The Winiarski Wood Fired Agricultural Food Dryer

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Dr. Larry Winiarsk helped to design and build a prototype wood fired dryer for cacao beans with farmers in the wet mountainous region of Nicaragua. The dryer was financed by USAID, for the local group ACODEMUBE. The project was facilitated by the Winrock International Clean Energy Program. Larry spent about two weeks working with Winrock to build and test the first of twelve dryers.

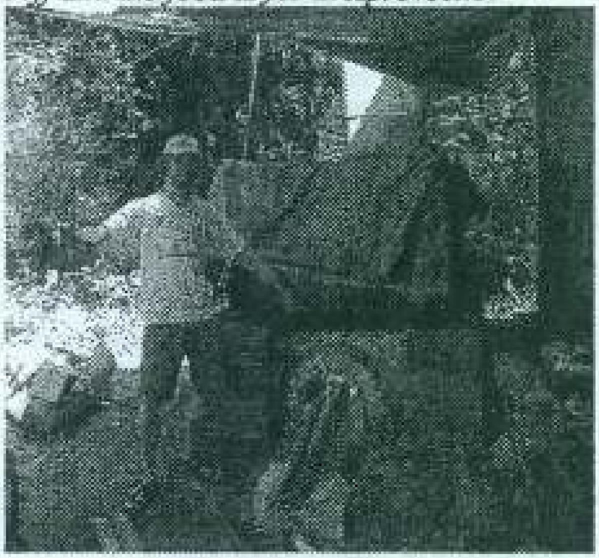
The dryer is based on the Rocket style plancha (griddle) stove design. Sticks of wood are fed into a foot square opening, the horizontal feed magazine, that leads to the base of a slightly higher three foot high vertical internal chimney made from ceiling tiles called baldosa. The feed magazine and internal chimney are in the shape of the letter "L". The combustion chamber and internal chimney are surrounded by light weight pumice rock that insulates around the small fire. The griddle is four feet wide by ten feet long and sits on top of a brick box containing the firebox and internal chimney. Pumice fills the entire box leaving only a one inch gap between the rock and the underside of the large griddle. Hot flue gases pass through this one inch gap exiting out of the back of the box into a 12 foot high 12" in diameter chimney.

A metal box, open at the bottom, elevated one inch above the griddle, holds the trays of beans. Heated air is sucked in through the one inch opening and is pulled through the trays. The moist air then travels through the drying box and exits in a chimney that surrounds the inner chimney connected to the fire. The larger external chimney, 20 feet tall, is warmed by the heat passing through the inner chimney, which helps to create better draft. This increased draft helps to shorten drying periods.

Larry Warinarski beside the food dryer built in Nicaragua.

After returning from Nicaragua, Dr. Winiarski encouraged students at the research center to build a duplicate dryer for testing. Jeff Stuts, a Humboldt State student, and a research assistant in the Advanced Studies in Appropriate Technology program at Aprovecho, built the dryer in about three weeks in the summer of 2002. The dryer base was made from cement block, covered with ¼" recycled steel plate. The dryer box was constructed from recylcled sheet metal as were the chimneys. The cost of the dryer was about $300 US.

Jeff and the food dryer at Aprovecho:



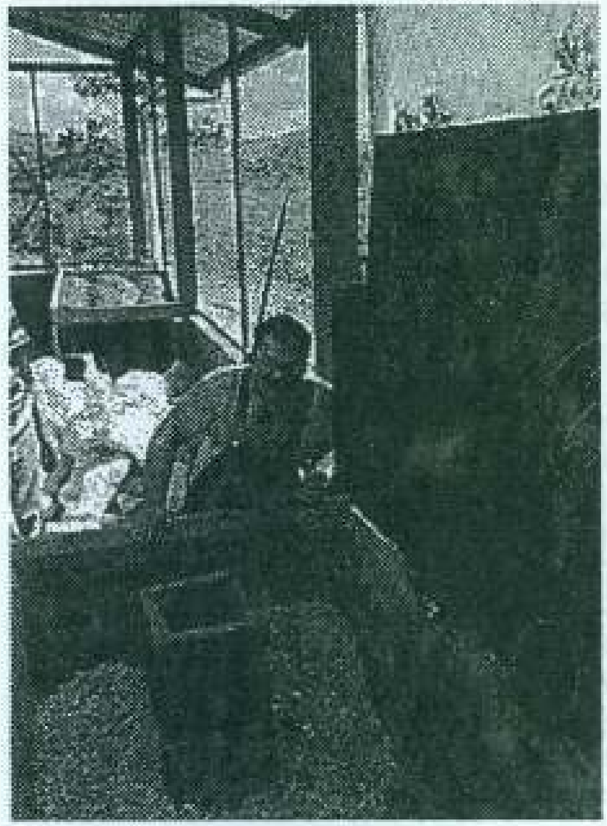
Because climates and conditions exists where food dehydration is not possible by solar energy alone, a wood –fired dehydrator is often helpful for preservation . The optimal temperature for food dehydration is between 120 and 130 degrees farenheight. Temperatures that exeed 130 degrees can begin to cook the food. (When starting to dry foods it is sometimes most efficient to go up to 150 to 160 F. in the initial stages of drying when lots of moisture will be evaporating out of the food.) A successful food dehydrator will be able to sustain these temperatures at a constant rate with even distribution for a variable period of time dependant on the type of food being dried.

Hot air temperatures surrounding the food increase the rate of evaporation. An equally necessary component to effective food drying is air flow. For a piece of food to be dried the water inside must be turned into water vapor and then moved out of the dryer. Hot air is able to hold more water than air at a lower temperature. Good air circulation and air flow is necessary because dry air and air with low moisture content have the capacity to hold and remove water vapor. Air that is completely saturated with water vapor will stop taking water from the food, and the dehydration process will be slowed.

To efficiently heat air and create good air flow and circulation food dryers: a) have a heat source, b) are relatively air tight, c) create dry air, d) have a large chimney or fan that moves dry air past the food. A large chimney, that is at least the length of the body of the dryer, will usually create the draft necessary for good air flow and circulation.

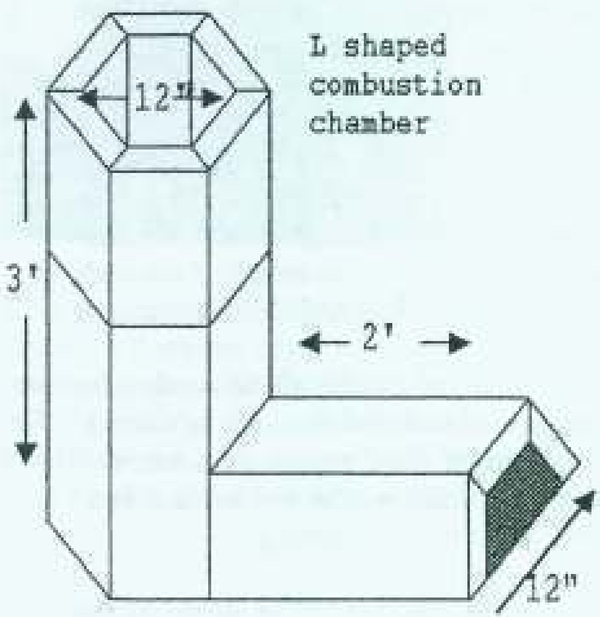
In the Winiarski dryer, a small fire is lit inside of an insulated Rocket elbow combustion chamber. ***The dryer uses about 10 pounds of wood per hour and as a rule of thumb consumes close to one pound of fuel to make a pound of dried apples or tomatoes***. The shape of and insulation around the combustion chamber will keep the fire burning at a higher temperature, will decrease fuel use, and will assist cleaner burning.

