Technical Report **R 454**

CONSTRUCTION AND EVALUATION OF A PROTOTYPE ELECTROMAGNETICALLY SHIELDED ROOM

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CONSTRUCTION AND EVALUATION OF A PROTOTYPE ELECTROMAGNETICALLY SHIELDED ROOM

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by

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ABSTRACT

An electromagnetically shielded room composed of 20-gage sheet-metal wall material with continuously soldered seams was constructed and evaluated at the Naval Civil Engineering Laboratory. The 20 x 20 x 8-foot room is a prototype model designed as a basis for determining specifications for the construction of large shielded room installations. Electromagnetic shielding evaluation of the room was performed in accordance with MIL STD-285, along with additional measurements at 1.0, 2.5, and 9.0 Gc/sec. The lowest value of shielding effectiveness was 65 decibels at 14 kc/sec.

Construction techniques for such design features as sheet-metal joints, soldered seams, power-line filtering, ventilation ducts, and cable raceways are discussed. Techniques for providing penetrations into the room for gas, water, and sewage were investigated. Measurements of the effect of small, controlled openings into the room were determined. The acoustic shielding properties of the room are also given in this report.

CONTENTS

INTRODUCTION

A 20 x 20 x 8-foot prototype electromagnetically shielded room has been constructed and evaluated at the Naval Civil Engineering Laboratory (NCEL). The room was designed as a basis for determining specifications for the construction of large shielded rooms at critical Navy installations, such as communication centers, missile test facilities, and computer complexes. The development and construction of the prototype room was based in part on a contractual development program.[1] The construction was undertaken to verify the feasibility of using soldered joint sheet-metal fabrication techniques. The contract indicated that the most economical method of obtaining large, permanent electromagnetically shielded rooms would be to use lightweight sheet metal with soldered joints, supported by an external framework. Furthermore, the development work was particularly oriented toward construction by any typical architectural and engineering firm, with a minimum of assistance from personnel trained in the reduction of electromagnetic interference.

The Design Division at NCEL performed the functions normally assigned to an architectural and engineering firm. These functions entailed the design and preparation of the engineering construction drawings for construction of the shielded room. The Design Division also verified that the work would conform to the basic specifications and criteria developed under Contract NBy-32220.

In addition, a contract was let to a radio-frequency interference engineering and consulting firm whose job was to (1) provide assistance in the monitoring of design criteria being incorporated into the plans and specifications for the purpose of preventing any degradation in the shielding effectiveness of the structure, (2) observe the application of plans and specifications during actual construction of the facility, and (3) carry out comprehensive testing and evaluation of the facility to determine whether the desired attenuation characteristics were being achieved.

The prototype shielded room was constructed inside building 557 at NCEL. The room has the following salient features, each of which will be covered in detail in this report:

1. Two specially constructed (but commercially available) doors, one for personnel and the other for heavy equipment.

2. Continuously soldered 20-gage sheet metal with a 1.25-oz/ft^2 zinc electroplating material, which provides the desired shielding.

3. Acoustic absorbent material on the walls and ceiling.
4. Electrical and signal cable raceways, which are provided in the floor (unclassified lines) and near the ceiling (classified lines).
5. Controlled penetrations for gas, water, sewage, and air lines.
6. Incandescent lighting, power-line filtering, and ventilation.

Many of these pertinent details are contained in a chronological series of construction photographs with a detailed description of each phase of the construction of the room.

CONSTRUCTION FEATURES

Significant steps in the construction of the shielded room are shown in Figures 1 through 20. Figure 1 shows the general orientation of the foundation of the room inside building 557; the exact location of the work is given in Figure 2 as part of the location plan.

In Figure 2 the exterior elevations of the room show the brickwork for the west and south walls and the open studs on the east and north walls. Since it was desirable to investigate the design with both masonry and stud walls, a cement block exterior was placed on only two sides of the room. The studding was left open to provide easy access to the shielded wall.

Construction details of the various foundation designs are also given in Figure 2. A system of 1-foot-deep trenches were built into the foundation to be used as electrical cable raceways. These are typical cable raceways used to interconnect electronic equipment located at various parts of a room.

A vapor barrier composed of tar paper wiped with asphalt was placed over the 2-inch concrete subfloor. The barrier, visible in Figure 1, prevents moisture migration from the concrete subfloor and resultant corrosion of the sheet-metal floor that is to be installed later. The steps taken in placing the vapor barrier between the sheet-metal floor and the cement slab poured on top are as follows:

1. The rough slab was surfaced with hot tar and tar paper.
2. The metal shield flooring was put in place (including soldering of the seams).
3. The inside surface of the metal was again coated with hot tar and tar paper. Another coating of tar was used to hold 1/2-inch-thick fiberboard in place and to wipe the surface of the fiberboard.
4. The finished floor was then poured over the fiberboard. (The fiberboard acts as a mechanical cushion to prevent stress and strain in the concrete slab from being transmitted to the sheet-metal floor seams.)

Figure 3 is a photograph of a later phase of the construction. The framework for the walls is nearly complete, and the equipment door has been installed in the north wall of the room.

The ceiling of the shielded room is designed to be suspended from the roof of building 557 as shown in Figure 4. Structural details of the roof supports are given in Figure 5. Vertical steel members are bolted to "U" channels which in turn are bolted to 3/4-inch-thick plywood sheets. These sheets are then cemented to sheet-metal panels which are soldered together at the seams to form the ceiling of the room. The bolts through the "U" channels shown in Figure 4 do not penetrate the sheet metal, since this would require holes through the sheet metal; each hole would then be a potential leak at some radio frequency. A closeup detail of the techniques used to cement the plywood panels to the sheet-metal sections is shown in Figure 6. The elevator bolt heads are countersunk into the plywood so that a flat surface is presented to the sheet metal. Contact cement was applied to both the sheet metal and plywood with a short waiting period before mating the two surfaces. The glue work was performed at the job site. Heavy weights were used to hold the surfaces in compression until the contact cement cured. With these techniques for gluing and pressing the surfaces, the contact cement was found to be unsatisfactory. When the ceiling sheet-metal seams were soldered, the edges of the plywood separated from the sheet metal. As a result, it was necessary to repair each of the places where the contact cement failed by use of a two-part potting resin. The sheet metal was blocked up from underneath while the resin cured. The resulting repairs made are shown in Figure 7.

The techniques used in attaching the sheet-metal wall to the framework are depicted in Figures 8, 9, 10, and detail 5 of Figure 5. A supporting strip (Figure 8) was first attached to the framework. A lip bent longitudinally in this strip was used to support sections of the metal against the wall. Successive sheets of metal were attached to each other by means of interlocking lips in each section. Once sections were joined, the lip was crimped and the resultant seam was soldered. Specially formed corner sections were necessary to maintain the soldered connections at the corners of the room. A section of the corner joint is shown in Figures 9 and 10; one is in place and another has been preformed before installation. During the construction period, it was found that the contractor was using standard sheet-metal soldering techniques along the seams. These standard methods make use of a soldering flux with a hydrochloric acid base. Within a short time after soldering had been completed, excessive amounts of corrosion were noticed on the walls and ceiling panels near the seams. The soldering flux had reacted with the zinc plating on the sheet metal, resulting in serious dissipation of the zinc coating, and continued reaction in the seams gave the same effect as a cold solder joint. As a result, it was necessary to resolder many of the seams, particularly along the walls and ceiling of the room. Immediately after the resoldering, each joint was carefully wiped with a neutralizing agent to prevent the recurrence of acid flux attack on the zinc coating. Dimensions and construction details of the wall shields are shown in the drawing of Figure 11. Figure 12 gives these details for the ceiling and floors of the room.

In Figure 13 the metallic shield of the room has been completed. The vapor barrier has been placed between the sheet metal and the poured floor. The secondary raised flooring will form the basis for cable raceways and a sewage line penetration.

Ventilation has been provided by a system of air-conditioning ducts in the room. The main duct enters the center of the sheet-metal ceiling at one point. At this point of entry a honeycomb air filter is secured inside the ducting. This air filter permits ventilation in the room, but presents a very high attenuation to any electromagnetic energy inside the air-conditioning duct. This filter is a waveguide-beyond-cutoff type and is very effective at wavelengths which are large compared to the diameter of each individual opening of the honeycomb. A section of the ducting is connected to the central entrance port and terminates at two air diffusers mounted flush to the false ceiling of the room. The location of one of these air diffusers can be observed in Figure 14. A slight positive pressure is maintained inside the room by a centrifugal air fan mounted near an exhaust vent on the wall of building 557 (see Figure 5, section E-E).

To prevent the penetration of the room by any nails, bolts, or other metallic fasteners, the interior studs were glued to the sheet-metal surface. This was done by applying a potting resin along the narrow edge of the two-by-four studs pressed against the wall and ceiling of the room. In order to assure adequate cure time for the resin, a number of false-work studs were incorporated, as shown in Figure 15. Also in this photograph, the finished floor has been completed and the cable raceways are partially covered with 1/4-inch steel lift-out plates. The detailed description of the interior framing and finish of the room is given in Figure 16.

A photograph of the completed interior of the room is shown in Figure 14. A 4-foot wainscot of hardboard has been incorporated to prevent damage to wall surfaces caused by moving heavy equipment. An overhead raceway has been incorporated to provide access to classified information power and signal lines. Provisions for power-line filtering have been incorporated in the east wall of the room for the classified power lines. Once these lines enter the room, they are physically placed at least 6 feet from any other signal or power-line cable in order to prevent accidental or intentional electromagnetic coupling to other unclassified lines. The power-line cables are carried in steel conduit, which further reduces the coupled or radiated energy from these lines inside the room.

Overhead lighting is provided by nine 300-watt incandescent lamps flush-mounted in the false ceiling. Fluorescent lighting is not used because of the possibility of broad-band noise radiation from this type of lighting. Figure 17 gives the details of room lighting and electrical connections.

SHIELDED-ROOM EVALUATIONS

Shielding Tests

Before the finished slab was poured, electromagnetic shielding tests[2] were made by an engineering firm specializing in shielded-room tests and evaluations. A summary of these tests is given in Table 1, and the details of these tests can be found in Reference 3. A leak detector[3,4] for radio-frequency interference was used to determine small imperfections and irregularities in the seams (see Figure 18). With this probe it was possible to pinpoint and correct any leaks that occurred in the room before completion of the interior finish work. Power-line filters and the air-conditioning duct had been installed before the tests were made.

In order to determine how well the soldered seam techniques used in this construction would perform over a period of time, the same electromagnetic interference tests were run 10 months after completion of the room. The interior finish of the room had been completed, but for these tests, the celotix acoustic material was removed to gain access to the sheet-metal wall. It was necessary to carefully clean the mating surfaces of each door before the room could be brought up to the original electromagnetic interference specifications. These tests would indicate that the sheet-metal seams remained virtually intact over a considerable period of time and that with routine cleaning maintenance of the door surfaces, satisfactory interference reduction could be maintained.

Acoustic Tests

A number of tests to determine the acoustic attenuation of the shielded room were made and are shown in Figure 19. The tests performed followed those developed at NCEL and are reported in References 5 and 6.

These measurements have been made at several locations in the room, as indicated by the family of curves of Figure 19. The acoustic transmission is greatest near the north wall air vent, and the least transmission through the room walls occurs through the walls containing celotex, sheet metal, and masonry.

Door Closure

Theoretical calculations[1] for the shielding effectiveness of a solid metal wall in prohibiting most types of incident electromagnetic waves in the frequency range from 14 kc/sec to 10 Gc/sec show values of attenuation beyond the range of available measurement instrumentation. In general, the same is true for a soldered sheet-metal enclosure. However, since it is necessary to make entrances in the enclosure, there must be a proper mating of the door and its frame to present a minimum electromagnetic discontinuity for the wall and door combination. Improper metal-to-metal contact in the door closure over extended periods of time has been, and still is, the most serious source of leakage in shielded rooms. The most satisfactory approach at present is the use of compressed finger stock of beryllium copper between a solid metal door and a specially fitted metal door frame whose contacting surfaces are provided with copper, brass, or other high conductivity metal. The frame is solidly mounted in the wall of the room and a continuous bond is made around its periphery by soldering to the wall. This is the technique used for both doors in the construction of the shielded room (see Figure 20 for door-mounting details). The door itself utilized a steel base construction with a sheet copper covering. These doors were obtained from a major shielded-room manufacturer and were selected in preference to wooden-based doors, which might possibly warp with age.

Room-Penetration Tests

A number of penetrations were intentionally placed in the sheet-metal wall of the completed room to permit three short pipes (see Figure 21) of various diameters to be mounted through the north wall and a fourth pipe to be mounted through the east wall, below floor level. Photographs of the mounted pipe sections are shown in Figures 22 and 23.

Each pipe was 2 feet long, and was provided with a brass collar, brazed to the geometrical center of the pipe. The penetrations were made at arbitrary locations. The collars around each pipe were used to secure the pipe to the wall. Sheet-metal screws were used to secure the collars to the sheet-metal wall during the soldering operation. Solid core solder and an organic flux were applied to provide an electrical bond between the collar and the wall. Both the inner surface of the collar and the immediate vicinity of the wall cutout had been pretinned before soldering.

A physical description of the pipes used in this penetration study are as follows:

1. Hard-wall copper pipe 11/16-inch inside diameter, 7/8-inch outside diameter, 2 feet long.

2. Cast-iron sewer pipe 1-1/2-inch inside diameter, 2-1/8-inch outside diameter, 2 feet long with bell flare on inside of room.

3. Steel water pipe 1-1/2-inch inside diameter, 1-7/8-inch outside diameter, 2 feet long.

4. Cast-iron sewer pipe 3-1/2-inch inside diameter, 4-inch outside diameter, 2 feet long with bell flare outside room. This is the section mounted in the east wall.

Preliminary tests of the solder joints were made at 14 kc/sec with a 21-mh loop for excitation outside the room and a 500-μh, shielded, 3/4-inch-diameter, hand-held exploratory probe inside the room near the joints. By going over each of the soldered joints with this probe, it was possible to pinpoint any leaks and resolder immediately.

Table 1. Summary of Shielding Effectiveness Tests on Shielded Room

Type of Field	Frequency	Shielding Effectiveness (db)	Test Locations
Magnetic	14 kc/sec	65	Top of center door seam of north wall door
		70	Value at all other places in room
Magnetic	100 kc/sec	90	Minimum value found in room
Magnetic	200 kc/sec	98	Minimum value found in room
Electric	150 kc/sec	113	Minimum value found in room
Electric	1 Mc/sec	115	Minimum value found in room
Electric	18 Mc/sec	132	Minimum value found in room
Plane wave	400 Mc/sec	95	Minimum value found in room
Plane wave	1 Gc/sec	90	Minimum value found in room
Microwave	2.5 Gc/sec	80	Near bottom of east side of north door
		76	At east wall power filters
		86	All other places in room
Microwave	9 Gc/sec	78	Middle of north wall door seam
		75	North wall air vent
		80	All other places

Magnetic field tests were then made with 1-foot-diameter loops, with the plane of each loop parallel to the wall at a distance of 1 foot from each side of the wall. A signal generator used in conjunction with a power amplifier provided excitation for the external loop. The loop used inside was the standard equipment provided with the noise meter. A reference level was established outside of the room with the loops 2 feet apart. Table 2 gives the results of the tests with the centers of the loops just below the center of the pipes. For comparison, the measurements made by the contractor (before the penetrations were made) are given in this table.

