Table 1 .... Approximate Space Efficiency for Warehouses of 1–5,000,000 Cu Ft Volume

Type: Coils A, Over Most of Pile Coils B, Large Proportion in Aisle	% Piling to Gross	
	Sq Ft	Cu Ft
Multistory, sprinklered, coils A, heavy	80	57
Multistory, sprinklered, coils B	76	60
Multistory, sprinklered, coils A & B	81½	66½
Multistory, sprinklered, coils A & B	75	59
Multistory, unsprinklered, coils A & B	77	63
One story, wide aisle, coils A	73	57

two low ceiling areas adjacent to one high ceiling area, or one moderate height and one high ceiling floor. A basement may be provided below the freezer area to provide space for utilities and cooler space.

For many years the accepted refrigerated warehouse plan was a basement and 3 to 12 or more floors above, with heights from 10 to 12 ft, floor to floor, and piling heights from 7½ to 10 ft. These multi-story houses comprise by far the majority of existing operating space. However, new materials and methods of construction, plus mechanized product handling are tending to give the one story, or modification of the one story, the *maximum* capacity per dollar of investment with a minimum of overall operating expense including cost of investment, refrigeration, and labor.

The necessity of developing plant designs to result in a minimum of overall costs has resulted in the practice of restricting office facilities and utility areas to a bare minimum. Platform area is of major importance so as to assure efficiency in the operation of loading merchandise in and out.

BUILDING SIZE DETERMINATION

Size is generally rated in cubic feet of gross refrigerated volume. Auxiliary space and walls are not included in this volume. From a design standpoint, the utility of a warehouse is more accurately stated by its usable piling volume and the resulting load capacity in pounds. The ratio of piling area to refrigerated square feet will vary greatly with floor plan and type of construction, as deductions must be made for interior columns, normal aisles, access to piles of reasonable depth, and clear space for air circulation between walls and piles. Piling area will be between 60 and 80 percent of refrigerated area, with 70 to 80 percent good for public warehousing. Piling height should be not less than one foot below overhead obstructions such as coils, sprinklers, or beams. Usable height will be from 70 to 90 percent of floor to ceiling, resulting in a piling volume of from 40 to 65 percent of gross refrigerated volume, with from 55 to 65 percent good practice for larger public warehouses (Table 1). A public warehouse carrying a variety of goods will average from 17½ to 22 lb per cu ft of piling volume on a net weight basis. Individual commodities may be as low as 6 lb or up to 45 lb per cu ft. Design for expected tonnage of goods to be stored is preferable to broad use of gross refrigerated volume.

Ceiling heights should be sufficient to allow for ample air circulation above the pile. The space above the pile will vary with the type of refrigerating equipment from one ft for an unobstructed ceiling to three ft or more with overhead coils, ducts, and sprinklers.

There is wide deviation among experienced warehousemen as to what piling heights are most desirable for overall economy. Height ranges from 6½ to 20 ft are suggested. The

Table 2 .... Piling Heights Using Pallets Without Auxiliary Support

Commodity	Units High in Pile	Pallets in Pile	Over-all Height, Ft
Eggs, wood cases	12	3	14½
Apples, boxes	12	3	13⅜
Grapes, lugs	21	3	14¼
Canned goods, cartons		3–4	15–18
Tierces, on end	4	4	13
Cans, 30 lb	12	3	14¼
Butter, 63 lb cubes	12	4	14
Butter, 63 lb cubes	12	6	15
Frozen fruits & vegetables, cartons		3–4	15–18
Frozen juice concentrate, cartons		4–5	18
Turkeys, boxes approx. 100 lb	18	3	13½–15
Boned meat, fiber cartons, if flat		3–4	13–15

differences are derived from the type of commodities handled, size of lots, and movement. The 8 to 10 ft range of the typical multi-story building has many adherents as an efficient height for either hand or mechanized handling.

An impressive brief has been made for the 6½ ft height to provide for mechanical handling of pallets, one high, to be moved with light equipment in a multi-story building designed for 150 lb per sq ft floor loading.

On the other side are many proponents of high piling, from 14 to 20 ft. The differences generally reflect the class of commodities stored, but some of the high piling group feel it worthwhile to make use of crates, braces, pallet corner irons, pallet racks and other devices to obtain height for commodities which do not pile well. It has also been brought out that, in the one story building additional height above 14 ft involves only the added height of wall and columns with comparatively small cost of construction and added refrigeration load. Therefore, even partial use of such added height can well be profitable. Commodities best suited to high piling are solidly packed cartons, rigid boxes, 30 lb cans, or smaller cans in cartons, and barrels. The use of braces and other equipment allows high piling of many other commodities and packages, but at more cost for additional warehouse equipment, labor, and lost productive piling volume because of the pallet area occupied by such devices.

Piling heights resulting from the use of pallets only for some large volume commodities are listed in Table 2.

