COOPERATIVE EXTENSION

Energy

PUBLICATION

Reducing Energy Costs of Walnut Dehydration

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Reducing Energy Costs of Walnut Dehydration

The cost of energy used in walnut drying is rising dramatically. Industry projections indicate natural gas prices will increase 7 to 10 percent above the inflation rate, and electricity prices will increase at about the same pace as inflation. Dehydrator operators can reduce consumption of drying fuel and electricity by one-half — and so cut costs — by following some of the methods listed in this publication (Table 1).

TABLE 1. Methods to Save Energy in Walnut Dehydration.

Method	Fuel Savings	Electricity Savings
	(%)	*(%)*
Prevent overdrying	30 - 50	30 - 50
Recirculate drying air	20 - 30	0
Reduce air velocity	0 - 15	0 - 55
Correctly install and adjust burner	0 - 10	0
Reduce dryer operation during early morning hours	No estimates available	

The average walnut dehydrator in California uses 20 therms of natural gas per ton of nuts or the equivalent of 22 gallons of propane per ton. Average use of electricity is about 5 kilowatt hours (kwh) per ton. In dollars, this means a cost for natural gas of $12 per ton at the estimated 1981 price of 60 cents per therm, for propane of $13.20 per ton at the estimated 1981 price of 60 cents per gallon, and for electricity of 25 cents per ton at the estimated 1981 price of 5 cents per kwh.

Drying operation costs may differ because of variations in dehydrator design, operation and harvest timing. A more accurate way to estimate costs for an operation is to assume that, on the average, drying one ton of nuts for one hour requires 1 therm of natural gas or slightly more than 1 gallon of propane for air heating, and about ¼ kwh of electricity for operating the drying fan.

This energy is effectively used or wasted in various places in the dryer (see Figure 1). As much as 20 percent is lost at the burner. A small percentage of energy escapes through the drying bin walls. Most energy loss in the dryer occurs when heated air leaves the drying bins. There are, however, methods to reduce energy loss.

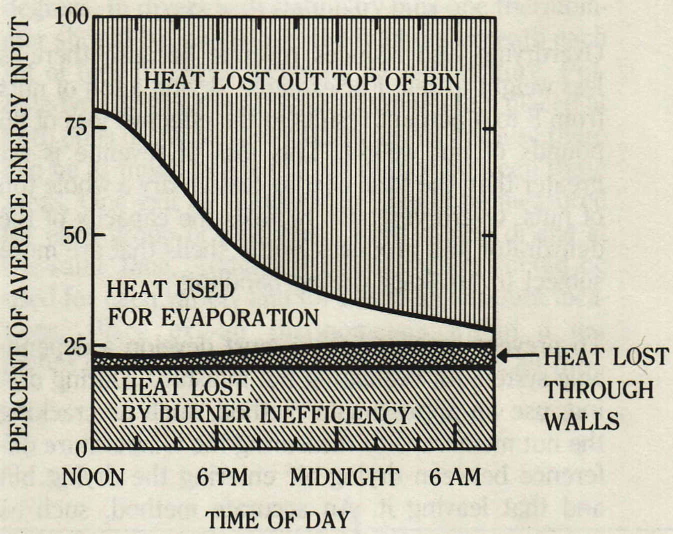

Figure 1. Percent of heat used effectively and percent lost in a typical walnut dehydrator.

Methods to Save Energy

Prevent Overdrying

The most obvious way to reduce energy use and costs is to prevent overdrying. While most walnut buyers or processors will accept nuts at 8 percent whole nut moisture (wet basis measurement) surveys show that most dehydrator operators dry to between 4 and 6 percent whole nut moisture. The result: Extra drying costs. For example, it takes about 5 hours more drying time to take walnuts from 8 to 6 percent moisture (Figure 2).

