Radiant Ray Frost Protection as Applied to the Exposed Face of Sugar Beet Storage Piles

READ A. WILKINSON[1]

In areas where sugar beet storage piles are being constructed during the late fall, a problem of frosted unstorable beets presents itself. These beets because of nightly exposure to the mild freezing temperature are frozen sufficiently to form a spoilage plane which endangers all surrounding beets.

Attempts to combat this problem have to date consisted mainly of common frost control methods such as canvas coverings, smudge pots, wind machines, etc. These methods have not proven entirely successful; consequently, the further search for efficient control has centered upon the possibility of utilizing radiant energy.

The first encouraging attempts consisted in the use of an oil burning unit developed at Michigan State College. This was abandoned because of several objectionable features such as low efficiency, adaptability and safety.

The recent industrial application of radiant heat from infrared bulbs has to date been confined to high energy levels for drying and heating in the metals, food, plastics, paper and textile industries. Its use in low energy levels such as a frost guard unit for beet piles, to our knowledge, has never been tried. However, because of the successful industrial application of electrical infrared radiant energy and the fact that the infrared bulbs transmit "near" infrared energy not absorbed by air, a decision was made to apply it to the problem of frost protection.

In experimental work previously attempted with regard to the action of frost upon sugar beets it was determined that the critical temperature below which the cell structure would rupture due to freezing was approximately 27° F. Another determination arrived at from frost protection experiments carried on by the University of California was that it required at least a 10 to 13 B.T.U. per square foot application to prevent freezing of fruits or vegetables for ambient temperatures down to 24° F.

Considering the above limiting data, the circular face of pile and the adaptability of a light compact mobile unit, an electrical radiant ray frost guard was designed. The original unit consisted of a 140° circular bank of 48 375-watt lamps of special heat-resistant glass to withstand intermittent moisture conditions. The energy level of this unit was 4.73 watts or 16.18 B.T.U. per square foot per hour with a power demand of 18.0 K.W.

Preliminary trial applications were made in order to determine the lamp location for maximum coverage and efficiency. A radiometer was used to make such a determination. When the unit was located upon the ground 9 feet back from the beet pile base only about 40 to 50 percent of the face, located directly *in* front of the lamps, was sufficiently covered with the 13 B.T.U. per square foot or more necessary for adequate protection.

In order to remedy this condition two changes were made: First, the unit was suspended from the piler boom at the point of intersection between

[1] **Agricultural Engineer, Amalgamated Sugar Company.**

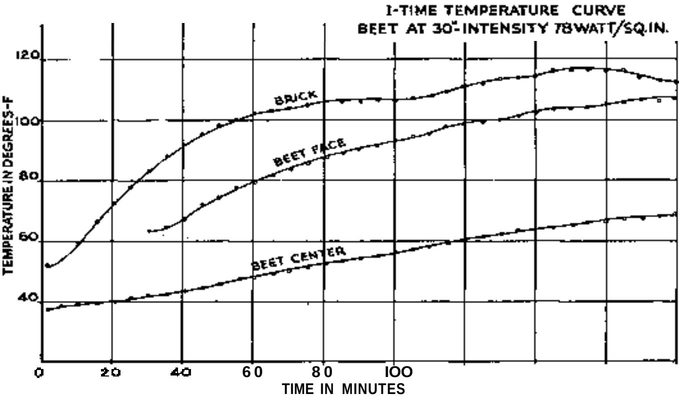

Figure 1.

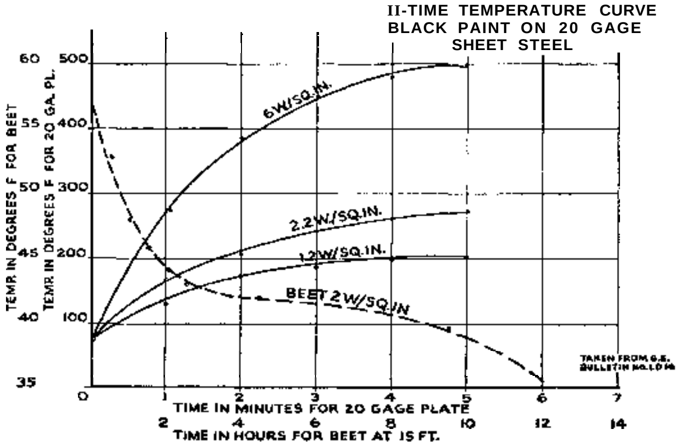

Figure 2.

the longitudinal center line of the beet pile and the chord extending from the two inside points of the pile arc. Second, the circular lamp bank was enlarged from 140° to 180°, thus increasing the energy level to 7.5 watts and 25.6 B.T.U. per square foot with a new power demand of 28.5 K.W.

From further preliminary trial data a typical performance curve was drawn which consisted of plotting time against temperature change. Similar curves are plotted in industrial applications for various materials, whose absorptivity is known and energy level calculated which are nearly uniform. However, in frost protection very few factors are constant and results can only be attained by maintaining an energy level high enough to prevent the temperature of beets from going below approximately 27° F. Consequently, similar characteristics between the curves for beets and that for other materials would not be expected because of these variations in outside temperatures, beet temperatures, moisture conditions, wind velocities, slopes of pile, distance of beets from source of energy and color of beets. Furthermore, for this reason the data from trials made is extremely difficult to correlate and group so that specific conclusions and recommendations can be drawn.

