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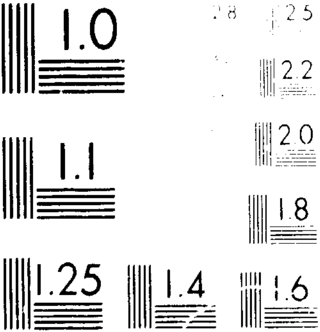
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JANUARY 14, 1975

PRECOOLING, REFRIGERATED STORAGE AND TRANSPORT OF PERISHABLE PRODUCE FOR THE EXPORT MARKET

ISRAEL

(DP/ISR/73/014/11-01/06)

PROJECT FINDINGS AND RECOMMENDATIONS

TERMINAL REPORT PREPARED FOR THE GOVERNMENT OF ISRAEL

by

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Acting as executing agency for the United Nations Development Programme

This report has not been cleared with the United Nations Industrial Development Organization which does not therefore necessarily share the views presented.

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SUMMARY

The two leading Israeli companies engaged in the export of perishable produce were analyzed to pinpoint their problem areas, determine possible causes of the problems and recommend ways to arrive at solutions or prevent future problems. The companies examined were AGREXCO and THE CITRUS MARKETING BOARD. Attention was given to the problems of precooling, refrigerated storage and transportation.

Agrexco deals with all export commodities except citrus fruit. All their perishables are transported by refrigerated ships except strawberries, small melons and sometimes grapes. These are transported by air cargo. The Citrus Marketing Board deals only with citrus which is transported on non-refrigerated, ventilated ships. Each has common problems that are focused mainly on difficulty in achieving and maintaining product temperature.

Prevention of waste and spoilage and preservation of product quality during post-harvest handling and transport depends chiefly upon proper temperature management. Yet, investigations of precooling and transport systems revealed that primary consideration is given to packaging methods and handling procedures at the expense of effective cooling and temperature management. Fibreboard cartons are not ventilated sufficiently to allow for free passage of air through the containers; palletized unit loads are not stacked to provide for free air movement through the stack; some pallets are overwrapped with master containers that completely block air flow through the stack and containers, and cooled products are subjected to ambient air temperatures and solar radiation, often for periods that completely nullify whatever value might have been obtained by the precooler. These practices constitute the primary problem areas.

Secondarily, but equally important, is the inability of the precoolers to satisfactorily achieve their specified design product temperature reduction. This is partly attributable to poorly ventilated cartons but also to poor system design. In two of the precoolers, no provision is made to circulate air through the cartons, thus, even if the cartons were amply ventilated, satisfactory cooling would not be accomplished. The precooler for air transport is designed to circulate air through the cartons to accomplish cooling in two hours. This is possible with the existing system if the cartons were ventilated and stacked properly. However, the precooler is highly inefficient because of poor design in the air handling and refrigeration system, and heat gain to the precooler from ambient atmosphere.

The two main problems, therefore, are insufficient cooling and heat gain to the cooled product resulting from poor handling practics. Correction of the problems would require substantial modifications, most of which the industry cannot economically justify. Research on these problems will provide solutions and design information that can be incorporated into future designs for more efficient and effective precooling and handling systems.

INTRODUCTION

BACKGROUND

Through its expanding export market, Israel is improving its balance of trade with other nations of the world. Special emphasis is placed upon expansion of its agricultural products. Its geographic and climatic conditions enable Israel to grow a wide variety of agricultural products in abundance Among these are fruits and vegetables of high quality which enjoy a good market as fresh produce in Europe and Japan, and to some extent in the United States.

Because of the highly perishable nature of most fresh fruits and vegetables, it is imperative to provide a closely controlled program of temperature management, based on product requirements, throughout the postharvest marketing period. Perishable produce that is not cooled as soon as possible after harvest, and kept at the proper temperature during postharvest handling, transport and distribution, will either decay or deteriorate from excess repening, or both. Adequate temperature management, on the other hand, will insure maintenance of the high harvest quality and prevent waste from spoilage or deterioration during marketing.

To accomplish this the two chief commercial firms engaged in the export of perishables have constructed centralized precooling and refregerated storage facilities near the transport loading docks. The two firms are AGREXCO (abbreviation for Agricultural Export Company) and THE CITRUS MARKETING BOARD. Their business is selling fresh fruits and vegetable to foreign markets.

Agrexco deals with avocados, sweet peppers (capsicum), eggplant, grapes, celery, melons, strawberries and stone fruits. The strawberries, small melons and grapes are transported by non-refrigerated air cargo, the others by refrigerated ships.