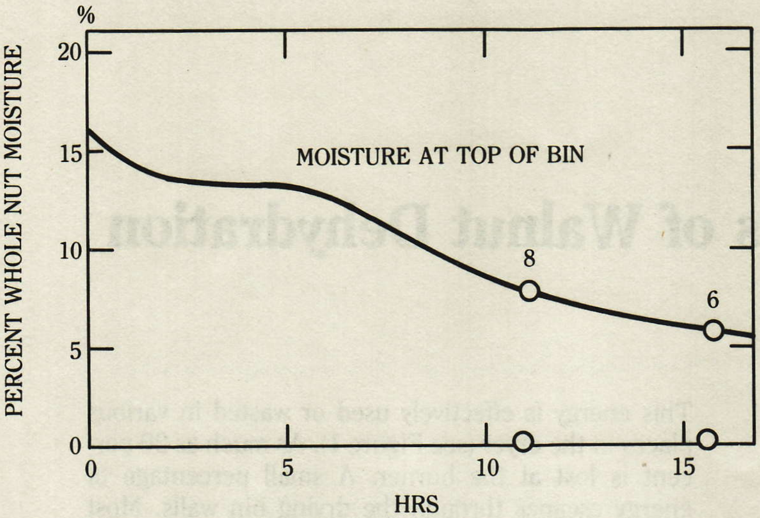

Figure 2. Moisture content versus time required during a typical drying cycle. Note: Rate of drying slows after the nuts are dried to 8 percent moisture.

Overdrying also reduces revenue because there is less weight to sell. For example, drying a ton of nuts from 8 to 4 percent results in the effective loss of 86 pounds of nut weight. This loss of revenue is far greater than the total cost to custom-dry a whole ton of nuts. Overdrying also reduces the capacity of the dehydrator and produces brittle shells that are more subject to breakage during handling.

To prevent overdrying you must develop a dependable system for evaluating nut moisture. During drying, use an approximate method, such as cracking the nut membrane or measuring the temperature difference between drying air entering the drying bin and that leaving it. An accurate method, such as using an electronic moisture meter, an infrared moisture balance or a microwave oven, should be used as a final check before removing nuts from the dryer.

Proper use of all these methods is described here, but to assure success remember: (1) A minimum of 10 (and perhaps as many as 20) nuts should be selected to estimate average moisture. (2) The fact that nuts at the top of a drying bin are wetter than those at the bottom must be considered. Sampling nuts from the center of the bin or taking half of the sample from the top and half from the bottom will provide a good estimate of average moisture. If neither method is feasible, measure the moisture of the top nuts and estimate the average with the aid of Table 2.

The table shows that three factors affect the nut moisture at the top of a bin which corresponds to an average 8 percent moisture: air velocity out of the bin, bin depth and initial nut moisture content. Low air velocities, deep bins and high initial nut moisture will all produce a large difference in moisture content between the top and the bottom of the bin. Thus, the moisture at the top will be high when the bin average reaches 8 percent moisture content. Conversely, high air velocities, shallow bins and low initial nut moisture will produce a more uniform moisture profile and, consequently, a lower reading at the top of the bin will correspond to 8 percent average moisture.

Air velocity can be measured simply by determining the weight of paper that will float on the air coming off the nuts. Table 3 gives approximate air velocities for four different types of paper. Bin depth refers to actual depth of nuts.

TABLE 2. Nut Moisture Content (% W.B.) at Top of Bin That Corresponds to an 8% Average Moisture.

Bin Depth		4 Feet			6 Feet			8 Feet		
Air Velocity *(fpm)*		50	100	150	50	100	150	50	100	150
Initial	15%	11.6	9.9	9.4	12.8	10.8	9.9	13.7	11.7	10.7
Nut	25%	14.0	11.3	10.4	16.9	12.7	11.4	19.0	14.2	12.2
Moisture	35%	16.7	12.6	11.1	20.4	14.9	12.7	23.8	17.2	14.4
(% W.B.)										

TABLE 3. Air Velocity Measurement.

Type of Paper	Velocity That Will Cause Paper Sheet to Float
	(fpm)
Newspaper (half sheet)	40 - 50
New magazine cover	60
Half of manila folder	80 - 90
Side of large breakfast cereal box	150

Many operators have expressed concern about shipping some nuts with high moisture content, even though the load as a whole is at 8 percent because high moisture nuts may be considered off-grade. One solution: Store the nuts for 24 to 48 hours before shipping to allow the moisture to equalize throughout the nuts. Although constructing storage bins or holding the nuts in some other manner may be an added cost, consider how expensive it is to overdry.

Approximate methods

Cracking nut membrane

A common method of estimating moisture is to bend the membrane that separates the halves of the kernel. If it cracks, the nut is considered below 8 percent moisture. If it bends without cracking, the nut is above 8 percent. This method is only effective if the operator periodically calibrates his "feel" for what cracking is against an accurate moisture meter.

