ATTRA
Appropriate Technology Transfer for Rural Areas

HORTICULTURE TECHNICAL NOTE

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Introduction

You have spent months working in the fields, and now have a bountiful harvest of beautiful fruits and vegetables. You want to ensure that your customers will also enjoy this healthy harvest. How can you best maintain the quality and safety of your produce as it travels from the field to the table? How can produce be stored so that it does not need to be sold immediately? High-quality, disease-free produce with a good shelf life is a result of sound production practices, proper handling during harvest, and appropriate postharvest handling and storage.

Production Practices

Production practices have a tremendous effect on the quality of fruits and vegetables at harvest and on postharvest quality and shelf life. To start with, it is well known that some cultivars ship better and have a longer shelf life than others. In addition, environmental factors such as soil type, temperature, frost, and rainy weather at harvest can have an adverse effect on storage life and quality. For example, car6(an)tTa8oace lic temperature reaches 80º F; symptoms are black spots on these root crops (2).

Food safety also begins in the field, and should be of special concern, since a number of outbreaks of foodborne illnesses have been traced to contamination of produce in the field. Common-sense prevention measures include a number of *don'ts* (3):

- Don't apply raw dairy or chicken manure or slurries to a field where a vegetable crop such as leafy lettuce is growing.
- Don't apply manure to an area immediately adjacent to a field nearing harvest maturity.
- Don't forget to clean equipment that has been used to apply manure to one field before moving it to another field in production.
- Don't irrigate with water from a farm pond used by livestock.
- Don't harvest fruit from the orchard floor for human consumption as whole fruit or nonpasteurized juices, especially if manure has been spread or animals allowed to graze.
- Don't accumulate harvested product in areas where birds roost.

A grower *should* constantly evaluate water used for irrigation, and compost all animal manures before applying them to fields. There are many good sources of information on growing conditions and production practices that promote postharvest quality. Consult textbooks, Extension publications, and trade journals, and become involved with grower organizations to find out more.

Harvest Handling

Quality cannot be improved after harvest, only maintained; therefore it is important to harvest fruits, vegetables, and flowers at the proper stage and size and at peak quality. Immature or overmature produce may not last as long in storage as that picked at proper maturity (4). Cooperative Extension Service publications are an excellent source of

One of the most important functions of refrigeration is to control the crop's respiration rate. Respiration generates heat as sugars, fats, and proteins in the cells of the crop are oxidized. The loss of these stored food reserves through respiration means decreased food value, loss of flavor, loss of salable weight, and more rapid deterioration. The respiration rate of a product strongly determines its transit and postharvest life. The higher the storage temperature, the higher the respiration rate will be (4).

For refrigeration to be effective in postponing deterioration, it is important that the temperature in cold storage rooms be kept as constant as possible. Appendix I charts the optimum temperature ranges for various crops. Exposure to alternating cold and warm temperatures may result in moisture accumulation on the surface of produce (sweating), which may hasten decay. Storage rooms should be well insulated and adequately refrigerated, and should allow for air circulation to prevent temperature variation. Be sure that thermometers, thermostats, and manual temperature controls are of high quality, and check them periodically for accuracy (5).

On-farm cooling facilities are a valuable asset for any produce operation. A grower who can cool and store produce has greater market flexibility because the need to market immediately after harvest is eliminated. The challenge, especially for small-scale producers, is the set-up cost. Innovative farmers and researchers have created a number of designs for low-cost structures. Some of these ideas are detailed in Appendix II and in the enclosures attached to this document. Additional designs are available in publications listed in the **Resources** section.

Pre-cooling

Pre-cooling is the first step in good temperature management. The *field heat* of a freshly harvested crop—heat the product holds from the sun and ambient temperature—is usually high, and should be removed as quickly as possible before shipping, processing, or storage. Refrigerated trucks are not designed to cool fresh commodities but only maintain the temperature of pre-cooled produce. Likewise, most refrigerated storage

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- **Hydro-cooling**: Dumping produce into cold water, or running cold water over produce, is an efficient way to remove heat, and can serve as a means of cleaning at the same time. In addition, hydro-cooling reduces water loss and wilting. Use of a disinfectant in the water is recommended to reduce the spread of diseases. Hydro-cooling is not appropriate for berries, potatoes to be stored, sweet potatoes, bulb onions, garlic, or other commodities that cannot tolerate wetting.

