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NAVFAC-DM-32.2

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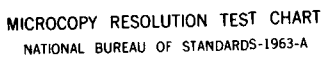
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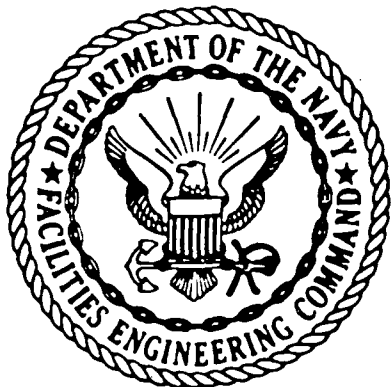
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COVERED STORAGE

DESIGN MANUAL 32.2

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER NAVFAC DM-32.2	2. GOVT ACCESSION NO. AD-A723638	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) NAVFAC Design Manual DM-32.2 Covered Storage		5. TYPE OF REPORT & PERIOD COVERED Design Criteria Final
7. AUTHOR(s) Naval Facilities Engineering Command 200 Stovall Street Alexandria, VA 22332 (Code 0461)		6. PERFORMING ORG. REPORT NUMBER DM-32.2
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Facilities Engineering Command 200 Stovall Street Alexandria, VA 22332		8. CONTRACT OR GRANT NUMBER(s)
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Facilities Engineering Command (Code 0432) 200 Stovall Street Alexandria, VA 22332		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS Engineering and Design
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		12. REPORT DATE June 1982
		13. NUMBER OF PAGES 83
		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report) Unclassified/Unlimited		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report) Unclassified/Unlimited		
18. SUPPLEMENTARY NOTES		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Building requirements; cold storage warehouse; controlled humidity warehousing; facility groups classification; flammables-hazardous materials warehousing; heavy materials warehouse; modernization of existing warehousing; planning considerations.		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) Design criteria are presented for facilities in category class 400 for use by experienced architects and engineers. The contents include criteria for cold storage facilities, other covered storage facilities, modernization of existing warehouse buildings, site planning, system selection, safety requirements, and environmental control. A		

ABSTRACT

Design criteria are presented for facilities in category class 400 for use by experienced architects and engineers. The contents include criteria for cold storage facilities, other covered storage facilities, modernization of existing warehouse buildings, site planning, system selection, safety requirements, and environmental control.



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FOREWORD

This design manual is one of a series developed from an evaluation of facilities in the shore establishment, from surveys of the availability of new materials and construction methods, and from selection of the best design practices of the Naval Facilities Engineering Command, other Government agencies, and the private sector. This manual uses, to the maximum extent feasible, national professional society, association, and institute standards in accordance with NAVFACENGCOM policy. Deviations from these criteria should not be made without prior approval of NAVFACENGCOM Headquarters (Code 04).

Design cannot remain static any more than can the naval functions it serves or the technologies it uses. Accordingly, recommendations for improvement are encouraged from within the Navy and from the private sector and should be furnished to NAVFACENGCOM Headquarters (Code 04). As the design manuals are revised, they are being restructured. A chapter or a combination of chapters will be issued as a separate design manual for ready reference to specific criteria.

This publication is certified as an official publication of the Naval Facilities Engineering Command and has been reviewed and approved in accordance with the SECNAVINST 5600.16.



W. M. Zobel
Rear Admiral, CEC, U. S. Navy
Commander
Naval Facilities Engineering Command

COVERED STORAGE DESIGN MANUALS

<u>DM No.</u>	<u>Superseded Chapters in basic DM-32</u>	<u>Title</u>
32.1	1	Ammunition and Explosives Storage
32.2	2,3	Covered Storage
32.3	4	Open Storage

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STORAGE

Section 1. CRITERIA FOR COVERED STORAGE BUILDINGS

1. SCOPE. The planning, construction, and operation of covered storage facilities requires consideration of many factors. These involve siting, layout, area, height, and internal details necessary for the efficient and proper operation of the facility. Criteria for covered storage buildings of the types frequently designed for naval activities are presented in this manual. Particular reference is made to buildings that vary according to the nature of the intended activity of the building. The following classifications show the more common types required for naval shore activities:
 - a) Warehouses for hazardous materials, heavy materials, dehumidification, aviation, medical supplies, boxing, crating, and cold storage.
 - b) Receiving, shipping, and issue buildings.
 - c) Preservation buildings.

Certain Marine Corps expeditionary units require permanent warehousing facilities while in garrison. These Marine Corps facilities may include offices, an armory (in accordance with Department of Defense Storage and Materials Handling Manual, DOD 4145.19-R-1, and U.S. Navy Physical Security Manual, OPNAVINST 5510.45), and a camp maintenance workroom.

2. CANCELLATION. This manual on covered storage, NAVFAC DM-32.2, cancels and supercedes Chapters Two and Three, NAVFAC DM-32 Covered Storage of November, 1967, Change 1 of May, 1968, Change 2 of March, 1969, and Change 3 of September, 1973.
3. RELATED CRITERIA. Criteria related to the design of covered storage buildings are as follows:
 - a. DOD Construction Criteria. Refer to, and comply with, all pertinent criteria in Department of Defense Construction Criteria Manual, DOD 4270.1-M.
 - b. Requirements of Other Commands or Bureaus. Cold storage installations must meet specifications of the management command or syscom exercising control over them. General criteria of the management command or syscom usually are incorporated in the General Development Map of the activity. Specific requirements must be coordinated with the cognizant management command or syscom.
 - c. Definitive Drawings. The drawings contained in Definitive Designs for Naval Shore Facilities, NAVFAC P-272, Part 1, are an integral part of NAVFAC design policy and shall be used in conjunction with this publication.
 - d. Standard Drawings. Consult NAVFAC standard drawings for details on the following:

- a. General warehouses for naval supply activities.
 - b. Dehumidification for standard general warehouses.
 - c. Installation of warehouse dehumidification machinery.
 - d. Conversion of existing structures to dehumidified storage.
 - e. Cold storage buildings for naval supply activities.
- e. Other Sources. Certain criteria related to covered and cold storage appear in the following sources:

<u>Subject</u>	<u>Source</u>
Architecture	NAVFAC DM-1
Architectural Design	
Optional Materials of Construction	
Administrative Facilities	NAVFAC DM-34
Color for Naval Shore Facilities	P-309
Heating, Ventilating, Air Conditioning and Dehumidifying Systems	NAVFAC DM-3.3
Cold Storage Insulation	
Evaporators	
Dehumidification Systems	
Heating Systems	
Ventilation Systems	
Economic Analysis Handbook	P-442
Electrical Requirements	NAVFAC DM-4 Series
Facility Planning Factors for Naval Shore Facilities	NAVFAC P-80
Family Housing	NAVFAC DM-35
Fire Protection Engineering	NAVFAC DM-8
Sprinkler Systems	
General Provision and Geometric Design for Roads, Streets, Walks, and Open Storage Area	NAVFAC DM-5.5
Hospital and Medical Facilities	NAVFAC DM-33
Maintenance Facilities	NAVFAC DM-28 Series
Battery Shops	
Mechanical Engineering	NAVFAC DM-3
Plumbing	
Packing	NAVSUP PUB-503
Pavements	NAVFAC DM-5.4
Preservation and Packing	NAVSUP PUB-502

<u>Subject</u>	<u>Source</u>
Seismic Design for Buildings	NAVFAC P-355
Soil Mechanics, Foundations, and Earth Structures	NAVFAC DM-7
Storage and Warehousing Facilities and Services	NAVSUPINST 4450.21 Series
Structural Engineering	NAVFAC DM-2 Series
Trackage Railway trackage	NAVFAC DM-5.6
Troop Housing	NAVFAC DM-36 Series
Warehouse Modernization and Layout Planning Guide	NAVSUP PUB-529
Waterfront Operational Facilities	NAVFAC DM-25
Weight Handling Equipment and Service Craft	NAVFAC DM-38
4. CLASSIFICATION OF FACILITY GROUPS. A major supply activity should comprise the facilities listed below:	
a. <u>Storage Areas</u> . Storage facilities (together with related rail and road access) accomplish the basic mission of a storage activity and, accordingly, are the determining factors in the major storage activity layout.	
b. <u>Railroad Yards</u> . Provision should be made for receiving, classification, delivery, and forwarding tracks arranged for minimum switching movements.	
c. <u>Waterfront Facilities</u> . Coastal storage activities require sufficient water frontage for piers and wharves, and sufficient land areas for related transit sheds, warehouses, weight handling equipment, and open storage.	
d. <u>Supporting Facilities</u> . Administrative, personnel, service, and housing groups should be located in accordance with operational requirements of the specific project.	

Section 2. PLANNING CONSIDERATIONS

1. SITE PLANNING. Overall layouts of major storage activities or areas shall be as stipulated by the General Development Map of the activity. General planning considerations shall serve as the basis for establishing relationships between buildings and other facilities. Future expansion of all buildings should be considered when developing the General Development Map in addition to the following:
 - a. Vehicle Access. All covered storage buildings must be provided with access for trucks, materials handling apparatus, and fire apparatus. Sufficient truck parking and turning space must be provided.

- b. Rail Access. Larger buildings must have rail access beside or into them.
 - c. Utilities. The source and location of all major utilities (water, electric, sewage, and steam) both above and below ground must be known. The facility site should be selected so as to take advantage of direct access to needed utilities while preserving the expandability and maintainability of the utility system.
2. STORAGE/HANDLING SYSTEM SELECTION. The functional concept planning for new facilities or the modernization of existing facilities should consider concepts similar to those presented in NAVSUP PUB-529. The evaluation of alternative materials handling systems, the selection of handling and storage equipment, design of operations, the arrangement of the building should consider all of the following factors:
- a. Parameters. The following parameters should be observed when collecting data and analyzing systems.
 - (1) The normal pallet load size (including pallet) is 40" x 48" x 36" high (1020 mm x 1220 mm x 915 mm), or 40 cu. ft. (1.13 cu. m) which is equal to 1 Measurement Ton (M/T). Maximum DOD allowances for loaded pallets with overhanging loads is 43" x 52" (1090 mm X 1320 mm). All planning should normally accommodate such loaded dimensions except in special cases; e.g. in S/R system racks where it may be necessary to maintain the 40" X 48" (1020 mm X 1220 mm) dimension.
 - (2) Activity is based on a one-item order document.
 - (3) Storage costs, handling costs, and handling times in NAVSUP PUB-529 have been synthesized. The accuracy of these standards relative to the actual performance of an activity must be determined before meaningful evaluations can be performed. (See Section 20 of NAVSUP PUB-529.)
 - (4) Support area requirements have not been defined and must be considered on an individual activity basis. (See NAVFAC P-80 and Appendix B of NAVSUP PUB-529.)
 - (5) In most instances, it is less expensive over the life of a project to build high, utilize cube, and decrease ground cover. This should be considered when making system evaluations.
 - b. Procedures. The following steps should be followed in developing a facility concept. Refer to Sections 12 and 13 of NAVSUP PUB-529 for details.
 - (1) Define Inventory. Inventory levels must normally be stated in terms of 40 cu. ft. (1.13 cu. m) (M/T) pallet loads or 0.5 cu. ft. (0.014 cu. m) shelf boxes.
 - (2) Define Daily Transactions. Activity levels must be stated in terms of daily quantities of pallets stored and retrieved, and line item document issues.

- (3) Define Available Space. The area available for system installation must be defined for both new facility designs or the conversion of existing facilities.
- (4) Compute T/I Ratio. Compute the system Transaction/Inventory (T/I) ratio based upon the defined inventory and transaction quantities.
- (5) Select System. Evaluate and select alternative system and base on the computed T/I ratio.
- (6) Determine the relative system cost for each alternative system and select the appropriate system.
- (7) Determine building size for selected system.
- (8) Evaluate and size support areas.
- (9) Develop composite building layout.

c. Handling Equipment. Materials handling equipment can be classified into one of the following categories:

- (1) Pallet Handling Equipment. This equipment may be either vehicular (truck like) or specifically designed (storage/retrieval machine) for transporting and storing the 40" x 48" (1020 mm x 1220 mm) pallet.
- (2) Order Picking Equipment. This represents a wide variety of equipment designed to aid a worker in the selection, packaging, and transportation of supplies.
- (3) Transport Systems. These systems are designed for the movement of supplies between two or more locations within or outside of a facility.

d. Storage Equipment. Storage equipment can be classified as follows:

- (1) Pallet Rack
- (2) Shelving/Bins
- (3) Special. Special storage equipment can consist of devices such as cantilever rack, vertical sheet storage rack, pallet stacking frames, rigid and collapsible metal bins, etc.
- (4) Tolerances. Refer to NAVSUP PUB-529 for installation tolerances for the above storage equipment.

3. SYSTEM CONSIDERATIONS. The following topics should be considered when planning or revising materials handling systems:

a. Receiving/Shipping Operations.

- (1) Types of vehicles to be serviced.
- (2) Location of rail and road access.
- (3) Location with respect to other facility operations.
- (4) Support areas such as staging areas and offices.

b. Order Picking Operations.

- (1) Type of supply being processed.
- (2) Documentation requirements.
- (3) Packing requirements.

c. Support Areas. The areas required to support a storage facility include:

- (1) Non-administrative Supervisory Offices. Office space must generally be provided for supervisory personnel such as foremen, crew leaders, etc. These offices are generally designed to accommodate one or two people and should provide space for one desk and two chairs per person as well as filing space. These offices should be located near the associated activity area. They may consist of prefabricated partition type enclosures as well as more permanent forms of construction such as concrete block.
- (2) Restrooms. Separate restroom facilities are generally provided for administrative and general warehouse personnel. Fixture allowances should be in accordance with requirements presented in DOD 4270.1-M and NAVFAC DM-3.
- (3) Warehouse Employee Services. Depending upon the size of the facility, employee service areas will generally consist of break rooms, canteen/vending machine facilities, and locker rooms. The size of these facilities should be adequate to accommodate the expected number of employees. Multiple installations may be required to place these facilities within reasonable or required distances from employee activity areas. Refer to NAVFAC DM-1, NAVFAC DM-3, and DOD 4270.1-M for specific requirements.
- (4) Receiving/Shipping Offices. Separate office areas are generally required in larger facilities to expedite the flow of paperwork associated with the increased activity. Small facilities with few employees will generally use a single multi-purpose office. Shipping and receiving operations should occur at opposite ends of the truck dock area. Office location and arrangement should provide separation of work functions and maintain security by controlling access to the facility by outsiders. The offices should permit an unobstructed view of the inside and outside dock areas. Restroom facilities for both truck drivers and employees can be integrated into the office design.

The typical receiving office illustrated in Figure 1 provides space for a building/site security system and office space for receiving personnel. The secured entrance, lobby and restroom for truck drivers provides for controlled entry of outsiders into the facility. Separate restrooms are provided for administrative personnel.

The typical shipping office illustrated in Figure 2 provides a separate entrance, lobby, and restroom for truck drivers. A large central office area is used by shipping department personnel and separate restroom facilities for administrative employees are available.

- (5) **Crating Operations.** In many general purpose storage facilities, it is necessary to crate large or odd shaped items for storage or shipping. Variability in requirements for materials, product size, and tools necessitates individual design of crating areas. Refer to NAVSUP PUB-529, NAVSUP PUB-502, and NAVSUP PUB-503 for criteria.
- (6) **Packing Operations.** Requirements for small item packaging can be met through the use of a multi-purpose packing table work station. A typical configuration is illustrated in Figure 3. Small item packaging generally requires a supply of cartons; filler material; tape, glue, or other sealing devices; labels; and a scale. The design of small item packing facilities, like crating operations, must be approached on an individual facility basis. See NAVSUP PUB-529, NAVSUP PUB-502, and NAVSUP PUB-503 for criteria.
- (7) **Parking.** Adequate parking space for all facility employees should be provided within a reasonable distance of the facility entrance. Parking areas should be separated from the truck docks and other activity areas by fences. Overall site security should be enforced by separating the storage facility from the remainder of the base and further isolating parking from receiving/shipping activity. See DOD 4270.1-M for parking requirements.

- d. **Traffic Flow.** The orderly flow of people and equipment is essential to the conduct of a safe operation. The arrangement of the facility on the site and the internal arrangement of the operating systems should be evaluated to reduce or eliminate areas of conflicting traffic. Interaction with base traffic flow must be considered.
- e. **Safety.** The inclusion of adequate safety systems is essential to the conduct of accident free operations. Particular attention should be given to providing adequate safety markings on walls and floors, providing a defined area for fork truck battery charging and refueling, and providing adequate fire protection.

4. **SYSTEM COSTS.** Various alternatives may be feasible to satisfy a given requirement. Each alternative under consideration must be considered in terms of its full life-cycle total funding implications (regardless of funding source), as well as its benefits. Selected equipment should be identified, evaluated and priced as early as practicable in order that true project cost can be determined. Refer to NAVFAC P-442.

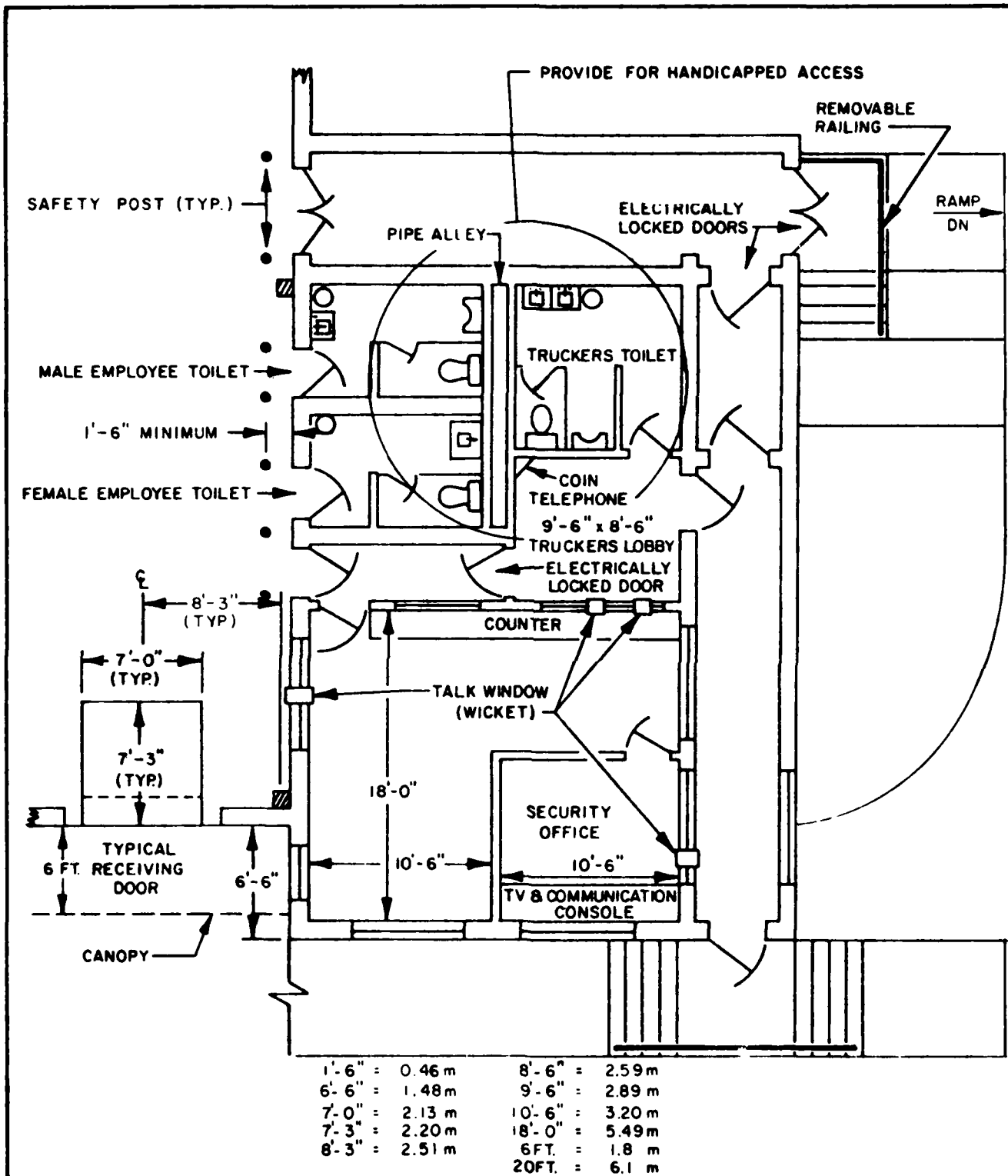


Figure 1
TYPICAL
RECEIVING OFFICE ARRANGEMENT
(Functional Dimensions)

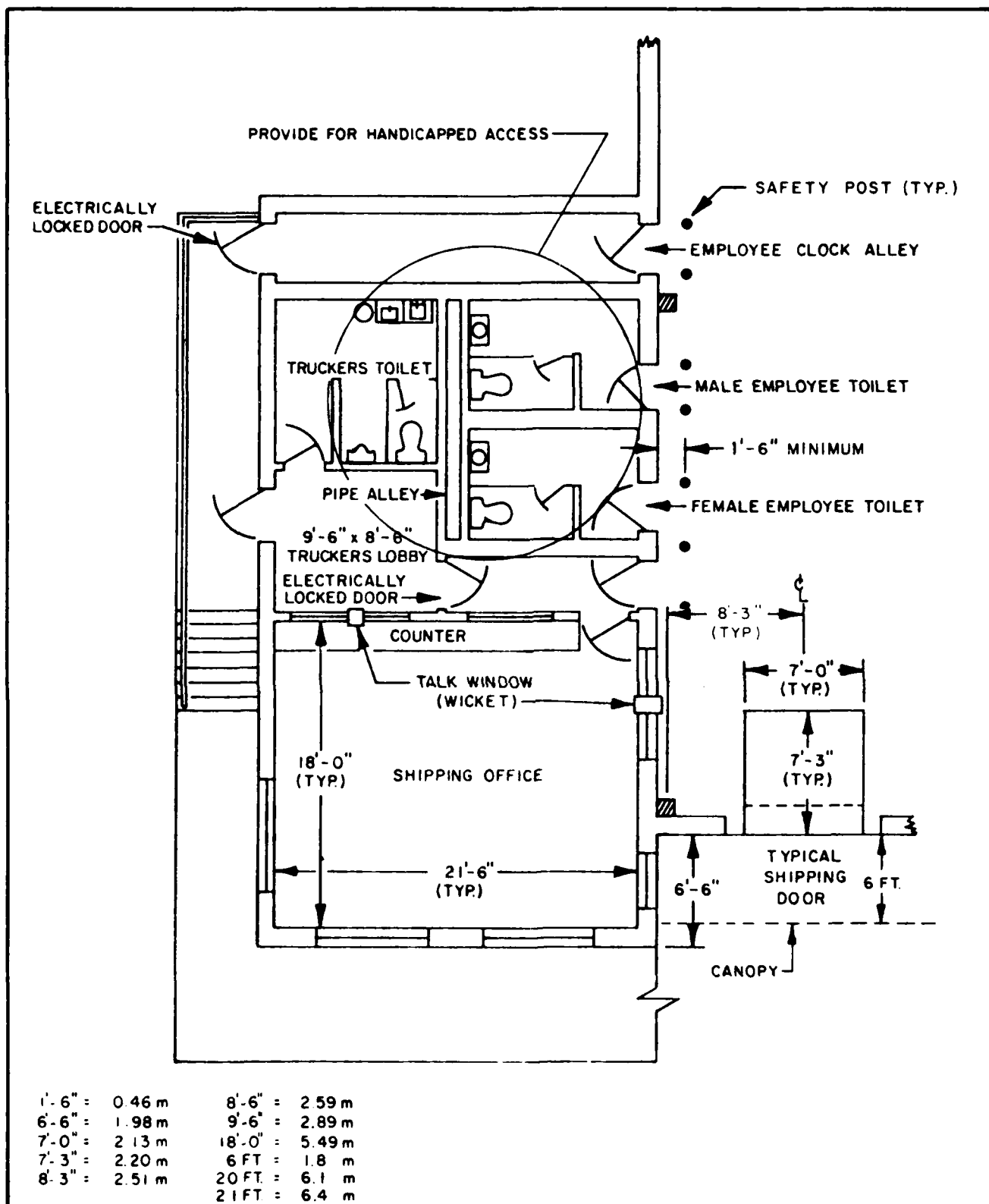


Figure 2
TYPICAL
SHIPPING OFFICE ARRANGEMENT
(Functional Dimensions)

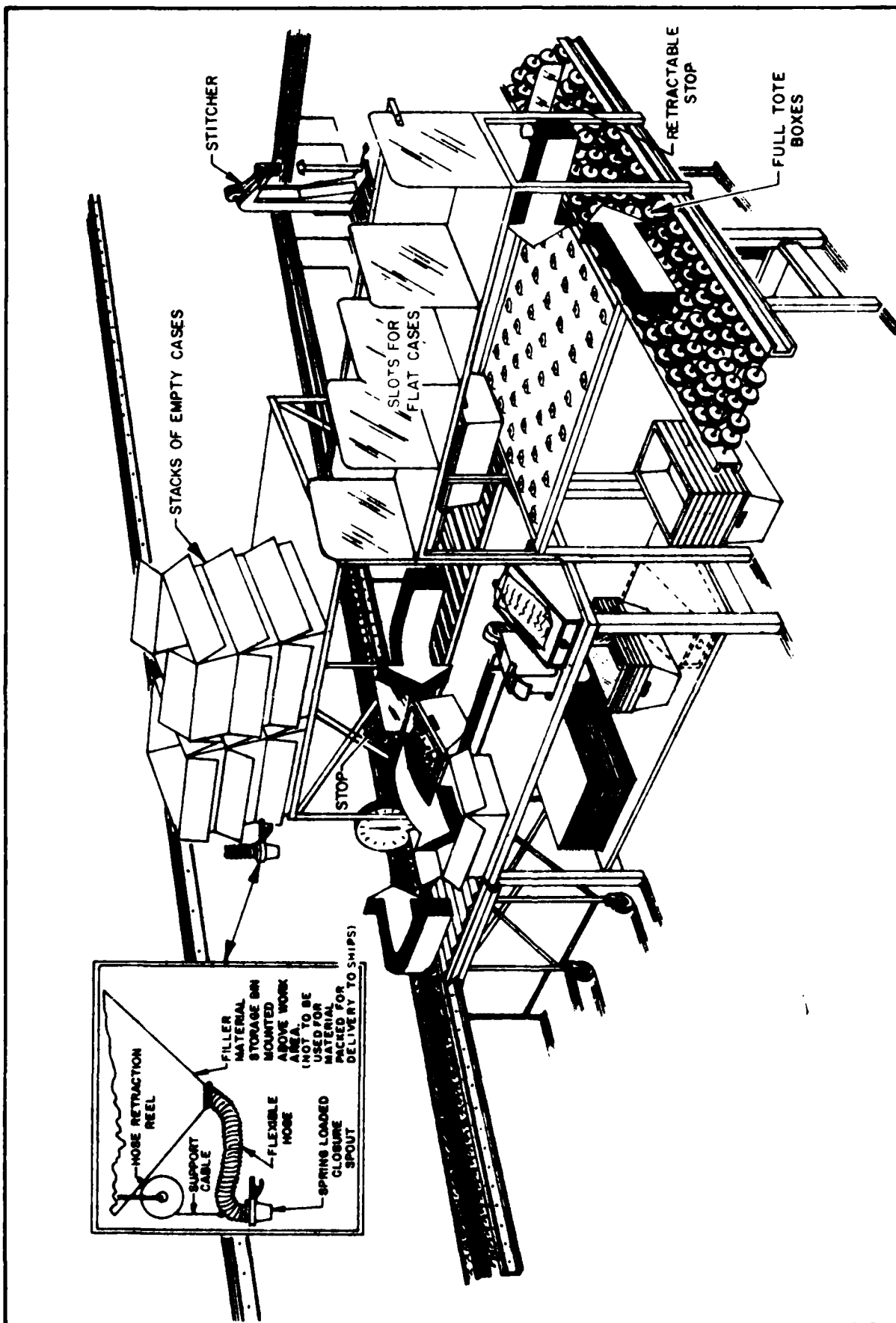


Figure 3
TYPICAL
PACKING STATION

5. **TECHNICAL APPROVAL.** Technical review and approval of functional plans and specifications prior to and at the 35 percent design stage by the Naval Supply Systems Command (Storage Branch) is required in consonance with the NAVSUPINST 4450.21 series.