Reliable estimates with this technique require that a number of nuts be sampled and an average moisture estimated. Otherwise, an occasional wet nut sampled here and there can cause you to overdry most of the batch just to take care of those few nuts that came in from the field with an unusually high moisture content.

Also, realize that when whole nuts are first removed from the dryer, the meat and membrane are wetter than they will be hours later. When drying has been just completed, the shell is somewhat overdried and the meat and membrane are underdried. Thus, nuts taken directly from the dryer will have a wetter membrane than those that have had time to equalize. (For this reason, also, nut meats with broken shells should not be used for moisture determination.)

Temperature difference

As walnuts are dried, the temperature of the exhaust air steadily increases. Figure 3 illustrates a typical temperature pattern. If 110° F air is used for drying, the nuts will be at 8 percent moisture when air leaving the nuts reaches a temperature in the range of 103° to 105° F. Exact temperature depends on the depth of nuts and air velocity. And, of course, a fairly constant temperature of 110° F must be maintained. A change in any factor will alter the temperature used to determine the 8 percent moisture level. Therefore, every dryer operator should first use one of the more accurate methods to determine precisely what this temperature is for any particular facility. This, then, will provide a standard by which drying progress can be estimated.

When measuring temperatures, use good thermometers. Often, inexpensive ones can be off by several degrees. In dryers with stationary bins one thermometer should be installed in the inlet underneath each set of bins to check incoming air temperature. Pothole-type dryers should have thermometers placed at both ends of the air distribution tunnel because there can be as much as a 10° F difference between these areas. One exit air temperature should be measured for each group of bins which were started drying at the same time. Additional thermometers should be used for each variety and for lots from different locations. Place exit-air thermometers within a few inches of the top of the nuts, directly in the air flow.

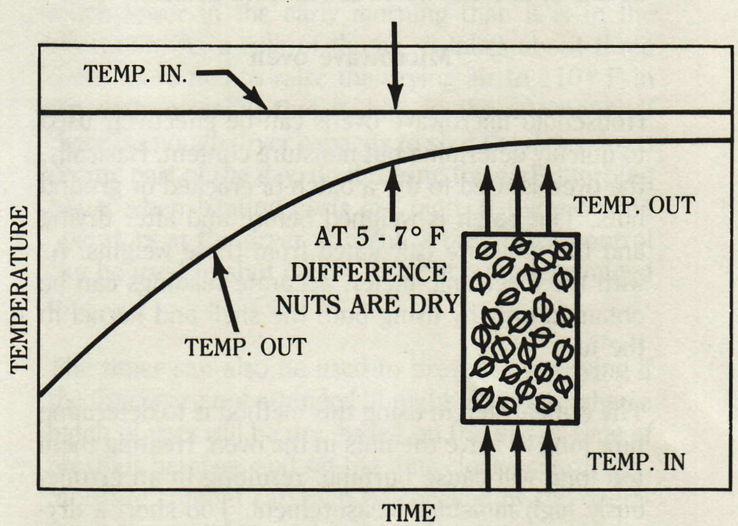

Figure 3. Temperature of air leaving walnuts increases during the drying process.

With enough experience, it may be possible to use the temperature differential method with special instruments to automatically control the drying operation. A device called a differential thermostat, available from most companies that sell regular thermostats, automatically compares temperatures at two points. It can be set for a predetermined temperature difference and when the temperature difference drops to that setting, the burner or both the fan and burner will shut off automatically.

Accurate methods

Portable electronic moisture meters

The standard moisture meter in the industry has been the infrared moisture balance, but its high cost and the fact that it takes about 20 minutes to analyze a sample have caused growers to rely on easier-to-use portable meters. These devices, sold as grain moisture testers, can be used with walnuts if the meter reading is adjusted with a calibration chart. Whole nuts, kernels and shells, must be either ground in a blender, or a hand-cranked meat grinder, or broken with a hammer into small pieces (less than ⅜ inch).

These meters provide a moisture reading in 15 seconds. Their ease of use and accuracy have caused them to be widely used. Calibration charts and the details of use can be obtained from dealers.

Microwave oven

Household microwave ovens can be effectively used to quickly determine nut moisture content. Basically, the oven is used to dry a batch of cracked or ground nuts. The batch is weighed before and after drying and the moisture calculated from these weights. As with the electronic meter, accurate readings can be obtained only by using both the shell and kernel in the test.

The critical step in using this method is to determine how long to leave the nuts in the oven. Heating them too long will cause burning, resulting in an erroneously high moisture measurement. Too short a drying time will incompletely dry the nuts, resulting in a falsely low moisture measurement.

