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CMB-5 Health and Safety Manual

los alamos
scientific laboratory
of the University of California
LOS ALAMOS, NEW MEXICO 87544

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CMB-5 Health and Safety Manual

by

W. N. Miner
R. O. Elliott
D. L. Douglass
F. W. Schonfeld

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CMB-5 HEALTH AND SAFETY MANUAL

INTRODUCTION

Much of the work in Los Alamos Scientific Laboratory Group CMB-5 relates to studies of the physical metallurgy of plutonium and its alloys and compounds, and the Group's facilities and equipment in the Chemistry and Metallurgy Building (SM-29, TA-3) and at the Ten-Site Laboratory (TA-35) have been designed to provide a practicable amount of personnel protection against the hazards associated with that element. These hazards, which arise from plutonium's fissioning, toxic, and pyrophoric characteristics, are well described in the literature; they are merely mentioned here. First, lethal quantities of neutrons and gamma rays are emitted from the critical mass formed when enough plutonium, usually a few kilograms, is assembled in one place. Second, plutonium is highly toxic, mainly because of its alpha radioactivity, and the maximum permissible concentration of plutonium in air is only 2×10^{-12} $\mu\text{Ci}/\text{cm}^3$. Third, plutonium and many of its alloys and compounds are pyrophoric; fine particles and turnings ignite readily when exposed to air, and, depending on the quantity of material involved, can be difficult to extinguish.

The equipment and procedures used in studying plutonium are similar to those employed in investigating nonradioactive materials. However, because of the unusual health hazard and the strict accountability that accompany work with plutonium, the equipment is enclosed in glove boxes or other protective enclosures and the procedures are closely controlled.

The total plutonium inventory in CMB-5 is normally between 9 and 15 kg, but the large number of alloy specimens individually weighing less than 10 g, and the necessity for storing the specimens and plutonium stocks in separate containers to preserve their identity and to prevent cross-contamination preclude a criticality hazard, at least in the practical sense. Any significant increase above the normal level of the plutonium inventory would require a review of the criticality hazard.

Other radioactive materials, such as americium and neptunium, are also studied in CMB-5. Work with these materials involves hazards similar to those associated with plutonium, and the precautionary statements concerning plutonium that follow in this manual should be interpreted broadly as being applicable to other radioactive material as well.

Before being put into operation, all new equipment and procedures are reviewed cooperatively by CMB-5 and Health Division representatives. It is standard practice to

test such equipment and procedures with nonradioactive materials before using them with plutonium.

New employees are informed of the health hazards associated with plutonium through lectures given by Health Division personnel, and are introduced to safe operating procedures through the information contained in this manual, in the *Chemistry and Metallurgy Safety Manual*, and in the *LASL Health and Safety Manual*, and through close supervision by their supervisors or other experienced employees.

Consideration of safety is of day-to-day concern to all CMB-5 employees. Each person in the group is encouraged to show his personal interest in safe operating procedures by following the established rules and by bringing to the attention of his supervisor or the group leader any practices or equipment that he thinks may constitute a hazard.

SAFETY REGULATIONS AND PROCEDURES

A set of safety rules and related information concerning nonradioactive materials is included in the second edition of the *Chemistry and Metallurgy Safety Manual*. Information from that manual and also from the *CMF-5 Health and Safety Booklet* (1959), the *CMF-5 Safety Regulations and Operating Procedures* (1961, revised through 1969), and the *LASL Health and Safety Manual*, was used in compiling this *CMB-5 Health and Safety Manual*.

Radioactive Contamination and Control

The Chemistry and Metallurgy (CMR) Building, with its high-capacity ventilation system, removable and replaceable sheet-metal walls, and asphalt-tile flooring which is relatively easy to decontaminate or replace, was designed specifically for work with plutonium.

Wing 2, in which CMB-5 conducts most of its activities, extends eastward from the north end of the spinal corridor of the CMR Building. The wing measures approximately 100 by 200 ft. A central corridor extends nearly the length of the wing and is flanked by two rows of laboratory modules. Two personnel corridors, one north and one south of the laboratory modules, parallel the central corridor, and beyond them, extending the length of the wing, lie office modules. At the west end of the wing, entry and exit is provided through the men's and women's change rooms. Air-filtering equipment and

ventilation blowers are located at the east end of the wing.

On the main floor are 28 laboratory modules, each measuring approximately 12 by 24 ft. Most of the modules are individual laboratories, but a few have been combined, by removal of inner walls, to form larger rooms that can accommodate large items of equipment. Compartmentation is important in controlling the spread of plutonium contamination, in that a spill in one laboratory can usually be confined and cleaned up without affecting adjacent modules. In the basement, are several laboratories and offices on the north side, one laboratory on the south side, a heat-treating facility at the east end, and a staff shop at the west end of the wing. A small amount of space in Wing 4 of the CMR Building is also being used by CMB-5 personnel.

Work with plutonium is confined to the laboratory modules. The only plutonium specimens allowed in the office areas are those that have been packaged for shipment outside the wing.

In the laboratories, plutonium is handled in glove boxes, furnace housings, open-front hoods with vertically sliding doors, and in other specialized types of enclosures. In general, the enclosures are made of stainless steel and have smooth interiors to facilitate cleaning. The enclosures are small enough to allow access to all parts of their interiors through a reasonable number of glove ports. For easy maintenance, motor drives, pumps, valves, and associated equipment are located outside the enclosures insofar as is feasible.

Ventilation is of primary importance in a plutonium laboratory. Air enters the CMR Building through large intake ducts where it is washed to remove dust and is then conducted to the various wings where it is admitted to the laboratory rooms through ceiling inlets. Exhaust ducts in the floor carry the air to a filtering system where it is cleaned before being released to the outside atmosphere.

The air flow in Wing 2 is equivalent to about 40 complete air changes per hour in each laboratory module, and the velocity of air flow across the front of open-front hoods is greater than 125 ft/min. Periodically, Group H-5 personnel measure the air flow into each hood and label the hood "satisfactory" or "unsatisfactory." Any "unsatisfactory" hood must not be used until the air flow has been corrected and the label changed. Pressure differences in the wing cause some flow of air from the offices and corridors into the laboratories and thence to the exhaust system. The pressure within the enclosures in the laboratories is slightly lower than that in the open laboratories. Thus, the pressure gradient ensures that any leaks in the enclosures will cause air to be drawn into the enclosures and retard the escape of contamination into the open laboratory. When the ventilation system is being restarted after a shutdown, the sequence of operations automatically ensures that the contaminated areas in the wing will be the first to have air drawn through them.

On occasion, maintenance requirements make it necessary to reduce the rate at which exhaust air is removed from the laboratory areas. Usually the group

office receives advance notice of any plans to reduce exhaust velocity, and the information is then passed on to all personnel in the wing. More rarely, a mechanical breakdown or power outage may cause an unscheduled interruption. If the ventilation drops to half speed or lower (as you can tell by the unusual limpness of the glove-box gloves and the relative quietness of the exhaust fans), stop whatever work you may be doing in the laboratory and check with your supervisor. Offices and corridors are regarded as being safe from contamination during a slowdown of the exhaust air system, but if the exhaust system should fail completely the wing would be evacuated (see "Emergency Procedures" below).

Material being transferred into or out of glove-box trains is passed through air locks or through open-front enclosures serving the same purpose. Doors isolate each glove-box section in a train, and a contamination gradient is maintained within the train so that operations that produce the largest amount of small particles or dust are performed in the box farthest from the air lock or hood. The glove boxes are frequently cleaned as a matter of normal routine, not only to reduce the amount of contamination within the enclosure but also to keep different types of alloy scrap segregated and to minimize the fire hazard.

Protective Clothing.

Protective clothing, which is available in the change rooms at the entrance to the wing, consists of canvas shoe covers, smocks, coveralls, socks, underwear, caps, and surgeon's rubber gloves. Full-face mask respirators are provided to all personnel who work with plutonium. You must wear shoe covers in all parts of the wing, except in the uncontaminated area in the attic. For normal work in the laboratory modules, you should also wear a smock, and you must wear a respirator whenever you are engaged in an operation that may expose you to airborne plutonium contamination. The full-face mask respirator offers protection to about 100 times tolerance (tolerance is 4 dis/min/m³). You should also wear coveralls when the surface contamination level exceeds 2000 counts/min. A complete change of clothing (socks, underwear, cap, coveralls) is required when the contamination level exceeds 20,000 counts/min. Wear surgeon's rubber gloves or plastic gloves whenever you work with plutonium or plutonium-contaminated equipment, including glove boxes. The surgeon's gloves provide a secondary contamination barrier if the gloves attached to the glove boxes should be punctured. When leaving the wing, place your protective clothing in the laundry chutes near the wing exit. Do not wear your protective clothing back into the change room. Always check your hands for contamination when leaving the wing.

Protective Equipment

Portable alpha counters are conveniently available in all areas of the wing, and some counters have been

permanently installed in those modules where many specimens are normally handled. Each counter has an attached alpha source. Before using a counter to check for contamination, make sure it is working properly by exposing the probe to the alpha source. After each transfer of plutonium or contaminated material, check your hands and protective clothing for contamination. Remove any contaminated clothing. Place rubber gloves in a waste can used only for contaminated material, and place smocks, carefully folded with the contamination inside, in the laundry chute in the change room, if the contamination level is less than 20,000 counts/min. If the contamination exceeds that level, seal the clothing in a plastic bag, place it in a contaminated-waste can, and notify the Health Physics Surveyor. If you have the slightest reason to suspect that there is any loose contamination in a laboratory module, use an alpha counter to check your protective clothing, including both smock and shoe covers, before you leave the module.

