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POSTHARVEST INSTITUTE FOR PERISHABLES

Precooling of Harvested Vegetables

by

Karl Buehler

Postharvest Institute for Perishables

College of Agriculture

University of Idaho

GTS Report

PIP/Thailand/May 87/91

University of Idaho

in cooperation with

United States Agency for International Development

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PRECOOLING OF HARVESTED PERISHABLES

I. INTRODUCTION

The Thailand Ministry of Agriculture desires to reduce the postharvest deterioration of fresh vegetables and tropical fruits by improving management of precooling, cooling, and storage technologies. Mrs. Dara Buangsuwon, subproject leader for Postharvest Quality Improvement, Pathology Division, Thai Ministry of Agriculture, contracted through the USAID/Thailand Mission with the Postharvest Institute for Perishables for technical assistance in this area. (See Scope of Work, Appendix A)

PIP specialist Karl Buehler, a private sector consultant with expertise in refrigeration and food handling traveled to Thailand on May 29, 1987 and worked on the project through June 30, 1987. He worked directly with the Division of Plant Pathology and Microbiology personnel: Ms. Noot, Mrs. Youis, Mrs. Som, and Mr. Martin Nagler, and with the Advisor to the Minister of Commerce, Mr. Chaiwat Chandarasrivongs. Mr. Buelhler stressed the need for improved postharvest handling of perishables, and demonstrated the proper application of refrigeration principles for precooling, refrigerated trucks, and refrigeration research equipment. He also presented a short outline of the principles of controlled atmosphere storage.

II. PRECOOLING -- DISCUSSION AND DEFINITION

Fresh fruits and vegetables are living things which continue to respire after harvest. Before harvest the produce is attached to the plant and draws its energy from the inflow of sap. After harvest, respiration depends on the energy reserves within the produce. As these reserves are used up, the produce changes (deteriorates) and finally dies. Field heat creates conditions which increase the rate of deterioration; therefore, removing field heat from the harvested produce as soon as possible is essential to maintain freshness in the produce.

Produce to be precooled for storage and produce that is to be frozen must be selected at the desired stage of maturity, free of blemish and/or disease. Precooling and/or freezing the produce does not improve the quality of the stored produce. The quality of the finished produce is only as good as the produce received at the precooling facilities.

In most instances, it is recommended that the produce be cleaned and sorted before chilling. This can be accomplished by air flotation, screening and sizing. In some cases the use of water washing equipment should be considered. The type of equipment used will vary, depending on the product. In general, the water and product are agitated, and the "violent" movement of the water is very effective in removing soil, insects and other foreign material.

After precooling, the product must be placed in cold storage facilities immediately. In some instances precooling is done in the harvest area, and then the product is loaded in refrigerated trucks for transport to areas closer to the market or export facility. Figure 1 illustrates this chain of events.

The following is a typical temperature/time precooling graph showing the precooling temperature cycle:

Figure 2.
Temperature/Time Precooling Curve

Product: Asparagus Spears
Temp. In: 24°C
Temp. Final : 0°C

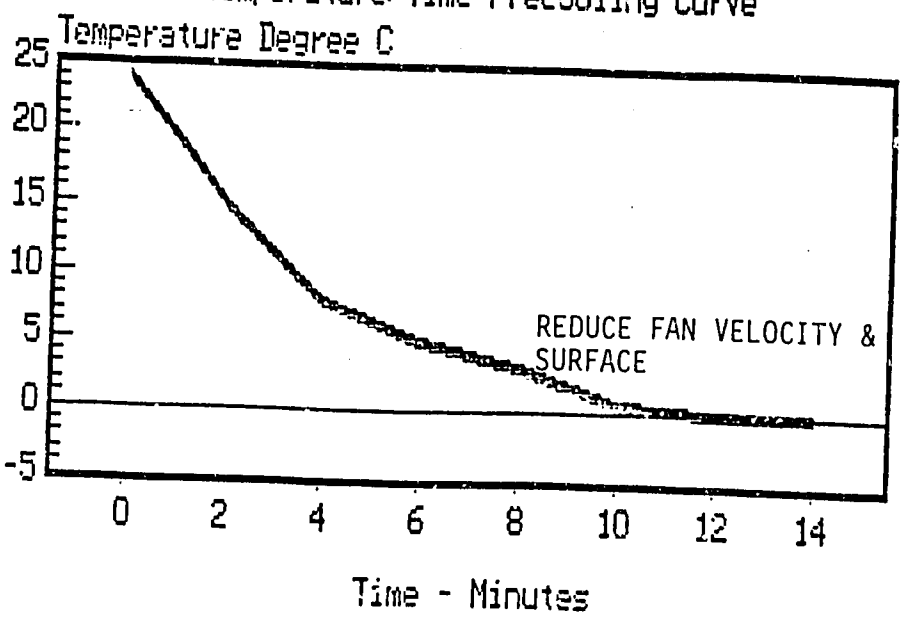
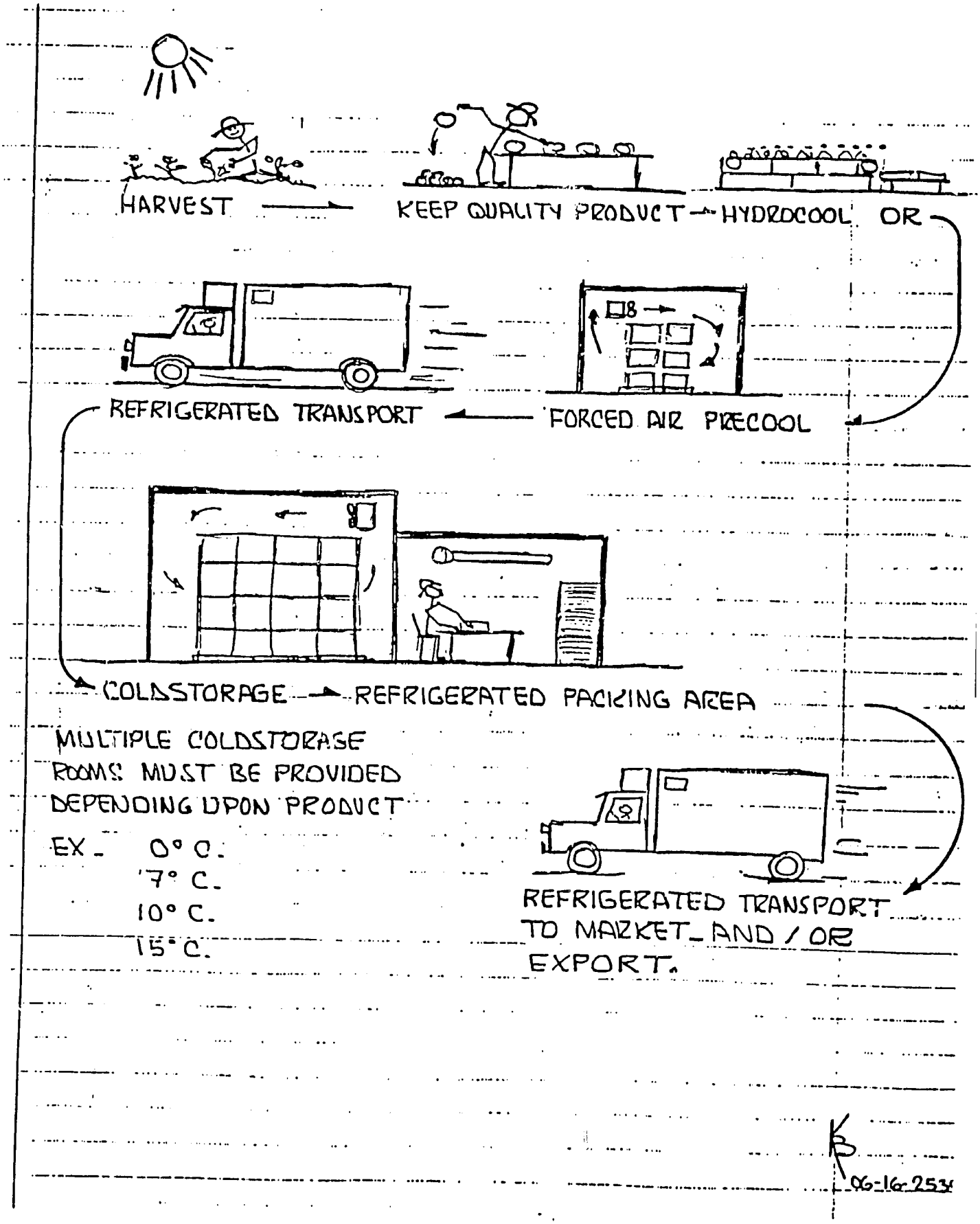