The combustion chamber is best built out of fire resistant tiles, fire bricks, or bricks that are as refractory and insulative as possible. (Please contact Aprovecho for easy to make recipes for home made fire brick.) Insulation completely surrounds the combustion chamber.



Notes about picture: Insulation is being placed on the inside of the dryer. Notice the combustion chamber in front of Larry. The insulation should surround the combustion chamber as shown. It should come within an inch to the top of the base, leaving a 1" air space for the hot flue gases to travel back to the inner chimney.

Insulation is air, pockets of air surrounded by a very light material. Earth, sand, adobe will not work here. Instead use wood ash, pumice rock, vermiculite or perlite. A insulated combustion chamber will start much easier and has many benefits. Insulation also sits beneath the steel plate so the heat goes into the steel, to warm air used for drying, not into the box under the steel where the heat would be wasted!

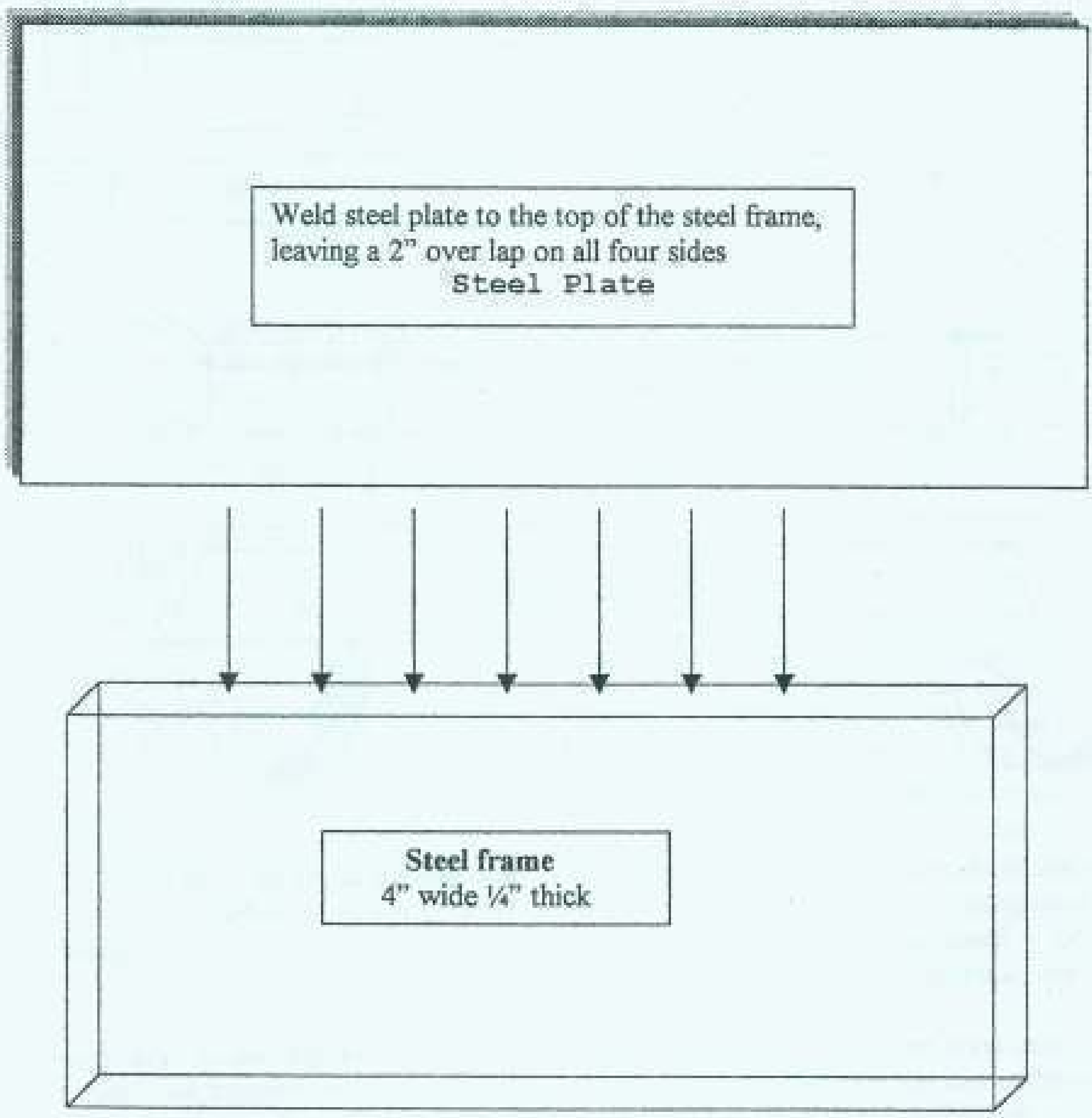


The hot flue gasses rise out of the top of the "L" shaped combustion chamber and flow under a large steel plate four feet by ten feet. The hot gases travel through a one inch air gap underneath the steel plate for the entire length of the dryer. At the end of the dryer, the hot gasses, which have expended most of their heat, go down a small opening and into a chimney. The draft created by the chimney helps to pull the hot gasses through this one inch air-gap but the rocket combustion chamber creates enough draft initially to push the first gases into the chimney. No priming in the chimney is necessary.

The steel plate should be attached to the box on which it sits so smoke cannot escape and find its way into the air used for drying. We don't want smokey tasting food! A four inch strip of ¼" steel is welded underneath the edges of the plate inset 2" from the sides. This smoke barrier enters a gutter full of loose material like pumice rock, perlite, vermiculite, sand, fine dirt, etc. so that if the steel plate distorts when hot the smoke cannot escape.

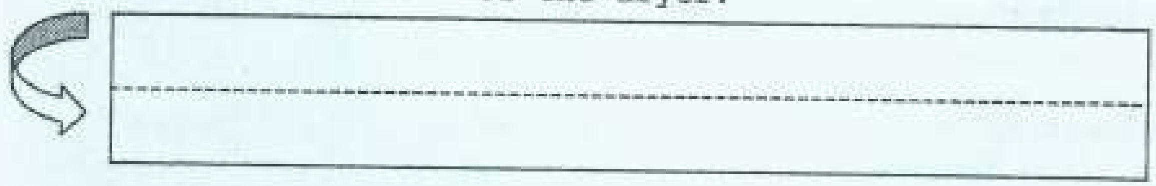
Note: Even though the base is not being used as a direct cooking source. The steel structure being illustrated will be called the plancha, because of it's general simularity.

