TABLE 3.—*Epochs of sunspot maxima and minima.*

Minima.			Maxima.		
Epoch.	Weight.	Period.	Epoch.	Weight.	Period.
1610.8	5		1615.5	2	
		8.2			10.5
1619.0	1		1626.0	5	
		15.0			13.5
1634.0	2		1639.5	2	
		11.0			9.5
1645.0	5		1649.0	1	
		10.0			11.0
1655.0	1		1660.0	1	
		11.0			15.0
1666.0	2		1675.0	2	
		13.5			10.0
1679.5	2		1685.0	2	
		10.0			8.0
1689.5	2		1693.0	1	
		8.5			12.5
1698.0	1		1705.5	4	
		14.0			12.7
1712.0	3		1718.2	6	
		11.5			9.3
1723.5	2		1727.5	4	
		10.5			11.2
1734.0	2		1738.7	2	
		11.0			11.6
1745.0	2		1750.3	7	
		10.2			11.2
1755.2	9		1761.5	7	
		11.3			8.2
1766.5	5		1769.7	8	
		9.0			8.7
1775.5	7		1778.4	5	
		9.2			9.7
1784.7	4		1788.1	4	
		13.6			17.1
1798.3	9		1805.2	5	
		12.3			11.2
1810.6	8		1816.4	8	
		12.7			13.5
1823.3	10		1829.9	10	
		10.6			7.3
1833.9	10		1837.2	10	
		9.6			10.9
1843.5	10		1848.1	10	
		12.5			12.0
1856.0	10		1860.1	10	
		11.2			10.5
1867.2	10		1870.6	10	
		11.7			13.3
1878.9	10		1883.9	10	
		10.7			10.2
1889.6	10		1894.1	10	
		12.1			12.3
1901.7	10		1906.4	10	
		11.7			11.2
1913.6	10		1917.6	10	

SMUDGING AS A PROTECTION FROM FROST.

By HERBERT H. KIMBALL and FLOYD D. YOUNG.

[Weather Bureau, Washington, D. C., June 7, 1920.]

There are three quite different types of oil-burning heaters in general use on the Pacific coast. They are commonly designated high-stack, short-stack, and open or lard-pail heaters.[1] The distinguishing characteristic of the high-stack heater is that abundant draft is provided, and almost complete combustion of the oil results, with the formation of only light smoke. On the contrary, the lard-pail type of heater has insufficient draft for complete combustion, and a dense smoke results. The short-stack heater is intermediate to the other two types with respect to both combustion and smoke.

Where the location of orchards or other vegetation to be protected is near a city or town of considerable size the smoke cloud from numerous lard-pail or short-stack heaters may be highly objectionable. On the other hand, it is maintained by some that the smoke cloud is a necessary accompaniment of efficient orchard heating, since it retards not only nocturnal cooling of the ground and lower air strata, but also the escape of the heat produced by combustion from air near the ground, where it is most needed, to higher levels.

Some measurements of the rate at which heat is given off by different types of heaters, and of comparative rates of nocturnal radiation under and outside a smoke cloud produced by heaters, will be of interest in this connection.

Through the kindness of Mr. J. E. Adamson, of Pomona, Calif., a Scheu (high-stack) and a California (low-stack) heater were received at the central office of the Weather Bureau early in 1919. On the evening of January 21 they were set up on the Weather Bureau grounds at a distance of 10 feet from Smithsonian pyranometer No. 2,[2] which had its glass cover removed, and the flat surface containing the blackened strips in a vertical plane squarely facing the heaters.

Before the heaters were fired the pyranometer shutter was opened and the outgoing radiation to the sky and surrounding buildings measured. The loss of heat was found to be at the rate of 0.045 calories per minute per square centimeter. The Scheu heater was then lighted and measurements given in Table 1 were obtained.

TABLE 1.—*Measurements of radiation from a Scheu orchard heater, Jan. 21, 1919.*

[Surface of pyranometer vertical and at level of center of lower section of stack.]