Table 2. Shielding Effectiveness of North Wall With and Without Penetrations

Test Location	Frequency (kc/sec)	Shielding Effectiveness (db)
7/8-inch-OD pipe	15 120	82 113
2-1/8-inch-OD pipe	15 120	82 112
1-7/8-inch-OD pipe	15 120	76 110
North wall without penetrations*	14 100 200	85 118 120

* Taken from p. 18 of Reference 3.

Shielding Measurements on Small Openings in the Room

A number of measurements of the signal level inside the room were made near controlled openings from 5/8 inch to 1-1/2 inches in diameter. These openings were examined at frequencies of 22 and 150 kc/sec. The region near each opening was investigated by using a very small loop probe as a sensor and a large (10-inch diameter) loop outside the room for excitation. The equipment used in these tests is shown diagramatically in Figure 24. The pickup loop was especially constructed for these tests and consisted of a 500-μh electrostatically shielded coil with provisions for coupling into an unbalanced input circuit. The coil was not tuned so that a broad range of frequencies could be measured, although by tuning the device, greater sensitivity could have been obtained. Preliminary tests indicated that the sensitivity was adequate for the purposes of these tests.

Because the pickup probe was rather small in diameter (3/8 inch), it was possible to make a point by point search in a region both parallel and perpendicular to the wall. In this way, a three-dimensional contour of the magnetic field intensity inside the room adjacent to the opening could be determined. A family of curves for each of the openings was obtained (Figure 25 through 28). The values of shielding effectiveness were obtained by making readings at the various specified points in the room and then comparing these readings to one made with the probe outside the room and immediately adjacent to the exciting loop at the wall surface.

Although a large amount of information is contained in the curves of Figures 25 through 28, a comparison of the values of magnetic shielding at 21 kc/sec obtained for two different hole sizes will help clarify the use of these curves. As an example, it is desired to know the shielding effectiveness 4 inches away from a hole along the wall and 1-7/8 inches out from the wall. In Figure 26 the shielding effectiveness is 65 decibels for a hole 7/8 inch in diameter. Under the same conditions the shielding effectiveness is 60 decibels for a hole 1-1/2 inches in diameter (see Figure 28). Thus, in going from a 7/8-inch to a 1-1/2-inch hole, the shielding effectiveness decreased by 5 decibels at the same point in space. Conversely, selected values of shielding effectiveness have been chosen and are used as the basis of the polar contour plots shown in Figures 29 through 32. Using the data of Figure 32, approximately 50 decibels of shielding can be obtained if a radial distance of 4.2 inches from the center of the 1-1/2-inch-diameter hole is maintained. In this way, if known openings are present in a shielded room, protection from potential undesired low-frequency magnetic fields can be obtained by spatial separation from the shielded wall and reference to the data given here.

The shielding effectiveness possible in the presence of a particular opening will depend upon the geometry of the opening. An opening that occurs occasionally in walls of shielded rooms is a longitudinal slit — that is, an opening created when two sections of a wall come together and fail to make electrical contact or where a door is improperly closed. For this reason, a small slit of controlled size was used as the basis for a set of magnetic field measurements at 21 kc/sec similar to those made for the circular openings. The slit was excited by a current-carrying wire passing across the slit along the outside of the shielded wall. Figure 33 gives data taken in the direction along the slit, and Figure 34 gives data taken across the slit.

DISCUSSION OF CONSTRUCTION TECHNIQUES

The construction of the prototype shielded room has provided an opportunity to observe and evaluate the use of soldered sheet metal as a building material for rooms of the size considered here. The levels of shielding effectiveness obtained upon acceptance of the room from the contractor (and given in Table 1) met the design goals of the initial study and development. A second series of tests after 10 months confirmed the quality of the design with soldered sheet-metal sections. Continuous soldering of the seams provided a good metallic bond essential for large values of shielding effectiveness in the radio-frequency spectrum.

Standard soldering techniques used in the sheet-metal industry should not be used in the construction of a shielded room of this type. For example, it takes an experienced, skilled sheet-metal workman to stitch-solder a vertical seam with no resultant leaks. Careful application and use of soldering flux and soldering iron cleaning compounds is of primary concern. Only a nonreactive or noncorrosive inorganic-type flux will be suitable for this type of soldering work. A neutralized or "cut acid" flux can be prepared[3] by allowing zinc chips to react chemically with muriatic acid (20% Boume, 45% hydrochloric acid, commercial grade) until no further reaction can be observed. It is necessary to use caution when making this type of flux as the initial reaction of zinc chips and muriatic is semiviolent, and the fumes given off by the reaction are toxic. Edges of panels to be soldered should be pretinned, preferably by dipping the edges in a dip-solder vat.

The seam area to be soldered should receive a light wiping of flux immediately before the application of heat. Only minimum amounts of flux should be applied. Any spillage or overapplication of flux should be removed immediately with a thorough cleaning with water or an appropriate neutralizing solution. Should the protective coating of the metal become damaged from the application of excessive heat, the area should be cleaned and tinned with an additional application of flux and solder.

The suspension of the sheet-metal ceiling by means of plywood panels bonded to the sheet metal held up satisfactorily in the prototype room. However, a contact cement bond should not be used unless mating parts are formed under sufficient pressure in a press in accordance with cement manufacturers recommendations. Preferably the bond should be made with a potting resin and hardener. Experience indicates that contact cement cannot be properly applied at the job site.

Provisions in the design should be made for expansion joints in the sheet-metal panels to allow for expansion and contraction caused by soldering during the construction phase and stresses on soldered seams under later in-service thermal variation and shock.[7]

The doors of any shielded room limit the amount of shielding effectiveness that can be obtained and maintained. An important part of routine maintenance of a shielded room is proper care and cleanliness of the door mating surfaces and the peripheral finger stock. The metal contact surfaces should be cleaned with steel wool, and any oily accumulations should be removed with a solvent, such as ethyl methyl ketone. During use corrosive oils and stains are accumulated on the finger stock and mating surfaces by excessive and careless contact with hands and fingers, and preventive measures should be taken to minimize this abuse as well as mechanical damage to finger stock.

RECOMMENDATIONS

In the event that another electromagnetically shielded room be constructed, the following items, based on the experience gained with the construction of the prototype room, are recommended:

1. Parts requiring the use of an adhesive (particularly plywood to sheet metal) should be bonded in a controlled manner which will result in the rated strengths of the adhesive before arrival of bonded components at the job site.

2. Noncorrosive solder fluxes should be used to provide long-term shielding integrity of soldered seams.

3. Sheet-metal workmen should be subject to close inspection for proper workmanship, and seam integrity should be checked electromagnetically during soldering periods of the construction phase.

4. Sewage, water, and gas pipes should be installed through the shielded walls by the use of brazed flanges on the pipes securely soldered to the wall to prevent loss of shielding effectiveness.

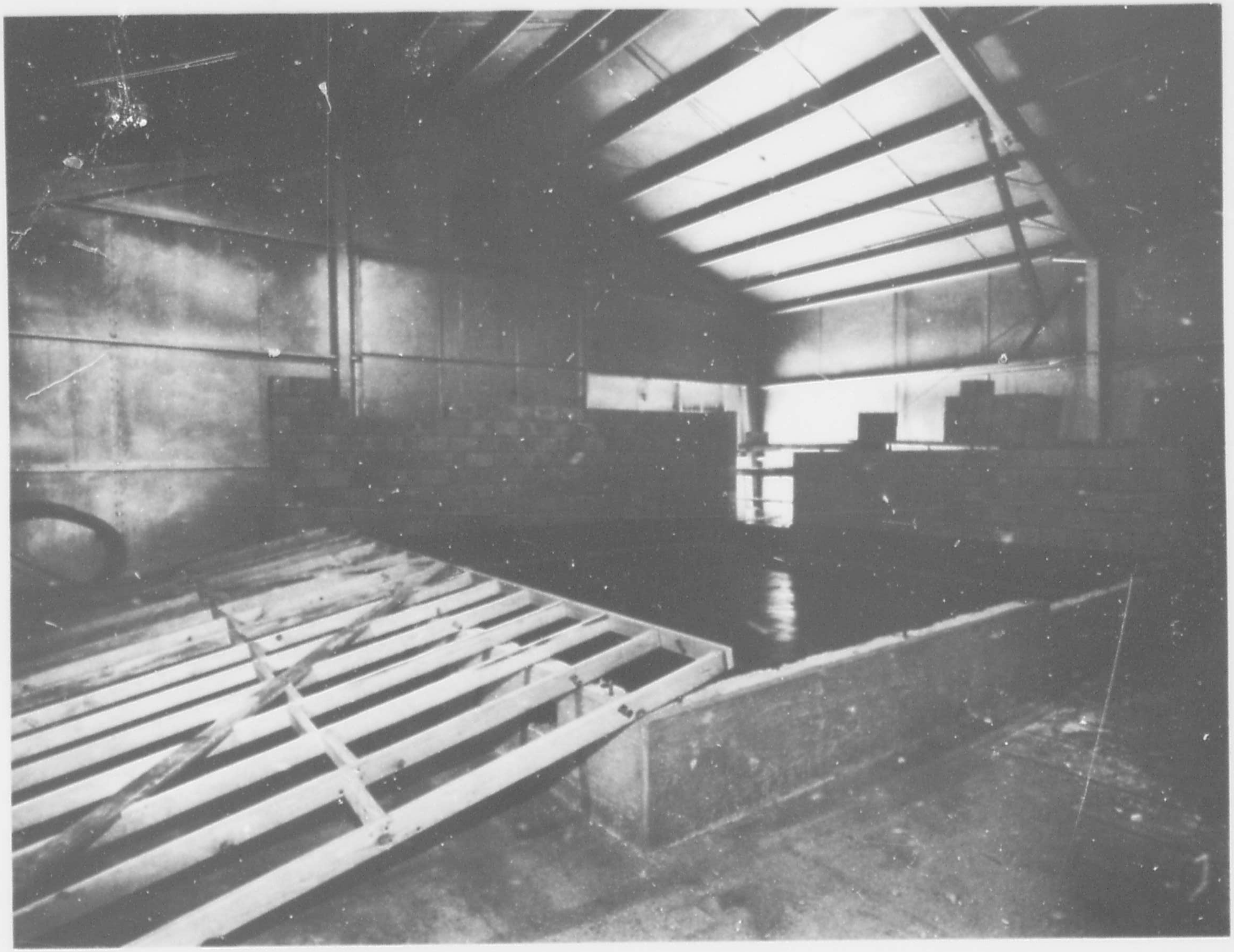

Figure 1. View of shielded building foundation and outside block wall. Direction of camera is southwest.

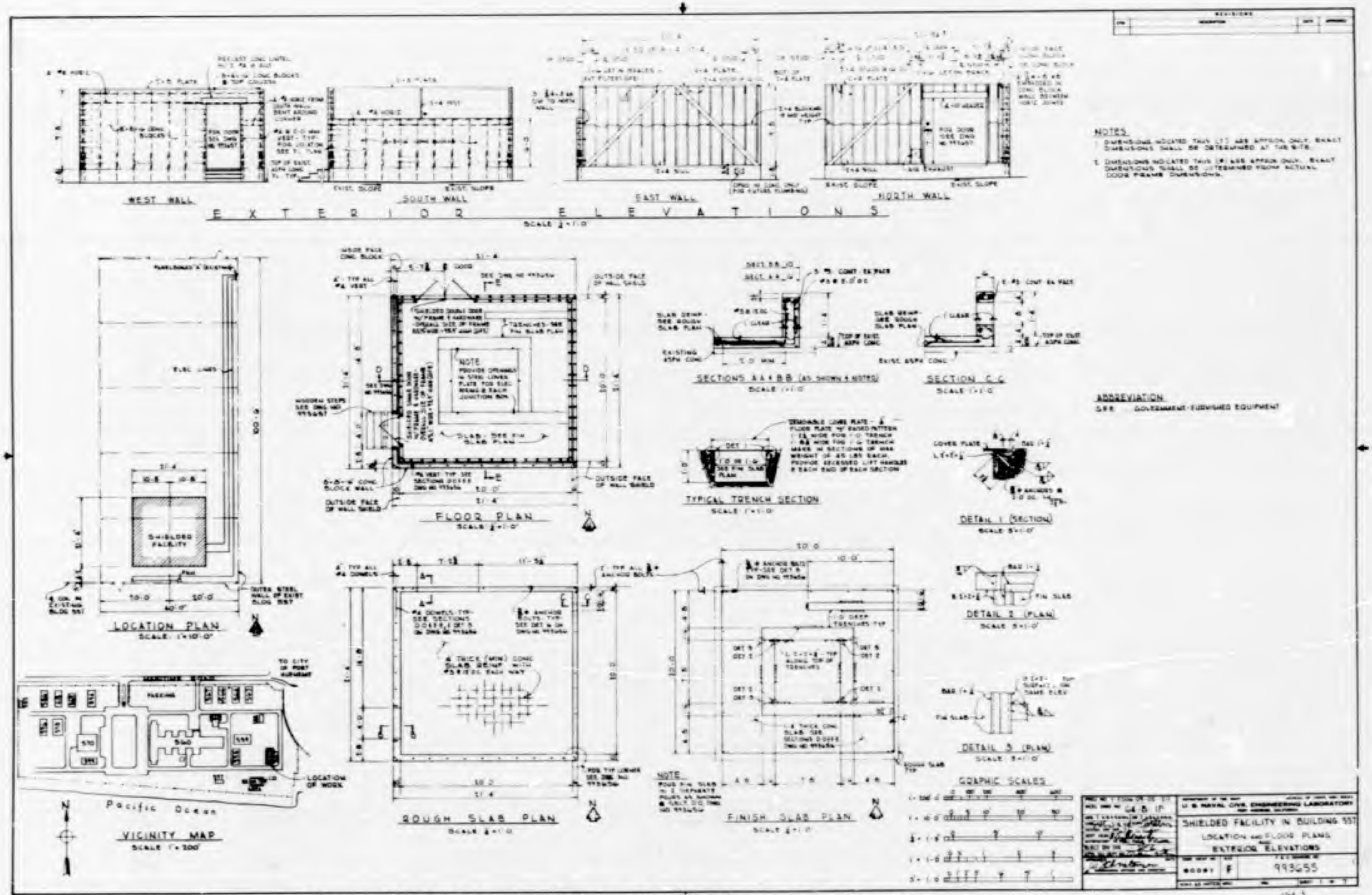

Figure 2. Location and floor plans and exterior elevations.