Section 3. BUILDING REQUIREMENTS

1. **BASIC DESIGN.** The ease and rapidity of materials handling and maximum clear storage space are the prime considerations in storage buildings.
2. **BUILDING SHAPE AND PROPORTIONS.** Observe the following restrictions:
 - a. Travel Distance. Buildings or increments of buildings should be arranged for minimum handling operations. A square building is desirable in terms of minimizing exposed wall area for a given floor area. An aspect ratio (ratio of length to width) of 1.25 or less is considered square. An aspect ratio of 3.00 should not be exceeded for warehousing operations.
 - b. Irregular Shapes. Avoid, if possible, irregular shapes such as U or L.
 - c. Height. Within limits, storage costs per unit stored, over the life of the project, decrease as height is increased.
3. **BUILDING SPACING.** To facilitate normal operations and to aid fire prevention and protection, provide for the following minimum distances separating warehouses:
 - a. Rail Side. Allow 120 feet (36.6 m) between faces of walls.
 - b. Truck Side. Allow 175 feet (53.3 m) between faces of walls.
 - c. Warehouses In Line. Allow 150 feet (45.7 m) between faces of walls.
4. **MODULAR DESIGN.** The modular building bay dimensions presented in NAVFAC P-272, Part 1, have been developed using the systems requirements established in NAVSUP PUB-529. The bay spacing presented in the definitive drawings represents a universal approach that will accommodate eleven of the systems detailed in NAVSUP PUB-529, excluding the high rise S/R (storage/retrieval) machine system. This universal bay size will generally not represent the optimum column spacing for every system. For large facilities designed for a specific system, greater utilization of building cube will be obtained by selecting a column spacing matching the requirements of the material handling system. When selecting a column spacing pattern, the following should be considered:
 - a. Universal Bay Size. If a general purpose facility is required or a specific materials handling system has not been selected, versatility should be maintained by selecting the universal pattern subject to the following considerations:
 - (1) The universal pattern will not represent the optimum spacing for all systems.

- (2) The facility may be more costly than necessary because of the inefficient use of space. Generally, a smaller building can be constructed if the optimum column spacing is used.
 - (3) Use of the universal pattern will permit the building to fulfill a variety of missions due to its ability to function with many materials handling systems.
- b. Optimum Bay Size. Use of the optimum bay size for a particular materials handling system will provide the most efficient use of building cube capacity. In addition:
- (1) Use of the optimum bay size will generally reduce the size of the required building due to more efficient use of building cube.
 - (2) Ultimate versatility of the facility will be reduced because the column pattern will not fit every system.
- c. Comparison of Bay Sizes. The information presented in the Building Bay Size Comparison Table, Table 1, provides comparison information to enable a designer to measure the effects of changes to the building bay size. Use of the universal bay size generally results in a 5 percent to 10 percent decrease in utilization of potential storage area.
- d. Clear Storage Height. Specific requirements govern the clear storage height requirements for covered storage facilities. For storage heights less than 15'-0" (4.6 m), at least 1'-6" (0.5 m) is required between the top of the load and any overhead obstructions and sprinklers. For storage heights above 15'-0" (4.6 m), at least 3'-0" (0.9 m) of clearance is required. See DOD 4145.19-R-1 for details. If specific clear height requirements for a particular height of storage (number of storage levels) are specified, it is possible to develop modular building heights based upon ranges of storage levels. The information contained in the Required Clear Building Height Table, Table 2, presents the clear height requirements for specific levels of storage, as well as three clear heights covering a range of storage levels. Construction of a covered storage facility, to a modular height greater than that required for the desired system or level of storage, will result in unutilized cube and extra construction and operating costs. A general guide for determining the necessary height of storage states that it is less expensive per storage location to store high with less ground cover than to store low with a large amount of ground cover. This general rule must be evaluated in relation to local land, construction, and equipment costs as well as the amount of available expansion area and future growth requirements.
5. DOCKING FACILITIES. Provide adequate maneuvering space to facilitate loading and unloading operations at warehouse rail and truck docks, as illustrated in Figure 4. For information concerning such factors as overall tractor-trailer lengths, necessary turning radii for such units, required apron space, and clearances, refer to Time Saver Standards and NAVSUP PUB-529. All docks and platforms should be protected by full width canopies. All building corners and dock areas should be protected from vehicle impact by using concrete filled steel pipes as illustrated in Figure 5. Also observe the following:

TABLE 1
BUILDING BAY COMPARISON TABLE*

S Y S T E M	Optimum Bay Size ¹	Modular Equivalent Bay Size ²	Bay Dimension For Fit ³	Space Utilization In Universal Bay ⁴
Counterbalance Truck	39'-8" x 39'-8"	39'-8" x 59'-4"	64'-0"	92.7%
Reach Truck	30'-9" x 45'-10"	30'-8" x 45'-10" 30'-8" x 61'-0"	33'-0" 64'-0"	92.9% 95.3%
Side Reach Truck	26'-8" x 39'-10"	26'-2" x 64'-2"	64'-0" (a)	100.3%
Sideloader Truck	27'-8" x 41'-4"	27'-8" x 41'-4" 27'-8" x 55'-0"	33'-0" 64'-0"	83.8% 85.9%
Turret Truck (small)	26'-8" x 39'-10"	26'-8" x 64'-2" 26'-2" x 64'-2"	33'-0" 64'-0" (a)	80.1% 100.3%
Turret Truck (large)	25'-8" x 38'-4"	25'-8" x 63'-8"	64'-0"	99.5%
Shuttle Truck	24'-0" x 35'-10"	24'-0" x 59'-6"	64'-0"	92.9%
Manual Order Picker	31'-0" x 49'-0"	31'-0" x 60'-0" 31'-0" x 60'-0"	33'-0" 64'-0"	93.9% 93.8%
Order Picking Truck	33'-0" x 49'-0"	33'-0" x 49'-0" 33'-0" x 57'-0"	33'-0" 64'-0"	100.0% 89.1%
Manned S/R Machine	31'-0" x 49'-0"	31'-0" x 60'-0" 31'-0" x 60'-0"	33'-0" 64'-0"	93.9% 93.8%
Carrousel	32'-6" x 45'-6"	32'-6" x 45'-6" 32'-6" x 58'-6"	33'-0" 64'-0"	98.5% 91.4%
Mini S/R Machine	29'-6" x 48'-6"	29'-6" x 48'-6" 29'-6" x 58'-0"	33'-0" 64'-0"	89.4% 90.6%

*Standard Space Analysis Module dimensions used unless otherwise noted.

¹From line 2(c) in Layout Planning Charts 1 and 11, NAVSUP PUB-529.

²Equivalent size obtained by adding aisles to modular layout to obtain an approximate 33'-0" x 64'-0" bay dimension. Some modules required reducing the back tie dimension to 6" to obtain a fit.

³Dimension of the universal building bay in which the repeating rack/aisle pattern is aligned.

⁴Ratio of the Modular Equivalent dimension to the indicated Bay Dimension. Comparisons are made only for those combinations producing a utilization in excess of 80%.

(a) Rack back tie dimension (longitudinal flue space) reduced to 6" to provide a fit in the 64'-0" bay. This is necessary to accommodate 66" storage aisles.

TABLE 2
REQUIRED CLEAR BUILDING HEIGHTS*

S Y S T E M	P a l l e t S t o r a g e L e v e l s**									
	2	3	4	5	6	7	8	9	10	
Counterbalance	8'-6"	12'-6"	18'-0"	22'-0"	-	-	-	-	-	
Reach Truck	8'-6"	12'-6"	18'-0"	22'-0"	-	-	-	-	-	
Side Reach Truck	9'-0"	13'-0"	18'-6"	22'-6"	26'-6"	-	-	-	-	
Sideloader	9'-0"	13'-0"	18'-6"	22'-6"	26'-6"	30'-6"	34'-6"	-	-	
Turret Truck	9'-0"	13'-0"	18'-6"	22'-6"	26'-6"	30'-6"	34'-6"	38'-6"	42'-6"	
Shuttle Truck	-	14'-0"	18'-6"	22'-6"	27'-0"	31'-6"	36'-0"	40'-6"	45'-0"	
S/R Machine	-	-	-	-	-	-	-	-	44'-6"	
	S t o r a g e U n i t L e v e l s									
	1	-	2	-	3	4	-	5	-	
Manual Order Picking	8'-6"	-	18'-0"	-	26'-0"	-	-	-	-	
Order Picking Truck	-	-	17'-0"	-	24'-0"	31'-0"	-	38'-0"	-	
Manned S/R Machine	-	-	-	-	24'-0"	31'-0"	-	38'-0"	-	
Carrousel	9'-6"	-	-	20'-0" ¹	-	29'-0" ²	-	-	-	
Mini-S/R Machine	-	-	-	23'-0" ³	-	-	33'-0" ⁴	-	43'-0" ⁵	
Modular Building Clear Height	18'-6"									

*Including sprinkler clearance - 1'-6" for stacks 15'-0" and less - 3'-0" for stacks over 15'-0 - does not include clearance allowances for draft curtains.

**Based on a standard 4'-0" vertical spacing; see alternative spacings in Appendix C of NAVSUP PUB-529.

¹Two storage unit levels.

²Three storage unit levels.

320 ft. high system.

430 ft. high system.

540 ft. high system.

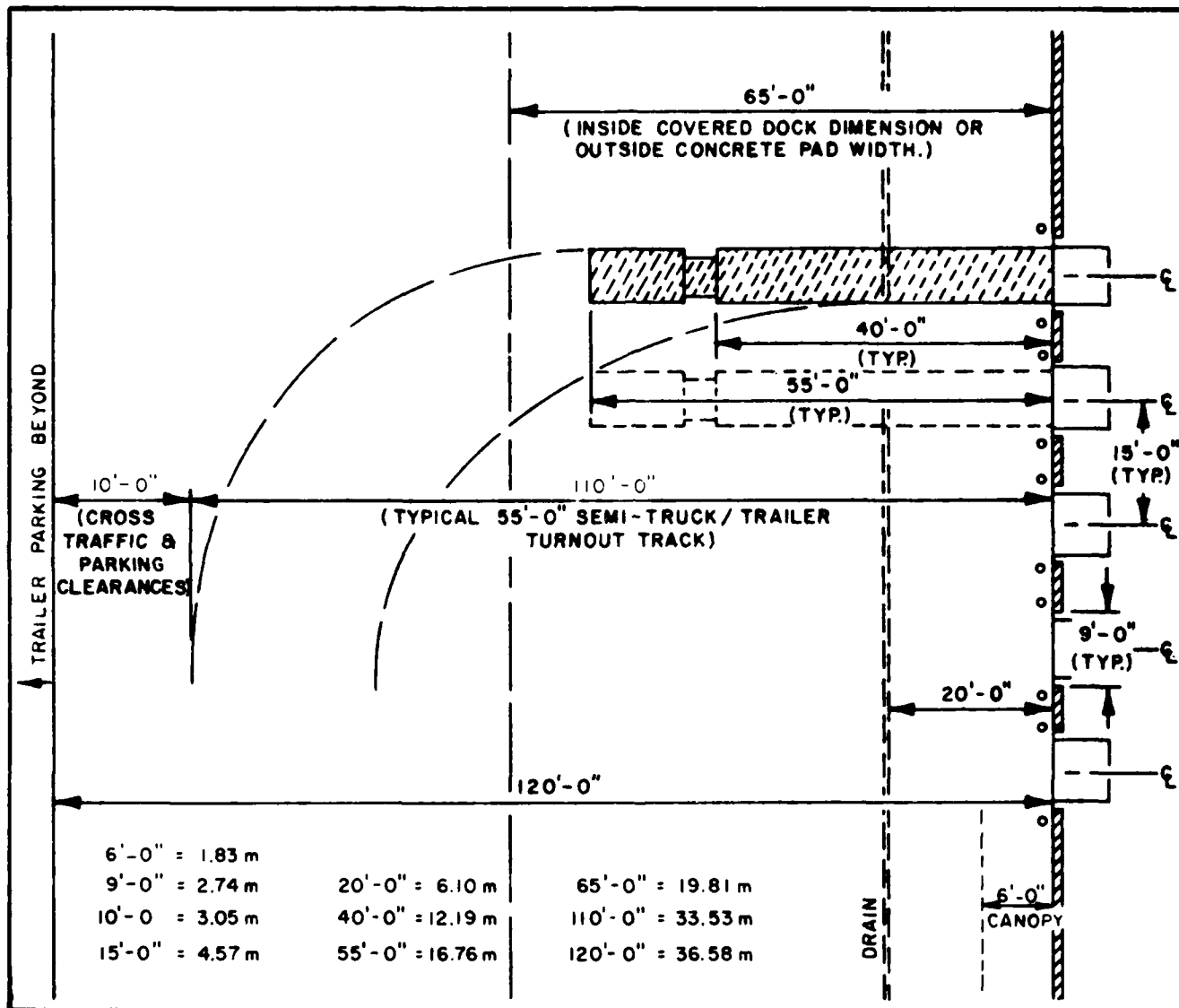


Figure 4
TYPICAL TRUCK APRON LAYOUT

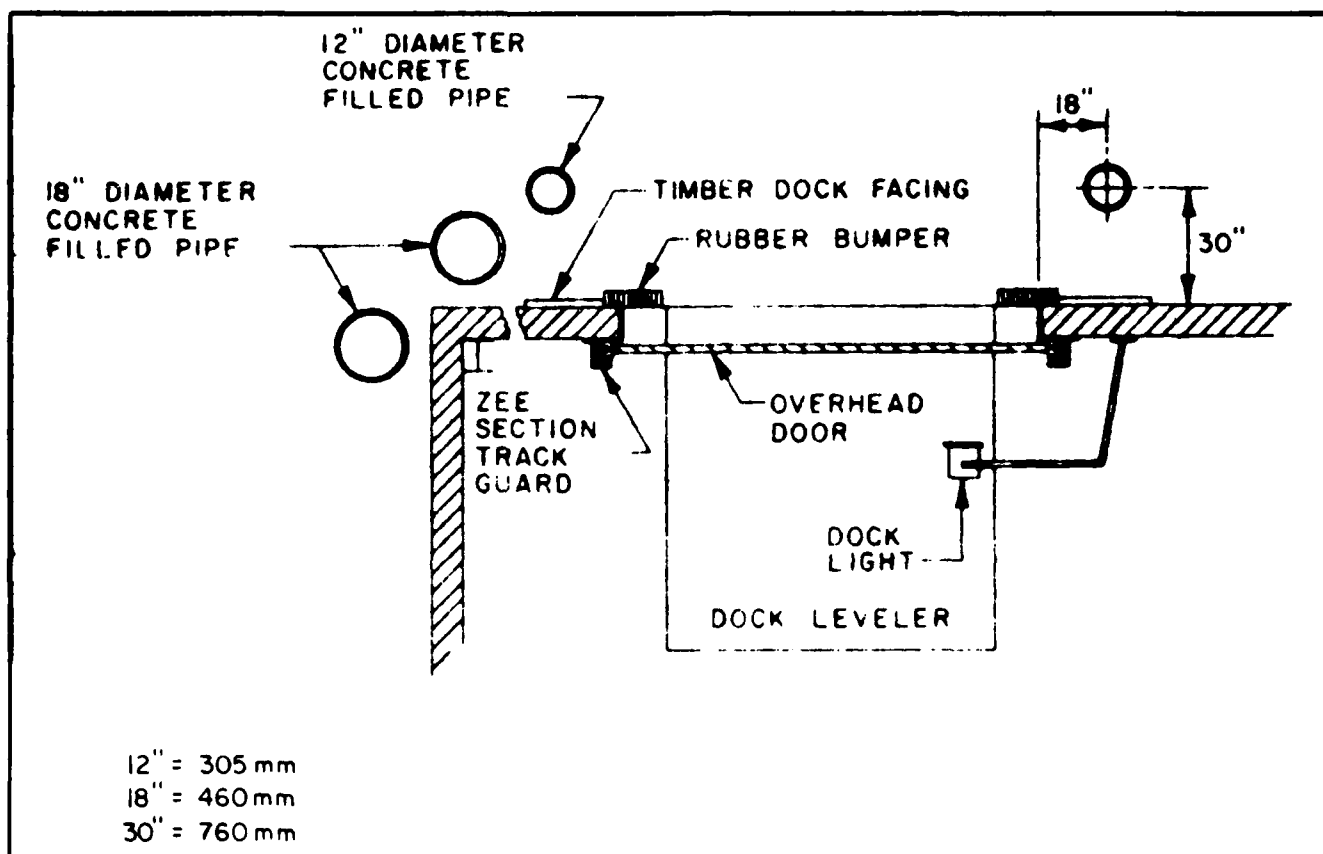


Figure 5
BUILDING
PROTECTION DEVICES

- a. Rail Platforms. Platforms for rail goods shall extend the full length of the building and be 15 feet (4.6 m) wide. Although variable, the height above rails usually will be 3'-10" (1.2 m). The platforms should be equipped with track mounted dock boards.
- b. Truck Docks. Truck dock height will range between 44 and 50 inches (1120 mm and 1270 mm). A 48 inch (1220 mm) height should be used for most large tractor-trailer units. Adjustable dockboards should be used to adjust for variable bed heights and spring deflections. The apron area should slope away from the building as illustrated in Figure 6. Door openings should be equipped with door seals to seal the opening between the truck and warehouse, as illustrated in Figure 7. Exterior truck platforms are not recommended. As an option, a dock adjacent to the ramp of the building may be equipped with a 5-ton (4500 kg) monorail, interrupted at the door with a moveable (swing) section. A 12 x 12 foot (3.6 m x 3.6 m) door should be specified with this option.

Sufficient length shall be provided to load and unload flat bed and lo-boy trucks and move material in and out of the warehouse, including inside movement, by a rolling A-Frame hoist or other suitable material handling equipment. The outside supports shall have protective barriers.

- c. Rail Docks. Provisions for the handling of goods in rail cars should be included in the design of all large storage facilities. There are two types of rail dock in addition to exposed platforms:
 - (1) Outside Docks. Outside rail docks are characterized by through-the-wall access to rail cars without using an outside platform. Inflatable seals should be used to seal the space between the rail car and the warehouse. A wall mounted dock board should be included to provide access to the rail car.
 - (2) Inside Docks. Inside docks are characterized by placing the tracks inside of the building, usually in a pit constructed deep enough to place the car floor at the same level as the warehouse floor. These installations should include track mounted dock boards. Because of the large amount of warehouse storage space occupied by this type of dock, inside docks are not recommended except under extreme circumstances in which sheltering of the car or additional security is required.
- d. Ramp Access. Provide a minimum of one ramp per building with maximum 10 percent slope as follows:
 - (1) One ramp at the end of rail platforms.
 - (2) One ramp at one warehouse truck dock door.

6. CONSTRUCTION. Generally, for economy and availability of components, use conventional structural steel frames with insulated metal siding or siding of protected metal or corrugated aluminum. Alternate systems may be used, including reinforced concrete frame construction with precast or masonry walls. Tubular interior columns should be used. Proper allowance for seismic and wind loads shall be included as required by NAVFAC P-355 and DOD 4270.1-M.

a. Roofing. The following criteria apply:

- (1) Combustible roofing is permitted only in emergency construction.
- (2) Normal roofing shall consist of steel decking, slabs of reinforced concrete, or precast concrete panels with rigid insulation and built-up roofing.
- (3) Gutters and downspouts should be used. Positive measures must be taken to prevent accumulations of mud, snow, or ice in loading areas.

b. Exterior Walls. Exterior walls should be of insulated metal siding, brick or concrete masonry, or tiltup precast concrete panels. The first 4 feet (1.2 m) of wall above the floor should be of reinforced masonry construction to protect the structure from fork truck impact and provide additional security. Walls located on sides designated for future expansion should be removable.

c. Fenestration. Windows shall be provided for office and service structures. A continuous narrow band of high windows may be justified in large warehouses by savings in electric lighting costs. Skylights should be considered to supplement inside lighting.

d. Floors. Warehouse floors should be constructed of reinforced concrete poured on-grade over a suitable vapor barrier. Floor flatness requirements apply to storage areas only. Specific construction requirements should be observed as follows:

- (1) Concrete 28-day compressive strength should be a minimum of 3,000 pounds per square inch (210 kg/sq. cm).
- (2) Minimum crack control reinforcement should consist of number 6 welded wire fabric in a 6 inch by 6 inch (150 mm x 150 mm) mesh.
- (3) The finished surface of storage areas shall be checked for smoothness with a 10 foot (3 m) straightedge. When placed anywhere on the finished floor, in any direction, the plane of the floor surface shall not deviate from the plane of the straightedge by more than 1/8 inch (3 mm) at any location along the straightedge nor shall there be more than 1/8 inch (3 mm) deviation in any 10 foot measurement. The elevation difference between any two points on the floor will not exceed 1/2 inch (13 mm). Consult the equipment manufacturer for recommended tolerances for a specific storage handling equipment system.
- (4) Floor thickness will be determined by a combination of live load, dead load, type of concrete, and subgrade conditions. The nomograph in Figure 8 is based upon information contained in Appendix D of NAVSUP PUB-529 and provides a means for determining the floor load capacity or the required floor thickness for varying conditions of concrete strength and subgrade reaction. For more detailed information on floor and foundation design, NAVFAC DM-7 should be consulted. As a practical minimum, floors in covered storage facilities should be no less than 6 inches (150 mm) thick.

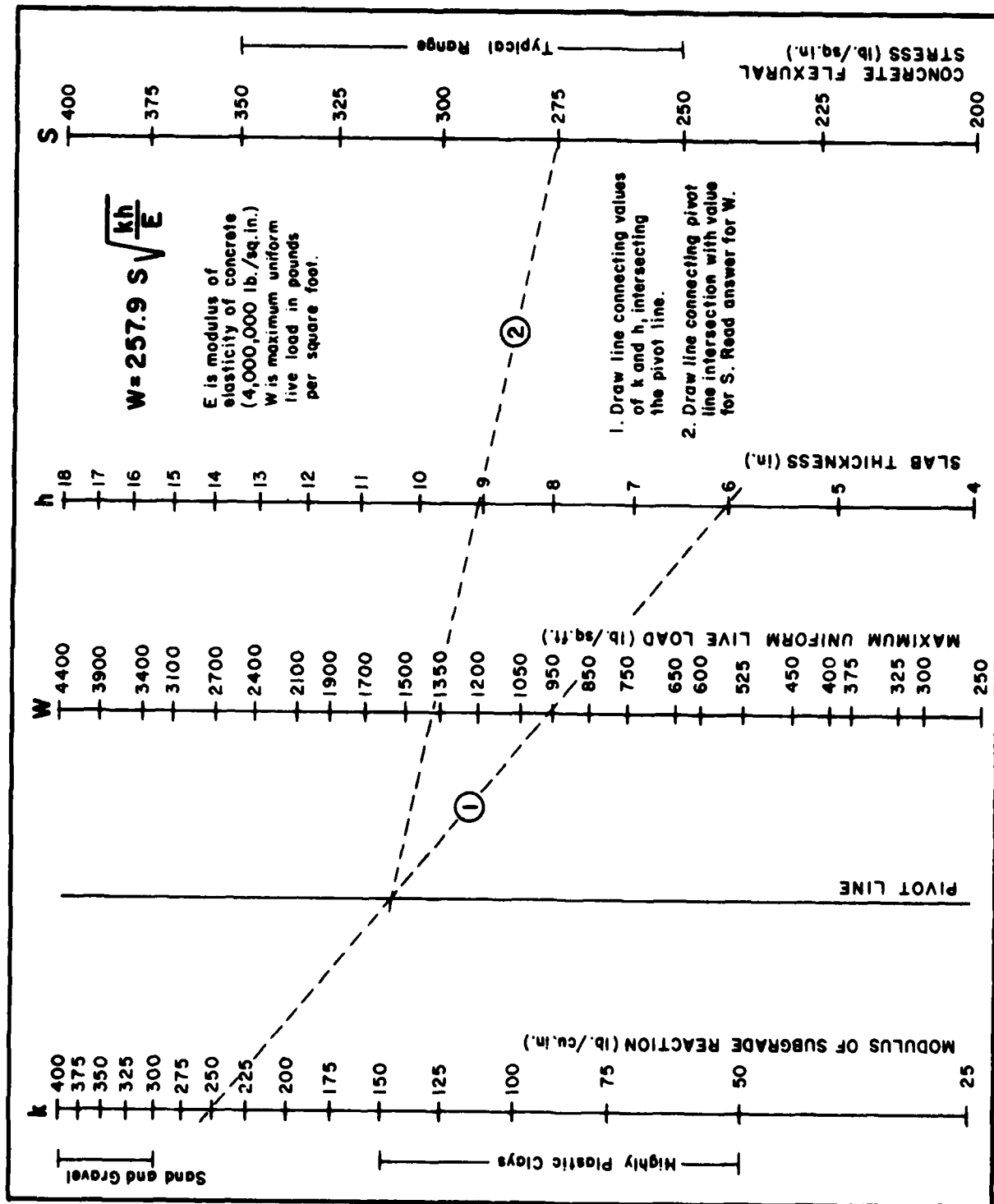


Figure 8
FLOOR LOADING NOMOGRAPH

- (5) Floor hardeners, dressings, and/or toppings may be required in areas of exceptionally high activity such as main aisles, towline paths, or industrial shop areas. Sealers may be desirable to control dust.
 - (6) The location of floor joints, reinforcement steel, and in-floor utilities must be coordinated with the vehicle guidance system and aisle requirements. The floor should be designed for any configuration of racks and shelving if a specific layout is not known or is subject to change.
7. **FIRE SAFETY.** All storage structures shall be designed to comply with the applicable sections of the fire safety codes governing the activity. Rack storage system fire protection shall comply with the requirements of Rack Storage of Materials, National Fire Protection Association (NFPA) 231C.
- a. **Firewalls.** Firewalls should be of brick or concrete masonry of sufficient thickness to develop a 4 hour fire resistance, have independent structural stability, and be continuous to the roof. Warehouse areas shall not normally exceed 40,000 sq. ft. (3716 sq. m) confined by fire walls. When such warehouses are located at depot-type activities, areas confined by fire walls may be increased up to 80,000 sq. ft. (7432 sq. m) if the facility complies with certain requirements. Refer to NAVSUP PUB-529, Section 11. Firewall projection above the roof shall be subject to the following:
 - (1) Where roof decks are made of heavy noncombustible materials such as concrete or gypsum, parapets are not required provided the firewalls fit tightly against the inside of the roof deck.
 - (2) Where roof decks are Factory Mutual approved Class I steel decks, a 1 foot (0.3 m) parapet is required.
 - (3) All other roof decks require a 30" (760 mm) parapet measured from the top surface of the lower roof to the top of the parapet.
 - b. **Doors.** In heater rooms and transformer vaults, doors shall be metal covered or industrial type metal doors or fire doors, as required. Metal overhead doors shall be chain hoist operated, except when frequent use demands motorized operation. Openings in 4 hour rated interior firewalls shall be protected by a fire rated door on each side of the wall. Refer to NAVFAC DM-8 and DOD 4270.1-M.
 - c. **Sprinklers.** All storage facilities shall be protected by suitably designed sprinkler systems. Requirements for in-rack sprinklers and fire pumps shall be investigated. Comply with the requirements of NAVFAC DM-8 and NFPA 231C.
 - d. **Roof Venting.** Provide automatically operating roof vents to allow a venting ratio that is based upon the heat release of the contents in accordance with the Guide for Smoke and Heat Venting, NFPA 204. Recommended venting ratios of vent area to floor area are 1:150 for low heat release; 1:100 for moderate heat release; and 1:30 to 1:50 for high heat release. Use of the roof vents as skylights to reduce electrical lighting requirements should be considered.