Contaminated-waste cans have been placed in each laboratory module where plutonium is handled. These yellow-painted cans are to be used only for solid contaminated material. The janitor assigned to the wing periodically removes the contaminated trash. While wearing a smock or coveralls, rubber gloves, and a respirator, he seals the plastic bag in the can by taping it closed, removes the bag for transfer to the contaminated dump, and places a clean plastic bag in the waste can.

Film badges are issued to each person in the group who works with radioactive material. Wear your film badge whenever you are working with or near penetrating radiation. When you are not wearing your badge, keep it in the rack provided at the front (west end) of the wing. These film badges are periodically collected, processed, and interpreted. A record of each person's exposure to radiation is maintained in the Health Division files. The badges of people who work regularly with x-ray equipment are also processed to reveal any unusual exposure due to a high level of x radiation. Do not use your regularly issued film badge for experimental purposes. The radiation level to which your badge has been exposed is taken as an accurate measure of your personal exposure to radiation and is entered in your record. Using your film badge for anything other than its intended purpose might make your record inaccurate. If you require a film badge for some special purpose, contact the Health Physics Surveyor assigned to the wing. He will obtain a "planted" badge for you which will not affect your record.

Signs posted at the entrances to the laboratory modules containing x-ray equipment call attention to the radiation hazard and restrict entry to authorized personnel only.

Air samplers have been placed in each laboratory module in which plutonium work is performed. These samplers routinely and continuously draw laboratory air through filter papers. At the end of each day, the filter papers are changed and the used papers are examined for evidence of plutonium contamination. If a higher than allowable level of contamination is found, an investigation

is made to determine the cause. At the discretion of Health and Safety personnel, the offending module may be closed and operations suspended until the situation has been corrected.

Whenever an operation that might cause a high level of contamination in the laboratory atmosphere is to be performed, a "special air test" must be requested from the Health Physics Surveyor. People working in the module under these conditions must wear respirators in addition to their canvas shoe covers and smocks or coveralls. Warning signs stating that a special air test is in progress are placed at the module entrances to restrict access to only those people actually performing the work. When the job is completed, the module is carefully monitored for stray contamination, which must be cleaned up before the module can be reopened for routine work.

Two emergency carts containing items that would be useful in controlling plutonium spills, and in decontamination operations, are kept in the wing. One cart is located in the central corridor on the main floor, the other is in the north corridor of the basement. Items on the carts include extra smocks, canvas shoe covers, rubber gloves, respirators, cheesecloth, masking tape, wax paper, and cleansing tissue.

Alpha detectors have been installed in the plutonium storage vaults to warn of any above-tolerance level of loose plutonium contamination within the vaults. The procedure to be followed in entering the vaults is described below under "GENERAL OPERATING PROCEDURES."

Wear appropriate safety glasses or face shields whenever there is a possibility of flying particles, chemicals, or harmful rays damaging your eyes. Nonprescription devices may be obtained from Safety Stock, General Warehouse, SM-30. Prescription safety glasses may be provided for those employees who ordinarily wear corrective lenses and whose work requires that they wear safety glasses at least once a week. If you need prescription safety glasses, take an up-to-date prescription to one of the following:

Los Alamos Optical (1907 Central),

Schaumburg Optical Service (1733 1/2 Central, Room 1), or

W. K. Batson (optometrist, Los Alamos Credit Union Building),

where the prescription will be transferred to an industrial order form. Then give the completed form to the CMB-5 Group Secretary. When the order form has been approved by the CMB-5 Group Leader, it will be sent to H-3, where the purchase order for the glasses will be written. If you are required to wear a full-face mask, you may obtain a set of lenses to be installed in your mask. When you receive your glasses or lenses, you should take them to the optician or optometrist who made out the initial order form and have them fitted.

Contact lenses are not protective devices and shall not be worn in the laboratory unless they are needed to supplement normal prescription glasses. In fact, contact lenses may increase the hazard associated with chemicals and dust. Liquids splashed into the eye will seep under a contact lens and may do irreparable harm before the lens can be removed and the eye flushed with water. The same is true of abrasive particles. If you wear contact lenses, have that information entered in your medical record in Group H-2. It may assist the doctor in prescribing appropriate treatment for you in an emergency.

Protective Procedures.

A Health Physics Surveyor, employed by Group H-1, is on duty in the wing at all times during normal working hours. One of his duties is to provide assistance to CMB-5 personnel in controlling radiation hazards. As part of his normal routine, he checks the laboratory modules and equipment, the offices, and the corridors for plutonium contamination; attends to the air-sampling devices; performs special air counts; monitors all material leaving the wing; and inspects the plutonium storage areas for alpha contamination and for excessive beta, gamma, and neutron radiation. All material leaving a contaminated area must be monitored and tagged by the Health Physics Surveyor.

Other routine protective procedures include the scheduling of plutonium urinalyses for all CMB-5 employees and the processing of "nose swipes" which are required of everyone who has been exposed to above-normal levels of contamination or who has worked in an area in which a special air test was being conducted. Before leaving the contaminated area of the wing, you must check your hands at one of the alpha counters that have been placed near the exits from the laboratory area to the change room. If any count above background is observed, wash your hands with a decontamination solution and cold water. Scrub your hands two or three times, but not so vigorously as to break the skin. If the count still remains high (more than 500 counts/min), report to the Health Physics Surveyor for further treatment. (Note: Your hands must be dry before being checked with an alpha counter, because even a thin film of water will absorb the alpha particles and cause the counter to give a low or zero reading.)

If a person is seriously injured, the Medical Center (9-662-4201) and the Industrial Medicine Group, H-2 (4336) must be notified. Phone 9-911 for emergency ambulance service. A person who has received a minor injury should report promptly to the First Aid room (A-124) in the Administration Wing of the CMR Building, where a registered nurse is usually on duty from 8 to 10 a.m. and 1 to 5 p.m. First aid assistance may also be obtained at the Group H-2 offices on the main floor in the south end of the west wing of the Administration Building. Report all injuries, including minor cuts, bruises, and burns, to your supervisor and to the nurse in the First

Aid room or to other H-2 personnel. Don't work with plutonium if you have any open cuts or abrasions.

Any hazardous work performed outside normal working hours requires group leader approval and the presence of at least two persons. In CMB-5, work in any of the laboratory areas, the vaults, or the shop is considered hazardous whether or not plutonium-bearing materials are actually being handled.

Drinking (except from the drinking fountains in the personnel corridors) and eating are prohibited in the restricted area of the wing. The restricted area includes the basement and the main floor beyond the change rooms. Smoking is allowed in the offices and corridors but not in the laboratory modules.

Plutonium Spills

In general, most plutonium spills, if detected promptly and handled correctly, can be confined to small areas and cleaned up without serious problems. The first step, and perhaps the most important one, is to think before you act. What you do and how you do it could result in a relatively easy clean-up job, or in a mess that might make it necessary to evacuate the wing. Remember that plutonium is not easily absorbed through the skin, and contaminated clothing may be cleanable. The greatest danger lies in inhaling plutonium dust, but if you are wearing a respirator—as you should be whenever you are doing any sort of work that could result in a spill—you can well afford to take time to consider the situation and decide how best to handle it. If you are not wearing a respirator, don one of the emergency ones available in most of the laboratory modules and in the storage vaults.

Once a spill has occurred, the problem becomes one of confining the contamination to as small an area as possible to facilitate cleanup. Ask someone from outside the immediate contaminated area to call the Health Physics Surveyor and to be available to provide assistance and communication between the contaminated and uncontaminated parts of the module or wing. Be careful not to spread contamination by walking with contaminated shoe covers through the laboratory modules or corridors. Remove contaminated clothing, roll it up with the contamination inside, and hand it to someone outside the contaminated area for processing or disposal. Don clean coveralls or a clean smock, and block off the contaminated area by marking it with chalk or by placing masking tape at eye level across the doors or corridors leading to it. Before leaving the contaminated area, monitor your canvas shoe covers and, if they are contaminated, replace them with clean covers so you won't track contamination into clean areas.

Consider how the clean-up operation can be accomplished most efficiently. If necessary, call the CMR Building H-1 Monitoring Section (4482 or 4093) for additional help, but remember that usually the fewer people there are in the contaminated area, the less chance there is of spreading the contamination.

Decontamination can often be accomplished by using water-moistened cheesecloth pads and a detergent or scouring powder. Masking tape or other sticky tape can be used to pick up (or cover up) particles of plutonium that are too small to be seen with the naked eye. Cleaning is best accomplished by starting at the periphery of the contaminated area and cleaning toward its center; if a vertical surface is contaminated, start cleaning at the top and progress downward. LAMS-2319, "Procedures for Plutonium Decontamination of Various Surfaces," lists cleaning agents and their uses for decontaminating a variety of materials. A copy of this report is available in room 2149.

Initial clean-up operations are performed by CMB-5 personnel or by personnel of the decontamination section of H-1. The janitor assigned to the wing should not be allowed to scrub the area until after the loose contamination has been removed.

Save any residues or cleanup materials for later shipment to the Recovery Section if any appreciable amount (1 mg or more) of plutonium is involved. If contaminated with less than 1 mg of plutonium, solid materials may be discarded in the contaminated trash and liquids may be given to H-1 for disposal. If you have any doubt as to the amount of plutonium in the cleanup materials, send them (solid or liquid) to the Recovery Section.

After decontamination has been accomplished, but while the details of the incident are still fresh in mind, you should write a detailed description of the incident and the steps taken for decontamination. (Report forms are available in room 2149 to help you describe the incident.) Your report may help someone else to avoid a similar spill in the future or to perform a more efficient cleanup.

