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AEC RESEARCH AND DEVELOPMENT REPORT

AUTOMATIC FIRE EXTINGUISHING SYSTEMS FOR GLOVE BOXES AND SHIELDED CELLS AT THE SAVANNAH RIVER LABORATORY

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Health and Safety
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AUTOMATIC FIRE EXTINGUISHING SYSTEMS FOR GLOVE BOXES AND SHIELDED CELLS AT THE SAVANNAH RIVER LABORATORY

by

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June 1971

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ABSTRACT

An automatic fire-extinguishing system has been designed and tested for protection against non-metallic fires in glove boxes and shielded cells at the Savannah River Laboratory. The shielded cells and a number of glove boxes are currently protected by manually actuated systems pending conversion to automatic systems as operations permit.

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INTRODUCTION

Fires or explosions in glove boxes and shielded cells at atomic energy sites are potentially very serious because of the large quantities of highly radioactive materials that could be dispersed by destruction or breach of the protective containment. Preventive measures can significantly reduce the potential for fires and explosions, but cannot eliminate the occurrence of operating errors and unforeseen incidents. Because it is difficult to anticipate all situations that may arise, effective alarm and extinguishing systems are needed to supplement preventive measures.

SUMMARY

For fire protection in glove boxes and shielded cells at the Savannah River Laboratory, a modular fire-extinguishing system was developed with the assistance of Fenwal Incorporated. The modular approach can provide simple reliable systems with considerable flexibility, but at reasonable cost, through use of commercial components. The extinguishing agent is Halon 1301 (bromotrifluoromethane).[1] The system is not suitable for extinguishing metal fires.

The system can be changed from a simple manual operation to a fully automatic supervised system by adding plug-in components. Furthermore, when automatic protection is no longer required, the added components can be removed or the entire system can be detached for use wherever needed.

The cost of components for the manual system activated by an electric switch is about $200, and that of the automatic system is about $280. Labor cost of the installation depends upon location and tie-in with other alarm or functional systems, but normally is not more than two or three times the components cost.

At the Savannah River Laboratory, those glove boxes where fire protection is considered necessary and all shielded cells are equipped with manually operated Halon 1301 extinguishers attached to the boxes or in-cell piping by snap-on connectors pending conversion to automatic systems as operations and scheduling permit.

DISCUSSION

In a comprehensive study of fires, explosions, and incidents with serious potential that have occurred in shielded cells and glove boxes at atomic energy sites, the modes of initiation and propagation were identified and preventive measures were suggested for each cause.[2] This work also showed that preventive measures alone are not adequate protection, that extinguishing systems are a necessary backup, and that the installation of automatic fire extinguishing systems has been deterred because of uncertainties in the selection of appropriate extinguishing agents, adverse experience with detectors (particularly in remote environments) and the high cost of some of the systems. Therefore, extinguishing agents were studied and various detectors were tested at Fenwal Incorporated to establish guides for selecting extinguishing systems suitable for glove box and hot cell application.

DETECTORS

Tests showed that thermal detectors, particularly those that are rate-anticipating, are suitable for cell and glove box applications and are more reliable, especially for shielded cells where maintenance and testing are difficult.[2] Tests also showed that for early detection a detector should be placed near the top center of a small cell or box; additional detectors are desirable in larger boxes or cells, particularly above principal pieces of equipment or above areas where a fire might be expected to originate.

EXTINGUISHING AGENTS

Studies of the properties and applications of extinguishing agents and subsequent tests to compare carbon dioxide and Halon 1301 showed that Halon 1301 can replace carbon dioxide to provide faster, more effective extinguishing capability and to eliminate some of the problems associated with carbon dioxide and other agents. Although Halon 1301 will not extinguish metal fires, it can be used to prevent the propagation of metal fires to surrounding materials and, particularly, to protect absolute filters in exhaust ducts. Only 5 vol % of Halon 1301 is needed for most fires because it reacts chemically with the intermediate products involved in the propagation of flame. The reaction is fast, and the inhibiting reaction starts before the effective concentration is attained.