1. Creating the plancha

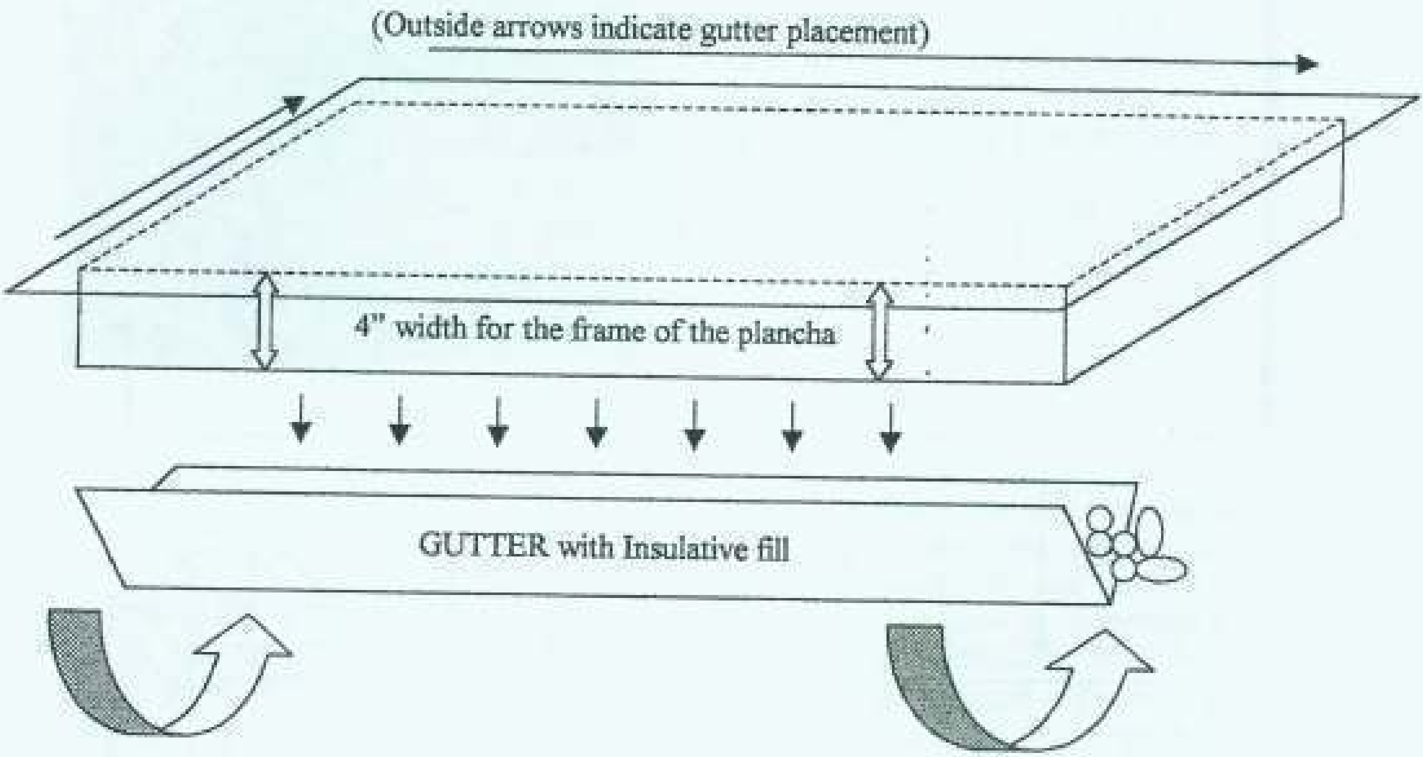


2. Creating the gutter (optional, see notes below)

Taking a piece of 6" wide sheet metal bend it in half to create a V shaped gutter. This should be done three times: Two for each length wise side and one gutter for the back of the dryer.

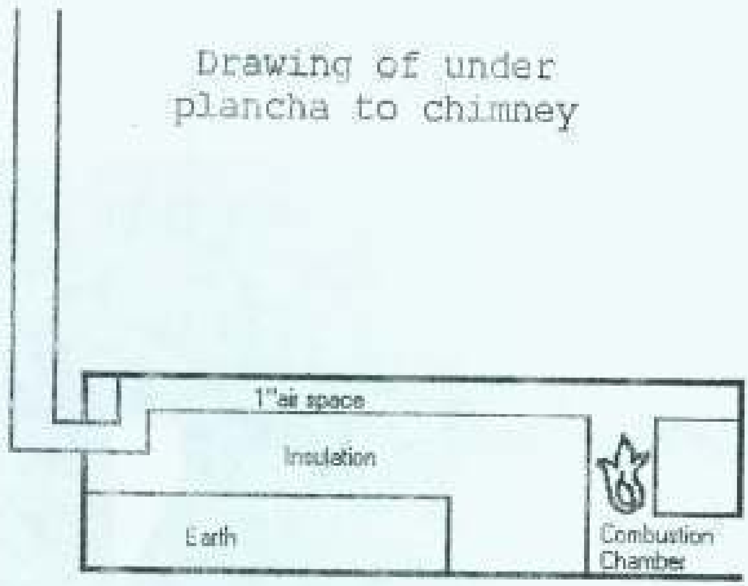


3. The placing of the plancha within the gutter



The frame is placed within the gutter. This gutter surrounds the dryer on three sides, there is no gutter in the front of the dryer (the front being above the Combustion Chamber) Insulation is placed within the gutter. This is done to keep the hot flue gases within the chamber, not adding a smokey flavor to the food being dried.

This picture is an example of what was done with the food dryer at Aprovecho. The dryer in Nicaragua was not constructed with a gutter, as illustrated. Larry instead filled the base with insulation and then placed a finer layer of insulation along the perimeter of the *plancha. Once the frame was placed on top of this base of insulation it became embedded within the smaller particle insulation, and was able to keep the hot flue gases from escaping.*

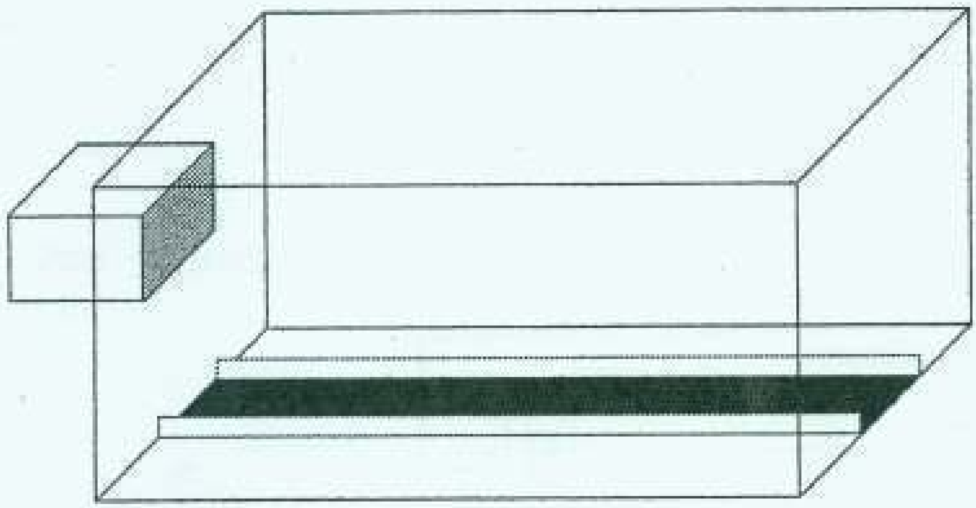


As the hot flue gases are traveling in the small one inch thick gap under the steel plate the heat is forced to rub against the undersideof the metal efficiently warming it. The steel plate in turn heats up ambiant air above itself which is then pulled into a box full of shelves of sliced food. The dryer box is located one inch above the steel plate and supported by short spacers resting on top of the steel.

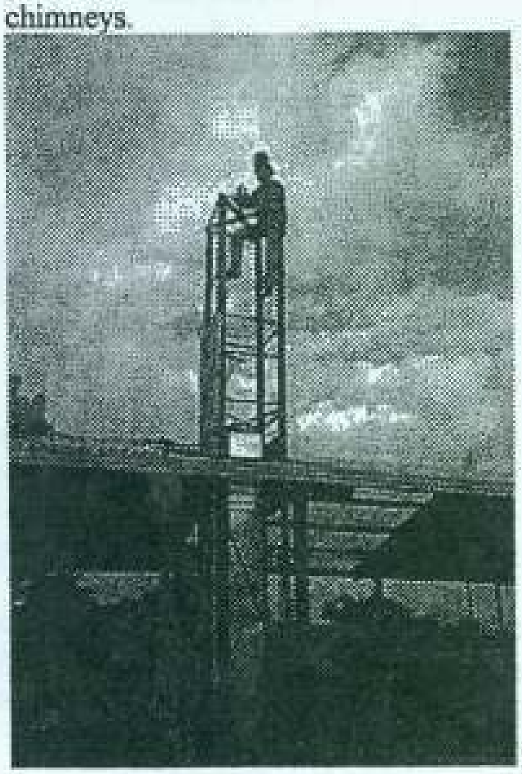
The box has a sheet metal bottom which creates another one inch channel efficiently heating ambiant air. The warmed air passes into the sealed box through a four inch wide opening in the boxes' metal floor which runs down the entire 10 foot length of the box. As the air inside of the dryer box begins to rise in temperature it increases the rate of evaporation in the food slices. The warm, humid air inside of the dryer box is pulled out of a hole cut into the back of the dryer box , attached to a large chimney. This large 3 foot by 3 foot by 15 to 20 foot high second chimey provides enough draft to keep the air that is becoming saturaturated moving through and out of the dryer. In the test dryer at Aprovecho, air moved out of the dryer box at between 6 to 8 mph, powered by the draft of the chimney.

