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THE USEFULNESS OF EXPOSURE CONTROL COUNTERMEASURES IN REDUCING RADIATION FATALITIES

Final Report

June 1967

Prepared for

OFFICE OF CIVIL DEFENSE
Department of the Army
Washington, D.C. 20310

Contract No. N228(62479)70307

Work Unit 3221B

through the

Technical Management Office
U.S. NAVAL RADIOLOGICAL DEFENSE LABORATORY
San Francisco, California 94135

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by

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Ann Willson
William H. Van Horn

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Approved by: M. B Hawkins, Manager
Radiation Technology Department

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ABSTRACT

An investigation of the lifesaving potential of exposure control countermeasures (applied shielding, group shielding, shelter rotation, limited decontamination, overcrowding, and movement) under specific radiological environments is the subject of this report. Scenarios were developed to depict "real" post-attack situations with radiological fallout levels suitable for evaluation of exposure control countermeasures. These scenarios, all for the city of San Jose, California, include two shelter locations and two vital facilities (the EBS radio station and a food warehouse) which are assumed to have sustained light blast effects and fallout. An analysis was performed of the lifesaving capabilities of each individual countermeasure and a combination of various countermeasures for each shelter location. The sensitivity of each countermeasure to informational inputs was also studied as was the use of the countermeasures in promoting the early restoration of vital facilities.

It was concluded that the exposure control countermeasures that were investigated all show some degree of lifesaving capability. Group shielding, overcrowding, and applied shielding were found to be the most effective countermeasures. Limited decontamination, shelter rotation, and remedial movement proved to be the least effective countermeasures. Various combinations of exposure control countermeasures displayed an additive effectiveness and have an excellent capability for reducing fatalities. Finally, it was concluded that exposure control countermeasures, knowledgeably used either singly or in combination in a high radiation field, are capable of saving many lives that would otherwise be lost. It is recommended, therefore, that the use of exposure control countermeasures be investigated further, particularly in the application to communities where large shelter deficits are known to exist, such as the suburban or bedroom communities that surround most large metropolitan areas. Also, consideration should be given to incorporating exposure control countermeasures into the community shelter plan program.

ACKNOWLEDGEMENTS

This study was conducted for the Office of Civil Defense through the U.S. Naval Radiological Defense Laboratory (NRDL). Dr. Donald A. Bafus, Project Monitor, provided valuable assistance and direction. Mr. Melvin McDonald of the San Jose Civil Defense Office was very helpful in arranging for the field survey of San Jose and provided a great deal of useful information.

The authors gratefully acknowledge the assistance of URS personnel who contributed to various aspects of this study. Robert H. Black provided the dose criteria information. Allen Saltzman provided valuable guidance on editorial content and publication requirements. Project Manager was W. H. Van Horn, and the entire effort was conducted under the supervision of M. B Hawkins, Manager of the Environmental Technology Department.

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Section 1
INTRODUCTION

The advent of heavy fallout levels following a nationwide attack could cause many casualties in those areas where there are insufficient fallout shelters for the populace. This situation can be partially remedied by using exposure control countermeasures in refuges* which are available to the population. The purpose of this study was to evaluate the lifesaving capability of such exposure control countermeasures. Case studies of actual shelters and refuges under assumed radiological environments were used as bases for the evaluation of known exposure control countermeasures.

The exposure control countermeasures (ECC's) that have been evaluated in this investigation are.**

- Group shielding
- Shelter rotation
- Applied shielding
- Limited decontamination
- Overcrowding
- Remedial movement

Since exposure control countermeasures are most effective in saving lives at very early times following attack (Ref. 1), the selection of an effective countermeasure or a combination of countermeasures is highly dependent on reliable information on radiological situations and shelter characteristics; the availability of manpower and material resources must also be considered. Hence, these parameters will be included in the evaluation of exposure control countermeasures.

* Refuges are defined as an area in a building which offers a radiation protection factor between 20 and 40. Protection factor (PF) is defined as the ratio of the radiation intensity from a smooth, infinite contaminated plane to the radiation intensity at a given location within a structure.

** Definitions for the exposure control countermeasures are given on page 8.

Prior studies have investigated the technical feasibility of exposure control countermeasures. Previous work at URS (Refs. 1, 2, and 3) delineated the technical management, and operational feasibility of selected ECC's (postattack evacuation, applied shielding, exposure scheduling, limited decontamination, dose equalization, and remedial movement) in ideal situations. These three URS reports also presented planning aids for the implementation of ECC's.

General Technologies Corporation conducted a study (Ref. 4) evaluating the controlled movement of groups of people in a radiation field and found that mutual (or group) shielding of people in large groups produced a significant reduction of dose.

This report consists of six major sections supplemented by two appendices. Section 1 discusses the objectives and background of the study. Section 2 explains the approach used to investigate the problem. Section 3 presents the rationale used in selecting attack environments and other basic parameters. In the interests of making a more readable report, the detailed descriptions of the ECC case studies have been placed in Appendix A. This appendix is a vital part of this report and contains most of the background for the discussion and conclusions and should be carefully perused by the serious reader. Appendix B contains supplemental data and assumptions used in the ECC analysis. For the more casual reader the tabulated results of the case studies and a discussion of the applications and limitations of ECC's are presented in Section 4. Section 5 explores the sensitivity of selected ECC's to radiological information inputs. Section 6 includes conclusions based on the results of the study and recommendations for future work.

Although originally intended as an element of the five-city study, it became obvious during the early course of the investigation that the inputs necessary to performing the 5-city oriented analysis were not available. Therefore, in consultation with the project monitor, the direction of this study was changed to meet the following objectives:

- Determination of the types of situations in which exposure control countermeasures are applicable

- Estimation of the payoff (in terms of lives, dose, or time saved) resulting from the use of exposure control countermeasures individually or jointly

- Determination of the interaction (with particular attention to synergistic or detrimental effects) among exposure control countermeasures for a number of different situations

Section 2
APPROACH

The evaluation of exposure control countermeasures involves three steps, namely:

1. Is the ECC technically feasible?
2. If so, is the ECC operationally practical?
3. If so, what is the effectiveness of the ECC?

The definitions of technical feasibility, operational practicality and effectiveness applicable to this study are listed below:

- Technical feasibility is the characteristic of being able to perform a useful function in an ideal situation, in which the only restraints are the basic scientific, engineering, and environmental phenomena involved.
- Operational practicality involves the ability to perform an operation or function in a real situation. Even though a countermeasure may be technically feasible, for one reason or another it may not be possible to "mount the operation" at the level of effort required. In many cases, this constraint is related to the availability of resources, e.g., manpower, fuel, equipment, etc., compared to the quantities actually required. Another very important restraint on operational practicality is information. Many operations involving countermeasures appear practical and even highly effective to the designer. However, if these are examined from the standpoint of the reliability of information that the planner of the operation must have in order to implement an effective measure, the operation loses much of its practicality.
- Effectiveness is the degree that a given ECC reduces radiation fatalities to shelter or refuge occupants. (The effectiveness of an ECC can also be measured as the degree that it reduces the dose received by shelter or refuge occupants. While dose reduction is an important factor — and is discussed briefly in Section 5 — the emphasis in this study is on effectiveness as measured by fatality reduction.)

A countermeasure's effectiveness can best be ascertained by analysis and consideration of all parameters and conditions inherent in a countermeasure.

This analysis can be accomplished most effectively by an in-depth study of a single shelter or shelter complex. By using such a case study approach, the requirements necessary for implementation and operation of a countermeasure can be easily delineated and the lifesaving potential of each countermeasure determined for a variety of shelter geometries, population distributions, and radiological environments.

The steps used in the analysis were:

1. The ECC's and their specific functions were delineated. For each ECC, personnel, equipment, and supply requirements were estimated.

2. Two sample areas were selected for study. One area was in the central business district; the second was in a residential area. The shelter capacity within each sample area was greater than 1000 persons.

3. Scenarios were prepared for each sample area for each of the following general situations:

   a. Shelter radiologically inadequate

   b. Shelter endangered by internal and external threats

   c. Early departure of selected shelterees needed for restoration of vital services

   d. Early emergence of personnel for recovery phase

4. Baseline values for fatalities were established for each case, i.e., the fatality level when no ECC's were used.

5. All applicable ECC's were considered for each scenarios, and a technical feasibility study of each ECC was performed describing the time-phased sequence. The hazards to which personnel would be exposed during operation were predicted.

6. An operational practicality study was performed taking into account the availability of information needed to implement operations and environmental situations which would impede or prevent operations.

7. ECC's dependent upon accurate information were analyzed for their sensitivity to informational inaccuracies.

8. All feasible and practical countermeasures were tabulated in terms of lifesaving capability, cost (resources and manpower), and reliability (probability of achievement).

Section 3
BASIC CRITERIA FOR CASE STUDIES

This section discusses the basic criteria used in the case studies (reported in Appendix A), including exposure control countermeasures, selection of sample areas, dose-mortality prediction, and scenario selection.

EXPOSURE CONTROL COUNTERMEASURES

A description of the six exposure control countermeasures considered is given in Table 1. Details are included on the mechanics of operation, radiological inputs required for implementation, and equipment requirements.

SELECTION OF SAMPLE AREAS

San Jose, California (one of the cities in the Five-City Study) had a population in 1965 of 317,000, but only 58,000 identified fallout shelter spaces in Categories 2–8 (PF 40–1000) (Ref. 7). The difference between population and shelter spaces is partially alleviated, however, by 73,600 identified Category 1 spaces (PF 20–40), making San Jose an attractive choice for the examination of the use of ECC's in radiologically inadequate shelters.*

The two sample areas in San Jose, one in the central business district and the other in a residential area, provided different physical environments in which to evaluate the ECC's. These sample areas are "typical" for the San Jose region in that the majority of the Category 1 space is located in buildings that have fallout shelters.

Sample Area No. 1

Two shelters were studied in sample area No. 1: the U.S. Post Office and a 10-story commercial building. The U.S. Post Office, located on the

* A number of cities throughout the nation also have a deficit of NFSS spaces.

Table 1

DESCRIPTION OF EXPOSURE CONTROL COUNTERMEASURES*

ECC	MECHANICS OF OPERATION	RADIOLOGICAL INPUTS REQUIRED FOR IMPLEMENTATION*	EQUIPMENT REQUIREMENTS FOR IMPLEMENTATION
Group Shielding	Assembling the shelterees in close proximity to increase mutual shielding.	Time of arrival of fallout and dose rate in shelter.	Radiacs
Shelter Rotation	The movement of shelterees between a shelter with a high dose rate and one with a low dose rate, so as to equalize the dose between the two shelter groups.	Dose rate in both shelters.	Radiacs
Applied Shielding	Reducing the dose rate by increasing the mass at lightly shielded areas.	Actual or potential dose rate in shelter and major sources of penetration (e.g., windows, roof).	Radiacs
Limited Decontamination	Removal of radioactive contamination by manual, hydraulic or mechanical means.	Accumulated dose. Dose rate of contaminated areas surrounding the shelter.	Firehoses or brooms, and other special decontamination equipment
Overcrowding (Temporary reduced shelter allocation)	Exceeding the rated capacity of a shelter with a low dose rate for a limited time.	Arrival of fallout actual or potential dose rate on both shelters.	Radiacs
Remedial Movement	The movement of people from a threatened or hazardous shelter through a potentially hazardous environment to a safer location.	Accumulated dose. Dose rate in both shelters and on travel route.	Radiacs Communication Equipment

* A basic requirement for all cases is the recognition by shelter occupants of a potential or actual radiation threat.

corner of West St. John and N. 1st Street, represents the primary shelter studied in area No. 1. The post office (shown in Fig. 1a) is a two-story reinforced concrete structure with a full basement. It occupies an area of approximately 19,000 sq ft. A fallout shelter with a listed capacity of 1,500 is located in the basement. The first floor of the post office has an approximate PF of 20* and was assumed for the case studies to serve as a refuge with a capacity of 1,500, thus making a total of 3,000 shelter/refuge spaces in the building.

A second shelter was chosen expressly for the evaluation of remedial movement under a fire threat. This shelter, located in the basement of the 10-story commercial building at 18 W. 1st Street – approximately 1 block south of the post office, has a listed capacity of 508 and an approximate PF of 1,000.

Sample Area No. 2

Lincoln High School at 555 Dana Avenue, San Jose, California (shown in Fig. 1b), was selected as the primary shelter to be studied in sample area No. 2. Located in a residential neighborhood, Lincoln High School is part of a three-school complex that includes Hoover Jr. High School and Trace Elementary School, which comprise shelter complex number 17 in the San Jose civil defense system. Lincoln High School, a two-story concrete structure with a partially exposed basement, occupies approximately 25,000 sq ft of area and contains 2,540 shelter spaces in Category 1 (PF 20–40), 474 spaces in Category 2-3 (PF between 40 and 100), and 1,050 spaces in Category 4-8 (PF between 100 and 1000). For the purposes of this study, only 3,000 of the shelter spaces were considered, these being: Category 1 space on the 1st and 2nd floors (PF ≈30 for both floors) – 1,000 shelterees each, and the

* The blueprints of the various shelter buildings were not available. Therefore, assumptions of window area, wall mass, roofs, etc. were made based on observation. The PF estimating method of calculating the radiation protection was used throughout the report (Ref. 6).

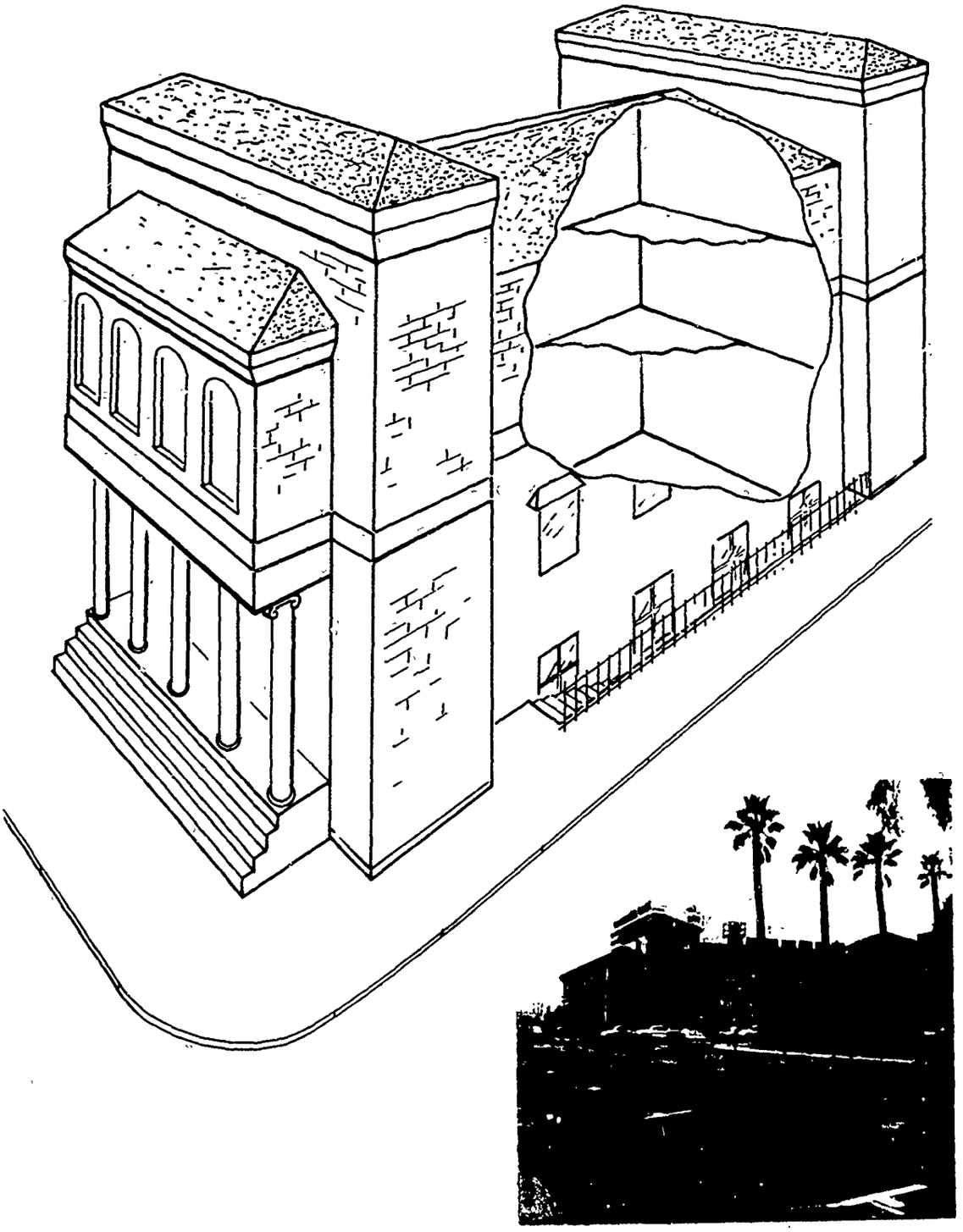

Fig. 1a. Post Office

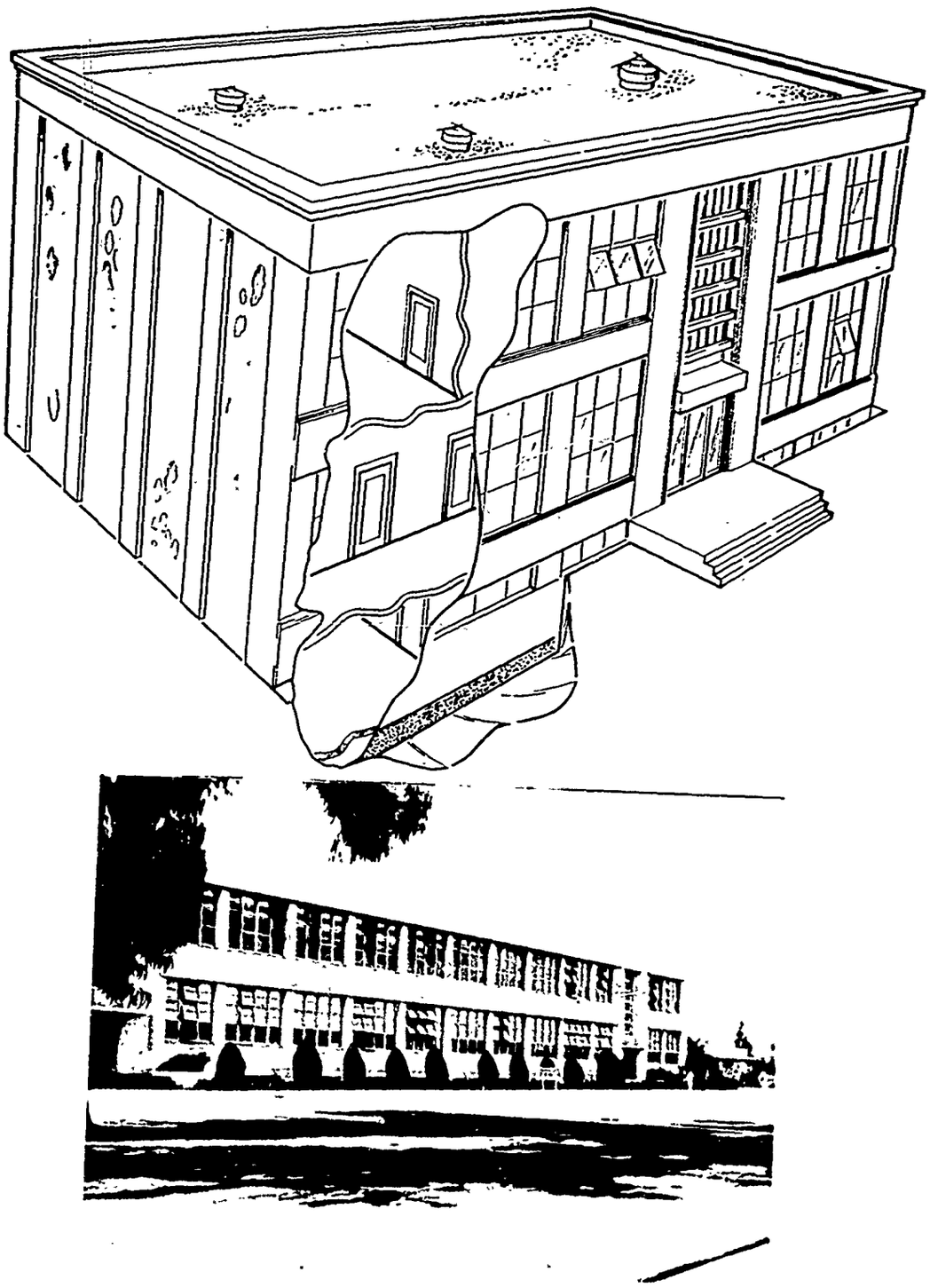

Fig. 1b. Lincoln High School

Categories 4 – 8 space (PF ≈120) in the basement – 1,000 shelterees.

Table 2 summarizes the parameters pertaining to the two major shelter/refuge cases studied.

DOSE-MORTALITY PREDICTION CONCEPT

Evaluation of the worth of an exposure control countermeasure could be done merely on the basis of "dose saved." However, this measure has limitations in that it is difficult to place a definitive value on dose which has been saved; e.g., a "dose saving" of 100 R is meaningful when total dose is 300 R, but inconsequential when total dose is 800 R. Accordingly in this study a "lives saved" concept was used to indicate effectiveness.

A simple dose-mortality curve, Fig. 2, was constructed in the manner described in Ref. 8 by setting the 50-percent mortality dose equal to any LD-50 and zero dose equal to 0.01 mortality, i.e., natural incidence. Linear probability paper was used (as in Ref. 9) and the mortality function shown as a straight line. Doses greater than and less than the LD-50 are expressed as fractions of the LD-50, i.e., Dose/LD-50.

The case studies were related to specific fallout arrival times and standard dose rates. For this purpose, LD-50 values of 550 R for a 3-day dose and 600 R for a 7-day dose were arbitrarily selected.* The 3-day dose period, which includes the range of times in which one would expect to implement the ECC and receive the major benefits therefrom, was used unless otherwise stated.

The use of "lives saved" as a measure of effectiveness required that computations be made of fatalities occuring in a given situation in which

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* In retrospect, the use of an LD-50 of 450 R for 3-day dose would probably be more acceptable to radiation medical authorities, such as those on the National Committee on Radiation Protection and Measurement (Ref. 9). However, because of the approach taken herein, i.e., "dose with no countermeasure" equals LD-50, the results in "lives saved" are independent of the LD-50 value used.

Table 2

TABLE OF SHELTER/REFUGE PARAMETERS

SHELTER/ REFUGE	SHELTER CAPACITY	SHELTER PF	REFUGE CAPACITY	REFUGE PF	NO. OF FLOORS IN BUILDING	PLAN AREA OF BUILDING IN SQ FT
U.S. Post Office Area 1	1,500	85	1,500	20	2	19,000
Lincoln High School Area 2	1,000	120	2,000	1st Floor 30 2nd Floor 30	3	25,000

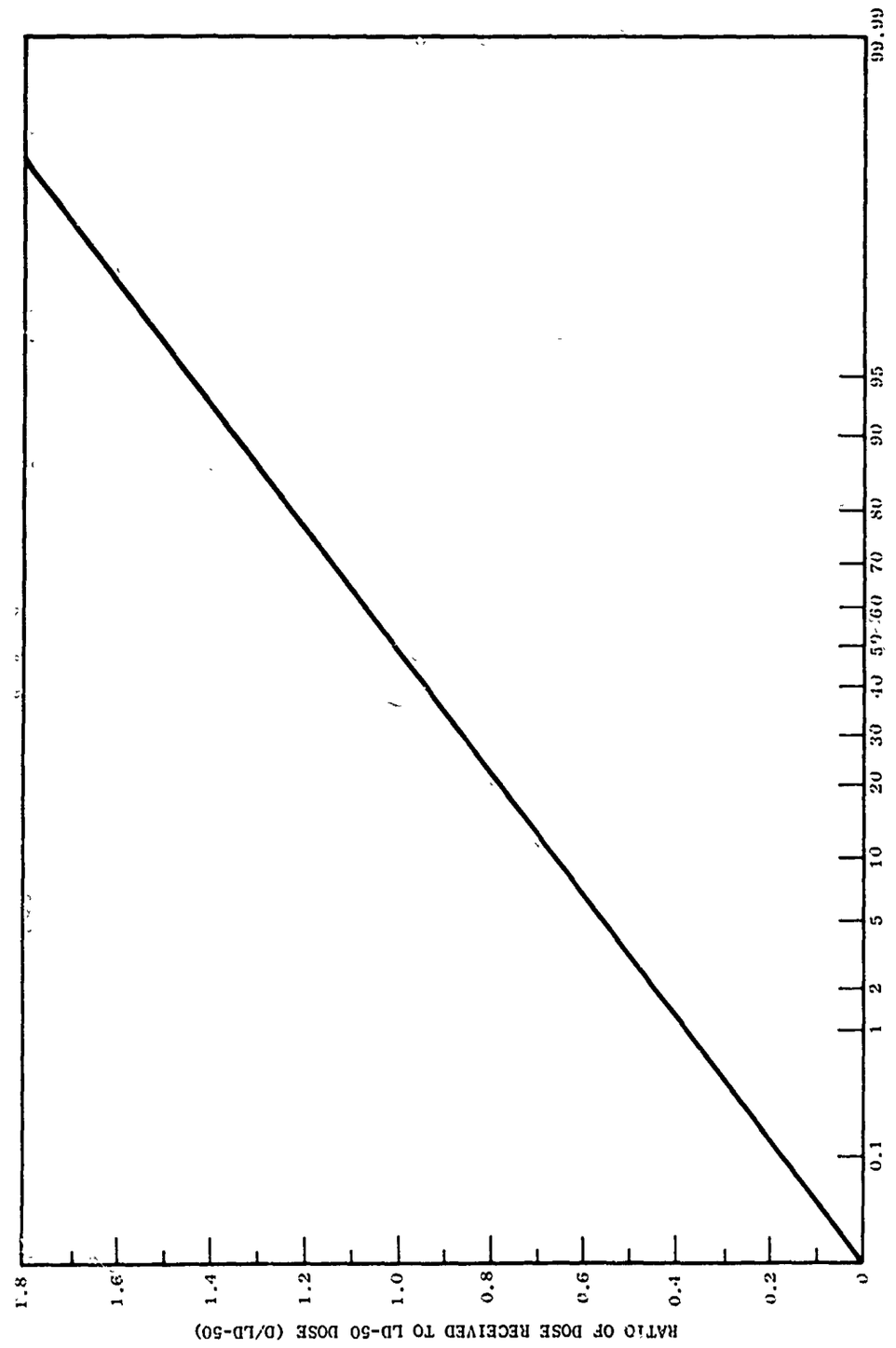

Fig. 2. Percent Mortality vs Ratio of Dose Received

no countermeasure is used and of fatalities in the same situation but in which ECC's are used. The difference in fatalities between the two cases is the "lives saved". The effectiveness of an extremely effective countermeasure (e.g., one that reduces the dose by a factor of 100) as a function of dose is shown on Fig. 3, which is derived directly from the mortality function in Fig. 2. The relatively low effectiveness (as measured by fraction of the total population saved) at the lower dose levels (e.g., D/LD-50 = 0.6) is related to the low risk associated with low radiation doses.

