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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

RE: TRUMP-S Project

ASLBP No. 90-613-02-MLA

AFFIDAVIT OF WALTER A. MEYER, JR. RESPONDING TO PORTIONS OF INTERVENORS' REBUTTAL

I, Walter A. Meyer, Jr., being duly sworn, hereby state as follows.

1. I am the Reactor Manager for the University of Missouri Research Reactor (MURR) a position I have held since March 1, 1989. My background, qualifications, and involvement in the MURR Facility Emergency Plan and its implementing emergency response procedures are described in the Affidavit of Walter A. Meyer, Jr. Regarding Emergency Planning (Oct. 29, 1990) (Oct. 29 Meyer Affidavit). 1/

2. I have reviewed "Intervenors' Responses to Licensee's Written Presentation," Section III, Concerns No. 2 and 4, pages 37-44 (Dec. 24. 1990) ("Intervenors' Rebuttal") or ("Int. Reb.") and Declaration of TRUMP-S Panel ¶¶ 60-72 (Dec. 24, 1990) (Int. Exh. 20) as well as the "Declaration of

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1/ This affidavit was filed with "Licensee's Submittal in Accordance with 'Memorandum (Memorandum of Conference call of October 19, 1990)'" (Oct. 30, 1990).

Donald W. Wallace" (Dec. 24, 1990) ("Wallace Declaration" which is Int. Exh. 21).

3. Intervenors argue that the Columbia Fire Department (CFD) will not fight a fire involving radioactive materials in the Alpha Laboratory or MURR Facility. They further allege that the MURR Facility Emergency Plan ("Emergency Plan") (and its implementing procedures), the CFD fire fighting equipment, and design of the Alpha Laboratory are inadequate from a fire safety standpoint.

4. As is shown in this Affidavit, the assertions of the Intervenors are incorrect and based on a selective application of several recommended fire protection practices that they claim are applicable. Furthermore, Intervenors ignore the fire protection practices that the Licensee has implemented. In order to respond to the unfounded claims and misstatements in the Intervenors' Rebuttal and Mr. Wallace's Declaration, this Affidavit will include discussions of the following:

1) The MURR Facility Emergency Plan, which applies to all activities within the MURR Facility including the Alpha Laboratory;

2) Facility Emergency Procedures FEP 3 "Fire Procedures" (March 22, 1990) and FEP 3(a) "Control Room Response to Alpha Laboratory Fire" (July 11, 1990) which would guide the Facility Emergency Organization's (FEO) response to a fire in the Alpha Laboratory;

3) The response of the CFD to a fire at the MURR Facility, including the Alpha Laboratory, that may involve radioactive materials;

4) The fire loading in the Alpha Laboratory and the general basement area (outside the Alpha Laboratory) and the severity of a postulated fire in these areas;

5) The features of the design and placement of the Alpha Laboratory in the MURR are consistent with NFPA guidelines;

6) The adequacy of the CFD equipment to protect fire fighters from radioactive hazards associated with the TRUMP-S experiments; and

7) Other activities which also serve to protect against a fire in the Alpha Laboratory.

THE MURR Facility Emergency Plan

5. There is no regulatory requirement that Licensee develop an emergency plan in order to utilize the uranium, plutonium, neptunium and americium allowed by the amendments to its materials licenses. However, since the TRUMP-S experiments are being performed in the Alpha Laboratory located in the basement of the MURR Facility, this research project benefits from coverage by the MURR Facility Emergency Plan ("Emergency Plan"), which is applicable to those experiments. Oct. 29 Meyer Affidavit, ¶ 12.

6. The Emergency Plan was described in detail in ¶¶ 12-17 of the Oct. 29 Meyer Affidavit. This plan satisfies the emergency planning requirement for a research reactor in 10 CFR Part 50, Appendix E and is in accordance with Reg. Guide. 2.6 "Emergency Planning for Research and Test Reactors" Rev. 1 (Mar. 1983) and ANSI standard ANSI/ANS 15.16-1982 "Emergency Planning for Research Reactors." See Letter to Robert M. Brugger (UOM) from Cecil O. Thomas (NRC) (July 12, 1984). It has been reviewed and approved by the NRC on five separate occasions. Oct. 29 Meyer Affidavit, ¶ 13.

7. Mr. Wallace's claims that the Emergency Plan "addresses no specific potential emergencies" and is "nothing more than an organizational chart and emergency classification table" are without merit. Wallace Declaration, ¶ 11. NRC guidance provides that emergency plans "should be an expression of the overall concept of operation that describes how the elements of advance planning have been considered and that provisions have been made to cope with emergency situations." Reg. Guide 2.6, p. 2.6-1. The Emergency Plan contains the elements of advanced planning necessary for a broad range of emergency situations. See Oct. 29 Meyer Affidavit, ¶¶ 12, 33.

8. As is clear from review of Section 3.0 "Classification of Emergency Conditions" (MURR Facility Emergency Plan pp. 8-10) and Table I "Emergency Classes" (Id. at 25-27), the Emergency Plan has considered a

number of "specific potential accidents" 2/ that would surpass the radiological considerations of a fire in the Alpha Laboratory involving the TRUMP-S materials. Furthermore, the Emergency Plan provides specific corrective and protective actions, based on emergency class, such as containing the release of radioactive materials and initiating facility evacuation. The implementation procedures (SEPs and FEPs) provide further guidance and more detailed "protective actions" for incidents within each emergency class. The Emergency Plan provides the framework for implementing Licensee's emergency planning, including a description of the emergency organizations (including the offsite organizations to respond in the event of an incident), postulated emergency situations and emergency responses, emergency equipment, and provisions for validating emergency preparedness (including training and participation in emergency drills by the MURR staff and the emergency support organizations such as the CFD).

9. Mr. Wallace erroneously claims that the separation of the implementing procedures into Site Emergency Procedures (SEPs) and Facility Emergency Procedures (FEPs) is "poorly planned and unnecessarily complicated." Wallace Declaration, ¶ 19. As I indicated in my earlier affidavit, the SEPs were created to guide communications and coordination with offsite organizations if an emergency is determined to have offsite consequences. The FEPs are used in conjunction with the SEPs and direct the response to facility emergencies that have primarily onsite consequences. If a facility emergency is determined to have the potential for offsite consequences, the appropriate SEP is utilized. Oct. 29 Meyer Affidavit, ¶ 6. Furthermore, these procedures are implemented by the Emergency Director and provide guidance to the FEO. MURR Facility Emergency Plan § 4.0. Therefore, they are implemented by senior licensed reactor operators who have received training on these procedures and participate in annual emergency drills. See SEP-9 "Training Procedure for Emergency Preparedness" (Jan. 11, 1989); Oct. 29, Meyer Affidavit, ¶¶ 16,36-38. Thus, the FEPs and SEPs are not poorly planned nor do they seem complicated to those who are trained to use them.

10. Mr. Wallace also claims that "[t]he 'Emergency Class' and 'Action Levels' in the Emergency Plan are inadequate for effective Fire Department

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2/ These range from release of a "concentration of airborne radioactive material at the stack monitor exceeding 3800 MPC when averaged over 24 hours" and a "[p]rolonged fire or explosion within the facility that can result in a release of radioactivity that would cause exposures of the public or staff approaching 1 rem whole body or 5 rem thyroid" (Emergency Plan pp. 9, 25) to "plant conditions . . . with a level of significance of major fuel damage and conditions that indicate actual or imminent failure of containment integrity and primary system integrity." (Id. at 10, 27). These exceed the types of accidents that might occur at the Alpha Laboratory.

response." 3/ Wallace Declaration, ¶ 19. The "Emergency Classifications" and "Action Levels" for the Emergency Plan are consistent with those provided in ANSI/ANS Standard 15.16 - 1982, "Emergency Planning for Research Reactors" § 3.4. See also Reg. Guide 2.6, p. 2.6-1 (which indicates that the ANSI/ANS standard is "generally acceptable to the NRC Staff as a means for complying with the requirements of 10 CFR § 50.54 and in Appendix E . . . to 10 CFR Part 50").

11. The American National Standards Institute/American Nuclear Society (ANSI/ANS) Standard defines three emergency classifications 4/ "Notification of Unusual Events," "Alert," and "Site Area Emergency" ANSI/ANS 15.16-1982 at § 3.4.1-3.4.3. The Licensee's Emergency Plan adopts the ANSI classifications and definitions. See MURR Facility

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3/ In regard to an emergency plan for the research reactor, the Commission explicitly stated that "[e]mergency procedures that implement the emergency plan need not be incorporated into the plan but should be listed by title in an annex to the emergency plan." Reg. Guide 2.6, p. 2.6-2. When additional emergency planning requirements were imposed on certain fuel cycle and materials licensees, the NRC provided similar guidance, stating that an applicant should "describe procedures, but the procedures are not to be submitted for NRC approval" since changes to procedures were anticipated which would result in frequent and time consuming license amendments. See NUREG-0762, "Standard Format and Content for Radiological Contingency Plans for Fuel-Cycle and Material Facilities", p. 2, Rev. 1 (Nov. 1987) (emphasis added); Draft Reg. Guide DG-3008, at 2. Thus, the NRC has frequently acknowledged that an emergency plan should not, as a practical matter, contain the detailed procedures that Mr. Wallace implies are required.

4/ An additional emergency classification ("General Emergency") -- where offsite protective actions could be necessary -- was proposed for some licensees. See ANSI/ANS Standard 15.16-1982, § 3.4.4. However the standard provides that "[e]ach emergency plan shall include only those standard classes appropriate for dealing with accident consequences determined to be credible for the specific facility." Id. at § 3.4. It also recognized that "[t]his [the fourth] class of accident is not credible for most research reactors" and "therefore, most research reactors would not include this class as part of their emergency plans." Id. at § 3.4.4. The Licensee determined that "there are no credible accidents identified for the MURR Facility that would result in radiological effluents exceeding PAG at EPZ boundary or exceeding the Notification of Unusual Events action levels in Table I at the site boundary." (MURR Facility Emergency Plan, § 3.0) and concluded that the General Emergency classification was not necessary. The NRC concurred with this conclusion.

Emergency Plan § 3.0, pp. 8-10. Similarly, the "action levels" (i.e. the conditions which define a particular radiological incident and establish the threshold for an emergency classification and the appropriate initial emergency response measures) in the MURR Facility Emergency Plan are consistent with those provided in the ANSI standard. <u>See</u> ANSI/ANS Standard 15.16-1982, Table I; MURR Facility Emergency Plan, Table I, pp. 25-27.

12. This methodology for classifying potential accidents (so that the appropriate responses may be determined) was not intended to provide direction to the CFD for fighting fires. As is demonstrated in the Oct. 29, 1990 Meyer Affidavit (¶¶ 37-40, 50-53), the protective equipment, experience, training (including emergency preparedness drills and facility tours) for the CFD, and the assistance of knowledgeable MURR staff (by providing detailed information on the location of any radiological or chemical hazard and monitoring for any radiation or airborne radioactivity) determines what response should be taken by the CFD to a fire in the MURR Facility.

13. Mr. Wallace argues that the CFD should have "responsibility for both fire and emergency medical incidents whether those incidents involve radioactive materials or not." Wallace Declaration, ¶ 19. His related suggestion is that the "Fire Department should be called on <u>EVERY</u> fire and most emergency medical incidents beyond simple first aid needs." <u>Id</u>.

14. The fire procedures (FEP-3, step 2 and FEP-3(a), step 1) 5/ require the Shift Supervisor or the Senior Operator in the Control Room to contact the CFD in the event of any fire. To the extent that Mr. Wallace expresses concern about emergency medical incidents not involving radioactive materials, those concerns are beyond the scope of this proceeding. Nevertheless, the Licensee has a specific procedure (FEP-4, "Medical Emergency Procedure" (July 3, 1985)) for responding to injuries at the MURR Facility. Since the Licensee has some onsite first aid capabilities to treat minor injuries and the University of Missouri Hospital and Clinics (UMH&C) is approximately 1 mile away, it is unnecessary to call the CFD for every medical emergency. The CFD will be called when appropriate for medical emergencies. The MURR Facility Emergency Plan (§ 2.3) contemplates that the CFD will provide support in the case of "life threatening injuries." Consequently, emergency medical "needs" have been

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5/ Contrary to the implications of Mr. Wallace's Declaration (¶ 19), FEP-3(a) does direct the Shift Supervisor to contact the CFD in the event of a fire in the Alpha Laboratory. <u>See</u> FEP-3(a) step 1; <u>See also</u> SEP-2 Table II, SEP-3 Table III, and SEP-4 Table IV (which state the CFD shall be notified in the event of a fire or the need for emergency rescue ability). Thus, FEP-3 is <u>not</u> the only procedure with instructions for contacting the CFD.

properly considered by the MURR Facility Emergency Plan and it is not "a plan for disaster." Wallace Declaration, ¶ 19.

15. Mr. Wallace claims that the MURR Facility Emergency Plan and fire protection procedures (FEP-3 and FEP-3(a)) do not provide "necessary prefire planning" for handling fires involving radioactivity. Wallace Declaration, ¶¶ 11, 13. I explained in my earlier affidavit why a prescriptive procedure directing the CFD on how to fight a fire would not be helpful. As I stated there:

> "The key to appropriately fighting a fire involving radioactive materials is to have present (1) capable fire fighting personnel, (2) facility personnel who are knowledgeable of the existing Facility and of radioactive and chemical contents of the fire location, (3) appropriate protective breathing apparatus and fire gear, and (4) suitable fire fighting equipment and resources, including the MURR Facility's (floodable) dry fire mains. When all of these are provided for, as they are under the MURR Facility Emergency Plan, the CFD Incident Commander, with the advice of the MURR Emergency Director can then make the appropriate decision as to how to fight that particular fire, taking into account the actual circumstances involved, rather than the specifics that would have to be written in any prescriptive procedure. It is the type of decision that fire fighters traditionally have to make in situations involving any hazardous substances; and the fire fighters will be better equipped to make such decisions at MURR than at many other locations because of the knowledge and assistance they will obtain from the MURR staff." Oct. 29 Meyer Affidavit, ¶ 53.

Facility Emergency Procedures FEP 3 and FEP 3(a)

16. My previous affidavit describes how the MURR Facility Emergency Plan and its implementing procedures, such as FEP-3 and FEP-3(a), would be applied to a fire in the Alpha Laboratory. Oct. 29 Meyer Affidavit, ¶¶ 44-60. This description will not be repeated here. However, Mr. Wallace's allegations about the adequacy of these procedures are in error. I will discuss some of these errors as follows.

17. Mr. Wallace claims that "precious moments will be lost while they [the first persons who discover a fire] go through channels. . . . " Wallace Declaration, ¶ 14. His concern is mistaken. FEP-3 (step 1) requires "Any individual discovering a fire shall notify reactor control (#13)

of fire, giving nature and location of fire." 6/ The Shift Supervisor (or Senior Operator in the Control Room) then notifies the Columbia Fire Department. FEP-3, step 2; FEP-3(a), step 1. Thus, the CFD would be promptly notified of any fire in the Alpha Laboratory.

18. The licensed operators who contact the CFD are knowledgeable of the facility and the Emergency Plan and thus can provide the CFD with accurate information regarding the location of the fire and any radiological or chemical hazards, as well as any need for medical assistance. By following these procedures, the MURR Facility Emergency Plan is initiated; the full resources of the MURR staff, the Facility Emergency Organization (FEO), and any necessary Emergency Support Organizations are brought to bear on the fire; and appropriate protective actions are taken to minimize the effect of the postulated fire, including facility evacuation. Mr. Wallace fails to recognize that by notifying the Control Room the FEO is mobilized to deal with a fire emergency.

19. Mr. Wallace also claims that FEP-3, items 8 and 9 "are not specific as to the potential for fires which involve radioactive materials." Wallace Declaration, ¶ 15. Mr. Wallace completely misunderstands this procedure. Like FEP-3(a), FEP-3 assumes that any fire in the MURR Facility may involve radioactive materials. FEP-3 directs the Emergency Director to "investigate the fire and determine steps to minimize hazard to both personnel and property," which includes an assessment of offsite radiological consequences. See FEP-3, step 3. If determined to be appropriate, the ventilation is secured to reduce the emission of smoke (minimizing the release of radioactive materials) and to smother the fire. FEP-3, step 7. If the fire is in the laboratory and cannot immediately be brought under control, the facility is evacuated, minimizing the health hazard to MURR Staff from fire, smoke, and airborne radioactivity. FEP-3, step 8. The Emergency Director or his delegate meets the CFD personnel when they arrive outside the facility to provide information about fire location, and any specific chemical or radiological hazards and to assist in fire fighting efforts. See FEP-3, step 9 and subsequent note.

6/ The FEPs guide the personnel in the Facility Emergency Organization (FEO) who understand and utilize these procedures. However, there are over 200 people who work or do research at the MURR Facility. Many of these are not members of the FEO and have varying levels of knowledge of the facility. As part of the annual facility indoctrination and at the annual training seminar for non-FEO personnel, these members are instructed to call the Control Room in the event of an emergency. This process allows the Control Room, assisted by the FEO, to ensure that appropriate responses are taken for any emergencies that might occur at the MURR Facility, including fires.

20. Contrary to Mr. Wallace's complaint Licensee has not taken the position that "[n]o preplanning is necessary . . . [or that] fighting a fire involving radioactive materials is . . . no different than what local fire departments do routinely anyway." Wallace Declaration, ¶ 27. Quite the contrary, Licensee has completed substantial preplanning to ensure an appropriate response to any fire at the MURR Facility involving radioactive materials.