The length of drying time depends on the power output (carefully distinguish between input and output power) of the oven and the size of the sample. More powerful ovens dry faster than less powerful models, and larger samples take longer than smaller ones. An oven with 700 watts of output power will dry four 100-gram samples of about 10 nuts each in 8¼ minutes. A single 100-gram sample requires about 5½ minutes. These times work well for nuts between 4 and 12 percent moisture. Wet nuts coming in from the field or from the huller may take longer.

A power output of about 500 watts will require 9 to 10 minutes drying time for four 100-gram samples. For units below 500 watts, the drying time increases greatly.

To determine a drying time for any combination of power output and sample size, check the time it takes to burn a sample load and subtract 30 seconds from this time. The onset of burning is marked by an off-odor and dark nut color rather than by smoke. It may be advisable to check a microwave sample against one from an infrared moisture balance or an electronic moisture meter to verify the drying time.

Be aware of two problems with microwave ovens. First, most ovens have "hot spots" and occasionally a sample will burn even at the correct drying time. Check an unusually high moisture reading to see if the sample has burned; disregard readings from any sample that appears burned. Secondly, after nuts are taken out of the oven they continue to lose moisture; therefore, the final weight measurement must be taken 5 minutes after removal.

Recirculate Dryer Air

During most of the drying cycle the warm air being exhausted from the bins still has quite a bit of heat that can be used. Recirculating 50 percent of this exhaust air will reduce fuel usage per ton by 10 to 25 percent. This can be done in dryers enclosed in a building by using an air duct to connect the drying room to the burner and fan room. The air duct should have a cross-sectional area about as large as the largest cross-sectional area of the plenum chamber beneath the drying bins. If this size duct is not feasible, use a smaller duct with a fan. In dryers covered only with a roof, drop plastic or canvas curtains from the eaves to form an air passage above the bins. This will direct a portion of the drying air back to the burner (see Figure 4). On cold nights there may be some condensation on the underside of the dryer roof. This con-

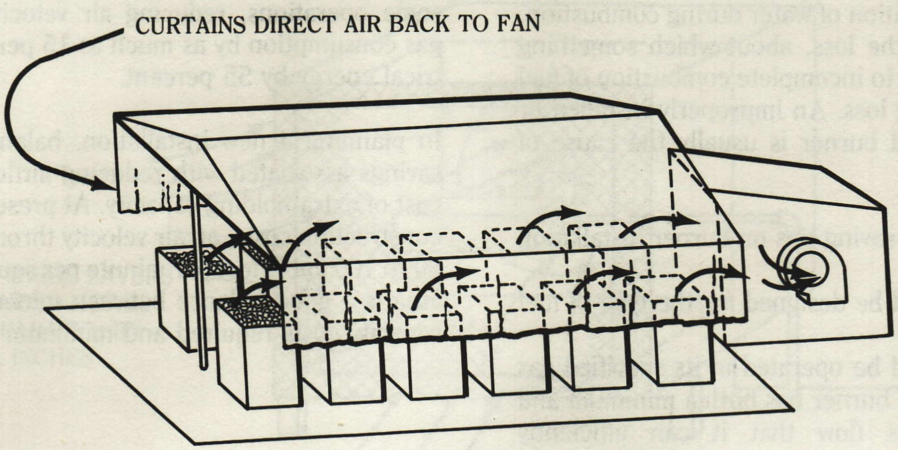

Figure 4. A method of recirculating drying air in a covered pothole-type dryer.

densation may be a nuisance, but if it falls on the nuts, it will dry quickly and should not affect total drying time.

The level of recirculation possible by modifying existing dryers will not significantly increase drying time. Most dehydrators cannot recirculate more than 50 percent of the exhaust air because of air leakage. This level of recirculation will result in a 5 to 15 percent increase in drying times. (This increase in drying time is considered in the estimate of per ton energy use saving.)

Dryers should be set up so that the level of recirculation can be regulated. A door to the outside, placed near the air inlet of the fan, can be opened resulting in very low recirculation levels. With the door shut, inlet air is drawn from the dehydrator area and recirculation is at a maximum. The door is shut when the air coming out of the nuts is 15° F warmer than outside air. Recirculating when the air coming out of the nuts is cooler than this will save energy but will result in longer drying times than beginning when there is a 5° F difference.

