

# DESIGN OF SMALL FRUIT DRIER USING GEOTHERMAL ENERGY

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## INTRODUCTION

A fruit drier was originally proposed for a project at the Los Azufres geothermal field in Mexico (Lund and Rangel, 1995). Since the drier was to be used in a demonstration project to interest local fruit growers and processors, the size was minimal to expedite construction and minimize cost. The design was based on preliminary work reported by Herman Guillen (1987). The design is described here, as it can be adapted to many small or experimental situations.

The actual design will handle about 900 kg (2000 lbs) of fruit (wet) per drying cycle. Cutting, storing and packaging of the fruit should be done on site in a separate building. A cold-storage facility may be designed to keep fresh fruit when harvest exceeds the capacity of the drier.

## BUILDING DESIGN

The drier building was designed to be about 4.00 m long, 1.35 m wide and 3.2 m high (13 ft x 4.5 ft x 10.5 ft)(Figure 1). The actual dimensions will depend upon the size of the local building materials and required production rate.

The walls were recommended to be constructed of concrete block, the ceiling and roof of timber, and the floor of reinforced concrete. The floor will have a slight depression down the middle and slope toward the front doors to drain any juices from the drying fruit and for ease of cleaning. The heat exchangers and fan motor will be housed on the roof so that the latter is away from the hot air stream.

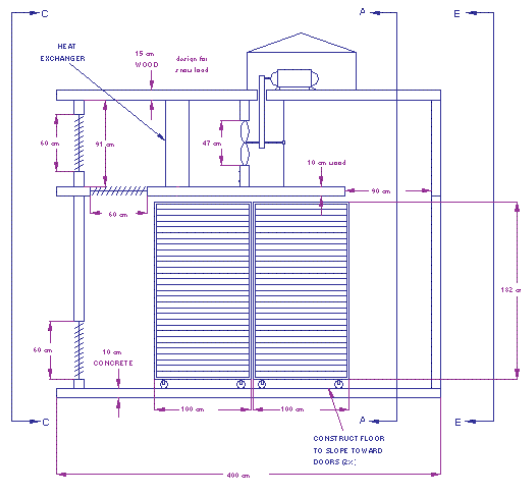


Figure 1a. Detailed drawing of tunnel dehydrator.

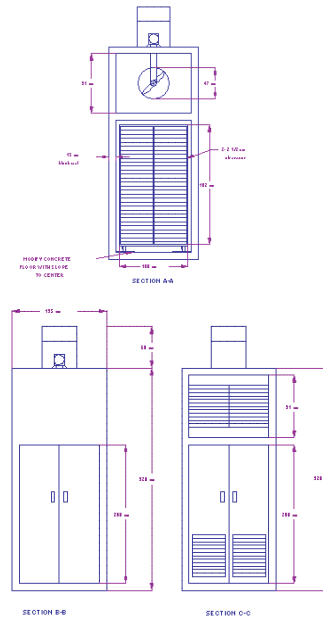


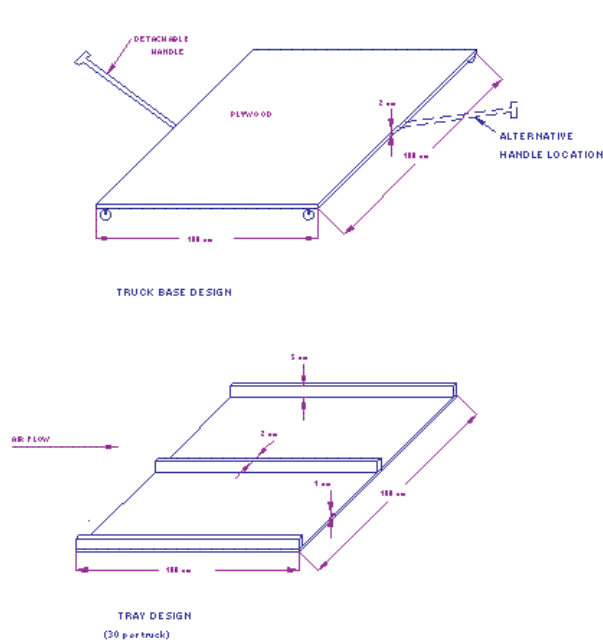
Figure 1b. Cross sections of dehydrator.

The trucks and walls are designed so that there is no more than about 2.5 cm (1 inch) of clearance on either side and at the top. This will maximize the air velocity and efficiency of the system.