21. As detailed in my earlier affidavit, the CFD has participated in emergency action drills on how to fight a fire involving radioactive material. The MURR also sponsors emergency preparedness training for the CFD. Furthermore, the fire fighters in the two stations likely to respond to a fire at the MURR have toured the facility to familiarize themselves with the facility layout and the location of radioactive and hazardous materials. Oct. 29 Meyer Affidavit, ¶¶ 36-39.

22. When the CFD arrives at the facility they are met by either the Emergency Director with layout drawings which provide the location of the fire and any chemical or radioactive hazards. Id., ¶ 49. Furthermore, the fire fighters are escorted by MURR staff personnel to determine the radiological risk as the fire area is approached. Id., ¶ 50.

23. Mr. Wallace has mischaracterized the Licensee's position. 7/ The Licensee has always believed that preplanning for fires involving radioactive materials is necessary. That is exactly what has been accomplished through the existing fire protection procedures (FEP-3 and FEP-3(a)) and the existing preparation (including training, drills, and coordination) with the CFD, which are adequate to deal with fires anywhere in the MURR Facility involving radioactive materials, including the Alpha Laboratory.

24. The last of Mr. Wallace's allegations regarding the fire procedures is that the elements "which describe technicians with radiation monitoring devices accompanying fire fighters in their approach to the seat of the fire presume that no radiation or extremely low levels of radiation will be detected." Mr. Wallace also concludes that "no fire fighting will take place if the MPC [Maximum Permissible Concentration] is detected" and that

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7/ Mr. Wallace's quotation from the NFPA Handbook is also taken out of context. Wallace Declaration, ¶ 27. The paragraph states in full:

> "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."

NFPA, Fire Protection Handbook, p. 10-125 (16th Ed 1986) ("NFPA Handbook") (Attachment B).

The Licensee maintains procedures for dealing with fires and other emergencies at the facility - Facility Emergency Procedures in particular, FEP-3, FEP-3(a); Site Emergency Procedures (SEPs); the TAM Emergency Procedures; and the SOPs. These procedures and the MURR Facility Emergency Plan include provisions for shutting down the reactor and isolating the Alpha Laboratory. Furthermore, MURR personnel are thoroughly familiar with these procedures. This paragraph and the remainder of this section of the NFPA handbook (see pp. 10-125 to 10-126, "Plan for handling fires," Attachment B) describes protective actions which are of the type that have already been adopted at the MURR Facility.

"down wind evacuation would be the incident commander's goal if any airborne radioactivity were present." Wallace Declaration, ¶ 17.

25. As is demonstrated in ¶¶ 30-32 below, the October 24, 1990 Affidavit of Mr. Erman L. Call, 8/ the Affidavit of the CFD Fire Chief (Lic. Exh. 22), and all other objective evidence, the CFD will fight a fire involving radioactive materials.

26. Mr. Wallace's claim that no fire fighting will take place if the MPC is detected is also in error and demonstrates Mr. Wallace's lack of knowledge about radioactive materials. The NFPA Fire Protection Handbook (page 10-124, Attachment B) states:

> "Maximum Permissible Concentrations (MPC) of various radioisotopes in air and water are commonly stated as limits intended to apply to persons who are continuously exposed to the concentrations named. Consequently, the concentrations are far below the exposures which could be tolerated for infrequent exposure, as would most often be the case with fire fighters or emergency workers."

Thus, encountering the MPC of radioisotopes in a particular area would not prevent the CFD from fighting a fire.

27. In fact, the NFPA recommends that fire fighters would be allowed to receive a one time whole body dose of no more than 100 rem in life threatening situations and 25 rem to protect the facility, eliminate the escape of effluents, or control fires. See NFPA Handbook at 10-125 (Attachment B); NFPA Practice 801 § 2.3.2(f) (1986) (see Attachment 2 to Int. Exh. 21); NFPA Practice 802 § 2.2.6 (1988) (Attachment C). The MURR Facility Emergency Plan (§ 5.0.1, p. 12) utilizes the same approach as the NFPA recommendations with respect to exposures of emergency personnel.

28. When CFD personnel arrive at the MURR Facility, they will be met by the Emergency Director or one of the licensed Control Room operators who would be in touch with the Emergency Director. The contact person will provide the CFD Incident Commander with the specific locations of the fire, any chemical or radioactive hazards, and any known injuries or unaccountable persons. Oct. 29 Meyer Affidavit, ¶ 49. The CFD Incident Commander, with advice from the MURR Emergency Director, would decide whether to dispatch fire fighters to the location of the fire. The fire fighters would be escorted by MURR personnel, who would determine the radiological risk as the fire area is approached. Oct. 29 Meyer Affidavit, ¶

8/ This Affidavit was filed as an attachment to "Licensee's Submittal in Accordance with "Memorandum (Memorandum of Conference Call of October 19, 1990)" (Oct. 30, 1990).

50. The Emergency Director will stay in contact with the CFD Incident Commander (and the fire fighters) and provides the CFD guidance on the acceptability of any radiological hazards.

29. Mr. Wallace's claim that CFD activity would be limited to down wind evacuations if "any radioactivity were present" is plainly false. The Emergency Director would determine whether a particular laboratory or the entire MURR facility should be evacuated. For example, FEP-1 and FEP-2 recommend evacuation of non-FEO personnel when airborne radioactivity exceeds 5 MPC to minimize exposure.

Fighting a Fire Involving Radioactive Materials

30. Mr. Wallace's claim that "no fire officer would knowingly lead or send his crew into a fire where radioactive materials were burning or being directly exposed to fire conditions" is contrary to standard fire fighting practices and all the objective evidence presented. Wallace Declaration, ¶ 15.

31. Battalion Chief Call stated that the CFD would fight a fire involving radioactive materials at the MURR Facility, including the Alpha Laboratory. See Affidavit of Erman L. Call, Exhibit A (Oct. 24, 1990). Additionally, this has been confirmed by the Affidavit of the CFD Fire Chief. See Lic. Exh. 22.

32. Morover, the NFPA practices, upon which Mr. Wallace relies throughout his Affidavit, indicate that fire departments will fight a fire involving radioactive materials. NFPA Practice 801, "Facilities Handling Radioactive Materials" § 2.3.1.1, (1986); NFPA Practice 802, "Nuclear Research Reactors" § 2.2.6 (1988) (Attachment C); NFPA Handbook, p. 10-125 (16th Ed., 1986) (Attachment B). [9] This practice was confirmed by Mr. Purington, the expert on fire protection and fire fighting who was retained by the Licensee. See Lic. Exh. 19 ¶ 4, pp. 5-9.

Postulated Fires in the Alpha Laboratory General Basement Area

33. Attachment A to this Affidavit is a calculation developed by the MURR Staff which contains a detailed fire loading analysis for the Alpha Laboratory and the general basement to the MURR Facility. This calculation was performed in accordance with the guidance and direction of Mr. Purington. A fire loading is the measure of the maximum heat that would be released if all the combustibles in a given area were burned. It is expressed

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[9] Mr. Wallace's reference to page F-9 actually refers to NFPA Handbook p. 10-125. (Attachment B).

in equivalent weight of combustibles (lb/ft²) or in BTU/ft². 10/ This analysis was conducted in accordance with the techniques provided in the NFPA Handbook Section 7/Chapter 9 (16th ed., 1986) (Attachment B). In accordance with Mr. Purington's instructions fire loadings were calculated separately for the Alpha Laboratory and then for the remainder of the MURR basement. See Lic. Exh. 19, ¶ 6, p. 13. The results are as follows:

Table 1

	Combustible Area	Content
Alpha Laboratory	500 ft²	1.39 lb/ft² or 11,131 BTU/ft²
MURR Basement (derated) see ¶ 35	3424 ft²	0.50 lb/ft² or 3,977 BTU/ft²

As indicated in the NFPA Fire Protection Handbook (p. 7-113, Attachment B) and contrary to Mr. Wallace's claims of "substantial" (¶ 27, p. 8) and "considerable" (p. 9, Conclusions) fire load, these are considered extremely low fire loads. 11/

34. The analysis of the fire loading considered the contents of the Alpha Laboratory and the MURR basement area. See Affidavit of Chester B. Edwards Jr. Regarding the Adequacy of the Alpha Laboratory Equipment, Fire Related Features in the Alpha Laboratory, and the Storage and Transfer of Actinides and Archived Materials, ¶¶ 20-22, 34-38 (Nov. 13, 1990) (Lic. Exh. 4); Affidavit of Dr. Leon C. Krueger Regarding the Potential for a Fire From Actinides Being Performed in the Alpha Laboratory, ¶¶ 11-20 (Nov.

10/ The fire load is commonly expressed as the equivalent weight of the combustibles divided by the fire area in square feet (lb/ft²). The equivalent combustible weight is defined as the weight of "ordinary combustibles" (having a heat of combustion of 8000 Btu/lb.) that would release the same amount of heat in a particular space as the existing combustibles. This "equivalent combustible weight" allows for comparison between products with varying heats of combustion (i.e., that would release different amounts of energy in a fire, i.e., wood, paper products, plastics and oil). The fire loading may also be expressed as the average amount of energy released over the fire area (BTU/ft²). NFPA Fire Protection Handbook, p. 7-111 (Attachment B).

11/ "The fire load of an occupancy is described as low if it does not exceed an average of 100,000 Btu per sq. ft. of net floor area of any compartment . . . " NFPA Handbook, p. 7-113 (Attachment B).

13, 1990) (Lic. Exh. 5). In accordance with Mr. Purington's instructions the Licensee did not include the wooden structural members protected by the type X (fire rated) gypsum wallboard or the plywood roofing above the Alpha Laboratory which is protected by fire retardant paint. See Lic. Exh. 19, ¶ 6, p. 13.

35. The vast majority of combustibles in the MURR basement are contained in metal cabinets or containers (e.g., the combustible low level radioactive waste are stored in metal barrels). See Lic. Exh. 4 ¶ 38. Since such materials will not burn completely and do not contribute fully to the fire loading (and in accordance with Mr. Purington's directions), these materials were considered to be "derated." See Lic. Exh. 19, ¶ 6, p. 14; NFPA Handbook Section 7/Chapter 9, p. 7-111 (Attachment B). The derated fire load is determined by the sum of the equivalent weight of free combustibles plus the product of the derating factor (K) times the equivalent weight of the enclosed combustibles. Id. at p. 7-113. The derating factor for fully enclosed combustibles such as [illegible] in the basement area are 0.1 Id. Thus, the derated fire loading [illegible] basement area is 0.50 lb/ft² or 3,977 BTU/ft². 12/ See Attachment A.

12/ Mr. Wallace argues that the MURR basement houses "numerous" and "substantial" fire loadings, including: 1) flammable hydraulic oil, 2) barrels of combustible radioactive wastes, and 3) a natural gas line. Wallace Declaration ¶ 27. As is indicated by Chester Edwards' Affidavit (Lic. Exh. 4) the hydraulic oil in the basement is contained inside the freight elevator (located primarily in the freight elevator's self-contained hydraulic oil reservoir (Id. at ¶ 35)) and two hydraulic presses and their self-contained hydraulic oil reservoirs (Id. at ¶ 37). This oil is completely contained inside metal machinery. Similarly, the low level radioactive wastes in the basement are compressed and encased in metal barrels Id. at ¶ 38.

Finally, there is a low pressure natural gas distribution piping system in the general basement area. This natural gas system is a one (1) inch steel pipe located in the ceiling of the MURR basement with a safety valve and an isolation shut-off valve at its entry point into the MURR Building. Id. at ¶ 36. In the event of a fire at the MURR Facility, a licensed control room operator can be dispatched to turn off the natural gas distribution system within a matter of minutes. This safety valve would automatically shut off natural gas flow in the event of a line break. Furthermore, the likelihood of rupturing this gas line is remote. Thus, the natural gas distribution system was not considered in the fire loading analysis. Moreover, as demonstrated by Mr. Purington (Lic. Exh. 19, ¶ 15, p. 24), in the event of a leak in the gas lines the natural gas would accumulate at the ceiling (it is lighter than air) and be removed by the building ventilation system making the explosion postulated by Mr. Wallace unlikely.

36. The walls and ceiling of the Alpha Laboratory are covered by 5/8 gypsum wallboard fire rated type X. See Lic. Exh. 4, ¶ 20. This wallboard has a 40 minute resistance rating (i.e., it would protect the studs and joists in the Alpha Laboratory for 40 minutes in a fully developed fire). NFPA Fire Protection Engineering Handbook (1990) Table 3-8.1, p. 3-131 (1990) ("Engineering Handbook", Attachment D). As indicated in Mr. Purington's Affidavit (Lic. Exh. 19, ¶ 6, p. 13), this wall board is adequate to protect the wooden support members in the walls of the Alpha Laboratory from a fire of the type which could reasonably be expected to occur in the laboratory or the MURR basement.

37. Mr. Wallace argues (Int. Exh. 21, ¶ 22) that there will be a "ground level release" from the MURR basement driven by an alleged large increase in pressure resulting from a fire in the MURR basement. The Intervenors' Review Panel (Int. Exh. 20, ¶¶ 63-67) reiterates the same erroneous claims. In characterizing the movement of smoke out of the Alpha Laboratory in MURR building basement, Mr. Wallace and the Panel ignore the "stack effect." Air in a building, particularly in the presence of fire, is warmer and less dense than outside air. Thus, the buoyant air inside of a building will rise to the top of the building through any vertical shaft until it is expelled. This effect is known as the stack effect and is a particularly significant factor for movement of smoke inside a tall building such as the MURR Facility. 13/

38. The facility exhaust ventilation ducting from the basement area via the mechanical equipment room and/or the hot cell exhaust to the MURR Facility exhaust stack represents the tallest vertical shaft available at the MURR Facility. 14/ Even if the facility exhaust fans are secured (see FEP-3 step 6; FEP-3(a) step 6), smoke and air will exhaust through the main stack due to a passive draft in the ventilation system. Morris Affidavit

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13/ "In shorter buildings, the influences of the fire (such as heat, convective movement and fire pressure) are the major factors which cause smoke movement . . . In tall buildings, these factors are modified by the stack effect." NFPA Fire Protection Handbook "Smoke Movement in Buildings", p. 7-128 (Attachment D).

14/ There are several ways that smoke from the Alpha Laboratory could enter the Facility ventilation system. In addition to the glove box exhaust and the room exhaust within the Alpha Laboratory, any smoke which might escape the Alpha Laboratory to the basement area would be drawn through the Facility ventilation exhaust system from the hot cell and/or the mechanical equipment room. See Affidavit of J. Steven Morris Regarding Errors in Petititioners' Analyses, ¶ 54 (June 14, 1990); Lic. Exh. 4, ¶¶ 28, 29, 30.

Regarding Safety Analysis, (Lic. Exh. 3) ¶ 50. 15/ This "stack effect" will draw smoke out of the basement through the Facility ventilation system and exhaust stack. Any increase in the temperature of the basement will increase the stack effect and make the exhaust ventilation stack the major path of any smoke release from the basement.

39. As I have previously explained (Oct. 29 Meyer Affidavit) in the event of a fire the exhaust dampers for the Alpha Laboratory are not automatically secured, but will be secured only if it is appropriate considering all of the relevant circumstances. See FEP-3(a) step 9. Even if these dampers are secured (see Wallace Declaration, ¶ 22), this will only stop the ventilation from the Alpha Laboratory. The Facility ventilation system would still draw smoke from the basement area via the mechanical equipment room or the hot cell exhaust or both. Both of these pathways are HEPA filtered prior to exiting the exhaust stack. Lic. Exh. 3 ¶ 54 note 35. Furthermore, the pressure increase that Mr. Wallace claims to be created by a basement fire (Wallace Declaration, ¶ 22), would be extremely small and would be limited to the room of fire origin (or the Alpha Laboratory in the fire postulated by Mr. Wallace). Other factors like stack effect become dominant in smoke movement through the remainder of the facility, and the facility ventilation system. Therefore smoke exiting the Alpha Laboratory would be released at the MURR Facility stack.

40. The NFPA Fire Protection Handbook in section 7/Chapter 10 "Smoke Movement in Buildings" (pp. 7-125, 7-126, Attachment B) describes what happens to smoke once it leaves the hot smoke zone (the room of fire origin or the Alpha Laboratory in Wallace's scenario). The "Cool Smoke Zone (Rest of the Building): This includes those areas in the building where mixing and other forms of heat transfer have reduced the effect of the driving force of the fire to where buoyant lift in the smoke body is a minor factor. In these areas, movement of smoke is primarily controlled by other forces such as wind and stack effect and the mechanical heating, ventilation and air conditioning [(HVAC)] or other air movement systems." (emphasis added) Thus, NFPA principles support the Licensee's view that any smoke exiting the Alpha Laboratory would be drawn through the Facility ventilation system exhaust and exit through the stack.

15/ "The major driving force causing smoke movement are stack effect, buoyancy, expansion and the heating, ventilation, and air conditioning (HVAC) system. . ." p. 3-143, Engineering Handbook (Attachment D). "Although shutting down the HVAC system prevents it from supplying air to the fire, this does not prevent smoke movement through the supply and return air ducts, air shafts and other building openings due to stack effect, buoyancy or wind." p. 3-144, Engineering Handbook (Attachment D).