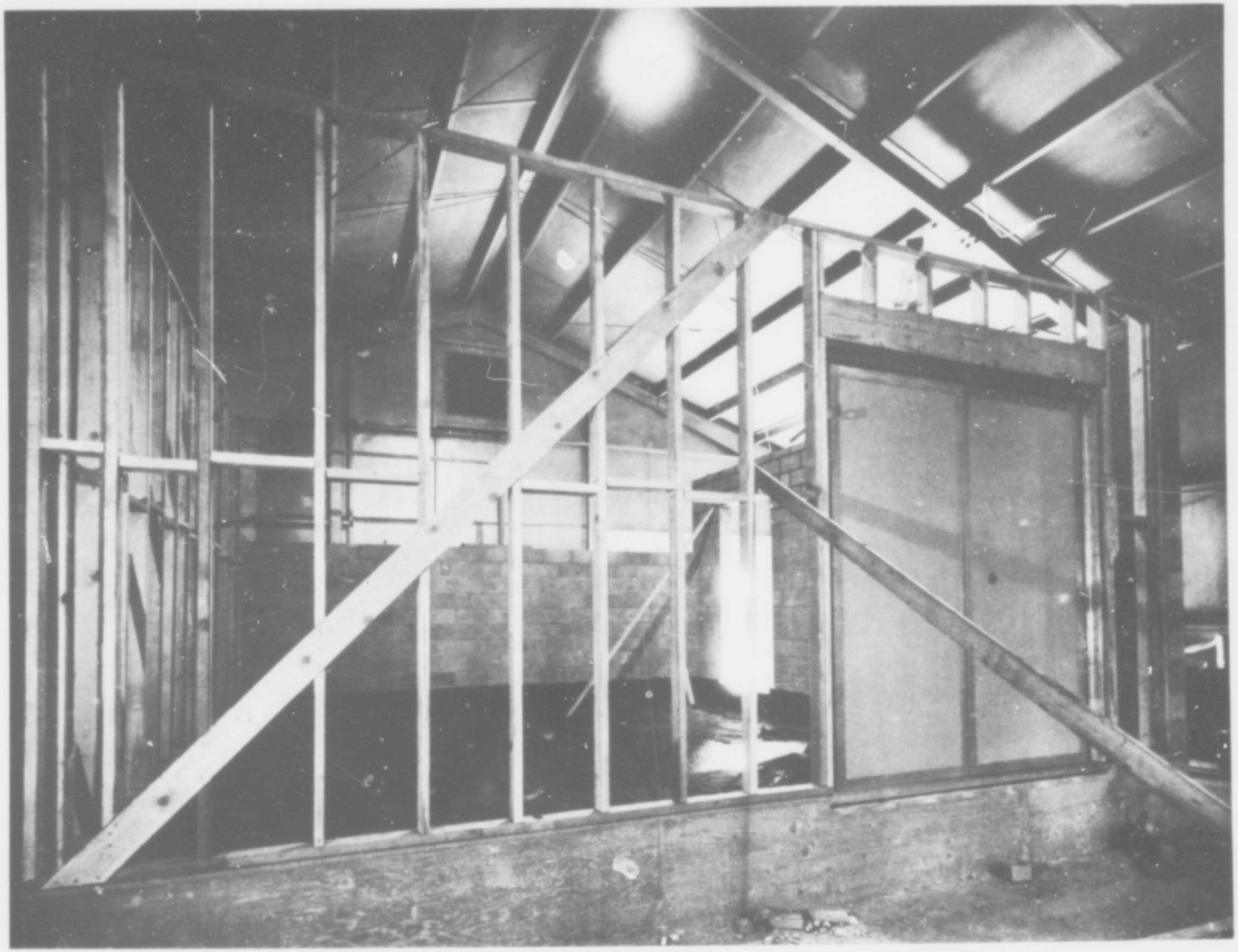

Figure 3. Exterior view of north wall showing equipment door mounted in frame.

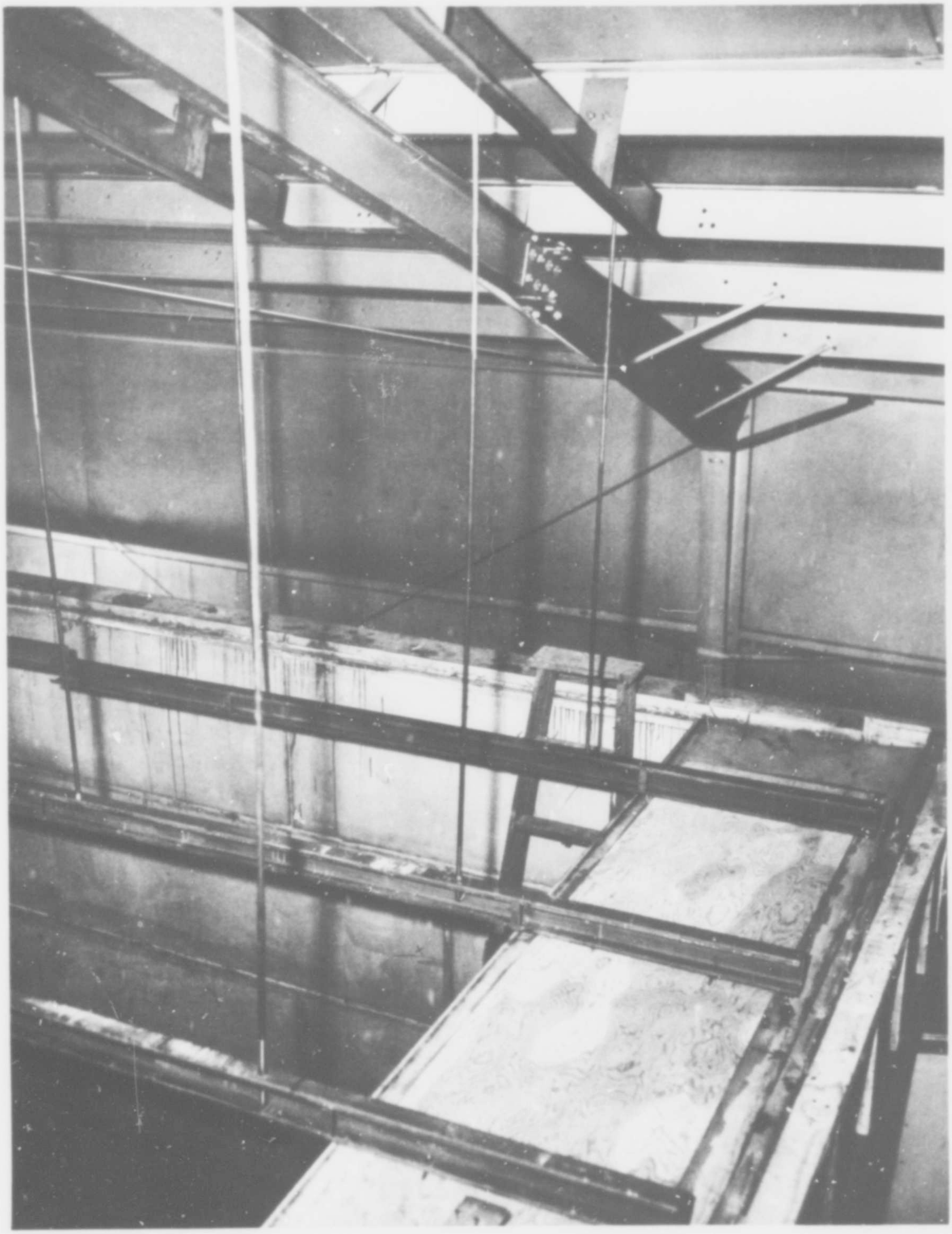

Figure 4. View looking down on partially completed ceiling. Wall shown is west wall.

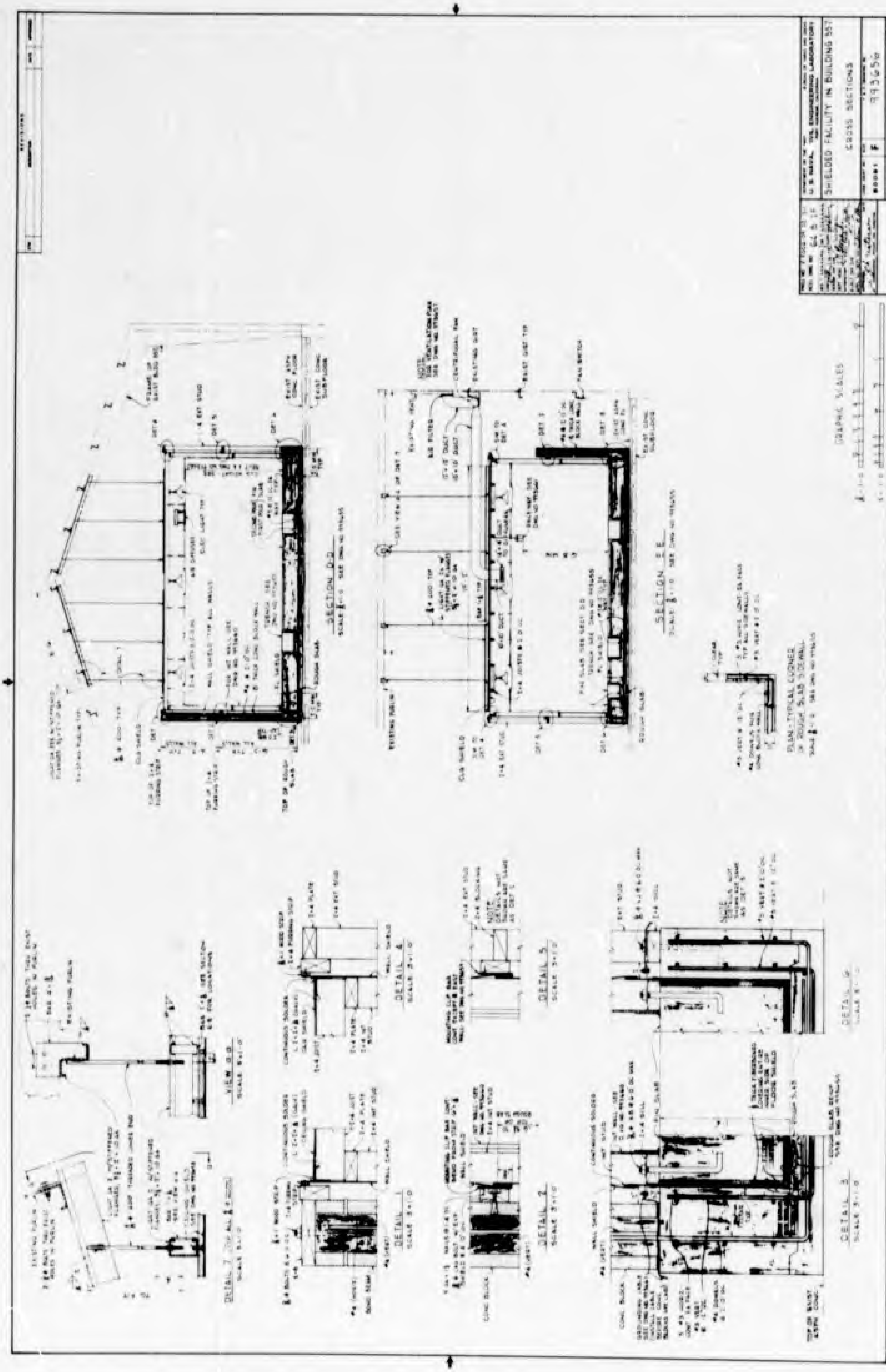

Figure 5. Cross sections of shielded room.

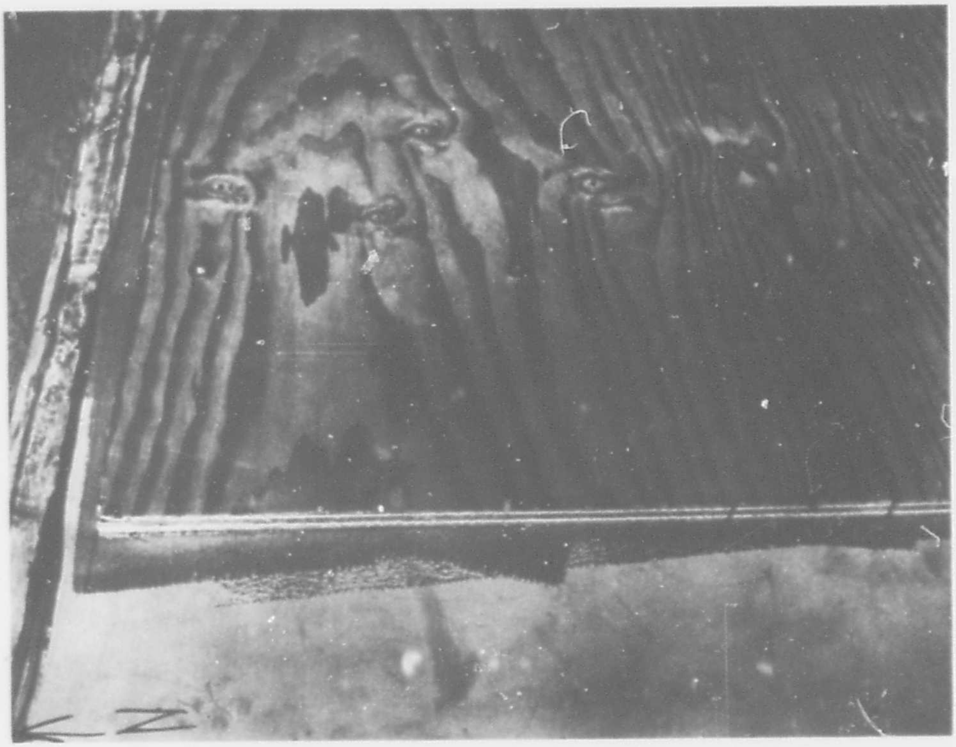

Figure 6. Plywood cemented to sheet-metal sections used in construction of ceiling. Elevator bolts shown do not penetrate sheet metal.

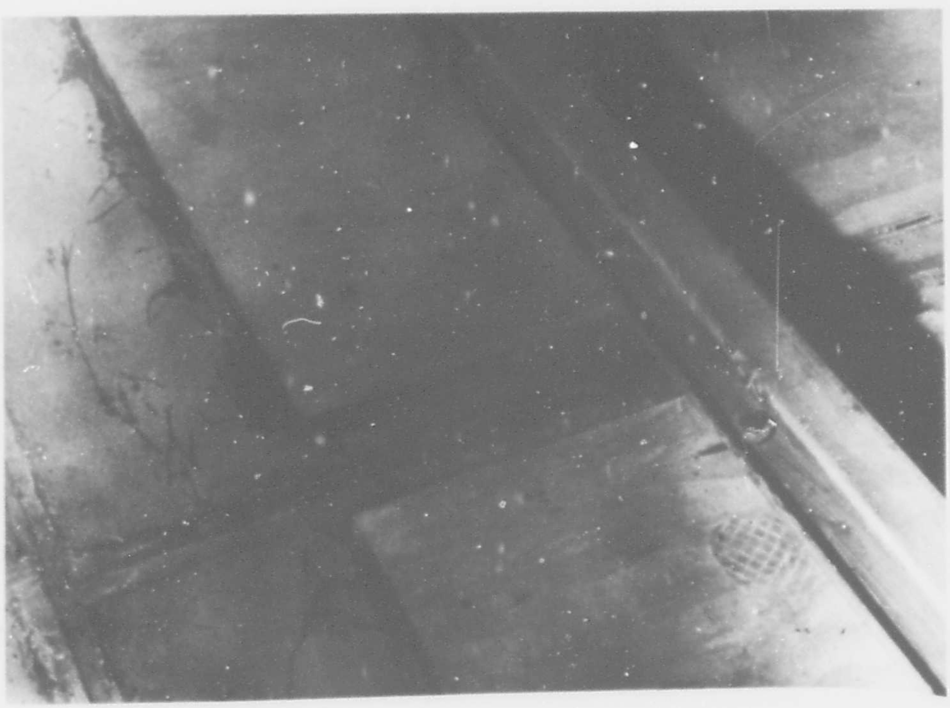

Figure 7. Closeup view of work done on ceiling supports. The plywood panels have been recemented and pressed into place.