Figure 4 gives a family of curves showing the fraction of exposed population saved as a function of dose for a realistic range of dose reduction factors.* The lives saved to the left of the peak values are restricted primarily to that fraction of the population that would perish in the no-ECC case. The decrease in effectiveness to the right of the peaks is due to the inability of the ECC to reduce the doses to nonlethal levels.

Previous work on the development and evaluation of the ECC's leads to the general conclusion that their effectiveness as measured by dose reduction factors would probably range between 0.667 to 0.25. For this range of values, the doses in which the fraction of lives saved is greater than 5 percent range between D/LD-50 = 0.55 and D/LD-50 = 6.0.** The base line, no-countermeasure dose ratio D/LD-50), of 1.0 was selected for this study. In Section 5, a modified version of Fig. 3 is presented which allows the extrapolation of results to other dose conditions.

SCENARIO SELECTION

Specific attack environments were required as a basis for evaluations of the lifesaving capabilities of ECC's. Two attack environments (or scenarios)

---

* 0.1 to 0.5. The Dose Reduction Factor (DRF) is the total dose over the period of interest when the countermeasure is used divided by the dose for the same period when no countermeasure is used.

** This range corresponds to doses of from 300 to 3300 R for an L/D-50 of 550 R.

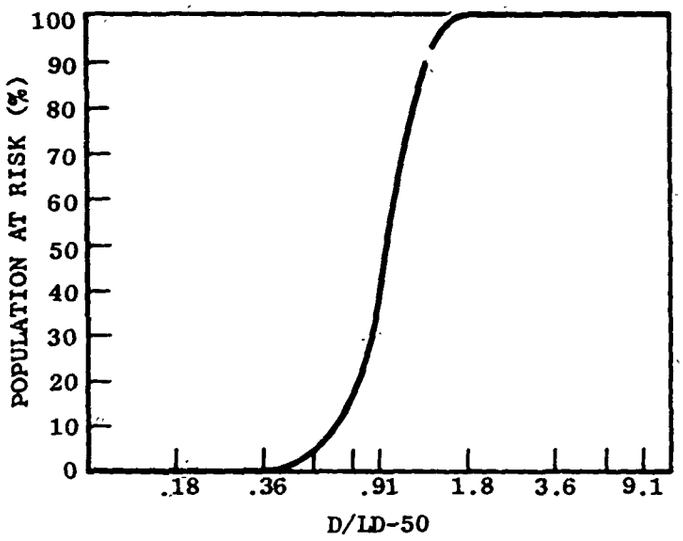

Fig. 3. Population Which Could be Saved at Various Dose Levels by a "Perfect" Countermeasure

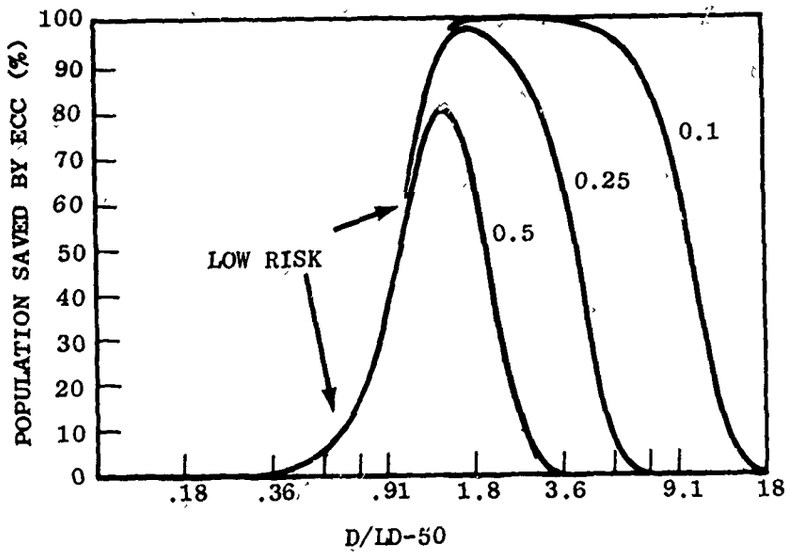

Fig. 4. Population Saved by ECC's Having Various Dose Reduction Factors

were needed, one for each shelter, to establish the base case (i.e., no countermeasures used). Table 3 lists for each scenario the several times of arrival and times of cessation of fallout and the standard intensity to give a 550-R 3-day dose in the refuge. Scenario A was used for the post office refuge and scenario B for the high school refuge. The assumed time of attack (H hour) for both scenarios was 10:00 p.m.

Table 4 lists the scenarios used for each phase of the analysis. Special scenarios were used where the regular scenarios did not provide the required conditions. These special scenarios are described in detail in Appendix A.

Table 3

PARAMETERS USED FOR SCENARIOS A AND B

	t_a^e (H + hr)	t_c (H + hr)	I_o (R/hr)*
SCENARIO A: POST OFFICE REFUGE	1/2	1.5	3,100
	1	2.0	3,850
	2	3.5	4,950
	3	5.3	5,850
	4	7.2	6,650
SCENARIO B: HIGH SCHOOL REFUGE	1/2	1.5	4,520
	1	2.0	5,650
	2	3.5	7,240
	3	5.3	8,450
	4	7.2	9,570

LEGEND: t_a^e = effective time of fallout arrival which is the time at which half of the total dose during the period of fallout deposition has been received.

t_c = time of fallout cessation

I_o = standard intensity i.e., dose rate at or extrapolated to one hour after detonation

* To give 3-day doses of 550 R in the refuge

Table 4

SCENARIOS USED FOR THE ECC ANALYSIS

PHASE OF ANALYSIS	ACTIVITY	SCENARIO	
	ECC	(A) Post Office	(B) High School
I Countermeasures in Refugos	Group Shielding	x	x
	Applied Shielding	x	x
	Shelter Rotation	x	x
	Limited Decontamination	x	x
	Overcrowding	x	x
	Remedial Movement	Special Scenario	Special Scenario
	ECC - Combination	---	x
II Recovery Operations	Restoration of Vital Facilities	x for: (t_a^e = 1/2 hr only)	---
III Sensitivity Analysis	H hour	x for: (t_a^e = 2 hr only)	---
	Dosimeter and Dose rate meter	(t_a^e = 1/2 hr only)	
	Decay constant	(t_a^e = 2 hr only)	

LEGEND: t_a^e = time of effective fallout arrival

Section 4
DISCUSSION OF RESULTS

The capability of individual or combined exposure control countermeasures to reduce the dose to shelter or refuge occupants is described in detail in Appendix A.* The limitations involved in using these countermeasures and their time-phased implications, as these pertain to the fallout environment, will be discussed in this section.

A qualitative tabulation of the manpower, resources, and planning required to implement individual exposure control countermeasures is given in Table 5. These are indicative of the ease or difficulty with which a countermeasure can be implemented; for instance, group shielding and overcrowding require no manpower or special resources and only simple planning, which means they could be implemented easily and quickly. Shelter rotation requires no additional manpower or special resources but does require sophisticated planning. Without such planning the implementation of the countermeasures could result in more deaths than would non-implementation; this reversal of effectiveness can also occur for remedial movement. Applied shielding and limited decontamination, on the other hand, require manpower, special resources, and moderately complex planning; the major difference between these countermeasures is the special resources that are required. Applied shielding can use any dense material, e.g., books, filing cabinets, desks, etc., while limited decontamination requires decontamination equipment and supplies (i.e., fire hoses and water) which if not available would make limited decontamination difficult or impossible.

A comparison of the capability of the various exposure control countermeasures to save lives is presented in Figs. 5 through 9. These comparisons are derived from the graphs of each ECC and combination of ECC's reported in

* The case studies, as previously noted, have been placed in Appendix A. For a fuller understanding of the discussion in this section, the reader is referred to Appendix A.

Table 5

MANPOWER, RESOURCE AND PLANNING REQUIREMENTS FOR ECC'S

	MANPOWER (1)	SPECIAL RESOURCES (2)	PLANNING
1. Group Shielding	None	None	Simple
2. Shelter Rotation	None	None	Critical
3. Applied Shielding	Much	Movable Dense Material	Moderate
4. Limited Decontamination	Much	Special equipment and supplies	Moderately Difficult
5. Overcrowding	None	None	Simple (Supply rationing) (Heat analysis)
6. Remedial Movement	Little	Transportation Public Works Engineering	Critical (Communications)

(1) From shelter population: does not include planning and supervision
(2) All ECC's need RADEF instrumentation

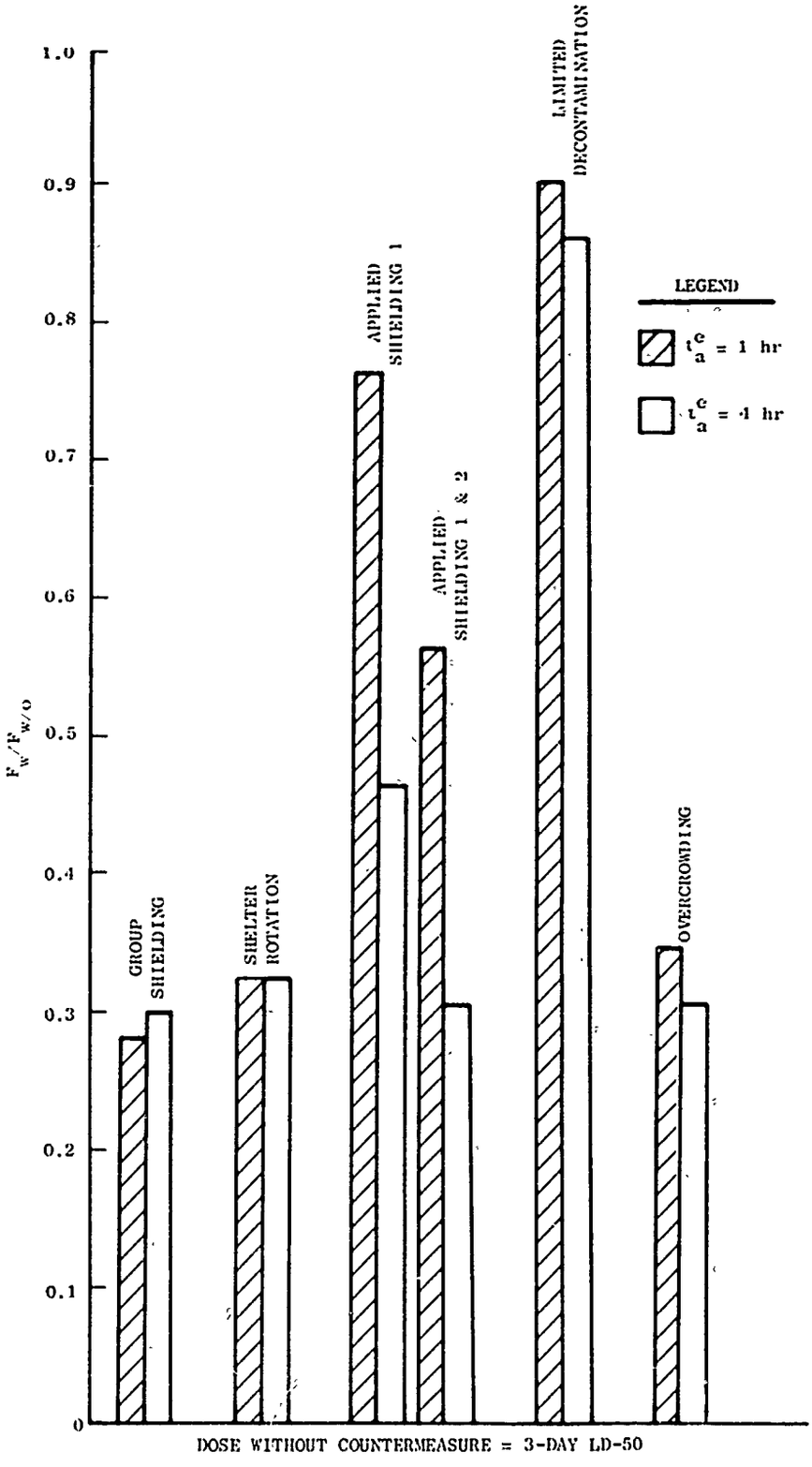

Fig. 5. Operational Practicality of ECC's in the Post Office Refuge

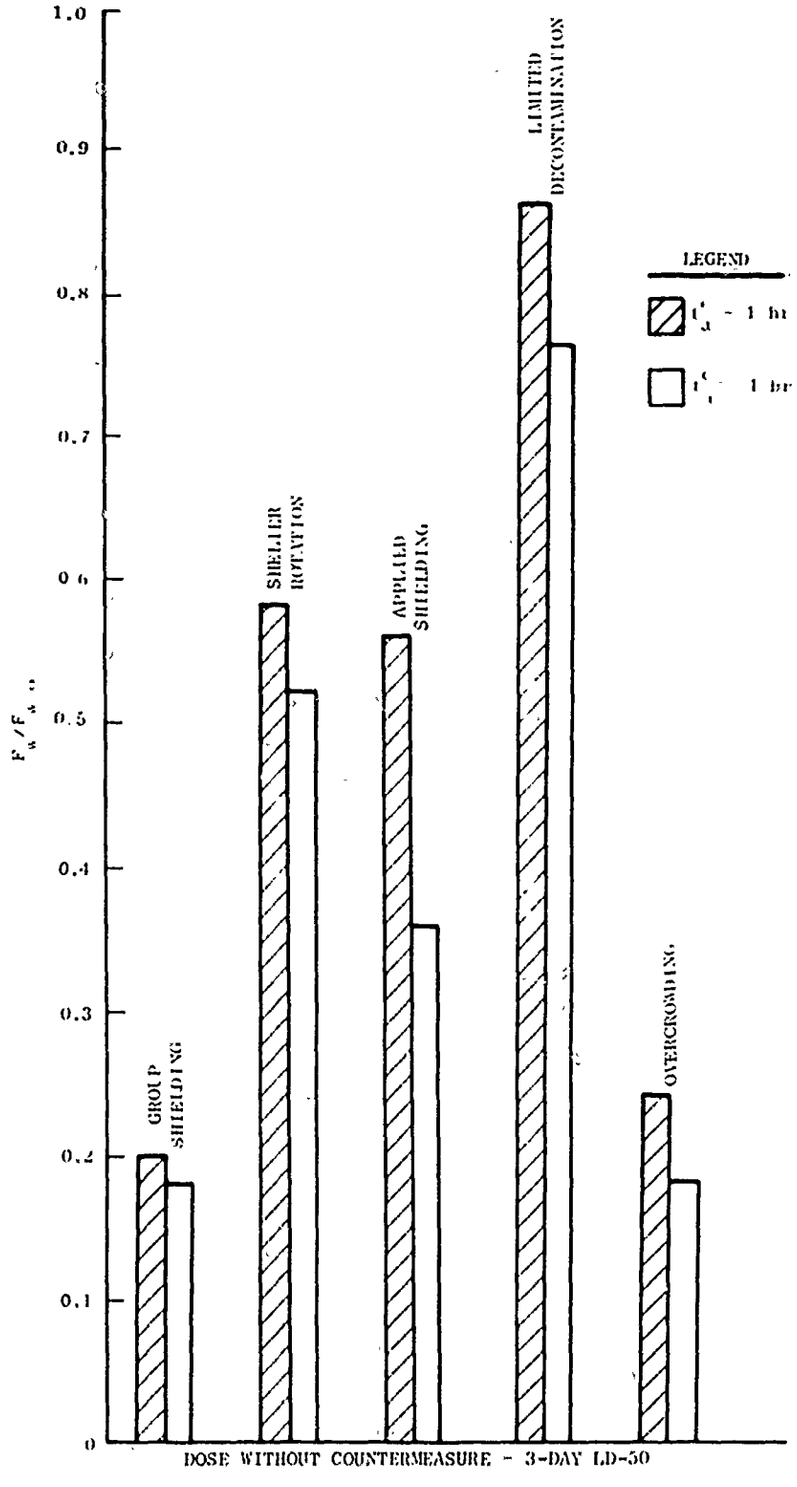

Fig. 6. Operational Practicality of ECC's in the First-Floor Refuge of the High School

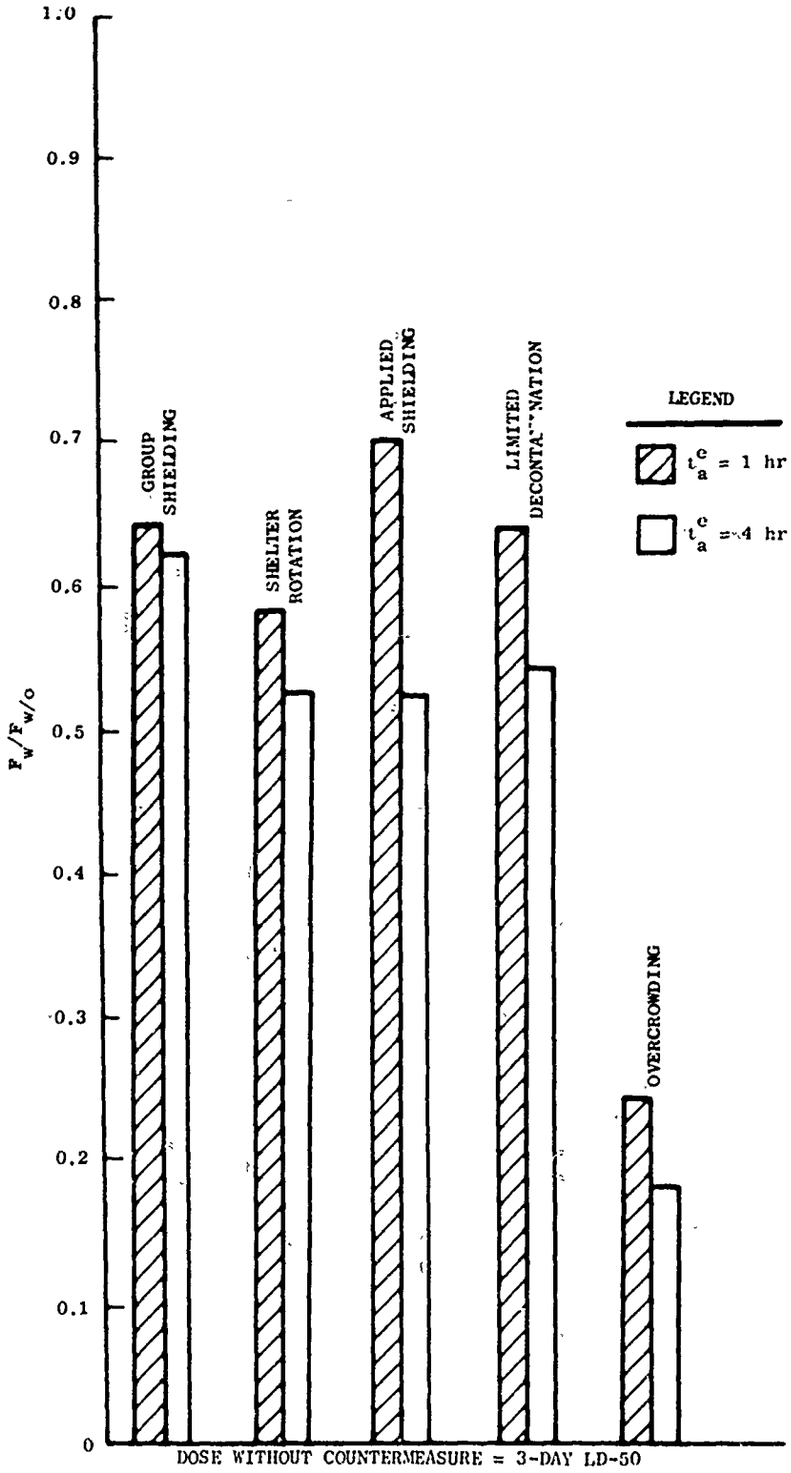

Fig. 7. Operational Practicality of ECC's in the Second-Floor Refuge of the High School

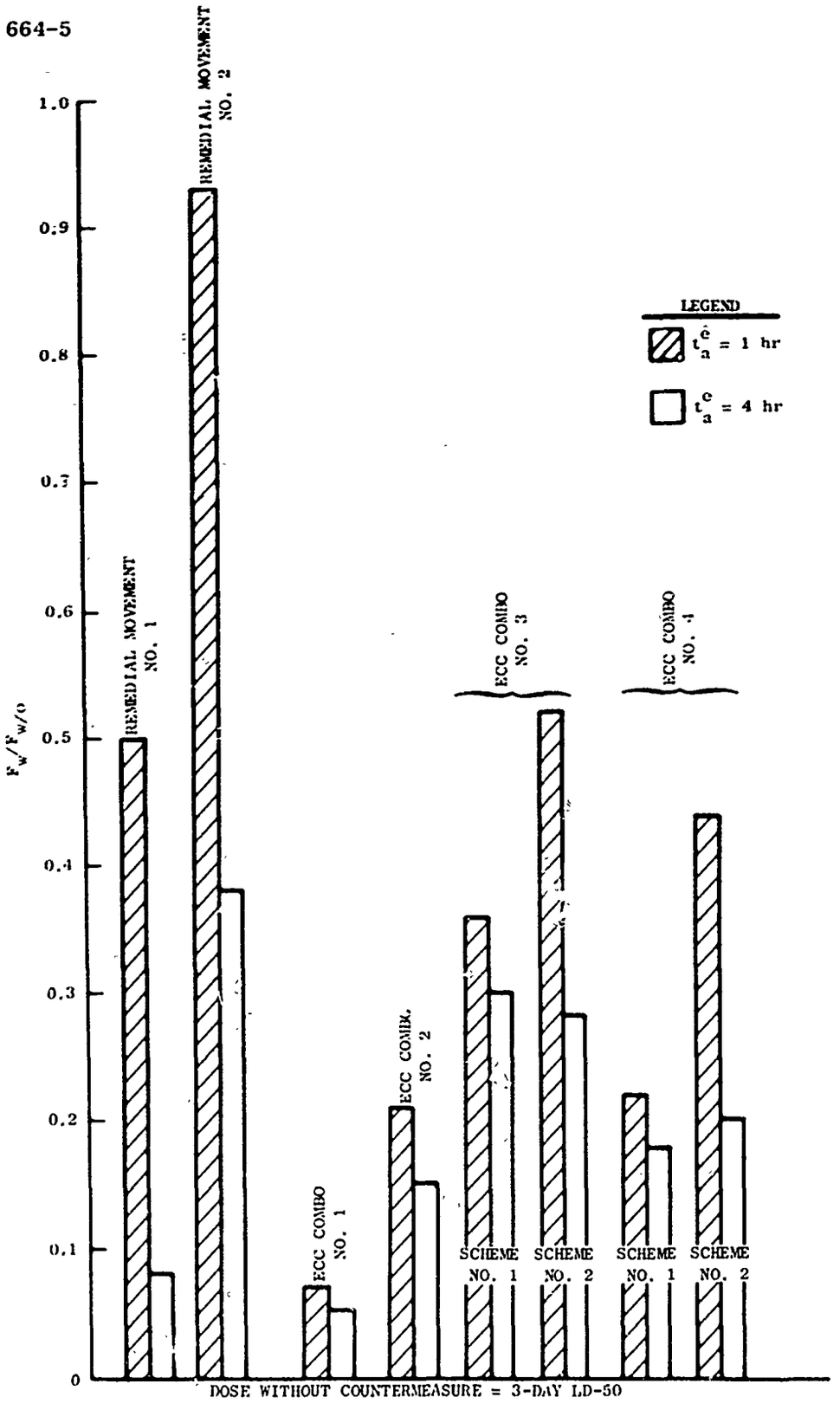

Fig. 8. Operational Practicality of Remedial Movement and ECC Combinations in the High School Shelter/Refuge

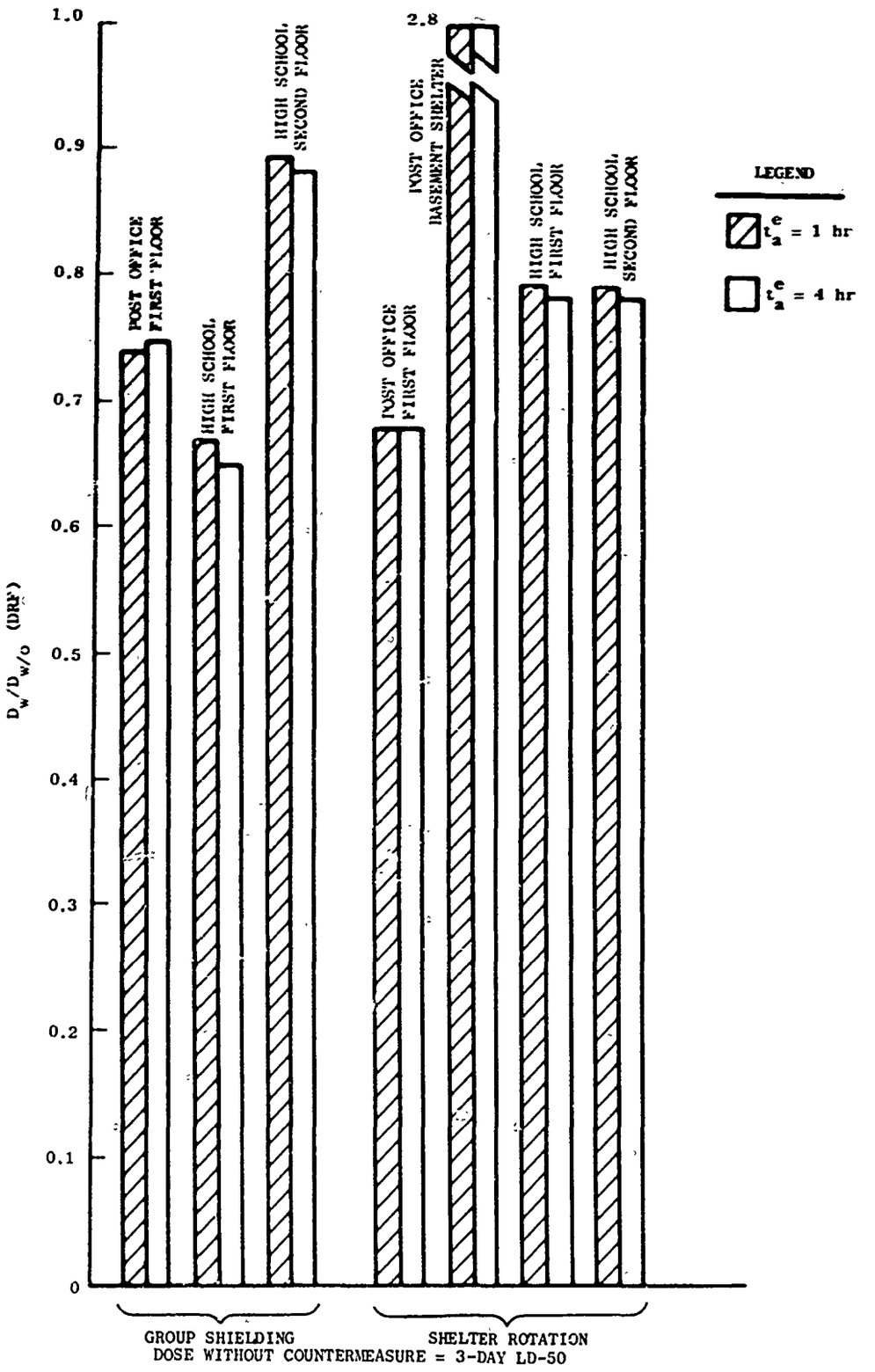

Fig. 9. Dose Reduction Factors for Group Shielding and Shelter Rotation in the Post Office and High School

Appendix A. This lifesaving capability is shown as a ratio of the percentage of fatalities that would occur with the countermeasure (F_w) to the percentage of fatalities that would occur without the countermeasure ($F_{w/o}$), i.e., the fatality reduction ratio is $F_w/F_{w/o}$.* Thus, the lower this ratio, the more effective the countermeasure in saving lives.

