Energy Considerations in Cone Drying

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The cone drying process and associated energy needs are re viewed. A summary is given of 20 responses to a national survey of the ways extraction plants presently use energy to dry cones. Energy saving considerations are presented.

Energy conservation is important in making the best use of existing fossil fuel supplies, but the need to reduce escalating production costs caused by high energy demands is of even greater immediate importance to nursery personnel. Forest nurseries are large users of energy for cone drying, which, with associated work, often has a high seasonal impact on energy consumption.

This discussion is limited to the use of energy from fossil fuels to heat air, which in turn dries cones. Additional energy must be available to offset the absorption of heat by the kiln itself and to compensate for heat loss as the warm air is exhausted. Energy use per bushel of cones varies with the age of the kiln and the techniques in practice. Details on energy usage and practices employed by some extraction plants in different parts of the United States are given in the following section.

Cone Drying

At collection time, the moisture content of pine cones may be as high as 110 to 140 percent (1). The moisture content usually decreases through evaporation to 50 to 70 percent by the time the cones reach the processing plant. There, the cones are placed on pallets or in racks to air-dry for 2 weeks or more. The cones' moisture content is usually 35 to 50 percent when they are loaded into the kiln. Heated air is passed over the cones until they are dried to a moisture content below 10 percent. At this point, the cones are open, and the seeds are shaken out. In this artificial drying, up to 20 pounds of water per bushel of cones is removed.

Drying of the pine cones occurs by evaporation at the cone surface, which creates a moisture gradient and causes internal moisture to move toward the surface. If the air is not moved away from the cone, the ambient vapor pressure may become greater than that of the cone, and the cone absorbs the moisture from the air. This condition is known as stagnation and leads to cone mold and deterioration. Stagnation can be prevented by either natural or forced air circulation, which moves the moist air from the cones, maintains a favorable moisture gradient, and decreases the liklihood of cone mold.

Energy Measurement

Regardless of the fuel involved, a common energy measurement is used. It is called the British thermal unit (Btu). Technically, this is the quantity of heat required to raise the temperature of 1 pound of water 1° F at or near its point of maximum density. In practical terms, it relates to fuels as shown in table 1.

Energy is required to vaporize water from the cone surface, establish a moisture gradient within the cone, and move the water vapor away from the cone. In nature, solar radiation bills most of the energy need. The combination of temperature and relative humidity forms the equilibrium moisture content. Equilibrium moisture content is defined as the moisture content at which a hygroscopic material neither gains nor loses moisture when surrounded by air at a given relative humidity and temperature. Table 2 displays the equilibrium moisture content of wood at nine levels of relative humidity (*3*).

A high temperature alone accounts for very little drying. The major factor in drying is the relative humidity (table 2). Relative humidity is defined as the ratio between the amount of water

Table 1.—*But equivalents of various energy sources*

Energy source	Amount	Btu's
Natural gas	1 ft^3	1,000
Propane gas	1 gal	92,000
No. 2 diesel fuel	1 gal	130,900+ (depends on quality)
Microwave	1,000 MHz	55

Table 2.—*Equilibrium moisture content of wood (3)*

Relative humidity	Temperature ° F					
	70°	80°	90°	100°	110°	120°
100	31.0	31.0	30.5	30.0	29.0	28.5
90	21.0	20.5	20.0	19.5	19.0	18.5
80	16.0	16.0	15.5	15.0	15.0	14.5
70	13.0	13.0	12.5	12.0	12.0	11.5
60	11.0	11.0	10.5	10.0	10.0	9.5
50	9.0	9.0	9.0	8.5	8.5	8.0
40	7.5	7.5	7.0	7.0	7.0	6.5
30	6.0	6.0	6.0	5.5	5.5	5.0
20	5.0	5.0	4.5	4.5	4.0	3.5

the air is carrying and the amount it could carry at the same temperature when fully saturated. The lower the relative humidity of air at a given temperature, the faster the rate of drying. As air is heated, the relative humidity is decreased. Air at 70° F and 100-percent relative humidity will hold 0.035 pounds of water per pound of air, while at 120° F and 100-percent relative humidity, it will hold 0.1832 pounds of water per pound of air. Thus, saturated air at 70° F, when heated to 120° F, is carrying only 19 percent of its capacity at saturation. Thereby, the heated air increases evaporation and speeds the drying process.

Drying Requirements

The amount of water to be removed can be calculated or estimated for energy measurement purposes. Red pine, loblolly pine, coulter pine, and lodgepole pine all average 35 pounds per bushel of cones. If the cones are green and have a 50-percent moisture content, each bushel will contain 17.5 pounds of water (35 pounds x .50). All of these species are fully opened at a moisture content of about 9 percent. Thus, when open, the cones contain 3.2 pounds of water per bushel (35 pounds x .09). Therefore, the water to be removed in drying is 14.3 pounds per bushel of cones (17.5 - 3.2).

