Table 3 .... Average Daily Refrigeration Loads in Tons of Refrigeration, by Months[a]

A = One story, 2,000,000 Cu Ft; 90% Freezer or Convertible
B = Multistory, 3,500,000 Cu Ft; 75% Freezer or Convertible

Month	Warehouse A			Warehouse B		
	Total	Product Freezing	Balance: Leakage and Misc.	Total	Product Freezing	Balance: Leakage and Misc.
Jan.	131	59	72	169	41	128
Feb.	110	31	79	183	39	144
March	116	36	80	230	55	175
April	118	29	89	232	56	176
May	131	32	99	254	45	209
June	175	45	130	348	43	305
July	162	34	128	315	16	299
Aug.	151	28	123	269	9	260
Sept.	144	24	120	233	13	220
Oct.	127	28	99	219	12	207
Nov.	132	36	96	201	16	185
Dec.	160	80	80	199	68	131

[a] For midwestern United States.

Heat from goods received for storage can be approximated from the quantity expected daily and from knowing the source. Generally 10 to 20 F deg of cooling can be expected but for some newly processed items, and for fruits and vegetables direct from harvesting, 60 F deg or more cooling may be required. For general public cold storage, this load should run 4 to 8 tons per million cu ft, allowing for items received direct from harvest in a producing area.

Heat is produced by many commodities in cooler storage, principally fruits and vegetables. This heat of respiration is a sizable factor even at 32 F and is a continuing load throughout the storage period. For further information, see Chapter 65 of the 1961 GUIDE & DATA BOOK and Chapter 46 of this volume). Refrigeration loads should be calculated for maximum expected occupancy of such commodities.

The refrigerating load to be provided for freezing will vary from zero for the purely distribution warehouse, to the major portion of the total load for a warehouse near a producing area. In such areas a large portion of the storage load may be obtained because of the availability of freezing facilities, or because storage may even be secondary to the freezing operation. The freezing load will depend on the commodity and the temperature at which it is received. Allowing 1 ton of refrigeration per ton of product frozen per day in still air, and allowing 1.3 to 1.6 tons per ton of product frozen per day in blast freezers, will approximate the actual requirements. This should be based on maximum daily receipts to be frozen. Daily and yearly loads will be in proportion to the quantity received and practically independent of outdoor temperatures.

Operating experiences of two warehouses during one year are tabulated in Table 3. The first is a one story building; the second is an older multi-story building with a refrigerated volume of approximately 3,500,000 cu ft. Loads are averages for the period. *Higher daily loads, which may be twice the average, will occur during each month because of variations in outside temperature, quantity of goods handled, and weight received for freezing.*

REFRIGERATION SYSTEM SELECTION

Direct expansion refrigeration systems are used almost exclusively in modern design. The refrigerant is either controlled by thermal valves or recirculated with a pump from an accumulator system. This system is relatively more advantageous for heavy concentrated loads, such as blast freezers, and is usually preferred for room unit coolers with forced air circulation.

The indirect brine system has advantages in simplicity of operation, ease of control, avoidance of possible leakage of refrigerant into storage areas, and other factors which, in practice, tend to offset the savings of the direct system. Brine is particularly desirable for convection coil installation and for widespread systems. However, the high initial and operating cost of a brine system has almost eliminated this system on new construction, although it is still in use in many existing warehouses.

The refrigerant used is generally ammonia. However, one of the halocarbon refrigerants may be used where circumstances dictate. Refrigerant 12 has been used on several installations in recent years. The initial cost and operating cost are slightly higher than with ammonia equipment, but this additional investment in some cases is justified to meet local conditions.

ROOM COOLING EQUIPMENT—AIR UNITS

Heat transfer equipment in the storage or freezer room in present practice is almost universally units with fans for forced air circulation. The additional refrigeration load and attending operating cost increase is more than offset by the saving in initial investment over an installation with conventional bare or finned pipe coils hung from the ceiling, and the costly defrosting procedures.

Diffusers or unit coolers may be of the *dry pipe* type with plain or extended pipe surfaces, or of the *spray* type. If properly designed for the service, they will refrigerate these spaces efficiently and hold the perishables without damage. Since forced air circulation is used in this design, it is more important that the cooling surfaces of the units be of sufficient extent so that a small temperature difference can be maintained between the circulating air and the refrigerant. It is also important that air temperature drop through the coil be small to maintain high humidity in the room. Experience has shown that the air of a forced air circulating system must be at a higher relative humidity than the air circulation by convection currents. Otherwise, perishables will lose much moisture.

Regardless of the type of air units selected, the air distribution is of utmost importance. For uniform temperature, and air motion, room coils widely distributed over the ceiling give the most nearly ideal results. When using air units, the air should be distributed as nearly as possible to simulate the conditions secured with pipe coils. Ducts, mounted as high as possible in the room, with slotted outlets have been used in many installations to secure these results. Not only do temperature conditions in the room justify proper duct distribution, but they are needed for the comfort of the personnel working in the rooms. This is highly important for a stable working force.

