Handling, Precooling, and Temperature Management of Cut Flower Crops for Truck Transportation

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ABSTRACT

Cut flowers from California flower producing areas can be transported successfully to Midwest and east coast markets by refrigerated highway trucks if proper transit temperatures are maintained. Initial temperatures of cut flowers may range between 35°F (2°C) and 59°F (15°C). If the flowers are properly packed in vented standard-sized boxes, forced-air precooled, and placed in a spaced load pattern in the truck, transit temperatures can be maintained between 32°F (0°C) and 37°F (2.7°C). Forced-air cooling of flowers before shipping removes enough heat from the product to enable the refrigeration system on the truck to maintain proper flower temperatures in transit. Precooling units are available that can cool from 4 to more than 100 boxes of flowers in less than one hour. Flower boxes that are 20 inches wide and 12 inches high, stacked in a pigeon-hole loading pattern, provide sufficient air circulation in the truck.

KEYWORDS: Cut flowers, ornamentals, transportation, packaging, precooling, carnation, rose, chrysanthemum, truck, temperature, standardization, containers.

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HANDLING, PRECOOLING, AND TEMPERATURE MANAGEMENT OF CUT FLOWER CROPS FOR TRUCK TRANSPORTATION

By Roger E. Rij, James F. Thompson, and Delbert S. Farnham[1]

INTRODUCTION

The United States produced about 1.3 billion cut flower blooms in 1977, which had a wholesale value of $211 million. The major kinds of cut flowers produced are carnations (507 million blooms), roses (419 million blooms), gladioli (166 million spikes), chrysanthemums (112 million blooms), and pompons (36 million bunches). Of the 23 States producing flowers commercially, California is the largest, with about 52 percent of the U.S. production, having a value of about $83.5 million a year (*2*).[2]

Shipment of cut flower crops by refrigerated highway truck from growing areas in Florida and Colorado to major markets in northeastern States and the Midwest has been a common practice for a number of years. Traditionally, about 80 percent of the cut flowers from California have been shipped out of State by air freight, but due to an increase in freight rates and a reduction in the number of flights, the floral industry has been shipping a greater proportion of flowers by refrigerated highway trucks to midwestern, southern, and east coast markets. Currently, about 50 percent of the flowers produced in California are shipped by refrigerated highway truck, and the percentage is increasing.

Time and temperature are major factors controlling deterioration during the marketing of cut flowers (*5, 6, 7, 8, 9, 10, 11, 12, 13, 15, 16, 17*). Shipping flowers by air has the advantage of reduced transit time, compared with other modes of transportation, but it does not provide controlled temperatures (*10, 12, 13, 16*). Although truck shipments have longer transit times than air shipments, the truck refrigeration unit can provide ideal conditions for the maintenance of flower quality through proper temperature management (*8, 9*). Most flowers have a low tolerance for adverse temperatures, even for short periods.

Current flower handling and packaging methods were developed for air freight shipments. Since air freight does not provide a controlled temperature environ-

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[2]Italic numbers in parentheses refer to Literature Cited, p. 20.

ment, packaging and handling were developed to protect the flowers from extremely high or extremely low temperatures. For transport by refrigerated truck, new packaging and handling methods had to be developed to take advantage of the controlled temperature environment provided in the truck.

This publication presents information on improved methods for handling and cooling cut flowers shipped by refrigerated truck. This information was developed by adapting recommended handling procedures for fruits and vegetables for use with flowers and by conducting experiments to verify the effectiveness of the procedures on flower shipments.

GROWER PRACTICES AFFECTING FLOWER QUALITY

The quality of cut flowers is influenced by many factors that occur prior to packing the graded flowers for long distance transport. Handling the flowers improperly prior to packing can negate the benefits of good precooling and temperature control practices during shipment.

Greenhouse Factors

Poor greenhouse heating, ventilating, and cooling systems can lead to flowers infected with Botrytis or other disease organisms that may develop further in transit. Such flowers have a short life and low overall quality.

Applications of phytotoxic sprays, long exposure to high or low light intensity, and improper fertilization are other factors that affect the keeping quality of the blooms. Excess fertilization of chrysanthemums causes soft flowers with poor vase life, and nitrogen-deficient soils cause hard stems that will not draw water after harvest.

Proper handling of cut flowers after cutting in the greenhouse and during movement to the grading shed is essential to quality maintenance. Severe heating and wilting of the flowers can occur during this period. Flowers bundled together in clear polyethylene and tied with a rope or string for carrying to the packing shed can overheat and "cook." Use of porous wraps of open, woven materials allows heat to dissipate and thus reduces injury on warm days.

Dirty water and storage buckets reduce flower quality. The water within a flower stem is under tension at harvest so flower stems will quickly draw in bacteria and other micro-organisms from a dirty bucket of water. Cell sap and other nutrients bleed into the water from cut stems, providing a substrate for growth of bacteria and other micro-organisms. Water in greenhouse storage buckets should be changed daily and the containers scrubbed.

Flowers harvested in the heat of the day can be stressed because of high temperatures. This is especially true with dark-colored flowers, which can be as much as 10°F (5.5°C) warmer than white flowers during midafternoon. Overheating can also occur when flowers are handled in bundles or boxes that prevent respiratory heat from escaping.

Exposure of flowers to air pollution occasionally occurs. Special cooling precautions may help during periods of high air pollution. Air pollution and ethylene problems created by growers can be easily corrected if they are recognized. Examples of self-made air pollution include:

- Gas leaks in the greenhouse or packing shed
- Worn out space heaters that emit ethylene and other combustion gases into the greenhouse
- Short exhaust vents on heaters that permit fumes to be drawn into open greenhouse vents
- Flowers infected with Botrytis, Alternaria, and other disease organisms that produce their own ethylene
- Bruised flowers that give off ethylene
- Use of gasoline or propane-powered forklift trucks and vehicles in the greenhouse or packing shed

Grading Shed Factors

Air pollutants, both self-made and naturally occurring, are also problems in the packing sheds as are dirty water and buckets. Additional factors contributing to loss of quality are:

- Use of poor quality water
- Failure to use a preservative, a proven conditioning treatment, or dry handling (whichever is best suited for the particular kind of flower)
- Rough handling by grading crew
- Exposure of flowers to long periods without refrigeration
- Inadequate inventory control, permitting old and decaying blooms to accumulate in the cold room
- Improper control of temperature and humidity

The major flower crops (roses, chrysanthemums, and carnations) should be stored at 32°F (0°C). Temperatures of 41° to 45°F (5° to 7°C) allow the flowers to deteriorate. Long rotation periods also can be a problem. Roses turn blue at the end of 10 days when placed in water for as little as 4 hours prior to dry storage (*15*). Rewarming flowers when they are packed for shipping also contributes to deterioration of quality.

Handling Factors — Grower to Shipper

Poor temperature and humidity control are common on many of the trucks and vans used by wholesalers to gather flowers from individual growers. Ethylene contamination from exhaust can also occur. Loading and unloading of cold flowers into a warm room causes moisture to form on cold blooms. This creates conditions ideal for development of Botrytis decay and other postharvest diseases. Truck engines can contaminate a shipping shed with ethylene if permitted to idle while flowers are unloaded.

PRECOOLING

Temperature has a direct effect on the respiration rates of flowers (*16, 17*) and on the activity of decay-causing organisms. The respiration rate is an index of the rate a flower (or other plant organ) is using up its stored reserves of sugar and other metabolites, and is, therefore, an index of the loss in shelf life. The chemical reactions associated with respiration result in the production of heat. The amount of heat generated varies with the commodity and with its temperature. In general, the respiration rate increases two to four times for each 18°F (10°C) increase in temperature. Thus, more heat is produced at high temperatures and less at the low temperatures to which the product is cooled. Microbial organisms also are more active at high than at low temperatures. Precooling and storage at optimum temperatures is required to reduce this generation of heat and to slow decay.

Unless flowers are undergoing a special postharvest treatment (*11*), such as pulsing with a preservative solution, opening, or tinting with dyes, they should be kept at the storage temperatures listed in Appendix 1. Unpacked flowers can be quickly cooled and kept at proper temperature by placing them in a refrigerator. In most cases, the field heat can be removed from bunched flowers in about 20 min by placing individual bunches in a refrigerator. Packing the flowers in boxes or stacking bunches in piles will restrict the movement of refrigerated air to the flowers and will increase the time required to remove the field heat. It can take 2 to 4 days to cool a stack of packed boxes of warm flowers. A warm load of flowers in a refrigerated truck will never reach recommended temperatures during a 3- to 4-day trip (*19*).