In the past, a few dehydrators could recirculate almost all exhaust air; their improper use did result in long drying times and caused the notion that recirculation did not save energy because it increased drying time.

Reduce Operation During Early Morning Hours

On many days in the fall, outside air temperature is much lower in the early morning than it is in the afternoon. As a rule of thumb, it takes about three times more fuel to raise the drying air to 110° F in the early morning that it does in the afternoon. If there is enough dryer capacity to shut the dryer down during part of the day, do it during the early morning hours when heating costs are high. If there are no operators at the dryer at night, a time clock control can be used to shut off the dryer at a predetermined time.

The timer can also be used to prevent overdrying if the dryers are not attended at night. Estimate when a batch of nuts will be dry, based on the drying time of previous batches, and set the time clock accordingly. Moisture content can then be checked by the operator in the morning, and if the nuts are not quite dry, the dryer can be turned on for a few more hours during a warmer time of the day.

Correctly Install and Adjust Burner

Proper installation and adjustment of burners can save fuel. Natural gas and propane burners commonly lose up to 20 percent of their total energy output. Ten percent loss, regardless of burner design, is due to the natural formation of water during combustion. The other half of the loss, about which something can be done, is due to incomplete combustion of fuel and to radiant heat loss. An improperly installed or improperly adjusted burner is usually the cause of this loss.

Here are some fuel-saving tips on burner installation and adjustment:

- Burner should be designed for the type of fuel to be used.
- Burner should be operated in its specified gas flow range. (A burner has both a minimum and maximum gas flow that it can efficiently handle.)
- Burner should be properly maintained. If gas can be detected in the drying air, if the burner is producing a large amount of yellow flame, or if there are carbon deposits on the burner, it should be immediately repaired or replaced.
- Shield the flame to prevent radiant heat loss and to provide safety. Typically, a burner shield consists of an inner shield of sheet or expanded metal surrounding the burner area and an expanded metal screen across the inlet area (Figure 5). The inner layer absorbs the radiant heat and transfers it to the moving air.

Reduce Air Velocity

To reduce gas and electrical energy use, a dehydrator should be operated at its lowest feasible air velocity. While, as a rule of thumb, doubling the velocity will reduce drying time by 30 percent, the cost for this will be higher heat and electrical energy use (Figure 6).

In an existing facility, air velocity can be reduced, if there is extra dryer capacity to allow drying time to be increased. To reduce velocity, change the pulleys on the motor and fan to slow the fan speed. Also, operate the dehydrator only when it is full or nearly full. Turning on a 20-ton capacity dehydrator with only 10 tons of nuts in the bins causes the fan to force the heated air through the nuts too fast for efficient drying. If a dehydrator must be operated partially full, it is possible to use a damper assembly or a variable speed device to reduce the fan output.

A constant air flow through bins can be maintained by adjusting the fan to produce a constant static pressure in the air-supply duct. Either purchase or make a pressure gauge (Figure 7) to measure pressure in the supply duct. Table 4 shows the relationship between static pressure and velocity for walnuts. For some operations, reducing air velocity can reduce gas consumption by as much as 15 percent and electrical energy by 55 percent.

In planning a new installation, balance the money savings associated with reducing airflow against the cost of extra holding capacity. At present energy and construction costs, an air velocity through the nuts of 80 to 100 cubic feet per minute per square foot of bin area is a good balance between minimizing holding capacity costs required and minimum energy use.

New Method of Drying

Research is being conducted to dry nuts with unheated air, a concept similar to drying grains, especially rice, in on-farm storage bins. The system utilizes the drying potential of outside air to remove moisture from the nuts and requires added heat only during prolonged periods of high humidity. This method, still in the experimental stage, can potentially reduce heat energy costs by more than 90 percent.

Methods That Will Not Save Energy

Drying walnuts with a tempering procedure has not proved practical in reducing fuel use. In tempering, the fan and burner are turned off at regular intervals during drying. Tests where the fan and burner were turned off for 10, 20 or 30 minutes out of every hour increased drying times in proportion to the total time the dryer was off. Although the 20-minute and 30-minute cycles slightly reduced natural gas consumption per ton, greater savings in both natural gas and electricity can be obtained by reducing air velocity enough to result in the same drying time caused by tempering. Reduction of the air flow also allows use of a smaller fan and motor, resulting in lower installation costs and electrical demand charges.

