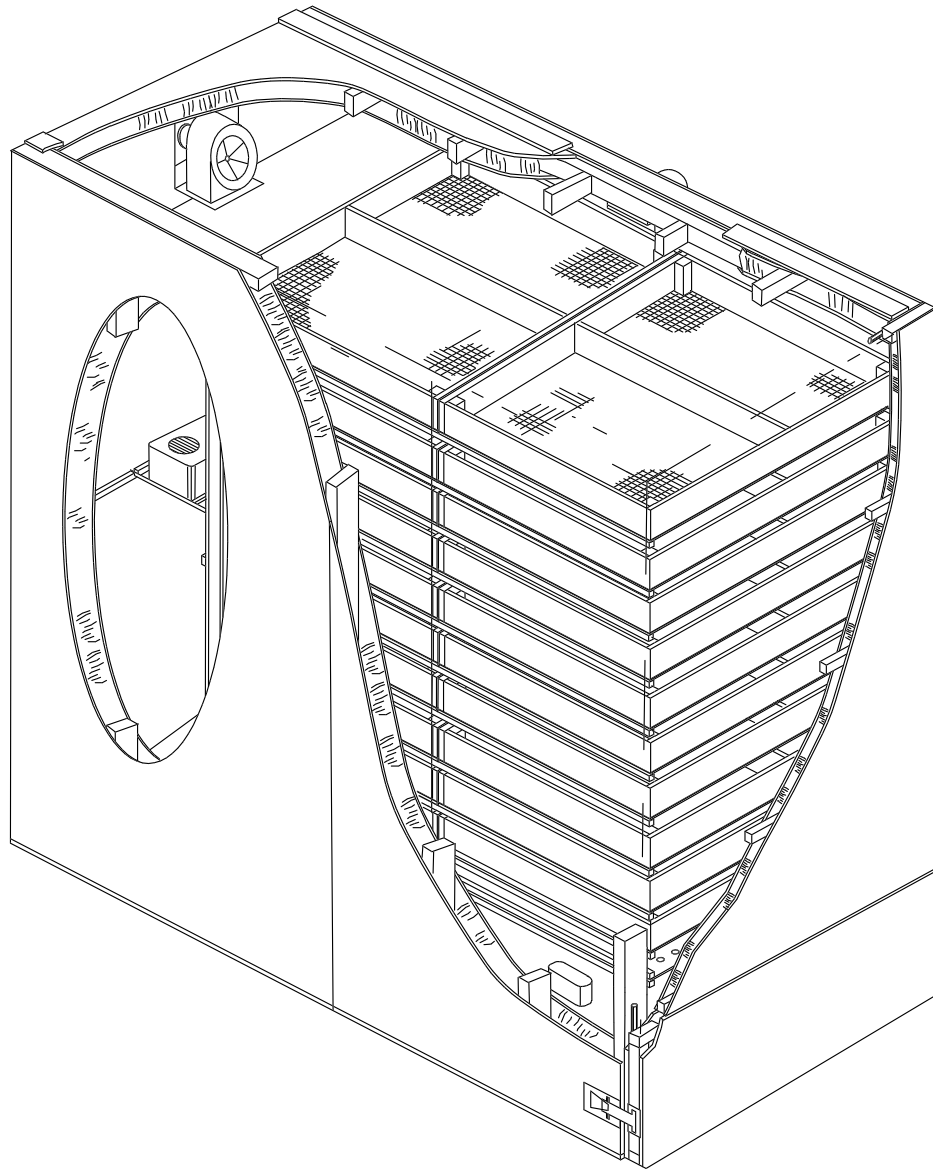


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CABINET DRYER



Agricultural Building Systems Handbook

B.C. MINISTRY OF AGRICULTURE AND FOOD

280-391

CABINET DRYER

This dryer can be utilized for drying many different crops. The wooden construction of the cabinet dryer is suitable for low-temperature drying using heated forced-air. The product to be dried is placed in thin layers on trays stacked in a column within the dryer chamber. Heated air is circulated vertically through the column with a circulating fan. Fresh air is brought into the cabinet and moist air is exhausted by using a dehumidistat to control an exhaust fan and air intake shutters. A perforated plywood floor is used to uniformly distribute the air within the dryer. The dryer trays are tight-fitting in the cabinet to prevent air from bypassing the material to be dried.