Louvered doors are provided for entering, recirculating and leaving air. The louvers will be manually set, but could be set automatically as controlled by temperature and humidity sensors.

## TRUCK AND DRYING TRAY DESIGN

Two trucks are recommended, each with a base of 1.00 m by 1.00 m and 1.82 m high (3 ft x 3 ft x 6 ft) when loaded with trays (Figure 2). The truck base has four casters (pivot wheels) and a detachable handle that can be attached at either end. This will allow the trucks to be reversed when halfway through the drying process time. The base can be constructed of plywood approximately 2 cm (3/4 in.) thick. Each truck to carry 30 trays. Each tray will carry approximately 15 kg (35 lbs) of fruit (wet) for a total of 450 kg (1000 lbs) per truck and almost one tonne per drying cycle for the two trucks. During the drying operation, the moisture content of the fruit will change from about 80% to 20% by wet weight. Drying time is approximately 24 hours (Thompson, 1994).



**Figure 2. Truck and tray design.**

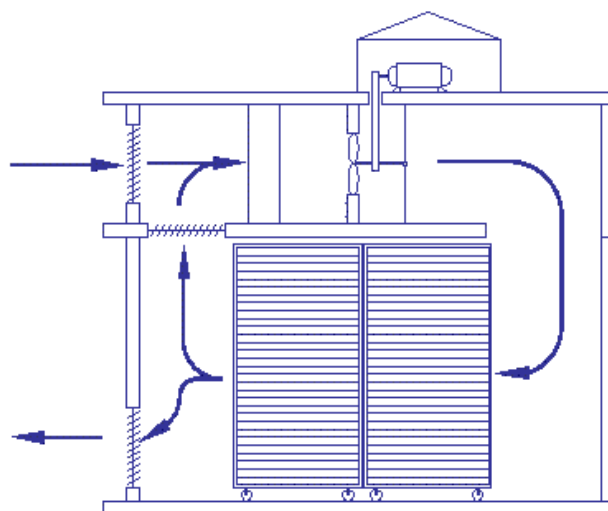
The trays can be constructed of 1-cm (1/2-in.) thick plywood and have 5-cm high by 2-cm wide (2-in. x 1-in.) wood strip attached to either edge, along with one down the center (parallel to the air flow) for strength and stacking. The plywood trays should have 1-cm (1/2-in.) diameter holes drilled in them for drainage of fruit juice produced during drying and for better circulation of the air.

### HEAT EXCHANGER DESIGN

The required air speed for fruit drying is high; ideally about 240 to 300 m/min. (800 - 1,000 ft/min.), with a minimum of 150 m/min. (500 ft/min.) (Thompson, 1992). Estimating that the trays and fruit block 50% of the tunnel, then the cross section for air flow will be 1.00 m x 2.00 m x 0.50 = 1.00 m<sup>2</sup> (10 ft<sup>2</sup>). Thus, a minimum capacity of 150 m<sup>3</sup>/min. (5,000 ft<sup>3</sup>/min.) will be needed with 240 to 300 m<sup>3</sup>/min. (8,500 to 10,000 ft<sup>3</sup>/min.) ideal.

A minimum of 0°C (32°F) outside entering air temperature and a maximum of 70°C (158°F) drying temperature was assumed. The ideal temperature for pear drying, the most abundant fruit near Los Azufres, is 60°C (140°F) and the maximum is 74°C (165°F). The geothermal resource was assumed to enter at 120°C (250°F) and exit at 100°C (210°F). Based on these assumptions, the required heat exchanger will need two rows of 8-finned tubes at 91 cm by 91 cm (36 in. x 36 in.) cross section (Rayner, 1992). A lower temperature resource can be used, requiring a modification in the heat exchanger design.

This is the design for the most severe conditions. The geothermal flowrate can be adjusted by a valve to compensate for changing outside air temperature. A three-way valve with a temperature sensor in the air stream could be used for automatic control. The air flow will enter through a 60 cm x 100 cm (24 in. x 40 in.) louver, through a 91 cm x 91 cm (36



**Figure 3. Tunnel dehydrator air flow pattern.**

in. x 36 in.) duct in the top of the building, and then flow down through the trucks (Figure 3). The air can then be exhausted or it can be recycled if the outside air temperature is very low. In many dehydrators, at least 90% of the air is recycled to conserve input energy.