Tests also showed that the increase in volume during discharge and evaporation of the small quantity of agent does not upset the control of atmospheric pressures in cells or boxes, and, because of the greater vapor density, Halon 1301 has a more prolonged effect than carbon dioxide in preventing rekindling of a fire. Because normal pipe, tubing and fittings can be used in Halon 1301 systems, the cost is less than that for carbon dioxide although the cost of the agent is higher. Carbon dioxide systems require high pressure hardware.

SELECTION OF SYSTEMS

All cells and glove boxes in which significant quantities of radioactive material are handled or in which a fire might occur have fittings for connections to extinguishers or extinguishing systems. To assist those responsible for determining whether or not fire protection is necessary and the degree of protection required, fire protection guidelines were developed that are based on radiological hazards and are consistent with the general Laboratory guides for radiological health protection for all operations. The guides at the Savannah River Laboratory for protective measures on the basis of potential hazards are illustrated in Table I.

TABLE I

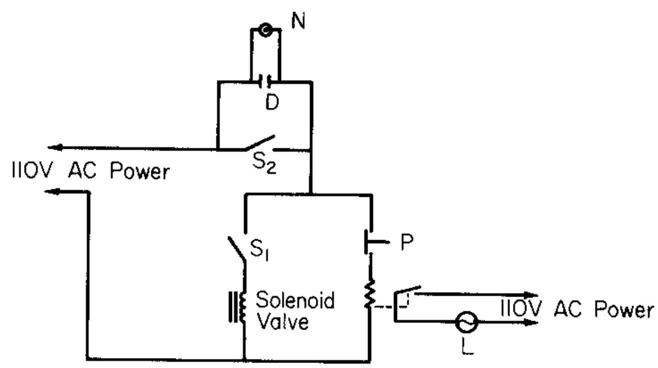
Guide for Minimum Fire Protection
Based on Potential Radiological Hazard

	Content of Glove Box			Recommended Extinguisher System
	β, γ Body Burdens	γ Dose Rate	α Curies	
Tracer	<100		$<10^{7}$ d/m ^{244}Cm or equivalent	Wall-mounted manual nearby
Low	>100		<1	Wall-mounted manual in lab
Medium		<100 R/hr at 3 inches	>1, <500	Box-mounted manual-electric
High		>100 R/hr at 3 inches	>500	Automatic system

All laboratories in which radioactive materials are handled now have manually actuated Halon 1301 fire extinguishers available. Laboratories where metal fires are possible also have extinguishers or extinguishing agents appropriate for the particular metal or metals.

Shielded Cells

Shielded cells will be equipped with fully automatic supervised systems except those that normally are operated with an inert atmosphere. A schematic diagram of the supervisory wiring system is shown in Figure 1. In addition to automatic actuation, the systems will have a manual discharge switch and a "disarm" switch to prevent discharge of the extinguisher so that either the detector can be tested without discharging the Halon 1301, or the system can be temporarily disarmed when the planned operations might actuate the extinguishing system. The switches are guarded with a snap-up cover (aircraft type) to avoid accidental tripping.



S_1 Detector Test Switch (Disarm Switch)
S_2 Manual Discharge Switch
D Detector
N Neon "Supervisory" Lamp
L Lamp Indicating Detector Fired
P Push-to-Test Button Switch

FIG. 1 WIRING OF SUPERVISORY SYSTEM

The quantity of agent and thus the size of the cylinder will vary with the size of cells and the exhaust airflows. The larger cells (6'd x 6'w x 10'h) are protected with about 27 lb of Halon 1301 contained in a 15 lb carbon dioxide type cylinder. The cylinders are labelled and have two distinctive bands, one white and one gray. Draft-tube nozzles will be used to expedite mixing of the agent with air in the cells. For the larger cylinders, squib-actuated valves should provide faster release of the extinguishing agent. For small cylinders, solenoid valves can be used.

