AD 708552

PSD-PG-80-1

November, 1962

Professional Guide Series:

INCORPORATION OF SHELTER INTO SCHOOLS

INTERIM EDITION

DDC
RECORDED
JUN 30 1970
RECEIVED
B

DEPARTMENT OF DEFENSE • Office of Civil Defense

This document has been approved for public release and sale; its distribution is unlimited.

72

SUMMARY OF TECHNICAL PUBLICATIONS PROGRAM

PROTECTIVE STRUCTURES DIVISION

December 1962

Professional Manuals (100 Series)

100-1 Design & Review of Structures for Protection from Fallout Gamma Radiation

100-2 Design & Review of Structures for Protection from Initial Nuclear Radiation

100-3 Design & Review of Structures for Protection from Initial Thermal Radiation & Fire

100-4 Design & Review of Structures for Protection from Nuclear Blast

100-5 Design & Review of Structures for Integrated Protection from Nuclear Weapons

100-6 Architectural & Engineering Planning for Nuclear Protection

100-7 Use of Prestressed Concrete for Protective Structures

Professional Guides (80 Series)

*80-1 Incorporation of Shelter into Schools

80-2 Incorporation of Shelter into Hospitals

80-3 Modifications of Existing Buildings for Shelter Purposes

*80-4 Incorporation of Shelter into Apartment & Office Buildings

80-5 Incorporation of Shelters into Churches

80-6 Incorporation of Shelter into Parking Garages

80-7 Emergency Operating Centers

80-8 Reducing Vulnerability of Industrial Plants

80-9 Expedient Community Shelters

*80-10 Catalog of Shelter Components

80-11 Reducing Vulnerability of Residential Structures

80-13 Incorporation of Shelter into Tunnels, Mines & Other Special Structures

80-14 Simplified Methods of Shielding Analysis

*Published to date

PREFACE

This Professional Guide is one of a series of technical publications prepared under direction of the Protective Structures Division, Office of Civil Defense. The purpose of the Office of Civil Defense Technical Publications Program is to assist architects and engineers in the planning and design of structures that contain protective features.

This publication was prepared for the Department of Defense, Office of Civil Defense by Eberle M. Smith Associates, Incorporated, Architects and Engineers of Detroit, Michigan from materials developed in various studies of fallout radiation protection in schools and from data compiled during the construction of shelters under the federally sponsored Prototype Shelter Program. Also included is material from a previous publication, "School Shelter, an Approach to Fallout Protection" prepared in collaboration with Engelhart, Engelhart, Leggett and Cornell, education consultants, New York, N. Y. The text of this publication has been reviewed by the American Institute of Architects and other appropriate associations and Federal agencies.

Design examples include work by Ammann & Whitney, Consulting Engineers, New York, N. Y.; Malmfeldt Associates, Architects, Hartford, Connecticut; Frank M. Standhardt, A.I.A., Roswell, New Mexico; and Eberle M. Smith Associates.

This publication is presented as an interim edition to meet the immediate need of architects and engineers, and to allow the professions to contribute their experience for consideration in preparation of the final version. Comments should be sent directly to the Protective Structures Division, Office of Civil Defense.

The Technical Publications Program consists of five categories:

Professional Manuals present the technology of design and review for protection against weapons effects.

Professional Guides orient this technology to the incorporation of protective features into normal use structures, such as: schools, apartment buildings, industrial plants.

Technical Memoranda present subjects not of sufficient scope to warrant presentation as a manual or guide. These generally consist of performance requirements for shelters and shelter components.

Design Studies present, in general outline form, suggested designs for incorporating protective features into normal use structures.

Engineering Case Studies are engineering reports on the design and construction of specific projects.

Listings of publications now under preparation are included on the inside covers of this guide. Those currently available are indicated by an asterisk. Request for copies should be made on company letterhead to the Protective Structures Division, Office of Civil Defense, Washington 25, D. C., or to Regional Offices listed in Appendix D.

TABLE OF CONTENTS

Introduction

I Changing Patterns in Schools

II Design Characteristics of Schools as related to Shelter

2-1 The Typical Modern School
2-2 Spaces and Facilities
2-3 Plan Variations
2-4 Emergency Use of School Facilities
2-5 Mechanical Systems
2-6 School Code Requirements

III Design Information for Shelter in Schools

3-1 Radiation Protection
3-2 Blast Protection
3-3 Net Area per Occupant
3-4 Ventilation
3-5 Water Supply
3-6 Food
3-7 Noise Control
3-8 Health
3-9 Mental Health
3-10 Fire Safety
3-11 Administration

IV Application of Design Information

4-1 Existing Schools
4-2 New Schools of Conventional Design
4-3 New Schools Constructed Underground
4-4 Points to Check

V Special Problems

5-1 Interruption of Essential Utilities
5-2 Extreme Climates

VI Design Examples

6-1 Three Proposed Underground School Shelters
6-2 Abo Elementary School, Artesia, New Mexico
6-3 Hartford Public High School, Hartford, Connecticut
6-4 Proposed School Shelter at Ground Level

TABLE OF CONTENTS - (Continued)

APPENDIX A - Analysis of Thermal Environment in Abo School

APPENDIX B - Weapons Effects

APPENDIX C - Glossary of Terms

APPENDIX D - Regional Offices

INTRODUCTION

There are many factors which make school shelter important in any national shelter program. Over one-quarter of the population of the United States is comprised of students in elementary and secondary schools and in institutions of higher learning; this group represents the future of our nation. Schools have traditionally taken a position of leadership in community activities, recreation programs, continuation studies, vocational training, and first aid, life-saving, civil defense and disaster indoctrination.

In addition, schools are well distributed in relation to population, and as our population shifts and grows, new school construction grows with it, so that, next to housing, schools are the most prevalent building type in the country. Frequently the school is the most substantial and best equipped building in the community. Schools have a staff already trained in administration and in the operation and maintenance of mechanical equipment. It is only logical that community civil defense planning should take advantage of the permanent organization, responsible leadership and superior facilities of the school system.

On the other hand, instruction is the prime function of the school, and it has to meet the exacting requirements of this function every day of its useful life, which may be forty years or more. This function need not be impaired by other requirements based on disaster, such as those now in force for fire safety or those discussed in this publication for safety against nuclear attack. Funds for school construction are used to buy fire alarms, extinguishers, panic hardware and emergency exit lighting as well as classrooms. In certain areas they also buy structural resistance to earthquakes; or shelter from tornadoes. The basic purpose of this guide is to indicate the ways that shelter against nuclear attack also can be incorporated economically in school construction without detriment to the education program. To this end it will discuss the problems that must be considered in the preliminary planning of the school shelter and information for the guidance of the architect/engineer in preparing working drawings and specifications. In addition, it will discuss generally some special problems which arise with regard to climate, locality or specific weapons effects, and which are treated in detail in other publications of the Office of Civil Defense.

CHAPTER I

CHANGING PATTERNS IN SCHOOLS

From the earliest beginnings in our country public education has undergone continuous change under the increasing pressures of population, industrialization and urbanization.

Improvements in transportation, communications and technology have contributed to the development of new kinds of schools differing from their predecessors in organization, size, setting and educational program.

During the early 19th century, the one room schoolhouse, where a single teacher attempted to instill the three R's, deportment and moral values into children of all ages, gave way in urban areas to the rigidly disciplined "Lancastrian" school room, where the teacher drilled 50 head pupils, or monitors, who in turn drilled ten students each. Reading and writing schools of that time were separate, autonomous units, even though situated in the same building. This early, and successful experiment in group instruction at low cost gradually evolved into the grade school we know today with a separate teacher for each grade, a system of promotion from one grade to the next and a corresponding progression of subject matter. At the same time the course of instruction was expanded, test-books came into common use, the school term was lengthened and the years of schooling were increased.

The grade school called for a new architectural approach. The earliest true example of grade school design is the Quincy Grammar School, built in Boston in 1848, and so well suited to the needs of the time that its influence is still felt today. It had four stories, an attic and a basement, and included twelve classrooms with fixed desks and seats as well as an auditorium on the fourth floor capable of seating all of the 660 students. For the next fifty years this became the archetype of the urban elementary school, erasing all memory of its predecessors and to some extent inhibiting the development of other approaches.

In the 1870's there were introduced some radical innovations in education, including the kindergarten, the public high school and courses of instruction in domestic arts and manual training. By 1910 elementary schools began to appear with spaces specifically designed as kindergarten rooms, domestic art rooms and shops. In these schools, the size of a class was gradually reduced to 40 or less, and the total space provided rose to 80 or more square feet per pupil. At the same time the regimentation and drill of the 19th century were being superseded by the learning-by-doing concepts of the 20th. Rooms became bigger and furniture became light and portable to permit varied and mobile activity by groups of widely differing size.

Schools also began to make provisions for the physical well-being of their pupils, through programs of physical education, through tests of eyesight, hearing and physical fitness, and through increased emphasis on safety and health in the design of school buildings. Minimum standards were established for exits, fire resistance and plumbing. Great progress was made, and is still being made, in the environmental aspects of school design, particularly those affecting the vision, hearing and comfort of students and teachers.

Prior to the development of economical, readily available electric power and efficient lamps and fixtures, classrooms were dependent on natural light. Usually they faced north or south to minimize the variations in light due to the daily passage of the sun from east to west. Windows were made large enough to furnish light on cloudy days and were furnished with shades, control vanes, or venetian blinds to reduce the intensity of light on bright days. Glass block was introduced to diffuse the natural light and eliminate glare. Overhangs and screens were designed to prevent direct entry of the sun's rays, and heat absorbent glass was developed to reduce the thermal effect of sunlight. As classrooms grew larger, considerable architectural ingenuity was employed to bring additional natural light through clerestories and skylights so as to maintain a reasonably uniform intensity throughout the room.

In recent years the improvements in electric lighting have virtually eliminated any dependence on natural light in the classroom. Classrooms planned for teaching by television, film strips and slides ordinarily have provisions for eliminating natural light altogether, and some school districts, such as San Mateo, California, and Artesia, New Mexico are experimenting with compactly planned schools in which many or all of the classrooms are without windows to the outside.

Acoustic treatment in schools has not only been concerned with reducing noise levels and reverberation within the classroom but also with preventing transmission into the classroom of noise from other portions of the building or from outside. Special acoustic treatment is usually required for vocal and instrumental rooms, auditoria and indoor spaces for physical education and competitive sports.

The traditional one room rural school house was opened during the winter months when there was comparatively little for farm children to do. Heat was furnished by a wood-burning stove and ventilation by various holes and cracks except on the few warm days when windows could be opened. In schools of today, heat and mechanical ventilation are supplied to individual rooms or zones according to their needs, usually by an automatic control system which may include individual room thermostats, an outdoor thermostat, timing devices to cut down operations during the night cycle and associated valves and controls. With the increasing trend toward summer sessions and all-year community use of school buildings, many districts are making provisions in new construction for mechanical cooling in hot weather. Because school budgets are tight, air-conditioned schools are seldom found outside the warmest parts of the country. Where they have been constructed, teachers have been relieved of irksome, and often futile efforts to improve classroom comfort by opening windows, and have stated that pupils are more alert and receptive.

As may be noted by reference to the engineering analysis for Abo School (See Appendix A) windowless schools enjoy unique advantages with respect to completely controlled thermal environment. Insulated exterior walls typically gain or lose less than a tenth of the heat that would be transmitted through a comparable area of windows. The costs of mechanical heating and cooling are much reduced in a windowless school, consequently, and the provision of air-conditioning becomes economically feasible.

In summary, the pattern of school development has been in the direction of more flexible use of space for widely varying activities by groups of widely differing sizes. Increasing use is being made of visual, mechanical and electronic teaching aids. The trend is toward complete reliance on artificial light, with characteristics varied to suit the teaching situation. The concept of "environment for learning" has been extended to include controlled ventilation, temperature and humidity in addition to lighting, acoustics and classroom furnishings.

CHAPTER II

DESIGN CHARACTERISTICS OF SCHOOLS AS RELATED TO SHELTER

2-1 The Typical Modern School

Records since World War II show that the greatest building boom in educational history has taken place and is forecast to continue at an even greater pace. The building trend during this period, with the notable exception of certain urban areas, has been toward single story structures without basements. One story construction saves the cost of stairways and provides faster, safer and more convenient egress in case of emergencies. Most schools have ample windows with operating sash, thus making available natural light and ventilation when desired, even though adequate electric lighting and mechanical ventilation are provided. As will be discussed in a later chapter, a few modern schools have been designed with air conditioning and, in some cases, without windows. With these exceptions, the trend has been toward schools which offer little possibility of shelter against nuclear attack or even tornadoes.

2-2 Spaces and Facilities

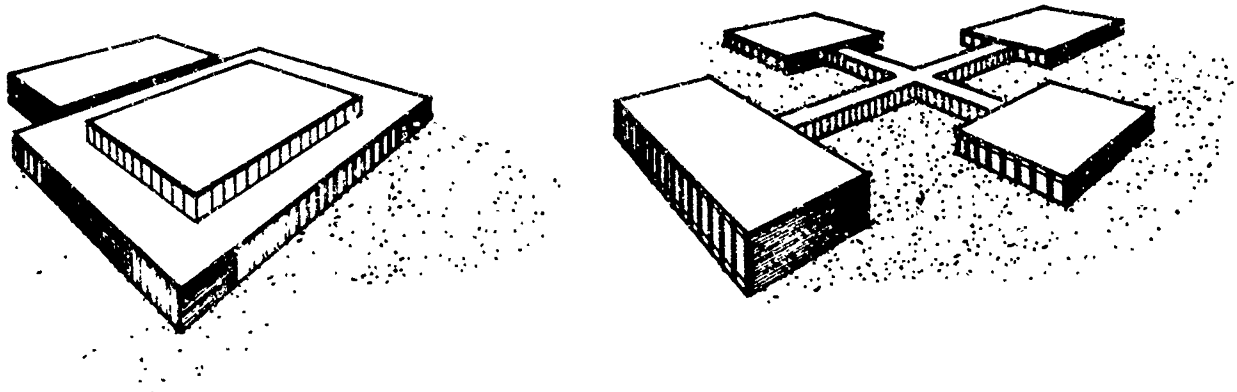
Elementary school facilities usually include the following:

1. Classrooms, designed for maximum multiple-use, usually square or nearly so, perhaps 800 to 900 square feet in area (kindergartens are about 50% larger) with ceiling height 8-1/2 to 9-1/2 feet. Usually at least 25% of the outside wall is windows and occasionally a door to the outside is provided. Students spend most of a six-hour school day in one of these rooms.

2. Multi-purpose Room, designed for maximum multiple-use with free uninterrupted space at least 40 ft. by 60 ft. with a ceiling height of at least 14 feet. Windows are not usually mandatory.

3. Corridors, 8 feet to 12 feet wide varying in accordance with plan arrangements.

4. Storage Areas, amounting to 1 to 3 square feet per student.



COMPACT PLAN CLUSTER PLAN

Figure I

5. Administration Area, including private offices, general office, clinic and teacher's room.

6. Toilet Rooms, separate for boys and girls, often provided as part of the "self-contained" classroom for grades K through 3 and as separate "gang" toilets for higher grades.

7. Mechanical Equipment Room and Kitchen, specialized use areas compactly and efficiently designed around large items of fixed equipment with little free or open space.

Additional spaces common to secondary schools and occasionally found in elementary schools may include the following:

1. Library
2. Choral and Instrumental Music Rooms
3. Cafeteria
4. Gymnasium and Locker Rooms
5. Auditorium and Stage
6. Shops

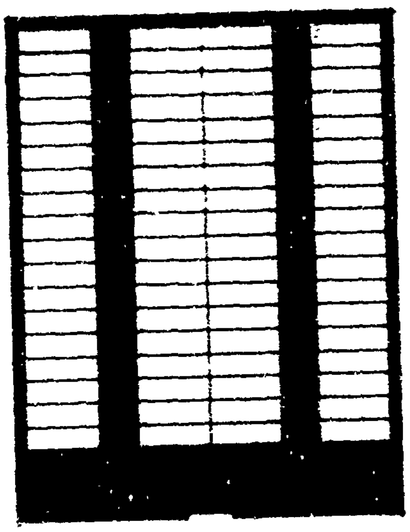
With the exception of the Gymnasium, which is usually sized to accomodate a standard basketball court, the size and facilities of these areas vary considerably according to the educational program and the degree of community use. They all include a substantial amount of free unobstructed area and often may be designed without windcws.

