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UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

ATOMIC SAFETY AND LICENSING BOARD

Before Administrative Judge
Peter B. Bloch

In the Matter of THE CURATORS OF THE UNIVERSITY OF MISSOURI (Byproduct License No. 24-00513-32; Special Nuclear Materials License No. SNM-247)	Docket Nos. 70-00270 30-02278-MLA ASLBP No. 90-613-02-MLA RE: TRUMP-S Project

DECLARATION

OF

DONALD W. WALLACE

Intervenors' Exhibit 21

DS03

DECLARATION OF DONALD W. WALLACE

I, Donald W. Wallace, declare as follows:

1. I am a fire professional with over twenty-five years experience in the fire prevention and fire response field.

2. I am Captain of a NFPA-rated Class I Fire Station of the Los Angeles Fire Department. (The NFPA is the National Fire Protection Association).

3. I was appointed a Los Angeles City Firefighter in 1964; appointed Captain I in 1979; and Captain II in 198?, a position which I continue to hold.

4. I was Chairman of the Los Angeles Fire and Police Protective League, 1972-1974-1976. 1967-1969 I was Director and Secretary of Professional Firefighters, Inc. 1971-72 I was Field Representative, International Association of Firefighters. I was President of United Firefighters of Los Angeles City, Local 112, from 1971-76. I am a Life Member (one of two), United Firefighters of Los Angeles City.

5. My fire station was identified by the Rocketdyne Division of Rockwell International in its Radiological Contingency Plan as one of the fire stations "available for support in any emergency situation that may arise at the Santa Susana site," where the TRUMP-S project was originally planned to be conducted.

6. In my capacity as a private citizen, I chair the Rocketdyne Cleanup Coalition, an organization of community groups and individuals concerned with the history of accidents and radioactive and chemical contamination at Rockwell's Santa Susana site. Through this involvement, and because of item 5 above, I am familiar with issues associated with the TRUMP-S project that has now been moved to the University of Missouri.

7. The views presented here are my own alone and do not necessarily represent those of the Los Angeles Fire Department nor of any other organization with which I may be associated.

8. I have been asked to review certain assertions made by representatives of the University of Missouri concerning fire issues associated with its request to amend its NRC license to conduct the "TRUMP-S" project at its MURR facilities. My review has included relevant sections of the following documents:

University of Missouri application for license amendment for TRUMP-S
Declaration of Henry Ottinger of 14 October 1990
Affidavit of Erman Call of 24 October 1990
Affidavit of Walter A. Meyer, Jr. of 29 October 1990
Declaration of TRUMP-S Review Panel, 15 October 1990
Emergency plan for the University of Missouri Research Reactor,

reprinted December 8, 1989
Facility emergency procedures, particularly FEP 3 and 3A "Fire Procedure"
sections of Licensee's Affidavits of 14 November that deal with potential for and plans for response to fire involving TRUMP-S

9. The University's Affidavits of 24 October and 14 November make a number of claims, including: (1) that the emergency plan and associated facility emergency procedures prepared for the Missouri University research reactor prior to TRUMP-S even being contemplated are adequate for dealing with any potential TRUMP-S accident, including a serious fire, (2) that planning in advance how to fight a fire that could involve transuranic radioactive materials is neither "necessary, or would even be useful." (Meyer affidavit) (3) that in a serious fire, the smoke would be sealed within the building, or if any were released, none would be at ground level, (4) that the alpha laboratory "is constructed primarily of concrete and fire resistant materials" with virtually no combustible or flammable materials in the laboratory or basement, making a serious fire non-credible, (5) that the fire can be expected to be controlled in a "brief time period from a few minutes to ²1.2 hour" (Osetek), (6) that a serious fire would put at risk at most a small fraction of the TRUMP-S radioactive inventory, (7) that the local fire department would fight a fire in which radioactive materials were burning, and (8) that placement of the alpha lab in a basement is a positive fire safety feature. In what follows I will attempt to address these and related issues raised by the University.

10. In short, I have been asked for my professional opinion about the University's assertions about the potential for a fire at the facility which could involve the plutonium and americium and other transuranics, given the information available in the record described above, and regarding its assertions as to the need for and/or adequacy of specific fire and other emergency planning and procedures. And lastly, I have been asked regarding my knowledge of reference works or guidelines which describe proper emergency planning for radiological emergencies involving fire.

11. In my opinion, the various plans can be summarized in two words: inadequate and confusing. The Emergency Plan for the Research Reactor is standardized bureaucratic "newspeak." It is repetitive and insubstantial. It addresses no specific potential emergencies. The "Emergency Plan" is nothing more than an organizational chart and emergency classification table. It provides no plan for fighting a fire at the facility. I note further that it is on its face a plan for emergencies regarding the research reactor, was written long before TRUMP-S arrived at the University, and in no way addresses TRUMP-S. But its principal failure is that it is devoid of specific content and provides no direction for how to respond to a fire.

12. The Facility Emergency Procedures ("FEPs") in general are somewhat better and a more complete "emergency plan" than is the misnamed document referenced above. But they too are quite inadequate.

13. "FEP-3, Fire Procedure," and "FEP-3a, Control Room Response to Alpha Laboratory Fire" are each a mere one page and do not provide the necessary prefire planning and procedures that are necessitated in advance planning for fires at facilities handling radioactive materials.

14. Both fail to require that the first person to discover a fire contact the Fire Department. A basic component of good emergency planning is to prevent delays in notification of the Fire Department. Presuming that the staff at MURR are all competent adults there is no reason to encourage or require that precious moments be lost while they go through channels to report a fire. There is every reason to train all staff in the proper way to report a fire or other emergency directly to the Fire Department.

15. FEP-3, items 8 and 9, are not specific as to the potential for fires which involve radioactive materials. This important omission in both the "Emergency Plan" and the FEPs is the subject of the disagreement between Henry Ottinger and Battalion Chief Erman Call. I believe that Mr. Ottinger understood clearly the essence of his discussions with B.C. Call. I know of no fire officer who would knowingly lead or send his crew into a fire where radioactive materials were burning or being directly exposed to fire conditions.

16. The policy of the Los Angeles City Fire Department, as explained to me by two of our Hazardous Materials Squad Commanders, is to NOT fight fire in these conditions. The proper job for the Fire Department under those conditions is to evacuate people downwind from the fire. The L.A.F.D. has a computer and a program to forecast probable toxic plumes downwind from such an incident. No firefighters in Los Angeles are issued protective clothing or breathing apparatus which protects them from the radiation hazards which can be expected from fires in or directly exposing radioactive materials. To the best of my knowledge no such protective clothing is issued to members of the Columbia Fire Department. The National Fire Protection Association Manual states explicitly:

> Fire fighters and other emergency personnel operating in areas where radiation exposure is a danger must be fully trained and provided with suitable protective clothing.

NFPA Manual, 16th edition, p. F-9, attached, emphasis added

16. The materials presented to date do not demonstrate that the Columbia Fire Department has the equipment and training specified in the NFPA Manual as necessary for response to fires at facilities handling radioactive materials. The minimal emergency planning documents put forward by the University certainly do not so demonstrate.

17. In short, most fire departments are not equipped to fight fires in facilities with severe radiation hazards. The elements of the MURR plan which describe technicians with radiation monitoring devices accompanying firefighters in their approach to the seat of the fire presume that no radiation, or extremely low levels of radiation will be detected. Although it is never stated, it is clear from the context of the plans and in Battalion Chief Call's affidavit that NO firefighting will take place if the MPC is detected. I expect that downwind evacuation would be the incident Commander's operational goal if ANY airborne radioactivity were present.

18. Some additional issues are raised by my review of the affidavit of Walter A. Meyer, Jr.

19. The separation of the emergency plan into on-site (FEP) and off-site (SEP) elements is poorly planned and unnecessarily complicated. The Columbia Fire Department is the primary agency with responsibility for both fire and emergency medical incidents whether those incidents involve radioactive materials or not. There are no instructions for notification of the Fire Department in any FEP but #3. The "Emergency Class" and "Action Levels" in the Emergency Plan are inadequate for effective Fire Department response. The Fire Department should be called on EVERY fire and on most emergency medical incidents beyond simple first aid needs. The lack of recognition in the planning documents of these needs discloses a plan for disaster rather than a disaster plan.

20. As previously noted, the discussion of the role of the Columbia Fire Department fails to mention the possibility that radiological assessment of the area may reveal radioactive contamination above the limits any sensible Incident Commander would order his crews to approach. This planning failure is evident throughout the documents I reviewed.

21. The discussion of the design features of the Alpha Lab leave me with several questions from a firefighting point of view?

a. What is the "fire load" in the lab and MURR basement? In other words, What is combustible? What is the size and distribution of combustibles? What are the fire and smoke characteristics of the combustibles?

b. Does the lab and MURR basement have fire sprinklers or other automatic fire suppression equipment? An automatic sprinkler system is required by the Los Angeles Building Code for all basements in commercial or industrial properties in Los Angeles. The NFPA standard for facilities handling radioactive materials also mandates them. I see no mention of a sprinkler system for the Lab and MURR basement in any of the documents I reviewed. The provision of various types of fire extinguishers is prudent but certainly not an adequate substitute for automatic sprinklers. I saw no mention that Lab personnel have been trained in the selection and proper use of fire extinguishers. I saw no mention of extinguishers designed for Class A fires (ordinary combustibles).

c. What are the avenues of toxic or radioactive smoke spread during a fire? The description of the location and construction features of the Lab would have one believe that a below grade concrete box with three openings is an ideal containment area for fire and smoke. Quite the contrary, basement fires are among the most dangerous and difficult fires known. Extremely high temperatures, inefficient combustion and consequent dense smoke with high levels of carbon monoxide rising through the only access points are hallmarks of basement fires. Both the emergency plan and Mr. Meyer's affidavit reveal a very poor understanding of necessary fire related design features and appliances for basement laboratories. The description of the rubber gasketed doors and the various windows are offered as safety features. The windows and rubber gaskets would be very likely to fail under fire conditions where the temperature would easily exceed 2000 degrees F, perhaps reaching 3000.

The need to confine and control the spread of potentially radioactive smoke is directly contradicted by the need to ventilate the intense heat and dense smoke usually encountered in basement fires. I can only conclude that an unsprinklered basement is a very poor location for a process involving radioactive materials.

