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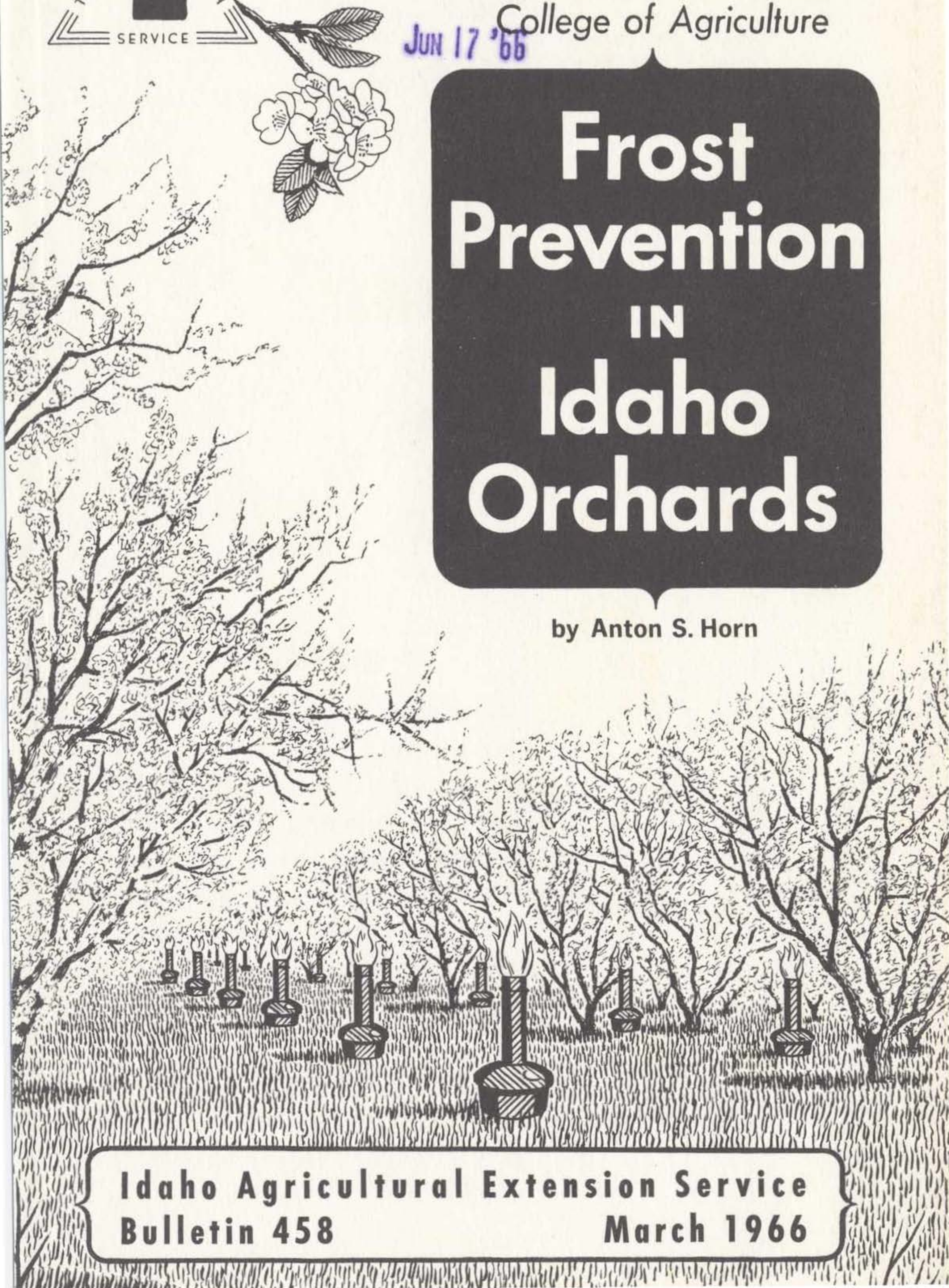
Frost Prevention in Idaho Orchards

by Anton S. Horn



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Spring frosts are an annual threat to Idaho orchards, but alert fruit growers can usually prevent crop losses by orchard heating—if they have sufficient warning. Frost warnings are furnished to growers by the U. S. Weather Bureau. Thermometers can be strategically placed in the orchard to indicate temperature. You will find critical temperatures listed inside the back jacket of this bulletin. Protection requirements will vary during the spring bloom and fruit development periods.