Figure 5 compares five exposure control countermeasures and their effectiveness in reducing fatalities in the first-floor refuge of the post office. For this case group shielding proves to be the most effective countermeasure, followed closely by overcrowding and shelter rotation. Applied shielding shows moderate lifesaving capability for Scheme 1 and a better capability for the combination of schemes, particularly for the later arrival time. Limited decontamination, however, shows only a slight ability to reduce fatalities. A comparison of the ECC's in the first-floor refuge of the high school is made in Fig. 6. As was the case in the first-floor refuge in the post office, group shielding was the most effective countermeasure, followed very closely by overcrowding. Shelter rotation in this case is not so effective because three groups have to share the only good shelter (in the basement), thus reducing the benefit to all. Applied shielding shows a fair ability to reduce fatalities, particularly for later arrival time; once again limited decontamination shows little effectiveness in reducing fatalities. The comparison of the capability of the ECC's to reduce fatalities on the second-floor refuge of the high school, Fig. 7, shows a marked difference from that of the first floor of the high school. In this instance overcrowding is by far the most effective countermeasure and, with shelter rotation, displays the same degree of effectiveness as that of the first-floor case. Group shielding, which previously has been the most effective countermeasure in the two first-floor refuge cases, now only shows moderate value in reducing fatalitics; the same observation applies to applied shielding. This decreased

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* The findings reported herein are restricted to the case in which the 3-day dose with "no-countermeasure" equals the 3-day LD-50, i.e., generalization to other cases is not intended.

effectiveness is attributable to shelter geometry; that is, group shielding and, in this case, applied shielding mainly protect against the ground direct radiation contribution which for the second-floor refuge is not the major source. However, limited decontamination for the first time is comparable in effectiveness to the other countermeasures. This increased effectiveness is due to the fact that the limited decontamination is acting on the major source of contribution by removing the fallout from the high school roof.

Figure 8 displays the capabilities of remedial movement and the ECC combinations to reduce fatalities in the high school shelter refuge. Remedial movement, studied under a special scenario, proves to be the most sensitive of any of the countermeasures to fallout time of arrival. Remedial movement (case 1) shows a difference in fatalities of a factor of 5 between the early and late time of arrival. The second remedial movement case shows almost no capability to save lives at the early time of arrival and a moderate to good capability for lifesaving at late times of arrival. The ECC combinations shown in Fig. 8 displayed a varied capability to reduce fatalities to the high school shelter/refuge occupants. Posture 1 (which uses the high school basement shelter) was generally more effective than Posture 2, which did not use the basement shelter. However, Scheme 1 of ECC combination 4 (second-floor group overcrowds first-floor refuge to perform group shielding, following which applied shielding is initiated) is as effective as Combination 2 and indicates that a high-protection shelter is not vital to the success of ECC's in reducing fatalities among occupants of refuges.

Using ECC's to aid the restoration of two vital facilities was investigated and the detailed case studies are presented in Appendix A. Decontamination and applied shielding were the ECC's used to reduce the dose levels at the vital facilities. The results (which are given as dose to the operating crews of the facilities versus time of countermeasure initiation) show that the use of these ECC's permits early operation of the vital facilities.

As discussed in Section 3, the value of an ECC can be expressed as a dose reduction factor (DRF). DRF's have been determined, from the operational practicality case studies, for a number of ECC's and are listed in Table 6. Also shown in Table 6 are the D/LD-50 and dose ranges over which ECC's serve a useful purpose by reducing fatalities.

DRF's for two ECC's, group shielding and shelter rotation, for several test cases are shown in Fig. 9. As can be seen, t_a^e is not an important variable in any case. Location of the shelter/refuge is somewhat important for group shielding, accounting for variations in DRF's of between 0.64 and 0.88, but is critical for shelter rotation where variations range from 0.67 to 2.8! For this latter case, i.e., the post office basement shelter, the average dose received with the countermeasure is 280 percent higher than if no countermeasure were employed. Thus, no generalizations can be made about the value of shelter rotation, i.e., in some cases it can reduce the average dose while in other cases it can increase the average dose.

Another interesting point can be derived from Fig. 9. Although the capability of the ECC's to reduce dose appears to be only moderate (with the obvious exception of the one case of shelter rotation in the post office), the corresponding reduction of fatalities, as shown in Figs. 5, 6, and 7, is much better. For example, consider the first-floor high school case for group shielding. The DRF is only 0.64 but the corresponding reduction in fatalities is 0.18. In other words, by providing a dose reduction of 36 percent, 615 lives would be saved.

The results of these analyses are based on the assumption that the anticipated 3-day dose in the refuge equals the LD-50. Actually, the measures will be useful over a range of fallout radiation levels. Figure 10, which is an expansion of Fig. 4, provides the basis for estimating the applicable range. On the assumption that the measure would not be used if less than 5 percent of the exposed population would be saved, a countermeasure with a DRF of 0.25 would have a useful range of D/LD-50 between 0.55

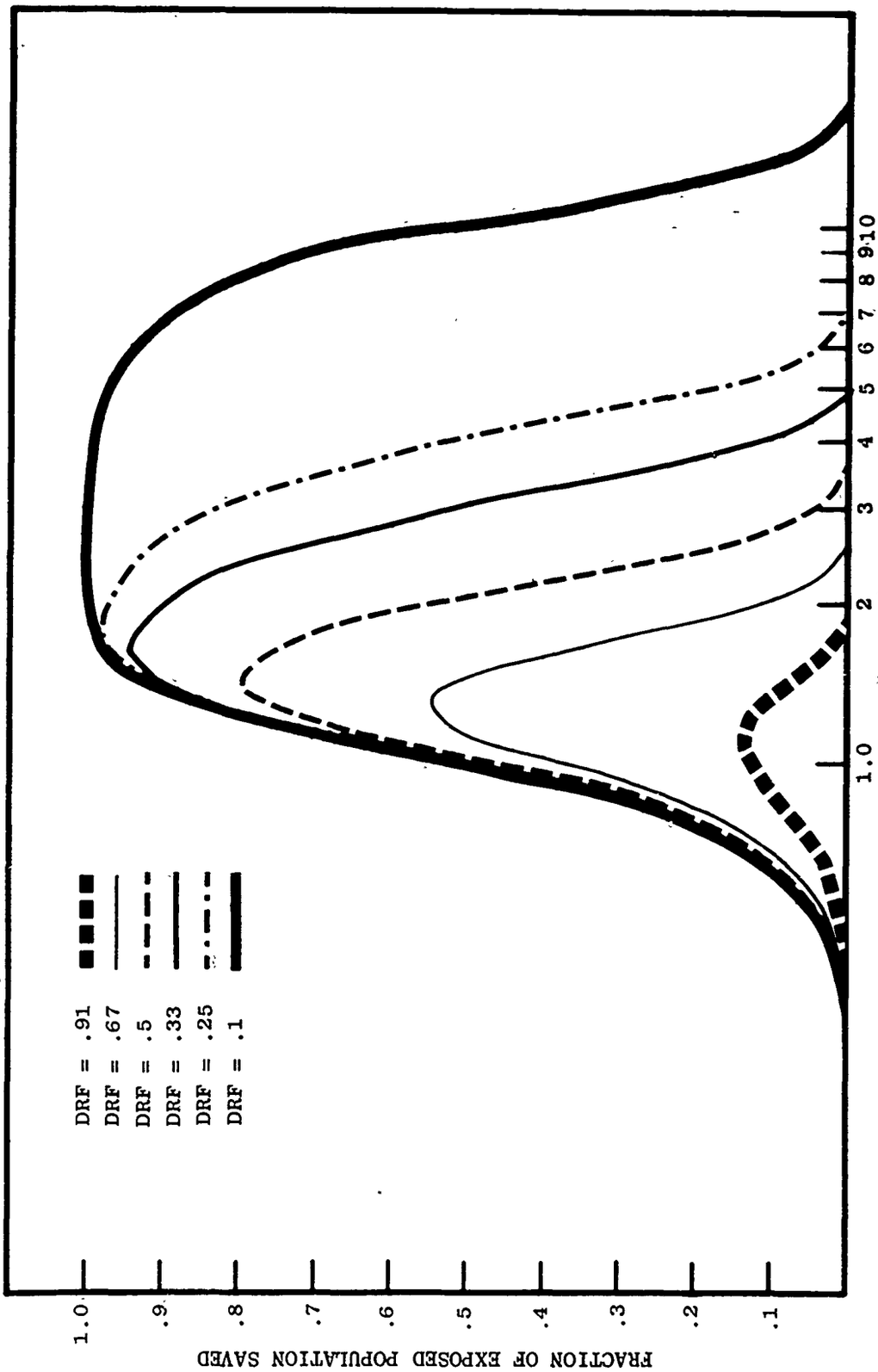

Fig. 10. Fraction of Population Saved vs Anticipated 3-Day Dose Without Countermeasures for Various Dose Reduction Factors (DRF's)

Table 6

DOSE REDUCTION FACTORS AND USEFUL FALLOUT LEVEL FOR SELECTED ECC's

COUNTERMEASURE (OPERATIONAL PRACTICALITY)			DRF	USEFUL RANGE* D/LD-50 DOSE (R)
GROUP SHIELDING	BEST CASE	1st Floor of High School with t_a^e = 2 hr	0.62	0.4-3.0
	WORST CASE	2nd Floor of High School with t_a^e = 1/2 hr	.91	0.4-1.9
APPLIED SHIELDING	BEST CASE	Post Office Refuge, Schemes + 2, with 4 hr t_a^e = 4 hr	.72	0.4-2.3
	WORST CASE	2nd Floor of High School with t_a^e = 1/2 hr	.94	0.4-1.4
LIMITED DECON.	BEST CASE	2nd Floor of High School, Decontamination Beginning at H+12 hr with t_a^e = 4 hr	.72	0.4-2.3
	WORST CASE	Post Office Refuge Decontamination Beginning at H + 48 hr with t_a^e = 1/2 hr	.98	0.4-1.1
ECC COMBO 1	BEST CASE	1st and 2nd Floor of High School with t_a^e = 2 hr	.48	0.4-4.2
	WORST CASE	1st and 2nd Floor of High School with t_a^e = 1/2 hr	.62	0.4-3.0

* To reduce casualties to less than 5 percent of the exposed population - based on anticipated dose in refuge.

and 7. The fallout radiation levels (expressed as anticipated 3-day dose) corresponding to an LD-50 of 550 R would be 300 R and 3850 R.

COMPARISON OF RESULTS

Figures 5 through 9 have compared the relative effectiveness of the various ECC's for the different refuge locations. Certain general trends apparent from observing these graphs will be discussed here. In almost every case for operational practicality, the exposure control countermeasures prove more effective at later times of fallout arrival than they did at the earlier times of arrival. (This was not necessarily true for technical feasibility.) This correlation reflects the organizational and implementational problems associated with each countermeasure. Further, those countermeasures which require the longest implementation time show the greatest variation in effectiveness between the earliest and latest arrival time. Another general trend is that for similar shelter configurations, i.e., first-floor post office refuge and the first-floor high school refuge, the same countermeasures show the same relative degree of effectiveness for both cases.

Section 5
SENSITIVITY ANALYSIS

A sensitivity analysis was performed on the information inputs required to plan and institute ECC's. The effect of the reliability of four basic information inputs on the countermeasures effectiveness were studied:

- Time of attack (H hour)
- The dose rate meter reading
- The dosimeter reading
- The decay constant

The post office refuge at North 1st Street in San Jose was the site chosen for analysis. Two ECC's (technical feasibility cases), applied shielding and shelter rotation, were studied to see the effect of variation in information inputs.

Shelter rotation was chosen for this analysis because it requires radiological calculations to be made in planning to equalize doses between shelter groups. Applied shielding was chosen because it is representative of those countermeasures which can be initiated in the absence of radiological inputs.

Table 7 gives the various parameters that were used for this investigation, listing the informational inputs, the specific scenario used with each input, and the degree of variance that was applied to each informational input. Each of these inputs was varied independently of the others to determine its effect on the countermeasure. A plot of percentage of fatalities versus percent error in information was used in presenting the results. For each case a curve is given that indicates the percent fatalities that would be expected to occur without either of the countermeasures being applied. This approach gives a visual indication of the sensitivity of the input information for the particular countermeasure. If the countermeasure proves sensitive to that particular

Table 7

PARAMETERS USED IN SENSITIVITY ANALYSIS

INFORMATIONAL INPUT	SCENARIO* PARAMETERS	INFORMATION VARIANCE
Time of Burst (H hour)	t_a^e = 2 hr I_o = 5000 R/hr	Varies 1-1/2 hr on either side of true time of burst
Dose Rate Meter (R/hr) and Dosimeter(R) Readings	t_a^e = 1/2 hr I_o = 3,100 R/hr	Percent Error range is ± 80% reading from true reading
Decay Rate	t_a^e = 2 hr I_o = 5000 R/hr	Decay Exponent varies from 1.0 to -1.8

* The I_o applies to the zero or no-error case

informational input, it would cross the no-countermeasure line, indicating that more fatalities would occur by implementing the countermeasure on the basis of informational error than would occur if no action were taken. For the two exposure control countermeasures studied, this base case is different. For applied shielding, only the 1,500 people on the first-floor refuge are involved. Under the attack environment specifying 50 percent fatalities, 750 of the occupants would die if no applied shielding were initiated. However, if shelter rotation is implemented, the 1,500 people in the basement shelter are also involved, making a total of 3,000. This means that if the countermeasure were not implemented, the maximum number of fatalities that could occur would be 50 percent for all of those persons on the first-floor refuge, or 750 persons, which is 25 percent of the total of 3,000.

Dosimeter or Dose Rate Meter in Error

An error in reading the actual dose with a dosimeter or the actual dose rate with a dose rate meter can be shown to produce the same effect in planning for a countermeasure; therefore, these two sources of error have been combined for evaluation. Figure 11a. shows the effect that an error in either of these instruments would have on the applied shielding countermeasure. The no-countermeasure and applied shielding curves parallel each other, indicating that an error in the instrument has no real effect on the actual execution of the countermeasure. For this case, the minus value of the error shows that a much higher dose rate is actually being received than the instruments would indicate.

Figure 11b. shows the effect that instrument error would have on shelter rotation. For this case an instrument error of greater than minus 50 percent (that is, the instruments are reading less than half of what the actual dose or dose rate is) produces more fatalities than would occur were the countermeasure not used, which indicates that the effectiveness of shelter rotation is sensitive to the instrument readings necessary for planning the proper rotation.

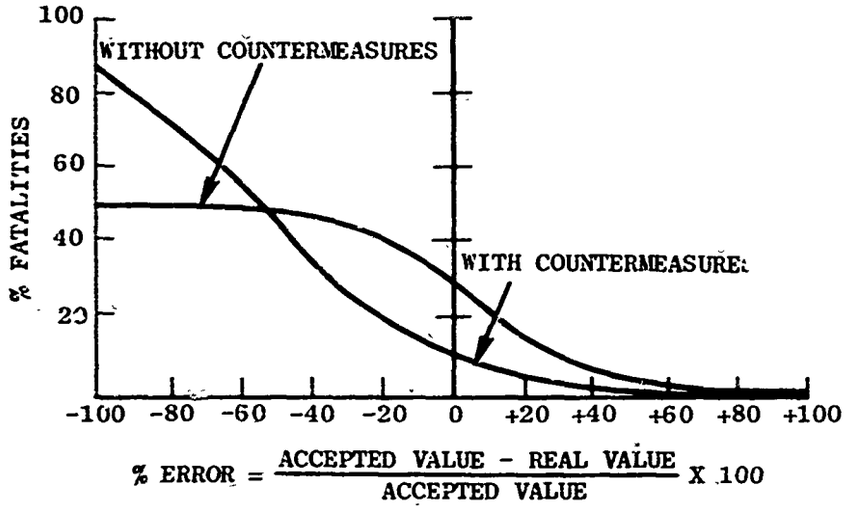

Fig. 11a. Shelter Rotation with Dosimeter or Dose Rate Meter in Error

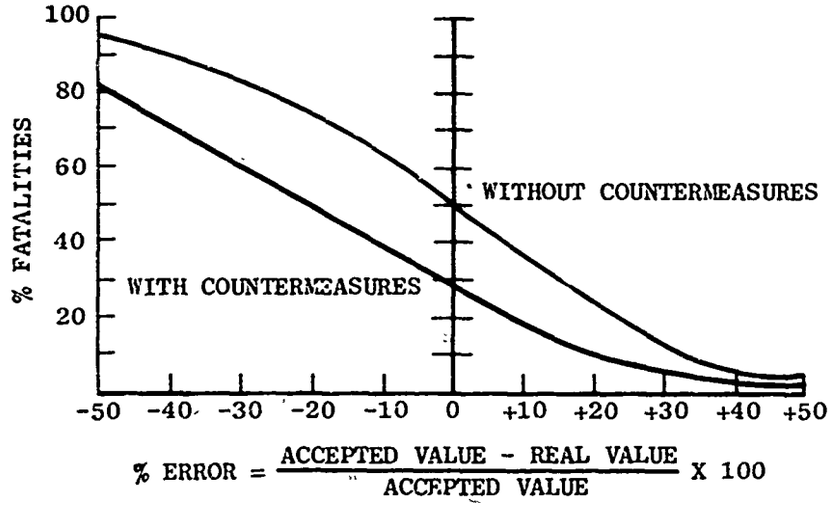

Fig. 11b. Applied Shielding with Dosimeter or Dose Rate Meter in Error

NOTE: "Accepted Value" assumed to be equal to LD-50

Variation in the Radiation Decay Constant

Most radiation predictive methods and all of the calculations in this report are based on the radiation decay rate of $t^{-1.2}$. Although this is a commonly used value (Ref. 1), in reality variation in decay rate could be expected.* Therefore, the sensitivity of the two countermeasures to this variation in the radiation decay rate was ascertained. Figure 12 illustrates the effect that a change in the radiation decay rate of between $t^{-1.0}$ through $t^{-1.8}$ can have on the effectiveness of applied shielding and shelter rotation. The applied shielding countermeasure proves insensitive to the change inasmuch as throughout the whole range of decay rates, applied shielding reduces fatalities more than if no applied shielding were used. Shelter rotation however proves quite sensitive to any change in the decay exponent below -1.2 and would produce 80 percent fatalities with a decay exponent of -1.0, against only 50 percent fatalities if the shelter rotation scheme were not used.

Error in Time of Burst (H Hour)

Knowing the time of burst associated with incoming fallout is a necessary input for radiological calculations; if the time of burst is unknown, it is difficult to assess the standard intensity (I_o) of the incoming fallout. The effect that an error in estimating time of burst would have on the two countermeasures being studied is shown in Figs. 13a and 13b. An error in determining the time of burst has only a small effect on applied shielding (as shown in Fig. 13a).** Figure 13b shows that shelter rotation is very sensitive to an underestimation of the time of burst.

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* As an example and as shown in Russell, (Ref. 16) and Jones (Ref. 17), the use of U-238 in a weapon can induce a major change in the total energy emitted by fallout during the first 20 days or so. This results also in divergences in the decay rate from $t^{-1.2}$. At various times, for what is postulated as the worst case, the decay exponent may vary from about -1.0 to -1.8, although over longer times the variations are not so great.

** However, if implementation is not started promptly after the "true" time of burst, the applied shielding may not be in place by the time fallout arrives.

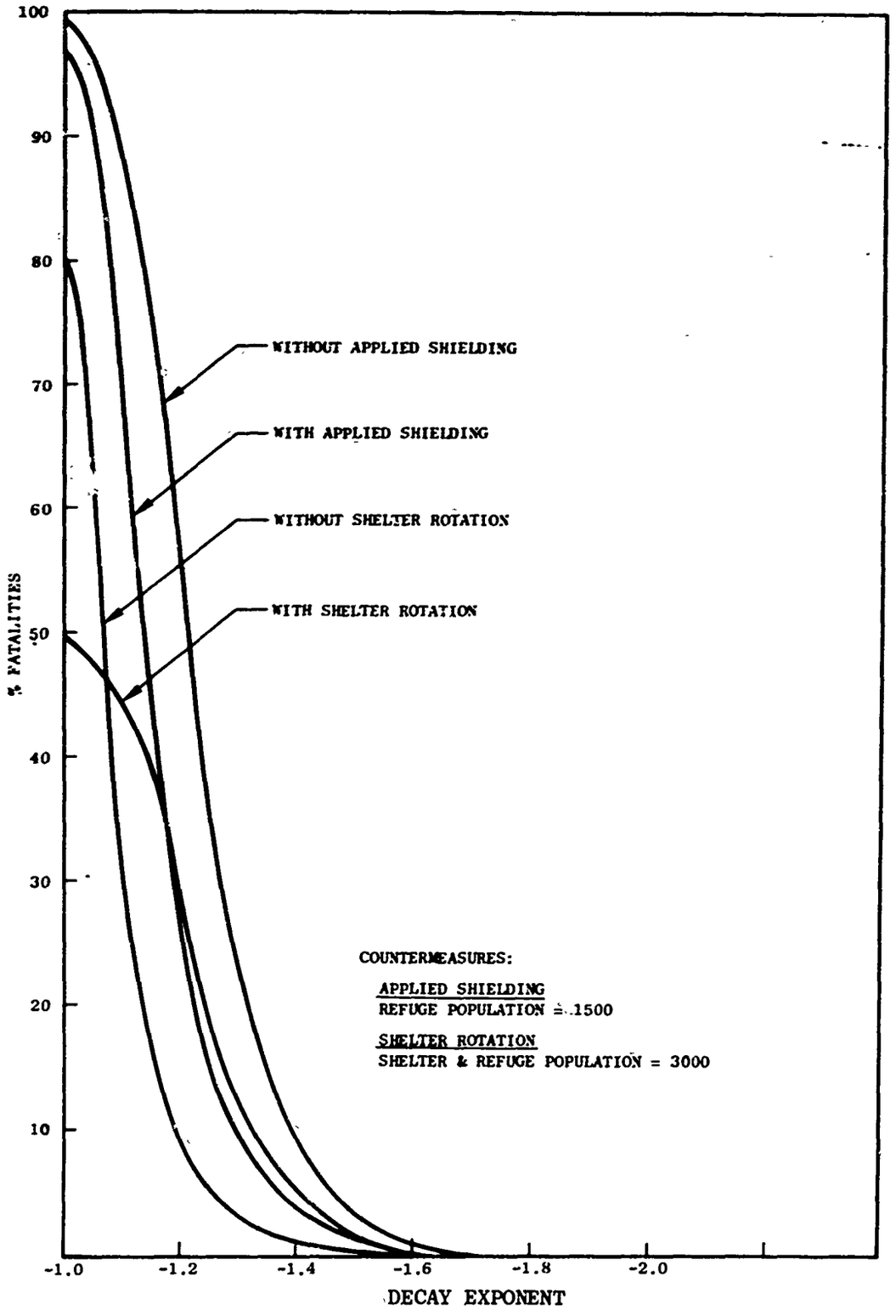

Fig. 12. Percent Fatalities as a Function of the Decay Exponent

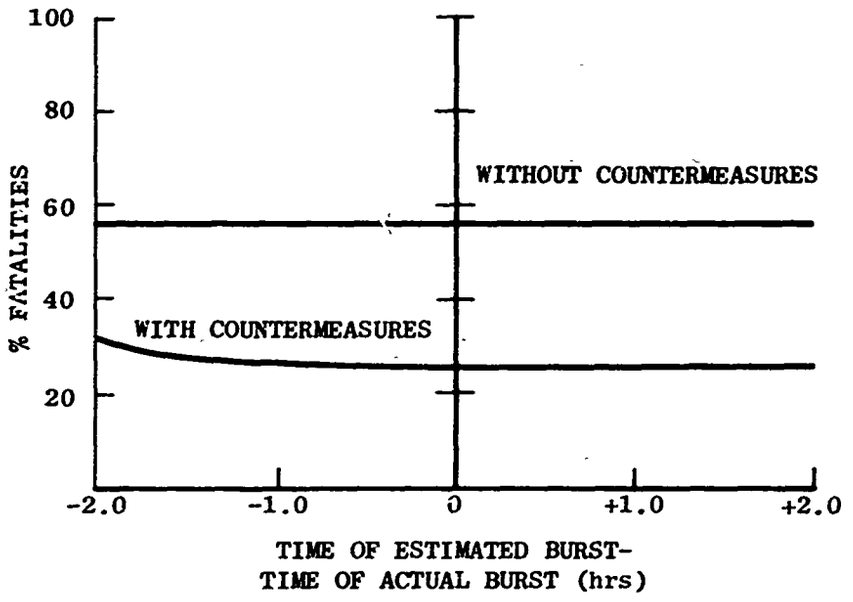

Fig. 13a. Applied Shielding with Error in Time of Burst

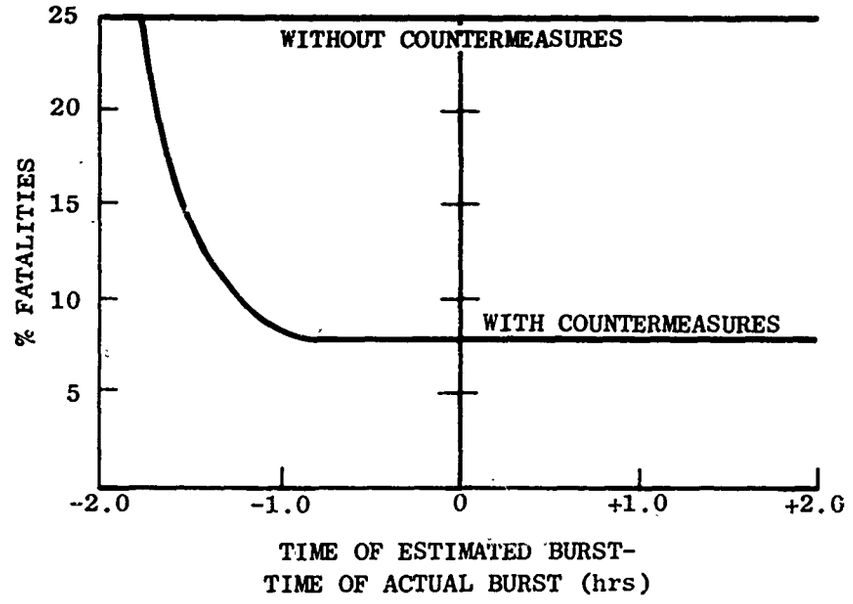

Fig. 13b. Shelter Rotation with Error in Time of Burst

NOTE: Real arrival time is held constant. Accepted arrival time is varied.