Multiple installations of dry coil units to secure air distribution without ductwork has been used. The quantity of air circulated per ton of refrigeration with this system is considerably higher than required for sprayed unit systems. Proper application is therefore highly important. For single story buildings, penthouse installation of sprayed units with duct distribution of the air has been used successfully to more fully utilize all floor space in the storage area.

DEFROSTING METHODS—AIR UNITS

Removal of frost from the cooling surfaces of the dry pipe type diffusers is accomplished by spraying water over them, by hot refrigerant gas, by bypassing warm air over the coil while the unit is isolated from the cold space, or by electric heating. These methods of defrosting find application for this type of diffuser whether placed in coolers or freezers. Piping or other means must be provided for supplying defrosting spray and removal of liquid and frost.

To eliminate defrosting and to maintain cooling efficiency, spray type diffusers are often chosen. For coolers maintained at temperatures near the freezing point, a common salt solution is sprayed over the cooling surfaces. Salt must be added from time to time in the basin at the bottom of the unit so that the freezing point of the solution is kept below the temperature of the refrigerant. A glycol type spray may be used in either coolers or freezers. Glycol spray systems include a concentrator at each unit or one centrally located for several units to maintain proper concentration of the spray by evaporating excess water picked up from the storage room air. The concentrator may be heated either with steam or electric power. Operation costs on spray units should include costs of salt or glycol plus heating and maintenance requirements.

ROOM COIL INSTALLATIONS

Where local conditions or individual preference justifies pipe coils, plain or finned, several characteristics should be considered in selection and arrangement.

Ceiling coils in freezer space have a long life and are simple and economical in operation, requiring no fan maintenance or cost for fan power. Defrosting of coils is more difficult and requires more labor than for unit cooler types, but it is required much less frequently. In many operations defrosting is required only once or twice a year with prime surface coils. Coil efficiency deteriorates and temperature difference increases as defrost time is approached. Coils in cooler rooms should be concentrated in aisle areas to avoid the possibility of drip damage in rooms above 32 F. This concentration will also provide the moderate circulation required for removing the heat of respiration and for controlling the humidity and other atmospheric conditions required by stored products; and it will facilitate defrosting. Freezer coils may be concentrated in aisles or arranged one or two pipes deep over the room area. The objections to the latter arrangement in coolers do not apply to freezers, except when defrosting. As compared with plain pipe, use of finned pipe will reduce the lineal feet and weight of coils, but their installed cost, relative to that of plain pipe, may vary depending on local conditions. Finned coils will usually require more frequent defrosting than plain pipe coils.

FREEZING FACILITIES

In private refrigerated warehouses, provisions for freezing fresh perishables are normally a part of the processing before the product is moved into the warehouse. In public warehouses there is frequently a demand for rapid freezing of some products brought to the warehouse. This requirement can be met with a blast freezer as a portion of one of the freezer spaces, or by still air in one of the freezers for those products where rapid air velocity is not recommended. Semi-permanent partitions to separate a portion of the freezer space with provisions for circulating higher air quantities should be sufficient to meet this part time requirement in most cases. However, the anticipated freezing load should be examined carefully if it represents a substantial volume, as a separate permanent freezer facility should be installed, if justified, so the normal freezer storage operation is not penalized.

REFRIGERATION PLANT EQUIPMENT

Refrigeration plant equipment should be designed for maximum load of the plant. All equipment should be in multiple units to provide for economical operation at light loads, and for continuity of operation in case of failure of one unit.

For temperatures below 0 F, two-stage compression should be used. This may be by compound compressors having capacity control on each stage. But for variable loads of the refrigerated warehouse, separate high stage and low stage, or booster, compressors are recommended. Each should have capacity control or the units should be of different capacity for balancing both high stage and low stage operating conditions. If blast freezers are included, pipe connections should be arranged so sufficient booster capacity for the blast freezers can be operated at a lower suction pressure, while the other booster capacity is at higher suction pressure for the freezer room load.

In a two-stage system, provision should be made for precooling the liquid refrigerant at the high stage suction pressure. This will reduce the low stage load by 10 to 20 percent with a worthwhile power saving on that portion of the load. A good automatic purger to remove air and other noncondensable gases from the system is essential. For ammonia plants it is advisable to have an oil separator connected to all points of the refrigerating system where oil may accumulate, including traps on compressor discharge, condensers, intercoolers and evaporators, so that oil may be removed periodically without loss of ammonia.

WAREHOUSE COSTS

The cost of construction of refrigerated warehouses has risen rapidly in recent years along with general building costs. These, particularly for the structure, vary for different sections of the country.

Most recent construction has been one story buildings with