Glove Boxes

Most extinguishers mounted on glove boxes will have electric switch-operated valves for manual or automatic operation. Where the hazard is very low, the squeeze-grip manual extinguishers may be used for economy.

The connection diagrams for the "manual" or "manual-electric," "manual-electric with detector and alarm," and the "fully automatic" systems are shown in Figure 2. Of course, consideration of the amount and type of combustible materials, sources of ignition, method of handling, operations involved, and monetary value of equipment may, upon evaluation, increase the degree of protection required.

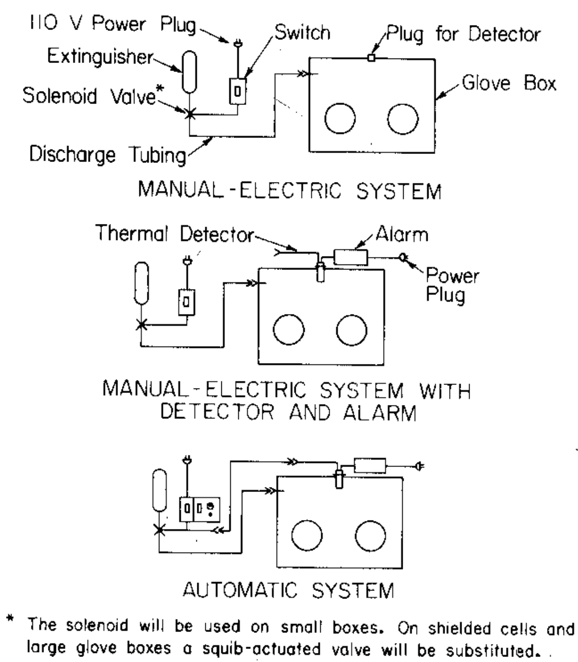


FIG. 2 CONNECTION DIAGRAMS FOR ALTERNATIVE FIRE PROTECTION MEASURES

The manually actuated extinguishers are actuated by pulling a safety pin and squeezing a handle grip that is basically the same as that on conventional small carbon dioxide extinguishers. The manual-electric system is actuated by closing the line switch (110 V) indicated in Figure 2. To add detection and alarm to the manual system, a thermal detector is plugged into a small gasketed hole in the top of a glove box; the associated alarm box is connected to the normal 110-volt AC power (Figure 2).

To convert to fully automatic actuation, the manual switch box will be replaced by a supervisory control box which can then be plugged into the detector alarm unit (Figure 2). A connection is also made from the alarm unit to the building alarm system on all automatic systems and may be on the detection and alarm unit when used with the manual system. The automatic system has a manual discharge switch and a "disarm" switch. Normally solenoid valves will be used on small boxes (20-50 ft^3). The Halon 1301 will be released into a glove box directly through the bulkhead fitting for the snap-on connector without any nozzle. Squib-actuated valves will be used on larger glove boxes to ensure quick release of Halon 1301 and hence, rapid attainment of the desired 5-6% concentration of the agent in the box. Draft-tube nozzles will be used on the larger systems to expedite mixing of the agent with air. Flexible tubing will be used to connect the extinguisher to boxes.

The manual extinguishers (2-3/4 lb Halon 1301) presently mounted on selected glove boxes in the Laboratory and on some of the small cells will be wall-mounted. These extinguishers will continue to provide protection at low unit cost for laboratories with glove boxes in which the potential hazard is very low and will also provide backup for general fire protection in those laboratories equipped with electrically-operated extinguishers whether they are manual or automatic.

