Title

ENGINEERING STUDY OF RADIOLOGICAL FIRE PREVENTION AT LAWRENCE RADIATION LABORATORY, BERKELEY, CALIFORNIA

Permalink

https://escholarship.org/uc/item/2504424h

Author

Young, Jensen.

Publication Date

1970

For American Industrial Hygiene Association
Conference, Detroit, Michigan, May 11-15, 1970

UCRL-19465
Preprint
c.2

ENGINEERING STUDY OF RADIOLOGICAL FIRE PREVENTION AT LAWRENCE RADIATION LABORATORY, BERKELEY, CALIFORNIA

Jensen Young

January 1970

AEC Contract No. W-7405-eng-48

UCRL-19465

LAWRENCE RADIATION LABORATORY
UNIVERSITY of CALIFORNIA BERKELEY

41

DISCLAIMER

ENGINEERING STUDY OF RADIOLOGICAL FIRE PREVENTION AT LAWRENCE RADIATION LABORATORY, BERKELEY, CALIFORNIA*

Jensen Young

Lawrence Radiation Laboratory
University of California
Berkeley, California 94720

January 1970

Abstract

A fire in a radioisotope facility could result in widespread contamination of the environs. The levels of contamination, the areas of spread, the number of people contaminated, and the health hazards involved are hard to predict. For instance, it is conceivable that if a radioisotope involved in a fire were in a completely sealed container, no contamination would result. On the other hand, if large quantities of radioisotopes were in a flammable container located in an unsprinklered area, and if meteorological conditions were just right, the levels of contamination off-site might be sufficient to be a health hazard to the population involved.

The many unforeseeable and unpredictable factors make it even more imperative that we practice fire prevention rather than rely on fire fighting. It could be hazardous, time-consuming, and expensive to decontaminate fire debris. If people could be indoctrinated to reduce fire hazards in their areas, a great step forward would be made. Elimination of accumulated flammable materials, or substitution of nonflammable materials, should be encouraged. Automatic fire suppressors (such as

sprinklers) and alarms should be installed in high-fire-hazard areas.

In this report we discuss and evaluate some of the engineering steps taken at the Lawrence Radiation Laboratory, Berkeley, California, to reduce the hazards of fire in radioisotope areas. These include the selection of fire-retardant materials for enclosures to meet the variable and unpredictable demands of researchers, fire tests on enclosure components, modification and testing of a fire extinguisher for glove boxes, evaluation of radioisotope storage areas, and a critical look at mechanical ventilation in a radiological fire.

Introduction

The effects of fires in radioisotope areas can be far-reaching. The results range from personnel exposure and property loss to poor public relations and facility down time. Needless to say a large fire involves large property losses ($40 to 50 million at Rocky Flats, Colorado!). However, decontamination of a facility after even a small fire can also be expensive.[2, 3] Loss of property is unfortunate, but property can usually be replaced. On the other hand, personnel exposure can never be completely recompensed, so this becomes our chief concern.

For the above reasons, the Safety Services Department in 1961 embarked on a continuing program to evaluate and reduce fire hazards in radioisotope areas. This report covers the progress to date.

Fire Tests of Glove Boxes

Radioisotopes in quantities large enough to be hazardous are stored and handled in enclosures. The types of research carried out in these enclosures, the physical forms of the radioisotopes involved, the materials of construction, and the sizes of the enclosures are variable. The characteristic common to all of these, however, is their vulnerability to fire. These enclosures are subjected to a multitude of experimental environments. The researchers vary in abilities from the very sophisticated senior scientist to the inexperienced graduate student. It is a tribute to the ingenuity and vigilance of the Safety Services Department and of the researchers (or perhaps simply to Lady Luck) that the Laboratory has not suffered a glove-box fire of any consequence.

Early in the game we recognized that the most vulnerable components of any glove box were the gloves themselves. They would deteriorate under fire conditions and be the first breach in the enclosure. However, rubber gloves are necessary for working in boxes, and at present there is not substitute for them (new materials for gloves are presently being evaluated by Factory Mutual Research Corporation).[4] Nonflammable glove-port covers can reduce this problem. Other components, nevertheless, should be selected to be as fire-retardant as possible.[5]

Enclosure Shell

It must first be recognized that Safety Services designs and fabricates almost all the glove boxes used at LRL, Berkeley. This is a totally research-oriented laboratory where there are no production lines for the isolation of radioisotopes. This means that our enclosure requirements are somewhat unique. We design almost as many "special" enclosures as we assemble "standard" units; these "standard" units are frequently just the starting point for alterations and modifications to meet the researcher's needs. Thus we need to stockpile construction materials and have assembly methods that are versatile and easily adaptable.

Prior to 1961 the standard enclosure was made from 3/4-in. plywood panels. This material satisfied all our requirements for economy and versatility, but it was flammable. To reduce the fire hazard, early in 1961 this department investigated other glove-box construction materials. Fireproof plywood panels were considered but discarded because of their rough surfaces, where contamination could lodge. Metallic boxes were the obvious choice but they also presented a number of problems, such as:

- The initial cost of fabrication was considerably higher than for wooden assemblies.
- Corrosion-resistant coatings on the box shell would be compromised every time a penetration into the shell was made.
- Alterations were difficult to make.
- Greater storage area would be needed, since complete shells instead of panels would have to be stored.
- Lead time for fabrication of the assembly would have to be increased.
- Interchangeability of box components would be reduced.

After a number of experiments, a sandwich of 1/2-in. plywood with 1/8-in. asbestos millboard on each side was selected as the standard material of construction for the box shell.[6] Full-scale fire tests were conducted to evaluate enclosures made of this new material. From these results, we concluded that this construction material was satisfactory for our needs. (See Appendix for description of tests.)

Sheet metal enclosures are being designed and fabricated for special situations; however, they are not being routinely constructed.

Viewing Windows

Construction materials for the viewing window have always presented a problem. Quarter-inch safety glass set in a metal frame was used at one time. However, this material was not satisfactory for several reasons:

- It would collapse under heat.
- Cutting 5-in. or 8-in. glove ports set up stress in the rest of the window.
- Alterations to the window were difficult, expensive, and time-consuming.

Fire-retardant acrylic resin material, Plexiglas type 5009, has proved unsatisfactory also. Fire tests indicated that it would burn vigorously when heated to its combustion temperature (see Appendix). Additionally, the maximum recommended continuous service temperature is 125–140°F, versus 180–200°F for type G Plexiglas, and the chemical resistance is less than that for type G.

Our present front windows are made from 3/4-in. type G Plexiglas with a metal frame around the edges. We recognize that this is not the best material to use as far as fire resistance is concerned, but it does meet our other needs:[7]

- It has good optical clarity.
- It is readily available.
- Fabrication is easy; machinability is excellent.
- It can withstand a moderate amount of stress and rough handling.
- It has good corrosion resistance.
- On-the-spot alterations are easily made.

Top or Lighting Window

Our fire tests (see Appendix) indicated that the best of the materials tested for the top window was industrial-type wire glass. It would crack under fire conditions in the box, but it would still maintain its shape.

Dollies

Wooden dollies to support the glove boxes are being replaced with metal units.

Evaluation of Other Enclosures

Inert-Atmosphere Boxes

These units are constructed of all-metal shells with Plexiglas windows. They do not present fire hazards except for the window and gloves.

Cave Boxes for the 4-Foot and 6-Foot Water-Shielded Neutron Facility

From a fire standpoint, these are the most vulnerable units at the Laboratory; they also house the highest levels of radioactivity used in enclosures. Remote manipulation processes require the use of much plastic material in the box construction. The front and rear portions are made of Plexiglas sheets to permit illumination and vision. The manipulator socking, made from flexible vinyl sheet, isolates the master-slave manipulators and keeps them free from contamination.[8]

The fire hazard inherent in these enclosures is well recognized by all concerned. Therefore, conscientious efforts are made in fire prevention. Flammable materials inside and outside the box are kept to the bare minimum. An in-cell CO_2 fire-suppression system is installed in each cell; it can be activated by either temperature rate of rise or manual control.