41. Mr. Wallace also claims that the CFD will have to ventilate the basement area to dissipate heat in order to get to the Alpha Laboratory and fight a fire. Wallace Declaration, ¶¶ 22-24. However, Mr. Wallace's suggestion for fighting a radioactive fire in the Alpha Laboratory is contrary to the "cardinal rule" of fighting a fire involving radioactive materials -- "ventilation should be kept to an absolute minimum." Purington & Patterson, "Handling Radioactive Emergencies," pp. 101-102, (1977) (Attachment E); IFSTA § 209, p. 188 (Attachment F). Moreover, in view of the low fire loading (and resulting low maximum temperature) and the rapidity with which the CFD would arrive at the MURR, ventilation should not be needed. Consequently, Mr. Wallace's claim is invalid.

NFPA Practices and the Alpha Laboratory

42. Intervenors Rebuttal and the Wallace Declaration refer to several of the National Fire Protection Association (NFPA) recommended practices in an attempt to demonstrate that the Alpha Laboratory and the Licensee's procedures for responding to a fire are inadequate. See e.g. Int. Reb. at pp. 38,42; Wallace Declaration, ¶¶ 21,27. There is no NRC regulation or other NRC requirement that makes the NFPA practices applicable to the activities performed under a material license. Furthermore, there are no local (state or municipal) requirements that a Licensee comply with these practices. These practices serve only as recommendations not as mandatory requirements. 16/ Nevertheless, as is demonstrated below, the activities being conducted in the Alpha Laboratory have taken into account the recommendations of the NFPA.

43. In regard to the fire safety of equipment used for handling and processing radioactive materials, the NFPA has stated that:

16/ This fact has been recognized by the NFPA "Recommended Fire Protection Practices" in § 801, which specifically states:

"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." NFPA Practice 801, § 1-3 (1986) (emphasis added). Since, the Licensee is an entity of the State of Missouri, it is the "authority having jurisdiction" with respect to the MURR facility.

> "Fire prevention may be improved by a combination of techniques by reducing to a minimum the amount of combustible material, eliminating or safeguarding the sources of ignition or by inerting the glove box with a gas such as argon, helium, or nitrogen." NFPA Practice - 801 § 5-4.7 (1986). "An effective fire protection program for glove boxes is one that necessarily involves a study of all parameters and the interactions which enter into their construction and operation." Id. at § 5-4.7.1.

The TRUMP-S experiments are being performed in an inert atmosphere (the Argon Glove Box) and with small amounts of material (less than 1 gram) Lic. Exh. 5, ¶¶ 11, 16; Lic. Exh. 2, ¶¶ 18, 19. The Alpha Laboratory and MURR basement have very low amounts of combustible material and sources of ignition are virtually absent. (Lic. Exh. 19, ¶¶ 6, 16, pp. 14, 24)

44. Mr. Wallace implies that a basement should not be used because it may create an "oven" in the event of a fire, with difficulties created in reaching the fire. Wallace Declaration, ¶ 27. Although Licensee appreciates that a basement may be more difficult to reach than a building open on all sides, this aspect is more than compensated by the other advantages or the design of the Alpha Laboratory. The Alpha Laboratory utilizes the existing ventilation and liquid effluent systems for the MURR Facility. This includes stack monitors for the continuous monitoring of airborne radioactive effluents. Licensee facility has the capacity in its contaminated water collection system (sumps and tanks) to hold in excess of 25,000 gallons. This system would be utilized to collect contaminated run off from any fire fighting activities in the MURR basement. The stack monitor and a number of the other monitors in the Alpha Laboratory (such as the smoke detectors) alarm in the Control Room which is staffed on a 24-hour basis by licensed Reactor Operators. Furthermore, there is an existing Emergency Plan for dealing with radiological emergencies. The MURR facility also provides security for the Licensee's laboratories and radioactive materials and health physics support. Finally, the Alpha Laboratory is located in a remote part of the facility, away from personnel cross traffic. See NFPA Practice 801 § 3.2.1.1. When all these safety features are combined with the extremely low fire loading of the MURR basement, it becomes clear that the MURR basement is an appropriate location for the Alpha Laboratory.

45. The Licensee had not provided sprinklers in the Alpha Laboratory because of the low levels of combustibles and the tour every four hours for fire surveillance provided by the licensed Reactor Operators. Mr. Purington has reviewed the configuration of the Alpha Laboratory, and concluded that while not mandatory to provide adequate fire protection (as a result of the limited fire loading), sprinklers would provide enhanced fire protection. Lic. Exh. 19 ¶ 7, pp. 18, 19. In keeping with Licensee's design philosophy for the Alpha Laboratory of adding features beyond what is necessary for adequate safety, a point recognized by Mr. Dan Osetek (Lic.

Exh. 1, ¶ 19, p. 5), Licensee plans to install a sprinkler system for the Alpha Laboratory within a few months. The Licensee has also agreed with the recommendation of Mr. Purington to replace the window in the Alpha Laboratory with a wire glass window within several months (Lic. Exh. 19, note 15).

46. Mr. Wallace questions whether the "dry (floodable) fire system" is properly sized and equipped for the fire load in the [Alpha] Lab[oratory] and the basement." Wallace Declaration, ¶ 21.d. The dry fire mains can provide an adequate supply of water to extinguish a fire in the Alpha Laboratory and basement. The dry fire main system can supply approximately 1200 gallons per minute to the fire mains in the basement area. See Oct. 29 Meyer Affidavit, ¶ 31. Mr. Purington has concluded that this supply of water is adequate. See Lic. Exh. 19, ¶ 12, pp. 22, 23.

47. Intervenors' Rebuttal (p. 42) indiscriminately alleges that Licensee's facility or procedures conflict with a number of NFPA recommended practices. To the extent that these practices are supported by Mr. Wallace's Declaration they are addressed in the body of this affidavit. See ¶¶ 44-47. The remainder of these alleged conflicts have no support whatever. Furthermore, several of the provisions relied upon by Intervenors have no relevance to the MURR Facility or the activities being performed under the Licensee's material licenses. See NFPA Practice § 8.01, ¶ 2.7.1.1 and 2.7.1.2 (relating to "Nuclear Reactor Fuel Element Manufacture") and 2.8.2 (relating to "Nuclear Fuel Reprocessing"). Consequently, the Intervenors' alleged conflicts are without merit.

The Columbia Fire Department Equipment

48. Mr. Wallace claims that the CFD has not been issued "protective clothing or breathing apparatus which protects them from radiation hazards that can be expected from fires on or directly exposing radioactive materials." Wallace Affidavit, ¶ 16. The normal fire fighter turnout gear with self-contained breathing apparatus (SCBA) is considered adequate to protect fire fighters from exposure due to airborne alpha radioactivity (an internal radiation hazard) that might be presented from TRUMP-S materials. The Alpha Laboratory has insufficient radioactive material to present a significant external radiation hazard from gamma radiation. See ¶ 51.

49. Normal fire fighter gear will protect fire fighters against radioactive hazards. See Affidavit of Mr. Purington (Lic. Exh. 19, ¶ 5, pp. 9-10). This fact is widely recognized, for example:

1) NFPA-802, "Recommended Fire Protection Practices for Nuclear Research Reactors," 2-2.7 (Attachment C), states "the problem of internal radiation exposure is entirely

> different from the external exposure problem . . . this is really no different than the problem presented by trying to define inhalation limits for smoke, carbon monoxide, and other products of combustion. Fortunately, the mandatory use of self-contained breathing apparatus in radiation emergencies can materially reduce the problems."

2) International Fire Service Training Association (IFSTA-209) Fire Fighter Occupational Safety; p. 182 (Attachment F), states "Alpha particles do not present a penetration hazard to humans . . . to combat Alpha radiation hazards a fire fighter should be clothed in full protective gear including positive breathing apparatus."

50. The CFD fire fighters are equipped with heavy coats and pants and Self Contained Breathing Apparatus (SCBA). See also Oct. 29 Meyer Affidavit ¶ 50, 52. The SCBA used by the CFD have positive pressure facepieces, Lic. Exh. 19, ¶ 5, pp. 9,10. Smoke will not penetrate a positive pressure facepiece because air movement past the facepiece seal is always to the outside. Consequently, there is little risk of an internal exposure to a fire fighter wearing a SCBA with positive pressure facepieces. 17/

51. The only significant potential for external exposure to the fire fighters from the materials used in the TRUMP-S experiments is from gamma radiation emitted from americium-241 either by direct radiation or cloud dose. If 1 gram of americium-241 (3.43 Ci) were present in the glove box (unshielded) the direct dose rate to a fire fighter from a point source of this radioactive material would be less than 100 mrem/hour at 10 ft. If 1 gram of americium-241 were consumed in a fire (with a release fraction .001) and released into the MURR basement (14[illegible] m^3) the external dose to a fire fighter from airborne radioactivity would be approximately 0.064 mrem/hr. This does not constitute a significant radiological hazard to fire fighters. 18/

17/ "Self-Contained Breathing Apparatus: In the demand mode a protection factor of 100 is provided; while in the pressure mode, the protection factor is unlimited." Purington & Patterson, Handling Radiation Emergencies, p. 28 (Attachment E).

18/ The CFD personnel will be accompanied by MURR personnel as they engage in any fire fighting activities in the Alpha Laboratory. The MURR personnel will monitor the dose rate from any airborne radioactive materials (and ensure that appropriate radiological safety precautions are taken and indicate if other radiological or chemical hazards are present).

Fire Protection Methods

52. The NFPA Fire Protection Handbook (p. 10-121, Attachhment B) describes three important methods for fire safety in nuclear facilities. These include:

1) Designing the plant to limit the consequences of a fire,
2) Fire prevention, and
3) Quick detection and suppression of fires.

53. Mr. Wallace focuses only on the design of the Alpha Laboratory. Mr. Wallace's erroneous claims about the Licensee's design are responded to in ¶¶ 42 - 47 of this Affidavit. A description of the ample fire safety features incorporated into the design of the Licensee's Alpha Laboratory will not be repeated here. See Oct. 29 Meyer Affidavit ¶¶ 24-32; Licensee Exh. 4, ¶¶ 12-38; Licensee Exh. 5, ¶¶ 10-21.

54. Mr. Wallace is silent about fire prevention measures, such as low fire loading of basement area, the use of glove boxes with inert atmospheres to perform the TRUMP-S experiments (NFPA 801, 5-4.7, Fire Prevention), and the provision of fire resistent membrane (5/8 inch type X gypsum wallboard) on wooden framing members of the Alpha Laboratory which provide a 40 minute protection rating. The reactor operators also perform "fire watch" tours of the MURR Facility every four hours. The operators are directed to detect and eliminate any potential fire hazards. A University of Missouri fire safety officer also tours the Facility every six months and a MURR fire safety inspector conducts monthly tours of the facility for fire safety. Oct. 29 Meyer Affidavit at ¶ 30. The CFD reviews of this facility and the Alpha Laboratory are described in my Oct. 29 Affidavit. Id. at ¶¶ 31-32.

55. Mr. Wallace is also silent with respect to quick fire detection and suppression. The Alpha Laboratory has a fire detector in the argon glove box as well as the Alpha Laboratory. Both of these detectors alarm in the reactor Control Room which is manned 24 hours/day so detection of any fire would immediately prompt a response. Oct. 29 Meyer Affidavit, ¶ 28. The Reactor Operators tour the MURR Facility every 4 hours and would detect fires in the Alpha Laboratory. Furthermore, there are fire extinguishers in the Alpha Laboratory and surrounding basement to allow an immediate response to a small fire. Oct. 29 Meyer Affidavit, ¶¶ 22-29. The Control Room Reactor Operators and the persons authorized entry into the Alpha Laboratory have been instructed on the types of fire extinguishers to be used in fires at the MURR facility.

56. The CFD is able to respond to MURR emergencies in much less than 10 minutes. A response time of approximately 10 minutes has occurred on three separate emergency drills with the CFD when the trucks were dispatched without sirens for reasons of traffic safety. Oct. 29 Meyer Affidavit, ¶ 45.

57. Thus, all three of the methods for ensuring fire safety including the design of the Alpha Laboratory, fire prevention, as well as the quick detection and suppression of fires, were considered in the construction of the Alpha Laboratory.

CONCLUSIONS

58. a. As demonstrated by the low fire loading in the Alpha Laboratory, calculated using NFPA principles and guidance from Licensee's fire protection and fire fighting expert, a fire would not be as severe as alleged by Mr. Wallace.

b. There are numerous fire safety aspects of the Alpha Laboratory (such as low fire loading, the existing ventilation and liquid effluent systems, the dry fire mainsystem, smoke detectors, the 24-hour staffing of the MURR Facility, and fire watch tours) that are ignored by Mr. Wallace and make the MURR basement an appropriate location for the Alpha Laboratory.

c. The most likely pathway for smoke from any fire involving the materials or the Alpha Laboratory would be through the filtered facility exhaust system.

d. The MURR Emergency Plan and implementing procedures, which include planning and procedures for fires anywhere at MURR, are adequate for protecting against fires involving the materials in the Alpha Laboratory.

e. All the objective evidence indicates that the CFD will fight a fire in the Alpha Laboratory even if it involves radioactive materials. The CFD is adequately equipped to fight a fire with their SCBA and normal fire fighting gear. The potential for radiological hazard to fire fighters from materials used in the Alpha Laboratory is low.

Subscribed and sworn
before me in
BOONE County
Missouri this 28th day of
January 1991.

Walter A. Meyer, Jr.
Reactor Manager

Sharon Wesselman
Notary Public

Sharon Wesselman, Notary Public, State of Missouri
My commission expires February 21, 1991
Boone County, Missouri

My Commission Expires

2-21-91

ATTACHMENTS

Attachment A - Licensee's Fire Load Calculation (Jan. 24, 1991).

Attachment B - NFPA, Fire Protection Handbook (16th Ed. 1986).

- Section 7/Chapter 9 "Confinement of Fire in Buildings," pages 7-111 to 7-113, 7-126 to 7-128.
- Section 10/Chapter 17 "Nuclear Facilities," pages 10-121 to 10-126.

Attachment C - NFPA Recommended Fire Protection Practice 802, "Nuclear Research Reactors" §§ 2.2.6, 2.2.7 (1988).

Attachment D - NFPA, Fire Protection Engineering Handbook (1990).

- Section 3/Chapter 8, "Analytical Methods for Determining Fire Resistance of Timber Members" Table 3-8.1, pages 3-131.
- Section 3/Chapter 9 "Smoke Control," pages 3-143, 3-144.

Attachment E - Purington & Patterson, "Handling Radioactive Emergencies," pages 28, 101-102 (1977).

Attachment F - IFSTA - 209 "Firefighter Occupation Safety," pages 182, 188 (1979).

LICENSEE'S EXHIBIT 20,
ATTACHMENT A

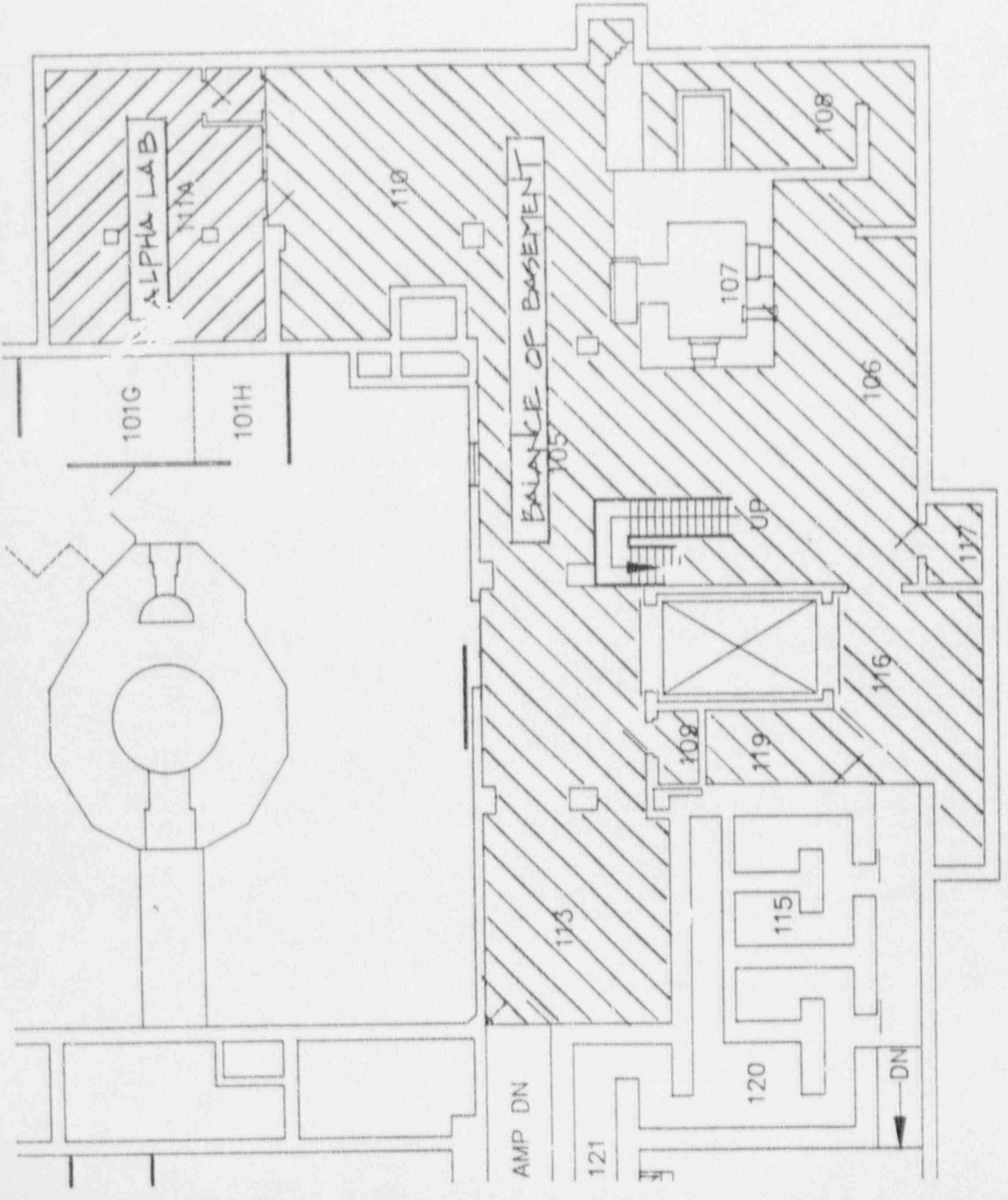
Fire Load Calculation

These fire load calculations have been prepared by Licensee staff using procedures in the NFPA Fire Protection Handbook (pp. 7-111, 7-112, 7-113, Attachment B) and following the instructions of Mr. Robert Purington, a fire protection engineer.