A few orchards are located on sites with adequate air drainage or are protected by large bodies of water. In these cases the frequency of spring frost hardly justifies the expense of orchard heating most years.

Your orchard may not be so favorably situated and could require some heating nearly every year. Heating can be regarded as a form of crop insurance. The question of whether orchard heating will pay dividends depends largely upon the quality, amount and price of the fruit you produce. The cost of equipment, fuel and operation is the same for a given acreage whether trees are young or old, small and inferior or top quality, heavy producers. The crop can be protected from frost by judicious orchard heating in most years. You need a crop every year to keep your business profitable.

Types of Frosts

Frosts are of two general types:

"Advective" Frost or freeze frost is the result of a horizontal movement of a cold air mass that brings freezing temperatures over a large area. The temperature decreases with the increasing altitude. There is more frost damage to fruit and other plant parts as elevation increases.

A more difficult protection problem faces the grower when an advective cold air mass occurs because the cold air moving through the orchards the first night is normally accompanied by strong winds.

If the winds aren't too strong, protection can be provided by sprinkling. A mixture of water and ice maintains a temperature near 32 F. As long as there is any unfrozen water present the temperature cannot go below this point. So it's important to continue to supply water as long as the temperature of the surrounding air is below 32 F. Sprinkler irrigation on tree fruits is not always practical because it can result in serious limb breakage due to heavy ice coating but it works fine on low-growing plants or strong-limbed trees.

You can get some protection for fruit trees from the radiant heat given off by heaters. This warmth radiates from the metal surfaces and open flames directly to the trees in spite of any wind or inversion effect.

"Radiation" Frost is frequently less severe or of a more local nature than advective. Radiation frost is the result of the earth's loss of heat through long-wave radiation and its surface becoming colder than the adjacent air. The air layer next to the earth loses heat by conduction to the earth's cold surface and becomes cooler and denser than the air immediately above, thus creating a temperature inversion near the ground. Such an inversion may vary in depth from a few inches to several hundred feet. As this conduction and radiation process continues during a spring night, the surface temperature frequently drops below 32 F. with frost formation. The cooler air near the ground is heavier than the warmer air at the top of the inversion and is stable. It will remain stationary as long as the inversion exists unless the lay of the land is such that the cooler, heavier air can flow downhill. The movement of this heavier surface air on gentle slopes (flowing like water to the lowest level) can deepen the cold air layers in valleys. Air movement down a steep slope may be of sufficient speed to cause tumbling. This mixing with warmer air from above causes a temperature rise.

For air drainage to be effective in retarding the temperature drop on a clear, calm night over a broad uniform slope, the fall must be greater than 150 feet to the mile, reports Floyd D. Young in USDA Farmers Bulletin 1588. The steeper the slope the more effective is the air drainage process. The coldest locations are depressions either enclosed or with outlets so small that the cold air drains into the depression faster than it can move out. The areas upslope remain warmer as the cold air drains away and is replaced by warmer air. Stagnation and stillness of air in pockets allows more rapid cooling. This is why the fruit grower who plants on a slope that has good air drainage may avoid damage from this type of frost.

Windbreaks, barns, and other obstructions interfere with air drainage and trees immediately upslope from them are likely to sustain frost damage. Quite often blossoms over the entire fruit tree at the bottom of the slope will be frosted where the colder air has become deepest during the night time drainage. The upper portion of trees in the middle of the slope, where colder air is shallow, may escape damage. The blossoms of the entire tree near the top of the hill where the air is warmer may be completely safe.

