P.S.D.C. — TR — 1
15 OCTOBER 1964

OFFICE OF
CIVIL DEFENSE

AD612624

CORPS OF ENGINEERS
U.S. ARMY

TECHNICAL REPORT

DUAL PURPOSE COMMUNITY FALLOUT SHELTERS 200 & 1000 PERSONS

COPY	OF	
HARD COPY	$.	
MICROFICHE	$	

DEPARTMENT OF THE NAVY
BUREAU OF YARDS AND DOCKS

PROTECTIVE STRUCTURES DEVELOPMENT CENTER

FORT BELVOIR, VIRGINIA

Best
Available
Copy

Qualified requestors may obtain copies of this report from Defense Documentation Center.

The DDC will make copies of this report available to the Clearinghouse for Federal Scientific and Technical Information, National Bureau of Standards, Department of Commerce, for sale to the general public.

CLEARINGHOUSE FOR FEDERAL SCIENTIFIC AND TECHNICAL INFORMATION CFSTI
INPUT SECTION 410 11

LIMITATIONS IN REPRODUCTION QUALITY OF TECHNICAL ABSTRACT BULLETIN DOCUMENTS DEFENSE DOCUMENTATION CENTER (DDC)

1 AVAILABLE ONLY FOR REFERENCE USE AT DDC FIELD SERVICES COPY IS NOT AVAILABLE FOR PUBLIC SALE

2 AVAILABLE COPY WILL NOT PERMIT FULLY LEGIBLE REPRODUCTION REPRODUCTION WILL BE MADE IF REQUESTED BY USERS OF DDC

A COPY IS AVAILABLE FOR PUBLIC SALE

B COPY IS NOT AVAILABLE FOR PUBLIC SALE

3 LIMITED NUMBER OF COPIES CONTAINING COLOR OTHER THAN BLACK AND WHITE ARE AVAILABLE UNTIL STOCK IS EXHAUSTED REPRODUCTIONS WILL BE MADE IN BLACK AND WHITE ONLY

TSL-121-2 65

DATE PROCESSED

PROCESSOR

PSDC-TR-1

DUAL PURPOSE COMMUNITY FALLOUT SHELTERS
200 and 1000 Persons

15 October 1964

This report has been reviewed in the Office of Civil Defense and approved for publication. Approval does not signify that the contents necessarily reflect the policies of the Office of Civil Defense.

Prepared By

PROTECTIVE STRUCTURES DEVELOPMENT CENTER
JOINT CIVIL DEFENSE SUPPORT GROUP
OFFICE OF THE CHIEF OF ENGINEERS/BUREAU OF YARDS AND DOCKS

For

OFFICE OF CIVIL DEFENSE

PREFACE

The study covered in this report was conducted under authority of the Department of Defense, Office of Civil Defense. Funds were made available for management and operation of the Protective Structures Development Center by Project Order Number OCD-OS-62-256 dated 23 June 1962.

The period covered by this report is July 1962 through August 1963.

The study was made at the Protective Structures Development Center, Fort Belvoir, Virginia, a part of the Joint Civil Defense Support Group, sponsored by the Corps of Engineers, U.S. Army, and the Bureau of Yards and Docks, U.S. Navy.

Cdr. Bergen S. Merrill, Jr., CEC, USN
Chief, Protective Structures Development Center

Michael M. Dembo
Chief, Structures and Equipment Development Section

This report was prepared by H. C. Lamb.

Significant contributions to the report were made by:

C. Argiroff - US Army Engineer District, Detroit, Michigan
W. L. Gibson - US Army Engineer District, Norfolk, Virginia
L. M. Jaysane - Office of the Chief of Engineers
L. C. Nelson - Office of the Chief of Engineers
H. G. Rudberg - Joint Civil Defense Support Group
L. M. Selman - US Army Engineer District, Mobile, Alabama
C. W. Svaeri - Protective Structures Development Center

This issue supersedes PSDC TR-1 (Interim) dated December 30, 1963.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

SUMMARY

This report covers the background of the Protective Structures Development Center, Fort Belvoir, Virginia; and the design, construction, cost analysis, preliminary testing and evaluation of the prototype dual purpose 200 and 1000-person community fallout shelters.

The report concludes that:

a. The building design provides for an excellent dual-purpose shelter. However certain modifications, which are listed in Section 5, may be made to the design for further improvements in similar structures.

b. No unusual construction problems were encountered.

c. The cost per person sheltered in the 1000-person shelter was approximately $152 compared to $300 in the 200-person shelter.

d. During normal operation and acceptance tests, the heating and ventilating systems of the shelters maintained design conditions.

e. Most electrical features have proven to be satisfactory during normal use; however, some minor changes which are listed in SECTION 5.4 should be incorporated in future shelters.

f. Additional investigation of the acoustics of the shelters and methods of reducing noise from mechanical equipment is desirable.

SECTION 1. INTRODUCTION

1.1 SUBJECT

The purpose of the study covered in this report was to evaluate the adequacy of the design and to analyze data obtained during construction of a prototype 1000 and 200-person dual purpose community shelters. The two shelters were erected as part of a single construction contract during the period June through November 1962 at the Protective Structures Development Center (PSDC), Fort Belvoir, Virginia.

1.2 BACKGROUND

The Protective Structures Development Center was established to:

a. Develop, test, evaluate and improve the design and construction of protective structures.

b. Develop, test, evaluate and improve the design, construction and operating characteristics of equipment associated with protective structures.

c. Provide a repository for technical information about protective structures and associated equipment.

d. Provide a full-scale radiation testing facility.

e. Provide an area where manufacturers can erect shelter structures and components for test and evaluation.

f. Provide facilities for use by authorized research groups.

Design and construction of the Center was under the direction of the U. S. Army District Engineer, Norfolk, Virginia. The construction contract was awarded 30 June 1962. The following table contains an itemization of the principle features of the overall construction contract:

Table 1.1

Itemization of Overall Construction Contract

Item	Contractor	Cost
A-E Contract (DA-44-100-ENG 5327)	Mills, Petticord and Mills Alexandria, Virginia	$ 21,700.00
Construction Contract (DA-44-110-ENG 5332)	Permanent Builders Company Bladensburg, Maryland	212,244.50*

*To five foot line of the 1000 and 200 person shelters together. Overall cost of construction including the two shelters, Radiation Tent Facility (not described in this report) and site work was $521,305.75.

The prototype 1000 and 200-person shelters were built to provide design and construction data, for study and evaluation of design features and as facilities for testing and evaluation of shelter equipment. The shelters are reinforced concrete structures each having one story aboveground and a basement. Beneficial occupancy date was 21 November 1962.

SECTION 2. INVESTIGATION

2.1 DESCRIPTION

2.1.1 Design.

The 200 and 1000-person shelters were constructed from plans prepared in accordance with OCD definitive designs of the Shelter Design Series C 45-1 published August 1962. See Appendix F for Shelter Plans and Sections. Each was designed as a one-story and basement shelter to serve a dual function; administrative functions during normal occupancy, and as shelter during an emergency.

For normal occupancy it was necessary to provide utilities and site improvements such as roads, sidewalks and parking lots. Exterior utilities provided for the shelters include a 6" water main connected to the local water company system, a septic tank and tile drainage field and an electrical distribution line connected to the local utility company line.

For emergency conditions space is provided for storage of food and supplies sufficient for 14 days. A 1000 gallon underground water storage tank is provided for the smaller shelter and a 4000 gallon water tank is located at the larger shelter. Both shelters provide approximately ten square feet per person for its rated capacity, excluding unusable areas such as mechanical and generator rooms. Shelter statistics are summarized in Table A-1 of the Appendix. As prototype shelters the information gained from their use will be used in developing standard shelters.

2.1.1.1 Architectural. The exterior building dimensions are approximately 37 feet square for the 200-person shelter and 76 feet square for the 1000-person shelter. The height from the basement floor to the first floor is 10'-2" in both shelters. The minimum ceiling height is approximately 9'-0" in the basement and first floor of each structure as shown on the plans. No decoration or ornamentation was used on the exterior other than a hard smooth surface finish for concrete walls and roof, and a flag pole at the 1000-person shelter.

Interior partitions are concrete masonry block except where solid concrete walls are required to provide radiation protection. The basement and first floor walls and ceilings are exposed finish. Interior first floor walls of both shelters and interior walls and ceilings of all toilet areas and all doors and trim have been painted.

Floors in the toilets on both floors of each shelter are ceramic tile with ceramic tile base and wainscot. Asphalt tile and rubber base were used in the first floor shelter areas, offices and vestibules of both shelters. All other floors of both shelters are concrete finish. The doors in both structures are hollow metal, class "B", with a one hour fire rating.

Roofs of both shelters are reinforced concrete slabs sloping 1/2" per foot from the ridge. The roof was designed to have a smooth concrete finish to facilitate the blow off of fallout particles. This surface is also compatible with the possible future installation of roof washdown or blowdown systems and for the testing of such equipment. The deletion of built-up roofing material also reduces the fire hazard and reduces the cost of construction.

2.1.1.2 Structural. The structures were designed in conformance with the A.C.I. Building Code (318-56). The floors of both shelters were designed for a live load of 100 psf and the 13" flat slab roofs were designed for a live load of 20 psf. Four columns with drop panels support the first floor and the roof of the 1,000-person shelter. One center column with a drop panel supports the first floor of the 200-person shelter. Exterior wall thickness is 10" for the basement walls of both shelters and 15" above the first floor of the larger shelter and 16" for the smaller shelter. The first floor walls and roof slab were designed to provide a minimum protection factor of 100 at the center of the building. Reinforced concrete walls in the mechanical equipment rooms which provide radiation shielding from the filters of the air handling units and from apertures in the generator room are also structural members. These walls in the 1,000-person shelter were designed as cantilever beams, assuming that the floor and roof slabs act as effective beam flanges for a distance of 2 feet on each side of the wall center line (see Figures 2.1 and 2.2) and that the vertical shear is carried by the exterior walls. This design made it possible to avoid using a column or bearing walls in the basement under the mechanical equipment room.

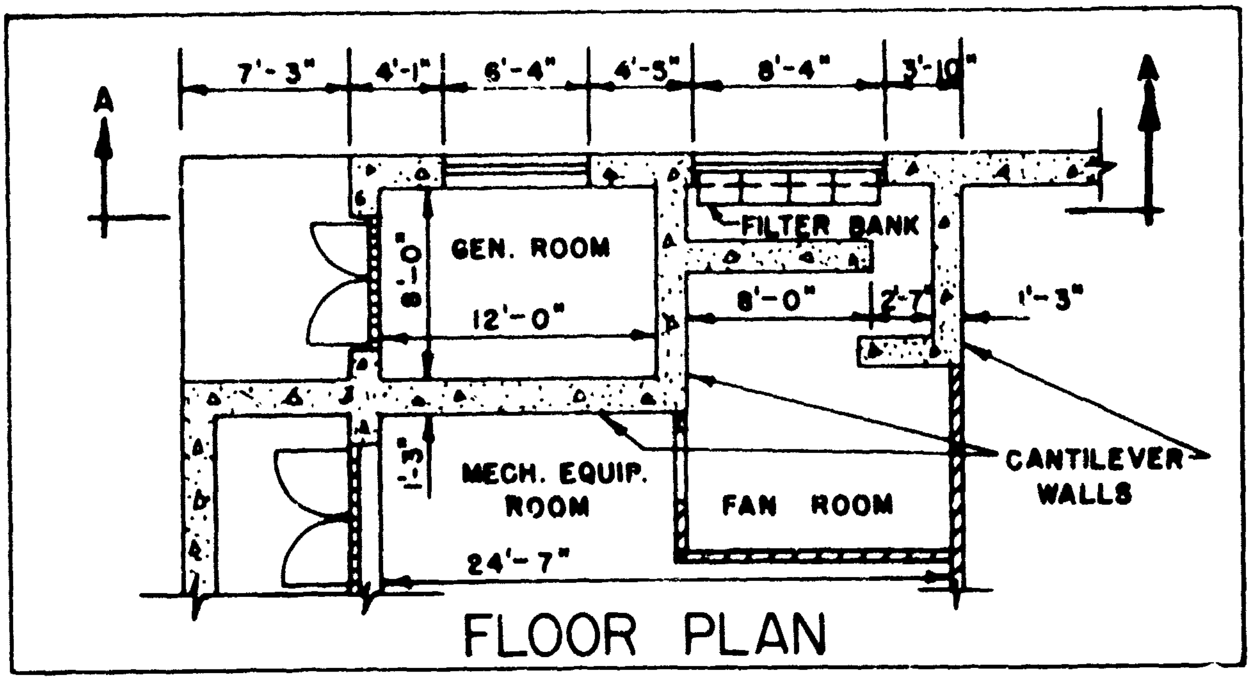


Figure 2.1

Reinforced concrete walls of 1,000-person shelter in mechanical room area.

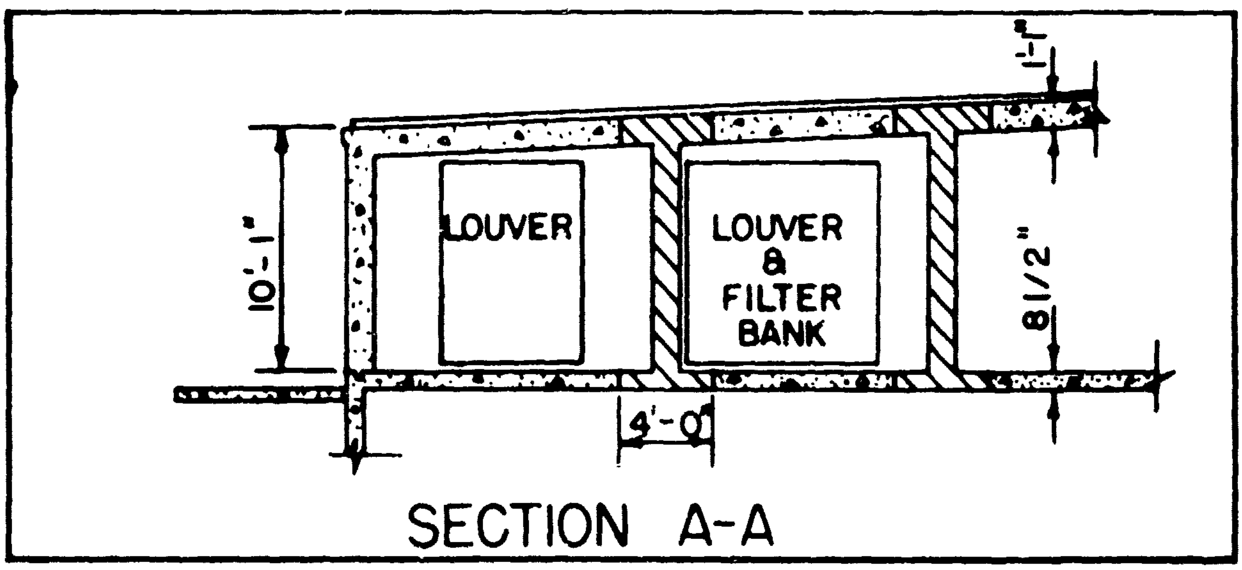


Figure 2.2

Effective section for concrete wall design in 1,000-Person Shelter.

In the 200-person shelter, the interior walls of the generator room were designed to take advantage of the diaphragm action to avoid using an additional column in the basement. In this design it is assumed that the wall supports part of the roof and floor load, that torsion restraint is provided by the roof and floor slab, that vertical shear is taken by the exterior walls, and that horizontal shear is taken by the roof and floor slabs.

Normal design methods were used throughout the other portions of the building except that minimum wall and roof slab thicknesses were based on radiation shielding requirements. Neither structure was designed for blast protection.

2.1.1.3 Mechanical. The air conditioning system provides for automatic heating, cooling and ventilation for summer and winter normal operation and for emergency handling of large quantities of unheated and uncooled air. The system includes an air handling unit (with heating and cooling coils), refrigeration compressor, air cooled condenser, oil-fired hot water boiler and an emergency ventilating fan. The equipment is located on the first floor of each building except for the air cooled condenser which is mounted on the roof. A small power exhaust fan is located on the roof over the toilet area of each building.

The air handling unit will circulate 9 cubic feet of air per minute (CFM) per person of total shelter capacity. It will supply between 1 and 9 CFM of filtered outside air per person depending on control settings and outside air temperatures, or will supply a constant 3 CFM of filtered makeup outside air under manual emergency control. The emergency fan will supply 21 CFM of outside, filtered air per person of total shelter capacity. The air handling unit and the emergency fan can be operated together and bring in a maximum of 30 CFM of filtered outside air per person.

Two duct systems are used in each shelter. The normally used duct system distributes air from the air handling unit to the various rooms within the building. The emergency duct system forces air into the large room on the first floor and the large room in the basement through a large opening near the ceiling of each room at a point adjacent to the mechanical equipment room. All exhaust air flows through the mechanical equipment room and is discharged to the outside through relief dampers located near the outside entrance of the mechanical equipment room. The relief dampers are set to maintain 1/4 inch static pressure (water gage) inside the structures during normal operation.

The hot water boiler with a forced circulation system will provide sufficient hot water to the heating coil in the air handling unit to maintain an inside temperature of 72°F during normal winter operation. The air handling unit is the multi-zone type which permits separate control of temperatures in the above and below ground shelter areas. Room thermostats in each of the large above and below ground shelter areas modulate hot and cold deck dampers at the discharge of the air handling unit.

The following is a listing of mechanical design criteria for the normal and emergency ventilating systems:

1. Local Environment

   a. Summer Outside Air Design Temperature: 95°F D.B. and 78°F W.B. represents temperatures which are not exceeded more than 1% of the time for the entire year for the Washington, D.C. area.

   b. Summer Inside Air Design Temperature: 78°F D.B. and 65°F W.B.

   c. Winter Outside Air Design Temperature: 10°F D.B. represents the dry bulb temperature which has a 13-year frequency of occurrence for the entire year for the Washington, D.C. area.

   d. Winter Inside Air Design Temperature: 72°F D.B.

2. Emergency Conditions

   a. Outside Air Design Temperature: Same as for normal summer design.

   b. Inside Air Design Temperature as follows:

Effective Temperature	Dry Bulb	Wet Bulb	Air Velocity
85°	98°F	80°F	200 fpm

Table 2.1 below lists machine room sizes and equipment therein for the 1000 and 200 person shelters. For location of mechanical equipment and location of machine rooms in relation to general floor layouts see Shelter Plans, Appendix F.

Table 2.1
Mechanical Equipment

Item	1000 Person	200 Person
Net Area of Machine Room	456 sq. ft.	131 sq. ft.
Compressor (Tons Refrigeration)	20	3.7
Boiler (Hot Water)	351 MBH	108 MBH
Air Conditioning Unit	8,540 cfm	1,300 cfm
Emergency Ventilating Fan (1¼" s.p.,w.g.)	21,460 cfm	4,100 cfm

2.1.1.4 Electrical. The 120/208-volt, 3-phase electric power and 120-volt, 1-phase lighting systems and equipment for the 200 and 1000-person shelters have been designed to permit dual use of the structures. Sufficient power is available from local transformer stations adjacent to the buildings to operate all electrical equipment connected to the normal and emergency sections of the main distribution panel, including heating, ventilating, hot water and air-conditioning equipment.

Provision has been made for the future installation of a 25-kw and 5-kw emergency diesel engine driven generator for the 1000 and 200-person shelters, respectively. Each generator room is equipped with louvers, junction box for generator connections, and capped diesel fuel oil supply and return pipe lines from the underground storage tank. It is anticipated that the facilities of these generator rooms will be used for testing and evaluation of generators and associated equipment.

During emergency conditions the refrigeration compressor and condenser fan motors for the air-conditioning equipment can be made inoperative by opening the appropriate 3-pole circuit breakers in the main distribution panel of each shelter. The emergency section of the distribution panels are connected to the normal power supply and also through a manual power transfer switch to the emergency generators. Table 2.2 indicates equipment on the normal and emergency power distribution systems.

Table 2.2

Equipment Connected to Normal and Emergency Power Distribution Systems of 1000 and 200-Person Shelters

Item	Normal	Emergency
Refrigeration compressor	X*	X*
Condenser fan	X	X
Air handling unit fan	X	X
Emergency ventilating fan	X	X
Toilet exhaust fan	X	X
Oil burner	X	X
Circulating pump	X	X
Draft inducer	X	X
Hot water heater	X	--
Water coolers	X	--
Receptacles	X	Approx. half
Lights	X	Approx. half

*X indicates items connected to the particular power distribution system.