Some of the combustible occupancy of the MURR basement were derated to indicate their limited contribution to a fire as specified in the NFPA Handbook (pp. 7-112, 7-113).

	Weight pounds	Heat of Combustion BTU/Lb	Equivalent Combustible Weight pounds	Equivalent Combustible Weight Enclosed in Metal Containers pounds
Lab:				
Polycarbonate				
Glove box windows	177.8	13323	296.1	
Tubing	2.0	13323	3.3	
Doors	177.7	8000	177.7	
Gloves	8.3	19690	20.3	
Paper				
Misc.	50.0	8000	50.0	
Backing on Gypsum Board	125.8	8000	125.8	
CPU, Monitor, Printer	10.0	18000	22.5	
		Total	695.7	
		Lab Fire Area	500 sq. ft.	
		Fire Load	1.39 psf	11,131 BTU/sq. ft.
Balance of Basement:				
Oil				
Texaco Rando HD-32	2126.3	19440	5166.9	5166.9
MFA Industrial 200	73.5	19700	181.0	181.0
Opti-Fluor	274.9	17973	617.6	617.6
Trash (Barrel)				
Loose	92.0	8000	92.0	92.0
Compact	690.0	8000	690.0	690.0
Metal Cabinets				
Paper etc.	1785.0	13445	3000.0	3000.0
Doors	177.7	8000	177.7	
Plywood	258.2	8000	258.2	
Hepa Wood Frame	85.1	8000	85.1	
Wood Crate	206.3	8000	206.3	
		Total	10474.8	9747.5
		Weight of Free Combustibles	727.3 lb	
		Derating Factor(K)	0.1	
		Derated Fire Load	1702.0 lb	
		Basement Fire Area	3424 sq. ft.	
		Specific Fire Load	0.50 psf	3,977 BTU/sq. ft.

Figure 1. Alpha Laboratory and MURR Basement



LICENSEE'S EXHIBIT 20, Attachment B

Fire Protection Handbook™

Sixteenth Edition

ARTHUR E. COTE, P.E., Editor-in-Chief
JIM L. LINVILLE, Managing Editor

NFPA
National Fire Protection Association
Quincy, Massachusetts

tests to determine how actual building fires compared with the temperatures represented on the curve (Ingberg 1927, 1928). The tests included two actual buildings that were allowed to burn to destruction and a series of fires in fire resistive test buildings containing contents representative of office, record room, and household occupancies. The principal variable considered in these occupancy fire tests was the amount of combustible materials present, which is defined as the fire load. Although the ventilation in the test buildings was not reported, the windows were equipped with steel shutters that could be adjusted to control ventilation and maximize fire severity. The quantitative importance of ventilation on fire severity was not identified until more than 25 years after these tests. These tests conducted by the NBS provided quantitative data on the temperature history of fires that was representative of various occupancies and fire load at that period of time. Fire load was expressed as the weight of ordinary combustibles in the room divided by the floor area of the room. Loading is the average amount of ordinary combustible material per square foot (m^2) of floor area. The temperature history of the fully developed fires in the three test occupancies was approximately bounded by the standard time-temperature curve.

The NBS developed the concept of equivalent fire severity to define the severity of actual fires that had various temperature histories. This concept states that the area above a base line under the time-temperature curve of a test fire, which is expressed in degree hours, is an approximate representation of the severity of a fire involving ordinary combustibles. The base line used represents the temperature the materials can be exposed to without impairing their fire resistive capabilites. Two fires with differing temperature histories are considered to have equivalent severity when the area under their time temperature curves is similar. This concept permitted comparison of any fire test data to the standard time-temperature curve by relating the area under the test curve to the area under the standard curve.

FIRE LOAD

The original concepts of fire severity and fire load are very important even though they are technically obsolete. These concepts are the basis for many of the fire resistance requirements of building codes and for government agencies. In many cases, use of this original fire severity/fire load relationship was more severe than is indicated by more accurate analysis. Such results are conservative since the resultant error is on the safe side.

Analysis of NBS tests developed an approximate relationship between fire loading and an exposure to a fire severity equivalent to the standard time-temperature curve. The weight per square foot or square meter of ordinary combustibles (wood, paper, and similar materials with a heat of combustion of 7,000 to 8,000 Btu per lb (16 282 to 18 608 J/kg)) was related to hourly fire severity as described in Table 7-9B.

The fire severity/fire load relationship was the first method developed to predict the severity of a fire that would be anticipated in various occupancies. It was used to determine resistance required of fire barriers as well as structural components. Although the technique has its limitations, the fire severity/fire load relationship still provides an approximate but conservative estimate of the probable maximum fire severity in residential, institutional, and some commercial occupancies. Fire load should not be used as an approximate indicator of fire severity with combustibles having a high heat release rate and when fire conditions can produce temperatures significantly higher or lower than the standard time-temperature curve.

TABLE 7-9B. Estimated Fire Severity for Offices and Light Commercial Occupanices

Data applying to fire-resistive buildings with combustible furniture and shelving

Combustible Content Total, including finish, floor, and trim psf	Heat Potential Assumed* Btu per sq ft†	Equivalent Fire Severity Approximately equivalent to that of test under standard curve for the following periods:
5	40,000	30 min
10	80,000	1 hr
15	120,000	1½ hrs
20	160,000	2 hrs
30	240,000	3 hrs
40	320,000	4½ hrs
50	380,000	7 hrs
60	432,000	8 hrs
70	500,000	9 hrs

* Heat of combustion of contents taken at 8,000 Btu per lb up to 40 psf; 7,600 Btu per lb for 50 lb, and 7,200 Btu for 60 lb and more to allow for relatively greater proportion of paper. The weights contemplated by the tables are those of ordinary combustible materials, such as wood, paper, or textiles.

† SI units: 1 psf = 4.9 kg/m²; 1 Btu/ft² = 1.14 J/m²

Fire load is a measure of the maximum heat that would be released if all the combustibles in a given fire area burned. Maximum heat release is the product of the weight of each combustible multiplied by its heat of combustion. In a normal building, the fire load includes combustible contents, interior finish, floor finish, and structural elements. Fire load is commonly expressed in terms of the average fire load, which is the equivalent combustible weight divided by the fire area in square feet or square meters.

Equivalent combustible weight is defined as the weight of ordinary combustibles having a heat of combustion of 8,000 Btu per lb (18 608 J/kg), that would release the same total heat as the combustibles in the space. For example, the equivalent weight of 10 lb per sq ft (48.8 kg/m^2) of a plastic with a heat of combustion of 12,000 Btu per lb (27 912 J/kg) would be:

$$10 \text{ lb per sq ft} \times 12{,}000 \text{ Btu per lb} = 120{,}000 \text{ Btu per sq ft}$$

$$120{,}000 \text{ Btu per sq ft} \div 8{,}000 \text{ Btu per lb ordinary combustibles} = 15 \text{ lb per sq ft}$$

Technically accurate methods for relating fire severity, fire load, and fire resistance requirements are complex but can be advantageously used in important specific applications. Such methods require consideration of parameters other than the fuel load, such as ventilation, type of enclosure walls, and ceiling. These methods are complex and currently too difficult for general use in design or selection of barrier fire resistance.

TABLE 7-9C. Characteristics of Fire Loads in Office Buildings

	Government Buildings			Private Buildings		
	No. of Rooms Sampled	Total Fire Load, psf		No. of Rooms Sampled	Total Fire Load, psf	
Room Use		Mean	Std. Dev.		Mean	Std. Dev
General	342	7.3	4.4	479	7.7	4.3
Clerical	77	5.8	5.2	146	6.8	4.0
Lobby	15	2.6	1.4	45	5.0	4.2
Conference	39	4.2	6.1	57	5.9	4.6
File	10	17.9	11.9	20	16.2	12.9
Storage	35	11.7	19.2	77	13.2	11.7
Library	2	30.2	7.8	10	23.6	10.8

Notes: Fire load was not reduced to account for combustibles that do not burn completely because they are in steel enclosures. Weight of combustibles was converted to an equivalent weight of combustibles having a heat of combustion of 8,000 Btu/lb.

SI units: 1 psf = 4.88 kg/m²

Occupancy Fire Load

A number of surveys have identified the fire loads found in various occupancies (Berry and Minor 1979; Culver 1978; Campbell 1978). (See Tables 7-9C, 7-9D, and 7-9E, and Figure 7-9B.)

TABLE 7-9D. Samples of Typical Fire Loads

Type of Room	Contents Fire Load psf	Standard Deviation psf
Living Room	3.9	1.13
Family Room	2.7	.65
Bedroom	4.3	1.15
Dining Room	3.6	1.02
Kitchen	3.2	.77
Hospital Patient Room	1.2	.36
Nursing Home Patient Room	2.6	.62

SI units: 1 psf = 4.88 kg/m²

Data from some fire load surveys as well as the inherent nature of combustible contents likely to be encountered suggests that the dispersion of fire load within a certain class of rooms can be approximated by either a normal or moderately skewed frequency distribution curve. (See Fig. 7-9C.) The standard deviation, included in Tables 7-9C and 7-9D, can be used to determine the probability that a particular fire load value will not be exceeded in a class of rooms. A fire load which is one standard deviation above the mean value of a normal distribution curve would represent an upper boundary for 64.13 percent of the fire loads in rooms of that class. Two standard deviations above the mean would bound 97.75 percent of the fire loads in that class of rooms, and three standard deviations, 99.86 percent of the fire loads. Thus, if a fire barrier were to be designed on the basis of two standard deviations above the mean, there would be a 97.73 percent probability that this fire load would not be exceeded in a similar room.

The above percentages are exact only if the distribution of fire loads is perfectly normal. If the distribution is more accurately defined by a moderately skewed curve, the percentages only represent close approximations.

TABLE 7-9E. Fire Severity Expected by Occupancy[*]

Temperature Curve A (Slight)
- Well-arranged office, metal furniture, noncombustible building.
- Welding areas containing slight combustibles.
- Noncombustible power house.
- Noncombustible buildings, slight amount of combustible occupancy.

Temperature Curve B (Moderate)
- Cotton and waste paper storage (baled) and well-arranged, noncombustible building.
- Paper-making processes, noncombustible building.
- Noncombustible institutional buildings with combustible occupancy.

Temperature Curve C (Moderately Severe)
- Well arranged combustible storage, e.g., wooden patterns, noncombustible buildings.
- Machine shop having noncombustible floors.

Temperature Curve D (Severe)
- Manufacturing areas, combustible products, noncombustible building.
- Congested combustible storage areas, noncombustible building

Temperature Curve E (Standard Fire Exposure—Severe)
- Flammable liquids.
- Woodworking areas.
- Office, combustible furniture and buildings.
- Paper working, printing, etc.
- Furniture manufacturing and finishing.
- Machine shop having combustible floors.

[*] See Fig. 7-9B for the temperature curves identified in this table

Derated Fire Loads

Ordinary combustibles that are completely or largely enclosed in steel containers will not burn completely during a room fire and therefore will not contribute a full 8,000 Btu per lb (16 282 J/kg) to the fire load. The General Services Administration has developed guidelines for determining a derated fire load for office buildings, which can be applied to other occupancies having similar classes of combustibles (GSA 1977). The total contents fire load is divided into three categories: (1) weight of materials completely enclosed in containers such as steel desks or file cabinets, W_E; (2) weight of materials enclosed on five sides

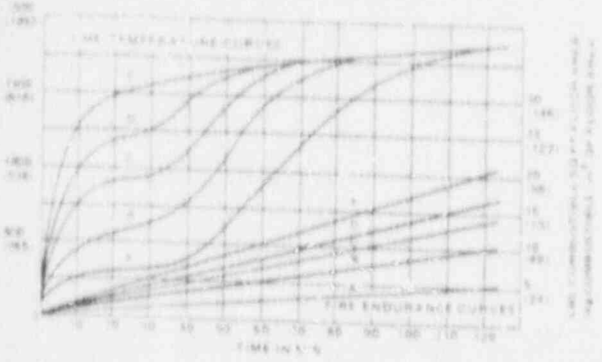


FIG. 7-9B. Possible classification of building contents for fire severity and duration. The straight lines indicate the length of fire endurance based upon amounts of combustibles involved. The curved lines indicate the severity expected for the various occupancies. (See Table 7-9E). There is no direct relationship between the straight and curved lines, but, for example, 10 lb of combustible per sq ft (48.8 kg/m²) will produce a 90 minute fire in a "C" occupancy, and a fire severity following the time-temperature curve "C" might be expected.

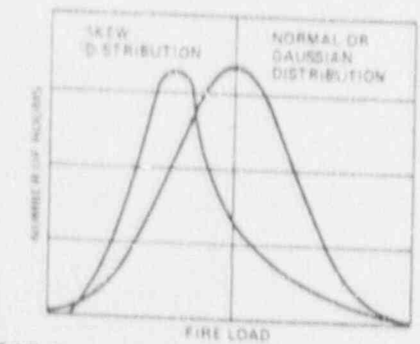


FIG. 7-9C. Expected distributions of sample fire loads.

such as in a steel bookcase, W_{PE}; and (3) weight of free combustibles, W_{FE}.

Completely enclosed combustibles will be heated by the room fire and pyrolyze; and the escaping pyrolysis products will burn. Therefore, the heat that the enclosed combustibles release depends upon the extent to which they are pyrolyzed. This is related to the intensity and duration of the room fire, which in turn is related to the total combustibles in the room. The extent to which the enclosed contents are derated is determined by considering the ratio of the total weight of enclosed combustibles, W_E, to the total weight of all combustibles in the room, F_T. Thus:

$$F_T = W_E + W_{PE} + W_F$$

A derating factor is assigned to W_E as tabulated below:

Ratio W_E/F_T	Derating Factor, K
under 0.5	0.4
0.5 to 0.8	0.2
over 0.8	0.1

Ordinary combustibles enclosed on five sides by steel, such as in a bookcase, are derated to 75 percent of their weight.

The total derated fire load is given by:

$$F_{DR} = K \times W_E + 0.75\ W_{PE} + W_F$$

The specific fire load is then computed by dividing by the floor area.

This derating procedure can be applied if other than ordinary combustibles are included in the fire load. The total weight of other combustibles must be expressed in terms of an equivalent weight of ordinary combustibles that would release the same total heat in burning. This is accomplished by multiplying the weight of the other combustibles by the ratio of their heat of combustion in Btu per lb. to 8,000 Btu per lb (18 608 J/g), the heat of combustion of ordinary combustibles.

British Fire Loading Studies

The British have attained a similar objective by grading building occupancies according to hazard. Three classifications, low, moderate, and high fire loads, are defined in terms of Btu per sq ft or J/m² as follows:

Occupancies of Low Fire Load: The fire load of an occupancy is described as low if it does not exceed an average of 100,000 Btu per sq ft (114 000 J/m²) of net floor area of any compartment, nor an average of 200,000 Btu per sq ft (228 000 J/m²) in limited isolated areas, provided that storage of combustible material necessary to the occupancy may be allowed to a limited extent if separated from the remainder and enclosed by appropriate grade fire resistive construction. Examples of occupancies of normal low fire load are offices, restaurants, hotels, hospitals, schools, museums, public libraries, and institutional and administrative buildings.

Occupancies of Moderate Fire Load: The fire load of an occupancy is described as moderate if it exceeds an average of 100,000 Btu per sq ft (114 000 J/m²) of net floor area of any compartment but does not exceed an average of 200,000 Btu per sq ft (228 000 J/m²), nor an average of 400,000 Btu per sq ft (456 000 J/m²) on limited isolated areas, provided that storage of combustible material necessary to the occupancy may be allowed to a limited extent, if separated from the remainder and enclosed by fire resistive construction of an appropriate grade. Examples of occupancies of normal moderate fire load are retail shops, factories, and workshops.