Comparison of Results

Results of the three cases studied show that shelter rotation is highly dependent on accurate radiological information and that if this information is lacking or in error, the implementation of shelter rotation could prove to be dangerious since it could conceivably cause the death of more people than non-implementation, i.e., no shelter rotation.* Applied shielding, on the other hand, is relatively insensitive to the informational inputs and would therefore appear to be safely used under most radiological circumstances.

* The results of this study have been predicated on fallout from a single weapon burst; if fallout were the result of multiple weapon bursts detonated at different times, the difficulty of predicting dose would be even further complicated.

Section 6

CONCLUSIONS AND RECOMMENDATIONS

The following are the conclusions that have been drawn from the results of the analysis reported herein on exposure control countermeasures. Although these results cannot be applied to all cases, they are applicable over a wide range of conditions in which ECC's are most effective.*

GROUP SHIELDING

Group shielding appears to be the most attractive of all the individual ECC's for a specific shelter geometry. Group shielding is easily implemented and requires little planning. The informational requirements for group shielding are low, with the major informational input being the time of fallout arrival or the knowledge that a radiation field is threatening the shelter occupants. For this reason group shielding is especially effective at early fallout arrival times since it requires the least implementation time of all the ECC's. The capability of group shielding to reduce fatalities is better than any individual ECC for first-floor shelter/refuges, or similar geometries.

However, group shielding presents certain implementation difficulties, namely the unwillingness of persons in a shelter (1) to initially crowd together and (2) to rotate regularly and methodically once in a constricted array. Further research into these problem areas is indicated before group shielding can be accepted as a functional exposure control countermeasure.

SHELTER ROTATION

Although superficially effective in reducing fatalities, shelter rotation, upon closer examination, is a rather unattractive countermeasure for the following reasons:

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* The range of dose values for which a countermeasure is effective is dependent on its DRF (dose reduction factor) for any given DRF, Fig. 10 indicates the range of dose levels over which the ECC is effective.

- Shelter rotation jeopardizes the occupants in a low-dose-rate shelter by forcing them to exchange places with occupants of a high-dose-rate shelter.

- To be effective, shelter rotation requires that an adequate shelter be located in the immediate vicinity of the high-dose-rate shelter (to avoid a high travel dose). However, if shelters are close, then overcrowding would be preferable since it does not jeopardize the occupants of the better shelter and is also more effective in reducing fatalities among the high dose rate shelter occupants.

- Shelter rotation, unlike overcrowding, is highly sensitive to radiological informational inputs. If any of these inputs are grossly in error, the end result could be that more deaths would result from rotating between shelters than if no rotation had been performed.

APPLIED SHIELDING

Applied shielding is most effective for later fallout arrival times but can produce some reduction in fatalities even at earlier times. In general, however, applied shielding can be considered to be a positive countermeasure in the sense that any additional shielding serves to reduce dose and is beneficial to the shelter occupants.

Time is required to put shielding in place; this time delay causes applied shielding generally to be much less effective at early fallout arrival times. However, if shelter occupants were aware that their refuge was radiologically deficient they could commence the applied shielding operation immediately after attack and prior to fallout arrival, thus increasing effectiveness. Applied shielding, like group shielding, is sensitive to shelter geometry, and may suffer loss of effectiveness for some shelter geometries.

REMEDIAL MOVEMENT

Remedial movement, for the cases studied, proved to be the countermeasure most sensitive to fallout time of arrival; it is almost useless in reducing fatalities at the very early times of arrival, while at later times of arrival it proved competitive with other ECC's. Therefore movement at very early times should be undertaken only (1) over very short

distances, or (2) if shelter occupants are forced to move by other than a radiation threat, for example, fire. A basic requirement is knowing the location of an available shelter (which would probably require an intact communication network). Also, knowledge of the radiological environment along the movement route is a necessary input to a successful remedial move. Without adequate inputs, remedial movement could very well prove to be an extremely dangerous undertaking to those leaving the shelter.

OVERCROWDING

Overcrowding is effective in reducing fatalities to occupants of high-dose-rate shelters if a good shelter is readily available and if overheating is not a serious problem. Overcrowding was found to be almost as effective as group shielding for first-floor refuges and superior for the second-floor refuge. Overcrowding, like group shielding, is particularly useful at early times following fallout arrival because it requires little implementation time or planning. However, unlike group shielding, it has a serious limitation in some environments, when overheating is a concern. Therefore, in certain areas of the United States (for instance, the Southwest or Southeast) where overheating from the normal complement of shelter occupants is a possible problem because of climate, overcrowding would probably have to be of very short duration. However, overcrowding even for only a few hours at the earliest fallout arrival times might be combined with shelter rotation to provide a considerable reduction in fatalities.

LIMITED DECONTAMINATION

For the cases that were studied, limited decontamination proved to be the least effective of the countermeasures in reducing fatalities to the shelter/refuge occupants. Limited decontamination as an exposure control countermeasure could save only a very few lives and would be considered as a lifesaving countermeasure only in rare circumstances. Under the operational practicality limitations, where it was assumed that water would not be available for decontamination purposes for at least 24 hours, limited

decontamination proved very ineffective for both first-floor refuges and only comparable to other ECC's for the second-floor refuge of the high school (although even in this case the reduction in fatalities was not large). Limited decontamination, if performed immediately following fallout cessation, could probably be an effective countermeasure. However, this is usually the period when radiation levels are extremely high and decontamination at this time would probably result in extremely high doses for the decontamination crews, even if crew rotation were practiced. Immediate decontamination also presumes that a decontamination medium is readily available, such as water for firehosing, which is not too likely.

Decontamination of more extensive areas, however, can serve a useful purpose, as was shown in the analysis of the recovery of vital facilities. Although decontamination in this sense does not save lives directly, it does allow critical facilities, otherwise radiologically untenable, to be manned and operated at early times after attack.

COMBINATION OF ECC's

A combination of ECC's proved more effective than individual ECC's in reducing fatalities to refuge occupants. However, a proper sequencing of the ECC combinations would be vital.

Probably the major limitation of using a combination of ECC's is that the shelter manager, who would direct the exposure control operation in a refuge, would have to have a fair knowledge of radiation calculations and shielding. This knowledge, along with the knowledge of fallout time of arrival, is critical in maximizing the number of lives that could be saved. If this information is available, the use of a combination of exposure control countermeasures could be extremely effective in saving lives in radiologically inadequate refuges.

THE PRACTICALITY OF EXPOSURE CONTROL COUNTERMEASURES

The six exposure control countermeasures have all shown some degree of lifesaving capability, some more so than others. However, exposure control countermeasures, intelligently used, either singly or in combination, are capable of saving many lives that would otherwise be lost when threatened by high radiation fields.

Exposure control countermeasures are not limited to situations where the saving of lives is the prime consideration. Although this study has been directed toward delineating the lifesaving capabilities of ECC's, these ECC's would also prove very valuable in reducing dose levels to shelterees in radiological environments which are not severe enough to threaten life. The use of ECC's under nonfatal dose level conditions could provide a manpower pool for use in early recovery operations, such as decontamination (Ref. 10), which might otherwise have to be postponed for fear of overdosing emergency crews.

RECOMMENDATIONS

On the basis of this study the following recommendations are made:

1. The results of the study, although valid for the cases examined, cannot be extrapolated to the total number of lives that could be saved on a nationwide basis. Further investigation is needed, particularly in those metropolitan areas where large shelter deficits are known to exist. A study of this nature could be directed toward investigating the so called "bedroom communities" that surround most large metropolitan areas. These bedroom communities lack the tall or massive structures in which the majority of fallout shelters are located. In light of the recent interest in moving people from the center (CBD's) of large cities to the outskirts to protect the people from direct weapon effects, it becomes imperative that shelter facilities (or the lack of them) in these surrounding suburban or bedroom communities be investigated to see if the use of ECC's could increase shelter capacity.

2. Exposure control countermeasures used either individually or in combinations can save lives in radiologically inadequate refuges (PF less than 40).* The use of these ECC's however is based on the premise that shelter managers or the threatened population are aware

of the potential of these countermeasures and have the radiological expertise to initiate them. It is recommended, therefore, that consideration be given to incorporating ECC's into the Community Shelter Plan (CSP) program. For example a refuge would be posted stating the usefulness of various ECC's to enable the occupants of that refuge to increase the PF. Such a program would require some additional education for the fallout shelter analysts and further education for the prospective shelter managers and the general public in the use of exposure control countermeasures.

3. It is recommended that the techniques developed in this study for evaluating the effectiveness of exposure control countermeasures be extended to other functions which, under emergency operations, might have lifesaving or life-sustaining potential. Life saving, which is the most meaningful measure of effectiveness, has been shown in this report to relate only indirectly to common indices of effectiveness, such as countermeasure factor or dose reduction factor. The possibility of deriving measures of effectiveness for other countermeasures in terms of lives saved appears to be most desirable because, in addition to providing an absolute measure of worth for the countermeasure, such a unit of effectiveness would provide a common denominator for the comparison of all countermeasures, so that ultimately lives saved could be equated with the cost (which might be in units of preattack dollars or postattack manpower or resources) of the countermeasures considered.

4. The concept of emergency operations recently proposed by Strope (Ref. 15) places increased emphasis on various transattack activities, including those classed as exposure control countermeasures. It may be desirable, in the light of this new concept and because exposure control countermeasures have a demonstrated lifesaving capability, to study these countermeasures in a number of additional scenarios, preferably those generated as a part of the Five-City Study. These scenarios would be selected to reflect the operational area concept and the assignment of a specific damage or action category to each operational area. Any such analyses would be computerized to reduce analytical costs, to permit greater flexibility in the analyses, and to allow inclusion of sensitivity analyses. Such a study would help to define the specific value of ECC's in an operational framework and would provide an important input to the Five-City study.

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* It is also possible that some ECC's could save lives in fallout shelters (PF $\geq$ 40) when dose rates are very high.

Section 7
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Appendix A

ANALYSIS OF THE TECHNICAL FEASIBILITY AND OPERATIONAL PRACTICALITY OF ECC's

INDIVIDUAL EXPOSURE CONTROL COUNTERMEASURES

The analysis of the technical feasibility and operational practicality of exposure control countermeasures is discussed in this appendix. This analysis has been conducted in two phases. The first and major phase considers the use of ECC's to reduce the exposure of refuge occupants. The second phase of the analysis investigated the use of ECC's in the restoration of vital services, e.g., communication systems, utilities, etc.

The capability of the six ECC's (listed in Table 2) to reduce the radiation exposure to the occupants of the post office and high school refuges is described in this section. The results are presented in graphs showing the percentage of fatalities in the refuge studied vs effective fallout time of arrival. The base case (i.e., no countermeasures applied) is shown for all the countermeasures. This base case assumes 50 percent fatalities unless otherwise stated.

The technical feasibility and operational practicality of each ECC are displayed on the same graphs for each countermeasure. The major assumptions made in analyzing each ECC are summarized under each countermeasure; additional assumptions are included in the Appendix B.

GROUP SHIELDING

Group shielding utilizes the principle that a number of bodies in close proximity create a mutual shielding effect which reduces the dose received by the group from an external radiation field. Childers and Jacobs (Ref. 4)*

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* The actual increase varies with group size. Also, a standing group of people dispersed at 10 sq ft/person will create a CF of approximately 1.45. (See p. A-2.)

reported that groups of 100 people in first-floor shelters could reduce their average dose* by a factor of approximately 3 (assuming dose equalization through a constant random mixing of the people in the shelter).

The basic assumptions used for the group shielding analysis are:

- A closely packed formation allows 1.56 sq ft per person (Ref. 4)
- Average height of persons in the group is 5 ft 6 in.
- Average weight of persons in the group is 140 lb
- Group shielding is maintained for no more than 8 hr**

Post Office Shelter – Scenario A

The 1500 people in the first-floor refuge (PF-20) would initiate the group shielding countermeasure by forming their group into a compact circle with an area of approximately 2,300 sq ft.

Technical Feasibility

Group shielding with a countermeasure factor (CF) of 3, was assumed to begin immediately following fallout arrival, raising the overall countermeasure factor ("CF") of the refuge to 60.*** Figure A-1a shows for technical feasibility, that the reduction in fatalities varies from the maximum 46 percent for 1/2 hr t_a^e (from 50 percent down to 4 percent) to 38 percent for the 4-hr t_a^e. The decrease in effectiveness for later times of arrival is attributable to the slower decay of the fallout at those times.

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* The countermeasure factor (CF) (Ref. 5) is defined as the factor by which the dose rate to a person or group is reduced through the use of the countermeasure.

** Reshuffling every 60 min.

*** The term overall countermeasure factor ("CF") is also used herein to designate the combined effectiveness of two or more countermeasures, such as shielding and decontamination, or shielding by the structure and group shielding. In this case, the refuge protection factor (PF) was calculated to be 20. For purposes of this study, it is assumed that the countermeasure factor, CF, for the structural shielding is equal to the calculated PF. Therefore, the "CF" is 3 x 20 or 60.

Operational Practicality

A delay by the shelter manager in recognizing the potential fallout hazard and the time required to initiate the countermeasure were taken into account by starting the application of the countermeasure at some time after the arrival of fallout (t_a^e). Also random motion to achieve perfect dose equalization within the group would be most difficult; therefore we assumed that 20 percent of the group (300 people) would realize a CF of only 2.5, while the remainder of the group would receive a CF of 3.0. Figure A-1a shows that for operational practicality, the reduction in fatalities ranges from 33 percent for 1/2 hr t_a^e (from 50 percent down to 17 percent) to a fairly constant 36 percent for all other arrival times. The shape of the curve for operational practicality differs from that of technical feasibility because of the time required to recognize the threat and implement the countermeasure. Therefore, the earliest arrival time (instead of the latest) becomes the worst case. This apparent anomaly occurs because dose accumulates so fast at early times that a considerable exposure has been received prior to the time the countermeasure can be initiated.

High School Refuge - Scenario B

Group shielding in the high school refuge would be similar in nature to that performed in the post office. Group shielding would be initiated at the same time on both the first and second floors of the high school. Each group shielding operation would consist of 1,000 shelterees formed into a rectangle 25 ft by 65 ft. The group on the second floor would form their group shielding directly over the group on the first floor.

Technical Feasibility

The technical feasibility of group shielding is shown in Fig. A-1b. The countermeasure, initiated at t_a^e, was computed to increase CF on the second floor by a factor of 1.33 and on the first floor by a factor of 5. The reduction in fatalities for the second floor ranges from 27 percent (from 50 percent down to 23 percent) for the 1/2-hr t_a^e case to 23 percent for the 4-hr t_a^e case. For the first floor the reduction in percent fatalities ranges from 48 percent for the 1/2-hr t_a^e case to 42 percent for the 4-hr t_a^e case.

Operational Practicality

The same considerations (i.e., time required to recognize a threat and to initiate the countermeasure) used for the post office case were used for the high school refuge. Since complete random mixing to equalize dose is most unlikely, the following assumptions pertaining to the dose distribution were made:*

- First floor - 75 percent of that floor's occupants benefit from a CF of 5, and 25 percent, a CF of 4. The overall countermeasure factors were 150 and 120 respectively.
- Second floor - 75 percent of that floor's occupants benefit from a CF of 1.33 and 25 percent a CF of 1.16; "CF's" were 40 and 35 respectively.

The operational practicality for group shielding on the second floor, indicated in Fig. 1-1b, varies from a reduction in fatalities of 15 percent (from 50 percent fatalities down to 35 percent) for the 1/2-hr t_a^e, to a reduction of 20 percent for the t_a^e's for 2 and 4 hr. The first-floor effectiveness ranges from a 38-percent reduction in fatalities for the 1/2-hr t_a^e to approximately 41 percent for the 2- and 4-hr t_a^e's.

The large differences found between the first- and second-floor group shielding results are attributed to (1) the extra shielding provided the first floor group by the second-floor group directly overhead (but not vice versa) and (2) shelter geometry.**

Comparison of Results

Both the technical feasibility and operational practicality curves for the two refuge cases have similar shapes. The differences occurring in re-

* The variation in the dose distribution between the post office and high school is due to the different size groups that participate in the countermeasure.

** Group shielding has only been investigated for its capability to shield against ground-direct and wall-scattered radiation (Ref. 4); however, it would appear that it would also offer some protection from overhead contribution and should be studied further.

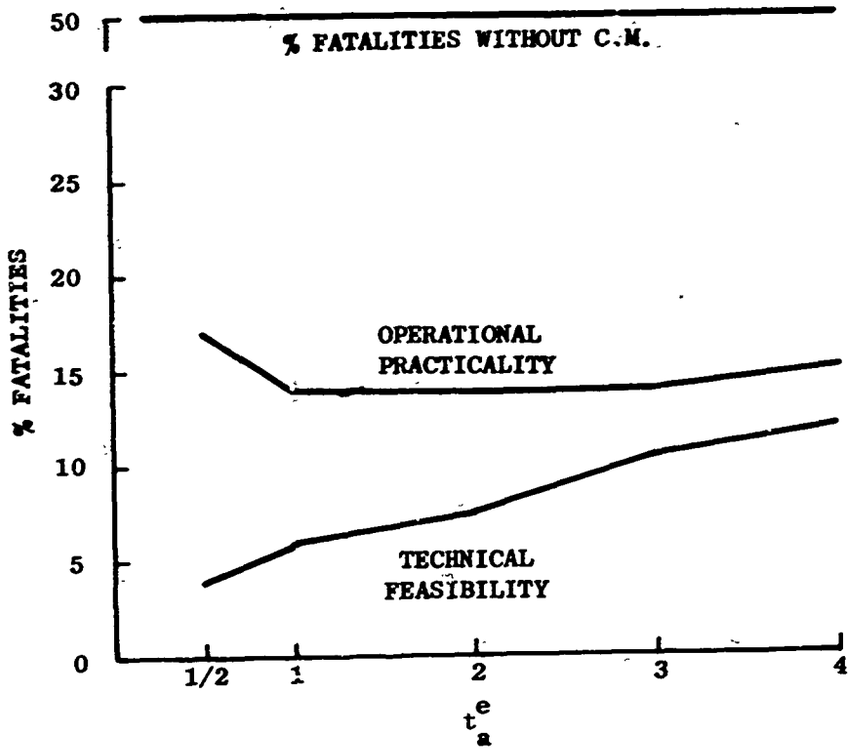

Fig. A-1a. Group Shielding in the Post Office Refuge

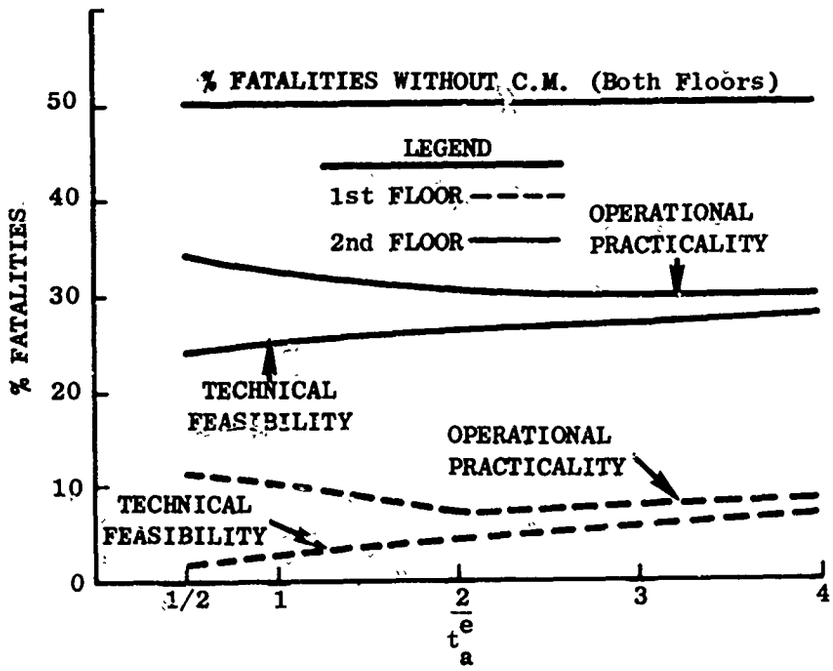

Fig. A-1b. Group Shielding in the High School Refuge

duction of fatalities between the post office refuge and the first and second floors of the high school refuge attributed to shelter geometry. In the case of the first-floor group in the high school, the protection factor increase observed would have been the same as that for the post office group if the second-floor group had not been present.

SHELTER ROTATION

Shelter rotation is a method of dose equalization which involves the manipulation of two groups of shelterees, one from a high-protection shelter and one from a low-protection shelter, between these shelters so that the dose of the two groups is equalized. Basic assumptions that were used for the shelter rotation analysis are as follows:

- For technical feasibility - movement of shelter groups was assumed to occur at the optimum time, i.e., only one movement would be made and the dose received by the two groups equalized.
- For operational practicality - unequal dose distribution was assumed to occur because of the difficulty of moving two or more large groups at the same time. Movement of shelter groups would be delayed beyond the optimum moving time because of the time required to recognize the threat, plan the countermeasure, and persuade the occupants of the good shelter to participate.

Post Office Shelter - Scenario A

The 1,500 people in the post office first-floor refuge exchange places with the 1,500 people in the post office basement shelter. The first-floor refuge has a PF of 20, while the post office basement has a PF of 85.

Technical Feasibility

Figure A-2a illustrates the technical feasibility of shelter rotation in the post office building. A 19-percent reduction in fatalities is achieved (from 25 percent to 6 percent) for all times of arrival; the fatalities for the 1/2 hour time of arrival is slightly higher but not significantly so.

Operational Practicality

The operational practicality of shelter rotation as shown in Fig. A-2a assumes that 30 percent of the shelterees received a 10-percent higher dose due to the difficulty in moving the large groups simulataneously. The reduction in fatalities is approximately 17 percent for all times of arrival.

High School Shelter - Scenario B

A somewhat more intricate shelter rotation problem was used for the high school shelter than for the post office. Three groups, each composed of 1,000 persons, would be involved. One group ould be located in the basement shelter of the high school (PF 120), the other two groups would be located in the first- and second-floor refuges of the high school (PF 30). The shelter rotation maneuver would involve the manipulation of all three groups between the upper floor refuges and the basement shelter. This would mean that only one group would be in the basement shelter at any one time, while the other two groups would be in the lesser protected refuge areas.

Technical Feasibility

Figure A-2b depicts the technical feasibility of shelter rotation in the high school. An 18-percent reduction in fatalities was achieved (from 33 percent to 15 percent) for fallout times of arrival from 1 to 4 hr; the 1/2-hr time of arrival case was slightly less effective.

Operational Practicality

Although the same number of people were involved in the shelter rotation operation in the high school as were involved in the shelter rotation operation in the post office, a greater number of people (45 percent instead of 30 percent) were assumed to receive a 10-percent increase in dose. This reflects the more intricate movement schemes that would have to be used in performing the three-way move. The operational practicality of shelter rotation is shown in Fig. A-2b an average reduction in fatalities of 15 percent was received for the 1- to 4-hr arrival time cases. The 1/2-hr arrival time once again showed a slightly less effective reduction in casualties.

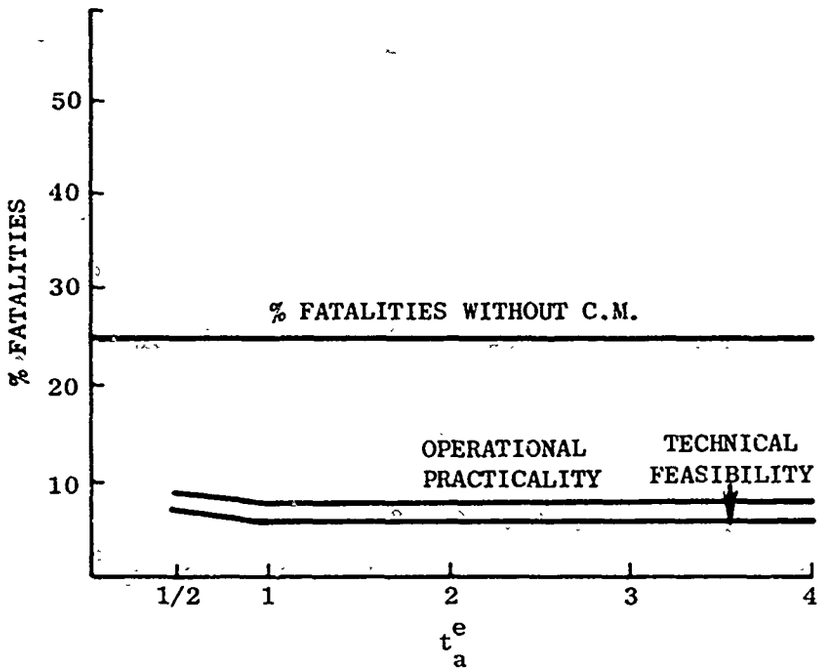

Fig. A-2a. Post Office Shelter Rotation

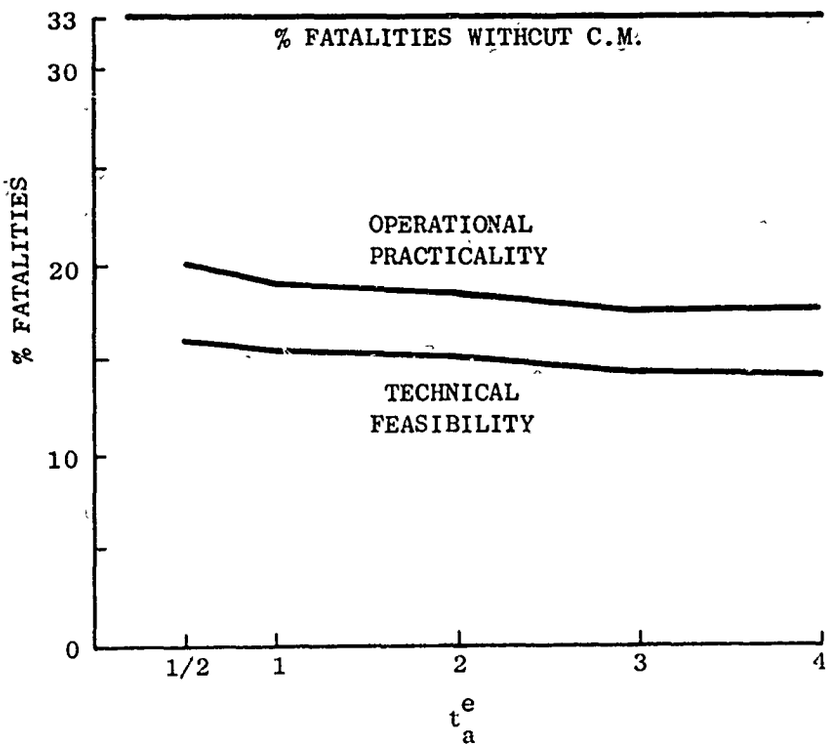

Fig. A-2b. High School Shelter Rotation

Comparison of Results

The results of shelter rotation in both cases studied were similar. The differences in reductions of fatalities in the two buildings was caused by the different PF's in their respective shelters and the different rotation schemes that were used. The high school case involved three groups that would rotate between the one shelter area and two refuge areas. This means that each group uses the good shelter only one-third of the time, whereas in the post office, in which only two groups rotate, each group can spend approximately one-half of their time in the basement shelter.