The primary boxes in the interior of the cells are practically immune to a room fire. They are surrounded by 4-ft or 6-ft steel water tanks, which should stop most fires. On the other hand, a box fire within the cell might not result in a complete disaster. Each cell is separately ventilated through high-efficiency filters with high- and low-volume fans. In case of a cell fire, the ventilation rate could be increased. This would direct the contaminated gases or smoke through fire-retardant air filters before discharge to the environs.

Glove-box Fire Extinguisher

As mentioned earlier in this report, the Laboratory has never experienced a glove-box fire in which radioactivity has been released.

We feel that our insistence that the researcher maintain good housekeeping within enclosures and good fire-prevention attitudes is a major contributing factor to this safety record. Furthermore, we have found that at the low air exhaust rates for the enclosures (5 – 15 cfm), fires become self-extinguishing.

Nevertheless, under certain conditions a glove-box fire might get out of control. We decided, therefore, to provide a standby fire extinguisher "just in case."

Our design criteria for the extinguisher were as follows:

- It must be effective against paper, cardboard, wood, or organic solvent fires (dry powder units are used for pyrophoric materials).
- It must be simple, for untrained persons to use.
- Minimum pressurization of the enclosure must be required.
- The extinguishing material should not make recovery of rare and costly radioisotopes impossible.

With these criteria in mind, we tested carbon dioxide, dry powder, and Halon 1301 ("Freon" FE 1301, a Du Pont product) against alcohol and gasoline–kerosene fires in glove boxes. CO_2 units worked well, but it was difficult to control the pressurization of the enclosure by the CO_2. Dry powder was most effective, but we felt that recovery of radioisotopes from the powder would be difficult. Halon 1301 met all our requirements. By metering the Halon with a needle valve, we could control the input to the enclosure to a flow that extinguished the fire without pressurizing the enclosure (about 4 cfm). After the fire, there was no residue to clean up, since Halon vaporizes at room temperature.

The next step was to devise an easy method to inject the Halon into the enclosure. The idea of installing special ports or attachments to the hundreds of enclosures at the Laboratory was rejected. The expense and the possibility of radioactive contamination during modifications would have been unwarranted in view of our past fire safety record. A glove-penetration method was adopted after a suitable probe had been designed. This probe consists of a removable 1/8-in.-diameter stainless steel tube with a sharpened tip (see Fig. 1). The small tube size, although sufficient to carry the needed Halon, does not cause excessive tearing of neoprene gloves. After use in a fire, the probe can be removed and passed into the enclosure for disposal (Fig. 2). One minor difficulty with the use of these extinguishers is that once the cylinder seal is broken by depressing the handle, the Halon cannot be turned off. The unit becomes a "one shot" device. However, this should not pose any serious problems, since the unit will discharge harmlessly until it is expended.

Radioactive Sources

The radiological hazard from sources involved in a fire depend upon:

- Quantities and types of radioisotopes present.
- Design of source and materials of construction.
- Location of source in a fire, including storage container and shielding.
- Extent of fire damage to source.

For purposes of this report, the sources at the Lab are grouped in three categories: high-level, intermediate, and low-level.

High-Level Sources

High-level sources are those that contain more than 0.1 curie α emitters or more than 5 Ci β emitters (involvement of these quantities of materials in a fire might present a health hazard to persons off-site).[9] Of the approximately 1020 sources at the Laboratory, only 20 are in this category. Of these, four are large permanent or semi-permanent units. Massive radiation shielding surrounds each. In addition, each source capsule is singly or doubly jacketed in a stainless steel container. The probabilities are excellent that these sources would survive a large-scale fire.[10]

Of the remaining 16 sources, 13 are neutron emitters (PuBe, PuF, PuLi, RaBe) and are encased in metal capsules; three are radium sources in metal capsules. Many of these sources are located in the Building 72 calibration range (located in holes in the cement floor). However, since these are not permanent sources, they can be moved from building to building. These sources have good structural integrity and under fire conditions the probabilities are good that they would survive intact.

Intermediate-Level Sources

These sources are classified as follows:

Alpha emitters: less than 0.1 Ci but greater than several μCi.

Beta emitters: less than 5 Ci but greater than several hundred μCi.

About 150 sources fall within these limits. These sources, if exposed to fire, would probably not be a health hazard to persons off-site. They could, however, pose a serious health hazard to persons in the same room, such as unprotected fire fighters. Additionally, contamination of persons, equipment, and the building could be a serious problem. About 80 of these sources are conservatively considered to be dangerous under a fire situation; that is, they would have a poor probability of surviving a fire. The remaining sources would have a good to excellent chance of surviving a fire. Fire-retardant boxes or safes are recommended for storing dangerous sources when they are not being used.

Low-Level Sources

These sources are classified as follows:

Alpha emitters: less than several μCi.

Beta emitters: less than several hundred μCi.

Under fire conditions these sources might cause technical contamination of people, equipment, and the building. The radiological hazards are of a lower order of magnitude than for any of the other sources.

Storage Areas

The largest storage area for all types of radioisotopes is located in Building 70, room 147A. This facility includes a storage pit, and fire-retardant storage cabinets are being planned. The storage pit was lined with a wooden frame, but this frame is being replaced in the course of alterations to the pit. Another storage area is in Building 75. Material is stored in removable metallic tubes which are inserted into metallic liners in a pit. Sprinklers protect this area from fires.

Smaller storage areas are scattered throughout the Laboratory. Some consist of Berkeley boxes, others are lead-shielded containers or holes in concrete floors. Materials processed from the 4-ft and 6-ft water-shielded neutron facility are often stored in the rear lazy susans of the water-shielded caves.[8] These storage areas are immune to fire damage. Apparatus with induced activity from the 88-inch cyclotron is stored in concrete pigeonholes closed with lead doors. This area is also immune to fire damage.

Massive pieces of depleted uranium are stored in the Building 75 yard and Building 5 shed; other pieces are used at the Bevatron for shielding purposes. What would happen to this material under fire conditions is not clearly defined. Massive pieces ordinarily do not burn, but a few exceptions have been noted.[11] However, since the relative toxicity of uranium is low, the overall hazard is considered to be low.

Ventilation

Ventilation would play an important role in the spread of contamination from a radiological fire. Contaminated smoke and hot gases would be exhausted from the building, would be injected into the atmosphere, and would then spread to the environs. Knowledge of ventilation systems will give us some insight into the hazards involved.

Berkeley Box Manifold Components and Filters

Berkeley Boxes are connected to special exhaust systems. These consist of 4-in. round ducts leading to a set of parallel exhausters on the roof. The function of these systems is to maintain draft on the boxes at all times. If one exhauster should fail, a standby exhauster would automatically take over. Emergency generators back up P G and E electrical supply. All buildings have all-metal manifold ducts with the exception of Building 70 (in which several plastic units are being phased out).

Each manifold has its own electronic control unit situated in its respective room. Under room fire conditions, a manifold would probably continue to operate until heat caused a short circuit to occur in the control unit. No fire dampers exist anywhere in the system. However, manual dampers are positioned at the manifold for each Berkeley box. The damper could be turned to shut off or reduce the air flow if warranted.

Fire dampers or temperature-rise fan-shut off units are not recommended for manifold systems. There are numerous reasons for this:

- Draft on the Berkeley boxes is essential for the containment of radioisotopes. Any malfunction of the fire dampers or fire thermostat during normal operation could cause serious hazards.
- The fire dampers or the fire thermostat would have to be corrosion-resistant. A coating material might reduce the effectiveness of the devices.
- Heat sources (hot plates, heat lamps, and furnaces) are commonly used in glove boxes. Hot air generated from these devices might result in a false signal.

- In a room fire, one would hope that not all the glove boxes connected to a manifold would be involved. It would be better to shut off the draft on those units directly involved and maintain draft on all the other units.

