COOLING POTATOES WITH NIGHT AIR, REFRIGERATION, ICE, OR EVAPORATION

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Cooling potatoes in storage is most commonly done with cool night air, and, in many cases, some evaporative cooling. Refrigerated air is used occasionally and, of course, cools very well but is a little more expensive. Ice may, in some cases, be feasible and adequate for short periods of cooling.

From the standpoint of controlling disease or rot organisms, it is advisable to cool the potatoes quickly when they are placed in storage. However, lowering their temperature too far and too fast may interfere with needed suberization or wound healing. It appears that lowering the temperature to 50° F. immediately or within the first 24 hours is most desirable. After suberization is complete, their temperature may be lowered on down to 45° F. or whatever storage temperature is desired.

AMOUNT OF COOLING REQUIRED

Cooling is the removal of heat. The amount of heat to be removed is mainly from two sources, the field heat of the potatoes and the heat of respiration. Other minor sources of heat include the heat that is transferred through the walls and roof, outside air infiltration, and miscellaneous items such as electric motors, tractors, trucks, and men working.

Heat of Product. Field heat within the potatoes is referred to as heat of product. A certain amount of heat must be removed from a tuber at field temperature to bring it down to 50° F. This depends on specific heat which amounts to 0.82 BTU's per pound of potatoes for each degree F. from field temperature to 50° F. Thus to cool a ton of potatoes from 60° down to 50° we will have to remove 2000 lbs. x 0.82 x (60°-50°) = 16,400 BTU's.

Heat of Respiration. Potatoes are living things and as such respire. In this process, they give off heat. The amount of heat given off depends upon their temperature and the amount of wound healing taking place. Figure 1 shows graphically the amount of heat of respiration given off during the first 30 days in storage.

The wound healing period is considered to be the first 10 to 15 days in storage. Suberization or wound healing causes much more heat of respiration than normal so these curves begin high, decrease during suberization and then level out for the long storage period.