Figure 8. Interior view of lower northwest corner of shielded building.

Figure 9. Southeast corner of shielded building showing detail of sheet-metal strip used at the corner seams. Also shown is a strip not yet in place.

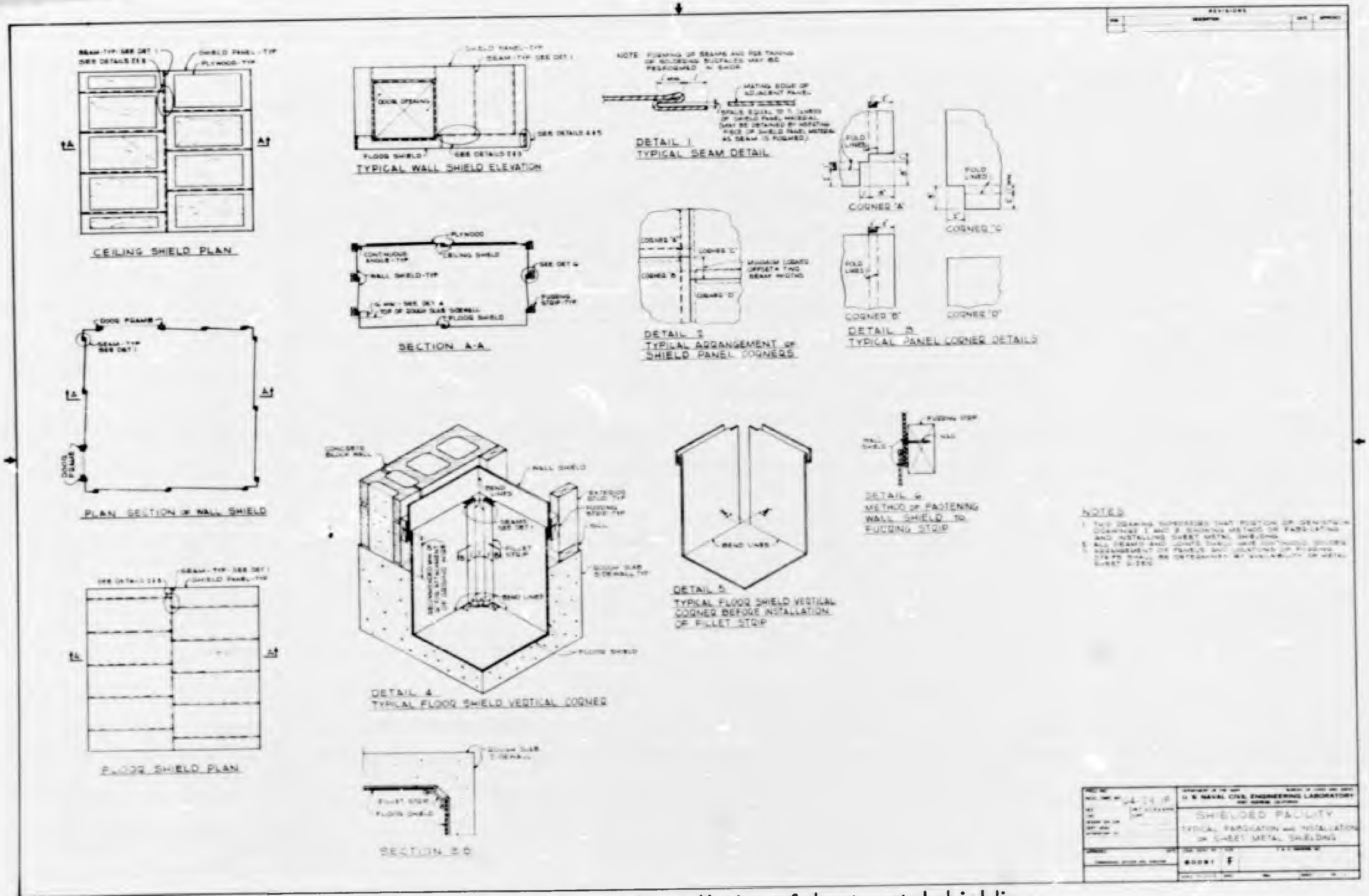

Figure 10. Typical fabrication and installation of sheet–metal shielding.

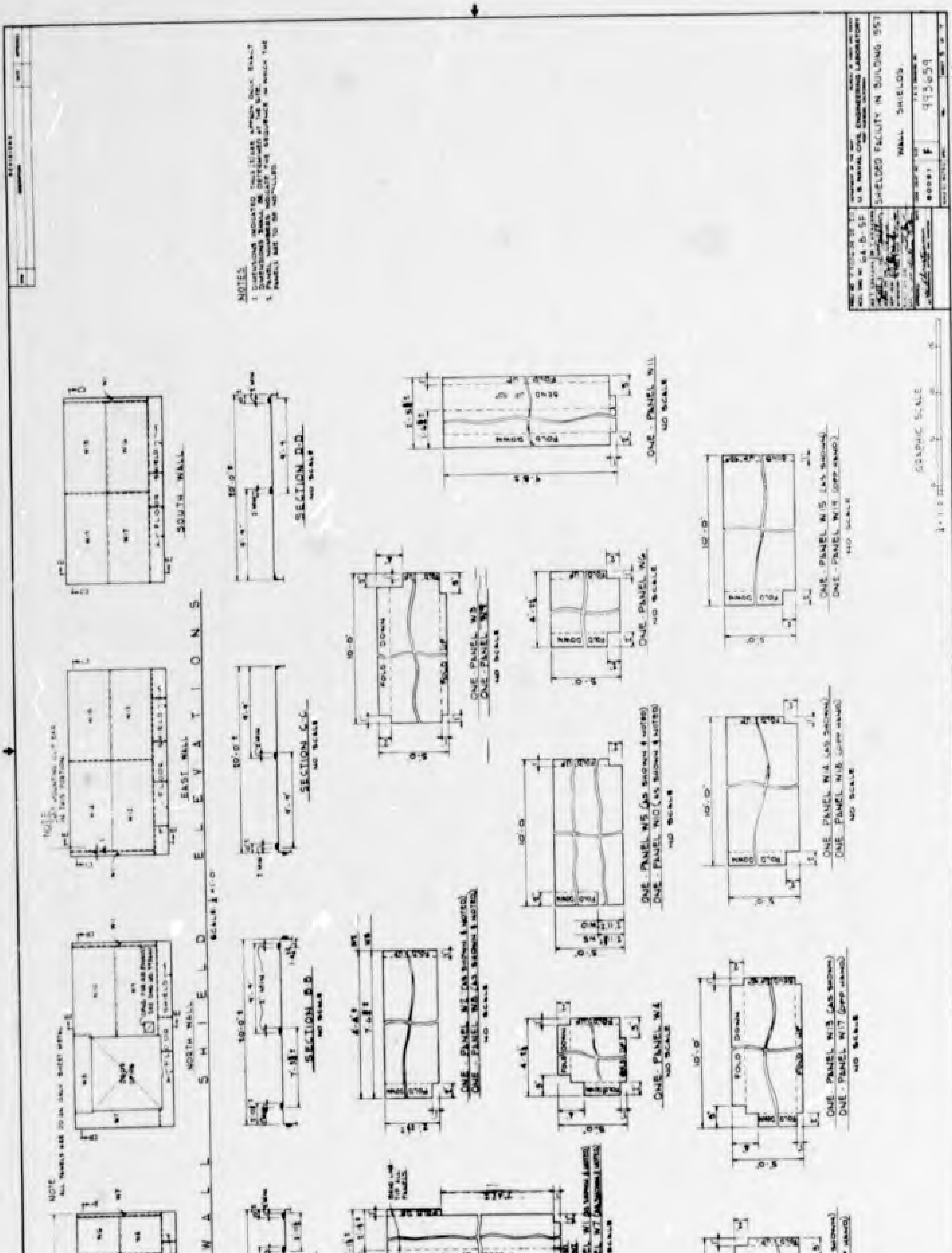

Figure 11. Wall shields.

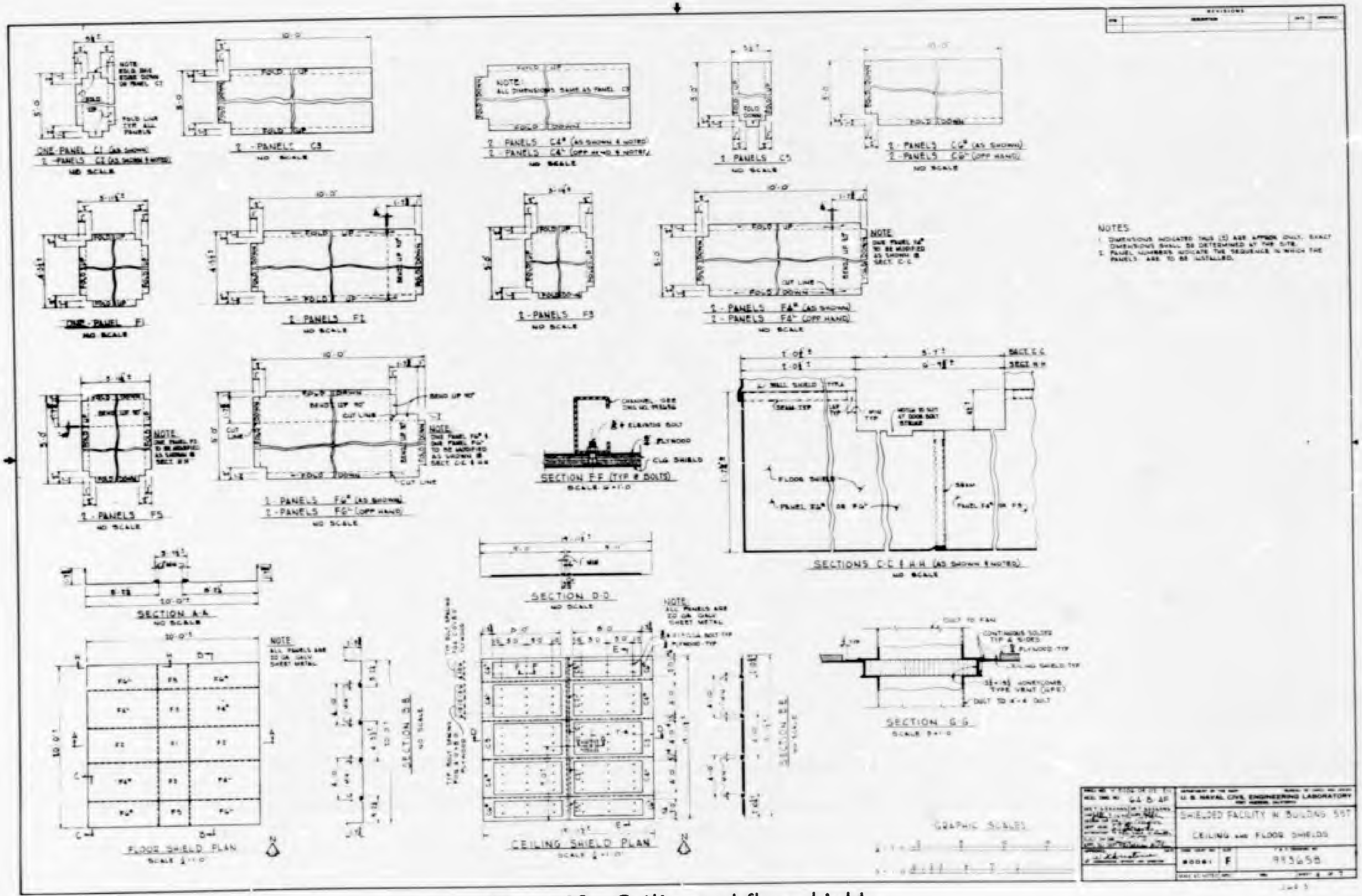

Figure 12. Ceiling and floor shields.

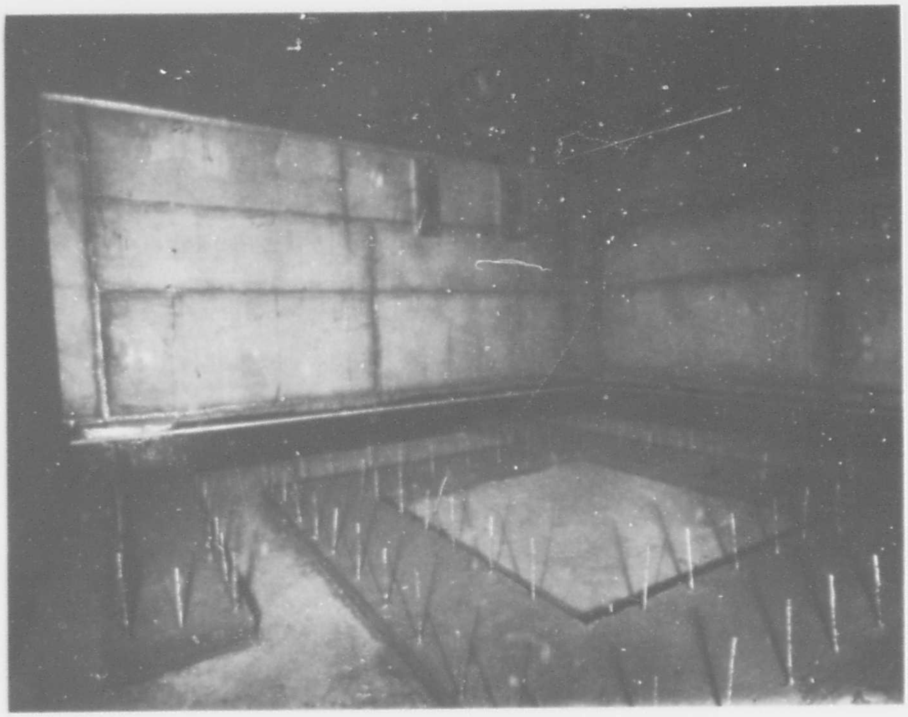

Figure 13. Interior of shielded building, southeast corner. Flooring for cable runways and sewage line has been poured.

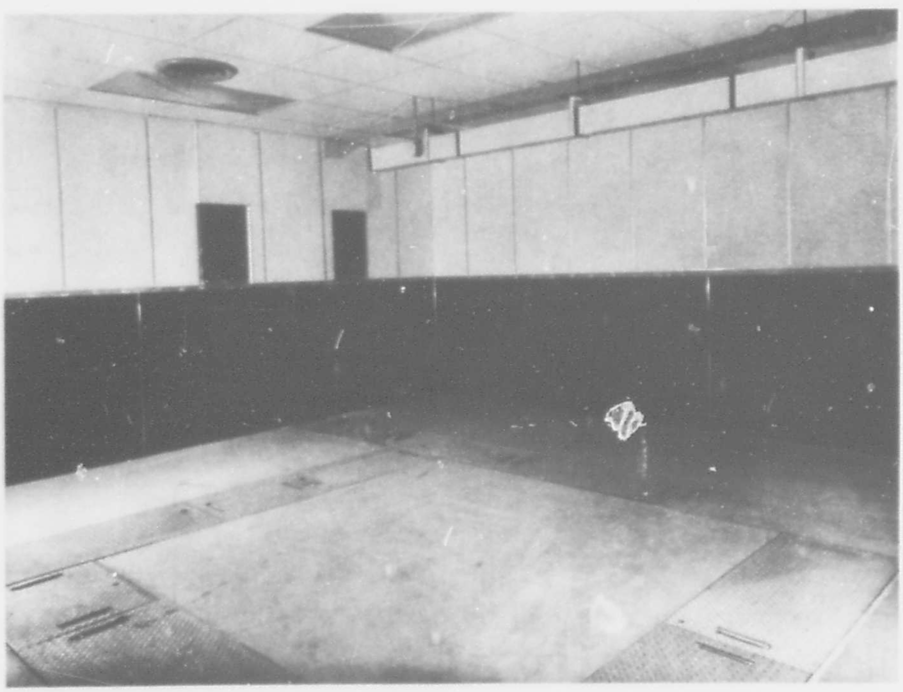

Figure 14. Interior view of shielded building looking toward the southeast corner. The construction work is complete.