Contaminated air from each Berkeley box travels through 2-in. round flexible duct to a high-efficiency particulate filter and then to the manifold. The flexible duct is composed of Fiberglas and neoprene sheets laminated over a wire core, and then resin coated. In a fire, the resin and neoprene would burn off, leaving the Fiberglas; the duct would still be functional (see Appendix).

The filter unit is constructed of all fire-retardant materials as follows:

High-efficiency media - all Fiberglas with a maximum of 5% organic binder.

Separators, asbestos.

Adhesive, self-extinguishing.

Frame, 3/4-in. fire-retardant plywood.

Paint, fire retardant.

In a fire, the filter would maintain its integrity for about 5 min against air temperature up to 700°F (see Appendix).[12] Depending on the nature of the fire, the filter might plug up if much smoke were generated, or it might burn through if hot embers were embedded in the filter media. If a burn-through occurred, we could expect environmental contamination.

Hoods, Room Ventilation

Rooms in which radioisotopes are used are ventilated either by hood exhausters or by separate room exhausters. For this discussion, we will treat these two systems alike. All-metal ductwork carries the room exhaust to the roof, where it is discharged through a single fan. In the event of a fire, any smoke, soot, or radioactive contaminant generated would be discharged out the stack.

Fire dampers have been suggested to automatically shut off the flow of air in case of a fire. These units are spring-loaded or weighted devices which spring shut when a fusible link is broken. The hope is that the hot, contaminated gases would be trapped in the room and not be discharged to the environs. The flaw in this thinking is that the hot gases would still escape from the room. The supply air for almost all our laboratories originates from a central building fan. If the hood exhaust were turned off, the room would pressurize and force contaminants through room cracks or around the door frame. In addition, pressure buildup from the heat could shatter door or building windows. These gases would then travel out the windows or through the corridors and then throughout the building. Exhausters in other rooms would pick up the contaminated gases and discharge them to the environs. Fire dampers or fire thermostats on these other exhausters might not operate because the air temperature might then be below their activation points. A complete building-ventilation shutdown might be the only answer. This, of course, would give rise to many problems of its own. The most serious problem would be jeopardizing an unsuspecting researcher's health or life if toxic vapors were being generated in a hood or enclosure in another room and the ventilation were suddenly turned off.

Fire thermostats can also be placed in ducts. If the air in the duct exceeds a preset temperature, the fans are turned off. These units by themselves, however, would not prevent contaminated gases from escaping; the duct would act like a chimney and the hot gases would be drawn from the room. A fire damper would still be necessary, and this would raise all the objections listed above.

Additional reasons why the ventilation should not be automatically turned off are covered in Health and Safety Information Bulletin Number 173, which advises, "Don't hesitate--ventilate".[13] Firefighters might be driven out of a room or building by intense heat and blinding smoke. If a fire smoldered in an unventilated room, combustible gases might accumulate and then take off with explosive force when air is introduced. Ventilation alleviates these problems.

Whether to manually shut off these systems or leave them running is not a simple decision to make. Obviously it would be better to confine as much of the contamination as possible on-site rather than spreading it off-site. This means turning off the ventilation as soon as possible after a fire is detected. However, this is a situation for which no firm policy should be made. Only responsible persons at the scene of the fire who have participated in preplanned action should make this decision. Under certain fire-fighting conditions, it might be wiser not to shut off the fans, in order to clear away smoke and hot gases.

We have seen from the above discussion that it would be almost impossible to prevent radiological contamination to the environs in case of a serious fire. A possible solution to this dilemma would be to install fire-retardant, high-efficiency filters on the roof for all stack exhausts. If the gove-box filter burned through, or if contaminated gases were discharged through hood or room exhausters, these filter units would act as the final clean-up devices. There is much merit in this suggestion; however, the initial investment would be high. Additionally maintenance and upkeep would be expensive. Money would be better spent on the installation of sprinkler systems.[14]

Summary

Since 1961 the Safety Services Department has pursued the problem of fire hazards in radioisotope areas. During this period glove-box construction materials and component parts have been fire-tested and modified. The final product is a compromise between the demands for fire safety and the flexibility required for a research-oriented institution.

Fire extinguishers for glove boxes were tested and one was selected and modified for use. This unit does not cause adverse pressurization of the glove box, nor is recovery of rare radioisotopes hindered.

Glove-box ventilation appears to be satisfactory for fire safety. However, ventilation from radioisotope areas may spread contamination to the environs in the event of a large-scale fire. Ventilation systems should not be automatically shut off without careful preplanning that takes the consequences into consideration. Sprinkler systems are recommended for high-fire-risk areas.

Radioisotope storage areas generally are satisfactory. Some sources, however, are vulnerable to fires and when not in use should be stored in fire-retardant boxes.

Acknowledgments

The author acknowledges the great amount of effort put into this evaluation program by other members of Safety Services. First of all the development of fire-retardant enclosures and ancillary fire equipment was encouraged by Patrick W. Howe, Richard P. Grill, and Robert M. Latimer. James T. Haley offered valuable suggestions and assistance; the Fire Department under Elmer Silva was always present during our fire testing. Glove boxes for testing were built by the Enclosures Section under Will D. Phillips, and ventilation problems were ably handled by Wayne T. Pearce and Richard L. Boltin. Herbert P. Cantelow's evaluation of environmental contamination was invaluable, as was Dale Allaway's evaluation of radioisotope sources. This report was carefully read and constructive comments were made by Myron D. Thaxter, Will D. Phillips, Herbert P. Cantelow and James T. Haley.

Appendix: Fire Tests

Fire Test: Internal and External Fires

Box construction. These tests were conducted early in January 1961. The purpose was to test the destructive effect of fire inside a standard plywood Berkeley box and inside one constructed of asbestos-millboard (1/8-in. asbestos millboard laminated on each side of 1/2-in. plywood).

Box No. 1 was the standard plywood box.

Box No. 2 was the asbestos millboard box.

In the early portion of the tests, difficulty was experienced in trying to maintain a fire inside the enclosure (see Fig. 3). The low air flow rate used (5 – 15 cfm) was inadequate to keep a fire burning. After several false starts, a fire was sustained by partially opening a side door on the enclosure, and thus increasing the air flow.

Results of the test are shown in Figs. 4 and 5. The asbestos-millboard box was almost intact.

Thereafter, external fires were started on each of the boxes. The results are shown in Fig. 6.

Conclusions:

1. Under normal air flow conditions (5 – 15 cfm), an internal box fire could not sustain itself.
2. An internal or external box fire did not materially damage a box constructed of asbestos millboard.
3. The box gloves were destroyed in an external fire.
4. The safety-glass window (box No. 2) was damaged.

Fire Test: Filters

Filter units were used to ventilate the glove boxes in the first fire tests. Figure 7 shows Filter 1 (upper) used with box No. 1--standard plywood; Filter 2 (lower), used with box No. 2--asbestos-millboard.

Note that the interiors of both filters appear to be in good shape. DOP filter testing was not done, since the equipment was not available at that time.

Fire Test: External Fires

These tests were conducted during the latter part of January 1961. The purpose was to test box-shell and window material against external fires.

The test boxes were as follows:

Box No. 1: Standard plywood construction, unframed Plexiglas window.

Box No. 2: Asbestos-millboard (1/8-in. asbestos-millboard laminated on each side of 1/2-in. plywood), metal-framed Plexiglas window.

Box No. 3: Full-view box, constructed of asbestos millboard.

The sequence of events is shown in Figs. 8 and 9. Note in Fig. 8b that the rubber gloves rapidly ignited and formed the first breach in the enclosures. Note in Fig. 9 that the surface of the Plexiglas windows ignited.

Figure 10 shows the results of the tests on the standard plywood box, the asbestos-millboard box, and the asbestos-millboard full-view box.