Emergency Procedures

The procedure to be followed if there is a massive spread of plutonium contamination may include evacuation of the wing, or even of the building. The decision to evacuate an area will be made by the senior group representative present. If evacuation is necessary, call the building control-room operator (4161 or, if no answer, 5036). Tell the control-room operator what kind of an announcement to make and whether it should be broadcast throughout the building or only in the affected wing. For example, if evacuation of Wing 2 is desired, the control-room operator will announce the fact over the Wing 2 public address system. Each person in Wing 2 should then leave the wing by the nearest exit. If you leave through a security door, deposit your protective clothing at the exit, and remain outside the building near the exit until you have been checked by H-1 personnel. If you leave through a change room, follow the normal procedure for disposing of your protective clothing, but wait near the main entrance to the building for clearance by H-1 before leaving the vicinity.

Nuclear Safety

As explained above, a criticality hazard is not thought to exist in CMB-5 under current operating conditions. The total plutonium inventory is normally between 9 and 15 kg and includes several hundred individual specimens. The necessity for packaging these specimens separately to preserve their identity and to prevent cross-contamination, and the fact that, typically, 97% of them have individual weights of less than 100 g (60% weigh less than 10 g) make it practically impossible to juxtapose them into a critical mass.

Plutonium solutions do not appear to be a criticality hazard in CMB-5. The only solutions normally produced in the group are the electropolishing solutions used in metallography and the thinning solutions used in electron microscopy. Such solutions may contain from 5 to 10 g of plutonium/liter (7.8 g/liter requires an infinitely large volume for critical configuration) and are collected in 1-liter bottles. No more than 12 of these bottles of solutions may be stored or sent to the Recovery Section at one time. The mechanical fabrication facility in CMB-5 can handle several kilograms of plutonium at one time, but has never been used to process specimens containing more than about 500 g of plutonium as metal, alloy, or compound.

Although both the type of specimens used and the kind of work done seem to preclude a criticality hazard in CMB-5, representatives of both CMB-5 and the Nuclear Safety Committee have provided the following rules for administrative control and to form the basis for procedures to be developed if future work might involve such a hazard.*

1. No more than a total of 1 kg of plutonium (as metal, alloy, or compound) shall be stored on each shelf section in the storage vault or safe.

2. No more than 2.5 kg of plutonium shall be present at one time in any single glove box or other type of laboratory enclosure.

The Nuclear Criticality Safety Committee has recommended not installing monitoring devices that would actuate alarms in the event of accidental criticality. Such alarms are considered not only to be unnecessary in CMB-5 but to be possible hazards in themselves because false alarms could cause serious confusion. Emergency procedures specifically related to accidental criticality have not been provided, but procedures for use in the event of extensive fires or contamination are given in this manual and would be adapted to take account of a criticality hazard if one should arise.

The following information on criticality is included as a matter of general interest: Up to 200 kg of plutonium

*These rules and the criticality information given here pertain to ²³⁹Pu. Plutonium-238 does not present a criticality hazard.

metal can be stored at a density of 1 kg/ft³ in thin metal cans, provided no unit exceeds 4.5 kg. Up to 200 liters of an aqueous solution of plutonium can be stored at a density of 0.8 liter/ft³ in nominal containers, provided no single unit exceeds 4 liters. These limits include safety factors of more than 2. The critical mass of plutonium salt is intermediate between those of the metal and aqueous solution. A sphere of delta-phase plutonium metal weighing only 8 kg is critical with full water reflection, but it must weigh 16 kg to be critical in air. Five hundred grams of plutonium in aqueous solution can be made critical with full water reflection, but 900 g in aqueous solution are required to achieve criticality without a reflector.

Fire Prevention and Control

An American District Telegraph Co. ADT Therm system has been installed in Wing 2 of the CMR Building to detect fires in the open laboratories. In each laboratory module, temperature-sensing devices in the ceiling detect any abnormal increase in temperature. A sudden temperature rise actuates the system and relays an alarm to fire alarm headquarters. The firemen who respond to the alarm go first to the building control room near the main entrance where they should be met by someone who can direct them to the exact location of the fire. There are also 13 manually operated fire alarm boxes within Wing 2, three in the attic and five each on the main floor and in the basement.

In the central and personnel corridors of the main floor are 10 fire extinguisher cabinets, each containing two 15-lb extinguishers. At eight of these cabinets there are hoses with fine-spray nozzle attachments. When the water is turned on in any of these hoses, an alarm is relayed to fire alarm headquarters. In the basement, CO₂ fire extinguishers are located in room 2000 (shop), in the corridor near room 2058, outside the entrance to room 2074, at the east end of the north corridor, in the center of the south corridor (room 2061), in the center of room 2034, and at the north and south sides of room 2034A. Pressurized water extinguishers are located at the east end of the south corridor (room 2061) and at the east and west ends of room 2023. In the change rooms and in the cold areas of the wing, there are pressurized water and CO₂ extinguishers. Both the attic and the basement are protected by fire-detection systems and sprinkler systems.

For all metals, dry graphite powder is an effective fire controlling agent. However, the method of using the graphite powder is important. The graphite should be copiously sprinkled on, or loosely applied to, the burning metal. If the density of the metal is lower than that of graphite, graphite applied by the shovelful may sink below the surface of molten metal and cause the metal to splash and spread the fire rather than extinguish it. If possible, the burning metal should be scooped onto a thick layer of graphite before being covered with more graphite, in order to protect the surface on which the metal is burning.

Do not use water or any of the chlorinated hydrocarbons on metal fires. Use of these agents may cause a violent explosion, and the decomposition of the chlorinated hydrocarbons may release toxic quantities of phosgene.

In some operations, filings and dust from plutonium alloys may accumulate. These small particles are pyrophoric and thus constitute a serious fire hazard. It is often desirable to convert them to the oxide by deliberately burning them in small amounts (less than 1 g) in place in the glove boxes to avoid a more serious fire hazard later. Small amounts of filings may be safely burned in crucibles or on a 1/4-in.-thick copper or aluminum alloy plate on the floor of a glove box. However, certain precautions should be taken. Remove any other combustible material from the glove box; have graphite powder at hand to control the fire; and handle any burning material with tongs. Avoid contact between the burning material and the rubber gloves. Burning plutonium in contact with stainless steel (a glove-box floor) forms a eutectic whose melting point is well below that of steel or plutonium.

Glove boxes in which plutonium is cut, filed, or ground are equipped with helium inlets to inert the atmosphere for fire control. A concentration of at least 30% of helium in the atmosphere will prevent plutonium chips and turnings from burning.

One of the essentials in minimizing the fire hazard is good housekeeping, which applies with equal emphasis to the open laboratory, glove boxes, and all other enclosures. Do not allow flammable materials to accumulate.

The procedure to be followed in case of fire depends on the type of fire, its size, and its location.

Plutonium or Metal Fire Within a Glove Box

1. Don a full-face mask, or Scott Air-Pak, depending on the severity of the fire.
2. Evaluate the fire. Have another person call the Fire Department by means of an alarm box if there is any possibility that the fire cannot be easily controlled. Do not leave the fire unattended. This statement (and similar ones below) does not mean that anyone should expose himself to serious danger by remaining close to a fire. The intent is to provide assistance to the firemen by having someone in the area who can accurately report on such things as the extent of the fire and the type of burning material.
3. Send someone to the building control room to direct the fireman.
4. To control the fire, flood the box with helium and/or smother the burning material with graphite powder.
5. A CO₂ fire extinguisher may be used to cool the exterior of the glove box, but do not use CO₂ directly on the burning metal.

6. Keep a fire watch until it is certain that no further danger exists.

Plutonium Fire in the Open Laboratory

1. Don a full-face mask, or Scott Air-Pak, depending on the severity of the fire.

2. Evaluate the fire. Have another person call the Fire Department by means of an alarm box. Do not leave the fire unattended.

3. Send someone to the building control room to direct the firemen.

4. Remove flammable material from the vicinity of the fire.

5. Try to smother the burning plutonium by scooping it up, placing it on a layer of graphite powder in a metal bucket, and covering it.

6. Assist the firemen as requested.

7. Keep a fire watch until it is certain that no further danger exists.

Nonradioactive Material Fire in the Open Laboratory

1. Evaluate the fire. Don suitable protective breathing apparatus if toxic material is burning. Have another person call the Fire Department by means of an alarm box. Do not leave the fire unattended.

2. Send someone to the building control room to direct the firemen.

3. Remove flammable material from the vicinity of the fire.

4. Try to extinguish the fire by using the recommended procedure for the specific type of burning material: (a) graphite powder for burning metal; (b) CO₂ fire extinguisher for electrical fires, burning solvents, oil, etc.; (c) water for burning wood, paper, etc.

5. Assist the firemen as requested.

6. Keep a fire watch until it is certain that no further danger exists.

Call the Fire Department (9-911) whenever you have the slightest doubt of your ability to control and extinguish a fire, or whenever it appears that property damage may result. Even if you are sure you have extinguished a fire, call the firemen so they can inspect the general area and satisfy themselves that the fire is completely out. Report all fires to the H-3 Safety Group

(4644) and the CMB Safety Office (4893). Notify the Fire Department (9-662-4325) whenever fire extinguishers have been used, so that they may be refilled or replaced.

Under extreme conditions, it may be advisable to evacuate the wing or the building. The senior group representative present is responsible for making this decision, and the procedure to be followed is described above in the section entitled "Emergency Procedures."