Figure 15. Interior view of shielded building looking northeast. Finished floor has been installed and floor cable trenches are partially covered. False work has been put in to support two-by-four ceiling studs.

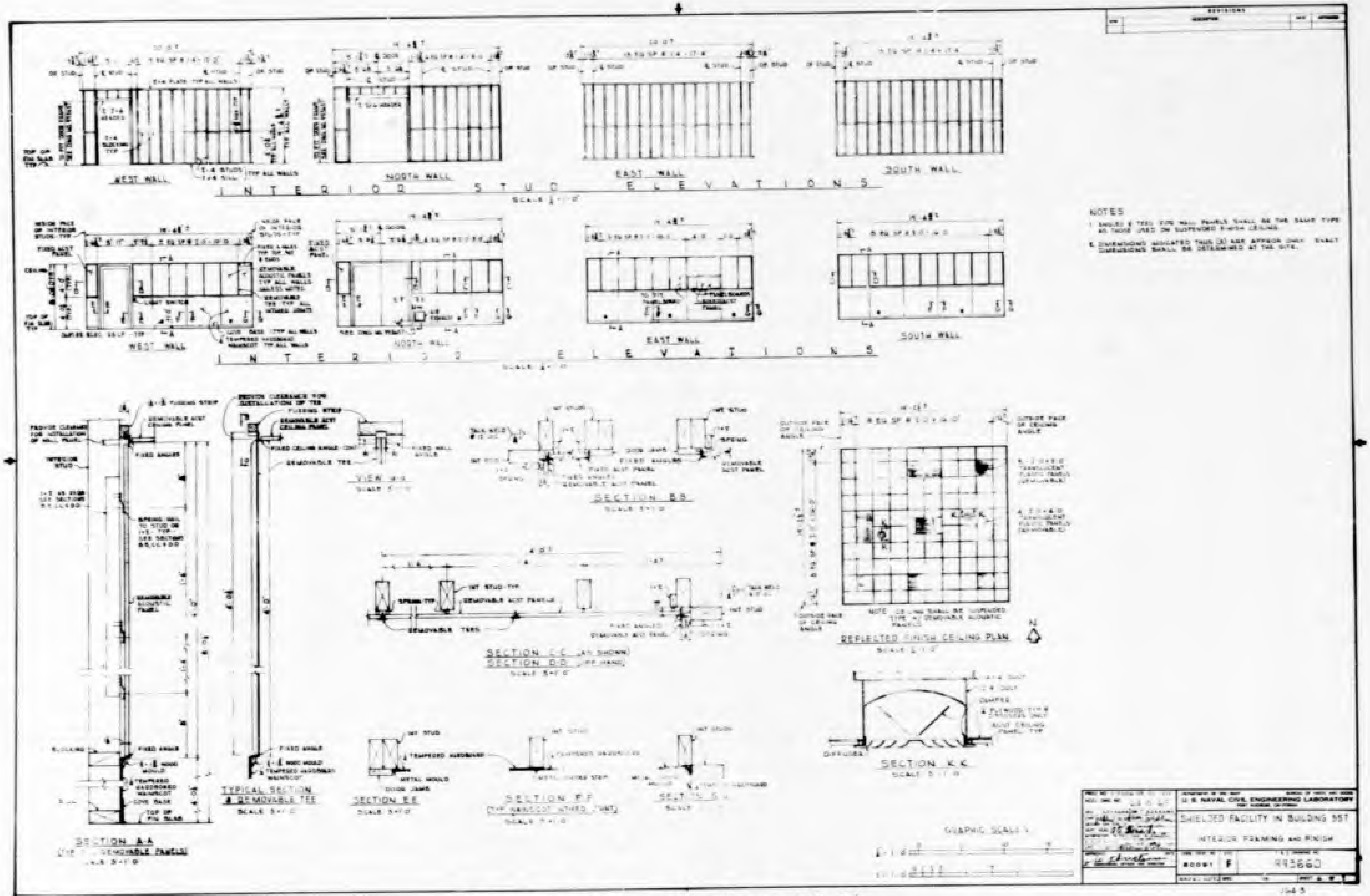

Figure 16. Interior framing and finish.

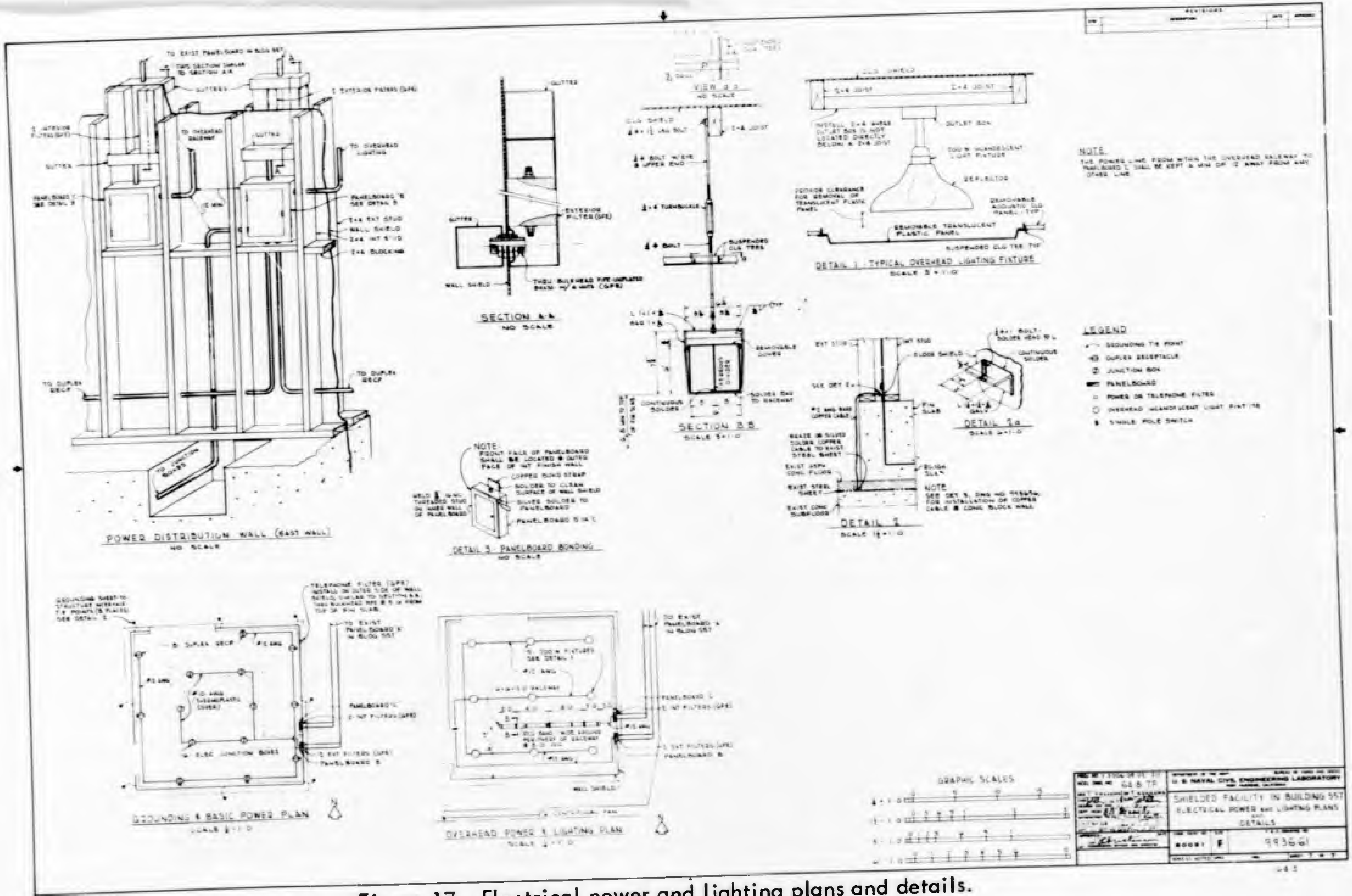

Figure 17. Electrical power and lighting plans and details.

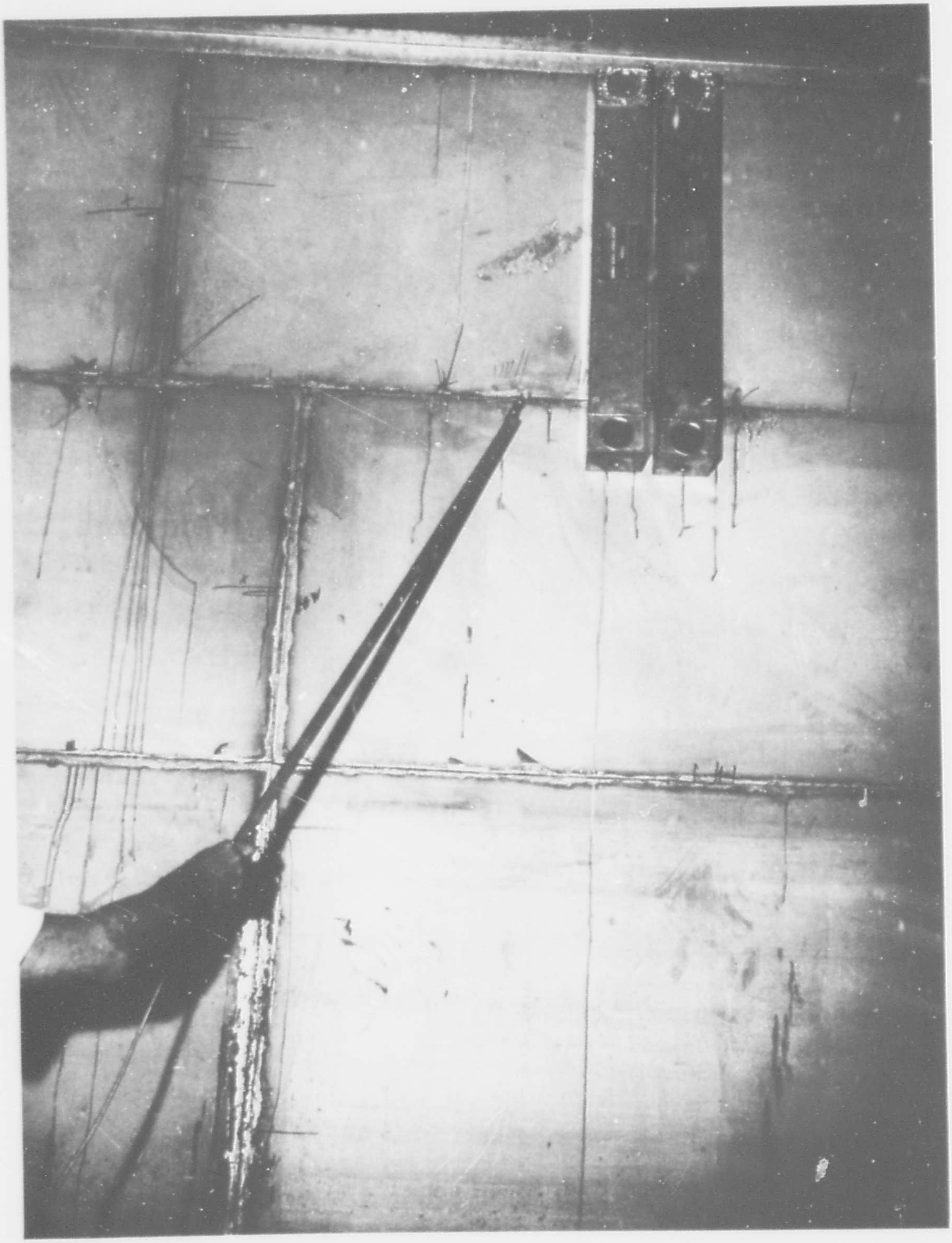

Figure 18. High-frequency probe used to determine the location of radio-frequency leaks in the seams of the shielded enclosure.

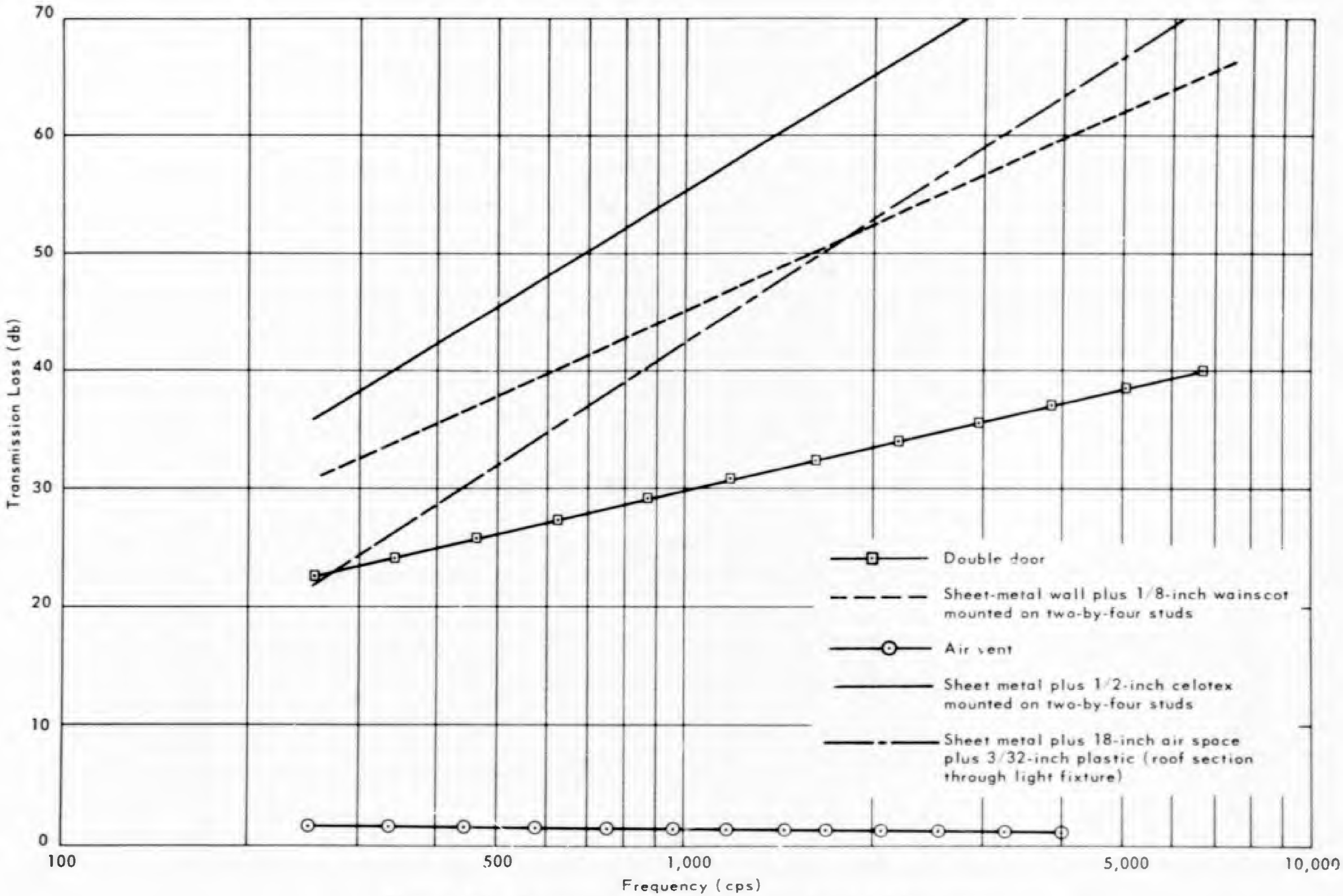

Figure 19. Acoustic transmission loss for shielded room.