- e. Smoke and Draft Curtains. Draft curtains should be included in storage facilities in accordance with NFPA 204. Draft curtains should define areas of 20,000 square feet (1,860 sq. m) or less and should be positioned so as not to interfere with storage operations.
 - f. Fire Alarms. Storage facilities should be equipped with both local and fire department fire alarms which transmit a coded signal to the fire department. Sprinkler systems should be equipped with automatic flow alarms which also transmit a coded signal to the fire department.
 - g. Hose Connections. Hose connections shall be provided at suitable locations to permit coverage of all areas of the warehouse.
8. ENVIRONMENTAL CONTROL. Provide heating and cooling in all offices in all heating zones and in all types of warehouses. Whenever possible, warehouses should be heated from a central source. Individual heating plants are to be used only when a source of steam or hot water is not available or when distribution costs would be prohibitive. For inside design temperatures and insulation requirements, see NAVFAC DM-3.
- a. Heating System. The heating system shall be a steam, hot water, gas fired hot air, or solar system. Locate unit heaters or hot air registers at cargo doors and over aisles between stored material. Direct fired hot air systems shall not be used for flammables warehouses.
 - b. Heating Plant. The heating plant shall be located in a heater room with no access to the storage area. When the heating plant is located inside the warehouse, the following shall be observed:
 - (1) Provide a wall with a 2 hour resistance rating between the heater room and storage area.
 - (2) All access to the heating area shall be from the outside only.
 - c. Air Conditioning. Office areas in cooling zones shall be air conditioned by either high efficiency small area units or a central system as appropriate.
 - d. Humidity Control. Appropriate humidification devices should be considered for office heating systems to permit comfort at lower inside temperatures.
9. ELECTRICAL REQUIREMENTS. Electrical system design and installation shall be in accordance with the requirements of the National Electrical Code, NFPA 70. Electrical requirements are as follows:
- a. Illumination. Provide illumination in accordance with the recommendations in Table 3 and DOD 4270.1-M. The use of skylights should be considered to supplement artificial illumination. Where possible, high efficiency lighting systems should be used instead of conventional incandescent lights. Lighting requirements may be minimized by providing specialized lighting on the materials handling equipment as required by the user. Guidelines for the following areas should be observed:

TABLE 3
LIGHTING STANDARDS FOR FEDERAL SUPPLY
SERVICE DISTRIBUTION FACILITIES

Location	Light Source	General Luminaire Type	Intensity Min.-Max. Foot-Candles (lux)
Bulk Storage (in aisles)	Mercury Vapor	Direct	20 - 30 f.c. (215 - 320) lux
Bulk Storage (stocking areas)	Mercury Vapor	Direct	15 (Min.) f.c. (160) lux
Bin Storage	Fluorescent	Direct	40 - 50 f.c. (430 - 540) lux
Bin Packing	Fluorescent	Direct-Louvered	40 - 50 f.c. (430 - 540) lux
Parcel Post	Fluorescent	Direct-Louvered	40 - 50 f.c. (430 - 540) lux
Shipping	Fluorescent	Direct-Louvered	30 - 40 f.c. (320 - 430) lux
Receiving	Fluorescent	Direct-Louvered	30 - 40 f.c. (320 - 430) lux
Export Packing	Fluorescent	Direct-Louvered	30 - 40 f.c. (320 - 430) lux
Flammable Liquids	Incandescent or Mercury Vapor	Direct ¹	15 - 20 f.c. (160 - 215) lux
Truck Wells	Incandescent or Mercury Vapor	Direct	20 - 25 f.c. (215 - 270) lux
Truck Dock ²	Incandescent or Mercury Vapor	Direct	25 - 30 f.c. (270 - 320) lux
Rail Dock ³	Incandescent or Mercury Vapor	Direct	20 - 25 f.c. (215 - 270) lux
Rail Dock Entrance	Mercury Vapor	Direct	30 - 40 f.c. (320 - 430) lux
Equipment Maintenance	Fluorescent	Direct-Industrial	40 - 50 f.c. (430 - 540) lux
Battery Charging Area	Fluorescent	Direct-Industrial	25 - 30 f.c. (270 - 320) lux
Small Storage Rooms	Fluorescent	Strip-Lights	10 - 15 f.c. (110 - 160) lux
Fire Alarm Stations	Incandescent	Red-100 Watt	---
Exterior Lighting ⁴	Mercury Vapor	---	0.5 - 1.0 f.c. (5 - 10) lux

¹ Fixtures and installation shall be in accordance with the requirements of the National Fire Protection Association and the National Electrical Code for the type of hazardous occupancy involved.

² In addition to general illumination, a "Reel Light" for a 150-Watt lamp should be provided to serve each truck dock for illumination of truck or trailer interior.

³ In addition to general illumination, a "Reel Light" for a 150-Watt lamp should be provided for every 25 feet (8m) of rail dock for illumination of rail car interior.

⁴ Parking lots, maneuvering areas, outside storage, and, where required, fence lighting.

NOTES:

- Emergency lighting systems shall be provided and installed so that the failure of any individual lighting element cannot leave any space in total darkness.
- The foot-candle (lux) levels required are based on generally maintained intensities measured at 30" (0.76m) above the floor in space unoccupied by stock or equipment.
- Other Distribution Facility areas such as offices, laboratories, snack bars, stairways, etc., are covered in the PBS Mechanical and Electrical Engineering Handbook and/or the Illuminating Engineering Society Lighting Handbook.
- All fluorescent ballasts for indoor use shall be high power factor, rapid start, automatic reset, Class P, thermally protected type.
- Exterior lighting shall be controlled by skip-a-day type time switch.

- (1) Storage Areas. Position lighting fixtures directly over the storage aisles.
 - (2) Order Picking Areas. Position lighting fixtures over the order picking aisles or use directional lighting to illuminate the face of the storage structure.
 - (3) Offices. Provide task lighting for those areas requiring light levels greater than those provided for the general office area.
- b. Lighting Fixtures. Provide vapor proof fixtures for shower rooms and explosion proof fixtures with guards for hazardous materials storage areas.
 - c. Receptacles. Locate convenience outlets at least every 10 feet (3 m) of wall space in offices and every 50 feet (15.2 m) in all other areas.
 - d. Battery Chargers. Provide circuits to power battery chargers for battery operated handling equipment.
10. PLUMBING REQUIREMENTS. Provide plumbing fixtures and capacity in accordance with DOD 4270.1-M plus the following:
- a. Cold Water. The probable maximum flow rate for cold water, exclusive of fire protection requirements, will be 55 gallons per minute (3.5 L/s).
 - b. Hot Water. For hot water storage, provide a minimum of 30 gallons (115 L) of capacity. Additional capacity may be required for washdown operations.
 - c. Sprinklers. Water demand will be based on the hydraulic design of the sprinkler system.
11. OTHER REQUIREMENTS. Observe the following special requirements:
- a. Specific Buildings. For functions and particular requirements of specific covered storage buildings, see Table 4.
 - b. Emergency Lighting. Provide a battery powered emergency lighting system to provide exit and storage aisle lighting.
 - c. Clock System. Provide an electric clock in each office.
 - d. Communications. Provide telephones, service entrances, telephone cabinets, conduit runs, and telephone outlets. Locate at least one telephone in each office.
 - e. Battery Chargers. Provide an equipped and well ventilated area for the charging of materials handling vehicle batteries. Refer to NAVFAC DM-28 for information regarding enclosed battery charging areas.
 - f. Safety Markings. Provide safety markings in accordance with the requirements of P-309.
 - g. Safety Regulations. Comply with safety requirements of the Occupational Safety and Health Act (OSHA).

TABLE 4
SPECIAL REQUIREMENTS FOR COVERED STORAGE BUILDING

Building Type	Functions	Special Requirements
General warehouse.	All purpose structure for storing and handling supplies not requiring special considerations.	Fire separation between buildings; 150 ft. (45.7m) minimum; between outer faces of exterior walls on opposite warehouses: 175 ft. (53.3m); from truck dock to any obstruction or buildings: 120 ft. (36.6m)
Heavy materials warehouse.	Storing and handling heavy and bulky supplies incapable of being handled by forklift trucks, but which may be handled more economically by overhead traveling cranes.	Overhead electrical traveling cranes to handle loads too heavy or bulky to be handled by forklift trucks. Elimination of firewalls because of interference with operation of overhead traveling cranes. Railroad service tracks within building. Flooring elevations at same level as top of rail of inside railroad tracks. Doors for truck entry into building and truck entrances at floor level. Ventilation: continuous ridge ventilators in unheated and nonhumidified buildings only. Heating: storage areas are not heated.
Aircraft (aeronautical materials) warehouses.	Storage of spare parts and component assemblies of aircraft.	Truck and rail access. High, clear storage space and large doors. Overhead traveling cranes. Heating required only for personnel comfort. Dehumidification required. Bins or storage shelves.
Flammables - Hazardous materials warehouse.	Storing and handling of hazardous, highly combustible materials.	Floor elevations: 6 in. (150mm) below the floor elevation of outside platforms or provide floor trenches to control drainage. Metal wall scuppers at floor with metal insect screens. Corrosive materials storage areas with external access doors. Ventilation: continuous-ridge ventilators and screened louvers.
Dehumidified warehouses.	Preserving of stores at maximum relative humidity of 40 percent.	Proper equipment for dehumidifying. Additional electrical requirements. Measures to effectively seal openings.
Medical warehouses.	Storage of medical supplies. Two classifications: Small auxiliary facility for hospital or dispensary. Large medical supply warehouse.	Diversified functional elements include: Refrigeration. Dehumidification. Narcotics vaults. Heated spaces. Small facility is located and designed to best fit in local needs and support the parent structure. Large supply warehouse is a large building designed to meet present and foreseeable needs over wide areas for specified periods and situations.
Receiving, shipping, and issue buildings.	Receiving: central point for receipt of shipments. Shipping: central point for outloading. Issue: standard storage buildings arranged for issuing supplies.	Based on the needs for receipt, unpackaging, inspecting, sorting, assembling, storage, repackaging, issue, reshipment, and other necessary handling. Special interior arrangements to carry out its mission and possibly special outloading facilities and techniques. For example, provisions for local issue are met by special interior layouts, such as in packaging and sorting space, assembly space, inspection, bins, counters, enclosures, space for item accounting, and provisions for personnel traffic. Requirements are determined largely by the characteristics of the using agency.
Miscellaneous facilities bins.	Bulk storage bins: storage of large lots of loose, solid materials. Warehouse bins: provide additional storage space in warehouse buildings.	Varying, depending on the needs of the installation and materials to be contained. Materials, shape, and size determined by local needs. Arrange in double rows, back to back, and at right angles to main aisles; single rows may be arranged against walls. Passageways between open faces of bins should be a minimum of 36 in. (915mm) wide. Metal units: Width: 36 in. (915mm) Height: 8 ft. 3 in. (2.51m) Depth: 18 in. (460mm)
Boxing and crating buildings.	Boxing and crating material.	One portion of building outfitted for necessary industrial operations; another portion, for processing depot supplies; and the remainder devoted to storage of manufacturing stocks and assembled items.
Preservation buildings.	Special operations for preserving supplies.	Special equipment and facilities for preserving supplies before being placed in storage.
Cold storage.	Preserving stores in a controlled climate ranging from below zero to 40°-50°F (4°-10°C).	Proper equipment for cooling. Additional electrical requirements. Measures to effectively seal openings. Additional insulation requirements. Maximum utilization for storage space.

- h. Door Clearance. Provide openings of sufficient height and width to permit passage of materials handling equipment.
- i. Security System. Provide stored materials with security measures including vaults and alarm systems.

Section 4. CONTROLLED HUMIDITY WAREHOUSING

1. DEHUMIDIFICATION. Warehouses designed for dehumidified storage shall be vapor sealed to prevent entrance of moisture from points of higher vapor pressure. Refer to NAVFAC DM-3.3 for additional design criteria.
2. NEW CONSTRUCTION. For new construction, the following sealing methods and materials should be used:
 - a. Floors. Vapor barriers having a permeance characteristic of one perm or less, laid on a porous fill and finished to a smooth surface, shall be provided beneath concrete slabs laid on grade.
 - b. Walls. Insulation shall not be provided for walls. Two coats of cement water paint should be applied on exterior exposed surfaces of concrete masonry unit walls. Sprayed on cement mortar coating (about 1/8 inch (3 mm) in total thickness) may be an alternative method.
 - (1) Joints. All joints in precast concrete construction shall be sealed and caulked and made as airtight as practicable.
 - (2) Sides and End Laps. All sides and end laps of metal or similar type walls shall be sealed with bituminous mastic as erected.
 - (3) Firewall. If only certain areas are to be dehumidified, the firewall (including fire doors) between the dehumidified and general storage areas shall be made airtight.
 - (4) Junctions. Exterior junctions between walls and roofs shall be made as airtight as practicable.
 - c. Roofs. Special vapor barriers shall be omitted. All sides and end laps in steel or similar roof decking shall be coated with bituminous mastic as laid. Scuttles shall be gasketed and fitted with inside and outside locks.
 - d. Doors. Active cargo doors shall be gasketed by means of extruded, nonferrous weatherstrips housing sponge rubber seals. One door to each exterior side wall of each compartment shall be motor operated. The other doors shall be chain hoist operated, from the inside only, with provision for future motor operation. Active cargo doors at end walls shall be similarly gasketed and chain hoist operated.
 - (1) Personnel Doors. Provide two 3 foot by 6 foot, 8 inch (1 m x 2 m) personnel doors, hinged and gasketed, located near motor operated doors.
 - (2) Fire Doors. Fire doors between dehumidified and nondehumidified areas shall be gasketed and made as airtight as practicable.

3. CARBON MONOXIDE CONTROL. Dehumidified warehouses are sealed against moist air infiltration and moisture transmission. Artificial ventilation must be supplied if gasoline driven materials handling apparatus will be operated in a dehumidified warehouse and the average concentration of carbon monoxide in the space will exceed 100 parts per 1,000,000 parts of air. Dehumidified facilities with gasoline powered equipment must be provided with portable carbon monoxide detection equipment to periodically check for carbon monoxide concentrations. Ventilation is obtained by opening operable material transfer doors. A 20-ampere electric power outlet receptacle shall be provided at each operable transfer door to operate a portable circulating fan when natural ventilation is inadequate. Use of electric vehicles is recommended where practicable.
4. CONVERSION OF EXISTING STRUCTURES TO DEHUMIDIFIED STORAGE. Generally, requirements for new construction shall be applicable for walls and roofs. To convert structures, accomplish the following:
 - a. Ventilators. Remove roof ventilators and roof over the openings.
 - b. Openings. Seal all louvered openings and windows in walls.
 - c. Excess Doors. Deactivate and seal excess cargo doors.
 - d. New Doors. Ensure that all new doors (required to replace existing doors) conform to the new construction requirements mentioned above.
 - e. Active Doors. Existing cargo doors that are to remain active shall be gasketed and shall otherwise conform to requirements for new construction. Provide sliding doors with suitable cam action hangars to allow them to be drawn up tight against gaskets when closed.

Section 5. FLAMMABLES-HAZARDOUS MATERIALS WAREHOUSE

1. CONSTRUCTION. Construction requirements for flammables-hazardous materials warehouses should be in accordance with the provisions of the Flammable Liquids Code, NFPA 30, Section 1910.106(d) of the OSHA Standards, and NAVFAC DM-8.
 - a. Structural Elements. Structural elements shall be noncombustible.
 - b. Firewalls. Firewalls with a 4 hour rating shall be provided to limit fire areas to a maximum of 20,000 square feet (1800 sq. m) and to separate acid/corrosive materials storage areas from the remainder of the structure.
 - c. Doors. Fire doors shall be of the rolling steel type and, where practicable, should be eliminated in firewalls. Metal doors shall be provided for personnel use.
 - d. Ventilation and Explosion Relief. Wall mounted explosion relief panels must be provided. Their weight should be less than 1.5 pounds per square foot (7.3 kg/sq. m). Acid/corrosive materials storage areas must have their own explosion relief system. Provide a ventilation ratio of effective vent area to floor area of at least 1 to 30 using roof vents or other suitable means.

e. Sprinklers. Sprinkler systems must comply with the requirements of NFPA 30 and NFPA 231C.

- (1) Drainage. Suitable means of providing drainage in the event of sprinkler activation must be provided.
 - (a) Floor Elevation. The interior storage floor surface shall be 6 inches (150 mm) below the surface level of adjoining dock, office, and support areas to prevent the flow of burning liquids into these areas. Vehicle access ramps shall be provided at all doorways into such areas. Floor drain trenches at doorways and in aisles as described below may be used in lieu of floor elevation changes.
 - (b) Scuppers. Wall mounted scuppers with rodent barriers shall be installed along outside walls to provide drainage for sprinkler discharge. Discharge through the wall scuppers shall be collected and channeled into a suitable containment system. The containment system must have a separate section for material in classification codes 3, 4, 5, 6, 7 and 8 of table 4.
 - (c) Floor Drains. Floor trenches, covered with steel grating in the storage aisles, should be considered for the capture and control of the sprinkler and burning liquid flows. Solid cover plates should be used in main traffic cross aisles. Such drains can be designed to collect the discharge, channel it away from the building, and extinguish the collected liquid in a specially designed tank. The use of such drains shall be required if floor elevation changes are not used for control of liquid flow. The location of floor drains must be coordinated with the location requirements of the vehicle wheel tracks and guide wire. A sloped floor may be used to facilitate drainage provided that floor flatness requirements are met and that the slope of the floor is a plane sloping in one direction only. Drains must lead to the same separate sections of the containment system as prescribed for scuppers.
 - (d) Pallet Rack. Pallet rack and any associated mechanical vehicle guidance systems shall be installed in such a manner as to permit the unimpeded flow of liquids to the collecting scuppers or trenches.
- (2) Design. The design of sprinkler systems shall comply with the requirements of Sprinkler Systems, NFPA 13 and NAVFAC DM-8.
- (3) Plumbing. Sufficient water flow capacity for fire fighting requirements must be provided. Acid/corrosive materials storage rooms shall be equipped with an emergency shower and eye wash.

2. SEGREGATION OF MATERIALS. Materials having different hazardous characteristics shall be provided separate storage according to the General Segregation Requirements for Hazardous Materials listed in Table 5.

Section 6. COLD STORAGE WAREHOUSE

1. CONSTRUCTION. Observe the following requirements:

TABLE 5

GENERAL SEGREGATION REQUIREMENTS FOR HAZARDOUS MATERIALS*

Material Category	Classification Code	2(A)	2(B)	3	4(A)	4(B)	4(C)	5(A)	5(B)	6(A)	6(B)	7	8	9
Flammable Compressed Gases **	2(A)	-	0	2	1	2	1	2	4	0	0	2	1	0
Nonflammable Compressed Gases **	2(B)	0	-	2	0	1	0	0	2	0	0	1	0	0
Flammable or Combustible Liquids	3	2	2	-	2	2	2	2	3	2	0	2	1	0
Flammable Solids	4(A)	1	0	2	-	1	1	1	2	0	0	2	1	0
Flammable Solids Labeled Spontaneously Combustible	4(B)	2	1	2	1	-	1	2	2	1	0	2	1	0
Flammable Solids Labeled Dangerous When Wet	4(C)	1	0	2	1	1	-	2	2	0	0	2	1	0
Oxidizers **	5(A)	2	0	2	1	2	2	-	2	0	1	1	2	0
Organic Peroxides	5(B)	4	2	3	2	2	2	2	-	2	1	2	2	0
Class A Poisons	6(A)	0	0	2	0	1	0	0	2	-	0	1	0	0
Class B Poisons or Irritating Materials	6(B)	0	0	0	0	0	0	1	1	0	-	0	0	0
Radioactive Materials	7	2	1	2	2	2	2	1	2	1	0	-	2	0
Corrosive Materials	8	1	0	1	1	1	1	2	2	0	0	2	-	0
Other Regulated (ORM) Materials	9	0	0	0	0	0	0	0	0	0	0	0	0	-

Segregation Code

(Segregation requirements may be accomplished by steel lockers)

- 0. No segregation requirement
- 1. Away from (Horizontal separation at least 10 feet, projected vertically)
- 2. Separated from (Separate storage room)
- 3. Separated by a complete storage room from (in all directions)
- 4. Separated laterally by a complete storage room from

*Adapted from 49CFR 176.83, Table 11

**Flammable and nonflammable compressed gases and gases classified as oxidizers shall be stored in sheds.

- a. DOD Requirements. Refer to DOD 4270.1-M for building heat gain maximums, equipment, and vapor barriers.
- b. Construction Details. See Appendix A for illustrations of typical construction and insulation methods.
- c. Fenestration. Fenestration is not allowed in storage areas. Offices, equipment rooms, toilet and locker areas should utilize security type windows with wire glass.
- d. Floors. Floors of different rooms may have different insulation thicknesses, but all finished floors should be at one level to avoid the use of steps or ramps. Differences in insulation thicknesses should be adjusted by the level of the rough floor slabs. Floors should be provided with drains to permit periodic washdown and cleaning operations. A sloped floor may be used to facilitate drainage provided that floor flatness requirements are met and that the slope of the floor is a plane sloping in one direction only.
- e. Insulation. All refrigerated structures and the low temperature piping and mechanical equipment shall be insulated. Refer to NAVFAC DM-3.4 for criteria on insulation.
- f. Exterior Finish. Provision should be made in design for movement of the building structure including both expansion and contraction. The outer surface should be designed to effectively withstand prevalent conditions of weather, wind load, and corrosive environment. The exterior finish should also be fire resistant, water proof, and prevent the entry of vermin. When the exterior surface is used as the vapor barrier, design details should include pertinent recommendations listed under Vapor Barrier System below.
- g. Vapor Barrier System. Every installation shall be protected by a vapor barrier system. Observe the following requirements:
 - (1) Location. Place vapor barriers on the warm side of the insulation. Conditions of reverse vapor flow should be accounted for.
 - (2) Properties. All vapor barrier systems should be capable of withstanding expansion and contraction in any direction without developing heat, air, or vapor leaks. The following properties should be investigated:
 - (a) Permeance. Permeance should be no more than 0.1 perm.
 - (b) Life. Vapor barrier systems should have a minimum life expectancy of 25 years.
- h. Interior Finish. Interior finishes should be utilized and may be mounted apart from the insulation. The following characteristics should be considered:
 - (1) Ability to Pass Water Vapor. Interior finishes should have a permeance significantly greater than that of the vapor barrier system.

- (2) **Sanitary Characteristics.** No interior finish should be used that may cause contamination of stored products. Interior surfaces should meet existing health and sanitary regulations.
- (3) **Appearance.** The appearance of the interior finish should be considered secondary to its meeting of functional requirements.
- (4) **Mechanical Protection for Insulation.** The interior finish should provide protection for the insulation; otherwise, an auxiliary means of protection must be provided. The following factors should be considered:
 - (a) **Chemical Compatibility.** The interior should be chemically compatible with the surface to which it is applied.
 - (b) **Fire Retardance.** The interior finish should have a flame spread rating of 75.0 or less and a smoke developed rating of 100 or less. Comply with the requirements of NAVFAC DM-8 and DOD 4270.1-M.
 - (c) **Protection from Direct Water Entry.** The interior finish should provide protection from the direct entry of water during washing and cleaning operations.
 - (d) **Freedom from Rot, Corrosion, and Odor.** Interior finishes should not absorb from or impart to the stored product any odors. The material should not be susceptible to decay caused by corrosion or rotting.
 - (e) **Repairability.** Interior finishes should be repairable at the operating temperature of the refrigerated room or structure.
- i. **Sealants, Fasteners, and Adhesives.** Fasteners and adhesives used for installing insulation should not impair the integrity of the vapor barrier system. Metal skewers should not be used as fasteners. Adhesive and sealants should not be used in multi-layer construction in a manner that will create restrictive vapor dams which may cause internal condensation and possible frost formation. Fasteners and adhesives should be applied only to reasonably smooth surfaces.
- j. **Built-up Roofing Over Deck Insulation.** The extreme conditions under which a built-up roofing system must operate when over a cold storage facility increases the possibility of failure. The installation of built-up roofing over cold storage areas should be incorporated as part of the cold room insulation work to permit a more forceful coordination and inspection of the roofing that is applied over the insulation.
- k. **Doors.** Door heaters shall be included when needed to prevent frost and moisture accumulation on door gaskets. Re-circulating air curtains on both sides of all doors between areas of differing temperature should also be considered.
- l. **Refrigeration Systems.** Refer to NAVFAC DM-3.4 for guidance on the selection of refrigeration systems for cold storage warehouses.