Internal Structure of Dehydrator Box

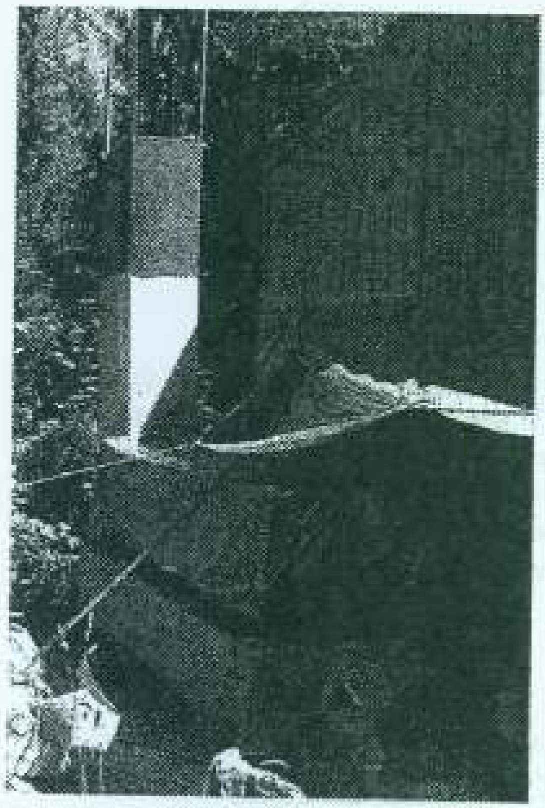
With connection to chimney

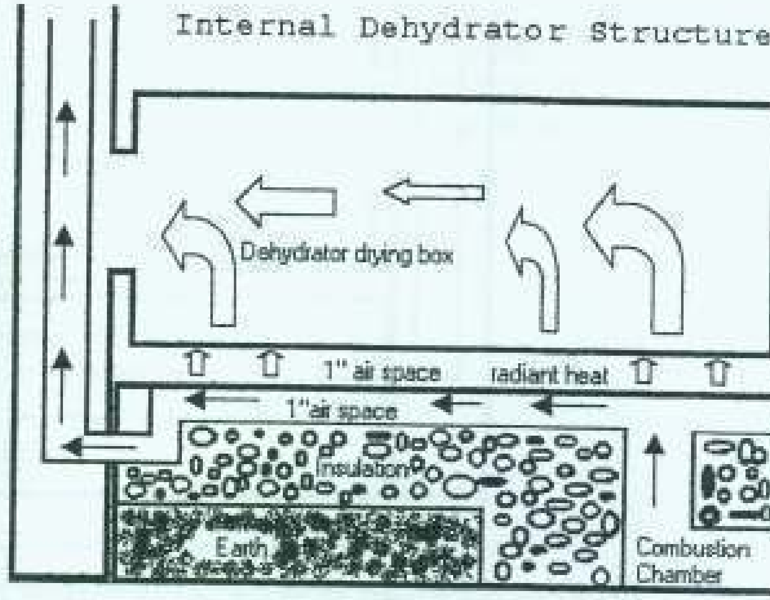


The smaller chimney (12 inches in diameter, ten feet high) that is attached to the fire is inside this larger chimney that creates draft in the drying box.. The smaller chimney expells the hot flue gases five feet below the top of the larger chimney which increases draft in the larger and surrounding chimney. Having the one chimney inside the other is one of the design criteria that makes the Winiarski dryer perform well. The larger chimney can be taller, that increases draft. The Nicaraguan dryers have 20' tall external chimneys.



Construction of the Nicaraguan chimney



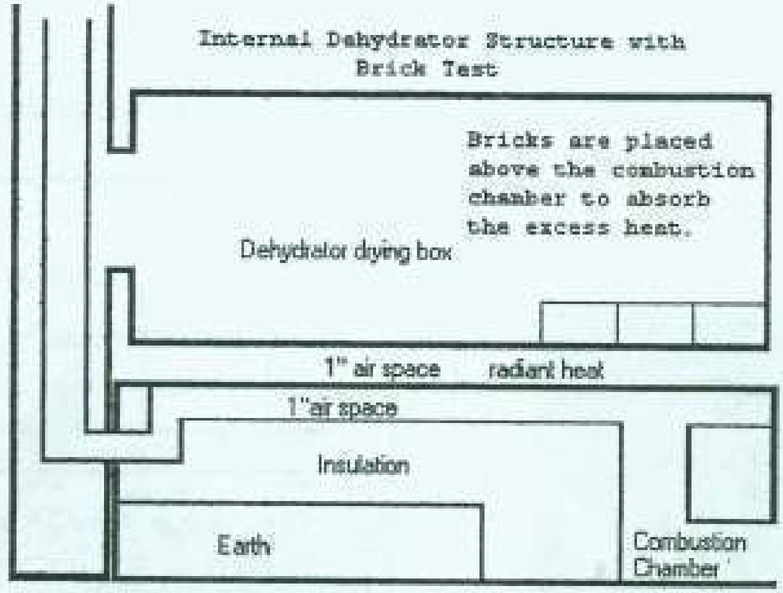


Aprovecho dryer (smaller chimney than Nicaraguan dryer)

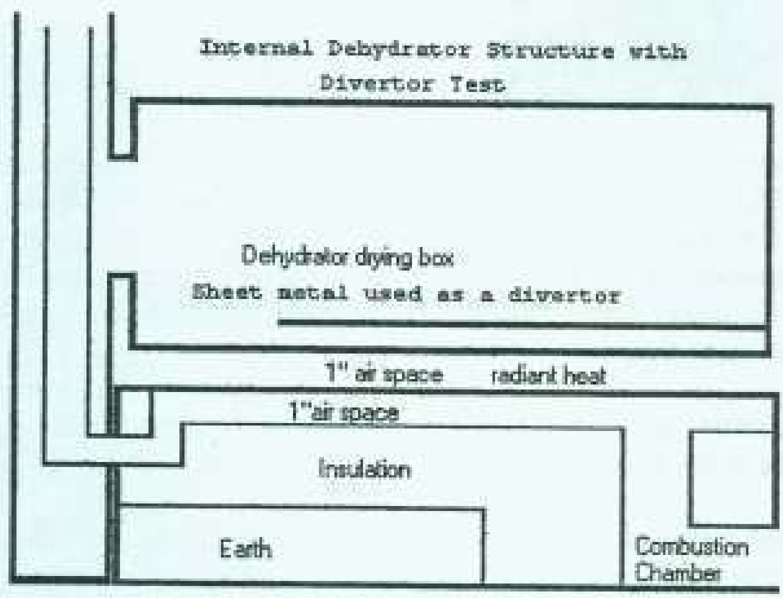
One of the purposes of this paper it to describe efforts made by Jonathan Pilch and Mona Cancino, 2002-3 ASAT students at Aprovecho, to even out temperatures in the drying chamber. Uneven temperatures inside of the dryer due to the hot temperatures closest to the combustion chamber and low temperatures at the back of the dryer can be modified by adjustments to the dryer. Even temperatures make the dryer easier to use since trays of food finish at the same time as food is more evenly dried.

