COLD STORAGE CONSTRUCTION AND OPERATION AS PRACTICED BY OHIO FRUIT GROWERS

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In Ohio we have two types of storages differing in construction and cost. One is the low cost wood frame constructed building usually using aluminum corrugated reflective insulation, ("Infra" is best known) and its cost is about one-half that of the other storages which are usually constructed of concrete block and using board forms of insulation. These facts are important since we believe it is possible to build a very good refrigerated storage using lumber with 2 x 4 inch studs and reflective insulation. We believe such a storage will last for a long time and retain its heat insulating properties if properly constructed and maintained from year to year. This is especially true if transite or asbestos cement type sheeting is used, especially on the exterior. Also the insulation must be the heavy or thick grade and be installed tightly by the use of wood furring strips. This material never loses its insulation value, but if it is not fastened very tightly to the wood members, warm outside air will readily infiltrate past the flanges, and through no fault of the insulation the refrigeration power bill mounts fast.

The more expensive type storage using cement blocks may retain some of the low cost of the former storage by again using the reflective type insulation. However, to do this it is necessary to use studs fastened to the block walls to hold the insulation and this doubles the cost of the insulation. For this reason, the block forms of insulation are popular for such buildings.

INSULATION.

Each phase of construction will be discussed somewhat thoroughly in the following paragraphs. Reflective insulation stops almost all of the radiant heat passing through a stud wall or air space and this means 60 to 80 percent of the total heat passing through a wall, ceiling or floor. Ohio growers like the corrugated type since it is easy to install and low cost when installed. The three-layer material is equivalent to about 4 inches of board type material and costs only 8 to 9 cents per square foot. Installed properly, it might cost 15 cents per square foot. This is about one-fourth the cost of comparable insulation in the board form. The building wall required is sufficient to hold the insulation and thus cannot be charged to the insulation as is the case in some other types of buildings. It is affected by alkalies and some metals and thus care must be used in such matters as nailing (aluminum nails) and keeping it away from other surfaces where it would lose much of its insulation value. It is interesting to know that many large storages in the northwest use this material exclusively. It is replacing the formerly used low-cost loose-fills which were difficult to keep dry. This does not, however, preclude the use of loose-fills where

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newer-type vapor seals are properly used and installed. The fiber insulation people now know how to do an excellent job and the materials have their place in storage construction.

When our growers want a storage with low up keep and insurance cost and a long life, they go to block walls and block-type insulation at a little greater cost, but probably well justified. Our growers have also discovered the value of light aggregate blocks over sand and gravel blocks with some 45% improvement in insulation value. This can be increased to 77% by filling the cores with ground cork. Usually they use the same aggregate of which the block is made. This then supplies as much as 1.5 inches of corkboard equivalent.

For insulation on these block walls, we like the newer expanded plastics since they are water and nearly vapor proof and thus eliminate the vapor-proofing required by many other types of insulation. They are known by their trade names such as, Dylite, Styrofoam, Dyfoam, and Armalite with heat flow factors as low as .23 which is somewhat better than corkboard .28 to .30. Their cost is also very competitive, from 13 to 15 cents per board foot. They are very light weight, easily installed with mastic or even cement mortar by growers themselves. They have fire-retardent forms and may be left exposed, but it is wiser to protect the inside surface with cement plaster. They are still cheaper than corkboard, especially since they can be used in two-one and one-half inch layers with the joints between boards overlapped. This 3 inches is very close to the standard 4 inches of corkboard or its equivalent. With the light weight aggregate blocks, the storage is very well insulated.

In a discussion of insulation there is one matter too often neglected. Joints at ceiling and floor junctions with the walls are critical points for heat entrance and the joints should all be staggered so they are well insulated and moisture vapor tight. Twenty five percent more insulation is used in the ceiling unless there is an air space between the insulation and the roof which can be fan-ventilated to lower the temperature over the insulation to at least the out-door temperature. With reflective insulation, this is not necessary since with down-flow of heat this insulation retards heat flow 50 to 60% better than on the walls.