The modular system permits variation in the location and mounting of extinguishers as well as in the selection of the degree of protection, although in all installations the inlet for Halon 1301 into the containment is at the top. For example, extinguishers normally are mounted on the glove boxes (Figure 3), but in special cases, they may be mounted adjacent to glove boxes or under them (Figure 4) for convenience. There is also freedom in the method of mounting to make them readily accessible but to avoid potentially hazardous interference with normal operations conducted in glove boxes, particularly the transfer of process materials and waste (Figure 5). Similarly, in shielded cells where space at the front is often limited, larger extinguishers are mounted on the wall (Figure 6), and an extension handle is located beside the cell window, convenient to the operator, to actuate the extinguisher. In another shielded facility three cylinders are located on the floor beside three cells (Figure 7). Adjacent flexible connections to the piping into each of the three cells makes it possible to connect a cylinder to each cell or three cylinders successively to one cell.

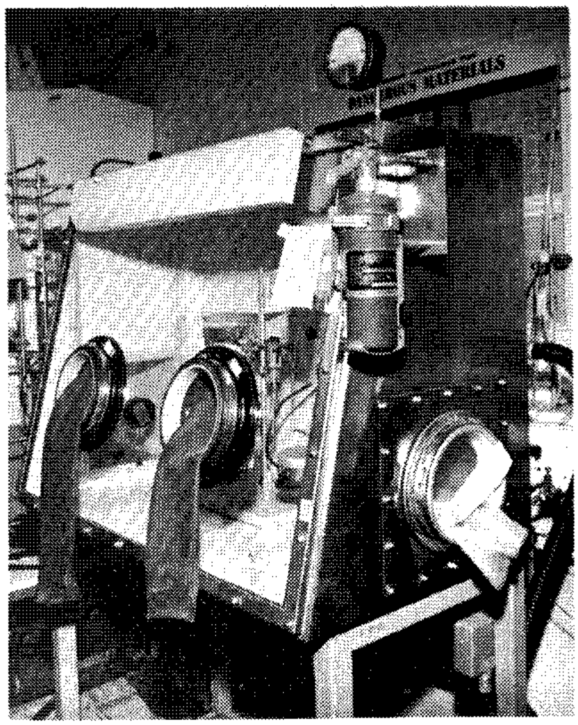


FIG. 3 HALON 1301 EXTINGUISHER ON GLOVE BOX

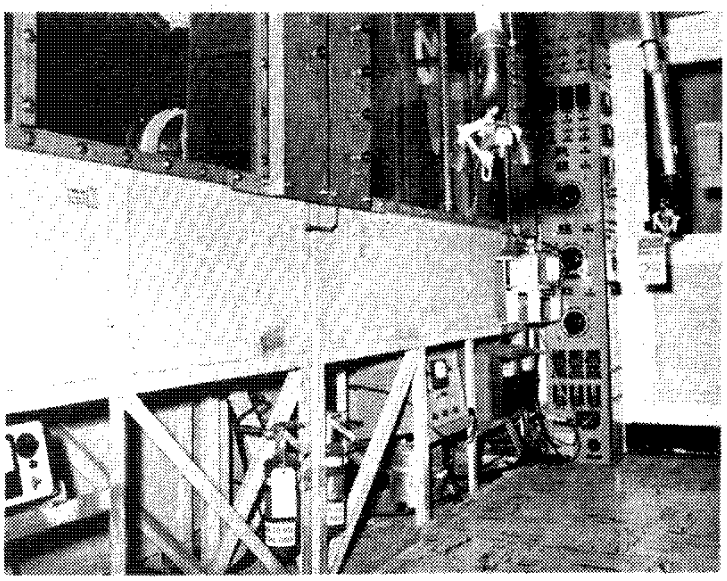


FIG. 4 HALON 1301 EXTINGUISHER UNDER GLOVE BOX

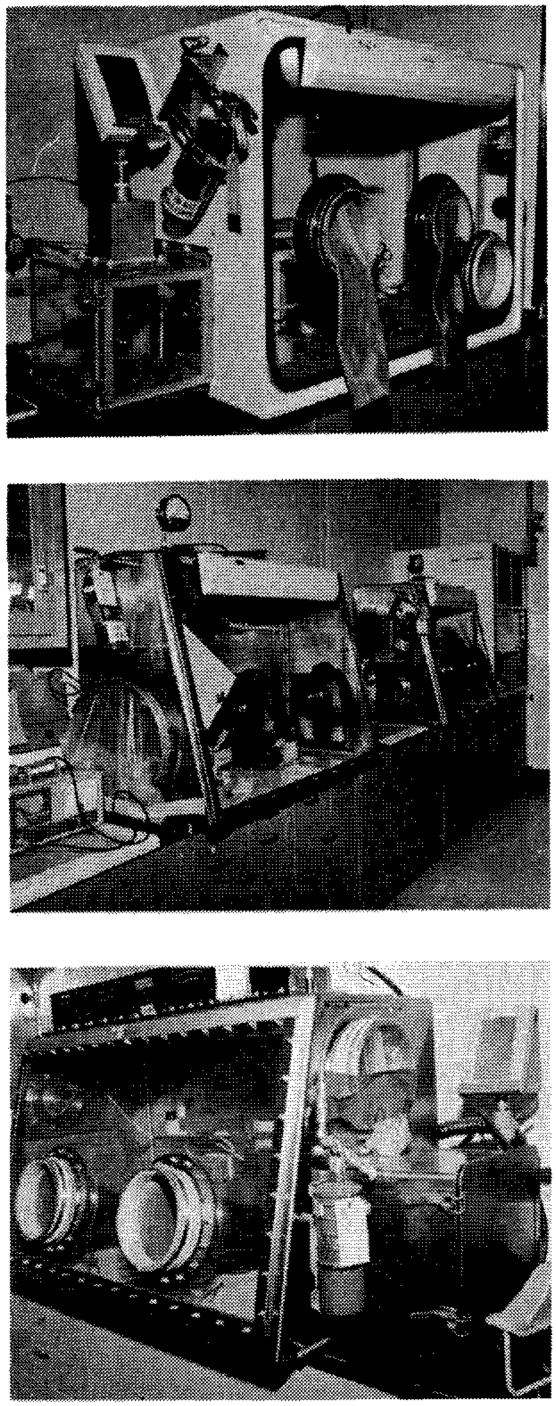


FIG. 5 ALTERNATIVE ARRANGEMENTS FOR EXTINGUISHERS ON GLOVE BOXES

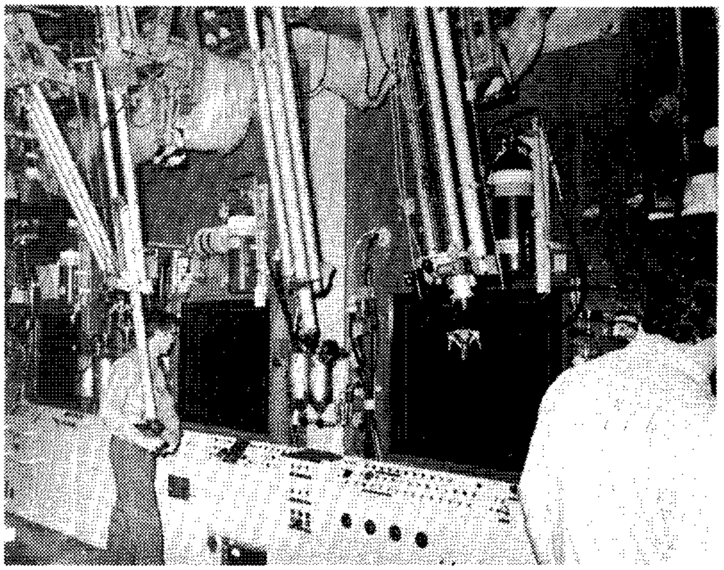


FIG. 6 EXTINGUISHER ON SHIELDED CELLS

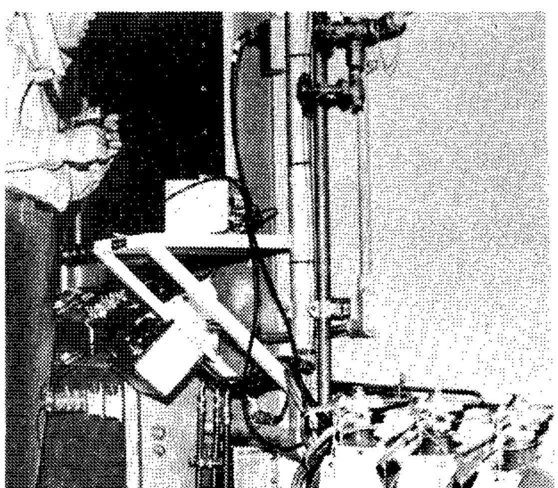


FIG. 7 EXTINGUISHERS WITH FLEXIBLE CONNECTIONS

TESTS OF AUTOMATIC SYSTEMS

Although tests conducted earlier in a small glove box (20 ft^3)[1] with squeeze-grip manual extinguishers clearly demonstrated the advantages of Halon 1301 over carbon dioxide for fires in containment systems, a prototype automatic system assembled by Fenwal was tested on the same box (Figure 8). The detector was inserted in the center of the top of the box, and the cylinder was charged with about 3/4 lb of Halon 1301. The times required for the detector to respond to the heat from n-butanol varied from 3 seconds with an 81 square-inch surface (9 in x 9 in pan) to about 30 seconds for a 7 square-inch area (3-in.