Occupancies of High Fire Load: The fire load of an occupancy is described as high if it exceeds an average of 200,000 Btu per sq ft (228 000 J/m²) of net floor area but does not exceed an average of 400,000 Btu per sq ft (456 000 J/m²) of net floor area, nor an average of 800,000 Btu per sq ft (912 000 J/m²) on limited isolated areas. Examples of occupancies with normal high fire load are warehouses and other buildings used for the bulk storage of commodities of a recognized nonhazardous nature.

The low fire load grading of occupancies used by the British is approximately equivalent to the classification of occupancy represented by the Temperature Curve A; moderate fire load grading by Temperture Curves B, C, and D; and the high fire load grading by Temperature Curve E in Figure 7-9B.

other forces, such as wind and stack effects and the mechanical heat, ventilating, air conditioning or other air movement systems. In these areas the movement of smoke is essentially the same as the movement of any other pollutant.

SMOKE MOVEMENT IN THE HOT SMOKE ZONE

The volume of combustion products entrained in a rising plume in the hot smoke zone is relatively small, compared with the volume of air in the total mixture. Consequently, the smoke produced by a fire will approximate the volume of air drawn into the rising plume. Figure 7-10A illustrates the process.

In those situations where the height of the plume as measured from the top of the fire to the level of the smoke layer, as shown in Figure 7-10A, is more than about twice the height of the solid body of flame, it is reasonable to estimate the amount of smoke using developed formulas (Thomas et al 1963) and presented in the book, "Smoke Control in Fire Safety Design" (Butcher & Parnell 1979).

The formulas involved were derived from research conducted at the British Fire Research Station more than 20 years ago. This work showed that the amount of smoke could be reasonable estimated solely as a function of the height of the fire plume over a "virtual fire source." The research indicated that the virtual source for a free burning fire having a circular shape would be approximately 0.15 diameters below the burning surface.

The mass of gas drawn into the fire can be estimated as:

$$M = 0.096\,Pq_o y^{3/2}\,(g\,T_o/T)^{1/2}$$

where:

M = rate of smoke production (kg/s)
P = perimeter of the fire (m)
q_o = density of ambient air (kg/m^3)
y = distance from floor to bottom of smoke layer (m)
g = acceleration due to gravity (m/s^2)
T_o = absolute temperature of the ambient air (°K)
T = absolute temperature of the flames of the smoke plume (°K)

Typical numerical values of the parameters are:

q_o = 1.22 kg/m^3 @ 17°C
T_o = 290 K
T = 1100 K
g = 9.81 m/s^2

Using these values, the rate of smoke production becomes:

$$M = 0.188\,P\,y^{3/2}$$

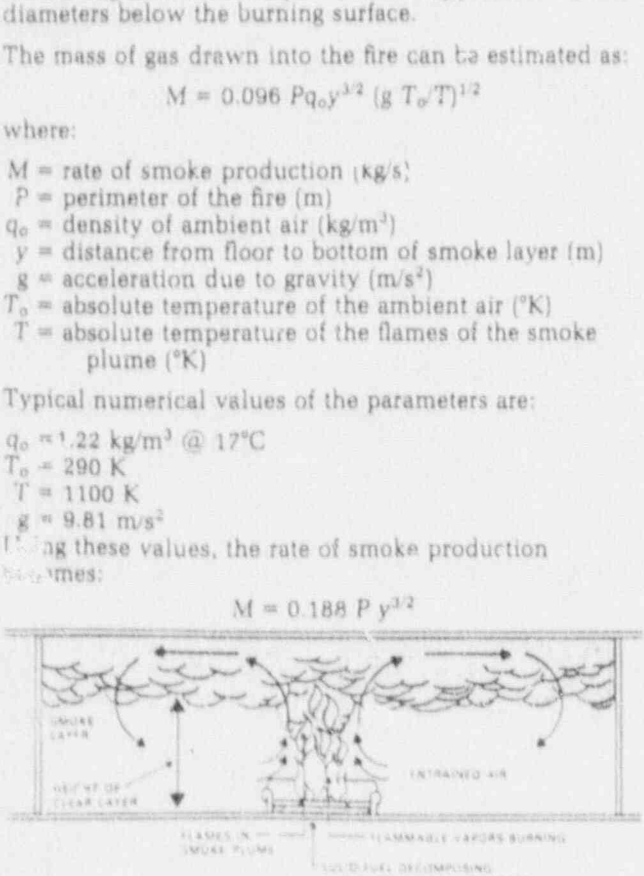


FIG. 7-10A. The production of smoke from a fire.

The simple expression $M = 0.188Py$ includes a series of assumptions, the most important of which are:

1. The tip of the flame is a significant distance below the bottom of the smoke layer. The formula, while useful, is much less accurate in spaces having a low ceiling relative to the height of the fire involved.
2. The fire bed itself covers an area having a length and width that are reasonably approximate to each other. The original formula is based on the assumption of a circular fire. The degree of error in the formula increases as the relationship of length to width increases.

Flame Height

A reasonable estimate of flame height (Alpert and Ward 1963) can be obtained from the expression:

$$H_f = 0.011\,(k\dot{Q})^{0.4}$$

where:

H_f = flame height (m)
k = wall effect factor. The value of k to be used is:
$k = 1$ when there are no nearby walls.
$k = 2$ when the fuel packages near a wall.
$k = 4$ when the fuel package is in a corner.
$\dot{Q}$ = fuel heat release rate (watts).

The results of this formula is shown graphically in Figure 7-10B.

Plume Gas Temperature

Detailed engineering formulas for properties of fire plumes have been presented (Heskestad 1982). In simpler terms, however, (Alpert and Ward 1963) an empirical estimate plume temperature is provided at a given point above the fuel as:

$$\Delta T = \frac{0.222\,(k\dot{Q})^{2/3}}{H^{5/3}}$$

where

ΔT = maximum temperature increase (°C) above ambient (room) temperature.
$\dot{Q}$ = total heat release rate (W).
k = wall factor. The value of k is:

$k = 1$ when there are no nearby walls
$k = 2$ when the fuel package is near a wall
$k = 4$ when the fuel package is in a corner

H = distance (m) above the top of the fuel package (for a pool of flammable liquid, such as gasoline or heptane, H is the distance above the fuel surface minus one pool diameter).

Smoke production is, therefore, dependent upon the perimeter of the fire and the effective height of the gas column above it. As the fire continues to burn, the rate of smoke production will vary as the distance y changes. Figure 7-10C illustrates this variability.

The mass rate of smoke production, M, can be converted into a volumetric rate of production by dividing the expression above by the density of the air (as smoke) at T°C. This factor becomes 1.22 (290/T+273) kg/m^3. Table

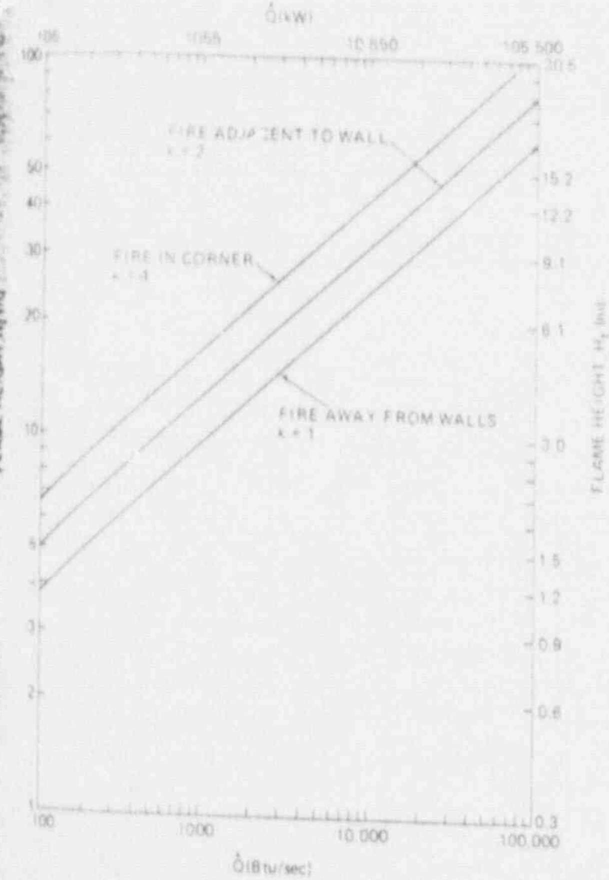


FIG. 7-10B. Flame height versus fire heat release rate.

7-10A illustrates the relationship between mass rates and volumetric rates of flow.

Smoke Filling of a Space

Numerous mathematical models involving complex interrelationships to describe the filling of a space with smoke, the transfer of heat energy from that smoke, and the flow of that smoke through large openings are in advanced stages of development and validation. There are, however, several estimating formulas that have been proposed by various researchers. Several of these are presented here.

The filling time of a space down to the level of the top of the burning item (Cooper 1982) has been estimated to be:

$$t_f = 200A/\dot{q}^{0.8}$$

where

t_f = time to fill the space to the burning surface (sec.)
A = floor area of space (^{2})
$\dot{q}$ = burning rate (kW)

A modification for a crude estimate of filling time (t_e) to some point other than the fire surface (Nelson 1985) has been proposed as:

$$t_e = t_f\left(\frac{h-d}{h}\right)^{5/2}$$

where

h = distance from top of the fuel to ceiling
d = distance from top of the fuel to bottom of smoke layer

Where there are open windows or doors involved, these proposed formulas can be used only for broad estimates to the point where smoke descends to the height of the window or door soffit. After that, movement through the openings must also be considered in smoke flow. Where the openings are large so that there is an outflow of smoke through the upper portion of the opening and an inflow of makeup air through the lower portion, complex relationships, not easily expressed in Handbook type formulas, are involved.

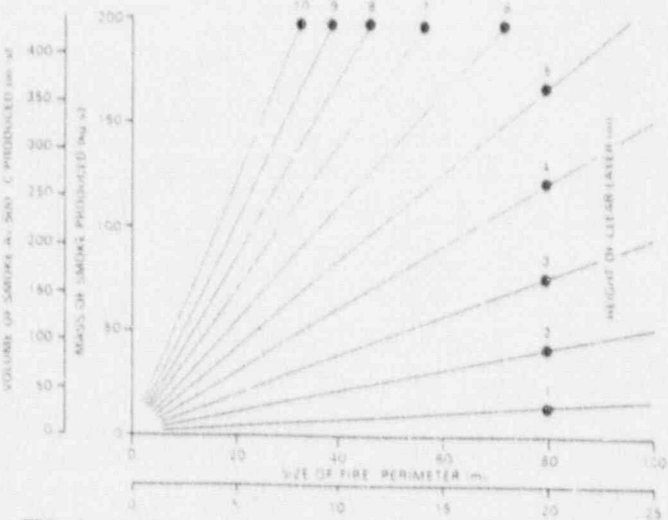


FIG. 7-10C. Rate of smoke production as a fire continues to burn.

Where the flow is through an opening of a relatively small size and is either entirely above the smoke layer, or where the portion of interface is small compared to the full size of the opening, e.g., the space between a door frame and the vertical side of a closed smoke barrier door, it is possible to use adaptations of Bernoulli's equation to estimate the smoke movement. The basic formulas have been assembled (Klote & Fothergill 1983) and adapted to the following statement (Nelson 1985):

$$f = 49A\left(\frac{1}{T_o} - \frac{1}{T_s}\right)^{1/2} h^{1/2}\left(\frac{T_s}{T_o}\right)^{1/2}$$

TABLE 7-10A. Conversion of Mass Rates of Flow of Smoke into Volume Rates of Flow.

Mass rate of flow		Volume rates of flow			
		m^3/sec		ft^3/min	
kg/sec	lb/sec	at 20°C	at 500°C	at 20°C	at 500°C
200	440.8	164.9	436.9	346928	925354
100	220.4	81.9	218.5	173464	462783
90	198.4	73.8	[illegible]	156308	416399
80	176.6	65.6	174.8	138941	370226
70	154.3	57.4	152.9	121573	323842
60	132.2	49.2	131.1	104205	277670
50	110.2	41.0	109.2	86838	231286
40	88.2	32.8	87.4	69470	185113
30	66.1	24.6	65.4	52103	138517
20	44.1	16.4	43.7	34735	92557
10	22.0	8.2	21.8	17346	46278
9	19.8	7.4	19.7	15631	41640
8	17.7	6.6	17.5	13894	37023
7	15.4	5.7	15.3	12157	32384
6	13.2	4.9	13.1	10420	27767
5	11.0	4.1	10.9	8684	23128
4	8.8	3.3	8.7	6947	18511
3	6.6	2.5	6.5	5210	13852
2	4.4	1.6	4.4	3473	9256
1	2.2	0.8	2.2	1735	4628

where:

f = flow (m^3/min)
A = area of opening (m^2)
T_a = ambient temperature (K)
T_s = smoke temperature (K)
d = depth of smoke from centerline of opening to bottom of smoke layer (m)

In conventional units the formula is:

$$f = 7214A\left(\frac{1}{530} - \frac{1}{T}\right)^{1/2} h^{1/2}\left(\frac{T}{530}\right)^{1/2}$$

$$\Delta P = 7.64\left(\frac{1}{530} - \frac{1}{T}\right)h$$

where:

f = flow (ft^3/min)
A = area of opening (ft^2)
T_a = ambient temperature (°R)
T_s = smoke temperature (°R)
ΔP = pressure difference (in. of water)

Figure 7-10D shows typical results from this formula.

SMOKE MOVEMENT IN COLD SMOKE ZONES

As smoke is transmitted from the area of fire origin it is cooled by entrainment of air, transfer of the heat from the smoke body to building materials, primarily those in the walls and ceilings, and (to a lesser extent as the smoke cools) by radiant energy losses. When smoke from a fire area flows through a relatively small crack, the entrainment of cool air on the unexposed side tends to cool the smoke very quickly. Where the leakage is through larger openings there may be less entrainment relative to the mass of smoke movement at such junctures and therefore, cooling will be slower. However, once the smoke has cooled to a significant degree, the smoke is transported in the same manner as any other pollutant and the primary moving forces are those presented by stack effect, wind effect, and mechanical air movement systems.

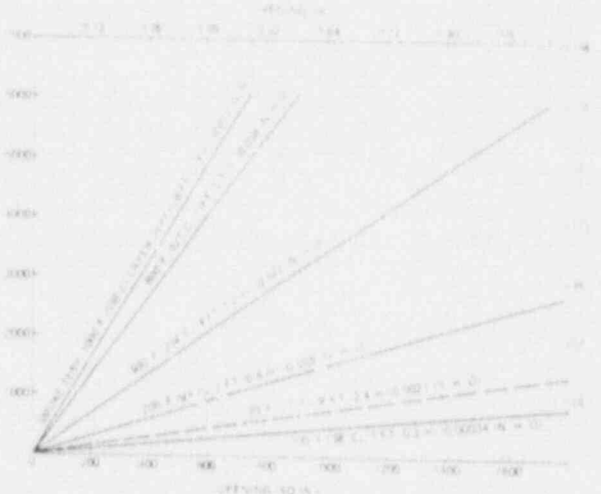


FIG. 7-10D. Volume of smoke flow through an opening.

SMOKE MOVEMENT IN TALL BUILDINGS

Smoke can behave very differently in tall buildings than in short buildings. In the shorter buildings, the influences of the fire (such as heat, convective movement, and fire pressures) are the major factors which cause smoke movement. Smoke removal and venting practices reflect this behavior. In tall buildings, these same factors are modified by the stack effect, which is the vertical natural air movement through the building caused by the differences in temperatures and densities between the inside and outside air. This stack effect can become an important factor in smoke movement and in building design features used to combat that movement.

The predominant factors that cause smoke movement in tall buildings are (1) the stack effect, (2) the influence of external wind forces, and (3) the forced air movement within the building. The following text describes the theoretical natural air movement which is affected by the first two factors. (Forced air movement caused by the building air handling equipment is presented elsewhere in this HANDBOOK). At this point, however, it should be noted that air movement is considerably influenced by the mechanical systems of the building. Many design solutions to the problem of tenability utilize emergency operation of the mechanical systems.

NUCLEAR FACILITIES

Revised by George Weldon, P.E.

In general, radioactive substances and operations involving radioactive materials or devices and equipment which present radiation hazards have the same fire and explosion features as similar materials and operations without radiation hazards. However, due to the hazard to personnel and the possibility of long term contamination of property from exposure to sudden accidental escape of radioactive substances, the subject of protection from radiation hazards deserves special consideration, especially the procedures that must be followed during emergencies.

NUCLEAR REACTORS

A nuclear reactor is a device or assembly for initiating and maintaining a controlled nuclear chain reaction in a fissionable fuel (uranium or plutonium). Nuclear reactors are used to produce energy, to study the fission process, or to produce radioactive materials within the reactor or in a material exposed by the reactor's radiation or radioactive particles. Basically, nuclear reactors may be divided into (1) nuclear power reactors of large size, up to 3,500 MW (megawatts thermal) or 1,100 MW(e) (megawatts electrical), and (2) research reactors that operate at power levels from a few watts to many megawatts. In 1985, there were [illegible] operating or near operating nuclear power reactors and an additional 30 nuclear power reactors with construction permits in the United States alone. Construction of many others has been delayed—some indefinitely. Dozens of research reactors are now operating, but in general the number of research reactors is not increasing.

Nuclear reactors that include a containment vessel, generating equipment, and heat removal equipment can be as large as the largest fossil fueled electrical generating plants. Most research reactors, however, are so small that they may occupy only one small corner of a room in a typical laboratory building at a research facility or college campus. Therefore, the magnitude of hazard presented by each kind of reactor varies considerably.