Conclusions:

1. Rubber gloves were the first component to fail.
2. Plexiglas windows burned on the surface (boxes 2 and 3) but did not burn through after 20 minutes' exposure to fire.
3. The metal frame around the Plexiglas window was of some aid in preventing the edge of the window from catching fire.
4. Asbestos-millboard construction was far superior to plywood under exposure to fire.

Fire Test: Top or Lighting Window

Various top or lighting window materials were tested for fire exposure (Fig. 11a). These were

1/4-in. wire glass,
1/4-in. Plexiglas,
1/8-in. Plexiglas and 1/8-in. Pyrex,
1/4-in. safety glass.

Wire-glass window (Fig. 11b) held up best. It cracked, but it maintained its shape. All other materials cracked or bowed much more.

Fire Test: Plexiglas Windows

Two types of Plexiglas were tested for fire exposure:

Type G: ordinary Plexiglas;

Type 5009: Fire-retardant Plexiglas. See Figs. 12 and 13.

Conclusions: Both types of Plexiglas burned completely through.

Fire Test: Flexible Tubing

The flexible tubing (neoprene-Fiberglas laminate over wire convolutions, and resin coated) used to ventilate glove boxes was exposed to fire, as shown in the far right-hand side of Fig. 12. Results are shown on Fig. 14.

Conclusions: The resin burned off, exposing the Fiberglas, but the duct retained its shape and functional capacity.

Footnote and References

*Work done under auspices of the U. S. Atomic Energy Commission.

1. Atomic Energy Law Reports, No. 727, May 23, 1969, Commerce Clearinghouse Washington, D. C.

2. Plutonium Fire Outside of Glovebox Leads to $30,000 Contamination Cleanup Cost, Serious Accidents Issue No. 264, United States Atomic Energy Commission, May 13, 1966.

3. Fire During Glovebox Cleanup Leads to $23,000 Damage via Contamination Spread, Serious Accidents Issue No. 269, United States Atomic Energy Commission, July 8, 1966.

4. Evaluation of Improved Fire Resistant Glove Materials for Gloveboxes, Factory Mutual Research Corporation, Norwood, Mass., 1969.

5. Glovebox Fire Safety, Factory Mutural Research Corporation, Norwood, Mass., 1967.

6. W. D. Phillips, Use of Asbestos-Millboard Surfaced Plywood Panels in Hot Laboratories, Lawrence Radiation Laboratory Report UCRL-10180, April 1962.

7. Glovebox Window Material, Factory Mutual Research Corporation TID-24896, 1969.

8. Patrick W. Howe, Thomas C. Parsons, and Leonard E. Miles, The Water-Shielded Cave Facility for Totally Enclosed Master-Slave Operations at Lawrence Radiation Laboratory, UCRL-9657, Oct. 9, 1961.

9. Herbert P. Cantelow, Hazardous Quantities of Radioisotopes in Case of Fire or Catastrope, (Lawrence Radiation Laboratory), unpublished communication, 1966.

10. Patrick W. Howe, Joseph E. Rainey, and Harvey F. Soule, Inspection of a Fire-Damaged Source, Lawrence Radiation Laboratory Report, UCRL-9271, June 29, 1960.

11. R. B. Smith, The Fire Properties of Metallic Uranium, Technical Information Service, Atomic Energy Commission, Washington, D. C.

12. J. L. Murrow, Effect of Fire Intrusion and Heat on HEPA Filter Units, in Proceedings of the Ninth Atomic Energy Commission Air Cleaning Conference, September 13-16, 1966, CONF 660904, p. 96.

13. Don't Hesitate - Ventilate, Health and Safety Information, Issue No. 173, United States Atomic Energy Commission, November 7, 1963.

14. Could Sprinkler Protection Have Reduced This $200,000 Radiochemistry Building Fire Loss?, Serious Accidents Issue No. 175, United States Atomic Energy Commission, April 5, 1961.

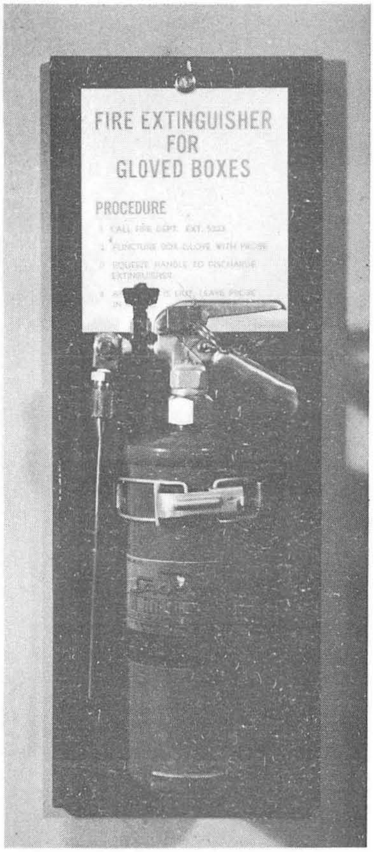


Fig. 1. Glove box fire extinguisher. (XBB697-4673)

Fig. 2. Extinguisher near glove boxes. (XBB697-4673)

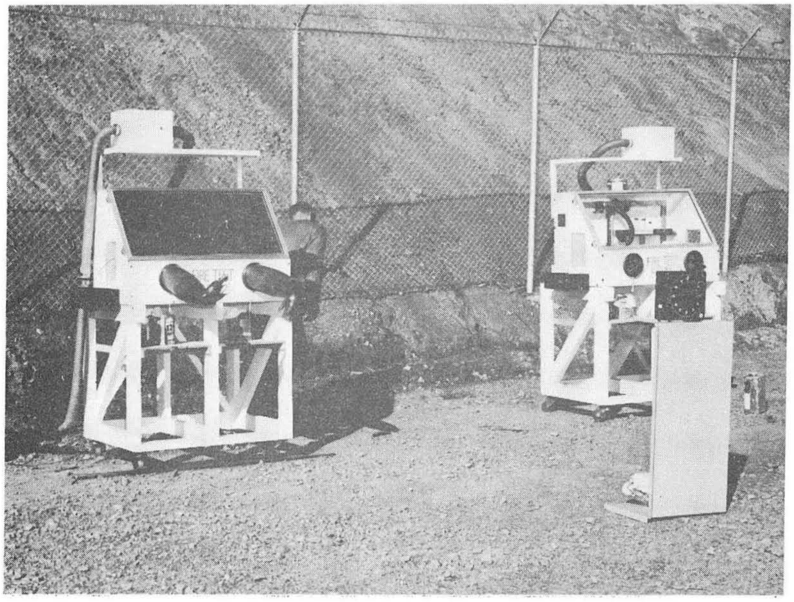


Fig. 3. Setup for fire tests, internal fire just started. (Health Pro 805)

Fig. 4. Standard plywood box after internal fire. (Health Pro 812)

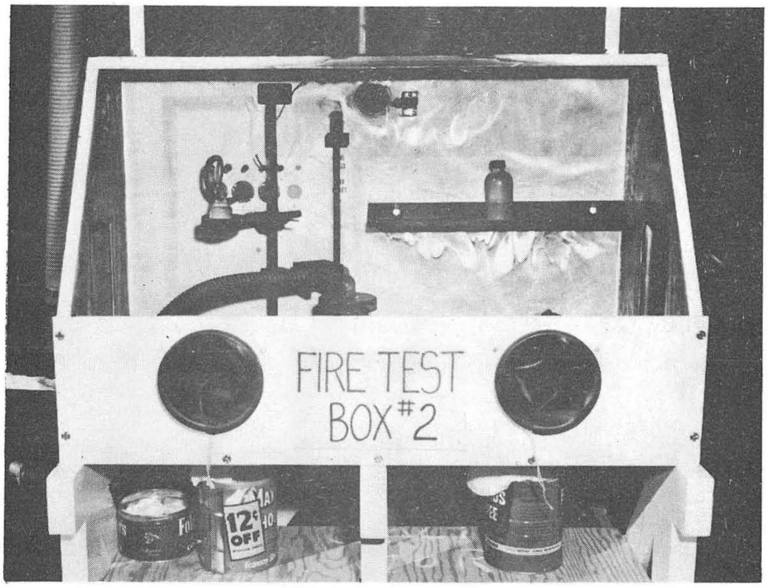


Fig. 5. Asbestos-millboard box after internal fire. (Health Pro 803)