Although the possibilities and combinations are many, there are three main ways to even out the temperature in the drying box. These are:

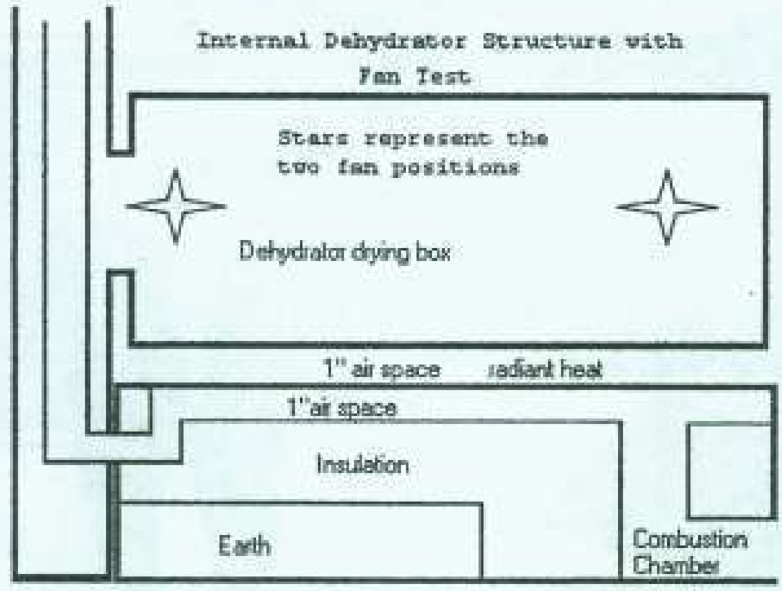
Absorbing the heat from the fire: This can be achieved through many different techniques. The easiest of them would be to put high mass bricks on top of the sheet metal base of the air-tight box of the dryer in the area above and near the combustion chamber. Placing mass near a hot spot works to even the initial disparity of temperatures but also diverts heat from the purpose of drying food.



Diverting the hot air from the fire to another part of the dryer: One way of doing this is to place sheet metal above the bottom of the hot spot in the dryer box. There are many variables to consider when doing this, such as how long and how wide the diverter should be. While heat rises quickly and easily it moves horizontally at a much slower rate. Placing this diverter angling upwards might be a good way to help the hot gases to move to the back of the dryer but doing so raises the trays of food near the back of the dryer.



Increasing air flow inside the dryer box: One potential method for increasing convection is to place 2' to 3' tall small 4" in diameter chimneys inside the dryer box. The hot air moves up the chimney creating a convective current – spreading the hot air more evenly throughout the dryer. This method might prove to be very important if you find that the food on the lower racks is drying much faster than the food on the top racks. Another way of increasing convection is to place a fan inside of the dryer. Fans can be placed in both the duct connecting the dryer box to the chimney or in the front of the dryer above the hottest spot in the metal plate.



Some Notes on Food:

As with many types of food preservation, treating the food will help to stop enzyme activity, slow the decomposition of the food, as well as maintain nutritive values. In the case of food drying, blanching is the best method. To blanch a food means to steam or boil the food for a short period of time, usually 2 to 3 minutes, before the drying process. The time that each food needs to be blanched varies from food to food.

Food can be dried on trays with oppenings for air to pass through. Screens are often used to make the bottom of the food drying trays. The material for the racks or screens will vary from location to location. In the test dryer at Aprovecho we used 13 trays each four feet wide by two and a half inches long, stapling fiberglass screening to a wooden rectangle. About 125 pounds of tomatoes filled the trays. At least twice this amount of food could be dried as a batch.

Gathering your food

Cutting your food

Placing your food on the screen

Drying your food

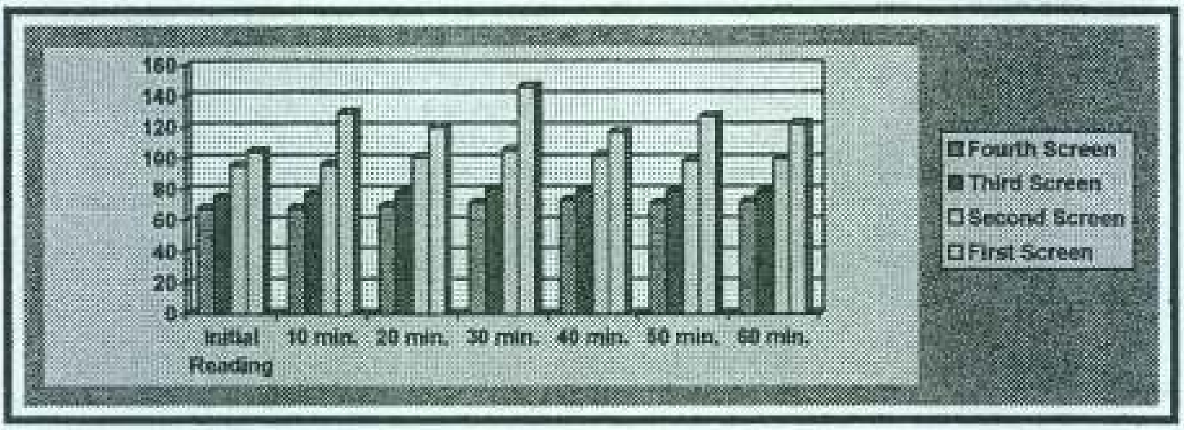
The total drying time, and the amount of wood burnt, will vary according to the water content inside of the food. It is important to slice food evenly, so that each piece of food has an equal amount of moisture and drys at the same time. Opening the dryer many times to check food and remove dried food will decrease the temperature inside of the box, and possibly add water-saturated air into the dryer, all of which will prolong the total drying time. It is recommended not to stop and start the dryer between batches.

Testing the dryer:

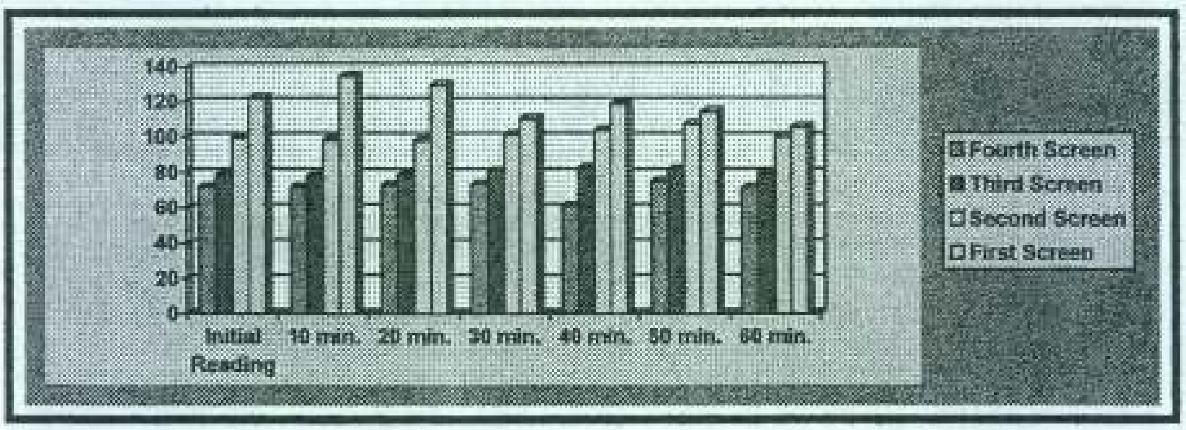
The first test performed on the dryer was with no adjustments. Four trays were placed inside of the dryer filling the space btween the front and the back. A temperature guage was placed in the middle of each screen. The dryer was lit and allowed to come up to an equilibrated state. Each test was for one hour and the temperature was recorded at ten minute intervals. The results of these three tests were as follows:

(Readings are from the back of the dryer to the front – the fourth screen is the screen in the back of the dryer.)