To prepare commodities for air transport, Agrexco has a large, modern and impressive looking facility located on the premises of the LOD Airport near Tel-Aviv. The package product is received here, loaded onto special air cargo pallets, precooled, then placed in refrigerated storage awaiting shipment. In compliance with an International Air Carriers regulation, the entire cargo must be assembled at plane side for inspection by the captain before it can be loaded on board. This normally requires from 30 minutes to one hour. Perishables are never held longer than 24 hours at the facility.

For sea transport, Agrexco has refrigerated holding rooms and sheltered area for receiving and loading out in the vicinity of the seaport at ASHDOD. Here the packaged product is received on disposable pallets and placed in a refrigerated room at a temperature commensurate with the product requirement. The product is usually held in the refrigerated room overnight for cooling and transferred to the shipping dock the next day for loading on board. The pallet load is removed from the dock and placed in the ships compartment by crane. As a rule, during this operation the product is without refrigeration for 3 hours or more, often in a hot environment. In this time much heat is gained, thus negating much of the refrigerating value obtained the previous night. This facility is not equipped for fast precooling. In addition, the carton design and stacking patterns, often with palletized containers to facilitate handling, virtually preclude cooling even under the most ideal conditions.

Although designed for transporting perishables, many of the ships are old vessels employing manually controlled refrigeration and air distribution systems that do not have capability to accomplish any significant cooling in transit. The product should therefore be thoroughly cooled before it is loaded onto these vessels.

The Citrus Marketing Board deals with citrus products only. As a rule, citrus products are not as perishable as stone fruits and many vegetable products, but they do have a temperature sensitive metabolism and are also subject to decay which can be controlled by temperature management. Therefore it is always practical and sometimes necessary to remove the essential heat as soon as possible and keep the fruit cold throughout marketing. Some citrus, particularly grapefruit, do not need the low temperatures required for other perishables.

The Citrus Marketing Board has a centralized precooling and refrigerated storage facility located nearby the shipping dock at ASHDOD. Fruit is received from the packinghouse in fibreboard cartons that are stacked on a special pallet rack which is an integral part of a unique handling system at the precooling plant. As the fruit arrives at the plant, the entire load is drawn vertically upward through an overhead door and placed on rails where it is mechanically positioned for precooling and holding. From the standpoint of materials handling this is a highly efficient system. Also the structural and equipment aspects of the facility are excellent. However, from the standpoint of product cooling, the facility is inadequate. Because of the poor air distribution system design, tight stacking of cartons, inadequate carton ventilation and failure to schedule cooling in relation to product temperature, the abundance of refrigerating capacity available is not used effectively and efficiently. Thus the cost is high and many boxes of fruit are never cooled to the proper temperature.

The procedures used for transferring the fruit to the loading dock and loading onto shipboard are similar to those used for other perishables. Thus the same problems of heat gain apply.

Citrus fruit is transported on non-refrigerated ships. The ships are equipped with manually controlled ventilation systems, that could be more harmful than beneficial unless extreme caution is exercised in their operation.

In the case of citrus as well as other perishables, consideration is given to packaging and handling ease at the expense of adequate temperature management. This is the source of the majority of the problems encountered.

There is no export market for apples because production does not exceed local demand. Their local marketing period is extended for nine months, or longer, by means of controlled atmosphere storages. These storages are efficiently operated employing the best available technology, construction features and equipment. Thus there are no refrigeration problems in the postharvest handling and conditioning of apples.

When the market is good, bananas are exported to Europe. However the refrigeration problems are not significant because they do not need the low temperatures required by most other perishables. Green bananas are held at about 58°F until ready for ripening. They are usually transported on refrigerated vessels that have facilities for maintaining this temperature. The primary problems with bananas are in handling from the field to the packinghouse and in packaging.

At present, lettuce is a minor export commodity but is expected to increase tenfold within the next few years. Some sweet corn is also exported but not in large quantities. Both of these commodities are highly perishable and absolutely must be precooled rapidly and kept cold throughout marketing to preserve their quality and prevent spoilage.

Potatoes are grown but not in sufficient quantity to permit export. Their marketing period can be extended up to 6 months, or longer by refrigerated storage. However, the technology, as applied to conditions in Israel, has not been fully developed and thus needs some research attention.

OBJECTIVES

This report presents observations and analyses on those commercial firms dealing in export commodities and on research needs and approaches leading to solutions to their problems in heat transfer and refrigeration. The information presented was gathered as part of a project presently being carried out by the Division of Environmental Engineering, Agricultural Engineering Institute, A R O, Israeli Ministry of Agriculture in cooperation with UNIDO.

Immediate and long range objectives are listed in the Project Document. These objectives recognize the need to provide industry with solutions to their more pressing problems in the handling, precooling and transport of perishables for export as well as to develop new techniques, methods or systems that will do an effective job more efficiently. This study is geared toward that end with special attention given to the evaluation of commercial operations and the development of plans for future research based on these findings.