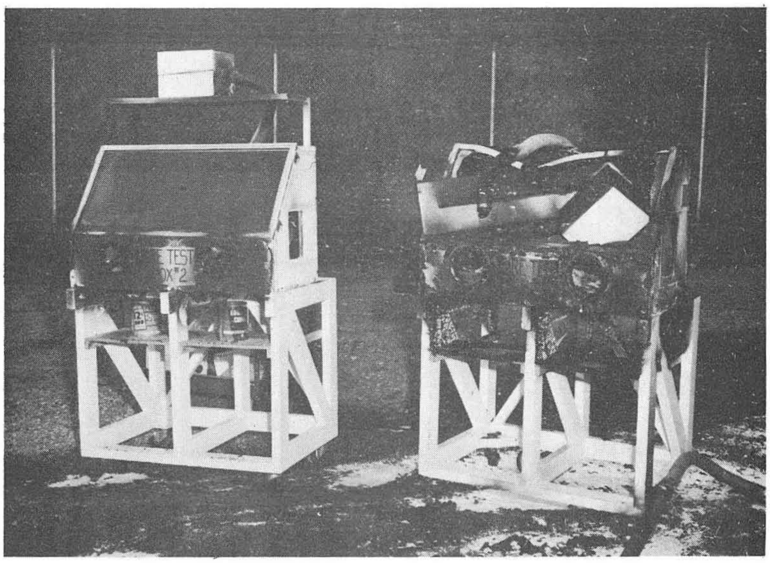


Fig. 6. Asbestos-millboard box (left) and standard plywood box (right) after external fire test. (Health Pro 811)

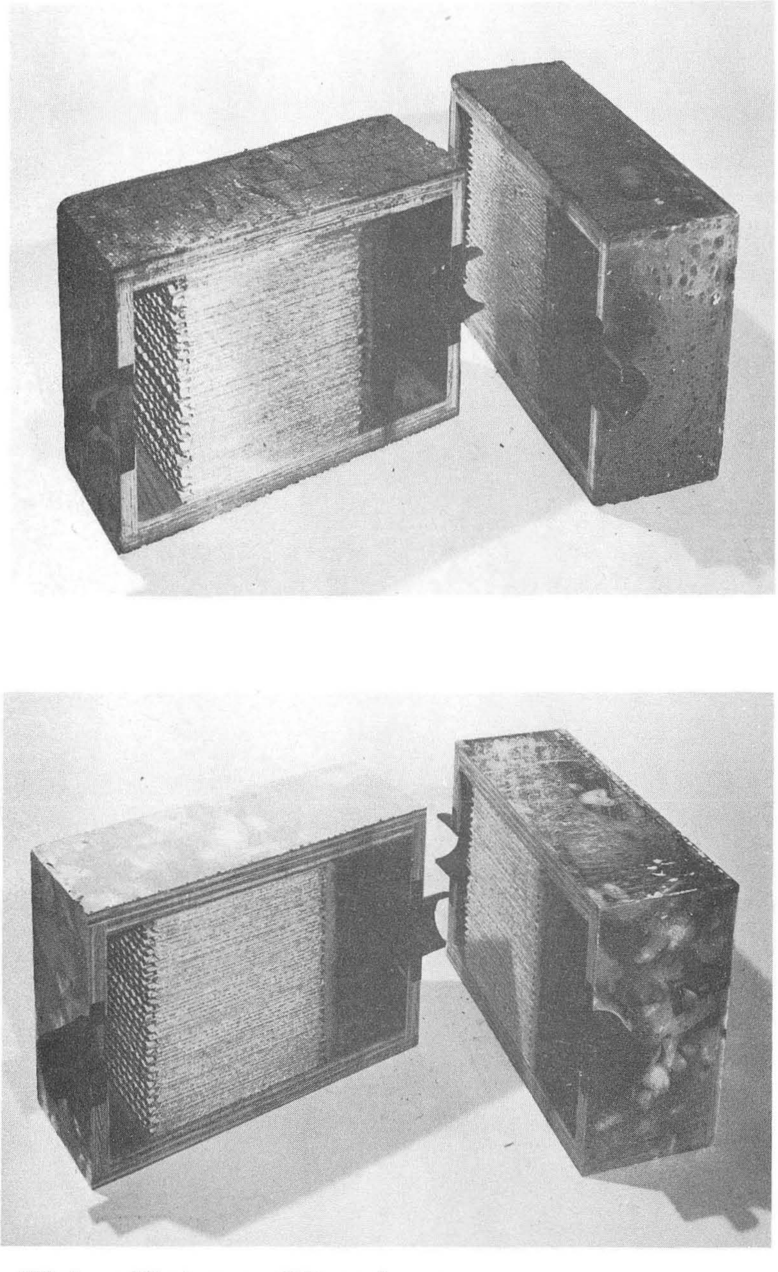


Fig. 7. High-efficiency filter from:
(upper) standard plywood box, (Health Pro 815)
(lower) asbestos-millboard box. (Health Pro 816)

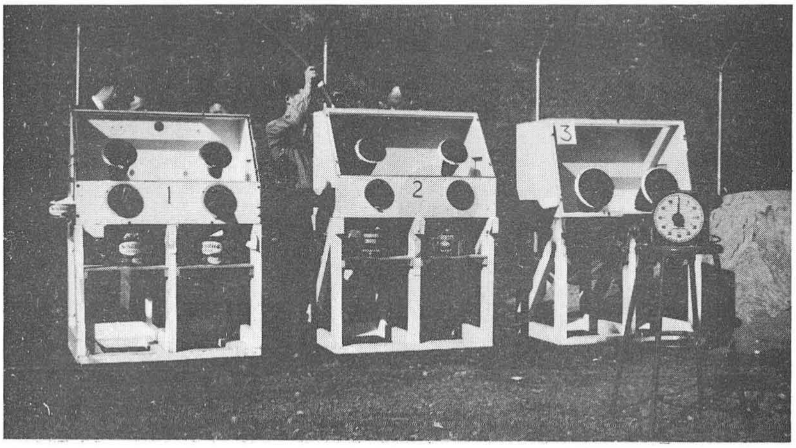


Fig. 8. Box 1: Standard plywood construction, unframed Plexiglas window

(upper: Health Pro 818)

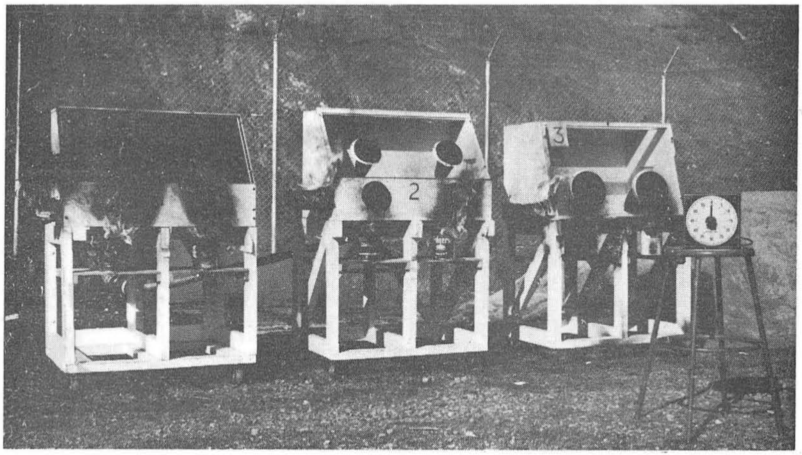


Fig. 8. Box 2: Asbestos-millboard box with metal-framed Plexiglas window

(middle: Health Pro 821)

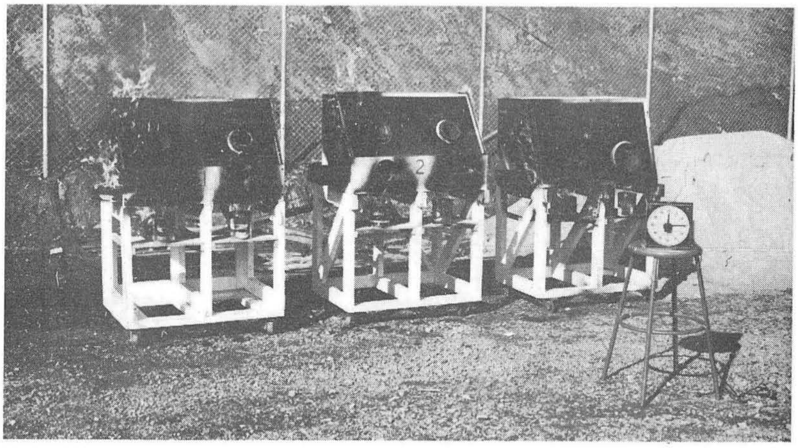


Fig. 8. Box 3: Full-view box constructed of asbestos-millboard.