2-3 Plant Variations

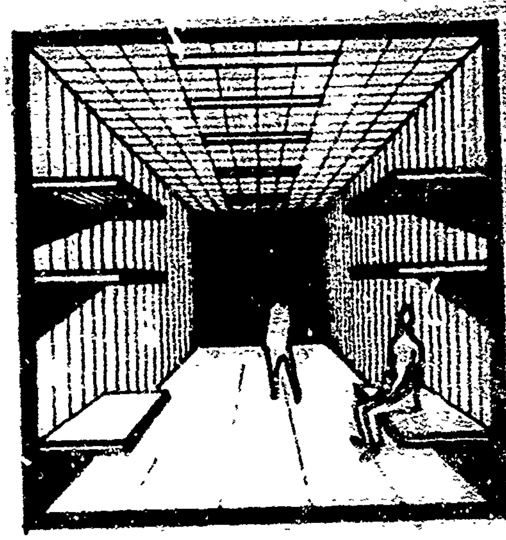
Most school plans fall into one of two general classifications. (See Figure 1.) Where teaching program, site and budget considerations require that a school be as compact as possible, the physical plant may be developed as a single unit with classrooms of approximately equal relationship to each other and to the auxiliary areas. Where the teaching program attempts to strengthen the bonds of interest and development between students in several classrooms of similar age and grade division, the plant may be developed in several groups or clusters, each with several closely related classrooms. Each group of classrooms is of approximately equal relationship to other groups and to the auxiliary areas.

2-4 Emergency Use of School Facilities

One of the most economical ways of obtaining shelter is to take advantage of inherent strength, shielding and mechanical capacity in some portion of the normal school space which can be readily converted



DORMITORY PLAN



CORRIDOR ARRANGEMENT

Figure 2

to shelter. The saving arises not only from economy in the initial construction, but also in the maintenance. Since the area is in constant use, the various systems serving it will be constantly maintained and kept in first class operating condition. In addition, shelter occupants, whether from the school or the community, will not have to become accustomed to unfamiliar surroundings, equipment or administrative personnel.

A classroom of average size provides sleeping space for 150 persons (see Figure 2); eating space, including chairs and tables, for 90 persons; or general activity space for at least 60. When an entire school is planned for emergency use, it often becomes possible to shelter an entire neighborhood; a desirable goal in order to keep children together with their families.

Certain functions which are necessary to emergency use do not require large areas. The space requirements for care of the sick, for administration, for emergency toilets and for preparation of food are better met in some of the smaller specialized normal-use spaces. A clinic or teachers' room equipped with sanitary facilities converts readily to use as infirmary space. Storage rooms, from which nonessential equipment or supplies can be removed, can serve as emergency toilets. If no kitchen is available, a workroom with a sink is adequate for preparation of food under emergency conditions.

2-5 Mechanical Systems

Some of the systems designed for normal operation of a school may also be adequate, with minor modifications, for shelter operation, if they can be kept in service. There will be little or no demand for heat in the shelter, and normal lighting levels and water supply will be more than adequate. On the other hand, the sanitary facilities near or inside the shelter may need to be supplemented and the ventilation is likely to require special consideration.

At one time many schools were ventilated through ductwork from central fan rooms. This system is still in use in many areas, but has been supplanted in many others by unit ventilators placed in the classrooms and drawing a proportion of fresh air directly from outside.

The central fan system is the optimum for dual use shelter. A conventional central air system may be adequate under shelter conditions with minor modifications of ductwork and controls. A booster fan may be required when high efficiency filters are installed in the emergency air supply. If necessary, the system can be adapted to cooling and dehumidification of the air supply through installation of a cooling coil in series with the fan.

2-6 School Code Requirements

Many localities prohibit the use of basement areas for instructional purposes and in some localities there are restrictions on the use of windowless construction. Wells and private sewage disposal plants are not permitted in many cases where the school has access to public water supply and sanitary sewer.

All restrictions of this nature have been promulgated to protect the health and safety of children. With due consideration to the school shelter program as a logical extension of this philosophy, and with proper safeguards, it has been found possible to achieve shelter objectives without violating the spirit of code requirements. For example, when the shelter is to be used, concrete blocks or other portable shielding materials frequently will suffice to protect windows and areaways which open into the shelter areas.

CHAPTER III

DESIGN INFORMATION FOR SHELTER IN SCHOOLS

3-1 Radiation Protection

Shelter in schools should be shielded according to the maximum predicted intensity of radiation and, in any case, should have a protection factor of at least 100 with respect to fallout radiation. High protection factors are appropriate in shelters for children to avert genetic damage from radiation and to reduce exposure to a value where children can expect to live out a normal life span, even in an environment with substantially increased background radiation. Since the effectiveness of radiation barrier materials increases exponentially with thickness, the protection factor can be improved substantially above the minimum with a relatively small increase in expense.

3-2 Blast Protection

Where blast protection is planned in a school, the design should also take into account the associated effects of initial nuclear radiation, thermal radiation and other fire hazards.

Overpressure in a shelter should be held to levels which will not cause serious physical damage to the occupants. This may require that all openings above a certain size have a quick-acting mechanical closure against rapid pressure increases.

Loose or brittle materials capable of becoming missiles under blast loads should not be placed inside the shelter. Exits should be planned to avoid blockage or jamming by shock or debris.

3-3 Net Area per Occupant

Net area per occupant should be at least 10 sq. ft. By comparison, children carry on ordinary classroom activities with 25 square feet or more net area per child.

Cafeteria style food service can be conducted on the basis of staggered dining periods, allowing 9 sq. ft. per student sitting.

Children of elementary school age may require as much as eleven hours of sleep per night, although there is often much variability among children of the same age, or even in the day-to-day sleeping pattern of a given child.

Sleeping arrangements can be handled in one of two ways:

1. Decentralized sleeping spaces - several separated "self-contained" units, each making provision for sleeping as well as other activities during the emergency period for, say, 50 persons. This approach tends to lessen control problems, but would require daily conversion of the space from sleeping to other activities.

2. Centralized sleeping (dormitory) space, which could be used on a two-shift around-the-clock basis. This is the more efficient system, but presents problems of control, since disturbances from one or more children (or adults) could affect the half of the shelter population which happened to be in the sleeping area.

Bunks approximately 2'-1" x 6'-4" will accommodate adults and should be taken as a standard unless the required number of child-sized bunks can be established. For maximum utilization of space, bunks should be placed side by side in as many tiers as the ceiling height permits and should be entered from one end. Sleeping space requirements per person, including aisles, may be estimated as follows:

2 tiers	9 sq. ft.
3 tiers	6 sq. ft.

At least nine feet of ceiling height is recommended where 3-tier bunks are used, with flush mounted (or better, recessed) light fixtures.

Storage space for food, water, bunks, medical supplies and portable equipment should be from 1 to 2 cu. ft. per person sheltered.

If located conveniently, normal use toilets may be adequate for the shelter, provided there is adequate water for flushing and the waste disposal system can be kept in operation. Otherwise emergency toilets should be provided to raise the total number available to one per 25 occupants. Emergency toilets may be chemical, disposable or an austere trough type with flushing provisions.

Since the air supply filters may tend to accumulate contaminated particles during the period of fallout, they should be placed in a space which is either well shielded or is remote from the shelter area. Some shelters may require additional mechanical space to accommodate an engine generator for emergency electrical power, or a sewage ejector for emergency waste disposal. Air supplied to the engine generator room for cooling purposes should be filtered. This can often be accomplished by routing the shelter exhaust air through the generator room.

It is often desirable to group shelter spaces in a single area rather than to have a number of smaller shelters at various locations throughout the school. Management and communications problems are minimized under such an arrangement, and there are likely to be other benefits, such as a simpler, more economical mechanical system and a reduction in the number of openings required for access and for air intake and exhaust.

It will further simplify administration if the shelter area is planned so that the occupants can be kept in groups of manageable size and so that various activities, such as sleeping, eating and active recreation, can be carried on in separate adjoining spaces. Convenience for normal use should be given preference over convenience for shelter use.

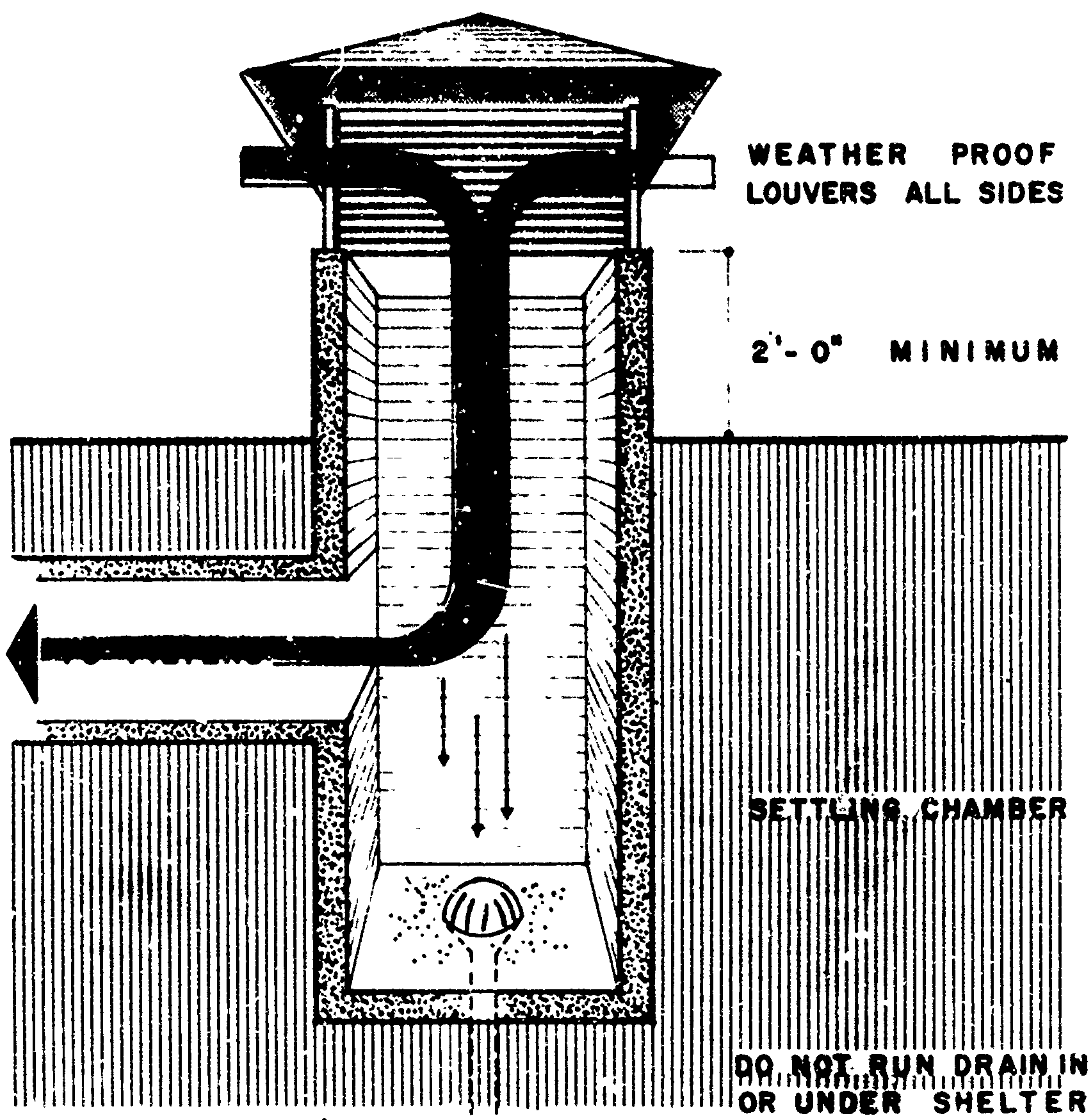
3-4 Ventilation

The ductwork of the central fan system can frequently be modified to serve the shelter by dampering off or by-passing sections not required under emergency conditions. If the emergency ventilating system is planned to furnish at least 3 CFM of fresh air to every person in the shelter, the carbon dioxide concentration in the air will not exceed 0.5 percent by volume and should not prove harmful even to active persons. The oxygen supply also will be ample.

Another function of the ventilation system is to maintain temperature and humidity below the point where a sedentary human body generates more heat than can be lost by convection, radiation and evaporation, with a consequent rise in body temperature. The threshold of this condition is in the neighborhood of 85 degrees effective temperature, a term used to describe any combination of temperature and relative humidity giving the same feeling of comfort (or discomfort) as 85 degrees F. at 100 percent relative humidity, under the "still" air conditions prevalent in shelters.

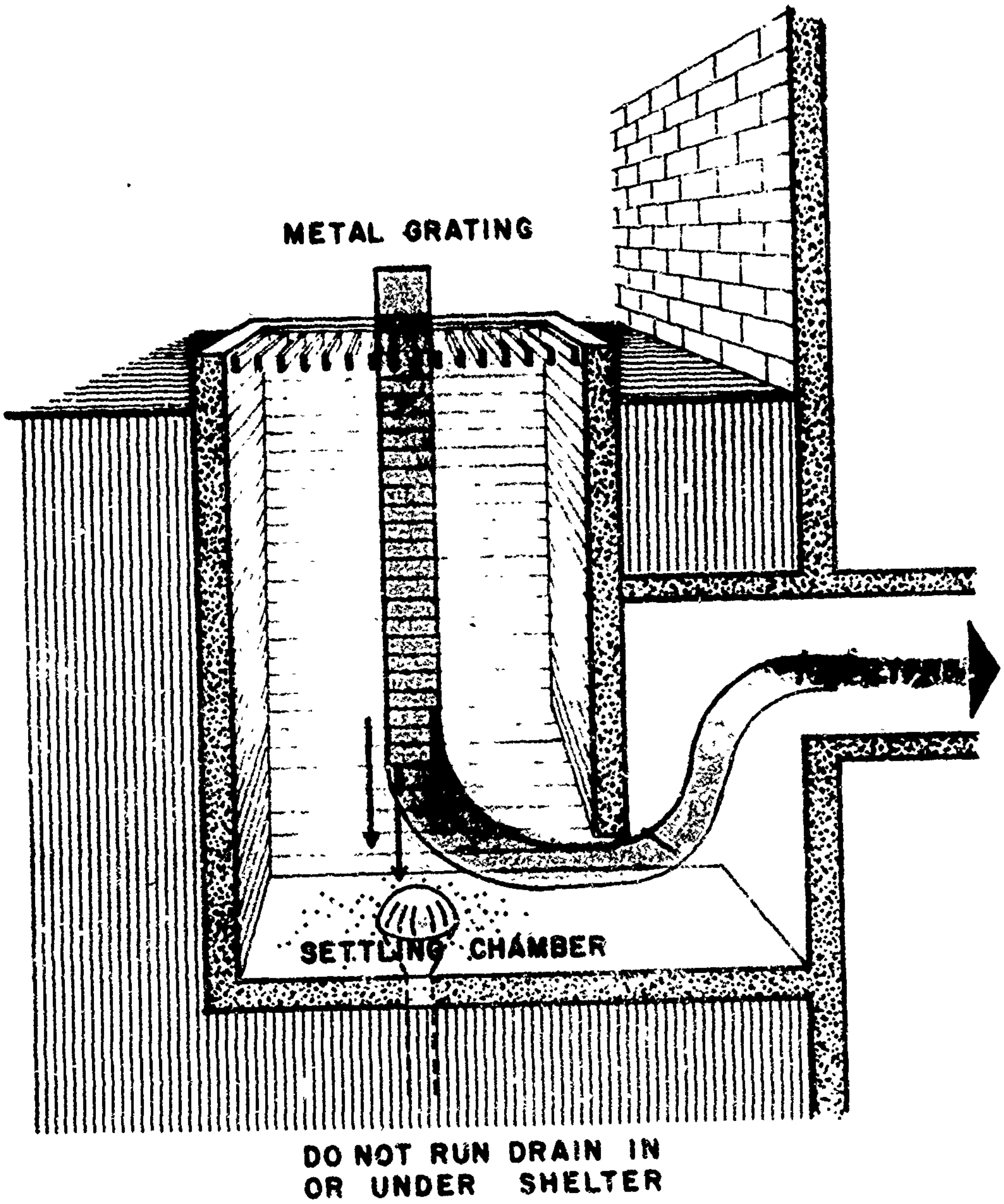
When it is desired to make provision for future installation of filters for chemical and biological warfare agents, a booster fan or some other means of overcoming the additional static resistance of these filters should be considered. Keeping the shelter under a slight positive pressure, in order of 1/4 inch of water, will help prevent the infiltration of air-borne toxic agents of this type or of combustion gases from outside conflagrations.