2. **SPRINKLERS.** A dry pipe sprinkler system or dry pendant sprinkler heads should be provided for refrigerated spaces. Wet pipe systems should be provided in other areas in accordance with NAVFAC DM-8.
3. **ELECTRICAL REQUIREMENTS.** Requirements for electrical systems are as follows:
 - a. Lighting Fixtures. Provide vapor proof fixtures with guards for all refrigerated spaces. Consider the use of high pressure sodium (HPS) lighting for bay areas. Consider the use of mineral insulated type cable in refrigerated spaces.
 - b. Illumination Levels. Provide lighting level of 10 footcandles (107.6 lx) 4 feet (1.2 m) above the floor, for refrigerated spaces with additional lighting on the materials handling vehicle. Provide levels of illumination as indicated in DOD 4270.1-M for all other areas.
 - c. Other Equipment. Provide electrical service for the following equipment:
 - (1) Power operated doors.
 - (2) Refrigeration compressors.
 - (3) Material handling equipment battery chargers.
 - (4) High temperature alarm for refrigerated areas.
4. **INSPECTION AREA.** For large activities, provide a veterinary inspection area with fork truck access to permit inspection of incoming goods. For activities with resident veterinarians, inspection facilities (lab and office) shall be provided in accordance with Defense Personnel Subsistence Center (DPSC) requirements.
5. **STORAGE REQUIREMENTS.** The required number of pallets for any building depends on the number of personnel and the number of days of storage to be served by the building (see Table 6). To conserve space and use the maximum storage height, pallet racks and narrow aisle fork trucks should be used. If floor stacking of pallets is used, the following parameters should be followed:
 - a. Storage Height. Pallets should be stored four high (16 feet, 0 inches or 4.9 m).
 - b. Spacing of Pallets. The minimum spacing between walls and pallets shall be 6 inches (150 mm) and the minimum spacing between pallets shall be 4 inches (100 mm).
 - c. Maximum Aisle Width. Aisle width between pallets shall be 8 feet (2.4 m) maximum. Narrow aisle fork lift trucks shall be used to provide the minimum possible aisle width.

Section 7. HEAVY MATERIALS WAREHOUSE

- . **CONSTRUCTION.** Observe the following requirements:

TABLE 6

PALLET STORAGE QUANTITIES FOR COLD STORAGE WAREHOUSES

(Requirements for Refrigerated Subsistence to Support 1,000 Men)*

Storage Location	Pallet Requirements				
	Daily Receipts of Bread/Milk**			Monthly Receipts of Bread/Milk**	
	Days of Supply		Percent of Total	Days of Supply	Percent of Total
	10	30		30	
Freeze -5°F	9	27	34.6	51	50
Chill +35°F (Cured meats/dairy)	7	21	26.9	21	20.6
Chill +35°F (Other)	4	12	15.4	12	11.8
Chill +50°F	6	18	23.1	18	17.6
TOTAL	26	78**	100	102**	100

*Data excludes refrigerated requirements for storage of film, batteries, medical supplies and other non-subsistence items.

**Pallet quantities and percentages are for use in the absence of other data based on experience. Assume that each pallet load of subsistence averages approximately one measurement ton (M/T) or 40 cubic feet. On the basis of this assumption, note that by multiplying 78 pallets and 102 pallets required for a 30-day supply by 40 cubic feet gives totals of 3,120 and 4,080 cubic feet, respectively, required to support 1,000 men for 30 days. This reconciles favorably with allowances of 3 and 4 cubic feet per man per month contained in the NAVFAC P-80 for Category Code 431-10, Refrigerated Warehouse.

- a. Fenestration. Windows shall be provided for office and service structures. A narrow row of windows along the top of exterior walls should be considered to supplement electric illumination.
 - b. Floors. Floors should be designed for the expected load conditions. Minimum thickness should be 6 inches (150 mm), reinforced for crack control. Special toppings or hardening compounds may be necessary for areas subjected to extreme loading or traffic conditions or requiring the use of air film transporters. Additional floor thickness may be required for areas subject to heavy loading.
 - c. Craneways. Craneways should be designed for the intended load capacity and type equipment to be used. The location of craneways should avoid interference with areas of personnel activity or the building structure. Adequate clearance between adjacent cranes or between the crane and the building structure must be provided.
2. SITE PLANNING. The location of a heavy materials warehouse will be determined by the source of materials, the destination of materials, associated shop operations, and internal shop operations required to rough size material before being sent to its destination. The following should be considered:
- a. Rail Access. Receipt and shipment of many items will require movement by rail. The building location will be affected by the ability to provide rail access from nearby tracks. The possibility of running a track through the building should be considered. The inside track should be at floor level and equipped with crossing plates to provide a continuous, smooth crossing over the entire length of the track. A rail pit, placing the car floor at the building floor level, is not recommended since such a pit will divide the warehouse and prevent efficient use of the facility.
 - b. Truck Access. Appropriate dock and apron space should be provided for truck access to the building. A combination of floor level drive-in doors and docks with dock levelers should be provided to handle any combination of vehicles. The drive-in doors should accommodate flatbed and semi-trailers and be located to permit overhead crane loading and unloading.
 - c. Expansion. The building should be situated so as to provide for expansion in proportion to the requirements expected of the associated operations to be supported by the heavy materials warehouse. Provisions should be made for the expansion of the building width and/or length to accommodate growth.

Section 8. MODERNIZATION OF EXISTING WAREHOUSE BUILDINGS

1. PURPOSE. It is the intent to bring the existing semi-permanent and permanent warehouse buildings to a level comparable with current standards for new construction, in accordance with criteria in the appropriate design manuals. Buildings selected for modernization should be architecturally acceptable and structurally sound. Existing low-rise buildings can be used for support functions and be located adjacent to new high-rise facilities.

2. ARCHITECTURAL REQUIREMENTS. General architectural requirements include the following:
 - a. Floors. In administration offices where the present floor surface is concrete, install resilient floor tile with appropriate base. If the present floor is wood, tile, or linoleum, provide new tile only if the existing floor is excessively worn and unattractive. Concrete floors in storage areas shall be repaired if the surface is in poor condition.
 - b. Painting. The painting of some spaces may be in an unacceptable state or of colors contrary to those prescribed by criteria, according to use or occupancy. The painting of such spaces should be renewed. Refer to NAVFAC DM-1 and P-309.
3. STRUCTURAL REQUIREMENTS. When it is determined that the structural system will not meet the design loads, those members which are considered inadequate should be strengthened, modified, and/or replaced.
 - a. Structural Systems. Structural systems should be inspected and, where deficiencies are noted, the following should be performed:
 - (1) Steel Members. Clean off any corrosion and apply rust-resistant paint.
 - (2) Concrete Members. Fill cracks with suitable fillers; patch any spalling areas.
 - (3) Wood Members. Tighten all bolts, screws, and other fastenings; where necessary, impregnate timber with anti-mildew and/or anti-termite solutions.
 - b. Modifications. Where modifications are made to improve functional operations, the structural system may be modified, providing that the new loading distribution created by such modifications does not overload existing members.
4. ELECTRICAL REQUIREMENTS. For electrical requirements, refer to NAVFAC DM-4. All undisturbed wiring and equipment judged to be in safe, operable condition should be reused.
5. MECHANICAL REQUIREMENTS. For mechanical requirements, refer to NAVFAC DM-3. Reuse acceptable fixtures and equipment.
6. FIRE PROTECTION. For fire protection requirements, refer to NAVFAC DM-8.

REFERENCES

(Publications containing criteria cited in this manual)

ASHRAE Guide, American Society of Heating, Refrigeration, and Air Conditioning Engineers, Inc., 345 East 47th Street, New York, NY 10017.
ASHRAE Guide and Data Book (latest edition).

DOD 4270.1-M, Department of Defense Construction Criteria Manual,
Department of Defense, the Pentagon, Washington, DC 20301.

DOD 4145.19-R-1, Department of Defense Storage and Materials Handling Manual,
Department of Defense, The Pentagon, Washington, DC 20301.

NFPA, National Fire Protection Association, Batterymarch Park, Quincy, MA 02269.

- NFPA Standard No. 13 - Sprinkler Systems
- NFPA Standard No. 30 - Flammable Liquids Code
- NFPA Standard No. 70 - National Electrical Code
- NFPA Standard No. 204 - Smoke and Heating Venting
- NFPA Standard No. 231C - Rack Storage of Materials

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- DM-1 - Architecture
- DM-2 Series - Structural Engineering
- DM-3 - Mechanical Engineering
- DM-3.3 - Heating, Ventilating, Air Conditioning, and Dehumidifying Systems
- DM-4 Series - Electrical Engineering
- DM-5.4 - Pavements
- DM-5.5 - General Provisions and Geometric Design for Roads, Streets, Walks, and Open Storage Area
- DM-5.6 - Trackage
- DM-7 - Soil Mechanics, Foundations, and Earth Structures
- DM-8 - Fire Protection Engineering
- DM-25 - Waterfront Operations Facilities
- DM-28 - Maintenance Facilities
- DM-33 - Hospital and Medical Facilities
- DM-35 - Family Housing
- DM-36 - Troop Housing

- DM-38 - Weight Handling Equipment and Service Craft
- P-80 - Facility Planning Factors for Naval Shore Facilities
- P-309 - Color for Naval Shore Facilities
- P-355 - Seismic Design for Buildings
- P-442 - Economic Analysis Handbook

Military/Federal, and NAVFAC Guide Specifications are available to all parties, free of charge, from the U.S. Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, PA 19120. AUTOVON: 442-3321; Commercial: (215) 698-3321.

NAVSUP Publications.

Publications may be obtained from the U.S. Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, PA 19120.

- NAVSUPINST 4450.21 Series - Storage and Warehousing Facilities and Services
- NAVSUP PUB-502 - Preservation and Packing
- NAVSUP PUB-503 - Packing
- NAVSUP PUB-529 - Warehouse Modernization and Layout Planning Guide
- OPNAVINST 5510.45 - U.S. Navy Physical Security Manual

Occupational Safety and Health Standards, (OSHA), Department of Labor, Bureau of Labor Standards, Wage and Labor Standards Association, Washington, D.C. 20210.

Time Saver Standards, F. W. Dodge Corporation, New York, NY 10018.

Appendix A

ILLUSTRATIONS OF TYPICAL COLD STORAGE CONSTRUCTION AND INSULATION

The Figures contained in Appendix A illustrate typical methods and means for the construction and insulation of cold storage facilities. These illustrations should be used in conjunction with the comments in Section 6 of NAVFAC DM-32.2 regarding cold storage facility criteria as well as the Definitive Drawings in NAVFAC P-272 illustrating typical facility configurations.