Another method of performing shelter rotation would employ the use of dosimeters in the shelter refuge groups being rotated, i.e., when one group's dose reached a predetermined amount higher than the other group's, rotation would be performed. This method is advantageous in the sense that it relies only on the information of the dosimeter, and does not require radiation calculations. However, this method could entail many movements, particularly at early times following fallout arrival, when as many as 10 or 12 moves might be necessary in the first 9 hr (approximately 50 percent of a 1-month dose is received in this period). This method was not investigated in this study due to the size of the shelter/refuge groups involved in the rotation schemes. It was felt that moving 3,000 people 10 or 12 times in 9 hr would prove too cumbersome or not operationally practical. However, it could be applicable for smaller shelter or refuge groups.

APPLIED SHIELDING

Applied shielding is a procedure in which additional mass is placed between the source of radiation and the shelter or refuge area, thus reducing the total dose received by the shelter occupants. There are several ways that applied shielding can be used; in most cases the most beneficial application of this countermeasure would be the placing of additional mass (sandbags, books, filing cabinets, furniture, etc.) in the openings in a shelter or refuge where the least radiation protection is available, i.e., windows and doorways. Another method would be the placing of additional mass on the ceiling above the shelter

area to reduce overhead contribution. Both of these methods have been investigated in this study, both individually and jointly, to provide more complete analysis of their capability to increase the protection of a shelter or refuge.

The basic assumptions used in the analysis of applied shielding for the two shelter buildings are as follows:

- General - The shelter occupants would recognize that their refuge provided insufficient protection and they would therefore begin the applied shielding countermeasure immediately following an attack even though not necessarily threatened by a fallout field.*
- General - An estimate of the total mass available in the two shelter buildings was made through the use of Table B-1, "Building Content Load and Volume Factors," which indicated for the class of building analyzed that in all cases there was ample mass available to carry out the specified applied shielding schemes.
- General - The actual placing of the mass in designated locations requires a certain length of time (depending on available manpower); and although it is realized that during this period certain shielding benefits would be realized by the people in the shelter from the partial placing of the applied shielding, for ease of calculation it was assumed that the applied shielding did not become effective in reducing dose until the total operation was complete.
- Technical feasibility - It is assumed that the shelter occupants would begin applied shielding operations 1/2 hr following their entrance into the shelter.
- Operational practicality - The time required to put applied shielding in place (implementation time) is increased to account for designation of resources, crew rotation, and planning.

Post Office Shelter - Scenario A

Two applied shielding schemes were used in the post office refuge. Scheme 1 requires that 100 lb/sq ft of mass be placed in the first-floor doors and windows. This would increase the "CF" of the refuge from 20 to 25. The Scheme 2 requirements are to place 20 lb/sq ft of mass on the floor above (2nd floor). Scheme 2 requires a longer implementation time, and if applied by itself, would raise the "CF" of the first-floor refuge from 20 to 23; however, if Scheme 2 is coupled with Scheme 1, the "CF" of the refuge is increased from 20 to 30.

Technical Feasibility

Figure A-3a shows the technical feasibility of Scheme 1 for applied shielding. Figure A-3b shows the technical feasibility of the combination of Schemes 1 and 2 for applied shielding. The reduction in fatalities achieved with Scheme 1 ranges from 18 percent (from 50 percent ot 32 percent) for the 1/2-hr time of arrival to a fairly constant 25 percent for times of arrival of 2 hr and beyond. The combined use of Scheme 1 and Scheme 2, however, proves even more effective, resulting in reductions in fatalities ranging from 20 percent for a 1/2-hr time of arrival to 38 percent for 3- and 4-hr times of arrival. The improved capability of the combined schemes to reduce the dose to the shelter occupants indicates that even with the longer implementation time that is required, the payoff is much better due to the higher PF offered by the combination of both schemes.

Operational Practicality

The operational practicality of Scheme 1, as indicated in Fig. A-3a, shows that for the 1/2-hr time of arrival the reduction in fatalities is approximately 12 percent, increasing to a high of 25 percent for the 3- and 4-hr times of arrival. The operational practicality of the countermeasure is similar to the technical feasibility of the countermeasure for the later times of arrival of 3 and 4 hr. This is due to the ease of implementing Scheme 1. Even with the additional time factors that are included for operational practicality, the countermeasure is installed and effective at the same time as the technical feasibility case for the later times of arrival. The operational practicality of the combination of Scheme 1 and 2 as shown in Fig. A-3b indicates that a better payoff is achieved by using the more involved countermeasure requiring a longer implementation time. Reduction in fatalities range from 13 percent for 1/2 hr times of arrival up to 35 percent for the 4 hr time of arrival.

High School Shelter - Scenario B

Only one applied shielding scheme was used in the high school shelter. This scheme required placing 80 psf of mass in the windows and doorways of the first and second floors, raising the PF on the first floor from 30 to 40 and the PF on the second floor from 30 to 35.

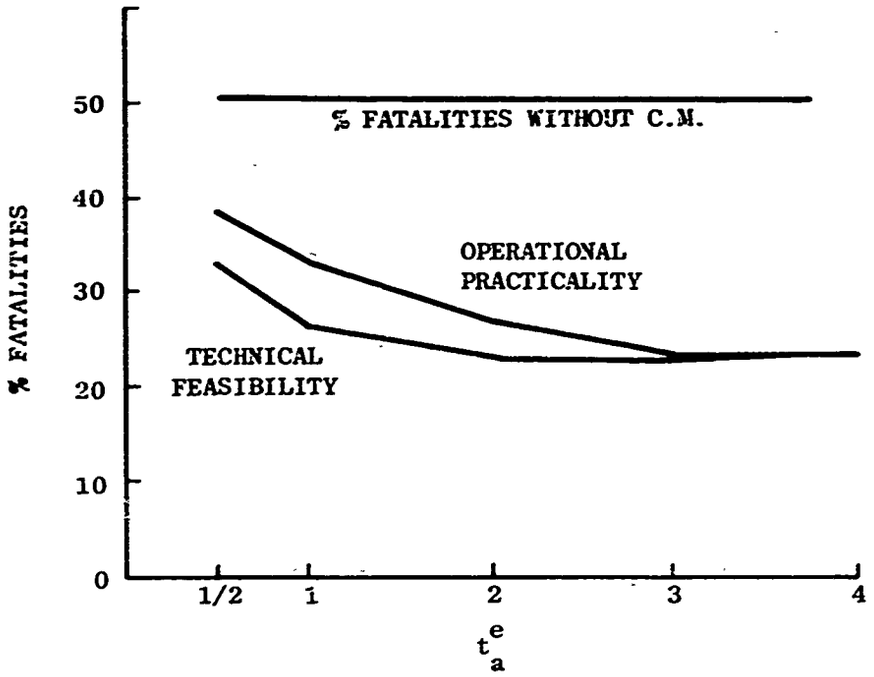

Fig. A-3a. Applied Shielding – Scheme No. 1

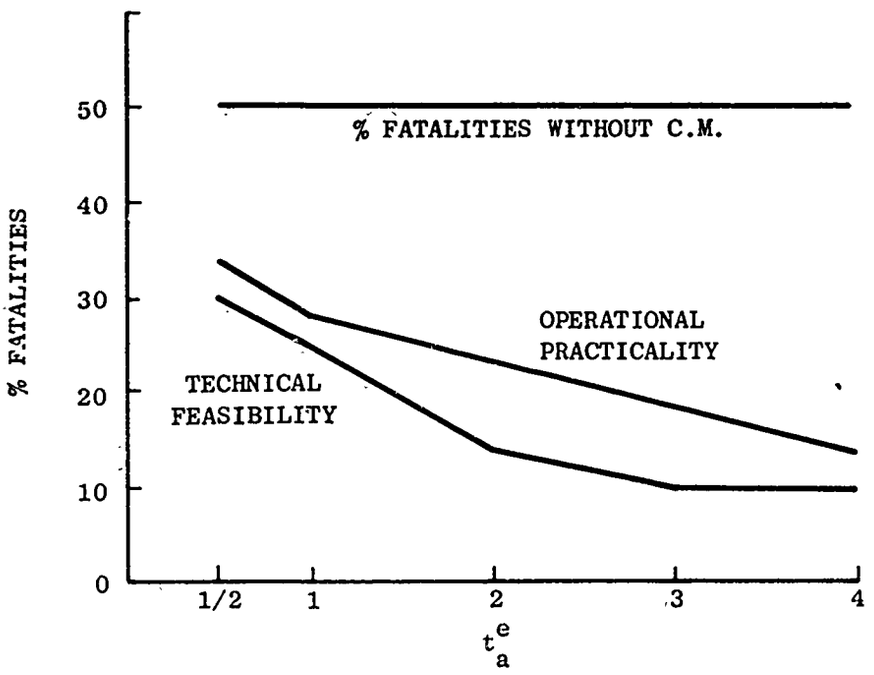

Fig. A-3b. Applied Shielding – Schemes No. 1 and 2

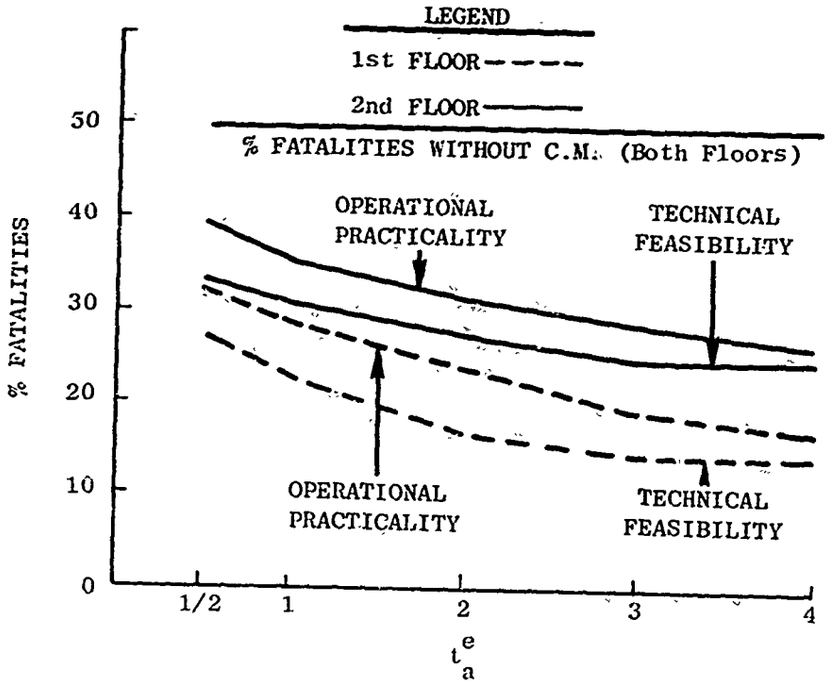

Fig. A-3c. Applied Shielding – High School

Technical Feasibility

Figure A-3c shows that on the second floor, the technical feasibility of applied shielding reduces fatalities 13 percent for the 1/2-hr time of arrival and 22 percent for arrival times of 3 and 4 hr. On the first floor of the refuge, a reduction in percent fatalities of 22 percent is achieved for the earliest time of arrival, rising to a reduction in fatalities of 35 percent for the 4-hr time of arrival.

Operational Practicality

Under the operational practicality assumptions, the countermeasure on the second floor reduces fatalities from 10 to 21 percent for the 1/2-hr through 4-hr times of arrival. The first-floor case shows a reduction in fatalities of 18 percent for the 1/2-hr time of arrival to 30 percent for the 4-hr time of arrival. The applied shielding countermeasure is less effective on the second floor because the applied shielding scheme used in the high school reduces mainly the ground-direct contribution. This is of less importance on the second floor, where the major source of contribution for that floor is the roof.

Comparison of Results

The effectiveness of applied shielding in reducing dose to the shelter occupants was similar for all the cases studied. For all the cases the countermeasure was least effective at the earliest times of arrival and most effective at the latest times of arrival. Differences in shelter geometry and applied shielding schemes were the major reasons for each case not showing the same reduction in fatalities.

LIMITED DECONTAMINATION

Limited decontamination is the removal of fallout from a major source of radiation i.e., a roof, a parking lot, a street, etc. For this analysis, decontamination of the roofs of the two shelter buildings was investigated. The basic assumptions used for this analysis are as follows:

- General - Firehosing the roof was the decontamination method used.
- General - The firehosing technique would remove 90 percent of the contamination from the roof of the shelter buildings being studied.
- General - The crews that would perform the decontamination would be rotated sufficiently so that no one person would pick up a lethal dose.
- General - The doses that the decontamination crews would receive was taken into account in calculating the final reduction in fatalities for all the shelter occupants.
- General - The reduction in dose achieved by the countermeasure was not assumed to become effective until the decontamination operation was completed.
- Technical feasibility - The decontamination operation was assumed to start immediately following the cessation of fallout with a seven-man crew that could decontaminate 10,000 sq ft/hr.
- Operational practicality - Due to a possible disruption in the water supply, different times of starting the decontamination operation were investigated.

Post Office Shelter - Scenario A

The protection of the first-floor post office refuge is increased by a factor of 1.5 ("CF" = 30) by decontamination of the roof.

Technical Feasibility

Figure A-4a shows that decontamination initiated immediately after fallout cessation would reduce fatalities by 25 percent at the 1/2-hr time of arrival (from 50 percent to 25 percent) and would reduce fatalities by 31 percent for the 2- to 4-hr times of arrival.

Operational Practicality

Decontamination of the post office roof starting at four different times was investigated for the operational practicality evaluation. Figure A-4a shows the results for these decontamination operations beginning at 8, 16, 24, and 48 hr. The 24- and 48-hr decontamination operations show little difference and provide a reduction in fatalities of only 2 to 7 percent for the 1/2- through 4-hr times of arrival because the shelterees would already have received most of the dose.

High School Shelter - Scenario B

Decontamination of the high school shelter's roof would affect the two refuges on the first and second floor differently. The protection on the first floor would only increase by a factor of 1.3 ("CF" 39), however, the protection on the second floor would increase by a factor of 2.2 ("CF" 67). This is caused once again by shelter geometry, since the major radiation contribution to the second-floor refuge is from the roof.

Technical Feasibility

As Fig. A-4b indicates, decontamination performed immediately following fallout cessation decreased the fatalities on the second floor at the 1/2-hr time of arrival by 32 percent (from 50 to 18 percent) and by as much as 40 percent for the 4-hr time of arrival. The effect on the first floor however is quite different, i.e., the reduction in fatalities is only 18 percent for the 1/2-hr time of arrival and 21 percent for the 4-hr time of arrival.

Operational Practicality

Three initiation times were evaluated for the decontamination of the high school shelter's roof. The results of beginning decontamination operations at these times are shown in Fig. A-4b.

For the second-floor refuge, the 24-hr initiation time for decontamination reduces fatalities approximately 13 percent for the 1/2-hr time of arrival and produces a 25-percent reduction in fatalities for the 4-hr time of arrival. Limited decontamination is much less effective on the first floor. For the same 24-hr initiation time the reduction in fatalities is only 5 percent at the 1/2-hr time of arrival and increases to 12 percent for the 4-hr time of arrival.

Comparison of Results

The results for the decontamination analysis of the two shelter buildings correlated with each other. For both shelter buildings the technical feasibility

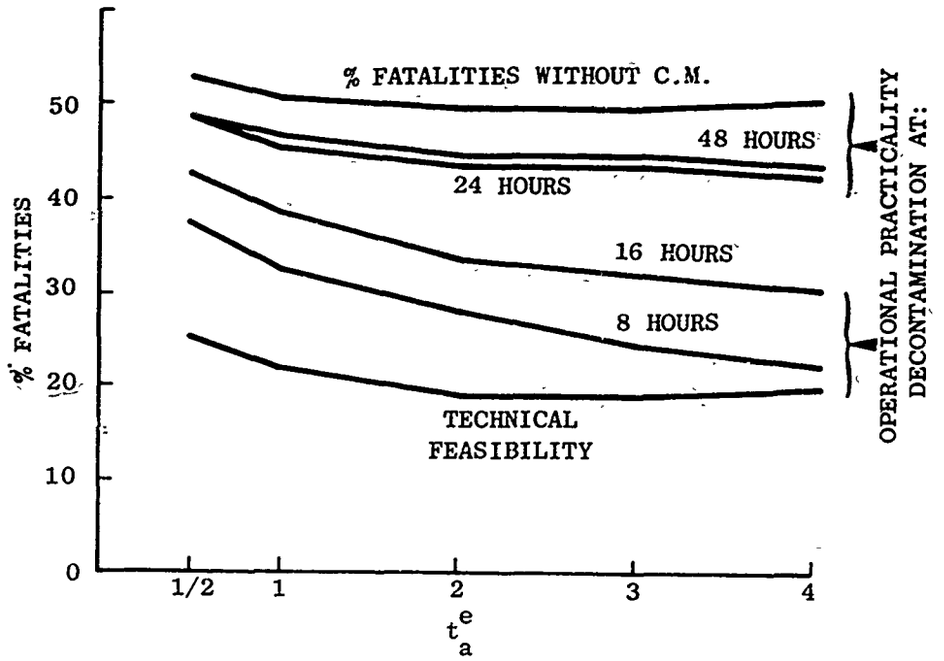

Fig. A-4a. Limited Decontamination – Post Office

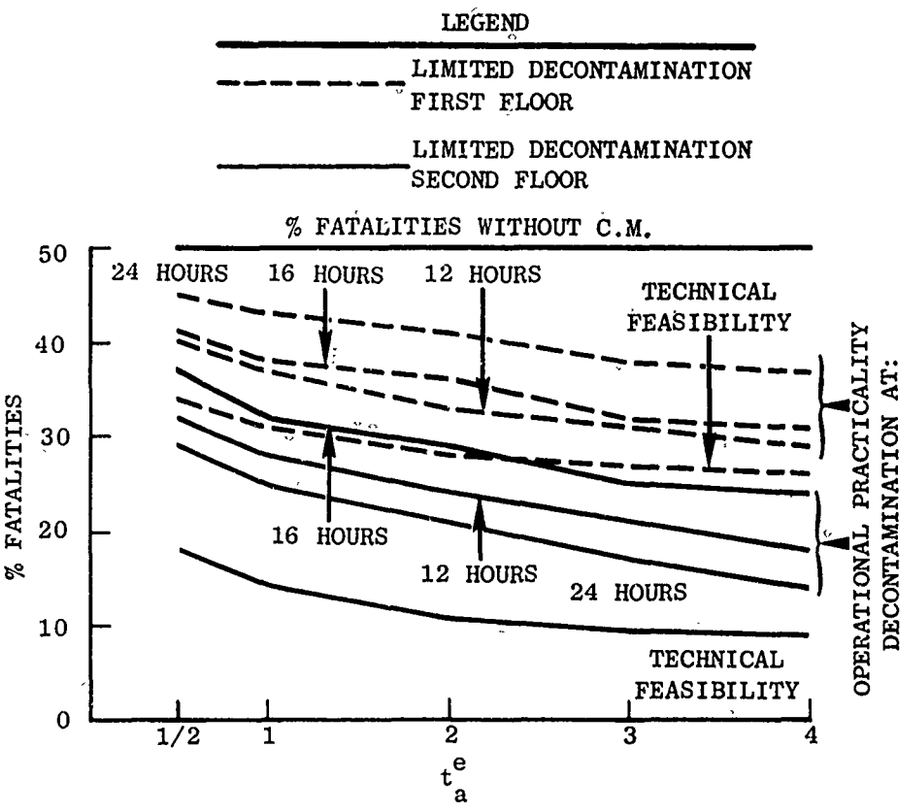

Fig. A-4b. Limited Decontamination – High School

of limited decontamination appeared attractive; however, under the operational practicality limitation, limited decontamination loses quite a bit of its effectiveness. The only instance where it appeared to give a reasonable payoff was the case of the second-floor refuge in the high school.

Both cases studied demonstrated that the operational practicality of decontamination decreases markedly as the initiation of the decontamination operation is delayed. However, by initiating limited decontamination immediately following fallout cessation, overexposure of at least some of the crew members might be difficult to avoid; further the necessary utilities would most likely not be available.

An example of an area which would be reasonably easy to decontaminate and which might appear effective for reducing the dose to shelterees was the parking lot behind the post office. Decontamination of the parking lot removed 90 percent of the fallout but was found to improve the "CF" of the post office by a 1.1 factor or about 10 percent. This example illustrates the importance of examining the technical feasibility of an operation prior to determining the operational practicality.

OVERCROWDING

Overcrowding or temporarily reduced shelter allocation* (Ref. 11) is the temporary placement of occupants of a high-dose-rate shelter or refuge in a filled (at 10 sq ft/person) low-dose-rate shelter. Overcrowding allows the occupants of the high-dose-rate shelter or refuge to receive additional protection during the high-intensity-fallout period, thus reducing their total dose. The main constraint associated with this countermeasure would be the

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* Although overcrowding and group shielding share certain characteristics, e.g., the floor space allotted to each occupant is reduced, these two ECC's are differentiated in this study. Overcrowding is concerned with moving persons into the best available shelter but does not consider their subsequent action (that is, they can stand, sit, or lie). Group shielding does not specify any criteria for the shelter but does designate a strict regime for the occupants, i.e., they must stand in a compact group to make the best utilization of the mutual shielding afforded by the body's mass.

overheating of the shelter's environment by the closely packed occupants. The basic assumptions made for the overcrowding analysis are as follows:

- Technical feasibility - Movement from the high-dose-rate shelter would start at the time of fallout arrival; overcrowding in the low-dose-rate shelter would begin at 1/2 hr after fallout arrival and continue for 12 hr. 12 hr.*
- Operational practicality - The period of time before the countermeasure would become effective for the low-PF shelter occupants was lengthened to 1 hr. The duration of overcrowding was reduced to 8 hr.

Post Office Shelter - Scenario A

The overcrowding countermeasure would commence with the 1,500 occupants of the first-floor refuge joining the 1,500 occupants of the basement shelter (PF 85) in the post office.

Technical Feasibility

Figure A-5a illustrates the technical feasibility of overcrowding in the post office shelter; the decrease in percent fatalities ranges from 45 percent for early times of arrival (from 50 percent down to 5 percent) to 43 percent for the 4-hr time of arrival.

Operational Practicality

The operational practicality of the countermeasure, as shown in Fig. A-5a, indicates a reduction in percent fatalities of 28 percent for the 1/2-hr time of arrival, 36-percent reduction for the 2-hr time of arrival, and slightly less for the 3- and 4-hr time of arrival.

High School Shelter - Scenario B

The overcrowding countermeasure would be instituted in the high school shelter with the occupants of the first-floor and second-floor refuges moving into the basement shelter, which offers a PF of 120.

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* Based on the overheating formulas given in Ref. 12. For both shelter buildings, the minimum time before the effective temperature would increase beyond 90°F would be 12 hr.

Technical Feasibility

Figure A-5b shows that for the technical feasibility of the countermeasure, fatalities are reduced 47 percent for the early times of arrival (from 50 percent down to 3 percent). For later times of arrival, a 44-percent reduction is shown.

Operational Practicality

The operational practicality of overcrowding, as indicated in Fig. A-5b, shows that for the 1/2-hr time of arrival a reduction in fatalities of 37 percent is realized. For the later times of arrival this increases to 41 percent.

Comparison of Results

The technical feasibility and operational practicality curves of the overcrowding countermeasure were similar in shape for the two shelter buildings studied. The difference in reduction of fatalities in each of the two buildings derived from the higher protection of the high school basement shelter.

REMEDIAL MOVEMENT

Remedial movement is the movement of people from a threatened or hazardous shelter through a potentially hazardous environment to a safer location. Because remedial movement involves operations external to the shelter/refuge building, a somewhat different approach from that used previously was taken for the analysis of this countermeasure. Two separate cases were studied. The first case investigated the percentage of fatalities of a group of shelter occupants versus the distance that they would have to move. The second case analyzed the effect of fallout time of arrival on percentage of fatalities of a group of shelter occupants for remedial movement to several specified shelters. For both cases, different scenarios were used to describe the environment in which remedial movement would occur.

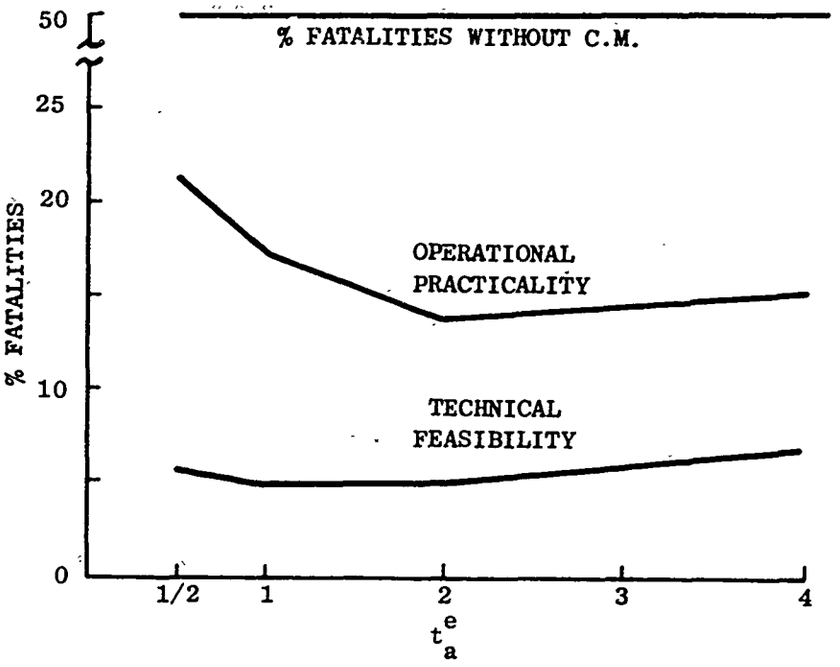


Fig. A-5a. Post Office Overcrowding.