In hot and humid climates, where school buildings frequently have equipment for cooling and dehumidifying the normal air supply, this equipment will usually be adequate to condition the emergency air supply and should be adaptable for this purpose. Where mechanical cooling alone is provided, it may be necessary in some cases to increase the rate of ventilation with outside air to help control high relative humidities within the shelter and to reduce condensation on interior surfaces which are



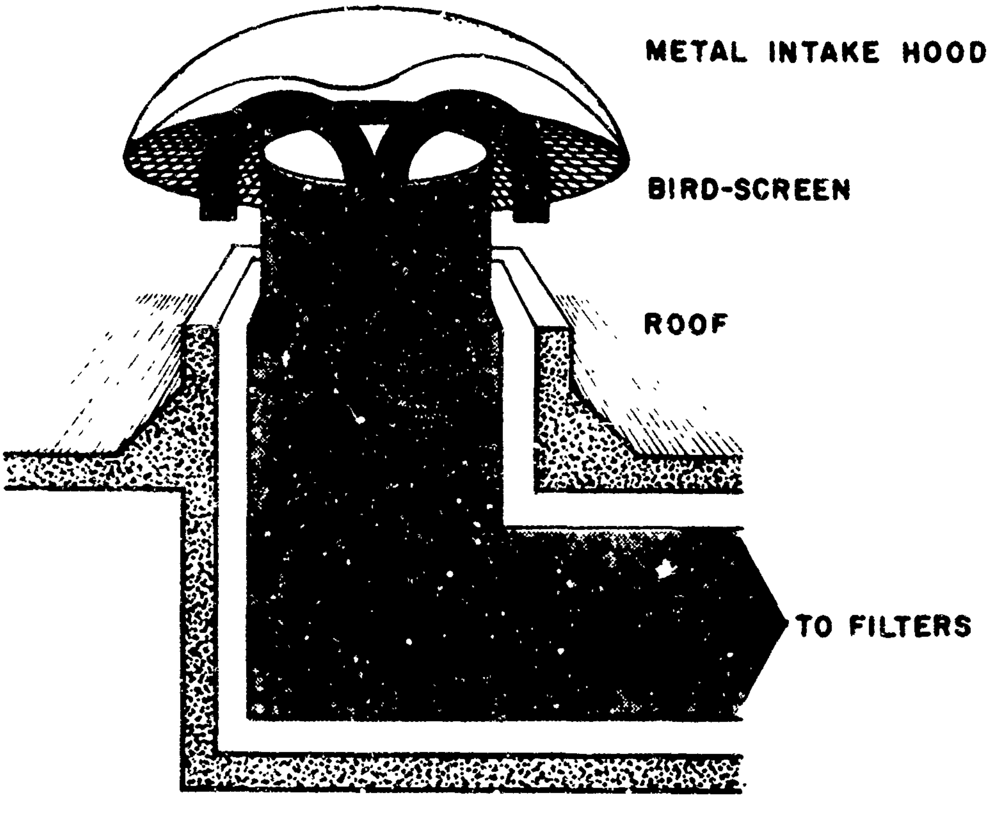
PENTHOUSE AT GRADE
WITH SETTLING CHAMBER

Figure 3



AREAWAY FRESH AIR INTAKE
WITH BAFFLE AND SETTLING CHAMBER
USE ONLY IF REMOTE INTAKE IS IMPRACTICAL

Figure 4



ROOF TOP FRESH AIR INTAKE

USE ONLY IF REMOTE INTAKE IS IMPRACTICAL

Figure 5

below the dew point temperature. Calculations for cooling requirements should take into account the conductive cooling effect of the surrounding earth when the shelter or intake duct is below ground. (See Appendix A)

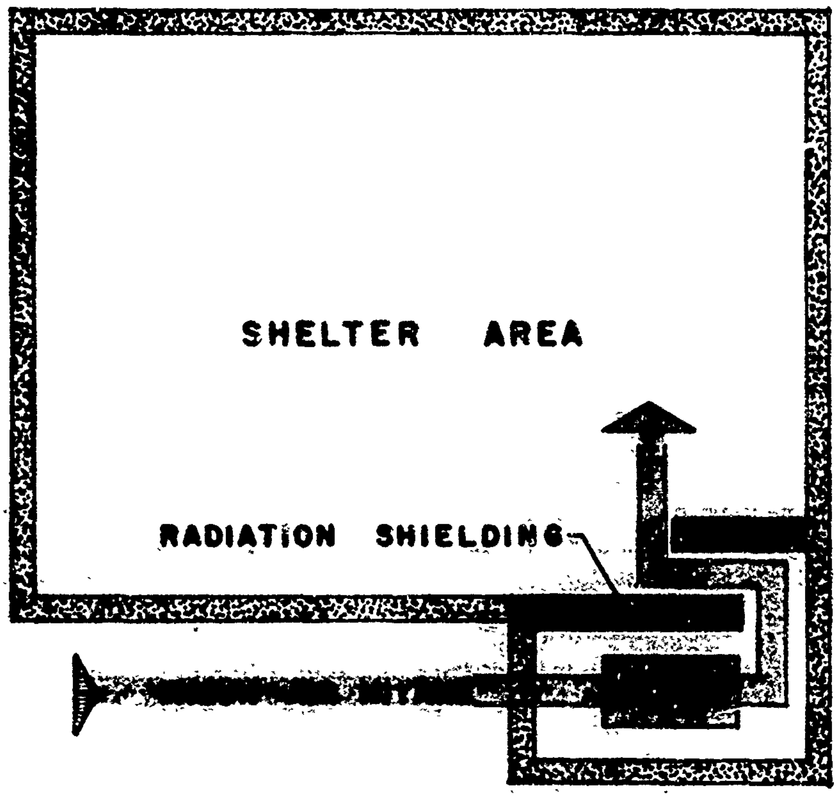
The principal modifications to the normal school ventilation system to adapt it to shelter use are in the intake and filter arrangements. The intake should be screened and weatherproof and should be placed in a location where it is not likely to be choked by debris or invaded by products of combustion.

During the period of fallout, a large percentage of the descending particles can be prevented from entering with the ventilation system by placing intake openings at least 2 feet above any surface (including snow) that might collect fallout, and by designing the intake so that the air turns through at least 90 degrees and enters in an upward direction at a low velocity, so that particles will tend to drop out. (See Figures 3, 4 and 5) A system of baffles and settling chamber in the intake duct is also a feasible method of excluding the large fallout particles of early fallout from the air supply. In any case, fresh air filters are essential, preferably located at the intake fixture. If filters are located within the building, shielding walls are required between the filter room and any occupied shelter space to protect the occupants from radiation due to contaminated material collected by the filters. (See Figure 6) The mass thickness of this shielding should be determined according to volume of entering air. It may be prudent to consider, in the original design of the fresh air system, location and space requirements for future installation of filters against chemical or biological warfare agents.

Filtered fresh air supplied to a shelter may vary from a minimum in winter to 100% in summer, with corresponding variations in the amount of recirculated air. Fresh air fans and recirculating air fans should have the capacity and flexibility to adjust to these different requirements. Although positive displacement rotary blowers have a more constant delivery under varying static pressures, cost considerations usually favor the use of centrifugal fans. The quantity of air delivered by a centrifugal fan at a given speed decreases as the system resistance increases, but this effect can be corrected by means of variable inlet vanes, adjustable dampers or a multi-speed drive.

In schools, separate exhaust fans are usually provided in areas which are sources of moisture, odors and other air-borne nuisances. These areas may include kitchens, sculleries, toilets, shower rooms, teacher's lounges, janitor's closets, shops and science rooms among others.

In order to keep the shelter under positive air pressure and to direct the air flow it may be necessary to close some of the exhaust



FILTER ROOM SHIELDING

Figure 6

dampers and to stop the exhaust fans. An ideal arrangement would be to supply air to sleeping and general activity spaces under sufficient pressure so that it will exhaust successively through kitchen, toilet rooms and (in some cases) the engine generator room to the outside.

3-5 Water Supply

Water should be made available to the shelter in as generous quantities as the situation permits. At least 3-1/2 gallons per person of drinking water should be available. Additional water supply will be useful for personal cleanliness, preparation of food, cleaning utensils, removal of wastes, cooling an engine-generator, cooling the air supply and emergency fire-fighting.

The water requirements for these various uses are not necessarily cumulative, since water used for cooling and dehumidifying the shelter may subsequently be used for engine cooling, personal hygiene, and ultimately, waste disposal. If the public water supply is drawn from wells, there is little danger of contamination from radioactive particles. If, however, water is stored in reservoirs, exposed surfaces may be contaminated. Soluble contaminants are not likely to be present in large concentrations. Although particle contaminants can be removed by filters and soluble contaminates can be precipitated out, removal procedures are more practicable at the water plant itself than in the shelter.

If it is determined that while the public water supply is likely to continue, it is also likely to be contaminated, contamination may not preclude the use of such water for waste disposal, heating, or cooling.

Where installation of a well is not feasible or not economically justifiable, and where the normal water supply cannot be relied upon, the supply of drinking water inside the shelter should be assured either by means of a storage tank or by storage in sealed, shatter-proof containers. Water in a storage tank can be kept fresh by placing the tank in series with the normal water supply and making provision for valving it off during emergencies.

3-6 Food

Prepacked food rations possibly might be supplemented at first with food from a normal use supply in the school kitchen. A semblance of familiarity in the diet could be retained by serving reconstituted milk or chocolate milk and soups or beverages warmed on electric hot plates. It would be desirable, psychologically, to keep a normal three-meal-a-day schedule. If the shelter is operated on two shifts, the food service would operate almost continuously, probably on a cafeteria basis.

3-7 Noise Control

If the normal use school facilities have been planned to hold noise levels down to the usually listed maxima of 32 decibels in classrooms and 40 decibels in multi-purpose spaces, shelter noise levels probably will not exceed 70 decibels. It will help if quiet and noisy activities can be carried on in separated spaces. Emergency mechanical equipment, especially a diesel engine-generator, should be provided with vibration isolators and placed in locations where they will cause the least discomfort.

3-8 Health

Shelter occupants are expected to suffer only transient effects from even a protracted period in the shelter, if reasonable provisions are made for disposal of wastes, personal cleanliness, disease control and first aid.

If normal sanitation practices are not feasible, wastes should be deposited in sealed containers and should be removed from the shelter as soon as it is safe to do so. Paper and burnable rubbish should not be allowed to accumulate because of the possible fire hazard.

Personal cleanliness can be accomplished by sponge bathing from portable wash basins in order to conserve water.

Since colds and other contagious diseases are to be expected among young children it is sensible to designate a space for isolation and continued bed rest capable of accommodating about five percent of the shelter population. Ideally, this space should have its own toilet and sink, a locked storage cabinet for sick room supplies and a hot plate for sterilization of equipment.

Because of limitations of staff and equipment, serious cases of physical or mental illness will receive little diagnostic or therapeutic care. Teachers and others who may have this responsibility would do well to take the basic National Red Cross First Aid Course and perhaps the Red Cross Home Nursing Course called "Care of the Sick and Injured."

3-9 Mental Health

Under emergency stress children tend to be more psychologically resilient than adults. Children of elementary school age respond more favorably to unusual situations if they are able to meet them in familiar social and physical environments. Shelter space arrangements should provide continuity of group relationships rather than adding disruptive influences by breaking up familiar groups. Food, rest, instruction periods, recreation and other features of the daily routine should also be as normal as possible under the circumstances.

Overcrowding, rationing of food and water and the general monotony of shelter life may aggravate basic emotional instabilities in some individuals. Major emotional upsets can have a contagious effect, and some means of control or confinement will be necessary for isolation of such persons.

3-10 Fire Safety

Fire prevention inside a shelter is primarily a matter of good housekeeping and common sense. The structure may be incombustible, but if paper and trash are allowed to accumulate, they can easily be ignited and can quickly produce enough heat and smoke to drive people outside.

Inflammable liquids, gases and open flame devices should not be permitted in the shelter for cooking or any other purposes. Not only is an open flame a possible fire hazard, but also, if combustion is not complete, it is a source of carbon monoxide.

Schools are customarily provided with portable fire extinguishers, which may be brought into the shelter and kept on hand for emergency fire fighting. They have the disadvantage that, one discharged, they cannot be recharged in the shelter. One or more pump-type water extinguishers with refillable tanks may be a useful addition. Carbon dioxide extinguishers or other types which tend to make the air unbreathable have no place in a shelter.

Some codes require that windowless classroom space be provided with sprinklers. If the shelter space is sprinklered, it would be sensible to provide a fire reserve tank to furnish water to the sprinklers in the event that normal water service is disrupted.

3-11 Administration

The administrative group for the shelter would be drawn, logically, from the school's normal administrative, teaching and maintenance staff. The head of this group would establish a daily schedule of all activities and then assume or assign responsibility in the areas of feeding, sleeping, sanitary services, health, morale, maintenance of utilities, communications and radiological monitoring.

Because of the difficulties of providing bunks for all occupants it will usually be most convenient to operate shelters on a double shift. Under such an arrangement it will be necessary for the administrators to divide their schedules. Because of the demanding nature of their responsibilities and the need for mutual support and an exchange of ideas on an adult plane it would be advantageous for the administrative group to have a separate rest area.

Although the normal organization pattern of a school is appropriate for a shelter, it will be effective only if teachers, pupils and families have been trained and prepared for their emergency roles. School administrators will need a detailed plan for placing and maintaining shelter and equipment in operation. There will be many small jobs to be done within a shelter during an emergency and it will be good for pupils to do them or to help do them. Drill and instruction pay off in emergencies. Schools in the United States undoubtedly can provide the civil defense training which is already required for so many European school children.

CHAPTER IV

APPLICATION OF DESIGN INFORMATION

4-1 Existing Schools

Because of the trend during the last few decades towards one-story construction, light structural framing and large glass areas in exterior walls, most existing modern schools are difficult to adapt for fallout or blast shelter. Some older buildings are two or more stories in height, with basement or crawl space below grade which may be relatively easy to adapt for fallout shelter. Many of these older buildings are of wall bearing construction and many have wood framing for the roof and classroom floors which would make them susceptible to blast and fire damage.

Individual classroom heating and ventilating package units are common in modern schools. The central fan systems found in most older schools and some new ones are much better suited to shelter needs, particularly where the shelter can be located near the fan and filter units. Where this is the case, the emergency fresh air supply can be opened to the system, the air flow can be diverted into the ductwork serving the shelter, other ductwork can be dampered off and necessary maintenance be performed without exposing operating personnel to a serious radiation hazard.

Where there is a need for additional space or facilities in the school, usually the most economical solution is to plan the addition to serve as shelter during an emergency. Where no such need exists, it may still be possible to find some area in the existing school which can be remodeled to provide adequate exits, shielding and area for shelter purposes. If shelter inside the building is not feasible, a detached shelter can be built near the school, and used normally for light storage or overflow activities.

If mechanical spaces or tunnels are used for shelter they should be checked to be sure that exits are adequate and that any steam or gas mains in the area are properly housed to minimize danger from possible rupture. Basements and storage rooms should also be checked for adequacy of exits and to be sure that the shelter area can be cleared quickly of any stored materials.