  Water removes heat about five times faster than air, but is less energy-efficient. Well water is a good option, as it usually comes out of the ground with temperatures in the 50–60º F range. Mechanical refrigeration is the most efficient method for cooling water. A thermal storage immersion hydro-cooler system can be fabricated economically to suit various volume requirements. Used stainless-steel bulk farm milk coolers may be an option. If hydro-cooling water is recirculated, it should be chlorinated to minimize disease problems (4).

  A study compared sweet corn quality after hydro-cooling with ice water, well water cooling, and refrigerated air cooling, and subsequent refrigerated storage. Hydro-cooling with ice water lowered the temperature of the ears most quickly. Well water cooling followed by refrigerated storage appeared to offer no advantage over refrigerated storage immediately after harvest (6).

- **Top or liquid icing:** Icing is particularly effective on dense products and palletized packages that are difficult to cool with forced air. In top icing, crushed ice is added to the container over the top of the produce by hand or machine. For liquid icing, a slurry of water and ice is injected into produce packages through vents or handholds without removing the packages from pallets and opening their tops. Icing methods work well with high-respiration commodities such as sweet corn and broccoli. One pound of ice will cool about three pounds of produce from 85º F to 40º F (7, 8).

- **Vacuum cooling:** Produce is enclosed in a chamber in which a vacuum is created. As the vacuum pressure increases, water within the plant evaporates and removes heat from the tissues. This system works best for leafy crops, such as lettuce, which have a high surface-to-volume ratio. To reduce water loss, water is sometimes sprayed on the produce prior to placing it in the chamber. This process is called *hydrovac* cooling. The primary drawback to this method is the cost of the vacuum chamber system (9).

Artichokes
Asparagus
Beets
Broccoli
Cantaloupes
Carrots
Cauliflower
Endive
Green onions
Leafy greens
Radishes
Spinach
Sweet corn
Watermelon

Strawberries
Blueberries
Raspberries
Tomatoes
Squash
Green beans
Cucumbers
Garlic
Okra
Bulb onions
Romaine lettuce
Herbs

Chilling injury

Many vegetables and fruits store best at temperatures just above freezing, while others are injured by low temperatures and will store best at 45 to 55 degrees F. Both time and temperature are involved in chilling injury. Damage may occur in a short time if temperatures are considerably below the danger threshold, but some crops can withstand temperatures a few degrees into the danger zone for a longer time. The effects of chilling injury are cumulative in some crops. Low temperatures in transit, or even in the field shortly before harvest, add to the total effects of chilling that might occur in storage (7).

Crops such as basil, cucumbers, eggplants, pumpkins, summer squash, okra, and sweet potatoes are highly sensitive to chilling injury. Moderately sensitive crops are snap beans, muskmelons, peppers, winter squash, tomatoes,

and watermelons (8). These crops may look sound when removed from low temperature storage, but after a few days of warmer temperatures, chilling symptoms become evident: pitting or other skin blemishes, internal discoloration, or failure to ripen. Tomatoes, squash, and peppers that have been over-chilled may be particularly susceptible to decay such as *Alternaria* rot (7).

Preventing moisture loss

While temperature is the primary concern in the storage of fruits and vegetables, relative humidity is also important. The relative humidity of the storage unit directly influences water loss in produce. Water loss can severely degrade quality—for instance, wilted greens may require excessive trimming, and grapes may shatter loose from clusters if their stems dry out. Water loss means salable weight loss and reduced profit (4).

Most fruit and vegetable crops retain better quality at high relative humidity (80 to 95%), but at this humidity, disease growth is encouraged. The cool temperatures in storage rooms help to reduce disease growth, but sanitation and other preventative methods are also required. Maintaining high relative humidity eraturK1(e)nmiditemort

Mixed loads

When different commodities are stored or transported together, it is important to combine only those products that are compatible with respect to their requirements for temperature, relative humidity, atmosphere (oxygen and carbon dioxide), protection from odors, and protection from ethylene (4).

In regard to cross-transfer of odors, combinations that should be avoided in storage rooms include: apples or pears with celery, cabbage, carrots, potatoes, or onions; celery with onions or carrots; and citrus with any of the strongly scented vegetables. Odors from apples and citrus are readily absorbed by meat, eggs, and dairy products. Pears and apples acquire an unpleasant, earthy taste and odor when stored with potatoes. It is recommended that onions, nuts, citrus, and potatoes each be stored separately (4).