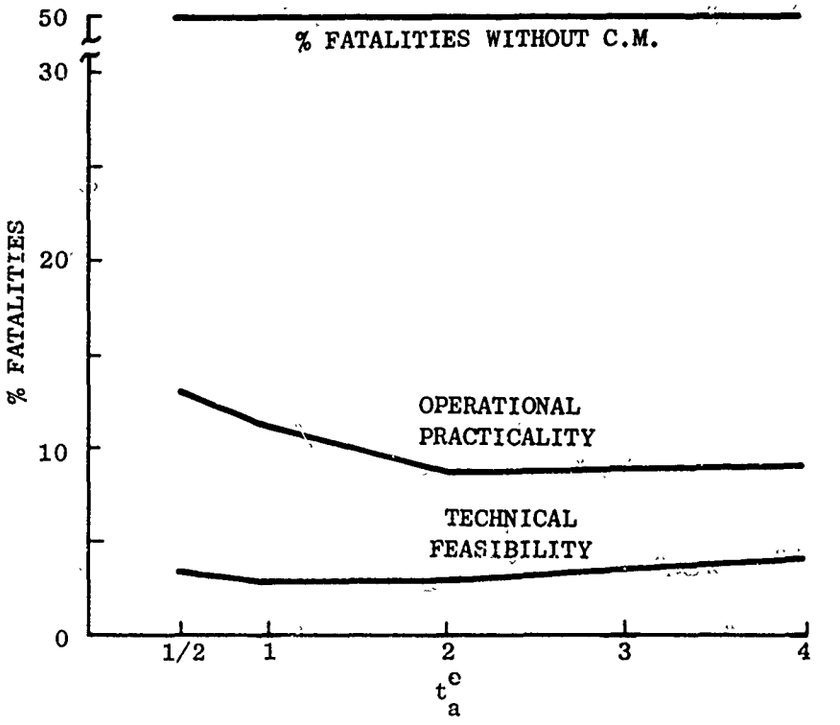


Fig. A-5b. High School Overcrowding.

- The use of the concept of setting the "no-countermeasure" dose equal to the LD-50 has no validity for studies of remedial movement since it is assumed that hazards or threats other than fallout necessitate the movement. The dose rates used in the evaluation were selected arbitrarily to give very low doses in the case-study shelters, but relatively high doses (i.e., 8,300 to 11,000 R 3-day dose) outside the structures.

The basic assumptions that were used for the remedial movement analysis are as follows:

- General - All the secondary shelters (i.e., those shelters that were the destinations of endangered moving shelterees) have a PF of at least 100.
- Technical feasibility - All remedial movement of shelter occupants would be by walking and would be at a maximum speed of 3 mph.
- Operational practicality - All movement speeds were reduced to less than 3 mph to account for traveling at night and other possible difficulties.
- General - During the course of the remedial move the group would have an average CF of 1.5.

Case 1 - Commercial Building Shelter

The commercial building shelter (described in Section 3) was used as the endangered shelter in order to evaluate the reduction of fatalities versus the distance that shelter occupants would have to move.

The scenario used for this case is:

> The thermal pulse from the nuclear weapon exploding over the southern part of the bay at 10 p.m. causes several initial ignitions in the upper stories of the commercial building. Effective fallout arrival (t_a^e) is 1/2-hr with an I_o of 3,100 R/hr.

Six shelters, which were located from 0.13 to 3.8 miles from the commercial building shelter, were chosen as secondary shelter locations to which the shelter occupants of the commercial building shelter would move. Assumptions made for this case are: it would take 1/2 hr from the time of detonation for the shelter occupants to realize that the upper stories of their shelter building were on fire and that if no action were taken all 500 occupants of the basement shelter would perish.

Technical Feasibility

For the technical feasibility case, the shelter occupants would try to contain the fire for 1 hr before realizing that it was hopeless. Remedial movement would then commence. Figure A-6a shows that for the technical feasibility of remedial movement, the shelter occupants could move up to 1/2 mile before fatal doses would begin to occur. Fatal exposure, however, increase sharply after 1 mile and reach 90 percent at a distance of 4 miles.

Operational Practicality

The operational practicality of remedial movement, as illustrated in Fig. A-6a, indicates that for this case, movement of the shelter occupants up to 4/10 mile results in few casualties. However, after this point the fatal doses increase very sharply to 100 percent at a 1-3/4 mile distance. The difference between the technical feasibility and operational practicality cases is due to the slower movement speed assumed for operational practicality and indicates the importance of a fast, well-planned move.

Case 2 - High School Shelter

The second remedial movement analysis investigated the influence of fallout times of arrival on percentage of fatalities for specified movement distances. The basement shelter of the high school (PF 120) with 1,000 occupants was used for this investigation. Two secondary shelters were chosen: shelter number 1, located 1 mile from the high school shelter, and shelter number 2, located 1-3/4 miles from the high school shelter.

Dose rate and arrival times were selected to give a 3-day dose in the shelter of about 70 R. The standard intensities therefore varied from 2,300 R/hr to 4,800 R/hr. The specific values used are given in Appendix B.

Although the fallout levels themselves would offer no threat to the occupants of the high school basement shelter, for the purposes of this study it was assumed that 2 hours following fallout arrival the occupants would be forced to move either by the danger of an advancing fire front, or by some internal threat.

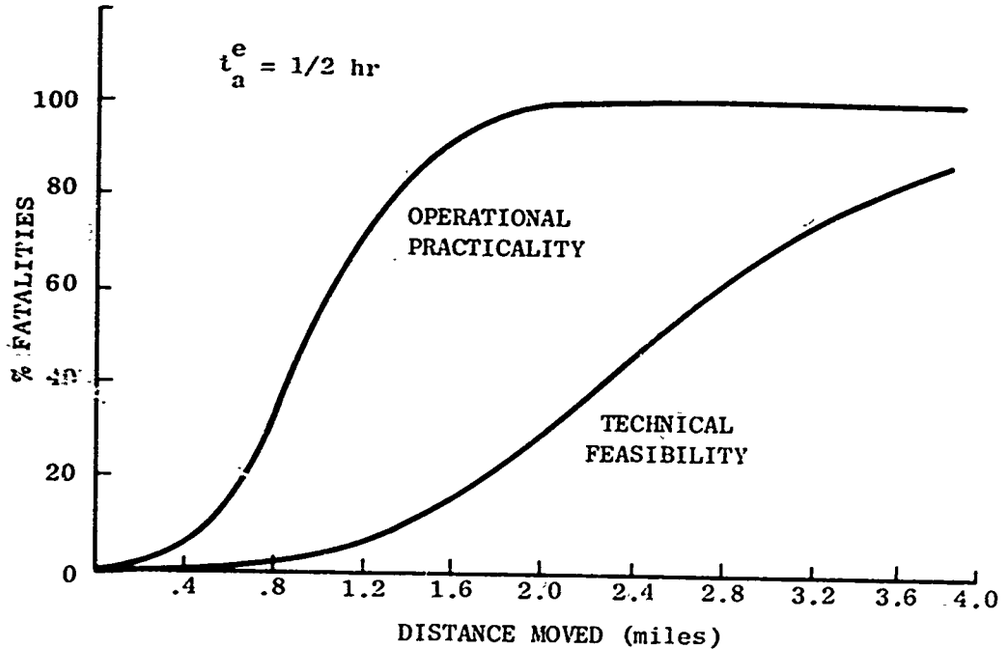


Fig. A-6a. Commercial Building Shelter – Remedial Movement.

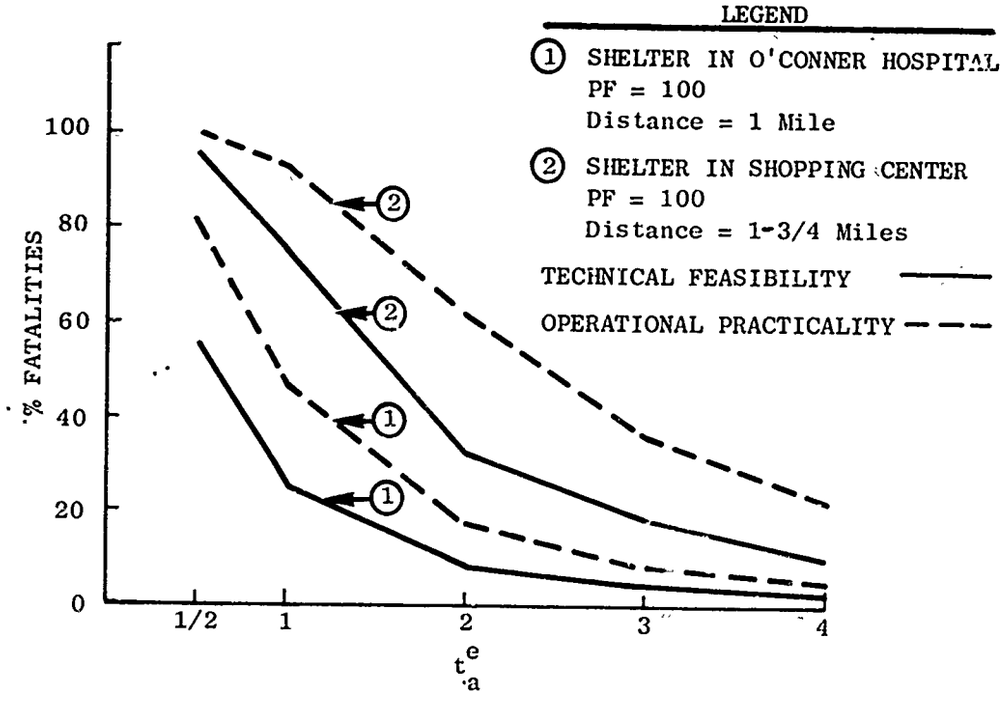


Fig. A-6b. High School Shelter – Remedial Movement.

Technical Feasibility

Figure A-6b shows that for the technical feasibility of remedial movement, the high school shelter occupants moving to shelter location number 1 would suffer 58 percent fatalities (from the radiation field) at the 1/2-hr time of fallout arrival and suffer approximately 4 percent fatalities for the 4-hr time of arrival. The movement to the more distant shelter, shelter number 2, would cause 96-percent fatalities at the 1/2-hr time of fallout arrival, decreasing to only 12-percent fatalities for the 4-hr time of arrival. The two curves indicate that remedial movement should be delayed as long as feasible from the radiological standpoint. From a realistic standpoint, the later one waits, the greater the risk that fire will prevent movement.

Operational Practicality

The operational practicality of remedial movement from the high school basement shelter to sheltered location number 1 produces 80 percent casualties at the 1/2-hr time of arrival but drops to only a 5-percent fatality level at the 4-hr time of arrival. Remedial movement to the more distant shelter location number 2 would cause 100 percent fatalities at the 1/2-hr time of arrival and 26 percent fatalities for the 4-hr time of arrival.

COMBINATION OF EXPOSURE CONTROL COUNTERMEASURES

The six exposure control countermeasures analyzed and discussed in the previous section have all shown some degree of lifesaving capability. However, all of them were evaluated as individual countermeasures, although there are no major constraints that would prevent joint use in any one case. Therefore, this section will analyze how effective these exposure control countermeasures could be if used jointly. Two of the countermeasures, remedial movement and limited decontamination, were not used for this joint analysis. Limited decontamination under the operational practicality assumptions relies heavily on the capability of the municipal water system to supply water to the shelter building being decontaminated, and if this water is not available within the first day or two the countermeasure is the least effective of the six investigated.

Remedial movement was investigated as a special case and used different scenarios employing threats other than radiation to force the shelter occupants into remedial movement. Since these outside threats were not present in the scenarios used in the combined ECC analysis, it was felt that remedial movement should stand by itself as a separate and distinct countermeasure.

The high school shelter was chosen for the analysis of the effectiveness of the various combinations of exposure control countermeasures because a greater flexibility for demonstration of the ECC's was available with the one shelter in the basement and two refuges on the first and second floor. Scenario B, cited in Table 3, was used to describe the environmental conditions.

Four combinations of the exposure control countermeasures were used for this evaluation. These combinations are listed in Table A-1.

Two shelter/refuge postures were studied; the first one, involving ECC Combinations 1 and 2, used the basement shelter and the first- and second-floor refuges to provide an analysis of the interaction between a refuge and a shelter located in the same building. The second posture, involving ECC Combinations 3 and 4, used only the first- and second-floor refuges of the high school. This limit was imposed to allow evaluation of ECC combinations in a building where only refuge(s) would be available to the occupants and no shelter would be located on the premises.

Posture 1

In the individual ECC analysis, certain countermeasures provided a higher payoff at earlier times than other countermeasures (e.g., overcrowding versus applied shielding). Therefore, posture 1 which includes ECC Combinations 1 and 2 (Table A-1), will use the optimum time phasing of the ECC's (e.g., those with an early high payoff would be used first for early arrival times). As this optimum time phasing changes with fallout arrival time, which assumes that the occupants of the shelter have some knowledge of the time of arrival of fallout, the sequence in which the countermeasures would be used will be changed for the later arrival times (3 and 4 hr). The basic assumptions used for the investigation of posture 1 are as follows:

Table A-1

SCOPE OF CASE STUDIES OF ECC COMBINATION
IN HIGH SCHOOL SHELTER

ECC Combination	Floor	PF or CF	Total No. of People Involved
1. Group shielding, overcrowding applied shielding, shelter rotation	Basement	120	1000
	1st	30	1000
	2nd	30	1000
			3000
2. Overcrowding, group shielding, applied shielding	Basement	120	
	1st	30	1000
	2nd	30	1000
			2000
3. Group shielding, applied shielding	1st	30	1000
	2nd	30	1000
			2000
4. Group shielding, applied shielding, overcrowding	1st	30	1000
	2nd	30	1000
			2000

- By combining the different exposure control countermeasures, each countermeasure's individual countermeasure factor that was found in the individual analysis would be multiplicative, e.g., with applied shielding in place on the second-floor refuge, an increase in "CF" from 30 to 35 is obtained; therefore, if a group shielding operation is then conducted, the countermeasure factor of 1.33 is multiplied by the "CF" of 35, giving a final "CF" of 46.

- Shelter rotation and overcrowding would be used in the basement shelter of the building while the other countermeasures would be initiated on the respective refuge floors.

- The percentage of fatalities are for the entire building, not the individual cases on each floor.

- The technical feasibility and operational practicality assumptions used with each individual countermeasure in the previous section are also applicable to the combination of ECC's.

ECC Combination 1

Combination 1 would be implemented by the 3,000 people in the shelter by using the following countermeasures: group shielding, overcrowding, applied shielding, and shelter rotation. For the early times of arrival (1/2, 1, and 2 hr) the ECC's would be initiated in the following order; overcrowding, group shielding and shelter rotation simultaneously, and finally applied shielding. For the later times of arrival (3 and 4 hr) applied shielding is instituted first, followed by overcrowding and then group shielding and shelter rotation simultaneously.

Technical Feasibility

Time Diagram 1 indicates the time intervals for each exposure control countermeasure used in the technical feasibility evaluation of Combination 1. This diagram shows that 1/2 hr after fallout arrival overcrowding would commence and continue for 12 hr, followed by group shielding lasting for 8 hr, during which time shelter rotation would also begin, and finally applied shielding would be emplaced.

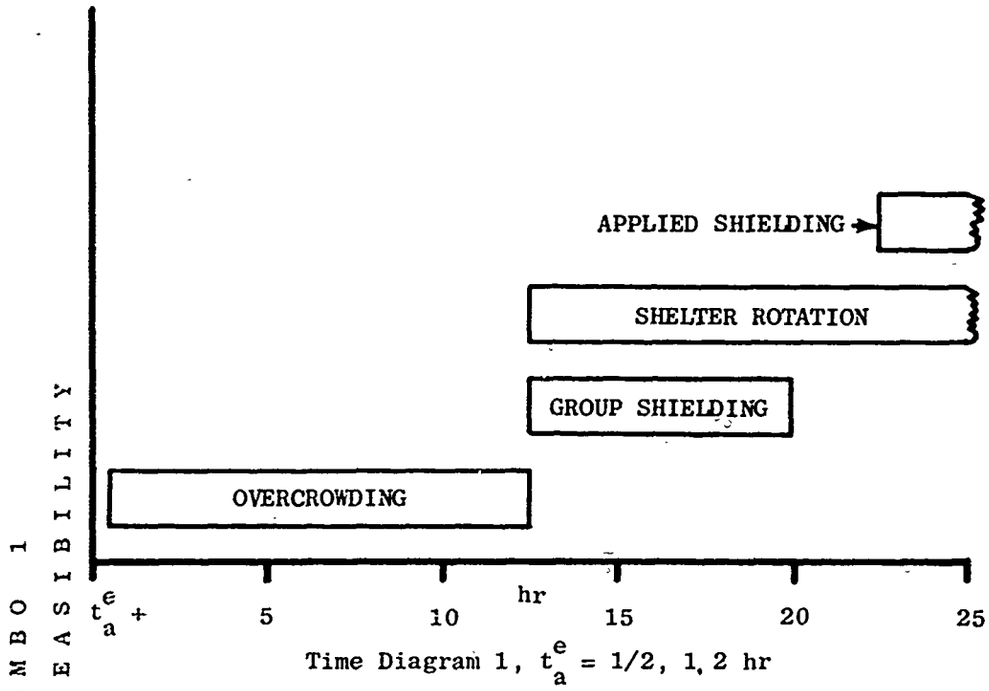
Time Diagram 2 shows the time phasing of the ECC's for the later (3 and 4 hr) times of arrival. This diagram shows that applied shielding would be initiated 1/2 hr after the attack commenced; overcrowding would then begin 1/2 hr after fallout arrival lasting for 12 hr and followed by group shielding and shelter rotation. The group shielding would last 8 hr. Figure A-7a shows that for technical feasibility, ECC Combination 1 reduces the fatalities among the shelter occupants 48 percent (from 50 percent fatalities to 2 percent fatalities) for all times of arrival.

Operational Practicality

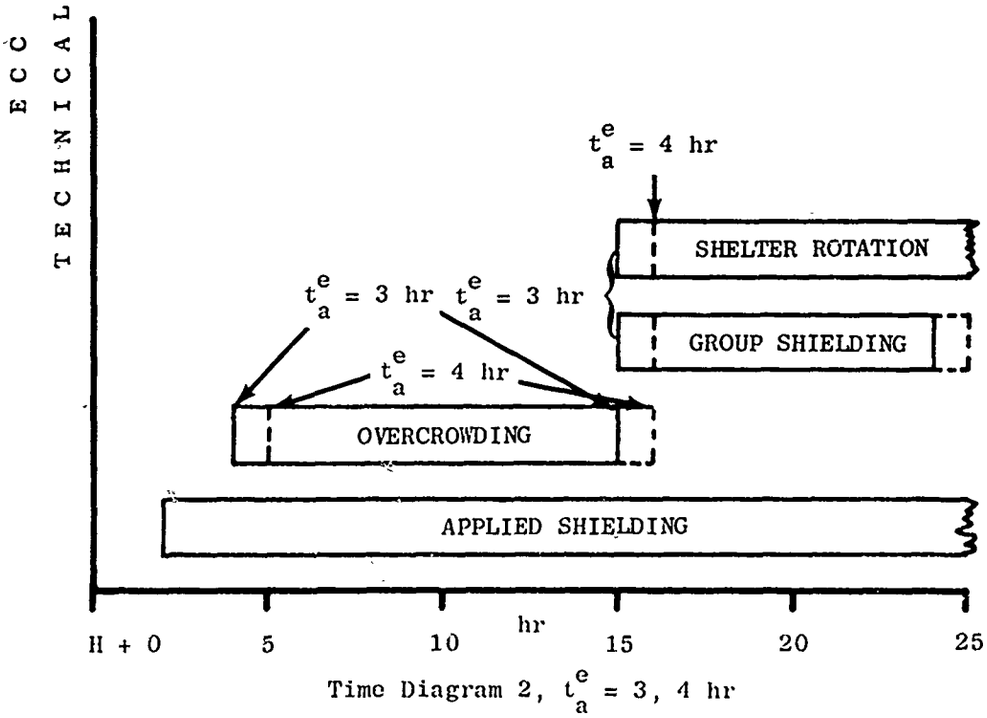
Time Diagram 3 indicates the time-phasing intervals for the operational practicality of ECC combination 1 for the 1/2-, 1-, and 2-hr fallout arrival times. Time diagram 4 depicts the time-phasing intervals for the later arrival times (3 and 4hr). The sequencing of the ECC's for the operational practicality case is similar to that of a technical feasibility case, with the major difference being the operational practicality assumptions used in the previous section for each individual countermeasure have been included in the diagram. The operational practicality of ECC Combination 1, as shown in Fig. A-7a, achieves a reduction in fatalities of from 44 to 47 percent for the various times of arrival. The sharp peak in the curve at the 3-hr time of arrival indicates that the sequencing of the ECC's for that time of arrival is not optimum (it was optimum for the technical feasibility case).

ECC Combination 2

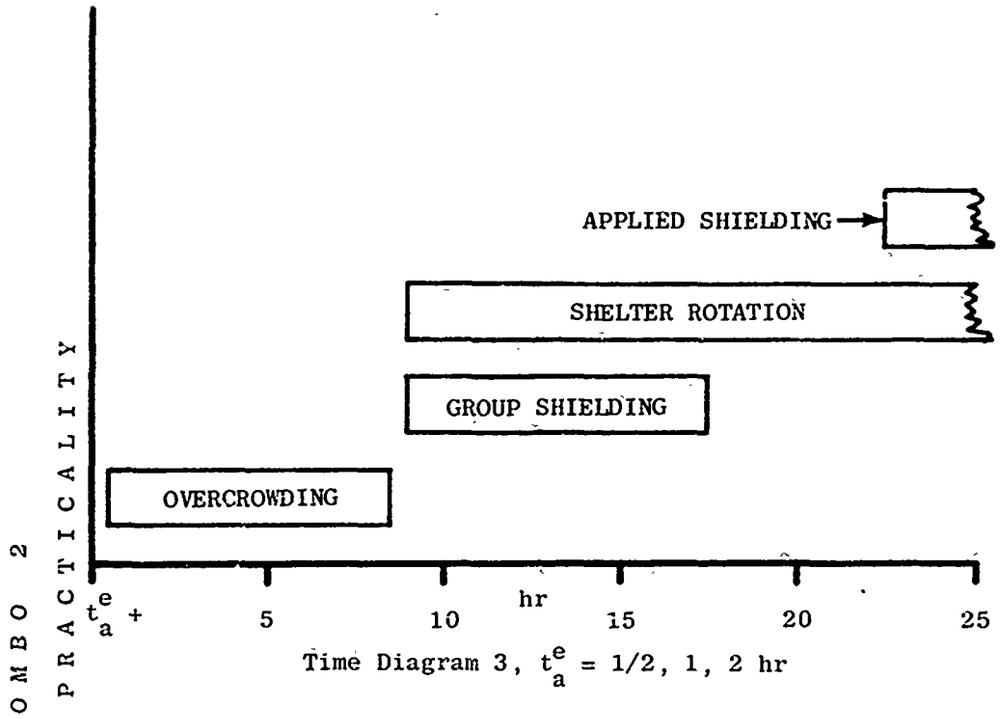
ECC Combination 2 (group shielding, applied shielding and overcrowding) is the same as ECC Combination 1 with one difference: Shelter rotation has been deleted as one of the countermeasures that is used. Shelter rotation was deleted because it requires a detailed knowledge of radiological calculations in order to equalize the dose to all of the groups participating; the three other countermeasures require only a rudimentary knowledge of radiation characteristics and can therefore be more easily implemented.



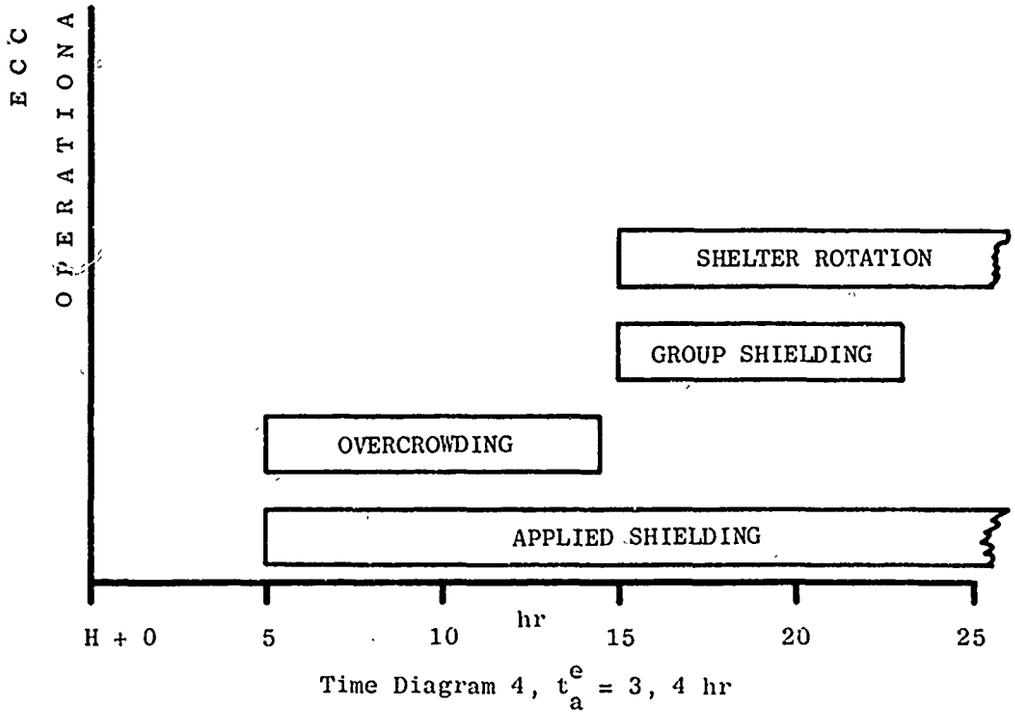
Time Diagram 1, t_a^e = 1/2, 1, 2 hr



Time Diagram 2, t_a^e = 3, 4 hr



Time Diagram 3, t_a^e = 1/2, 1, 2 hr



Time Diagram 4, t_a^e = 3, 4 hr

Technical Feasibility

The time phasing of ECC Combination 2 is the same as the scheme indicated on Time Diagrams 1 and 2 with the exception of shelter rotation. Figure A-7b shows the technical feasibility of ECC Combination 2. A reduction in fatalities of 48 percent is achieved (from 50 to 2 percent) for the different arrival times.

Operational Practicality

Time Diagrams 3 and 4 illustrate the time phasing of ECC Combination 2 with the deletion of shelter rotation. Figure A-7b shows that the reduction in fatalities ranges from 38 percent with a 1/2-hr time of arrival up to 43 percent for a 2- and 4-hr times of arrival. Once again the peak at the 3-hr time of arrival indicates that the initial sequencing of the earlier arrival times would have been more applicable for the 3-hr arrival time.

Comparison of Results

The difference in the capability to reduce fatalities between ECC Combination 1 and ECC Combination 2 is approximately a factor of two, which is caused by the deletion of shelter rotation from the second combination. Both countermeasure combinations displayed a definite capability to reduce fatalities in the situation standard.

Posture 2

In Posture 2 the interaction of selected exposure control countermeasures in the first and second floors of the high school refuge shelter was studied. ECC Combinations 3 and 4, as cited in Table A-1, were used in this analysis. In order to determine the optimum sequencing of the countermeasures, each of the combinations in this posture will be considered in two different time-phasing schemes. The assumptions used for this posture are the same as those given for Posture 1.