Nonradioactive Material Safety

Detailed safety rules for handling toxic and otherwise dangerous nonradioactive materials are given in the second edition of the *Chemistry and Metallurgy Safety Manual* and in various newsletters distributed by the Safety Office. Because this subject is well covered in those sources, and because such hazards, in themselves, are not radiation hazards, nonradioactive material safety is not discussed at length in this manual. It is appropriate, however, to restate briefly some rules that are especially pertinent to work performed in CMB-5.

Solvents

1. Do not use combustible solvents in the glove boxes unless you have obtained specific, written approval from the H-3 Safety Office. The use of acetone or ether in glove boxes is absolutely forbidden.

2. Do not use highly volatile or toxic solvents in the open laboratory. For example, carbon tetrachloride, which is used in preparation of metallographic specimens, may be used only in the glove boxes or chemical fume hoods.

3. Store flammable solvents in metal safety cans. If storage in glass bottles is necessary for cleanliness, use only 1-liter, or quart-size, or smaller, bottles.

4. Store no more than a total of 2 gal of flammable solvents in pints, quarts, or liters per module outside of an approved flammable liquid storage cabinet.

You may store quantities between 2 and 5 gal in safety cans or in 1-liter glass bottles in a cabinet under a fume hood. However, the cabinet must be vented, and its door must have a coat of flame-retardant paint and be marked "Flammable Liquid Storage." Quantities greater than 5 gal shall be stored only in an approved flammable liquid storage cabinet vented directly to the exhaust system.

Perchloric Acid

Perchloric acid solutions are not commonly used in CMB-5, but may be used occasionally to electropolish metals, subject to the following precautions.

1. No more than 500 ml of solution containing 1 part HClO_4 and 4 parts ethyl alcohol (20% perchloric-80% alcohol) shall be used at one time.

2. Keep the temperature of the solution below ambient. An ice and water cooling bath is satisfactory. If the solution is stored, it must be refrigerated.

3. Use the solution only in a chemical fume hood or other type of ventilated enclosure; it must not be used on a bench top or in other unguarded areas. Perchloric acid must be evaporated only in a hood having wash-down capability or a water wash manifold setup.

4. Wear safety glasses or a face shield.

5. Shielding, equivalent to a 3/4-in.-thick sheet of Lucite, must be provided for operator protection.

6. Before solutions are discarded to the acid drain, they must be diluted to about a 10:1 ratio and then neutralized. (A 5% perchloric-95% alcohol solution may be diluted 3:1 instead of 10:1). NaOH may be used for neutralization, but it is important that dilution be accomplished before neutralization in order to avoid a dangerous temperature rise in the solution.

7. Do not expose organic materials to perchlorate solutions. Use of rubber tubing is particularly hazardous because it may detonate when saturated with perchloric acid. Teflon has been found satisfactory.

8. Clean up any spills promptly, and leach the cleaning rags in water and neutralize them before discarding them.

9. Disposal of solutions contaminated with plutonium constitutes a special problem. Such solutions shall be diluted and neutralized before being sent to the Recovery Section. Therefore, their volumes must be kept as small as practicable. Polyethylene 1-liter bottles, no more than three-fourths full and vented, may be used to collect solutions for recovery. The amount of plutonium in the solutions must not exceed 10 g per liter, and no more than 12 bottles shall be stored or sent to the Recovery Section at one time.

Picric Acid

Picric acid (2, 4, 6-trinitrophenol) in dilute solutions as picral (usually about 5 g of picric acid crystals dissolved in 100 ml of ethanol) is used infrequently in CMB-5 as an etchant for steel. Because this acid is explosive when dry (when it has lost its water of crystallization), and is also highly toxic when ingested or inhaled, its storage and handling require special precautions. Do not use picral if another etchant, such as nitral (nitric acid and ethanol) can provide satisfactory results.

1. Keep picric acid crystals and picral solutions in glass, and do not allow solutions to evaporate to dryness. At moisture contents of less than 10%, picric acid becomes shock-sensitive. Some picrates, notably those with the heavy metals and ammonia, are more sensitive to heat and shock than is the pure acid. Keep the crystals and solutions away from heat and open flames.

2. Keep no more than the minimal amount of picric acid crystals on hand. If the acid begins to lose its crystalline appearance and become powdery, call Group H-3 (4893) to arrange for disposal. Do not attempt to open the bottle; the friction of unscrewing the cap may cause an explosion.

3. When handling picric acid or preparing picral solutions, wear rubber gloves and work in a chemical fume hood or other well-ventilated area of the laboratory. (The maximum allowable concentration of picric acid in air is 0.1 mg/m^3 .) Prepare only the minimal quantity of fresh picral as needed. Do not store solutions merely for possible future use.

4. Dilute spent picral solutions with water to prevent them from evaporating to dryness. Arrange disposal with H-3 (4893). Do not pour picric acid solutions into the acid drain system unless, in each instance, you have obtained permission to do so from H-3.

5. If possible, avoid contaminating picral solutions with plutonium or other radioactive material, because such contamination compounds the hazards and complicates disposal of the solutions.

Compressed Gases

1. Do not allow empty compressed-gas cylinders to accumulate in the laboratory. They must be monitored for contamination and, if clean, turned in to the Supply and Property Department as soon as they are emptied. Retain at least 25-psi residual pressure in an "empty" cylinder to prevent contamination from the atmosphere or other gases. If an empty cylinder is found to be contaminated with plutonium, arrange with the Health Physics Surveyor to send it to the decontamination section of H-1.

2. Gas cylinders must be placed in racks or otherwise tied down to keep them from being knocked over.

3. Use gas cylinder trucks in moving gas cylinders from one location to another.

4. When a torch or blowpipe is not in use, make sure that its gas supplies are shut off at the wall petcocks or at the gas cylinder regulating valves. Turn off the petcocks, then open the valves on the torch to relieve the pressure in the tubing. Never leave the rubber or plastic tubing under pressure.

Cryogenics

Liquid nitrogen and liquid helium are used routinely in CMB-5, and liquid hydrogen has been used occasionally in certain experiments in which less dangerous cryogenics could not be substituted. All proposed uses of liquid hydrogen at LASL must be reviewed and approved by the LASL Liquid Hydrogen Safety Committee before the work may be undertaken. Contact Group P-8 (4163) for information about the functioning of that committee. Some precautions to be taken in handling cryogenics are as follows:

1. Tape the exterior glass surfaces of dewars to minimize the hazard of flying glass if the dewars should break or implode.

2. Wear eye protection and loose-fitting gloves when transferring cryogenics. Do not touch frosted equipment with your bare hands. If hands or fingers become frosted, immerse the affected part in warm water for several minutes (do not rub) and report to a doctor.

3. Always transfer liquid helium (and hydrogen) by means of a slight overpressure of helium gas, never with compressed air or nitrogen gas. (Liquid nitrogen is transferred preferably by pressure of nitrogen or helium.) Helium and nitrogen may be vented directly into the laboratory module, because they are not flammable and the normal ventilation is sufficient to carry them off before they can significantly impair the quality of the air in the module. Hydrogen, because of its flammability, should be vented directly into the exhaust system, not into the open laboratory.

4. Be aware that liquified inert gases such as nitrogen or helium are capable, under certain conditions, of condensing oxygen from the atmosphere and causing unsuspected oxygen enrichment or entrapment in localized areas as well as oxygen deficiency in confined spaces. Also, be aware of the high-pressure gas hazard that is always present where cryogenics are being used or stored.

Machine Shop

A staff machine shop is maintained in room 2000 in the basement of Wing 2 for the use of CMB-5 employees. The safety rules listed in the *Chemistry and Metallurgy Safety Manual* apply in this shop as well as in any other shop at LASL. If you are not familiar with a piece of equipment, ask for assistance before you attempt to operate it.

Wear safety glasses at all times in the shop. Face shields are available at various locations in the shop and should be used whenever the safety glasses would not provide adequate protection. Silver soldering or brazing must be done in the hood provided for that work. Rules covering the uses of various items of power machinery in the shop are posted near the machines.

A purchase request approved by the group leader is necessary to obtain safety shoes from Safety Stock General Warehouse, SM-30.

Housekeeping

An important way to guard against personnel injury, fire, spread of contamination, and property damage is to practice good housekeeping, which is mainly a matter of cleanliness and orderliness. In connection with good housekeeping, it is important to label all bottles or containers holding liquids or solid chemicals to identify their contents.

Watch out for and correct such hazards as:

1. Excessive amounts of combustibles stored in glove boxes, laboratory modules, corridors, and offices.

2. Gallon-size bottles of flammable liquids used when small bottles or safety cans could be substituted.

3. Tools and materials underfoot or strewn around on bench tops.

4. Equipment and materials stored in corridors and pipe chases.

5. Blocked fire extinguisher cabinets.

Disposal of Hazardous and Other Waste Material

The rules given in this section apply to the disposal of both contaminated and uncontaminated waste material, as opposed to the packaging and shipment of plutonium-contaminated materials to the Recovery Section, which is described in the next section. In general, if the contaminated material contains any visible amount of plutonium (a slight film of dust on a specimen vial or discoloration on a cardboard container) or has been exposed to a very high level of plutonium contamination (e.g., glove-box gloves), it should be sent to the Recovery Section rather than discarded in the contaminated trash. Uncontaminated material and material contaminated to a lesser degree than indicated above may be handled as trash, subject to the following rules.

1. Don't place any chemicals or liquids in the waste-baskets or contaminated-waste cans. Do call Group H-3 (4644) to arrange for disposal of uncontaminated solid chemicals and any uncontaminated liquids such as volatile solvents or oil, which must not be flushed down the drain. Call H-1 (4093) to arrange for disposal of contaminated chemicals or liquids that are not to be sent to the Recovery Section. For example, used vacuum-pump oil that has been drained from a pump attached to a "hot" system should be collected in 1- or 5-gal cans and given to H-1 for disposal.