Under present procedures, the cooling of packed flowers is the weakest link in most handling systems. Producers of fieldgrown flowers find that they cannot take advantage of field packing because they lack a method of quickly removing field heat. Flower shippers also recognize that flowers shipped by truck do not always arrive in good condition because they reach excessively high temperatures in transit. Temperature problems in transit can be greatly reduced by use of forced-air cooling prior to shipping.

Forced-Air Cooling

Forced-air cooling is a method of moving refrigerated air through a packed box of flowers to quickly reduce their temperature (*7, 8, 9*). Most flowers can be cooled to recommended temperatures in 45 min to an hour, and some cut flowers can be cooled in as few as 8 min. For small volumes of packed flowers, this is done by stacking boxes around a fan inside an existing refrigerator. In larger systems, many fans are permanently mounted against a wall, and pallet or cartloads of boxes are positioned next to the fans. The refrigeration system is carefully designed and sized for forced-air cooling.

Cooling Time Calculations

In this publication, the time necessary to reach a desired temperature is expressed in terms of a typical cooling curve. The seven-eighths cooling time, or the time necessary to drop the temperature of the flowers seven-eighths of the way from the initial temperature to the temperature of the cooling air, is considered the most meaningful point in the cooling curve (fig. 1). The rate of

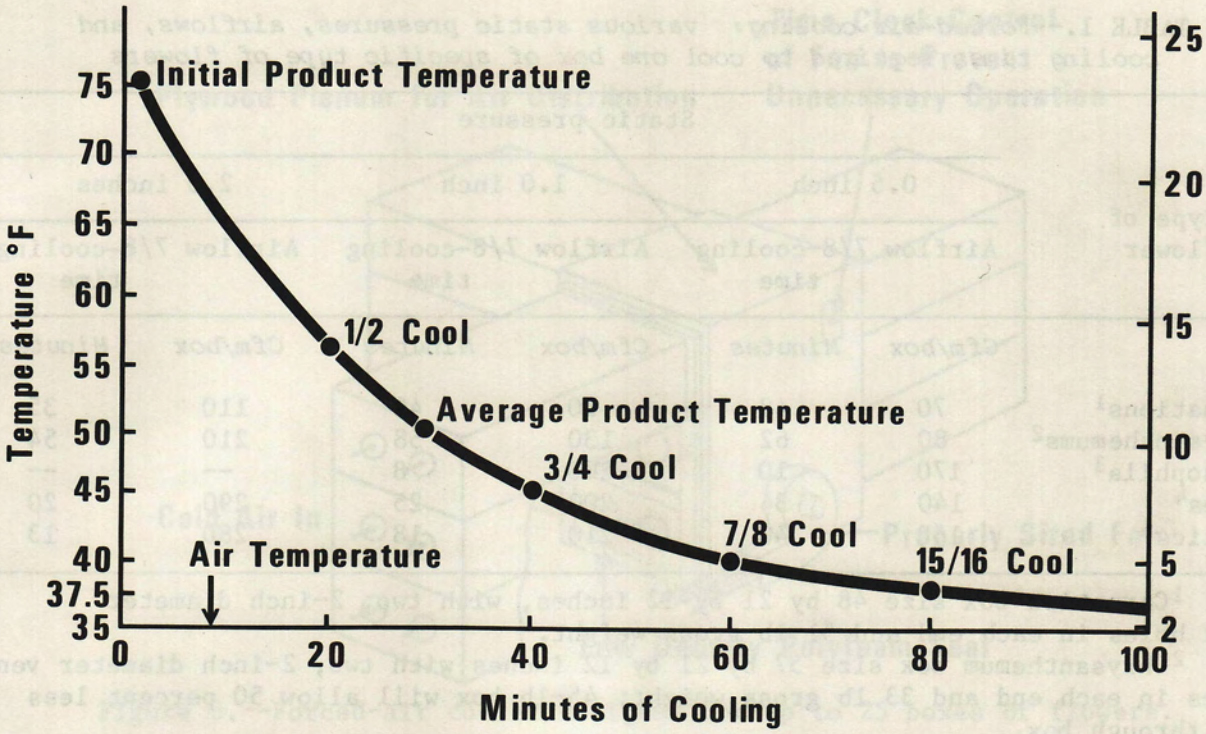


Figure 1.--Hypothetical cooling curve for cut flowers.

cooling becomes very slow as the temperature of the flowers nears the temperature of the refrigerated air. Consequently, the flowers are seldom cooled all the way down to the temperature of the cooling air. In figure 1, one hour of cooling (seven-eighths cooling time) is required to reach 40°F (5°C) (seven-eighths cooling temperature), and calculations indicate that 3 hours of cooling would be required to reach close to 35°F (2°C), the cooling air temperature.

Fans

Forced-air coolers utilize centrifugal (more commonly called squirrel cage) or axial flow (propellor) fans. Centrifugal fans are much quieter than axial flow fans but may require greater horsepower to operate. Fans are selected on the basis of two criteria--the required airflow, measured in cubic feet per minute (cfm), and the required static pressure, measured in inches of water. The specific requirements are determined by the types of flowers, the number of boxes, the venting of the boxes, and the rate of cooling desired.

Table 1 shows the airflow and pressure needed to cool one box of a specific type of flower. The airflow (in cubic feet per minute) requirement for a system can be determined by multiplying it by the number of boxes to be cooled and by adding an extra 25 percent capacity to compensate for air leaks. The number of boxes cooled should be based on the maximum number handled on a peak day (such as the period just before a holiday). It is not advisable to use higher air rates than those listed in the table. They will not significantly decrease cooling times and will require excessive amounts of energy. The pressure drop for the systems is equal to the pressure drop across one box plus 25 percent additional pressure as a safety factor. (Stacking boxes end to end is not recommended for the precooling operation.)

TABLE 1.--*Forced-air cooling: various static pressures, airflows, and cooling times required to cool one box of specific type of flowers*

Type of flower	Static pressure 0.5 inch Airflow	0.5 inch 7/8-cooling time	1.0 inch Airflow	1.0 inch 7/8-cooling time	2.0 inches Airflow	2.0 inches 7/8-cooling time
	Cfm/box	*Minutes*	*Cfm/box*	*Minutes*	*Cfm/box*	*Minutes*
Carnations[1]	70	48	90	40	110	35
Chrysanthemums[2]	80	62	130	58	210	54
Gypsophila[3]	170	10	260	8	--	--
Roses[4]	140	34	200	25	290	20
Statice[5]	150	40	210	18	280	13

[1]Carnation box size 48 by 21 by 12 inches, with two, 2-inch diameter vent holes in each end and 51 lb gross weight.

[2]Chrysanthemum box size 57 by 21 by 12 inches with two, 2-inch diameter vent holes in each end and 33 lb gross weight; 45-lb box will allow 50 percent less air through box.

[3]Gypsophila box size 42 by 21 by 12 inches with two, 3-inch diameter vent holes in each end.

[4]Rose box size 48 by 21 by 12 with two, 2-inch diameter vent holes in each end with 20 bunches in box.

[5]Statice box size 42 by 21 by 12 inches with two, 3-inch diameter vent holes in each end and gross weight of 75 lb.

Figures 2 and 3 illustrate two methods of setting up a small portable forced-air cooling system in an existing refrigerator.

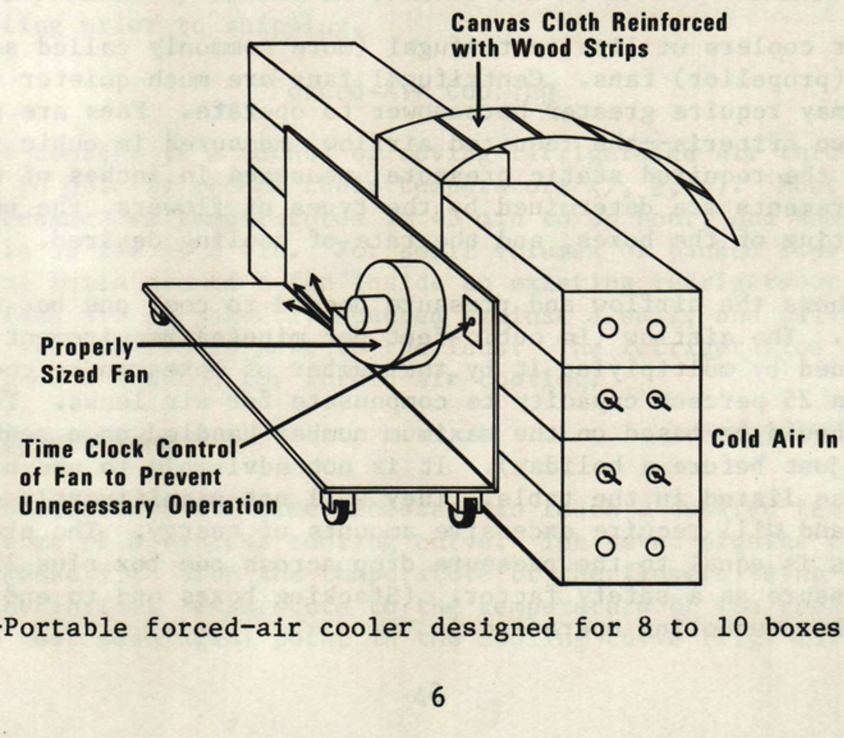


Figure 2.--Portable forced-air cooler designed for 8 to 10 boxes of flowers.