Light fixtures are of the flourescent type except for the exterior, stairway, closet, and equipment room lights. Conduit runs are concealed

Table 2.4

Protection Factors of the 1,000 and 200-Person Shelters

Detector Location	Protection Factor at the Center*
1,000-Person Shelter	
First Floor	105
Basement	2,640
200-Person Shelter	
First Floor	10[illegible]
Basement	2,560

*Detector position 3' above finish floor levels.

The protection factor is somewhat less near the periphery of the first floor of the buildings than at the center; for example, in the 1,000-person shelter the PF is 105 at the center of the first floor area and 94 at a point 10 feet from the midpoint of the northwesterly exterior wall.

2.1.2 Construction Techniques.

2.1.2.1 General. Construction of the 1000 and 200-person shelters was started on 11 July 1962 and was essentially complete on 21 November 1962, the beneficial occupancy date. The duration of work on principal construction features is shown by the construction progress chart of Appendix C. The labor force working on the two shelters was composed of up to 50 men. A summary of labor classified by skills or trades, and construction equipment used is included with the cost data in Appendix D.

2.1.2.2 Surveying. A Corps of Engineers survey party did the general surveying required for the Center. This included:

a. establishment of bench marks

b. layout of base line for the siting of the various structures

c. preliminary layout for utilities

d. establishment of boundary lines

The prime contractor had the responsibility for performing all other surveying required for construction of the shelters. Engineers employed by the contractor performed the following:

a. established temporary bench marks as required

b. staked out each structure

c. staked out utility lines

d. checked and verified invert elevations of utility lines, man holes and other installations

e. checked and verified elevations of footings of the structures

2.1.2.3 Excavation. Top soil was stripped to a depth of approximately 6 inches in the areas of the 1000-person shelter, parking lot, and drainage field using a 5 yard pan, bulldozer, front-end loader and trucks. Top soil was piled in a convenient location at the rear of the site. The same equipment was used to excavate for the shelter and the material was piled nearby. The rough excavation was shaped using the front-end loader with final trimming being done by hand.

A front-end loader and clam crane was used to excavate for the 200-person shelter. Trucks were used to transport the excavated material to a nearby area for storage.

2.1.2.4 Structural Work (1000-Person Shelter). Wall and column footings were hand trenched. Wood forms were used for the footings with maximum use made of natural earth cuts, as appropriate, for form faces.

Steel forms were used for the walls. The form panels were 4 feet long with widths up to and including 24 inches. Concrete for the basement walls was placed in four sections with vertical construction joints located at the midpoints of each wall. Damp burlap was used for curing concrete walls after the forms were removed. Finishers dressed the concrete in exposed walls after the removal of forms to remove fins and loose materials and to fill holes left by snap-off form ties and voids. Holes were filled with cement mortar.

Conventional plywood flat slab forms supported on wood joist framing and metal shores were used for the first floor slab. Construction of the first floor slab was begun as the work was completed on the basement walls. Concurrently work was started on the first floor wall forms.

The first floor slab was divided into four sections by construction joints along the center lines of the building. The placing sequence used provided a time interval of several days between adjacent sections to minimize the effect of shrinkage. The concrete was covered with waterproof paper and a thin layer of soil during the curing period. Forms were left in place for at least six days after the concrete was poured.

Work was continued on forms for the first floor walls so that a section was ready for placing upon completion of the floor slab. The construction techniques and sequence of work was similar to that of the basement walls.

Entrance baffle walls were formed and placed after the other first floor walls were completed and before the roof slab was placed.

Forms for the roof slab were similar to those used for the first floor. The roof was placed in two sections with a construction joint along the ridge. Careful control was required during the placing and curing of the roof slab to keep shrinkage cracks to a minimum since roofing material was not to be used. Two-part polysulfide joint sealer was used on construction joints and cracks to prevent leaks. See Section 2.2.2 for a discussion of the formation and repair of cracks in the roof slab.

The basement floor was placed last to save construction time. If the basement slab had been placed first it would have been necessary to wait until the concrete had attained the necessary strength to support the load of the slabs above before construction could proceed. By using this method up to two weeks of time was saved. An opening was left in the basement wall to permit access for pouring concrete and placing the gravel base course. The basement slab was divided into nine sections for pouring the concrete.

Interior masonry walls were constructed after the reinforced concrete work was completed.

2.1.2.5 Structural Work (200-Person Shelter). Construction techniques for the 200-person shelter were similar to those used for the 1000-person shelter, with the exception of the use of plywood forms for the exterior walls and the location of wall and slab construction joints.

The placing sequence and location of construction joints in the 200-person shelter varied from that used for the 1000-person shelter due to the smaller size of the structure. The basement walls were poured in two operations and the first floor walls, first floor slab, and roof slab were each poured in a single operation. The basement slab was poured in two sections.

2.1.3 Construction Costs.

2.1.3.1 Shelter Costs - Contract Price. The cost of the shelters at PSDC based on the contract price is summarized in Table 2.5. A summary of costs for the shelter structures as given in the contractor's Bid Proposal is provided in Appendix D, Table D-1.

Table 2.5

Cost Based on Contract Prices

	Total	Per Sq. Ft. of Gross Area	Per Sq. Ft. of Net Shelter Area	Per Person Sheltered
	$	$	$	$
1000-Person Shelter	152,226.00	13.18	15.22	152.23
200-Person Shelter	60,018.30	21.60	30.00	300.09

2.1.3.2 Shelter Costs - Estimated As Separate Units. Since the construction of the two shelters was accomplished as a part of a half-million dollar contract it was desired to determine if the shelter cost had been altered because of the large scale, efficient operation undertaken by the contractor. Accordingly, an estimated cost was determined by evaluating actual labor, material and equipment at prevailing rates plus allowable overhead. The estimated cost is as follows:

Table 2.6

Estimated Cost Based on Actual Construction

	Total	Per Sq. Ft. of Gross Area	Per Sq. Ft. of Net Shelter Area	Per Person Sheltered
	$	$	$	$
1000-Person Shelter	171,955	14.89	17.20	171.96
200-Person Shelter	81,036	29.28	40.52	405.18

The inspector's daily job report was modified before construction began to assure accurate reporting of labor and equipment; material was based on preconstruction government estimates. Overhead was at allowed rates, all as discussed in the following paragraphs.

2.1.3.3 Estimated Cost of Materials. Estimated cost of construction materials and installed equipment shown in Appendix D, Tables D-2 and D-3, was determined from average costs in the Washington, D.C. Area. The total estimated cost of materials and mechanical equipment was approximately $67,209 for the 1000-person shelter and $27,361 for the 200-person shelter.

2.1.3.4 Estimated Cost of Construction Equipment. Construction equipment costs are shown in Appendix D, Tables D-4 and D-5. The approximate operating time for each piece of equipment was determined from the project inspector's daily job reports. The costs shown in these tables were based on average costs for each type of equipment assuming it was owned and operated by the contractor although some special equipment, such as cranes, was rented on an hourly basis. The total estimated cost for construction equipment used was $2,909 for the 1000-person shelter and $1,477 for the 200-person shelter.

2.1.3.5 Estimated Cost of Labor. The approximate number of man-hours expended by the contractor and the labor costs of the various construction trades and/or skills utilized in constructing the shelters and associated items are shown in Appendix D, Tables D-6 and D-7. The wage rates are those determined as minimum for the area by the Secretary of Labor and/or from the contractor's payroll. The labor cost figures are based on a 40-hour week and do not include overtime and holiday pay rates or insurance, etc. The man-hours shown in the tables were obtained from the daily job reports submitted by the Area Engineer and are approximate. The total estimated contractor labor cost was $64,280 for the 1000-person shelter and $34,048 for the 200-person shelter.

Supervision of the construction was provided by the Area Engineer, Fort Belvoir, for the Norfolk District Engineer. The Area Engineer had a full-time inspector on the project, whose time was divided between shelter construction, radiation test facility construction and other related work at the Center. Additional supervision was provided by the Area Engineer and his staff. The prime contractor was represented by one superintendent who was responsible for supervision of all construction at the Center. The Superintendent's time is included in the labor summary above; however, government supervision and labor costs are not included in this report.

2.1.3.6 Estimated Cost of Insurance, Overhead and Profit. Costs in addition to those shown above include insurance and other payments on labor, contractor's overhead and contractor's profit which are assumed to be 12%, 10% and 10%, respectively. These costs are shown in Appendix D, Table D-8. The combined estimated cost of these items is $37,557 for the 1000-person shelter and $18,150 for the 200-person shelter.

2.1.3.7 Cost Comparison. Compared to the contract costs, the estimated isolated cost is about 13% greater for the 1000-person shelter and about 35% greater for the 200-person shelter. It is reasonable to assume that the cost of a small isolated structure will be relatively greater than for a larger project because of mobilization costs, less efficient utilization of labor and higher unit costs for materials. Costs are influenced by many factors, some of which may be obscure, particularly when several items are constructed under one contract. The accuracy of the cost data presented in this section is evaluated in Section 3.

2.1.4 Construction Problems.

Construction of the 1000 and 200-person shelters did not present any unusual or serious problems. Normal construction methods proved adaptable to building structures of this type.

2.2 TESTS AND OBSERVATIONS

2.2.1 Preliminary Operational Tests.

Preliminary tests conducted in the shelters include normal operation of the mechanical equipment, radio reception and sound level investigation.

2.2.1.1 Mechanical and Electrical. Normal operation of mechanical equipment during the short duration of occupancy has provided operational information for the 200 and 1000-person shelters. Further, limited test data has been obtained as a result of acceptance tests performed in connection with the construction contract The heating, ventilating and air conditioning systems of the shelters were found to maintain the design conditions.

Fuel oil and electricity cost data will be obtained from normal use of the building. The probable annual fuel oil consumption calculated by the degree-day method is 7,450 gallons for the 1000-person shelter and 2,150 gallons for the 200-person shelter at an estimated cost of $672.74 and $194.15 respectively (based on $0.0903/gal.).

2.2.1.2 Radio Reception. Radio reception was investigated in the structures using a portable, battery powered, transistor radio. For this test no exterior antenna was used. Standard AM broadcasts from several radio stations were received. It was found that in virtually every location within the shelter, including the basement, the audio level and quality was satisfactory.

2.2.1.3 Sound Level. During the dedication ceremonies for PSDC on 7 December 1962, sound level meter readings were taken inside the 1000-person shelter to determine noise levels produced by the approximately 220 people in attendance. A portable audio level meter and tape recorder were located in the west end of the first floor shelter area near the corner adjacent to the offices and were mounted 4' high. This location also permitted checking the noise level in the coffee and refreshment line areas. A second portable audio level meter was used in the basement shelter area near the front of the room to check the noise level before, during and after the dedication ceremony speeches. Readings were also taken at various locations about the rooms to obtain a check on the sound intensities.

The sound intensity level in the first floor shelter area varied between 65 and 80 decibels with about 12 to 150 people in the room. The average appeared to be about 75 decibels. The noise level for a normal office (with typewriters), averages about 45 decibels. The sound intensity level in the basement shelter area indicated 70-78 decibels before the ceremony, 64 db during the invocation, 54-70 db (average 66) during the introduction and speeches, 86-90 (average 88) during the applause, and 64-70 db after the ceremony upon dismissal. There were about 220 people in the basement for the ceremony. Air conditioning equipment was not in operation when the sound level readings were taken.

2.2.1.4 Illumination. Lighting intensities were measured in the 1000 and 200-person shelters for both normal and emergency conditions. The average values in foot candles measured at desk level are shown in Table 2.7.

Table 2.7
Lighting for 1000 and 200-Person Shelters

Area	Normal	Emergency
1000-Person Shelter		
Offices	46 f.c.	24 f.c.
Shelter Areas	18 f.c.	9 f.c
Toilets	54 f.c.	28 f.c.
200-Person Shelter		
Offices	40 f.c.	27 f.c.
Shelter Areas	16 f.c.	8 f.c.
Toilets	35 f.c.	31 f.c.

2.2.2 Structural Observations

Minor cracks developed in the roof slabs of both structures soon after the forms were removed. Cracks formed on several corners of the roofs in a line perpendicular to the negative diagonal corner reinforcing bars at the inner ends of the bars about seven feet in from the roof corners. See Figure 2.3. In some instances these cracks extend through the slab. These are flexural cracks which are located at the point where yield lines (i.e. corner pivot) would form if the slab were loaded to failure. Cracks also formed at the construction joint along the ridge of the 1000-person shelter, at the reentrant corners formed by the entrance and main roof slabs, and at a few isolated locations. Repairs to the slab were made by chipping out the cracks and applying a sealing compound. This sealer was also placed in the construction joint. No leaks have been observed in the roof of either structure since the sealer was applied. Examination of the roof slabs of both shelters approximately one year after erection reveals formation of hairline cracks. Hairline cracks have formed in the 200-person shelter roof slab directly over the interior column and at other corners. At the 1000-person shelter cracks have formed in a radial pattern directly above each of the four interior columns as shown in Figure 2.4, at other re-entrant corners and at several isolated locations. Cracks are due primarily to dead load flexural stresses and temperature stresses in the thick (13") roof slabs. See Section 5.2.4 for additional discussion of unprotected roof slabs.

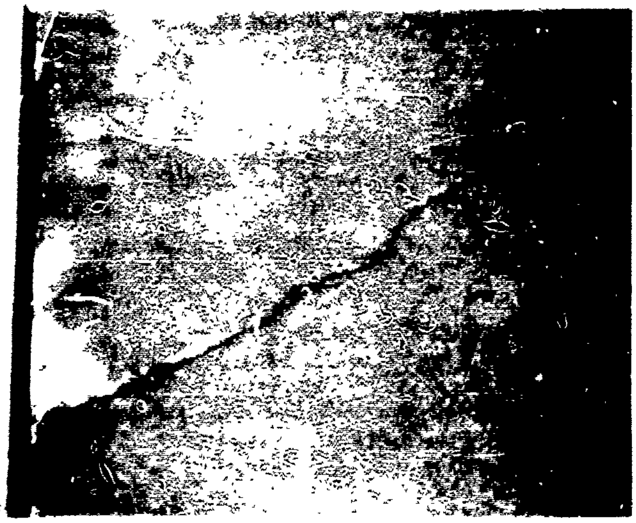


Figure 2.3. Crack at corner [illegible] the 200-person shelter.

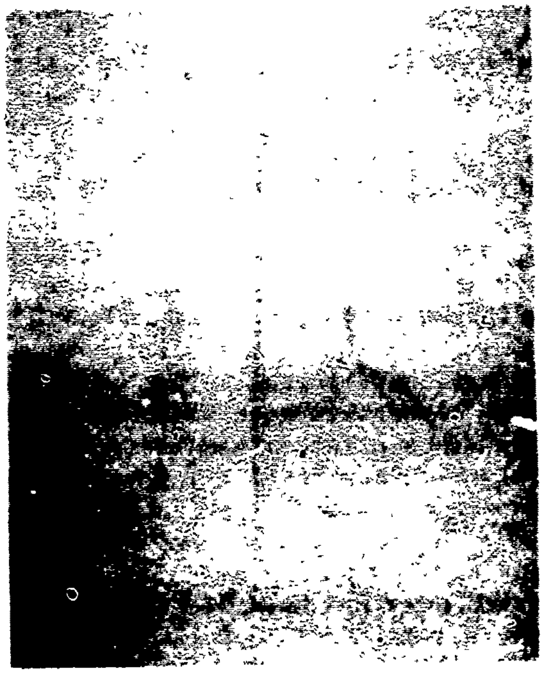


Figure 2.4. Cracks in the roof [illegible] son shelter over a column.

2.3 DEFICIENCIES

2.3.1 General.

Deficiencies listed have been determined from normal use of the shelters and limited tests. Further testing may disclose additional deficiencies and comments included here may be modified and elaborated upon after testing and evaluation has been completed.

Items which warrant attention have been listed as deficiencies even though some had been considered in the early stages of design but later deleted to keep costs at a minimum. Comments apply to both structures unless stated otherwise.

2.3.2 Architectural and Structural.

a. The mass thickness at the base of the exhaust fan curb (see Figure 5.1) is not adequate at the point over the exhaust duct since this is a point where an accumulation of fallout particles is likely to occur.

b. The radiation shielding provided by the floor slab in the intake plenum of the 1000-person shelter is not comparable to that of the baffle walls. An accumulation of fallout particles in the filter, which extends about 10 inches inside the building, would cause a high intensity of radiation in the basement area below the plenum floor.

c. The floor slab in the generator room of the 200-person shelter does not provide adequate shielding of the intake filter above. This condition is not as serious as that previously discussed in the 1000-person shelter (see b. above) because the filter is smaller and located higher above the floor.

d. A baffle radiation shield has not been provided for the outside air supply filter of the 200-person shelter.

e. It is not desirable to have the intake plenum located directly over the emergency generator, as in the 200-person shelter, because of the possibility of heat and noise transmission to the shelter area.

f. There is no covered access to the generator room from the shelter area.

g. The ladder in the 200-person shelter is not properly located in relation to the hatch to permit easy egress from the basement.

h. The insulation provided by the solid reinforced concrete walls is not sufficient for the comfort of personnel in the first floor offices. When the outside temperature is low personnel working near the wall are chilled by radiation to the cold surface.

2.3.3 Mechanical.

a. Noise transmission through the duct work is high.

b. No heat supply is provided in the stair wells.

2.3.4 Electrical.

a. Electrical receptacle has not been provided in the emergency generator rooms for a battery charger.

b. Battery powered emergency service lights and trickle-charge receptacle have not been furnished. Emergency battery lights are required in event of power failure prior to starting emergency generator.

c. Telephone conduits are not provided from the entrance panel to rooms where telephones are required.

d. No provisions have been made for the installation of radio antennae.

e. No clock outlets have been provided.

f. Electrical receptacles have not been provided in the central portion of shelter areas.

g. A light fixture has not been provided in the 1000-person shelter fan room near the damper door in vent duct to facilitate inspection.

h. Lighting is not adequate near the boiler in the mechanical room of the 1000-person shelter and no switch has been provided near the door to the shelter area.

i. Light fixtures in the generator room and at the outside entrance of the mechanical room of the 200-person shelter are not properly located.

j. Light switching arrangement for the stairway of the 200-person shelter is not convenient.

SECTION 3. DISCUSSION

3.1 EVALUATION OF DATA

3.1.1 Cost.

Costs were computed from the items of Tables D-2 through D-8, Appendix D, which were compiled from the following sources:

a. contractor's bid proposal

b. pay rolls

c. U.S. Department of Labor wage rates

d. Corps of Engineers daily job reports (time data)

e. estimates

Percentage increases for the individual shelters based on computed costs compared to contract costs were 13% and 35% for the 1000 and 200-person shelters, respectively.

These costs are necessarily approximate due to unavailability of actual construction materials and equipment costs. Further, labor costs for individual items within the contract are also approximate since the contractor's payrolls included work done on all projects under a single contract; for example, some labor costs charged to shelters could appropriately have been charged to general site improvements even though care was taken to include only labor within the building five foot line. Additionally, higher computed cost may be partly due to variations between estimated and actual materials costs or to a low bid by the contractor.

In any event, it is evident that the cost of an isolated individual shelter would be greater than the apparent contract cost for the same structure erected at the PSDC.

3.1.2 Tests.

Tests covered in this report are of a preliminary nature. Future testing will provide additional data for evaluation of the shelters and/or components. Recommendations for future testing are included in Section 5.

3.2 DUAL PURPOSE USES

Both structures lend themselves to a wide variety of uses in addition to shelter functions. The floor plans are suitable for use as a community center in which local civic groups and other organizations such as Boy Scouts, 4-H Clubs, etc., may hold meetings; as a recreation center; as storage space for items which could be quickly moved out of the shelter; and as a cultural center for exhibits and group activities.

In addition, the large shelter areas in each of the buildings may be subdivided into smaller spaces, such as offices, by using standard movable office partitions which allow circulation of air. The present interior masonry partitions may also be relocated to suit particular user requirements. In this case, appropriate modifications should be made to the electric wiring and duct systems to insure adequate lighting and ventilation.

Provisions have been made in the layout of space and the plumbing in the 1000-person shelter for additional toilet fixtures if required for particular dual purpose uses. Three water closets and three lavatories may be added to each women's toilet room; also one urinal, one water closet and two lavatories may be added to each men's toilet room if needed without modifications to the structure other than installation of appropriate metal stall partitions. The existing number of toilet fixtures was based on the normal use requirements of PSDC.

SECTION 4. CONCLUSIONS

4.1 GENERAL

In general the prototype 200 and 1000-person shelter designs are satisfactory; however, a few relatively minor modifications in the design (see Section 5, Recommendations) can improve the structures. For dual use as a community center, changes in the design can be made to provide the most useful facility as determined by the specific use requirements.

4.2 CONSTRUCTION

The prototype shelters did not present any unusual construction problems.

