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ROCKY FLATS GLOVEBOX SAFETY STUDIES

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On May 11, 1969, a major fire occurred in the Rocky Flats plutonium fabrication facility. The severity of the fire was increased because of the design of the glovebox systems and because of the availability of a large amount of combustible materials. Since the fire, laboratory investigations and full-scale glovebox and filter plenum tests have been conducted to evaluate materials and methods of construction for glovebox systems. As a result of these tests and conclusions from the fire investigation, glovebox systems can be constructed and operated in such a way that the potential for fire is minimized and, in the event of a fire, the extent of damage and the spread of contamination can also be minimized. The safety features of glovebox systems can be considered in terms of (1) operational procedures, (2) materials of construction, and (3) design. Each of these will be discussed in terms of recent Rocky Flats' experience.

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OPERATIONAL PROCEDURES

By carefully considering and closely controlling the operating procedures, the safety of any glovebox operation can be significantly increased and the risk of fire can be appreciably decreased. Most of these considerations fall in the category of common sense; however, many times these areas are overlooked or ignored because of possible inconvenience to the glovebox operator, schedules are given a higher priority than safety, or simply because the operation has been done in a certain way for years and no one has considered that it might be unsafe or that there could be a better way of doing it. The control of operating procedures is an administrative problem rather than a technical problem and many times the people that are in a position to apply this administrative control consider this to be a lesser part of their responsibilities or tend to overlook it entirely. For these reasons, the most immediate improvements in glovebox safety can probably be made in this area of operational procedures.

The following should be considered in the operation of glovebox systems and can be administratively controlled:

1. Minimize the amount of flammable materials in and on gloveboxes. It is generally not possible to eliminate all sources of flammable materials, but in many operations the amounts can be reduced without adversely affecting the operation. One common problem is that flammables will gradually build up in gloveboxes. Therefore it is necessary to both periodically remove the unnecessary materials and also to prevent their getting into the box in the first place. Consideration must be given to both materials that are required for the operation, as for instance cutting oils, plutonium, lathe chucks, etc., and to supporting materials such as cleaning solvents, rags, containers, etc.
2. Insure that each operation is completely reviewed for safety and that procedures are established. This is a normal procedure but many times supporting operations or changes in equipment or procedures are overlooked or considered to be no different than the original methods. This is an easy trap to fall into as many small, seemingly minor changes can result in a total appreciable change which is a major safety hazard. This is exactly what happened at Rocky Flats over a period of several years and caused the 1969 fire.

3. Insure that the safety procedures are adequate and are followed. Many times insufficient attention is given to establishing safety procedures and more importantly to insuring that they are adhered to without exception. Many times convenience or schedules are favored to the detriment of safety.
4. Consider all aspects of safety in reviewing operations. Right now most nuclear operations are very concerned about fire, because of the Rocky Flats experience. Because of this emphasis on fire, it is easy to neglect other areas such as nuclear safety, industrial safety, radiation exposure, toxic or hazardous materials, etc. This is another lesson from the Rocky Flats fire in which fire safety was inadvertently given less consideration because of the emphasis on radiation protection.
5. Do whatever is necessary to assure the operating people that management is concerned about safety. This is probably the most difficult area for administrative action, but since a large part of safety is an attitude or atmosphere, it is probably the most important aspect of administrative action.

MATERIALS OF CONSTRUCTION

The second area for consideration in glovebox safety is the materials used in the construction of the systems. This is particularly important in considering fire safety.

Probably the most vulnerable material to fire on a glovebox is the gloves. They are generally located low in the box where a fire might occur and they ignite at the relatively low temperature of about 200°C. Once the box is breached, any fire in or on the box will intensify because of the increased air flow caused by the pressure differential between the inside and outside of the box. Experience and laboratory studies have shown that lead-lined gloves that have been exposed to nitric acid are particularly susceptible to fire and will spontaneously ignite. Studies are underway at Rocky Flats to find a less flammable material than neoprene or an additive to make the neoprene less flammable. To date this effort has been unsuccessful. One possible method of protecting the gloves is to provide a cover over the gloves and inside the box. Several designs have been tested, including hinged metal and asbestos cloth, which do not inhibit the movements of the operator. These covers did not prevent the gloves from burning in full-

scale fire tests, but did delay the glove burning and provided a partial cover over the hole left by the burned glove.

