12-inch by 12-inch by 6-inch high efficiency filter. The glove box is connected to the 8-inch header with a 3-inch flexible neoprene duct. Another high efficiency filter is provided in the main header at a point before it leaves the building enroute to the plant off-gas stack. In some cases there are two magnahelic gauges used -- one from box to room to read .35 inch water and the other across the roughing filter to indicate any plugging.

ROCKY FLATS PLANT

Rocky Flats is primarily a production plant confronted with radioactive problems involving high levels of Alpha and some relatively low but troublesome levels of Gamma which can usually be adequately shielded by 1/4" Pb. or equivalent. Operability is of prime importance and ease of equipment maintenance is a close second. All operations in a box must be planned and the actual movements of the operator taken into account before designing the box. The gloves and windows must be carefully located and the angle of the window considered, to reduce glare from reflected light. Cleaning activities, services required, maintenance of equipment, and waste removal must be taken into account as well as the material handled.

To date the majority of work has been carried out with adequate safety, employing glove operation (in some case Pb impregnated) but consideration is being given to designs for remote operating techniques because circumstances are quite likely to compel the use of these in the not too distant future.

Most of the enclosure installations are of long runs housing conveyors. These are made by welding together in place 10 ft. sections. At right angles to these, connected by flanges, are special process boxes varying from 5 ft. to 12 ft.

The functional design for the production units has proved quite satisfactory, as faults have been largely eliminated over the years, and the component materials are being constantly replaced as characteristically better ones become available. The present arrangement would largely be repeated should a new installation be made. The value of extensive preplanning when undertaking the design of an enclosure facility cannot be over-emphasized.

As the result of an unfortunate fire at the Rocky Flats Plant (reported in CD-57-1485), great stress is placed on fire prevention. Since operations are involved with highly pyrophoric materials, problems in this area are greater and justify more extreme measures than with normal fire hazards.

The choice of the more important materials of construction for enclosures adopted at Rocky Flats is noted in the tabulations. For the frames and floors of constructed boxes type 304 stainless steel of 11 gauge thickness is used because of its ease of decontamination and resistance to corrosion. Where compelled by visibility requirements, Plexiglas 5009-B is used as the box material, but this is done reluctantly and only where fire hazard and heat are non-existent. Where sparking is to be avoided, aluminum is used for construction material.

In testing the boxes for tightness the glove ports of the box are sealed and under 4" negative pressure the box leak rate should be less than 1 cfm per 1000 cubic feet of volume.

Ventilation Systems

All dryboxes are ventilated and kept at about .7" negative water pressure. Where a controlled atmosphere is not necessary, the room air is taken in through absolute filters to each box and exhausted through another absolute filter. These streams are collected and put through a two to four stage common filter plenum before being exhausted through a blower to the main building exhaust plenum. In each of these booster systems a standby blower is installed to automatically take over in case of failure of the first blower. The blowers also are served by an automatic emergency electrical system powered by a standby diesel operated generator.

The controlled atmosphere system at Rocky Flats is a recirculating dry air system. This system controls the pressure to .7" negative water pressure, dries the air to -15^{o}F dew point or lower, removes the contamination, removes the gases organics, and controls the temperature. All drybox ventilation systems have a dumping feature that will automatically maintain negative pressures in case of a broken window or glove.

Waste Disposal

Solid wastes are generally disposed of in plastic waste bags through suitable waste ports. The material is placed in a cardboard container inside the bag through a port, the bag between the waste and the box is twisted into a tight restriction and taped, this restriction is cut in the middle and the two raw ends taped. Liquid wastes are generally drained through appropriate piping.

Pyrophoric Materials

Storage of pyrophoric material depends on the classification of material stored and the length of time in residence. In general, the table below may serve as a guide.

(a)	OXIDE	Store in sealed tin can about 40-50°F. Maintain a surveillance by temperature rise and continual personal observance.
(b)	TURNING IN PROCESS IN LATHES: AND OTHER CUTTING MACHINES	Store as generated in eleven gage stainless steel cans withheavy stainless steel counterbalanced lid. Place in location where no combustible materials are present.
(c)	TURNINGS TO BE REMELTED	Degrease, but not completely. Brickette to 70% theoretical density, seal in No. 3 tin can, store at 40-50°F until use. Surveillance is as indicated above.
(d)	FINISHED SHAPES	Store in reduced temperature area at about 30-40° dew point air.
(e)	ORDINARY COMBUSTIBLE MATERIALS	Rigid controls to eliminate usage. That material which must be used in limited amounts store in stainless steel cans with lids when not in use. When combustible materials are spent remove from line immediately by plastic bag technique.