The placement of the alpha lab in such a location violates two of the key NFPA recommendations: automatic sprinkler systems for facilities involving radioactive materials, and placement of them in one-story buildings without basements. (see NFPA Standard 801, attached).

d. The discussion of the dry (floodable) fire system is incomplete. Is the system a Class I, Class II, or Class III system? Was it designed for occupant use or Fire Department use? Is it properly sized and equipped for the fire load in the Lab and basement? Is there an adequate water supply from nearby hydrants or other sources to supply the dry system?

e. At no time in either the reactor emergency plan or in Mr. Meyer's affidavit is there a discussion of the possibility that radioactive materials might become airborne as a result of exposure to fire. There is much discussion of monitoring and assessment capability but never a discussion of what the MURR response team and the Fire Department are to do if this vaunted capability shows a positive and dangerous radioactive reading. Mr. Meyer seems to be saying that there is no combination of fire and radioactivity circumstances where the Fire Department would refuse to enter the burning Lab. That is not a position supported by a careful reading of Chief Call's affidavit. This is another serious deficiency in the emergency plan and tells me that I am reading puffery--not planning.

22. The discussion of airflow in buildings contained in the October "Declaration of the TRUMP-S Review Panel" at pages 24-25 is instructive but somewhat limited if it accurately describes the position of the University representatives that the basement will become a "dead space" and smoke will remain within the building. In fact, products of combustion and heated air behave very much like the same volume and pressure of normal air. Pressure increases with temperature and since the volume of the confining structure does not increase, the fire gases will find an avenue of escape. Under normal fire conditions the gases in a room will increase by three times or more. In a concrete basement, the expansion factor will be higher because of the higher than average temperatures. The smoke will not be contained within the building--that doesn't happen in real fires. It will pour out, through every opening it can find. My review of the materials makes clear to me that the release of smoke from the MURR basement will be primarily a ground level release--through the freight elevator shaft and up the stairs and under closed doors or through doors that are opened. (The university representatives seem to misunderstand the purpose of fire doors; they are designed to delay penetration of flame, not prevent outgasing of pressurized smoke-filled air. Furthermore, as indicated below, they are either going to be propped open in order to ventilate the fire; if a very mild fire, then repeatedly opened and closed as fire and other personnel enter and leave the affected areas; or, if kept closed, it will be because the Fire Department has chosen to not fight the fire.)

23. A basic misunderstanding of Fire Department ventilation practices is also evident in the university documents I reviewed. We ventilate to allow the heat to dissipate so that we can approach the seat of the fire. An ancillary benefit is increased visibility. No human, even a human encased in firefighter protective clothing, can tolerate ambient temperatures which are present in fully involved ordinary room fires. A fire in an unsprinklered basement with the fire doors closed will be untenable. The fire will have to be allowed to burn itself out or ventilation will have to be effectuated by the firefighters to allow them to get to the seat of the fire. There are no alternatives to these two choices.

24. And when I speak of ventilation by firefighters to get the heat down and visibility up so that they can approach the seat of the fire, I do not mean turning on the building ventilation, which is rightly to be turned off pursuant to the MURR emergency procedures and which cannot be relied upon anyway in a fire which likely is destroying much of the building wiring. Firefighters fighting such a basement fire would bring their own specialized high-pressure fans, open the doors to the facility, and either pull smoke out of one entrance to the basement or push it out by pressurizing the other entrance. My review of the basement drawings suggests that the logical response would be to place the fire department fans at the door to the cooling tower area and push the smoke through the basement and out the other set of doors, those at the top of the main steps to the basement. As smoke is expelled and temperatures decline, firefighters could slowly advance toward the seat of the fire.

25. Because of the failure to follow NFPA recommendations and going ahead and placing this radioactive materials laboratory in a basement, the fire department would be left with these two choices: let the fire burn itself out, which could take many hours and would result in the smoke from the fire (and potentially radioactivity) pouring out of the building from all the penetrations it can find, primarily at ground level; or providing forced ventilation from one entrance of the basement, forcing the smoke out the other. In either case, the air in the basement will be forced out at ground level.

26. As to the reference materials available to support my discussion and conclusions, the FIRE PROTECTION HANDBOOK, 16th Edition, published by the National Fire Protection Association (NFPA), has a good overview of all the subjects discussed above and an extensive bibliography of source materials. The NFPA is widely recognized in the fire service as the organization with the best available information on fire protection practices. Every Fire Department with which I am familiar uses NFPA Standards for operational practices as well as Fire and Building Codes. A thorough knowledge of the "Handbook" is a prerequisite for promotion to officer ranks in most Fire Departments. There is a wealth of information concerning every aspect of fire and life safety from basic fire chemistry to design and prevention. All these issues bear directly on MURR's application for a NRC license and should be studied prior to a decision. The most pertinent chapters are: Smoke Movement in Buildings; and Nuclear Reactors, Radiation Machines, and Facilities Handling Radioactive Materials.

27. One gathers from a review of the Emergency Plan and the affidavit of Mr. Meyer that the attitude of the University is that in case of a fire at

the nuclear facility, just call the local fire department. No preplanning is necessary as to what they should do; fighting a fire involving radioactive materials is assertedly no different than what local fire departments do routinely anyway. Mr. Meyer goes so far as to say:

> Intervenors seem to be concerned that there is no explicit procedure spelling out exactly how a fire involving radioactive materials, particularly transuranics, would be fought, or what a fire fighter should do. Intervenors' Written Presentation at 49. They are simply mistaken in their apparent belief that such a prescriptive procedure is necessary, or would even be useful.
>
> Meyer Affidavit, at p. 15

Mr. Meyer could not be more wrong. Perhaps the best response to his very dangerous view is found in the NFPA Handbook chapter on nuclear facilities, in the section entitled "Plan for Handling Fires":

> In plants involving a nuclear reactor, radiation machines, and in other facilities handling radioactive materials, the problems affecting decisions on how best to deal with a fire or other emergency <u>are not those types of problems that can be solved by simply calling the public fire department.</u> As many decisions as possible must be made with respect to the types of fire or emergency to be expected--<u>and these decisions must be made well in advance.</u>
>
> NFPA Handbook, 16th edition, p. F-9, emphasis added

The importance of automatic sprinkler systems is also made clear in the Handbook, as is the necessity of preparation for the collection and disposal of potentially contaminated water generated in the fire fighting process:

> Automatic sprinkler systems or specially designed piped water spray systems are the first choice for fire protection in any location where fires may occur in nuclear reactor plants, properties housing radiation machines, and facilities handling radioactive materials. Sprinklers can operate with full effectiveness under radiation or contamination conditions that would make approach by fire fighters impossible.
>
> In spaces where water used in fire fighting would be subject to possible contamination, the collection and disposoal of this water must be provided for in the local facilities; this means the facilities should have water-proofed floors and controlled floor drainage. Substantial capacity of such drainage systems would be required if hose streams and manual fire fighting were necessary. By contrast, sprinklers or a specially designed spray system would require relatively modest amounts of water for fire fighting.

The NFPA also issues special standards, such as NFPA Standard No. 801, "Recommended Fire Protection Practice for Facilities Handling Radioactive

Materials." I have attached NFPA-801, with certain passages emphasized. For example,

> Automatic sprinkler protection provides the best means for controlling fires involving combustible occupancies and should be provided unless it can be shown that their operation will definitely create a situation more hazardous than that brought about by uncontrolled fire.

And note that NFPA-801 recommends that buildings in which radioactive materials are to be used should "be of single-story height without basements or other below-grade spaces."

Thus, the placement of the alpha lab in an apparently unsprinklered basement goes against both recommendations standards of good practice.

Furthermore, NFPA-801 makes clear that construction in such facilities should be of limited combustible or noncombustible materials. A cursory reading of the materials presented by the University would suggest that the alpha lab is solid concrete, with no combustible or flammable materials permitted in it or in the MURR basement where it is located. A closer reading by a trained professional indicates that that is not the case. In fact, the alpha lab is of wood construction, employing a large amount of lumber, with the interior finished with drywall. I have done a preliminary estimate of the amount of lumber utilized, and it is a substantial fire load.

In addition, the MURR basement where the alpha laboratory is located houses flammable hydraulic oil, barrels of combustible radioactive wastes awaiting transfer, and numerous other fire loadings.

Additionally, a natural gas line runs through the basement, approaching to within 15 feet of the alpha laboratory.

There is nothing in this situation that would make a firefighter feel confident that a major fire was unlikely. A gas leak leading to a gas explosion, breaking the alpha lab and glove box windows and igniting all the flammable and combustible materials in the basement is just one such scenario. Smoldering cigarettes dumped into a waste cannister is another. A mistake with a acetylene or similar torch is another. Arson is another. Any of the multitude of traditional causes of fires could cause a fire that could involve the alpha lab.

Fire requires oxygen, heat, and fuel. The MURR basement has plenty sources of all three. And if a fire started anywhere within the basement, it could readily spread and engulf all combustible and flammable materials throughout the facility. The wood of the alpha lab would be readily ignited, and everything inside it and near it placed at risk. The transuranics in the storage drawer would also readily be placed at risk, given the intense temperatures such basement fires can produce.

Mr. Meyer says that, "In effect, the Alpha Laboratory is entombed inside a concrete vault isolated from the rest of the facility." In reality, the Alpha Lab is itself composed of a large quantity of highly combustible material, enclosed in a concrete oven that would substantially increase the temperatures in a fire and make firefighting extremely difficult. The alpha lab is essentially a small wood-frame house in a concrete oven--a significant fire hazard. The presence of radioactive materials makes the hazard extraordinary.

I note that the minutes of the February 14, 1990 Isotope Use Subcommittee state: "Smoke alarms for the rest of (MURR) besides the alpha lab) would be desirable, but are not affordable right now." Coupled with the lack of automatic sprinkler systems for the basement, the lack of smoke alarms elsewhere in the facility, where the fire could first start and then spread, seems a serious safety defect.

I wish to reiterate that smoke (and any attendant radioactivity) would escape the building at ground level. As the Review Panel points out, this is contradicted by the University's own emergency procedures, which mandate that the exhaust system be secured in a fire or other emergency, including closure of dampers. (See, for example, FEP-3a, Intervenor's Exhibit 12 in its October written presentation). Furthermore, even were this not done, smoke would rapidly clog the filters and either block that passageway or force the smoke to bypass the filters, losing the radioactivity filtration hoped for by Dr. Morris.