2. Contaminated items to be discarded should first be wrapped in clean paper and taped securely or placed within "cold" containers to eliminate the possibility of releasing contamination when the lid of the waste can is raised. Turn contaminated rubber gloves inside out to confine the contamination before discarding them.

3. Don't place loose glass in wastebaskets or contaminated-waste cans. Capillary tubing is especially dangerous because its small diameter enhances its sharpness. Protect yourself and others against injury by always placing your waste glass inside a cardboard or metal container, or by wrapping and tying it securely, before you discard it. Items too bulky to fit inside the contaminated-waste cans should be packaged and placed in the yellow 35-gal G. I. can in the central corridor.

4. Radioactive solutions containing less than 5 μ Ci of beta-gamma emitters may be flushed down sinks that are connected to the industrial (acid) waste sewer. When discarding solutions approaching these amounts, flush water down the sink drain for a reasonable length of time. Do not discard any solutions containing greater amounts of radioactive materials than those listed above before notifying H-7 (4301). Do not discard any liquids containing radioactive materials to sanitary sewers, stream beds, or the ground.

5. To arrange disposal of the following materials, call the groups indicated.

(a) Nonradioactive pyrophoric metals and alloys, water-active alkaline metals, and metal hydrides--call H-3 (4644).

(b) Radioactively contaminated mercury--call H-1 (5420).

(c) Nonradioactively contaminated mercury--call SP-3 (4331). (Chemical Warehouse.)

(d) Toxic or flammable gasses--call H-3 (4644).

(e) Beryllium metal and compounds--call H-5 (6140).

(f) Chemicals and solvents--call H-3 (4644).

(g) Wrap uncontaminated mercury batteries individually in paper or other nonconducting material and send them to LASL Salvage, SM-142. If batteries are contaminated, call H-1 (4093).

(h) Cyanide residues and containers--call H-7 (4301).

(i) For disposal of any materials not covered above, call H-3 (4644) if they are uncontaminated, or H-1 (4093) if they are contaminated.

6. In general, acidic chemical wastes can be handled in the acid sewer system without harmful effects. Concentrated acids, however, should be flushed down the drain with at least 15 to 25 times their volume of tap water. Arrange with H-7 (4301) for disposal of gallon quantities of concentrated acids.

7. Clear disposal of any normal equipment item (any item having a property number) through both CMB-AP (4541) and H-1 (4093) before sending the item to salvage or to the contaminated dump.

TRANSFER AND STORAGE OF PLUTONIUM

All plutonium transfers into or out of CMB-5 are accomplished by means of Special Source (SS) Material Transfer Receipts. These receipts are used even if the amount of material being transferred is technically unaccountable (< 0.5 g of ^{239}Pu or < 0.05 g of ^{238}Pu). This is to ensure that the complete history of each CMB-5 plutonium specimen is recorded in the group files.

Within the group, various individuals have personal plutonium inventories. Transfers from one of these personal accounts to another are made by means of "in-Group" transfer receipts. Each individual receiving a plutonium specimen signs the receipt and thereby accepts responsibility for the safe handling of that specimen. No transfers should be made unless accompanied by a receipt.

Each specimen fabricated in CMB-5, or received from an outside source, is given a CMB-5 identification number and is recorded in the specimen log book (room 2171). Near the end of each month (as of the 25th of the month) an inventory summary, based on the transfer receipts and log book entries, is prepared. The total amount of plutonium in the group is reported to Group A-3, and individual inventory summaries are given to each person having a separate account. Each of these persons is required to verify the summary sheet against the actual specimens in his possession and to sign it if he is satisfied that it is accurate. Any discrepancies thus disclosed by the physical inventory can then be resolved while the details of the month's transactions are still in mind.

Transfers of specimens out of the group for chemical analysis require an analysis request form in addition to the transfer receipt. Each analysis request form receives a CMB-5 reference number from the group secretary, who retains a copy of the request in the group files.

Normally, all transfers of > 1 g of ^{239}Pu (or > 0.1 g of ^{238}Pu) between limited LASL areas outside the CMR Building are handled by A-3 personnel. Any departure from this policy requires the approval of the A-3 group leader for each such transfer.

Plutonium-239

Specimen Handling and Storage

Plutonium specimens are transferred into and out of the group only in radioactively "cold" containers. In

general, the minimum requirement is that double containers be used. That is, the contaminated specimen is placed in a vial or jar whose outer surface is "cold," and which is placed within another container that is "cold" both inside and out for additional protection during shipment. Outer containers must be of metal. Within the group, specimens should also be transferred in double containers to prevent release of contamination if the container is accidentally dropped.

Several hundred individual plutonium or plutonium alloy specimens are normally stored in the group vaults or storage safe. These are all specimens that are not actually being processed in the glove boxes or other enclosures. The problem of storing the specimens safely, in view of the fire and contamination hazards, is one that has received much consideration in the group, and the following rules have been evolved in an attempt to minimize the hazards.

1. All specimens that are subject to deterioration through exposure to air and are to be kept in storage for more than 30 days must be sealed within evacuated glass or silica capsules, if the size of the specimen makes it practicable to do so. The capsules holding the specimens must be protected against breakage and packed in outer containers of metal.

2. Plutonium stocks may be stored in their original metal tube containers until used. Specimens and stocks that are frequently removed from storage and processed may be stored in plastic jars or vials within "cold" metal containers.

3. The use of cardboard containers as outer containers for storage is prohibited.

4. The identification number and composition of each specimen must be legibly indicated on the outside of its container.

Plutonium Scrap Handling and Shipment

Plutonium for the CMB-5 working inventory is normally received from CMB-11 in the form of 1/4- or 3/8-in.-diam cast rods. These rods are used as stock materials for fabricating alloy specimens. When a specimen is no longer needed, it is scrapped and sent to the Recovery Section in CMB-11 for reprocessing. Frequent collection and disposal of the scrap is desirable because:

1. It keeps the amount of plutonium in the CMB-5 inventory minimal and prevents specimen storage areas from becoming overcrowded.

2. It provides specimens less opportunity to deteriorate in storage and thereby add to the fire and contamination hazards.

3. It makes taking the monthly physical inventory quicker and easier.

The emphasis on turning in scrap frequently does not mean that usable specimens must be discarded. Any properly packaged specimen having legitimate and continuing research value may be kept in the group indefinitely.

CMB-11 and CMB-5 representatives have cooperatively devised the following scrap-packaging rules and procedures to simplify the recovery problem and allow safe storage of scrap until the plutonium can be recovered. These rules pertain to ^{239}Pu scrap or residues and to ^{239}Pu -contaminated materials that are to be sent to the Recovery Section. (The disposal of contaminated trash is discussed above in the section entitled "Disposal of Hazardous and Other Waste Material.")

1. Plutonium scrap must be segregated as to alloy composition and type of material according to the following categories:

- (a) The plutonium in alloys containing uranium, thorium, hafnium, zirconium, rubidium, molybdenum, niobium, beryllium, boron, cerium, and other rare-earth metals is difficult to recover. Package such alloys individually according to the alloying element and also according to their plutonium content, i.e., 0 to 25, 25 to 75, and 75 to 100 wt % plutonium. However, a number of such individual packages may be placed in a single container for shipment to the Recovery Section if the total plutonium weight in the container does not exceed 450 g.

- (b) Package alloys containing more than 1 g of sodium, potassium, lithium, cesium, or rubidium (or other highly reactive elements) separately.

- (c) Package alloys containing 20 wt % or more of aluminum separately.

- (d) Pure plutonium, Pu-Al alloys containing less than 20 wt % aluminum, and alloys containing elements not mentioned above shall be packaged individually but may be shipped to the Recovery Section in a single container if the total plutonium weight in the container does not exceed 450 g.

2. Segregate glove-box sweepings containing high plutonium values according to the instructions in item 1, above.

3. Miscellaneous "low-plutonium" waste.

In the following categories the plutonium content should be held to the practical minimum. If there is no visible plutonium contamination, mark the packages "Pu Nil." Package items listed below separately, so that the combined weight of the smallest "cold" container and its contents does not exceed 20 lb.

(a) Combustibles ONLY (paper, cardboard, abrasive paper, metallographic polishing cloths, cleansing tissue, cheesecloth, masking tape, etc.). See also item 5 below.

(b) Broken glass ONLY (do not include combustibles or other noncombustibles).

(c) Unbroken, empty glass bottles; jars; lids; and empty plastic containers.

(d) Broken, plastic metallographic specimen mounts from which the specimens have been removed.

(e) Filings containing a large proportion of plastic, such as those collected during the preparation of mounted metallographic specimens.

(f) Steel tools (files, saw blades, vises, wrenches, etc.).

(g) Rubber and plastic gloves, bags, and tubing.

(h) Aluminum foil.

(i) Ceramics (furnace parts, implements, and used crucibles). Segregate each item as to composition, e.g., MgO , Al_2O_3 , ThO_2 , ZrO_2 , CeS , and Lavite.

(j) Miscellaneous material such as furnace radiation shields, heating elements, crucible supports, thermocouple wires, and silica thermocouple insulation.

Use metal cans as the outer containers for scrap types 1 through 3.

4. Solutions

(a) Segregate solutions that contain elements listed in item 1(a) from solutions containing other elements.

(b) Do not add miscellaneous material, such as paper, wood, and rags, to solutions.

(c) Use polyethylene or glass 1-liter bottles to contain compatible solutions, and do not fill the bottles to more than three-fourths of their capacity. Puncture the bottle caps to prevent a dangerous pressure increase in the containers during storage. Seal the bottles in double plastic bags, and store and transfer them in stainless steel buckets or boxes.