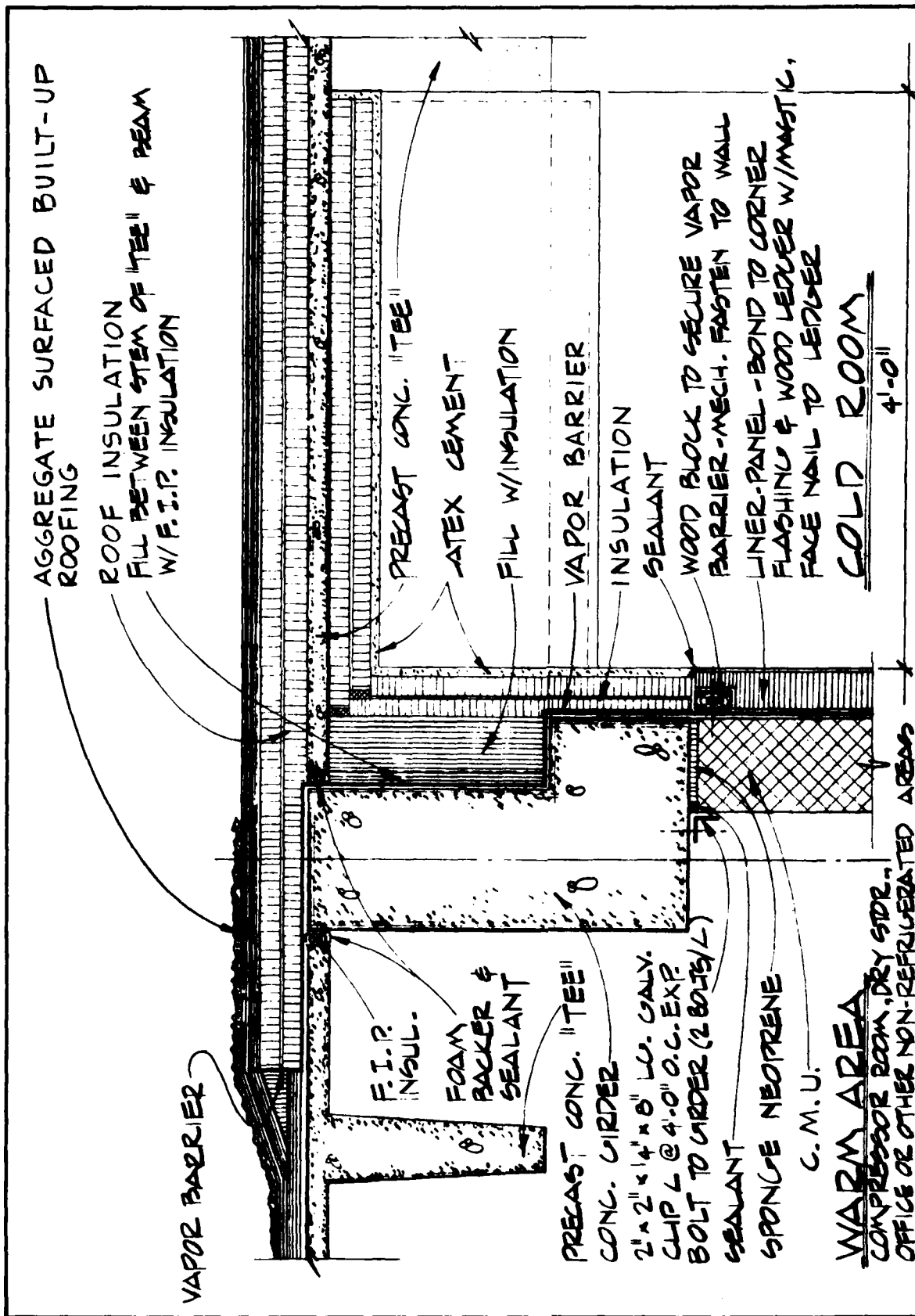


Figure 9

COLD ROOM INSULATION DETAIL 1

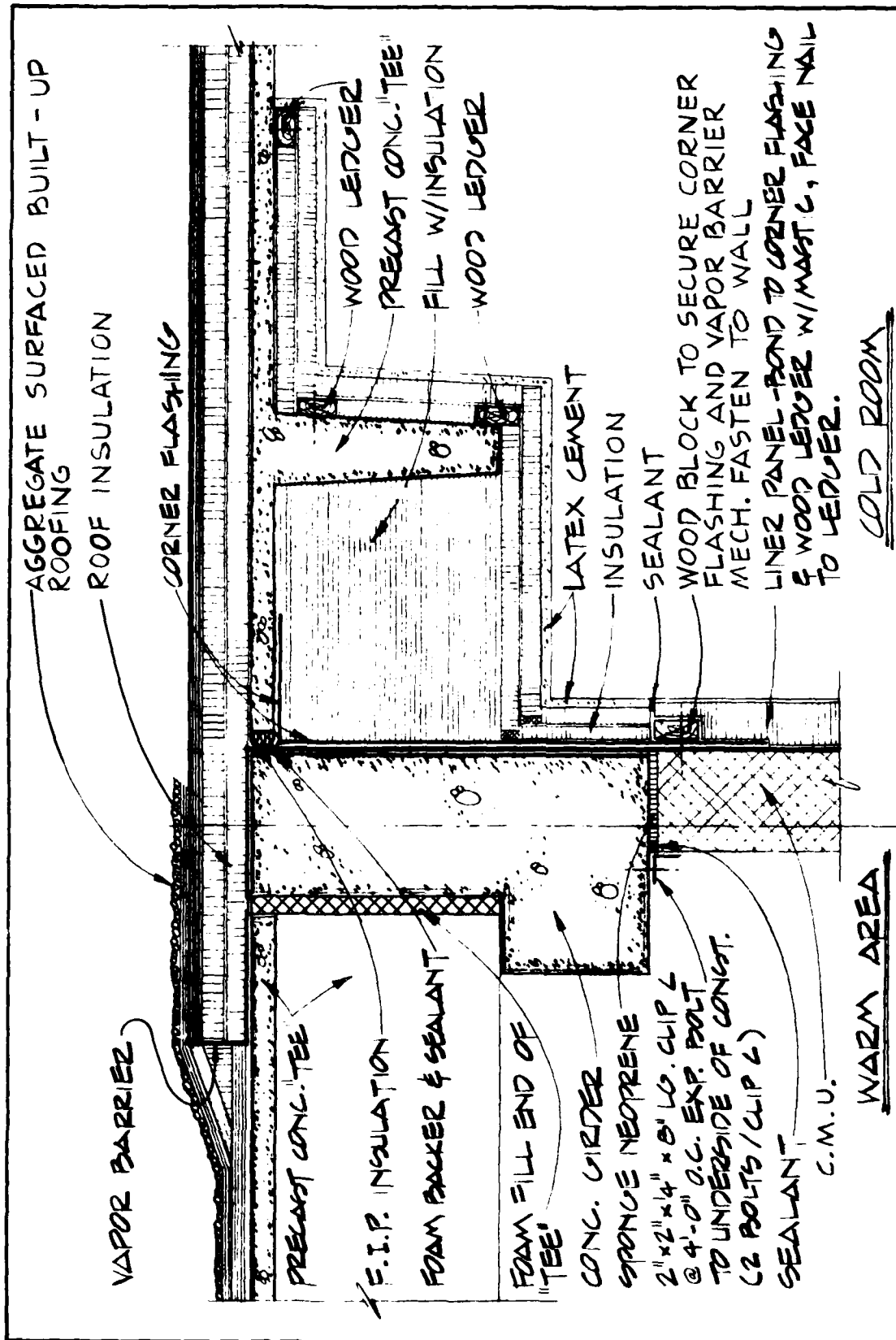


Figure 10

COLD ROOM INSULATION DETAIL 2

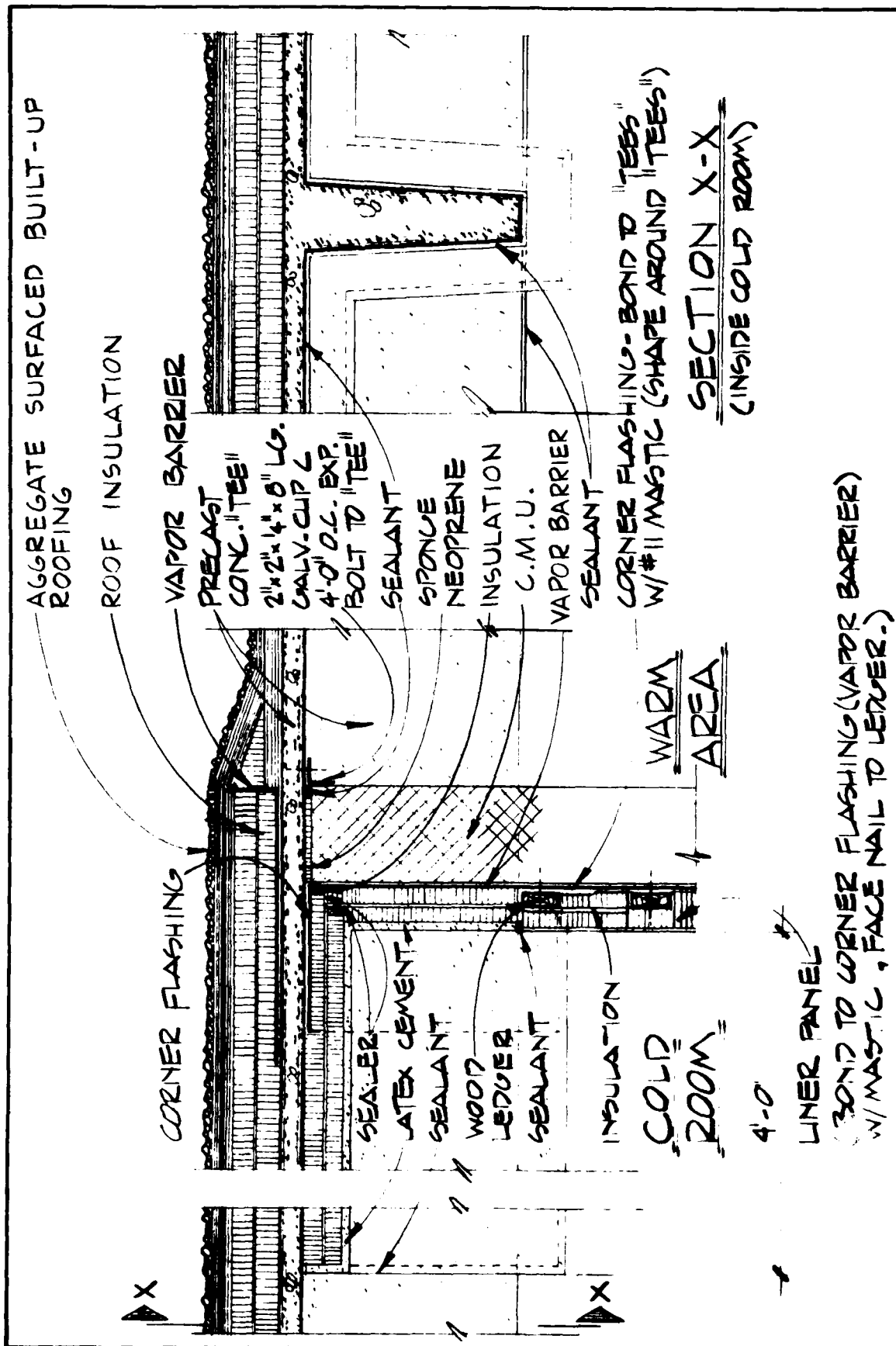


Figure 11

COLD ROOM INSULATION DETAIL 3

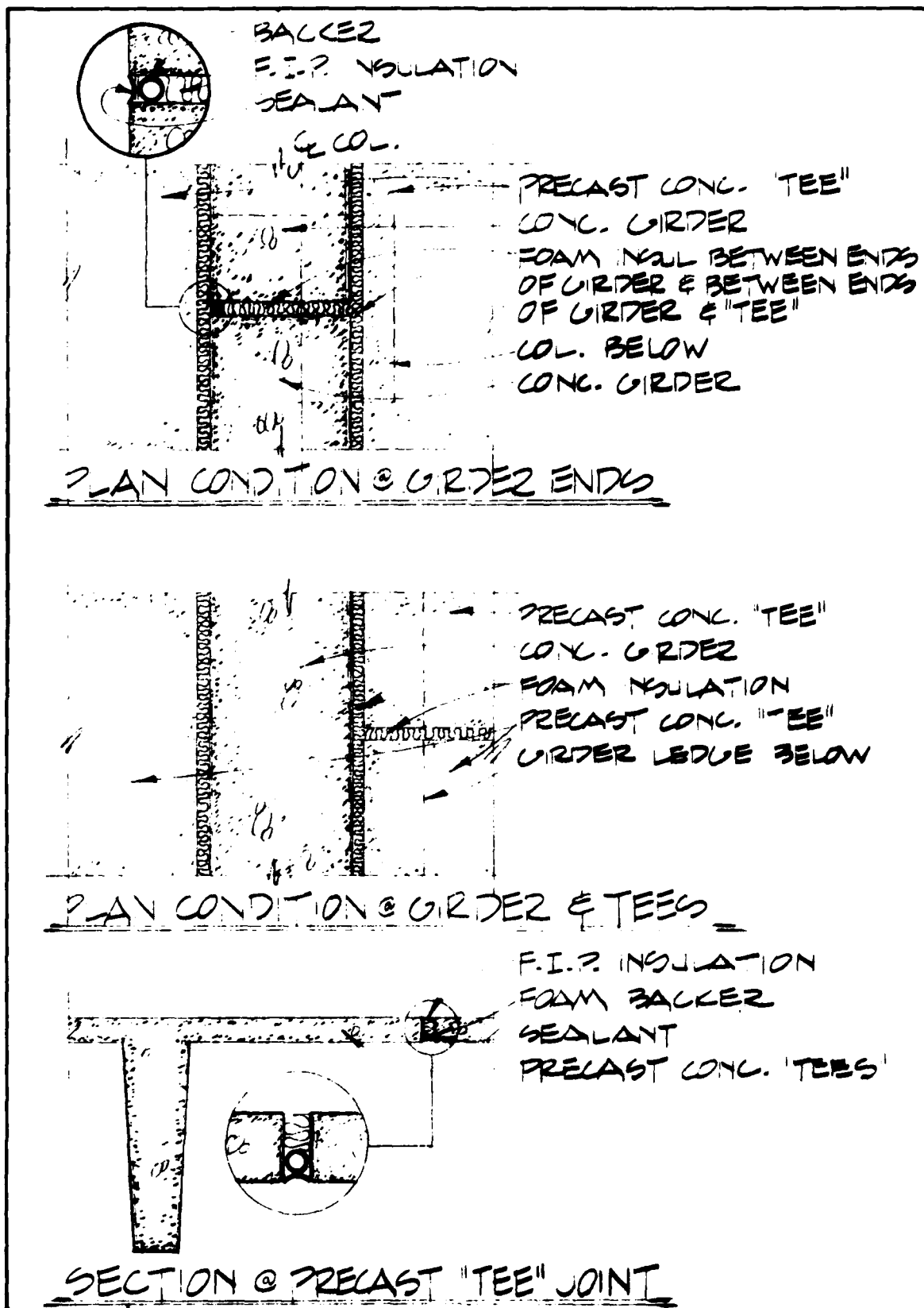


Figure 12

COLD ROOM INSULATION DETAIL 4

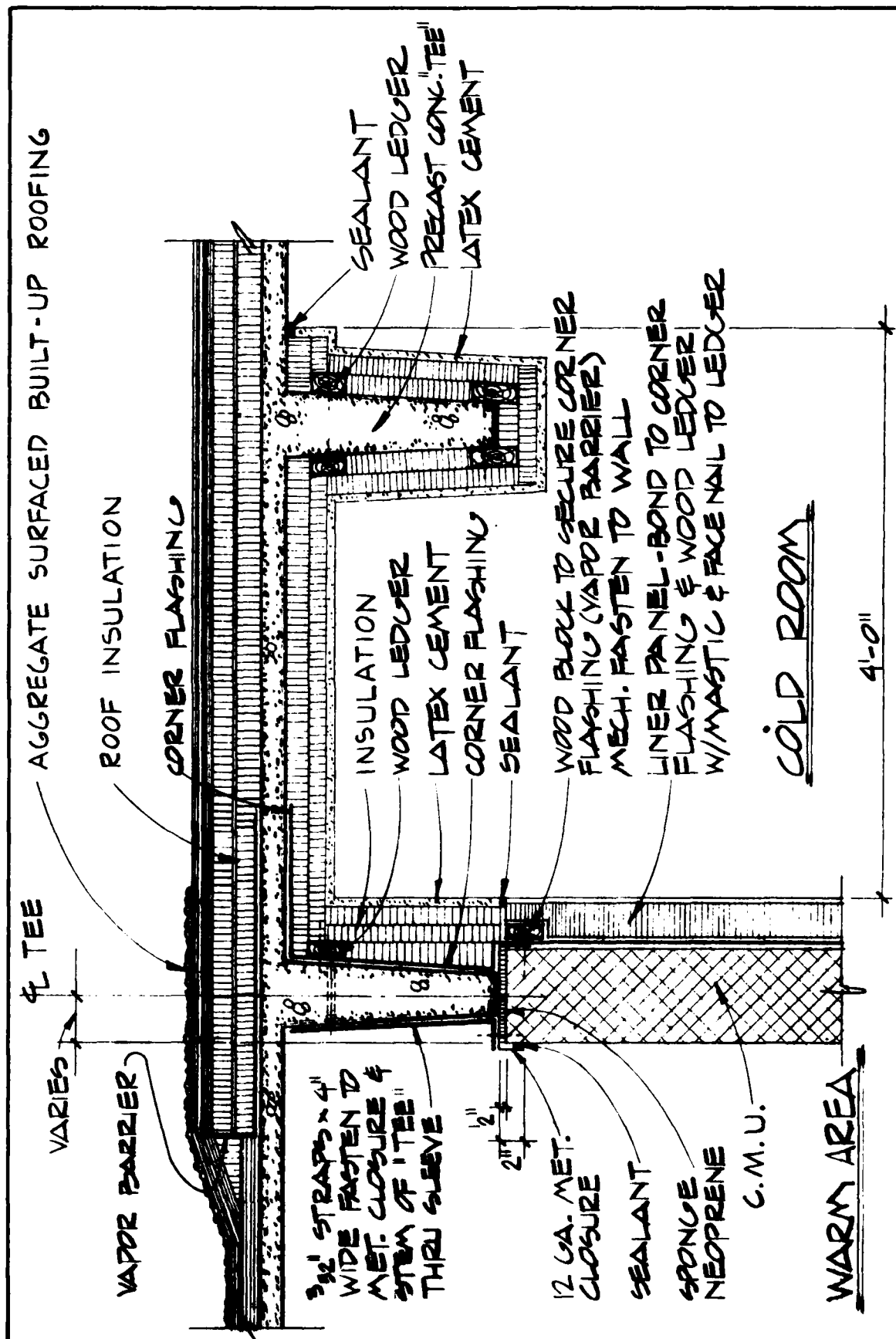


Figure 13

COLD ROOM INSULATION DETAIL 5

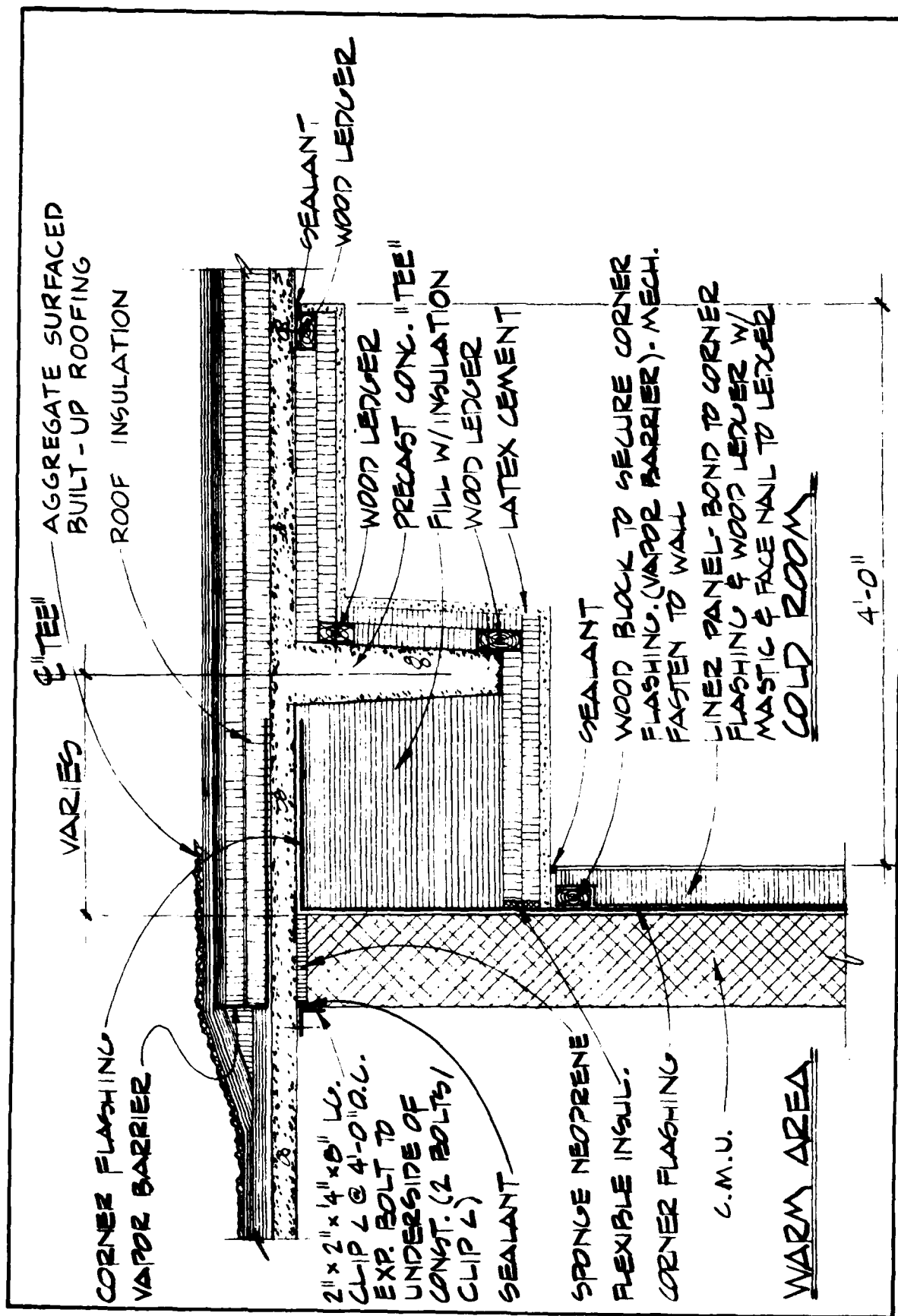


Figure 14

COLD ROOM INSULATION DETAIL 6

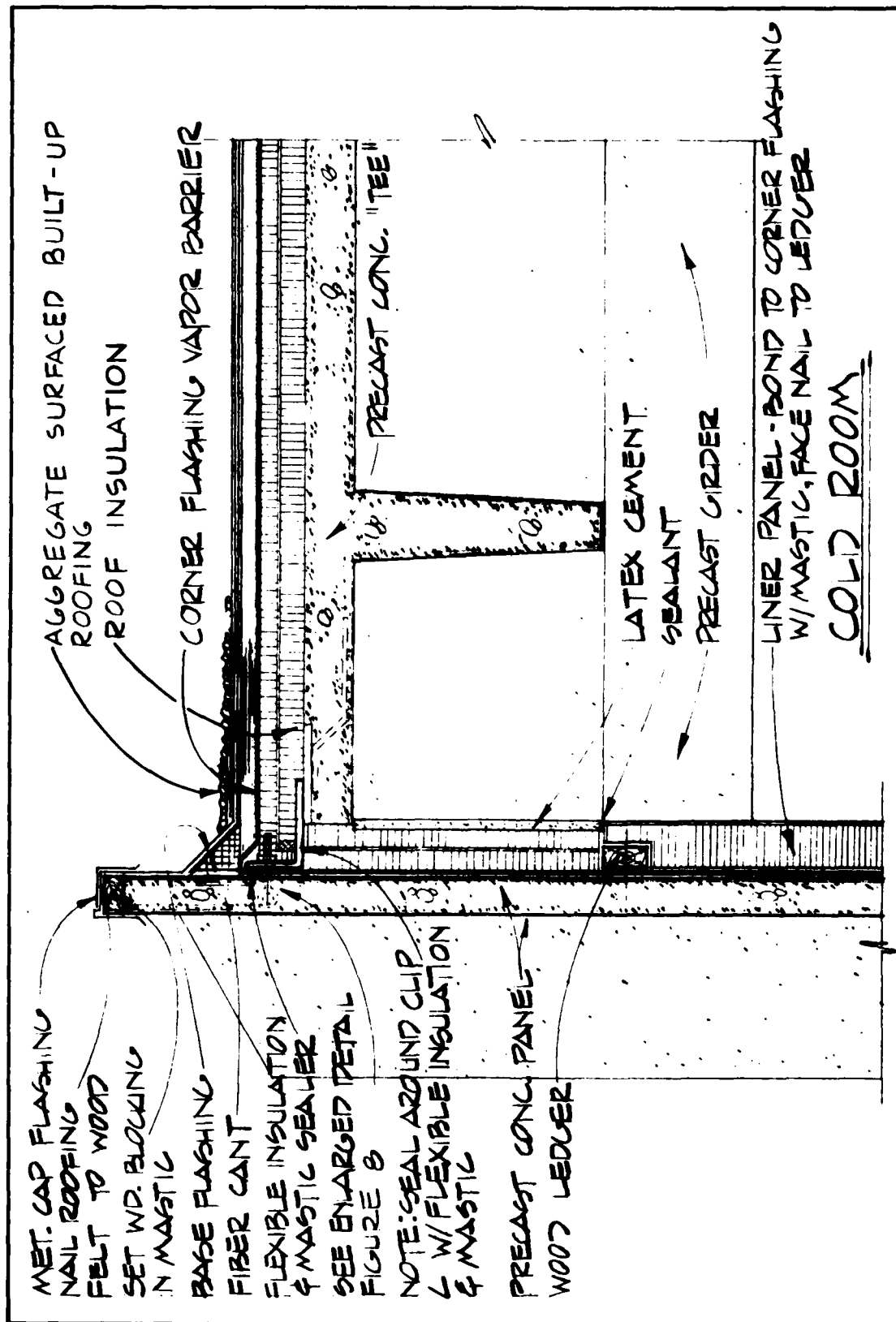


Figure 15

COLD ROOM INSULATION DETAIL 7

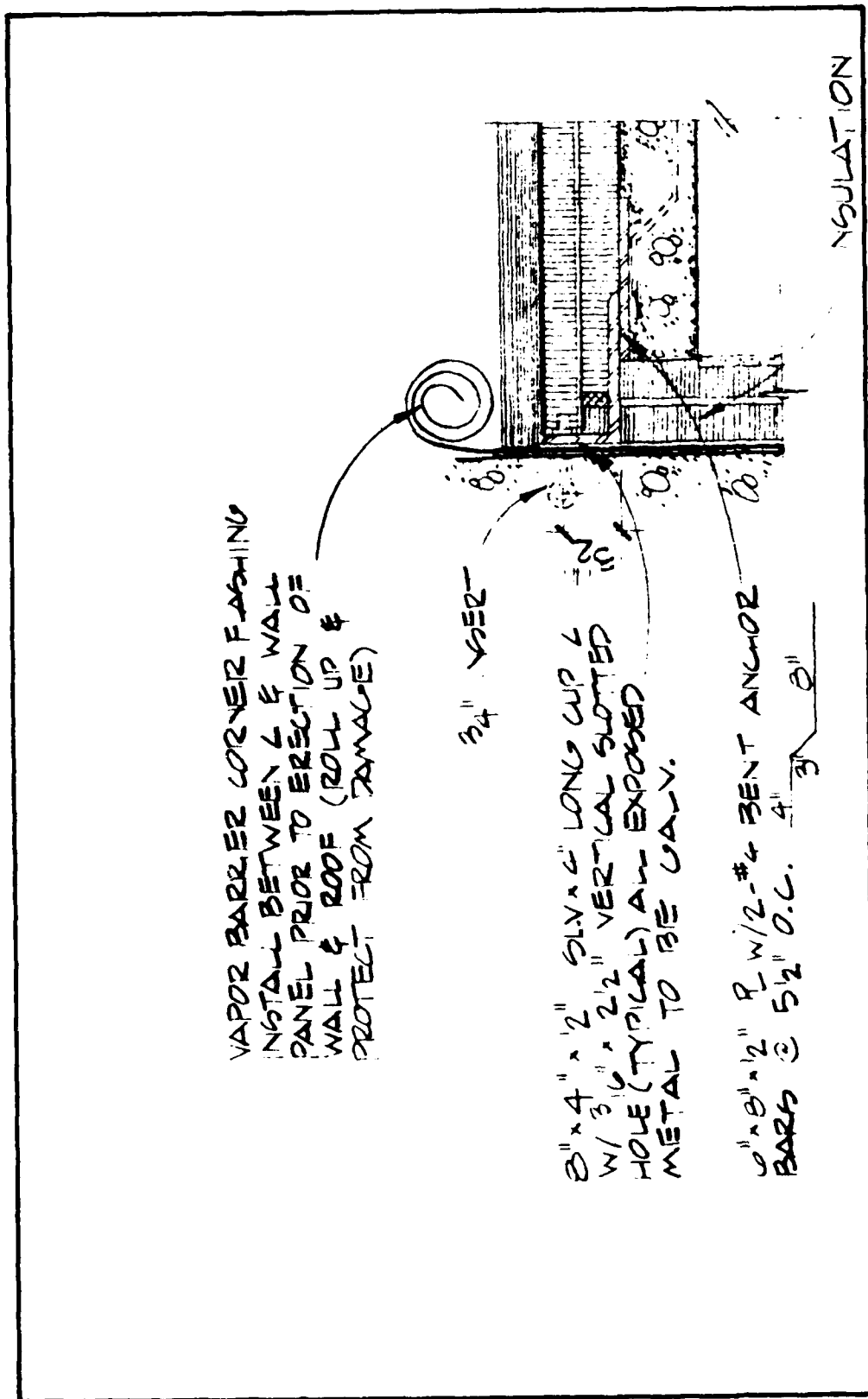


Figure 16
 ENLARGED COLD ROOM INSULATION DETAIL

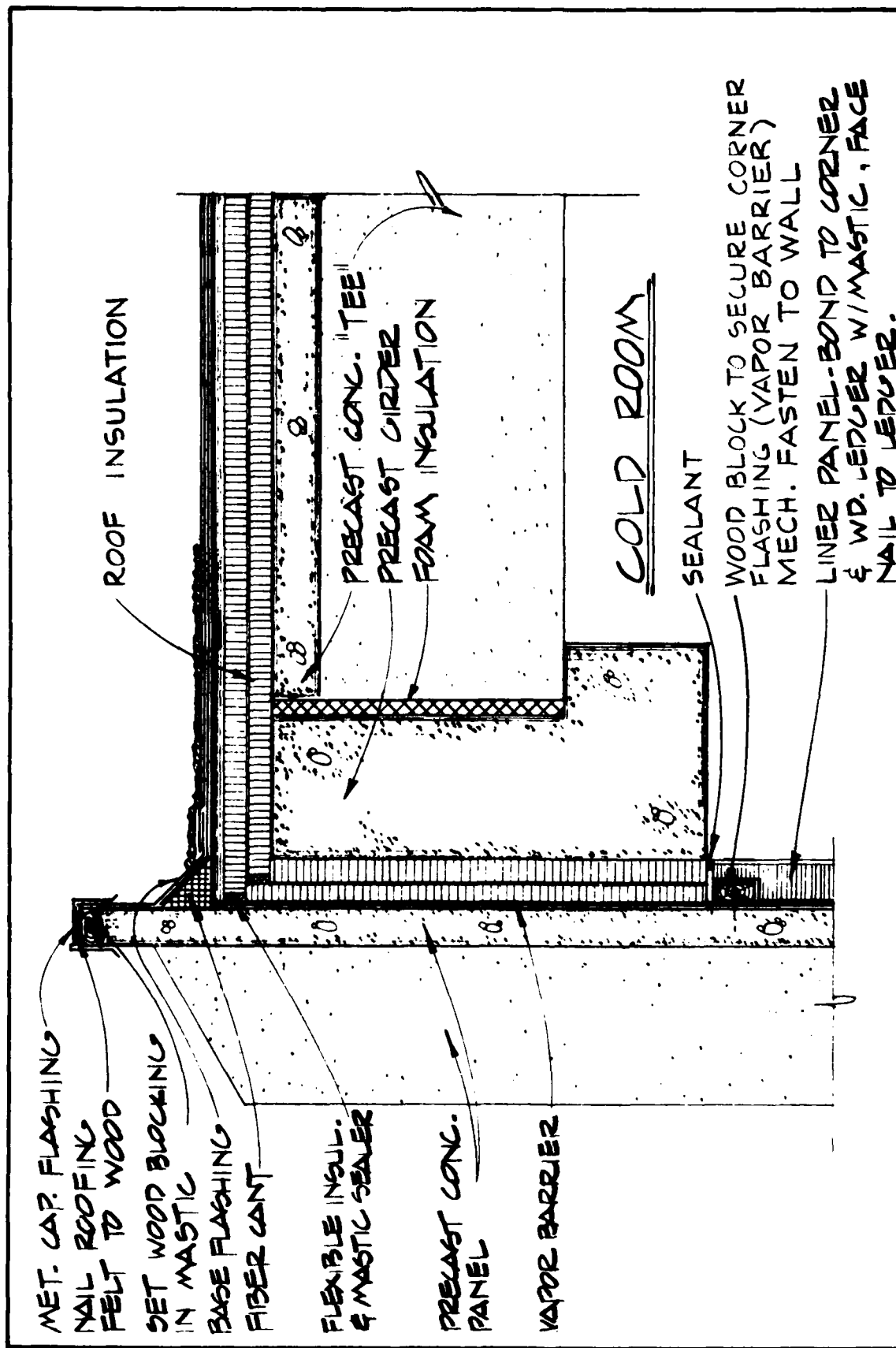


Figure 17

COLD ROOM INSULATION DETAIL 8