Figure 1. Postharvest Perishable Product Flow Chart



In summary, precooling is the removal of the postharvest heat from the freshly harvested product in sufficient time to prevent waste and spoilage, and to maintain all possible preharvest freshness and flavor, thereby assuring a high quality finished product for the market.

III. METHODS OF PRECOOLING

A. Hydrocooling

Hydrocooling is a popular and efficient precooling method because it is simple and effective. Chilled water made to flow briskly and uniformly over the surface of a warm commodity results in a rapid rate of heat transfer so that the commodity surface temperature becomes essentially equal to that of the cooling medium. There are three basic methods of hydrocooling: flooding, spraying, or immersion. Quite often a combination of the three is utilized.

The cooling time and final temperature of the product being hydrocooled is dependent upon the following:

a. Commodity field temperature and characteristics
b. Production (harvesting) rate
c. Temperature of chilled water
d. Rate of flow of chilled water (cooling medium)
e. Retention time (length of time product is in cooling medium)

In hydrocooling, product weight loss due to loss of hydrates (dehydration) is minimal.

B. Forced Air Precooling

Forced air cooling is accomplished by moving refrigerated air across the surface of the product to be cooled.

The advantages of forced air cooling are:

a. Ease of handling the product to be precooled.
b. Minimal sanitation requirements (as compared to hydrocooling).
c. Less deterioration of equipment due to rust and corrosion.

The disadvantages are:

a. Dehydration of the surface of products with a high percentage of moisture. A loss of surface moisture results in deterioration of the surface of the product and resultant weight loss.

b. Potential for frost or freeze injury to the product surface, resulting in product spoilage.

c. Possible high electricity use due to air refrigeration and fan requirements, depending upon system capacity requirements.

In order to provide a forced air precooling refrigeration system (or medium temperature, cold storage facility) to best meet postharvest precooling requirements, the following design criteria and equipment selection must be met (Note: the recommendations are directed towards a system that is used for conducting tests of various products, for example, the system at the Seed and Postharvest Pathology Group)

a. The refrigeration unit must be sized to handle the maximum anticipated refrigeration load requirements. In addition, it must be able to deliver partial load requirements with accurate suction pressurize/temperature control.

b. The air handling unit must provide a sufficient cooling surface to maintain a 90 to 95% relative humidity (R.H.) within the room. To accomplish this, the selection of the unit must be based on a maximum of 8° F temperature difference (TD) across the coil surface.

c. The total surface area of the air refrigeration unit must be utilized. During the early stages of the cooling cycle, a rapid heat transfer takes place. For this to occur efficiently, the total surface area of the air refrigeration unit must be utilized. As the desired final precool temperature is approached, the temperature/time curve begins to "flatten out." At this stage the following steps should be taken:

   1. Reduce the air velocity flow across the product.
   2. Reduce the kilogram-calorie output of the air refrigeration unit. (As the desired final temperature is approached, the refrigeration load requirements are sharply reduced. Actually, after temperature pulldown, storage temperature conditions should be reached.)

To accomplish the above, the air refrigeration unit must be wired to provide two (2) coil sections, each section having its own thermal expansion valve and solenoid valve. The operation is usually automated by means of a room thermostat that controls an evaporative dual pressure regulator (EPR) valve to allow suction control at two temperature/pressure settings.