Conclusion

It is my conclusion, based upon my review, that:

a. A major fire that could involve the TRUMP-S radioactive materials is a real possibility over the time period in which those materials can reasonably be expected to exist on the university property.

b. Such a fire could be very severe.

c. Despite assertions to the contrary by the Applicant's witnesses, the alpha laboratory itself is constructed of a large quantity of combustible materials, and there is a considerable additional fire loading throughout the facility in which the laboratory is located.

d. Despite assertions to the contrary, the construction of this laboratory in a basement is a major fire hazard and violates strong recommendations by the National Fire Protection Association that such facilities not be constructed in buildings with basements. A basement fire will be extremely difficult to fight, with considerably elevated temperatures and a host of additional problems that will complicate and frustrate and delay successful control of the fire.

e. Essentially what the Applicant has done is construct a small, wood-frame house in a concrete oven. Heat from the burning combustibles will be re-radiated by the concrete walls, substantially increasing the heat to 2000 to 3000^{O}F. The fire will be very much more difficult to fight, reach higher temperatures, and likely take very much longer to bring to control, than would be a fire in a similar laboratory that had followed NFPA recommendations not to construct such radioactive materials labs in basements. (NFPA-801)

f. In such a basement fire, the entire basement will fill with intense smoke; pressures at least three times normal will result from the heat; and smoke will pour out of the building, at ground level. It is my view that it is non-credible to assume that the primary path of escape will be an exhaust system which the emergency plans rightly call to be shut down in an accident, sealed with dampers.

g. Prefire planning is essential in such a case, and the failure to conduct detailed procedures for fighting a fire involving radioactive materials is a serious deficiency in the MURR situation.

h. The MURR Reactor Emergency Plan is inadequate for protecting against incidents involving the TRUMP-S project.

i. A fire at MURR involving the TRUMP-S materials could realistically take several hours or more to contain, or burn itself out, depending upon whether the firefighters chose to fight the fire or primarily evacuate people downwind.

j. Fire prevention and response precautions are seriously inadequate.

k. Placement of this project in a wood-construction lab in an apparently unsprinklered basement is, I repeat, a recipe for disaster.

l. In estimating release fractions for the plutonium, americium and other transuranics in a serious fire of the sort credible for this facility, one should look at the high end of experimental data on release fractions in fire, because a basement fire in this situation could be long-lasting, high in intensity, and involve violent air currents.

I declare under penalty of perjury that the foregoing is true and correct.

Donald Wallace

dated this 24th day of December, 1990,
at CALABASAS, California

ily engaged in radiation work should not be subjected to unreasonable radiation levels; also a person outside the installation should not be subjected to excessive radiation level exposure through contact with radioactive waste or by other means. Air should be monitored continuously for the presence of radiation from fixed sources or from airborne radioactive matter. In emergencies, alarms should sound, and radiation levels be recorded by available commercial instruments.

Fire Department Radiation Exposures

Emergency exposures are usually allowed to exceed those tolerable to persons who work continuously with radioactive materials. In an emergency case, such as a necessary rescue operation, it is considered acceptable for the exposure to be raised, within limits, for single doses. The National Council on Radiation Protection and Measurement has recommended that in a life saving action, such as search for and removal of injured persons or for entry to prevent conditions that would injure or kill numerous persons, the planned dose to the whole body should not exceed 100 rems. During less stressful circumstances, where it is still desirable to enter a hazardous area to protect facilities, eliminate further escape of effluents, or control fires, it is recommended that the planned dose to the whole body should not exceed 25 rems. These rules may be applied to the fire fighter for a single emergency; further exposure is not recommended. Internal radiation exposure may be guarded against by adequate respiratory equipment.

External exposure at the time of a single fire emergency can be judged by the use of commercial radiation survey meters which measure radiation in roentgens or by counted disintegration rates, or by the close observation of the dosimeter indicators carried by individuals. Pocket sized dose rate alarms, which can be carried on the person, are also available. These give an audible signal dependent upon the radiation intensity. Film badges do not provide immediate information.

A rescue procedure which would combine external and internal radiation exposure is usually not attempted. Self-contained breathing apparatus should be used when instruments indicate the presence of any airborne radiation.

FIRE PROTECTION

As noted previously, substances and operations involving radioactive substances or devices presenting radiation hazards have the same fire and explosion features as those of similar materials and operations without radiation hazards. The loss caused by fire, explosion, and accident is affected by the presence of radiation or of radioactive substances in the following ways:

1. Possible interference with manual fire fighting due to the presence of harmful radiation or possible criticality of radiation levels.
2. Possible increased delay in salvage and in normal resumption of operations due to the necessity of decontamination of buildings, equipment, or materials.

Contamination of Property

Entire buildings, land, and important equipment can be rendered unusable for long periods of time because of severe radioactive contamination from the accidental escape of radioactive substances.

Radiological contamination may not stay in one area—it can sift through openings or ventilating systems in the form of dust or vapor, and spread the radioactive material throughout a structure. Careless movement of persons through a contaminated area could also spread contamination to an uncontaminated area.

Once a surface has become contaminated, a decision must be made as to how the particular contaminating material is to be removed, if this is possible. Vacuum cleaning can sometimes be used to remove radioactive dust from building surfaces. If vacuum cleaning is used, however, absolute filters must be used on the exhaust. Hosing with water can be used on some surfaces. Cleaning with soap and detergents is often a hand operation which must be carried out with continuous checks on the amount of exposure that may be tolerated by the persons doing the cleaning. Sand or vacuum blasting can be used on some surfaces and paint may cover alpha contamination.

Plant Fire Protection Organization

In properties where atomic energy is a factor, an in plant fire protection force is recommended. In nuclear reactors and many other such plants, 24 hr/day routines must be maintained for handling fires and emergencies.

Plan for Handling Fires

In plants involving a nuclear reactor, radiation machines, and in other facilities handling radioactive materials, the problems affecting decisions on how best to deal with a fire or other emergency are not those types of problems that can be solved by simply calling the public fire department. As many decisions as possible must be made with respect to the types of fire or emergency to be expected—and these decisions must be made well in advance. The particular fire fighting and personnel safety measures to be taken may involve shutting down or isolating parts of the plant or individual equipment items. The areas where special procedures are necessary must be identified and the procedures for these special areas thoroughly understood by all plant/facility personnel.

Fire/emergency arrangements include provisions for prompt notification of the public fire department, usually through a public fire alarm signal box. However, the plant fire protection department must preplan fire fighting operations with the local fire department so that the local department will be properly coordinated with the plant's own emergency plans. Emergency planning should include measures to prevent the spread of contamination and to promptly decontaminate the area in case of accidental release of radioactive substances.

Fire fighters and other emergency personnel operating in areas where radiation exposure is a danger must be fully trained and provided with suitable protective clothing. Respiratory protective equipment is a must, and competent radiological advisors, equipped with instruments for measuring area and local exposure, are necessary to guide emergency personnel. Dosimeters or other instruments for recording each individual's accumulated radiation exposure are helpful.

A nuclear reactor site must have a generous water supply to facilitate fire control and decontamination operations. Facilities must also be prearranged for safe disposal

INTERVENORS EXHIBIT 21, ATTACHMENT I

or storage of water that may be contaminated. The use of noncombustible materials for reactor buildings and equipment will help to avoid complications of fire hazards. For example, all finish materials used for decorative, acoustical, or insulation purposes should both be noncombustible and easy to decontaminate.

The hazard of a reactor structure exposing other buildings to radiation is prevented by appropriate distance separation or fire barriers. To prevent exposure to the reactor, it is always appropriate to separate shops and service spaces from the reactor equipment and structure itself. Wiring ducts in floors introduce an opportunity for the spread of fire or of contaminated liquid or gas from one space to another. Good duct seals separate one space from another. Subassembly or other operations in the preparation of fuel elements for reactors is carried on in work areas separated from the reactor in such a way that fire cannot reach the reactor space.

Equipment for Fighting Fires

Automatic sprinkler systems or specially designed piped water spray systems are the first choice for fire protection in any location where fires may occur in nuclear reactor plants, properties housing radiation machines, and facilities handling radioactive materials. Sprinklers can operate with full effectiveness under radiation or contamination conditions that would make approach by fire fighters impossible.

In spaces where water used in fire fighting would be subject to possible contamination, the collection and disposal of this water must be provided for in the local facilities; this means the facilities should have waterproofed floors and controlled floor drainage. Substantial capacity of such drainage systems would be required if hose streams and manual fire fighting were necessary. By contrast, sprinklers or a specially designed spray system would require relatively modest amounts of water for fire fighting.

If a fire occurs in a containment vessel during construction, the difficulties of access and visability warrant the provision of temporary fixed automatic extinguishing systems when combustibles cannot be effectively controlled. Temporary interior hose stations and an ample supply of portable extinguishing equipment should be within easy reach in all portions of the vessel. Because of the smoke confinement potential, only very fast manual response may be effective, hence the available manual fire fighting equipment should be in excess of normal construction practice to insure the earliest response.

Incompatible Materials

Careful design analysis is required to reduce the fire protection problems inherent in the use of materials that are incompatible in fire situations. As an example, the contemplated use of liquid metal as a reactor coolant/moderator requires special extinguishing systems not compatible with water; in fact, the possibility of a water-liquid metal reaction may justify the exclusion of water systems from the area. If such a decision is made, however, it imposes severe limitations on the presence of flammable oils, plastics, foam insulations, and other materials that generally require copious quantities of water for fire extinguishment. Where such mixed hazards exist, it is imperative that careful consideration be given to the potentials for a failure in one system to cause a failure in the incompatible system. In such cases, either protection systems must be provided that can ensure the extinguishment of fire in either system before it can cause a rupture of the other system, or a single protection system (such as inerting) must be developed that is adequate for either hazard. The difficulties inherent in such problems warrant the most thorough hazards analysis at the earliest design stages.

Bibliography

NFPA Codes, Standards, Recommended Practices and Manuals. **(See the latest *NFPA Codes and Standards Catalog* for availability of current editions of the following documents.)**

NFPA 10, *Standard for Portable Fire Extinguishers.*
NFPA 48, *Standard for the Storage, Handling and Processing of Magnesium.*
NFPA 72E, *Standard on Automatic Fire Detectors.*
NFPA 220, *Standard on Types of Building Construction.*
NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials.*
NFPA 259, *Standard Test Method for Potential Heat of Building Materials.*
NFPA 481, *Standard for the Production, Processing, Handling and Storage of Titanium.*
NFPA 482, *Standard for the Production, Processing, Handling and Storage of Zirconium.*
NFPA 801, *Recommended Fire Protection Practice for Facilities Handling Radioactive Materials.*
NFPA 802, *Recommended Fire Protection Practice for Nuclear Research Reactors.*
NFPA 803, *Standard for Fire Protection for Light Water Nuclear Power Plants.*

Additional Readings

UL 586, *Test Performance of High Efficiency Particulate, Air Filter Units*, Underwriters Laboratories Inc., Northbrook, IL.
ASTM E136, *Standard Test Method for Behavior of Material in a Vertical Tube Furnace at 750°C*, American Society for Testing and Materials, Philadelphia, PA.
IEEE 383, *Standard for Type Test of Class IE Electric Cables, Field Splices and Connections for Nuclear Power Generating Stations*, Institute of Electrical and Electronic Engineers, New York, NY.
NCRP 30, *Safe Handling of Radioactive Materials-NBS Handbook 92*, The National Council on Radiation Protection and Measurement, 1964.
NCRP 38, *Protection Against Neutron Radiation*, The National Council on Radiation Protection and Measurement, 1971.
NCRP 39, *Basic Radiation Protection Criteria*, The National Council on Radiation Protection and Measurement, 1971.
Standards of the U.S. Nuclear Regulatory Commission, Code of Federal Regulations, Part 20, Chapter 1, Title 10, U.S. Government Printing Office, Washington, DC.
Nuclear Safety, (bimonthly), U.S. Government Printing Office, Washington, DC.