Since the insulation of a storage floor can be quite costly, Ohio growers have tried various methods of reducing this cost. USDA researchers in the northwest tell us that it can cost from $1.00 to $1.25 per square foot to lay a sub floor of concrete and 3 inches of board form insulation. It becomes difficult to justify insulating the floor when we realize that dry ground will act as a fairly effective insulator. This depends upon two very important considerations, however, the water table must be generally below 10 feet from the surface, at least for a substantial portion of the season, that is during all of the storage season as a minimum, and the storage must be cooled down in advance of loading so that the heat may be pulled out of a substantial layer of earth beneath the floor. As the earth is cooled to greater depths, it places a greater heat resistance in the path of heat flow from the warm earth several feet below the surface of the floor.

Since heat transmission rates at the wall due to lateral movement of heat may be 5 to 6 times greater than at a distance of 5 feet in from the

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wall. This is partially overcome by extending the wall insulation down to the footer. A preferable method is to extend or continue the wall insulation laterally under the concrete wearing floor for 2 or 3 feet. In a storage so treated in the northwest, calculations indicate that the total cost of added refrigeration equipment fixed charges plus operating charges due to additional heat leakage from the uninsulated floor would justify an investment of approximately $0.40 to $0.50 per square foot to insulate the floor with the equivalent of 3 inches of board form insulation.

In Ohio we have endeavored to save money by using vermiculite-cement mixtures or vermiculite alone for floor insulation. In view of the data above, we have probably saved money over board-type insulation. However, the workers mentioned above have shown that comparing perimeter insulation with 9 inches of pumice concrete, the latter would not justify an investment of more than $0.13 per square foot. Actual cost of such floors is several times this amount. We must remember that if the water table is to be above 10 feet below the floor surface, it is necessary to use floor insulation. The easiest and cheapest way of waterproofing the insulation is to use polyethelene on the ground before placing the insulation. This should water and vapor-proof the insulation and eliminate the necessity of pouring an expensive concrete sub-floor. The plastic board forms of insulation are unexcelled for floor insulation due to their closed cellular structure that is impervious to moisture.

Although more data is still needed to reveal the full facts, those of you who are engineering minded might be interested in some data now available. Using a 40 x 60 x 12 foot storage of 10,000 bushel capacity, we can calculate that the cost of a concrete sub-floor and 3 inches of board form insulation might cost from $2400 to $3000 and the same storage floor with only a 3 foot insulated perimeter would cost from $600 to $750. The USDA figures show an uninsulated floor having a conductance of 0.1, but they are inclined now to use a figure of 0.15. Using an earth temperature of 60° and a storage temperature of 32°, this means that temperature difference across the floor would be 28°. The product of these two figures gives the heat flow per square foot of floor per hour of 4.2 Btu. We can only guess that perimeter insulation will reduce this by 50%, but since we have no data at present, it could be considerably lower than this. If we accept the 50% figure, this means that for a perimeter insulated floor, the figure would be reduced to 2.1 Btu. The figures obtained in only a few storages in the northwest are, 0.62 for a 3 inch cork insulated floor, 1.40 for a floor insulated with 12 inches of rolled pumice and 1.9 for a 9 inch concrete-pumice insulated floor.

REFRIGERATION.

There are several rules in selecting refrigeration equipment for apple storages that dare not be ignored if high humidity and low temperatures are to prevail. Ohio growers have found to their sorrow that you only get what you pay for and this means engineering ability more than anything else. There are no short cuts in this business, but there are legitimate methods of keeping costs down and still do an excellent job of cooling apples. Most of these methods are in the hands of the grower such as slower loading rates, loading night-cooled-out apples etc. It is the slow rate of cooling the fruit that makes all the trouble, for unless you attempt to cool each day's loading to design room temperature, the accumulating heat of respiration load soon accedes the capacity of the refrigeration system and you are lost

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unless you suspend loading for a day or so. Fortunately for the grower, fast cooling is actually cheaper in the end than slow cooling since delayed cooling adds about 50% to the respiration heat load and a sizable percentage to the total load for which the equipment is originally purchased. We shall discuss these items in connection with parts of the system.