FINDINGS

Postharvest handling, precooling, packing, storaging and transporting of most fruit and vegetable products grown in Israel were observed. The problem areas were found to be chiefly with the firms engaged in export. The following are analyses and evaluation of their operations.

A G R E X C O

Facility:

Centralized precooling and refrigerated storage for terminal warehousing of strawberries, small melons and grapes in preparation for transport.

Transport:

Non-refrigerated air cargo.

Handling:

Products are received in fibreboard cartons, stacked on pallets for fork truck handling. As they are received they are stacked on special air-cargo pallets, precooled, then palced in the refrigerated storage awaiting load out.

Precooling:

The following is a general analysis of the approximate refrigeration heat load and cooling capability of the precooling system.

The existing system has two compartments with a capacity for 10 tons of strawberries each. Two 33 horse power (hp) electric motors in each compartment drive centrifugal fans designed to deliver 22,000 cubic feet per minute (c f m) each, against a static pressure head of 5 inches water gauge.

Assume 20 tons of strawberries are to be cooled by a temperature reduction of 50°F in 2 hours. Refrigeration heat load on the existing system, in British thermal units per hour (btu/hr), is:

Product heat (including cartons) - - - - - - - - - -	1,000,000	btu/hr
Heat from fans and motors - - - - - - - - - - - - - - -	400,000	"
Transmission and infiltration heat - - - - - - - - -	25,000	"
Total -	1,425,000	btu/hr

This is approximately equivalent to 120 tons refrigeration.

Because of the inadequately ventilated cartons and poor air distribution system, the desired cooling rate is not accomplished. Thus the refrigerating capability is not efficiently utilized. This is further compounded by the unnecessarily high resistance to airflow which adds an additional unwarranted heat load to the refrigeration system.

The relationship between the volume rate of airflow and the system resistance to airflow should be such that the fan pressure does not exceed 2 inches water gauge. A properly sized fan will deliver 22,000 c f m against 2 inches water gauge at one-third the energy required for the existing fans. The heat load produced by the fans would thus be reduced to about 132,000 btu/hr and the total heat load would then be reduced to 1,157,000 btu/hu. This is approximately equivalent to 99 tons of refrigeration.

In a refrigeration system with a good coefficient of peformance, the evaporator coil (s) capacity is balanced with the capacity of the compressor. With the above total heat load and specified airflow rate, the reduction in air temperature across the coil would be 11°F. Thus the coil face area, depth and refrigerant temperature should be sufficient to provide this air temperature drop.

Adequately ventilated cartons combined with proper stacking arrangements would permit the air to flow through the cartons and over individual product surfaces. Thus, with the specified air quantity, strawberries can be cooled in 2 hours and cantaloupes in 3 hours, provided the refrigerating capacity is available.

Refrigerated Storage:

Assuming that the product is thoroughly precooled before going into the refrigerated storage, the heat load to the refrigeration system would be (1) heat of respiration, (2) heat gain by conduction through walls, floor and roof, (3) heat produced by lights, people, motors, etc. in the refrigerated area and (4) heat gain by infiltration through doors and other openings. The heat load of a well built storage should be substantially less than the precooling heat load for a comparable amount of product handled.

The existing storage is 86 feet in width and length and 14 feet in height. Based on the storage specifications for size, capacity, equipment in the refrigerated area and operations, the calculated refrigeration heat load would be as follows:

Respiration heat	4,000	btu/hr
Conduction through walls, floor and ceiling	70,000	"
Infiltration (½ air change per hour)	62,000	"
Forktrucks (2 at 3,500 each)	7,000	"
Fans and motors (8 - 1.5 hp)	36,000	"
[illegible]	17,000	"
[illegible] (2 at [illegible] each)	[illegible],000	"
	193,000	btu/hr
Add 10%	19,300	"
T o t a l	217,300	btu/hr

This is approximately equivalent to 18 tons of refrigeration. Infiltration heat load could vary substantially, depending upon number of open doors and frequency of movement through them.

Refrigeration Equipment:

The entire facility, including air conditioning for flower storage and offices, is served by four, R-22, 140 hp compressors to produce 90 tons of refrigeration each at a suction temperature of 14^{o}F. The compressors pump R-22 through heat exchangers to cool glycol, which is used as a secondary refrigerant throughout the facility. Two air handlers, each equipped with fans to deliver 22,000 cfm against 5 inches static pressure water gauge driven by 33 hp electric motors, are provided for each of the two precooling rooms. Calculations show that the four cooling coils have a total capacity of 1,200,000 btu/hr when operating at design conditions. The refrigerated storage is equipped with 8, 3 hp air coolers.