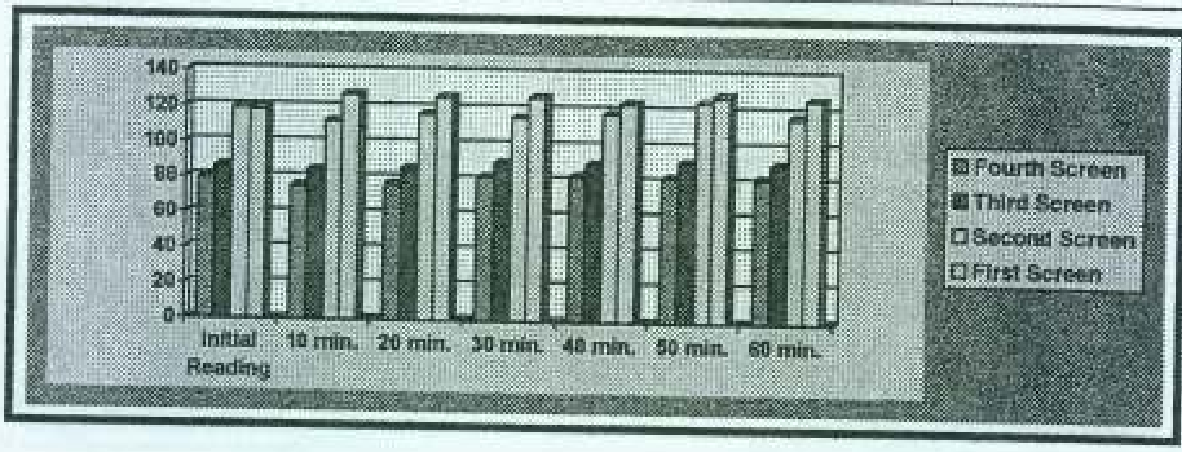
Test 1	Fourth	Third Screen	Second Screen	First Screen
Initial Reading	67.4	74.6	95.0	104.1
10 min	67.4	77.0	96.0	129.4
20 min	69.3	77.9	100.6	120.0
30 min	71.5	80.2	105.2	146.0
40 min	72.7	79.7	101.8	116.7
50 min	71.1	78.2	98.2	127.1
60 min	71.9	78.4	99.6	122.1



Test 2	Fourth Screen	Third Screen	Second Screen	First Screen
Initial Reading	71.9	78.4	99.6	122.1
10 min	71.7	77.7	98.2	134.5
20 min	72.7	78.6	97.8	129.6
30 min	73.3	80.7	101.2	110.2
40 min	61	82.7	103.7	118.6
50 min	75	81.8	107.2	114.4
60 min	71.1	79.7	100.0	105.4

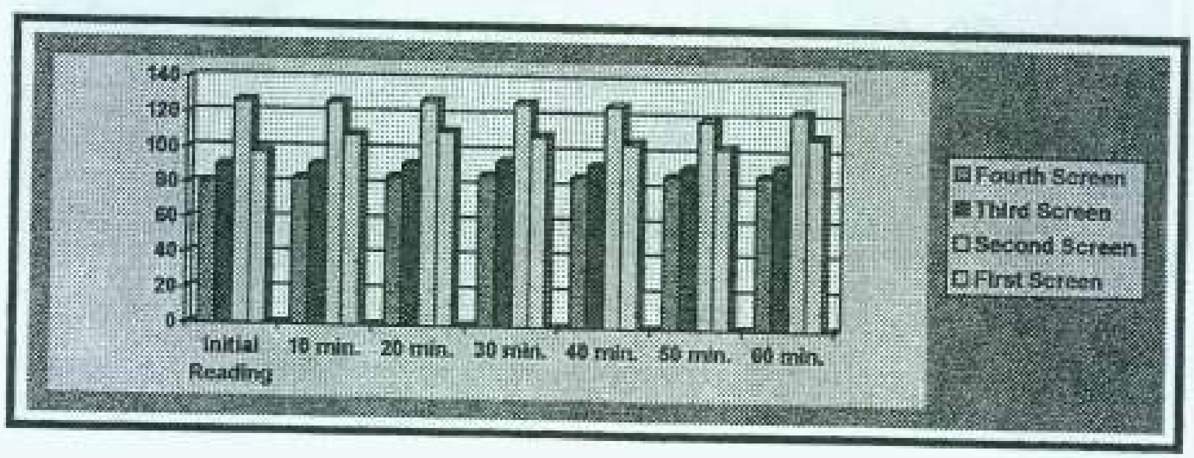


Test Three	Fourth Screen	Third Screen	Second Screen	First Screen
Initial Reading	79.1	86.1	119.3	118.6
10 min	75.1	83.9	112	126.9
20 min	76.4	85.5	116.5	126
30 min	81.2	89.3	115	126.3
40 min	82.1	88.7	117.6	123.3
50 min	81.7	90.5	124.3	127.9
60 min	81.5	89.1	116.4	126.2



The next test performed was an attempt at diversion. Sheet metal was cut (dimensions: width: 31 inches, length 47 inches) and raised about an inch above the oppening that runs along the length of the center of the dryer. The results were the following:

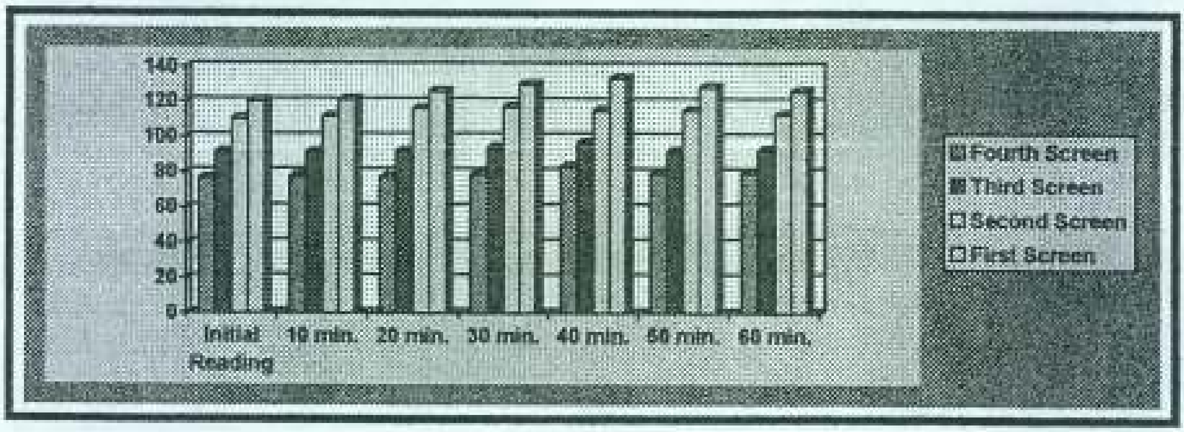
Test Four	Fourth Screen	Third Screen	Second Screen	First Screen
Initaial Reading	80.4	89.8	126.6	97.8
10 min	82.9	90.8	126.6	107.9
20 min	84.3	91.9	127.9	110.5
30 min	85.6	93.5	127.1	108.5
40 min	85.2	92.3	126.0	105.2
50 min	86.8	91.5	118.6	103.2
60 min	87.1	92.6	123.5	109.7



From this test we were able to see how a diverter improves the ability to control the hottest spot inside of the dryer. This particular test, however did not even out the temperatures very much.