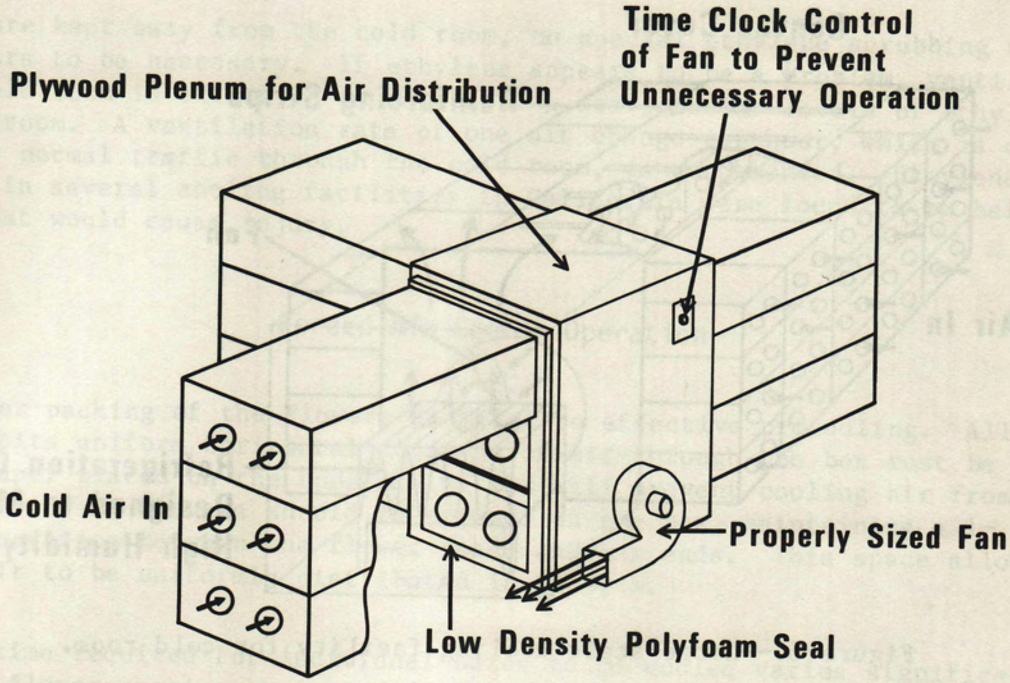


Figure 3.--Forced-air cooler designed for up to 25 boxes of flowers.

Precooling facilities that handle more than 30 to 40 boxes per hour must be designed specifically for flowers. Boxes are often handled in stacks of six to eight high and are set on wheeled dollies or pallets. The unit of boxes is placed in front of an air plenum called a cold wall (fig. 4). The holes in the plenum open automatically, causing cooling to begin. The units of boxes also can be stacked in two columns, separated by several feet, next to a fan opening. The space between the columns is covered by a canvas cloth, causing the air to be pulled through the boxes (see fig. 5).

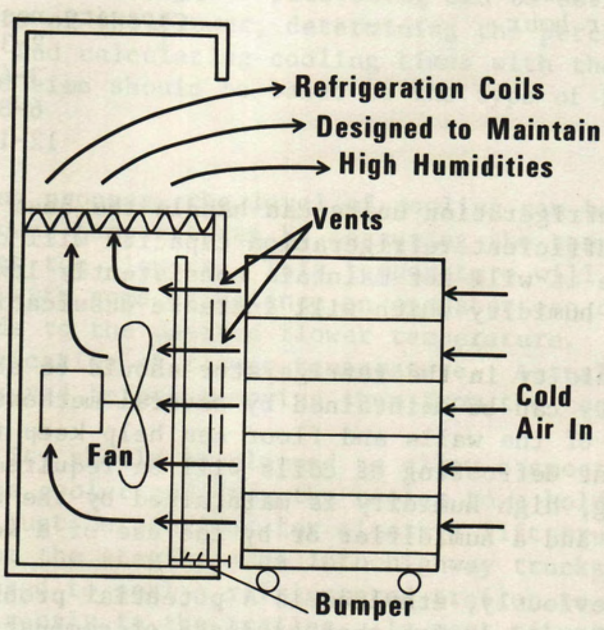


Figure 4.--Large-scale cooling facility or cold wall system.

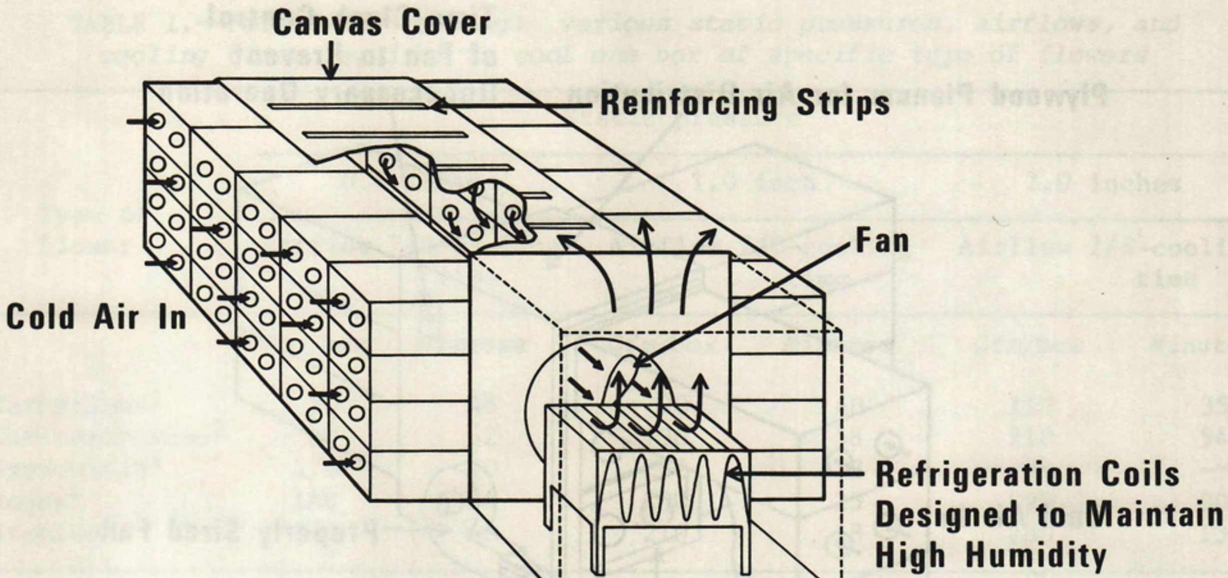


Figure 5.--Large-scale cooling facility for cold room.

Refrigeration

The refrigeration system must be designed to maintain a temperature equal to the lowest storage temperature of the crops being cooled (often 32°F). The actual refrigeration requirement necessary to cool flowers to 32°F (0°C) should be determined by an engineer but can be estimated as follows:

Maximum number of boxes cooled per hour	*Approximate refrigeration capacity needed (tons)*
5	2-3
10	3-4
20	6-8
40	12-16

Many existing refrigeration units can handle the heat load from 5 to 10 boxes per hour. Insufficient refrigeration capacity will cause increased cooling times because it will not maintain consistently low air temperatures. It may result in low humidity which will increase dessication of the flowers.

The relative humidity in the refrigerator should be about 95 percent. This high relative humidity can be maintained by several methods. In a small system, periodic hosing down of the walls and floor can help keep the humidity high, although more frequent defrosting of coils will be required. In systems designed for precooling, high humidity is maintained by the use of a large refrigeration coil surface and a humidifier or by the use of a wet coil system.