INSULATION

The method and materials used to apply insulating materials to walls, floors, and ceilings need careful consideration. The main object is to secure an insulation envelope which offers a maximum of resistance to heat and moisture penetration. This requires adequate and good quality insulation, and a good vapor seal on the warm side of the insulation. It is well to emphasize that no insulation is better than its vapor seal, but some insulations are impervious to water vapor transmission. It is still important to waterproof joints.

Once the water vapor passes the vapor barrier, a whole series of events begin to take place, all of which are highly detrimental to the refrigerated warehouse and its operation. For example, during warm and humid weather with accompanying high dew-point temperatures, the water vapor mi-

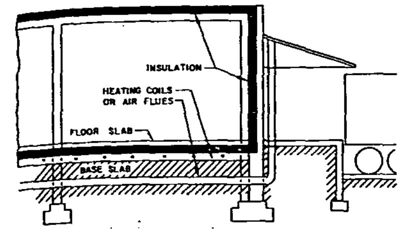

Fig. 2 .... Typical One Story Construction

grating through the insulation will be chilled to its dew point somewhere in the insulation, and will condense to water. In the case of a cooler, the insulation will remain wet; while in a freezer, ice will be formed. In both cases, the value of the insulation will gradually decrease until it is finally completely destroyed.

Part of the water vapor entering the insulation, after condensing or freezing, will revaporize or sublime. This vapor may again condense as it advances from the warm side to the cold side of the insulation. Additional infiltration moisture follows and thus the insulation gradually becomes less effective because of moisture buildup. Some moisture passes into the refrigerated space and collects on the refrigerating coils, but this action is not usually sufficient to dry out the insulation.

In the case of walls with insufficient insulation, the dew point of the migrating water vapor may, during certain periods, be reached at the inside wall surface and result in condensation and freezing at this point. This can also happen to a wall which originally had adequate insulation but which, through water or ice formation in the insulation, has lost its insulating value. In either case, the ice deposited on the wall will gradually push the insulation and its protective covering away from the wall until finally the whole insulation structure collapses.

A discussion of the value of protecting the insulation would not be complete without emphasizing the importance of water tight roofs with well designed and constructed flashings, water-proofed or water repellent walls, etc., all of which should receive thorough consideration.

Experience with various designs and kinds of insulating material applied to refrigerated spaces indicates that the greater the care used in its installation and in its protection from damage through exterior causes, the longer will be its life and usefulness.

Consideration is now being given to free standing insulation walls where no masonry is used. Inside buck-stays can be used to provide structural support for the walls. The warm side of the insulation is, therefore, left exposed for application of the vapor barrier and later maintenance repair if this becomes necessary.

Insulating materials preferably should not be placed on ceilings but on the floor or roof above. If that construction is not feasible and the insulation must be installed on a concrete ceiling, the first layer should contain wooden strips fastened to the ceiling to which the insulation can be securely nailed besides being suitably adhered in place.

Methods of application, and the structure to carry the insulation will vary with the type of insulation, but with each, skill of application and attention to effective air and vapor seals are essential to continued effectiveness.

Advisable thickness of insulation varies with average and extreme temperatures of the location, but is somewhat more than would give minimum cost of insulation and refrigeration. The additional protection is advisable to avoid localized warmer areas.

Insulation and vapor barriers are discussed in Chapter 22 of the 1961 Guide And Data Book.

CONSTRUCTION TYPES

Mill construction has been used formerly because of its initial low cost. The fact that this construction is not fireproof is a major fault. Also, after 20 years or more, the upkeep becomes high. Failure occurs when woodwork is exposed to dampness, especially where beams and girders pass through the insulation and rest on the bearing walls, or exterior columns, if any. It is now customary, in repairing such structures, to water-proof the ends of beams and girders where they pass through insulated enclosures.

Curtain wall construction, as shown in Figs. 2 and 3, is distinguished by the fact that the exterior columns of the building are split, the outer walls being carried up independently of the rest of the building. The floors, roof, interior columns, and the inner portion of the wall columns form one structure which is surrounded by the independent exterior walls. The insulation forms a continuous envelope between the building proper and the outer shell and is applied on the inner face of the outer shell.

Split columns are also often used at stair and elevator shafts and between the various sections of a large warehouse to provide as nearly as practicable an unbroken and unpierced insulation envelope. Even in this type of building, compromises must be made, as it is impossible not to pierce the insulation envelope with the building construction at some points.

While insulation for buildings of the curtain wall type is in most cases applied in sheets stuck to the curtain and partition walls, a number of buildings of this type have been insulated with loose fill material. The curtain wall should have a posi-

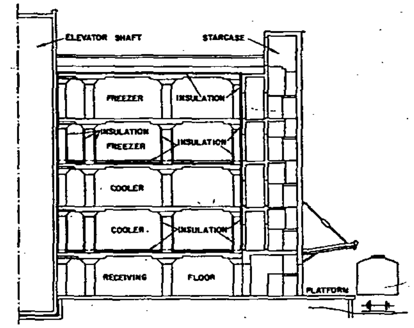

Fig. 3 .... Section of Multi-Story Building with Curtain Wall Construction