4.3 COST

Cost comparison of the two shelters demonstrates the advantage of building large capacity structures to reduce unit costs. In this case, the cost per shelter space provided in the smaller shelter is about $300 compared to $152 per space in the larger shelter as shown in Table 2.2. These are total costs of the building to the five foot line based on the actual contract cost.

4.4 MECHANICAL

During normal operation and acceptance tests the heating and ventilating systems of the 200 and 1000-person shelters maintained design conditions.

4.5 ELECTRICAL

Electrical features of the shelters have proven to be satisfactory under normal operations with the minor exceptions listed as deficiencies in Section 2.

SECTION 5. RECOMMENDATIONS

5.1 GENERAL

The following recommendations are suggested for improving and testing 200 and 1000-person prototype dual-purpose fallout shelters. The recommendations for improvements are intended to apply to fallout shelters in general although specific reference is made to the existing structures. It is expected that the ultimate shelter design may differ from the prototype test shelter.

5.2 ARCHITECTURAL AND STRUCTURAL

5.2.1 Fan Curb.

It is recommended that the width of the toilet exhaust fan curbs of both shelters be increased to insure adequate shielding over the exhaust duct as shown in Figure 5.1.

5.2.2 Intake Plenum Shielding.

To provide adequate radiation shielding it is recommended that the floor slab in the intake plenum of the 1000-person shelter be increased to a minimum of 15 inches. This will provide radiation shielding from fallout accumulated in the filter for the area directly below in the basement compar le to that provided by the baffle walls on the first floor.

The floor thickness of the generator room of the 200-person shelter should also be increased to 15 inches to provide radiation shielding in the basement from fallout accumulations in the intake filter.

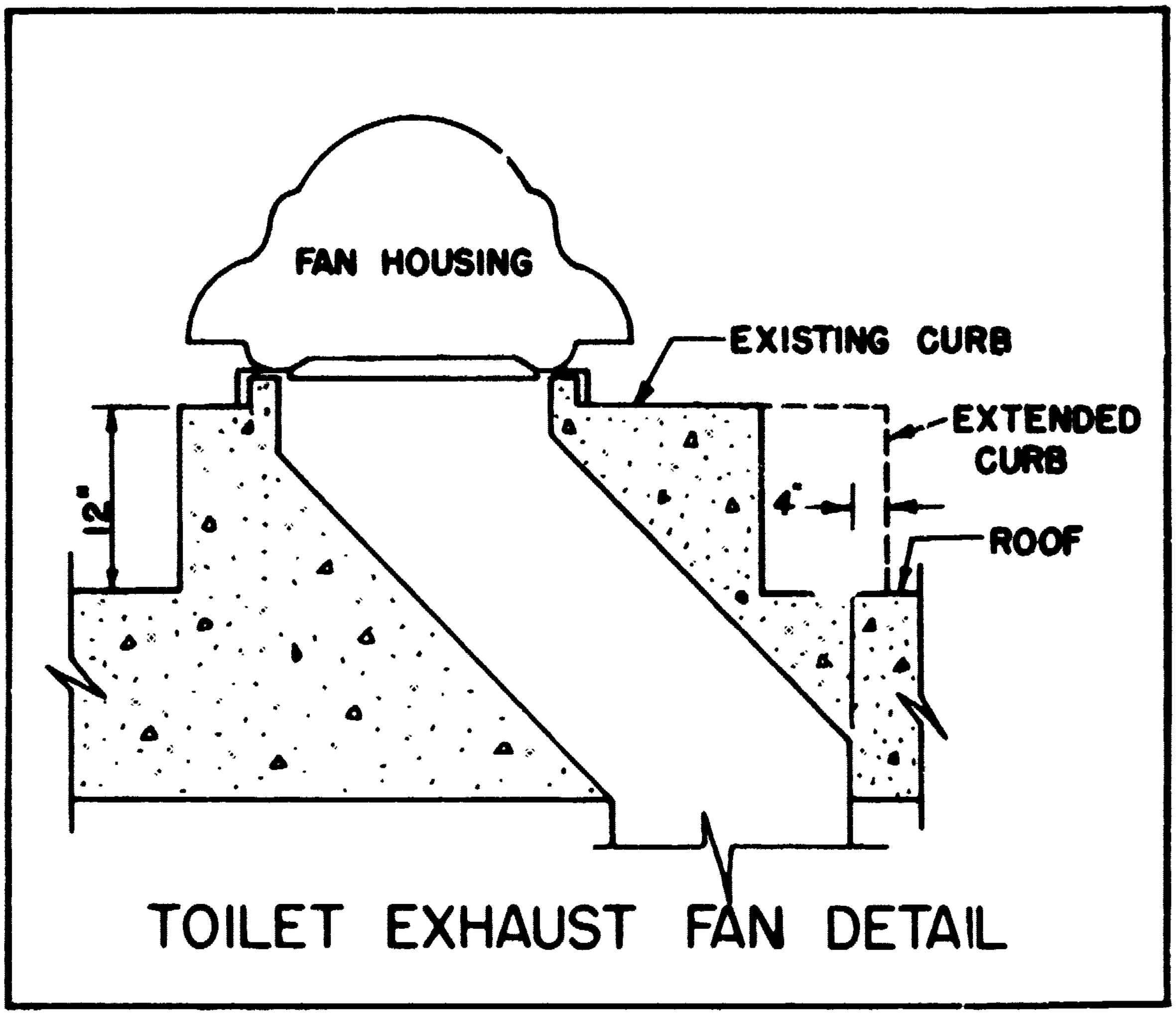


Figure 5.1 Toilet exhaust fan detail.

5.2.3 Outside Air Intake.

The intake for outside air supply to the 200-person shelter is not provided with any direct radiation shield similar to that in the 1000-person shelter. The present intake, due to its location near the ceiling, contributes less than if the opening were located closer to the floor, but it is considered important that such openings be minimized and that filters be well shielded. It is also undesirable to have the intake plenum located directly over the emergency generator because of heat and noise transmission to the shelter area. Further, fire storm damage to the equipment within the generator room is considered likely due to the location of the intake louver.

It is recommended, therefore, that the intake louver be relocated to improve the conditions stated above. As a minimum modification a baffle shield should be provided between the filter and the shelter area.

5.2.4 Roofing.

The unprotected roofs were intended primarily to provide a surface which would optimize dispersal of fallout through blow-off and facilitate operation and/or testing of washdown and blow-off systems. Additionally, omission of roof protection also served to reduce overall costs.

Experience to date, however, indicates formation of unavoidable cracks, for the structural system used, due to temperature and flexural stresses. The cracks which have formed, while not reducing the structural integrity of the roof slabs, will eventually penetrate through the slab. Ordinarily in roofs with some form of protection such cracks would not be detrimental. In the case of the structures under consideration it has been found that these cracks can be successfully repaired with a two-part chemical sealer without loss of utility of the roof surface.

A prestressed roof slab would have been relatively crack free and was considered during the design but was not used for reasons of economy.

Attainment of a water tight unprotected roof slab using conventional reinforced concrete is extremely difficult due to problems of control of concrete placing, curing, adequate formwork and general quality control of materials.

It is recommended that future shelters of the type described in this report include a protective covering over the concrete slab. The protective material should provide a smooth surface and bond well to the underlying concrete slab. In addition, the applied material should be non-flammable. Sprayed, rolled on or similarly applied vinyl or other thin elastomeric membranes are suitable for protective coatings provided they have the aforementioned attribute of being non-flammable.

5.2.5 Generator Room.

It is suggested that consideration be given to providing access to the emergency generator room from the machine room.

5.2.6 Entrances.

The entrances as presently designed in the 200 and 1000-person shelters are shielded by exterior baffles essentially as indicated by Figure 5.2, Case 3. This type of baffle has advantages where the interior of the building is required to be completely open with no interior partitions or when modifying an existing structure as a shelter. However, when a building is originally designed to serve as a dual purpose facility such as a community center as well as a shelter, it is important that the facility be constructed to provide a maximum usable area for minimum construction cost and provide a community with a pleasant appearing building with adequate shielding. The entrances shown by Figure 5.2, Case 1 and Case 2 will serve this end.

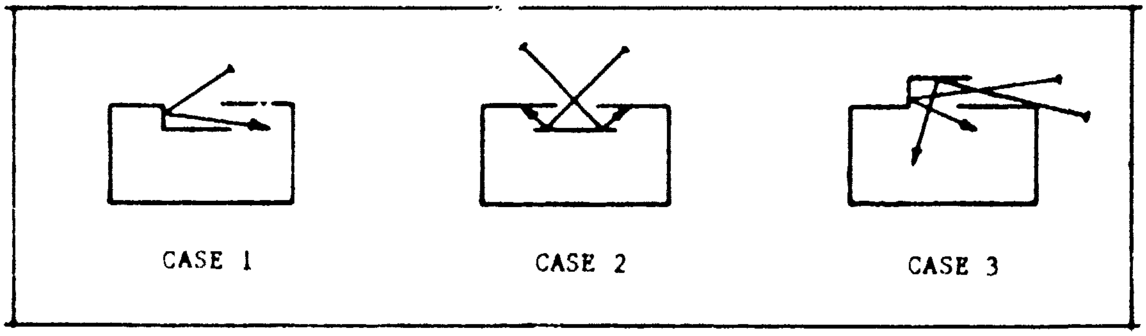


Figure 5.2 Baffled shelter entrances.

When baffles are constructed some gamma rays are deflected as shown in Figure 5.2. In Case 3, the deflection is primarily toward the interior of the shelter. In the 200-person shelter the reduction in protection factor at the center of the room is approximately 3% when considering radiation leakage from the entrances.

It is possible to design an interior baffle system and stairs using approximately the same space as required for the existing entrance and stairway. Two new designs are shown in Figures 5.3 and 5.4. Modified design A (Figure 5.3) has the least area and access to the basement is available by passing through the first floor shelter area. Modified design B (Figure 5.4) has a direct access from the main lobby to the basement.

The designs will provide architectural freedom, reduce the areas required for baffling and reduce construction cost. The reinforced concrete walls should be designed to take advantage of diaphragm action, thus eliminating the need of additional columns or a bearing wall in the basement.

A tabulated comparison is made using the entrance in the 200-person shelter.

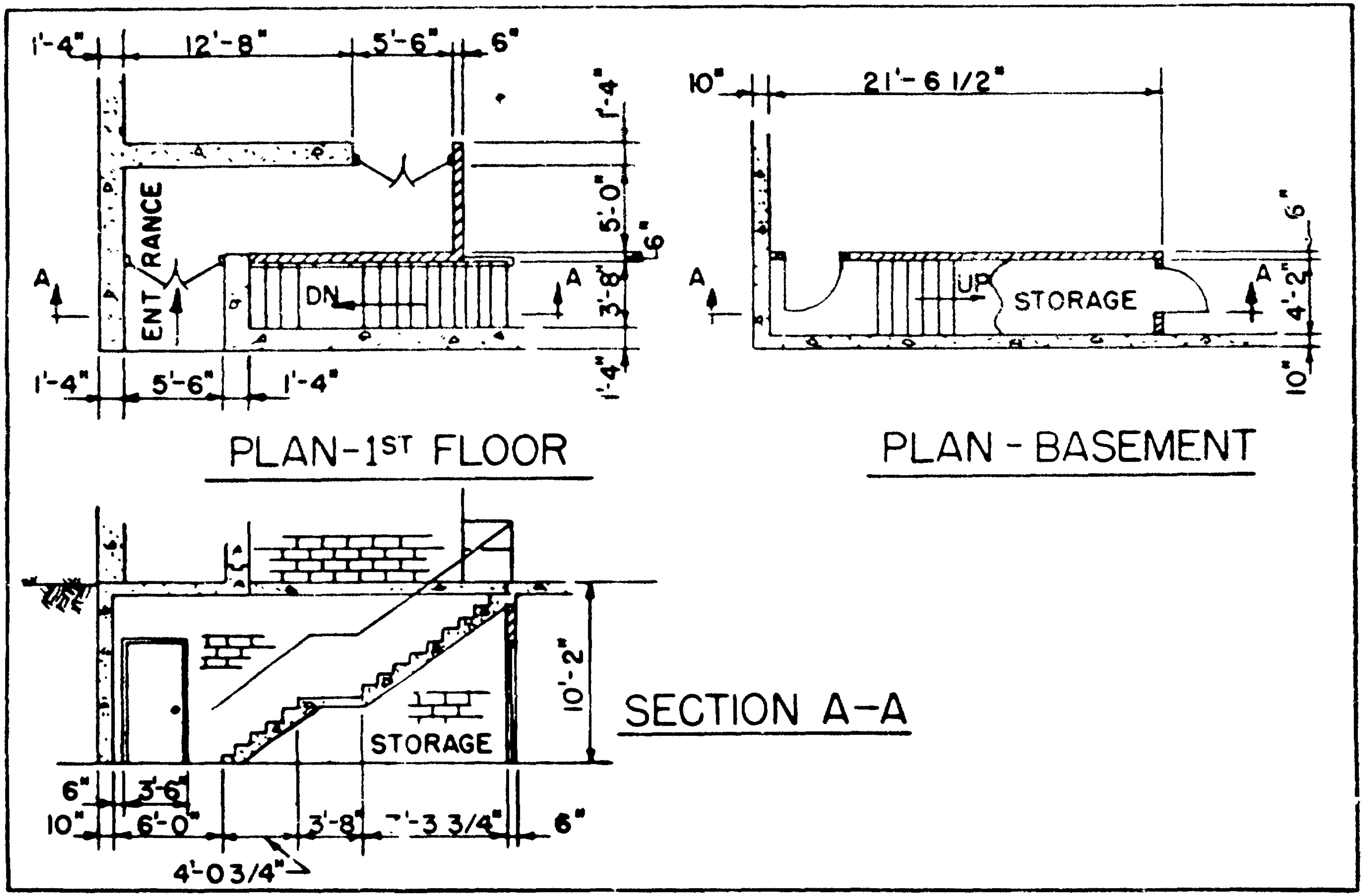


Figure 5.3 Modified entrance design A.

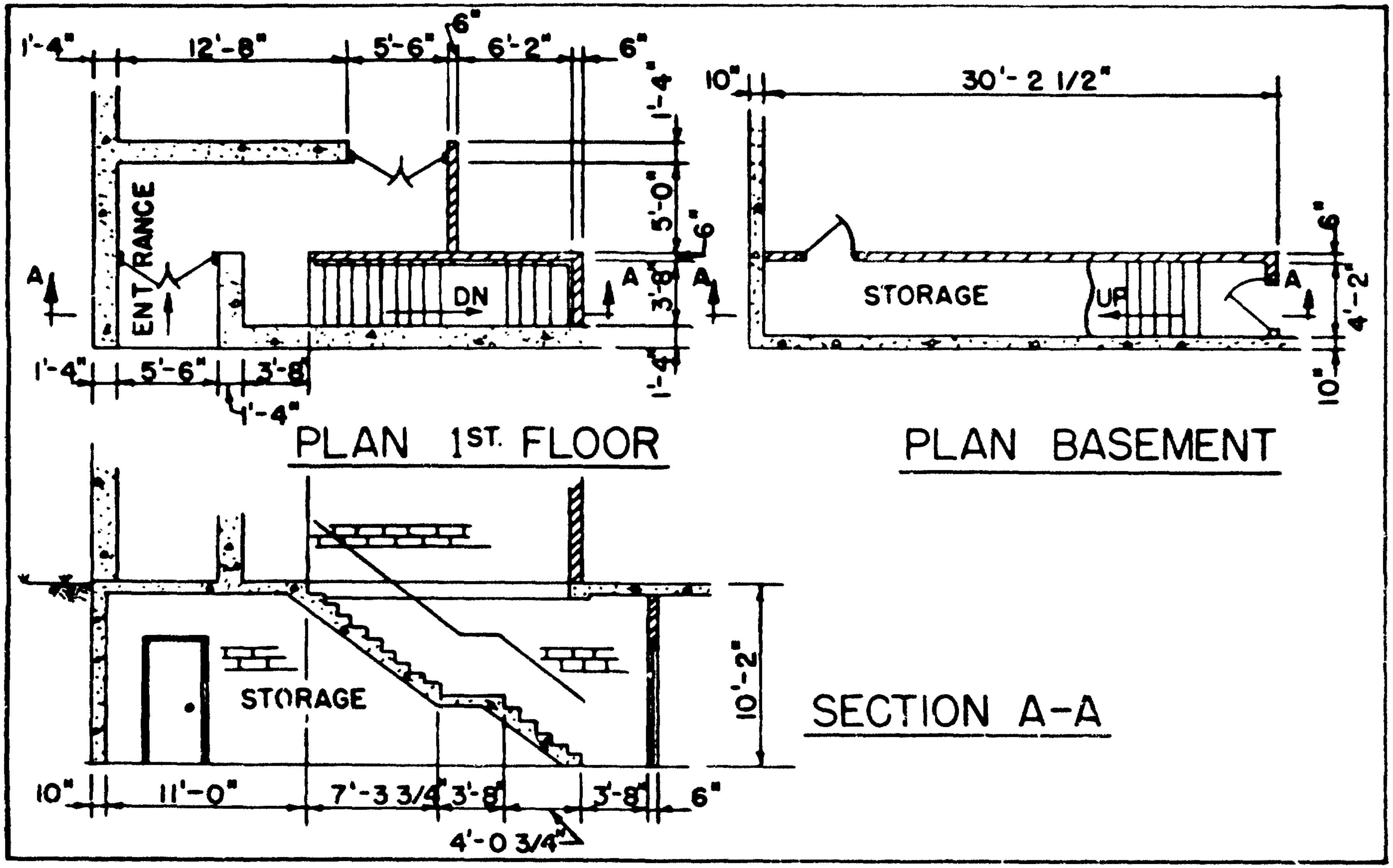


Figure 5.4 Modified entrance design B.

Table 5.1

COMPARISON OF ENTRANCES

	Existing Design	Modified Design A	Modified Design B
Area			
1st Floor	168	212	224
Basement	133	100	141
Sub-Total	301 sq. ft.	312 sq. ft.	365 sq. ft.
Baffled Entrance			
(exterior	79	---	---
TOTAL	380 sq. ft.	312 sq. ft.	365 sq. ft.
Storage Volume			
(includes janitor closet)	613 cu. ft.	203 cu. ft.	639 cu. ft.

The modified designs reduce the quantity of material required for the existing design approximately as follows:

260 sq. ft. of 6" masonry wall
45 cu. yds. of excavation
3-1/4 cu. yds. of concrete roof (80 sq. ft.)
25 ft. of side walk

This amounts to an estimated saving of $500 per entrance.

5.2.7 Toilet Rooms.

Four inch masonry walls were built outside the toilet room doors of the 200-person shelter as shown in the plans to preclude a direct line of sight from the shelter areas. Eliminating this line of sight is not essential in a shelter. However, it is important if a facility is to be used for dual purposes. By judiciously laying out fixtures within the toilet areas as shown in Figure 5.5 and increasing the width of the toilet rooms from 7'-9" to 8'-4" it is possible to eliminate the line of sight without using the masonry screening. The shelter area is increased by 41 sq. ft. per floor.

An inclosed duct is shown next to the door to the women's toilet on the "as built" first floor plan (see Appendix F). This can be revised to eliminate ductwork and masonry (see Figure 5.5) by placing the vertical exhaust duct within the pipe chase against the exterior wall. This also makes it possible to vent out of the side of the building in lieu of the roof which would be a distinct advantage if a roof washdown system is to be utilized.

5.2.8 Emergency Exit.

It is recommended that the ladder in the basement of the 200-person shelter be moved out to 13" from the wall to permit easy egress through the hatch.