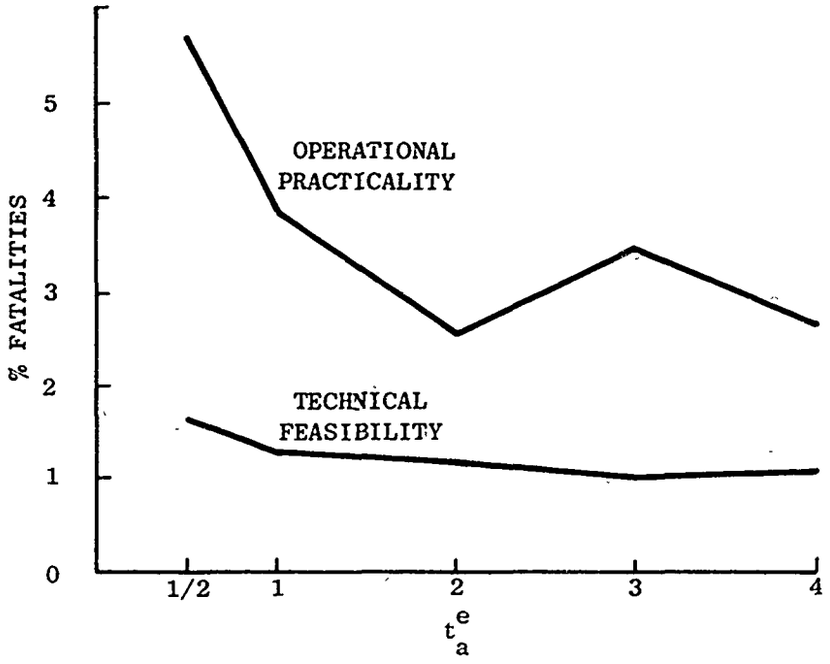


Fig. A-7a. ECC Combination No. 1 — Group Shielding, Overcrowding, Applied Shielding, Shelter Rotation

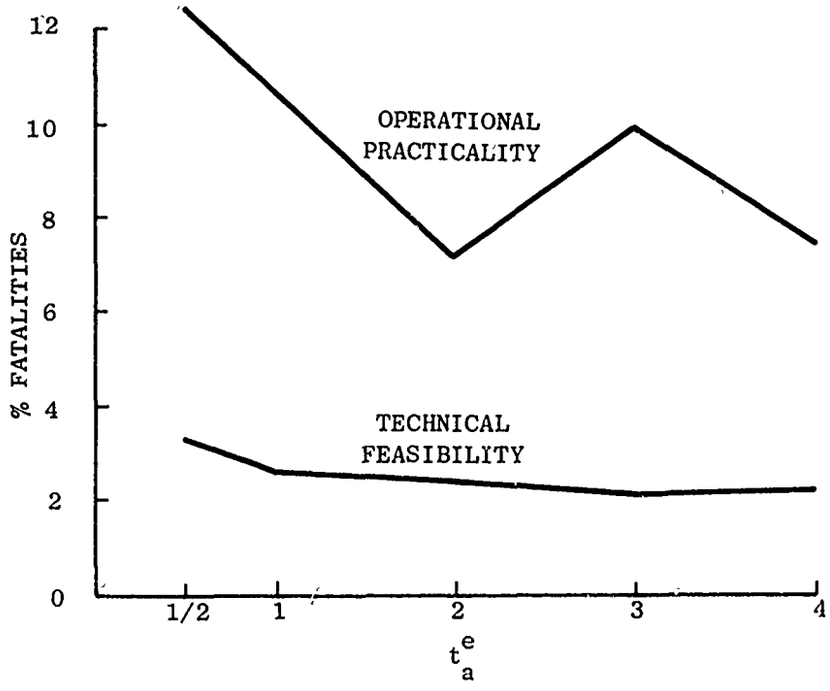


Fig. A-7b. ECC Combination No. 2 — Overcrowding, Group Shielding, Applied Shielding

ECC Combination 3

This combination employs the group shielding and applied shielding countermeasures on each floor of the refuge. Under Scheme 1 time phasing group shielding is initiated first and continued for 8 hr followed by the implementation of applied shielding, whereas Scheme 2 reverses the scheduling and initiates applied shielding 1/2 hr after the attack commences, followed by group shielding instituted immediately following the completion of the applied shielding or, for the 3- and 4-hr arrival time cases, 1/2 hr after the arrival of fallout.

Technical Feasibility

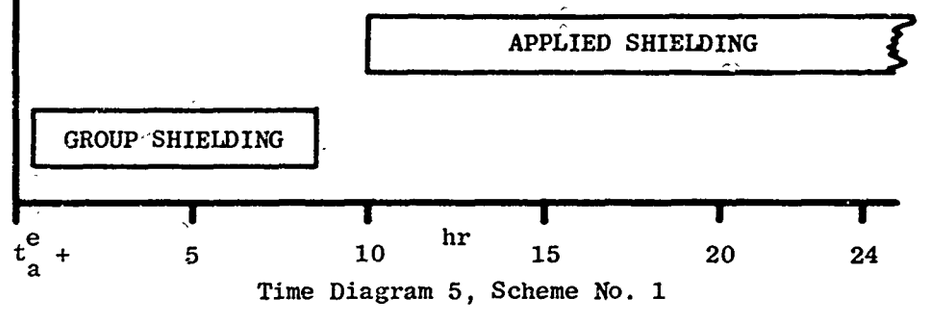
The time phasing for the technical feasibility of ECC Combination 3, Schemes 1 and 2, is given in Time Diagrams 5 and 6, respectively.

Figure A-8a illustrates the technical feasibility of ECC Combination 3, Schemes 1 and 2. Scheme 1 shows a reduction in fatalities of between 35 and 39 percent (from 10 percent to 15 percent); Scheme 2 shows a reduction in fatalities of from 30 to 40 percent for the different times of arrival. Scheme 1 is the most effective for times of arrival of 1-1/2 hr and less and Scheme 2 is most effective at the later arrival times. Scheme 1's effectiveness at early arrival time is due to group shielding being implemented initially, thus giving added protection to shelterees during the early high-intensity period. Scheme 2 is more effective at later time because the applied shielding is in place before fallout arrival and it complements the group shielding operation that follows. The analysis of these two schemes again shows the importance of countermeasure implementation time for each fallout arrival.

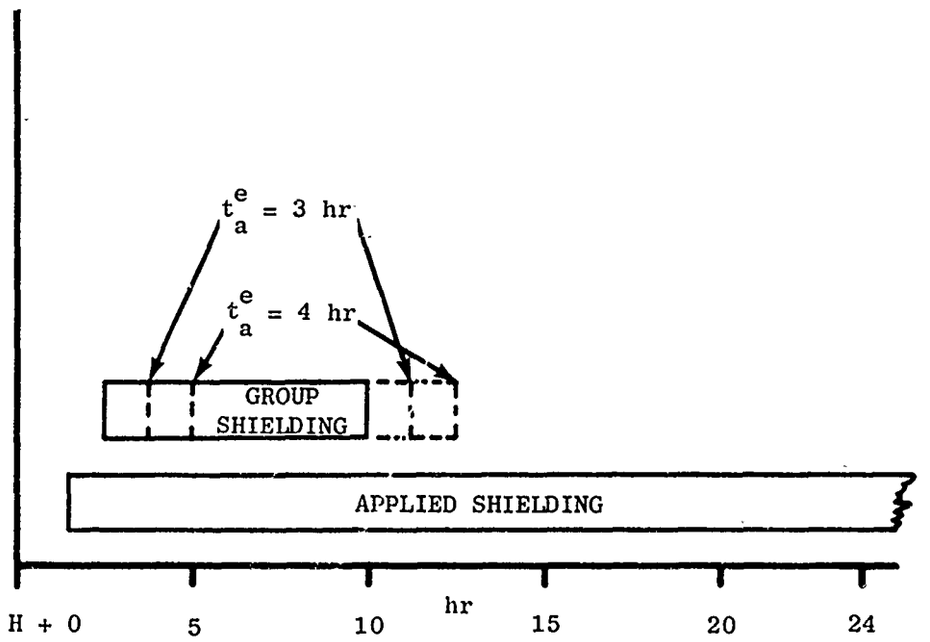
Operational Practicality

Time Diagrams 7 and 8 show the time phasing for the operational practicality of ECC Combination 3, Schemes 1 and 2, respectively; Figure A-8a illustrates the operational practicality. Scheme 1 realizes a reduction in fatalities of between

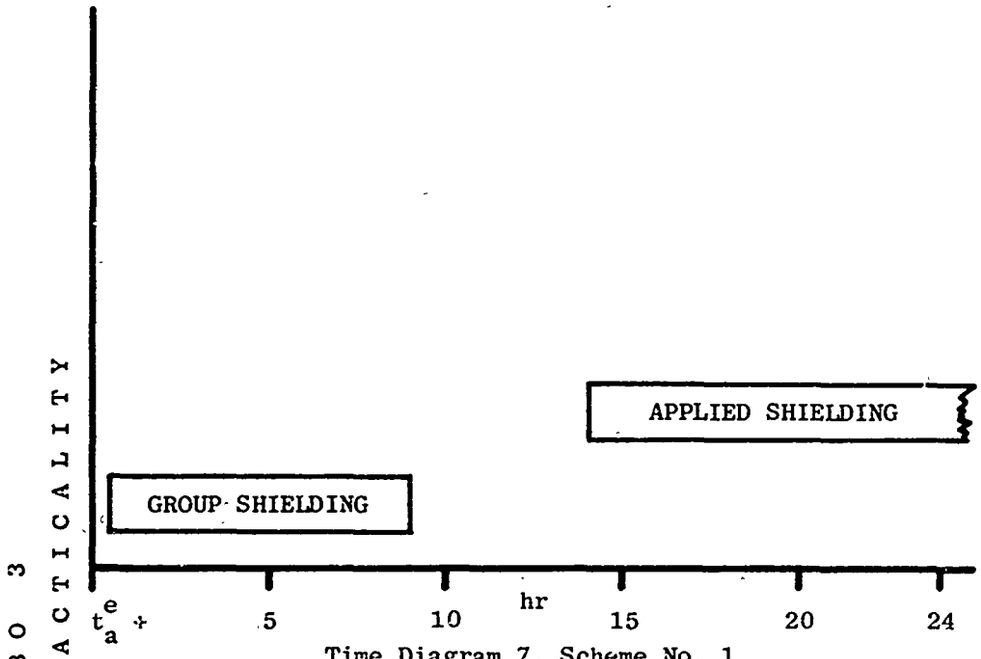
ECC COMBO 3 TECHNICAL FEASIBILITY



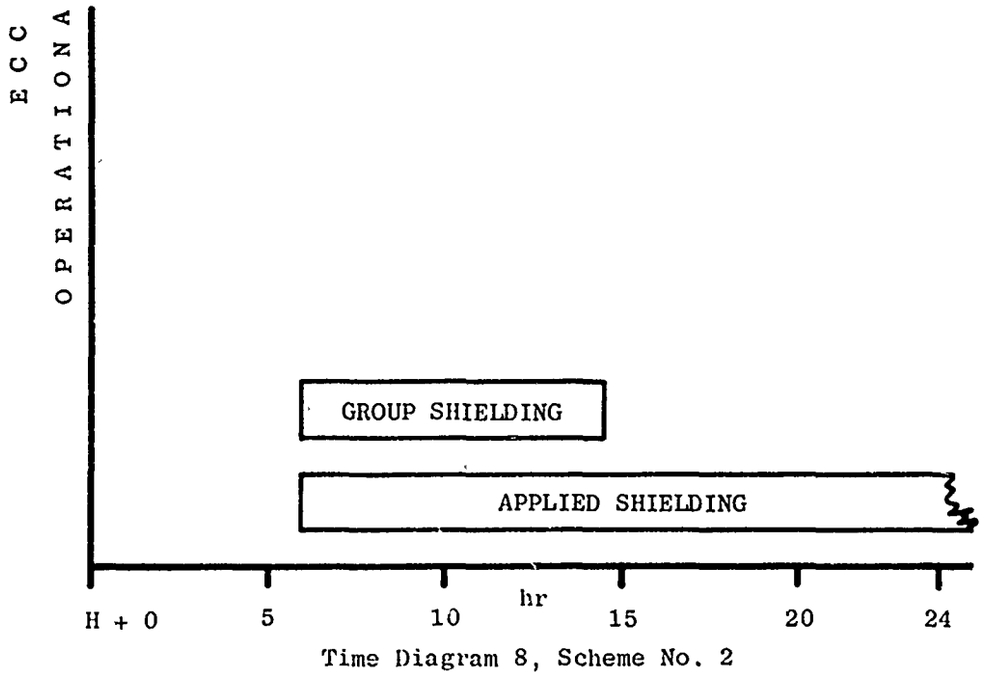
Time Diagram 5, Scheme No. 1



Time Diagram 6, Scheme No. 2



Time Diagram 7, Scheme No. 1



Time Diagram 8, Scheme No. 2

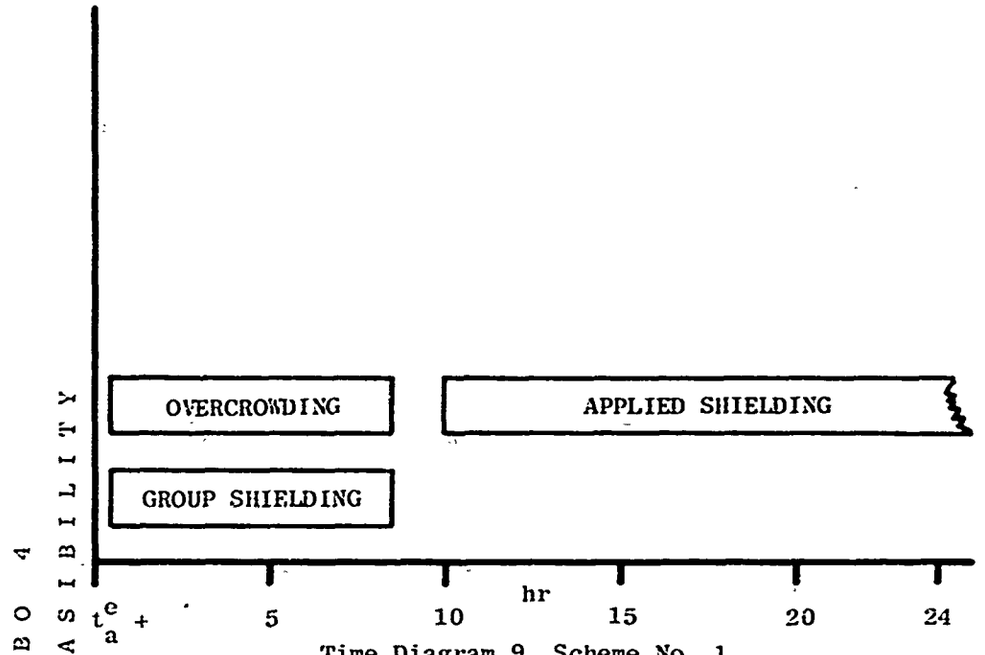
30 and 35 percent for the different times of arrival, while Scheme 2 shows a reduction in fatalities of between 20 and 35 percent for the same times of arrival. Under the operational practicality assumptions, Scheme 1 is the optimum scheme, being competitive with Scheme 2 only for the 4-hr time of arrival.

ECC Combination 4

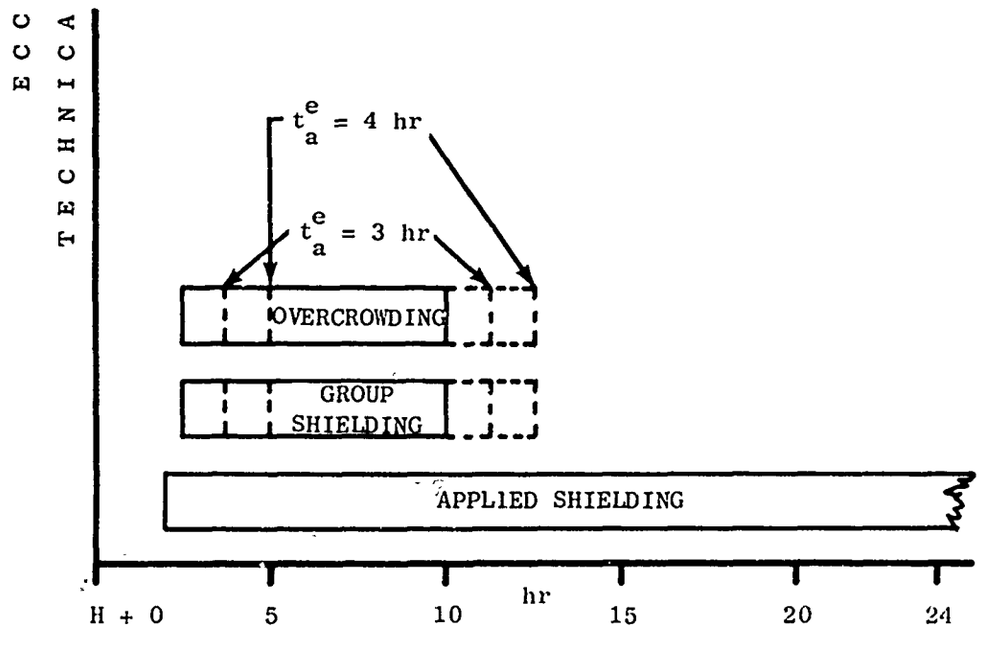
ECC Combination 4 investigates the use of group shielding, applied shielding and overcrowding in the first- and second-floor refuges of the high school. Overcrowding in this case applies only to the second-floor group, which would move downstairs to the first-floor refuge (thus overcrowding that refuge) to initiate group shielding. This manuever would allow the second-floor group to take advantage of the more advantageous geometry of the first floor for group shielding. Scheme 1 of ECC Combination 4 has both groups performing group shielding on the first floor, then installing applied shielding on both floors. (At the conclusion of the group shielding operation on the first floor, the second-floor group would return to their own floor, where they would place the applied shielding and then remain.) Scheme 2 installs applied shielding on both floors 1/2 hr after the attack occurs; upon completion of the applied shielding, or 1/2 hr following the 3- and 4-hr fallout arrival times, both groups would initiate group shielding operations on the first floor.

Technical Feasibility

The time-phased sequencing of ECC Combination 4 Schemes 1 and 2, for technical feasibility is given in Time Diagrams 9 and 10, respectively. Figure A-8b shows that for the technical feasibility of Scheme 1, fatalities are reduced approximately 43 percent (from 50 percent down to 7 percent fatalities) for all the times of arrival. Scheme 2 shows a reduction in fatalities ranging from 35 percent for the 1/2-hr time of arrival up to 45 percent for the later times of arrival. Once again, for technical feasibility, Scheme 1 proves to be the best before a 1-1/2-hr time of arrival, while Scheme 2 is more effective after this time.



Time Diagram 9, Scheme No. 1



Time Diagram 10, Scheme No. 2

Operational Practicality

Time Diagrams 11 and 12 show the scheduling for the operational practicality of ECC Combination 4, Schemes 1 and 2, respectively. The operational practicality of Scheme 1, as is shown in Fig. A-8b, reduces fatalities 36 percent for the 1/2-hr time of arrival. These increase to 42 percent for the later times of arrival. Scheme 2 proves to be much less effective, showing a reduction in fatalities of 22 percent for the 1/2-hr time of arrival but showing an increase to 40 percent for the 4-hr time of arrival. For this case, Scheme 1 is the optimum scheme for all times of arrival. Even with the later arrival time, Scheme 2, although close, is still not quite as effective.

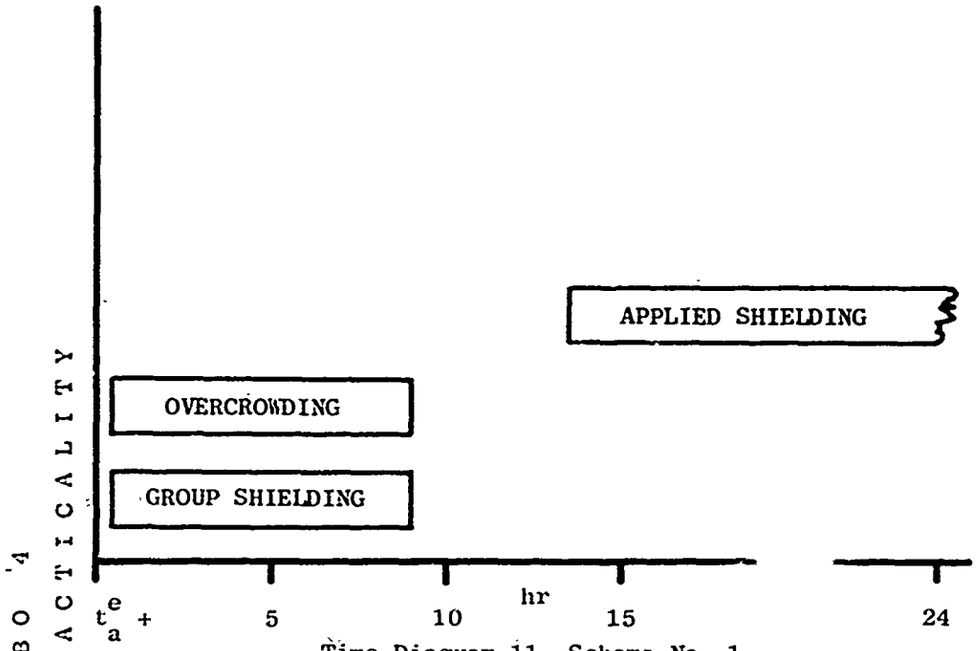
Comparison of Results

The major difference between ECC Combinations 3 and 4, was the use of overcrowding in Combination 4 to allow the second-floor occupants to benefit from the better shelter geometry that is available from their group shielding countermeasure on the first floor. This added maneuver further reduced fatalities, from an approximate 35-percent average to a 42-percent average.

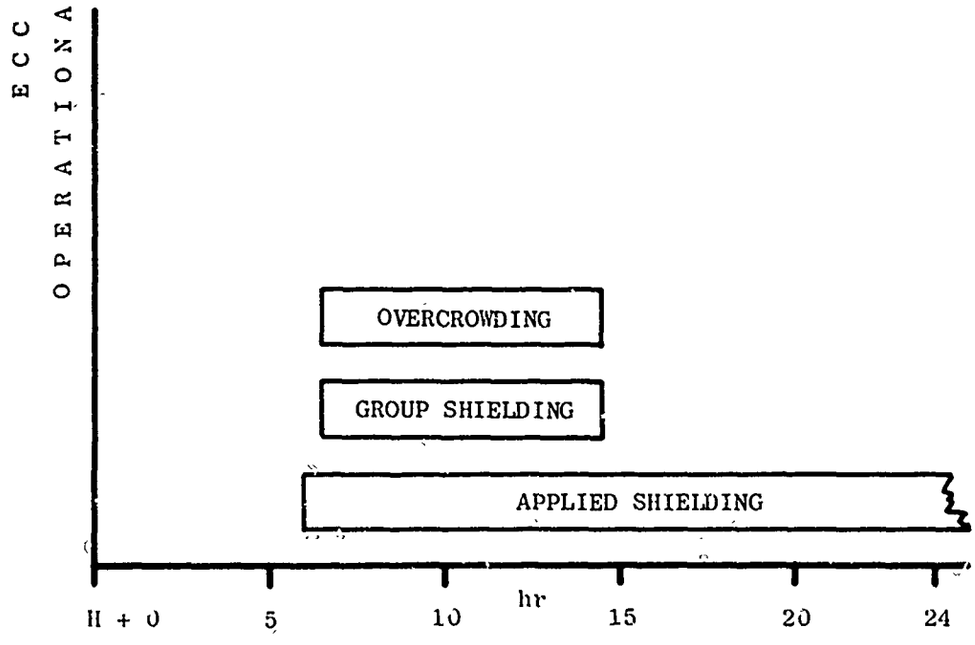
RESTORATION OF VITAL SERVICES

Following a nuclear attack most survivors in a city would hopefully be located in the various shelters and refuges scattered throughout the community. However, some services would still be required to operate at a minimum level of effort. Examples of these are: communications, water facilities, electric power, food distribution, and medical facilities. Certain exposure control countermeasures, mainly limited decontamination and applied shielding, could be used to help provide protection to personnel who would restore the operation of these vital services. This section will explore the possibilities of using these ECC's to restore two vital facilities in San Jose.

Three buildings were used in the investigation of the restoration of vital services, the shelter from which the working crews would come (the basement shelter in the post office building) and the two buildings housing



Time Diagram 11, Scheme No. 1



Time Diagram 12, Scheme No. 2

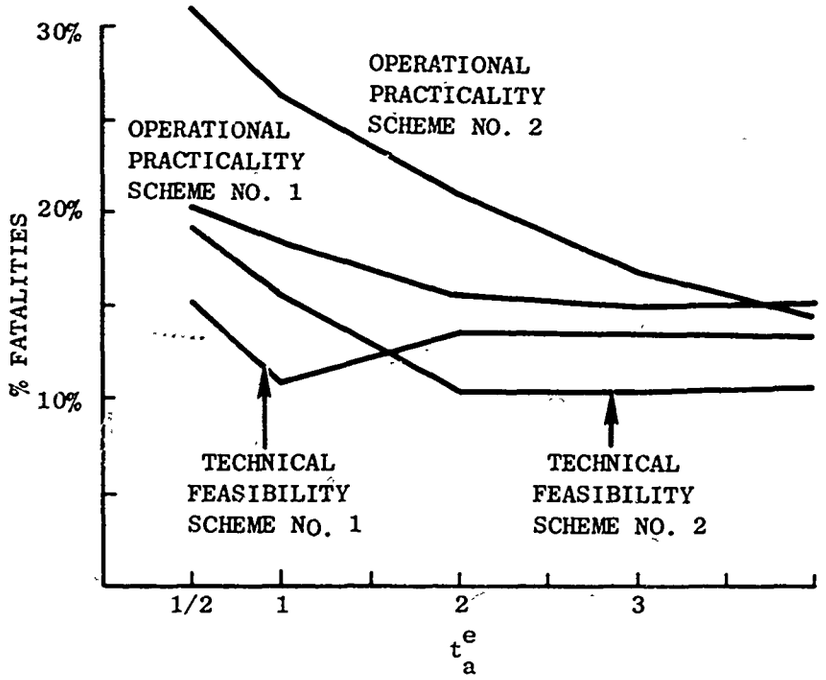


Fig. A-8a. ECC Combination No. 3 – Group Shielding, Applied Shielding.

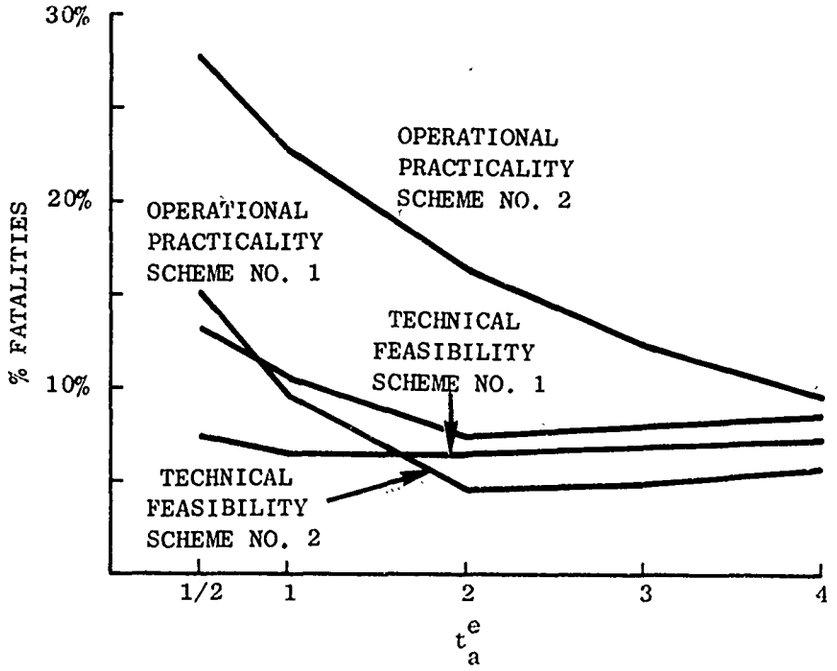


Fig. A-8b. ECC Combination No. 4 – Group Shielding, Applied Shielding, Overcrowding.

the two vital services. The first vital service was radio station KXRX, located approximately 2.4 miles from the post office shelter along highway 101 on the northeast edge of San Jose. The second vital facility was the Dole Corporation warehouse located at 5th and Virginia Street in San Jose, approximately 1.5 miles from the post office shelter. Both of these buildings were included in the study made by Research Triangle Institute (RTI) of decontaminating selected sites in San Jose (Ref. 13), and the results given in that report for these two buildings will be used for this analysis.