The actual temperature and air flow rates will have to be adjusted by trial-and-error to achieve the proper final product in terms of moisture, texture and color.

A second heat exchanger of the water-to-water type may be necessary to reduce the possible effects of corrosion or scaling from the geothermal water. This would consist of a small plate heat exchanger with a secondary loop supplying passive water to the water-air heat exchanger in the drier building. The plate heat exchanger could be sized to handle the future heating load from adjacent buildings.

### FAN UNIT DESIGN

Since the Los Azufres field is at 2,864 m (9,400 ft) elevation (air density ratio equals approximately 0.70), a minimum design volume of air was recommended. Fortunately, the evaporation rate will also be increased at this elevation due to the reduction in outside pressure relative to the vapor pressure in the fruit, thus allowing the use of the minimum design air flow.

The tube axial fan was, thus, designed for 215 m<sup>3</sup>/min. (7,500 ft<sup>3</sup>/min.) and 2 cm (3/4 in.) of water pressure head loss (air flow friction loss) at 0.722 g/L (0.0451 lb/ft<sup>3</sup>) air (1.20 g/L [0.0750 lbs/ft<sup>3</sup>] at sea level). This will require 1.05 BHP or a 1.5 hp motor (1.12 kW). The fan will be 61 cm (24 in.) in diameter and have 5 blades with a 10.5 degree blade tip pitch. Due to the high temperature of the air flow, the fan motor will have to be located on top of the building outside of the hot air stream. Details of the fan and housing are shown in Figure 4 (Rayner, 1992).

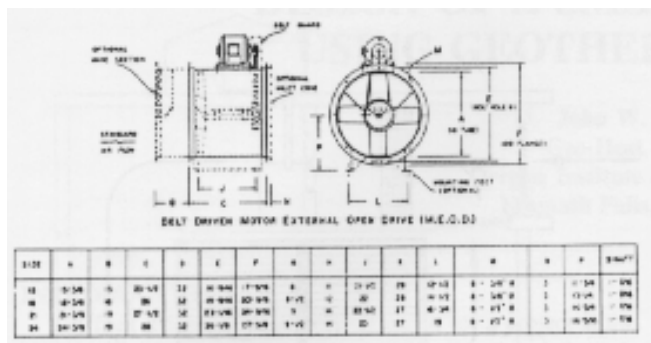


Figure 4. Details of fan unit.

## ESTIMATED COSTS

The estimated costs are as follows:

Building	\$2,000
Truck and trays	500
Heat exchanger	800
Fan unit	1,700
Controls/piping	1,000
Total	\$6,000

The use of local materials and labor may reduce the above costs.

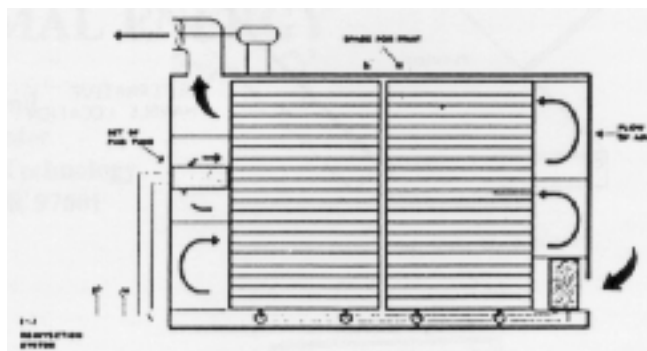
## CONCLUSIONS

A building was constructed at Los Azufres in early 1995 and the drier began operation in April. The design was modified as shown in Figure 5 (Sanchez-Velasco and Casimiro-Espinoza, 1995). The main modifications were the use of stainless steel trays instead of wood, and changes in the air flow patterns. The air was circulated through the trays five times before being exhausted. As a result, drying was uneven, too much in the first (lower) pass and too little in the fifth (upper) pass.

The dehydrator has a capacity of 400 kg (880 lbs) of fruit. The energy consumption is 10 kJ/sec (570 Btu/min.) at a geothermal flowrate of 0.03 kg/sec (0.5 gal/min.) which keeps the dehydrator at 60°C (140°F).

Modification of the design is presently being undertaken and it has handled, plums, peaches, pears and apples. It is hoped to improve the economics of storing, handling and shipping these products as well as attracting national and international investors in expanding the pilot project to a commercial-sized operation.

Figure 5. Scheme of fruit dehydrator.



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