In most cases it will be necessary to add shielding material above or around the shelter area to improve the protection factor. It may prove feasible to install an internal bracing system to support the added weight of this material and to give basement walls and ceilings

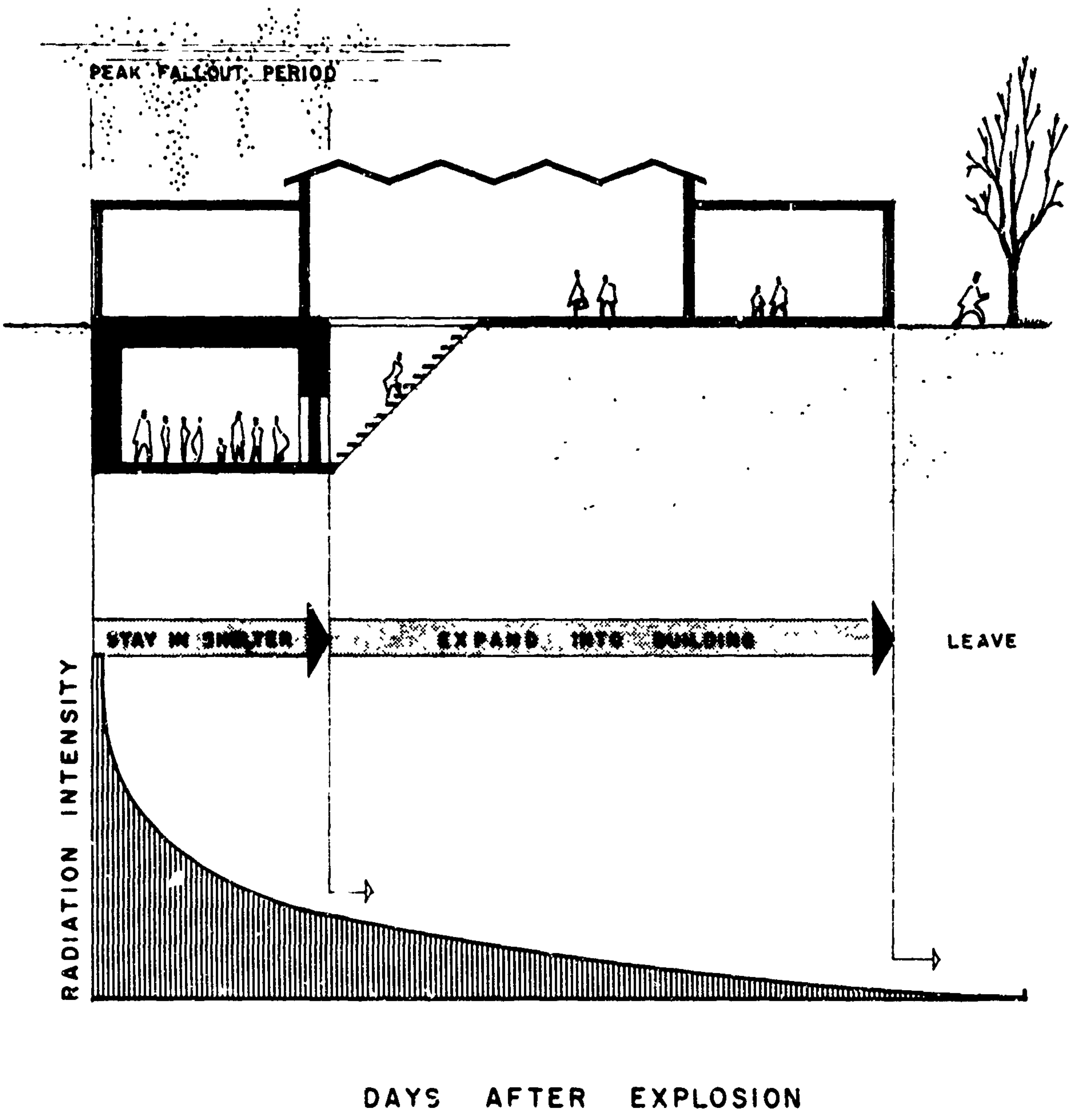

PEAK FALLOUT PERIOD
STAY IN SHELTER
EXPAND INTO BUILDING
LEAVE
RADIATION INTENSITY
DAYS AFTER EXPLOSION

Figure 7

improved resistance to blast and debris loads. Where it is necessary to support such loads, it is best to have the shelter in a portion of the building which is structurally compact.

In existing buildings it may be useful to consider a two-stage or graduated shelter; that is, the use of one space with a relatively high protection factor into which the occupants can be crowded at, say, 6 square feet of net area per person during the initial shelter period, followed by expansion into more comfortable but less protected areas of the building when the radiation hazard has diminished. (See Figure 7)

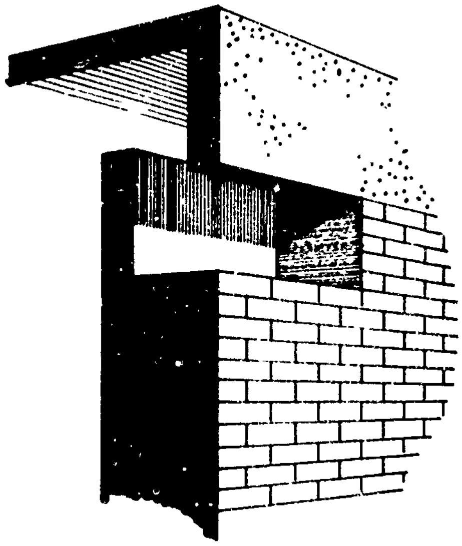
4-2 New Schools of Conventional Design

Even where conventional classrooms with exterior windows are retained, it is possible in new schools to provide shelter in auxiliary spaces which may be without windows or located below grade. Among these may be such spaces as cafeteria and kitchen, clinic, recreation space, music rooms, project areas, counseling rooms and library. Large spaces such as the auditorium and gymnasium are also suitable, but may be expensive to construct as shelter because of the high ceilings and long spans involved.

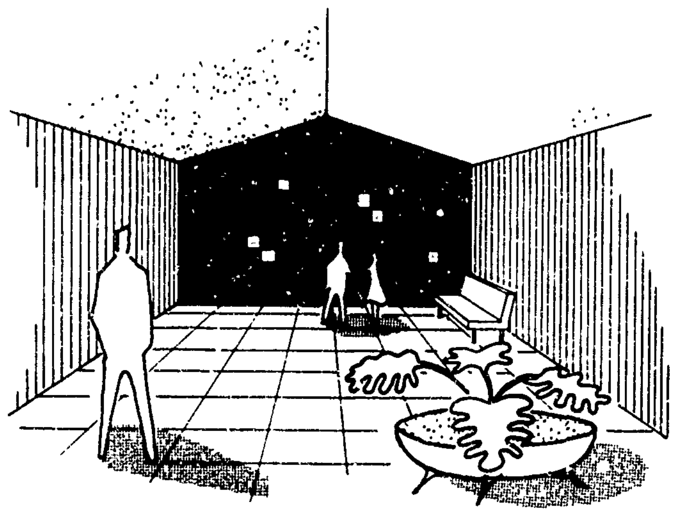
Shelter below grade is usually the most economical protection. Auxiliary spaces can often be placed below grade without violating code or compromising educational objectives. They may also be placed at central locations in classroom units above grade if sufficient shielding mass is provided in the walls and roof.

Where shelter is placed below other portions of the building, care should be taken to insure that shelter exits and air supply will not be cut off due to fire or blast damage in these other portions.

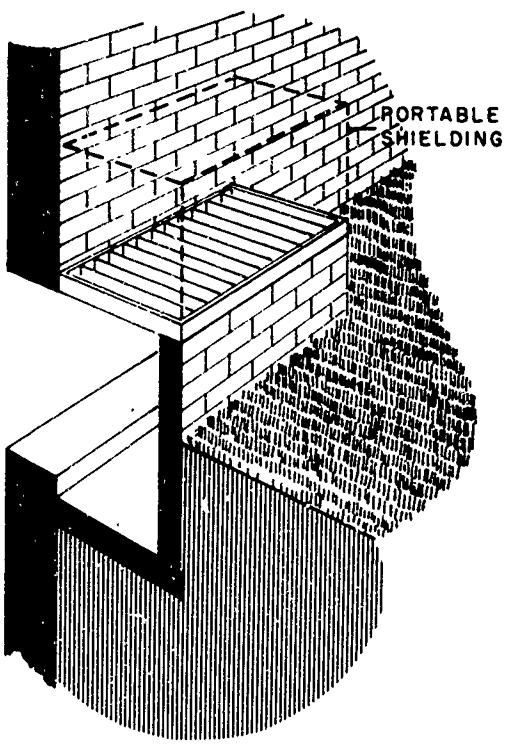
The principle challenge to imaginative design in windowless space is in the creation of an introspective environment that is psychologically comfortable. Advantage can be taken of the several architectural means of developing spatial variety and visual relief and of variations in light levels, colors and materials. A quality of spaciousness is an effective antidote for claustrophobia. It is often possible to interrelate and interconnect spaces so as to give a quality of visual extension to them, yet arrange them in such a way that it is not possible to survey the entire volume at a single glance or become aware of the limits of the space. Project and exhibit spaces and plant material can be used effectively. It is even possible to introduce natural light into the shelter through various ingenious expedients without compromising its protective function. (See Figure 8)



BAFFLE OPENING



LIQUID FILLED GLASS BLOCK



AREAWAY

NORMAL USE - NATURAL LIGHT DETAILS
Figure 8

4-3 New Schools Constructed Underground

One of the more revolutionary concepts in the school design of recent years has been that of the windowless school. Originally developed as a logical solution to the problem of providing an optimum environment for learning, these schools have controlled lighting, year round air-conditioning and acoustic balance. No difficult problems result when a school of this type is placed underground and some substantial economies may be realized. An underground school makes use of a very effective and economical material, earth, as a shield against fallout radiation, and has a substantial inherent resistance to blast.

The educational basis of the design approach in windowless schools is that sustained performance on the part of the teacher and the pupil in the exchange of ideas requires the elimination of environmental factors tending to produce stress and fatigue. In designing for a feeling of physical well-being, careful attention is given to the problems of heating, cooling, air circulation, lighting, sound control, arrangement of facilities and aesthetics. Classrooms are well adapted to the use of teaching aids involving the use of projection equipment, recording equipment, radio and television. All walls are available for use and there are no limitations on possible arrangements in classroom furniture.

In terms of unit cost of construction, the windowless schools, even with complete sprinkler systems and air conditioning, in most cases have been less expensive than conventional schools in the same locality. The principal reason for this is that, once the requirements for daylighting are eliminated, it becomes possible to use very compact plan arrangements with many interior spaces. This results in a reduced area of exterior wall and shorter lines of travel from one part of the building to another and to the exits. An automatic emergency lighting system is required to provide adequate exit lighting in the event of power failure.

The underground location tends to reduce the heating and cooling requirements and operating costs of the mechanical system. In addition, since the building is protected from weather, little needs to be done in the way of outside maintenance.

Not only is the underground school perfectly adaptable to shelter purposes, but also, since it has an emergency capacity of more than three times its normal day-to-day occupancy, it becomes an important unit in the civil defense planning of the community as a whole.

4-4 Shelter Planning Check List

When planning a school shelter, the following check list of major items should be given careful consideration.

1. Adequate exits for normal and emergency use. Door swings should be correct for normal use.

2. Fresh air intake properly designed to eliminate large particles and is located where it is not likely to be affected by debris or fire.

3. Fresh air supply effectively filtered for emergency use.

4. Adequate shielding provided around the filter room.

5. Provision for balancing the addition static head introduced into the ventilation system by emergency filters.

6. Ventilation system designed to keep shelter under positive pressure.

7. Where an emergency generator has been provided, adequate filtered air supplied to the generator room.

8. Full advantage taken of all area that could be used as shelter.

9. Outside utilities evaluated as to probability of service being maintained during emergency.

10. Fuel storage tanks and supply lines safely located.

CHAPTER V

SPECIAL PROBLEMS

5-1 Interruption of Essential Utilities

Although some schools have their own wells and sewage disposal systems, an increasing number depend on public utilities for these services, as well as for electric power. These services will be adequate for shelter requirements provided they can be maintained during the emergency period.

In order for power, water supply and sewage disposal plants to function during the emergency period, essential operating personnel must be provided with shelter, and the plant must be so situated and constructed as to survive nuclear attack without critical damage. These requirements are much easier to meet for conventional water supply and sewage disposal plants than for conventional power plants. Moreover, water can be stored in the shelter and sewage can be ejected on an improvised basis, so that interruption of these services need not be a serious inconvenience.

By contrast, loss of power is a critical problem, since, in a large basement shelter, it means loss of ventilation. Standby sources of light and of heat for cooking can be provided, but manual operation of air handling units is not usually practicable in a large shelter, nor is it economically feasible to construct shelters of sufficient volume to make ventilation unnecessary.

Standby batteries are not regarded as a practical source of emergency power for dual use shelter in schools because of their bulk, relatively short service life and their basic incompatibility with the electrical characteristics of the normal school lighting and mechanical loads.

If normal power is likely to be interrupted, an emergency engine driven electric generator should be provided of adequate size and with sufficient storage of fuel to maintain at least ventilation and minimum lighting over a two-week period. It may also be economically feasible to operate pumps, sewage ejector, and similar first priority equipment from this generator.

It is extremely important that fuel storage is located in an area protected from thermal effects in order to eliminate the possibility of ignition. Supply lines also should be protected from possible severance by ground shock or structural debris.

To avoid generator overload, circuits can be arranged so that, after a power failure, all large motors connected to the emergency power source must be restarted manually and individually. In some cases, reduced voltage starting devices should be considered to reduce starting loads on the generator.

Gasoline engine-generators are available in the smaller sizes. Since gasoline cannot be stored more than about a year without deterioration, it should be used and replaced on a regular schedule. Alternatively, the carburetor may be designed to accept liquefied petroleum gas or natural gas. Liquefied petroleum gas requires a pressurized storage tank; some states forbid burial of these tanks.

Diesel engine-generators are rugged and reliable, but are more expensive than gasoline units in the smaller sizes and are harder to start. Diesel fuels of the straight run type, such as kerosene, can be stored indefinitely; heavier types may settle after a time.

Engines may be water-cooled if a reliable water supply is available. If water is in short supply, it may be advantageous to use remote radiators (outside the shelter) and to locate the generator inside the protected area where it can be serviced and maintained.

5-2 Extreme Climates

Heating will seldom be a major problem in a shelter, since crowded human beings ordinarily will generate more than enough heat to maintain environmental temperature at 50 degrees F., which is considered acceptable for warmly-clothed people in good health. School shelters will ordinarily be at a comfortable temperature at the beginning of the emergency period. In extremely cold climates it may be advisable either to continue operation of the normal heating system or to provide an emergency heat source. Open flame heat sources should not be used because of the fire hazard, the oxygen depletion and the build-up in carbon dioxide which they will create within the shelter. Electrical resistance heating or heat recovered from the cooling system of an engine generator may be used instead.

In hot weather the rise in temperature and humidity due to human metabolism often can be kept within acceptable limits (85 degrees F. effective temperature) by taking advantage of the conductive cooling effect of the surrounding earth or by increasing the rate of ventilation with outside air.

The adequacy of earth conduction for limiting the temperature rise in underground shelters during hot weather depends upon many factors, including the following:

1. Area of wall, floor and ceiling surfaces per occupant.

2. Thickness of overhead cover.

3. Thermal properties (density, specific heat, conductivity, and moisture content) and initial temperature of the surrounding earth, concrete and other construction materials.

4. Quantity, temperature and humidity of the ventilating air.

5. Physical activity and metabolic characteristics of the occupants.

6. Presence of other heat sources.

7. Configuration (size and shape) of the shelter.

A relatively large surface area per person is characteristic of most small shelters and of larger shelters having a narrow elongated shape, such as shelters in tunnels. Data from several tests indicate that in most localities the cooling effect of the surrounding earth is sufficient to maintain an acceptable thermal environment in small shelters during an occupancy period of two weeks assuming that the soil is neither unusually dry, light, nor initially warm.

In the case of a large shelter which does not have mechanical cooling and dehumidifying equipment and relies upon earth conduction, the ventilating system should be designed to supply large quantities of outside air to the occupied spaces during hot weather and to reduce the supply to a minimum during cold weather. Drafts and stagnant areas can be avoided through the use of a simple system of distribution ducts and diffusion outlets. The intake of fresh air through a long buried conduit will tend to reduce daily and seasonal air temperature variations. (See Figure 9)

Where outside effective temperatures exceeding 85 degrees F. are expected, the air supply may have to be cooled and dehumidified. This can be done inexpensively by passing the air through coils cooled with well water, if an adequate well can be developed on the site.

