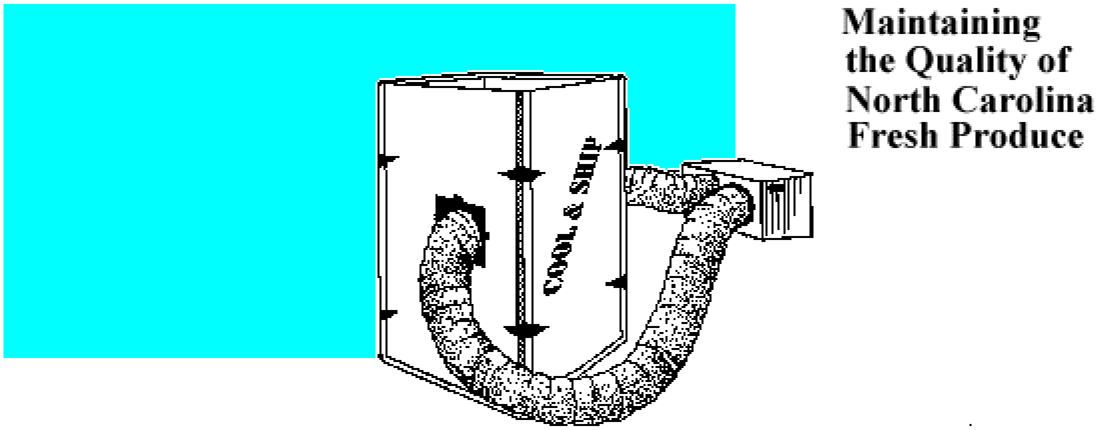


COOL AND SHIP:
A LOW-COST, PORTABLE FORCED-AIR COOLING UNIT

There is growing interest in the commercial production of high-value specialty fruit such as strawberries, blackberries, raspberries, and blueberries. Much of the small fruit grown in North Carolina is currently marketed through pick-your-own establishments or roadside stands. A strong demand for these small fruit items from grocery stores and restaurants has prompted many growers to consider expanding their production to take advantage of these new marketing opportunities.

These commodities, however, are extremely perishable and normally require immediate postharvest cooling before shipping to prevent degradation. Expansion into the commercial small fruit market would usually require a considerable investment in postharvest cooling and handling facilities, and possibly refrigerated transport. The risks associated with a new venture and the considerable cost involved prevents many growers from taking full advantage of this marketing opportunity. Small portable cooling units designed to "plug in" too small; insulated shipping containers have been used by the world's airlines and ocean freight carriers on a limited basis for more than 30 years. These units typically have been utilized for maintenance cooling of precooled, highly perishable produce during transit or during extended stopovers or delays. This publication gives instruction for building and using a similar, inexpensive cooling system. The **Cool and Ship** system provides rapid cooling for modest amounts of small fruit and is versatile, portable, reusable, and inexpensive. The system uses an air-conditioning system and common building materials, and may be easily assembled by the user.

Why Cool?

Small fruit such as blackberries, strawberries, and blueberries are very perishable and require immediate cooling after harvest to prevent a rapid decline in quality. At warm temperatures, softening and decay can occur in less than four hours. Rapid and thorough cooling is essential to quality maintenance.

The preferred and most commonly used cooling method for small fruit is forced-air cooling. Forced-air cooling uses a refrigerated room equipped with fans that pull large volumes of cold air through palletized packages of produce. The close contact between the moving, cold air and the warm fruit causes a much more rapid decrease in temperature than would occur otherwise. In addition, forced-air cooling removes droplets of water (dew or rain) from the surface of the fruit. Warm, wet fruit is very susceptible to postharvest rots.

Although growers sometimes receive a premium price for cooled produce, the benefits of cooling are often more indirect. They may include better appearance, a much longer shelf life, and the pride that comes from marketing a high-quality product. However, the most important indirect benefit is the marketing advantage cooled produce has over uncooled produce. In a buyer's market, with other factors being equal, cooled produce always sells better because buyers associate cooling with quality.

Advantage of the Cool and Ship System

Inexpensive—low initial cost compared to a stationary cooling facility.

Reusable—can be disassembled for easy transport.

Transportable—no need for a refrigerated truck.

Versatile—can be used for a variety of produce.

Energy Efficient—takes less energy than a stationary facility.

Protects the Produce—prevents condensation or contamination.