In order to change the air velocity within the refrigerated area, the air refrigeration unit fans must be equipped with the following options, depending upon the application:

1. Two-speed fans
2. Variable-speed fan drive
3. Multiple fans (2 or more) on one air unit.

Generally, a minimum of two air refrigeration units is recommended, especially if the cold room is to be operated at $0^{o}C$, which would require a suction temperature of approximately $-3.8^{o}C$. Under these conditions, it is necessary to periodically defrost the air refrigeration units. With two units in operation, a sequential defrost can be done -- one unit on defrost while the other unit is in operation, maintaining the proper room temperature. When using thermo-expansion valves to control the liquid refrigeration feed to the air refrigeration unit, the superheat of the suction gas outlet must be adjusted. The superheat of suction gas at the air unit outlet should not exceed $5^{o}F$. This is critical in order to maintain a 90 to 95% relative humidity.

C. Vacuum Cooling

Vacuum cooling is cooling by evaporation. The product to be cooled is placed in a steel tube or chamber which is hermetically sealed and then rapidly evacuated.

Fruits and vegetables vary in their adaptability to vacuum cooling. The rate of cooling and the final temperature of the product is affected largely by the ratio of the surface area of the product to its mass, and the rate with which the product gives up water from its tissues. Vacuum cooling is used primarily for products such as lettuce, celery, cauliflower, green peas, and sweet corn. The equipment requirements are rather extensive, complex, and expensive. It is felt that the introduction of vacuum cooling to the Seed and Postharvest Pathology Group facilities would be premature at this time.

D. Ice Cooling

Using ice to precool and/or to maintain cool temperatures for transportation is still effective in many applications throughout the world. Melting ice maintains a temperature of $0^{o}C$ to $2^{o}C$, an ideal temperature for many products. For precooling of perishables, it is an option that should be considered.

It should be noted that, along with the application of hydrocooling (which can be considered "liquid ice"), the use of ice in conjunction with research and development work is a practical alternative.

In summary, each precool/storage facility must be design-engineered to best accommodate the perishable postharvest product.

IV. REFRIGERATED TRUCK OPERATION FOR PRECOOLING

The following are specifications for refrigerated truck precooling:

1. Direct all the air from the air refrigeration unit across the face area of the stacked product, resulting in minimum air bypass (Figure 3).
2. Provide a means of placing the aluminum trays (or equivalent) upon steel frames for even spacing so that the air can be distributed evenly throughout the loaded product.
3. Provide a fabric, plastic or canvas blanket that can be unrolled and positioned on top of partial loads to control the air flow pattern (Figures 3-C & 4-C).
4. Provide for access to the air refrigeration unit for maintenance (Figure 4-A).

A. Discussion of Air Flow

Direct measurement with an air velometer indicates there is 10,800 cubic feet per minute (ft^3/min) (305.9 m^3/min) of refrigerated air off the air refrigeration unit of the vehicle.

Directing this air through a plenum chamber (Figure 3-A) to the end of the truck ensures complete control of all the air from the air refrigeration unit.

The product to be chilled can be placed up against a "stop" (B) from the floor to the bottom of the plenum chamber (A) and across the entire width of the truck. The proper containers must be provided for the fresh product so that refrigerated air is directed uniformly around the product to be chilled. The "stop" (B) should be made of pipe-tubing or suitable heavy-duty screen mesh material to allow chilled air to pass through and return to the intake of the air refrigeration unit (Figure 3).