Time.	Radiation from heater. cal. min. cm.²	Remarks.	Time.	Radiation from heater. cal. min. cm.²	Remarks.
p. m.			p. m.		
7:50	0.217	Heater red hot.	8:16	.....	Air temperature 46.2° F.
7:53	.245				
7:54	.249		8:17	.107	Funnel slightly red.
	.234		8:19	.259	Very red.
7:55	.276		8:20	.276	
7:56	.255		8:21	.263	
7:57	.249		8:22	.265	
7:58	.242		8:24	.274	
7:59	.198	Drafts partly closed.	8:25	.286	
8:00	.121	Drafts partly closed; only small section of pipe red.	8:27	.272	
			8:29	.099	Almost no red.
8:10	.124	Lower section of funnel slightly red.			
	.132				

It will be seen that when the stack of the heater had become red-hot the pyranometer appeared to be receiving heat from it at an average rate of 0.250 gram calories per minute per square centimeter of normal surface; when very red the intensity was about 10 per cent greater. With only a slight indication of red the apparent radiation was at the rate of about 0.100 gr. cal.

The above rates must be increased by 0.045 gr. cal., the measured rate of cooling, to obtain the true rate of heating. This gives 0.320, 0.295, and 0.145 calories for the radiation from the heater when the stack is very red, red, and only slightly red, respectively.

Similar measurements made with an Adamson high-stack heater in an orange grove at Pomona, Calif., on February 26, 1920, after adding 0.032 for the measured rate of cooling, give 0.252 calories for the radiation from a red-hot heater and 0.117 calories when the stack had lost its redness.

The following measurements have been obtained on the rate of radiation from short-stack and lard-pail heaters, the pyranometer in each instance being exposed as in the measurements on the high-stack heaters.

[1] See Farmer's Bulletin 1096, pp. 20-21, for illustrations and descriptions of these heaters.

[2] For a description of this instrument, see Smithsonian Misc. Coll. 66, Nos. 7 and 11.

Place.	Date.	Kind of heater.	Rate of cooling.	Measured heating.	Total heating.
			Cal.	*Cal.*	*Cal.*
Washington, D. C.	Jan. 21, 1919	California	0.045	0.055	0.100
Pomona, Calif.	Feb. 26, 1920	do	.032	.072	.104
Medford, Oreg.	Apr. 3, 1920	Lard pail	.027	.053	.080

The high-stack heaters, with their nearly complete combustion of oil, radiate more than twice as much heat as the short-stack heaters and three times as much as lard-pail heaters. It has been noted by Young[3] that they do not show this degree of increased efficiency in raising the air temperature near the ground, perhaps because the high and hot stack facilitates the escape of heated air to higher levels.

At Pomona, Calif., on December 30–31, 1918, and on January 1–2, 1919, Young obtained measurements on the rate of nocturnal radiation in an orange grove throughout nights on which heavy smoke was produced by the use of short-stack heaters, using for this purpose Weather Bureau pyrgeometer No. 2.[4]

Comparison of these with similar measurements obtained on nights when there was was no smoke indicate a decrease in the rate of nocturnal radiation on December 30–31 from 0.110 calories per minute per square centimeter to an average of 0.098 calories, and on January 1–2 from 0.115 to 0.103 calories, or an 11 per cent decrease on December 30–31 and a 10 per cent decrease on January 1–2. The readings under the smoke cloud were irregular, as we would expect, and on both nights showed maximum depressions of 28 per cent.

At Medford, Oreg., on the night of April 17–18, 1920, Young measured the rate of nocturnal radiation in an orchard in which lard-pail heaters were lighted at midnight and in a neighboring orchard in which there was no firing. The results indicate a decrease in the rate of radiation under the smoke cloud from 0.109 calories to an average of 0.099 calories per minute per square centimeter, or a 9 per cent decrease, with a maximum decrease of 26 per cent.

We may summarize our results as follows:

The presence of a dense smoke cloud diminishes nocturnal radiation on an average about 0.011 calories per minute per square centimeter of surface, with maximum effects of nearly 0.030 calories.

At a distance of 10 feet the intensity of radiation from a lard-pail heater is about 0.080 calory per minute per square centimeter; from a short-stack heater, about 0.100 calory; from a high-stack heater when just turning red, 0.120 calory; and when completely red, from 0.250 to 0.300 calory.[5]

Since the intensity of radiation varies inversely as the square of the distance from the source of heat, at a distance of 15 feet from the heaters it will be less than half, and at 20 feet about one-fourth that given above.