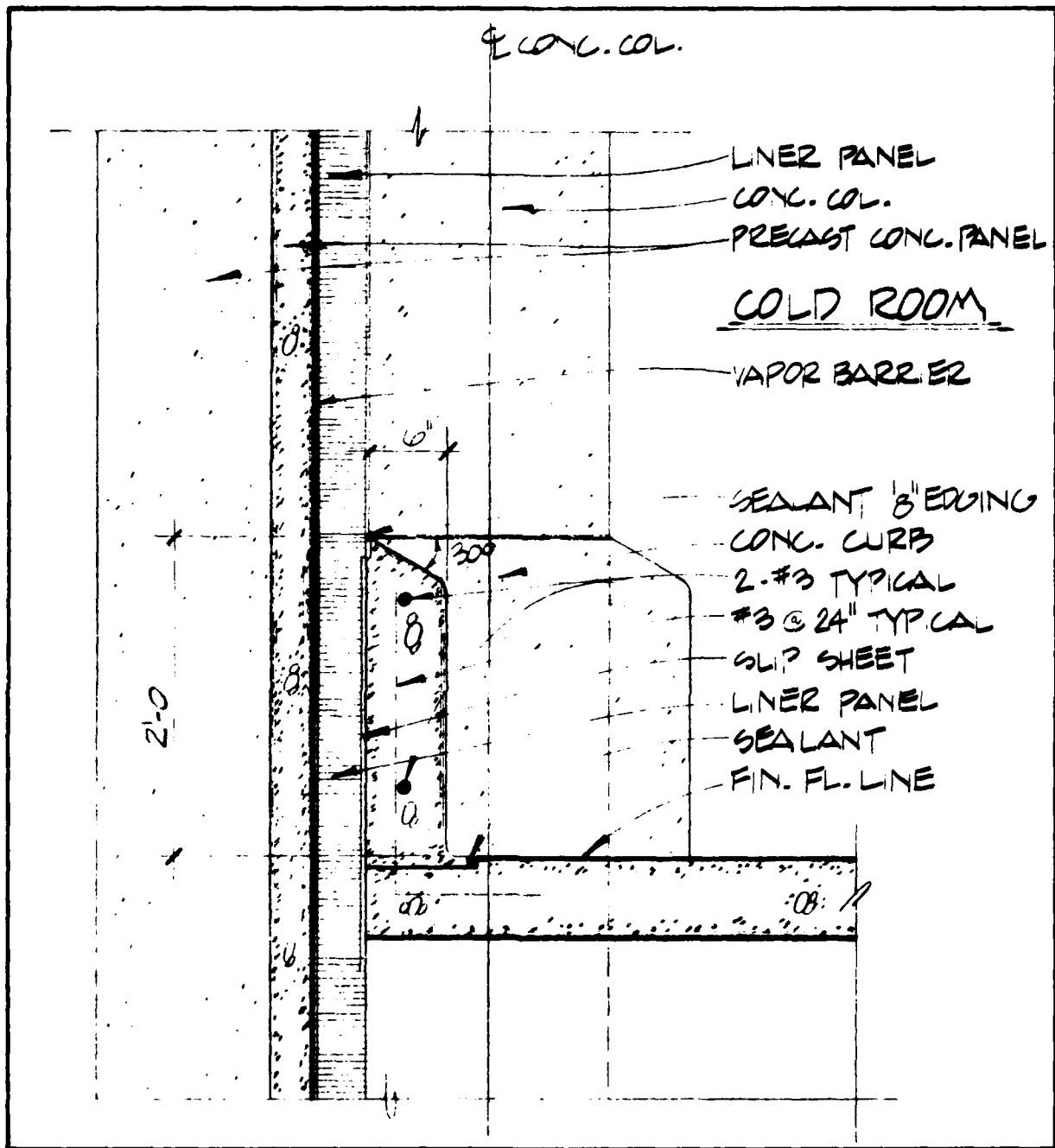


Figure 18
COLS ROOM INSULATION DETAIL 9

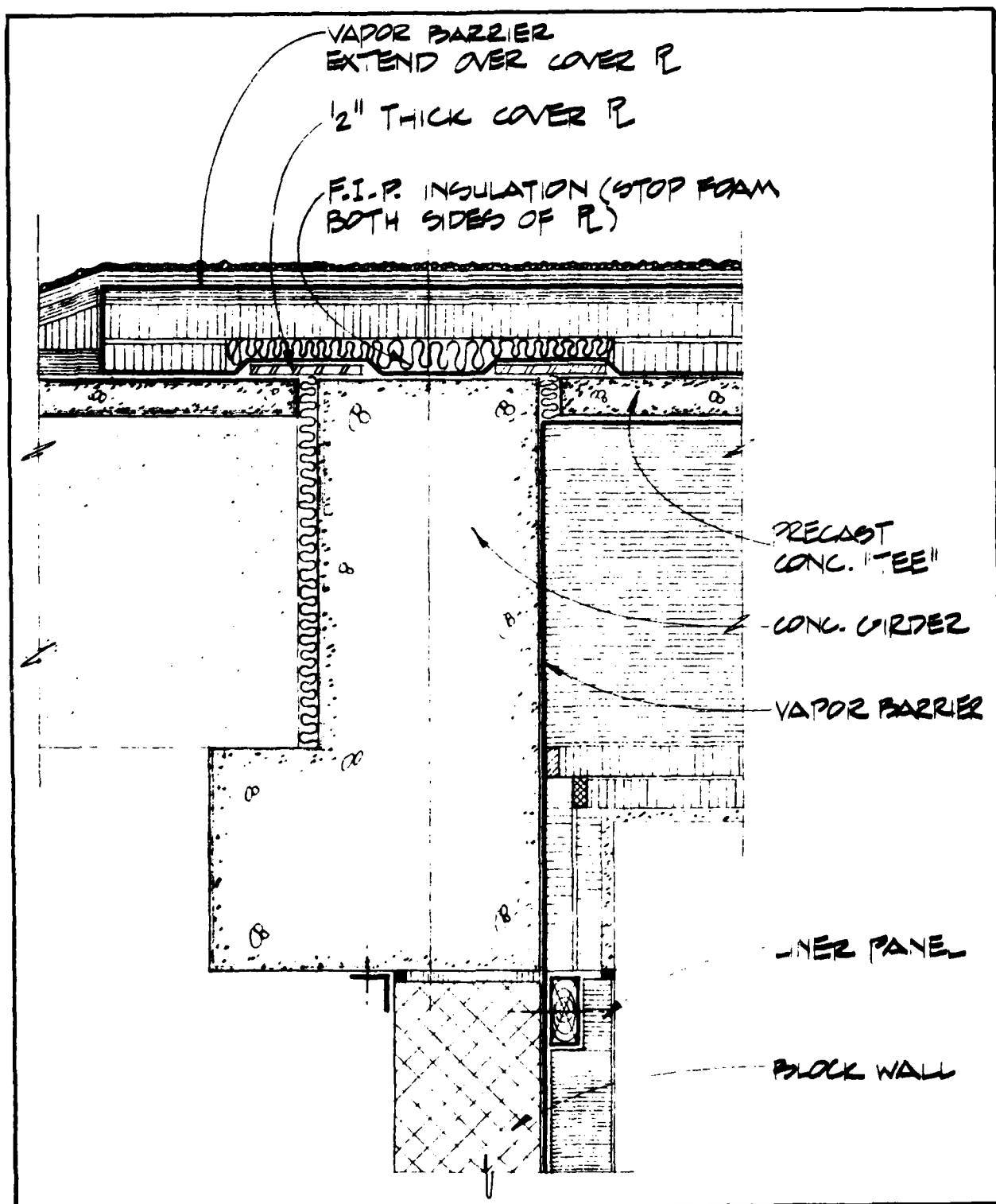


Figure 19
 COLD ROOM INSULATION DETAIL 10

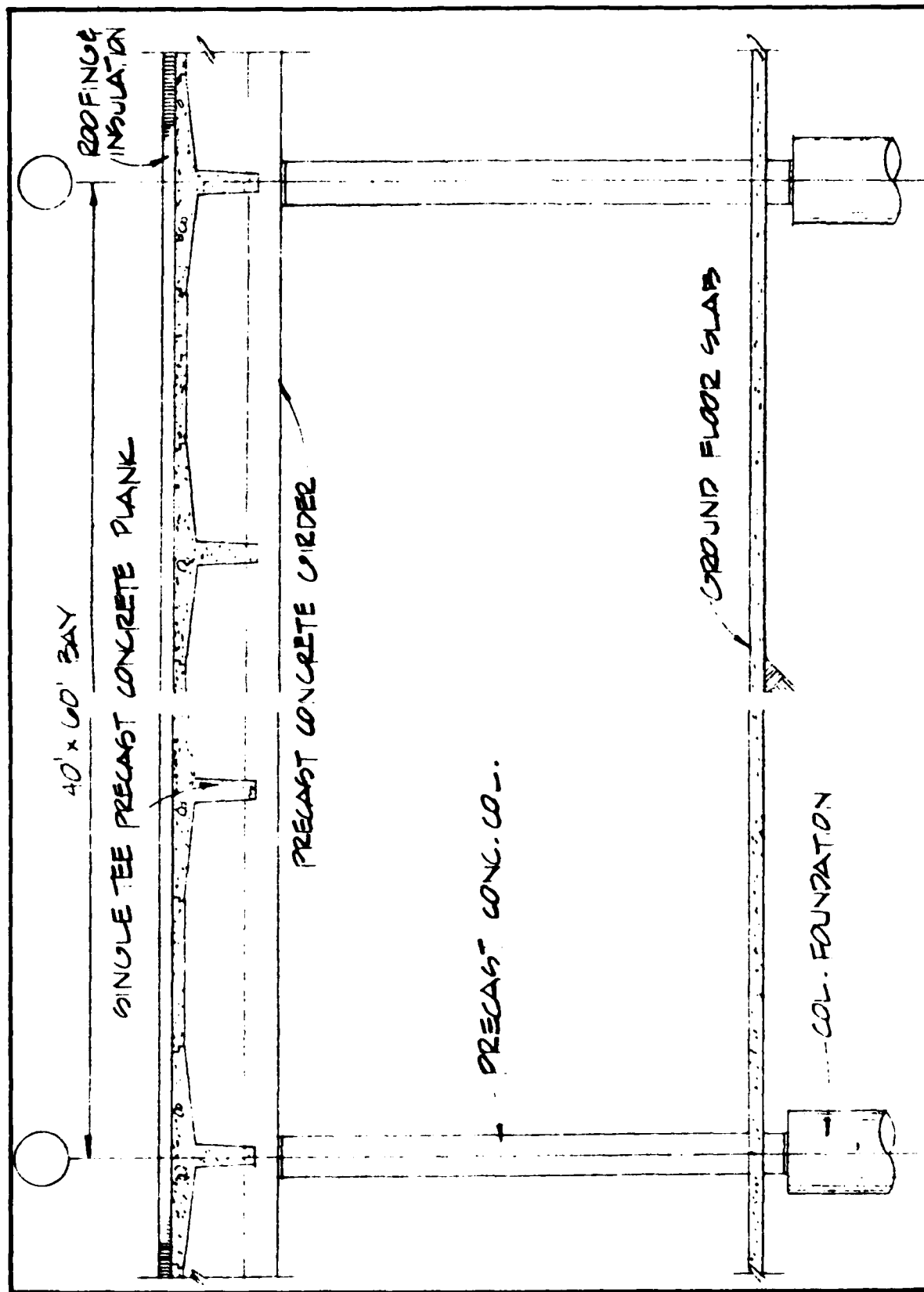


Figure 20
PRECAST CONCRETE SINGLE TEE CONSTRUCTION

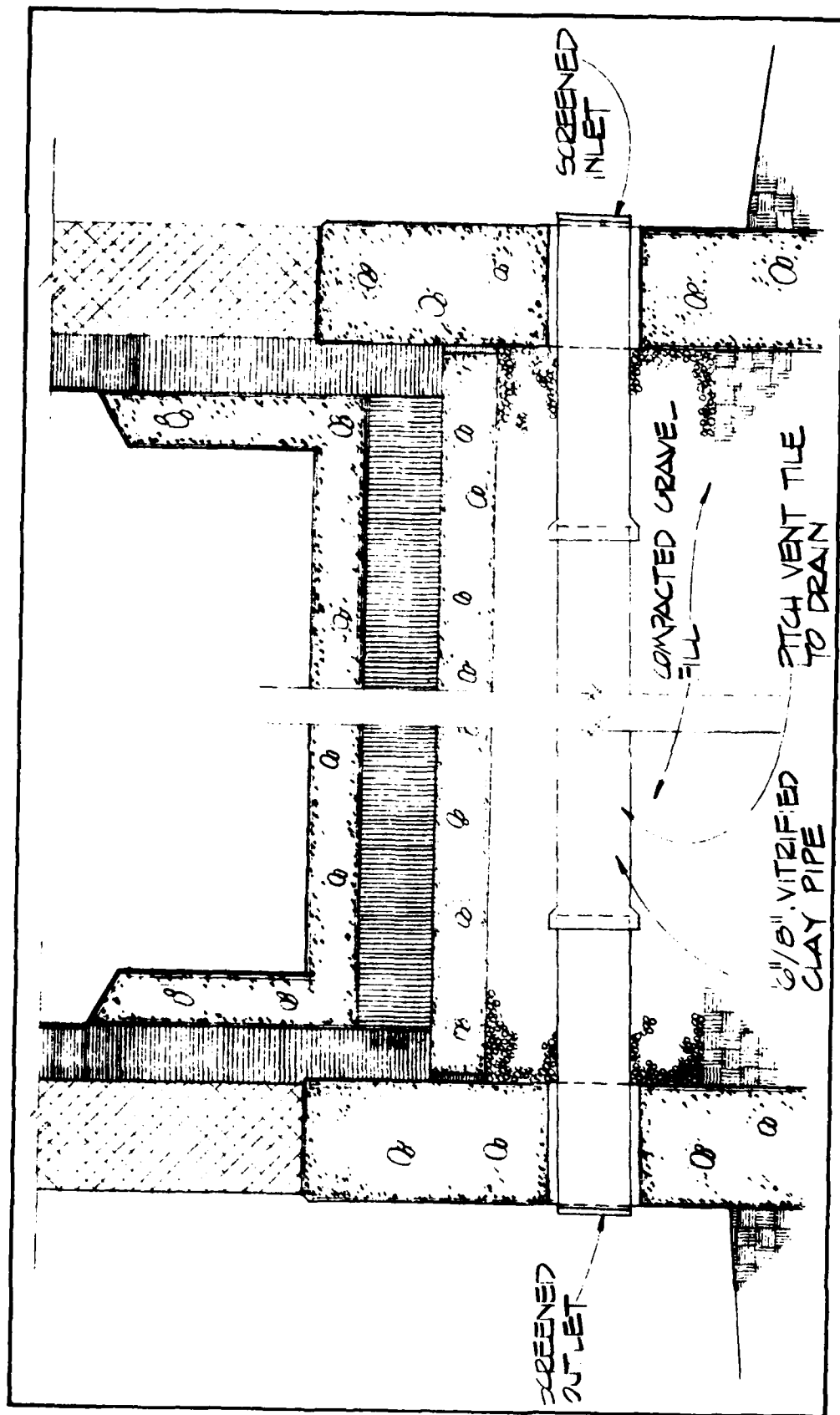


Figure 21

TYPICAL UNDERFLOOR AIR DUCT HEAT SYSTEM FOR SLAB ON GROUND FREEZERS

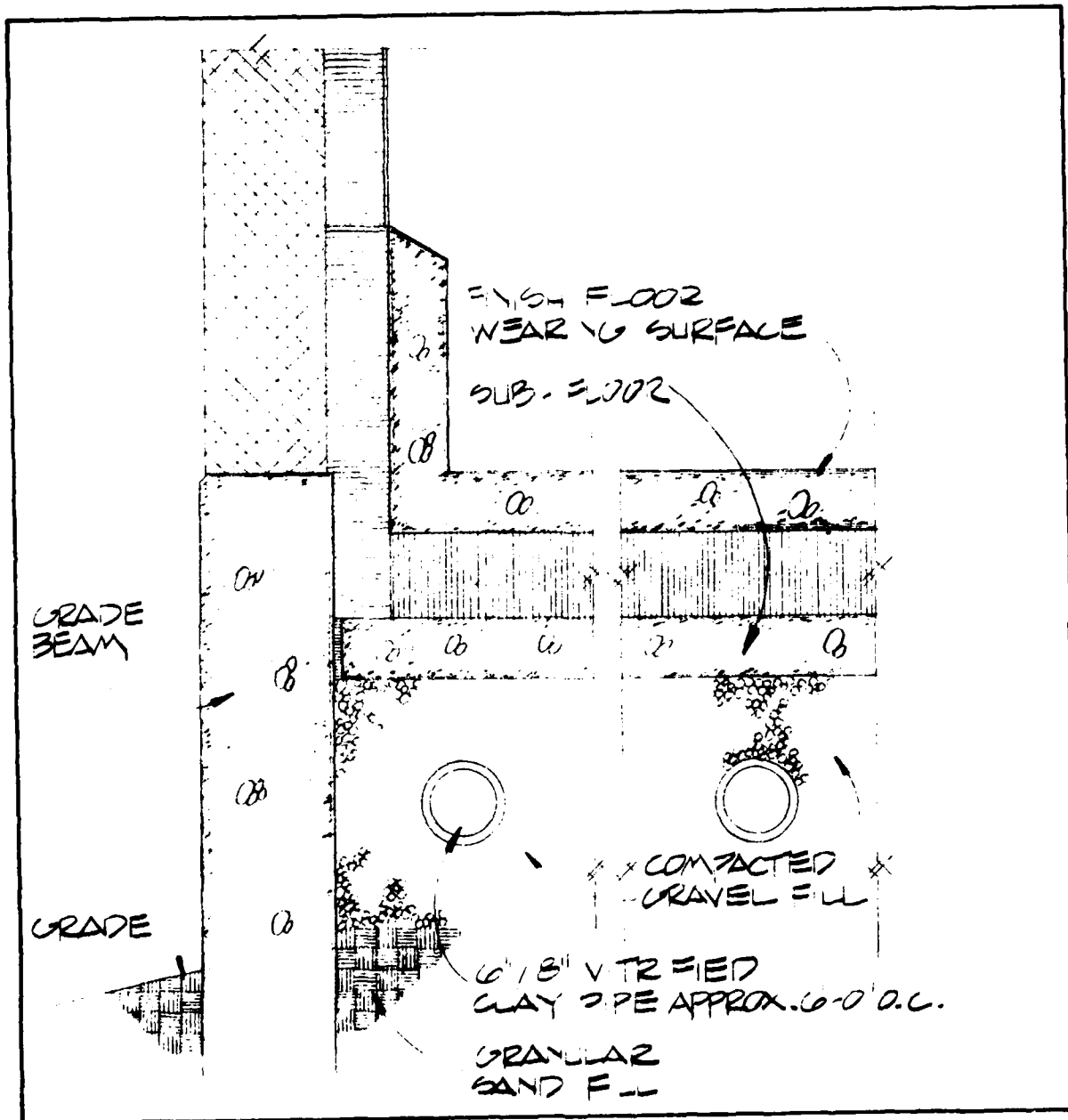


Figure 22
 TYPICAL UNDERFLOOR AIR DUCT HEAT SYSTEM

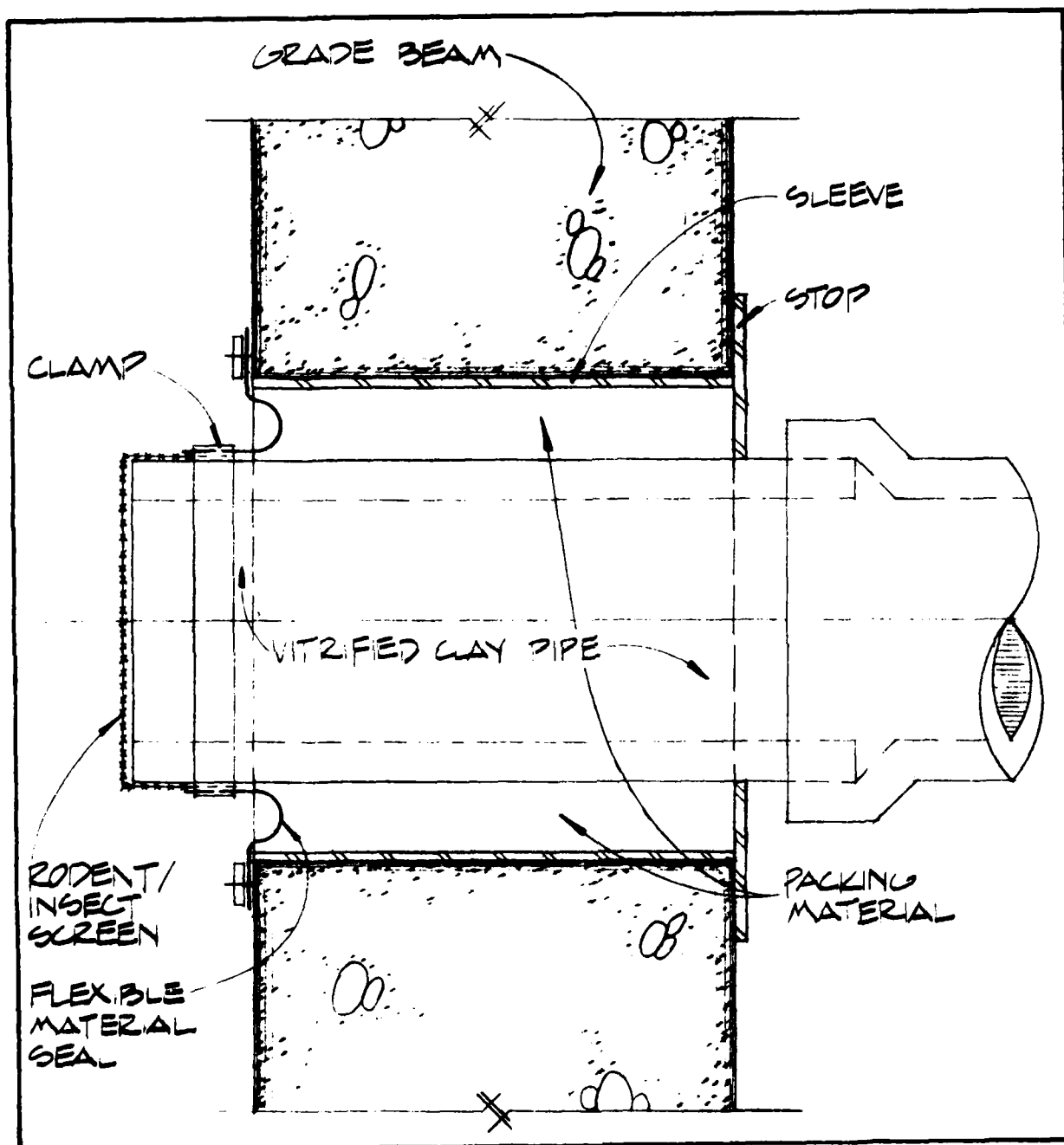


Figure 23

UNDERFLOOR AIR DUCT HEATING SYSTEM
THRU WALL DETAIL

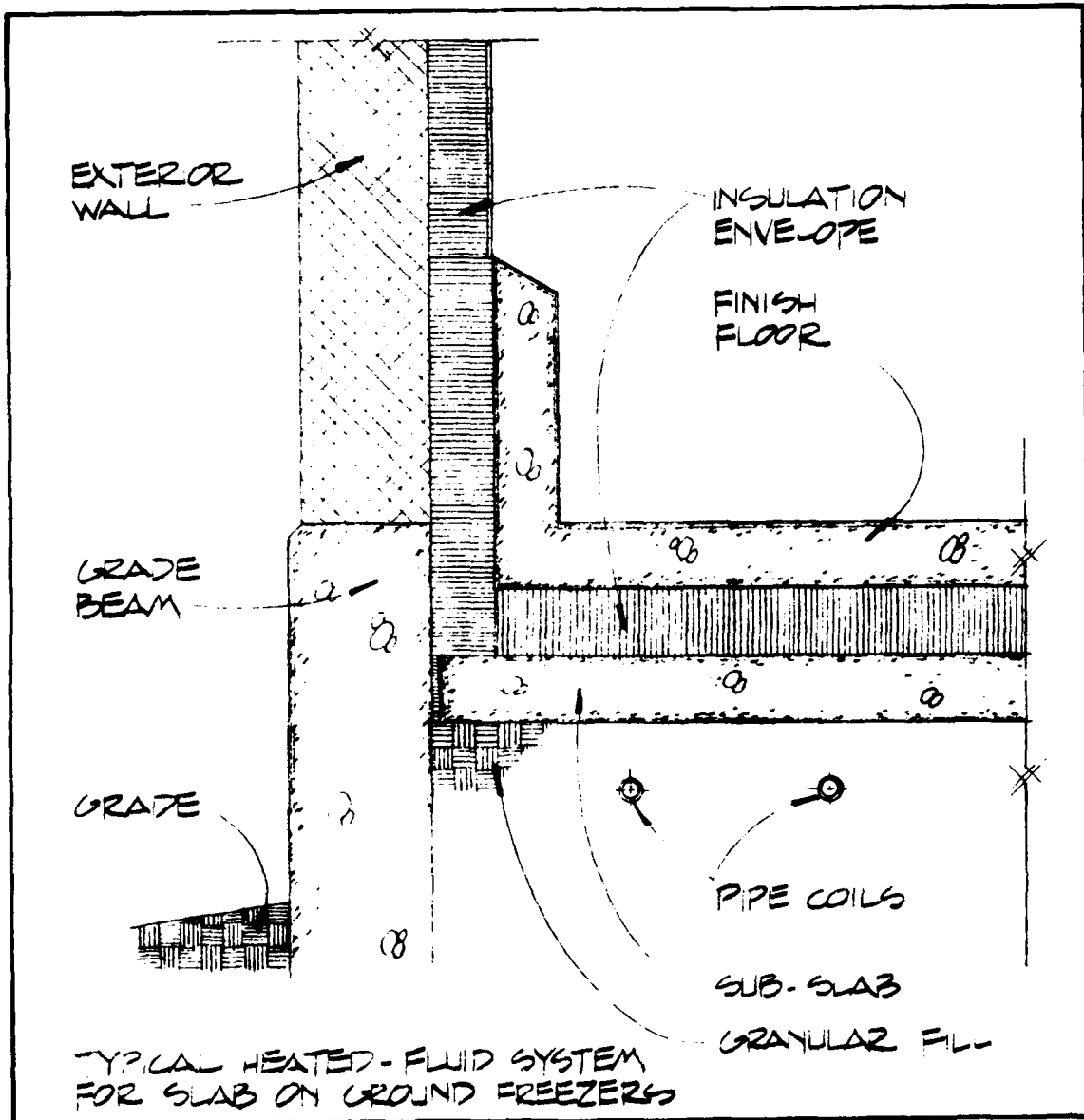


Figure 24
UNDERFLOOR WARMING SYSTEM DETAIL

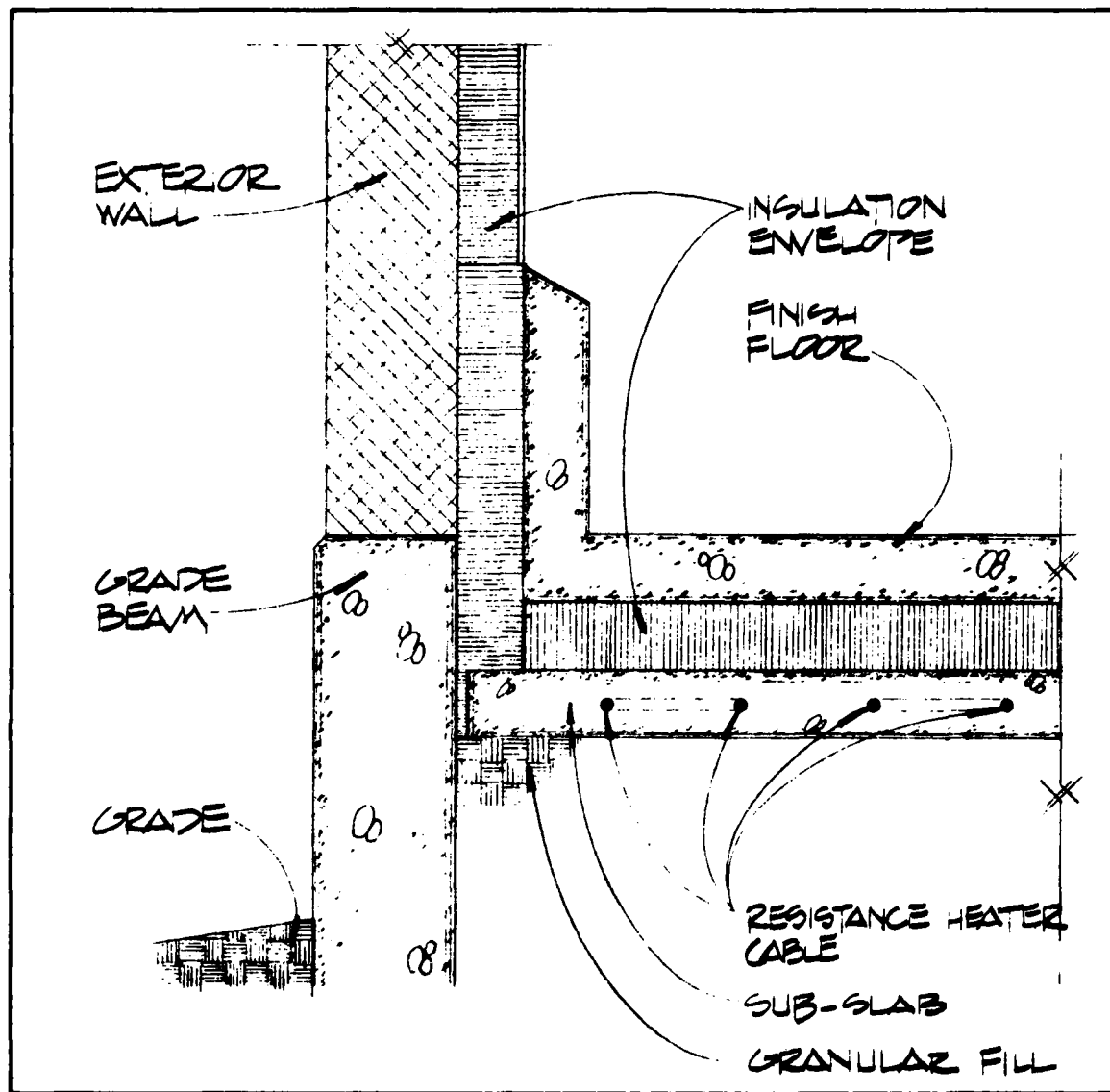


Figure 25
TYPICAL ELECTRIC-RESISTANCE HEATING SYSTEM