Figure 3. Refrigerated Truck

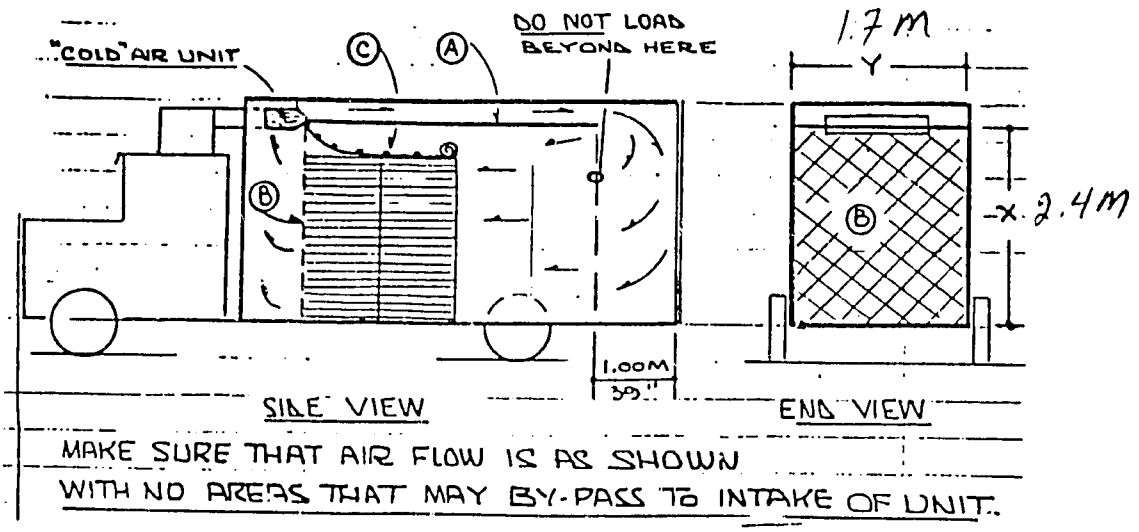
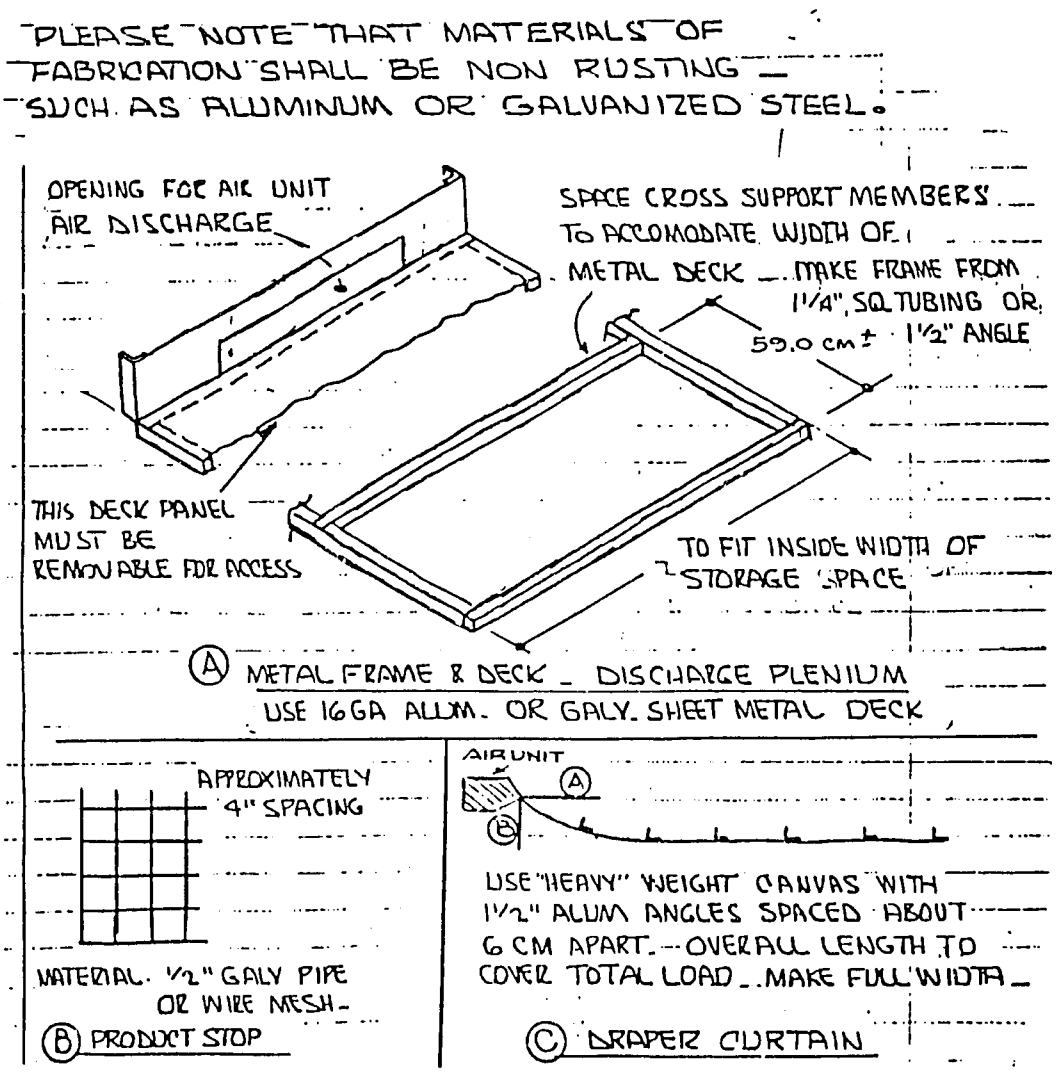


Figure 4. Suggested Fabrication for a Refrigerated Truck



B. Sample Calculation for Air Flow

What is the velocity of air which is flowing through the product as it returns to the air refrigeration unit?

1. Cross sectional area of truck box (Figure 3).
   $1.7\ m \times 2.4\ m = 4\ m^2$

2. Estimated area of product displacement is 50% of cross sectional area.
   Therefore, $.50 \times 4\ m^2 = 2\ m^2$ of open area for air flow.

3. The calculated air velocity passing "through" the product:
   There is a total air volume of $306\ m^3/min$ from the air refrigeration unit. The total open area for the air to pass through is $2\ m^2$.
   $306\ m^3/min - 2\ m^2 = 153\ m/min$ or $502\ ft/min$

This is a very favorable chilled air velocity for precooling. In order to increase or decrease the air velocity "through" the product, the following options are available:

A. Load the product at a lower height in the truck and drape the top with a curtain (C) to reduce the area that the air must flow through (Figure 3).

B. Adjust the spacing of the product to be chilled in order to either increase or decrease the air velocity. It is important that a uniform spacing be maintained to obtain uniform chilling of the product.

C. Recommendations for Measuring Air Velocity and Temperature

Accurate records of precooling experiments should be kept, and there should be a means of measuring air velocity and air temperature.

Air Velocity:	A velometer (portable turbine wheel type) for instant reading.
Temperature:	A battery-operated portable digital readout with three thermocouple probes.

D. Recommendations for Refrigerated Truck Precooling Experiment

The following is a suggested data collection format for refrigerated truck precooling or, in some instances, recooling/freezing. Each type of product must be tested individually to best determine post-harvest requirements. Asparagus is used as an example:

Thai Ministry of Agriculture Field Data Sheet

1. Location: Kasetsart University, Bangkok
2. Date: June 8, 1987
3. Product: Asparagus, Fresh Harvest
   - A. Production Rate: 500 lbs/hr or 227 kg/hr
   - B. Ambient Temp/RH: 30° C RH 90% Est.
   - C. Ave. Field Temp of product: 24° C
   - D. Product Criteria: Mature asparagus spears cut to uniform length. Product has been washed and sorted.
   - E. Precooling Equipment Used: Refrigerated vehicle
   - F. Product Stacking Method: The asparagus spears are placed in perforated aluminum trays. Trays are to be put in the racks provided in the truck loading section.
   - G. Procedure: The refrigerated area is to be precooled to 0°C before loading the product. After sorting & washing, the asparagus is placed one layer deep in the aluminum trays and put in the refrigerated truck racks. Loading of the truck will be accomplished as rapidly as possible.
4. Postharvest Precooling and/or Freezing Test Data
   - A. Time product loaded and doors closed -- refrigeration on: 11:00 am
   - B. Temperature readings shall be taken at intervals shown in Figure 5 so that precooling and/or freezing curves can be plotted. Please note