Equipment

Building the Cooling Container

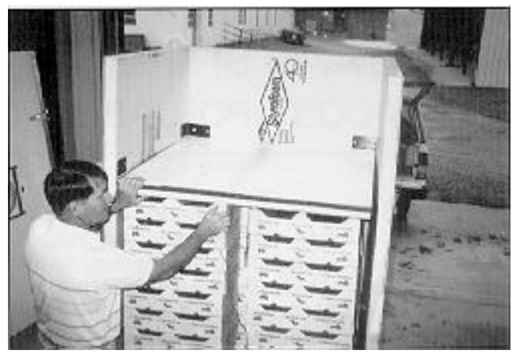
The cooling container shown in the centerfold drawing consists of a top, bottom, and four side panels of 2- inch-thick sheets of extruded polystyrene insulation, commonly referred to as blueboard. This insulation material is manufactured in panels measuring 4 feet by 8 feet, is safe for use as food packaging, and is reasonably durable when handled with care. Sheets of polystyrene beads (whiteboard) may be substituted for blueboard, but they are not nearly as durable.

A sheet of 1/4-inch-thick CDX-grade plywood or chipboard is bonded to the insulation material for added rigidity and protection from damage. Exercise care when selecting the adhesive. A white glue compatible with both the wood and the polystyrene insulation material must be used. Spread the glue evenly in a thin layer on the insulation board with a brush or wide putty knife.

Carefully position the plywood on the insulation and firmly press together. As the composite panels are completed, they may be stacked one upon the other on the floor or other flat surface. Adding weight to the top of the stack is beneficial because full contact between the plywood and insulation is essential for a strong bond. Be careful to wipe off any excess glue that squeezes out between the panels. Five full-sized panels are required for each container (four for the sides and one cut into halves for the top and bottom).

Considering the size of the fruit packaging is important when building the cooling container. The inside dimensions of the container shown in the drawing are 40 inches deep by 44 inches wide by 72 inches tall. It will hold 144 half-pint masters, 96 pint masters and 60 quart masters while still providing sufficient void space for proper air circulation. Al- though desirable, it is not necessary that the cooling container be completely full. The pictorial view of the drawing shows an acceptable fill of 84 1 2-pint masters. The top of the cooling container is designed to move vertically, as shown in Figure 1, to accommodate various stack heights. This arrangement allows a tight fit and eliminates air short-circuits over the top of the stack of masters.

Figure 1. Fitting the top in place.



The maximum outside dimensions of the cooling container (as shown in the top views of the centerfold drawing) was limited to 48 inches because of the maximum size of the materials. However, this size is also convenient because it will fit between the wheel wells of a full-size pickup truck. An inlet and outlet plenum or air gap (also shown) of at least 1 1/2 inches must be maintained on either side of the stack of masters for air distribution. Cold air inlet and outlet holes, the size of the air distribution ducts, are cut in the center of opposing sides adjacent to the two plena. The cutouts are saved and used to seal the holes once cooling is completed.

The sides of the cooling container are fastened by pair of loose-pin strap hinges on each corner. Eyebolts are substituted for the hinge pins to facilitate assembly and disassembly. An adhesive-backed foam strip approximately 3/4 inch wide by 3/8 inch thick is used as a gasket to seal all joints between the sides, top, and bottom. The outside plywood surface s painted with two coats of outside gloss enamel for protection. The sides should be numbered at each of he top corners to be certain they fit together properly. The cost of the materials for each container is approximately $150, and the unit takes two persons approximately 1 1/2 hours to construct.

The sides should be numbered at each of the two top corners to be certain they fit together properly.

Refrigeration Unit

Often, even relatively low-capacity commercial refrigeration units are not sold as a complete unit but as components. The selection of compressors, condenser coils, evaporator coils, piping, and other components is customized for each application. The selection process requires technical competence and contributes a significant amount to the overall cost of a system. The addition of forced-air capability to such a facility likewise requires custom engineering in the selection and application of fans and controls.

On the other hand, residential air conditioning components are generally factory matched. As far as possible, major components are preassembled, requiring much less labor at the job site. Residential window units and air-conditioning systems for mobile homes are even more unitized and standardized, thus requiring little or no job-site assembly. However, unless the units are carefully selected, the use of residential air-conditioning systems for produce refrigeration can yield poor results.