As mentioned previously, ethylene is a potential problem in any enclosed area. If care is taken to insure that products of combustion from heaters or engines are kept away from the cold room, no special ethylene scrubbing apparatus appears to be necessary. If ethylene appears to be a problem, ventilation of the cold room is effective in maintaining near ambient levels of ethylene in the cold room. A ventilation rate of one air change per hour, which is often caused by normal traffic through the cold room, is recommended. Ethylene levels measured in several cooling facilities in California were found to be below the levels that would cause injury.

Forced-Air Cooler Operation

Proper packing of the flowers is vital to effective precooling. All paper that inhibits uniform horizontal movement of air through the box must be eliminated. Paper placed on the ends of the box will prevent cooling air from reaching the flowers. Flowers should be secured in the box, maintaining a 1- to 2-inch separation between the flower heads and box ends. This space allows the cooling air to be uniformly distributed in the box.

The time required for individual boxes to be cooled varies significantly. Different flower species cool at different rates. Incorrect placement of paper or sleeves can retard or prevent cooling. The number of boxes on the cooler can affect cooling times. These facts require that temperature of the products be monitored closely during cooling. Boxes should be removed only after the temperature of the flowers inside the box has been checked. A thermometer with a long hypodermic needle probe is ideal for checking temperatures. The temperature at both the warm and cool end of the box should be checked. Data sheets, indicating the initial and final temperature of all loads of boxes, should be kept.

The amount of time necessary for precooling can be estimated by measuring the initial temperature of the flower, determining the percent cooling time desired from table 1, and calculating cooling times with the formulas in Appendix II. The estimated time should be based on the type of flowers that take the longest to cool.

During the cooling process, the level of cooling can be estimated without actually measuring flower temperatures by measuring the temperature of the air after it passes through the flowers. This temperature will always be colder than the flowers, but with some experience an operator can determine what air temperature corresponds to the desired flower temperature. This method should only be used as an indication of flower temperature. Actual temperatures of flowers should be measured before removing them from the cooler.

The cooling facility should be planned to allow a smooth flow of boxes from the packing area to the cooler and from the cooler to a holding and staging area. Adequate space must be provided for electric lift trucks. Boxes should be loaded directly from the staging area into highway trucks. Foam or air-inflated pads can be used to seal a refrigerated trailer to a door in the staging area that opens directly to the trailer. In most situations, the cooler should be designed to allow for future expansion.

REFRIGERATED TRAILER EQUIPMENT

Methods of Refrigerating Trailers

Two types of thermostatically controlled mechanical units are most commonly used on refrigerated trailers. One type (nosemount) has the engine, condenser, and other accessories mounted on the nose of the trailer, with the evaporator coils and air-circulating fans located on the opposite side of the bulkhead, inside the trailer. The other type (undermount) has the power unit and accessories mounted under the frame of the trailer, with the evaporator coil and fans high inside the front end of the trailer (*4*).

Mechanical refrigeration units are rated according to their ability to remove heat. The capacity of a unit is expressed in the number of British thermal units (Btu's) per hour that the unit can remove at 100°F (38°C) outside and at either 35°F (2°C) or 0°F (-18°C) inside temperature. The refrigeration capacity needed for a particular vehicle will depend on the amount of heat to be removed and the extra (reserve) capacity desired.

If the thermostats that control the refrigeration unit are out of calibration, air temperatures will be above or below the actual setting. Calibration of the thermostat should have high priority on the refrigeration system maintenance schedule. A thermostat out of calibration by several degrees may result in severe damage to the product by chilling, freezing, or overheating. Because each make of thermostat varies, the operator's manual should always be consulted for particular characteristics of the thermostat before it is set.

Freezing may occur when the thermostat is set near 32°F (0°C) because the discharge air may be several degrees below the set point. The thermostat sensing bulb is usually located near the air intake where the air returns to the blower system. It measures the temperature of the air after it has been warmed by the heat in the load; however, the air being discharged from the refrigeration unit may be more than 10° colder than that measured by the sensing bulb. For example, if the thermostat is set at 33°F (1°C) and it is operating on the low side, then the air at the discharge point may be in the low twenties. Consequently, the product in the top layers of the load is in considerable danger of freezing.

Temperatures may range above or below the actual thermostat setting in most refrigerated vehicles due to cycling of the compressor (*4*). Some compensation in thermostat setting above the optimum is needed to prevent freezing or chilling damage. No easy rule or formula can be set forth. The best thermostat setting will have to be determined by the operator of each vehicle, based on the desired transit temperature, the openness of the load, and the operating characteristics of the equipment.

Air Circulation

Provision should be made for the refrigerated air to circulate uniformly to all parts of the load. For air movement, space is left between the ceiling and the top of the load, ribs are built into the side walls and rear doors, and rectangular or T-shaped grooves are used in the floors (fig. 6).

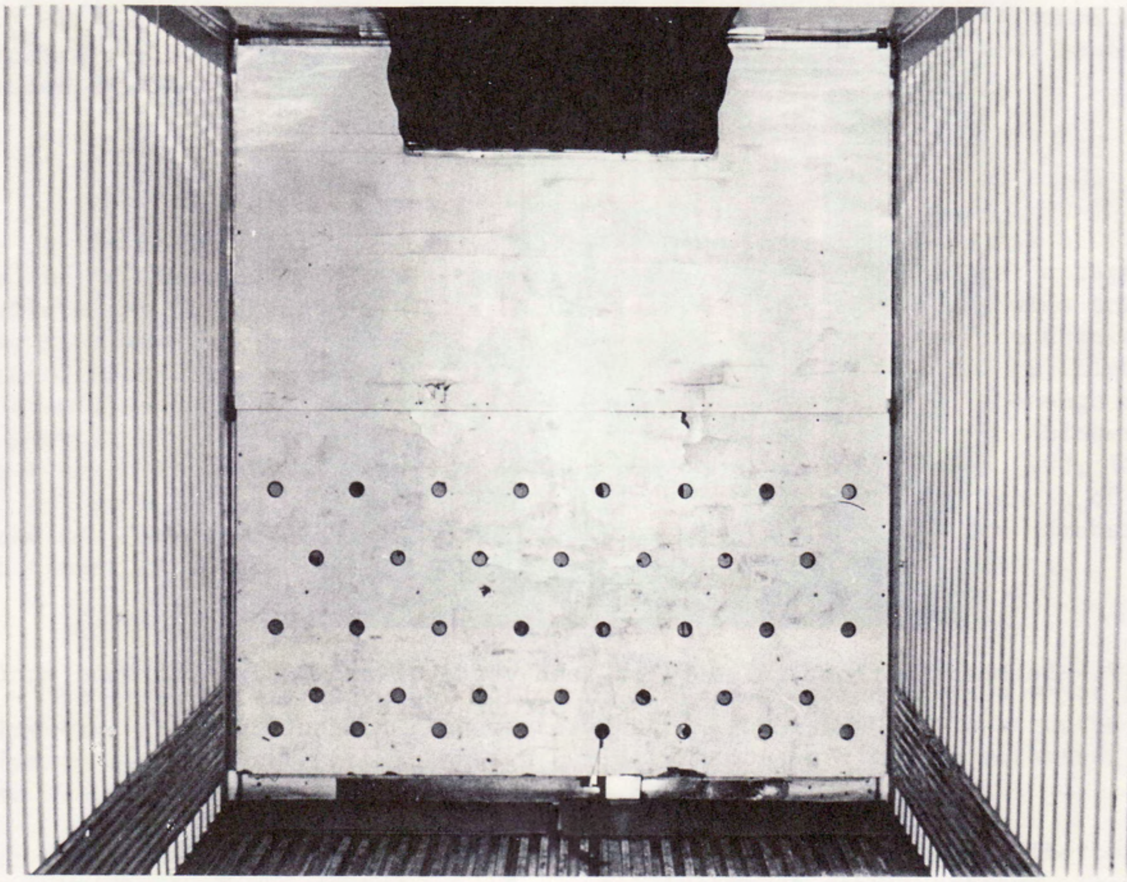


Figure 6.--One type of interior refrigerated trailer with false bulkhead walls; holes allow air to return to unit. Canvas ducts, suspended from ceiling, direct discharge air to rear. T-shaped floor grooves and side walls are ribbed.

Circulation of refrigerated air removes heat generated by respiration of the product and heat conducted through the walls, ceiling, and floor from the outside. To assure uniform air circulation, canvas ducts usually carry the air from the blower to the rear of the vehicle. Free passageways through the load must be provided for the air to return to the blower intake. At least 4 inches of free space should be left between the rear doors and the end of the last stack in the load. Bracing is needed to prevent the load from shifting backwards.