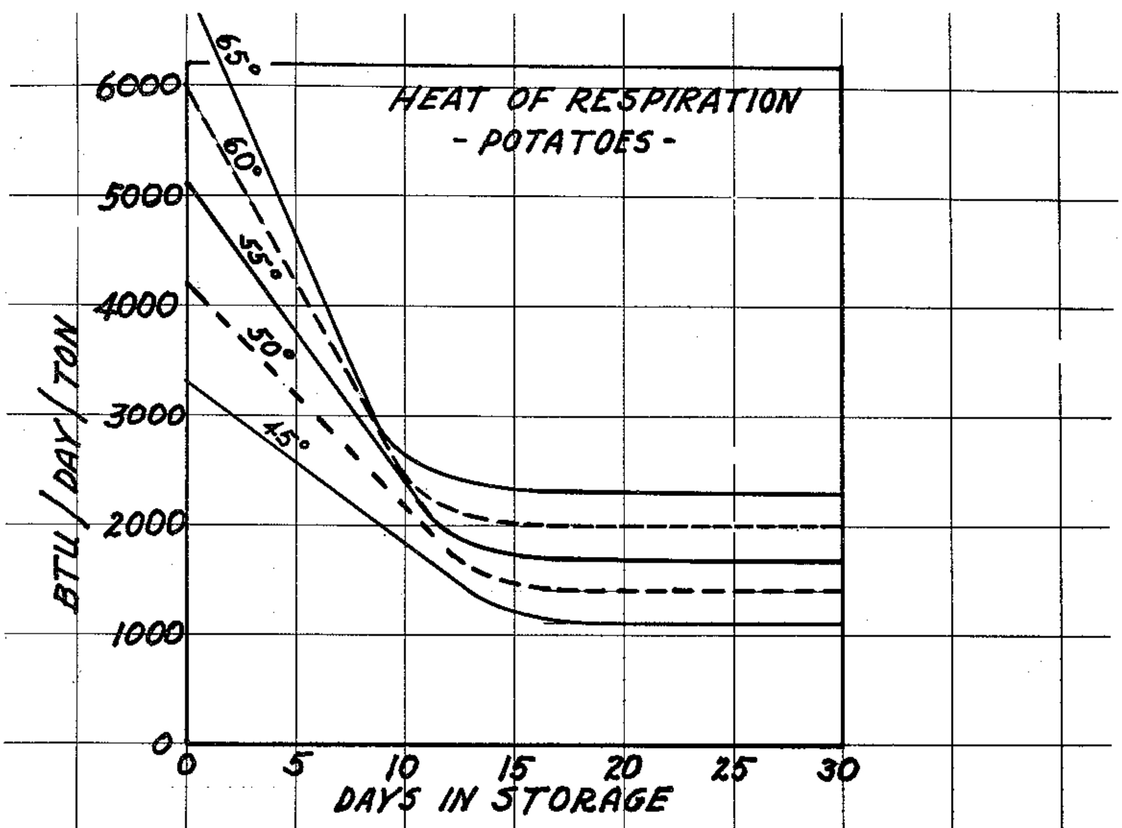

FIGURE 1

Heat of Transfer. Heat gain through walls, roof and by infiltration of air is referred to here as heat of transfer. It depends upon the difference in temperature between inside air and outside air, by the amount of insulation and by the amount of air exchanged between inside and outside. It is also affected by the size of the storage mainly because large storages have less outside surface per ton of capacity than small storages.

Figure 2 gives a factor of BTU's per ton of capacity, per degree of temperature difference between inside and outside for various sized storages. It is based on insulation values of 20 in the roof and 15 in the walls. The heat gain factor, when multiplied by the capacity of the storage and the degrees of temperature difference, will give the total estimated heat of transfer.

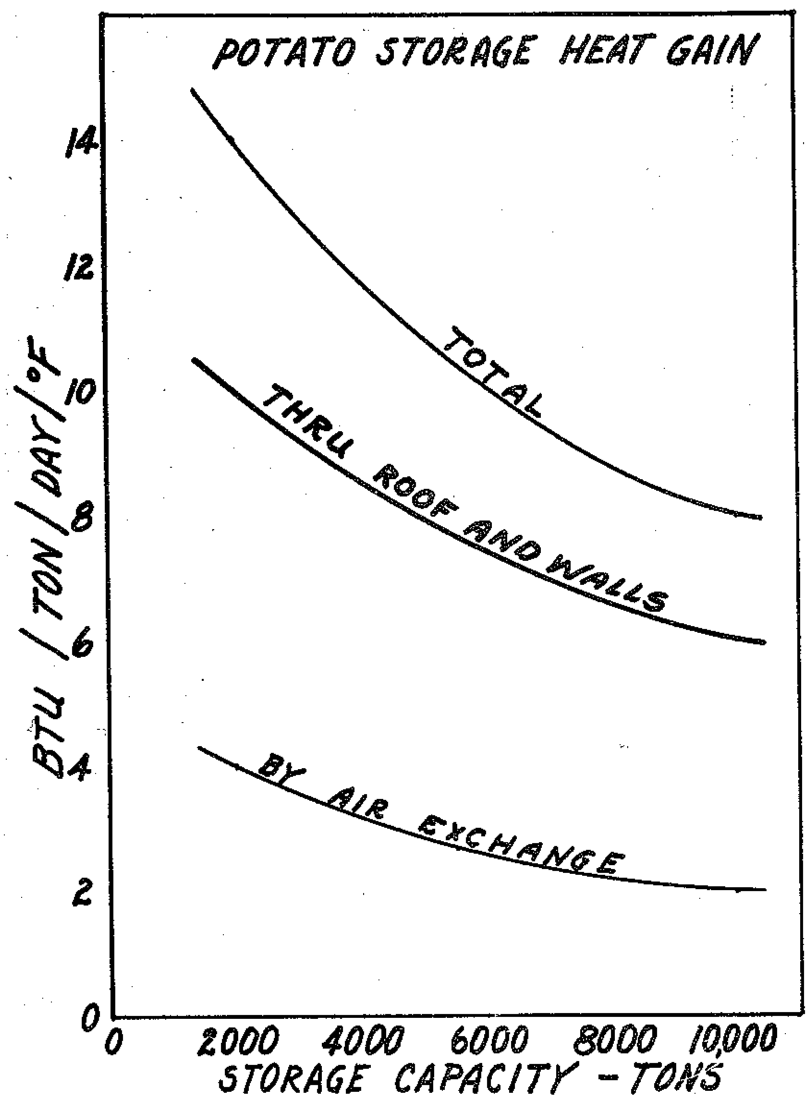

FIGURE 2

Miscellaneous Heat Gains. Other heat sources such as electric motors, tractors, trucks, and men working add heat to the storage. Although not a great deal, this heat, too, must be removed when cooling the potatoes.

Figure 3 puts all the sources of heat together graphically to show the total amount to be removed daily. The amount of heat is shown as the equivalent of "tons of refrigeration". This is merely a more convenient term to comprehend than BTU's because the numbers of BTU's are so large, usually in the millions, in an ordinary potato storage. A ton of refrigeration is equal to 288,000 BTU's per day. The term is also convenient to use for comparison with refrigeration or ice cooling. The melting of one ton of ice requires 288,000 BTU's. The term "ton of refrigeration" comes from this fact.