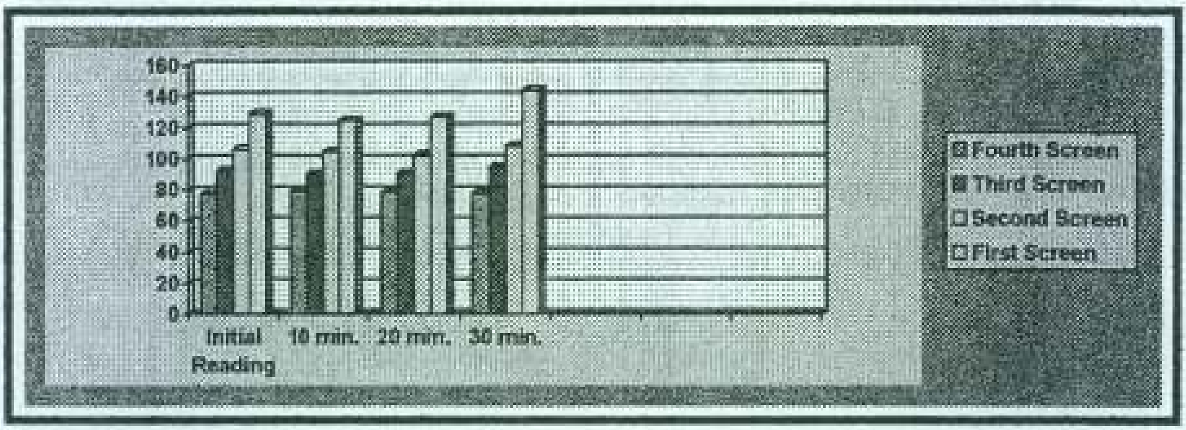
The next test performed was an attempt at absorbing the heat from the fire. We placed several high mass bricks around the hottest areas of the dryer according to our initial tests. There were eight bricks placed underneath the first screen and two underneath the second screen. Then we placed 12" by 15" slabs of concrete (two inches thick) along the oppening at the bottom of the dryer box. These were placed on top of the oppening under the first, second, and third screens. The results seemed to indicate that the problem with this method is that once the bricks reach a certain temperature they are no longer effective at heat absorbtion. The results were the following:

Test Five	Fourth Screen	Third Screen	Second Screen	First Screen
Initial Reading	76.5	91.3	110.3	120.2
10 min	77.6	91.4	111.5	121.1
20 min	77.3	91.9	116.0	125.8
30 min	78.7	94	117.0	129.7
40 min	83.2	96.6	115.1	133.3
50 min	79.4	91.9	114.8	128.4
60 min	79.8	92.5	112.7	125.9



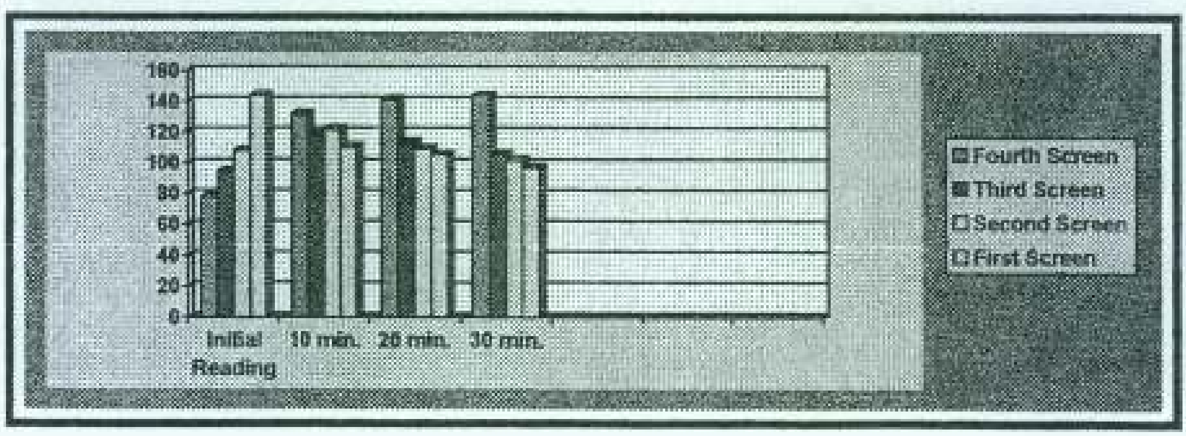
The next test is another attempt at using a diverter. In this test the diverter was the same width, but was longer. In this test, the diverter was underneath the first, second, and third screens. This test was thirty minutes long.

Test Six	Fourth Screen	Third Screen	Second Screen	First Screen
Initial Reading	77.3	92.1	106.0	128.6
10 min	79.8	90.2	104.5	124.5
20 min	78.2	90.6	102.3	126.6
30 min	77.6	94.5	107.9	143.9



The dryer is constructed so that outside air is being forced underneath the dryer box. This air flows over the metal plate and up inside of the box. At the time of our testing, outside air temperatires were between forty and fifty degrees. We hypothesized that very cold outside air was helping to cool the back of the dryer. To block cold air from entering the back of the box bricks were stuffed in the one inch oppening above the steel plate and underneath the dryer box.. The only air oppening was at the front of the dryer. We then performed a thirty minute test under the same conditions as the previous test. The results were the following:

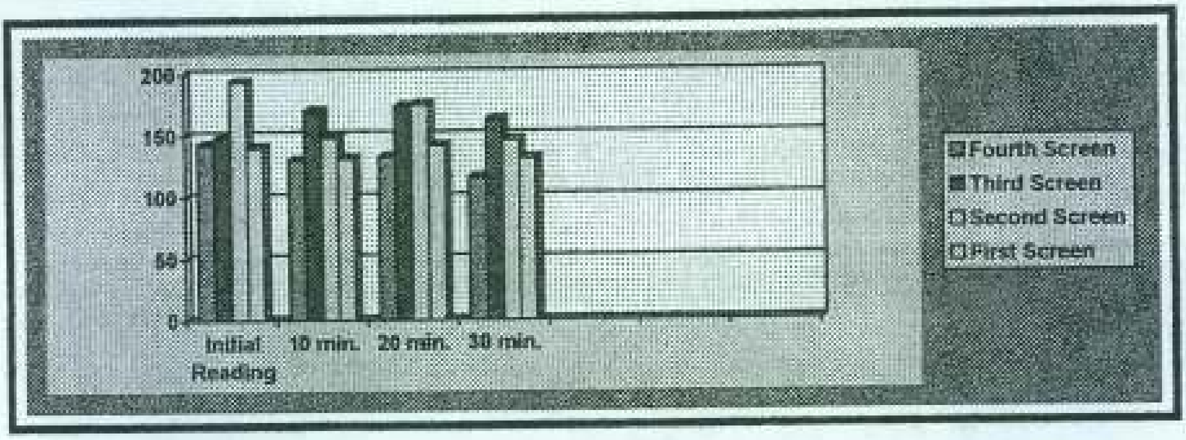
Test Seven	Fourth Screen	Third Screen	Second Screen	First Screen
Initial Reading	77.6	94.5	107.9	143.9
10 min	131.6	117.5	121.8	110.4
20 min	141.1	113.3	109.2	105.5
30 min	143.5	105.9	101.8	96.9



These results indicate that when the incomming cold air is removed from the dryer, the diverter is much more effective at moving the hot air from the front of the dryer to the back. In addition, the dryer was able to become hotter using less wood. This was the first test where the fourth screen had the highest temperature.