Both lengthwise air channels through the load and space for air movement under the load must be provided in flower shipments. Most modern trailers have deep-channel floor grooves for under-the-load circulation. Floor racks should be used in vehicles without grooved floors and in older trailers with shallow floor grooves.

The air returning to the blower through and under the load must not be blocked at the bulkhead. Channels are needed to direct the air to the blower intake. This can be accomplished by attaching vertical strips about 2 inches thick between the bulkhead and the first stack in the load or by constructing a "starter stack" with vertical channels to direct the air to the blower return (fig. 7).

Figure 7.--Bulkhead without false walls, and vertical and horizontal wood strip added to prevent air blockage.

BOX STANDARDIZATION

The lack of uniform size and style boxes prevents the use of effective load patterns. Irregular sizes of boxes often cause poor air circulation through the load and variation in temperature at various positions in the load. Loading various sizes and styles of boxes into a trailer also reduces the load capacity, which may increase the cost of transportation (fig. 8).

Figure 8.--A truck loaded with flower boxes and no provisions for air circulation.

In cooperation with the floral industry, three standard-sized boxes were selected for flowers that are packed flat (*19*). The sizes selected, based on outside dimensions, are as follows:

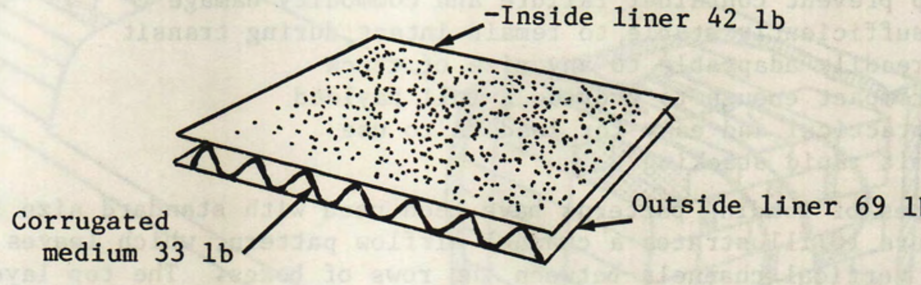
40 by 20 by 12 inches (102 by 51 by 30 cm)
48 by 20 by 12 inches (122 by 51 by 30 cm)
52 by 20 by 12 inches (132 by 51 by 30 cm)

The 20- by 12-inch (51 by 30 cm) dimension was selected on the basis of fit in the inside dimension of standard refrigerated trailers. A high percentage of trailers are 88 inches (223 cm) wide or wider. A 20-inch (51 cm) wide box allows four rows of boxes to be placed across the trailer plus an adequate allowance of space between boxes for air circulation. The 12-inch (30 cm) high dimension allows eight boxes high to be stacked in the trailer with enough space to prevent blockage of the flexible ducts carrying the air from the blower to the rear of the trailer. The dimensions of 40, 48, and 52 inches (102, 122, and 132 cm) were recommended to accommodate the various flowers and length of stems marketed. Hamper boxes need to be standardized to match the width dimension of cut flower flat boxes.

Box Style

The proper style and construction of individual boxes plays a major part in delivering the best quality flowers to market. Boxes must be constructed to maintain adequate strength in a high humidity atmosphere and to withstand overhead weight resulting from stacking eight boxes high.

The most common material used for flower boxes is corrugated fiberboard. Corrugated fiberboard is made up of several layers of containerboard, each with its own specifications. The types recommended for flower boxes (*3*) consist of a



Single wall corrugated

69-lb outerliner, a 33-lb corrugated medium, and a 42-lb inside liner with a 250-lb test board. The pound test board refers to the bursting strength of the liner board, expressed in pounds per square inch. The single wall corrugated sheet (double faced) should be manufactured with water-resistant adhesive because of high humidity conditions during precooling and transportation (*3*).

The recommended box style for flowers is a full telescope design box (fig. 9). This style adds extra stacking strength to the container, affording better protection to the flowers. The lid covers the staples or nails used to hold the

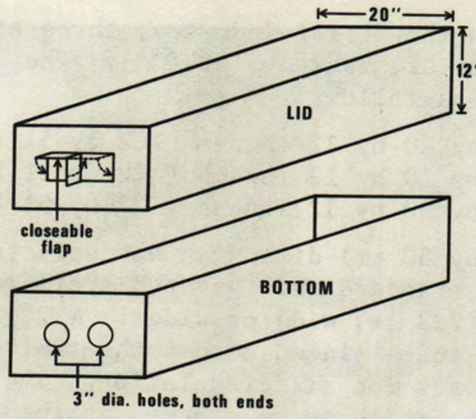


Figure 9.--Full telescope design box with vent holes.

wood cleats and affords protection to box handlers. The box "blanks" are usually shipped flat and assembled with staples on a box stitcher at the packinghouse. Care should be taken to use six staples per flap. Overstitching or understitching can cause weakening of the container (*1*). Boxes used for forced-air cooling must have air vents on each end of the box. Total vent size should equal an area equivalent to 5 percent of the total end area. The box lid can be made with flaps to allow sealing of the vents to help maintain flower temperature if the box is placed in an uncontrolled temperature environment during shipment.

Loading Patterns

Arrangement of boxes in a transport vehicle is important to provide adequate air circulation in the load. Stacking patterns used in trucks should meet the following requirements (*14*):

- Have adequate channels for air circulation throughout load
- Help prevent container failure and commodity damage
- Be sufficiently stable to remain intact during transit
- Be readily adaptable to any size of truck
- Be compact enough to provide a full payload
- Be practical and easy for loaders to use
- Permit rapid stacking

Two types of loading patterns have been used with standard size flower boxes. Figure 10 illustrates a channel airflow pattern, which leaves continuous lengthwise, vertical channels between the rows of boxes. The top layer of boxes is staggered every stack. This pattern allows air to circulate through the channels; however, shifting of the lightweight boxes during transit may block the air channels.

Figure 11 illustrates the recommended pigeon hole stacking pattern for cut flowers. This pattern allows air to circulate from the rear to the front of the trailer through lengthwise channels in alternate layers of the load and along the side wall in the other layers (fig. 11) (*20*). The top layer is staggered every other stack. Next to the front bulkhead, a head stack is required in the pigeon hole pattern to allow the air to return (move upward) to the refrigeration unit unless the bulkhead had built-in space as described in the equipment section. At present, the pigeon hole pattern is the best type of load pattern for cut flowers.

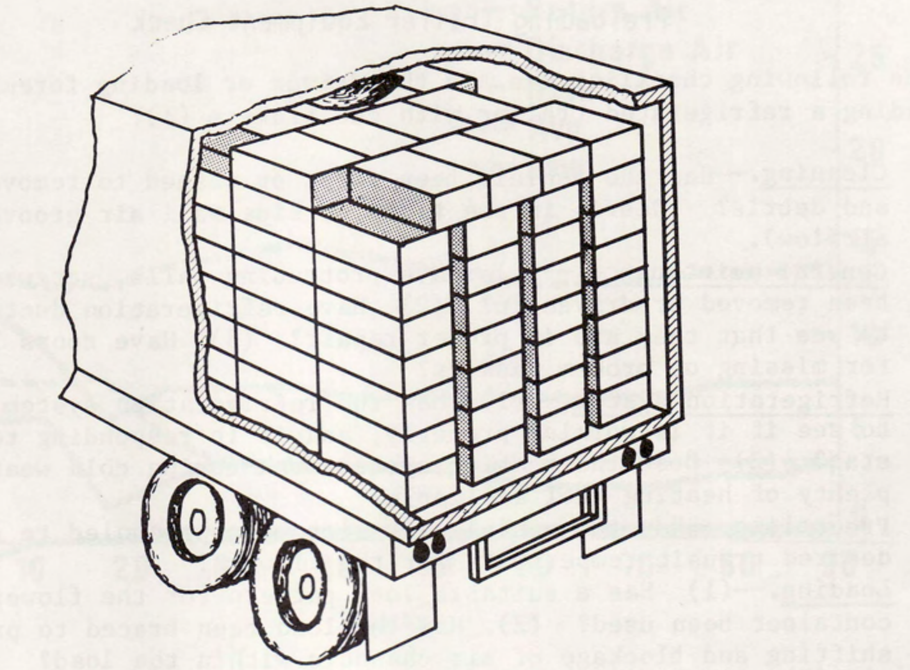


Figure 10.--Channel loading pattern with top layer of boxes staggered every stack.