The dryer design is based on using 4'x8' sheathing materials and utilizing a readily available 5 kW industrial electric heater as the heat source. The dryer could be made larger or smaller depending on the bulkiness and volume of the product to be dried. The heater capacity could also be changed to match the needs of the product to be dried and the management of the dryer. The plan uses a centrifugal (squirrel cage) circulation fan with an airflow of at least 750 cubic feet per minute (cfm) at ½" (water column) static pressure. The circulation fan must be of good quality and designed to run continuously. The plan calls for an exhaust fan with a capacity of about 100 cfm (could be a household bathroom fan). This dryer has 20 trays of 10 sq. ft. each for a total of 200 sq. ft. of tray area. The trays are 3½" deep. The overall dimensions of the dryer are 4'-10"x8'x8'. The dryer trays will hold about 900 pounds of fresh ginseng roots or 300 pounds of fresh echinacea tops.

The dryer design is based on the design of a research dryer that was used for drying ginseng. The research dryers used similar but smaller heaters and fans and were controlled by a datalogger with temperature and humidity sensors. The research dryers were operated successfully at 38 °C (100 °F) over several ginseng drying cycles.

Before constructing this dryer, check with your electrician and local building codes regarding wiring and fire concerns. Use electrical equipment that has been certified safe for use (CSA). Ensure that the circulation fan motor is rated to operate in air

temperatures of 120 °F or at least as warm as you intend to operate the dryer. Have your electrician select a heater and fan controls suitable to provide dryer temperature control and safety measures for the heater and fan. A high limit thermostat and a fan sail switch for the heater are two suggested safety measures. No claims are made regarding the suitability of this design for any use. Construction and use of the dryer shown in these plans are completely at your own risk.

CONSTRUCTION

The dryer has been designed to be constructed with full size sheets of plywood and sheathing materials. A suggested step-by-step listing of the construction process follows.

1. Consult with your certified electrician and local codes to ensure that your cabinet dryer meets all safety requirements.
2. Have your electrician select and order the fan, heater and controls for the dryer and locate their installation on your dryer plans. Wait until you receive the equipment before starting construction of the dryer to ensure that you can obtain the required equipment and check that the equipment will be suitable for use in your dryer.
3. Sheet 3 shows cutting layouts for the sheets of plywood. Be sure to mark the plywood pieces with their intended use while cutting the plywood. Mark leftover pieces as excess. Build the side walls, end walls and top and bottom panels (shown on Sheet 1) using 2x4 lumber, sheathing and fiberglass batt insulation. The end wall should be built in three pieces to allow easier access to the fan and heater once the cabinet is assembled.
4. One side wall should be framed with an opening near the top of the wall for an exhaust fan (refer to sheet 1). Purchase the fan before building the wall to ensure the opening is suitable for the fan. If necessary, install the fan housing during the wall construction and determine how the fan will be wired to the humidistat, manual switch and power source. The electrical wires could be placed inside the side wall, however, all holes in the inside face of the wall should be well sealed against air and moisture.