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NFPA 801

Recommended Fire Protection Practice for

Facilities Handling Radioactive Materials

1986 Edition

This edition of NFPA 801, *Recommended Fire Protection Practice for Facilities Handling Radioactive Materials*, was prepared by the Technical Committee on Atomic Energy, and acted on by the National Fire Protection Association, Inc. at its Fall Meeting held November 18-20, 1985 in Baltimore, Maryland. It was issued by the Standards Council on December 10, 1985, with an effective date of December 30, 1985, and supersedes all previous editions.

The 1986 edition of this document has been approved by the American National Standards Institute.

Origin and Development of NFPA 801

The Committee on Atomic Energy was organized in 1953 for the purpose of providing the fire protection specialist with certain fundamental information about radioactive materials and their handling, and to provide designers and operators of such laboratories with some guidance on practices necessary for fire safety. The first edition of NFPA 801, whose coverage was limited to laboratories handling radioactive materials, was adopted at the 1955 NFPA Annual Meeting.

In 1970 the format was revised, and it was updated to reflect current thinking and practices. It was also expanded to apply to all locations, exclusive of nuclear reactors, where radioactive materials are stored, handled, or used.

The 1975 edition was a reconfirmation of the 1970 edition with editorial changes.

The 1980 edition included a clarified statement regarding the presence of and levels of radiation; cautionary statements about the assumption of risks by the fire officer and the importance of training in the handling of radioactive materials by fire department personnel; a clarification concerning the variations of the intensity of a radiation field; and a restyling of the document to conform with the NFPA Manual of Style.

The 1985 edition revises and updates previous material for clarification in recognition of technology and terminology changes.

INTERVENORS EXHIBIT 21, ATTACHMENT 2

Natl. Fire Protection Assn.
standard No. 801

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This list represents the membership at the time the Committee was balloted on the text of this edition. Since that time, changes in the membership may have occurred.

NOTE: Membership on a Committee shall not in and of itself constitute an endorsement of the Association or any document developed by the Committee on which the member serves.

Contents

NFPA 801

Recommended Fire Protection Practice for

Facilities Handling Radioactive Materials

1986 Edition

Information on referenced publications can be found in Chapter 7.

Chapter 1 Introduction

1-1 Scope. This text deals with practices aimed at reducing the risks of fires and explosions at facilities handling radioactive materials and also with certain methods for minimizing personnel hazards and property damage by radioactive contamination resulting from fire or explosion. The recommendations are applicable to all locations, exclusive of nuclear research or power reactors, where radioactive materials may be stored, handled or used, including hospitals, laboratories, and industrial properties.

1-2 Purpose. The nature of radioactive materials is such that their involvement in fires or explosions can act to impede the efficiency of fire fighting personnel, thus resulting in increased potential for damage by radioactive contamination.

This text is prepared to provide an outline for the fire protection specialist, including fire service personnel, of basic information concerning radiation protection methods, and provides some guidance on fire protection practices to those persons responsible for the design or operation of facilities which involve the storage, handling, or use of radioactive materials.

Additional specific requirements for nuclear reactors are delineated in NFPA 803, *Standard for Fire Protection for Light Water Nuclear Power Plants*; and recommendations for research reactors are described in NFPA 802, *Recommended Fire Protection Practice for Nuclear Research Reactors*.

All other applicable NFPA codes, standards, and recommended practices should be followed.

1-3 Definitions.

Approved. Acceptable to the "authority having jurisdiction."

NOTE: The National Fire Protection Association does not approve, inspect or certify any installations, procedures, equipment, or materials nor does it approve or evaluate testing laboratories. In determining the acceptability of installations or procedures, equipment or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization concerned with product evaluations which is in a position to determine compliance with appropriate standards for the current production of listed items.

Authority Having Jurisdiction. The "authority having jurisdiction" is the organization, office or individual responsible for "approving" equipment, an installation or a procedure.

NOTE: The phrase "authority having jurisdiction" is used in NFPA documents in a broad manner since jurisdictions and "approval" agencies vary as do their responsibilities. Where public safety is primary, the "authority having jurisdiction" may be a federal, state, local or other regional department or individual such as a fire chief, fire marshal, chief of a fire prevention bureau, labor department, health department, building official, electrical inspector, or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the "authority having jurisdiction." In many circumstances the property owner or his designated agent assumes the role of the "authority having jurisdiction"; at government installations, the commanding officer or departmental official may be the "authority having jurisdiction."

Combustible. Any material which does not comply with the definition of either noncombustible or limited combustible.

Fire Prevention. Measures directed towards avoiding the inception of fire.

Fire Protection. Methods of providing for fire control or fire extinguishment.

Labeled. Equipment or materials to which has been attached a label, symbol or other identifying mark of an organization acceptable to the "authority having jurisdiction" and concerned with product evaluation, that maintains periodic inspection of production of labeled equipment or materials and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

Limited Combustible. As applied to a building construction material, a material, not complying with the definition of noncombustible material, that in the form in which it is used has a potential heat value not exceeding 3500 Btu per lb (8.14×10^6 J/kg) (*see NFPA 259, Standard Test Method for Potential Heat of Building Materials*), and complies with one of the following paragraphs (a) or (b):

(a) Materials having a structural base of noncombustible material with a surfacing not exceeding a thickness of ⅛ in. (3.175 mm) that has a flame spread rating not greater than 50.

(b) Materials, in the form and thickness used, other than as described in (a), having neither a flame spread rating greater than 25 nor evidence of continued progressive combustion, and of such composition that surfaces that would be exposed by cutting through the material on any plane would have neither a flame spread rating greater than 25 nor evidence of continued progressive combustion, as tested in accordance with NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials*.

Materials subject to increase in combustibility or flame spread rating beyond the limits herein established through the effects of age, moisture, or other atmospheric condition shall be considered combustible.

Listed. Equipment or materials included in a list published by an organization acceptable to the "authority having jurisdiction" and concerned with product evaluation, that maintains periodic inspection of production of listed equipment or materials and whose listing states either that the equipment or material meets appropriate standards or has been tested and found suitable for use in a specified manner.

NOTE: The means for identifying listed equipment may vary for each organization concerned with product evaluation, some of which do not recognize equipment as listed unless it is also labeled. The "authority having jurisdiction" should utilize the system employed by the listing organization to identify a listed product.

Noncombustible. A material which, in the form in which it is used and under the conditions anticipated, will not aid combustion or add appreciable heat to an ambient fire. Materials when tested in accordance with Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750 °C (1382 °F), ASTM E136, and conforming to the criteria contained in Section 7 of the referenced standard shall be considered as noncombustible.

Should. Indicates a recommendation or that which is advised but not required.

Units. Metric units in this document are in accordance with the International System of Units which is officially abbreviated SI in all languages. For a full explanation see the Metric Practice Guide, ASTM E380; ANSI Z210.1.

Chapter 2 Sources of Radiation — The Nature of the Fire Problem

2-1 General.

2-1.1 Radioactive materials are substances which spontaneously decay, emitting energetic rays or particles in the process. Certain elements occur in more than one form. The various forms are chemically identical, but differ in their atomic weights. These different forms of the same elements are called isotopes. Those which are radioactive are called radioactive isotopes. It is possible for an element to have one or more nonradioactive (stable) isotopes and one or more radioactive isotopes (radionuclides). Each of the radioisotopes emits a definitive type or types of radiation. In discussing radioactive material, therefore, it is always necessary to use the terminology which identifies the particular isotope, such as uranium-238 or, alternatively, 238 uranium.

2-1.1.1 Some radioisotopes occur in nature and may be separated by various physical or chemical processes and others are produced in particle accelerators or nuclear reactors.

2-1.1.2 Emissions from radioactive materials cannot be detected directly by any of the human senses. Of themselves, radioactive materials present no unusual fire hazards as their fire characteristics are no different from the fire characteristics of the nonradioactive form of the same element.

2-1.1.3 The presence of radioactive materials may complicate a fire fighting situation by presenting hazards of which the fire fighter may be unaware and may cause real or imagined hazards to fire fighters, which may inhibit normal fire fighting operations. The dispersal of radioactive materials by fumes, smoke, water, or by the movement of personnel may cause a radiation contamination incident which may contribute greatly to the extent of damage, complicate cleanup and salvage operations, and delay the restoration of normal operations.

2-2 Fire Problems.

2-2.1 Facilities handling radioactive materials should be designed and operated with special recognition given to the properties of radioactive materials. The effects of the presence of radioactive substances upon the extent of loss caused by fire or explosion are:

(a) Possible interference with manual fire fighting due to the fear of exposure of fire fighters to radiation.

(b) Possible increased delay in salvage work and in resumption of normal operations following fire, explosion, or other damage due to radioactive contamination and the consequent need for decontamination of buildings, equipment, and materials.

(c) Possible increase in the total damage resulting from contamination of buildings and equipment to the point that they are unusable.

2-2.2 Radioactive materials may be expected to melt, vaporize, become airborne, or oxidize under fire conditions. None of these alterations will slow down or halt the radioactivity. It is conceivable that certain radioactive materials under fire conditions might be converted to radioactive vapor or oxidized to a radioactive dust or smoke. This dust or smoke could be carried by air currents and subsequently deposited on other parts of the burning buildings or even on neighboring buildings or land. These loss and personal injury aggravating characteristics of radioactive materials justify a high degree of protection against fire and explosion at those facilities where this potential exists. The use of fire resistive building components and equipment is highly desirable in those areas where radioactive materials a[illegible] be stored or used. Some form of automatic protection, such as automatic sprinklers, would be highly advantageous wherever combustibles are encountered. The installation of automatic extinguishing systems will make it less necessary for personnel to expose themselves to possible danger, will start the fire control process automatically, will sound an alarm and make efficient use of the available water supply. However, caution should be exercised to assure that the hazards of criticality and reactivity be considered.

2-2.3 Some commonly encountered radionuclides are pyrophoric (e.g., plutonium) and, as such, should be given special consideration. Radionuclides generate heat and may have to be cooled in storage; these too require special consideration.

2-2.4 In view of the possibility of the spread of radioactive materials during a fire, certain precautions and procedures should be incorporated into emergency planning for fire fighting operations.

2-2.4.1 The property manager should keep the local fire department advised of the locations and general nature of radioactive materials on hand. Emergency planning is most necessary in order that fire fighters may function at maximum efficiency without exposing themselves to harmful radiation on the one hand and without causing unwarranted fears of radiation hazard to inhibit the fire fighting effort on the other. Specific provision should be made where necessary by the property manager and the fire department for monitoring service, protective clothing, and respiratory protective equipment, the need for which is determined by the nature of the specific hazard. The radiation hazard can usually be anticipated in emergency planning studies. (*See Chapter 6, Protection Against Fire and Explosion.*)

2-3 Radiation Hazards and Protection Methods.