Since the restoration of the vital facilities considered required more than 3 days, the results for this case will be presented in terms of the resultant 1-week dose to the operators of the two facilities.* The scenario used for this investigation assumes fallout to arrive 1/2 hr after the burst with a standard intensity of 3100 R/hr. The exposure of the crews that would perform the decontamination and applied shielding countermeasures at station KXRX and the Dole warehouse was calculated and found to be within nonlethal limits if the crews returned immediately to their post office shelter and remained there for the remaining shelter stay time. The operating crews for the facilities would remain in the post office shelter until decontamination was complete. The basic assumptions used in this analysis are as follows:

- Decontamination removed 90 percent of the fallout from the contributing areas.
- Exposure scheduling would be used to keep all crew doses within prescribed limits.

Radio Station KXRX

Radio station KXRX consists of a lightly constructed studio and transmitter building (area 1,700 sq ft and an average PF of 1.7) and a small concrete storeroom located behind the major building (PF of 8). Decontamination would be performed on the roofs of the broadcasting studio and storeroom.

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* For this analysis, a modified mortality function was used, the LD-50 for a 7-day dose was arbitrarily assumed to be 600-R.

Applied shielding at 100 psf would be applied around the perimeter of both buildings from ground to roof level, leaving one opening in each building for a doorway. These exposure control countermeasures increase the "CF" in the broadcasting studio from 1.7 to 19, and the "CF" in the concrete storehouse from 8 to 55. With a four-man operating crew, each individual could spend 75 percent of his time in the concrete storehouse and 25 percent of his time in the broadcasting studio. Figure A-9 shows the dose to the operators of station KXRX versus the time that decontamination was initiated. For the 55-hr initiation time the operators would receive a dose of approximately 138 R over the 1-week period, which declines to a dose of 112 R for the 150-hr initiation time, most of which dose would have been received in the original shelter.

Dole Corporation Warehouse

The Dole Corporation warehouse is a lightly constructed single-story building with an area of approximately 118,000 sq ft. The average PF in the building is 3.0. Decontamination was the sole ECC used in this case and involved firehosing the roof of the Dole warehouse and using a street sweeper on the parking lot and streets that surround the building. The resultant "CF" would change from 3 to 20 for the loading dock area and from 8 to 24 for the interior of the warehouse. Twenty occupants of the post office shelter would serve as the operating crew at the warehouse and would spend 25 percent of their time in the loading dock area and 75 percent of their time in the interior of the warehouse. Figure A-9 shows that the operating crew in the warehouse would receive a dose of 150 R for 1 week at the 55-hr decontamination initiation time and a dose of approximately 114 R at the 150-hr initiation time.

Comparison of Results

The results from this analysis of the feasibility of restoring vital sources indicate that applied shielding and limited decontamination have a definite value in the restoration of vital services. For both cases studied the implementation of the two ECC's enabled operating crews to reside at the vital facility and perform necessary operations.

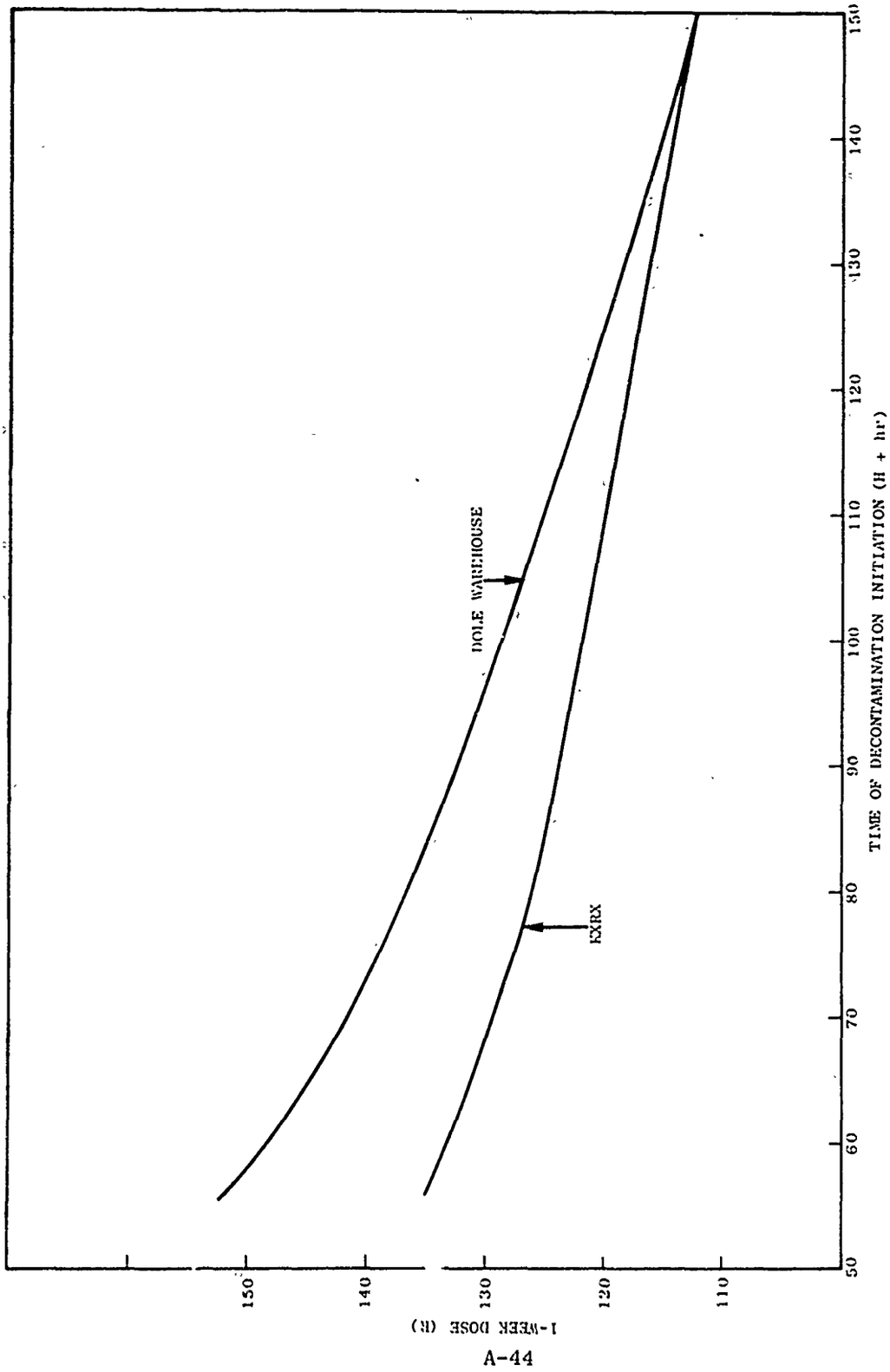

Fig. A-9. One-Week Dose for Operators of Dole Warehouse and Station KXRX (after decontamination t_a^e = 1/2 hr

Appendix B

DETAILED ASSUMPTIONS USED IN ECC ANALYSIS

This appendix presents the inputs used for the technical feasibility and operational practicality analysis of the exposure control countermeasures. All radiological calculations are based on a decay rate of $t^{-1.2}$.

POST OFFICE REFUGE AREA

Building Description:

post office plan area - 19,000 sq ft

average wall wt - 100 psf

average interior wall wt - 15 psf

average roof wt - 40 psf

average floor wt - 50 psf

percent aperture - 40%

ECC's

Group Shielding

Technical Feasibility - Average CF for the group = 3.0
Operation begins immediately following t_a^e

Operation Practicality - Initiation and planning times are given for the respective t_a^e

t_a^e	Planning and Implementation Time (hr)	Time of Effective Initiation (H + hr)
1/2	1	1 1/2
1	1	2
2	1/2	2 1/2
3	1/2	3 1/2
4	1/2	4 1/2

80 percent benefit from a CF of 3; 20 percent benefit from a CF of 2.5

Shelter Rotation

Technical Feasibility - one move between the two groups will be made to equalize dose, and this will be made at the optimum time.

Operational Practicality

Planning and initiation times are given below:

t_a^e	Planning Time (hr)	Earliest Initiation Time (H + hr)
1/2	2	2.5
1	2	3
2	1 1/2	3.5
3	1 1/2	4.5
4	1	5

Also 30 percent of the people would receive 10 percent higher than average dose due to different moving times throughout the group.

Applied Shielding

Technical Feasibility

Scheme 1

Place 100 lb/cu ft of applied shielding in all doors and windows of first floor -

20 windows 4 x 10 ft = 800 sq ft
8 doors 6 x 10 ft = 480 sq ft
1280 sq ft

1280 x 100 = 128,000 lb of mass required.

estimated man-hours of effort* = 85
time required to place = 1 hr

* Based on 66 man-hours per 1000 sq/ft floor area for a loading of 100 lb/sq ft.

Scheme 2

Add 20 psf to floor of second story

area = 19,000 sq ft x 20 = 380,000 lb of mass

required man-hours* = 285

time required to place = 2 hr

Available Mass

Assuming the post office is similar to an office building - From Table B-1 (Ref. 14)

Both schemes

Total floor area of post office - 3 x 19,000 - 57,000 sq ft

Mass available from Table B-1 12 x 57,000 = 689,000

Mass required both schemes -	508,000
Mass remaining	176,000

Operational Practicality

Scheme 1

Recognition and planning	1 hr
Organization and resource designation	1 1/2 hr
Technical Feasibility work time	1 hr
Total time to complete Scheme 1	3 1/2 hr

Scheme 2

Scheme 2 is more difficult to complete because of the greater amount of mass that has to be placed. The following are the time intervals used:

* Based on 66 man-hours per 1000 sq/ft floor area for a loading of 100 lb/sq ft.

Table B-1

BUILDING CONTENTS LOADS AND VOLUME FACTORS

Occupancy	Combustible Mass (PSF)	Total Mass (PSF)	Volume Factor K ($V = KA_pN$)* Total	Volume Factor K ($V = KA_pN$)* After Fire
Apts. and Residential	3.5	5	0.625	0.02
Auditoriums and Churches	1	1.5	0.25	0.007
Garage				
Storage	1	15	0.75	0.30
Repair	1	11	0.55	0.20
Gymnasium	0.3	0.5	0.09	0.003
Hospitals	1.2	3	0.375	0.03
Hotels	4	5	0.625	0.013
Libraries	24	26	0.75	0.027
Manufacturing				
Comb. Mdse. fabrics, furniture	13.5	18	1.8	0.07
Incombustible	1	11	0.55	0.20
Offices	7	12	1.2	0.10
Printing Plant				
Newspaper	10	23	0.9	0.20
Books	50	60	1.7	0.13
Schools	9.5	11	1.6	0.02
Storage				
Gen. Mdse.	14	35	6	0.3
Special		**		
Stores				
Retail Dept.	7.5	12	2	0.10
Wholesale	10	16	2.7	0.12
Restaurant	2	3.5	0.6	0.02

* V = Volume in cubic feet
A_p = Plan area in square feet
N = Number of stories
** 25 Percent of design load

SOURCE: Ref. 14

	1/2, 1 t_a^e	2, 3, 4 t_a^e
Organization and resource designation	2 1/2 hr	2 hr
Recognition and planning	1 1/2 hr	1 1/2 hr
Technical feasibility work time	2 hr	2 hr
Total time	6 hr	5 1/2 hr
Would begin 1/2 hr after Scheme 1 starts	1/2 hr	1/2 hr
Time Completed	H + 6 1/2 hr	H + 6 hr

Limited Decontamination

Technical Feasibility

Shelter/refuge roof (tar and gravel) - 19,000 sq ft

Method - firehosing

% Reduction - 90

Manpower required - 7 man team - 2 hoses (decon rate 10,000 sq ft/hr)

Total time - 2 hr

Time Factors

t_a^e	t_c Decontamination starts	"CF" 30 is obtained (Time decontamination complete - H + hr)
1/2 hr	1 1/2	2 1/2
1	2	3
2	3 1/2	4 1/2
3	5.3	6.3
4	7.2	8.2

Operational Practicality

Decontamination would be initiated at H + 8 hr, 16 hr, or 24 hr because of lack of water until those times.

Overcrowding

Technical feasibility

Overcrowding begins - t_a^e + 1/2 hr

Overcrowding duration = 12 hr

Operational practicality

Recognition, planning, and initiation time before countermeasure is effective for the five arrival times are given below:

t_a^e (H + hr)	Planning, etc. Time (Hr)	Time of Initiation (H + hr)
1/2	2	2 1/2
1	2	3
2	1 1/2	3 1/2
3	1 1/2	4 1/2
4	1 1/2	5 1/2

Remedial Movement

The radiological parameters which were used for remedial movement (which were different from those used for other case studies) are listed below:

t_a^e (H + hr)	I_o (R/hr - 1 hr)
1/2	2300
1	2800
2	3600
3	4200
4	4800

Secondary Shelter Locations - movement accomplished on foot

Secondary Shelter No. 1 - Post Office at N. 1st and St. John

PF=84 (basement)

distance 200 yards

Secondary Shelter No. 2 - Santa Clara County municipal court building, 200 W. Hedding Ave. Assume PF = 100

Distance 2 miles

Secondary Shelter No. 3 - De Anza Hotel 233 W. Santa Clara Ave.

Assume PF = 100

Distance 1/2 mile

Secondary Shelter No. 4 - 88 5th Street

Assume PF = 100

Distance = 0.35 mile

Secondary Shelter No. 5 - Apartment house, Santa Clara Ave. and 14th Street

Assume PF = 100

Distance 1 mile

Secondary Shelter No. 6 - Mayfair Shopping Center

Assume PF = 100

Distance 3.8 miles

Technical feasibility movement times - speed of movement 3 mph

Secondary site no.	Travel time (hr)	Distance (miles)
1	.087	0.13
2	17	2
3	0.2	0.5
4	0.16	0.35
5	0.35	1
6	1.2	3.8

PF while walking = 1.5

Operational Practicality travel times

Shelter	Travel time (hr)
1	0.11
2	0.9
3	0.26
4	0.21
5	0.46
6	1.5

CF while walking = 1.5

RESTORATION OF VITAL SERVICES (Ref 13)

Radio Station KXRX

Area of studio building	1700 sq ft
Wt of exterior walls	7 psf
Wt of roof	10 lb/sq ft
Area of concrete storeroom	75 sq ft
Wt of exterior walls	72 psf
Wt of roof	75 psf

ECC Schemes Used: Decontamination of roof, applied shielding around exterior walls

Applied Shielding

Total perimeter of buildings - 200 ft

Height of walls - 8 ft

Method - place 100 psf of sandbags around buildings

Total shielding required = 100 lb x 8 x 200 = 160,000 lb = 80 tons or thirty-two hundred 5-lb sandbags

Effort: - 160 man-hours or two 80-man teams working 1 hr each - Total time 2 hr

Decontamination (roof only)

Effort: One 6-man crew - 12 min

General

Operations: travel time includes loading and unloading (use of vehicles assumed) average CF = 2.0	1/3 hr
Two 80-man crews perform applied shielding; working time 1 hr per crew	1 hr/crew
One 6-man crew performs decontamination; working time 0.2 hr average CF = 1.5	0.2 hr/crew
Round trip travel time	1/2 hr

Dole Warehouse

Building area (roof) - 118,000 sq ft	paved parking area - 38,000 sq ft
Wall wt - 100 psf	streets - 197,000 sq ft
(Tar and gravel) Roof wt - psf	asphalt

ECC scheme used - Decontamination of the roof (firehosing), paved parking area (sweeper) and surrounding streets (sweeper)

Manpower - nine 7-man teams used for firehosing
five 1-man teams used for street sweepers
(team rotated every hour)

Time:	Travel, loading, unloading and preparation	1/4 hr
	Work time each time	1 hr
	Return travel, etc.	1/4 hr
	Total exposure	1 1/2 hr

CF while working = 1.5

CF for two-thirds of time while traveling = 2.5 — average about 2.0

CF for one-half of travel time = 1.5

HIGH SCHOOL REFUGE AREA

Building Description

Plan area - 25,000 sq ft

Average exterior wall wt - 80 psf

Average interior wall wt - 50 psf

% Apertures - 50

ECC's

Group Shielding

Technical Feasibility

Second-floor group receives CF of 1.33

First-floor group receives CF of 3.0 without second-floor group directly above; CF of 5 with group directly above

Operation begins immediately following fallout arrival.

Operation Practicality

For second-floor shelter - 75 percent of people receive CF of 1.33, and 25 percent receive CF of 1.16. For first-floor shelter (with group above) 75 percent of people receive a CF of 5 and 25 percent receive a CF of 4.

Initiation and planning time would also be required. These are:

t_a^e	Initiation and Planning Time (hr)	Time of Initiation H + hr
1/2	1	1.5
1	1	2
2	1/2	2.5
3	1/2	3.5
4	1/2	4.5

SHELTER ROTATION

A three-stage move would be performed to equalize dose with two movements being made by each group (basement shelter group, first-floor refuge group, second-floor refuge group).

Technical Feasibility

Movements will be conducted at the optimum times required to equalize dose.

Operational Practicality

Planning and implementation time would be:

t_a^e (H + hr)	Time (hr)	H + hr
0.5	2	2.5
1	2	3.0
2	1 1/2	3.5
3	1 1/2	4.5
4	1	5.0

Also due to individuals in the groups moving at less than the optimum times, 45 percent of the groups would receive a 10-percent higher dose.

APPLIED SHIELDING

Technical Feasibility

One applied shielding scheme was used, placing 80 psf of mass in the window and door areas of the first- and second-floor refuges.

Area of doors and windows - 6,000 sq ft

6,000 x 80 = mass required - 480,000 lb

Total floor area (3 floors) - 75,000 sq ft

From Table A-1 - building content load (schools) - 11 psf

Total available mass - 825,000 lb

Estimated effort - 320 man-hours

Total time required for placement - 2 hr

Placement would begin 1/2 hr after entrance into fallout shelter time applied shielding is effective - H + 2-1/2 hr

Operational Practicality

	t_a^e = 1/2, 1 hr	t_a^e = 2, 3, 4 hr
Recognition and planning time (includes 1/2-hr entrance into shelter)	1/2 hr	1-1/2 hr
Organization and resource designation	2-1/2 hr	2
Work time	2 hr	2 hr
Total time	6 hr	5.5 hr

LIMITED DECONTAMINATION

Technical Feasibility

Decontamination method used - firehosing roof

Roof area - 25,000 sq ft - concrete surface

Percent reduction achieved - 90

Manpower required - one 7-man team - 2 hoses (decontamination rate 10,000 sq ft/hr)

Time required - 2.5 hr

Crews rotate - every 1/4 hr

Decontamination commences at fallout cessation:

t_a^e	Initiation Time (t_c)	Time Decontamination Completed (H + hr)
1/2	1-1/2	4
1	2	4-1/2
2	3-1/2	6
3	5.3	7.8
4	7.2	9.7

Operational Practicality

A delay in decontaminating the roof might be caused by a lack of water. Therefore, decontamination initiation times of 12, 16, and 24 hr were studied.

OVERCROWDING

Technical Feasibility

Countermeasure would begin immediately following fallout arrival; and would become effective 1/2 hr after fallout arrival; duration of overcrowding = 12 hr

Operational Practicality

Duration of overcrowding - 8 hr

Planning and implementation time -

t_a^e	Planning and Implementation Time (hr)	Time CM is effective (H+ hr)
1/2	2	2.5
1	2	3
2	1-1/2	3.5
3	1-1/2	4.5
4	1-1/2	5.5

COMBINATION OF ECC's

The time diagrams given in the text for each ECC combination describe most of the operational practicality and technical feasibility assumptions. The table below lists the various CF changes brought about by the group shielding and applied shielding countermeasures. Also, all of the assumptions given for the individual ECC's were used for the analyses of the several combinations.

CALCULATION FACTORS

Floor	Initial PF (CF)	With Group Shielding Only Factor "CF"		With Applied Shielding Only Factor "CF"		Group Shielding with Applied Shielding in Place - Factor "CF"	
1	30	5	150	1.33	40	6.75	200
2	30	1.33	40	1.17	30	1.56	46

Appendix C

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Summary Report
of
THE USEFULNESS OF EXPOSURE CONTROL COUNTERMEASURES IN REDUCING RADIATION FATALITIES

Final Report
June 1967

by

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Prepared for

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Summary Report

THE USEFULNESS OF EXPOSURE CONTROL COUNTERMEASURES IN REDUCING RADIATION FATALITIES

Investigation of the lifesaving potential of exposure control countermeasures under specific radiological environment is the subject of this report. The exposure control countermeasures (ECC's) that have been evaluated in this investigation are:

- Group Shielding
- Shelter Rotation
- Applied Shielding
- Limited Decontamination
- Overcrowding
- Remedial Movement

A case study approach was used to asce tain the lifesaving capabilities of the ECC's. Scenarios were developed to depict real postattack situations with radiological fallout levels suitable for evaluation of exposure control countermeasures. The criteria used to select the radiological fallout levels were that the levels be high enough to produce an LD 50 (550 R over a 3-day period) to occupants of the refuges selected for study. The scenarios, all for the city of San Jose, California, include two shelter locations and two vital facilities (a radio station and a food warehouse) which were assumed to have sustained light blast effects and fallout. The technique used to evaluate the ECC's entailed finding answers—squentially—to three questions: Is the ECC technically feasible? If practical, what is its effectiveness?

An analysis was performed for each of the individual countermeasures and a combination of various countermeasures for each shelter location. Two further analyses were made, one to test the sensitivity of selected countermeasures to informational inputs and the other to determine the usefulness of the countermeasures in promoting the early restoration of vital facilities. The results

of the analyses are presented in graphs showing the percentage of fatalities in the refuges studied versus the effective fallout time of arrival.

From the results of the study it was concluded that all the exposure control countermeasures that were investigated show some degree of lifesaving capability. Although these results cannot be applied to all cases, they are applicable to a wide range of conditions in which ECC's are most effective. Specific conclusions are:

- Group Shielding - Group shielding appears to be most attractive of all the individual ECC's for a specific shelter geometry (first-floor shelter/refuges, or similar geometries). Group shielding is easily implemented and requires little planning. The informational requirements for group shielding are low, with the major informational input being the time of fallout arrival or the knowledge that a radiation field is threatening the shelter occupants.

- Shelter Rotation - Although superficially effective in reducing fatalities, shelter rotation, upon closer examination, is a rather unattractive countermeasure because (1) shelter rotation jeopardizes the occupants in a low-dose-rate shelter by forcing them to change places with occupants of a high-dose-rate shelter. Also shelter rotation is highly sensitive to radiological informational inputs; gross errors in inputs could result in increased deaths.

- Applied Shielding - Applied shielding is most effective for later fallout arrival times but can produce some reduction in fatalities even at earlier times. In general, however, applied shielding can be considered to be a positive countermeasure in the sense that any additional shielding serves to reduce dose and is beneficial to the shelter occupants.

- Remedial Movement - Remedial Movement, for the cases studied, proved to be the countermeasure most sensitive to fallout time of arrival; it is almost useless in reducing radiation fatalities at very early times of arrival, but at later times of arrival it proved competitive with other ECC's. Therefore, movement at very early times should be undertaken only (1) over very short distances, or (2) if shelter occupants are forced to move by other than a radiation threat, for example, fire.

- Overcrowding - Overcrowding is effective in reducing fatalities to occupants of low-PF shelters if a good shelter is readily available and if overheating is not a serious problem. Overcrowding was almost as effective as group shielding for first-floor refuges and superior for the second-floor refuge. Overcrowding also requires little implementation time or planning.

- Limited Decontamination - For the cases that were studied, limited decontamination proved to be the least effective of the countermeasures in reducing fatalities to the shelter/refuge occupants. Limited decontamination as an exposure control countermeasure could save only a very few lives and would be considered as a lifesaving countermeasure only in rare circumstances.

- Combination of ECC's - A combination of ECC's proved more effective than individual ECC's in reducing fatalities to refuge occupants. However, a proper sequencing of the ECC combination would be vital. The major limitation of utilizing a combination of ECC's is that the person directing the operation would have to have knowledge of radiation calculations and shielding.

- Practicality of Exposure Control Countermeasures - It can be finally concluded that exposure control countermeasures, knowledgeably used, either singly or in combination, in a high radiation field, are capable of saving many lives that would otherwise be lost.

It is recommended, on the basis of this study, that the use of exposure control countermeasures be investigated further, particularly in their application to communities where large shelter deficits are known to exist, such as the suburban or "bedroom" communities that surround most large metropolitan areas. Also, consideration should be given to incorporating exposure control countermeasures into the Community Shelter Plan.

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13. ABSTRACT

An investigation of the lifesaving potential of exposure control countermeasures (applied shielding, group shielding, shelter rotation, limited decontamination, overcrowding, and movement) under specific radiological environments is the subject of this report. Scenarios were developed to depict "real" post-attack situations with radiological fallout levels suitable for evaluation of exposure control countermeasures. These scenarios, all for the city of San Jose, California, include two shelter locations and two vital facilities (the EBS radio station and a food warehouse) which are assumed to have sustained light blast effects and fallout. An analysis was performed of the lifesaving capabilities of each individual countermeasure and a combination of various countermeasures for each shelter location. The sensitivity of each countermeasure to informational inputs was also studied as was the use of the countermeasures in promoting the early restoration of vital facilities.

It was concluded that the exposure control countermeasures that were investigated all show some degree of lifesaving capability. Group shielding, overcrowding, and applied shielding were found to be the most effective countermeasures. Limited decontamination, shelter rotation, and remedial movement proved to be the least effective countermeasures. Various combinations of exposure control countermeasures displayed an additive effectiveness and have an excellent capability for reducing fatalities. Finally, it was concluded that exposure control countermeasures, knowledgeably used either singly or in combination in a high radiation field are capable of saving many lives that would otherwise be lost. It is recommended, therefore that the use of exposure control countermeasures be investigated further, particularly in the application to communities where large shelter deficits are known to exist, such as the suburban or bedroom communities that surround most large metropolitan areas. Also, consideration should be given to incorporating exposure control countermeasures into the community shelter plan program.

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