(lower: Health Pro 822)

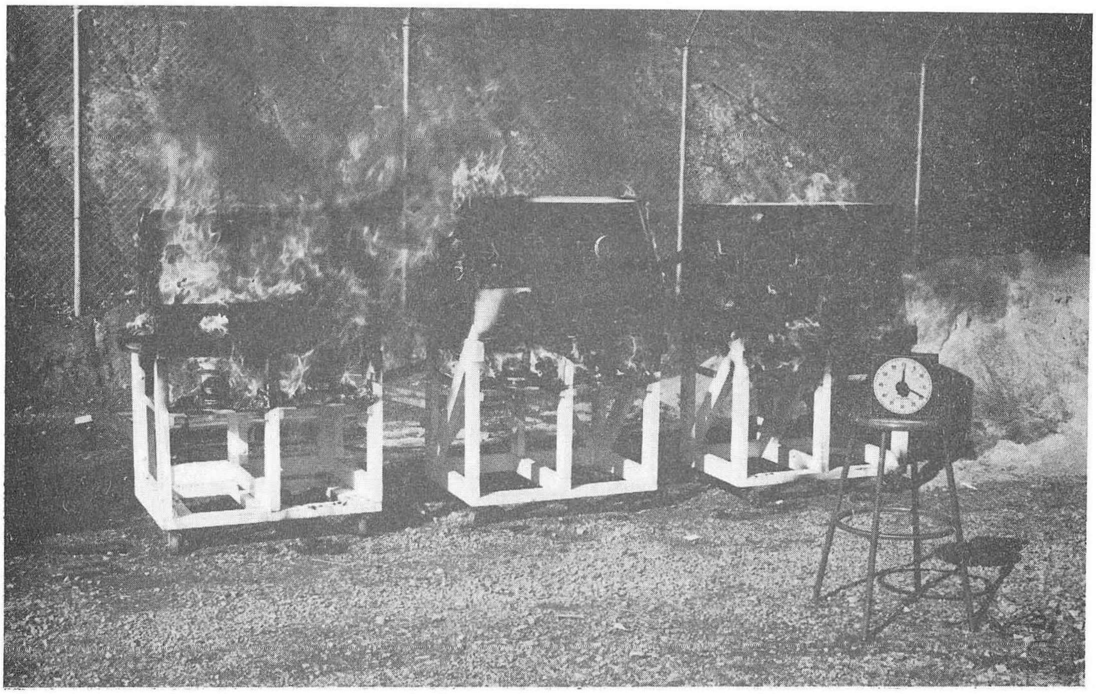
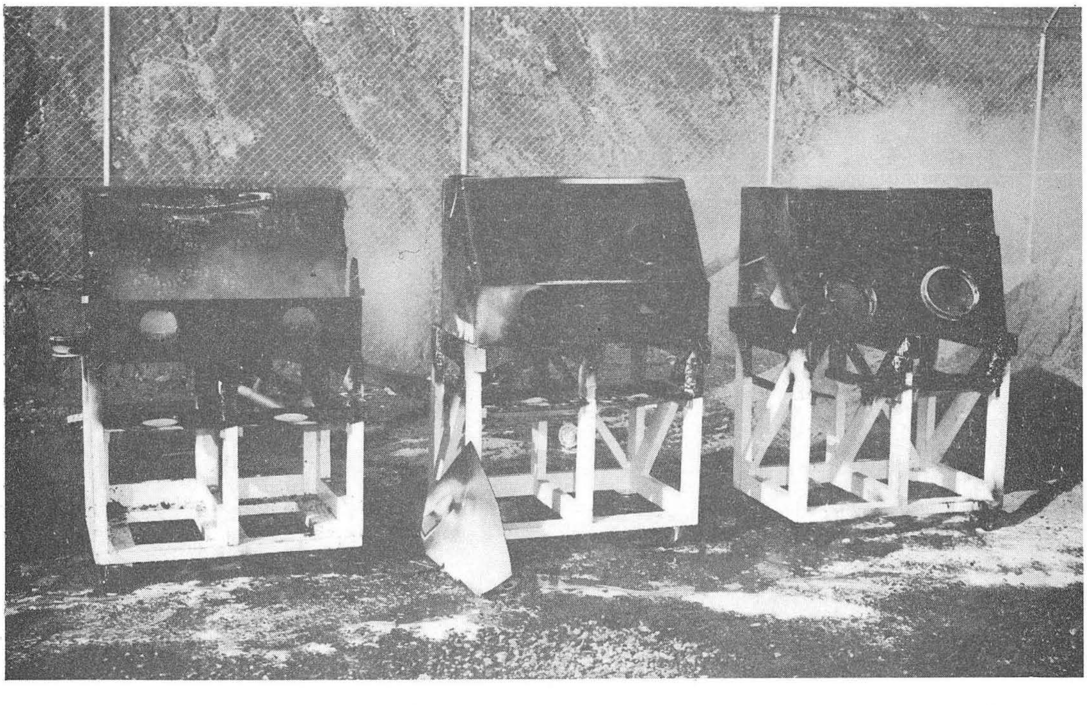
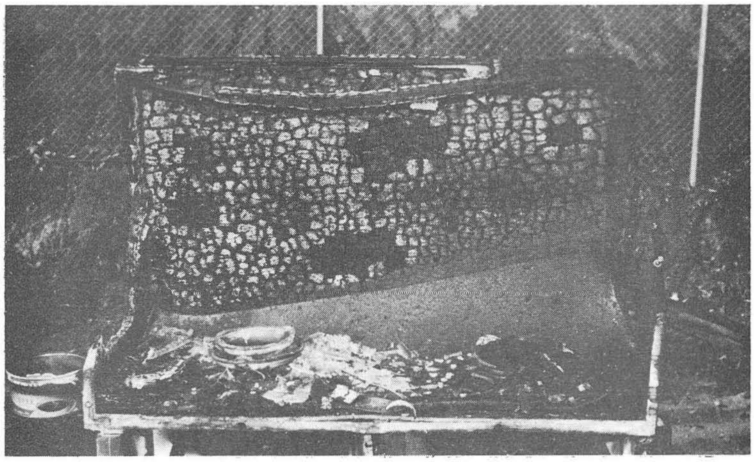