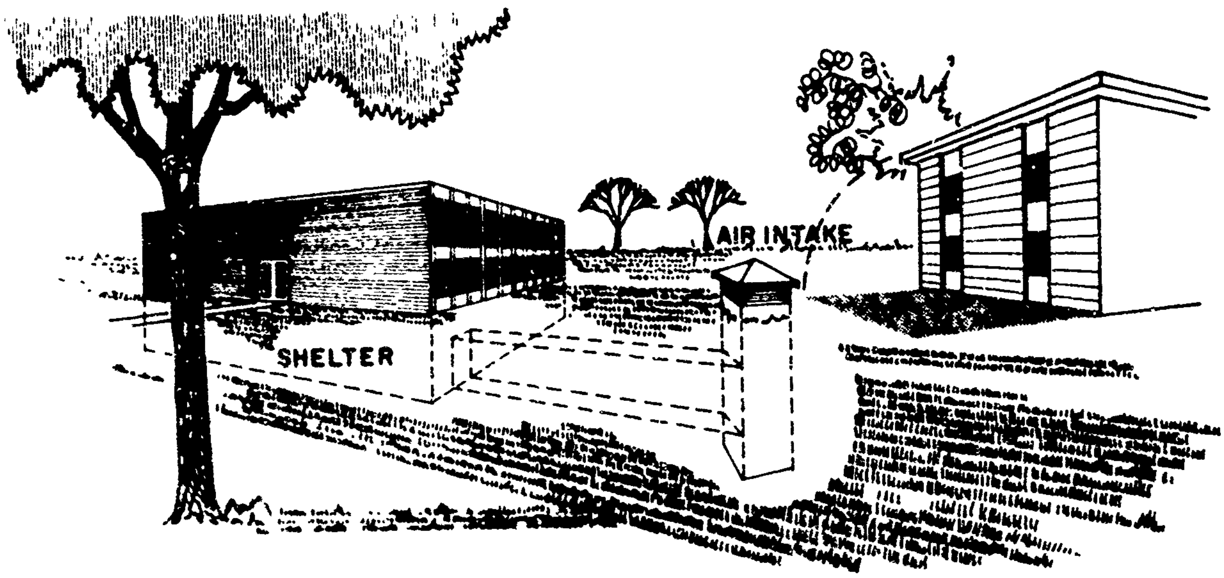


Figure 9

CHAPTER VI

DESIGN EXAMPLES

6-1 Three Proposed Underground School Shelters

The three underground reinforced concrete structures illustrated in Figures 10, 11 and 12 are designed for use as school classrooms under normal occupancy and as fallout shelter for total school populations of 350, 550 and 1100 persons respectively in the event of emergency. The designs are also suitable for use above ground if the mass of the walls and roof is increased to compensate for the loss of the shielding effect of the surrounding earth.

The equipment provided for normal use is also adequate for emergency use, except that sanitary facilities will be augmented with disposable type temporary toilets during an emergency. No additional entrances are required for emergency use. Food and water for a fourteen day stay are stored in the shelter.

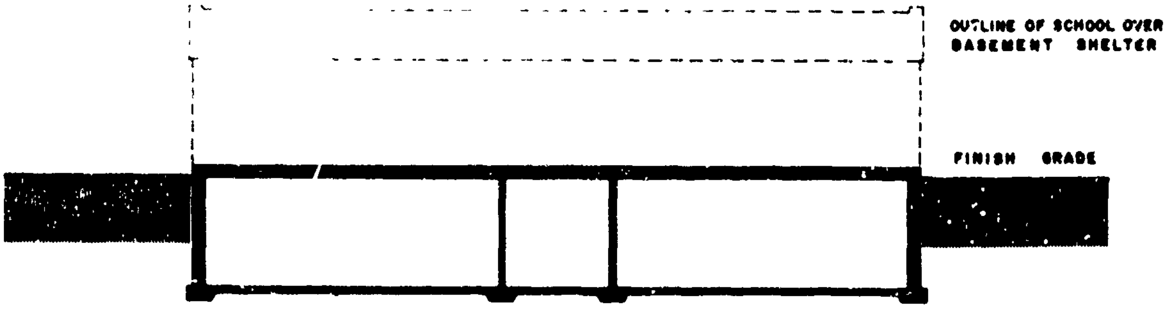
The shelter provides 10 square feet net area per occupant. The ceiling height is 9 feet. Sleeping accommodations are based on four-tier bunks used on a two shift basis. No special provisions are made for decontaminating personnel.

The design does not include equipment for cooling or dehumidifying air supplied to the shelter.

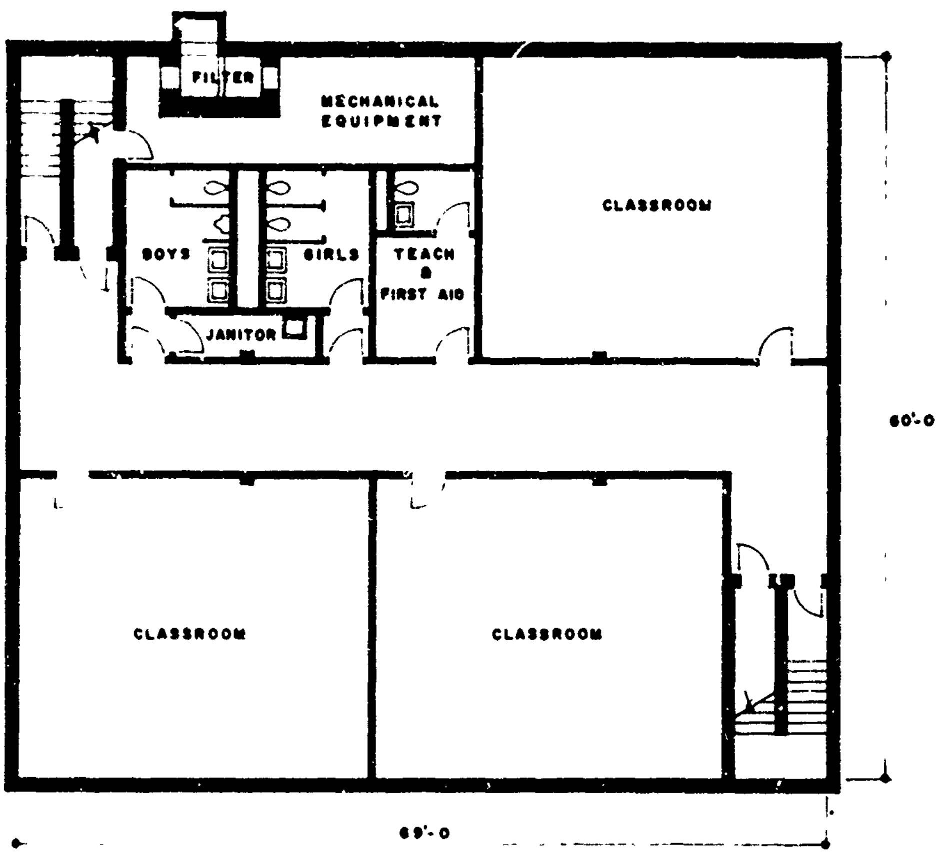
Heating, ventilating and lighting systems are planned to permit operation by emergency power if it is determined that normal power will not be available.

Under these circumstances, the only lighting fixtures included on the emergency circuits are those necessary to maintain 20 ft. candles in administrative and medical areas, 2 ft. candles in sleeping areas and 5 ft. candles elsewhere.

For a school in the northeastern United States with no special foundation problems and with utilities available at the site and operating during the emergency, the estimated shelter related construction costs are as follows:

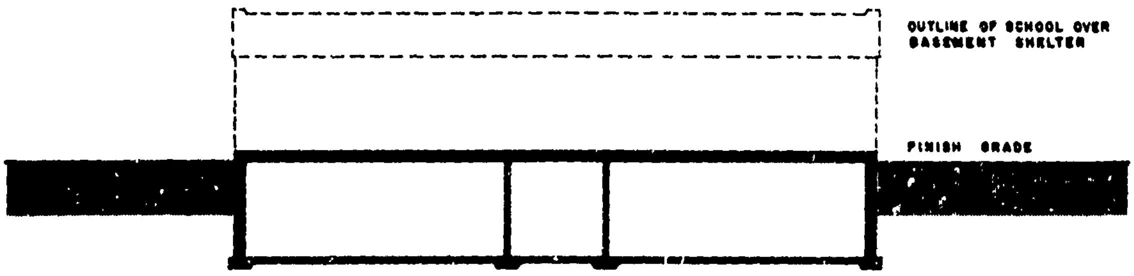


TYPICAL SECTION

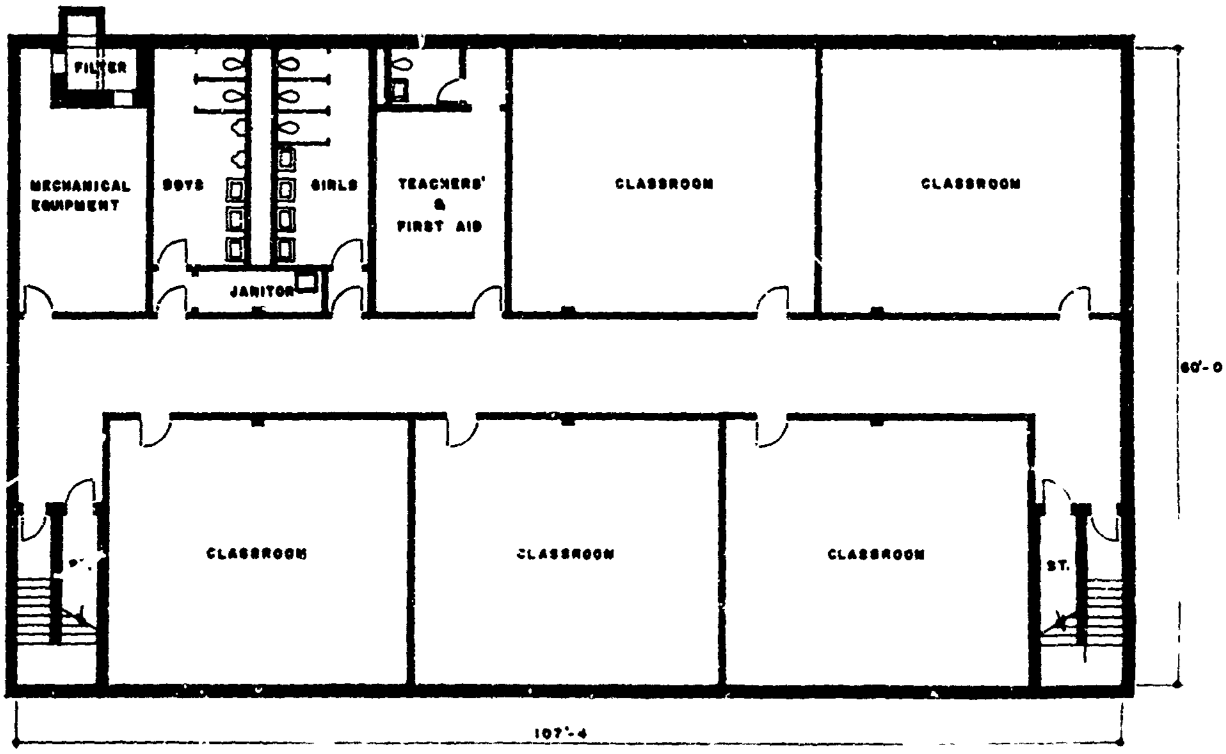


CLASSROOM SHELTER FOR 350 PERSONS

Figure 10

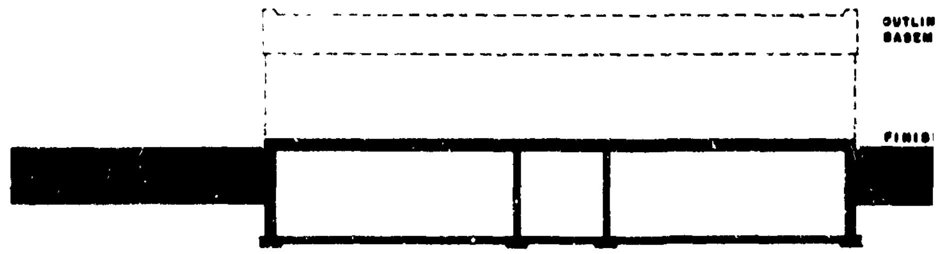


TYPICAL SECTION

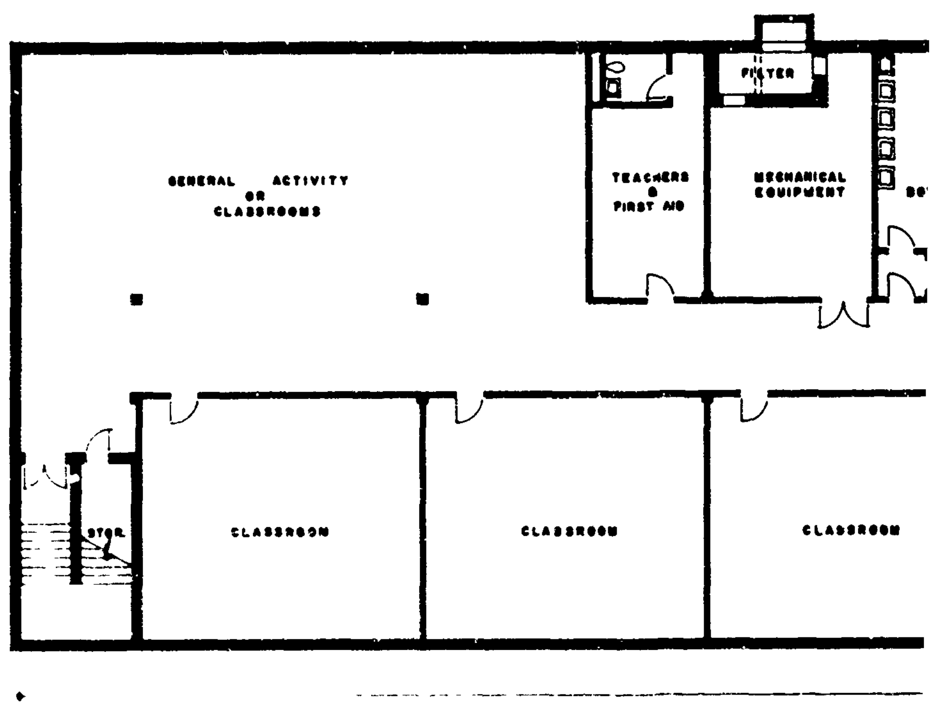


CLASSROOM SHELTER FOR 250 PERSONS

Figure II

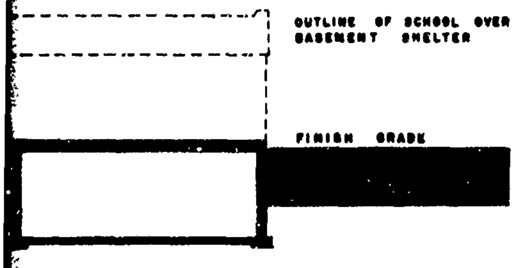


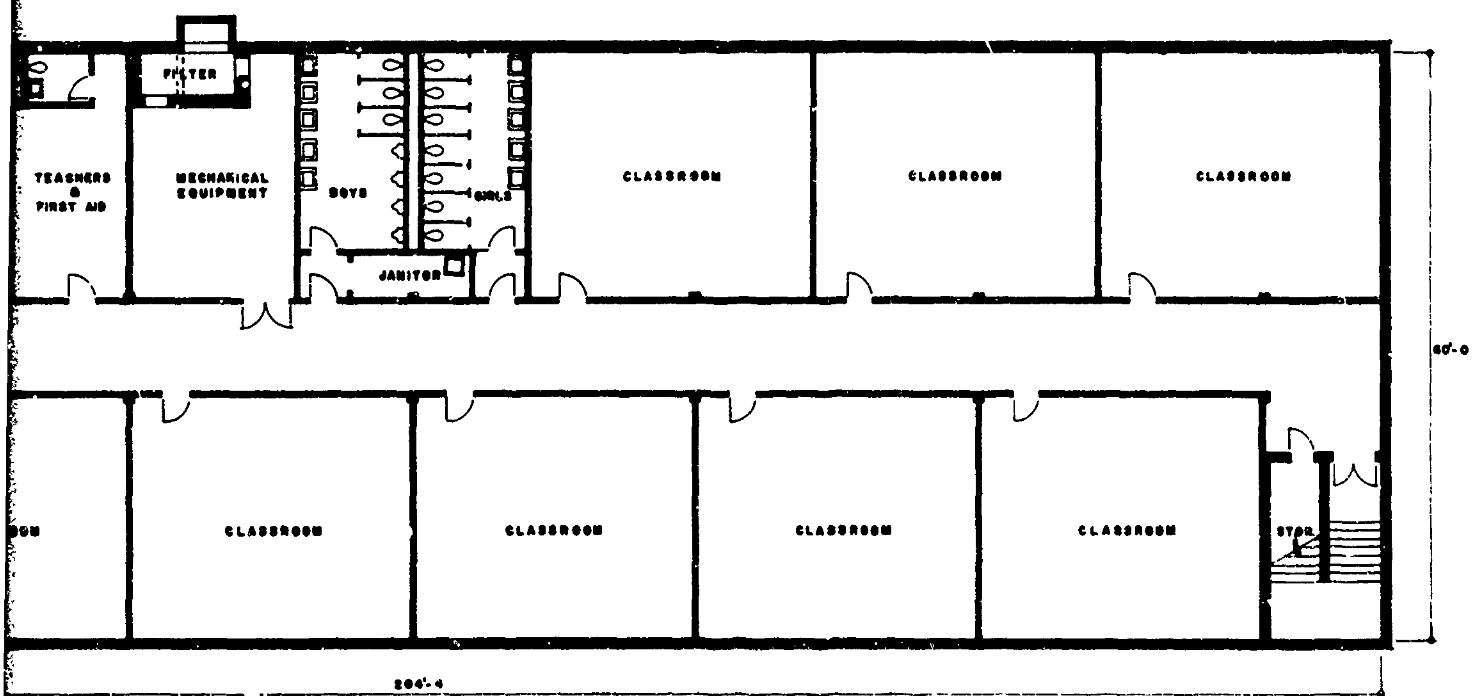
TYPICAL SECTION



CLASSROOM SH

1





CLASSROOM SHELTER FOR 1,100 PERSONS

Figure 12

Shelter Capacity	350	550	1100
Total Cost	$63,640.00	$90,480.00	$163,795.00
Gross Floor Area (sq. ft.)	4,140	6,440	12,260
Total Cost/sq. ft.	$15.40	$14.00	$13.40

If emergency power equipment is necessary, it will add about $1.50 per square foot to these costs.