Figure 5.
Typical Time/Temperature Curve

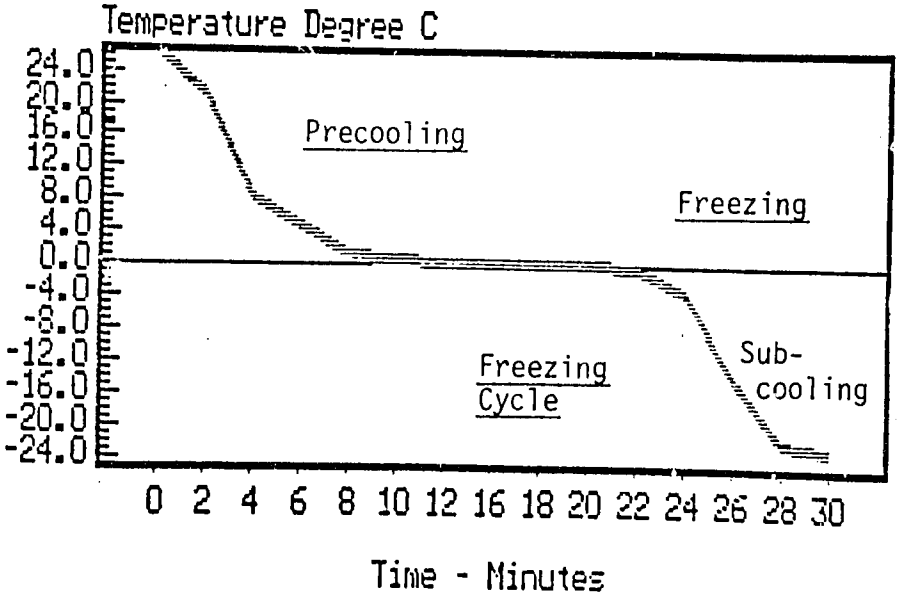
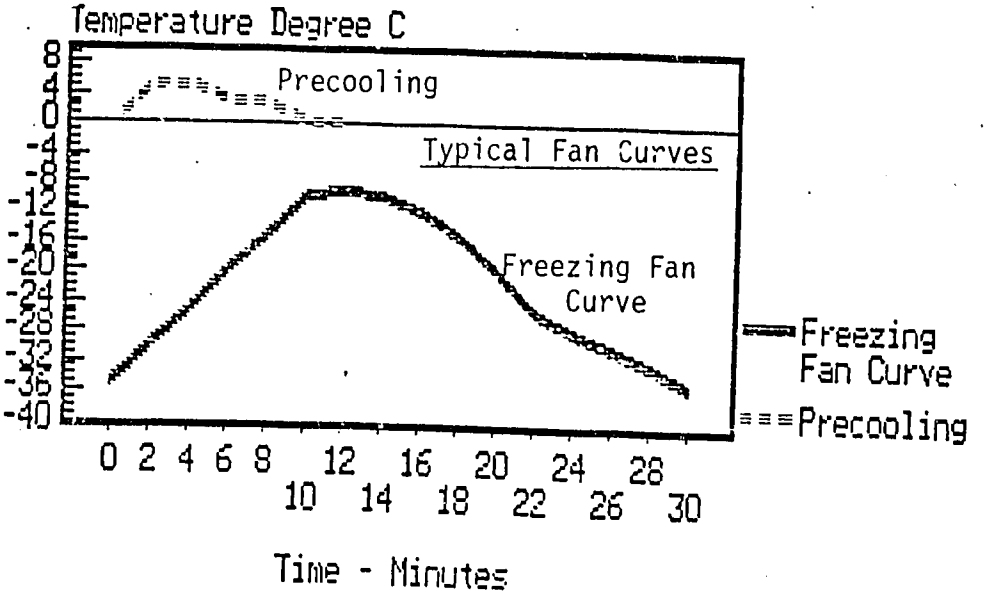


Figure 5.1
Typical Time/Temperature Curve



that the air velocity on the product is to be taken and recorded. Recording the relative humidity is also recommended.

C. Whenever possible, all pertinent data regarding the air fan or fans should be recorded. The ability to control the movement of refrigerated air, along with precise temperature and humidity control, is an essential postharvest criterium. This information is most important when preocooling cold storage and/or fast freezing food products with refrigerated air. The capability to adjust the air velocity to best meet the optimum conditions of the product is required as the product is taken through the precool cold storage and/or fast freeze cycle. The following information is highly desirable:

1. Quantity of fans
2. Manufacture of fan and model number, including the following:
   a. Diameter of Fan
   b. Type, e.g., vane axial, propellor, centrifugal
   c. Blade Pitch (where applicable)
   d. Fan Speed
3. Electric motor information (or motors)
   a. Manufacture
   b. Speed (one, two, or variable speed)

V. REFRIGERATION EQUIPMENT AT THE POSTHARVEST PATHOLOGY RESEARCH FACILITIES REVIEW AND RECOMMENDATIONS

A. Existing Equipment

1. Insulated Walk-in Units

There are presently a total of six (6) walk-in units at the facility. They were manufactured approximately 35 years ago in the U.S.A. All of them have fiberglass insulation. The interiors are galvanized sheet metal which is in an advanced stage of rust. The exteriors are painted grey. Unit numbers 1, 2, 3, and 5 are inoperative at this time.

In units 1, 3,and 5, the coil surface consists of horizontal plates with coils fed by a DX valve. They do not have fans. The inside dimensions are 7'10" wide, 6'0" deep, and 6'10" high. Wall thickness is 3 1/2", complete with insulated floor.

Unit numbers 2, 4 and 6 are equipped with air handling units, complete with fans. Their inside dimensions are 5'4" wide, 9'2" deep, and 6'10" high. Wall thickness is 3 1/2", complete with insulated floor (unit 2 is inoperative).