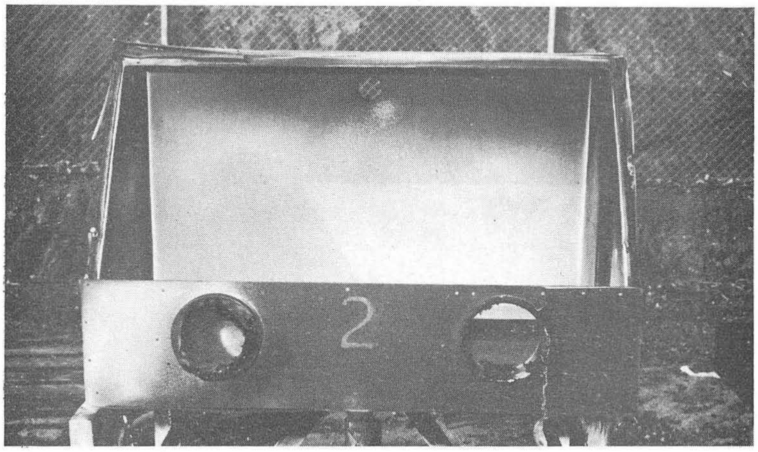
Fig. 9. Conclusions of external fire tests. (upper: Health Pro 823)



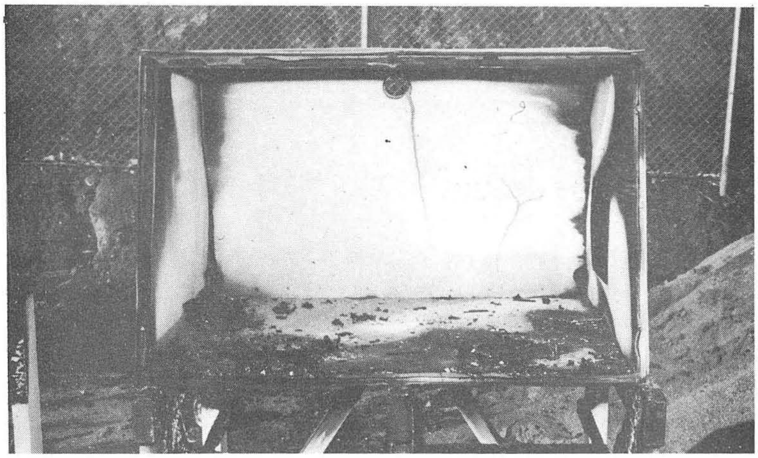
(lower: Health Pro 824)



(a) Health Pro 827



(b) Health Pro 826



(c) Health Pro 825

Fig. 10. Results of external fire on (a) standard plywood box, (b) asbestos-millboard box, and (c) full-view box.

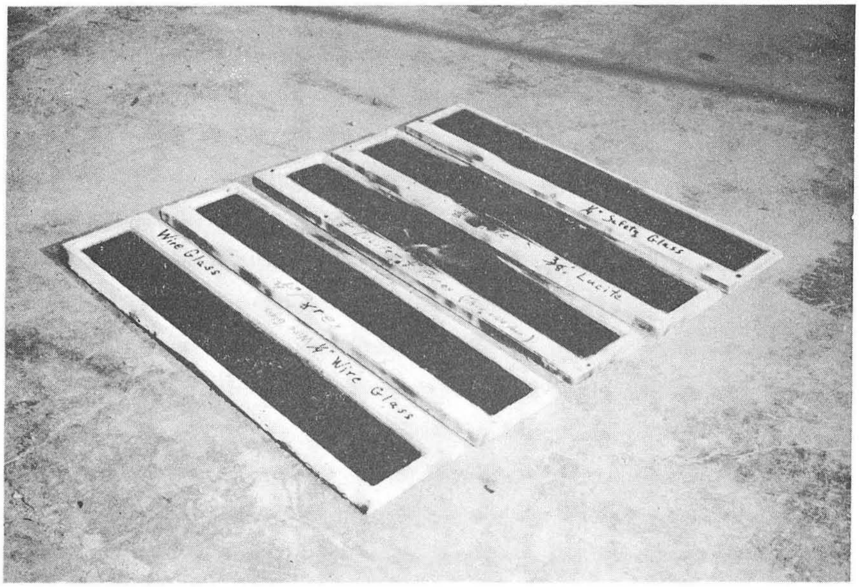
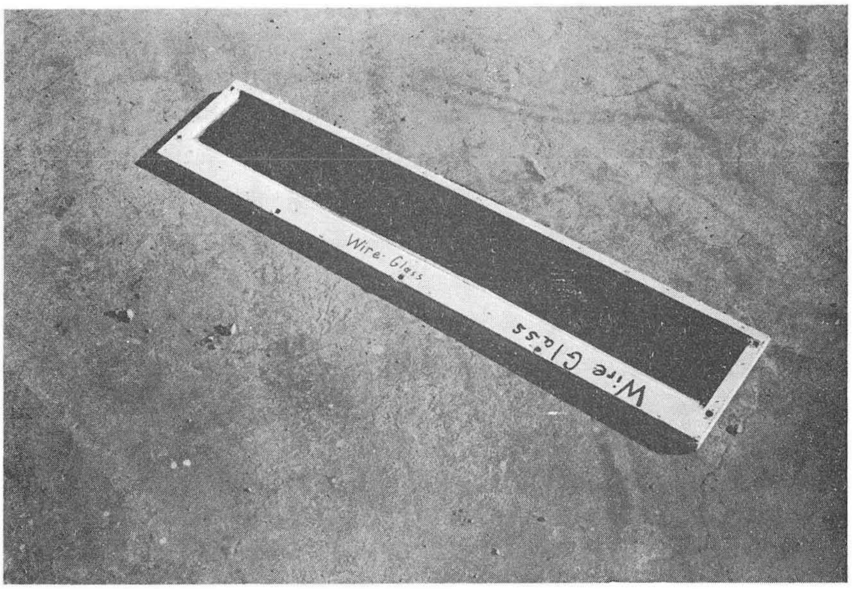


Fig. 11. Lighting windows after exposure to flames: (upper: Health Pro 836) various materials, (lower: Health Pro 837) wire-glass window.



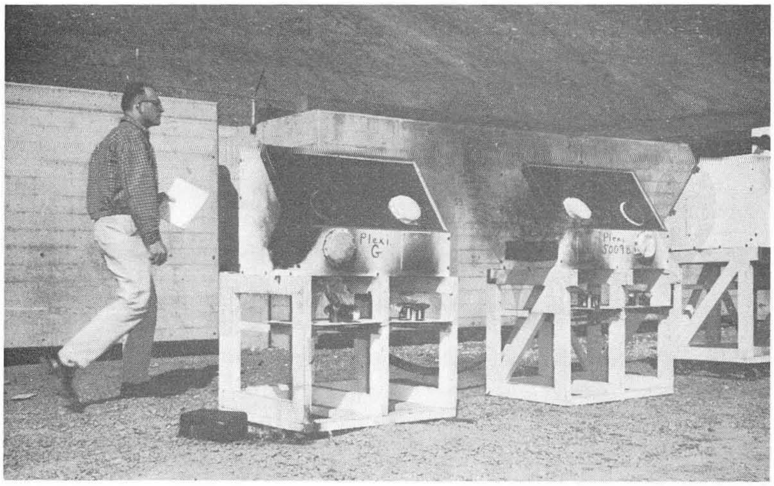
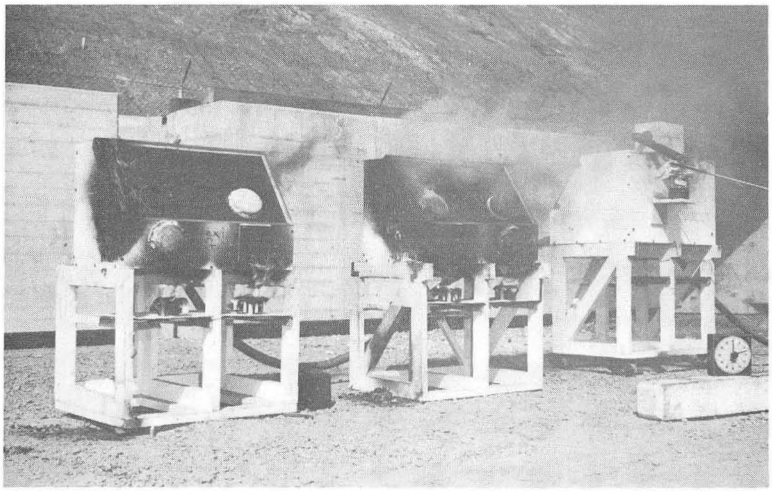
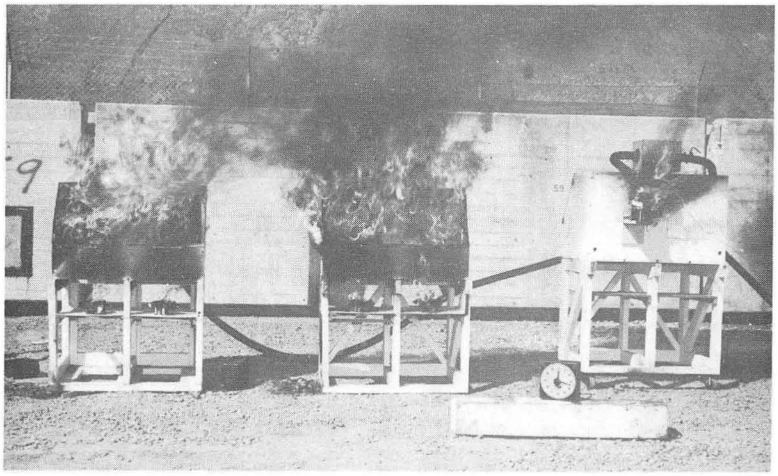