FOR SLAB ON GROUND FREEZERS

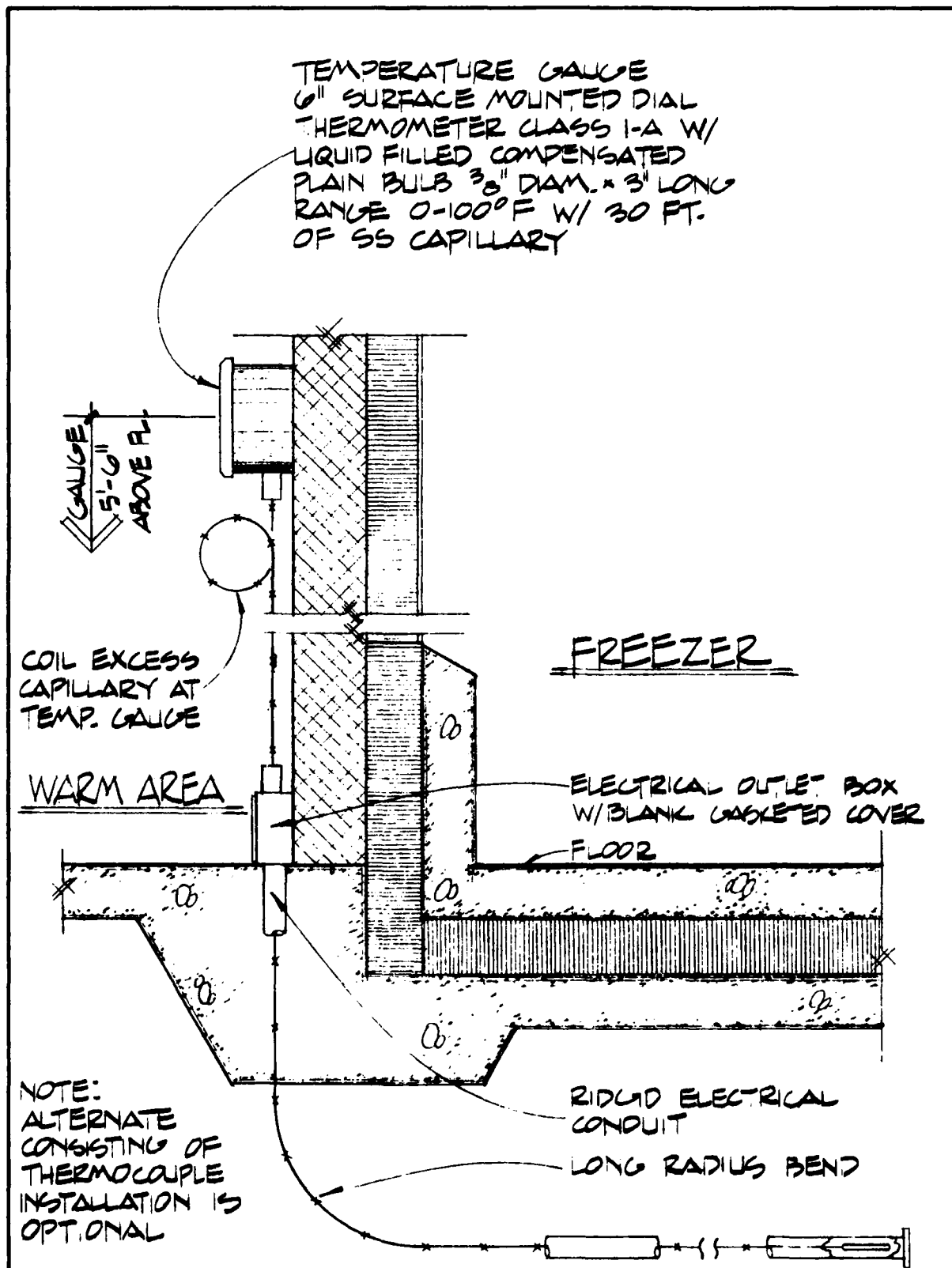


Figure 26

TYPICAL GROUND TEMPERATURE INDICATOR INSTALLATION

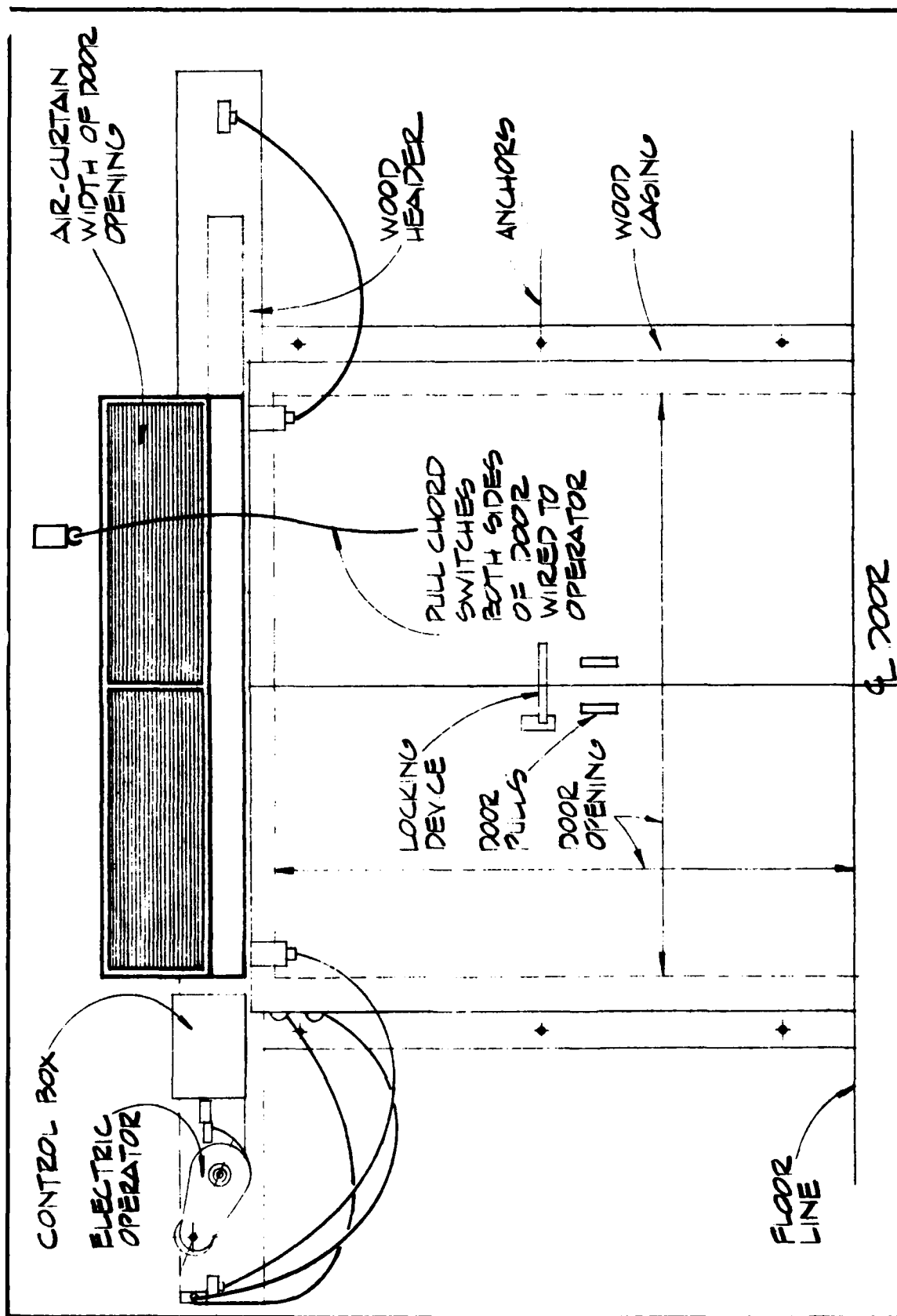


Figure 27
TYPICAL COLD STORAGE DOOR WITH AIR CURTAIN

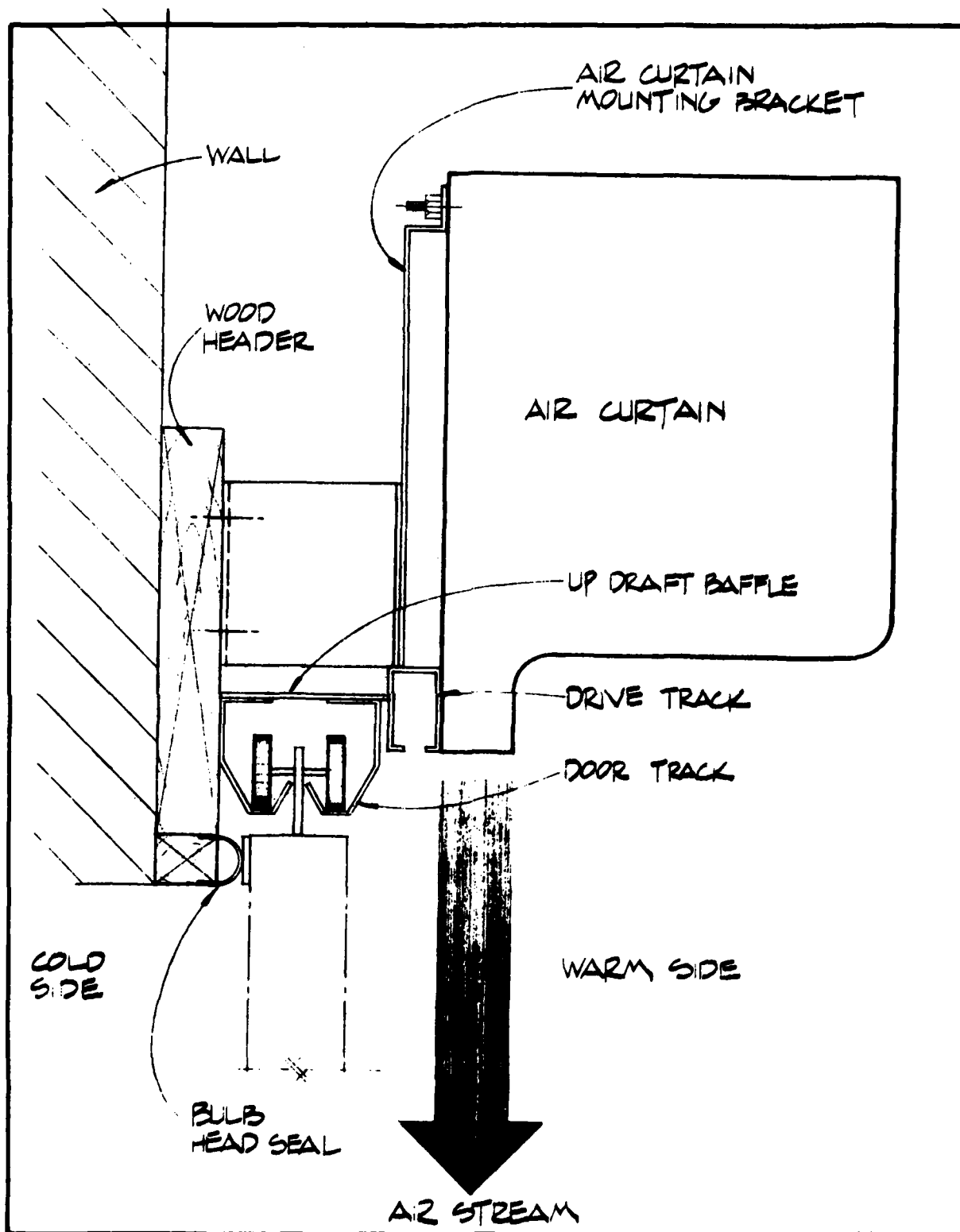


Figure 28

TYPICAL AIR CURTAIN DETAIL AT DOOR HEAD

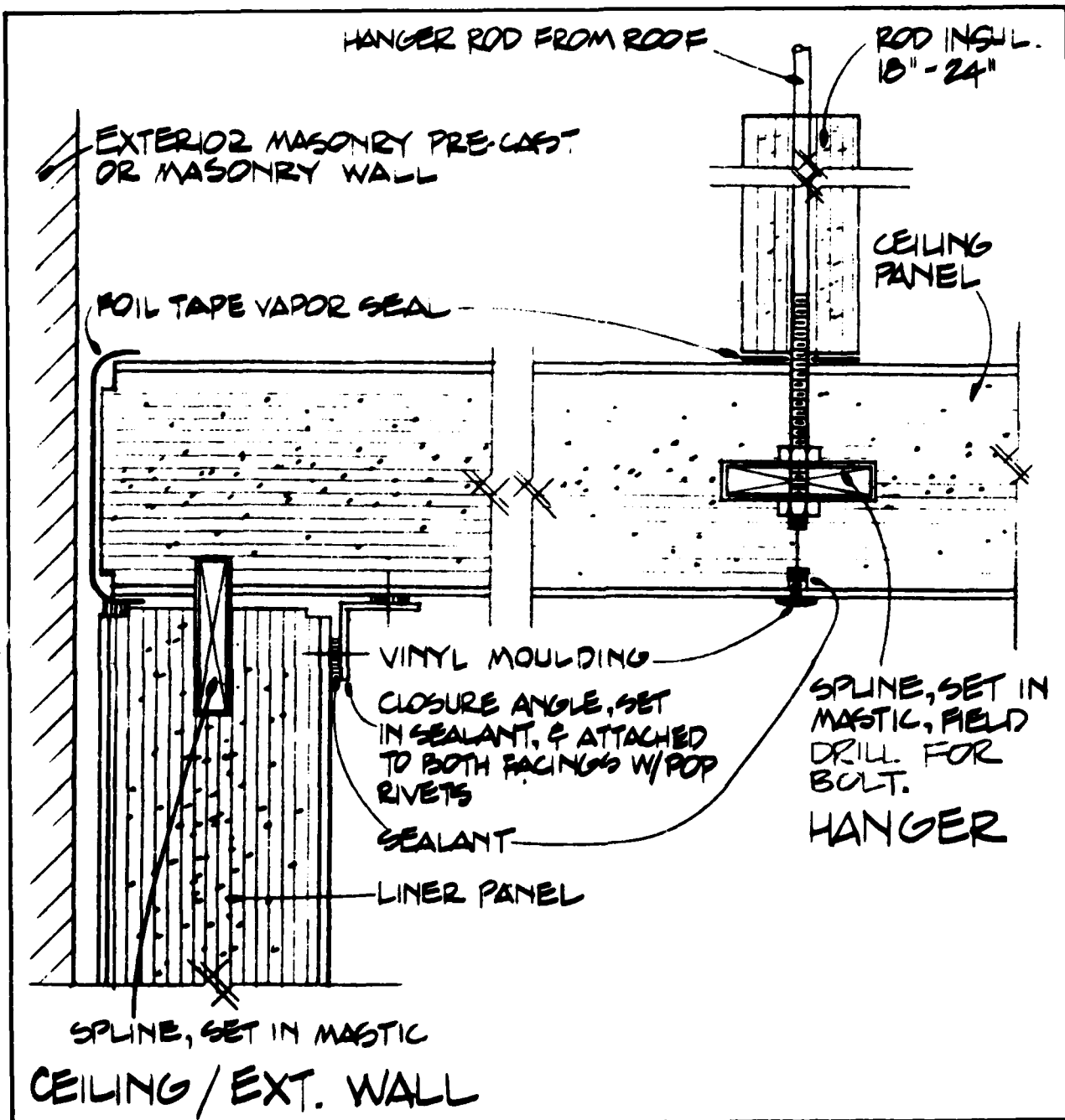


Figure 29
TYPICAL SUSPENDED CEILING PANEL/
WALL PANEL CONSTRUCTION

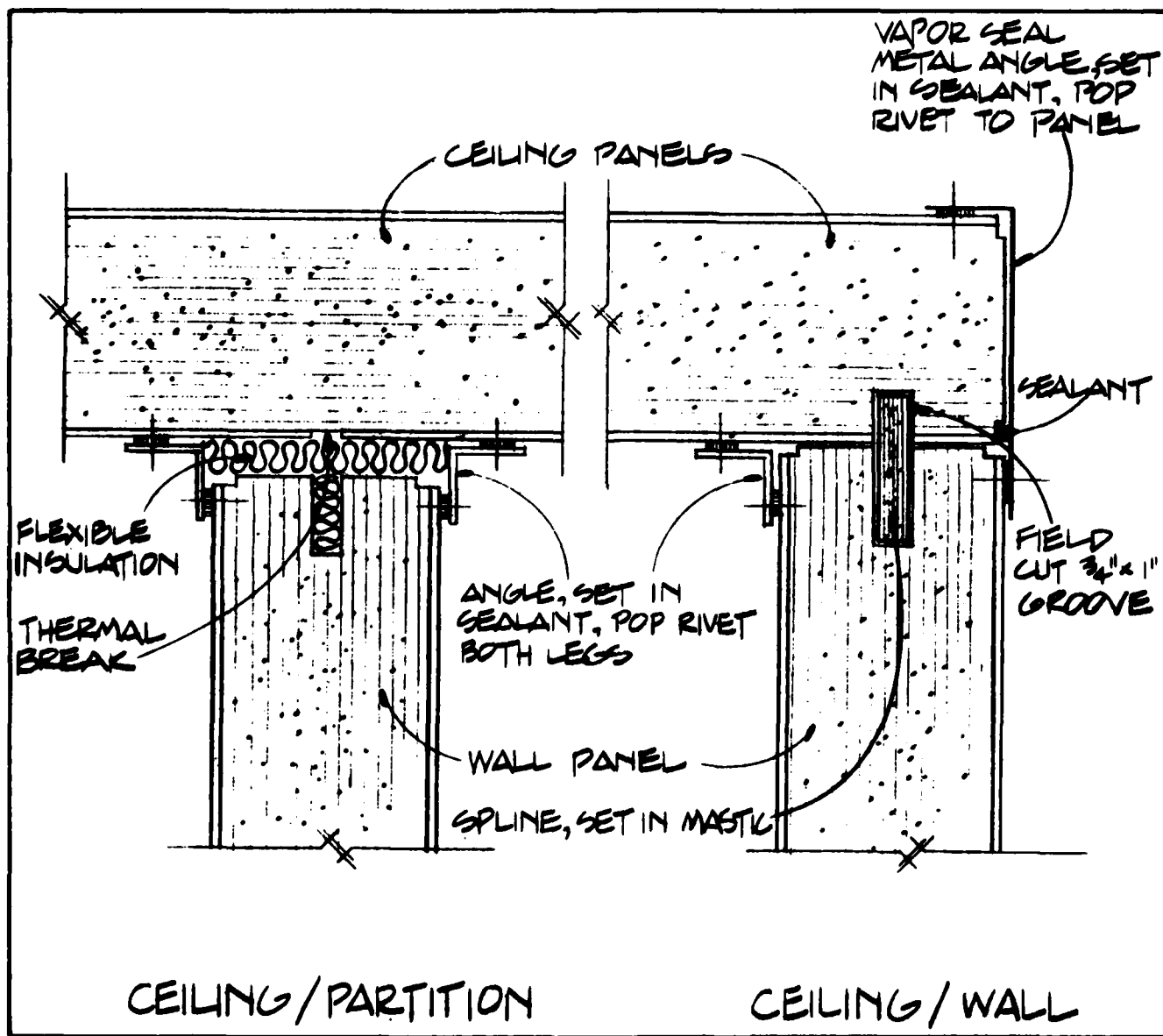


Figure 30
TYPICAL SUSPENDED CEILING PANEL/
WALL PANEL CONSTRUCTION

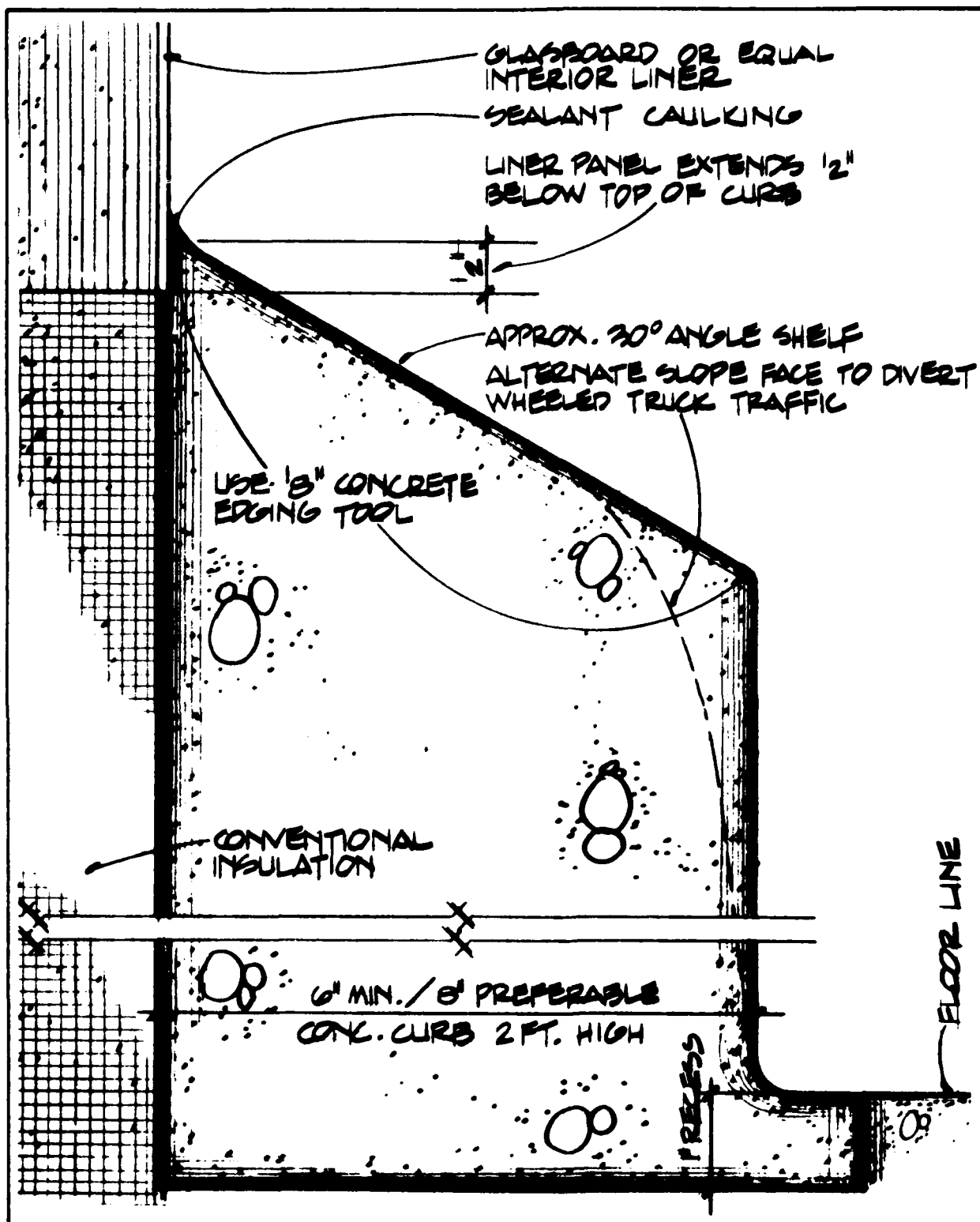


Figure 31
TYPICAL WALL CURB

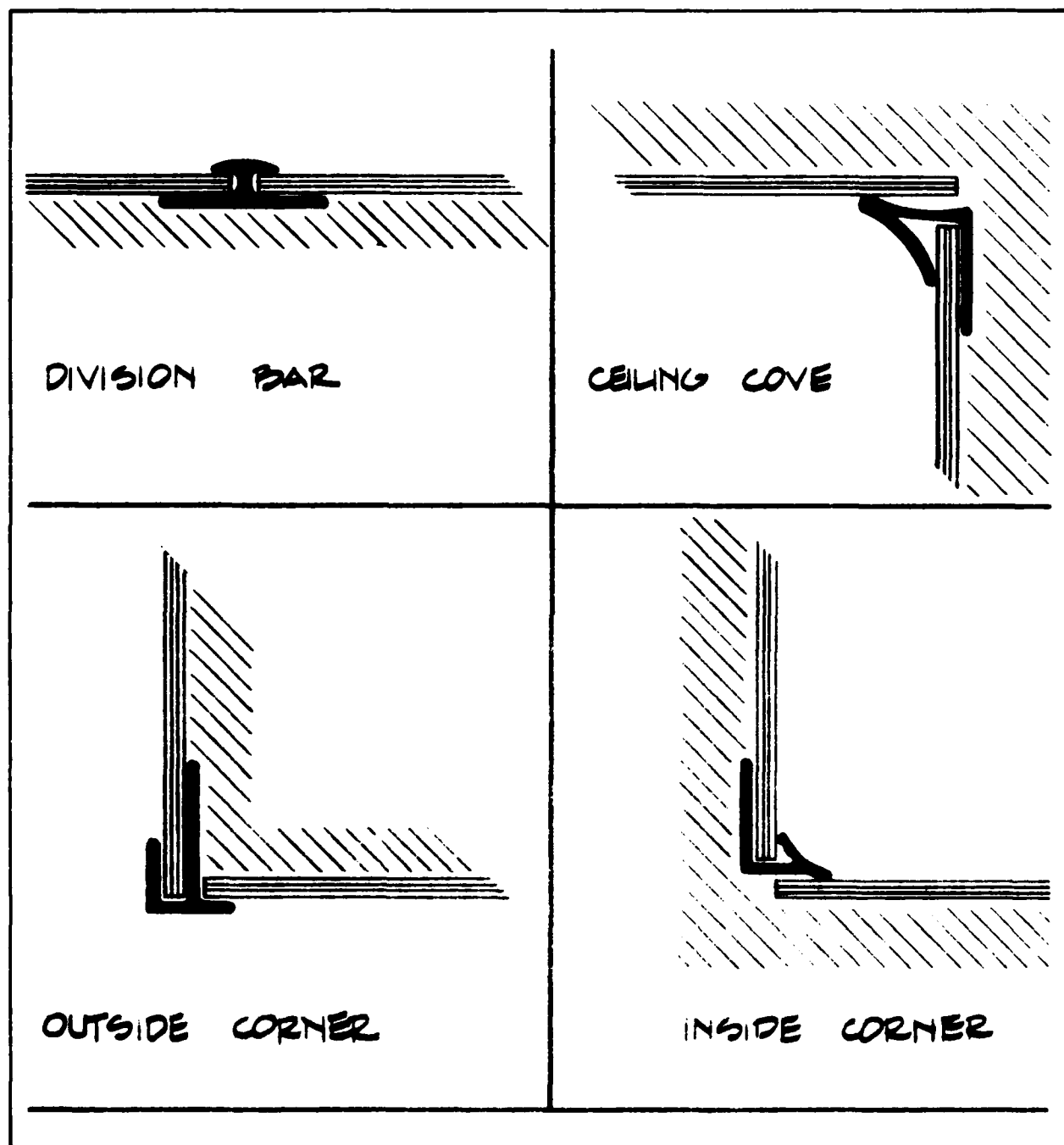


Figure 32
TYPICAL VINYL MOLDINGS
FOR USE ON INTERIOR WALL FINISHES