2. Condensing Units (Compressor Packages)

There are a total of four condensing units. As of this report, only two are working -- numbers 4 and 6. The condensing units are open-type belt driven compressors with air cooled condensers. It is not known whether freon R-12 or R-22 refrigerant is currently in the system. R-22 is recommended because it is more efficient due to its compression ratio in comparison with R-12. R-22 is approximately 50% more efficient than R-12.

3. Controls: Instrumentation Piping and Air Flow

Upon review of the refrigeration components it was found that there is a bare minimum of controls to operate the units.

1. The cold room thermostats have a differential range of approximately $6^{o}F$. This is not acceptable for research work.
2. There is a fixed speed on the air unit fan; therefore, the air flow velocity cannot be adjusted to accommodate various product testing.
3. The air handling units are not readily accessible for cleaning the condensate drain pan, as mentioned above. These should be two speed fan motors.
4. In most instances operations are conducted without essential items such as: discharge filter/drier, pressure gauges (both suction and discharge), isolation valves, and high pressure and low suction controls.

In summary, it appears that the present facilities are inadequate to meet the refrigeration requirements at the Postharvest Pathology Center.

B. Recommendations for Refrigeration Facilities

The following are recommendations regarding refrigeration facilities to accommodate research on the postharvest handling of perishable produce.

1. Provide a walk-in precool/freezing unit that is capable of the following:
   a. Removing the field heat from products while maintaining control of the air-off coil temperature and air velocity.
   b. Providing for fast freezing (blast freezing) when required.

   A double-circuited air-handling unit is required to accomplish the above. One circuit is to be used for product temperature pull down (precool) and the other circuit for the fast freezing cycle, both of which could be used

simultaneously when necessary. The air refrigeration unit should be equipped with two separate fans, each driven by two-speed electric motors. In order to maintain a 90-95% RH, the precool circuit surface area of both the primary and secondary units must be selected.

2. Provide three walk-in cold storage rooms capable of storing precooled perishables at controlled temperatures ranging from $0^{o}C$ to $20^{o}C$, depending upon the product. This is necessary because of the diversity of the product and storage temperature requirements.
   a. The replacement walk-in units should conform to the National Sanitation Foundation (NSF) standards.
   b. The air handling units should be selected to provide a 90-95% RH. Fans should be two speed.
3. Provide a commercial deep freeze unit with a 90 cubic foot capacity. This unit would serve as storage for frozen products and should be maintained at $-23^{o}C$.
4. Provide one condensing unit to supply refrigeration for the precool/freezing walk-in room and the three proposed cold storage walk-in rooms.

   The following is an outline of the specifications:
   a. Air cooled condenser
   b. Two dual-piston compressors, semi-hermetic, arranged to provide full capacity or partial load with one unit on stream. An alternate would be one helical rotary screw compressor unit.
   c. High pressure receiver
   d. Controls and instrumentation complete with shut off valves, isolation valves, suction and discharge pressure gauges, pressure relief valves, and electrical controls to provide automatic start/stop of compressor units to adjust to load conditions. A single screw compressor should be used to automatically unload/load as required. This should include manual controls and operational pilot lights.

   The condensing unit shall be mounted upon a steel frame as an integral unit and shall be protected from the elements with a galvanized sheet metal housing leaving easy access for maintenance.

5. Include a hydrocooler as part of the research facilities. As mentioned in the <u>Methods of Hydrocooling</u> section, hydrocooling is an essential method

of precooling. Refer to Figure 6 for suggested design of a laboratory type hydrocooler.

VI. CONTROLLED ATMOSPHERE STORAGE (C.A.)

Controlled Atmosphere (C.A.) storage is probably the most significant technological advance since the advent of mechanical refrigeration. Fresh fruits and vegetables are living things which carry on the process of respiration in which the sugars are oxidized in the presence of oxygen in the air. This process produces carbon dioxide, water vapour, and heat of respiration.

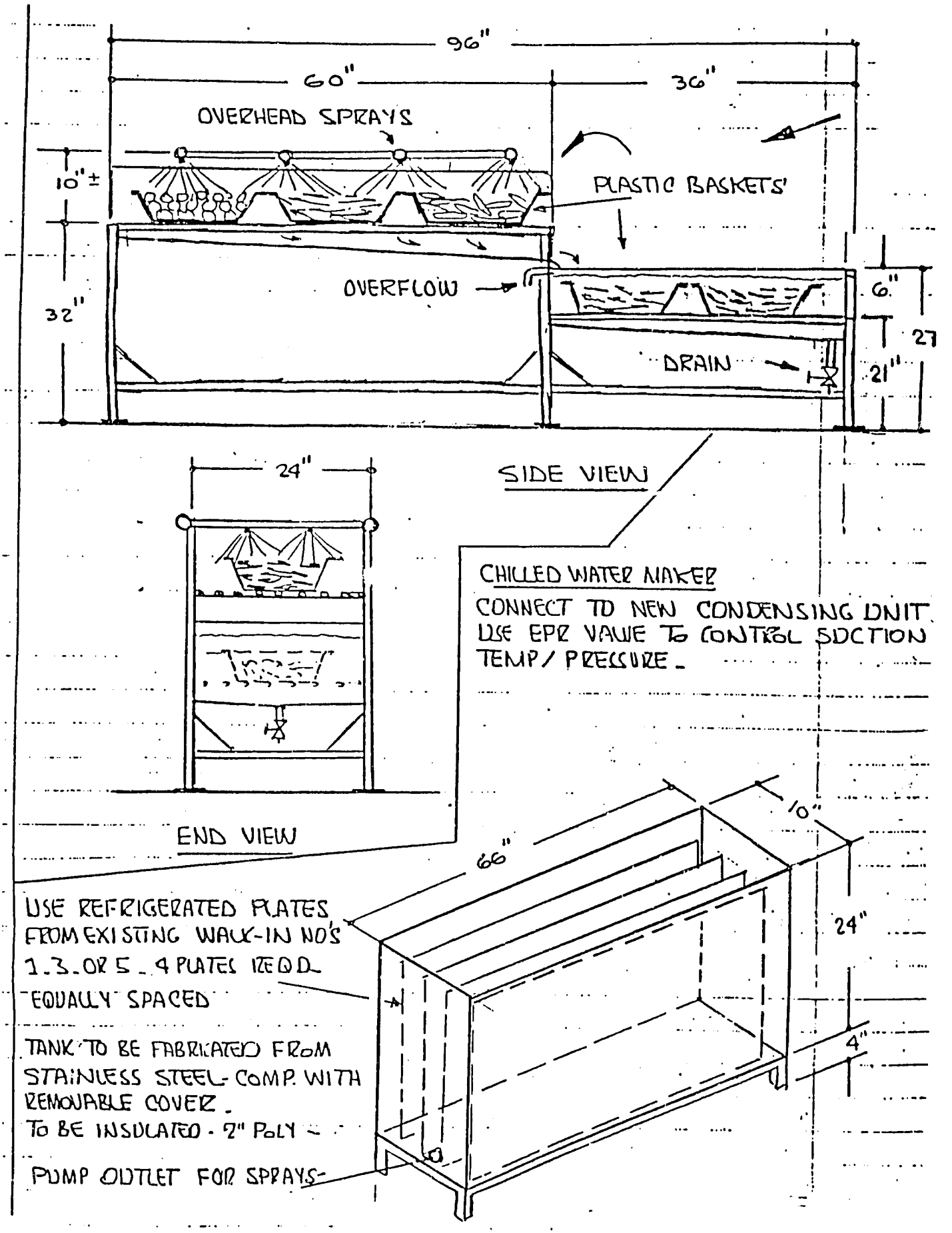
In order to prolong the storage life of the produce, the rate of respiration must be slowed. The rate can be retarded in several ways:

1. Lower the temperature. This is the basis for normal cold storage.
2. Reduce the amount of oxygen surrounding the produce since this gas is required for respiration.
3. Control the amount of carbon dioxide surrounding the produce.

A process that incorporates all three of the above is controlled atmosphere storage (C.A. storage). The insulated C.A. cold storage room must be design-engineered and constructed to meet the following design criteria:

1. Storage arrangements must allow for adequate air distribution throughout the loads.
2. Facilities must be "gas tight" and tested for tightness.
3. Facilities must be completely vapor-sealed.
4. All openings for pipes, conduits, etc. must be provided with seals.
5. Doors must be completely sealed.
6. A man-door that is sealed must be provided.

Figure 6. Suggested Hydrocooler for Postharvest



7. A window for observation must be provided along with a handle to remove samples of the produce for inspection.

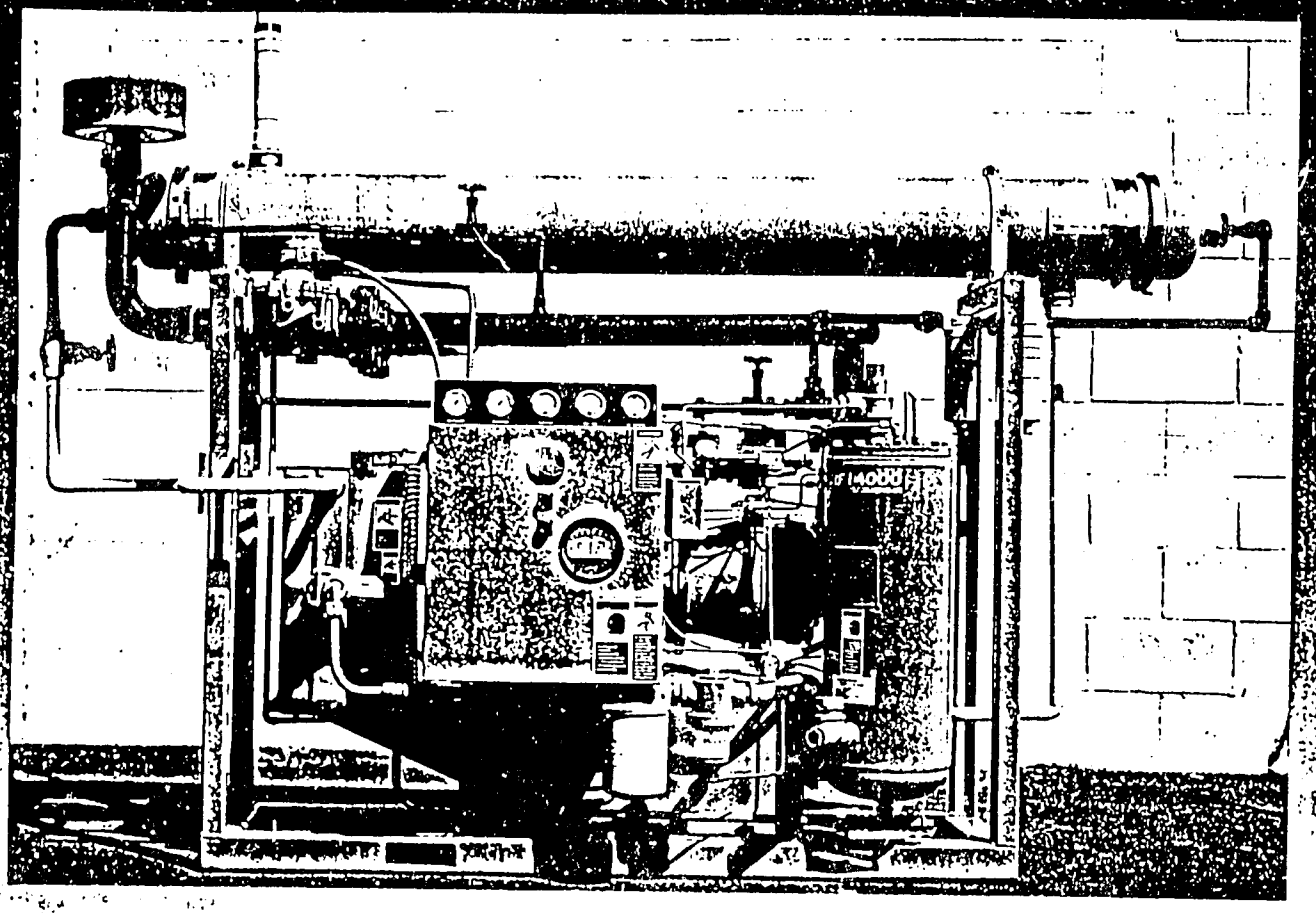
The equipment consists of a generator and a "scrubber."