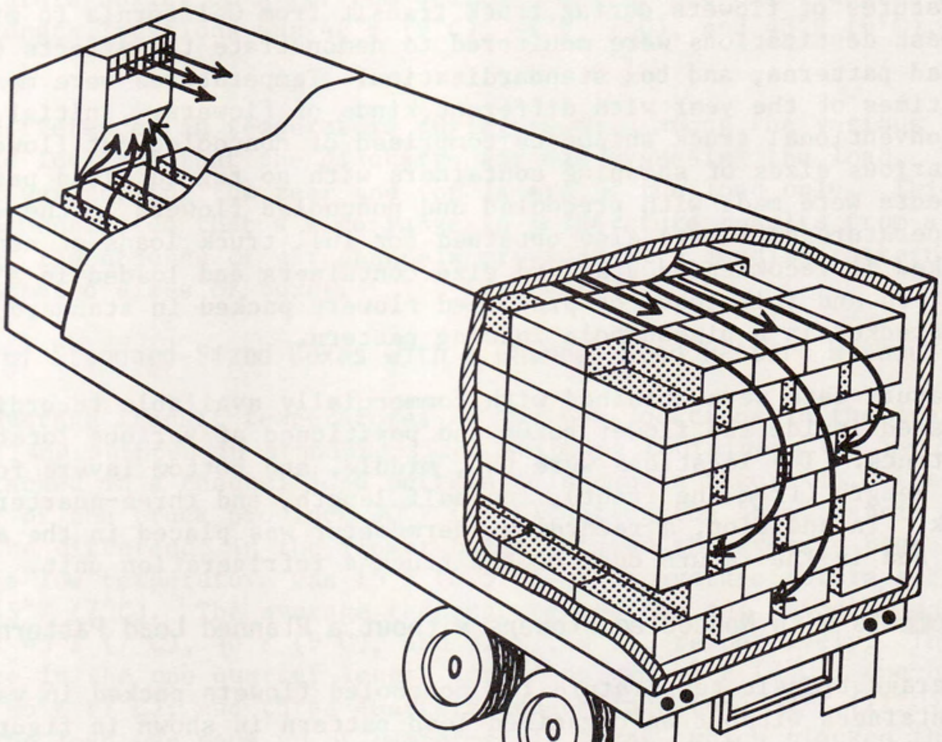


Figure 11.--Pigeon hole pattern with channels in alternate layers and channels down side wall.

Preloading Trailer Equipment Check

The following checklist can aid the driver or loading foreman in preparing and loading a refrigerated trailer with cut flowers (*4*):

- √ Cleaning.--Has the vehicle been swept or washed to remove dirt, odors, and debris? (Debris in the floor or side wall air grooves will impede airflow).
- √ General maintenance.--(1) Have protruding nails, screws, or staples been removed or driven in? (2) Have refrigeration ducts been checked to see that they are in proper repair? (3) Have doors been checked for missing or broken gaskets?
- √ Refrigeration system.--(1) Has the refrigeration system been checked to see if it is working properly, and is it responding to the thermostat? (2) Does the heating system work during cold weather and is plenty of heating fuel available?
- √ Precooling.--Has the vehicle interior been precooled to near the desired transit temperature for the flowers?
- √ Loading.--(1) Has a suitable load pattern for the flowers and type of container been used? (2) Has the load been braced to prevent load shifting and blockage of air channels within the load?
- √ After loading.--Is the thermostat set correctly?

FLOWER TEMPERATURES IN TRANSIT

Temperatures of flowers during truck transit from California to midwestern and east coast destinations were monitored to demonstrate the effects of precooling, load patterns, and box standardization. Temperatures were monitored at various times of the year with different kinds of flowers. Initial tests were with conventional truck shipments comprised of noncooled cut flowers packed in various sizes of shipping containers with no regular load pattern. Other shipments were made with precooled and noncooled flowers in the same truck. Temperature data were also obtained for full truck loads of noncooled flowers packed in recommended standard size containers and loaded in a channel loading pattern and full loads of precooled flowers packed in standard size containers stacked in a pigeon hole loading pattern.

Temperature data were obtained with commercially available recording thermometers placed inside the flower boxes and positioned at various locations within the truck. The locations were top, middle, and bottom layers for the one-quarter length (from the front), one-half length, and three-quarters length of the truck. In addition, a recording thermometer was placed in the air discharge duct and in the return duct of the truck's refrigeration unit.

Shipments with Noncooled Flowers Without a Planned Load Pattern

The average transit temperature for noncooled flowers packed in various sizes of containers without an organized load pattern is shown in figure 12. The refrigeration unit of the truck had an average discharge air temperature of 31°F (-0.6°C) for the 90-h trip; however, the difference between the highest and lowest temperatures inside flower boxes at various locations was 25°F (16°C). The average temperature during 90 h for top, middle, and bottom layer locations was 43°F (6°C), 45°F (7°C), and 46°F (8°C), respectively. The aver-

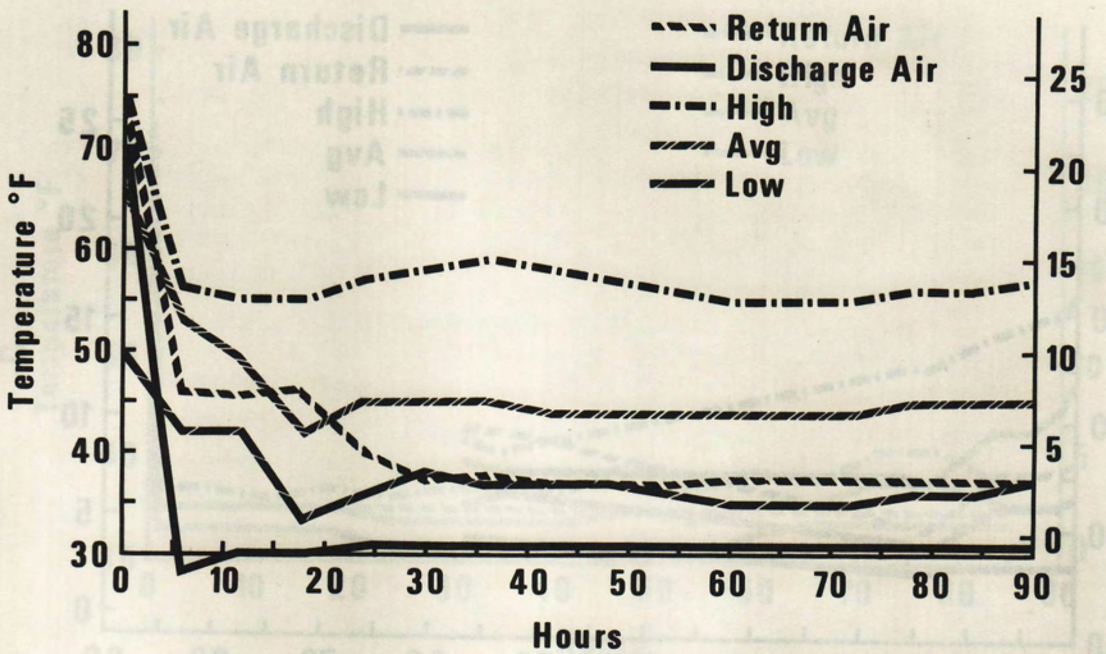


Figure 12.--Average transit temperature of noncooled flowers at various locations in a refrigerated truck, loaded with a mixture of box sizes without a planned loading pattern to provide air channels.

age temperature during 90 h for one-quarter length, one-half length, and three-quarters length locations was 48°F (9°C), 44°F (7°C), and 43°F (6°C), respectively.

The differences in temperature during transit among the various locations in the load indicate that the discharge air was bypassing the load. The discharge air was cooling the rear and top layers of the load only. This test shipment demonstrated that a wide range in temperature results from a lack of precooling, the absence of air channels provided by a loading pattern, and a lack of standard sizes of boxes.

Shipments of Standard-Sized Boxes with a Channel Load Pattern Without Precooling

The average transit temperatures at various locations in the load of flowers packed and shipped in standard-sized shipping containers (52 by 20 by 12 inches) stacked in a channel load pattern is shown in figure 13. The refrigeration unit of the truck provided 30°F (-1°C) during the 56-h transit period; however, the difference in the flower boxes between the average high temperature and average low temperature was 15°F (8.5°C). The average return air temperature was 45°F (7°C). The average temperature for the top, middle, and bottom layers was 45°F (7°C), 48°F (9°C), and 51°F (10°C), respectively. The average temperature in the one quarter length locations was 46°F (8°C); one-half length location, 45°F (7°C); and three-quarters length location, 52°F (11°C). The last stack in the load was made up of hamper-style boxes, which blocked the airflow through the lengthwise channels in the load. Blocking the channels caused the discharge air to bypass the rear stacks of boxes and the botton layers. Additional blockage of the channels resulted from shifting of the load at about 14 h into the transit period.