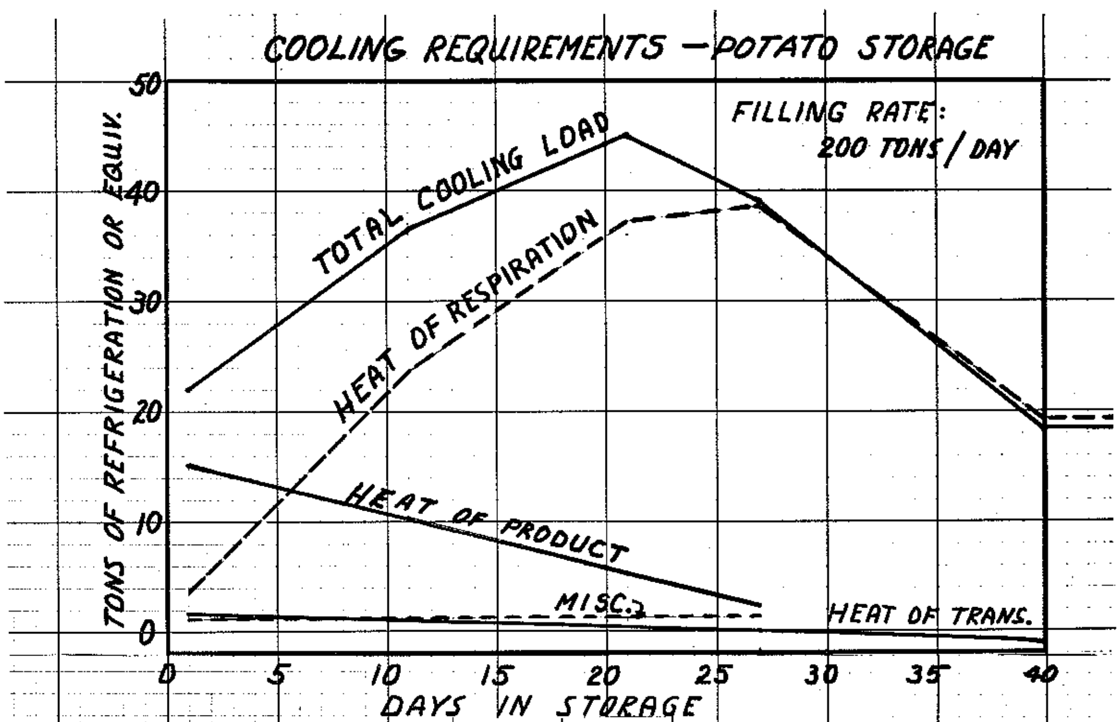

FIGURE 3

In Figure 3, the heat of product line starts high on the first day of storage and gradually decreases. These values are based on the premise that sufficient heat is removed from the potatoes in the first 24 hours to reduce their temperature to 50° F. It decreases every day because normally the average daily temperature decreases. The total amount of heat is based on placing 200 tons of potatoes in storage each day.

Heat of respiration is small the first day because there is only the first 200 tons in the storage. It increases each day as the amount of potatoes in storage becomes larger. On about the tenth day, the rate of increase lessens because the potatoes placed in the first day have completed their wound healing period. In 25 days, at 200 tons per day, the 5,000 ton storage used as an example, will be filled. Therefore, on the 26th day the heat of respiration begins to drop and, since no potatoes are brought in, there is no heat of product to remove. This is continuing the assumption that each day's potatoes are cooled to 50° F. the first day. After about 40 days, when all of the potatoes have completed their wound healing period, the heat of respiration line would continue horizontally during the remainder of the storage period.

Heat of transfer, although only a small part of the total, decreases each day along with the decrease of the average daily temperature. It actually goes negative; that is, heat is transferred out instead of in, when the outside average daily temperature is lower than inside temperature.

The miscellaneous heat gain virtually stops when the storage is full, doors are closed, piler motors, tractors, trucks and workers have been removed.

Normal Daily Temperatures at Moses Lake, Washington. The important months as far as cooling potatoes is concerned are September and October. Figure 4 shows the normal maximum, minimum, and average daily temperatures for Moses Lake, Washington, for these two months. Although the actual temperatures for any year never follow these lines exactly, they do tend to average out as indicated. Long time plans may be made using these temperatures with at least as much accuracy, and probably more, than any other set of temperatures.