Various national and international groups have addressed the need for fire protection requirements for nuclear power reactors and research reactors. These groups include the National Fire Protection Association (NFPA), the American Nuclear Society, the American National Standards Institute (ANSI), the United States Nuclear Regulatory Commission (NRC), the Mutual Atomic Energy Reinsurance Pool, and the American Nuclear Insurers. They are referenced in the Bibliography at the end of this chapter.

The "Defense in Depth" philosophy, which calls for the provisions that follow, is applicable to both power and research reactors. Those provisions are:

1. Fire prevention.
2. Quick detection and suppression of fires that occur.
3. Designing the plant to limit the consequences of fire.

Heat Removal

All nuclear reactors, even very low power training or research reactors, produce heat while operating. This heat either must be dissipated or used, depending upon the amount produced and the purpose for which the reactor is intended.

Reactor Control

Reactor control systems and safety systems are of utmost importance. The control system design is fitted to the technical characteristics of the reactor and is capable of producing power changes at acceptable rates. The control system design also makes it possible to produce and maintain the desired power level within the reactor in such a way that excessive temperatures are avoided. The safety system, which is an addition to the control system, is adopted to the characteristics of the reactor in the instrument and control system. It responds to signals from the instruments by automatic operation, in order to prevent operational variables from exceeding safe limits. On appropriate signals, the safety system warns of incipient performance changes and, if necessary, shuts down the reactor.

A reactor becomes "critical" when the total rate of production of neutrons, under control conditions, is such that self-sustaining reactions occur. Control methods must

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Mr. Weldon, P.E., is Engineering Manager for the Mutual Atomic Energy Reinsurance Pool, Norwood, MA be rapid and sensitive, and protected from fire. Since the control system is vital to the adequate functioning and safe operation of the reactor, the protection of the control room, cableways, emergency power supply, and electrically or hydraulically operated equipment is of prime importance. Protection for [illegible] areas should be fully consistent with that used in computer rooms containing vital records.

Construction Problems

Fire records indicate that one of the more vulnerable periods for fire damage in the lifetime of a large reactor system—such as found in nuclear power plants—exists during the construction stage. (See Fig. 10-17A.) Because the construction of such a plant usually requires many years, the construction hazards acquire a nearly permanent status and should be considered as if they were to be permanent.

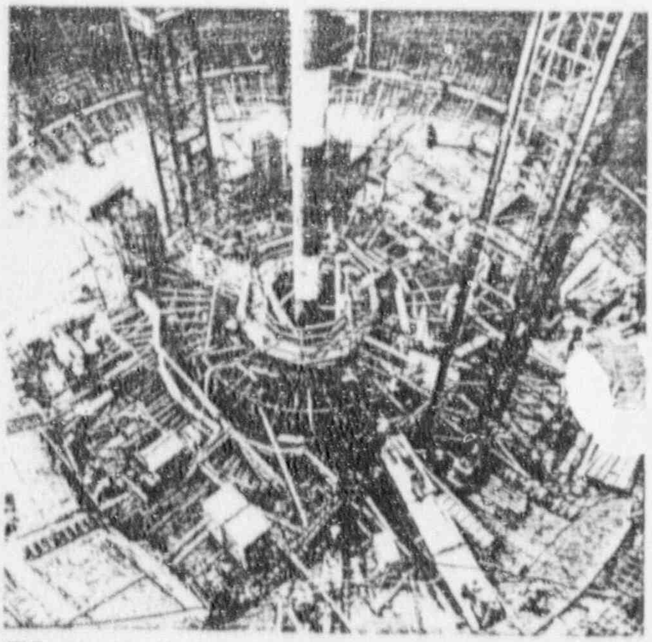

FIG. 10-17A. Nuclear facilities are most vulnerable to fire damage during construction, a period of several years, and thus require a good construction firesafety program.

Power reactors present unique fire protection problems during construction since they require a containment vessel as a final protection system. Construction techniques require the containment structure to be built early during the project. This means that much of the subsequent reactor construction takes place inside a large vessel that has limited exits for evacuation and limited fire fighting access. In addition, the vessel confines smoke and other products of combustion, which greatly increases the difficulties of evacuation and manual fire fighting. A good construction firesafety program should ensure that all penetrations of the containment vessel suitable for evacuation remain open and usable during the period that other construction is taking place within the vessel.

Due to the limited access for fire fighting and the lack of normal venting possibilities for smoke and gases, it is imperative to severely limit all combustible materials needed for construction. Metal formwork, scaffolding, platforms, stairways, etc., are preferable to wood. The use of wood in extensive quantities is limited to those kinds of woods appropriately treated to reduce inherent combustibility and flame spread ratings.

Installation of utilities and equipment in the containment vessel requires special care so a low level of combustibles is maintained. Since reactor equipment must meet very high levels of quality assurance, reactor equipment that has been subjected to fire and smoke damage is much more likely to require replacement than similarly exposed equipment in normal industrial installations. Special efforts are necessary to reduce the usual accumulation of packing cases, cartons, insulation, etc., to an acceptable level. This may take the form of conducting all uncrating operations outside the containment vessel and providing special handling devices to transport unpackaged items into the vessel.

Research Reactors

In general, these may present particular problems due to their location in existing buildings (which are sometimes of combustible construction), and the use of much combustible loading in the form of paraffin shielding, wall finishes, and instrumentation. Combustibles should be eliminated wherever possible. For example, water can be used in place of paraffin. Where combustibles cannot be eliminated, automatic sprinkler protection should be provided. Supervision of construction/operating personnel is especially important because a number of different operating groups may be involved with a single reactor.

RADIATION MACHINES

Radiation machines include mechanical and electrical devices that produce or make use of subatomic particles or electromagnetic radiation, or both. X ray machines are used in radiography, therapeutic treatment, and in studies of the behavior of radiation and its effects upon materials. Particle accelerators, while a source of radiation, are primarily devices for imparting extremely high energies to subatomic particles which enter and alter atomic nuclei, thereby providing the means for developing basic information concerning the structure and behavior of matter. Gamma ray sources in the form of radioactive isotopes are employed in radiography equipment. This equipment may produce intense radiation. The use of isotopes as a source of radiation is not discussed in this chapter.

X Ray Machines

Except for the radiation hazard while in use, the hazards of X ray machines are mainly the hazards of high potential and high energy electrical equipment. When shut down, there is seldom any appreciable residual radiation to interfere with fire fighting or salvage operations. Although no flammable gases or hazardous amounts of flammable liquids are ordinarily needed to operate X ray machines, they are frequently encountered in studies of the effects of radiation on a wide variety of substances.

Particle Accelerators

Particle accelerators include Van de Graaff generators, linear accelerators, cyclotrons, synchrotrons, betatrons,

betatrons. The machines are used, as the name implies, to accelerate various charged atomic particles to tremendous speeds and, consequently, to high energy levels. Particle accelerators furnish scientists with atomic particles, in the form of a beam, which may be utilized for fundamental studies of atomic structure. In addition, accelerators furnish high energy radiation which may be utilized for radiography, therapy, or chemical processing.

Particle accelerators emit radiation only while in operation. Attempts to extinguish a fire in the immediate vicinity of the machine should be delayed until the machine's power supply can be disconnected.

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. Some installations use such hazardous materials as liquid hydrogen or other flammable materials in considerable quantities. Large amounts of paraffin are used for neutron shielding purposes. Another factor is the possible presence of combustible oils used for insulating and cooling.

Industrial applications for particle accelerators 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 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 in areas containing hazardous amounts of combustible material or equipment. Special fire protection should be provided for any high voltage electrical equipment.

FACILITIES HANDLING RADIOACTIVE MATERIALS

The type of equipment used to process radioactive materials depends not only upon the work to be performed, but also upon the degree of hazard associated with the material and the process it is to undergo. Materials with low levels of radioactivity and with little or no inherent fire or explosion hazards require less protective equipment than others. For purposes of personnel protection the amount and kind of shielding required will depend upon the types of radiation emitted as well as the activity involved. In addition, the chemical and physical nature of the radioactive materials will dictate the degree of containment necessary, as well as the construction materials necessary in the containment system. All equipment to be used for handling and processing radioactive materials should be designed to minimize fire and explosion potentials as well as to protect personnel against harmful radiation exposure and prevent damage to property by contamination. 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.

Benches

Benches are used generally for handling relatively small amounts of alpha or beta emitting materials requiring little or no shielding when handled with gloved hands or tongs. No special ventilation for the bench is provided in most instances and its use is thereby restricted to materials which will not easily become airborne.

Benches should be of noncombustible construction with a nonporous continuous working surface which can be decontaminated easily. Usually, one or two layers of blotting paper on the bench top to absorb small spills will not increase materially the fire hazard.

Hoods

Hoods, sometimes referred to as "fume hoods," are similar to benches except for the addition of an enclosure and exhaust system for removing vapors. The nature of the operations conducted within the hood may require a filter system to prevent the spread of radioactive materials. Filters with a low degree of combustibility are desirable.

Glove Boxes

The term "glove box" refers to a system designed to contain materials, generally alpha radiation emitters, which present little or no external radiation hazard but which can present a serious problem if they become airborne. Glove boxes may be large and used in 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 necessary. (See Fig. 10-17B.)

Hot Cells

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 periscopes. Hot cells are constructed preferably of noncombustible materials and contain the minimum amount of combustibles consistent with operational requirements.

In addition to all of the fire and explosion hazards of glove boxes, hot cells also present increased damage potential due to the nature of the high gamma ray producing materials used. The safeguards recommended for glove boxes apply equally to hot cells. Where very high gamma radiation levels are encountered, consideration must also be given to the possible failure of containers as a result of radiation damage.

RADIATION EXPOSURE

Radiation Injury

The harmful effect of radiation is due to its ability to ionize the atoms present in the various compounds which compose the body. How the radiation actually damages the living cells is not exactly known. Unfortunately, the human body has no defense mechanism against radiation; nor can nuclear radiation be detected by any of the five senses. Thus, it is possible for an individual to receive a severe exposure to radiation without knowing it. This

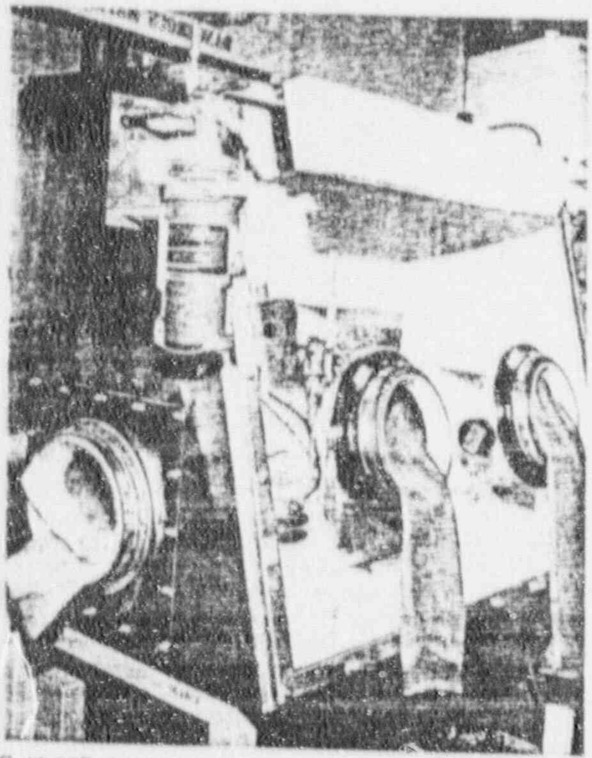

FIG. 10-17B. A typical glove box showing gloves extending from the ports in the viewing window at left. Note the portable fire extinguisher adapted for discharge into the box through a fixed piping arrangement.

danger requires that some form of instrumentation be used to detect radioactivity.

The amount of injury to a person from radiation varies with the type of radiation, how much of the body has been exposed, and whether it is a one time exposure or an accumulation of exposures to small amounts of radiation. Injuries from excessive exposures may not become apparent for days, weeks, months, or years.

Radiation experts report that, similar to many potentially hazardous materials, any exposure to radiation, either external or internal, has some element of risk, which may be too low to be measurable. Certain exposures are believed to be of reasonable risk balanced against the benefits from any activity using radiation exposure, such as medical and dental uses of radiation. Since the human race has evolved on a planet which has always been radioactive from the naturally occurring radioisotopes in the air, soil, and water, it is probable that a low "background" radiation is tolerable. The controversy on radiation exposure concerns the additional amounts that may be tolerable by humans. Standards have been set with the objective of lowering risks to the best practicable levels.

Occupational Exposure from Radiation in Air and Water

Radiological authorities have set very low limits of concentrations of radioisotopes in air and water based on quantities which may be inhaled or ingested. Complete treatment of the subject would require consideration of maximum permissible concentrations in both air and water, but the problem of airborne concentrations is of particular concern in fire situations, as fire fighters and other emergency personnel may be confronted with such material in the fumes, dust, smoke, and gases liberated by a fire in which radioactive materials are involved.

A hard and fast rule should be mandated that self-contained breathing apparatus (SCBA) is to be used whenever exposure to airborne radiation is a possibility. Maximum Permissible Concentrations (MPC) of various radioisotopes in air and water are commonly stated as limits intended to apply to persons who are continuously exposed to the concentrations named. Consequently, the concentrations are far below the exposures which could be tolerated for infrequent exposure, as would most often be the case with fire fighters or emergency workers.

Apparatus is available for taking a sample of an atmosphere. The number of radioactive emissions in the air can be counted with an appropriate counting instrument. From these counts, the extent to which the particular atmosphere is contaminated can be determined. (See Fig. 10-17C.)

Any space normally occupied by persons not primar

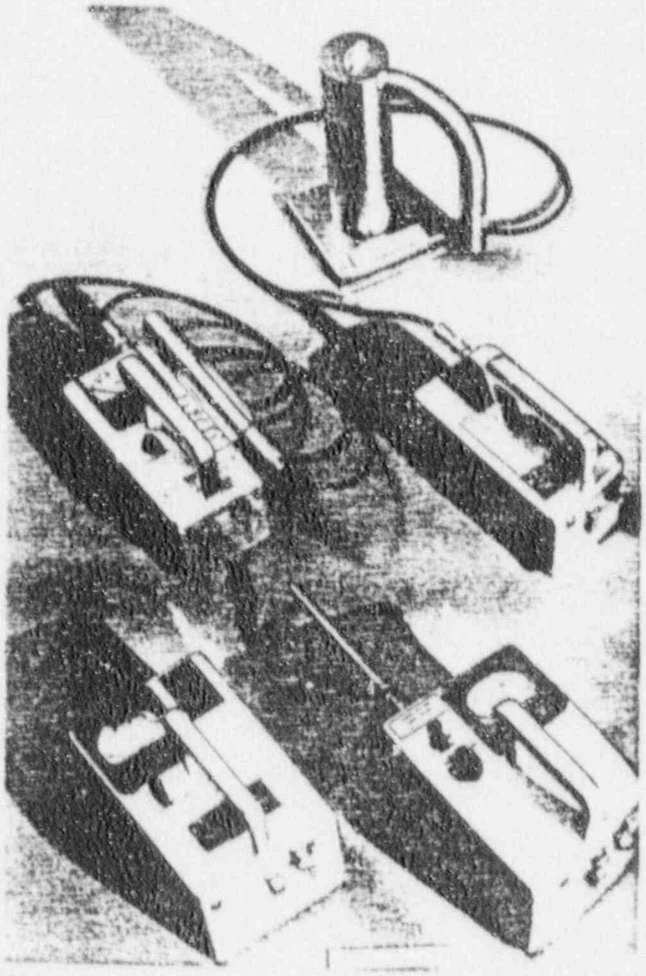

FIG. 10-17C. Portable instruments for measuring developed at Oak Ridge National Laboratory. The meters are for fast neutrons (bottom row at left), thermal neutrons (bottom row at right), beta-gamma (top row left), and for alpha particles (top row right) with an alpha scintillation detector at top of the picture.

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 and exposure through contact with radioactive waste or 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 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 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

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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.*
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LICENSEE'S EXHIBIT 20, Attachment C

NFPA 802

Recommended Fire Protection Practice for

Nuclear Research Reactors

1988 Edition

This edition of NFPA 802, *Recommended Fire Protection Practice for Nuclear Research Reactors*, was prepared by the Technical Committee on Atomic Energy, and acted on by the National Fire Protection Association, Inc. at its Annual Meeting held May 16-18, 1988, in Los Angeles, California. It was issued by the Standards Council on June 8, 1988 with an effective date of June 28, 1988, and supersedes all previous editions.

The 1988 edition of this document has been approved by the American National Standards Institute.

Changes other than editorial are indicated by a vertical rule in the margin of the pages on which they appear. These lines are included as an aid to the user in identifying changes from the previous edition.

Origin and Development of NFPA 802

This recommended practice was tentatively adopted at the Annual Meeting in May 1958. As a result of suggestions received during the period of its circulation, new text was added in the sections on the Boiling Water Reactor and on Educational and Training Reactors, and it was adopted in May 1960, as revised. A completely revised and updated edition was adopted in May 1974. Revisions in the 1983 edition included the substitution of ionizing in place of gamma to include other types of radiation to which one may be exposed. Changes to this edition include a caution to special problems which may be caused by graphite reactors. Other changes are editorial in nature to allow this document to comply with the NFPA *Manual of Style*.