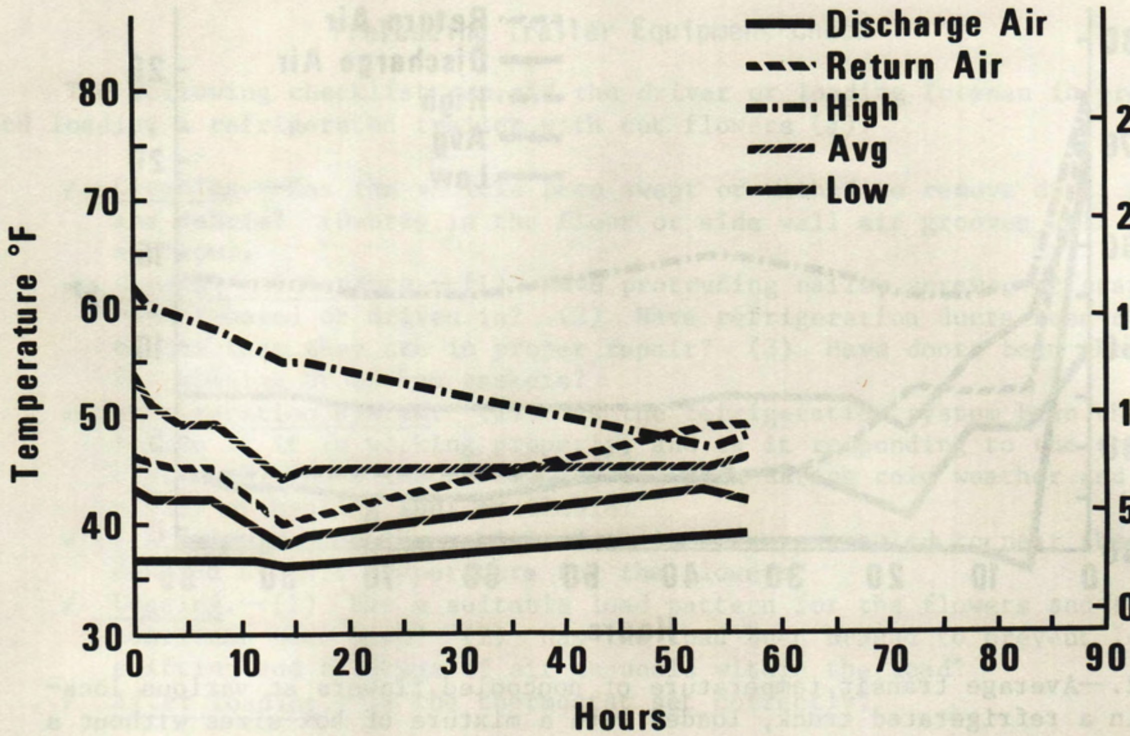


Figure 13.--Average transit temperature of noncooled flowers at various locations in a refrigerated truck and packed in standard size boxes loaded in a channel loading pattern.

This trial showed that the channel load pattern aided in removing heat from the flowers as long as it remained intact. The pigeon hole load pattern is more stable than the channel load pattern and is less prone to blockage.

Shipments of Standard-Sized Boxes With a Pigeon Hole Load Pattern With Forced-Air Cooling

Transit temperatures of forced-air cooled flowers packed in standard size, 52- by 20- by 12- inch boxes placed in a pigeon hole loading pattern are shown in figure 14. The average high temperature was 37°F (3°C), and the average low temperature was 32°F (0°C) during 48-h transit, a 5°F (3°C) difference. The air return temperature averaged 35°F (2°C). The average temperature for top and middle layer locations was 34°F (1°C) and for bottom layer was 35°F (2°C). The average temperature in the one-quarter length location was 33°F (0.5°C) and in the one-half and three-quarters length was 34°F (1°C). This trial illustrates that uniformly low temperatures can be achieved through proper forced-air cooling, box standardization, and use of a load pattern that provides adequate airflow.

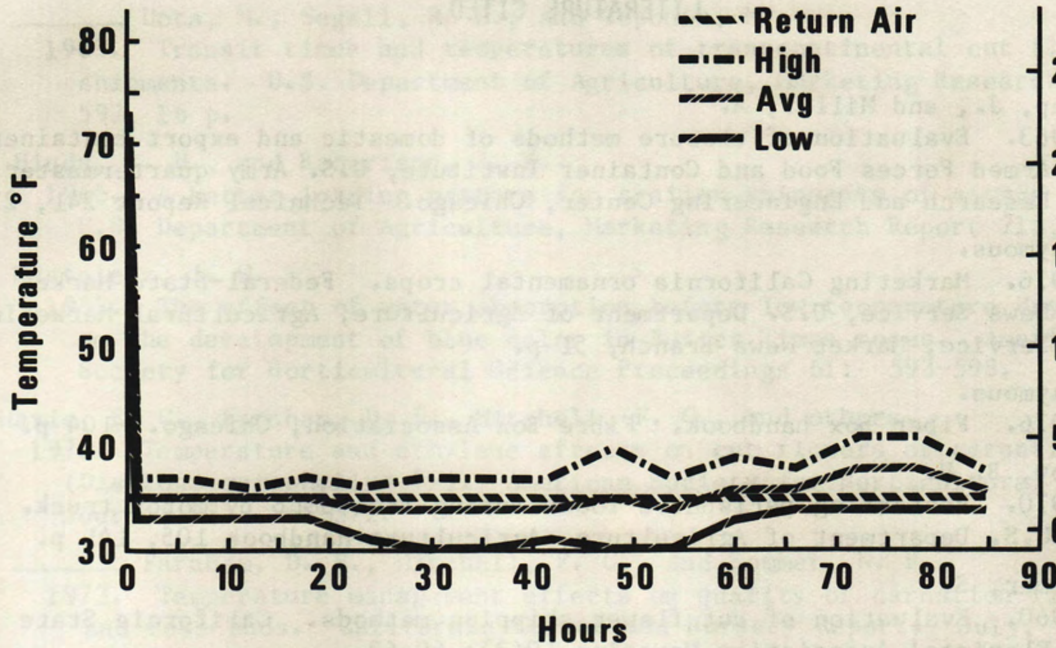


Figure 14.--Average transit temperatures of forced-air cooled flowers at various locations in the load; flowers packed in standard size boxes placed in a pigeon hole loading.

DISCUSSION

Cut flowers from California producing areas can be successfully shipped by refrigerated highway trucks maintaining proper transit temperatures and a high quality product. To achieve optimum results, certain conditions and practices have to be followed by growers, packers, shippers, and transport companies. At the grower level, high-quality flowers must be produced in the greenhouse through proper horticultural practices. After harvest, one of the most critical factors is maintaining proper temperature of the flowers. This publication presented information on improved methods for handling and cooling cut flowers for shipment by refrigerated truck. The refrigerated highway truck was not designed to carry perishable commodities that are temperature-sensitive, such as cut flowers. To effectively use the refrigeration capabilities of the truck, the cut flowers should be cooled to the proper temperature before loading.

Various types of forced-air coolers can be used, from small models that can cool 8 to 10 boxes per hour to larger facilities that handle 30 to 100 boxes per hour. Flowers must be packed in standard-sized boxes with vent holes to allow proper cooling. Standard-sized boxes that are 20 inches wide and 12 inches high can be loaded in the truck, using a pigeon-hole loading pattern. This method of stacking allows for proper air circulation throughout the load and enables the truck refrigeration unit to maintain desirable transit temperatures for the cut flowers.