(d) Attach a detailed list of the solution components to the container.

5. Special instructions concerning rags.

(a) Rags exposed to nitric acid solutions must be leached in water as soon as possible. The rags may then be allowed to dry in an open stainless steel container in a glove box or fume hood. They may then be sent to the Recovery Section according to the instructions in 3(a) above.

(b) Segregate and dry rags exposed to solvents, TBP, oil, or other organics as indicated in 5(a).

(c) Rags exposed to aqueous solutions that did not contain nitric acid may be allowed to dry without leaching.

(d) Label containers of rags being sent to the Recovery Section with as much of the following information as is applicable:

(1) Type of solution to which the rags were exposed.

(2) Type of acid present in aqueous solutions.

(3) Number of water leaches.

(4) Physical condition of the rags. (Are they badly decomposed, powdery, or practically unchanged from their original form?)

(5) Date of packaging, estimated plutonium content, and name of person who did the packaging.

Plutonium-238

The ^{238}Pu used in CMB-5 is mainly in the form of oxide pellets or pellet fragments whose individual weights range from a few milligrams to about 10 g, although a few fuel disks weighing as much as about 90 g each and fuel spheres weighing about 400 g each may be used occasionally.

Because the alpha activity of plutonium containing 80% of the isotope ^{238}Pu is roughly 200 times greater than that of ^{239}Pu , the contamination hazard accompanying work with ^{238}Pu is correspondingly greater. A body burden of ^{239}Pu is equivalent to about 0.6×10^{-6} g, but a body burden of ^{238}Pu is equivalent to only about 3×10^{-9} g. The intense alpha activity also enhances the production of neutrons. The neutron flux 10 cm from a 1-g sample of $^{238}\text{PuO}_2$ is about 11 n/sec-cm². (For neutrons having the energy of those produced by ^{238}Pu , 11 n/sec-cm² is equivalent to a dose rate of 1.5 mrem/h.) Furthermore, the heat generated in ^{238}Pu is about 0.4 watt/g, and, in a 10-g sample, that is enough to raise the sample temperature to nearly 100°C, because of the small surface area available for heat dissipation.

Because of these exceptional hazards,* use extreme care in working with samples containing ^{238}Pu . Monitor your working area frequently. Be sure that your glove-box gloves have no cracks or punctures. A tiny pinhole that might not release enough ^{239}Pu to be noticeable can cause a serious spread of ^{238}Pu contamination. When you remove anything from a glove box in which ^{238}Pu work has been done, remember that the item removed is probably 200 times more highly contaminated than it would have been if it had been exposed only to ^{239}Pu .

Be aware of the neutron hazard. Ask the Health Physics Surveyor to measure the neutron flux if you are working with more than milligram amounts of ^{238}Pu , and limit the duration of your exposure as he may request.

In packaging samples consisting largely of ^{238}Pu , use glass or metal vials (not plastic). Do not use any flammable packing material where it will be exposed to heat from the sample. Crumpled aluminum foil is a good packing material. If practicable, divide the sample among several vials to reduce the quantity of material per vial. Of course, you must protect the glass vials against breakage.

Packaging of ^{238}Pu Residues

Plutonium-238 residues must be packaged in standardized containers (see below) for shipment to the Recovery Section. Containers holding organics, such as rags, paper, or plastic, in intimate contact with PuO_2 must be vented. All containers must be labeled as to type of residue, amount of ^{238}Pu , and which layer of the internal packaging is contaminated. Each external container being sent to the Recovery Section must be uncontaminated inside and out and must contain no more than 20 g of ^{238}Pu .

Approved Containers for ^{238}Pu Residues.

The following containers available in LASL stock have been approved for use in packaging ^{238}Pu residues:

1. Can, tinned-steel, slip-fit lid, 4-1/8-in.-diam by 11-3/8-in.-high (GS-2583/2Z-8). If this can is contaminated externally, it may be sealed within a 12-mil plastic bag that is "cold" outside and placed in a 3-gal can (GS-2546/3HH-7). Two smaller sizes of slip-cover cans, 3-3/4-in.-diam by 4-in.-high (GS-2582/2Z-1) and 3-3/4-in.-diam by 11-in.-high (GS-2560/2Z-46) will fit inside a type-1 container.

2. Can, 3-gal, friction-lid, 8-1/4-in.-diam by 14-in.-high (GS-2546/3HH-7). This can may be used to hold bagged type-1 cans or other bagged items, such as glove-box gloves, that may not fit in smaller metal cans.

3. Drum, steel, 30-gal, with bolt-locking lid (LG-1102/W-DOCK). This drum may be used to hold

several smaller cans or single large items that will not fit inside a smaller can. Place large contaminated items in a cardboard leverpack drum (LG-1109/7A-TOP), which, in turn, is sealed within a 12-mil plastic bag and then placed in a 30-gal steel drum. If the drum is not vented (i.e., does not have a hole drilled in it), attach a label saying, "This drum should be vented."

Packaging of Liquids Contaminated with ^{238}Pu

Because the containers described above may leak, do not use them to hold wholly or partially liquid residues. Instead, package liquids in compatible glass or plastic 1-liter bottles with vented caps. Enclose the bottles in double plastic bags, and place the bagged bottles in stainless steel buckets (GS-2496/3AA-23). Enclose cans containing any liquid-soaked material in double plastic bags, to retain the liquid if the cans should leak, and enclose the bagged cans in vented metal containers.

GENERAL OPERATING PROCEDURES

General operating procedures that pertain to the radioactive hazards in routine operations in CMB-5 are described below. In addition to these procedures, others covering the detailed operation of particularly hazardous operations being carried on in the group have been written and approved and are kept on file in the CMB-5 and H-1 group offices. Whenever a new operation is initiated, and is not covered by an existing general or specific procedure, a detailed procedure describing the new work will be written and approved by the appropriate groups of H Division before the work may be performed.

For convenience and emphasis, a few of the safety rules that were discussed in preceding sections are summarized and repeated here.

1. Wear your film badge and any other appropriate, prescribed personnel-monitoring devices in radiation areas.

2. Wear appropriate protective clothing including a full-face mask in all areas where radioactive contamination is possible, but do not wear your protective clothing outside those areas.

3. Survey your hands and clothing, including shoe covers, for contamination before leaving a contaminated area, and remove or contain any loose contamination by approved decontamination techniques. Before you move any equipment or material from a contaminated to a clean area, have the Health Physics Surveyor monitor it to make sure it is free of contamination.

4. Post signs or erect barricades to warn of special hazards, and remove the signs and barricades when the hazards no longer exist.

*However, ^{238}Pu does not present a criticality hazard.

5. Report as soon as possible to your supervisor and to Group H-2 any injury that occurs in a radiation area, and any suspected cases of ingestion or inhalation of radioactive material.

6. Use approved packaging and labeling procedures for all radioactive materials.

7. Be familiar with the approved operating procedures for any work that you are to perform. Be sure to ask your supervisor or an experienced coworker for any assistance you may need in order to understand and do your job properly and safely.

Radiation Monitoring

Monitoring of work areas to find plutonium contamination before it can spread further is an important step in personnel protection, and each person in CMB-5 should be familiar with the instruments used to detect alpha radiation. Two general types of alpha counters are in use in CMB-5. One is a portable unit that operates on battery power, and the other is a permanently installed unit that operates on 115-V ac power. Both counters employ probes that have an active area of about 9 in².

To operate the portable units, turn on the power switch (HV) and also turn the selector switch from "OFF" to the most sensitive position (X100). Then check the instrument with a known alpha source (attached to the instrument) to make sure that it is working properly.

To check a surface for contamination, move the probe slowly across the surface, close to, but not touching it. Readings taken 1/4 in. from a contaminated surface are only 70 to 80% of those taken in contact with the surface, and readings taken 1/2 in. away are only 50 to 60% of the contact reading. However, if the probe touches any loose contamination it may become contaminated itself and give false readings, so avoid physical contact between the probe and the surface being checked. Only dry objects can be checked reliably with an alpha counter. Even a thin film of water or oil can absorb alpha particles and cause a low or zero reading.

Smear or swipe tests are often used to locate and identify loose contamination. Rub a piece of filter paper, cheesecloth, or cleansing tissue on a contaminated surface, and then check the paper or cloth to see whether any of the contamination was removed from the surface.

When you are through using the portable alpha counter, turn off both switches to conserve the batteries. Worn-out or weak batteries can cause the instrument to give false readings. The ac instruments operate continuously but otherwise are used in much the same manner as the portable instruments. Notify the Health Physics Surveyor if your alpha counter does not seem to be working properly.

In addition to the alpha counters, which are available in all areas where plutonium work is being done, the Health Physics Surveyor has on hand a variety of other

types of survey instruments to use in checking for beta-gamma and neutron radiation.

Opening Internally Contaminated Packages

Whenever you open a package containing radioactive or radioactively contaminated material (or any other material that you do not know is uncontaminated), do so in a glove box or hood, and wear your respirator and other appropriate protective clothing so you will be protected if the material has not been packaged or labeled properly, or if the inner packaging has been breached. In the absence of personal knowledge to the contrary, always assume that a package is "hot inside."

Glove Boxes

Transferring Material into and out of a Glove Box

In transferring material into or out of a glove box, you must remember that every item that has been inside a contaminated glove box is contaminated and must not be brought into the open laboratory unless it is enclosed in an externally clean container.