5. Build the plenum wall shown on Sheet 1. The width of the plenum wall should match the finished dimension of the top and bottom panels so it creates a snug fit when assembled (see Dryer Assembly - top view on Sheet 2). The doors should also be built using the same sheathing and 1½" styrofoam board construction as used for the plenum wall. The width of the doors is dependent on the assembled width (outside dimension) of the dryer cabinet.
6. Cut sheets of ¾" exterior grade plywood into 1¼" wide strips as shown on Sheet 3. Cut the strips parallel to the length of the plywood to maximize the strength of the strips. Cut 24 strips at least 67 ¾" long, 18 strips at least 47 ⅞" long and 2 strips about 22" long. These strips will be used as supports for dryer trays, the perforated floor, and the fan floor. The plenum wall requires 2 strips about 64" long and 4 strips about 12" long. Two strips 91 ¾" long are required to support the top panel of the dryer cabinet.
7. Cut 14 strips of ⅜" plywood sized 6"x48" from the plywood sheets used for the door and plenum wall. Also cut 2 strips measuring about 4" by 48" leaving sufficient material to cut plywood for the tray undersides. These 16 strips of plywood will be used to join the panels of the dryer cabinet and form a base for the cabinet.
8. On the inside of each side wall, mark a vertical line 67 ¾" from the door to locate the plenum wall (see Dryer Assembly - top view on Sheet 2). To locate the bottom of the plenum wall mark a line 14" up from the bottom of each side wall (note the exhaust fan is located at the top of one side wall). Then fasten a short (about 12" long) plywood cleat to the inside face of each side wall to support the bottom of the plenum wall. Use 1¼" long #8 wood screws to attach all of the ¾" plywood cleats. With one side wall lying flat on the floor or bench, hold the plenum wall in its assembled position on the inside face of the side. Using the plenum wall as a gauge, fasten a plywood cleat (about 64" long) to the inside faces of the side walls to provide backing support the plenum wall. (These cleats will be located in the return air plenum when the dryer is assembled.)
9. Assemble the bottom, top and side wall panels (the plenum wall is installed later). Start by placing the outer face of one of the side wall panels on the floor. Next place the top and bottom panels on opposite ends of the side wall panel (note; the cleat to support the plenum wall is at the bottom) bracing them to hold them in place. Fasten the top and bottom panels to the first side wall with screws through the 6" wide by 4' long strips of ⅜" plywood (see Dryer Assembly-front view on sheet 2). Two 4' long strips should be used for each joint. Next place and fasten the second side wall panel on top of the top and bottom panels and tack it in place. Square and brace all four corners on the door end of the cabinet then fully attach the second side wall panel to the top and bottom panels with the 6" wide strips of ⅜" plywood. Install strips of ⅜" plywood to the bottom of the bottom panel to provide a base (refer to bottom right hand corner of sheet 2). Raise the cabinet to stand on its bottom panel. Check the cabinet to ensure it is still square.
10. Install the lower part of the end wall fastening the end wall to the side wall with screws through the 6" wide ⅜" plywood (refer to sheet 2, Dryer Assembly – top view). Place the middle section of end wall in place without fastening it to the side walls. Install the top section of end wall and fasten it to the side walls with screws and strips of 6" wide ⅜" plywood so that the middle section will be easy to remove. Allow room for any weather stripping that may be required to create an airtight seal. Remove the middle section. Check to make sure the cabinet is still square.
11. Before the plenum wall is installed in the cabinet, fasten the cleats to support the perforated floor and dryer trays to the plenum wall starting with a cleat along the bottom edge. The cleats are 1¼" strips of ¾" plywood (see sheet 3). The first tray support cleat should be 6" above the perforated floor (see Dryer Assembly - front view on Sheet 2). Now install the plenum wall in the cabinet against the cleats already fastened to the side walls. The plenum wall should fit snugly inside the cabinet. If the side walls are bowed out, use metal angles and wood screws (refer to step 13) to pull the side walls tight against the plenum wall.
12. Fasten the perforated floor and tray support cleats to the side walls to match the cleats on the plenum wall. Be sure that the top edges of the tray support cleats are smoothly aligned to allow the trays to be pushed along the supports without catching on the plenum wall supports.
13. To prevent the dryer side walls from bowing outward, fasten the same 1 ¼" wide strips of ¾" plywood (cleats) across the front of the dryer above and below the perforated plywood floor. Also install plywood strips between the fifth dryer tray side wall supports across the middle of the drying chamber and the front of the dryer (refer to sheet 2, Dryer Assembly – side

view). Use metal angles with screws to fasten these plywood strips to the strips on the side walls. Install metal angles at the top, middle and bottom of the plenum wall, and each of the cross strips on the dryer front and middle. Locate the middle cross support so that the screws into the side wall will penetrate through the plywood into a side wall stud for better holding power. If the walls are already bowed out during installation of the cross supports, cut the pieces to the correct length, fasten the angles onto the cross supports (at the end of the cross support) with screws, then put the cross supports into place and use the wood screws to fasten the metal angles to the side wall cleats and to draw the side walls tight against the cross supports. The same technique can be used to draw the side walls tight against the plenum wall (be sure to screw the metal angles into the proper position on the plenum wall first, then screw into the side wall to draw the side wall tight against the plenum wall).

14. Measure the cabinet to determine the actual assembled dimensions for the perforated floor and fan floor. Adjust the drawing dimensions to suit the cabinet, then cut the ½” plywood sheet to obtain the perforated floor and fan floor. Drill ½” diameter holes through the plywood on 2” by 2” centers in a grid pattern (see Perforated Floor on sheet 2).
15. Fabricate the heater supports from ¾” angle iron to match the heater’s dimensions (see “Heater Support Detail” on Sheet 1). The heater’s outlet must be facing down when mounted in the dryer. Notch two 1¼” wide cleats of ¾” plywood to receive the angle iron heater supports. Fasten one cleat to the plenum wall and the other to the lower end wall. The angle iron support should be level with the top of the bottom section of the end wall.
16. Determine where the *circulation fan* floor should be installed by placing the *circulation fan* motor in the middle of the hole in the top section of the end wall. Measure the distance from the top of the end wall to the bottom of the fan flange (see Dryer Assembly - side view on Sheet 2). Mark this elevation on the side walls and plenum wall of the cabinet. Install 1¼” wide ¾” plywood cleats ½” below this (allow ½” for the thickness of the fan floor) to support the fan floor. Fasten a ¾” plywood cleat across the open (end wall) side of the opening so that the fan floor is supported on all four sides.
17. Place the fan floor on the supports and locate the fan on the floor so that the motor will be centered in the