Many residential air-conditioning systems are designed to cool air to 65 to 70°F and therefore normally have evaporator coil temperatures of 45 to 50°F, which is too high to provide much useful produce cooling. Fortunately, there are some air-conditioning units available with evaporator coil operating temperatures low enough to provide acceptable produce refrigeration. Among these are modular mobile home air-conditioning units. With proper selection, these units of the 2- to 3-ton range can make an excellent and relatively low-cost source of cooling. (A ton of cooling will displace 12,000 Btu per hour.) In general, those units that use R-22 refrigerant will give satisfactory results. Carefully check the unit's specifications for refrigerant type and tonnage before making your selection.

A new, 3-ton mobile home air-conditioning unit may cost up to $2,000. Used equipment may be considerably less expensive. A suitable air-conditioning system should have a fan that is integral to the unit. Such systems are normally supplied with lengths of insulated flexible ducts 10 or 12 inches in diameter. These flexible ducts can be used to connect the air-conditioning unit to the cooling container. Sheet metal flanges and clamps normally supplied with the air-conditioning unit are suitable for connecting the ducts to the container panels. One duct carries cold air to the container and the other carries the warm air back to the unit. This forms a closed air system and is much more energy efficient than allowing the air to escape as it leaves from the container.

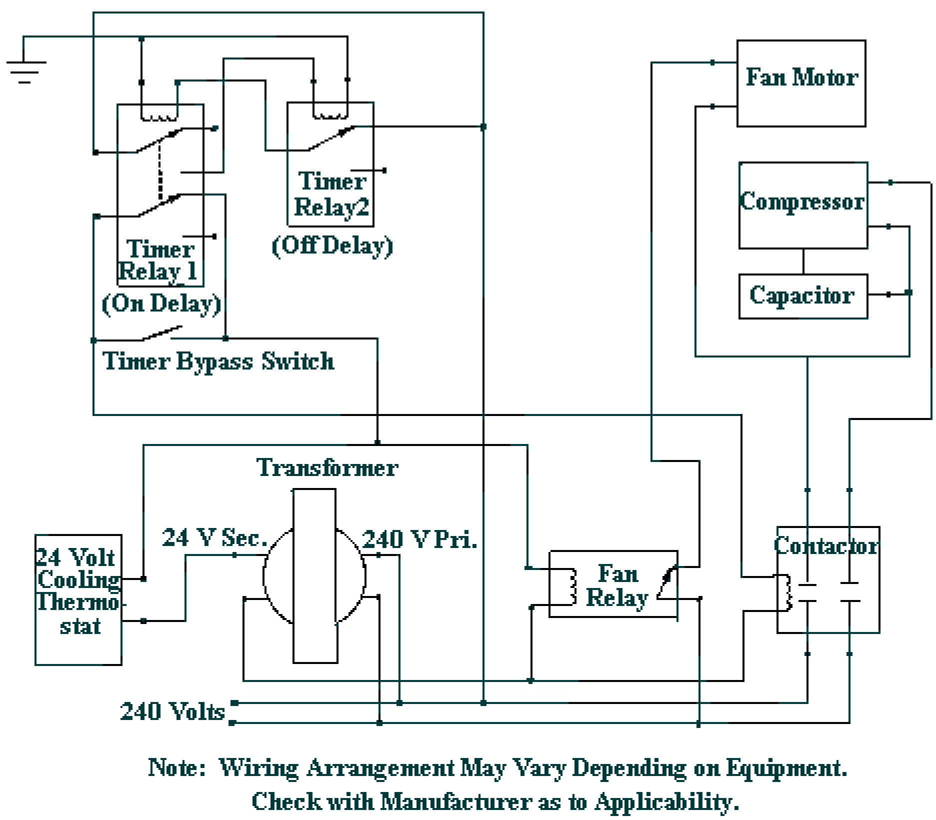
Figure 2. Air conditioning unit with cooling container.

A properly selected air-conditioning unit should operate satisfactorily with minor modifications. One such modification is the addition of a bulb-type thermostat mounted so that the bulb is in the air intake stream of the unit. This thermostat acts as a controller that stops the entire system when cooling is completed.

Postharvest cooling should be accomplished as rapidly as possible because the cooling coils also dehumidify the air. Frequently the coils operate at temperatures below the dew point of the air passing through them. When this occurs, humidity in the air is lost as condensation on the coils. The amount of water removed from the air increases with the size of the coils, the velocity of the air, the air's humidity, and falling coil temperatures. Even if the air is properly cooled, fresh produce exposed to very dry air for extended periods can suffer decline in weight and quality.