Wind Machines

Wind machines are sometimes used to mix the cold air near the surface of the earth with the warmer air above the tree tops. But often the inversion isn't large enough to raise the temperature to a safe level. During a freeze or "advective" frost the wind machines can do more harm than good.

When a large inversion is present, sometimes winds—natural or created—over 5 miles per hour mix the warmer upper air with the cooler air near the ground and this warms the air enough so damaging temperatures will not occur.

Small Heaters

Small heaters placed throughout the orchard are the most reliable method of frost prevention. Generally oil is used as fuel. Prestologs, wood, coal, old tires, or whatever you have that will burn and give off heat may also be used. The Prestologs can be burned in 5-gallon paint cans that have had the sides perforated to allow a draft to reach the fires. This reduces smoke. It is the heat and not the smudge or smoke that reduces radiation rate and prevents frost damage. Heat from Prestologs can be regulated by controlling the draft but you can't shut them off at will like an oil heater. A polyethelene bag can be used to cover cans to keep logs dry, but it must be removed before firing.

The Oregon Forest Research Center, Corvallis, found that obtaining heat comparable to oil requires the burning of about 2½ times as much weight in wood briquets and 3½ times as much weight in slabs. Because of this weight and consequent cost of transportation, wood fuels, to be competitive, must be used near the area of production.

The heat supplied is dispersed by both convection and radiation. The hotter the air the faster it rises. If you have a few very large fires the air gets so hot and rises so rapidly it may break through the inversion layer and, like a chimney, draw cold air from outside the heated area and do more harm than good. You want the warmed air to rise until it reaches air of the same temperature. This layer of warm air varies in height and is usually less than 100 feet above the ground. This height is called the ceiling. A low ceiling generally indicates a large inversion and an easy job of heating since the ceiling is not far above the trees. A high ceiling indicates a small inversion and a lot of heating will be necessary since much heat goes above the trees. Radiant heat is important when there is a small inversion. It requires many uniformly spaced small fires which are more efficient than a small number of large fires because the temperature of a large volume of air is raised slightly. You need a heavier concentration of fires at the borders of the orchard, especially on the windward side when there is a wind, to warm the incoming air.

Orchard heaters burn oil at the rate of about 1 gallon an hour, depending on draft opening. Return-stack heaters produce the least smoke and the most radiant heat.

Two types of heat come from heaters. The first is the "convective." This is the air warmed by contact with the heaters or hot gasses that come out of the heater. The second kind of heat is the "radiation" type. This heat is radiated from either the flame or the hot metal of the heater.

During a freeze or time of high ceiling and small inversion, best results are produced by heaters that have a high output of radiant heat. The hot-stack type of heater (combustion-chamber type) gives the highest percent of radiant heat.

More fuel is needed to raise temperatures a given amount during small inversions than during large, regardless of the type of heaters used.

Since less than half the heat radiated from the heater strikes the trees and the remainder goes to the sky or ground, it is generally agreed a number of small fires give better distribution of both convective and radiant heat than a small number of large heaters.