The heating by radiation is in addition to the heating by conduction and convection of hot air and gases from the burning oil and its immediate vicinity.

We must therefore conclude that the retardation of nocturnal radiation by the smoke cloud plays an insignificant part in frost protection.

[3] Farmers' Bulletin 1096, p. 20.

[4] For a description of this instrument see the MONTHLY WEATHER REVIEW, February, 1918, pp. 58–61.

[5] The air temperature at the time these results were obtained was about 45° F. All the heaters were nearly full of oil.

EFFECT OF TOPOGRAPHY ON TEMPERATURE DISTRIBUTION IN SOUTHERN CALIFORNIA.

By FLOYD D. YOUNG, Meteorologist.

[Author's Abstract.]

From observations in the Pomona Valley, Calif., it appears that there is little, if any, advantage to be gained by locating an orchard on the upper portion of a long, uniform slope with a fall of 150 feet or less to the mile. However, in even slight depressions of whatever shape or direction, on this slope, the frost hazard is likely to be considerably greater. This also applies to points located directly at the base of the slope, where the ground begins to rise in the opposite direction.

In figure 1 is shown a rough profile of a sloping valley floor, from the foothills on the left, down to and over the summit of an isolated ridge near the lowest part of the valley. The figures above each station represent the average minimum temperatures for 29 clear nights during the winter of 1917–18. The contrast between temperature inversions on the steep and the gradual slopes is brought out distinctly.

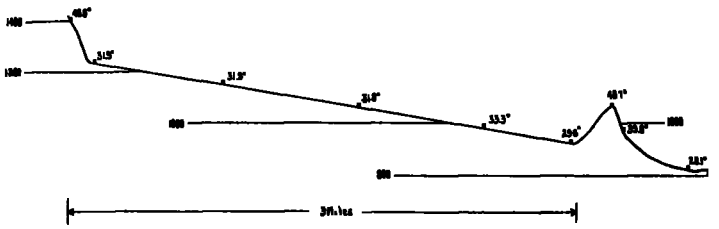

FIG. 1.—Profile of valley, showing average minimum temperatures for 29 clear nights at stations on slopes of varying steepness. Altitudes are in feet above sea level. The gradual slope is not so regular as shown here, but nevertheless there is little variation in the rate of fall.

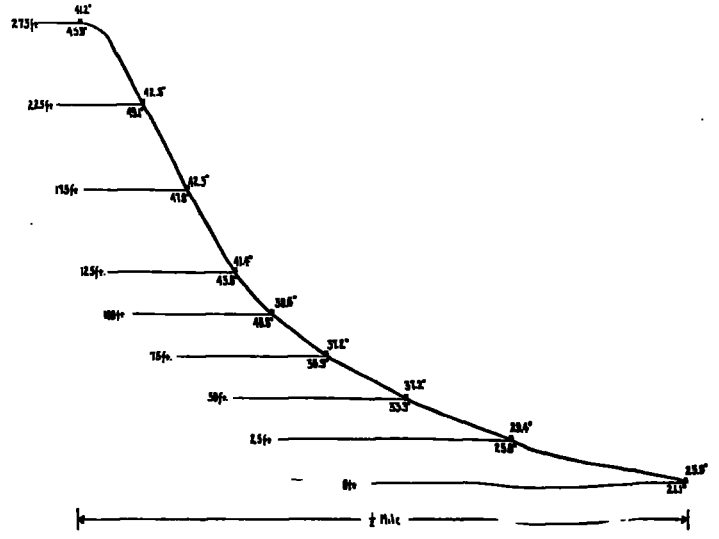

FIG. 2.—Profile of steep slope of ridge shown at the right in figure 1. Elevations are in feet above the base station. Locations of stations shown by small black squares. The average minimum temperature for 45 clear nights during the winter of 1918–19 is shown above each station. Minimum temperatures registered on the night of January 5–6, 1919, are shown below each station.

Temperature inversions on the steep slope shown at the right in figure 1 are shown in figure 2. At the end of the 1918–19 frost season, when these records were obtained, the fruit in an orange grove surrounding the base station was a total loss, while delicate avacado trees in full bloom, located at the 100-foot station, were practically uninjured.