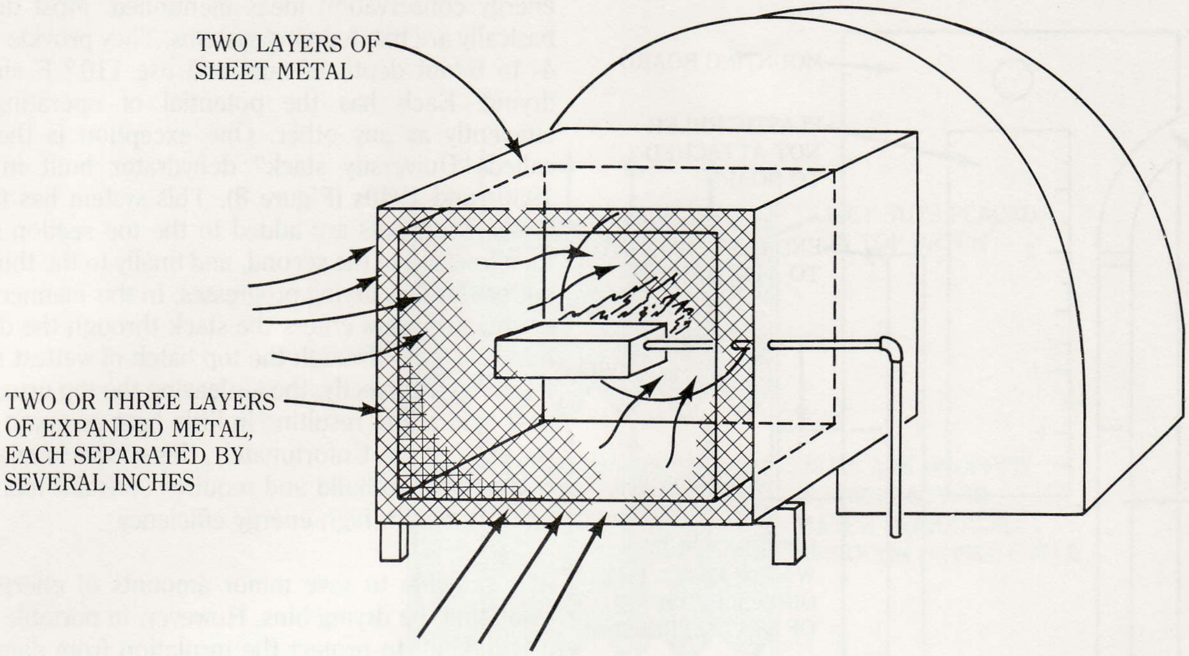

Figure 5. Typical method of shielding a burner to prevent radiant heat loss.

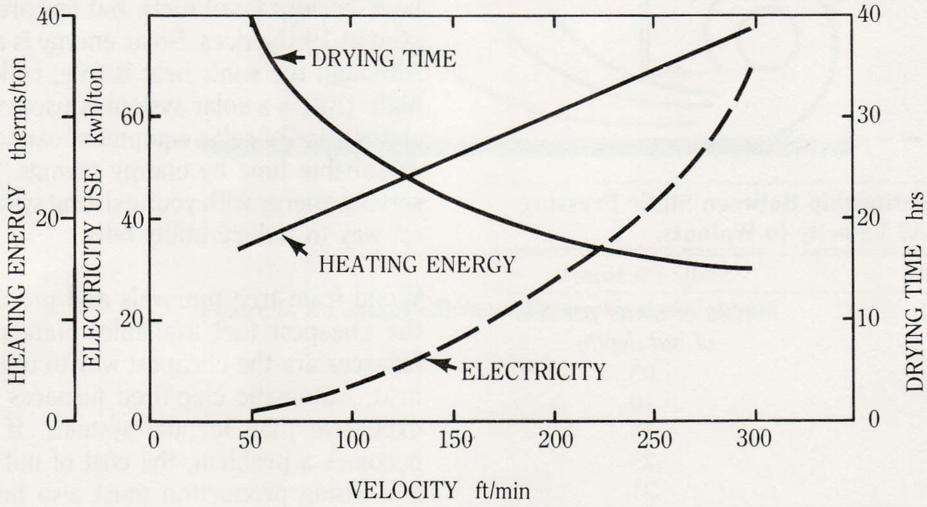

Figure 6. An example of the effect of increasing air velocity on energy use in a walnut dryer.