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."

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.

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.

Shall. Indicates a mandatory requirement.

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

Chapter 2 Reactor Safety Considerations

2-1 General. While it is beyond the scope of this publication to discuss the entire range of problems associated with the operation of reactors, it is appropriate to enumerate a number of identifiable problems which have a specific bearing on fire protection.

2-2 Fire Control Problems Due to Radiation Effects.

2-2.1 It should be kept in mind that almost every nuclear reactor will have areas of intense radioactivity associated with it. In fire fighting operations, it is essential not to disturb any part of the structure which is provided for shielding from radiation. In many cases the targets are themselves radioactive and the shielding may be combustible.

2-2.2 During fuel element changes or when the reactor is opened, the potential for radiation exposure to personnel is increased. Specialized shielding equipment, remote handling devices, and protected storage casks or water pools are used to reduce this potential for exposure to a minimum.

2-2.3 There is always the possibility, under emergency conditions, that admittance of personnel to the area housing the reactor or process areas would be forbidden due to high radiation levels or due to radioactive materials in dust or vapors which would be dangerous to inhale or ingest. It is essential that complete preplanning be carried out between the public fire department and the reactor management: where and how, and to what extent the public fire department would be called upon to function.

2-2.4 It is important that reactor operations management recognize that in those areas in which fire fighting forces may not be admitted under some accident situations, complete reliance must be placed on proper design, use of noncombustible materials, and built-in fixed protection.

2-2.5 The permissible radiation to which fire fighters and other emergency personnel may expose themselves is a subject on which no simple statement can be made. One kind of exposure comes from external exposure to ionizing radiation. Another comes from radioactive substances which may be inhaled or ingested.

2-2.6 The exact limits should be defined by the emergency program established for the particular installation. Limits for routine workers, as defined in NRC regulations applicable to NRC contractors and in the Code of Federal Regulations, Title 10, Part 20, applicable to NRC licensees, are based on continuing exposure at those levels for a working lifetime. It does not apply to emergency or once-in-a-lifetime exposure. There are no mandatory limits in this situation, although the *Bureau of Standards, Handbook 59* recommended a 25-rem emergency exposure limit without affecting the normally allowed accumulation rates for workers. Some facilities have adopted 50 rems as an emergency limit. On the other hand, the National Council on Radiation Protection Report No. 39, *Basic Radiation Protection Criteria*, suggests that under emergency conditions which involve life saving actions the planned whole body dose should not exceed 100 rems, and during other less urgent emergencies, such as fighting fires, the planned whole body dose should not exceed 25 rems. In emergency situations such as fire fighting, the actual exposures may be uncertain and exposures should be controlled by the amount of good to be achieved, just as for any other hazard fire fighters are expected to face. The pertinent point is that the exposure that can be permitted in emergency situations can be many times the routine day-after-day exposure limits and not pose a threat to the life of the fire fighter.

2-2.7 The problem of internal radiation exposure is entirely different from the external exposure problem and establishing limits for emergencies is impracticable in the face of measuring difficulties inherent in emergencies. This is really no different than the problem presented by trying to define inhalation limits for smoke, carbon monoxide, and other products of combustion. Fortunately, the mandatory use of self-contained breathing apparatus in radiation emergencies can materially reduce the problem. This problem is discussed more fully in the AEC publication *Living With Radiation, Part 1, Fundamentals*, and *Part 2, Fire Service Problems*.

2-2.8 Radioactive materials, like other particulate matter, may be transported in the smoke of a fire. If deposited on the body or clothing, it can create a potential exposure problem requiring decontamination procedures such as washdown, clothing removal, personnel showers, etc. Every facility should have procedures for decontaminating clothing, personnel, and equipment that may be exposed in emergency situations.

2-2.9 While many facilities provide, and require, special coveralls, shoe covers, etc. for all workers in the facility, it should be remembered that this is an administrative convenience for plant operations. It does not provide a level of radiation protection any greater than that provided by a fire fighter's turnout clothes. In no case should emergency response be delayed because of regulations intended for the administrative convenience of routine operations. Prefire planning should include recognition of such potential problem areas.

2-2.10 It is important that movement of personnel who may carry contamination from contaminated areas to uncontaminated areas be carefully controlled. Plans for such controls should be included in the facilities' emergency plans and fire fighting forces should be indoctrinated in the emergency systems.

2-3 Accident Involving Fissionable Materials.

2-3.1 The fissionable materials, uranium-233 and -235 and plutonium, should be used with provisions to prevent the accidental assembly of fissionable material into critical masses.

2-3.2 Since water is a reflector and moderator of neutrons, it is theoretically possible that an arrangement of subcritical fissionable material could be made critical by the introduction of water. Storage containers, shelving, and storerooms are required to be designed to prevent the accidental assembly of a critical mass. In many cases, the areas are designed to be critically safe even when completely submerged in water. Emergency planning should include the effects of fire fighting water on such areas, assuming disruption of the contents by the accident or by fire hoses. If manual fire fighting poses a potential hazard under the worst conditions, then it is essential that any required fire-extinguishing capability be self-contained and automatic in operation.

2-3.3 If, during a fire, an assembly of fissionable material should become critical, it could not explode like an atomic bomb since special conditions are necessary for such an explosion. Experience to date has shown that such reactions have been self-limiting, but do result in minor distribution of radioactive products over the immediate area accompanied by a brief, very intense, burst of nuclear radiation which could be lethal.

2-3.4 Reactors are normally loaded with a quantity of nuclear fuel greater than the minimum necessary to obtain an initial self-sustaining nuclear reaction. If loss of cooling results in melting or other fuel displacement, it is unlikely that a critical mass in a new form will result. The actual amount of fuel may vary from as little as about one pound to tens of thousands of pounds depending upon fuel enrichment, fuel form, reactor type, and many other factors.

2-4 Fire in Control Systems.

2-4.1 The possible effects of heat, smoke, and corrosive gases on the operation of control systems require attention to features of good practice and fire protection so as to minimize interference with operation of these systems. Features of good design include compartmentalization, minimizing combustible materials, and installation of automatic fixed extinguishing systems. The physical separation of alternative systems for control and safe shutdown of the reactor should be considered and provided to the extent practical.

2-4.2 Electrical control mechanisms involve combustible insulation. Hydraulic controls sometimes involve combustible fluids. The control panels may be exposed to fire damage if located near wood platforms or in spaces having combustible building finish or furnishings.

2-4.3 If fire involving a reactor control system causes reactor shutdown, the need for continued cooling of fuel elements will be reduced, but will not, in most cases, be eliminated.

2-5 Loss of Coolant or Moderator.

2-5.1 Another type of possible accident might be the loss of either moderator or coolant in a reactor operated for a time at or near full power. Sufficient residual heat might remain in the reactor fuel elements to melt them. The possibility of this occurrence in research reactors is extremely remote.

2-5.2 The possibility of chemical reaction of core or coolant materials under conditions of equipment failure must be taken into account. Coolant fires may, for example, result from leaks in sodium or organic coolant systems; sodium-water reactions may result from failures in sodium-water heat exchangers, and graphite may burn if air is inadvertently introduced into a very hot graphite core. Core design questions are involved in the choice of core materials, in the prediction of chemical reaction and radiolysis rates in the core, and possibly in the selection of in-core instrumentation for the detection of troublesome chemical situations.

LICENSEE'S EXHIBIT 20, Attachment D

SFPE Handbook of Fire Protection Engineering

First Edition

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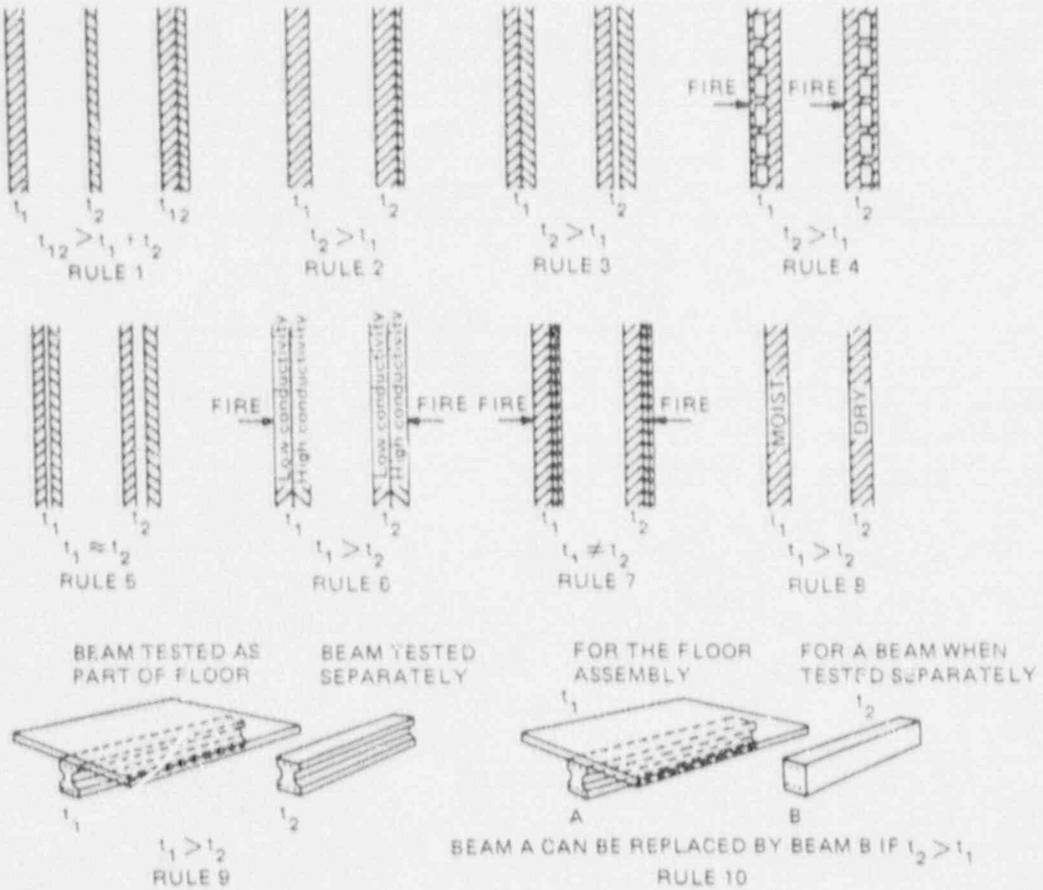

Fig. 3-8.1. Harmathy's ten rules of fire endurance.[6]

0.5-in. gypsum wallboard, if a wire mesh with 0.06-in.-diameter wire and 1 sq in. openings is fastened between the two sheets of wallboard. The *NBCC* also includes times for lath and plaster protection. The times given in Table 3-8.1 are based on the membrane's ability to remain in place during fire tests. The times assigned to the protective membranes are not the "finish ratings" of the material cited in test reports or listings. (A finish rating is defined as the time for an average temperature rise of 250°F, or a maximum rise of 325°F, on the unexposed side of the material.)

In addition to the wood stud and wood joist framing, the 1985 *NBCC* assigns a time of 5 min to wood roof and floor truss assemblies with spacings of 24 in. Wood trusses are assumed to consist of wood chord and web framing members not less than 2 × 4 in., nominal, and connector plates fabricated from at least 1-mm-thick galvanized steel with projecting teeth at least 8 mm long.[7]

The 1985 *SBC*[5] includes a provision for adding 15 min to the fire resistance rating of wood stud walls, if the spaces between the studs are filled with glass fiber, rock wool, or slag mineral wool batts weighing not less than ¼ lb/ft² of wall surface. The 1985 *NBCC*[7] has deleted the glass fiber insulation from the provision, for lack of test data. There are minimal requirements for the membrane on the side not

TABLE 3-8.1 *Time Assigned to Protective Membranes Based on SBC*[5*,**]

Description of finish	Time
	(min)
½-in. fiberboard	5
⅜-in. Douglas fir plywood, phenolic bonded	5
½-in. Douglas fir plywood, phenolic bonded	10
⅝-in. Douglas fir plywood, phenolic bonded	15
⅜-in. gypsum wallboard	10
½-in. gypsum wallboard	15
⅝-in. gypsum wallboard	30
½-in. type X gypsum wallboard	25
⅝-in. type X gypsum wallboard	40
Double ⅜-in. gypsum wallboard	25
½-in. + ⅜-in. gypsum wallboard	35
Double ½-in. gypsum wallboard	40

[*] Gypsum board should be installed with the long dimension parallel to framing members in walls and perpendicular to framing members in floor ceiling and roof ceiling assemblies, and all joints should be finished.

[**] These values apply only when framing members are spaced a maximum of 16 in. on center.

TABLE 3-8.2 *Time Assigned for Contribution of Wood Frame Based on SBC*[5*]

Description of frame	Time assigned to frame
	(min)
Wood studs, 16-in. on center	20
Wood floor and roof joists, 16-in. on center	10

[*] All studs should be nominal 2 in. × 4 in.; all joists should have a nominal thickness of at least 2 in. and spacing between studs or joists should not exceed 16 in. on center.

SMOKE CONTROL

John H. Klote

INTRODUCTION

In building fire situations, smoke often flows to locations remote from the fire, threatening life and damaging property. Stairwells and elevators frequently become smoke-logged, thereby blocking and/or and inhibiting evacuation. Today smoke is recognized as the major killer in fire situations.[1]

In the late 1950s, the idea of using pressurization to prevent smoke infiltration of stairwells started to attract attention. This was followed by the idea of the "pressure sandwich," i.e., venting or exhausting the fire floor and pressurizing the surrounding floors. Frequently, the building's ventilation system is used for this purpose. The term "smoke control" was coined as a name for such systems that use pressurization produced by mechanical fans to limit smoke movement in fire situations.

Research in the field of smoke control has been conducted in Australia, Canada, England, France, Japan, the United States, and West Germany. This research has consisted of field tests, full-scale fire tests, and computer simulations. Many buildings have been built with smoke control systems and numerous others have been retrofitted for smoke control.

In this chapter the term smoke is defined in accordance with the American Society for Testing and Materials (ASTM)[2] and the National Fire Protection Association (NFPA)[3] definitions which state that smoke consists of the airborne solid and liquid particulates and gases evolved when a material undergoes pyrolysis of combustion.

SMOKE MOVEMENT

A smoke control system must be designed so that it is not overpowered by the driving forces that cause smoke movement. For this reason, an understanding of the fundamental concepts of smoke movement and of smoke control is a prerequisite to intelligent smoke control design. The major driving forces causing smoke movement are stack effect, buoyancy, expansion, wind, and the heating, ventilating, and air conditioning (HVAC) system. Generally, in a fire situation, smoke movement will be caused by a combination of these driving forces. The following subsections are a discussion of each driving force as it would act independent of the presence of any other driving force.

Stack Effect

When it is cold outside, there is often an upward movement of air within building shafts such as stairwells, elevator shafts, dumbwaiter shafts, mechanical shafts, or mail chutes. This phenomenon is referred to as normal stack effect. The air in the building has a buoyant force because it is warmer and less dense than the outside air. This buoyant force causes air to rise within the shafts of buildings. The significance of normal stack effect is greater for low outside temperatures and for tall shafts. However, normal stack effect can exist in a one-story building.

When the outside air is warmer than the building air, a downward airflow frequently exists in shafts. This downward airflow is called reverse stack effect. At standard atmospheric pressure, the pressure difference due to either normal or reverse stack effect is expressed as

$$\Delta P = K_s\left(\frac{1}{T_o} - \frac{1}{T_i}\right)h \qquad (1)$$

where:

ΔP = pressure difference, in. H_2O (Pa)
T_o = absolute temperature of outside air, °R (K)*
T_i = absolute temperature of air inside shaft, °R (K)*
h = distance above neutral plane, ft (m)**
K_s = coefficient, 7.64 (3460).

For a building 200 ft (60 m) tall, with a neutral plane at the midheight, an outside temperature of 0°F (−18°C) and an inside temperature of 70°F (21°C), the maximum pressure

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* Because the Fahrenheit and Celsius temperature scales are so commonly used by design engineers, these scales are used exclusively in the discussions in the text and in figures. However, the reader is cautioned to use absolute temperatures in calculations where such temperatures are stipulated.

** The neutral plane is an elevation where the hydrostatic pressure inside equals that outside.

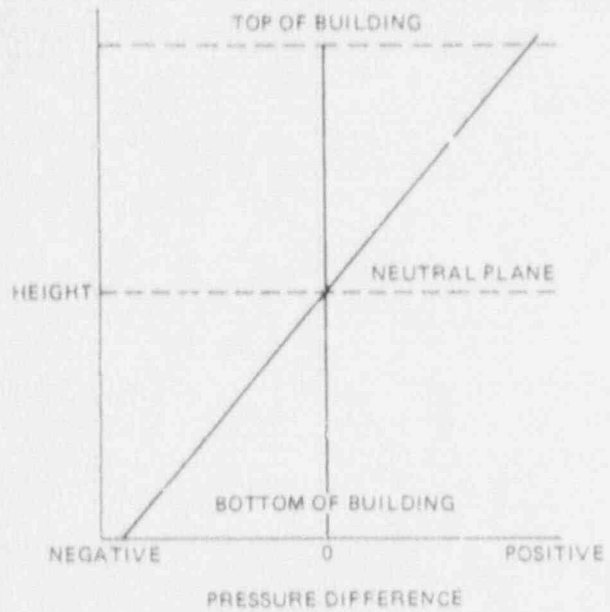

Fig. 3-9.1. Pressure difference between an inside shaft and the outside due to normal stack effect.

difference due to stack effect would be 0.22 in. H_2O (55 Pa). This means that at the top of the building, a shaft would have a pressure of 0.22 in. H_2O (55 Pa) greater than the outside pressure. At the bottom of the shaft, the shaft would have a pressure of 0.22 in. H_2O (55 Pa) less than the outside pressure. Figure 3-9.1 is a diagram of the pressure difference between a building shaft and the outside. In the diagram, a positive pressure difference indicates that the shaft pressure is higher than the outside pressure, and a negative pressure difference indicates the opposite.