opening in the end wall. The fan motor should be as close to the air intake louver as possible to allow the motor to run at a cooler temperature. Ensure there is sufficient room to install and open the intake air shutter in the opening as well. Mark and cut the opening for the fan outlet through the floor. Remove the upper section of the end wall. Install the fan floor in the dryer and mount the fan on the floor. Reinstall the upper section of the end wall.

18. Wire the *circulation fan* to an on/off switch.
19. Install a sail switch in the airstream below the circulation fan. The sail switch, when wired to the heater control, will ensure that the fan is working before the heater can operate.
20. Determine where to locate the thermostat for the heater. The thermostat should have a remote sensing bulb. The sensor should be placed in the air plenum centered under the perforated floor and at least 1” away from any solid object. The capillary tube lead on the remote sensor should be inserted through a hole drilled in the lower end wall of the cabinet where the thermostat is mounted.
21. Install a high temperature limit thermostat on the plenum wall below the heater.
22. Have your certified electrician wire the heater through both the sail switch and high temperature limit thermostat, then the heater thermostat, manual on/off switch and heater.
23. Install the center section of the end wall and test the electrical system including sail switch and high limit thermostat that should be set at 50°C (120°F) or lower.
24. Mount the exhaust fan in the side wall. The exhaust fan should have shutters that automatically close when the fan is off. Wire the fan to a dehumidistat mounted on the same side wall, just above the perforated floor and below the bottom tray near the front of the dryer (refer to sheet 2, Dryer Assembly – top view, - side view and – front view). The fan may also be wired to a damper motor that opens the air intake shutter in the back wall right in front of the circulation fan. Alternatively, the air intake shutter must open inward due to the suction in the cabinet caused by the exhaust fan and close under gravity when the exhaust fan turns off. If the cabinet dryer is located inside a building, be sure to connect an exhaust duct to the fan to take the

moist exhaust air outside of the building just like a bathroom exhaust fan would be vented in your house.

25. Install the 10" square shutter for fresh air intake in the upper section of the end wall (see sheet 2). The air intake shutter must work in combination with the exhaust fan to allow fresh outside air to enter the cabinet in the return air plenum where it will be heated by the electrical heater below. The intake shutter must open when the exhaust fan turns on and close when the fan shuts off.
26. Install the perforated floor.
27. Fasten a rubber gasket to the front face of the dryer (see Dryer Assembly - front view on Sheet 2).
28. Mount the upper door on household door butt hinges. If there is curvature in the door, install the door with the bow outward. This way the door latches will draw the door tight against the seal. Install three over-center (draw latches) door latches spread evenly over the height of the door.
29. The lower door can be attached with plywood cleats similar to the end wall.
30. Measure the dryer cabinet to determine the tray dimensions to obtain a close fit between the plenum wall and the door. Cut the materials for two trays (see sheet 3). Be sure that the face grain of the plywood runs parallel to the length of the piece for greatest strength. Cut the material for two trays leaving the lengths long rather than short. Assemble each tray by tacking the joints together temporarily. Do not install the wire mesh. Test the trays for fit in the dryer at several levels. If necessary trim the tray pieces until you are satisfied with the fit. The trays should be slightly narrower than the dryer cabinet to allow easy loading and removal of the trays. When the two trays are installed in each level, they should fit snugly between the plenum wall and the door. If there is too much of a gap between these components use a rubber gasket to create a better air seal to prevent air from bypassing the trays
31. Build a jig to facilitate assembly of the trays of uniform size and shape with square corners. Refer to the dryer tray detail on Sheet 1. A corner stabilizer made from soft-wood lumber in each of the four corners will make the tray more stable and durable. The soft-wood will hold the screws to fasten the joints better than the end grain of the plywood. The middle partition of the tray is important to support

the wire mesh and prevent it from sagging too much. When the wire mesh is firmly attached to the tray sides, the mesh will help to retain the rectangular shape of the tray. The 3/8" plywood strips on the underside of the tray assist in fastening the mesh to the tray and will allow the tray to slide more smoothly on the side wall supports.