On the other hand, if the cones are further predried without heat to a 35-percent moisture content, only 9 pounds of water need to be removed.

The microwave ovens found in many kitchens will open a green pine cone in about 6 minutes, but because the radiation excites the molecules to the boiling point (212° F), the seeds are killed. If the microwave could be placed in a vacuum, the water would boil at 100° F and therefore not hurt germination. MIVAC is such a system, and its use has generated some energy observations. Regardless of the biological material being dried, the energy requirements are always the same; 1,280 Btu per pound of water removed (2). At 100-percent efficiency, 1,060 Btu are required to evaporate 1 pound of water. Therefore, MIVAC is 83-percent efficient. Additional energy is required in conventional kilns to heat the air, walls, racks, and other parts. Heat is also lost through cracks, leaks, and exhaust. Because of these losses, efficiencies of 60 percent (1,770 Btu per pound of water) with conventional kilns would be very good. This equates to 25,311 Btu per bushel for green cones with a 50-percent moisture content.

Survey Results

A survey questionnaire on energy use and drying practices was sent to 190 extraction plants throughout the United States. Only 74 responded. One half of those responding considered energy in cone drying of current interest. The top 20 expressing concern about their energy costs were selected for the kiln monitoring. A summary of these 20 is given in table 3.

Actual monitoring was accomplished by plant managers with assistance from Forest Service regional nursery specialists and personnel at the Missoula Equipment Develop-4ment Center and the National Tree Seed Laboratory.

The 1980 survey showed that kilns varied from about 12,000 Btu per bushel (with very dry predried cones) to 200,000 Btu per bushel. All cones in the survey had a moisture content of less than 53 percent when they arrived at the processing plant and less than 47 percent when they were loaded into the kiln.

Table 3.—*Summary of characteristics of 20 kilns selected for monitoring survey*

Ownership	No.	Cone production (bu)	No
Federal	5	20-30 M	3
State	7	10-19 M	5
Private industry	6	5-9 M	4
Other	2	Less than 5	8
Fuel type	**No.**	**Number of seedlots**	**No**
Natural gas	3	400-600	4
Propane	10	50-100	6
Oil	5	10-20	2
Electricity	1	Below 10	7
Oil and solar	1	—[1]	1
Location	**No.**	**Kiln capacity (bu)**	**No**
Southeast	7	500 +	7
Northeast	4	100-499	3
West	9	40-99	5
		Less than 20	3
		—	2
Length of drying (hr)	**No.**	**Temperature used**	**No**
48-72	5	150°F	1
24-48	6	120° F	6
16-24	1	115°F	1
10-16	1	110°F	4
6-10	2	105° F	3
Less	1	100° F	2
	4	—	3
Predry	**No.**	**Major species**	
Yes	16	South:	Loblolly
No	4	North:	White pine aid shortleaf
		West:	Douglas-fir Engelmann spruce Coulter pine Ponderosa pine

[1]— = not available.

Moisture content of the dry cones sampled ranged from 6 to 9 percent.

Energy Saving Considerations

Early evaluation of cone drying (3) showed that the more pine cones were exposed to the air, the more drying took place (table 4).

Further, evaluation of equilibrium moisture contents (table 2) suggests that cones cannot be opened at humidities of 70 percent or more without increasing the moisture vapor-capacity of the existing air. This is a common occurrence in the South and Northwest during long periods of rain and drizzle.

This information suggests that predrying, recyling air, and reducing air losses should be emphasized.

Predrying cones. When cones are received at the drying plant, the moisture content can be reduced by spreading the cones in thin layers on trays and creating air movement. Portable greenhouses are excellent for this purpose because they have an air circulation system and also capture some solar energy to heat the air. When space is critical or time is short, the cones can be loaded into the kiln and the air flow system used without heat. This saves extra handling. The dryer the cones are before they are heated, the less artificial drying will be needed and the lower the energy cost will be.

Recycling air. The first air passing through the cones is usually saturated with water vapor and should be exhausted. When the cone moisture has dropped below 20 percent, the air is not being fully utilized. Energy use could be reduced by returning this air to the heating source. Because the air is already warm, less energy will be needed to raise the temperature to the desired level. Such systems can be automated by putting a sensor in the exhaust air and installing a bypass valve. One monitored kiln reduced energy needs by 40 percent simply through recycling the air.

Reducing heat loss. Insulation of kiln walls or duct work can reduce heat loss by as much as 50 to 80 percent. Also, simple steps such as shutting off areas not being used in the kiln, decreasing large open air masses with partitions, or enclosing small kilns in heated buildings will reduce energy needs.

Summary

There is no one cure for energy-use problems in all kilns. Each kiln presents a separate problem, which requires a complete evaluation to identify energy-saving measures. However, the survey showed that some kilns used 10 times as much energy per bushel of cones as others. A savings of 10 to 50 percent is probably possible on 90 percent of existing kilns by longer predrying, recycling the air, and reducing existing heat losses.

Literature Cited

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