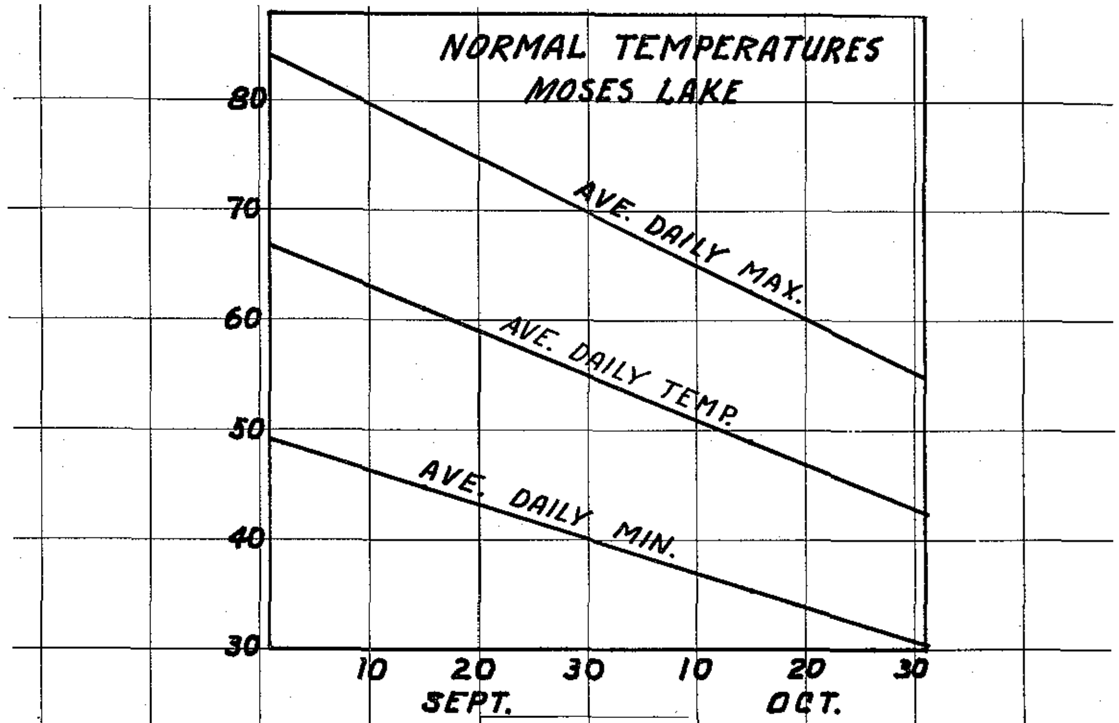

FIGURE 4

AMOUNT OF NIGHT AND EVAPORATIVE COOLING NORMALLY AVAILABLE

Night Cooling. Figure 5 indicates the amount of cooling available from a normal two day period in mid-September. Normal dry and wet bulb temperatures at Moses Lake are the basis. If the potatoes in the storage from a previous day's loading are to be maintained at 50° F., no outside air above 50° F. can be admitted. Thus, only air with a dry bulb temperature (ordinary thermometer temperature) below 50° F. can be used for cooling. In Figure 5, the normal night cooling is only that part of the graph where the dry bulb temperature is below 50° F. The graph measures 22 degree hours of night cooling. A degree hour is 1° below 50° for one hour.

Evaporative cooling. Heat is required to evaporate water. Thus, when water is evaporated into air, the heat must be obtained from somewhere. In the case of ventilating air, about the only source of heat is the air itself. Thus, when water is evaporated in a stream of ventilating air, heat is withdrawn from the air thereby lowering its temperature. The theoretical limit to lowering the temperature is the wet bulb temperature. The wet bulb temperature represents the point at which the air contains all the water vapor it can hold. Thus, no more can be evaporated into it. Therefore, the dry bulb temperature of air cannot be lowered below its wet bulb temperature by evaporation. Actually, on a practical basis, the dry bulb temperature can only be lowered about 80% of the difference between the dry and wet bulb readings, and this only with special equipment designed to obtain the maximum evaporation of water into the airstream.

The lower crosshatched area in Figure 5 shows the theoretical amount of evaporative cooling that would be possible. It amounts to 83 degree hours for a normal September day at Moses Lake.