Fig. 12. Front window test:

(upper: Plexiglas G, Health Pro 839)



(middle: Plexiglas 5009, Health Pro 840)



(bottom, Fire sequence, Health Pro 841)

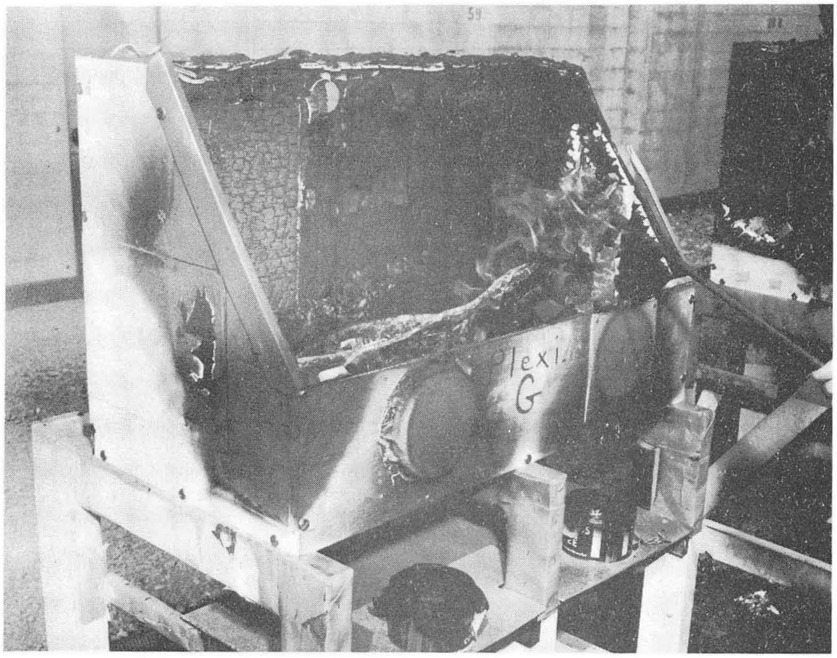


Fig. 13a. Plexiglas G window. (Health Pro 842)

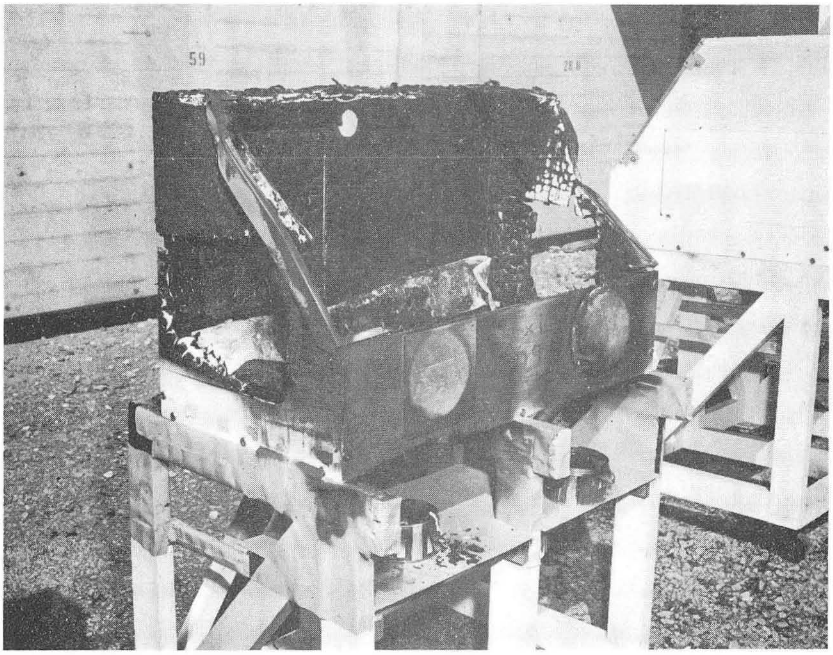


Fig. 13b. Plexiglas 5009 window following test. (Health Pro 843)

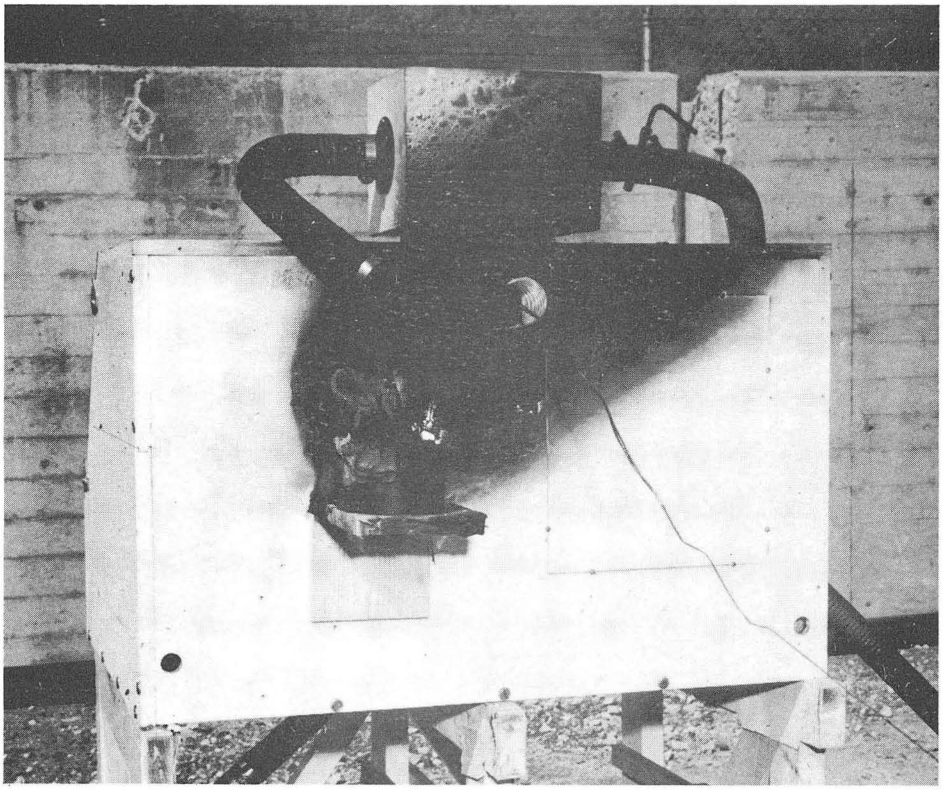


Fig. 14. Flexible tube after fire test. (Health Pro 844)

TECHNICAL INFORMATION DIVISION
LAWRENCE RADIATION LABORATORY
UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA 94720