

# PETROLEUM COKE-BASED BRICKS FOR FROST PROTECTION

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**R**ECENTLY a new family of frost protection devices has become available. Heaters are now being made from petroleum wax or coke and molded in various forms, such as candles, bricks or flat trays. Because these devices have a much lower heat output per unit than conventional heaters, and information about their protection ability is limited, preliminary tests were initiated to learn more about this type of heating.

The devices used in the tests have a heat output of only 8,000–10,000 btu/hr or about one-sixth of the output of a conventional orchard heater. For this reason, six times as many heaters may be needed to protect an area.

California fruit growers already like to circumvent heaters with substitutes such as wind machines, although they do not entirely eliminate the need for heater support in severe frosts. These new heating units are also expensive, because they are in the pilot stage and have not come into full local production. These heaters are useful in other states where frosts occur once or twice in a decade, and where the acquisition of heaters, wind machines, or sprinkling equipment may not be economical. Also, during hard freezes in Texas, where neither wind machines nor sprinklers help, these small units are expected to prevent severe losses (saving at least the trunks) when placed under citrus trees. In California these units are potentially useful in small areas, in low-growing crops, or in supplementing other frost protection devices.

Previous studies reported in *California Agriculture* indicate that these new units could have some advantages over the conventional heaters. The need of a great number—100 or more per acre—provides a closer spacing which means fewer “dark spots.” The small heat output of the individual units decreases the buoyancy effect, thus making more convective heat available to the plants, so that the high ratio of six small heaters to replace

one conventional heater may not be needed. A third factor may be the direct radiation from the red-hot surfaces of the bricks. These factors are difficult to evaluate and require many tests under various environmental conditions. This report discusses the data from three preliminary tests in spring, 1966.

A two-acre plot in the Davis vineyard was used to test the petroleum coke units. Three hundred 4 lb bricks were used per acre, spaced 12 ft apart in each row of grapes, and the rows were 12 ft apart. Two men followed a tractor and trailer load of bricks as they were driven through the vineyard and were able to place the bricks on two acres in 1¼ hours, but could probably have worked faster with better handling techniques and experience.

The units were lit with conventional orchard heater lighters which were well suited for the job since they poured a small amount of Diesel oil-gasoline mixture onto the coke while igniting, so that the waterproof plastic wrappings of the bricks were quickly burned away. No trouble was encountered in lighting these units and two men could light 150 heaters in 5 to 10 minutes. Lighting was carried out on three clear nights as soon as the temperatures had fallen below 40° F.

At the first lighting, March 17–18, half of the heaters were lit at 11:00 p.m., and the other half of the heaters were lit two hours later. This method of lighting was to compare temperature response at the two different burning rates and to prolong the heating effects, since the bricks were designed to burn only five hours. On the last two tests (March 23 to 24 and April 19 to 20), only 150 heaters per acre were used because the first test indicated no great advantage in using a larger number.

Field temperatures were monitored at half-hour intervals by reading 32 mercury thermometers mounted on stands

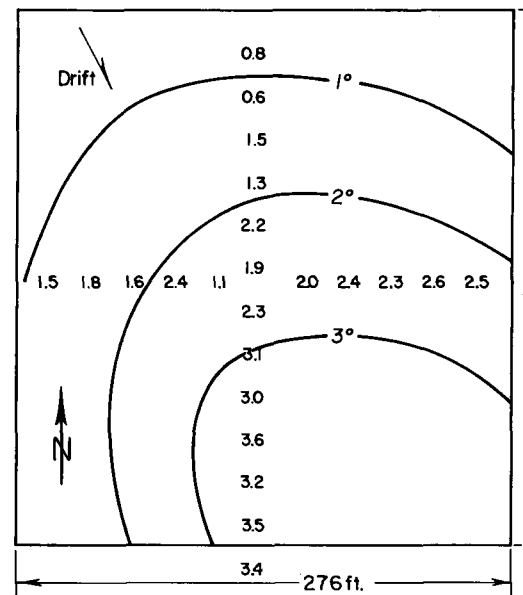
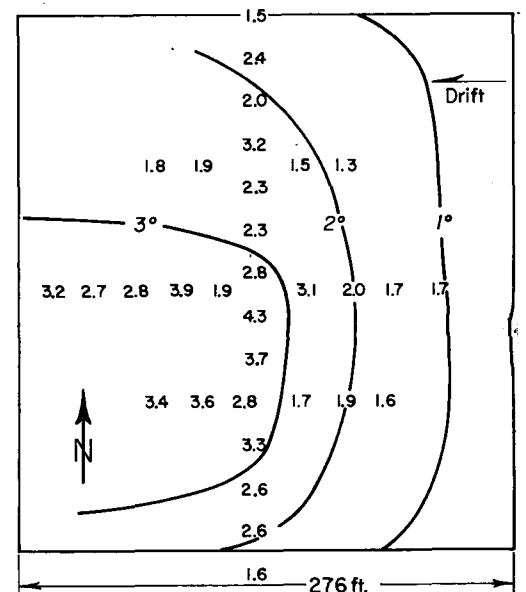