Storage crops

What about the crops that will not be transported and marketed fresh after harvest? Growers can extend their selling season into the winter months by growing root crops and other vegetables and fruits suited for long-term storage. The challenge is in keeping quality high by creating and maintaining the correct storage environment. As *Growing for Market* editor Lynn Byczynski notes,

> Most storage crops require low temperatures and high humidity, two factors that don't come together easily. Several others require low humidity and low temperatures. And then there are a few that fall in between…Root

POSTHARVEST HANDLING OF

Perishables Handling
Editor: Pam Moyer
Postharvest Technology
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Storage Conditions—Fruits and Vegetables MF978
Storage Construction MF1039
Storage Operations MF1033
Storage Options MF1030

For information on ordering print copies, contact:

Production Services
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e-mail: orderpub@oz.oznet.ksu.edu

The University of Wisconsin *has produced a very helpful set of "Work Efficiency Tip Sheets" for fresh-market vegetable growers. These materials were developed by the* Healthy Farmers, Healthy Profits Project*, with the goal of sharing labor-efficiency practices that maintain farmers' health and safety while increasing profits. Topics in the series include:*

A Specialized Harvest Cart for Greens A3704-1

Stooping or kneeling and crawling to harvest salad greens requires a lot of time and energy. An alternative is to build a simple cart that allows you to sit and roll while you harvest. The cart also holds your harvest container, so it rolls along with you. Parts for the cart will cost about $150.

Mesh Produce Bags: Easy Batch Processing A3704-2

Elements and benefits of the batch method for washing greens, aseeing

Delta Track
P.O. Box 398
Pleasanton, CA 94566
(800) 962-6776

Sells "Hygro Thermometers": about the size of a deck of cards, battery operated, digital display of temperature and humidity, records daily min./max. of each.

Spectrum Technologies
23839 W. Andrews Rd.
Plainfield, IL 60544
(800) 248-8873

Sells humidity monitors.

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Oshkosh, WI 54904
(920) 231-1711
e-mail: info@barrinc.com
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Distributor of used coolers, freezers, and refrigeration systems.

Cool Care Consulting, Inc.
4020 Thor Dr.
Boynton Beach, FL 33426
(561) 364-5711
e-mail: ron.roberts@coolcareinc.com
http://www.coolcareinc.com

Sells postharvest pre-cooling and refrigeration equipment, including forced air, ice, hydro, vacuum, modular, and mobile cooling units.

Bio Safe Systems
80 Commerce St.
Glastonbury, CT 06033
(888) 273-3088
e-mail: Rob@biosafesystems.com
http://www.biosafesystems.com

Sells organic-approved, eco-friendly washwater treatments/disinfectants.

The electronic version of Postharvest Handling of Fruit & Vegetables is located at:
http://www.attra.org/attra-pub/postharvest.html

The ATTRA Project is operated by the National Center for Appropriate Technology under a grant from the Rural Business-Cooperative Service, U.S. Department of Agriculture. These organizations do not recommend or endorse products, companies, or individuals. ATTRA is located in the Ozark Mountains at the University of Arkansas in Fayetteville at P.O. Box 3657, Fayetteville, AR 72702. ATTRA staff members prefer to receive requests for information about sustainable agriculture via the toll-free number 800-346-9140.

APPENDIX I

	Temperature F	% Relative humidity	Precooling method	Storage life Days	Ethylene sensitive
Apples	30-40	90-95	R, F, H	90-240	Y
Apricots	32	90-95	R, H	7-14	Y
Asparagus	32-35	95-100	H, I	14-21	Y
Avocados	40-55	85-90		14-28	Y
Bananas	56-58	90-95		7-28	Y