2-3.1 Significant levels of radiation exposure may occur under emergency conditions and could cause acute injury or death. This should be understood by fire fighters in order that they will understand that radiation exposures which are tolerable in the event of a fire or other accident, especially where rescue operations are called for, are unsuitable for day-in, day-out exposure.

2-3.1.1 Based on information provided by a health physicist, the level of radiation risk to be assumed should be decided by the officer in charge of the fire fighting operation, based on knowledge and the importance of the operation to be accomplished. In the absence of information from a health physicist, the risk should be assumed to be significant.

2-3.2 Nature of the Hazard of Radioactivity. In order that fire fighting personnel may understand how to effectively protect themselves against dangerous amounts of radiation, it is necessary that they be familiar with the basic nature of radiation and the safeguards which are generally provided under normal operating conditions at those facilities where this hazard is to be found. While quite brief and simplified, the following paragraphs should assist in identifying for the fire fighter those areas of concern:

(a) For brief definitions of some of the terms used, "radioactivity" may be defined as the spontaneous emission of rays or particles during change of an atom's nucleus. "Radioactive decay" means the spontaneous disintegration of a nucleus. Each radioactive isotope has a "half-life" — a period of time that is a characteristic of the particular isotope in which the intensity of nuclear radiation, ascribable to that isotope, progressively decreases by half. However, products formed by the radioactive decay of the original isotope may in turn be radioactive.

(b) The unit for measuring the quantity of radioactivity in the source material is the curie; also the millicurie (one one-thousandth curie) and the microcurie (one one-millionth curie). The term "curie" was originally designated as the standard to measure the disintegration rate of radioactive substances in the radium family (reported as 3.7×10^{10} atomic disintegrations per sec per gram of radium). It has now been adapted to all radioisotopes and refers to the amount of the isotope that has the same disintegration rate as 1 gram of radium.

The curie has been historically, and is still, the most commonly used unit for source strength. However, the SI unit for source strength is the becquerel. One becquerel is equal to one disintegration per second. Hence, one curie is equal to 3.7×10^{10} becquerels.

(c) Among the radiations likely to be encountered are alpha particles, beta particles, gamma rays, and neutrons. The first three come from many radioactive materials, but neutrons are likely to be present in the vicinity of nuclear reactors or accelerators only while they are in operation, or from certain special neutron source materials. Neutrons, alpha particles, and beta particles are small bits of matter — smaller than an individual atom. Gamma rays (and X-rays) are electromagnetic radiations (like radio waves but with much shorter wave lengths).

(d) All radioactive emissions are capable of injuring living tissue. The fact that these radiations are not detectable by the senses makes them insidious, and serious injury may be done without the recipient of the injury being aware of it at the time. Because of their relatively high penetrating power, gamma rays and neutrons may be a serious external hazard (i.e., may be very dangerous even when arising from a source outside of the body). Beta particles, being less penetrating, can be somewhat of an external hazard if approached within inches but are mainly an internal hazard; while alpha particles, because of their extremely low penetrating power, are entirely an internal hazard (i.e., can only injure the body if emanating from a source within the body after having entered the body in some manner).

(e) These radiations are measured in roentgens, a unit representing the amount of radiation absorbed or which will produce a specified effect. Radiation dosages are measured in rems, a dose unit which will produce a specified effect in man. The ultimate effect upon the human body will depend on how and where the energy is expended. In industry, safeguards are provided for the purpose of keeping radiation exposure to personnel to a practical minimum and under certain amounts.

The roentgen and rem have been historically, and are still, the most commonly used units for radiation dosage. The current SI unit for dosage is the sievert. One sievert is equal to 100 rem. A sievert is equivalent to one joule per kilogram.

(f) In an emergency case, such as a necessary rescue operation, it is considered acceptable for the exposure to be raised within limits for single doses. The National Council on Radiation Protection and Measurement has recommended that, in a life saving action, such as search for and removal of injured persons or entry to prevent conditions that would injure or kill numerous persons, the planned dose to the whole body should not exceed 100 rems. During less stressful circumstances, where it is still desirable to enter a hazardous area to protect facilities, eliminate further escape of effluents, or to control fires, it is recommended that the planned dose to the whole body should not exceed 25 rems. These rules may be applied to the fire fighter for a single emergency; further exposure is not recommended. Internal radiation exposure may be guarded against by adequate respiratory equipment.

2-3.3 Personnel Protection Methods. "Monitoring" is the process of measuring the intensity of radiation associated with a person, object, or area. It is done by means of instruments which may be photographic or electronic. Instruments used by personnel for radiation detection or measurement include:

(a) Film badge — a piece of photographic film which records gamma and beta radiation.

(b) Pocket dosimeter — measures gamma radiation.

(c) Geiger-Muller counter — measures beta and gamma radiation.

(d) Scintillation counter — measures alpha, beta, and gamma radiation.

(e) Ionization chamber — measures alpha, beta, and gamma radiation.

(f) Proportional counter — measures alpha radiation.

(g) Gamma survey meter — measures intensity of gamma radiation.

(h) TLD - Thermoluminescent Dosimeter. A crystal chip that records ionizing radiation.

2-3.3.1 Common effects of excessive (200 roentgens or more) nuclear radiation on the body include vomiting, fever, loss of hair, loss of weight, a decrease in the white blood cell count, and an increased susceptibility to disease. Radioactive materials absorbed into the body often tend to accumulate at a particular location (e.g., plutonium and strontium tend to collect in the bone) the radioactivity, concentrated in a particular organ, gradually destroys the cell tissue so that the organ is no longer capable of performing its normal function, and the entire body suffers.

2-3.3.2 Radiation injury requires prompt, highly specialized treatment. Instruments should be provided to detect radiation contamination in clothing or on the skin. There should be a routine monitoring of the degree of exposure to the various particles and rays. Personnel working in the facility will generally be required to wear pocket radiation meters or indicators which are examined periodically, and records of the exposure shall be kept for future reference.

2-3.3.3 The practice of placarding dangerous areas is for the protection of both regular operating personnel and those who, like fire fighters, may have to deal with an emergency situation. If fire fighters are to have the best protection, they should inspect, long before they are called to any fire, the premises where there may be radiation hazards to consider during fire operations. Also, by frequent follow-up inspections, they should reach an agreement with the scientists or other personnel directing the facilities as to steps to be taken in case of fire.

2-3.3.4 Fire fighters who may attend fires in properties where there are hazards of radioactivity should be given special training in what to wear for protection and what to do by way of cleanup or decontamination of their persons, clothing, or equipment afterward. In all cases, they should have and be trained in the use of suitable radiation monitoring equipment themselves or have monitoring specialists with them.

2-3.4 Protection from External Radiation. In the case of external nuclear radiation, the dosage, and hence the injury therefrom, may be kept to a minimum in several ways.

2-3.4.1 First, only the smallest possible portion of the body should be exposed, (e.g., the hands, rather than the entire body).

2-3.4.2 Second, by efficient organization of the work procedure, the time spent in the hazardous area and thereby, the time of exposure, may be kept to a minimum.

2-3.4.3 Third, the intensity of radiation during exposure may be minimized by maintaining the greatest possible distance (e.g., by using long-handled tools for manipulating radioactive materials); or by the use of suitable materials interposed between the radiation source and the person for shielding. Radiation intensity decreases (inversely) as the square of the distance from the source only when the source is a point source. This relationship is more complex with multiple point sources and does not apply to large sources until the distance is equal to one-half the maximum dimension of the source. Practically speaking, this could be 30 to 50 ft (9.1 to 15.2 m). The cases in which a fire fighter will encounter a single point source are probably in the minority, and therefore, the conservative statement should be used.

2-3.5 Protection from Internal Radiation. The possibility of radioactive materials entering the body may be reduced by the wearing of protective face masks and clothing while in a hazardous area. These masks should fit properly and be of a type which will prevent the entry of the particular radioactive materials encountered into the lungs or digestive system. Clothing should be of such a nature as to prevent the entry of radioactive materials into the body through wounds, scratches or skin abrasions. Eating, drinking, smoking, and chewing must be avoided while in, or while awaiting decontamination after being in, radioactive areas.

2-3.5.1 Personnel working with radioisotopes are commonly subjected to routine biomedical checks for possible ingested radioactivity. Where applicable, routine checks are also made to show that a permissible concentration of radioactive material in the body, the air, or elsewhere is not exceeded.

2-3.5.2 Biomedical checks are promptly conducted whenever human ingestion of dangerous quantities of radioactive materials is suspected for any reason. When fire fighters are exposed to radiation and there is any doubt as to the severity of the exposure, they should be given this kind of biomedical examination.

2-4 "Sealed" and "Unsealed" Radioactive Materials.

2-4.1 For purposes of this publication, a "sealed" radiation source is one which is tightly encapsulated (or the practical equivalent by bonding or other means) and is not intended to be opened at the facility. An "unsealed" source is one that is not so sealed and/or is intended to be opened at the facility.

2-4.1.1 The protection of properties against the spread of radioactive contamination as the result of fire or explosion is considerably simplified by the fact that many radioactive materials are shipped, stored, and in some cases used, without ever exposing the radioactive material itself to air. In many cases the shipping containers, or even the use containers, may have sufficient integrity to withstand a fire or an external explosion. Examples are: metallic cobalt 60 sources tightly encapsulated in steel and sealed sources used in "beta gage" thickness and measuring devices. It may be noted that there have been several instances of stainless steel encapsulated "beta gage" sources surviving appreciable fire exposures without release of the radioactive isotope contained therein.

2-4.1.2 The principal reason radioactive materials are sealed is to prevent spread of contamination. In some cases the manufacturer of the container may not thoroughly consider fire resistance and it is important to remember that a sealed source may burst if its contents are subject to thermal expansion as a result of exposure to fire.

2-4.1.3 Unsealed sources, such as may be found in laboratories during transfer and use, may be readily spread about during a fire or an explosion.

2-5 Applications.

2-5.1 The specific application for ionizing radiation is somewhat governed by the physical makeup of the source, whether it is in the "unsealed" or "sealed" form, and sometimes by its radiation intensity.

2-5.2 Most of the thousands of scientific and industrial uses of radioactive materials take advantage of one or more of the types of radiations emitted, i.e., alpha, beta, gamma rays, and neutrons. Certain radioisotope applications take advantage of the ultrasensitive detection capability of certain instruments for extremely small amounts of radioisotopes. Other uses take advantage of the ability of radiation to penetrate matter, while the extremely energetic sources have the ability to bring about biological, chemical, and physical changes.