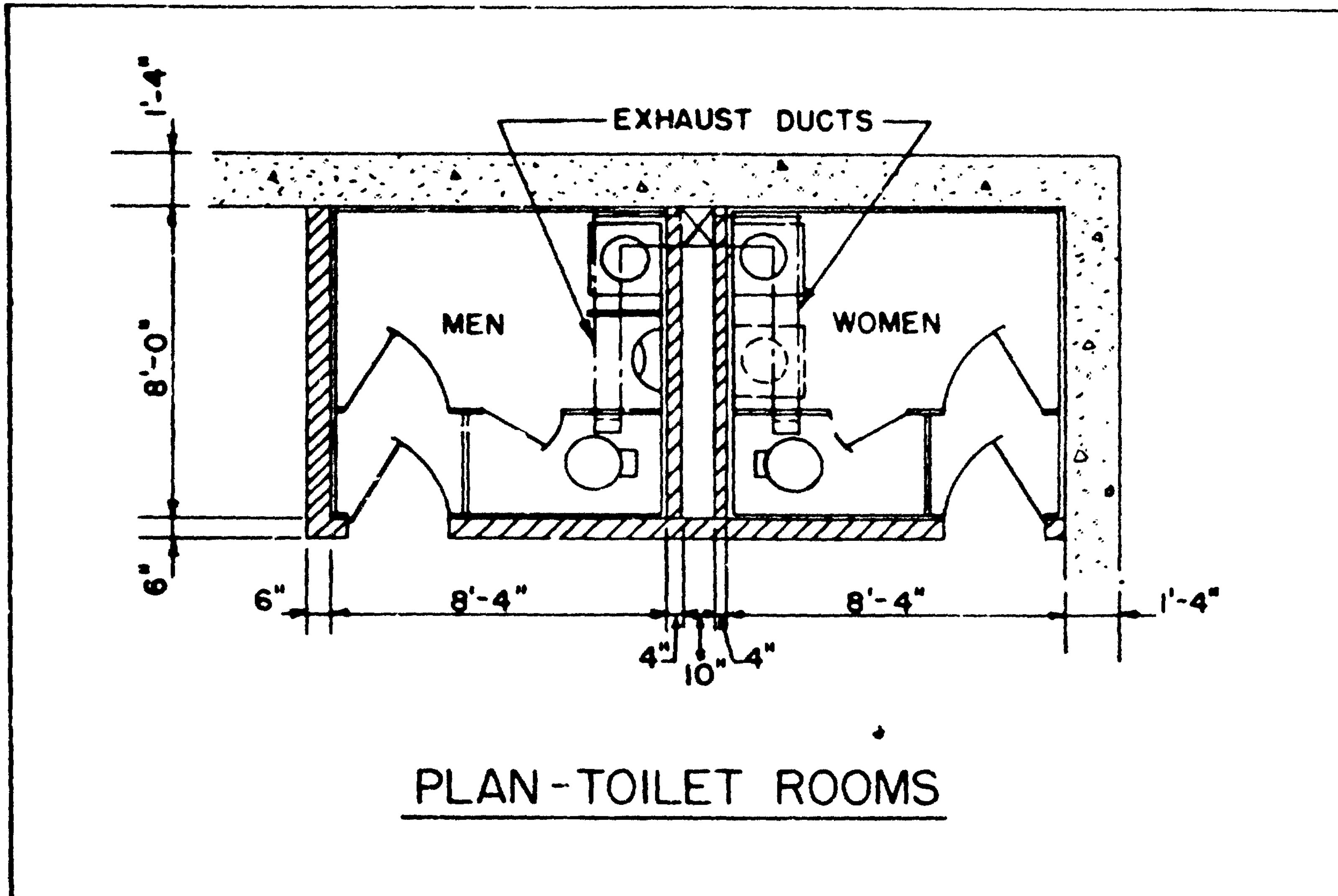


Figure 5.5 Modified toilet room for 200 person shelter.

5.2. Walls.

It is recommended that the insulating capacity of the exterior walls of all first floor office spaces be increased by adding 1/2" gypsum board with one side faced with aluminum foil on 1" x 2" wood furring. It is estimated that the additional cost for new construction will be about $[illegible] per square foot of wall area.

5.3 MECHANICAL

5.3.1 Ventilating System.

The air supply and return ductwork serving the air handling unit and the emergency ventilation fan, transmit noise generated by the system as well as other sources too easily from one space to another. It is recommended that sound traps be installed at suitable locations within the system to reduce the noise transmission to acceptable levels.

5.3.2 Heating System.

For future shelters it is recommended that duct work be provided to supply heat to stairwells and vestibules.

5.3.3.1 Vent Piping. It is suggested that mushroom caps be provided over plumbing vents to prevent collection of radioactive dust within the vent pipe during fallout period plus reduce back-pressure to plumbing traps due to blast overpressure.

5.3.3.2 Water Piping. For convenience, it is suggested the valve assembly for the normal/emergency water supply be rearranged so that the valve handles will face the operator.

5.4 ELECTRICAL

To improve future shelters it is recommended that:

a. An electrical receptacle be provided in the emergency generator room to permit the use of a battery charger for periodically charging the engine battery.

b. Battery powered emergency service lights be installed to provide minimum lighting after disruption of commercial power.

c. Telephone conduits be installed from the entrance panel located in the machinery room to rooms where telephones are required.

d. Conduit be installed in the roof for future radio antennae.

e. Clock outlets be installed in selected locations in office and/or shelter areas.

f. A receptacle be installed on each of the four columns in the shelter areas of the 1000-person shelter (each on a separate circuit).

g. A light fixture be provided in the 1000-person shelter fan room near the damper door in the vent duct to facilitate inspection.

h. An additional light fixture be provided in the 1000-person shelter machinery room near the boiler with a switch near the doorway to the shelter area.

i. The light fixture at the 200-person shelter machinery room outside doorway be relocated to clear door swing.

j. The light fixture and conduit in the 200-person shelter generator room be relocated to clear the duct.

k. Electrical conduit be concealed in walls and ceiling where possible except in machinery rooms.

l. Switches for stair lights in the 200-person shelter be wired to permit turning lights on or off from either floor.

5.5 FUTURE TESTING

5.5.1 Acoustics.

It is recommended that sound level tests be conducted at various locations in both shelters for the following conditions:

a. With the air handling unit operating as for normal heating and ventilating.

b. With the air handling unit and compressor operating.

c. With the emergency air supply operating at rates of 3 cfm to 24 cfm per person at the rated shelter capacities using normal power.

d. As in c. above except using the emergency generator for power.

APPENDIX A

TABLE A-1

STATISTICS

	1000-PERSON SHELTER	200-PERSON SHELTER
Construction Material	Reinforced Concrete	Reinforced Concrete
Size	76' x 76'	37'-2" x 37'-2"
Number of Floors	2	2
First Floor Slab Thickness	8-1/2"	8"
Roof Thickness	13"	13"
Wall Thickness		
Below Ground Level	10"	10"
Above Ground Level	15"	16"
Protection Factor		
Basement (at center)	2640	2560
First Floor (at center)	105	100
Water Storage	4000 gal.	1000 gal.
Fuel Oil Storage	3000 gal.	1000 gal.
Emergency Air Supply	30,000 CFM	5400 CFM
Decontamination Area	None	None
Net Area per Person	10 S.F.	10 S.F.
Volume per Person	96 cu. ft.	98 cu. ft.
Total Cost	$152,226.00	$60,018.50
Cost per Person Sheltered	$ 152.23	$ 300.09

Office of Civil Defense
Department of Defense
Washington 25, D. C.

Protective Structures Division
Technical Memorandum 61-3
August 7, 1962

MINIMUM TECHNICAL REQUIREMENTS FOR GROUP (COMMUNITY) SHELTERS

I General

The purpose of these minimum technical requirements is to establish official standards which will provide the basis for economical group (community) shelters where people can be effectively protected and austerely housed. Group shelters meeting these requirements will provide a tolerable environment for at least three (3) days of continuous occupancy. However, in most parts of the United States and for most times of the year, these requirements will permit a continuous occupancy for longer than three (3) days. Minor modifications to suit applicable building codes may be necessary. Care must be taken, however, not to diminish the protective characteristics of the shelter.

II Terminology

A. Fallout Shelter A structure, room or space designed to protect its occupants from fallout gamma radiation, and provide a protection factor of at least 100.

B. Protection Factor A factor used to express the relation between the amount of fallout gamma radiation that would be received by an unprotected person and the amount received by one in a shelter. (For example, an unprotected person would be exposed to 100 times more radiation than a person inside a shelter when the protection factor is 100.)

C. Blast-resistant Shelter A shelter meeting the requirements of II A and designed to protect its occupants against the effects of blast, and associated initial nuclear and thermal radiation, for a design overpressure of at least 25 pounds per square inch.

D. Limited Blast-resistant Shelter A shelter meeting the requirements of II A and designed to protect its occupants against the effects of blast, and associated initial nuclear and thermal radiation, for a design overpressure of at least 5 pounds per square inch.

E. Dual-purpose Shelter A shelter having a normal use which would not appreciably interfere with its use in emergency.

F. Group Shelter A shelter for ten (10) or more people.

G. Community Shelter A group shelter with a capacity of at least 50 persons.

III Space and Ventilation Requirements

A. Provision shall be made to prevent the build-up of vitiated air in shelter to a level hazardous to its occupants during the design period of occupancy.

B. At least 10 square feet of shelter floor area per person shall be provided.

C. At least 65 cubic feet of space per person shall be provided.

D. If the shelter capacity is based on minimum space requirements, then at least 3 cubic feet of fresh air per minute per person are required.

E. When ventilation is limited, the following table can be used for determining the relation of space requirements to ventilation:

Rate of air change (minutes) /1	Volume of space required per person (Cu. Ft.)
1,000 or more	500 /2
600	450
400	400
200	300
100	200
60	150
35	100
22	65

/1 Computed as the ratio: $\dfrac{\text{Net volume of space (cu. ft.)}}{\text{Fresh air supply (cfm)}}$

/2 Shelter capacity or occupancy time may be limited by the volume of the room and not by its area. This is particularly true if mechanical ventilation is inadequate. In many cases, however, interior stairwells, shafts, and ducts would create enough natural ventilation to permit a continuous occupancy for at least three (3) days.

F. Filters are required on mechanical ventilation systems. They should be capable of removing at least 90% of 50 micron particles.

IV Basic Structural Requirements

A. In general, conventional methods of design and construction for concrete, wood, steel, brick, structural tile and other products will be followed. Variations from conventional methods shall be theoretically and experimentally demonstrated as being capable of carrying design loads. Allowable stresses and/or load factors as defined in the applicable codes shall be used.

E. In areas subject to natural hazards (earthquakes, hurricanes, etc.), provisions shall be made to prevent structural damage by any of these natural events.

V Construction Requirements

A. The structure shall be designed for useful life of at least 10 years.

B. At least one unit of access and egress width should be provided for every 200 shelter occupants (a unit width is 22 inches, the space required for free travel of one aisle of persons). In no case shall the width be less than 24 inches; nor shall there be less than two widely separated means of egress from each building, except in some special cases such as mines. Emergency-type hatchways may be used as a means of egress. They shall be designed so that any normal-size adult can readily enter or leave the main shelter chamber.

C. Shelters offering resistance to blast shall not use construction materials that are of frangible nature. The use of these materials in fallout shelters is discouraged.

D. The interior surfaces of shelters offering resistance to blast which are susceptible to dusting shall be painted, coated, or otherwise treated to eliminate this possibility.

E. Shelters offering resistance to blast shall not have false ceilings, loosely-supported fixtures or other elements (such as open storage shelves) likely to create flying debris in the event of shock. The use of such items in fallout shelters is discouraged.

F. In areas subject to high ground water conditions, provisions shall be made to prevent flotation of the shelter.

G. Provisions shall be made to insure the shelter interior will remain reasonably dry. When necessary, such items as surface, perimeter and subgrade drainage, damp-proofing and water-proofing shall be accomplished.

H. Hazardous utility lines such as steam, gas, etc. should not be located in or near the shelter area unless provision is made to eliminate such hazards before the shelter is occupied.

I. Appropriate provisions shall be made for use of ordinary battery-operated radios. This may require installation of suitably designed antenna.

J. Provision shall be made for the prevention of infestation of the shelter area by insects, rodents, or other pests.

VI Fire Resistance

A. All shelters shall be constructed to minimize the danger of fire from both external and internal sources.

B. Exterior surfaces of shelters offering resistance to blast shall not be ignitable by the thermal pulse associated with the range of the design overpressure. This shal be determined by methods approved by the Office of Civil Defense.

C. Shelters offering resistance to blast and, when feasible, fallout shelters with entranceways to existing buildings shall be provided with closures which will heat-isolate the shelter chamber from the associated building. These closures shall also prevent the infiltration of noxious gases.

D. Shelters offering resistance to blast and, when feasible, fallout shelters shall have air-intake systems located to minimize the chances of heated air or noxious gases from outside fires being drawn into the system.

VII Radiation Shielding

A. The protection factor of a fallout shelter shall be determined by methods approved by the Office of Civil Defense.

B. In shelters offering resistance to blast, the shielding required to adequately reduce the initial gamma and neutron radiation shall be calculated at the range of the design overpressure, using methods approved by the Office of Civil Defense. Using these methods, the inside dose from initial radiation shall not exceed 20 rad.

C. If filters or plenum chambers or other areas where radioactive particles can accumulate are in or adjacent to a shelter area, they shall be properly shielded.

D. In the calculation of the protection factor, the radiation dose contribution to the shelter occupants coming from the entranceways, ventilation ducts or other openings in the shelter's barriers shall be considered.

E. Entranceways shall be properly designed to prevent the infiltration of fallout particles and to reduce the fallout gamma radiation hazard through the use of principles of geometry and/or barrier shielding.

VIII Blast Resistance

A. The blast resistance of a shelter and its components shall be calculated by methods approved by the Office of Civil Defense.

B. Shelters offering resistance to blast shall be capable of withstanding the design overpressure without structural collapse or serious injury to the occupants. The equipment associated with the shelter such as vent pipes, doors, storage tanks, ductwork and other blast-sensitive items shall be designed to perform satisfactorily at the same overpressure range.

C. In shelters offering resistance to blast, openings to the atmosphere shall be provided with appropriate devices to prevent a build-up of pressure within the shelter so that its occupants are subject to no greater than 5 psi. Care shall be taken to assure that duct systems and other blast sensitive items are properly protected.

IX Services

A. General provisions shall be made for the storage of basic shelter supplies by allotting at least one and one-half cubic feet per person. These supplies may include such items as water, sanitary kits, medical kit, radiation meter and food.

B. Water Supply

1. Provisions shall be made for a potable shelter water supply. The total quantity available shall not be less than 3½ gallons per occupant.

2. Approved disposable water containers, a suitable well or water storage tank shall be provided to assure an adequate potable water supply.

3. Water storage containers shall be non-frangible unless special provision is made to minimize the possibility of breakage.

4. In fallout shelters, stored water shall be kept in the shelter itself or in nearby, readily accessible areas of the building in which the shelter is located.

5. In shelters offering resistance to blast, stored water shall be either (a) kept in suitable containers within the protected area, or (b) kept in containers outside the shelter, in which case storage tanks and associated piping shall be able to sustain the design overpressure without leakage.

C. Sanitation

1. Provisions shall be made for the disposal of garbage, trash, and human waste in such a way as to preclude the creation of unsanitary conditions or offensive odors.

2. Regular or austere flush-type toilets, chemical or disposable toilets shall be available on the basis of one per 25 occupants. In fallout shelters, 50% of these may be outside the shelter area, if readily available in other parts of the building.

D. Electrical

1. Fallout shelters do not require emergency power if it can reasonably be assumed that regular power supplies will be available under fallout conditions.

2. Blast shelters shall have emergency power.

3. Emergency power shall be adequate to operate at least the following systems:

(a) Required ventilation.
(b) Required lighting.
(c) Emergency water supply (when provided).
(d) Emergency sewage ejection (when provided).

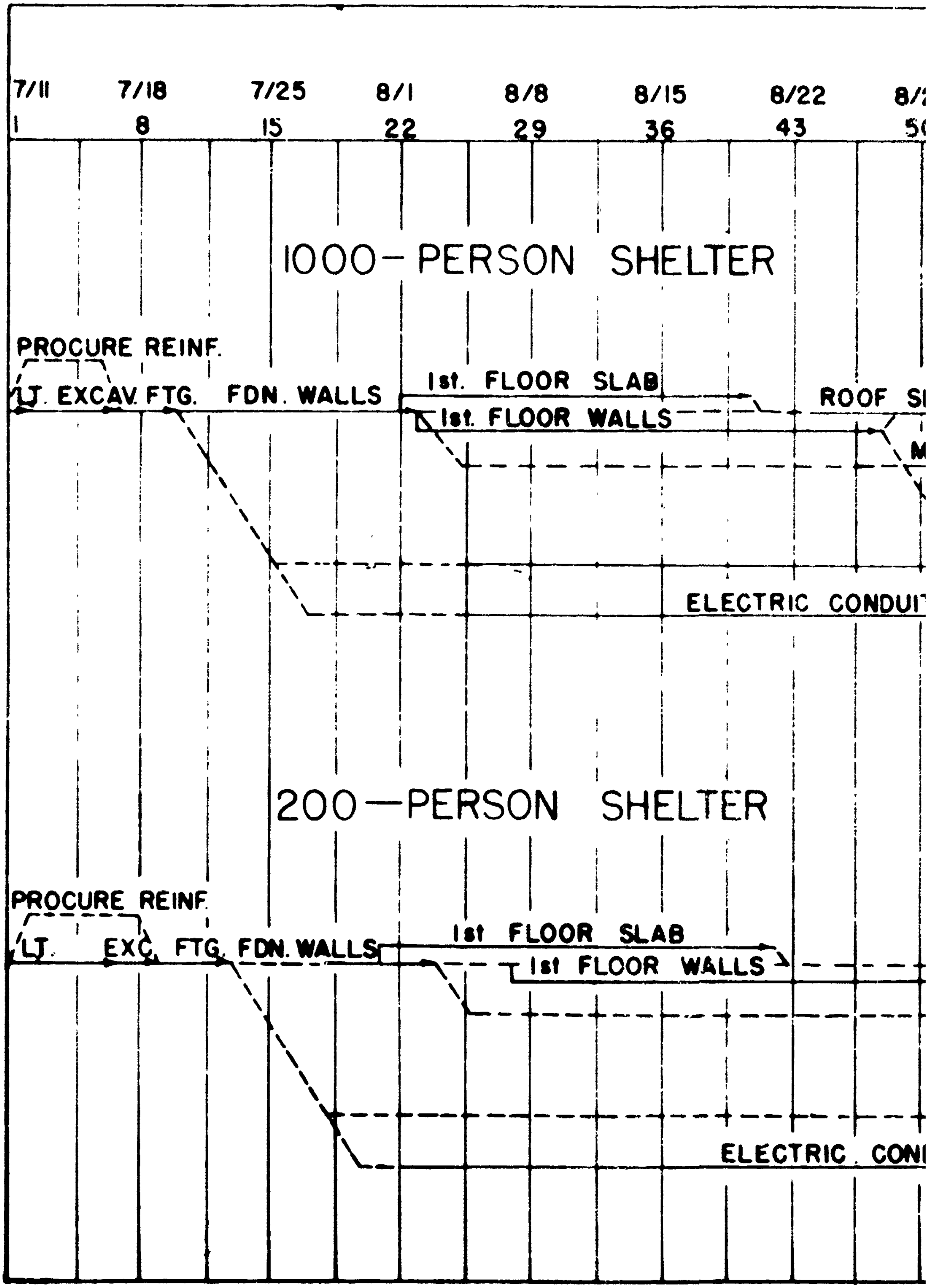
4. Emergency engine-generator sets shall have separate vents and be heat-isolated from the main shelter chamber. Special consideration must be given to the manner of installation of engine-generator sets and fuel tanks to minimize hazards from exhaust gases and fires.

5. Emergency engine-generator sets shall have a storage tank for a fuel supply of at least 2 weeks. In blast shelters, engine-generator sets and auxiliary equipment must be designed to perform in accordance with paragraph VIII C.

6. Emergency lighting levels shall be at least:

(a) Sleeping areas (floor level) -- 2-foot candles.
(b) Activity areas (floor level) -- 5-foot candles.
(c) Administrative and medical areas (desk level) -- 20-foot candles.