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The Portacooler

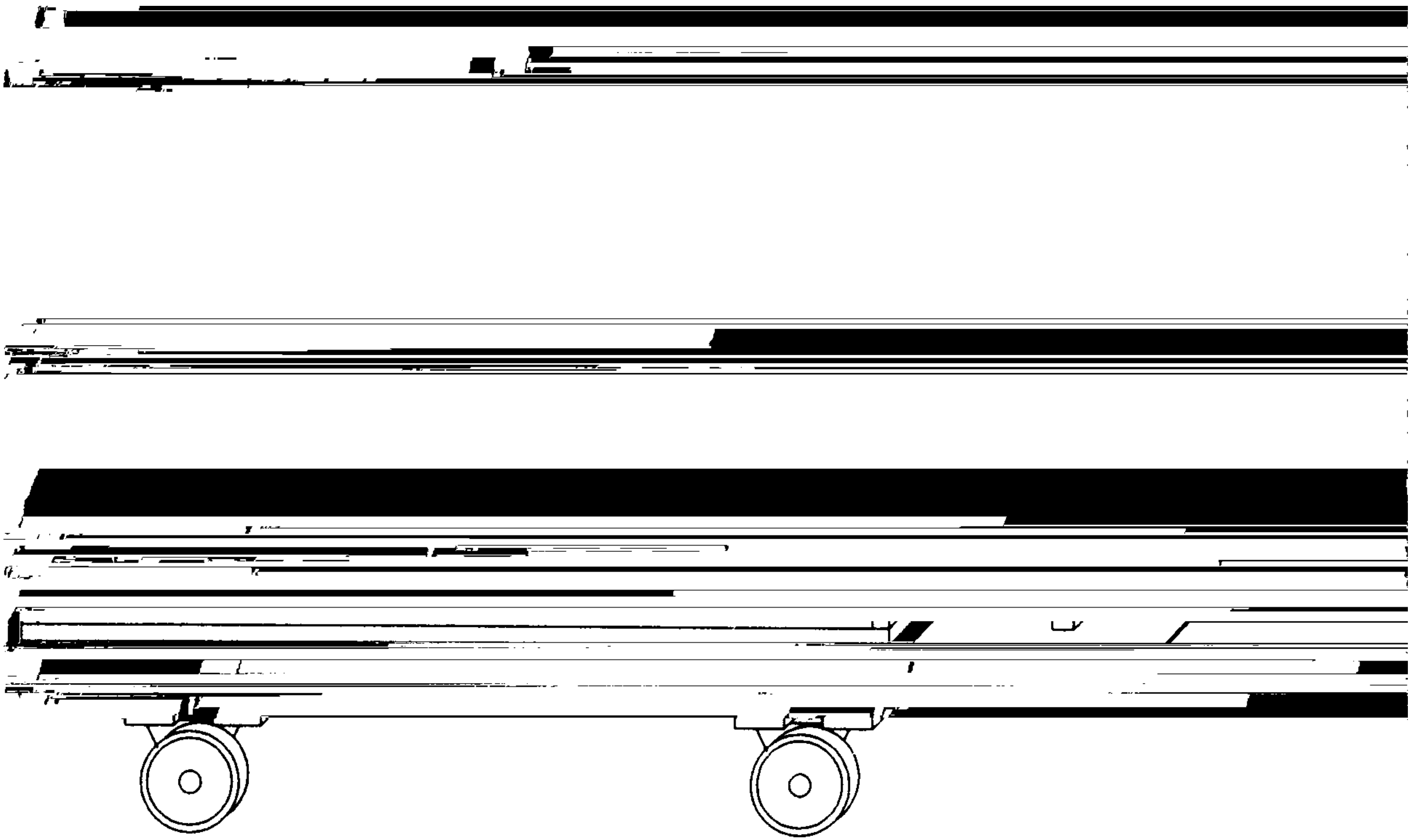
A portable precooler designed by USDA researchers can be built with readily available materials at a cost of around $1,200. The most expensive component is an airconditioner. If a used airconditioner is available, the initial investment will be decreased. The Portacooler can be towed to the field and used to reduce field heat of berries, vegetables, and other high-value crops immediately after picking.