When the temperature of the cooling coils falls below freezing, coil icing can occur. The degree to which ice accumulates on the coils is related primarily to the coil temperature, the amount of free water on the fruit, and the duration of cooling. Ice should not be allowed to accumulate on the coils for three reasons. First, ice acts as an insulator and limits the coil's ability to cool the air. Second, ice blocks the flow of air through the coils. Third, poor heat transfer from iced coils can cause liquid refrigerant to return to the compressor (a condition known as "slugging") causing compressor failure. There is little chance of coil icing as long as the temperature of the air returning to the air-conditioning unit is above 45°F. To prevent coil icing at lower temperatures, a simple alteration of the power control wiring may be made that causes the compressor to cycle on and off at a predetermined rate yet allows the evaporator coil (cold air) fan to operate continually. A typical relay setting would allow the compressor to operate at a 75 percent duty cycle on 6 minutes and off 2 minutes. Any evaporator coil icing that occurred during the time the compressor is operating is melted by the relative warm air from the cooling container during the compressor off time. A schematic diagram for altering the wiring is shown in Figure 3. **Always consult a licensed electrician and follow all electrical codes!**

Figure 3. Wiring Diagram.



Using the Cool and Ship System

In commercial markets, small fruit such as strawberries, brambles, and blueberries are normally packed and marketed to the consumer in half-pint, pint, or quart pulp or plastic containers. These containers may or may not have cellophane or mesh cover. Twelve half-pint or twelve pint containers are aggregated into a corrugated fiberboard master. Eight 1-quart containers fill a quart master. These masters are in turn stacked six to a layer on a shipping pallet in lots of up to 144, 96, or 60 in the case of half-pint, pints, and quarts, respectively.

Half-pint and pint masters have a width of approximately 13 3/8 inches and a length of approximately 20 inches. When arranged in two rows of three each they form a square approximately 40 inches on a side. Quart masters have a width of approximately 11 1/2 inches and a length of approximately 231/2 inches. When arranged in two rows of three each they form a rectangle approximately 47 inches wide by 34 1/2 inches deep.

Since a full cooling container may weigh more than 1,000 pounds, it is wise to construct the container in place on a pallet, truck, or trailer. Begin by assembling the bottom and three sides of the container as shown in the pictorial view of the centerfold drawing. Carefully position the masters on the insulated bottom. This placement inside the container is critical for proper airflow. For maximum cooling, air should flow through the stack, not around or over it. Build the stack of masters to the desired height, then put the top in place before positioning the last side panel. Make sure that the panels with the duct openings are properly positioned with the inlet and outlet plena. Air must flow across the masters (through the gaps) to give maximum cooling. Strips of foam material or folded cardboard may be used to seal between ends of masters and side panels. As the fourth side panel is put into place, make sure the foam gaskets fill all gaps between adjacent panels.

Depending on the temperature and amount of fruit to be cooled and the capacity of the cooling unit, it should generally take no more than 2 to 3 hours of active cooling time to reach an acceptable temperature. Numerous tests have shown that the cooling rate is uniform throughout the container. Pulp temperature variations should be no more than 2 or 3 degrees. The warm-up rate is generally no more than 1 or 2 degrees per hour, which is more than adequate to allow several hours for transport to market under summertime temperature conditions. If the fruit is to be held for longer than this before transport, additional cooling may be necessary and is advisable. A graph of a typical cool-down and warm-up cycle is shown in Figure 4.

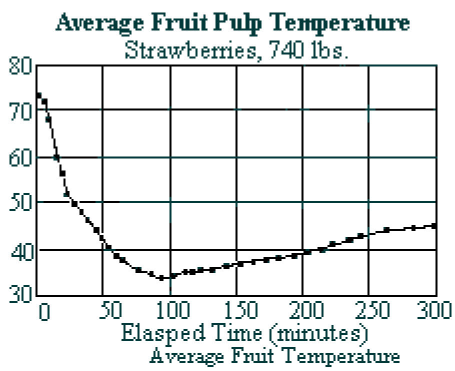


Figure 4. Actual cool-down and warm-up cycle.