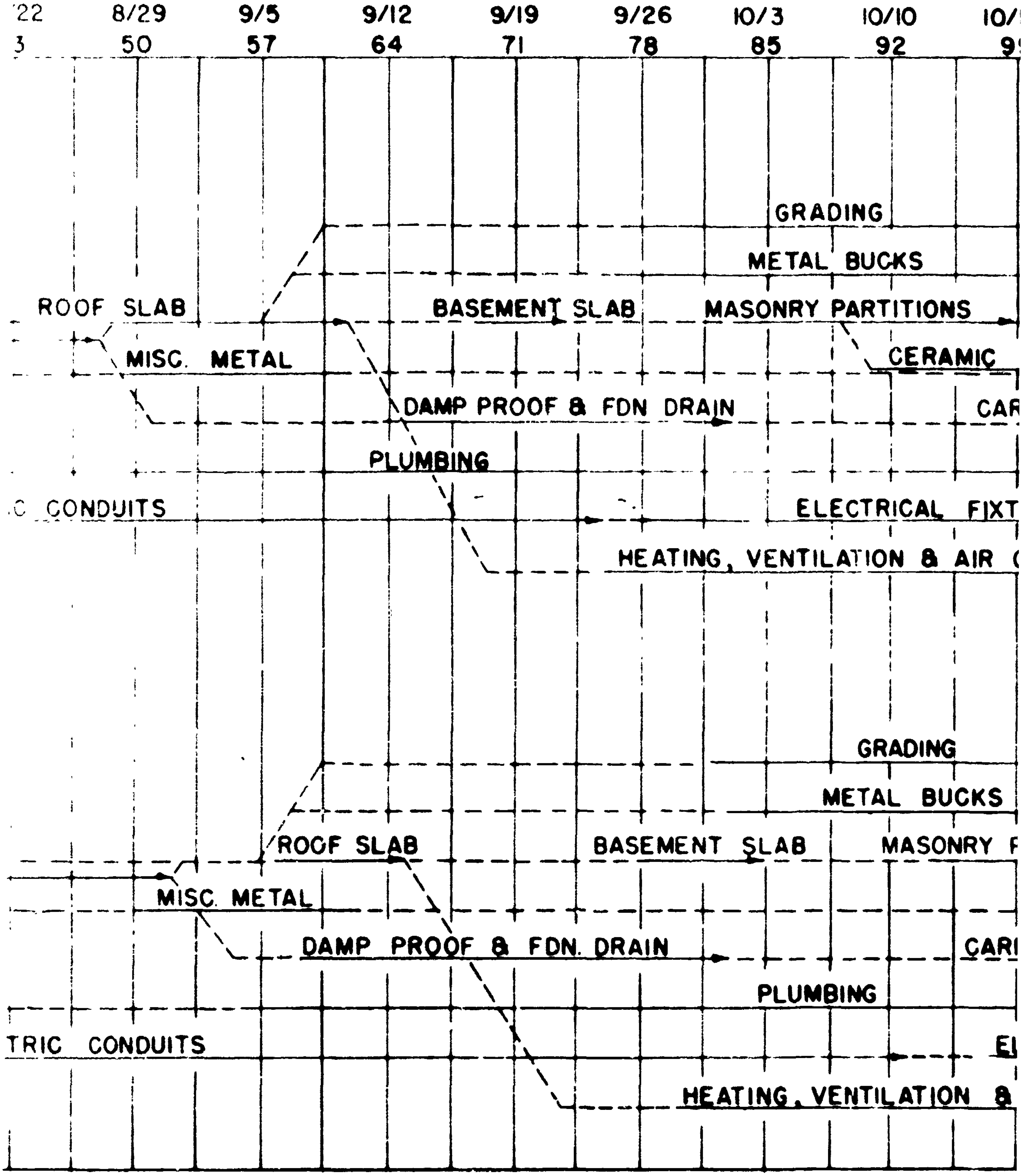
7. Normal use circuits may be modified by appropriate switching in order to meet the above requirements, and allow use of normal power sources when they are available.

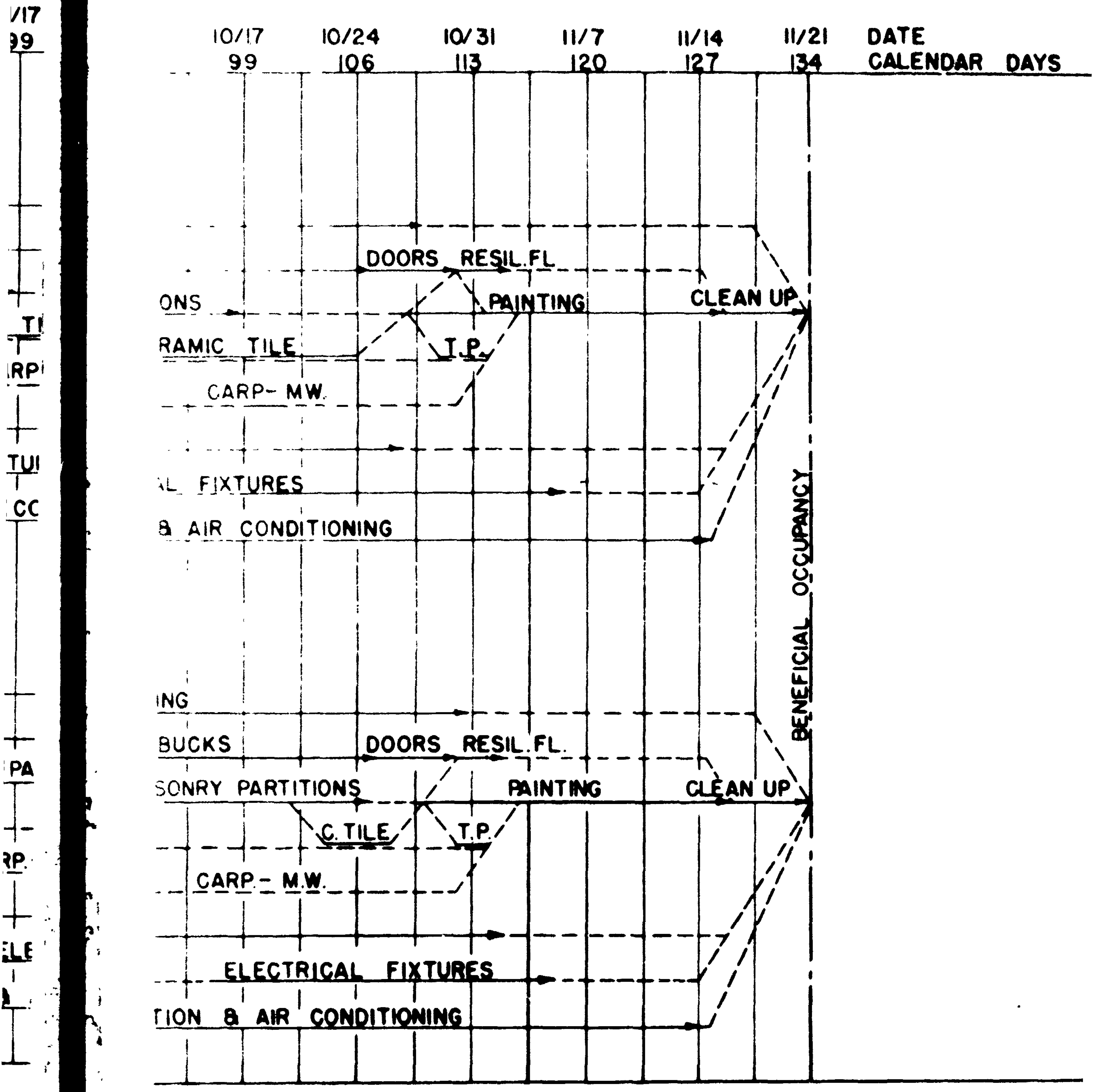


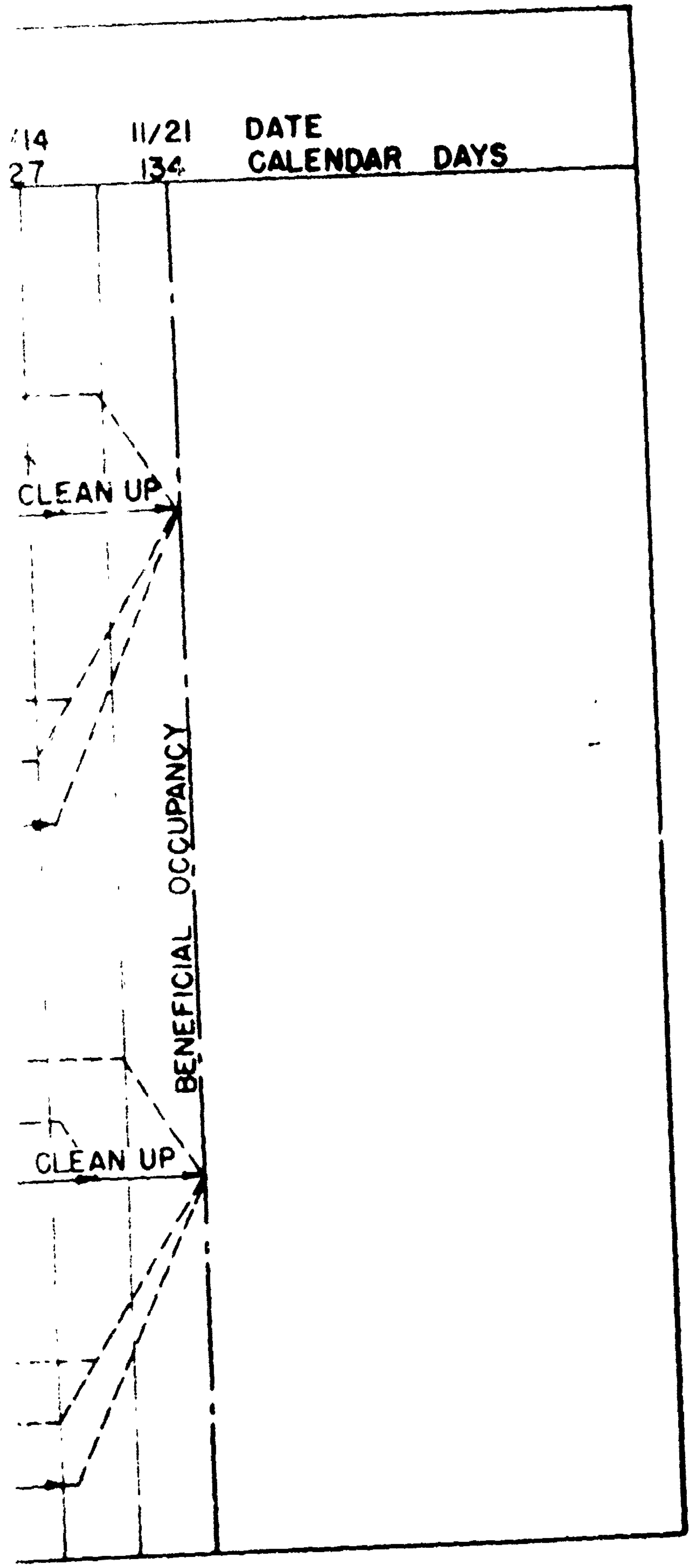
7/11
7/18
7/25
8/1
8/8
8/15
8/22
1
8
15
22
29
36
43
1000-PERSON SHELTER
PROCURE REINF.
LT. EXCAV. FTG.
FDN. WALLS
1st. FLOOR SLAB
1st. FLOOR WALLS
ELECTRIC CONDUI
200-PERSON SHELTER
PROCURE REINF.
LT.
EXC.
FTG.
FDN. WALLS
1st FLOOR SLAB
1st FLOOR WALLS
ELECTRIC

APPENDIX C

CONSTRUCTION PROGRESS CHART




10/17
99
10/24
106
10/31
113
11/7
120
11/14
127
11/21
134
DATE
CALENDAR DAYS
DOORS
RESIL.FL
ONS
PAINTING
CLEAN UP
RAMIC TILE
T.P.
CARP- MW.
FIXTURES
& AIR CONDITIONING
BENEFICIAL OCCUPANCY
ING
BUCKS
DOORS
RESIL.FL.
SONRY PARTITIONS
PAINTING
CLEAN UP
C.TILE
T.P.
CARP.- M.W.
ELECTRICAL FIXTURES
TION & AIR CONDITIONING


14
27
11/21
134
DATE
CALENDAR DAYS
CLEAN UP
BENEFICIAL OCCUPANCY
CLEAN UP

APPENDIX D

TABLE D-1

SCHEDULE OF PRICES BASED ON CONTRACTOR'S BID PROPOSAL

ITEM	PRICE
1000-Person Shelter	
Building	$ 103,113.00
Mechanical & Electrical	49,113.00*
	$ 152,226.00
200-Person Shelter	
Building	$ 34,140.00
Mechanical & Electrical	25,878.50**
	$ 60,018.50

*About 15% of this amount was for electrical.
**About 12% of this amount was for electrical.

TABLE D-2

MATERIALS LIST - 1000 PERSON SHELTER (ESTIMATED)

ITEM	UNIT	QUANTITY	UNIT COST	TOTAL COST
Concrete	cy	876	$ 18.00	$ 15,768
Reinforcing	#	100,200	.10	10,020
Mesh	sf	5,900	.04	236
Forms				
Footings	sf	1,200	.20	240
Walls, Floors, Cols., etc.	sf	21,040	.30	6,313
Roof	sf	5,620	.32	1,798
Roof curb	lf	220	.10	22
Floor keys	lf	310	.05	15
Vapor Barrier	sf	5,720	.01	57
Gravel Fill (slab)	cy	212	3.50	742
Curing & Finishing Materials	ls			900
Stair Risers	lf	140	4.00	560
Masonry				
4" Interior Partitions	sf	1,711	.25	428
6" Interior Partitions	sf	4,152	.32	1,328
Miscellaneous Metals	ls			994
Toilet Partitions	ea	4	90.00	360
Carpentry				
Information Desk	lf	13	20.00	260
Janitor Closet	set	2	75.00	150
Doors & Frames	ls			2,885
Ceramic Tile				
Floors	sf	600	.90	540
Walls	sf	980	.90	882
Paint	ls			805
Asphalt Tile	sf	4,400	.12	528
Rubber Base	lf	455	.30	137
Glazing	ls			216
Damp Proofing	sf	3,000	.03	90
Toilet Accessories	ls			72
Plumbing	ls			5,850
Heating, Vent. & Air Condit.	ls			12,625
Electric	ls			2,388
				$ 67,209

APPENDIX D

TABLE D-3

MATERIALS LIST - 200 PERSON SHELTER (ESTIMATED)

ITEM	UNIT	QUANTITY	UNIT COST	TOTAL COST
Concrete	cy	316.7	$ 18.00	$ 5,701
Reinforcing	#	25,914	.10	2,591
Mesh	sf	1,509	.04	60
Forms				
Footings	sf	465	.20	93
Walls, Floors, Cols., etc.	sf	8,977	.30	2,693
Roof	sf	1,470	.32	470
Roof curb	lf	160	.10	16
Floor keys	lf	180	.05	9
Vapor barrier	sf	1,372	.01	14
Gravel fill (slab)	cy	42	3.50	147
Curing & Finishing Materials	ls			256
Stair Risers	lf	70	4.00	280
Masonry				
4" Interior Partitions	sf	692	.25	173
6" Interior Partitions	sf	1,325	.32	424
Miscellaneous Metals	ls			494
Toilet Partitions	ea	4	90.00	360
Carpentry				
Janitor closet	set	1	75.00	75
Doors & Frames	ls			2,534
Ceramic Tile				
Floors	sf	252	.90	227
Walls	sf	526	.90	473
Asphalt Tile	sf	607	.12	73
Rubber Base	lf	180	.30	54
Paint	ls			346
Glazing	ls			84
Damp proofing	sf	1,788	.03	54
Toilet Accessories	ls			72
Plumbing	ls			3,045
Heating, Vent. & Air Condit.	ls			5,554
Electric	ls			989
				$27,361

TABLE D-4

CONSTRUCTION EQUIPMENT - 1000 PERSON SHELTER (ESTIMATED)

TYPE	HOURS	COST/HOUR	COST
Air Compressors	2	$ 7.99	$ 15.98
Cranes	39	15.06	587.34
Dozers (D-6)	51	8.69	443.19
Front End Loaders	149	6.92	1031.08
Mortar Mixers	24	2.00	48.00
Pans (5yd)	29	12.47	361.63
Tractors	14	3.82	53.48
Trucks	119	3.04	361.76
Welding Machines	3	2.38	7.14
TOTAL			$2909.60

TABLE D-5

CONSTRUCTION EQUIPMENT - 200 PERSON SHELTER (ESTIMATED)

TYPE	HOURS	COST/HOUR	COST
Cranes	25	$ 15.06	$ 376.50
Dozers (D-6)	15	8.69	130.35
Front End Loaders	114	6.92	788.88
Mortar Mixers	16	2.00	32.00
Tractors	8	3.82	30.56
Trucks	36	3.04	109.44
Welding Machines	4	2.38	9.52
			$1477.25

TABLE D-6

LABOR FOR 1000 PERSON SHELTER (ESTIMATED)

Classification	Rate/Hour	Man-Hours	Cost
Superintendent	$ 4.00	416	$ 1,664.00
Engineers	3.75	45	168.75
Foremen	5.625	1,343	7,554.37
Carpenters	4.00	2,899	11,596.00
Electrician	4.55	721	3,280.55
Electrician Apprentice	1.82	170	309.45
Finishers	4.025	2,133	8,585.32
Glazier	4.105	8	32.84
Insulators	4.95	103	509.85
Insulator Apprentice	2.62	55	144.10
Iron Workers	4.15	600	2,490.00
Laborers	2.65	6,783	17,974.95
Linemen	4.55	16	72.80
Masons	4.59	360	1,652.40
Mechanics	4.55	221	1,005.55
Mortar Men	2.85	24	68.40
Operators:			
Air Tool	2.80	2	5.60
Crane	4.17	39	162.63
Dozer	3.72	51	189.72
F. E. Loader	3.87	149	576.63
Pan	3.72	29	107.88
Tractor	3.72	14	52.08
Painters	3.825	152	581.40
Plumbers	4.50	354	1,593.00
Roofers	3.70	28	103.60
Steam Fitters	4.70	276	1,297.20
Sheetmetal Men	4.68	340	1,591.20
Tile Setters (Asphalt)	4.22	30	126.60
Tile Setters (Ceramic)	4.22	96	405.12
Tile Setters Helpers	3.22	24	77.28
Truck Drivers	2.425	119	288.57
Welders	4.15	3	12.45
TOTAL		17,603	$64,280.29

TABLE D-7

LABOR FOR 200 PERSON SHELTER (ESTIMATED)

Classification	Rate/Hour	Man-Hours	Cost
Superintendent	$ 4.00	211	$ 844.00
Engineers	3.75	16	60.00
Foremen	5.625	607	3,414.37
Carpenters	4.00	1,487	5,948.00
Electrician	4.55	368	1,674.40
Electrician Apprentice	1.82	157	285.74
Finishers	4.025	896	3,606.40
Glazier	4.105	8	32.84
Insulators	4.95	88	435.60
Insulator Apprentice	2.62	8	20.96
Iron Workers	4.15	131	543.65
Laborers	2.65	3,805	10,083.25
Linemen	4.55	16	72.80
Masons	4.59	232	1,064.88
Mechanics	4.55	129	586.95
Mortar Men	2.85	16	45.60
Operators:			
Crane	4.17	25	104.25
Dozer	3.72	15	55.80
F.E. Loader	3.87	114	441.18
Tractor	3.72	8	29.76
Painters	3,825	114	436.05
Plumbers	4.50	330	1,485.00
Roofers	3.70	12	44.40
Steam Fitters	4.70	243	1,142.10
Sheetmetal Men	4.68	198	926.64
Tile Setters (Asphalt)	4.22	26	109.72
Tile Setters (Ceramic)	4.22	64	270.08
Tile Setters Helpers	3.22	56	180.32
Truck Driver	2.425	36	87.30
Welders	4.15	4	16.60
TOTAL		9,420	$34,048.64

TABLE D-8

COST SUMMARY BASED ON CONSTRUCTION DATA AND MATERIALS (ESTIMATED)

ITEM	COST
1000 Person Shelter	
Materials (estimated)	$ 67,209
Construction Equipment	2,909
Labor	64,280
12% Labor Benefits, Insurance & Taxes	7,714
	142,112
10% Overhead	14,211
	156,323
10% Profit	15,632
Total	$ 171,955
200 Person Shelter	
Materials (estimated)	$ 27,361
Construction Equipment	1,477
Labor	34,048
12% Labor Benefits, Insurance & Taxes	4,086
	66,972
10% Overhead	6,697
	73,669
10% Profit	7,367
Total	$ 81,036

Figure E.1 Construction of 1000-person shelter. U.S. Army Photograph

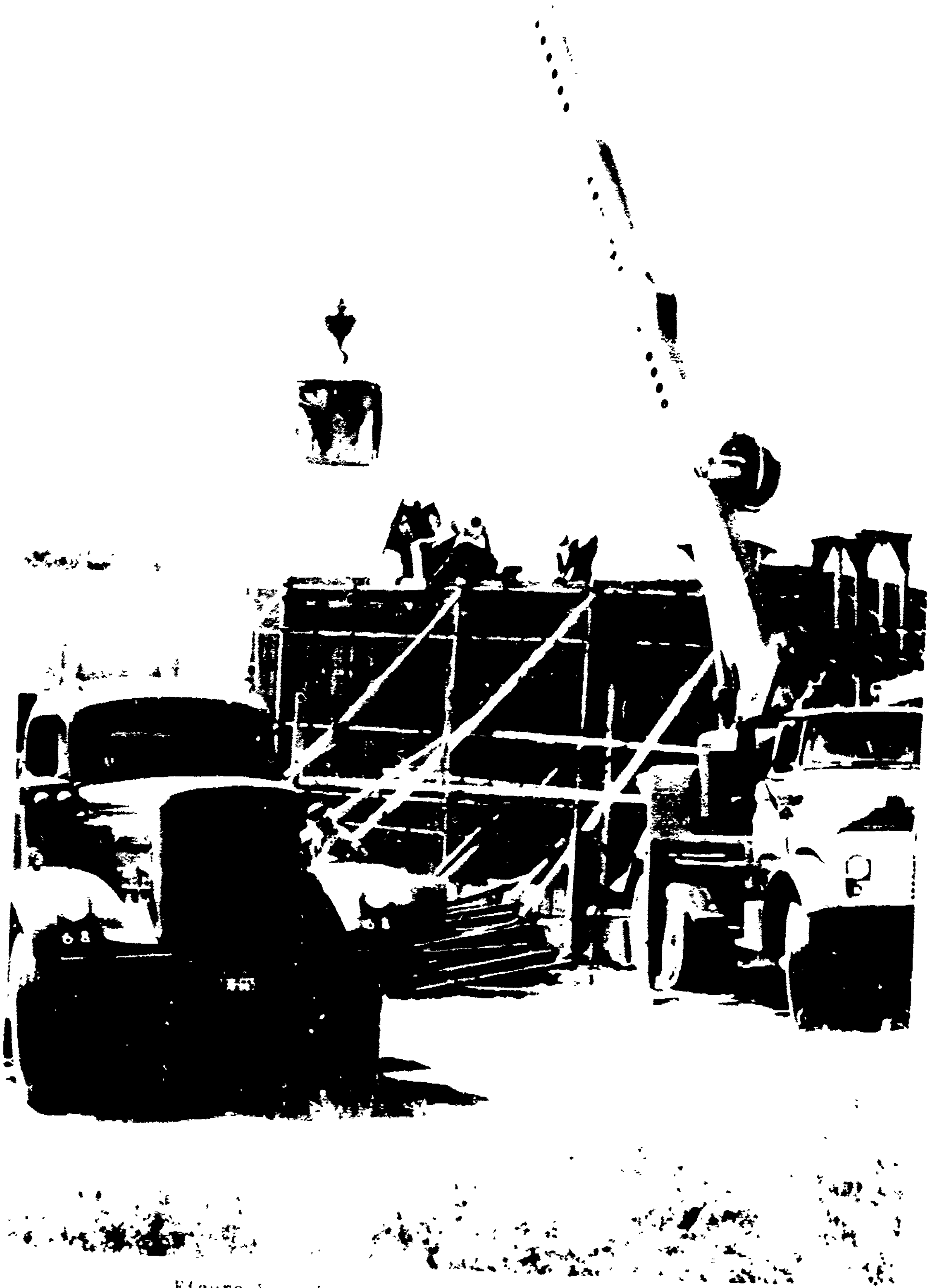


Figure F-. Pouring concrete at 100-person shelter.