EVAPORATORS OR COOLING COILS.

Ohio growers favor and have received good results with ceiling mounted cooling coils even in the largest storages. Due to the fact that the storage is held at close to freezing temperatures, the problems of frosting of the coils, removal of water on the coils and relative humidity in the room are greatly increased. There is only one way of maintaining high relative humidity in storage rooms and securing the maxiumu possible refrigeration from the system and that is to install large coils (ample number) of wide fin spacing (no more than 4 fins per inch) operating on a low or narrow temperature difference between the coil temperature and the return air temperature. It has been well established that with a constant air flow, the over-all coefficient of heat transfer, U, of the coil first increases as the frost begins to collect and then decreases as the frost thickens. The magnitude of the decrease in the U value would not generally be of concern in a refrigeration system. The reduction in air flow that would occur in an actual installation due to frost restricting the air passages lowers the efficiency of the refrigeration plant. The drop in air flow rate serves as the best guide of the adverse effect of frost on coil performance. If two coils have equal over-all dimensions, the coil of close fin spacing is more efficient than the one of wide fin spacing when the accumulation of frost is light. As the frost builds up, the trend reverses and the wide-finned coil becomes more efficient. This reversal is due to the excessive drop in air flow across the coil of close fin spacing as the frost accumulates. If a wide-finned coil and a close-finned coil are selected to give equal performances at frost-free conditions, the wide-finned coil will allow a higher refrigerant temperature at all conditions of frost and will therefore be more efficient. Therefore, in selecting a coil for an actual application, it is desirable to oversize the coil if it is to be operated at frosted conditions. The larger coil allows a higher refrigerant temperature and permits a longer period of operation before de-frosting is necessary. If the coil selection then is based on holding conditions of a maximum of 8 to 10 degrees between the coil and the return air temperature, off-cycle defrosting and high humidities in the room will prevail. Then during the loading period, more refrigeration may be obtained by widening the coil-to-air temperature difference a few degrees and resorting to time-clock or other type of positive defrosting. If there is one thing that gives trouble with an apple refrigeration system more than all else, it is the fast accumulation of frost. This reduces the air flow through the coil, the coil picks up less heat and thus becomes colder and hastens the frost accumulation. Frequent defrosting is not the answer, as this also reduces the heat pick-up. The only answer is large coils of wide-fin spacing operated at a narrow temperature difference. It is the best money a grower can spend.

I wish to make two suggestions that might interest refrigeration dealers. One is to design or purchase air static pressure flow controls for defrosting, and the other to use low pressure control valves in the suction lines to prevent too low coil temperatures during the holding period.

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PEAK LOAD DETERMINATIONS AND CONDENSING UNITS.

A rule of thumb for sizing equipment based on storage size might be one ton of refrigeration per thousand bushel capacity with a loading rate of 10% of total storage capacity per day, three-fourths ton per $7\frac{1}{2}$% loading rate and two-thirds ton per 5% loading rate. Since these figures are slightly low for very small storages and may be too large for very large storages, it is expected that the supplier will calculate in some detail the exact loads to be encountered.

The field heat load is always calculated on a basis of the daily loading being reduced to room temperature (32° or 35°) in 24 hours. This is because after the first few days of loading there is a cumulative daily "dead" load equivalent to removing the field heat from each days loading in 24 hours, which lasts until the last day of loading. If less capacity is supplied, the system would lose ground instead of keeping up with the refrigerating load. Even though due to insufficient air circulation around each fruit, the fruit does not cool to 32° in one but in three days, this different rate of pull down does not affect the field heat calculations (dead load) because of the accumulative load, but will affect the live load calculations.