The performance curves in Figure 1 are for a beet placed 30 inches from the lamps. Two thermometers were placed in the beet, one in the center of the beet and the other 1 inch deep in the surface layer facing the lamps. To provide a basis for comparison a brick, whose rate of absorptivity is known, was subject to the same energy level of 7.8 watts per square inch and a curve drawn for it also.

Characteristic of all such curves is the tendency to flatten out, showing that for each energy level the result is a maximum temperature beyond which that particular material will not rise. This is the temperature at which the energy radiated by, convected or conducted from the work is equal to the energy received from the heat source. Such flattening out is prominent *in* the curve for the brick and started after 60 minutes. For the surface of the beet a slight tendency to flatten is indicated at 80 minutes and becomes pronounced at 150 minutes. The center of beet curve does not start to flatten until 146 minutes have elapsed with a definite tendency at 170 minutes. The difference between the temperatures attained by these two beet curves is due to the change in the volume effected by the radiation.

To aid in comparing these curves with those of known values a set of curves for black paint on 20-gauge sheet steel subjected to three different energy levels is included. The tendency to flatten, as will be noted from these curves, diminishes with the reduction in energy level and working temperature. The curves for the beets also have this common characteristic, except that it is inverted.

In applying this information to actual tests several deductions may be made: First, the slow rate of absorptivity of a beet indicates that the time of application is an extremely important factor. Second, the greatest protection is possible on the portion of beet directly exposed to the radiant rays. Third, since the bank of lamps is constructed in a circular shape in order to fit the contour of the beet pile face the energy level decreases with

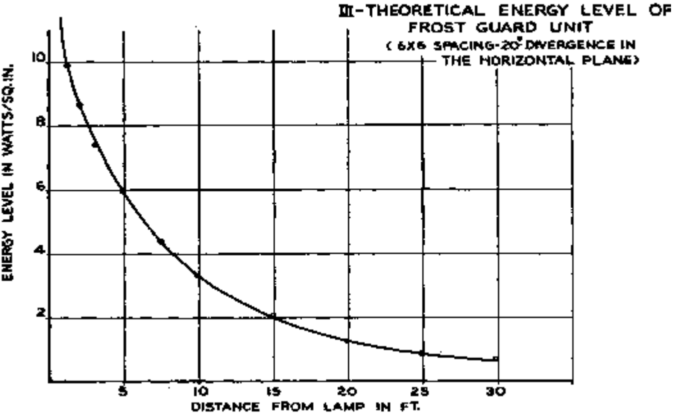

Figure 3.

IE-COMPARISON OF TEMPERATURE CHANGES
AVERAGE FOR ALL 1950 TRIALS

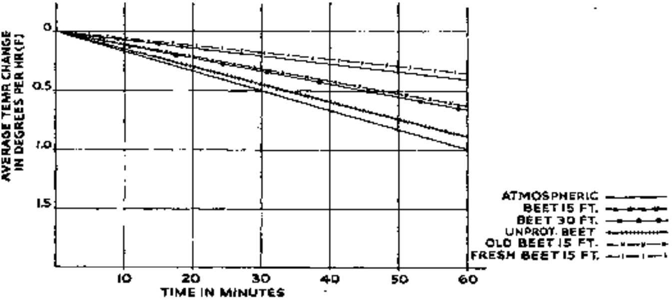

Figure 4.

distance from the unit. This is shown in Figure 3 where the theoretical values given are much higher than the actual average.

With all due consideration given the above information a series of trials was conducted as follows :

The bank of lamps was suspended from the Silver piler boom. Beets containing thermometers were placed on the face of the beet pile at 15 and 30 feet respectively from and within the range of the unit. As a check similar temperature data was obtained with respect to beets not subjected to the rays of the infrared bulbs. From the data obtained performance curves were plotted and conclusions formulated.

In Figure 4 the average temperature change of all trials is given in the form of straight line variations. A typical curve showing the actual temperature change is shown on Figure 2 and is inverted from the high energy curves also shown in this figure.

The following conclusions may be drawn from the accumulated data:

1. Protection from light frosts on the fresh face of sugar beet storage piles with this type of frost guard unit involving "near" infrared rays in low energy levels is possible and practical down to temperatures of 20° F.
2. For such protection it is neither necessary nor economically practical to provide sufficient energy to raise or even maintain the temperature of beets on the pile face. The main objective is to provide sufficient energy to reduce the rate of emissivity of the beet so that during the nightly period of exposure the temperature of the beet will not go below the critical temperature of approximately 27° F.
3. Due to the slow rate of absorptivity and emissivity of a beet the protection attained varies directly with the time of application.
4. Dependable protection cannot be attained unless the beets received are freshly dug and the temperature change between them and the ground, from which they are taken, is small.
5. Uniformity and effectiveness of protection depends considerably on the uniformity of slope of pile surface. It decreases with the departure of the angle of radiation from that normal to the pile surface. Data indicate good protection of exposed beet surface, with reduced protection in the shadow behind the beets.
6. The application of 10 to 13 B.T.U. per square foot is sufficient to provide protection, providing all conditions are fairly uniform. However, non-uniformity of pile face and beet temperatures require an output of 20 B.T.U. per square foot in order to be more assured of protection.

ACKNOWLEDGMENT—Material used in this paper was obtained from General Electric Bulletin L D-16. Assistance was received from S. M. Heiner and Theodore Gessel of Amalgamated Sugar Company.