Another vulnerable area for attack by fire in gloveboxes is the window. Tests have shown that fire-rated wire glass or safety glass are the most resistant window materials. If gamma shielding is required, a laminate of 1/4-inch lead glass between two 1/8-inch plate glass sheets or lead glass over the wire or safety glass seems to be the most satisfactory. In some cases, glass windows are not feasible because of warpage of the box, causing the glass to crack or because glove or bag rings must be attached to the window. In these instances, a plastic window must be used and polycarbonate (Lexan or Zelux W) and Plexiglas SE-3 appear to be the best materials. Polycarbonate has some advantages in that it is more fire, impact, and chemical resistant; however, it is significantly more expensive and the small advantage may not be worth the added expense. Homalite 101 is very resistant to chemical attack, but burns with a dense black smoke which would be a major problem in fighting a fire. Caution should be exercised in using so-called fire-resistant plastics such as polycarbonate or

Plexiglas SE-3. These materials will depolymerize to give highly flammable and sometimes toxic products. In addition, they will burn after the fire retarding agents have been vaporized out of the plastic.

In addition to the window material, the method of mounting the window is important. There are generally two methods. One uses flanges and bolts to hold the gasketed window against the outside of the box. The second method (Los Alamos window) utilizes a gasket to "float" the window in a hole in the box. This second type is quickly and easily changed, but has the disadvantage of allowing the window to fall into the box if the gasket burns, thereby allowing a draft to fan the flames. At Rocky Flats, "keepers" have been installed on the inside of the box over this type of gasket to provide some fire protection for the gasket and also to prevent the window from falling into the box in the event the gasket burns.

Most operations use neoprene gaskets for glovebox windows; however, other materials such as Viton, Fluorel, and silicone are more fire and heat resistant and could be used for gasket material. The cost of each of these is appreciably greater than for neoprene and they are less available in different sizes and shapes.

Some glovebox operations require additional neutron shielding to protect the operating personnel. Various materials have been evaluated for their shielding ability and fire-resistant characteristics. Water, of course, is the best in both areas; however, there is a reluctance to use water for shielding operations involving fissionable materials. Experiments have been conducted using encased, gelled water and this appears promising. In addition to being a good shielding material, it is also transparent, so that it can be used for window shielding. Other materials evaluated include Benelex, polyethylene, paraffin, Plexiglas, water-extended vinyl ester resins, graphite, Homalite, polycarbonate and polysulfone. The evaluations included shielding efficiency, decomposition temperature and products, ignition temperature, burning characteristics and estimated installed costs. Based on the results of these tests, Benelex coated with an intumescent paint appears to be the best over-all neutron shielding material for gloveboxes. It is important that the Benelex be coated with a fire-retardant paint and also important that this paint not be further coated with decorative or easily decontaminated paint as this will negate the protection of the intumescent paint.

In addition to considering gloves, windows and shielding, all other materials used in or on gloveboxes should be reviewed for their potential flammability in the particular operation. As for instance, many tons of flammable paints may be used, flammable filters are sometimes used when equally efficient nonflammable ones are available, conveyor pendants are sometimes made from highly flammable magnesium alloys, plastics are many times used inside gloveboxes for shelves or fixtures, oils and solvents may be a source of combustible material and finally, the radioactive material contained within the glovebox may be flammable and should be handled and stored accordingly.

Consideration should be given to all of these areas during the design and operation of any glovebox system.

GLOVEBOX DESIGN

The third area for consideration in glovebox safety is the original design of the system itself. Since it is nearly impossible to completely eliminate all flammable materials from glovebox operations, the system should be designed so that, in the event of a fire, it will be rapidly detected

and a warning given; it will be confined to a local area; and it will not destroy filters or other protective systems and allow radioactivity to escape.

A study has been made on various systems which may be used for fire detection in facilities which handle radioactive materials. Variables such as location, type of protection required, action to be taken, and guidelines for the selection of a fire detecting system were considered. Following are general guidelines for fire detection systems in the plutonium areas at Rocky Flats:

1. All heat and fire detection systems be electrically supervised to indicate any problem with the system (per NFPA Code 72-D).
2. All fire detection systems be in accordance with the National Fire codes of the National Fire Protection Association.
3. Storage areas containing ingots, parts, and/or buttons be protected with at least a zone-type detection system.

4. Storage areas containing chips, briquettes, and/or skull be protected with heat detectors on each individual storage container.
5. All gloveboxes be protected with a minimum of one heat detector in the exhaust line downstream from the glovebox filter or high in the box near the exhaust path.
6. Heat detectors be placed in conveyor lines transporting or storing plutonium. Detectors should be placed inside, at, or near the top of the line. The space between sensors should be about 10 feet, if possible, but should not exceed 20 feet.
7. Buildings be divided into appropriate zones. Each zone should have an audible alarm. Each signal from a detector should:
 - a. Activate the audible alarm.
 - b. Activate a signal light on the glovebox to indicate the source of the alarm.
 - c. Report the alarm to a zone panel within the building.

- d. Report the alarm to the central fire station.
8. All heat or fire detection systems be coordinated with and approved by the Rocky Flats Fire Protection Engineer.
9. The Rocky Flats Fire Protection Engineer makes recommendations to insure the most effective use of available systems and to minimize the number of different systems installed.
10. All heat or fire detection systems be reviewed by the Rocky Flats Fire Chief prior to installation. The Fire Chief should also make recommendations for more efficient or effective systems.