Fig. 1. Night temperature response March 17–18, 1966 in a 2-acre test vineyard 4½ hours after first 150 petroleum coke heaters were lit, and 2½ hours after second group of 150 heaters were lit. The drift was NNW, 1 mph with a 3° F inversion (difference 50 ft minus 5 ft).

about 3½ ft tall (unshaded from heater radiation) and placed throughout the field primarily in a cross pattern, as can be seen in figures 1 and 2. The numbers are the temperature differences observed at the thermometer locations inside the heated plot versus stations outside the heated area. Such area responses were plotted for each of the half-hour observations, and lines of equal heater responses were drawn. The three test nights yielded a set of 16 diagrams with very different response curves, a good example of which is given by figures 1 and 2. The influence of air movement can be seen by the location of the maximum response zone,

Fig. 2. Night temperature response April 19–20, 1966 in the 2-acre Davis test vineyard. Response shown 2¼ hours after 150 petroleum coke heaters per acre were lit. The drift was from the east at 3 mph with a 2° F inversion.



which was displaced to the edge of the two-acre plot. Normally a larger area would experience at least as high a temperature rise as the maximum response of the small test area (figures 1 and 2).

An analysis of all response diagrams reveals further strong dependence on inversion. Since the strength of the inversion varied greatly during the three test nights, and sometimes from one reading period to the next, data for a variety of conditions were obtained, as summarized in figure 3. Only the test periods involving 150 units or 600 lbs of fuel per acre were used. In one case with a 6°F inversion between 5 and 50 ft, a maximum response of 5°F was obtained, whereas in a 2°F inversion a 3°F response was obtained. The latter value, or the weak inversion, would be representative for actual frost nights.

Wind drift carrying cold air into the heated area reduced the temperature around the borders of the protected field. To reduce this effect, extra heaters could be placed along the borders or an extra row or two of heaters could be placed outside the protected area. The latter method seems to be preferable in the present test conditions because the results of the long test night of March 17-18, 1966, reveal that the advantage in doubling the number of heating units is realized only after the tenth row and not at the borders facing the drift. This is shown in figure 4, where six of the field diagrams for that night are compared by lines representing temperature cross sections along the drift which moved from NNW (see figure 1) at about one mph (measured at 6 ft). The lower curve, A, shows a cross section of the temperature response only one-half hour after the first 150 units per acre were lit. The temperature rise was still low, but may be sufficient at the early stage of a frost night. Curve B shows that this response had increased to a maximum of 3°F by 1½ hours after lighting. Curves C, D, and E show the increased response when the second group of heaters were lit so that 300 heaters per acre were burning. Curves C, D, and E show temperature response at 3¾, 4¼, and 5 hours after the first lighting and 1¾, 2¼, and 3 hours after all units were burning. The test run, F, was made six hours after the first, or four hours after the second set was lit. The first units had finished burning by that time so heat output was equivalent to about 150 heaters per acre.

The temperature response was greater when 300 units per acre were burning instead of 150 units per acre, but not doubled. This test indicates that when

greater amounts of fuel are consumed, a greater amount of the heated air is lost from the area to be protected due to increased vertical convection. Thus, the temperature rise in a protected area will not double if the fuel burning rate is doubled.