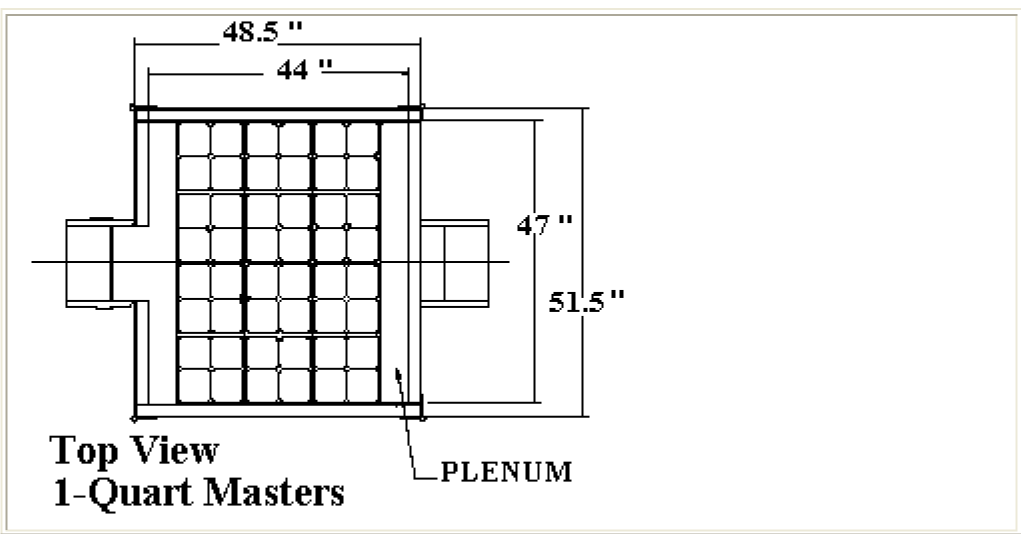
The cost of energy is an important consideration of any postharvest cooling operation. The energy requirements per pallet of cooled produce are less for the **Cool and Ship** system than for a more traditional forced-air cooling facility. With the same quantity of insulation, that part of the cooling load due to initial cool-down and conduction is much less for the container than a building. In addition, the service load is almost entirely eliminated. The service load is that refrigeration used to displace the heat from lights, air exchange, people, and other heat sources, and is normally 10 to 15 percent of the total load.

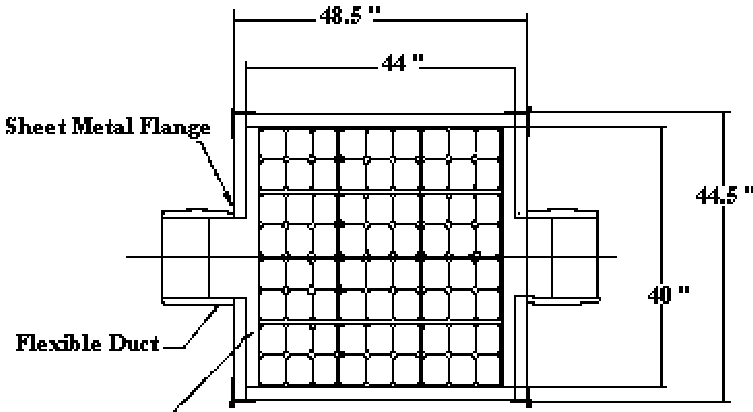
The major expense of the **Cool and Ship** system is the refrigeration unit. The insulated cooling containers are relatively inexpensive, and a grower may find desirable to have several available for use. It is even possible that several containers may be connected to the same refrigeration system for initial and subsequent maintenance cooling. As an alternative, several growers have built semi-permanent truck- or trailer-mounted cooling containers (Figure 5) that could be conveniently connected to a stationary refrigeration system.

Figure 5. Truck-mounted cooling container.