To transfer material into a glove box:

1. Don a respirator and rubber gloves.
2. Open the outer air-lock door slowly. (The air lock should be clean, but, if it isn't, opening the door slowly will prevent stirring up the contamination.)
3. Place a clean piece of paper on the air-lock floor.
4. Place the clean object to be transferred into the glove box on the clean paper, and close the air-lock door slowly. If a contaminated object is to be brought into the glove box, it will be inside an externally "cold" container. The container lid may be removed and placed on the paper in the air lock so that the contaminated object can be easily removed from the container in the next step, or the container with its contents may be taken into the glove box.
5. Check your gloves with an alpha counter; discard and replace them if they are contaminated.
6. Insert your gloved hands into the glove-box gloves, and slowly open the inner door to the air lock. This operation is done slowly to avoid stirring up contamination that might then be carried from the interior of the glove box into the air lock.
7. Use forceps to pick up the object in the air lock and carry it into the glove box. Be careful to touch only the object that is being brought into the glove box.
8. Slowly close the inner door of the air lock.

To transfer material out of a glove box:

1. Don a respirator and rubber gloves.
2. Open the outer air-lock door slowly, and place a clean, open container on clean paper on the floor of the air lock.
3. Slowly close the outer air-lock door.
4. Check your gloves for contamination, as above.
5. Open the inner door to the air lock and, with forceps, place the contaminated object in the open container. Be careful to touch nothing but the contaminated object with the forceps or gloves.
6. Slowly close the inner door to the air lock.
7. After waiting a few moments to let any contamination settle, slowly open the outer door to the air lock, place a lid on the container, and bring it near the air-lock entrance. Before bringing the closed container into the open laboratory, however, check its surface with an alpha counter. If the outer surface of the container is uncontaminated, it may be brought into the open laboratory where the lid can be taped closed. If the container is contaminated, it should be transferred back into the glove box and the whole procedure should be repeated.
8. When the container is found to be uncontaminated externally, and is removed from the air lock, the paper may be removed from the floor of the air lock. To keep any contamination on the paper, wash it in your gloved hand, pull that rubber glove off, inside out, over the paper and then pull your other glove off over the first. Then place the gloves in the contaminated-waste can, and close the outer door of the air lock.

Inspect the air locks periodically and clean them to keep them free of loose contamination. Use scouring powder or detergent and a moistened cheesecloth pad to remove loose contamination. Use a second moistened pad to rinse the surface, and a third pad, unmoistened, to dry the surface before you check it with an alpha counter.

Using Glove Boxes

In using glove boxes, you should keep a few precautions in mind.

1. Be aware that the gloves are flammable and relatively easily punctured and torn. Avoid any contact between the gloves and thermally hot objects or objects with sharp points or edges.

2. In attempting to reach into the corners of a glove box, don't stretch the gloves too tightly. Use tweezers or some other instrument to extend your reach sufficiently without stretching the gloves.

3. Inspect the gloves frequently for evidence of cracking or wear, particularly in creases and at the juncture where the gloves are attached to the glove box.

4. Always don a pair of surgeon's rubber gloves before inserting your hands into the glove-box gloves. Although the Health Physics Surveyor routinely checks glove-box gloves for external contamination, a leak may have developed since the gloves were checked.

Evacuatable, Inert-Atmosphere Glove Boxes

Some evacuatable, inert-atmosphere glove boxes are used in CMB-5. A typical evacuation and inert gas backfill procedure for one of these boxes includes the following steps.

1. Fasten the external metal covers in place over the glove ports, and evacuate the space between the covers and the gloves. If this space is not evacuated first, the gloves will be sucked into the box and ruptured during later evacuation of the box.

2. Open the main valve of the mechanical vacuum pump and evacuate the interior of the box.

3. After the box has been thoroughly evacuated, backfill it with commercial-grade argon from a cylinder equipped with a reducing valve. The argon is passed over $MgClO_4$ to remove water before being admitted to the box.

4. When the pressure in the box equals the ambient pressure in the room, stop the flow of argon and remove the metal glove-port covers. Slight adjustment of the pressure within the box is possible by means of foot-controlled solenoid valves that allow more argon to be admitted to the box or excess argon to be removed by the mechanical vacuum pump. Because there is no automatic pressure release to prevent pressurizing the box, the operator must exert careful control to prevent blowing out the gloves.

Samples and supplies are brought into the box and removed from it through an evacuatable air lock. The object being taken into the box is placed in the air lock, then the air lock is evacuated and backfilled with argon. The door between the air lock and the box can then be opened, and the object can be taken into the box without degrading the atmosphere in the box. An object is removed from the box by placing it on a piece of paper or in a container (to prevent contaminating the air lock) in the argon-filled air lock and then removing it from the air lock through the adjacent open-front enclosure. Make certain that the lids of all containers in the air lock are loose, so that the containers will be evacuated when the air lock is being evacuated.

Because the inert boxes are not connected to the building exhaust system, it is especially important that any leaks in the gloves be found and repaired quickly.

Because of the static atmosphere in the box, normal movement of the operators arms and hands in the gloves can "pump" contamination from the box into the room through holes in the gloves. Therefore, it is imperative to check your gloved hands as soon as you remove them from the glove-box gloves.

Changing Glove-Box Gloves

On occasion, a glove-box may develop a leak. It is important to find the leak while it is still small, and to patch it or replace the glove. Because the air pressure within a glove box is kept lower than that in the room, large amounts of contamination are not ordinarily released into the room through small punctures in the gloves. The primary spreading of such contamination is by the hands of an unwitting operator. Therefore, the importance of checking your hands frequently, and of wearing surgeon's rubber gloves, cannot be overemphasized.

The glove-box gloves are clamped to cylindrical (or elliptical) metal rings that encircle the glove ports on the boxes. A long hose-clamp holds the rubber glove tightly against the metal ring. In some designs, an internal expanding clamp supplements the outer contracting clamp, and aids in allowing the gloves to be changed easily and safely. The procedure described below pertains to the use of two clamps.

1. Request a special air test, and close the room to unauthorized personnel. Usually, two people should perform the glove change.

2. Wear full protective clothing, including a respirator and surgeon's rubber gloves, and have an alpha counter at hand.

3. Place wrapping paper on the floor in front of the glove box, and tape paper to the front of the glove-box stand.

4. Wipe down the interior of the glove box and the glove surfaces that are exposed to the glove-box atmosphere. Also, wipe off any objects in the box that are covered with loose contamination or dust, or move them to an adjacent box. A cheesecloth pad, lightly oiled, may be used in the wiping operation.

5. Insert a new glove into the punctured one.

6. Remove the inner, expanding clamp from the old glove, and then replace it so that both the new glove and the old one are clamped tightly to the metal ring of the glove port.

7. Remove the outer, contracting clamp from the old glove, and carefully pull the glove bead back about 1/2 in. from the front of the glove box but do not remove it completely from the metal ring. Otherwise, contamination may escape from the box into the open laboratory.

8. Use the alpha counter to check the portion of the metal ring that is thus exposed. Remove any loose contamination by wiping the ring with a damp pad of cheesecloth.

9. Slip the bead of the new glove over the bead of the old glove and work it onto the metal ring so that it butts against the front of the box.

10. Work the old glove loose from the outer surface of the metal ring by manipulating it through the new glove.

11. When the old glove has been worked loose, place the outer clamp in position around the new glove and tighten it so that the new glove, but not the old one, is held firmly to the box.

12. Remove the inner clamp and slip the old glove into the glove box.

13. Replace and tighten the inner clamp so that the new glove is held firmly against the inner surface of the metal ring.

14. Check the area around the glove port, the floor, any tools, and your protective clothing for contamination and clean up any found. Roll up the wrapping paper and place it in the contaminated-waste can.

15. Within the glove box, roll up the old glove and place it in a container for shipment to the Recovery Section.

if the operation has been performed deliberately and carefully, there will have been no release of contamination in the room.

Gloves that are held by a single clamp are changed in a manner similar to that described above, except that much greater care is necessary to avoid spreading contamination. The absence of the inner clamp allows contamination to work its way in between the glove and the metal ring, where it usually causes some contamination of the front of the box when the glove is loosened. Considerable dexterity is required in order to slip the new glove over the metal ring without allowing the old glove to slip entirely off the ring and thus expose the interior of the glove box to the atmosphere in the room.

Hoods, Furnace Housings, and Open-Front Enclosures

Frequently it is desirable to perform certain operations in an open-front hood or other enclosure (furnace housing, etc.) instead of in a glove box. Certain manipulations that might be difficult to perform in a glove box may be done much more simply and with adequate safety in a hood. The decision as to whether or not a hood can be used safely depends largely on the type of material that is to be processed. Certainly, any material that is covered with loose plutonium oxide should not be

exposed to the atmosphere in a hood. Air turbulence between the hood and the open laboratory may cause oxide particles to be drawn into the room. On the other hand, solutions, specimens that have clean surfaces, and objects that have a low level of contamination may be processed safely in a hood.

Use clean paper on the floor of the hood, wear rubber gloves, and wear a respirator if there is any possibility of airborne contamination escaping into the room. Have an alpha counter at hand for use in checking all objects that are removed from the hood.

A clean hood can be a convenient and safe place to perform some operations with plutonium, but if the hood is allowed to become highly contaminated it may become a source of contamination for the entire laboratory module.

When you are working with highly contaminated material in a furnace housing, and when the operation to be performed is likely to result in contamination of your surgeon's rubber gloves, you should wear two pairs of gloves. The inner pair may be taped to your smock sleeves, and the outer pair slipped on loosely over the inner pair. When the outer pair become contaminated, they can then be easily removed and replaced with fresh gloves without exposing your bare hands to contamination.