32. Build the remaining trays using the jig so that all the trays are interchangeable.

STARTUP

The dryer needs to be tested before drying any valuable products in your new dryer. Have your electrician ensure that the equipment and controls are working properly. Be sure to check the safety devices such as sail switch and high-limit temperature thermostat as well. Check the thermostat settings with a good quality thermometer. Humidistat readings can be checked with a handheld sling psychrometer. The sensor readings should be checked before every year at the start of the season. Test the operation of the dryer with some excess or cull material similar to what you plan to dry. Monitor the temperature and humidity in the dryer, loading rate and drying rate. When the dryer appears to be working properly try using the dryer with the intended crop.

OPERATION

Be sure that the fan is lubricated as necessary and the heater is cleaned regularly.

This dryer can be operated in a batch or continuous mode.

In the batch mode the dryer is loaded with a full batch of material to be dried. Set the heater thermostat to the desired drying temperature. Set the override safety thermostat 5-10 degrees above that but below 120°F (50°C). The heater will run until the temperature set-point is reached. To remove moisture from the cabinet, set the dehumidistat at the desired relative humidity. The exhaust fan will operate until the relative humidity is lowered to the set-point. While the exhaust fan is operating, ensure that fresh outside air is allowed into the return air plenum at the back of the dryer through an air intake shutter. Make sure that the intake shutter opens and closes using a shutter motor or through a gravity operated shutter.

The monitoring of temperature and relative humidity should be done in the air supply stream between the heater and the material to be dried to ensure the dryer air is warm and dry. If the dryer is heavily loaded with fresh moist material, the heater may be overloaded and may not be able to raise the temperature to the set-point while at the same time heating up enough fresh outside air to lower the relative humidity in the dryer. In this circumstance you will have to make a compromise between the desired temperature and relative humidity or reduce the loading rate.

Setting the temperature too high may damage the product and setting the temperature too low may allow spoilage to start before the material is dried. Relative humidities that are too high will prevent the material from drying below the corresponding moisture content of the material (for that relative humidity). This is known as the equilibrium moisture content and is dependent mainly on the relative humidity of the air. Using high temperatures and low relative humidities will tend to speed drying, however, be careful not to damage or overdry the material.

In the batch mode the heater will be working continuously at the beginning of the batch when the material is moist and very intermittently at the end of the batch period when the material is dry.

If the dryer is loaded gradually, one tray (or level) at a time from the bottom up such that when the dryer is full, the first tray loaded (bottom tray) is dry, then a more continuous loading pattern will be established. Once full, the first (bottom tray) trays are removed when dry, the remaining trays are lowered one level and the top level is filled with trays of fresh material. Be sure that the fresh material has already surface dried so that water from the fresh material will not stain the material below it in the dryer. The dryer air will be warm and dry at the bottom and cooler and 'wetter' at the top of the dryer as the air picks up moisture from the product as it travels up through the stack of trays. Thus the driest air dries the driest material. When the trays are lowered to the next level, rotate the trays end-to-end to ensure that drying is uniform throughout the dryer. The practice of rotating the trays will tend to even out the drying rate if the airflow is not evenly distributed within the dryer or air temperatures are not uniform. This loading method produces a *counterflow dryer*.

In the continuous, or counterflow loading mode, the heater will be working more continuously throughout the drying period. The heater will be able to handle higher loading rates in the dryer and temperature and

relative humidity set-points will be more easily attained. However, continuous counterflow loading requires more handling of the trays than batch drying. Batch drying of product like ginseng roots which take about two weeks to dry tends to concentrate the labour for digging and washing the root to a few days every two weeks. Continuous loading spreads the workload over more time which may be an advantage to the grower.

Rather than choosing either batch loading (all trays at once) or "continuous drying" (one or two trays at time), you could choose a modified loading system such as loading half the trays at the start and then the other half of the dryer trays when the material in the first half batch are half dry. Alternatively, one-third or one-quarter batches could also be used in a manner similar to the continuous loading. The modified loading system may be preferred to either the batch or continuous loading systems.

When loading the dryer ensure that the material is spread to a uniform depth in each tray. The material in the trays should not be densely packed to allow air to circulate freely around all surfaces. When drying any material for the first time, use thin layers. With experience you will be able to use heavier loading rates. You will find the roots of the largest diameter take the longest time to dry. If all but a few roots in a tray are dry, you may want to remove the tray and place the few roots that are not yet dry in the another tray until they are dry. Because the moist material shrinks so much, there will be lots of space in any tray that has material that is almost dry.

Prepared by:

Bert van Daltsen, P.Eng.
Agricultural Engineer.
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