Access

Removal of material other than waste (this is usually obsolete equipment) ordinarily done through air locks attached to the line or by removing a vision window.

Shielding

Radiation shielding is an ever-present problem. Thirty and fifty mil lead impregnated neoprene gloves are extensively used. These are purchased from a commercial source. Lead glass is often used over the vision window. This is generally 1/4" thick with a lead equivalency of .075". Additional shielding of lead over the stainless steel drybox or lead enclosures of the vessel or equipment inside the box are used when necessary.

SAVANNAH RIVER PLANT

The Savannah River Project is a production plant concerned primarily with Plutonium, but supporting laboratory work has introduced many diverse problems requiring enclosure techniques. Much development work has been carried out and numerous unique features have been applied to boxes.

Currently in use is a commercially supplied box, a polyester fiberglass panel unit with 3/16" plexiglas windows. It is contemplated that 1/2" plexiglas would soon become available and then the thicker material will be used. Under these circumstances the windows and glove ports will be "glued" on with cyclohexanone.

For the exhaust system, a Brecco quick disconnect is installed in a 3/4" line leading from the box to the header operating at 35" to 45" water negative pressure. The Brecco unit offers such resistance that a maximum of 17 cfm could be drawn from the box.

Glove boxes are fabricated in three styles:

(1) Marine plywood with 5 to 7 coats of Amercoat #33 and plexiglas front.

(2) Aluminum boxes for special heavy duty or high temperature.

(3) Micarta covered plywood with Melamine coating. Cracks sealed with plastic tape. These have given good service for five years and appear to be usable for many more years.

Ventilation Systems

The integrity of containment is maintained by use of special ventilation or Off-Gas Exhaust Systems and by the use of check valves to prevent radioactive materials from escaping through service connections. Dry or inert atmospheres are used wherever process conditions or material properties indicate the need. Boxes are maintained at negative pressure with respect to the surroundings. Except where a dry or an inert atmosphere is required, all gloved boxes are swept with air filtered at the intake as well as the exhaust.

The ventilation and Off-Gas Exhaust System of the Savannah River Laboratory are included in a paper "Laboratory Ventilation" by R. J Hale, published in the proceedings of the Sixth Hot Laboratories and Equipment Conference of March 19-21, 1958. Boxes for production work are maintained at a negative pressure of 0.75" of water. For experimental work, a normal air flow of 5-10 cu. ft. per min. is maintained with a negative pressure of approximately 0.5" in the box. Frequently, a gauge is installed on the boxes to indicate changes in differential pressure, and particularly ventilation failure.

Waste Disposal

Once radioactivity is introduced into a gloved box, all items and surfaces within the containment are considered to be contaminated. When dry waste or any item is removed from the containment it is packaged and transferred from the box into an air lock. In the air lock, it is carefully placed into a second container and surveyed prior to removal from the air lock into the general work area. Water which is not contaminated, such as condenser cooling water, is piped into and out of the boxes through valved service lines. Small quantities of active aqueous waste and all contaminated solvents are retained in bottles of glass or polyethylene. These bottles are packaged in a plastic bag or a small ice cream-type carton containing enough inert absorbent for all of the liquid in the bottles. The bag or carton is then moved into the air lock where it is handled in the same manner as dry waste. Boxes in which relatively large volumes of aqueous waste are generated are provided with direct lines from the equipment to permanent high level drain systems. In some cases the drain line in the box may terminate in a small funnel used as a waste sink.

Pyrophoric Materials

In work with some pyrophoric materials, the use of dried air rather than an inert atmosphere has been proposed since the air permits a slight oxide coating to form on the metal, partially desensitizing it.

Normally, pyrophoric materials are not stored in laboratory gloved boxes. Pyrophoric material in production boxes is isolated from all other flammable material and is not left unattended.

Shielding

Constant attention to the quantity and specific radioactivity of the materials processed is necessary because of the close proximity of the worker, particularly his hands, to the activity. Advance planning includes provision of adequate shielding for the proposed work. If the scope of the work changes so that the shielding is not adequate, operator technique as well as physical shielding are considered in corrective measures. Localized shielding, shielded tongs, forceps and other devices are used but there are practical limits to such use because of the confines of a gloved box. Overcrowding with bulky shields may increase the potential for an incident thus creating a greater hazard than that for which the shielding is required.

APPENDIX VI

BIBLIOGRAPHY

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BIBLIOGRAPHY

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