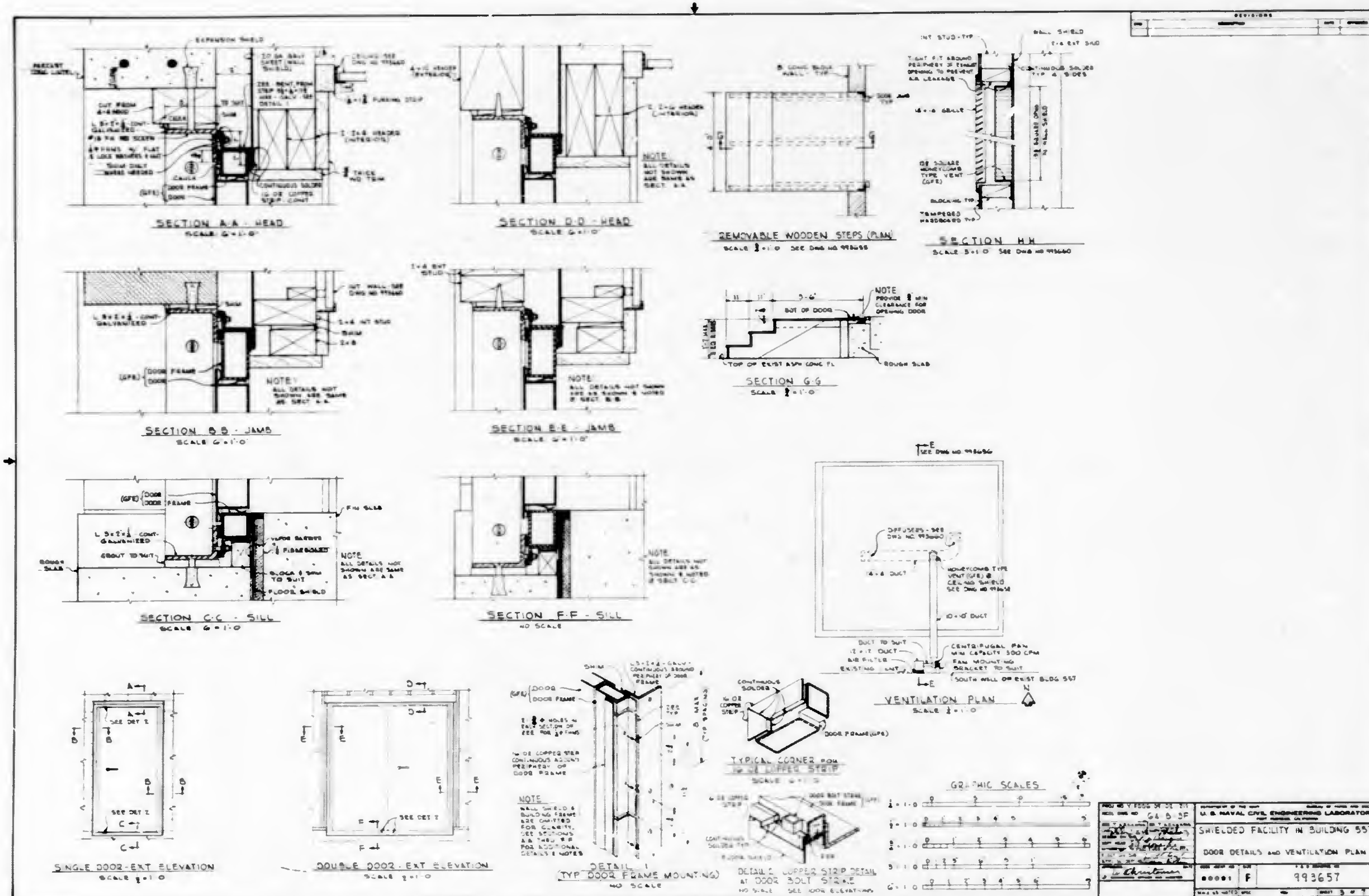

Figure 20. Door details and ventilation plan.

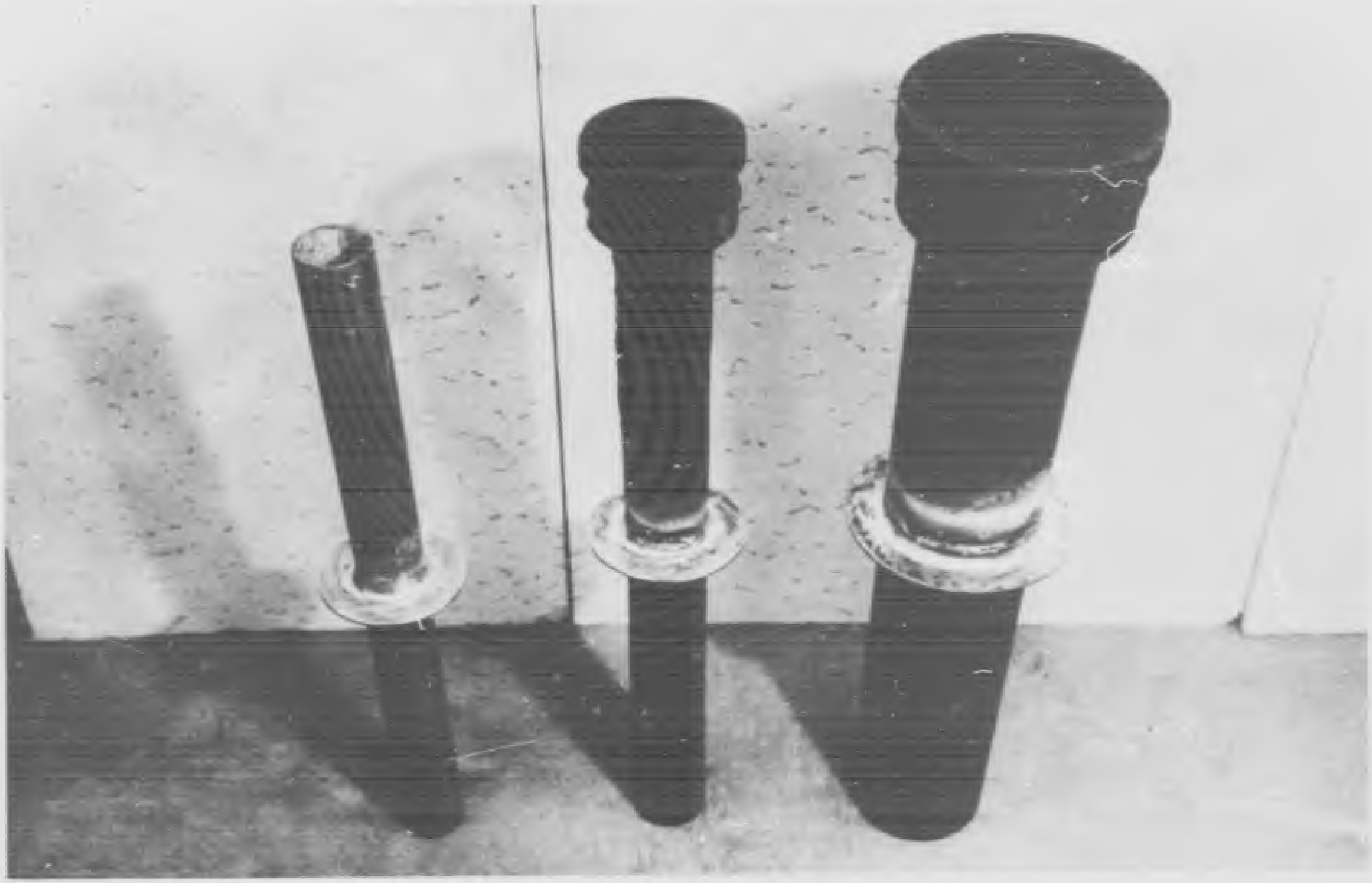

Figure 21. Sections of pipe used in penetration studies. From left to right, a 2-inch steel pipe commonly used for water mains, a section of small diameter galvanized sewage pipe, and a 4-inch-diameter sample of typical sewage pipe.

Figure 22. North wall of shielded room showing the acoustic tile removed and the three pipe penetrations mounted in positions suitable for tests.

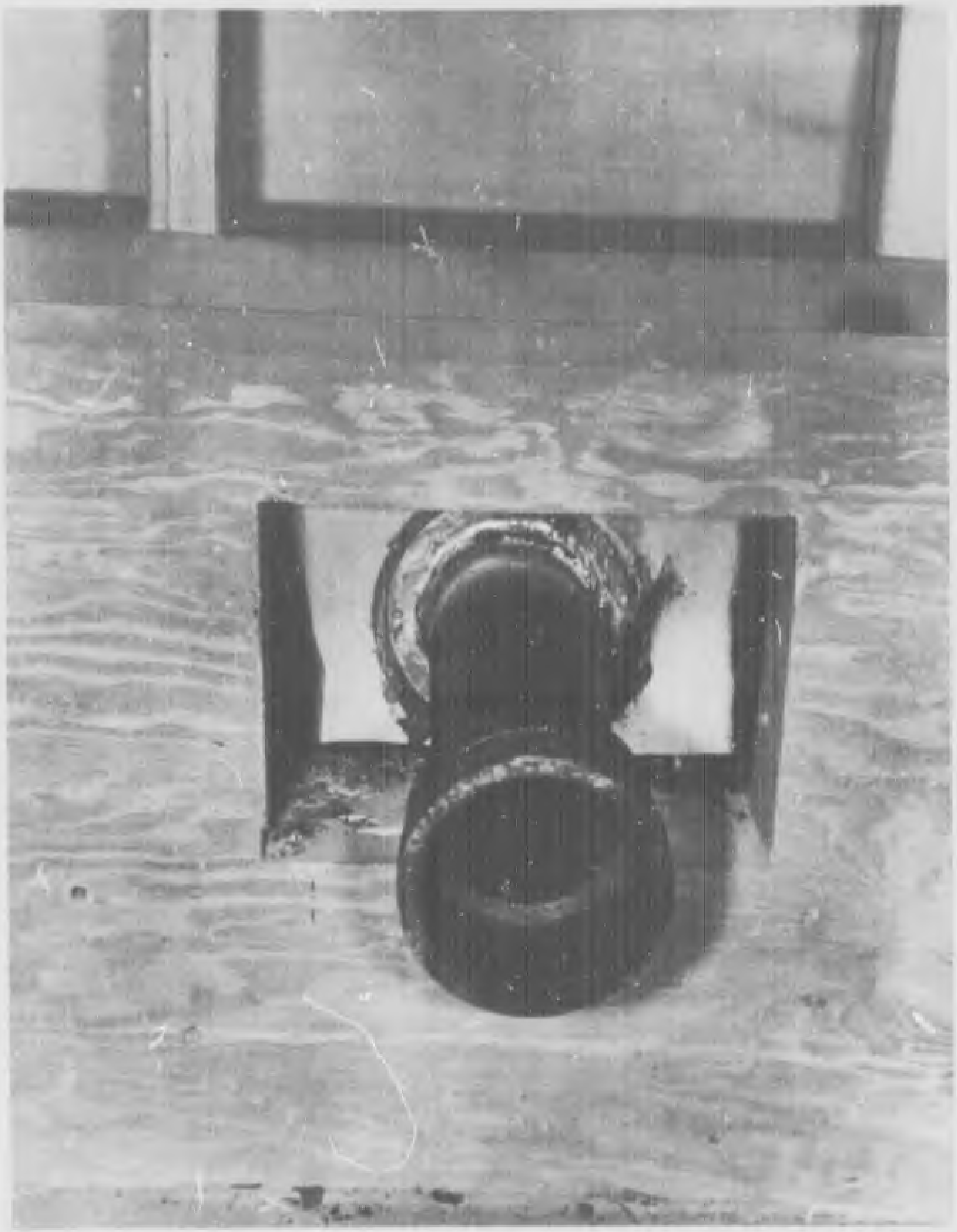

Figure 23. Exterior view of 4-inch sewage pipe mounted in east wall below floor line of shielded room. Brass screws as well as soldering have been used to secure the pipe to the sheet-metal wall.

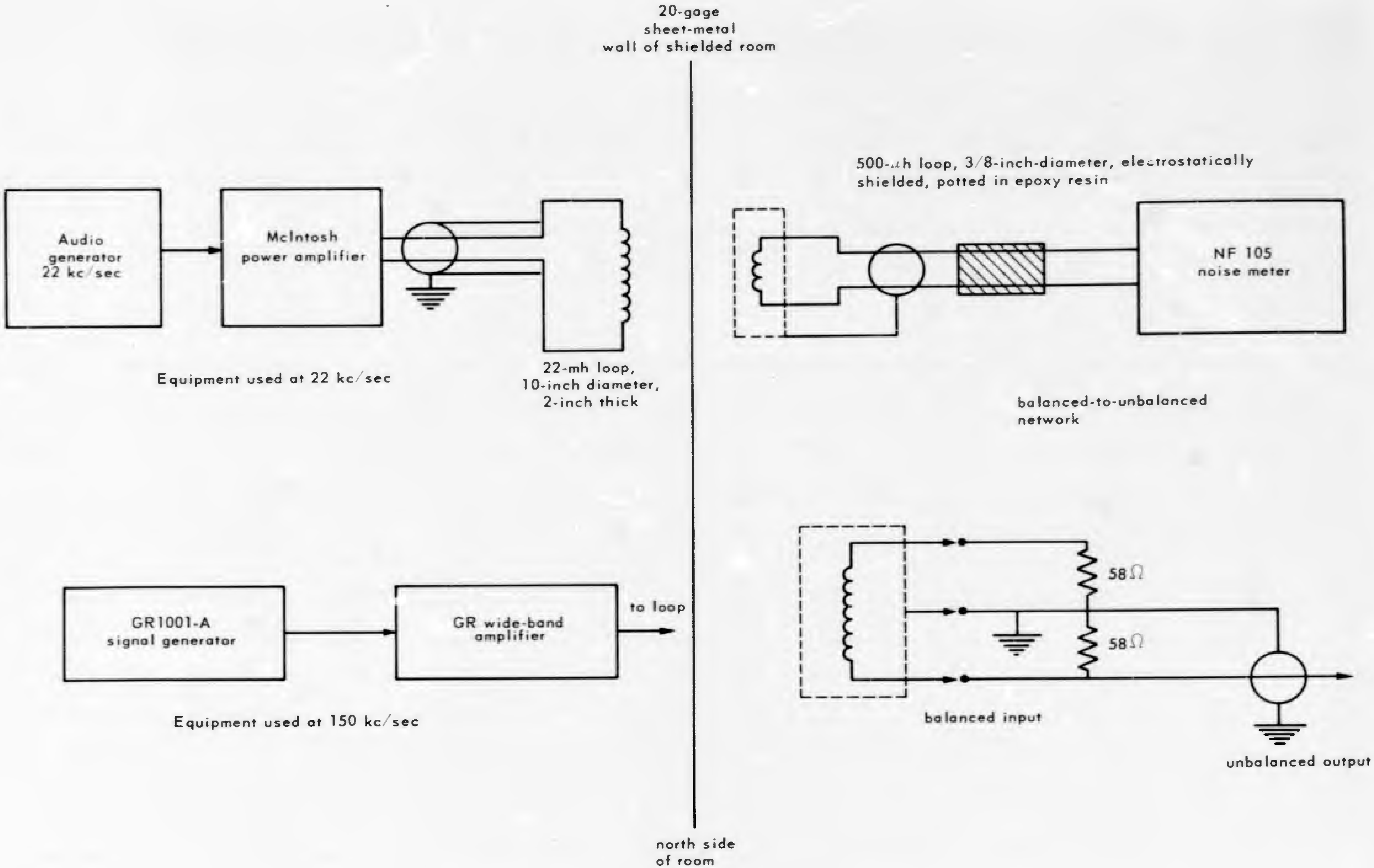

Figure 24. Test setup for penetration study.