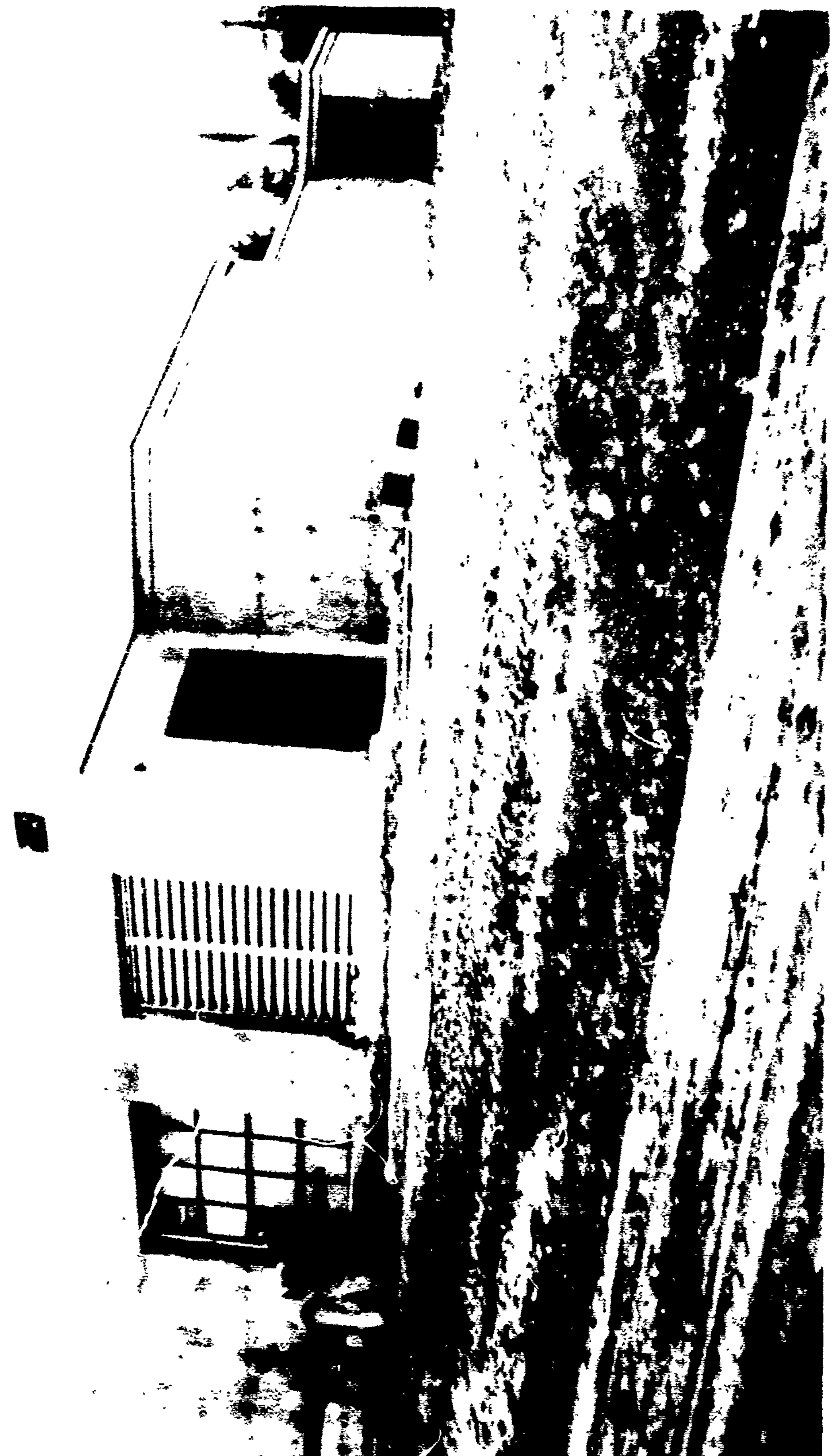


Figure E.3 Installing filters at 1000-person shelter. U.S. Army Photograph

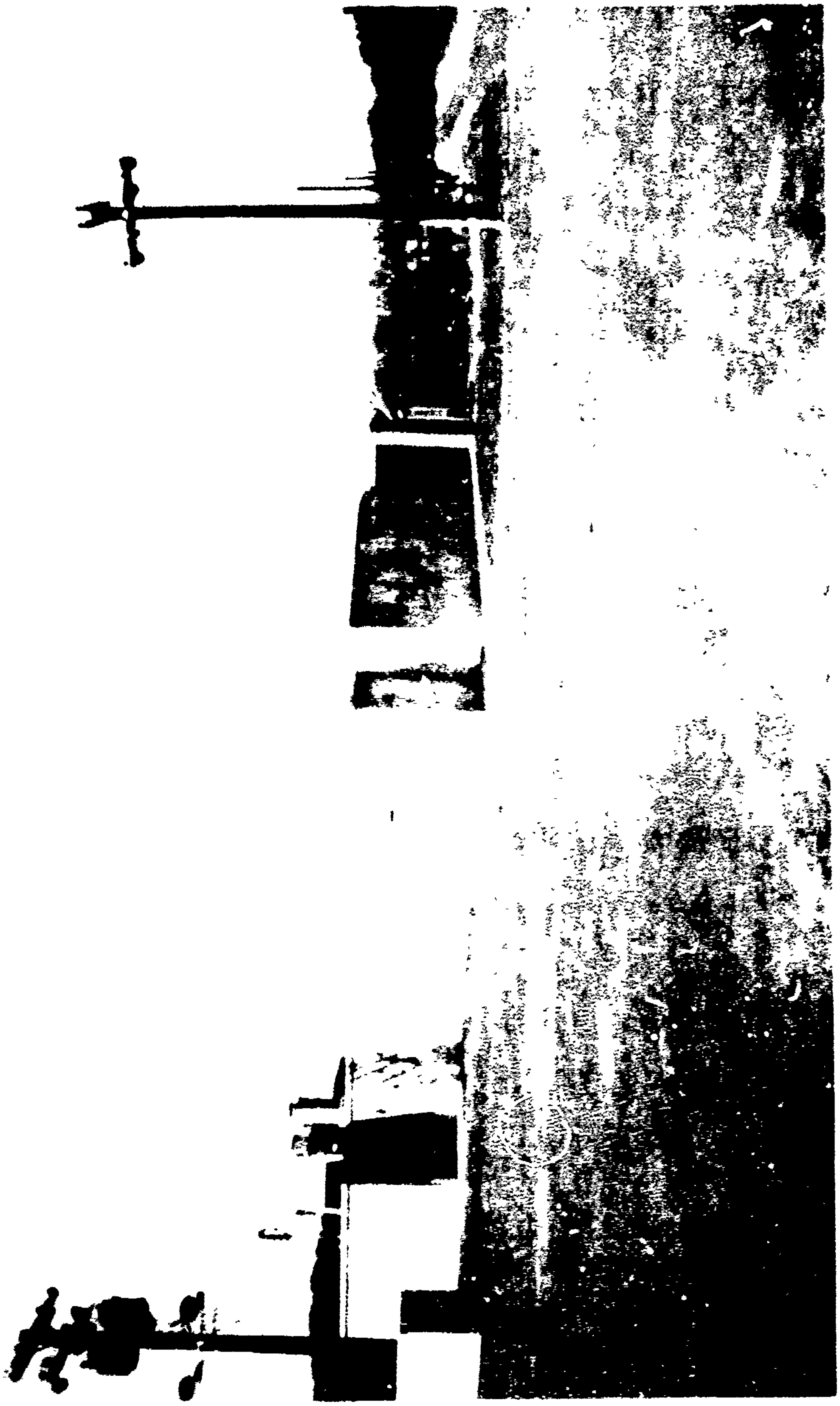
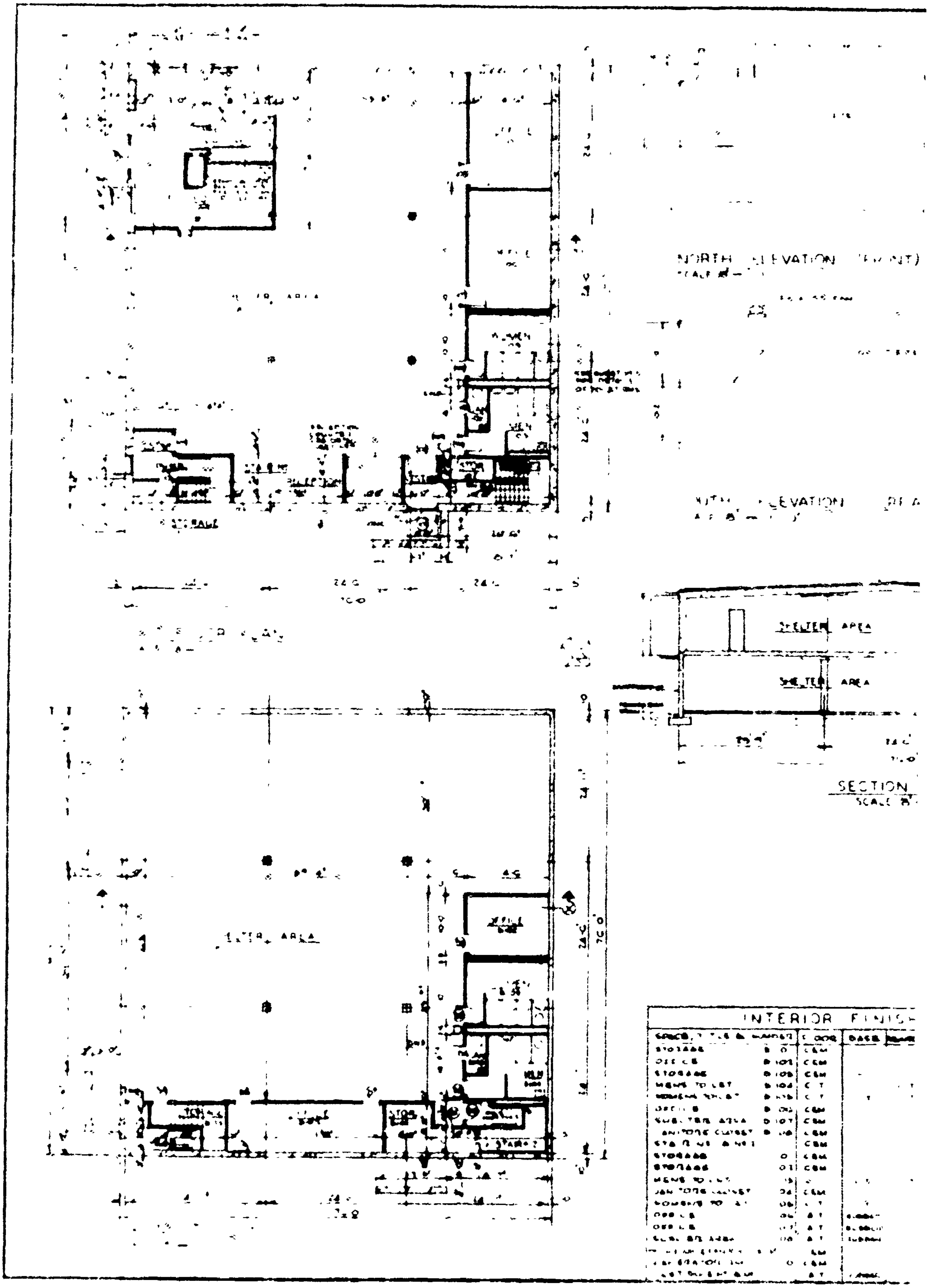


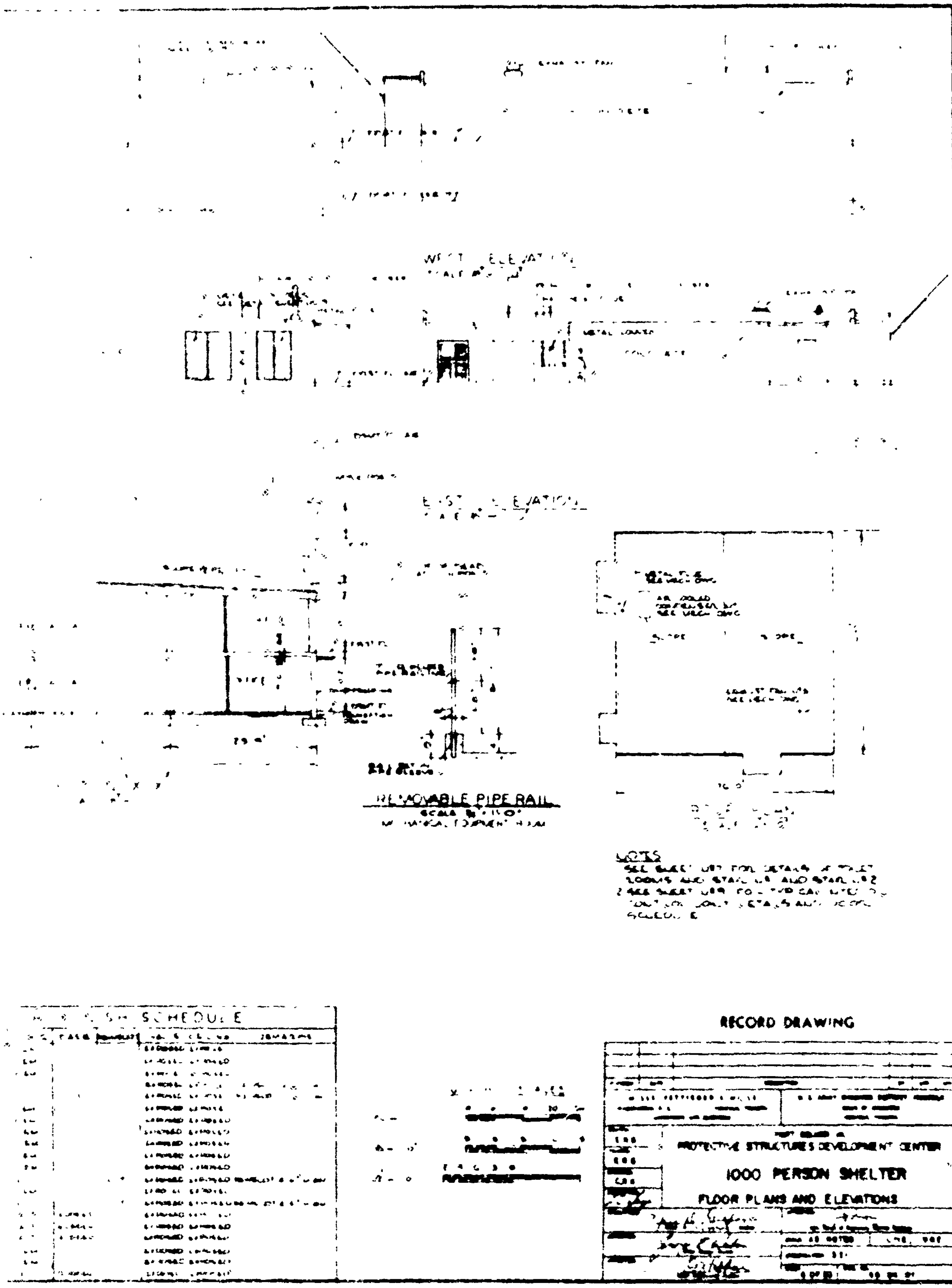
Figure E.4 1000-person shelter. U.S. Army Photograph

Figure E.5 Placing reinforcing steel at 200-person shelter.