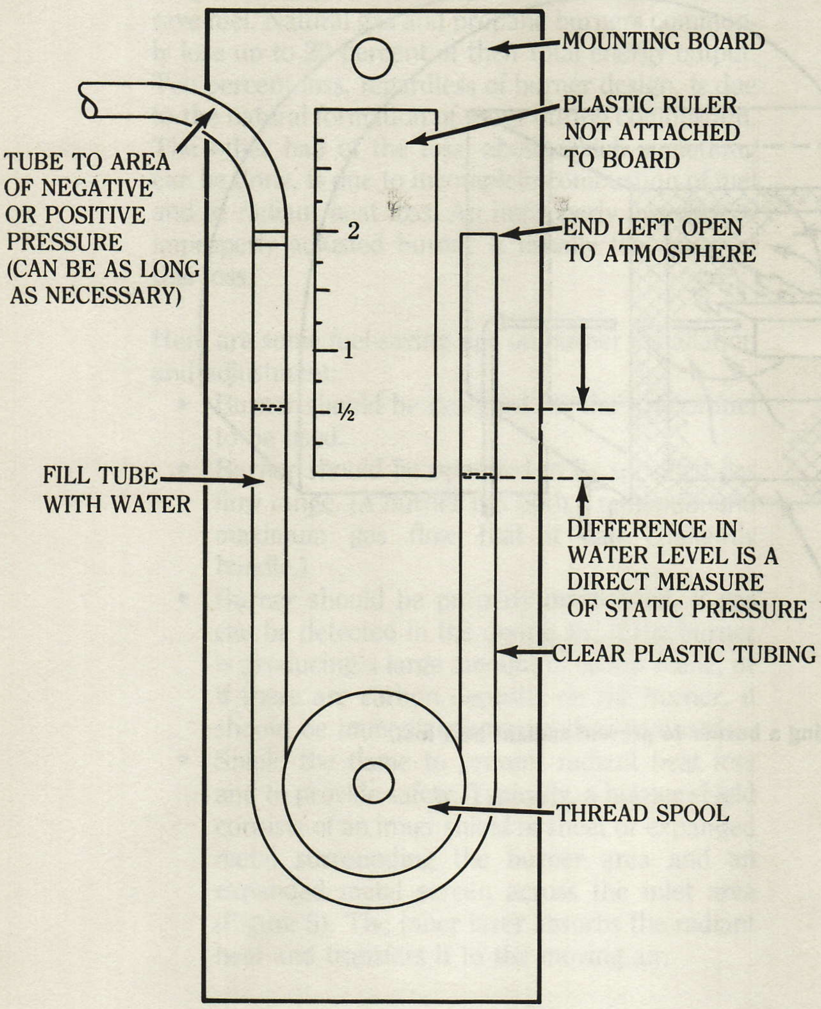

Figure 7. Schematic diagram of a simple tool to measure static pressure.

TABLE 4. Relationship Between Static Pressure and Velocity in Walnuts.

Velocity *(fpm)*	Static Pressure* *(inches of water per foot of nut depth)*
50	.05
75	.10
100	.15
125	.23
150	.31

*Multiply this number by the depth (in feet) of nuts in your dryer to find total static pressure in air supply plenum.

In general, changing to a new type of dryer will not reduce energy use, unless it utilizes some of the energy conservation ideas mentioned. Most dryers basically are batch drying systems. They provide for a 4- to 6-foot depth of nuts and use 110° F air for drying. Each has the potential of operating as efficiently as any other. One exception is the so-called "University stack" dehydrator built in the 1930s and 1940s (Figure 8). This system has three levels; fresh nuts are added to the top section first, then lowered to the second, and finally to the third or bottom level as drying progresses. In this manner, the drying air always enters the stack through the driest nuts and exits through the top batch of wettest nuts. If operated correctly, the air leaving the top usually is near saturation, resulting in little heat escaping with the exhaust air. Unfortunately, this system is relatively expensive to build and requires constant management to obtain high energy efficiency.

It is possible to save minor amounts of energy by insulating the drying bins. However, in portable bins it is difficult to protect the insulation from damage. Stationary bins are easier to insulate but the added cost must be carefully compared with a 2 to 4 percent potential energy savings. The energy savings would be even lower if the dryer is enclosed in a building, because much of the heat transferred through the walls is captured in the recirculating air.