2-5.3 The most common nuclear radiation applications can be grouped into the following categories:

(a) Radioisotope "tracer" applications utilize small amounts of short-lived, unsealed sources, involving easily detectable radiation emissions of the particular radioisotope employed. Such applications have found wide use in medical diagnosis, biological and agricultural explorations, water surveys, irrigation control, underground leak and seepage detection, atmospheric pollution, flow and transport rates in processing operations, lubrication and wear measurements, rapid chemical analysis for continuous process control, and activation analysis.

(b) Radioactive gages and process control instruments utilize the more penetrating types of radiation from sources which are sealed to prevent the radioactive material from leaking out. The radioactive material in no way enters into the system or process. This includes a wide range of operations from measuring thickness or density to monitoring height and levels in storage and process equipment.

(c) Certain of the intensive sources of radiation have the ability to ionize gases. One of the important applications is to prevent accumulation of static electricity on moving machinery. Here the ionized air effects an "atmospheric grounding" and prevents buildup of static charges (radium and polonium as low-penetrating alpha emitters have been used, along with the more penetrating beta-emitter krypton-85). These sources are also being used as activating agents with self-luminous (phosphorescent) paints and coatings for various markings, emergency lighting, and instrument panels.

(d) Radioactive materials are being employed in the development of atomic batteries (as "isotopic power fuels"). The small currents generated are utilized in low-current demand micro-circuits; also, the liberation of thermal energy during radioisotope decay is converted into useful electricity through thermoelectric couples or thermionic systems. The sources include some fission products and some of the radioactive materials obtained by neutron-irradiation of special target materials.

(e) Powerful sources are used in industrial radiography and nondestructive testing of critical process equipment. The leading industrially used isotope of high-energy emission is cobalt-60, which is obtained by the activation of cobalt in a reactor.

The industrial radiographer has a choice of X-ray machines or radioisotopes. In many cases the latter offers the most advantages. The increased availability of cobalt-60 has expanded its use greatly in more extensive radiographic inspection as a routine testing procedure. Steel thicknesses of from ½ in. to 6 in. (12.7 to 152 mm) can be radiographically evaluated and many companies are now licensed to provide such examination services.

Other radioisotopes which have less energetic gamma ray emissions than cobalt-60 are coming into wider use for lighter materials such as aluminum, copper, zinc, and thin sections of steel.

(f) Powerful sources of high intensity radiation such as from cobalt-60 are used in food preservation, and in radiological sterilization of pharmaceutical and medical supplies. Research and development indicate considerable promise in polymerization of plastics, vulcanization of rubber, improvement of wood properties, graft polymerization of plastics, and in catalyzing chemical reactions.

2-6 Nuclear Reactors.

2-6.1 Nuclear reactors present special problems that require individual study. They are used for electric power generation, research purposes, production of radioisotopes, and ship propulsions.

2-6.1.1 The fire protection requirements for nuclear power plants are published in NFPA 803, *Standard for Fire Protection for Light Water Nuclear Power Plants*. The general fire protection recommendations for research reactors are published in NFPA 802, *Recommended Fire Protection Practice for Nuclear Research Reactors*.

2-7 Nuclear Reactor Fuel Element Manufacture.

2-7.1 Certain radioactive nuclides are fissile (fissionable). Neutrons absorbed by such nuclides emit additional neutrons plus energy, largely in the form of heat. Because more neutrons are emitted than are absorbed, a self-sustained nuclear chain reaction is possible when certain conditions are met. These conditions include a minimum quanity of fissile material (critical mass) and other factors such as shape, geometry, reflection, and moderation (or slowing down of neutrons). Fissile materials to be used in a nuclear reactor are arranged in specific arrays using fuel elements in order to optimize conditions for fission to take place. When a nuclear chain reaction takes place where it was not intended, a "criticality" accident is said to have occurred.

2-7.1.1 The external radiation hazards present during fabrication of uranium-235 fuel elements is of a low order. Uranium-233 and plutonium-239 present severe inhalation hazards to personnel; therefore, an enclosed protection system must be used. These systems are called "glove boxes." They may be extensive, with appreciable glass or transparent plastic areas, and present unique fire protection problems. Under normal conditions, the radiation hazard, although present, can be largely protected against. On the other hand, if a "criticality" incident should occur, the type and quantity of radiation emitted create grave hazards to personnel. Even a small fire within a "glove box" can produce serious consequences if not properly controlled. Fire control systems and procedures for "glove boxes" should be carefully developed and applied before the boxes are used. Generally such protective systems are custom-designed for each particular application. (*See Section 3-4.*)

2-7.1.2 In handling fissile materials, precautions should be taken not only to protect against the normal radiation hazard, but also against the "criticality" hazard caused by the assembly of a "minimum critical mass." To avoid criticality during fire emergencies, fissile materials that have been arranged to minimize the possibility of a criticality occurring should be moved only if absolutely necessary. If it becomes necessary to move such fissile materials, it should be done under the direction of a responsible person on the staff of the facility and in batches that are below the critical mass, or moved in layers that minimize the possibility of a "criticality" occurring. Since water is a reflector and a moderator of neutrons, concern for a "criticality" hazard sometimes leads to the unjustified and unevaluated exclusion of fire protection water from the area where fissile materials are stored or handled. The possibility of water moderation and reflection bringing about a "criticality" accident can be calculated in advance. If, in fact, such a hazard exists, combustible material that would require the use of water for fire fighting should be eliminated. If combustible materials are unavoidably present in quantity sufficient to constitute a fire risk, water or other suitable extinguishing agent should be provided for fire fighting purposes. The fissile materials should be so arranged that water moderation and reflection will not present a hazard. In many facilities, fissile materials are stored and handled in sprinklered areas.

2-7.1.3 In addition to the hazards of radiation and the potential for accidental "criticality," fuel element manufacture will often involve the use of combustible metals such as uranium and plutonium and combustible cladding material such as zirconium. The prevention of fires involving combustible metals requires special techniques. (*See NFPA 48, Standard for the Storage, Handling and Processing of Magnesium; NFPA 481, Standard for the Production, Processing, Handling and Storage of Titanium; and NFPA 482, Standard for the Production, Processing, Handling and Storage of Zirconium.*)

It is important to remember that nuclear fuel elements are extremely valuable and extraordinary precautions may be necessary to protect them from the effects of an otherwise inconsequential fire.

2-8 Nuclear Fuel Reprocessing.

2-8.1 Reactors are generally capable of utilizing only a very small part of the fuel in its elements and as a result it is economical to recover the remaining fuel by processing the so-called "spent" elements in specially designed facilities. These plants contain large quantities of radioactive materials (fission products) extracted from spent nuclear fuel elements which were produced as by-products during nuclear fission. Processing operations will usually involve large quantities of flammable and/or corrosive liquids. Fire and explosion hazards will be present and the possibility of an accidental "criticality" incident, although guarded against and remote, will also be present.

2-8.2 The large quantities of highly radioactive materials present require massive shielding for personnel safety, and most chemical processing and maintenance operations are conducted entirely by remote controls. Fire hazards are present during the sawing and chopping of fuel elements containing combustible metals, either in the form of fuel or cladding, and in the chemical processing operation. Specially designed fire detection and control systems are used to protect these operations. Ventilating systems should be so arranged as to maintain their integrity under fire conditions. Such facilities handling large quantities of highly radioactive materials require the application of a high degree of fire protection planning in all areas.

2-9 Particle Accelerators.

2-9.1 Particle accelerators include Van de Graaff generators, linear accelerators, cyclotrons, synchrotrons, betatrons, or bevatrons. The machines are used, as the name implies, to accelerate various charged particles of which atoms are composed to tremendous speeds and consequently, to high energy levels. Radiation machines furnish scientists with atomic particles in the form of a beam, which may be utilized for fundamental studies of atomic structure. In addition, they furnish high energy radiation, which may be utilized for radiography, therapy, or chemical processing.

2-9.1.1 These machines emit radiation only while in operation and attempts to extinguish a fire in the immediate vicinity of the machine should be delayed until the machine power supply can be disconnected.

2-9.1.2 Certain "target" materials become radioactive when bombarded by atomic particles and for this reason monitoring equipment should be used during fire fighting operations to estimate the radiation hazard. The usual hazard presented by particle accelerators is largely that of electrical equipment. There are, however, some important exceptions to this. Some installations have used such hazardous materials as liquid hydrogen, or other flammable materials, in considerable quantities. Large amounts of paraffin have been used for neutron shielding purposes. Another factor is the possible presence of combustible oils used for insulating and cooling.

2-9.2 Industrial applications include chemical activation, acceleration of polymerization in plastics production, and the sterilization and preservation of packaged drugs and sutures. The general fire protection and prevention measures for these machines should include the use of noncombustible or limited combustible (Type I or Type II) construction housing, noncombustible or slow-burning (e.g. IEEE-383) wiring and interior finishing, and the elimination of as much other combustible material as possible (*see NFPA 220, Standard on Types of Building Construction*). Automatic sprinkler protection should be provided for areas having hazardous amounts of combustible material or equipment. Special fire protection should be provided for any high voltage electrical equipment.

Chapter 3 Arrangement of Facilities Handling "Unsealed" Radioactive Materials

3-1 Special Considerations.

3-1.1 There are special considerations which should be applied in the arrangement of facilities handling radioactive materials. The radioactive materials themselves may or may not present special fire characteristics, but the combating of a fire may be inhibited by the presence of radioactive materials, and the restoration of the property after the fire has been extinguished may be complicated by the problem of radioactive contamination. It should be recognized that radioactive contamination may be the most costly element in a fire loss; therefore, the control of a fire loss is inextricably related to the control of radioactive contamination. Some of the important features to be considered in this connection are:

(a) Grouping of facilities handling significant quantities of unsealed radioactive materials facilitates air cleaning, fire and process control procedures, and decontamination.

(b) Where the probability of radioactive contamination is a serious matter, the design of many other building components may become critical. Light fixtures, electric conduits, ceilings, heating and cooling systems, and operating equipment should be designed and installed with the view of facilitating decontamination.

3-2 Location with Respect to Other Buildings and within Buildings.

3-2.1 Facilities having quantities of radioactive materials that might become airborne in case of fire or explosion should be located well away from other important buildings or operations where contamination could interfere seriously with plant operations or where radioactive substances could come in contact with materials susceptible to damage.

3-2.1.1 In general, facilities handling radioactive materials should be so located that there is no through or cross traffic.

Particular attention should be given to the location of intakes and outlets of air cleaning systems. A breakdown in an air cleaning system can be more serious if the discharged air can immediately be drawn into another system. General isolation of radiation facilities from all other plant facilities causes an increase in both construction and operating costs, but should be undertaken if a study of the possible results of a contamination incident indicates that this is justified. In order to avoid unnecessary complication of accidents, such facilities should be located away from those handling explosives, or flammable materials.