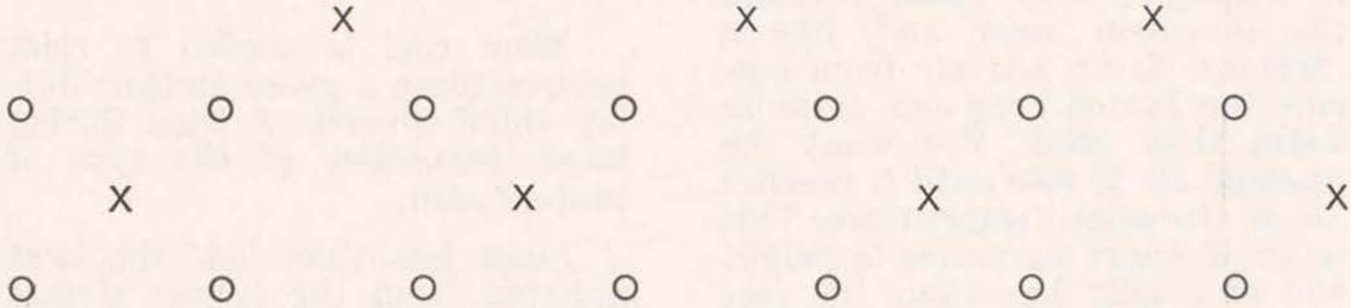
Placement of Heaters

The most even distribution of both radiant and convection heat is obtained when the heaters are placed at the rate of one heater to four trees in a staggered pattern in the centers of the spaces between the trees as shown in diagram I. If the heaters are placed between the trees in the tree rows the loss of radiant heat to the sky is reduced because more of it strikes the trees; but the distribution of heat is not so uniform because the heaters are close to one side of the tree (diagram II). Heaters between trees in the row leave the middle open for the refueling truck and sprayer to go through. You can usually supply sufficient warming with heaters in alternate rows or in the centers of spaces between the tree rows on nights with radiation frosts. During freezes you will find that damage increases in proportion to the distance of heaters from the trees due to loss of radiant heat.

It will generally be warmest in the center of the orchard under no wind drift conditions. The upwind side is cooler than the center and the downwind side with drift. You need extra heaters at the borders or just outside the orchard to protect the border rows. If no extra heaters are used the wind drift will carry the heat away from the first couple of rows on the windward side.

To keep from drawing air from outside the heated orchard, center heaters should be run as low as possible to maintain proper protective temperature. Run border heaters at normal rates. Old tires may be burned at the borders to supplement the regular heaters where the smoke is not objectionable.

DIAGRAM I. Heaters placed in tree spaces in a staggered pattern result in uniform distribution of both radiant and convection heat.



O = Trees X = Heaters

DIAGRAM II. Placing heaters in the tree rows puts them closer to the trees, consequently there is less loss of radiant heat because more of it strikes the trees. An additional advantage is that the refueling truck and sprayer can get through the orchard easily. Distribution of heat is not as uniform as it is where heaters are placed in center of tree spaces as in Diagram I.

O	X	O		O	X	O		O	X	O		O	X
O		O	X	O		O	X	O		O	X	O	
O	X	O		O	X	O		O	X	O		O	X
O		O	X	O		O	X	O		O	X	O	

O = Trees   X = Heaters

If you use the 5- to 10-quart lard-pail heaters it will take 150 or more per acre or 1 per tree with an outside border. They burn 3 to 3½ hours at full rate. About 50 large heaters, such as 5-gallon paint cans or slide cover heaters, per acre are needed for an orchard isolated from others being heated. You can get by with lighting ¼ of the heaters some nights and many nights ½ will be enough. There are different types of stack heaters, with various heights of stacks. They hold about 9 gallons and will burn at reduced rate all night without refueling. They may be used 35 to 50 per acre. Return-stack heaters are used at the same number per acre. These have a return pipe and are relatively smokeless when operated properly.

In areas where it is necessary to keep smoke at a minimum or where air-pollution ordinances are in effect, only clean-burning orchard heaters may be used. These include the return-stack heaters, jumbo cone type heaters, coke heaters, and other heaters and systems that are sufficiently smokeless to comply with the law or situation.

DIAGRAM III. Many growers find that if the heaters are placed in every other row they require less man hours to service and light due to better accessibility.

O		O		O		O		O		O		O	
O	X	O	X	O	X	O	X	O	X	O	X	O	X
O		O		O		O		O		O		O	
O	X	O	X	O	X	O	X	O	X	O	X	O	X

O = Trees   X = Heaters

Wind Machines Plus Heaters

Under certain conditions wind machines used in conjunction with uniformly distributed heaters give a response greater than wind machines or heaters used alone.

When to Light Heaters

It's important not to light the heaters too soon. Determine critical temperature for lighting by stage of bud, bloom or green fruit development. Time of firing should depend on how fast the temperature is falling, the expected minimum temperature, number of heaters to be lighted, and available manpower. A chart of critical temperatures for the various stages in the development of blossoms is found inside the back jacket of this bulletin. Make sure your thermometers have been tested. An error of one or two degrees too low would prompt the lighting of heaters an hour or two sooner than necessary, resulting in a waste of oil and labor. A degree or two too high might delay lighting until the damage was done.