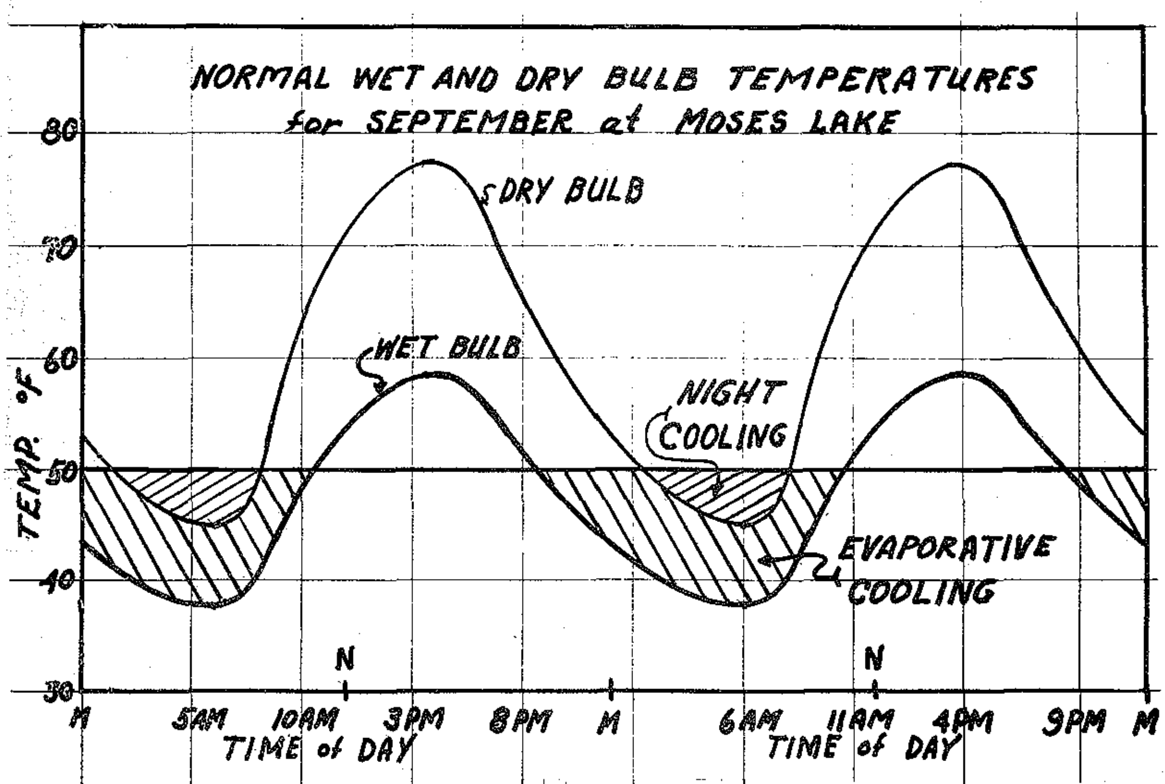

FIGURE 5

Figure 6 shows the normal amounts of night cooling and theoretical evaporative cooling available on typical September and October days at Moses Lake.