Generator: To utilize the heat of respiration for preheating the hydrocarbon gases and air mixture heat to assist the catalytic oxidation process.

Scrubber: To remove excess carbon dioxide gas (operated intermittently).

The gas composition is measured twice daily during the pulldown period and once daily during the holding mode. Analysis is usually by orsat analyzer. The unit is known as the "nicap separator." It is automatic in operation and a single unit that creates 99.9% pure nitrogen.

CONTROLLED ATMOSPHERE.



THE FUTURE HAS ARRIVED.

Someday in the future all controlled atmosphere systems will be condensed into one unit. That unit will have the capacity to create 99.99% pure nitrogen and it will have the ability to remove ethylene and other undesirable gases that hinder fruit storage.

The future is now. The NICAP Separator is a single unit system that has the capability of taking outside atmospheric air and creating extremely pure nitrogen **without the aid of scrubbers and burners.** The NICAP Separator requires far less space than current systems and with only one unit there is minimized maintenance! The NICAP Separator saves time, space and money!

And, through the utilization of NICAP's unique membrane filtering system, ethylene is removed from the atmosphere. Ethylene is a very potent gas, released naturally by fruit, which can cause fruit deterioration.

If you're interested in what lies ahead in the storage of fruit in controlled atmosphere, call Terry Campbell at 509-452-7666. He'll show you the future, today . . . the NICAP Separator.

Contact Terry Campbell at:

CENTRAL AG AND MANUFACTURING

702 W. Madison Ave.
P. O. Box 664
Yakima, WA 98907
(509) 452-7666

"The NICAP Separator now makes all other CA systems obsolete."

18

THE NICAP SEPARATOR

The NICAP Separator is the newest and most advanced technology in the industry today. This patented process operates efficiently and economically to provide the optimum in controlled atmosphere storage of food products.

While the NICAP Separator is new in the marketplace, it has been tested and proven under actual working conditions at Forney Fruit Company, Yakima, Washington.

SPECIFICATIONS

MODEL 001-87 5000 C.F.H.

DIMENSIONAL:	LENGTH	WIDTH	HEIGHT	WEIGHT
	104"	35"	70"	1500 lbs.

SEPARATOR:	165 P.S.I. -- 170°(F)
COMPRESSOR:	40 H.P.
SIZE:	60 HZ, 3 PHASE, OOP. 460 V, AC, 40°C. OPTIONS: 200-230V
SPEED:	1770 R.P.M.
STARTER:	460 V. MAGNETIC FULL VOLTAGE OPTIONS: 200-230V
CAPACITY:	LESS THAN 1% CO_2
O_2 REDUCTION:	1% PER HOUR -- 150,000 BUSHELS -- (6,000 BINS)

For More Information Contact:

TERRY CAMPBELL
CENTRAL AG & MANUFACTURING
509/452-7666

VII. PRESENTATION ON REFRIGERATION AND POSTHARVEST HANDLING OF PERISHABLE FRUITS AND VEGETABLES

Place: Department of Agriculture
Bangkok, Thailand

Presented by Karl Buehler
University of Idaho - Postharvest Institute for Perishables

I. Introduction

a. Preservation of food vital to all people of the earth.
b. Description of refrigeration
c. Why it is essential in the postharvest handling.

II. Methods of Precooling

a. Hydrocooling
b. Forced Air
c. Vacuum Cooling

III. After Precooling

a. Cold Storage (immediately)
   1. Controlled Temperature Humidity/Air Flow
   2. Different storage conditions depending upon the product
   3. Product storage arrangement
b. Packaging for distribution and/or export
   1. Use of controlled temperature conditions
   2. Precooling packing materials
   3. Return to cold storage/or refrigerated container/or transport

IV. Frozen Product

a. Brief history and product preparation
b. Next best method to farm fresh
c. Excellent item for export
d. Recommendation: research facilities be provided to fast freeze

V. Methods of Fast Freezing

a. Contact plate freezers
b. Blast freezers

c. IQF freezers

d. Immersion freezers/cyrogenic

VI. Controlled Atmosphere

a. Purpose

b. Controlled atmosphere described.

c. A look at the equipment required

d. C.A. cold storage room requirements

e. Refrigeration design considerations.

1. Air units
2. Compressor unit
3. Direct expansion or flooded system
4. Water defrost or hot - gas
5. Personnel safety

VII. Trends in Refrigeration

a. Energy savings

b. Helical rotary screw compressor

c. Heat reclaim

d. Evaporative condensers

e. Instrumentation and microprocessors

VIII. Summary

a. Preservation of food

b. Future world needs

c. Freeze drying

APPENDIX A

SCOPE OF WORK

AIDAC

For ST/AGR/AP Harvey Hortik

E.O. 12356: N/A

Subject: Procurement of Technical Services under PIP's BOA No. DAN-1323-A00-509300

Ref: State 298444

Request AID/W assistance issuing a work order for services to PIP to cover cost of this consultancy.

Scope of Work: To provide technical assistance for agricultural technology transfer project and assist Mrs. Dara Buangsuwon, Department of Agriculture Pathology Division, sub-project leader for postharvest quality improvement. It is desirable that incumbent have a commercial technical experience in pre-cooling tropical fruits and vegetables: mangosteen, rambutan, lychees, mango, pineapple, baby corn, okra, tomato and leafy vegetables. Experience with modified atmosphere such as carbon dioxide to reduce respiration in containers considered a plus but not a requirement for consultancy.

Estimated period of service approximately three to four weeks.

Start of service no later than June, 1987.