For example, when bud scales are separating and the small green tip is showing on apples the Delicious variety will stand about 16 F., at the delayed dormant stage only 22 F., at prepink 26 F., at full pink 28 F., and full bloom 29 F. for 30 minutes or less without frost damage.

Large Bodies of Water

Large bodies of water near orchards often retard the development of blossoms enough that they escape damage from early spring frosts. In the fall the water is frequently so warm it helps protect against severe early frosts which would damage the ripening crop.

Effect of Slope

Slopes facing the north are cool and moist compared to those facing south. The direction of the slope makes a difference in the amount of solar heat intercepted, resulting in both temperature and moisture differences which influence rate of bud or fruit development.

Effect of Soils

Soils of coarse sand or gravel do not store much heat from the sun because the air spaces in the soil act as an insulator. Clays and loams have small air spaces and serve as the best reservoirs of heat. Therefore crops on these soils are less likely to frost than those on lighter soils. By the same token a firmly packed soil that is plowed is made looser with many air pockets and therefore does not have the ability to conduct or store as the firmly packed soil. A cover crop on the soil will act as an insulator preventing damage to roots from winter injury, but a cover crop reduces the absorption of heat from the sun, and low growing plants on a soil with a cover crop are more likely to frost than those on a bare firm soil. The temperature advantage for a mature deciduous orchard with bare solid ground compared with one having a cover crop probably is slight or nil since the lower branches of the trees are several feet above the ground.

Crops growing on a dry soil are more likely to freeze than those on a moist soil. The moisture fills many of the pores between the soil particles and increases the conductivity of the soil and makes it a better reservoir of heat. In addition the water itself stores heat in the daytime and releases it at night.

And when water changes to ice heat is given off. By adding water to dry soil one can reduce danger of frost damage to crops.

Use of Irrigation Water

It is possible to use irrigation water for frost protection on strawberries and other row crops. You can raise air temperatures from $2\frac{1}{2}$ to 4 F. if initial water temperature is 65 F. and air temperature 26 F. Water gives off heat in cooling from its original temperature to the freezing point and by giving up its latent heat in forming ice.

Irrigation for frost protection is recommended for only one night because daytime evaporation chilling from irrigated surfaces makes a colder surface to start the next night if the frosty weather continues.

Most spring frosts in Idaho are of the radiation type, but it is also possible to have a combination of the two types of frost.

Artificial Fogs and Smokes

Smoke has little effect on slowing the fall of temperatures and increases air pollution. It can be said to be nearly transparent to heat. It does not radiate heat back to the earth as low clouds do. Artificial fogs or smoke screens are generally not successful because the particle size must be sufficient in diameter to blanket out-going infrared radiation. Natural clouds and fogs are composed of particles of about 10 microns.

The damage to vegetation appears to occur as internal cell structure is ruptured. Smoke cover during the hour after sunrise slows the temperature increase. The rate of thaw appears to reduce the amount of damage materially whether this is due to the slower thawing of vegetation or directly to shielding from the sun. When temperatures are sufficiently low the damage may occur when the fruit, blossom, or other plant part freezes and in such cases the rate of thaw is of lesser consequence.

Fog and smoke are a traffic hazard. Smoke coming into towns from orchards is a nuisance, but generally a community will tolerate this in small amounts because the people are in sympathy with the growers. And generally orchard heating only occurs a short time in the spring. If smoke ordinances are in effect, they must be met.

The fruit grower smiles when he sees heavy low clouds because they intercept outgoing radiation from the earth and re-radiate a part of the heat back to the surface. High thin clouds offer little resistance to radiation. Water vapor in the air not only retards loss of heat, by radiation, by intercepting and re-radiating outgoing heat, but slows down decrease in temperature in adding heat to surrounding air as it condenses to dew or fog. The temperature at which water begins to condense is called the **dew point.** The higher the amount of water vapor in the air the slower the fall in temperature. If the dew point is low, damage to crops can occur without formation of visible white frost. There is greater possibility of damage to crops when the dew point is low because of continued cooling below critical temperature. Dew points above 40 F. are considered high and those less than 20 F. low. Nights with a low dew point are often referred to as dry nights.