Figure E.6 200-person shelter. U.S. Army Photograph

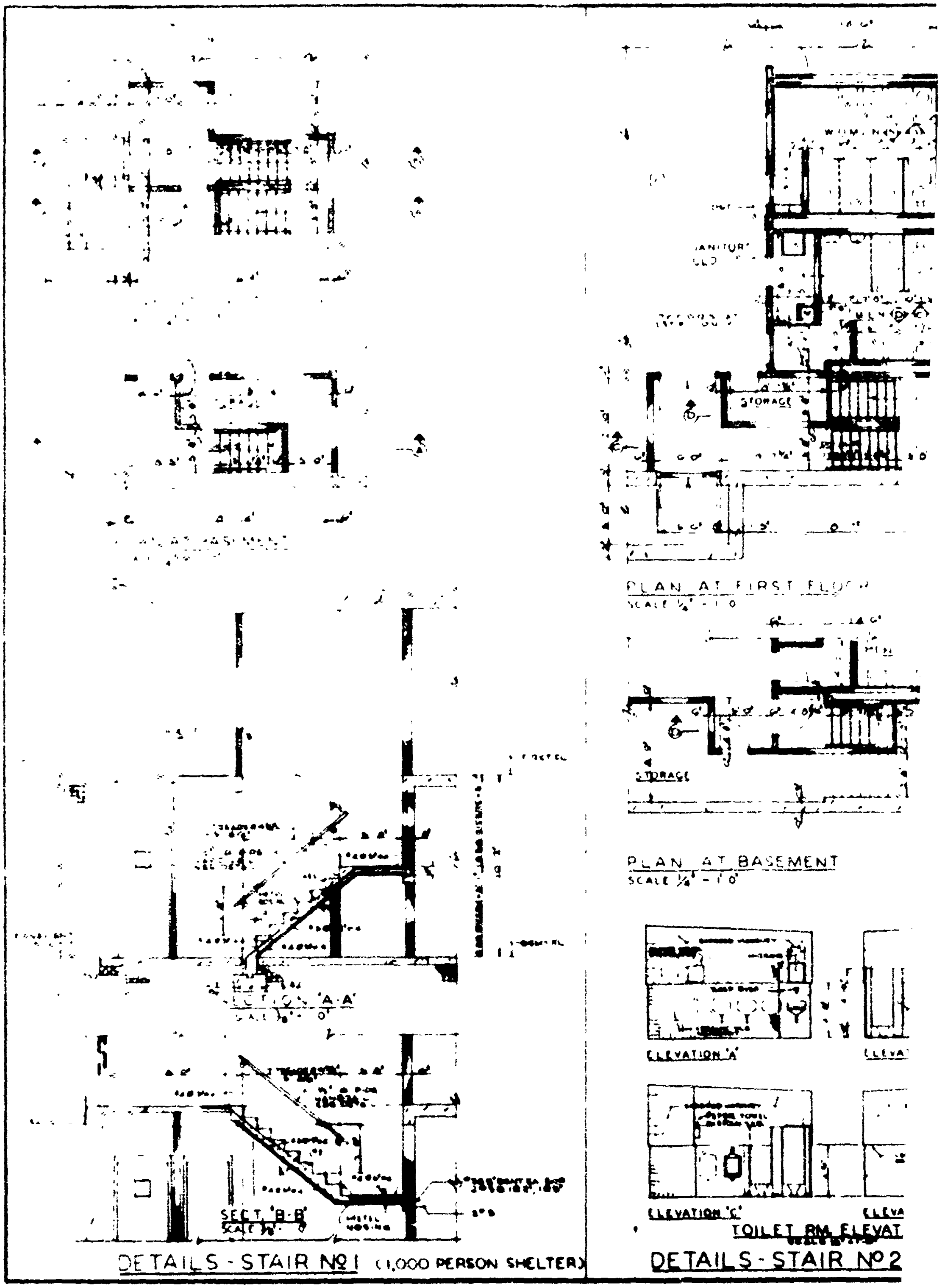

NORTH ELEVATION (FRONT)
SOUTH ELEVATION (REAR)
SHELTER AREA
SHELTER AREA
SECTION
SCALE
STORAGE
INTERIOR FINISH
STORAGE
OFFICE
STORAGE
OFFICE
STORAGE
STORAGE
JANITORS CLOSET
OFFICE
OFFICE

U S ARMY

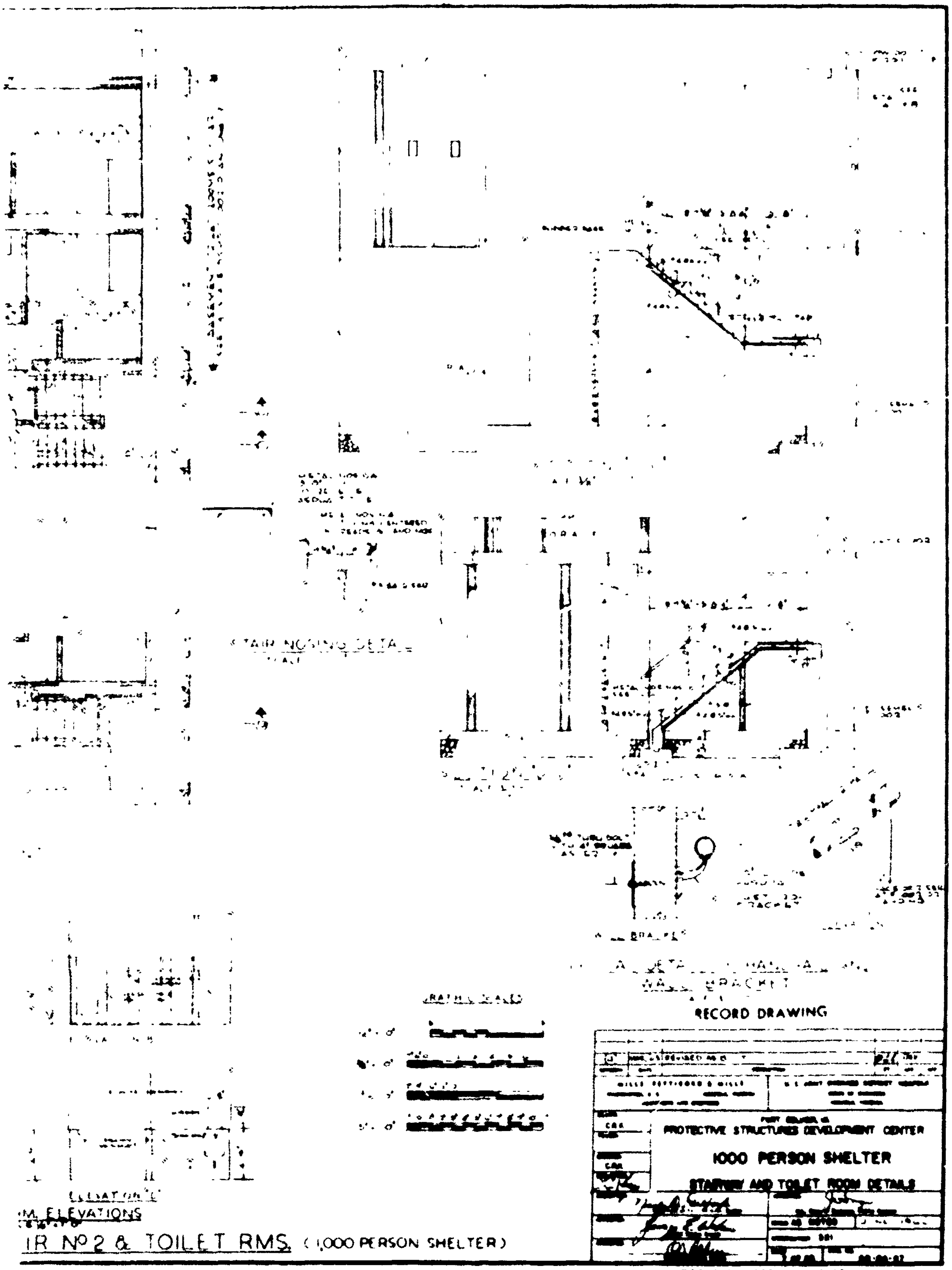


NORFOLK DISTRICT FILE NO FB 101

2


STORAGE
PLAN AT FIRST FLOOR
PLAN AT BASEMENT
SCALE 1/4" = 1'-0"
SECTION 'A-A'
SECT. 'B-B'
METAL NOSING
ELEVATION 'A'
ELEVATION 'C'
TOILET RM. ELEVAT
DETAILS - STAIR No 1 (1,000 PERSON SHELTER)
DETAILS - STAIR No 2