Three general types of fire detection systems are in use at Rocky Flats. The first is a Fenwall fused salt detection system, used on filter plenums. Second is a Fenwall "flower pot"-type system which is used for contact applications such as cans in which plutonium is stored. The third type is a Fenwall Detect-a-Fire rate-of-rise detector which is used in glovebox ventilation systems and for area detection systems. It is important that the proper detector devices be used in ,

its intended application; that is, contact-type heat detectors are inadequate for detecting fires or heat in ventilation systems. It is also important that the fire detection device be located in such a position that it will readily detect any increase in heat. For this reason, the Detect-a-Fire system used in gloveboxes is always placed high in the box near the exhaust duct. In some applications the use of multiple types of detectors is valuable.

The filtering system for a glovebox operation is generally a particularly vulnerable area for fire damage. In general, buildings and rooms are built to withstand two hours of fire without releasing contamination; however, little thought has been given to fire protection of filter plenums and in many cases, the present design would not prevent destruction of the system by a major fire of only a few minutes. The tests at Rocky Flats have indicated that one of the more effective ways of protecting filter systems is to insure that hot air never comes in contact with the filter itself. This can be accomplished by the use of a baffle system which acts as an air diffuser, a heat sink, and when sprayed with water, as a heat transfer curtain. By using this system, a small amount of moisture will reach the filters , but will do no damage. Tests have shown that this system

can be used at a 0.25 gallon per minute per square foot of filter face for two hours with no damage to the filters. A second and simpler method of insuring that hot air doesn't reach the filters is to put a baffle directly in front of the air inlet in order to obtain a more uniform air flow and to put a water sprinkling system against the baffle and counter current to the air flow. Water sprayed directly on the filter face at volumes as low as 0.2 gallon per minute per square foot of filter face will penetrate the filters within 5 minutes or less. It is believed that if the water penetrates the filter media, it will carry any soluble plutonium with it and essentially negate the protection provided by the filters. The type of spray nozzle used to spray directly on the filter face appears to make little difference in the time of water penetration. Fog-type nozzles are more effective in completely saturating the filters, but the water flow will penetrate the filter as quickly as more coarse water droplets will. It is concluded that a sprinkling system should not be used directly on a filter face unless it is considered to be the last resort and for use only in an extreme emergency. In no case should be final stage of filtration be sprinkled.

There is some question as to the number of stages of filtration needed to insure that plutonium contamination is not released to the general public. At Rocky Flats, the general rule is for buildings containing plutonium or other radioactive materials to have at least two physically separated stages of HEPA filters on all building ventilation exhaust systems. At least four stages of HEPA filtration are provided for all glovebox exhaust systems. For processes which use finely divided plutonium or plutonium compounds, one-stage filtration is provided at glovebox exhausts to minimize particulate accumulation to ventilation ducts. Calculations have indicated that this amount of protection will insure no contamination release to the public and will provide at least one stage of emergency back-up filtration. All ventilation systems will be exhausted onto building roofs or onto the ground to minimize the spread of contamination in the event of a release. Central ventilation control systems will be provided which will include all essential and emergency indicators, alarms and controls. This panel will be located in a fire-safe enclosure, independent of the building environment and will be provided with an outside emergency exit. Fire control dampers are to be installed on all exhaust and supply.

ducts which run between contaminated and non-contaminated areas and are for use as a final emergency system in the event the filter system is destroyed.

If neutron shielding is provided on the glovebox, it should be designed in such a way that it can be quickly removed for ready access behind the shielding. Prior to the May, 1969, fire at Rocky Flats, all shielding was permanently and securely attached to the glovebox. At the time of the fire, this prevented the firemen from gaining access to the box and allowed the fire to burn and propagate on the back side of the shielding.

Glovebox windows should be designed and installed in such a way that in the event of a fire, they will not fall into the box. At Rocky Flats, when using Los Alamos-type windows (they float in a gasket), a keeper is used to provide some protection to the gasket and to insure that the window will not fall into the box in the event that the gasket burns. In long sections of glovebox lines or on gloveboxes which have potentially hazardous operations, fire doors should be provided to insure that if a fire starts, it will not propagate throughout the entire line. The transfer and storage of flammable radioactive materials such as plutonium

should be carried out in such a way that if the material does spontaneously ignite, the fire will not propagate and contamination will not be released. This can be done by storing the material in metal cans with tight lids and not in contact with any flammable material such as plastic bags or paper cartons.

Design consideration is an important factor in the safety of glovebox operations and this should be given a high priority for new facilities. Many times operator convenience or process efficiency are considered with little regard for safety. After a facility has been completed and is in operation, it is relatively easy to make major changes which will cancel any safety features that may have been included in the original design. It should be the responsibility of everyone associated with the facility to insure that this does not happen.