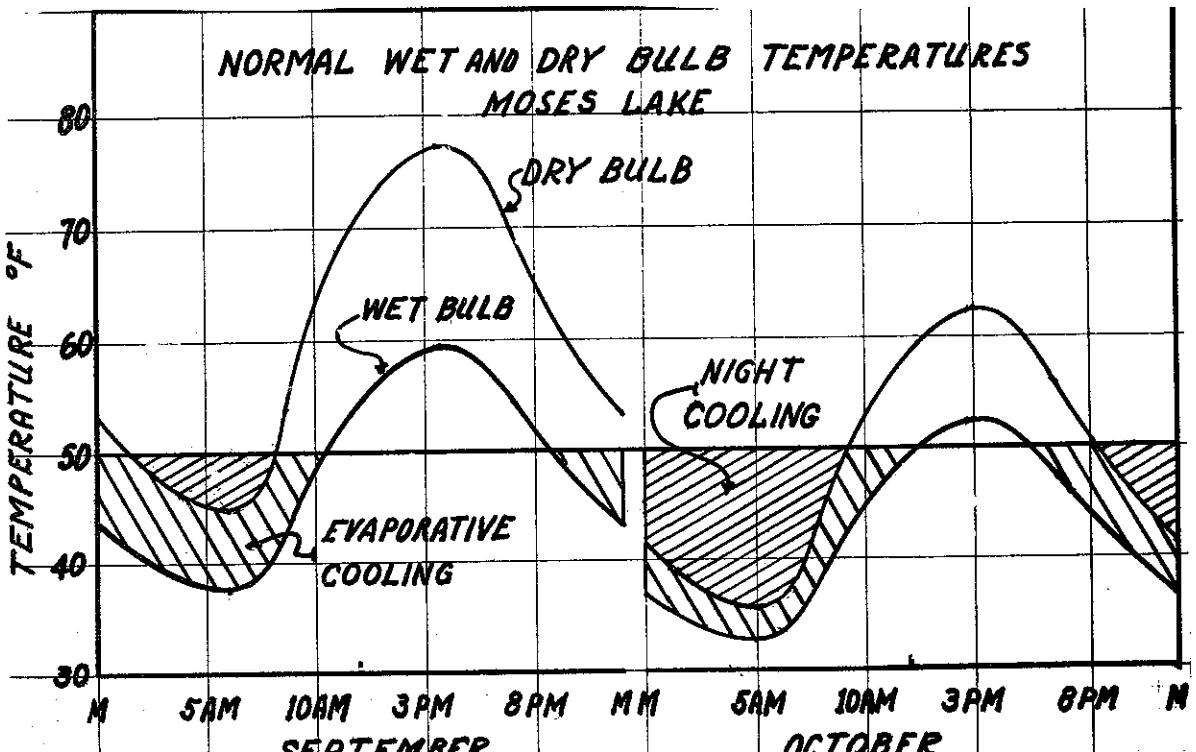

FIGURE 6

COMPARISON OF COOLING NEEDED TO COOLING AVAILABLE

Calculations have been made and graphs drawn for normal storage seasons beginning at two dates at Moses Lake, September 15 and September 25. Figures 7 and 8. In neither case does night air alone provide adequate cooling. However, by beginning on September 25, night cooling plus good evaporative cooling is adequate for the normal year. Figure 8.

The line representing Total Night and Evaporative Cooling should not be taken as a possibility unless special equipment is available to evaporate a large amount of water into the airstream. The Night Cooling is, of course, available in any normal season.

Extra Cooling Needed. The graphic lines in Figure 7 show that even with maximum evaporative cooling, if storage filling begins on September 15, additional cooling would be necessary to cool each day's potatoes to 50^{o} F. The amount of additional cooling each day is the difference between the Cooling Load Line and the Total Night and Evaporative Cooling line. The maximum occurring on October 6 is about four tons of refrigeration--or equivalent. In a situation such as this, ice may offer a solution. For about 16 days, from September 25 to October 11, from 1 to 4 tons of ice per day would be needed. If, however, no evaporative cooling was obtained, the amount of additional cooling needed would be the difference between the cooling load and the night cooling on any particular day. The maximum amount, also occurring on October 6, would be about 12 tons of refrigeration or ice. If refrigeration were to be used without taking advantage of the cooling in night air the full 45 tons of refrigeration would be required on October 6.

By beginning filling of the storage on September 26, and utilizing the full capabilities of evaporative cooling, no extra cooling would be needed in the normal year. See Figure 8.

Evaporative cooling is accomplished by evaporating water into the airstream. This is ordinarily done with a humidifier or by forcing air through a wet pad. To obtain the evaporative cooling indicated for October 15 in Figure 8 would require the evaporation of 76 gallons of water per hour into the airstream. It is assumed the amount of air is based on current recommendations of 17 cfm/ton or a total of 85,000 cfm for this 5,000 ton storage.

Thus far, charts and calculations have been based on normal weather, a situation that never really happens. The last two years, '68 and '69, have been cooler than normal. Night cooling plus whatever evaporative cooling was gained from the humidifiers was adequate for cooling potatoes in storages with adequate ventilating air and proper operation. In 1967, however, the situation was different. It was warmer than normal.