6-2 Abo Elementary School, Artesia, New Mexico

In a school district where windowless schools have already won acceptance, no serious problems were encountered in placing this entire school below grade (See Figure 13), where the advantages of low maintenance and excellent shielding from fallout radiation are added to those of the controlled environment which has proved excellent for classroom activities. The school has balanced lighting, air-conditioning, and good acoustics. It is designed for an occupancy of 540 pupils during normal school operation and is capable of sheltering 2400 persons during an emergency.

A well system provides water for cooling and emergency shelter use. One of the three stairways is provided with a shower near the outside entrance for decontaminating personnel. A 150 KW engine-generator has been installed to provide emergency power if required.

The total construction cost of the school, including site development, was $467,608.00 or about $13.55 per square foot. This unit cost is not appreciably different from those of comparable schools in the same district, which is an indication that fallout shelter in this type of school may be had for a relatively small cost.

6-3 Hartford Public High School, Hartford, Connecticut

The Hartford Public High School (Figure 14) is an excellent example of a dual purpose fallout shelter in auxiliary school space. Sheltered areas in the basement include the Cafeteria, Kitchen, Food Storage, Toilets and other adjacent spaces. The character of these spaces is such that they are easily adapted to various group activities under shelter conditions.

Features of the design include baffle type stairwells, remote fresh air intakes, air filters, an emergency engine-generator, a well storage tank, incinerators, and a 15 inch concrete slab over the entire shelter area. Shelter below grade has thus been provided for 2500 persons at an additional cost of $139,218.00 or about $55.70 per person sheltered.

6-4 Proposed School Shelter at Ground Level

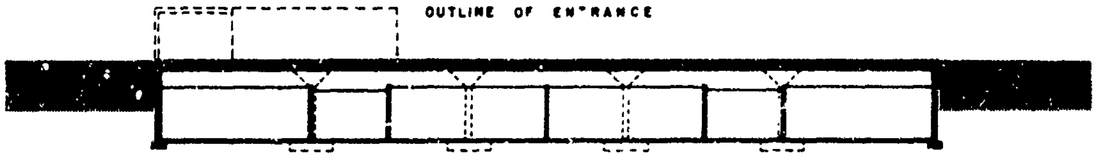
This one-story elementary school (Figure 15) is planned to provide shelter for 510 occupants (at 10 sq. ft. net area per occupant) in the central Multi-Purpose Room and the adjacent Kitchen, Toilets, Clinic, Offices and Storage Rooms. These spaces are connected by off-set corridors to wings containing the classrooms, which enjoy natural light, view and direct access to the outdoors.

Nearly all the sanitary facilities for the school are within the shelter, obviating the necessity for temporary facilities. Administrative offices are conveniently located for emergency use. The smooth sloped roof over the shelter area is designed to be easily decontaminated. Space is provided for installation of chemical and biological filters for the fresh air supply, cooling equipment, emergency engine-generator, and sewage ejector where conditions are such as to require their use.

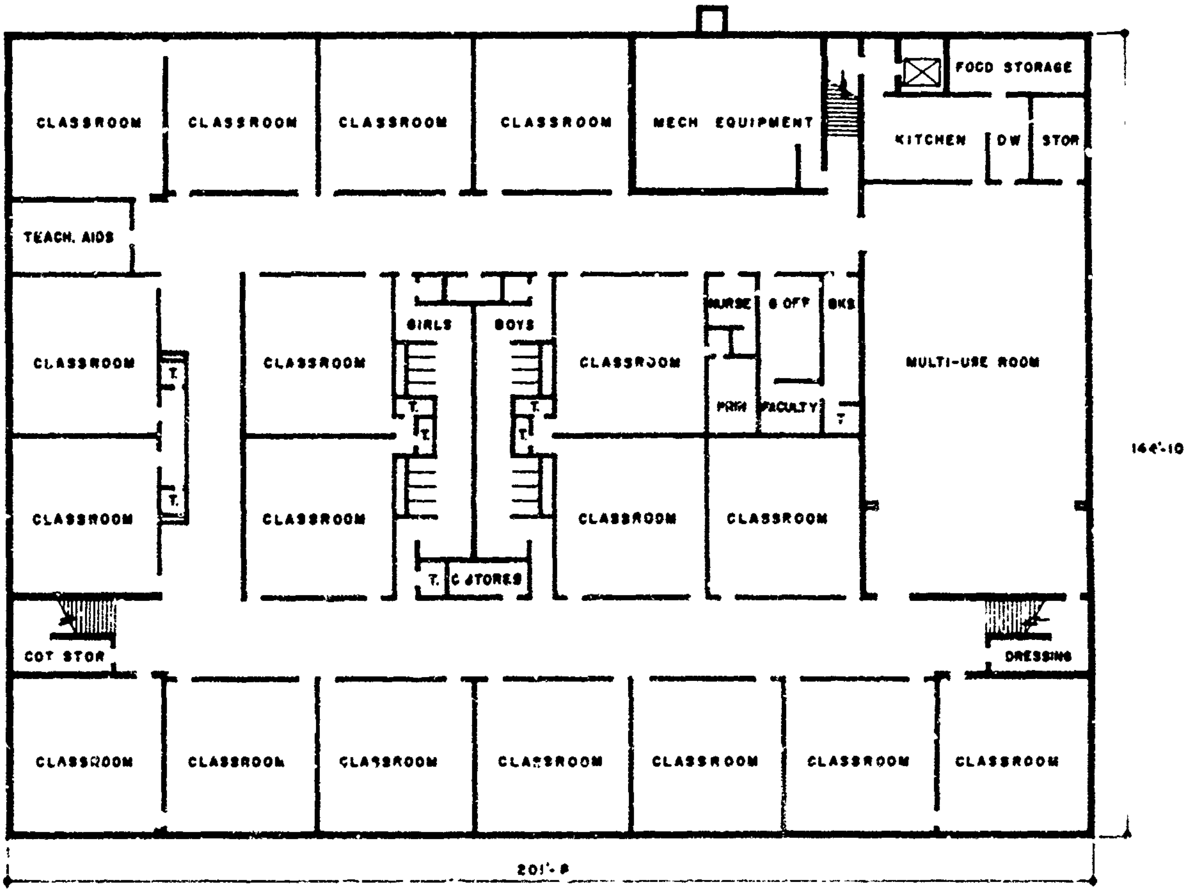
For a school in the north central United States with no special foundation problems and with utilities available on the site the estimated construction costs for the shelter portion alone are as follows:

Shelter Capacity	510
Total Cost	$154,600.00
Cross Floor Area, sq. ft.	8,947
Total Cost/sq. ft.	$17.28

The average unit cost of comparable schools in the area is approximately $15.16/sq. ft. If emergency power equipment is necessary, it will add about $2.40 per sq. ft. to the unit cost of the shelter area.