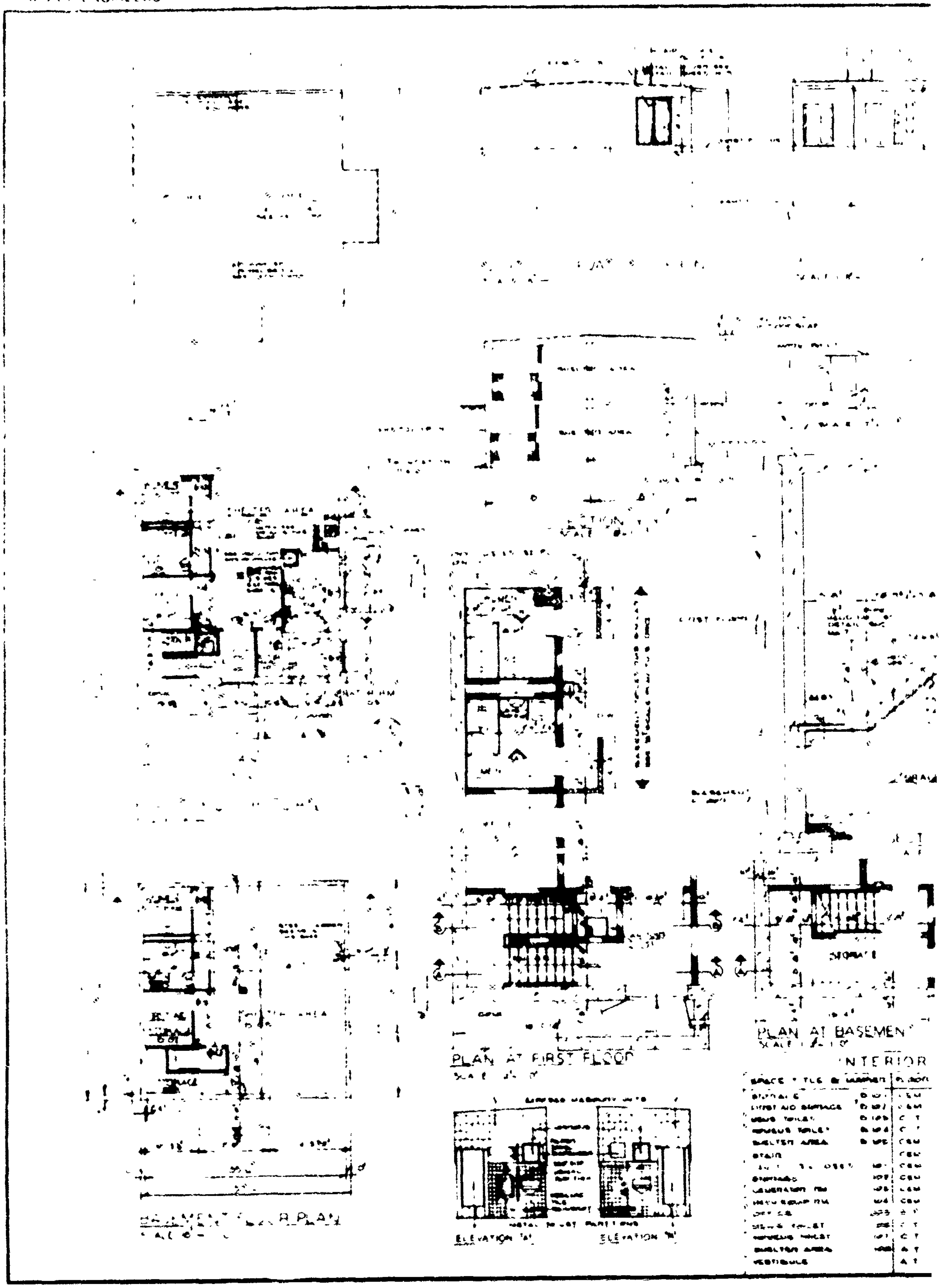
U S ARMY



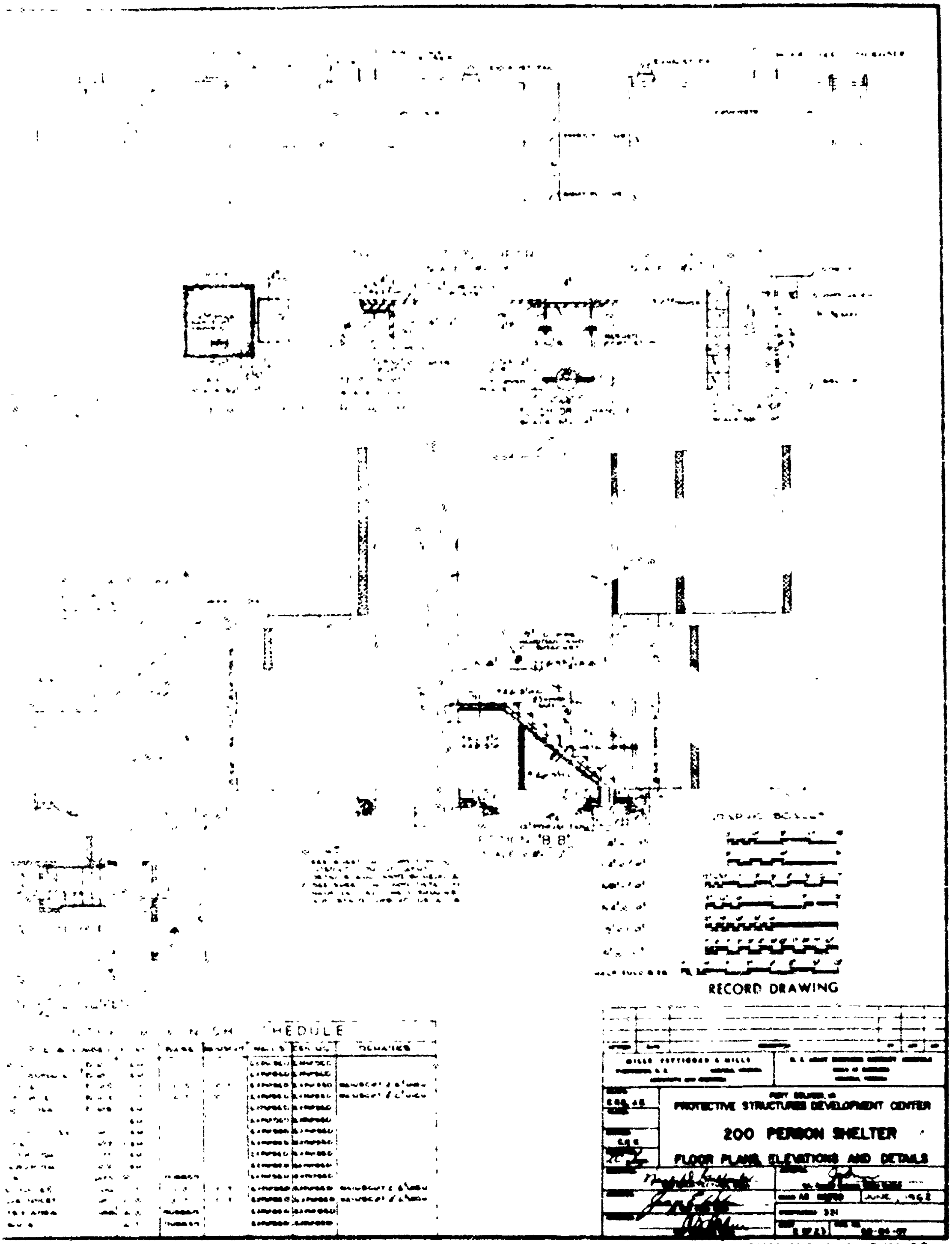
NORFOLK DISTRICT FILE NO. PD 101-27

2

CORPS OF ENGINEERS

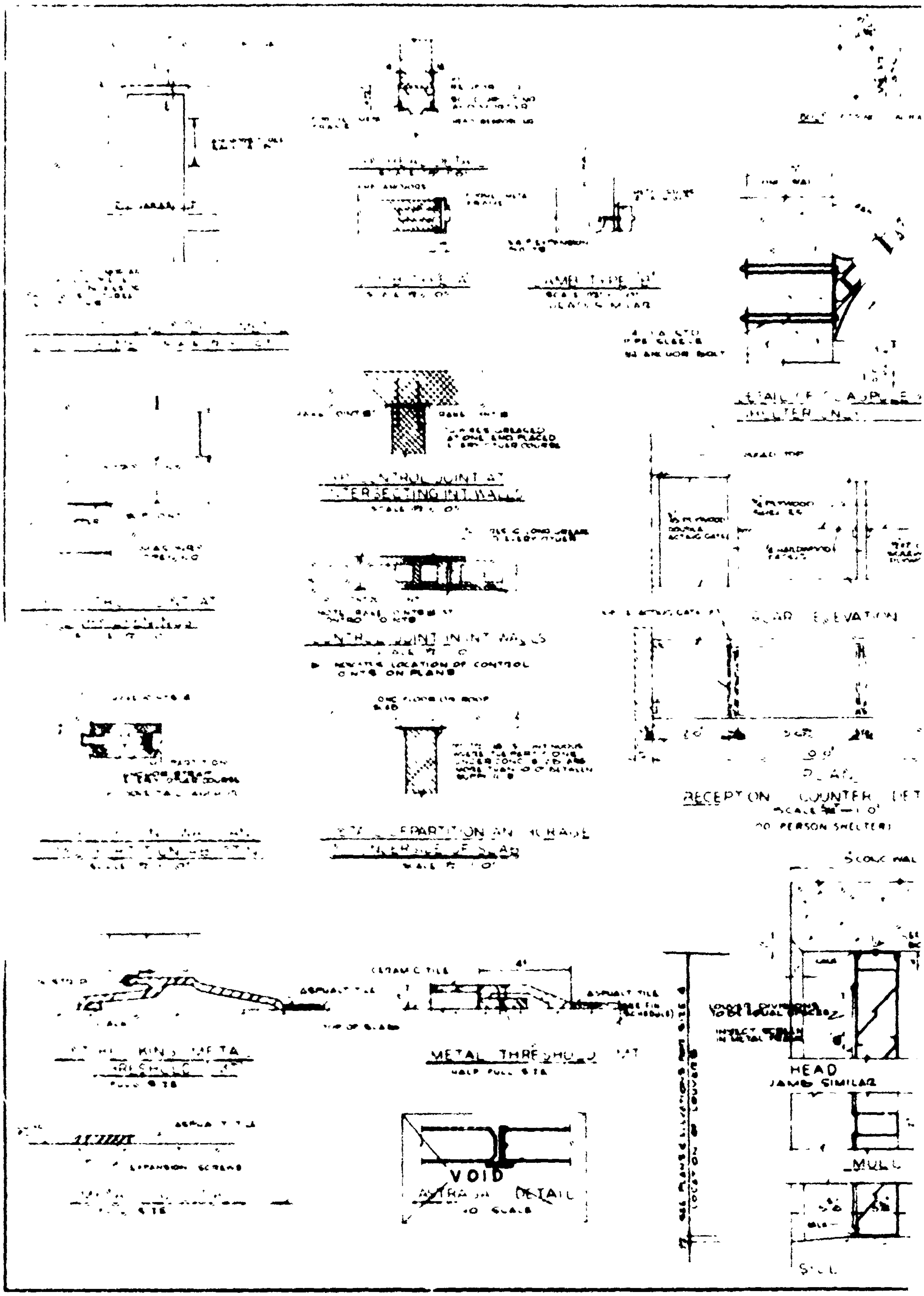


U S ARMY

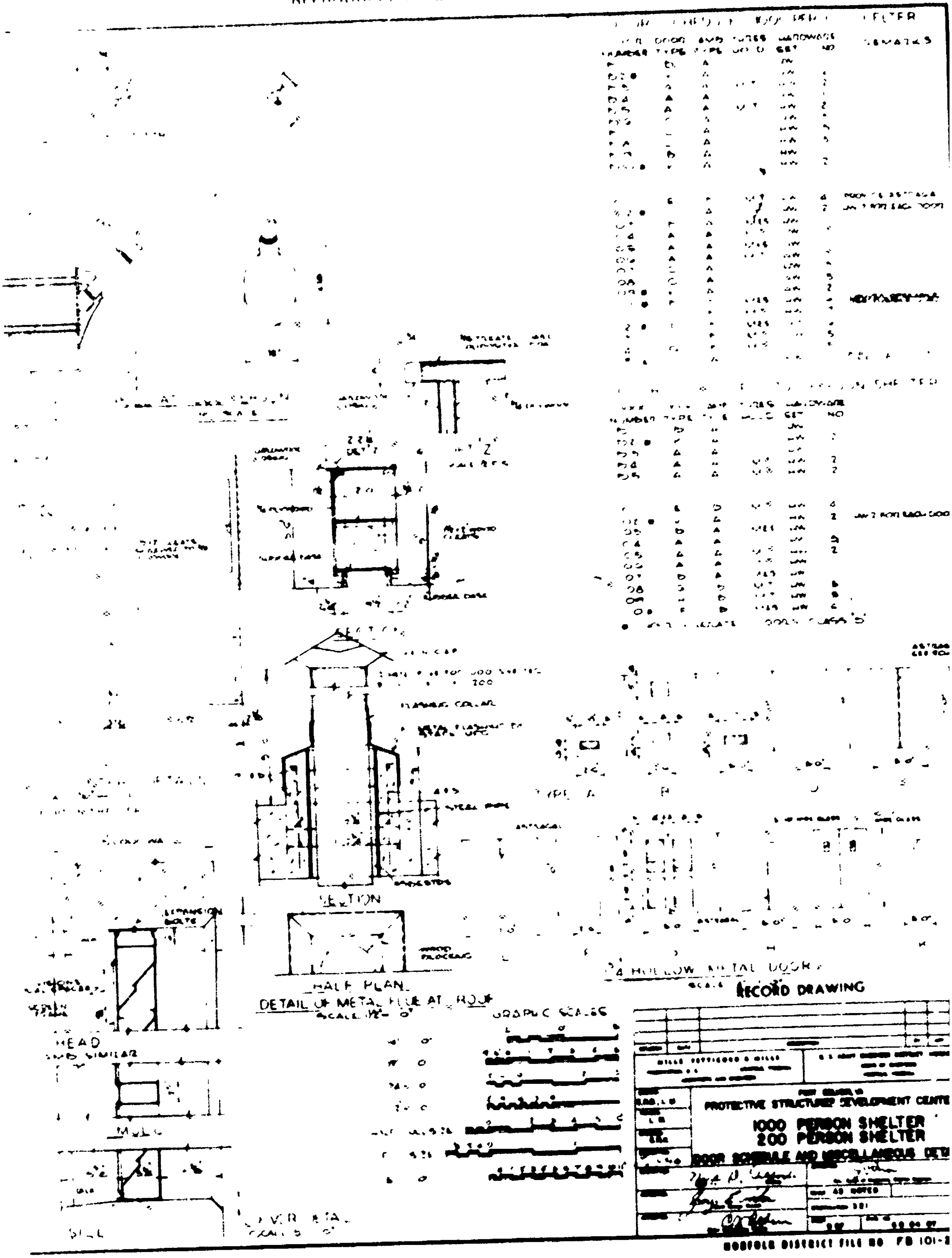


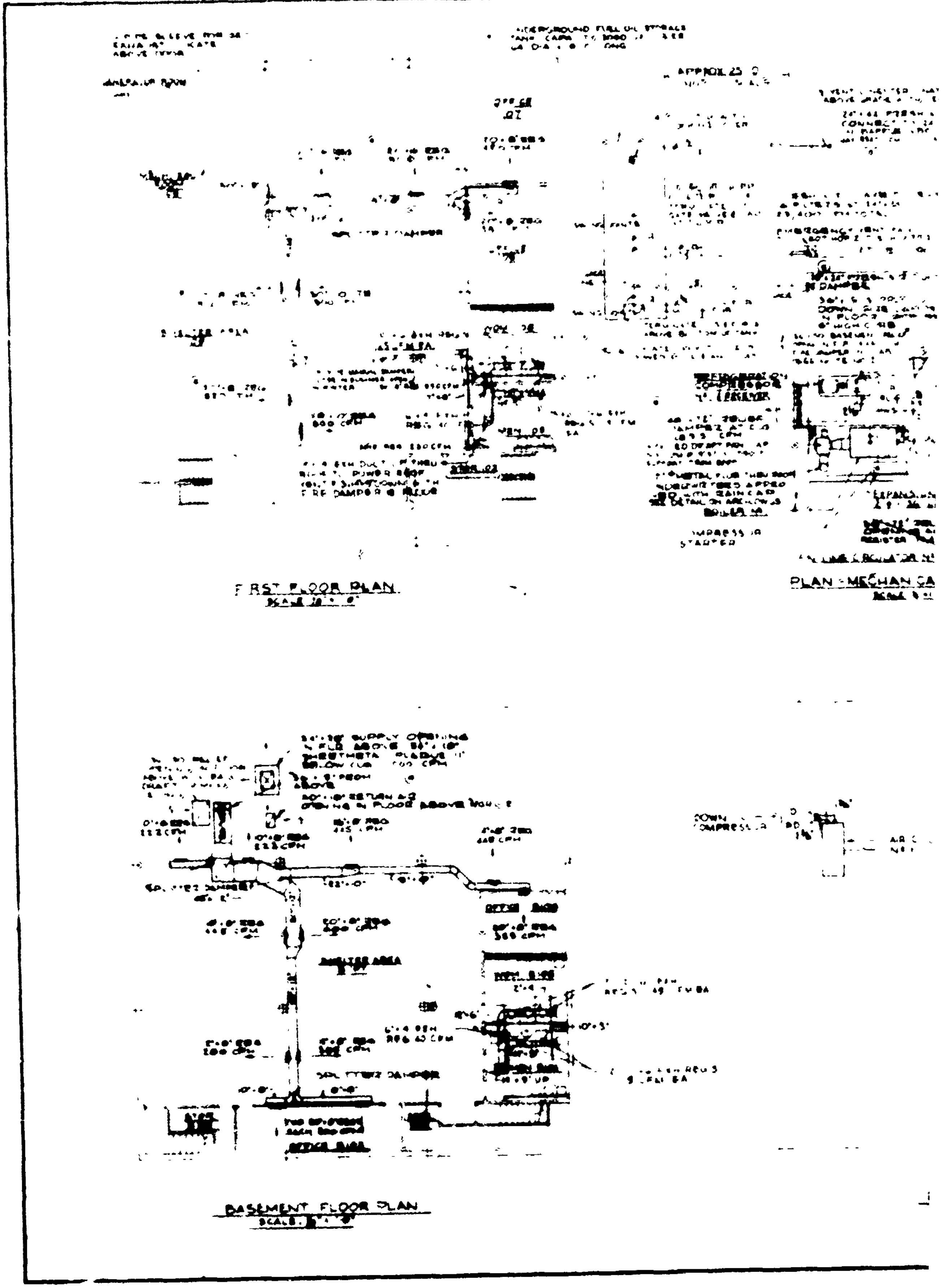
NORFOLK DISTRICT FILE NO. FB 101-28

PREVIOUS PAGE IS BLANK

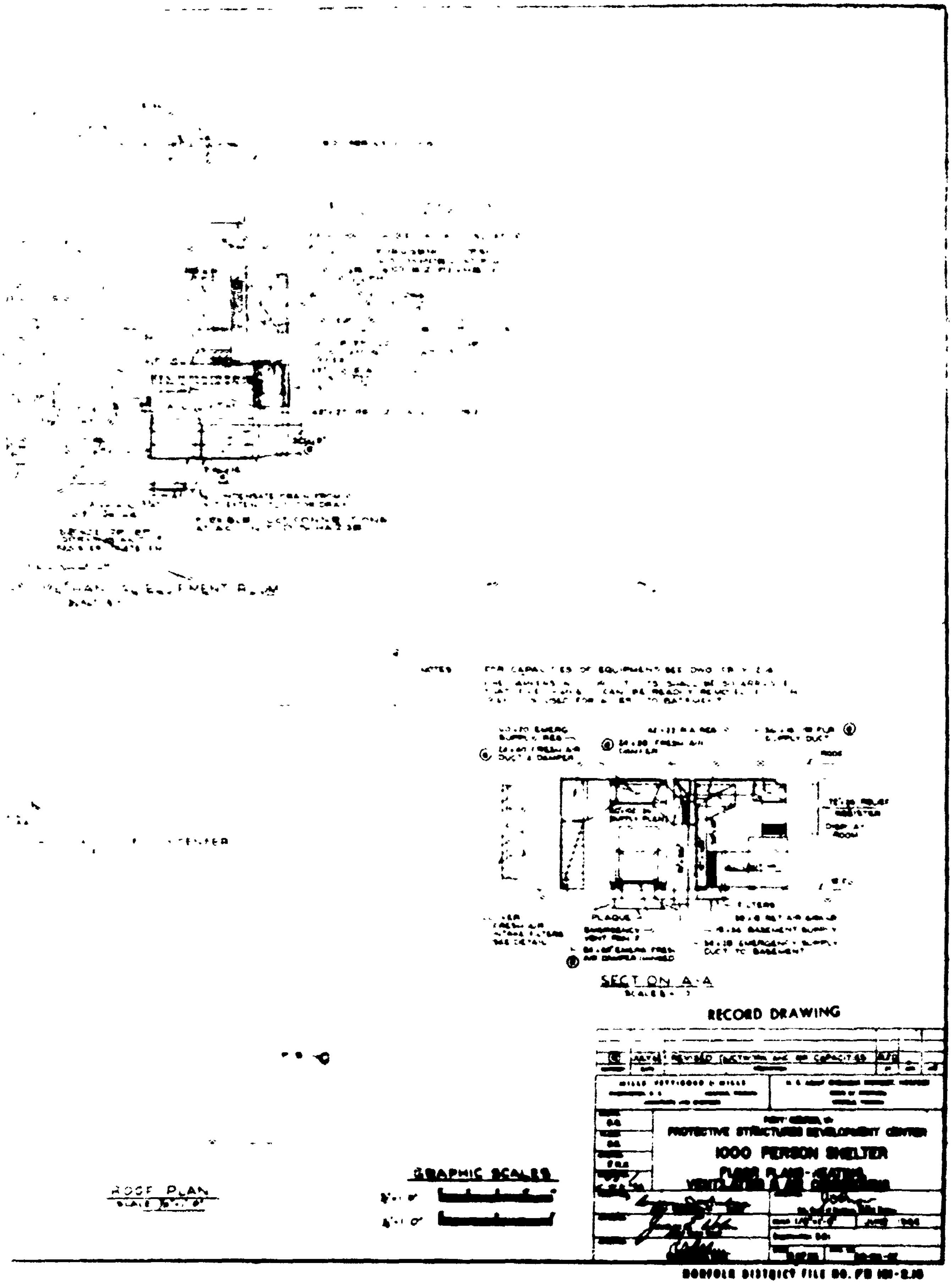

RECEPTION COUNTER DET
PLAN
VOID
METAL THRESHOLD
HEAD
JAMB SIMILAR
MULL
CERAMIC TILE
ASPHALT TILE
REAR ELEVATION

U S ARMY


REMARKS
HARDWARE
SECTION
FLASHING COLLAR
STEEL PIPE
EXPANSION BOLTS
WOOD BLOCKING
HALF PLAN
DETAIL OF METAL FLUE AT ROOF
GRAPHIC SCALES
HEAD
MULL
SILL
TYPE A
HOLLOW METAL DOORS
RECORD DRAWING
PROTECTIVE STRUCTURES DEVELOPMENT CENTE
1000 PERSON SHELTER
200 PERSON SHELTER
DOOR SCHEDULE AND MISCELLANEOUS DET
NORFOLK DISTRICT FILE NO FB 101-


FIRST FLOOR PLAN
BASEMENT FLOOR PLAN
SPLITTER DAMPER

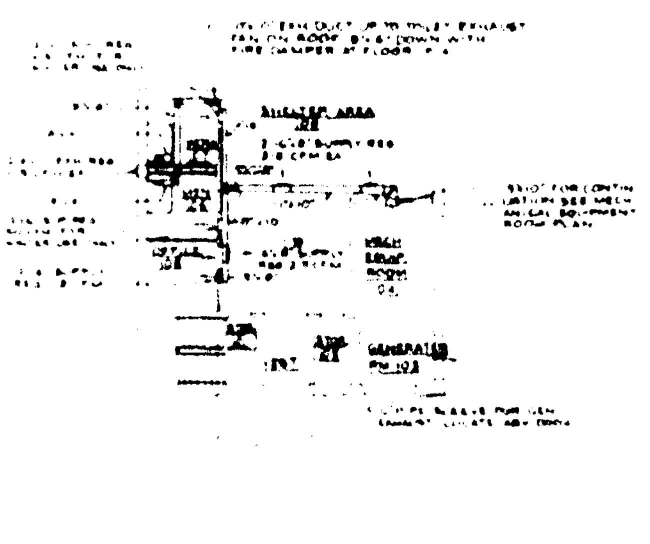
U S ARMY



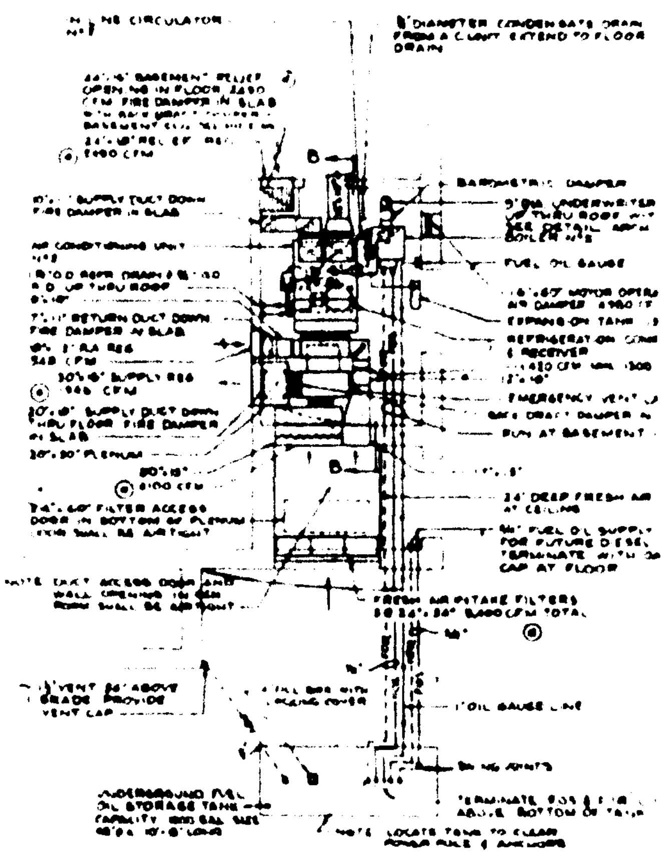
NORFOLK DISTRICT FILE NO. FB 101-2.10

2

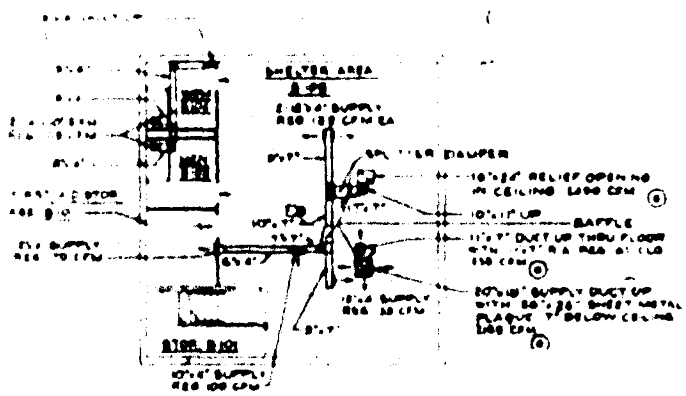
PREVIOUS PAGE IS BLANK



FIRST FLOOR PLAN
SCALE 1/8" = 1'-0"

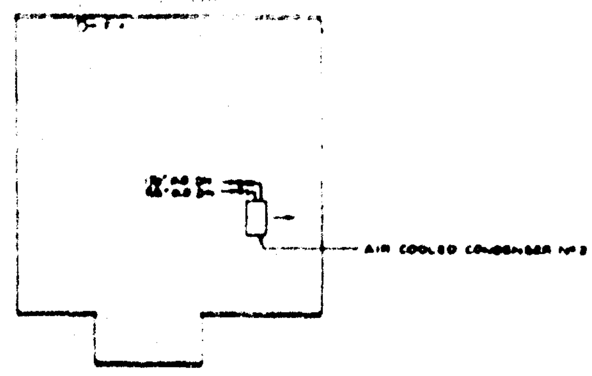


MECHANICAL EQUIPMENT ROOM PLAN
SCALE 1/4"

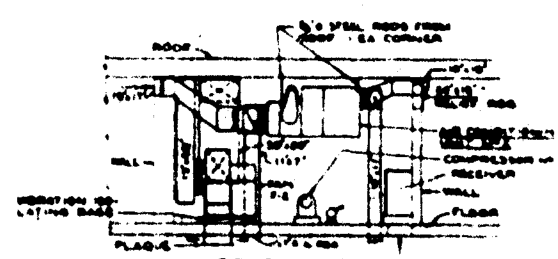


BASEMENT FLOOR PLAN
SCALE 1/8" = 1'-0"

UNIT NO	CFM STD AIR	MIN O.A.
1	8540	1085
2	1500	420



ROOF PLAN
SCALE 1/8" = 1'-0"



SECTION B-B
SCALE 1/4" = 1'-0"

U S ARMY

FAN SCHEDULE

FAN NO.	AIR STD AIR CFM	EXT SP IN WG	TIP SPEED FPM	TYPE	SERVICE	APPROX MOT HP
F 1	7,450 (6)	[illegible]	6180	DOUBLE WIDTH CENTR	EMERGENCY VENTILAT FAN	7½
F 2	4,100 (6)	[illegible]	5750	BELT DRIVE CENT UTILITY SET	EMERGENCY VENTILAT FAN	[illegible]
F 3	[illegible]	[illegible]	3870	CENTR POWER ROOF VENTILAT	TOILET EXH FAN	[illegible]
F 4	[illegible]	[illegible]	7780	CENTR POWER ROOF VENTILAT	TOILET EXH FAN	[illegible]

COMPRESSOR SCHEDULE

COMPRESSOR NO.	TONS REFRIGERATION	SUCTION TEMP °F	TYPE	VOLT	CY	PH	APPROX HP
[illegible]	(6) 10.0	45°	RECIPROCATING	208	60	3	10
[illegible]	3.7	45°	RECIPROCATING	208	60	3	5

CONDENSER SCHEDULE

CONDENSER NO.	HEAT REJECTION	CONDENS TEMP °F	AMBIENT TEMP °F	CFM	TYPE	APPROX HP
1	290,000 BTU/HR	125 MAX	100	[illegible]	AIR COOLED	3
2	(6) 59,000 BTU/HR	125 MAX	100	4,350	AIR COOLED	½

BOILER SCHEDULE

BOILER NO.	CAPACITY NET RATING	OPERATING PRESS	TYPE	FIRING RATE	REMARKS
1	351 MBH SBI	30 PSI	CAST IRON OR STEEL OIL FIRED	4.8	
2	108 MBH IBR	30 PSI	CAST IRON OR STEEL OIL FIRED	(6) 1.65	

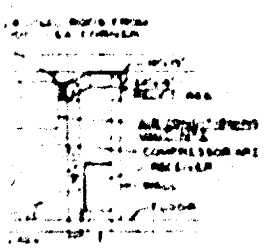
PUMP SCHEDULE

PUMP NO.	CAPACITY GPM	PUMPING HD FT	TYPE	SERVICE	APPROX MOT HP
1	35.7	18	IN-LINE CIRCUL	HOT WATER HTG	⅓
2	9.7	15	IN-LINE CIRCUL	HOT WATER HTG	⅙

AIR CONDITIONING UNIT SCHEDULE

UNIT	CFM STD AIR	MIN OA CFM	COOLING: ENT DB	ENT WB	LVG DB	LVG WB	MAX COIL FACE VEL	EXT SP	SENS CAP	TOT CAP	HEATING: CAP MBH	GPM	GENERAL: APPROX HP	TYPE
[illegible]	(6) 8,540	1,085	80°F	66.7°F	60°F	58°F	550 FPM	1½" WG	184 MBH	240 MBH	357.0	35.7	7½	HORIZ MULTI-ZONE FLR MTD
[illegible]	500	420	83.2°F	67.4°F	64°F	59.9°F	550 FPM	1½" WG	26.1 MBH	44.7 MBH	97.0	9.7	1	HORIZ MULTI-ZONE CLG MTD

NOTES: 1. [illegible] DAMPERS IN FLOOR CUT-OUTS SHALL BE SO ARRANGED THAT [illegible] DAMPERS CAN BE READILY REMOVED & FLOOR GRILLS USED FOR ACCESS TO [illegible]



B-8

GRAPHIC SCALES

RECORD DRAWING

PROTECTIVE STRUCTURES DEVELOPMENT CENTER

200 PERSON SHELTER

FLOOR PLANS - HEATING VENTILATING & AIR CONDITIONING

NORFOLK DISTRICT FILE NO. PB 101-2.10

DISTRIBUTION LIST

Addressee	No. of Copies
Office of Civil Defense, Office of the Secretary of the Army, Washington, D.C. 20310, Attention: Assistant Director for Civil Defense (RESEARCH)	89
Army Library, Civil Defense Unit, Pentagon Washington, D.C. 20310	3
Assistant Secretary of the Army (R&D) Washington, D.C. 20310 Attention: Assistant for Research	1
Chief of Naval Research (Code 104) Department of the Navy Washington, D.C. 20350	1
Chief of Naval Operations (Op-07T10) Department of the Navy Washington, D.C. 20360	1
Chief, Bureau of Naval Weapons (Code RRRE-5) Department of the Navy Washington, D.C. 20360	1
Chief, Bureau of Medicine and Surgery Department of the Navy Washington, D.C. 20360	1
Chief, Bureau of Supplies and Accounts (Code L12) Department of the Navy Washington, D.C. 20360	1
Chief, Bureau of Yards and Docks, Office of Research (Code 74), Department of the Navy Washington, D.C. 20360	1
U.S. Naval Civil Engineering Laboratory Port Hueneme, California	1
U.S. Naval Radiological Defense Laboratory San Francisco, California Attention: Dr. John Dardis	1

DISTRIBUTION LIST (Cont'd)

Addressee	No. of Copies
Stanford Research Institute, Menlo Park, California Attention: Civil Defense Technical Office	1
Advisory Committee on Civil Defense, National Academy of Sciences, 2101 Constitution Avenue, N.W., Washington, D.C., Attention: Mr. Richard Park	1
Defense Documentation Center, Cameron Station Alexandria, Virginia 22314	20
Chief, Joint Civil Defense Support Group, Office of the Chief of Engineers, Room G-312, Gravelly Point Washington, D.C.	1
Chief of Engineers, Attention: ENGTE-E, Department of the Army, Washington, D.C. 20310	1
Protective Structures Development Center, Fort Belvoir, Virginia, Attention: Technical Library	20