It should be emphasized that these temperature responses were also affected by the fluctuation of the inversion during this test night, as indicated by the figures in the last column of the graph legend. Curves C and F showed the same inversion, but in test run C, the maximum response was 4.4°F when all 300 units per acre were burning vs. only 3.2°F in run F when 150 units per acre were burning.

It has previously been found that with conventional orchard heaters a burning rate of 6.3 gal/hr per acre would give a 1°F response with a 4°F inversion. A gallon of fuel oil has a heat value of 140,000 btu/gal, or for every gallon burned one can expect to obtain this much heat. Thus, with conventional orchard heaters 880,000 btu/hr is required to obtain a 1°F response with a 4°F inversion. The manufacturer of the petroleum coke bricks tested states that the normal heat output of their units is 8,000-10,000 btu/hr. Burning 150 heaters per acre a 4°F response was obtained with a 4°F inversion, as shown in figure 3. This burning rate represented 1,200,000-1,500,000 btu/hr. To obtain this same response with conventional heaters, a burning rate of about 25 gal/hr or 3,500,000 btu/hr is required; or less than half as much heat was required with the petroleum coke as compared with conventional heaters.

The test confirms the often stated principle that a larger number of small units is more efficient than a small number of large units. With a large heater burning at a high rate the heated air rises rapidly out of the area to be protected. A conventional heater must protect a larger area and both the convective and radiant heating effects are reduced rapidly with distance from the source. That is, the heating is not as uniform and there are cold fringe areas between heaters. Even with many small heat sources there are cold fringe areas between heaters, although to a lesser degree, and the data shown in figures 1 and 2 vary slightly since some thermometers were closer than others to the heaters.

Further research is needed to learn more about this type of orchard heating. It should be re-emphasized that these results are preliminary and more data are needed to corroborate the temperature response figures. Also, temperature re-

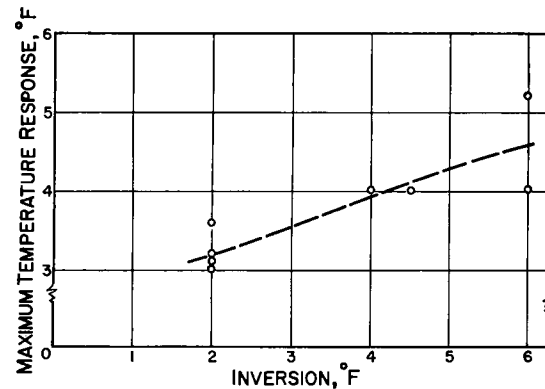


Fig. 3. Maximum temperature response of 2-acre heated area as affected by the temperature inversion for a burning rate of 150 petroleum coke heaters per acre. Inversion is determined by subtracting the temperature at 5 ft from the temperature at 50 ft elevation.

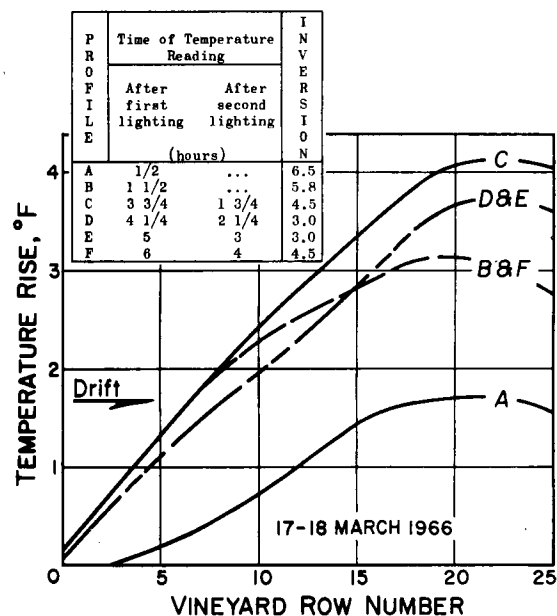


Fig. 4. Profiles of the temperature rise at various times in the test vineyard. Profile is drawn in the direction of wind drift. The burn rate was initially 150 heaters per acre and was increased to 300 heaters per acre 2 hours later.

sponse readings were only made 3½ ft from the ground, and more information about temperature response at other heights should be obtained to learn more about protecting a variety of crops.

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