Alternate Energy Sources

Many have wondered whether there are energy sources less expensive than natural gas or propane to provide heat for drying. There are other sources of heat, besides fossil fuels, but few are less expensive, even at 1981 prices. Solar energy is a good example. Although the sun's heat is free, collection costs are high. Unless a solar system is used all year, the purchase price of solar equipment cannot be repaid in a reasonable time by energy savings. Therefore, conserving energy with your existing system is the cheapest way to reduce utility bills.

Wood from tree removals and prunings is probably the cheapest fuel available. Manually-operated log furnaces are the cheapest way to utilize prunings for heat. Automatic chip-fired furnaces are much more expensive than manual systems. If fuel availability becomes a problem, the cost of not drying the nuts and losing production must also be considered. In this case, prunings are probably the cheapest and most reliable fuel source available.

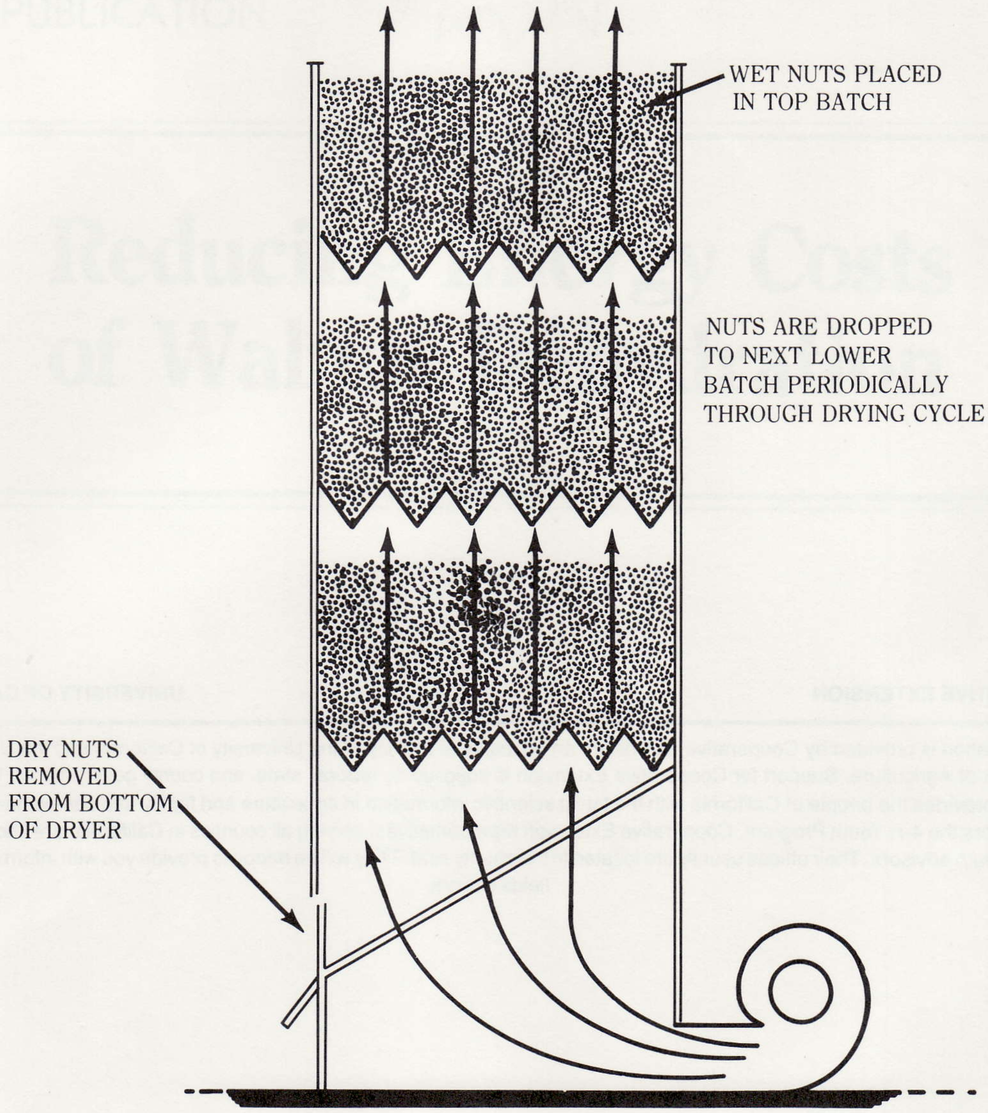

Figure 8. An energy-efficient "University stack" dryer.

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