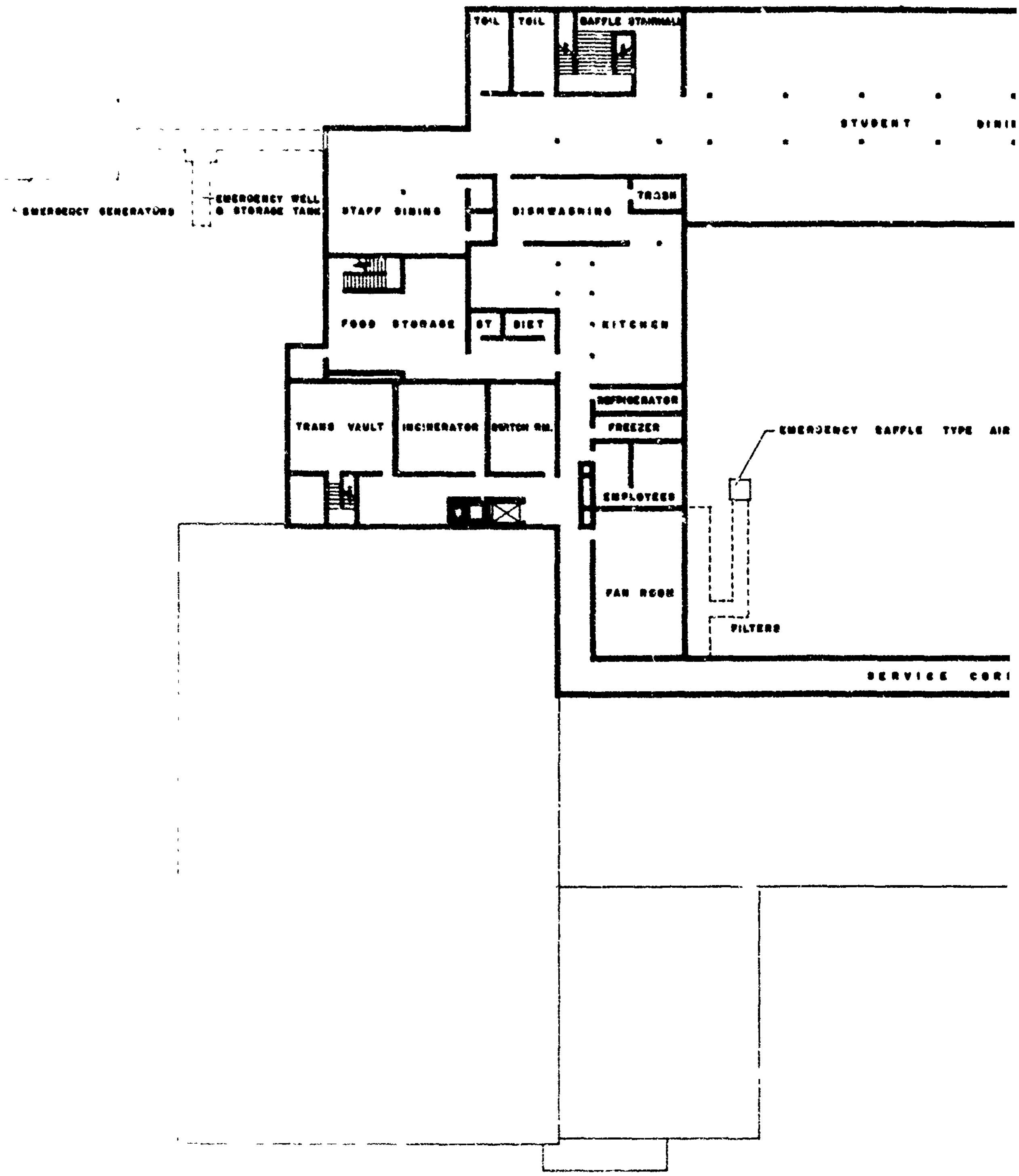


TYPICAL SECTION

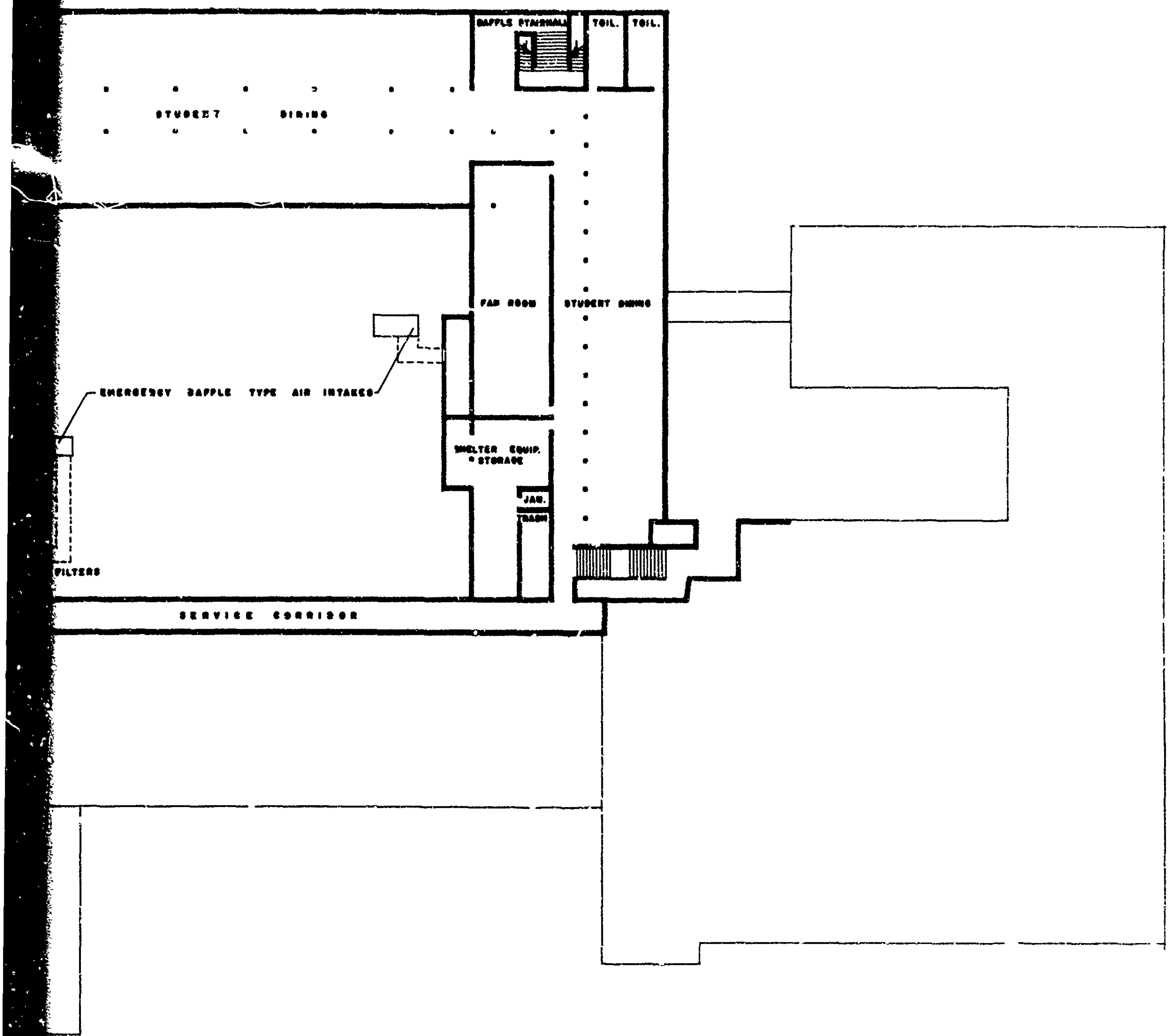


ABO ELEMENTARY SCHOOL AND FALLOUT SHELTER FOR 1940 PERSONS

Figure 13

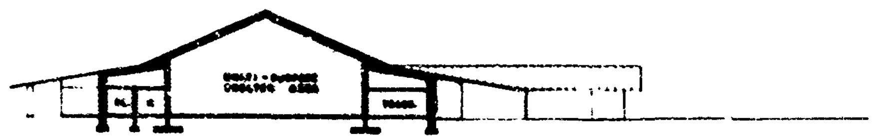


HIGH SCHOOL SHELTER FO

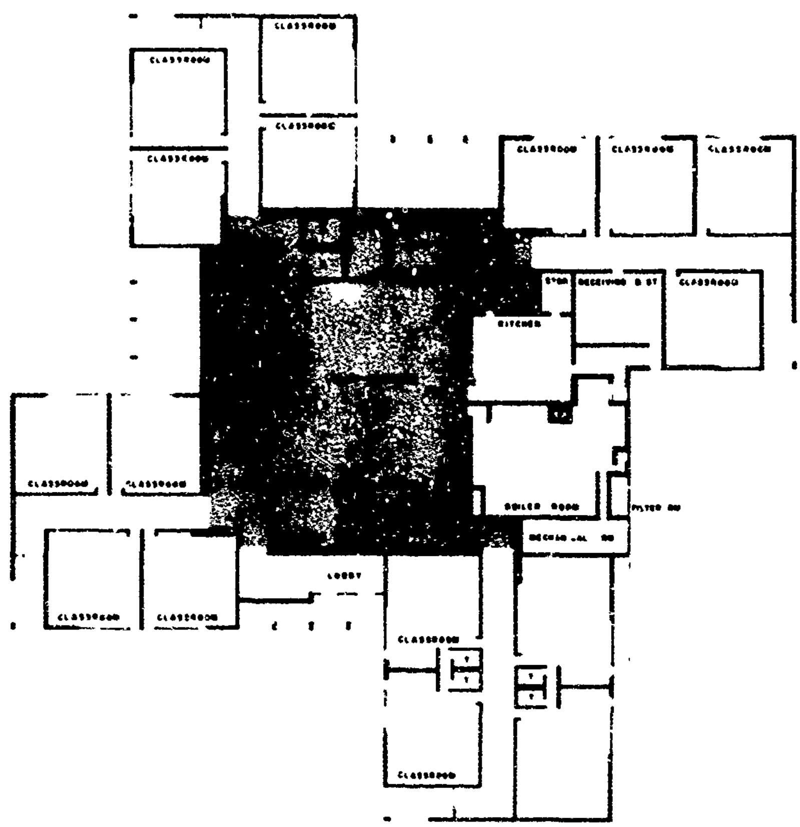


HIGH SCHOOL SHELTER FOR 2500 PERSONS - HARTFORD, CONNECTICUT

Figure 14



SECTION



PROPOSED SCHOOL SHELTER AT GROUND LEVEL

Figure 15

APPENDIX A

ANALYSIS OF THERMAL ENVIRONMENT IN THE ABO SCHOOL

The Abo School was planned to provide its students and teachers with a "stress-free" environment for learning, that is, an environment which eliminates the need for conscious or unconscious adjustment on the part of the individual to variations in lighting, background noise levels or temperature. The windowless classroom, obviously, is well-adapted to excluding the random noise and variable natural light which enter a conventional classroom through its windows. It is also capable of providing a thermal environment superior in every way to that of the conventional classroom, as may be shown by the following analysis.

A uniform thermal environment involves three factors:

1. The temperature of the surfaces which surround the classroom must be kept constant in order to avoid a sensation of heat or cold, due to radiation between the body and these surfaces.

2. Air movement and distribution must be kept constant.

3. A uniform optimum air temperature must be maintained within the classroom.

Windowless and underground classrooms have an almost uniform surface temperature at exterior walls, since these walls have a low coefficient of thermal transmission. In this respect they are much superior to conventional classrooms, as may be seen from the following table in which the mean surface temperature of the outside wall has been calculated for four types of schools under the winter and summer climates of Roswell, New Mexico.

Uniform air movement and distribution can be achieved through selection of the proper size and location for the air handling units. For the purposes of this analysis, the minimum fresh air supply has been set at 15 CFM per student which is ample to prevent oxygen depletion, carbon dioxide concentration, or any accumulation of unpleasant odors.

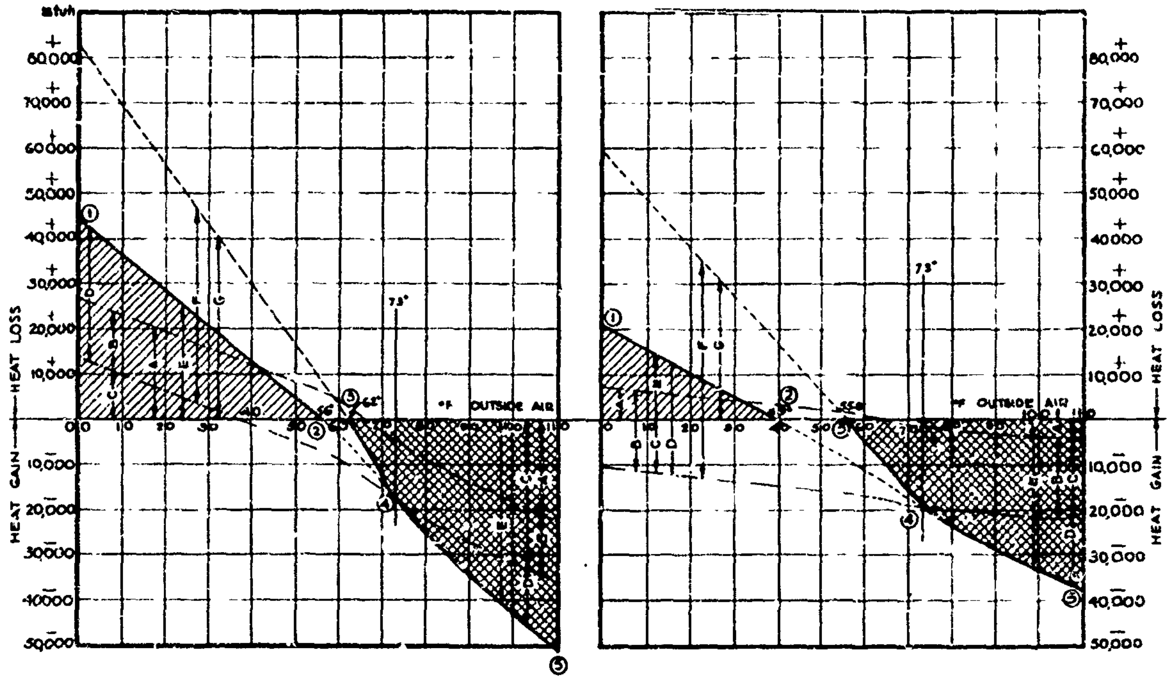
The problems of providing uniform optimum air temperature in the classroom may be approached by considering the thermal diagrams for a conventional school and a windowless school in which the heating or cooling requirement inside the room is plotted against the outside temperature. (See Figure A-1) In each diagram the heating or cooling required (solid line) is obtained by adding the heat gain from lighting and occupants (B) to th heat gain or loss of the unoccupied building (A) and correcting according to the heating or cooling effect of the fresh air introduced (D and F). Note that by increasing the fresh air supply from a minimum at point 2 to a maximum at point 3 it is possible to maintain a constant temperature inside the classroom throughout this interval by means of ventilation alone. For outside temperatures higher than point 3 (62 degrees F. in conventional schools; 55.8 degrees F. in a windowless school) the amount of heat generated by lighting and occupants is greater than the heat loss of the building and mechanical cooling will be required to maintain a uniform classroom temperature. In Roswell, New Mexico, classrooms would have temperatures in excess of 73 degrees F. (optimum) during 49.4% of the school hours of a typical 9 month school year, if they were not provided with air conditioning.

It may be noted by inspection of the diagrams that a windowless school requires much less heating and somewhat less cooling than a conventional school. If the four school types of Table No. 1 are analyzed for heating and cooling loads during a nine-month school period and a twelve-month year in the climate of Roswell, New Mexico, the results are as shown in Table No. 2.

The table shows that "stress free" environment in conventional schools involves considerably higher operating costs than in windowless or underground schools. Initial costs in the Roswell, New Mexico area, as shown by actual construction, are $1.35 per square foot for heating in a conventional school; $3.30 per square foot for heating and cooling in a conventional school; $2.48 per square foot for heating and cooling in a windowless school. The installation cost for heating and cooling in an underground school should be about $2.40 per square foot.

The difference in the initial cost of the mechanical system between a windowless school with air conditioning and a conventional school without it is usually more than offset by the economics obtained through the use of a more compact floor plan and the elimination of exterior openings requiring sash, glazing, calking, painting and venetian blinds or other devices to control light from outside. Consequently, the windowless school is capable of providing the optimum environment for education at an extremely attractive cost.

FIGURE A-1



TYPICAL CLASSROOM HEATING & COOLING REQUIREMENTS IN CONVENTIONAL SCHOOL

TYPICAL CLASSROOM HEATING & COOLING REQUIREMENTS IN WINDOWLESS SCHOOL

LEGEND

HEATING

COOLING

A. Heat loss or gain of unoccupied building.

B. Heat gain due to lighting and occupants.

C. Heat loss or gain of occupied building.

D. Heat loss or gain due to introduction of minimum fresh air.

E. Heat loss or gain of occupied building with minimum fresh air.

F. Heat loss or gain due to introduction of maximum fresh air.

G. Heat loss or gain of occupied building with maximum fresh air.

Solid Line - Heating or cooling requirements as a function of outside temperature

1-2 Heating range

2-3 Cooling by ventilation only

3-4 Cooling by ventilation and refrigeration

4-5 Cooling by refrigeration only

TABLE NO. 1

School Type	Winter			Summer		
	Minimum	Maximum	Average	Minimum	Maximum	Average
Conventional not air-conditioned	23°	73°	68°	85°	102.1°	86.9°
Conventional air-conditioned	23°	73°	68°	73°	98.4°	75.6°
Windowless air-conditioned	69.5°	73°	71.8°	73°	75°	73.7°
Underground air-conditioned	68.6°	73°	71.5°	73°	75.1°	73.6°

TABLE NO. 2

School Type	Conventional not A.C.	Conventional A.C.	Windowless A.C.	Underground A.C.
Btu/sq. ft. year heating	34,900	34,900	9,020	7,185
Btu/sq. ft. year cooling (9 months year)	-	13,600	17,460	17,000
Btu/sq. ft. year cooling (12 months year)	-	28,800	29,150	28,950
Btu/sq. ft. year heating and cooling (9 mos. year)	-	48,500	26,480	24,315
Btu/sq. ft. year heating and cooling (12 mos. year)	-	63,700	38,170	36,765
Comparative operating cost (9 mos. year)	131.5	184	100	94
Comparative operating cost (12 mos. year)	90.5	166	100	95.3
Comparative size of heating plant	139.5	139.5	100	98.7
Comparative size of cooling plant	-	133.1	100	98.5

NOTE: The comparative size of the heating and cooling plant for each of the four types of construction has been calculated according to A.S.H.R.A.E. recommendations.

APPENDIX B

EFFECTS OF NUCLEAR WEAPONS

The material presented herein is of an introductory nature intended to identify and dimension nuclear weapons effects. More complete information may be obtained from "The Effects of Nuclear Weapons," U. S. Government Printing Office, Washington 25, D. C. and Professional Manuals of the Office of Civil Defense Technical Publications Program.

This material is further restricted to low level blast and accompanying levels of initial nuclear and thermal radiation, and to the residual nuclear radiation associated with fallout.

General

All types of explosions - industrial, conventional high explosive weapons, and nuclear weapons - release a tremendous amount of energy within a relatively confined space over a very short interval of time. This energy release is largely in the form of heat energy; a portion appearing as a flash of light and a heat wave, and a portion coverting the explosion products into gases at extremely high temperatures. Inasmuch as these gaseous products are initially confined within a small volume, tremendous pressures exist. As the hot gases expand, a shock wave is developed which propagates outwards from the center of the explosion. This shock wave, or blast wave as it is more usually referred to, is very similar to a rapidly moving wall of water. As the wave encounters an object it engulfs the object with a resulting squeezing action and attempts to drag along the object with a resulting racking action.

In addition to the fact that the total energy release of a nuclear explosion is many thousand times that of a conventional high explosive, thus extending by many orders of magnitude the destructive range of the thermal energy and blast wave, the nuclear explosion is accompanied by two entirely unique weapon effects. These are the initial nuclear radiation and the residual nuclear radiation, commonly referred to as fallout radiation. Whereas the effects of conventional weapons are significant only within several hundred feet of the detonation, the tremendously greater energy release and fallout of a nuclear weapon make its effects of significance to several hundred miles. Thus, weapons effects are no longer a point problem, but an area problem.

Because of these fundamental differences - the effects of nuclear weapons acquire special significance in the architectural and engineering planning of all buildings.

Yield of a Nuclear Weapon

The size of a nuclear weapon, referred to as its power or yield, is expressed in terms of the energy that is released by TNT. Therefore, a one-kiloton (1 KT) nuclear weapon releases an amount of energy equivalent to that released by one-thousand (1,000) tons of TNT, whereas a one-megaton (1 MT) nuclear weapon releases energy equivalent to one-million (1,000,000) tons of TNT. Nuclear weapons have been detonated with energy releases ranging from a fraction of a kiloton through the 20 kiloton weapons detonated over Japan in 1946 to multi-megaton weapons detonated in nuclear tests conducted during the past several years. To describe the effects of large and small yield nuclear weapons, a 2 MT and a 100 KT weapon have been selected for illustrative purposes.

In the explosion of a nuclear weapon, the distribution of energy is determined by both the type of construction of the weapon and the location of the burst (fission, fission-fusion, fission-surface, underground burst). While the fission process maximizes the nuclear radiation effects, the fusion process maximizes the blast and thermal effects. An air burst below 100,000 feet tends to maximize the blast, thermal radiation, and initial nuclear radiation, while minimizing the residual nuclear radiation. A surface burst maximizes the residual nuclear radiation, while minimizing the air blast, thermal radiation, and initial nuclear radiation. An underground burst maximizes the shock effect while little or no thermal or nuclear radiation escapes.

The distribution of energy in a typical air burst of a fission weapon such as was detonated over Japan is as follows: about 85 percent is in the form of heat energy, of which about 50 percent produces blast and shock, and 35 percent appears as thermal radiation (heat and light rays); 5 percent constitutes the initial nuclear radiation produced within the first minute after an explosion; and 10 percent is residual nuclear radiation emitted over a very long period.

Blast Effects

In considering the destructive effect of the blast wave, the two most important characteristics are (1) the overpressure, i.e., the excess over atmospheric pressure caused by the compression of the air within the blast wave, and (2) the dynamic pressure, (the wind pressure caused by the motion of the air particles within the blast wave). Most conventional structures will be damaged to some extent when the overpressure in the blast wave is approximately one pound per square inch - the pressure at which glass windows will usually shatter with an occasional window frame failure.

It is pertinent to call attention to the fact that the above pressures and those to be discussed later are all in terms of pounds per square inch (psi), where one psi is equivalent to 144 pounds per square foot (psf). Inasmuch as conventional wind load design is for approximately 50 pounds per square foot and design floor loads are on the order of only 80 to 100 pound per square foot, the importance of the pressures encountered in the blast wave of a nuclear explosion is immediately evident.

As the blast wave advances away from the center of explosion, the overpressure at the front steadily decreases due to the increased volume and the pressure behind the shock front falls off. The overpressure, which is caused by the compression of the air within the blast wave, acts equally in all directions and thus tends to compress or squeeze any object engulfed by the blast wave. The dynamic pressure, which is caused by the motion of the air particles within the blast wave, acts in direction of the movement of the blast wave and this tends to push or drag any engulfed object.

The difference in the air pressures outside and inside the building produces a force which can cause damage. After the blast wave has completely engulfed the building, not only will the building walls and roof experience this force, but also the frame of the building will be subjected to a drag force caused by the dynamic pressure. Thus, when the blast wave encounters a building, there is at first a buildup of pressure on the front face. This is followed by a gradual unloading of the front face as the blast wave progresses past the face and sequential loading of the roof, the sides and lastly the back face.

The structural damage sustained by a building will depend on the relationship of the loading to the structural strength and rigidity. This structural strength and rigidity will in turn depend upon the basic structural system, materials of construction, sizing of individual elements, connection details, etc. The blast loading will depend upon the size and location of the nuclear weapon detonation, the building size, shape, and position.

In addition to the structural system of a building, the blast wave can also inflict damage on exposed items such as utility lines and connections to the building and mechanical equipment installed outside the buildings. To prevent damage to people, material, and other items inside a building, it is necessary to provide some positive method of excluding the blast from entering the interior of buildings, or to provide local protection within.

Nuclear Radiation

The nuclear radiations emitted following the detonation of a nuclear weapon are divided into two categories - initial and residual. The initial radiations (those emitted within 1 minute after the explosion) consist of gamma rays and neutrons capable of penetrating large distances in air and producing injurious effects in living organisms. Residual radiations, or fallout (those emitted after 1 minute) consist of alpha and beta particles and gamma rays.