Thermometers

It is wise economy to have thermometers that indicate temperatures accurately. Build a shelter to shield your thermometer bulb from radiating to the sky and also to prevent deposit of moisture on the thermometer. Provide for free circulation of air around the instrument.

You can build a suitable shelter by nailing two boards at right angles to each other at the top of a post. Mount the thermometer on two small cleats against one board as a back while the top board shelters it from the sky. The shelter should stand in the open and not under a tree. It should face north and away from any close heaters. The height of the thermometer bulb should be 4½ to 5 feet above the ground. If you paint the shelter and post white it will be easier to find at night.

When you read the thermometer at night be careful not to breathe on it because that will raise the temperature indication. Use a flashlight rather than matches or candles that can raise the thermometer a degree or more before you read it. **Don't hold the lighting torch up to the thermometer to read it.** Installation of a frost-alarm system to alert you in time to protect your orchard is desirable and will save considerable watching during the night. It is wise to have at least one thermometer outside the heated area to determine effectivness of your heating and indicate area temperature changes.

When to Turn off Heaters

You can be stampeded into turning off the heaters if a cloud comes over and the temperature rises. Frequently a cloud development will cause temperatures to rise above the critical level and growers will start to extinguish heaters in the belief danger is past. Watch out for decreasing cloudiness as temperatures will drop again to a dangerous level, and heaters may need to be lighted hurriedly once more.

Heaters should not be extinguished until thermometers outside the heated area show readings are above critical points and it is apparent that the temperature rise is permanent. **Don't extinguish the heaters too soon.**

In most cases you can protect your crops from frost if you have sufficient warning and use effective methods.

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Critical Temperatures Chart

Critical Temperatures

Temperature endured for 30 minutes or less
Sheltered Thermometer

Bud Scales separating. Small green tip showing on apples. Pears and Cherries inner bud scales showing at tip.

Delicious	16 F.	Romes	14 F.
Winesaps	15	All Pears	18
Goldens	15	Cherries	21
Jonathan	15		

Delayed Dormant. Bud scales widely separated but still attached. Squirrel-ear leaves on apples showing. Pear and Cherry blossom buds exposed.

Delicious	22 F.	Romes	20 F.
Winesaps	21	All Pears	23
Goldens	21	Cherries	25
Jonathan	21		

Pre Pink. Buds widely separated. Flower parts showing no color. Flower cluster still stuck together.

Delicious	26 F.	Romes	23 F.
Winesaps	25	Pears	
Goldens	24	Bartlett	24
Jonathan	23	Anjou	25
		Cherries	28

All Buds showing color and separated in cluster. Primary leaves fairly well developed on apples.

Delicious	28 F.	Romes	24 F.
Winesaps	26	All Pears	27
Goldens	26	Cherries	28
Jonathan	25	Prunes Italian	23

Center Bud in full bloom. Other buds opening.

Delicious	28 F.	Romes	25 F.
Winesaps	26	Goldens	26
Jonathan	26		

Full Bloom

Delicious	29 F.	Romes	27 F.
Winesaps	28	Pears	
Goldens	28	Bartlett	29
Jonathan	28	Anjou	30
		Cherries	28
		Prunes Italian	27

Small Green Fruits

All Apples	29 F.
All Pears	30
Cherries	30
Plums & Prunes	30

Fruit	Swollen Bud	Showing Color	Full Bloom	Green Fruit
Apricots	23 F.	25 F.	28 F.	31 F.
Peaches	23	25	27	30

Preceding critical temperatures are averages. If pre-bloom bud development is slow subtract a degree or two. If buds are moving fast add a degree or two. Based on field observations of weather bureau workers and others over a period of years.