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APPENDIX I

Storage recommendations for cut flowers, florist greens, cuttings, bulbs, and miscellaneous nursery stock[1]

Commodity	Storage temperature	Approximate storage period	Highest freezing point
Cut flowers:	°*F*		°*F*
Acacia	40	3-4 days	25.6
Anemone	45	1-2 days	28.2
Anthurium	56	3-4 weeks	----
Aster, China	40	1 week	30.3
Babysbreath	40	1-2 days	----
Bird-of-paradise-flower	45	3-4 days	----
Bouvardia	32-35	1 week	----
Buddleia	40	1-2 days	----
Calendula	40	3 days	----
Calla	40	1 week	----
Camellia	45	3-6 days	30.7
Candytuft	40	3 days	----
Carnation	32-36	3-4 weeks	30.8
Chincherinchees	40	6 weeks	----
Chrysanthemum	32-35	3-6 weeks	30.5
Clarkia	40	3 days	----
Columbine	40	1-2 days	31.1
Coreopsis	40	3-4 days	----
Cornflower	40	3 days	31.0
Cosmos	40	3-4 days	----
Daffodils (See Narcissus)			
Dahlia	40	3-5 days	----
Daisy, English	40	3 days	----
Daisy, Shasta	40	7 days	30.0
Delphinium	40	1-2 days	29.2
Eucharis	45-50	7-10 days	----
Feverfew	40	3 days	30.9
Forget-me-not	40	1-2 days	----
Foxglove	40	do	----
Freesia	32-33	2 weeks	----
Gaillardia	40	3 days	----
Gardenia	32-33	2-3 weeks	31.0
Gerbera	35	2 weeks	----
Ginger	55	3-4 days	----
Gladiolus	35-50	6-8 days	31.4
Gloriosa lily	40-50	1 week	----
Godetia	50	do	----
Heath	40	do	28.7
Heliconia	55	3-4 days	----
Hyacinth	32-33	2 weeks	31.4

See footnote at end of table.

Storage recommendations for cut flowers, florist, florist green, cuttings, bulbs, and miscellaneous nursery stock[1]--Continued

Commodity	Storage temperature	Approximate storage period	Highest freezing point
Cut flowers--Continued	°F		°F
Iris, bulbous	31-32	2-4 weeks	30.6
Laceflower	40	3 days	----
Lilac, forced	40	4-6 days	----
Lily	32-35	2-3 weeks	31.1
Lily-of-the-valley	31-32	do	----
Lupine	40	3 days	----
Marigolds	40	1-2 weeks	----
Migonette	40	3-5 days	----
Narcissus (daffodils)	32-33	10-21 days	31.8
Orchid	45-50	2 weeks	31.4
Poppy	40	3-5 days	----
Peony, tight buds	32-35	4-6 weeks	30.1
Phlox	40	1-2 days	----
Poinsetta	60	2-3 days	30.1
Primrose	40	1-2 days	----
Ranunculus	40	2-3 days	28.9
Rose (in preservative)	35-40	4-5 days	31.2
Rose (dry packed)	32	1-2 weeks	31.2
Snapdragon	31-32	3-4 weeks	30.4
Snowdrop	40	2-4 days	----
Squill	32-33	2 weeks	----
Statice(see lavender)	35	6 weeks	----
Stephanotis	40	1 week	----
Stevia	40	3 days	----
Stock	40	do	31.3
Strawflower, fresh	35	6 weeks	----
Sweet pea	31-32	1-2 weeks	30.4
Sweet-william	45	3-4 days	----
Tulip	31-32	4-8 weeks	----
Violet, sweet	33-40	3 days	28.8
Zinnia	40	1 week	----
Florist greens:			
Anthurium	40-45	----------------------	----
Asparagus (Plumosus)	32-40	----------------------	26.0
Boxwood	32	----------------------	----
Camellia	40	----------------------	----
Cedar	32	----------------------	----
Croton	35-40	----------------------	----
Dieffenbachia	55	----------------------	----
Dracaena	35-40	----------------------	29.1
Eucalyptus	35-40	----------------------	28.8

See footnote at end of table.

Storage recommendations for cut flowers, florist greens, cuttings, bulbs, and miscellaneous nursery stock[1]--Continued

Commodity	Storage temper-ature	Approximate storage period	Highest freezing point
Florist greens--Continued	°F		°F
Ferns:			
Adiantum (maidenhair)	32-40	---	---
Brake	32		
Dagger and Wood ferns	30-32	---	28.9
Leatherleaf (Baker)	34-40	---	---
Staghorn	55		
Woodwardia	32-40	---	---
Galax	32	---	---
Groundpine	32	---	---
Holly	32	4-5 weeks	27.0
Huckleberry	32	1-4 weeks	26.7
Ivy, English	32	---	29.9
Juniper	32	---	---
Leucothoe, drooping	35-40	---	---
Magnolia	35-40	1-4 weeks	27.0
Mistletoe	32	3-4 weeks	25.0
Mountain-laurel	32	1-4 weeks	27.6
Palm	45	---	---
Peperomia	35-40	---	---
Philodendron	35-40	---	---
Pittosporum	35-40	---	---
Podocarpus	40-45	---	27.9
Pothos	35-40	---	---
Rhododendron	32	1-4 weeks	27.6
Salal, lemon leaf	32	do	26.8
Scotch-broom	40	---	---
Smilax, southern	40	---	---
Ti (palm lily)	40	---	---
Bulbs, corms, rhizomes, tubers, and roots:			
Alstroemeria	40-50	---	---
Amaryllis	38-45	5 months	30.8
Anemone, Wacabri	70-75	2-3 months	---
Begonia	45-60	3-5 months	31.1
Bletilla orchid	35-40	---	---
Caladium, fancy-leaf	50-60	---	29.7
Calla	36-40	---	27.5
Canna	40-45	---	---
Crocus	48-63	2-3 months	---
Dahlia	40-45	5 months	28.7
Freesia	86	3-4 months	---
Gladiolus	38-50	5-8 months	28.2

See footnote at end of table.

Storage recommendations for cut flowers, florist greens, cuttings, bulbs, and miscellaneous nursery stock[1]--Continued

Commodity	Storage temperature	Approximate storage period	Highest freezing point
	°F		*°F*
Bulbs, corms...--Continued			
Gloxinia	50	5-7 months	30.5
Hemerocallis (daylily)	50	1 month	----
Hyacinth	55-70	2-5 months	29.3
Hymenocallis (Ismene)	55-60	----	----
Iris, Dutch	60-85	4-12 months	----
Lily:			
Gloriosa	63	3-4 months	
Longiflorium (Easter)	31-33	1-10 months	28.9
Candidum and Regal	31-33	1-6 months	----
Speciosum (Japanese)	31-33	do	----
Lily-of-the-valley	25-28	1 year	----
Muscari	48-50	2-4 months	----
Narcissus	48-63	do	29.6
Peony	33-35	5 months	----
Snowdrop	55-60	----	----
Squill	55-60	----	----
Taro	45	----	----
Trillium	33-35	----	----
Tuberose	40-45	4 months	----
Tulip (for forcing)	40-50	2-4 months	27.6
Tulip (for outdoors)	31-32	5-6 months	27.6
Cuttings:			
Azalea, unrooted	31-40	4-10 weeks	----
Carnation, rooted and unrooted.	31-33	5-6 months	----
Chrysanthemum, unrooted	31-33	5-6 weeks	
Chrysanthemum, rooted	31-35	3-6 weeks	
Evergreens and other woody ornamentals, rooted.	32-35	5-6 months	
Nursery stock:			
Asparagus rhizomes	30-32	3-4 months	----
Blueberry wood, unrooted	30	5 months	----
Christmas trees	22-32	6-7 weeks	
Conifer seedlings	32-35	4-6 months	----
Flower seedlings	35-40	2-6 weeks	----
Herbaceous perennials	27-28	4-8 months	----
Herbaceous perennials	31-35	3-7 months	----
Rose budwood	28-31	1-2 years	----
Rose bushes	32	4-5 months	----
Seeds	32-50	1 year	----
Strawberry plants	30-32	8-10 months	----

See footnote at end of table.

Storage recommendations for cut flowers, florist, florist green, cuttings, bulbs, and miscellaneous nursery stock[1] --Continued

Commodity	Storage temper- ature	Approximate storage period	Highest freezing point
Nursery stock--Continued	°F		°F
Tomato plants-------------	50-60	3-4 days---------------	----
Trees and shrubs----------	32-36	4-5 months-------------	----

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APPENDIX II

The following equation can be used to calculate the time required to cool a box of flowers to a specific temperature:

$$T = 1.107\ V \text{ Log} \left(\frac{S - M}{F - M}\right)$$

where

T = time (minutes) to cool to temperature F
V = 7/8 cooling time (minutes) from table 1
S = temperature (°F) of product initially
F = temperature (°F) of product when cool
M = temperature (°F) of cooling air entering box

If V cannot be found on table 1 because airflow is not known or a different flower box species is being cooled, the following formula can be used to calculate V:

$$V = \left(\frac{0.903\ T}{\log \ \frac{S-M}{F-M}}\right)$$

where T, S, F, M, are measured under actual operating conditions.

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