3-3 Planning for Decontamination. The extent to which decontamination might be necessary depends upon the amount of radioactive material being handled, its half-life, type of radiation emitted, and its chemical and physical form. Taking all of these into account, a realistic assumption should be made as to the extent of a possible contamination incident. When decontamination is necessary, it is accomplished by hand, often by personnel not skilled in the work of clean-up, but highly paid because of their other skills, and often in a hurry. All these factors tend to raise costs and thus justify capital expenditures to reduce them to a minimum through good emergency planning procedures. The basic purpose is to provide construction that will confine a contamination incident as closely as possible and which also will include easily cleaned surfaces.

3-4 Construction.

3-4.1 Buildings in which radioactive materials are to be used should preferably be of single-story height without basements or other below-grade spaces. Construction should be limited combustible or noncombustible (Type I or Type II) construction including interior finish, acoustical or insulating treatments, and partitions.

3-4.1.1 Floors. Selection of floor materials for any facility should meet the demands of comfort, appearance, cost, ease of maintenance, and resistance to wear, corrosion, fire and water. In addition, the particular work may require that the floor be electrically conductive or nonsparking. To all of these requirements the radioisotope facility adds the requirements that the floors have a continuous surface, that they have a low porosity and that they can be easily cleaned or replaced. Because of the weight of materials used for shielding purposes, the floor may be required to withstand heavier than normal loads.

3-4.1.2 Removable sheeting or strippable coatings meeting the requirements for limited combustible should be used for surfaces directly exposed to contamination. These coatings are applied as solutions which may contain flammable solvents and can be applied with spray guns to specially prepared bases and removed without great difficulty. The use of spray guns for applying such materials may be hazardous, especially in small areas or rooms. Care should be taken to provide sufficient forced ventilation in the area and to remove all sources of ignition to avoid a possible fire or explosion.

3-4.1.3 Care should also be used in removing and disposing of these coatings. Not only should their contaminated nature be considered, but some, when burned, liberate corrosive vapors which can cause extensive damage to sensitive equipment.

3-4.1.4 The practice of constructing combustible structures, or the use of house trailers with combustible interior finish for the housing of experimental equipment within or adjacent to a structure, provides the fuel for a hot, fast fire which can do serious structural damage to an unprotected steel building. Even in a sprinklered building the loss may be severe. Such structures should be built of noncombustible or limited combustible materials, or should be provided with automatic sprinklers, even if the building in which they are located is sprinklered.

Chapter 4 Service Facilities

4-1 Special Considerations.

4-1.1 The design and installation of such service facilities as light and power, heating and ventilation, storage, and waste disposal at facilities not handling radioactive materials usually present no major problems. The introduction of radioactive materials into a plant presents additional hazards to both personnel and property, which warrants special considerations of these services. Inadequate attention to the design features of service facilities has unfortunately contributed to the extent of decontamination found to be necessary following fires and explosions. It is considered good practice to analyze the design of each service for the purpose of determining what effect the service would have upon the spread of contamination following an accident. An appraisal of the seriousness of contamination spread may then be used to determine the necessity for modifying the design of the service facility under consideration.

4-2 Heating and Ventilating.

4-2.1 The design of the heating and ventilating system must ensure that airborne radioactivity of the building atmosphere is within permissible limits. The choice of either a central system of ventilation or a system composed of individual units is dependent upon that particular building and the processes it houses. A basic principle which should be followed is that there can be no reverse flow of radioactive gases or dusts from "hot" areas into areas of low or normal activity. If the area of high activity can be maintained at slightly below atmospheric pressure, the flow of air will have the proper direction to minimize the spread of contamination should an accident occur.

4-2.2 Hoods serve as the primary means of air removal from some facilities. Electric motors driving ventilating equipment should be located outside the exhaust stream to reduce the possibility of their being contaminated. No part of the exhaust system within the building should be under positive pressure. All hoods in a single area should be controlled by a master-switch in order that contaminants will not be drawn into the room from an unused hood.

4-2.3 The degree of contamination of the exhaust stream may be such as to require filtration, washing, or electrostatic precipitation before discharge to the outer atmosphere. Recirculation of air within an area wherein dangerous radioactive materials are handled should not be permitted under any circumstances. Careful attention should be given to the disposal of filters — especially if they are loaded with materials having any significant degree of combustibility. The use of combustible filters introduces a serious fire hazard into the ventilating system and requires automatic sprinklers or other special fire protection. In the absence of protection systems within the ducts and for the filter banks, fires in combustible filters become extremely difficult to extinguish.

4-2.3.1 The accidental burning of combustible filters carrying radioactive contaminants may create a serious contamination exposure situation which could involve large areas as the radioactive material is discharged from the exhaust system.

4-2.3.2 Self-cleaning filters which pass through a viscous liquid yield a radioactive sludge to be disposed of, and the filter system may require additional fire protection because of the combustible nature of the liquid. Such systems should generally be avoided in areas wherein radioactive materials are handled.

4-2.3.3 The use of filters of low combustibility, such as those which comply with Underwriters Laboratories Inc. Standard No. 58, is recommended. Their use considerably reduces the likelihood of the spread of contamination by fire. Roughing filters, when necessary, should be constructed of materials which will not contribute to the fire hazard.

4-2.3.4 Fresh air inlets should be located to reduce the possibility of radioactive contaminants being introduced. Such inlets should be located where it would be most unlikely for radioactive contaminants to be present. For example, they should not be located near storage areas of combustible radioactive waste material which upon ignition could discharge radioactive combustion products that may be picked up by the ventilating system.

4-3 Light and Power.

4-3.1 Lights, ventilation, and operation of much remote-controlled equipment are dependent upon a reliable source of electrical power. Location of transformers, switches, and control panels well away from "high activity" areas ensures that maintenance work can be done without direct exposure to radiation from such areas. The need for effective ventilation during and immediately after an emergency such as a fire is of considerable importance. An auxiliary power system should be available to provide temporary lighting, ventilation, and radiation monitoring equipment in those facilities wherein the radioactive materials being handled are potentially dangerous to personnel.

4-3.2 It is important that electrical equipment be selected for its ease of decontamination and early restoration to service in those areas wherein a contamination incident is considered likely. Electrical conduits leading from "hot" areas should be internally sealed to prevent entrance of radioactive materials.

4-4 Storage.

4-4.1 With exception to those amounts needed for immediate or continuous use, chemicals, materials, and supplies should be in separate storerooms and not in areas where work with radioactive materials is conducted.

4-4.2 Automatic sprinkler protection provides the best means for controlling fires involving combustible occupancies and should be provided unless it can be shown that their operation will definitely create a situation more hazardous than that brought about by uncontrolled fire. It is very important that radioactive materials not be stored in the same area as other materials, especially if either are flammable or combustible in nature.

4-4.3 Special consideration should be given to the storage of radioactive compressed gases as their release under fire or explosion conditions can result in a severe loss by contamination. Storage facilities for such gases should be designed with the peculiar characteristics of the gases in mind. Special noncombustible storage facilities located remotely from the main facility may be necessary in some cases.

4-4.4 If stored radioactive materials require a cooling system, the cooling system should be periodically checked and maintained in good working condition.

4-5 Waste Disposal.

4-5.1 The disposal of liquid radioactive waste usually will present no fire hazards unless the liquids are combustible. Such combustible liquids should be handled with recognition of their fire hazard as well as of their radioactivity.

4-5.2 Special attention should be given to the prompt disposal of combustible waste, particularly such waste as absorbent paper and rags which have been used to clean radioactive contaminated surfaces. It becomes especially important if the waste has been used to apply nitric acid or other oxidizing chemicals that are subject to spontaneous heating. Waste that is collected during normal activity should be stored in metal containers having tight self-closing covers, and should be removed from the operating areas of the facility at the end of each work day.

4-5.3 Care should be exercised in selecting the locations for the storage of radioactive waste material. Such material should not be located near the fresh air intakes to the air-conditioning systems nor the air intakes for air compressors. Should the products of combustion of waste materials containing long-lived radioactive materials be dispersed through air-conditioning or compressed air systems, a decontamination problem of serious magnitude could result.

Chapter 5 Equipment for Handling and Processing Radioactive Materials

5-1 General.

5-1.1 All equipment to be used for handling and processing radioactive materials should be designed to minimize fire and explosion potentials. There are many types of equipment and systems for handling radioactive materials but most may be classified as either benches, hoods, glove boxes, or "hot" cells.

5-2 Benches.

5-2.1 Benches are used for handling relatively small amounts of alpha- or beta-emitting materials. Benches should be of noncombustible construction with a nonporous continuous working surface which may easily be decontaminated. One or two layers of blotting paper on the bench top to absorb small spills will usually not materially increase the fire hazard.

5-3 Hoods.

5-3.1 Hoods are similar to benches, with the addition of an enclosure and an exhaust system for removing vapors. In addition to fire protection (*see Section 6-3.3*), the nature of the operations conducted within the hood may require a filter system to prevent the spread of radioactive materials. If filters are used, they should have a low degree of combustibility. (*See Section 4-2.*)

5-4 Glove Boxes.

5-4.1 The term "glove box" is used broadly to describe a system designed to contain materials, generally alpha-radiation emitters, which present little or no external radiation hazard but would present a serious problem if they became airborne. Such boxes may be large and used to conduct a wide variety of operations involving flammable liquids and gases, combustible solids, and toxic materials. The sides are fitted with long rubberlike gloves which permit manual operations to be conducted without personal contact with the hazardous materials. Special ventilation and fire protection systems are usually considered to be necessary.

5-4.2 Construction Materials. Construction materials should be noncombustible or limited combustible. Combustible construction materials or materials which are noncombustible but lack fire integrity introduce special problems. All surfaces should be nonporous and easy to decontaminate. Surface coatings are often used to provide a ready means for the removal of contamination but the fire hazards connected with their application should be considered.

5-4.3 Materials Handled in Glove Boxes. All materials to be introduced into these boxes, as well as the construction materials used, should be chosen to minimize the possibility of an explosion, fire, or uncontrolled exothermic chemical reaction. The confinement provided by the boxes together with often near-static air conditions are conducive to the production of explosive mixtures of flammable vapors and gases with air.

The quantity of combustible materials within glove boxes should be kept to an absolute minimum. Special extinguishing agents or systems, compatible with the materials being handled, should be provided within glove boxes in order to avoid the delay and hazard inherent in introducing the extinguishant from outside.

5-4.3.1 Care should be exercised when handling combustible metals within such enclosures. It is possible that low-melting point alloys such as iron-plutonium that are often more pyrophoric than the parent materials, may be formed.

5-4.4 Equipment Used in Glove Boxes. Electrical equipment, including motors and heat-producing devices such as ovens, hot plates, soldering irons and direct flame devices such as torches and burners, present special hazards which should be safeguarded.