Entering the Plutonium Storage Vaults

It is possible that a plutonium fire or spill may occur in a closed storage vault and thus present a hazard to anyone entering the vault. An attempt to provide a warning of that condition has been made by installing alpha-detection systems in the vaults. These systems consist of a probe and a standard alpha-emitting source within each vault and an alpha counter outside the vault. Any loose plutonium contamination within the vault is expected to actuate the counter to give an audible signal and a meter reading.

The procedure to be employed in entering a plutonium storage vault is as follows.

1. Look at the meter on the alpha counter. If it reads zero, check the operation of the counter.

(a) The power switch should be "ON."

(b) The indicator lamps should be glowing.

(c) Pull out the brass knob at the side of the vault to test the counter. (This removes the cover from the standard source and should cause the meter to indicate about 10,000 counts/min.)

(d) Push in the brass knob. (This covers the standard source and should cause the meter reading to return to zero.)

2. If the counter appears to be operating correctly and if no above-tolerance level of contamination is indicated when the standard source is covered, you may enter the vault in the normal manner.

If the meter reading is greater than zero when the standard source is covered, there may be loose contamination in the vault or a malfunction in the detection system. The only safe assumption is that the counter is working correctly and that, indeed, there is loose contamination in the vault.

If any above-tolerance level of contamination is indicated, take the following steps.

1. Inform the Health Physics Surveyor that the vault appears to be contaminated.

2. Don protective clothing including a respirator.

3. Before opening the vault, use a portable alpha counter to check for contamination at the edges of the vault door.

4. If there is any contamination, isolate the area by placing warning signs or masking tape across the corridor. Then slowly open the vault door and visually inspect from outside the vault to determine the source of the contamination. If there is an obvious fire or spill, follow the appropriate procedure listed in this manual. (Information concerning the existence of a serious fire within the vault will have been transmitted to fire alarm headquarters by means of the heat-sensing device installed in the vault ceiling.)

5. If there is no obvious fire or spill, cautiously enter the vault and locate the source of the contamination.

6. When the source of contamination has been found, accomplish decontamination by following the appropriate procedure listed in this manual.

7. If a thorough examination fails to reveal any loose contamination either inside or outside the vault, there is probably a malfunction in the alpha counter. Arrange with the Health Physics Surveyor to have the counter repaired.

Use of Radioactive Sources Producing Penetrating Radiation

Sources that produce large amounts of penetrating radiation (except for x-ray machines) are not in common use in CMB-5. However, such sources are used infrequently, and some general rules about handling them are appropriate for inclusion in this manual. The use of specific sources may well require special precautions, which will be determined as the need arises.

1. No source that produces penetrating radiation may be brought into the CMB-5 areas of the CMR Building without the approval of the Group Leader.

2. In general, sources that produce enough radiation to require lead shielding must be handled with tongs. As a guide, sources having a strength of 1 Ci or less must be handled with tongs at least 12 in. long, and for only short periods (not more than about 1 h/yr, as based on 1-Ci ^{60}Co , 22-in. body-to-source distance, 5 r/yr but not more than 3 r/calendar quarter criteria). A limited supply of 1-m-long tongs is available from H-1 for use in handling sources stronger than 1 Ci.

3. Be careful not to exert excessive pressure on radium sources, and do not expose any source to temperature extremes.

4. Keep a radiation-rate type of instrument, such as a Victoreen 440 or Cutie Pie, readily available to ascertain exposure dose rates and to determine that the source has, in fact, been returned to its shield after use.

5. Obtain a pocket dosimeter from H-1 for use if the routine exposure dose rate of gamma radiation is more than 2.5 mr/h.

6. Film badges must be worn by all persons working with or in the vicinity of any source, regardless of the dose rate.

7. Take all necessary precautions to ensure that neighboring personnel are not exposed to dose rates greater than 1 mr/h for any extended period. (The Health Physics Surveyor is equipped to make environmental radiation surveys.)

8. Radiation signs must be posted, and a rope or tape barricade erected at the 2.5-mr/h line for an exposed source. However, if the 2.5-mr/h line is at great distance from the source, then the exposure dose rates or the "stay time" for 100 mr must be indicated at the barricade.

9. The source must be stored within its shield when not in use, and the shield must carry a radiation type sign or tag appropriate to the exposure dose rate of the shielded source. Use care when lifting the shield (lead pig or cask). Be sure that the handles are firmly attached to the shield, and do not attempt to lift more than 50 lb (35 lb for women) unassisted.

10. Group H-1 personnel routinely leak-test all radium and mesothorium sources, but these and other sources should be swipe-tested both before and after use. To do this, wipe the surface of the source with facial tissue held by tongs. Then hold the tissue in contact with the probe of an alpha counter or an open-window G-M survey instrument. A reading greater than background indicates a

leak. In that event, or if the source is damaged or lost, notify the Health Physics Surveyor or call the H-1 Monitoring Section (4093).

11. Sources having a strength of 1 Ci or greater require an H-1 escort when being transferred between sites. An individual may not use a private vehicle to transport radioactive material belonging to LASL unless he has the written permission of his division leader.

Vacuum Systems

Much of the work with plutonium requires the use of vacuum systems to provide a nonreactive environment. Commonly, a system consists of a mechanical vacuum pump, or mechanical pump in series with a diffusion pump, which is connected to a vacuum chamber containing the plutonium and associated equipment. The exhaust from the mechanical pump must be filtered, or the exhaust port must be connected to the contaminated exhaust system of the building. Any disassembly of the vacuum system must be performed with due regard for the plutonium contamination hazard.

All mechanical pumps must be equipped with belt and pulley guards for personnel protection, or else be placed so that the pulleys and belts are next to a wall or barrier that will serve as a guard.

If a pump leaks oil, it should be repaired or replaced at once to eliminate the hazard of oil on the floor.

A few vacuum systems in the Group make use of ion pumps. The dc power supply for such a pump can operate at several kilovolts and several amperes, and both pump and power supply can cause arc burns and lethal shocks. It is essential that the pump and its power supply be grounded and that the high-voltage terminals and coaxial lead be adequately insulated and correctly installed to preclude accidental breakage or disconnection. Both the pump and power supply are capacitive circuits. Therefore, switch the meter selector to "kilovolts" and wait until the meter reads zero before connecting or disconnecting the high-voltage leads or otherwise working on the system.

Maintenance for the vacuum pumps is available in Group SP-3 (Instrument Repair Section, 4111).

Glass Vacuum Systems

Chemical and metallurgical research investigations concerned with gas/metal reactions may require the use of glass systems. Heating reactive metals in air may introduce unwanted complications into the experiment, and metal vacuum systems, although rugged and useful for many operations, lack the necessary flexibility and easy fabricability of glass systems. On the other hand, glass systems are fragile and require that certain precautions be taken in their design and operation, particularly when they are to be used in plutonium investigations.

The glass system must be installed within an enclosure to confine any plutonium contamination that

might result from breakage or other mishaps in loading and unloading it. If feasible, the system, or that part of it most likely to become contaminated, may be installed in a glove box. However, because of the difficulties in assembling and operating glass systems in such confined quarters, they are more often installed in well-ventilated open-front hoods or in the standard LASL "greenhouses," modified to provide ventilation at both the top and bottom of the enclosure. Bottom ventilation is important because the relatively high density of plutonium and its oxides causes contamination to settle through the air to the lower parts of the enclosure.

The enclosure must be provided with doors that can be closed if the interior becomes contaminated, and the doors should be large enough to allow convenient access for assembly and disassembly of the system.

In working with glass systems, wear safety glasses or a face shield in addition to the protective clothing required because of the plutonium hazard.

Glass blowing on a contaminated system may be done with compressed air, but not by mouth.

Mercury pumps must not be operated unattended for relatively long times unless an interlock is provided to turn off the power to the pump if the circulating cooling water fails.

Because mercury is often used in glass systems, attention should be paid to the control of its particular health hazards. Although dangerous concentrations of mercury vapor are unlikely to occur at room temperature in a well-ventilated room, such concentrations may exist if the mercury is heated. A mercury diffusion pump is thus a potential source of danger. Glass systems containing mercury should have catch pans large enough to contain all the mercury in the system if the glass breaks. Any spilled mercury must be cleaned up promptly and completely. Group H-5 personnel are equipped to measure the level of mercury contamination in a room, and may be contacted by calling the H-5 representative for CMB-5 at 6130.

Provision must be made for the automatic release of any unusual overpressure in the glass system. A mercury "blowoff" or a ground joint can provide such protection.

Systems containing fine powder should be evacuated slowly and carefully. Expansion of gases or moisture trapped within the powder may cause it to erupt violently and be carried through the system unless considerable caution is exercised.

If toxic gases are used, additional safety equipment such as a self-contained breathing apparatus may be required.

The use of liquid nitrogen as a refrigerant in cold traps creates a potential hazard. Tape the exteriors of glass dewars used to transfer liquid gases to prevent scatter of glass particles if the dewars break. If liquid gases are confined in a closed vessel, an explosion may result. Contact between liquid gases and the skin can cause serious burns. Oxygen, which has a higher boiling point than nitrogen, may collect in a dewar and become concentrated enough to constitute a fire or explosion hazard.

X-Ray Equipment

A number of x-ray machines of several different types are used in CMB-5. Signs placed at the entrances to the modules where the x-ray machines are situated warn of a possible x-radiation hazard in the modules and restrict entry to authorized personnel only.

All x-ray setups must be monitored and shielded to protect personnel against high levels of radiation, and each x-ray machine must be labeled with a sign warning that there is a radiation hazard when the machine is energized.

All personnel working near x-ray equipment must wear film badges.

For detailed information on x-ray protection recommendations, refer to the National Bureau of Standards Handbook No. 93, *Safety Standard for Non-Medical X-Ray and Sealed Gamma Ray Sources, Part I. General* (1964).

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