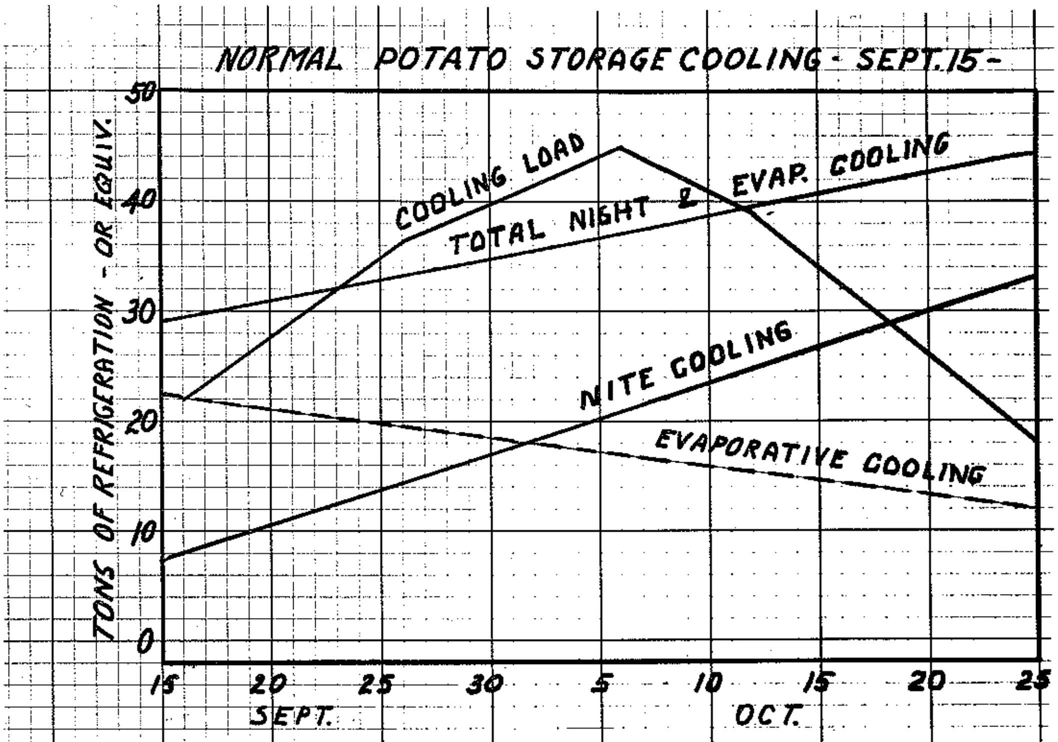

FIGURE 7

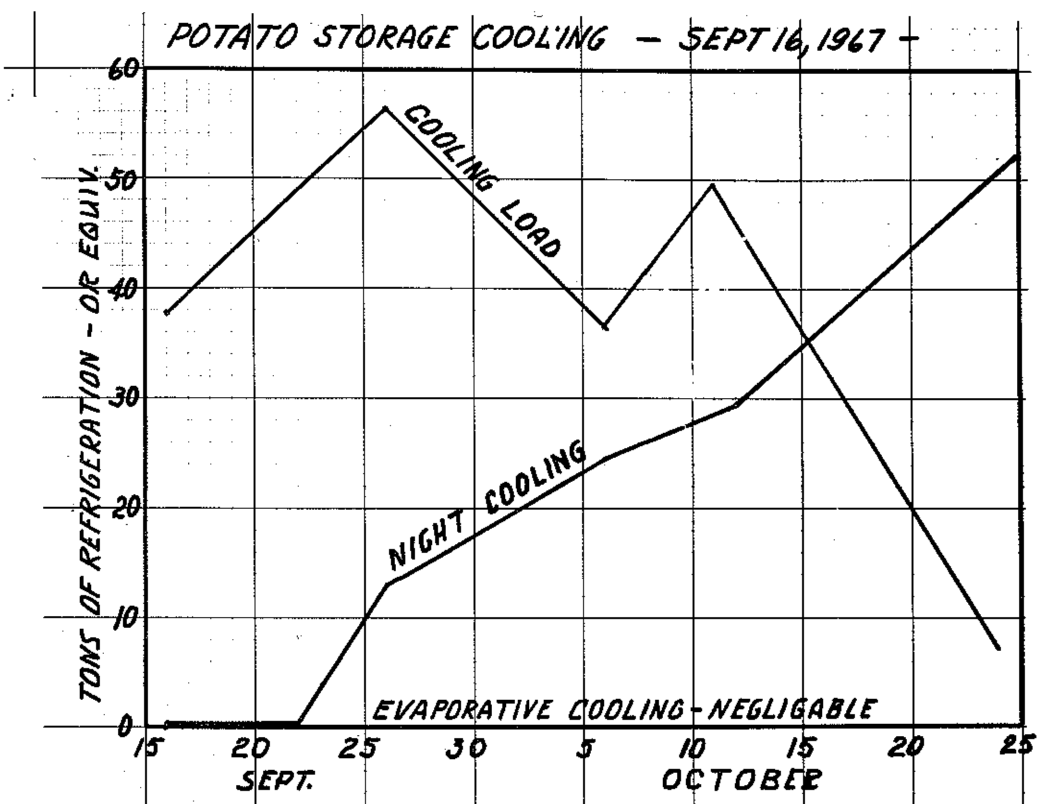

FIGURE 9

Figure 9 indicates what the situation would have been for a storage wherein the filling began September 16, 1967. Note the night cooling fell far short of being adequate and evaporative cooling was negligible. This was because the outside temperatures were consistently higher than normal, day and night. The high air temperatures caused higher tuber temperatures, which in turn meant more field heat to be removed and more heat of respiration. On the other hand, higher temperatures, even at night meant less cooling available. There were very few hours early in the season when air temperatures were 50° F. or below. Most of the time, even the wet bulb temperature remained above 50° F. or so close to it that the air, when cooled by evaporation, was still above 50° F. and, therefore, could not be used if part of the pile had been lowered to 50° previously. What actually happened without refrigeration in 1967 was that tuber temperatures were not lowered to 50° F. within 24 hours. This made them much more susceptible to rot organisms. Also, most harvesting did not begin by September 16 or even by September 25. For those potatoes that were not placed in storage until October, the temperatures had moderated sufficiently so that night and evaporative cooling could more nearly meet their requirements.