The structure of the Portacooler is a basic wood frame and plywood panel

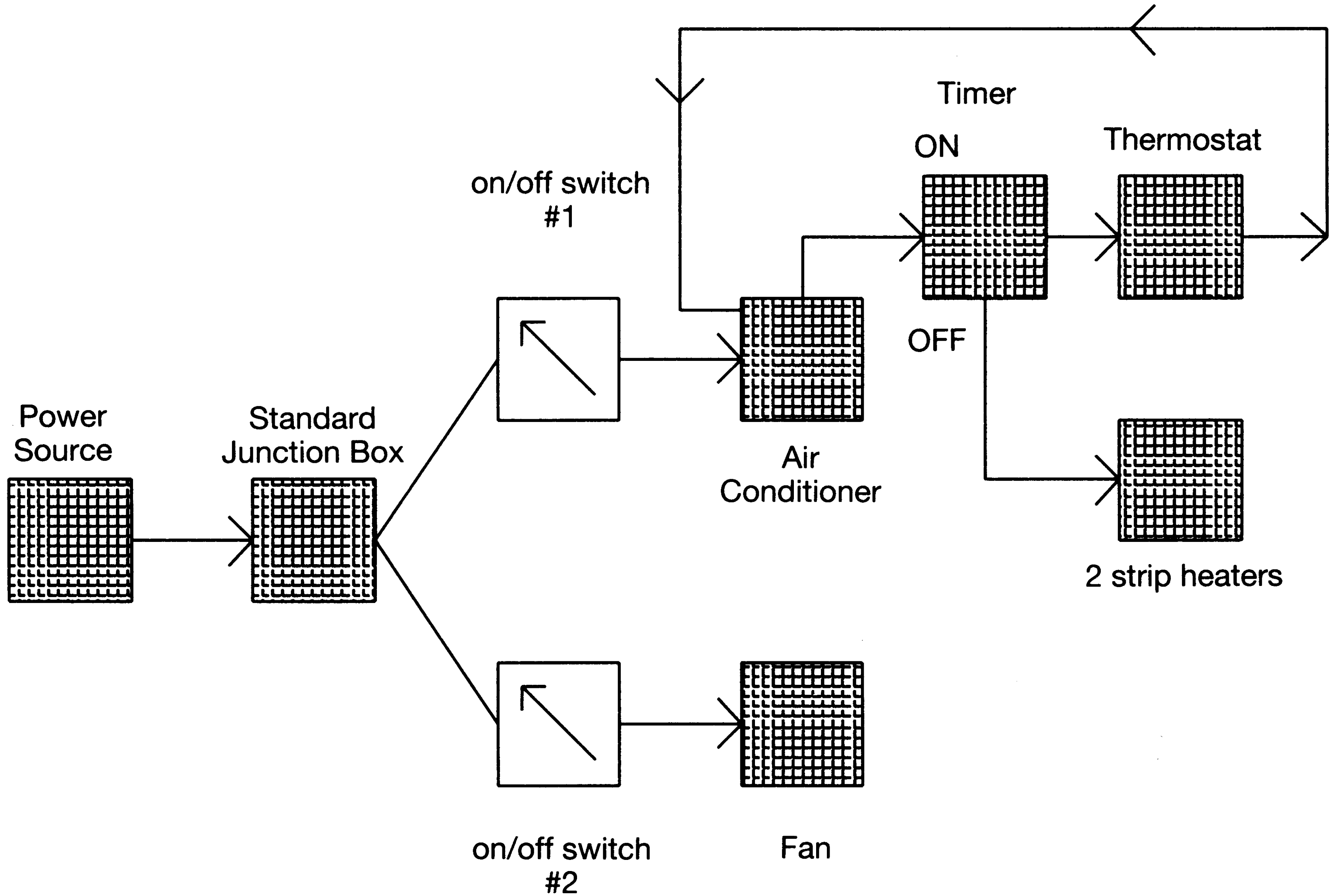
General Material List

- air conditioner, 12,000 Btu, 115 V..1
- centrifugal blower, 1/3 hp, 1210 c.f.m. 1
- 20-amp wall switch, with boxes and covers 2
- 4 by 8 ft, exterior AC, 1/4-in plywood..11
- lumber, 2 by 3 in, 8 ft long..30
- lumber, 2 by 4 in, 12 ft long..3
- lumber, 2 by 6 in, 8 ft long..1
- industrial wheels, 5-in diameter..2
- industrial wheels, 5-in diameter, swivel..2
- dry wall screws, 2 1/2-in long..5 lb
- dry wall screws, 1-in long ....1 lb
- water sealer..1 gal
- polyurethane coating ....1 gal
- weather stripping, 1-in wide roll 1
- insulation, 2 in, 4 by 8 ft sheets..5
- 1/4-in plywood, 4-in wide strips..12 ft
- door latch, sliding bolt..1
- thermostat, 115 B, 16 amp, remote bulb 1
- strap hinges, screw fastened, 3-in long..4
- lumber, 2 by 10 in, 4 ft long..1
- standard junction box 1
- strip heaters, 150 watt, 8 in, 115 B..2
- insulated wire..30 ft
- cycle timer, SPDT, 115 B, 20 amp, 1 hour 1

The design, construction, and research of the Portacooler was conducted by Joseph Anthony, Gerald Berney, William Craig, and Daniel P. Schofer. For further information, contact Daniel Schofer, Room 1211 South Bldg., 12 & Independence, Box 96456, Washington, D.C. 20090-6456.



Electrical Diagram



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