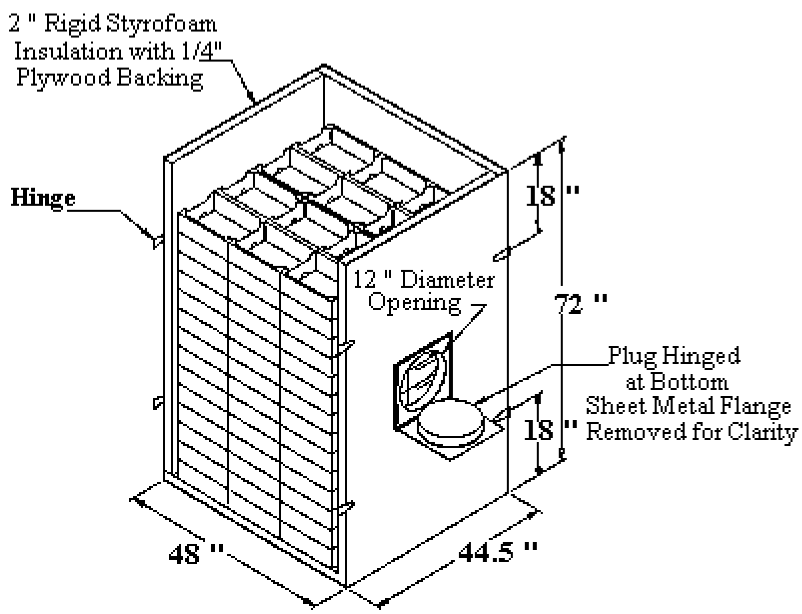
In any case, by using the insulated cooling container as a shipping container, the need for a refrigerated truck is eliminated.

The labor requirements of the system are similar to those for a conventional forced-air cooling system . Both methods require that the fruit be stacked onto a pallet. The stack of fruit is either enclosed in the **Cool and Ship** container or positioned for the forced-air fans. Once this is done, the actual cooling is accomplished with little or no direct supervision. With either method, once the fruit is on the pallet, it remains on the pallet until it is delivered to the buyers. Once in the hands of the buyer, the container could be reconstructed to a source of cool air for maintenance cooling, or the produce could be removed from the containers and placed into a conventional refrigerated room.

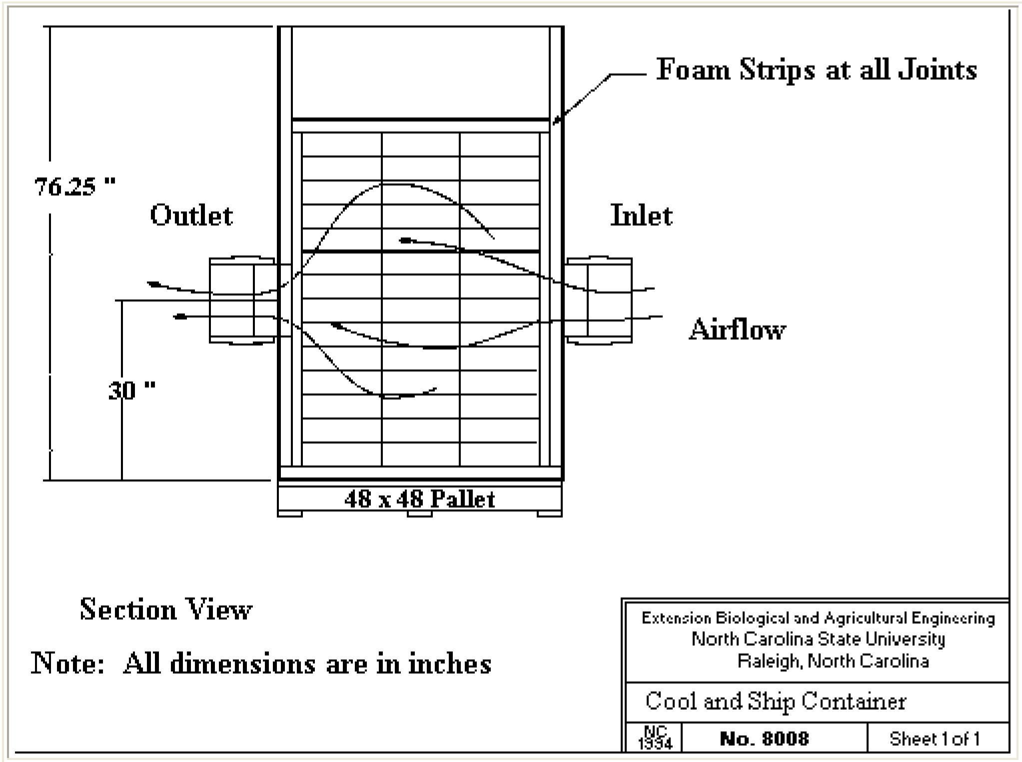




Top View
1/2-pint and 1-pint Masters



Pictorial View
Top and One Side Removed for Clarity



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