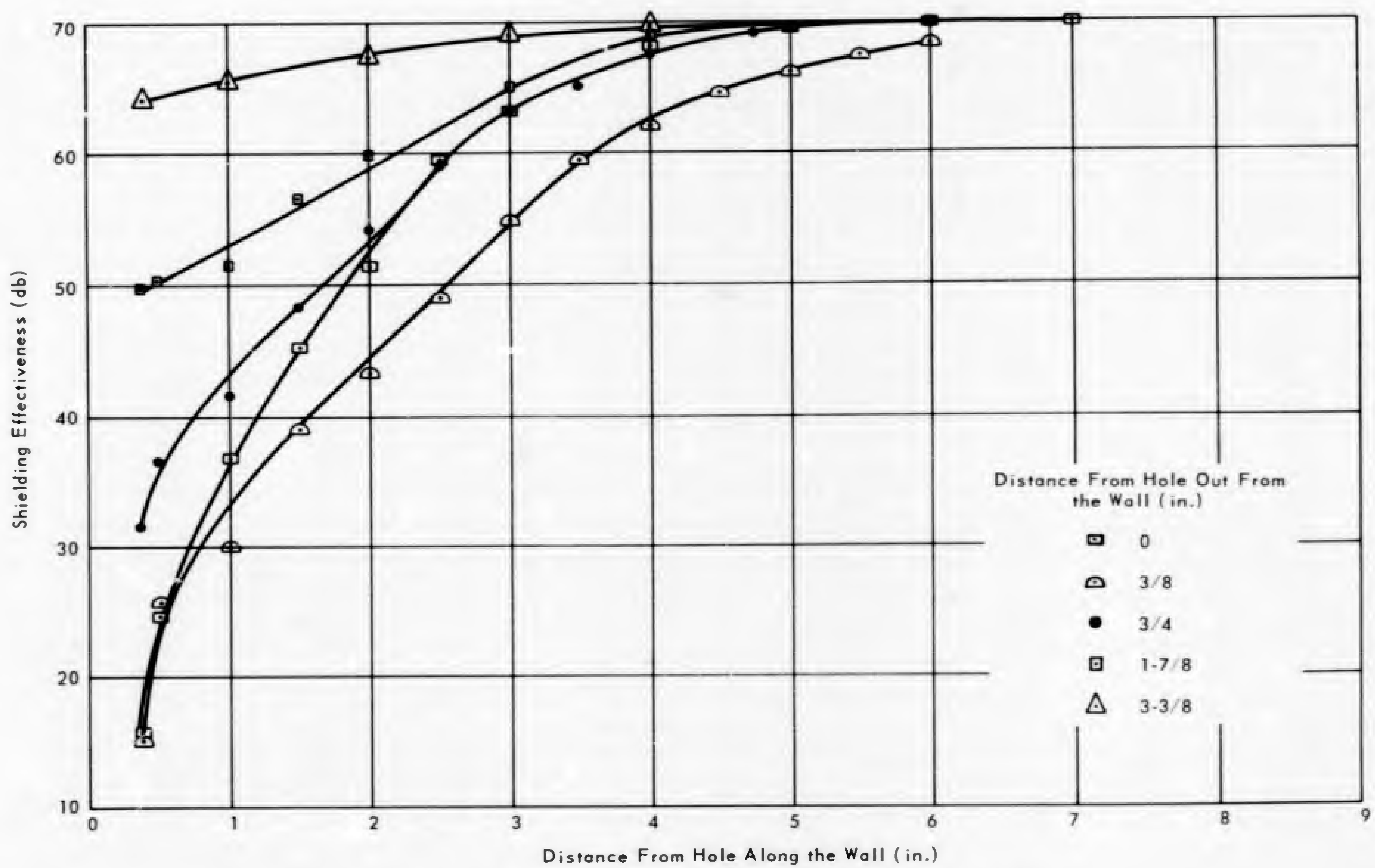

Figure 25. Shielding effectiveness for 5/8-inch hole.

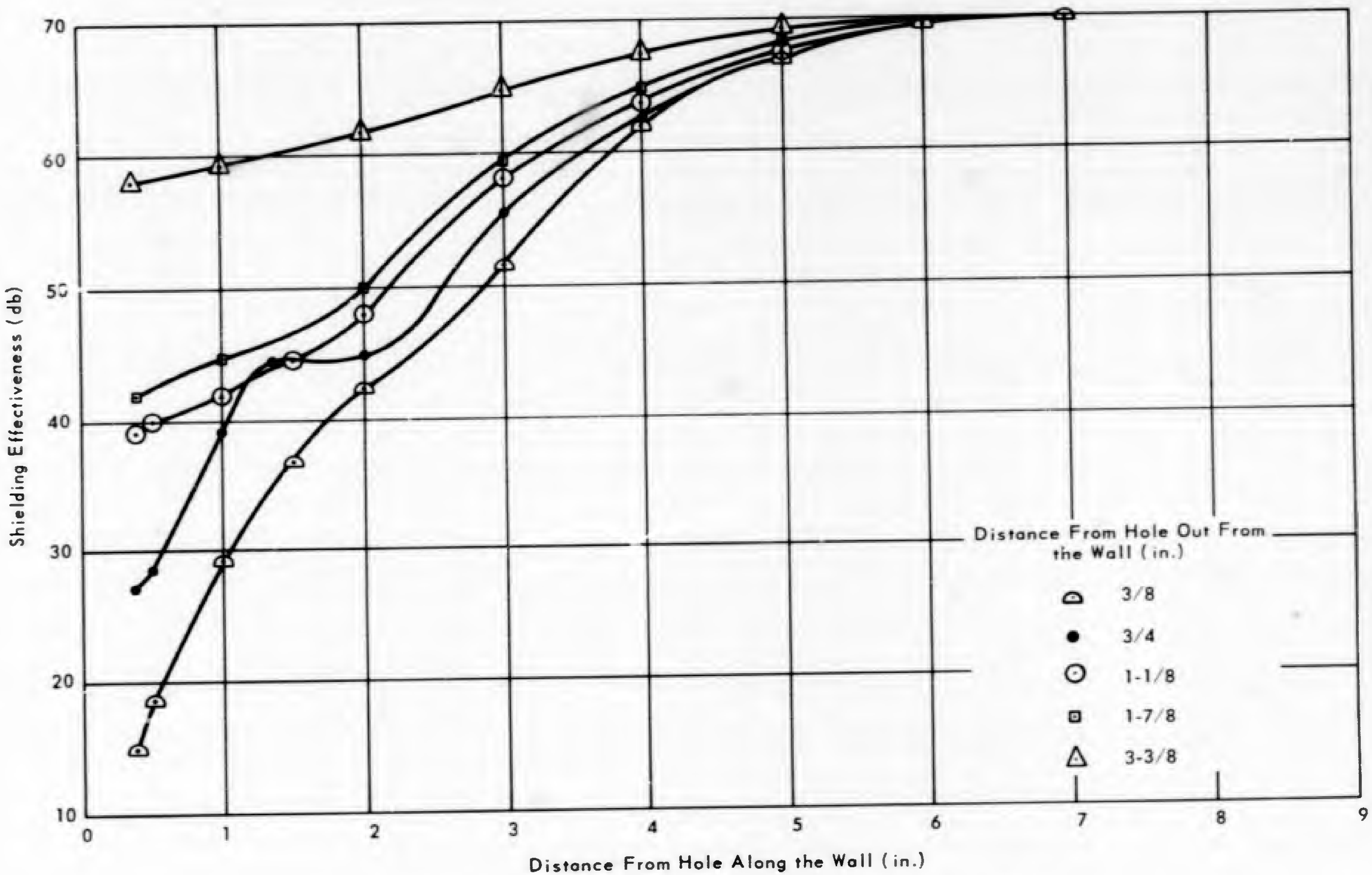

Figure 26. Shielding effectiveness for 7/8-inch hole.

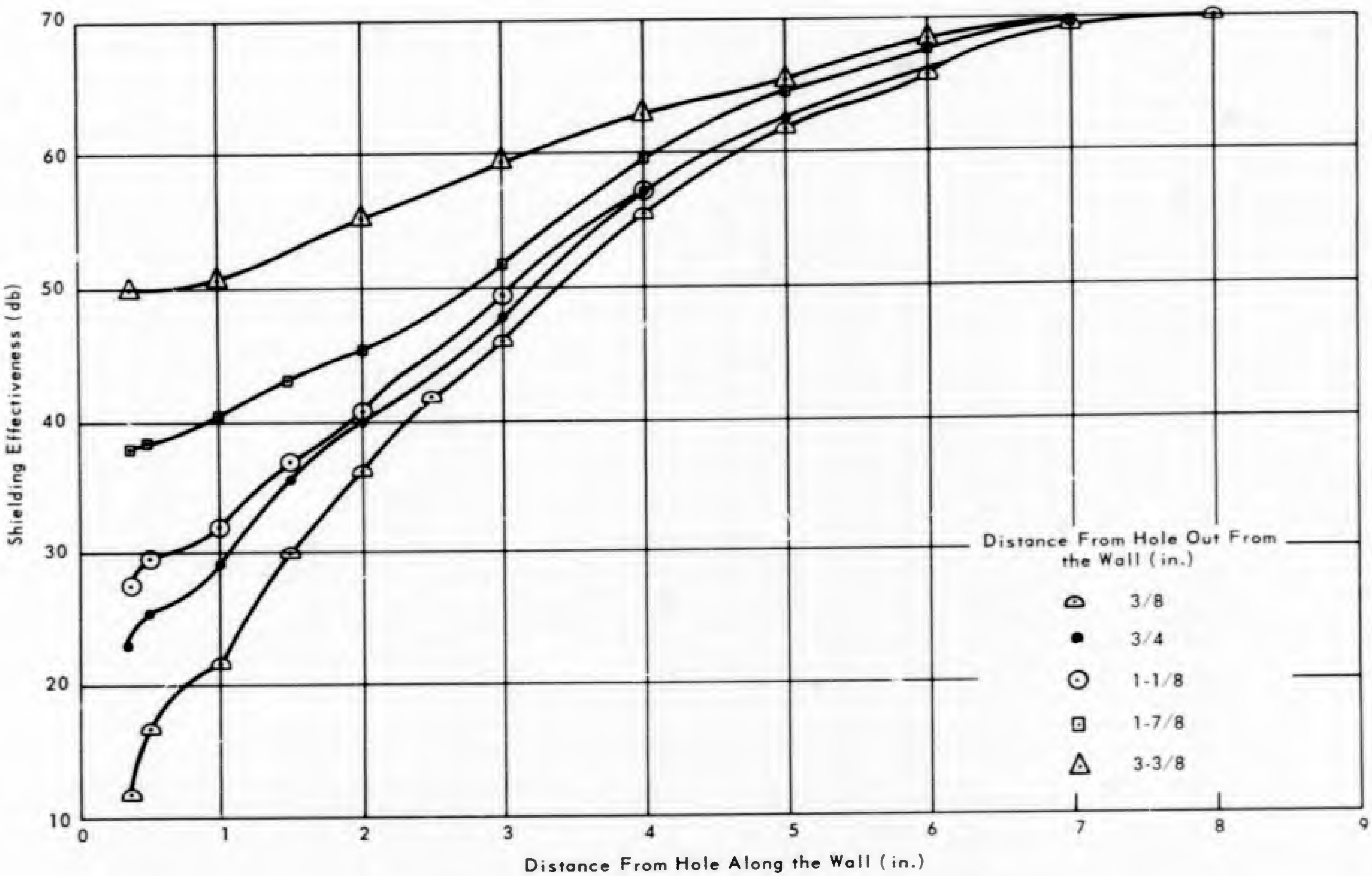

Figure 27. Shielding effectiveness for 1-1/8-inch hole.

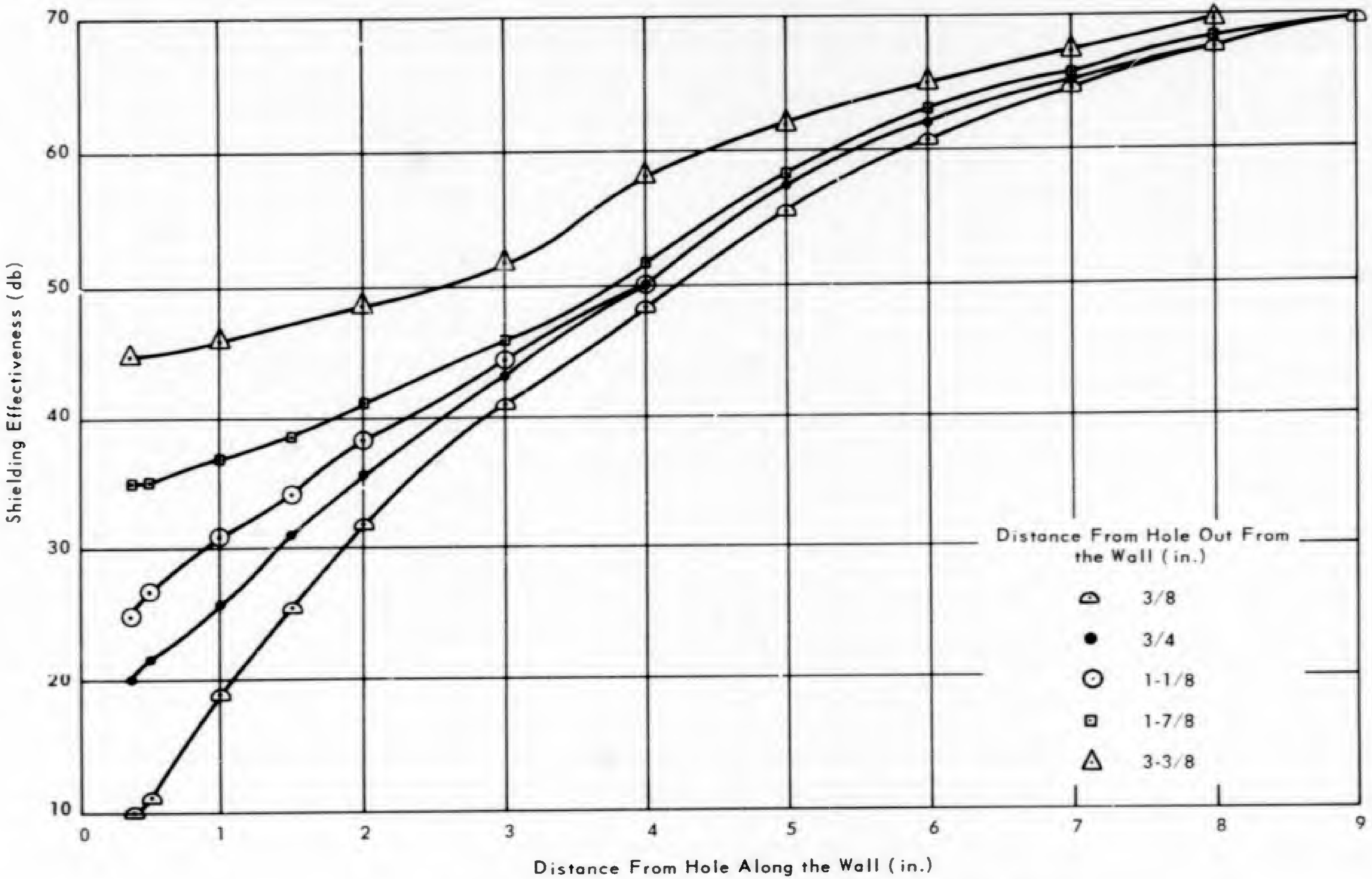

Figure 28. Shielding effectiveness for 1-1/2-inch hole.