The pull down live load due to respiration of the fruit which dare not be neglected is also cumulative, increasing daily during the loading period, until it peaks the last day of loading at approximately 40 to 50% above the respiration load for the full quantity of fruit stored at design room temperature. Reducing the rate of cooling the fruit, increases the total live load which must be handled. Consequently, the operating expense increases also. However, when it is evident that a reduced rate of cooling will be caused by conditions of poor air distribution, the increased heat load due to the increase of the live load so created must be taken into consideration and additional system capacity provided therefore. This additional load is frequently left out of calculations, and since it may amount to a 20 to 40% increase in live load or 8 to 10% of the total refrigeration load, it has caused many installations to be under-capacitated resulting in room temperature continuing to rise or bad frosting due to attempts to lower coil temperature by stepping up compressor speeds.

We have pointed out that the refrigeration load in apple storages peaks on the last day of loading then drops off rapidly to only a fraction of the peak load. Ohio growers have favored at least two compressors or condensing units for most all storages except the small ones. This includes two-speed motors on one or more of them for still more flexibility. Newer compressors have unloading (automatic) features which serves the same purpose. We have gone so far as to suggest to growers that speeding up one or more compressors above their design speed by means of changing to a slightly larger pulley is justified for the short loading period of 10 to 20 days, thereby obtaining more refrigeration without necessitating the purchase of larger compressors. The use of Freon 22 and a small change in the compressor valves will also allow more capacity to be obtained from a compressor using Freon 12. Finally, our growers often size compressors on the basis of 1/3 and 2/3 total capacity or 1/4 and 3/4 with the idea that if they are cross connected properly, they can be used singly to carry medium and light loads when they occur. They also allow two rooms to be used, one early during the peach season or at any time during the summer with provision for throwing all the refrigeration into one room for fast pre-cooling as each room is loaded. There are unlimited possibilities here.

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MISCELLANEOUS.

A few suggestions that have merit have come out of the practice of apple storage in Ohio and elsewhere.

1. Floor racks prevent floor heat from raising the apple temperature in the bottom crates and aid materially in better air circulation.

2. Dunnage strips between layers of crates also aid in fast cooling, but like floor racks take up much space and are seldom used. Their value cannot be questioned, but many storages operate well without them.

3. Minimum daily loading rates are valuable in lowering the initial cost of the refrigeration system. Uneven loading rates do no harm as long as they do not exceed design daily rates. They can be of great advantage in not overloading the system as overloading one day only raises the storage temperature temporarily with no harm to the system as long as the next day a lighter load is placed in the storage.

4. If at all possible, use swing doors that close after passage of each truck or use small access doors with canvas flap for conveyor loading. Six hours of an open door approximates one ton of refrigeration lost. The books guess at 0.5 ton per normal day of opening and closing.

5. Caulking around all openings (jambs) is cheap and very worth while.

6. Remember: If the air leaving the cooler is saturated with moisture at 25° and the room temperature is 35°, the relative humidity in the storage will be about 64%. Reduce this difference to 5° by raising the coil temperature 5° the relative humidity will be 84%. Using large coils with moderate cooling with each air passage, maintains high relative humidity and gets more work out of the compressors. The trick is to get the air to leave the coil at or within one degree of saturation, if more than this, the coil won't be doing much refrigerating.

7. Air cooled condensers are coming in fast. No more water freezing problems. But don't forsake water cooling if you have low temperature water at low pumping heads, as it will be cheaper and supply you more refrigeration when you need it the most.

8. Remember: Apples keep 25% longer at 30° than at 32°. Room thermostats usually have 2° differentials. We use 34 or 35° storage temperatures so we hold our apples at 33 to 34° and can getautomatic off-cycle defrosting. Defrosting controls are often advisable and are good insurance, and are an absolute necessity at 32° and below.

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