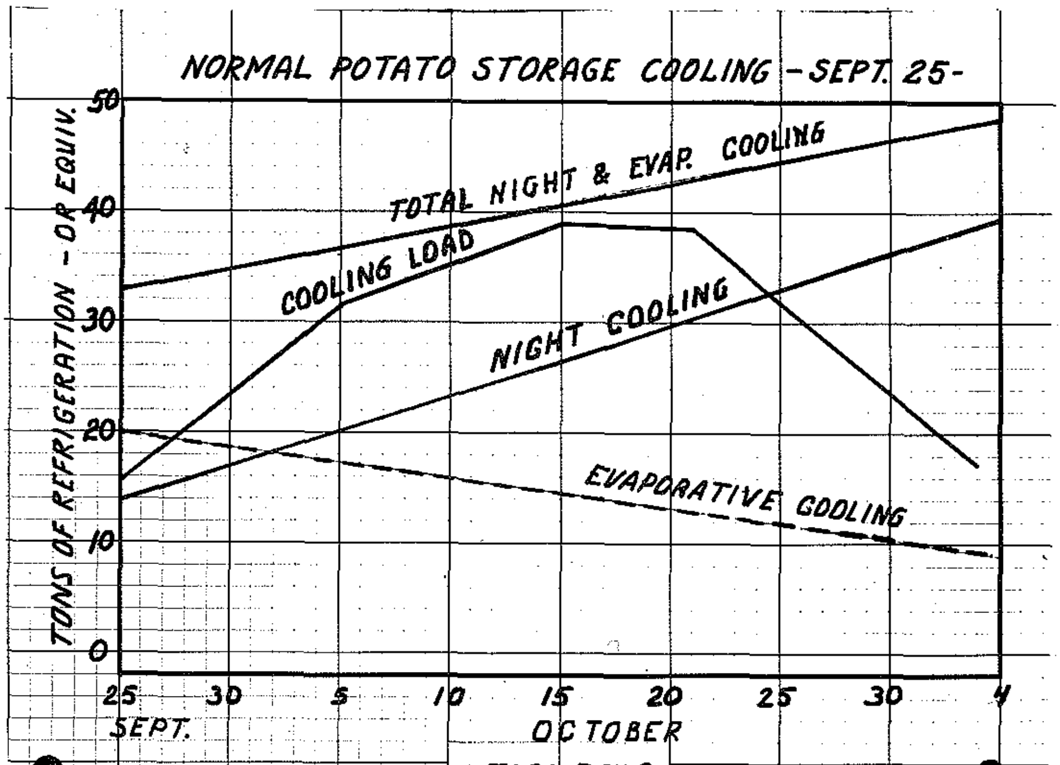

FIGURE 8

CONCLUSIONS

1. If potatoes are to be cooled to 50° F. their first day in storage and maintained at 50° F. during their suberization period, some refrigeration or ice cooling is normally necessary if storage begins as early as September 16.

2. If storage begins about September 25, and if maximum evaporative cooling is realized, potatoes can be cooled to 50° F. and maintained at that temperature in normal years without ice or refrigeration.

3. If temperatures are warmer than normal, considerable refrigeration is needed to cool the potatoes to 50°F. in the first 24 hours and maintain them at that temperature.

4. Based on placing 200 tons of potatoes per day into a 5,000 ton storage, with 17 cfm/ton ventilating air, the following amounts of refrigeration or ice per day would be required to cool potatoes to 50° F. in 24 hours and maintain them at 50° F.

Beginning Date of Filling	Refrigeration or Ice Required	
	Night Air and Evaporation	
	Used Tons/day	Not Used Tons/day
September 16 - Normal year	4 to 12	45
September 25 - Normal year	0 to 7	39
September 16, 1967 - Hot year	40	56

5. Refrigeration or ice is generally needed for the first week or two and then is not needed again unless potatoes are kept into the next spring or summer.

6. Portable refrigeration plants available for short periods when needed for potatoes may have some merit.