Stack effect is usually thought of as existing between the inside of a building and the outside atmosphere. The air movement in buildings caused by both normal and reverse stack effect is illustrated in Figure 3-9.2. In this case, the pressure difference expressed in Equation 1 would actually refer to the pressure difference between the shaft and the outside of the building.

Figure 3-9.3 can be used to determine the pressure difference due to stack effect. For normal stack effect, the term $\Delta P/h$ is positive, and the pressure difference is positive above the neutral plane and negative below it. For reverse stack effect, the term $\Delta P/h$ is negative, and the pressure difference is negative above the neutral plane and positive below it.

In unusually airtight buildings with exterior stairwells, reverse stack effect has been observed even with low outside air temperatures.[4] In this situation, the exterior stairwell temperature was considerably lower than the building temperature. The stairwell was the cold column of air and other shafts within the building were the warm columns of air.

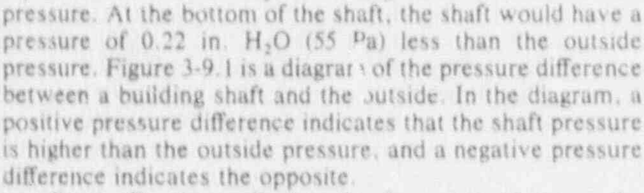

Fig. 3-9.2. Air movement due to normal (left) and reverse stack effect (right). Note: arrows indicate direction of air movement.

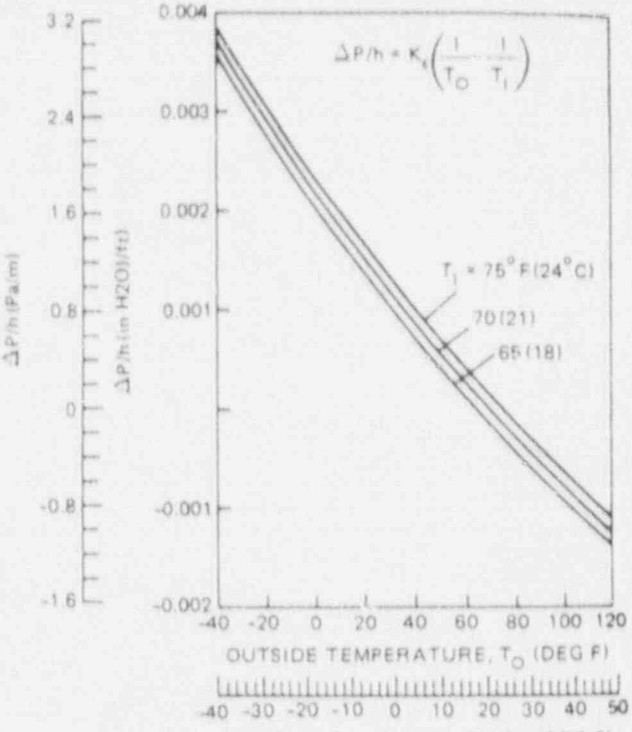

Fig. 3-9.3. Pressure difference due to stack effect.

When considering stack effect, if the air leakage paths between a building and the outside are fairly uniform with height, the neutral plane will be located near the midheight of the building. However, when the leakage paths are not uniform, the location of the neutral plane can vary considerably, as in the case of vented shafts. McGuire and Tamura[5] provide methods for calculating the location of the neutral plane for some vented conditions.

Smoke movement from a building fire can be dominated by stack effect. In a building with normal stack effect, the existing air currents (as shown in Figure 3-9.2) can move smoke considerable distances from the fire origin. If the fire is below the neutral plane, smoke moves with the building air into and up the shafts. This upward smoke flow is enhanced by any buoyancy forces on the smoke existing due to its temperature. Once above the neutral plane, the smoke flows out of the shafts into the upper floors of the building. If the leakage between floors is negligible, the floors below the neutral plane, except the fire floor, will be relatively smoke free until the quantity of smoke produced is greater than can be handled by stack effect flows.

Smoke from a fire located above the neutral plane is carried by the building airflow to the outside through openings in the exterior of the building. If the leakage between floors is negligible, all floors other than the fire floor will remain relatively smoke-free, again, until the quantity of smoke produced is greater than can be handled by stack effect flows. When the leakage between floors is considerable, there is an upward smoke movement to the floor above the fire floor.

LICENSEE'S EXHIBIT 20, Attachment E

Handling Radiation Emergencies

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here. For purposes of radiation protection such equipment may be classified as follows:

1. Filter Type Respirators: These are suitable only for dusts and not for radioactive gases and vapors. Half-mask respirators, when individually filled and properly adjusted, will provide a protection factor of ten against radioactive particles that are air-borne. (The protection factor is the concentration in the ambient air divided by the concentration being breathed inside the device.) Full respirators will provide a protection factor of 100.

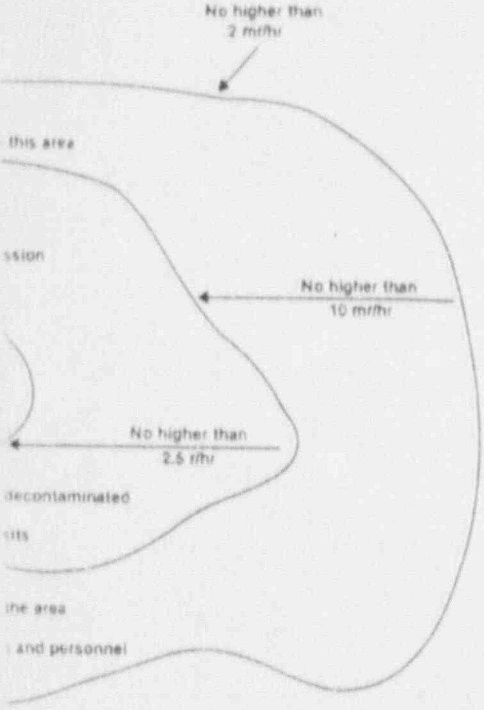
2. Self-contained Breathing Apparatus: In the demand mode a protection factor of 100 is provided; while in the pressure mode, the protection factor is unlimited.

All of the protection factors given are those recommended by the National Institute for Occupational Safety and Health (NIOSH).

The Use of Survey Instruments

There are certain practices and principles that are common to correctly using any radiation survey meter. The meters should be kept in a locked cabinet or in such a way that untrained or unauthorized persons cannot handle them. Otherwise, it soon will be found that the meters have been left on, running down the batteries, or have been dropped on the floor or otherwise knocked out of calibration. At least once a week the battery voltage and instrument response should be checked. This may be done in some instruments by simply turning them on and then turning to a battery check switch position. In other instruments the battery voltage must be checked with a volt-ohm meter according to manufacturers' instructions.

Instrument response is determined with a check source. This is a radioactive source on which the detecting element of the meter is placed and from which a certain meter reading should be obtained. It is important to make this check under geometric conditions that are reproducible. A jig to hold the source and detector always in the same geometry may be helpful. At the time of the check a visual inspection of pertinent mechanical and electrical elements should also be made. If either the battery voltage is low or the response of the instrument differs by more than 20 percent from the previously determined correct check source reading, the bat-



diation emergencies as recommended by
ergency Services.

be made large enough to encompass
loose radioactive materials. Even
rge at first it can always be reduced
ed and as the contamination picture
the intermediate zone is immaterial
oom. These operations include treat-
ersonnel, stockpiling and transferring
ing apparatus bottles, etc.
and equipment entering the hot zone
been checked for contamination and
A good procedure is to monitor
eaving the hot zone and repeat the
liate zone is left for the cold zone
ent that cannot be decontaminated

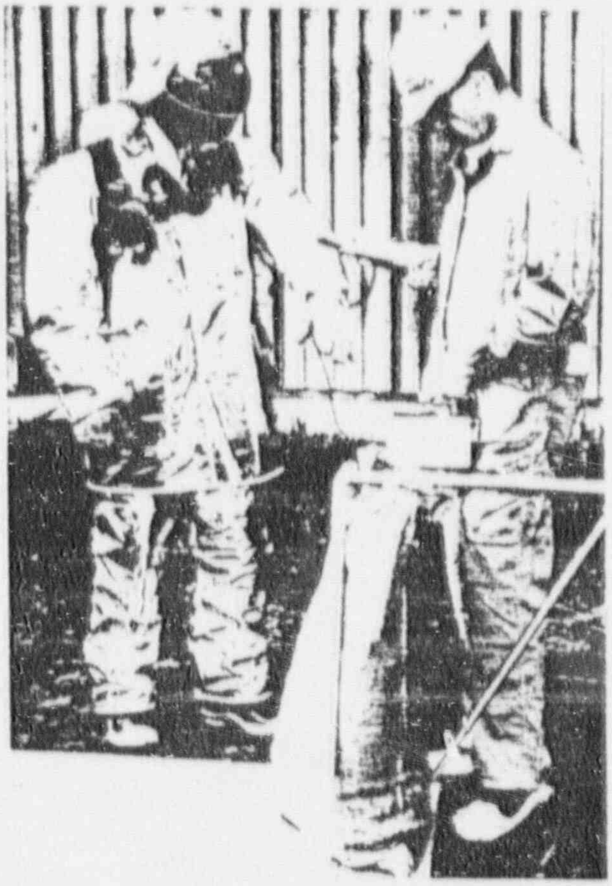


Fig. 5.6. Fire fighter being monitored on leaving the hot zone. Notice the bags for contaminated material. (From the University of California Lawrence Livermore Laboratory, and U.S. Energy Research and Development Administration)

should be sealed in plastic bags for subsequent decontamination or disposal.

Ventilation

In normal fire fighting, ventilation is usually the rule. This permits easier access to the seat of the fire and reduces the chances of a back draft. The reverse is true when fighting fires involving radioactive materials. The cardinal rule is use as little ventilation as safely possible. The aim here is to keep the potentially contaminated smoke inside the facility, preventing as much as possible its spread to the outside environment. Naturally, a certain amount of ventilation may be necessary to prevent back drafts and to permit quick access to the seat of the fire, but this ventilation should be kept to an absolute minimum. Once the fire is knocked down, the ventilation activities can cease and the facility should be closed up to keep any airborne contamination inside.

Ventilation Systems

There is always the question of what to do about ventilation systems — shut them down, or leave them running. The answer depends on the type of system and how much fire damage it has sustained. (See Chapter 4 for additional information on ventilation systems.)

Recirculating systems: A recirculating ventilating system may be pumping smoke throughout the facility. If so, shut the system down immediately. The smoked-up areas should be checked for possible smoke inhalation victims. Some recirculating systems can be switched to the "exhaust only" mode. These systems can be used to exhaust the smoke to the outside; however, try to be sure the exhausted smoke is not contaminated with radioactive materials. Some of these systems are equipped with filter banks that collect the particulate radioactive materials. A filtered system operating in the "exhaust only" mode should be handled the same as the "once-through" system described below (see Figure 5.7).

Some recirculating systems are equipped with extinguishing systems installed to protect the filter banks from fire. Others have smoke wash down (scrubber) systems. Verify that these systems are functioning properly. A hose line may be needed to protect the filter bank if the fire extends through the ducts to the filter bank.

If the fire doesn't involve the radioactive materials the "exhaust only" mode can be safely used.

Once-through systems (general and local): These systems have filters that prevent particulate radioactive materials from escaping to the outside environment. The general rule is to leave the ventilation on so long as it is filtering out the radioactive materials. This maintains the negative pressure with respect to the outside. However, the high efficiency filters used in these installations usually clog

LICENSEE'S EXHIBIT 20, Attachment F

Alpha Radiation

Alpha particles are difficult to detect

Alpha particles do not present a penetration hazard to humans. These particles can be stopped by a piece of paper or a layer of air a few inches thick. Even though alpha particles can be easily stopped from penetration, they still present a high hazard to humans if they are ingested, inhaled or enter the body through an open wound or sore. To combat alpha radiation hazards a firefighter should be clothed in full protective gear including positive pressure breathing apparatus. Under no conditions should a firefighter smoke, drink or eat until he has been completely decontaminated after contact with any possible alpha radiation sources. It should also be noted that alpha radiation is the most difficult to detect. A special alpha survey meter must be used within a very close range (within 1/2-inch of contaminated area) in order to detect alpha particle presence. If there is a possibility that alpha radiation exists within the incident scene, all precautions should be taken to prevent the spread of alpha contamination. Alpha radiation is commonly found in elements such as plutonium, uranium and cesium.

Beta Radiation

Beta particles have a greater penetrating range than alpha particles, but are less hazardous to the human body. Beta radiation can easily be shielded by a thin sheet of metal and/or moderate distance. Firefighters should always be in full protective clothing including positive pressure self-contained breathing apparatus when dealing with any possible radiation hazard. Beta radiation is easier to detect than alpha radiation and is commonly found in most radioactive materials.

Gamma Radiation

Gamma rays are difficult to shield

Gamma radiation is the most difficult form of radiation to shield. Gamma rays can easily penetrate any material with the extent of penetration depending on the strength of the gamma source, the distance from the material and the density of the material (Figure 9-25). The greater the density, the less the penetration. A firefighter may encounter gamma radiation sources in hospitals, industrial plants, military operations, nuclear power plants, mining sites, aircraft hangers and all forms of transportation. For further information on locations of radioactive source storage in your area, contact the state health department or the nearest regional Nuclear Regulatory Commission office.

X-Rays

X-Ray machines present little or no hazard to the firefighter as long as the machine's electrical power is shut off. X-Rays are considered as powerful as gamma rays and should be considered an immediate hazard if the machine is found to be in operation.

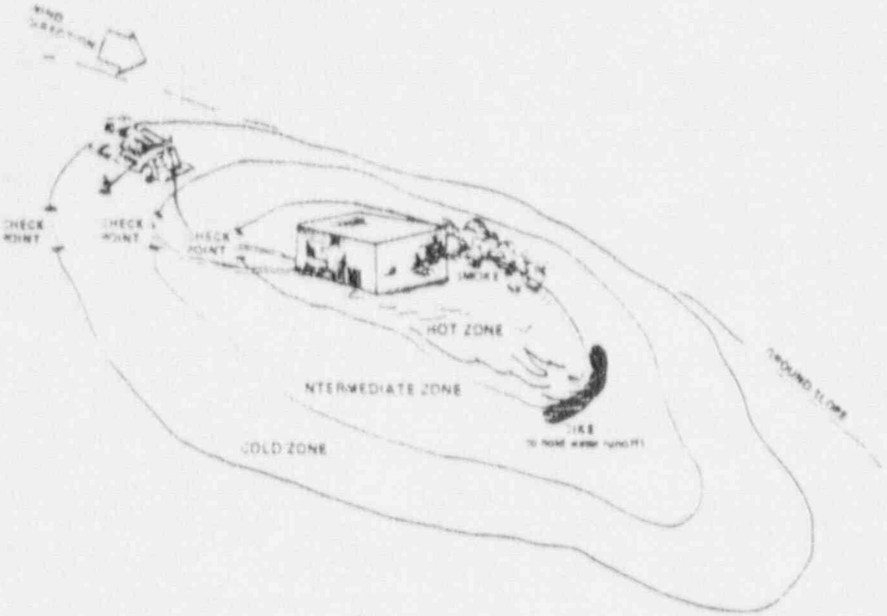


Figure 9-33 Zoning a fireground will aid in controlling the spread of radioactive contamination. Consider wind direction to control smoke and dust and ground slope to control run-off.

FIRE FIGHTING

Fire should be extinguished with as little water or extinguishing agent as possible. It should be pointed out that this restriction is designed to lessen runoff water, which can spread radioactive materials, rather than for reasons of critical danger. Water runoff can be controlled by dams, dikes or a channel into a retention tank or reservoir. In some cases the runoff can be diluted by flushing with hose streams. However, dilution operations should be under the direction of radiation experts who can determine the safe levels of dilution.

Fire fighting ventilation should be kept to an absolute minimum. Some ventilation may be necessary to prevent explosions or to channel heat and smoke out of a building. Under certain conditions, it may be appropriate to shut down the ventilation systems to limit the spread of contaminants; in other situations, it is best to leave them on. This decision depends on the type of ventilation, the extent of the fire and many other variables. For "local" ventilation, the system should be left on as long as the filter has not been destroyed since it tends to keep the radioactive materials in the enclosure. However, if the filter has been destroyed or is ineffective for some other reason, the system should be shut off because it will spread radioactive materials outside the building. If the ventilation is the "once through" type the same criteria apply. However, in the case of recirculating systems it is important that they be shut down immediately if there has been a spill of radioactive materials. If the system is left operating, the chances of spreading contamination throughout the building are very high.

After the fire is extinguished, all openings to the contaminated area should be sealed off. Doors and windows