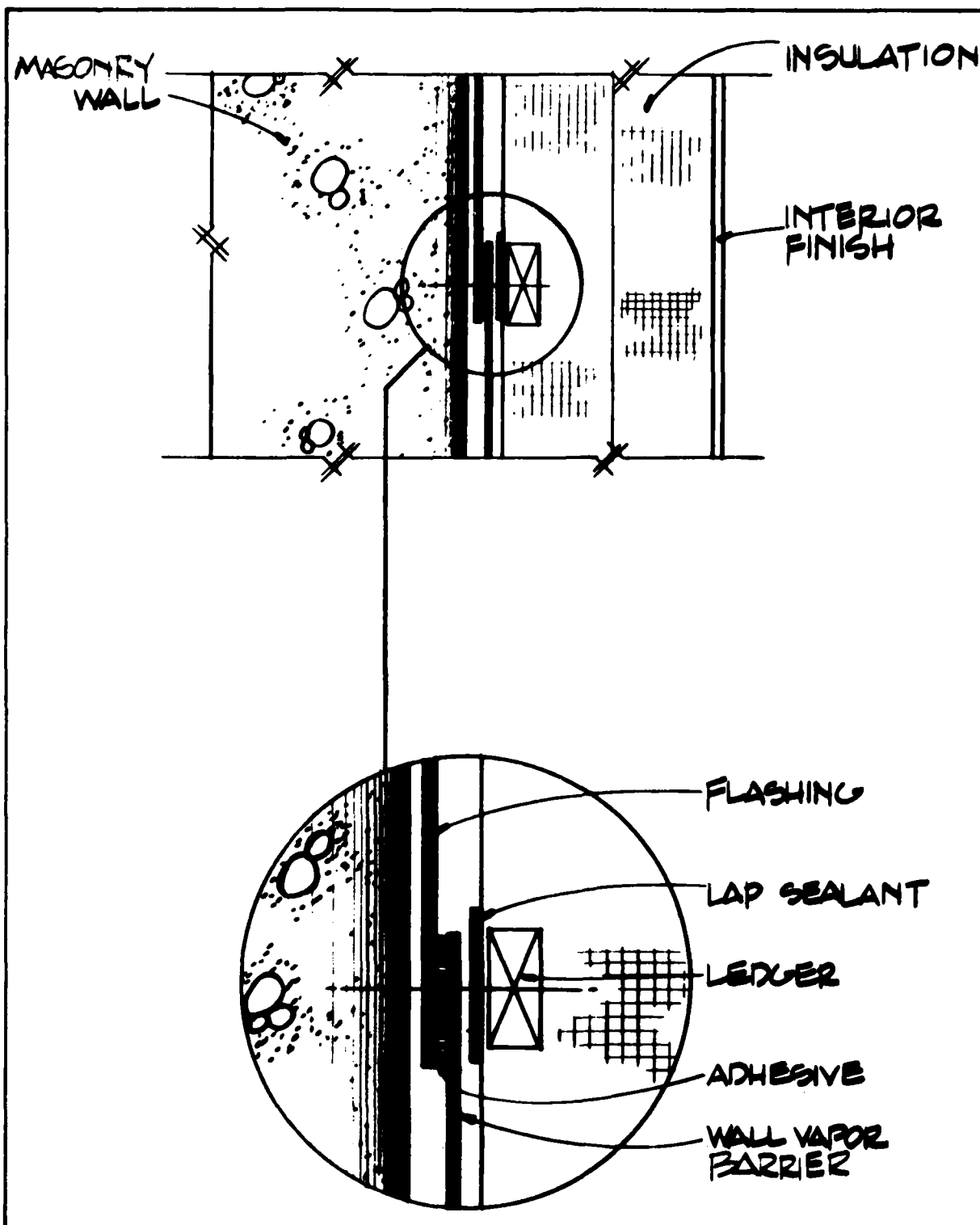


Figure 33
TYPICAL FASTENER DETAIL AND VAPOR BARRIER
PENETRATION AT
MASONRY WALL/ROOF JUNCTURE

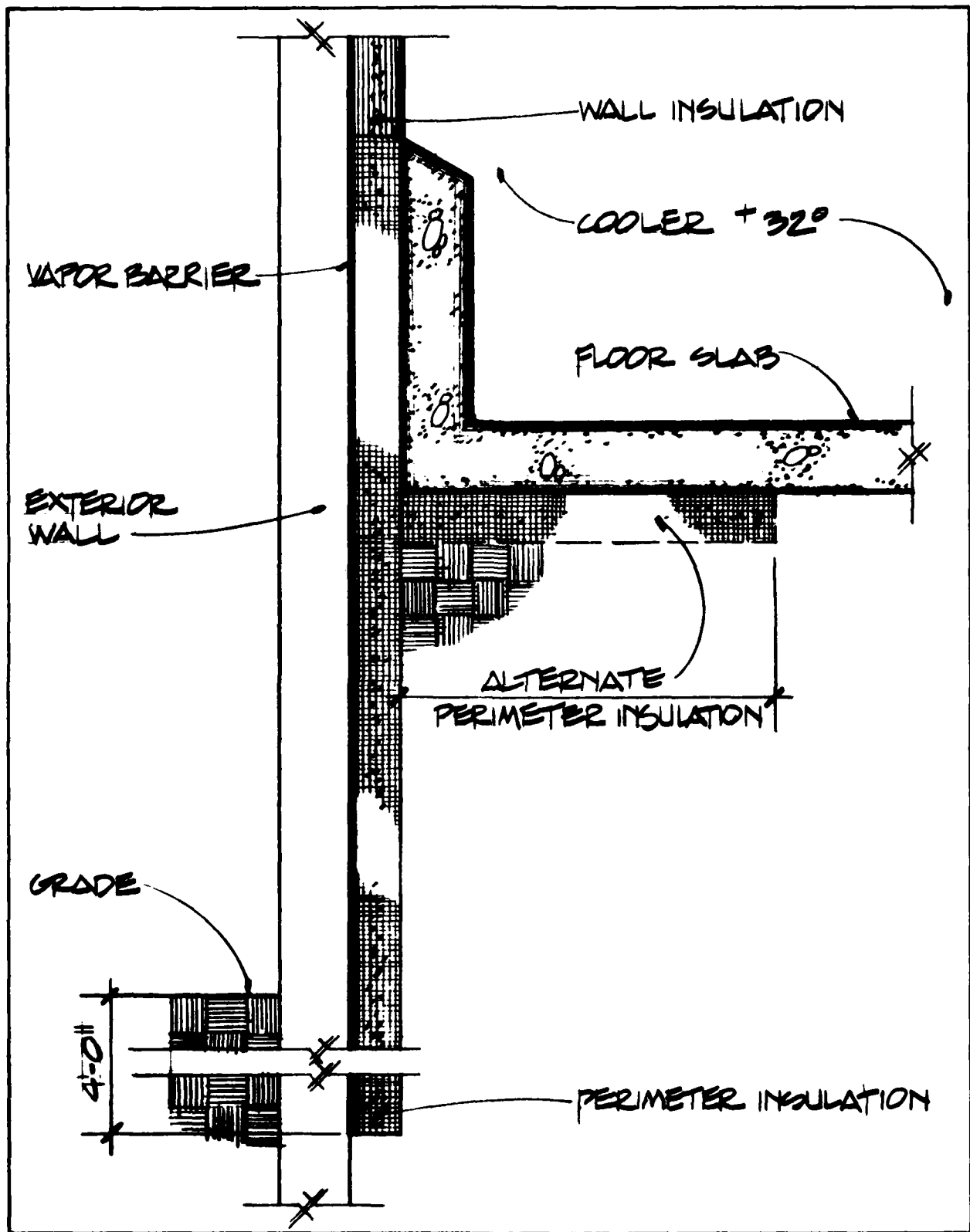


Figure 34
TYPICAL COOLER FLOOR INSULATION

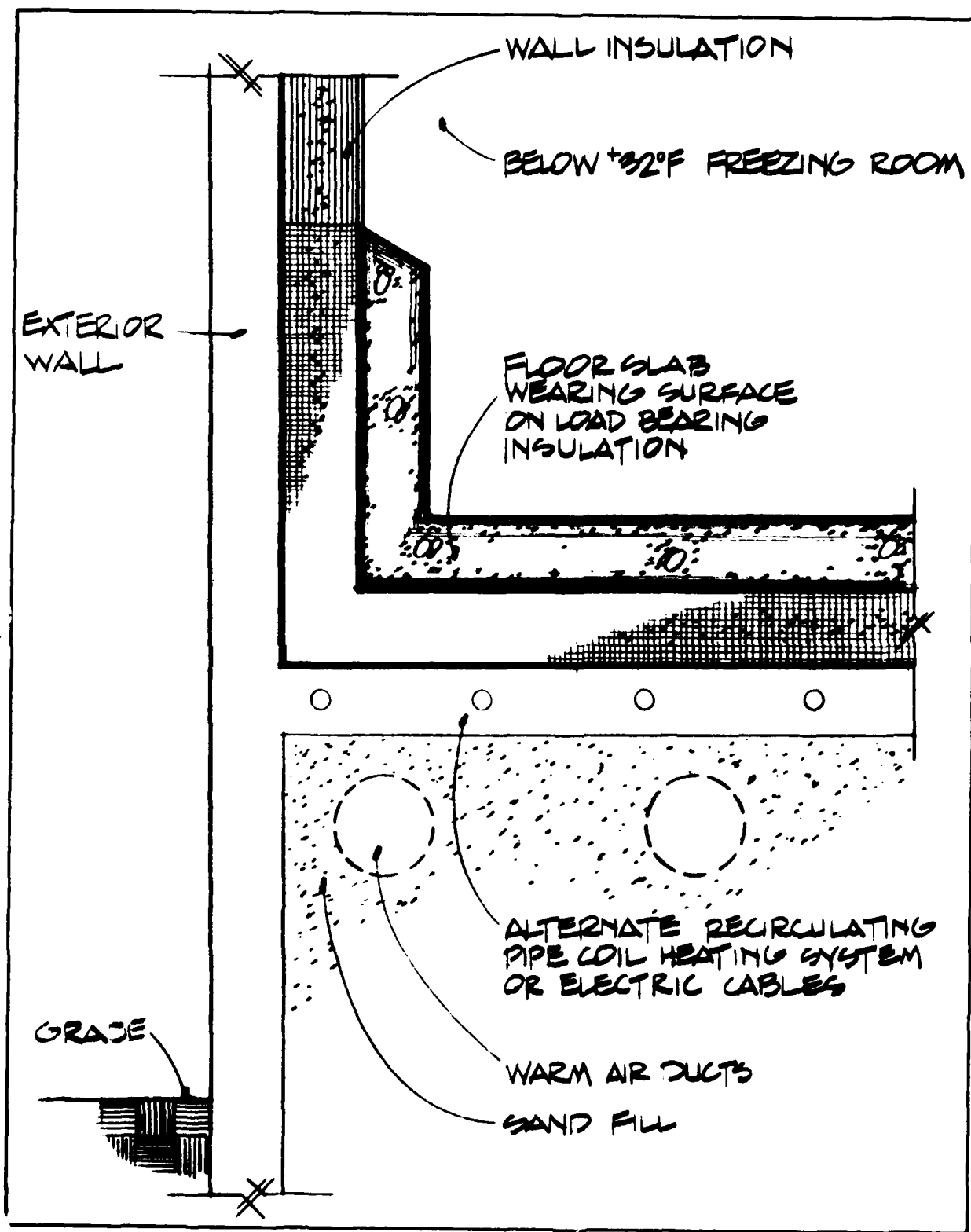


Figure 35
TYPICAL FREEZER FLOOR INSULATION

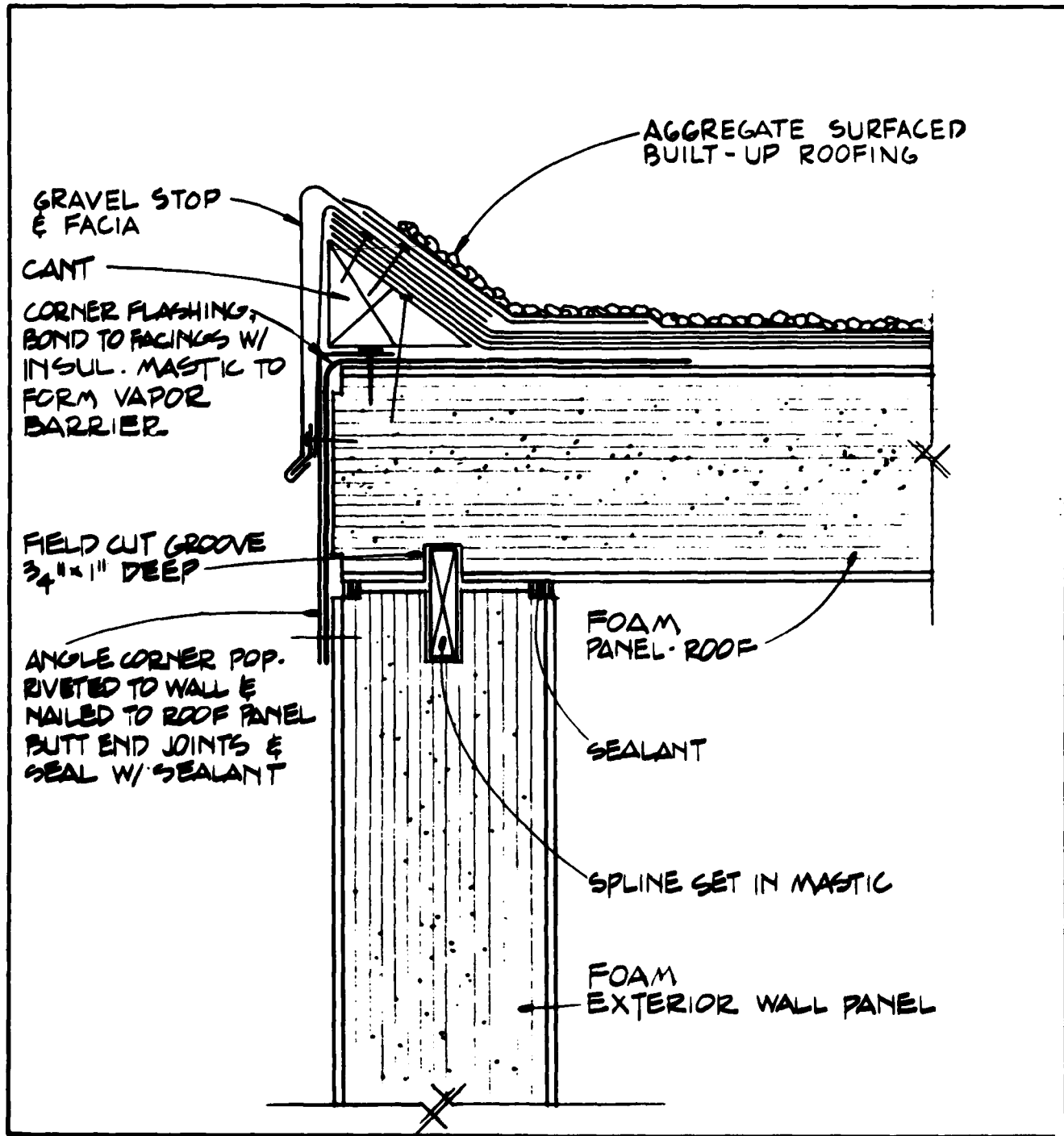


Figure 36

TYPICAL EXTERIOR WALL PANEL/ROOF PANEL CONSTRUCTION

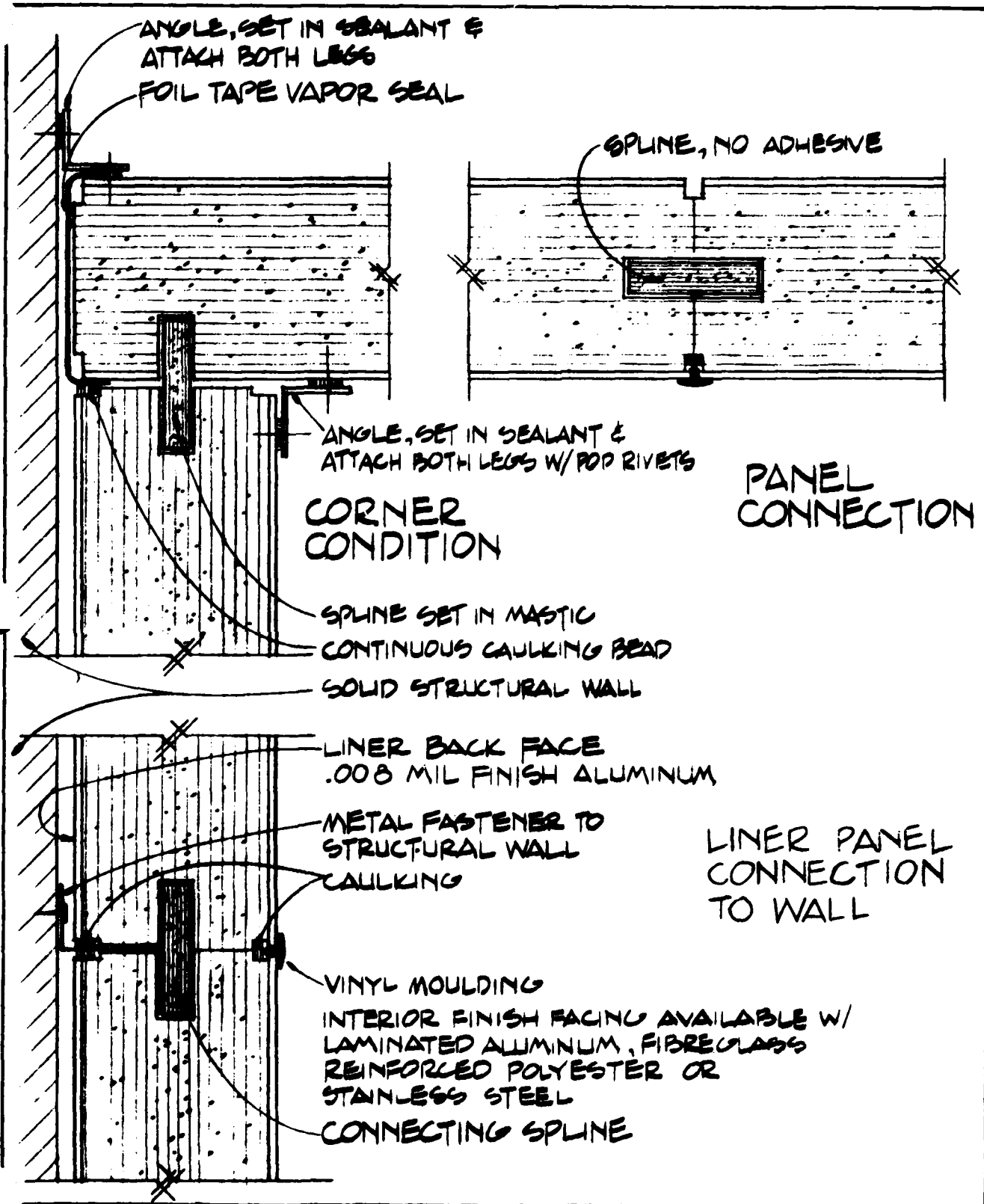


Figure 37

TYPICAL WALL PANEL CONSTRUCTION

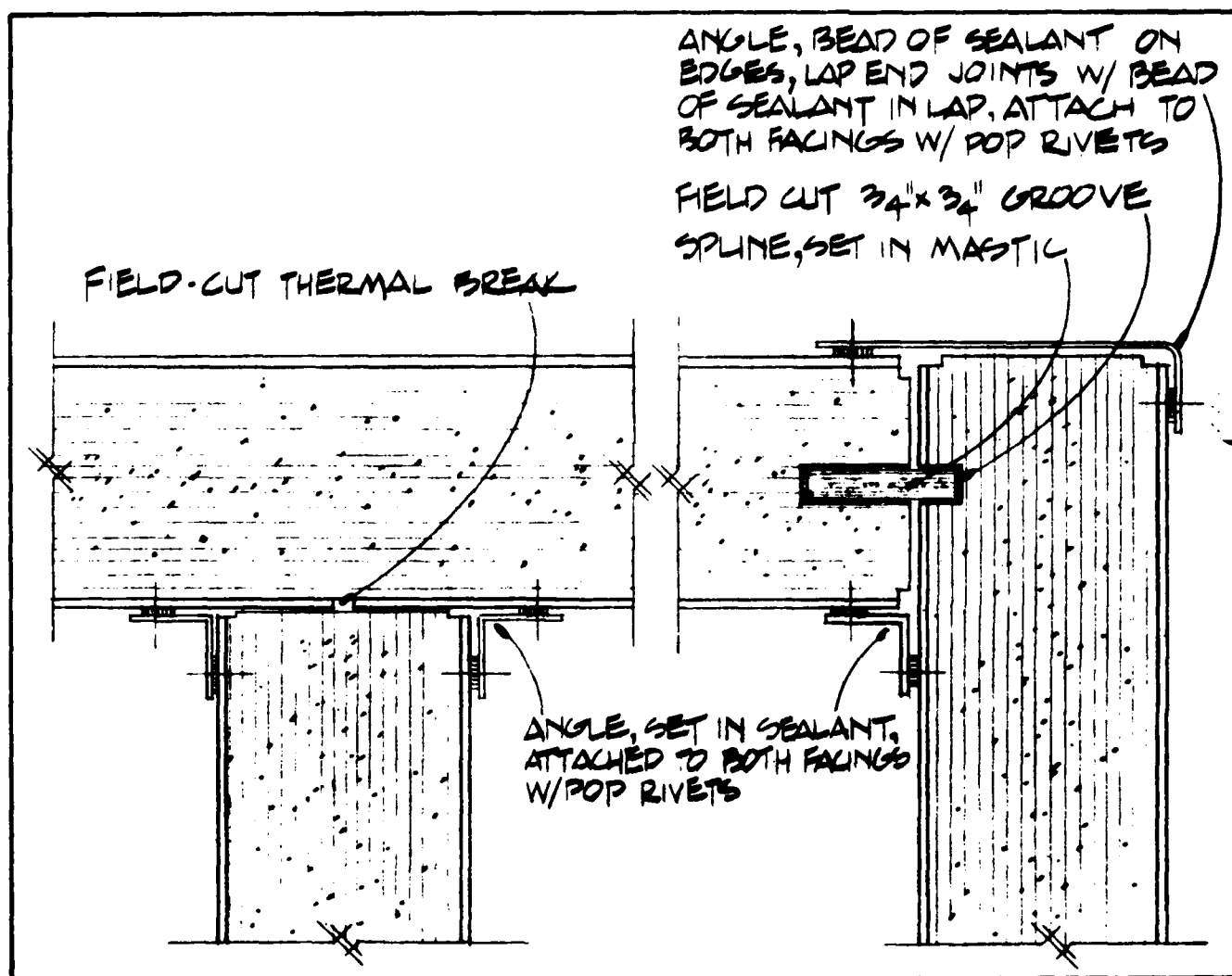


Figure 38
TYPICAL WALL PANEL CONSTRUCTION

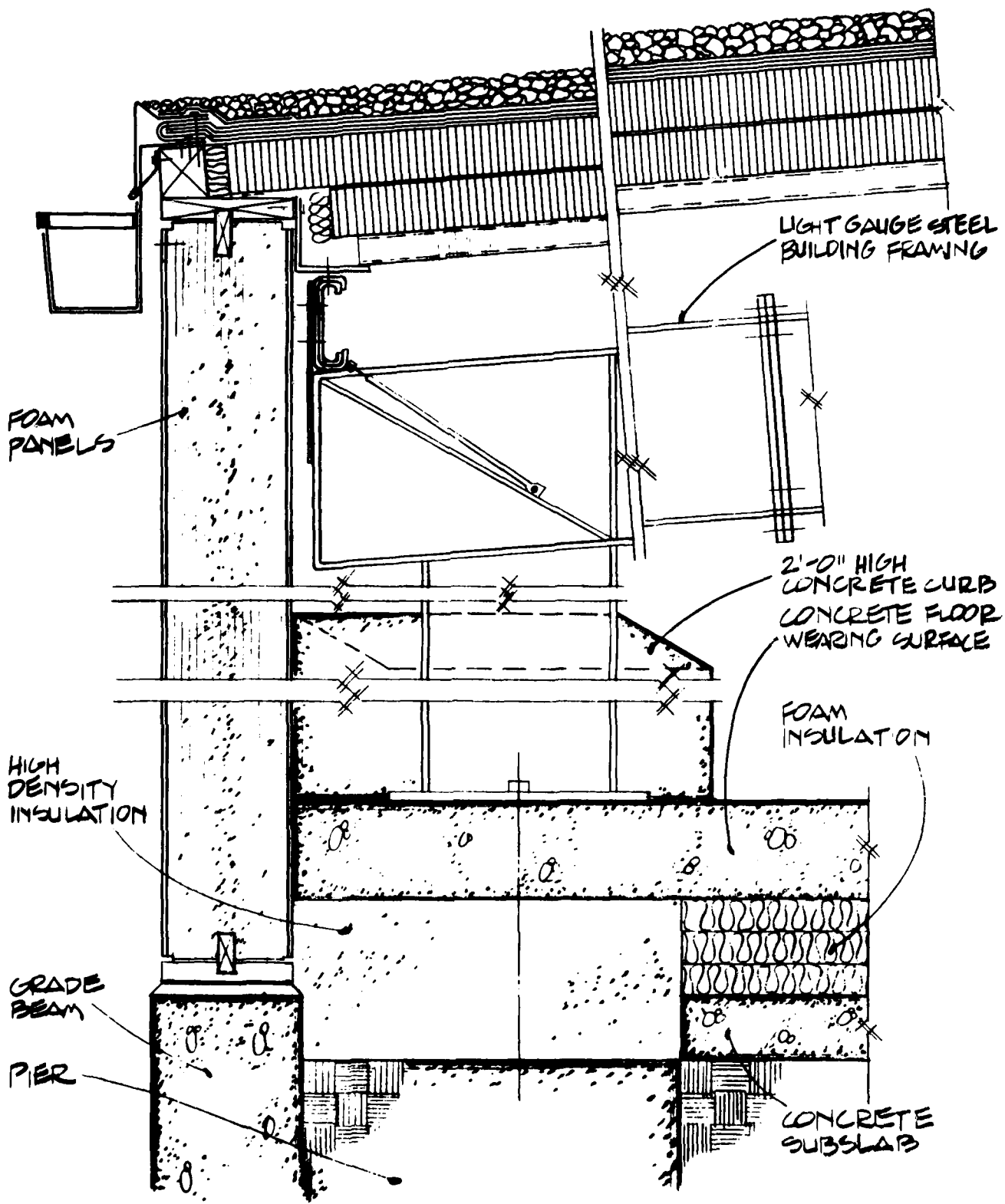
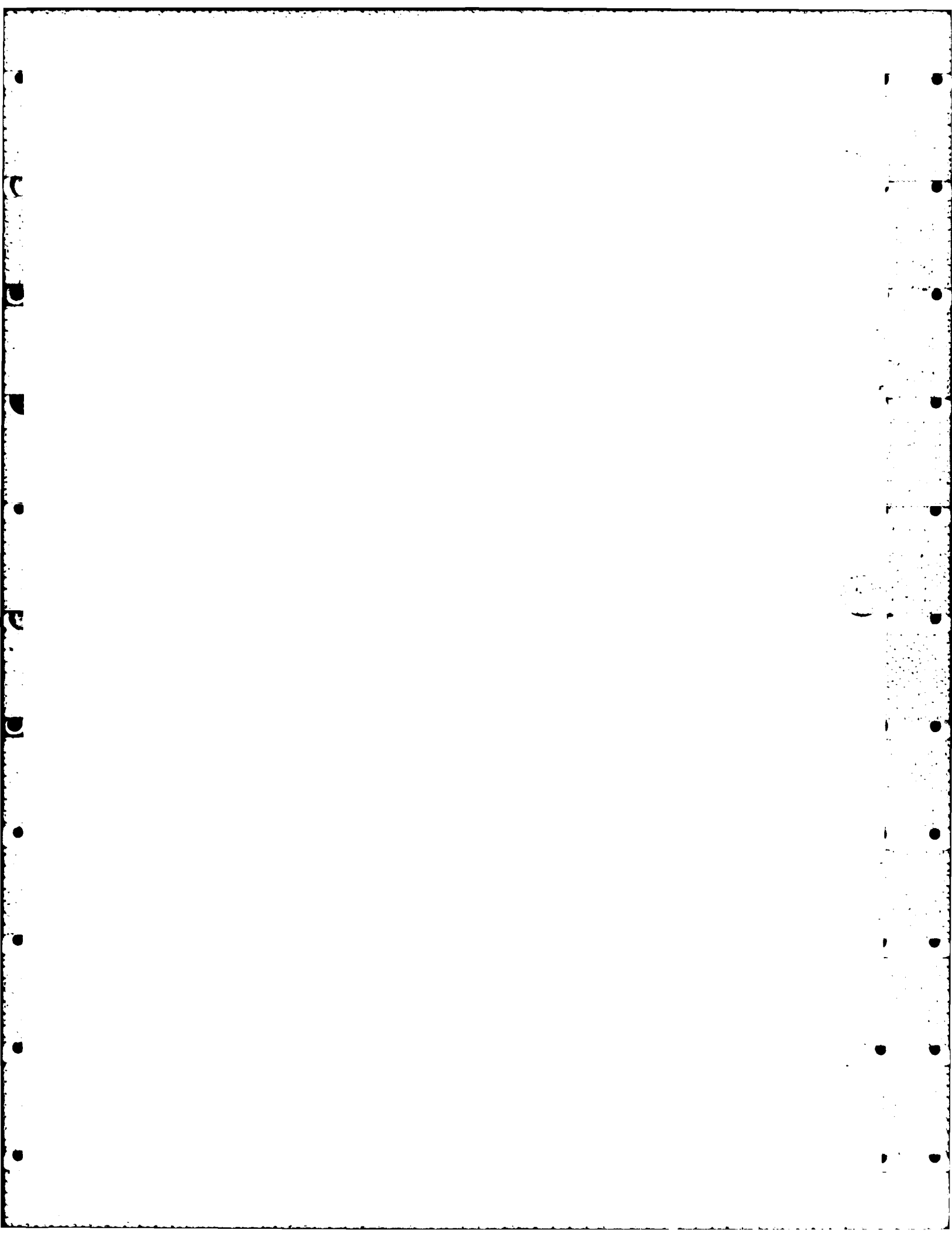


Figure 39
TYPICAL PRE-FABRICATED INSULATED BUILDING



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