-dia. cup). With two loosely wadded paper towels in the pan, the response time was about 25 seconds, and with two wadded towels in a one-pint ice cream carton (11 in^2 opening), the time was 45 seconds. There was little variation in response times for different locations of the fires in the box except when the fire was directly under the detector. Upon discharge of the Halon 1301, the time required to extinguish the fires was less than two seconds.

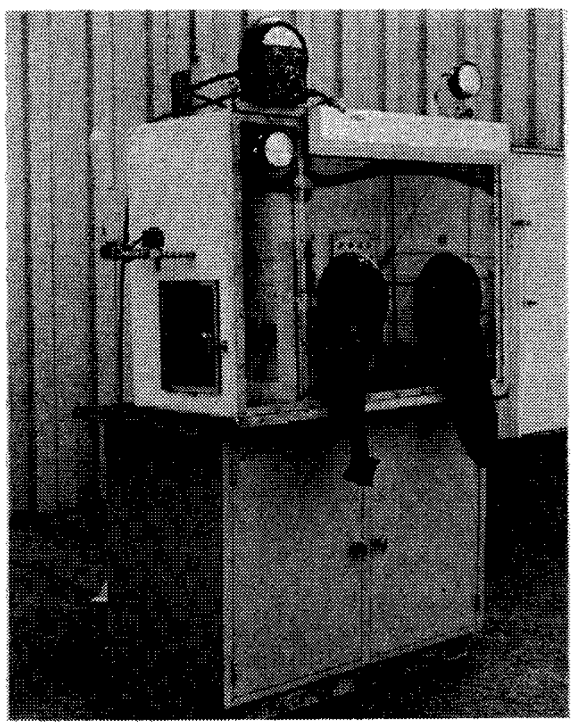


FIG. 8 PROTOTYPE AUTOMATIC FIRE EXTINGUISHING SYSTEM

REFERENCES

1. *Standards on Halogenated Fire Extinguishing Agent Systems (Halon 1301)*. NFPA Bulletin No. 12, National Fire Protection Association, Boston, Mass. (1970).

2. A. J. Hill. *Fire Prevention and Protection in Hot Cells and Canyons*. USAEC Report DP-1242, E. I. du Pont de Nemours & Co., Savannah River Laboratory, Aiken, S. C. (1971).

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