Initial Nuclear Radiation

The initial nuclear radiation problem, like the blast and thermal radiation problems, is a local one, seriously affecting only the area within a few miles of ground zero. For example, the initial nuclear radiations from a 2 MT weapon would probably cause no deaths to individuals beyond two miles from ground zero, affecting an area of perhaps only 12 square miles. In contrast, the residual (fallout) radiations can cause deaths hundreds of miles away, thus affecting areas of over a thousand square miles. The following tabulation lists the effects of initial nuclear radiation on exposed personnel in the open at various distances from 100 KT and 2 MT weapons. These effects decrease rapidly with distance and cause no serious radiation sickness even at 2 miles from a 2 MT weapon.

INITIAL RADIATION EFFECTS ON
EXPOSED PERSONNEL

Effects*	Distance from Burst (Miles)	
	100 KT	2 MT
LD 100	0.95	1.5
LD 50	1.00	1.6
LD 20 & SD 100	1.05	1.7
LD 0 & SD 50	1.10	1.8
SD 25	1.15	1.9
SD 10	1.20	2.0
SD 0	1.30	2.1

*Effects are expressed in terms of the percentage of the exposed population who would become sick or die. Thus, LD 50 or "Lethal Dose 50," means that 50% of the personnel would die, whereas SD 10 or "Sick Dose 10," that 10% would become sick.

Residual Nuclear Radiation (Fallout)

When a nuclear weapon is detonated on or near the ground so that the fireball contacts the ground, thousands of tons of pulverized and vaporized soil and other materials are carried into the atmosphere in the nuclear cloud. These particles are propelled by a strong updraft and will rise very rapidly to a great height. For example, within eight minutes following a 2 MT surface burst, the cloud may reach its maximum altitude of 70,000 to 80,000 feet. The cloud contains vast quantities of radioactive particles. The particles range in size from visible bits and flakes to submicroscopic particles.

Radioactive fallout is the surface deposition of the radioactive material which has been formed and carried aloft by the nuclear explosion. The particles are then acted upon by two forces - gravity and the winds. The large particles settle to the ground rapidly, the smaller ones more slowly. The rate and place of fall depends on the particle's size, shape, and weight, and the wind speed and direction at various altitudes.

Under normal wind conditions, the heavier material may fall within an hour of two into a roughly circular pattern around ground zero. The lightest particles formed will enter the stratosphere and remain suspended for long periods and probably travel many thousands of miles before descending. The intermediate weight particles will probably reach the earth within a few hundred miles of ground zero. These particles may be expected to form a generally elongated cigar shaped pattern of contamination on the ground.

The radioactive material which is carried in the fallout consists of: (1) fission products which are particles created in the fissioning of the weapon material; (2) particles made radioactive by the neutrons released at the time of the explosion - these particles may have been part of the weapon, casing, weapon tiggering mechanisms, or earth and debris; and (3) the unfissioned uranium or plutonium of the weapon itself.

The unfissioned material generally emits alpha particles, whereas the fission products and the neutron-induced radioactive products are beta and gamma emitters. The alpha radiation may be ignored in the radiation shielding design for protection against fallout since it can be stopped by a thin layer of clothing or the skin itself. The alpha radiation can be a hazard if it enters the body either by ingestion, inhalation or through skin abrasions. However, even this usually may be ignored relative to the ingestion hazard posed by the much more numerous beta and gamma emitters.

Beta particles, which are high energy negative and positive electrons, can be dangerous both internally and externally. The external problem is a relatively trivial one since beta particles are stopped by small thicknesses of solids; their range in wood, water or body tissue being only about a tenth of an inch. Thick clothing will also stop them. They are hazardous, however, when they come in direct contact with the skin or are ingested or inhaled.

Gamma rays, which are high energy electromagnetic radiations like X-rays, are very penetrating and determine completely the amount of material needed for shielding against fallout. Radioactive fallout particles emit gamma rays varying in energy. Even relatively thin shields afford some protection against the rays of lower energy, whereas, adequate protection against the more energetic rays may require considerable mass thicknesses of material.

The basic requirement for protection against fallout is to provide a shield against gamma radiation. Such a shield will protect against the beta radiation as well. The alpha-, beta-, and gamma-emitters must also be excluded from the protected area. This may necessitate both the decontamination of entering personnel and/or the filtration of air.

Beta and gamma rays are emitted by the nuclei of so-called "radioactive" atoms. In the process of emitting these rays a radioactive atom becomes a stable atom, identical with any other atom of its species, and no longer constitutes a hazard. Thus, the intensity of radiation from fallout constantly decreases or decays with time. (See Figure B-1) Radioactive fallout decays by approximately a factor of 10 for every multiple of 7 in time. For example: if the gamma intensity is 5000 roentgens an hour after the burst, its value 7 hours after the burst will be down to 1/10 of 5000 or 500 roentgens; its value 49 hours (approximately 2 days) after the burst will be down to 1/100 of 5000 or 50 roentgens; its value 14 days after the burst will be down to 1/1000 of 5000 or 5 roentgens and so on.

Biological Effects of Nuclear Radiations

In general, the biological effects of exposure to nuclear radiations result from the ionization of and damage to, molecules in the body tissue. The nuclear radiations of primary interest in the problem of protection are the gamma rays.

The basic unit of exposure dose is the roentgen (r). The dose rate, or intensity, measured in roentgens per hour (r/hr), is the time rate at which the radiation dose is delivered.

Some of the effects of nuclear radiations on living organisms depend not only on the total dose, but also on the dose rate. For example, 700 roentgens over the whole body delivered in a short time (less than an hour) would almost inevitably prove fatal to a human. However, if the same dose were delivered over a long period (10 years), at a more or less uniform rate there would probably be no noticeable effects. The reason is, that most of the cells damaged by radiation can be replaced by new cells provided the percentage damaged by radiation is not too high. If recovery cannot keep pace with the damage, injury will result. This explains one of the most characteristic features of radiation injury: the lag that usually occurs between even severe exposure to radiation and the development of pathological symptoms.

Rather large acute radiation doses are not uncommon under ordinary circumstances. For example a flourescent screen examination usually results in a received dose of 4 to 40 roentgens, and X-ray pregnancy examination may result in a dose as high as 70 roentgens. These are not, however, whole body exposures, so that the injury is less severe than the case for nuclear radiation.

Thermal Radiation

Because of the enormous amount of energy liberated in a nuclear weapon, very high temperatures are attained. As a consequence of the high temperatures in the ball of fire, (similar to those in the center of the sun), a considerable portion of the nuclear energy appears as thermal radiation. For every 1 KT of the nuclear explosion, approximately 400,000 kilowatt hours of energy are released as radiant thermal energy within a second of the detonation.

Thermal radiation will contribute to overall damage by igniting combustible materials. In addition, it is capable of causing skin burns on exposed individuals at distances from the explosion where the effects of blast and initial nuclear radiation are not critical. The thermal energy from a specified explosion received by a given surface will be less at greater distances from the explosion for two reasons: (1) the spread of the radiation over an ever-increasing area as it travels away from the fireball, and (2) attenuation of the radiation in its passage through the air. Unless scattered, the thermal radiation from a nuclear explosion travels like light in straight lines from its source - the ball of fire. Any solid, opaque material, such as a wall, a hill, or tree, located between the object and the fireball will thus act as a shield and provide protection from thermal radiation. Transparent materials, on the other hand, such as glass or plastics allow thermal radiation to pass through only slightly reduced in intensity.

The proportion of the energy appearing as thermal radiation will be greater for an air burst than for a surface burst - where the ball of fire actually touches the earth or water. In a sub-surface burst, either in the earth or underwater, nearly all the thermal radiation is absorbed by the earth or water.

The ignition of combustible materials by thermal radiation depends upon a number of factors, the most important are: (1) the nature of the material itself, (2) the thickness and moisture content of the material, (3) the amount of thermal energy falling on a unit area and (4) the intensity of radiation.

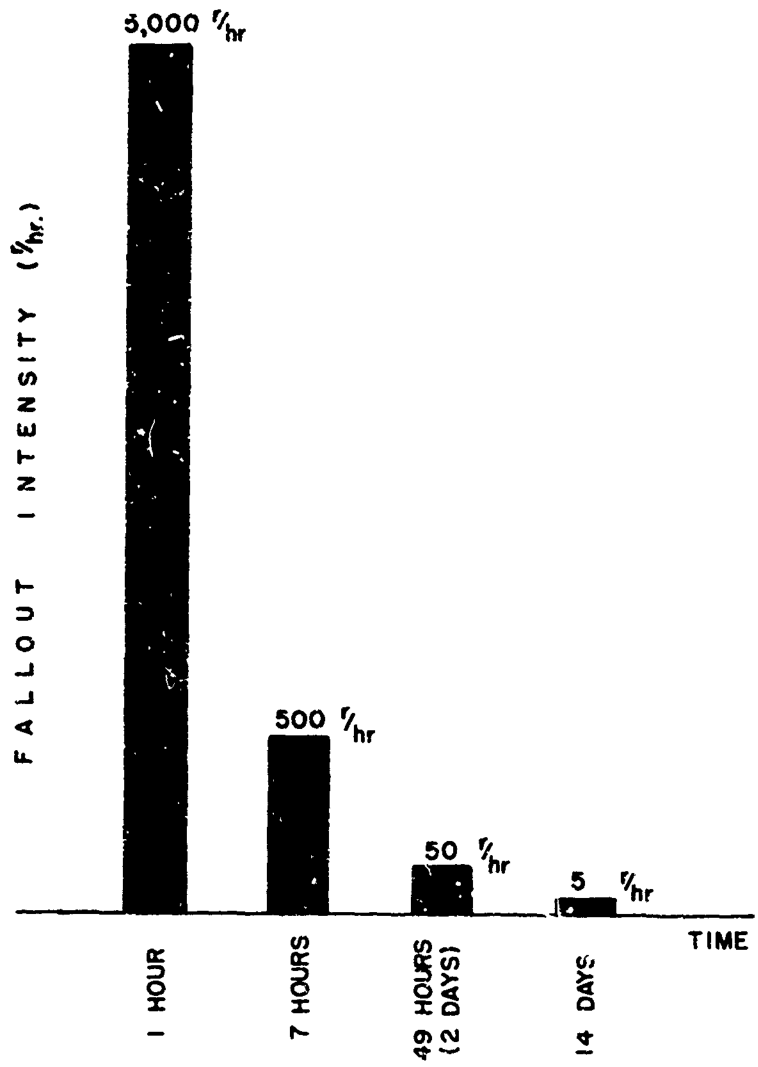


FIGURE B-1

DEPARTMENT OF DEFENSE
OFFICE OF CIVIL DEFENSE

DECREASE OF FALLOUT ACTIVITY WITH TIME

APPENDIX C

GLOSSARY OF TERMS

Air Burst: The explosion of a nuclear weapon at such a height that the expanding fireball does not touch the earth's surface.

Fireball: The luminous sphere of hot gases which forms a few millionths of a second after a nuclear explosion and immediately starts to expand and cool.

Blast Loading The loading (or force) on an object caused by the air blast from an explosion striking and flowing around the object. It is a combination of overpressure and dynamic pressure loading.

Blast Wave: A pressure pulse of air, accompanied by winds, propagated by an explosion.

Contamination: The deposit of radioactive material on the earth's surface and other exposed surfaces following a nuclear explosion.

Core: That portion of a multi-story building assigned to the vertical elements required for distribution of mechanical services and for circulation, such as ductshafts, pipeshafts, elevators and stairwells. It may also contain other spaces which are repeated on each floor, such as toilet rooms and janitor's closets.

Radioactive Decay: The decrease in activity of any radioactive material with the passage of time, due to the spontaneous emission from the atomic nuclei of either alpha or beta particles, sometimes accompanied by gamma radiation.

Fission Products: The complex mixture of substances (about 200 isotopes of more than 30 elements) resulting from nuclear fission.

Flash Burn: A burn caused by excessive exposure of bare skin to thermal radiation.

Fusion:	The process whereby the nuclei of light elements combine to form the nucleus of a heavier element with the release of substantial amounts of energy.
Gamma Rays:	Electromagnetic radiations of high energy and great penetrating power originating in the atomic nucleus and accompanying many nuclear reactions
Initial Nuclear Radiation:	Nuclear radiation, primarily neutrons and gamma rays, emitted from the fireball and the cloud column during the first minute after a nuclear explosion.
Net Area:	Space usable for human occupancy excluding walls, toilets, storage and mechanical rooms.
Overpressure:	The transient increase in pressure in the shock wave of an explosion, usually expressed in pounds per square inch.
Roentgen:	A unit of exposure dose of gamma radiation.
Shear Wall:	A stiff structural element incorporated as a wall or part of a wall in a building and designed to be capable of resisting horizontal forces such as those due to wind, earthquake and blast.
Shielding:	Any material or obstruction which absorbs radiation and protects personnel or materials from the effects of a nuclear explosion.
Shock Wave:	A pressure pulse in the surrounding air, earth or water initiated by the expansion of the hot gases produced in an explosion.
Skeleton Framing:	A system of construction in which the supporting elements of the building structure form an open framework and in which the exterior and interior walls carry no vertical load other than their own weight.
Surface Burst:	The explosion of a nuclear weapon at a height above the surface less than the radius of the fireball.

Thermal Radiation:	Electromagnetic radiation emitted from the fireball as a consequence of its very high temperature, consisting essentially of ultraviolet, visible, and infrared radiations.
Yield:	The total effective energy (nuclear radiation, thermal radiation and blast) released in a nuclear explosion, usually expressed in terms of the tonnage of TNT required to release equivalent energy in an explosion.

APPENDIX D

REGIONAL OFFICES

OCD Region 1
Oak Hill Road
Harvard, Massachusetts

Connecticut
Maine
Massachusetts
New Hampshire
New Jersey
New York
Rhode Island
Vermont

OCD Region 2
Olney, Maryland

Delaware
District of Columbia
Kentucky
Maryland
Ohio
Pennsylvania
Virginia
West Virginia

OCD Region 3
P. O. Box 108
Thomasville, Georgia

Alabama
Florida
Georgia
Mississippi
North Carolina
South Carolina
Tennessee

OCD Region 4
Battle Creek, Michigan

Illinois
Indiana
Michigan
Minnesota
Wisconsin

OCD Region 5
P. O. Box 2935
University Hill Station
Denton, Texas

Arkansas
Louisiana
New Mexico
Oklahoma
Texas

OCD Region 6
Denver Federal Center
Building 50
Denver 25, Colorado

Colorado
Iowa
Kansas
Missouri
Nebraska
North Dakota
South Dakota
Wyoming

OCD Region 7
Naval Auxiliary Air Station
Santa Rosa, California

Arizona
California
Hawaii
Nevada
Utah

OCD Region 8
Everett, Washington

Alaska
Idaho
Montana
Oregon
Washington

Technical Memoranda Series (60 Series)

*61-1 Minimum Technical Requirements for Family Shelters

*61-2 Information on the Submission of Shelter Designs for Review by the Office of Civil Defense (Superseded by TM 62-20)

*61-3 Minimum Technical Requirements for Group (Community) Shelters

61-4 General Information on Family Shelters

61-5 Minimum Technical Requirements for Filters Community Shelters

61-6 Minimum Technical Requirements for Engine-Generator Sets for Shelter Purposes

62-5 Minimum Technical Requirements for Shelter Doors & Hatches (Blast)

62-6 Minimum Technical Requirements for Manual Ventilators

62-7 Minimum Technical Requirements for Anti-Blast Valves

*62-9 Minimum Technical Requirements for CBR Filters for Use in Emergency Operating Centers

*62-14 Prevention and Control of Pests in Fallout Shelters

*62-18 Information on the Submission of Projects for Development and Test at the Protective Structures Development Center

*62-20 Information on the Submission for Standardized Shelter Designs for Review by the Office of Civil Defense

Design Studies & Engineering Case Studies

1. Family Shelters (DSF 65 series)
*2. School Shelters (DSS 55 series)
*3. Community Shelters (DSC 45 series)
*4. Garage Shelters (DSG 35 series)
5. Emergency Operating Centers (EOC 30 series)
6. Emergency Command Posts (ECP 25)
7. Industrial Plants (I 20)
8. Hospitals (H 15)
9. Apartments & Commercial Buildings (AC 10)
10. Special Structures (SS 5)

*Published to date