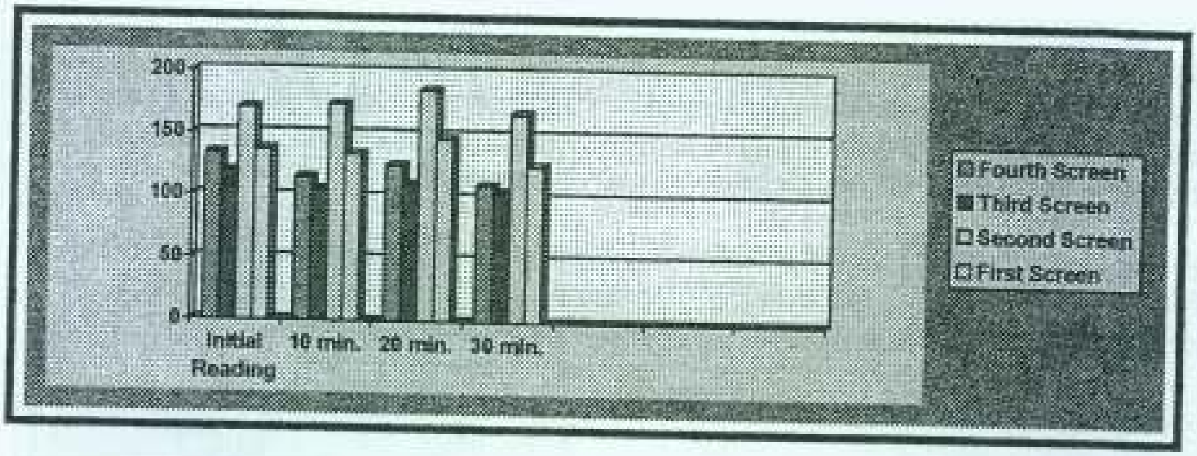
For the next test, we removed the diverter from the inside of the dryer, and tested the dryer with nothing inside of it, except for the screens. The sides and back of the dryer were again stuffed with cotton rags. The results were the following:

Test Eight	Fourth Screen	Third Screen	Second Screen	First Screen
Initial Reading	142.3	147.4	193.3	140.1
10 min	129.6	169.7	147.8	130.9
20 min	132.5	173.3	175.0	141.9
30 min	115.5	162.2	145.8	130.9



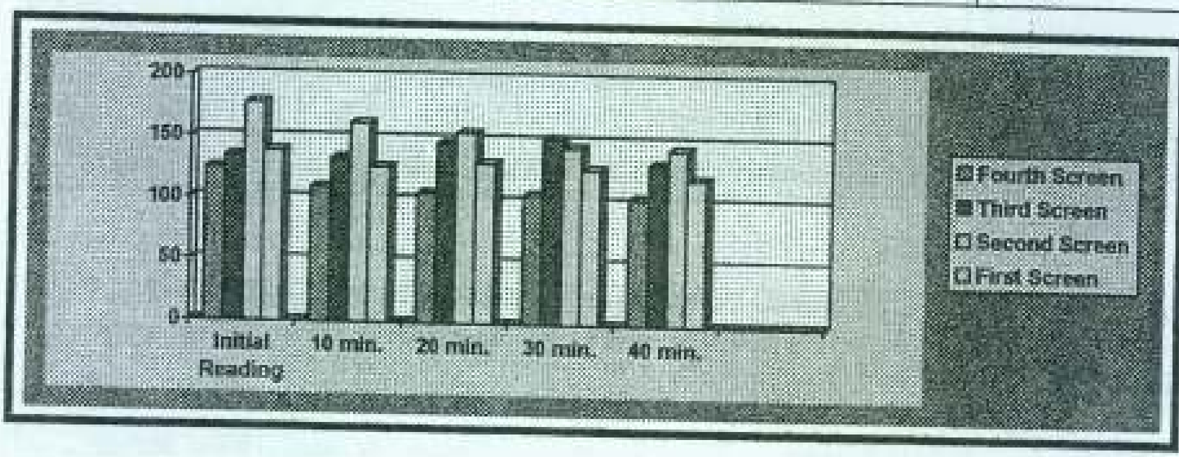
Recognizing that the middle was the hottest area in this test we took out the bricks that were covering the outside air-intake from these hot spots, in particular the third screen region. Our results were the following:

Test Nine	Fourth Screen	Third Screen	Second Screen	First Screen
Initial Reading	133.3	119.0	170.0	136.6
10 min	114.2	105.4	173.0	133.5
20 min	124.6	109.3	185.1	145.7
30 min	109.1	103.4	166.5	124.6



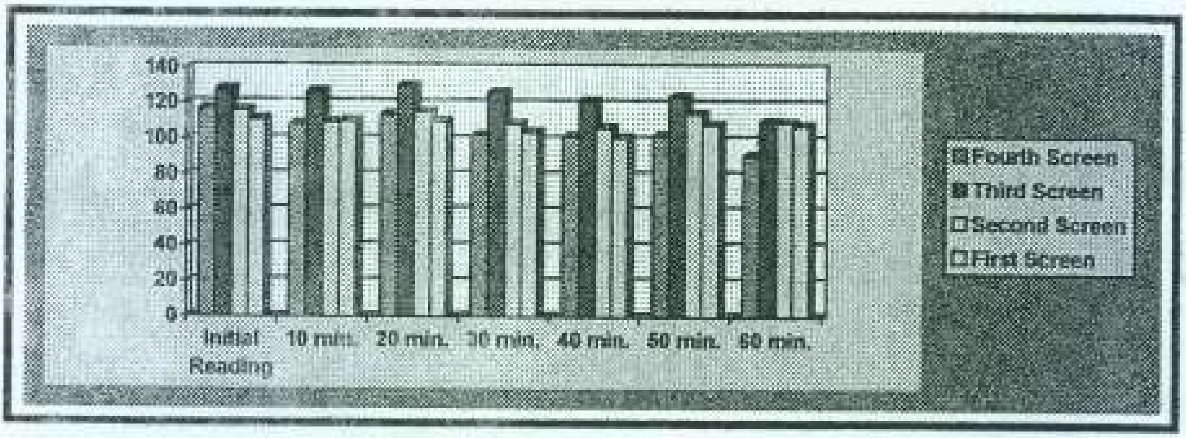
We then decided to remove the bricks from the areas adjacent to the second screen only. The results were the following:

Test Ten	Fourth Screen	Third Screen	Second Screen	First Screen
Initial Reading	124.1	133.8	177.5	139.0
10 min	109.3	133.0	161.7	126.2
20 min	105.5	146.2	154.8	130.1
30 min	104.7	150.4	143.9	125.9
40 min	102.8	130.8	143.0	118.9



The problem that we still were experiencing was low temperatures in the back of the dryer. For our next test we again placed a diverter inside of the dryer. The diverter was 8 feet in length and spanned the entire width of the dryer. We did this because we found that a diverter which did not span the entire width created very high temperature on the sides of the dryer where the diverter did not cover. On this test, both sides of the dryer were stuffed with bricks. The front and the back remained open to outside air. The results were the following:

Test Eleven	Fourth Screen	Third Screen	Second Scren	First Screen
Initial Reading	117.0	127.7	116.0	110.8
10 min	108.1	126.6	109.4	110.2
20 min	113.5	129.8	115.3	110.0
30 min	102.3	126.3	108.6	104.0
40 min	101.8	121.5	106.5	101.0
50 min	102.3	123.9	114.5	108.2
60 min	91.0	110.0	109.7	107.8



Closing off the air flow and internal heat diversion seem to be two effective ways of evening out the temperatures inside of the dryer. Using the two stratagies of diverting air inside the box, which could be accomplished simply with sheet metal, and blocking off openings in the one inch gap between the metal top and bottom of the dryer box can create adequete controls over internal temperatures. The humidity and temperature of air in each location will determine where the interventions should be made but tuning the dryer should result in relatively even temperatures.

Our recommendation would be to build the dryer and then spend a week or so playing with the variables until temperatures are as even as needed. If you prefer, we can assist the process here by doing some of the experimentation with you. Please feel free to get in touch!

Mona Jonathan