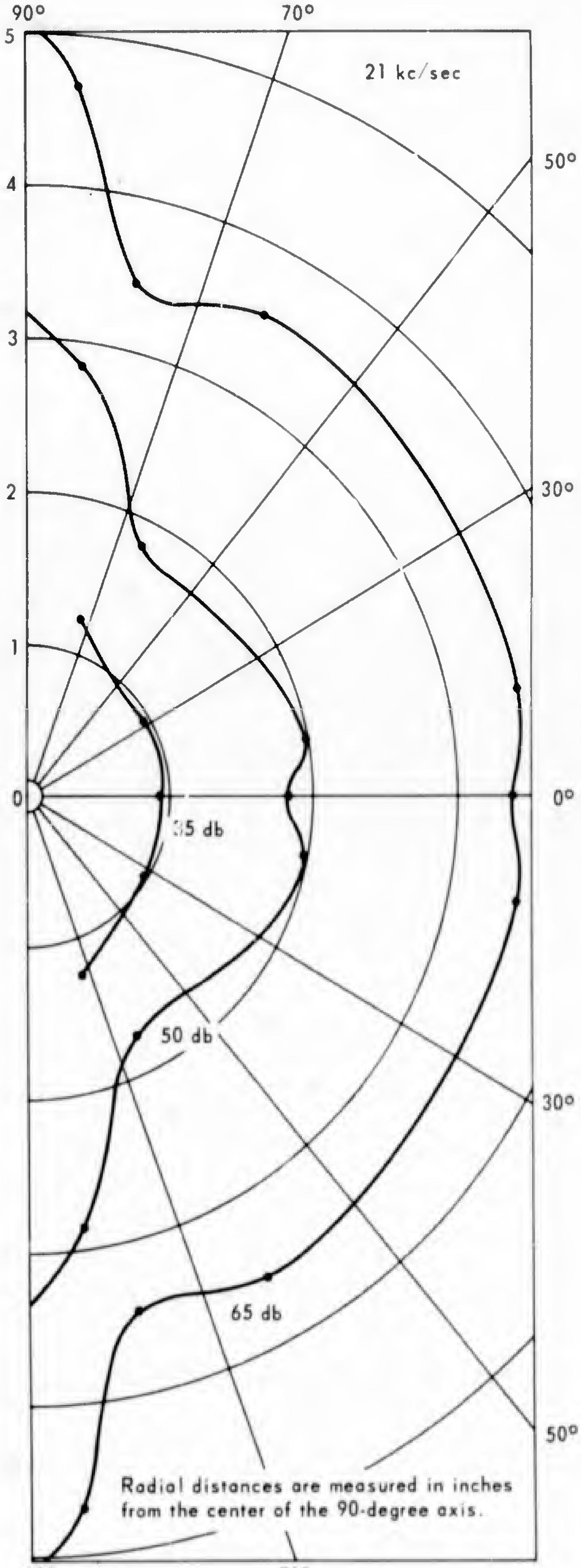

Figure 29. Equal contour lines for 5/8-inch hole.

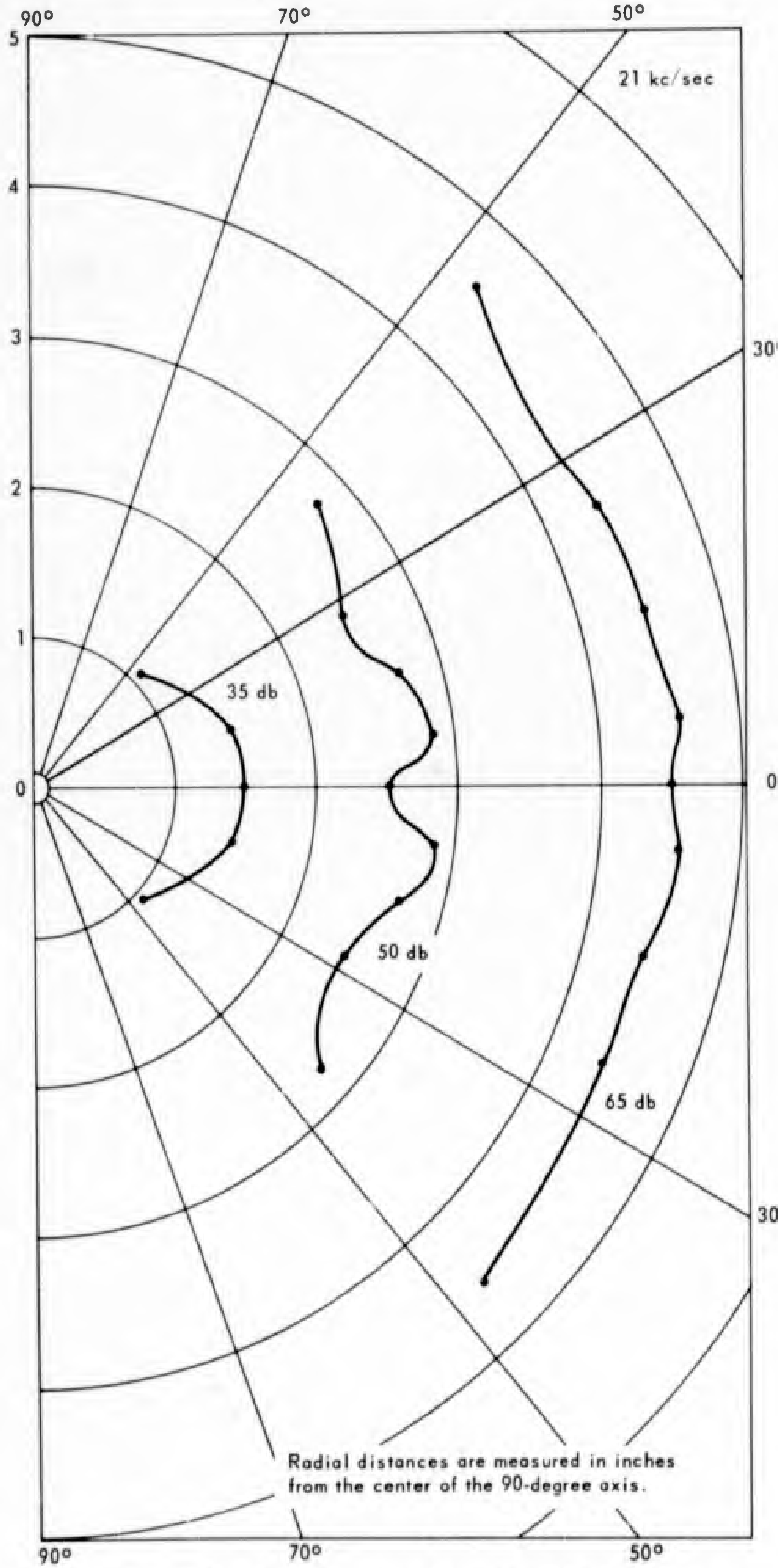

Figure 30. Equal contour lines for 7/8-inch hole.

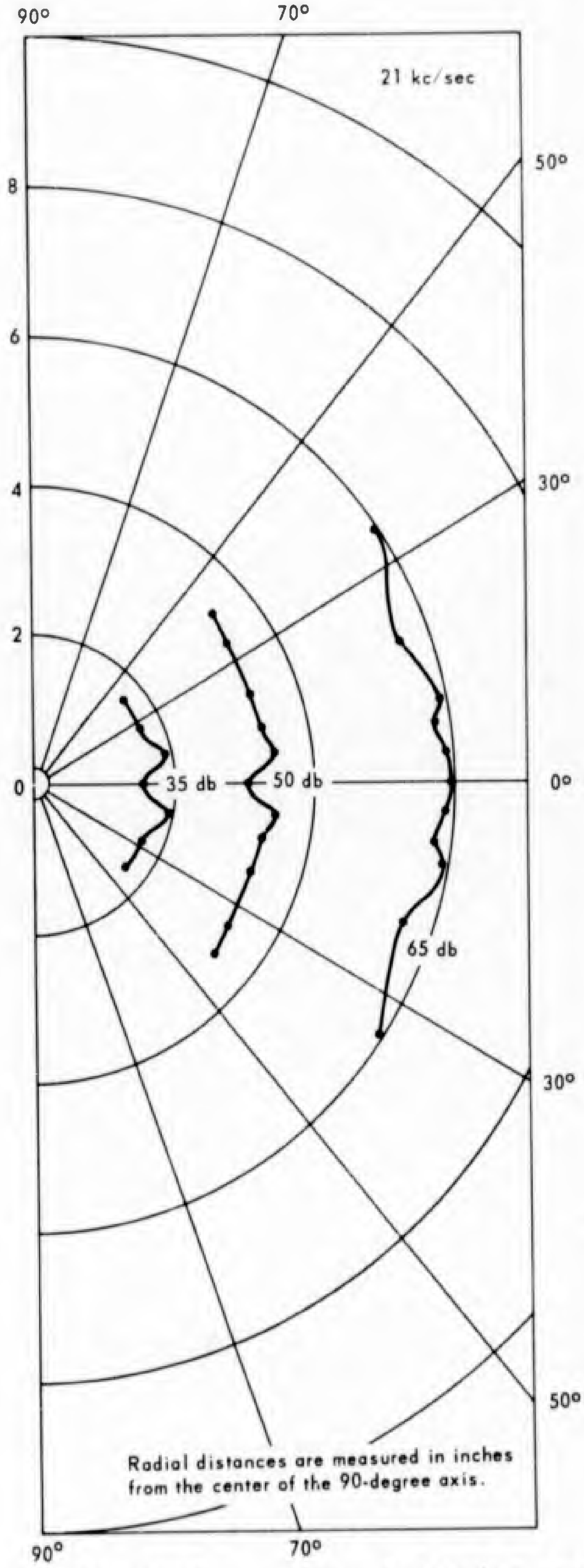

Figure 31. Equal contour lines for 1-1/8-inch hole.

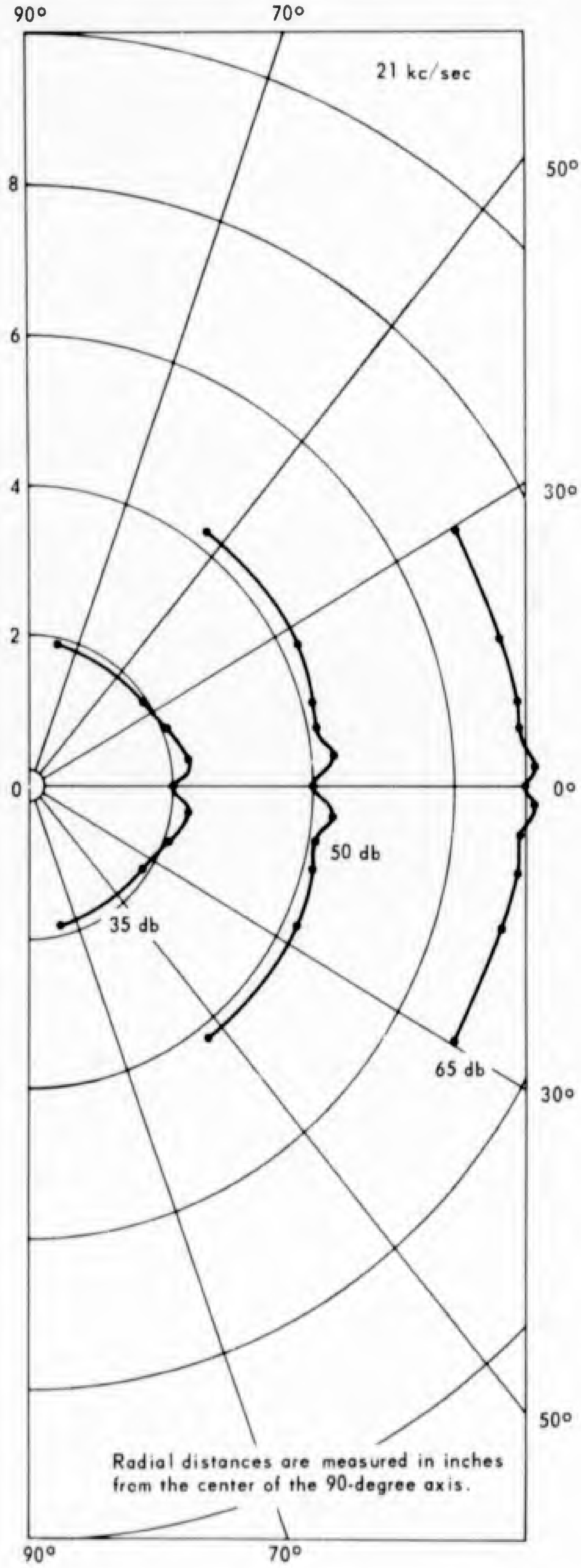

Figure 32. Equal contour lines for 1-1/2-inch hole.

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13. ABSTRACT

An electromagnetically shielded room composed of 20-gage sheet-metal wall material with continuously soldered seams was constructed and evaluated at the Naval Civil Engineering Laboratory. The 20 x 20 x 8-foot room is a prototype model designed as a basis for determining specifications for the construction of large shielded room installations. Electromagnetic shielding evaluation of the room was performed in accordance with MIL STD-285, along with additional measurements at 1.0, 2.5, and 9.0 Gc/sec. The lowest value of shielding effectiveness was 65 decibels at 14 kc/sec.

Construction techniques for such design features as sheet-metal joints, soldered seams, power-line filtering, ventilation ducts, and cable raceways are discussed. Techniques for providing penetrations into the room for gas, water, and sewage were investigated. Measurements of the effect of small, controlled openings into the room were determined. The acoustic shielding properties of the room are also given in this report.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
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Radio-frequency measurements						
Soldered sheet-metal seams						
Shielded room construction						
Acoustic shielding						
Construction of electromagnetically shielded room						

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