5-4.4.1 The small volume and low air velocity conditions provide for less than normal heat removal. The vulnerability of rubber gloves to melting or burning through as a result of very brief contact with heat sources requires that glove port covers be kept immediately available.

5-4.5 Ventilating Systems. Glove boxes are usually connected to a special ventilating system and are normally under constant air flow. Fire dampers are not often installed because of interference with contamination control. The ventilating systems should be designed to constantly maintain a negative pressure within the boxes even under fire conditions. In this connection, consideration should be given to two principal problems.

(a) Smoke and soot from burning material can quickly clog roughing and high efficiency filters in the exhaust system. This may cause rapid spread of the radioactive materials outside the box as a result of pressure created by the fire.

(b) The flexible connections, if any, between the glove boxes and the exhaust system should be of fire retardant materials.

5-4.6 Containment and Fire Control. The containment system may lose its integrity due to fire or explosion originating in or outside the glove box. For fire originating outside the glove boxes, automatic sprinklers are commonly used and are effective for conventional fire control and extinguishment. Fire occurring within the glove boxes may involve materials of construction or combustibles within the boxes. These situations may be difficult to control unless advance consideration has been given to the specific fire problem which may develop under the specific conditions of glove box use. Where such hazards exist, consideration should be given to an automatic fire detection and control system within glove boxes. This system should detect and control the fire before it destroys the glove box integrity or creates smoke which clogs the filters. Where explosion possibilities exist within a glove box, provision should be made for explosion suppression or venting by a predetermined path to a safe area.

5-4.6.1 It is important that airborne contamination does not spread beyond the confines of the room or building in which it originates. This indicates the need for the most efficient and prompt suppression and isolation of fire. To the extent that water from the sprinkler system cleanses the air of airborne contamination, it can reduce a serious three-dimensional airborne contamination problem to a much more manageable two-dimensional waterborne contamination problem.

5-4.7 Fire Prevention. Fire prevention may be improved by the conventional techniques of reducing to a minimum the amount of combustible materials, by eliminating or safeguarding sources of ignition, or by inerting the glove box with a gas such as argon, helium, or nitrogen. In some cases, moisture-free air may be used to prevent the formation of combustible and sensitive metal hydrides.

5-4.7.1 An effective fire prevention program for glove boxes is one that necessarily involves a study of all parameters and the interactions which enter into their construction and operation. Since the specific fire that might occur in a glove box can usually be anticipated and, in fact, can be studied in advance under controlled conditions, it is possible to provide a control and extinguishment system tailored to the specific hazard.

5-4.7.2 The development of a process and the process hazard control system must proceed simultaneously. The operation should not be permitted to begin until the control system is fully operable.

5-5 "Hot" Cells.

5-5.1 A "hot" cell is a heavily shielded enclosure in which gamma-emitting radioactive materials can be handled by persons using remote manipulators while viewing the operation through shielded windows or monitors.

5-5.1.1 While possessing all of the fire and explosion hazards of glove boxes, the damage potential is increased by the nature of the high gamma-ray producing materials used. The safeguards recommended for glove boxes apply equally to "hot" cells.

Chapter 6 Protection Against Fire and Explosion

6-1 General. The hazard of radioactivity may, without adequate emergency planning, act to seriously impede fire fighting operations and result in unnecessary injury to personnel and increased property damage. By anticipating emergency fire and explosion situations and by providing special training for fire fighting personnel, the total hazards of radioactivity can be considerably mitigated. Special techniques and equipment will often be required.

6-2 Organization for Emergencies.

6-2.1 In a well-organized facility wherein radioactive materials are located, fire control starts well before the fire occurs. The need for prefire planning for such facilities cannot be overemphasized. A firm statement of policy by the management of the facility as to the intent of the plan, its scope, its importance, and its organization will materially assist in its effective application. It should be published, reviewed at periodic intervals, and kept current.

6-2.1.1 The areas of consideration of facility management in designing their emergency program should include, as a minimum, the following:

(a) A self-inspection program.

(b) A private fire fighting organization and an outline for its training.

(c) A private security organization and an outline for its training.

(d) Personnel control as it relates to emergency situations.

(e) Health physicist responsibilities.

(f) Liaison with public emergency organizations.

(g) Procedures for loss minimization and decontamination.

(h) The safeguarding of valuable process data and records.

(i) Community relations.

6-2.1.2 The above items are basic in nature and should be molded into a well-considered organizational approach to meet the specific needs of each facility. No organization to cope with emergencies can be expected to function efficiently without training and practice on the part of all involved. Familiarity with established procedures and how to implement them quickly is a necessary ingredient for effective control of fire and explosion-connected emergencies.

6-3 Fire and Explosion Prevention and Control.

6-3.1 Self-Inspection Program. Personnel best qualified to prevent the occurrence of fire are those who have an intimate knowledge of those factors likely to create a fire situation at a specific facility. Many insurance related and public fire protection organizations provide effective fire inspection services at intervals, but the value of these services can be greatly enhanced by thorough self-inspections of the facility by knowledgeable people on the premises who have a good understanding of the hazards to be safeguarded.

6-3.1.1 To be effective, a self-inspection program should be formal and conducted objectively. The reports of these inspections should be reviewed by management at a level that can initiate corrective action. For best results, the self-inspection report forms should be specifically designed for each facility and include all aspects of basic fire protection as well as those indigenous to the facility.

6-3.2 Automatic Sprinklers. Effective protection against fire damage is provided by automatic sprinklers. Combustible contents or the presence of flammable liquids or gases calls for automatic fire protection even if the building construction is noncombustible or limited combustible. The instinctive concern on the part of the facility management about unnecessary water damage is not borne out by the record. To reduce the danger of accidental discharge of water on delicate apparatus, which may be susceptible to water damage, a specially engineered sprinkler system such as a preaction system with advance alarm may be used. Individual items can, if necessary, be shielded with hoods. Lack of sprinkler protection usually results in fire control efforts by high pressure hose streams and the resultant water damage will far exceed that which would have been caused by sprinklers.

6-3.3 Other Fire Control Systems. Where automatic sprinklers cannot be provided due to the presence of water-reactive materials or the proven possibility of criticality, alternate automatic fire extinguishing systems should be considered (*see NFPA 803, Standard for Fire Protection for Light Water Nuclear Power Plants, Section 10-1*).

6-3.4 Portable Extinguishers. Incipient fires may be controlled by portable fire extinguishers. This phase of fire control is particularly important, even though automatic sprinklers have been provided. A supply of portable hand fire extinguishers suitable for use on the specific hazards should be provided (*see NFPA 10, Portable Fire Extinguishers*). Special fire potentials sometimes encountered involve unusual chemicals or combustible metals. Some special extinguishers are effective on incipient fires in combustible metals such as may be found on benches, in hoods, or in glove boxes. Generally, the extinguishant must be tailored to the particular metal involved. Dry powder extinguishers, approved for combustible metal fires, are effective on most such materials.

6-3.5 Fire Detection. The need for, and the type of, detection services most desirable should be related to the hazard, the extinguishing controls available, public and private fire departments, and all combinations of these.

Various devices, operating on different principles, are available for detecting fire (*see NFPA 72E, Standard on Automatic Fire Detectors*). Additional considerations prior to selection should include:

(a) Response characteristics.

(b) Maintanence requirements.

(c) Testing requirements.
(d) Adaptability to environment.
(e) Accessibility.

Chapter 7 Referenced Publications

7-1 The following documents or portions thereof are referenced within this recommended practice and should be considered part of the recommendations of this document. The edition indicated for each reference is current as of the date of the NFPA issuance of this document. These references are listed separately to facilitate updating to the latest edition by the user.

7-1.1 NFPA Publications. National Fire Protection Association, Batterymarch Park, Quincy, MA 02269.

NFPA 10-1984, *Standard for Portable Fire Extinguishers*

NFPA 48-1982, *Standard for the Storage Handling and Processing of Magnesium*

NFPA 72E-1984, *Standard on Automatic Fire Detectors*

NFPA 220-1985, *Standard on Types of Building Construction*

NFPA 255-1984, *Standard Method of Test of Surface Burning Characteristics of Building Materials*

NFPA 259-1982, *Standard Test Method for Potential Heat of Building Materials*

NFPA 481-1982, *Standard for the Production, Processing, Handling and Storage of Titanium*

NFPA 482-1982, *Standard for the Production, Processing, Handling and Storage of Zirconium*

NFPA 802-1983, *Recommended Fire Protection Practice for Nuclear Research Reactors*

NFPA 803-1983, *Standard for Fire Protection for Light Water Nuclear Power Plants*

7-1.2 Other Publications. The following is a selection of additional referenced material:

The following publication is available from Underwriters Laboratories Inc., 333 Pfingsten Road, Northbrook, IL 60062:

UL 586, *Test Performance of High Efficiency Particulate, Air Filter Units*

The following publications are available from the American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103:

ASTM E136, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750°C*

ASTM E380 (ANSI Z210.1), *The Metric Practice Guide.*

The following publication is available from the Institute of Electrical and Electronics Engineers, 345 East 47th St., New York, NY 10070:

IEEE 383, *Standard for Type Test of Class IE Electric Cables, Field Splices and Connections for Nuclear Power Generating Stations.*

Appendix A Additional Publications

This Appendix is not a part of the requirements of this NFPA document but is included for information purposes only.

The following is a selection of additional reference material.

The National Council on Radiation Protection and Measurement has issued a number of reports on specific radiation protection subjects. These reports are available from NCRP Publications, P. O. Box 4867, Washington, DC 20008, or from the U. S. Government Printing Office. Some applicable publications include:

NCRP 30, *Safe Handling of Radioactive Materials-NBS Handbook 92*, 1964

NCRP 38, *Protection Against Neutron Radiation*, 1971

NCRP 39, *Basic Radiation Protection Criteria*, 1971

Standards of the U. S. Nuclear Regulatory Commission for protection against radiation are published in the Code of Federal Regulations as Part 20, Chapter 1, Title 10, available at most libraries. Revisions are printed in the Federal Register, available at subscribing libraries or by subscription from the Government Printing Office.

A bimonthly magazine, *Nuclear Safety*, is available from the Government Printing Office. It covers many areas of interest, including general safety, accident analysis, operating experiences, and current events.

Specific requirements for facilities handling radioactive materials have been issued by the American Nuclear Insurers, The Exchange, 270 Farmington Ave., Farmington, CT 06032, and the MAERP Reinsurance Association, 1151 Boston-Providence Turnpike, Norwood, MA 02062.

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True copies of the foregoing were mailed this 24th day of December 1990, by United States Express Mail, postage prepaid, to:

USNRC

The Honorable Peter B. Bloch
Administrative Law Judge
Atomic Safety and Licensing Board
U.S. Nuclear Regulatory Commission
Washington, DC 20555

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