General Observations and Conclusions:

The facility is constructed of high quality material and first class workmanship. It has excellent design and layout criteria from the standpoint of materials handling. However, there are problems resulting from poor design of the precooling plant and refrigeration system. In summary, many of the problem areas can be corrected or substantially improved by: (1) providing cartons and stacking arrangements to minimize resistance to air flow through the stacks; (2) reduce pressure drop in the air distribution system to not more than two inches water gauge; (3) size fans to give needed volume rate of airflow at no more than 12 hp per fan; (4) providing flower storage and office air conditioning refrigeration systems separate from precooling and refrigerated storage systems; (5) consider enclosed receiving dock and refrigerated shipping dock; and (6) consider transfer containers from refrigerated storage to plane-side to minimize heat gain at load out.

A G R E X C O

Facility:

Centralized precooling plant and refrigerated storage for terminal warehousing and preparation for shipping of avocados, sweet pappers (capsicum), watermelons, eggplant, tomatoes, grapes celery and stone fruits.

Transport:

Most of the above listed commodities are transported in refrigerated ships to the European common market countries. Generally, the ships are old vessels, eauipped to haul perishables, but not designed to efficiently accomodate transport of pallet loads.

A typical ship is equipped with three 150 hp, R-22 compressors. A secondary brine refrigerant is pumped through cooling coils located in each of 14 compartments. A total of 86 vane axial fans circulate the air over the coils, through sub-floor ducts, up through the load and overhead back to the coils. The fans can deliver approximately 3,500 cfm each against a static pressure of o.8 inches watergauge. A typical ship has a total cargo space capacity of approximately 254,000 cubic feet. The total air distribution capability for this space is approximately 300,000 cfm. This is slightly more than one air change per minute, or about 0.1 cubic feet of air per pound of product. This is more than adequate for ventilating a cold storage room but not enough to affect any appreciable cooling.

The total refrigerating capacity is approximately 4,500,000 btu/hr. On the basis of a load density of approximately 12 pounds per cubic foot, the total product load is approximately 3,000,000 pounds. Assuming that all the refrigerating capacity is available for cooling, the cooling rate would be roughly 1.5°F per hour. However, a refrigerating capacity of approximately 1,000,000 btu/hr is needed to overcome the heat gain by respiration, fans and motors and from conduction and infiltration into the refrigerated space, leaving sufficient cooling capacity for about one °F per hour.

Handling:

Products are received at the refrigerated warehouse packed in cartons and stacked in pallets for forktruck handling. All handling, including loading on board the ship, is completely palletized. Upon receipt of the product, it is placed into a refrigerated room where it remains until it is scheduled for load out.

The length of time the product remains in the refrigerated room, hence the potential for cooling, depends upon receiving and loading out schedules.

Tightly stacked, poorly ventilated cartons, over-wrapped with a master pallet container, could take several days for adequate cooling. At load out, the product is removed from the refrigerated room and transferred to the shipping dock for loading. The product is normally without refrigeration, sometimes subjected to high ambient temperature and solar radiation, for several hours during this transfer.

Precooling:

Except for a vacuum cooler, which is not often used, the facility is not equipped with specialized precooling equipment. Cooling is accomplished in the refrigerated storages. This is acceptable for products that do not need fast cooling, and possibly for products that are subject to chill injury at lower temperatures, but fast precooling is important for the highly perishables. Products handled by AGREXCO that would fall into that category are grapes, celery and stone fruits.

A recent development in palletized handling employs a pallet size, master container, which overwraps all the cartons on a pallet. This type of container is ideal for protecting the product from heat gain during load out, but is not compatable with cooling in palletized stacks.

Conventional "room cooling" normally takes from 24 to 48 hours, or possibly longer depending upon the commodity, containers, etc., provided adequate refrigerating capacity is available.

Refrigerated Storage:

The refrigerated storages are separated into an old and new section, spanned by a sheltered, non-enclosed loading dock. The old section consists of three storage rooms. Two are 40 feet long, 50 feet wide and 23 feet high. The third is about 10% larger. The new section consists of three storage rooms having a combined total of roughly 155,500 cubic feet of storage space.

Refrigeration requirements for each section are calculated on the basis of the existing sizes, handling requirements, storage capacity using a load desdity of 12 pounds per cubic feet. The calculations assume that the product is thoroughly precooled before it is placed in the refrigerated storage. Respiration heat load is based on avocados stored at 50°F. The heat loads are:

Respiration	240,000	btu/hr
Conduction throughly walls, floor, and ceiling	90,000	"
Infiltration (one air change per hour)	166,000	"
Forktrucks (2 at 3,500 btu/hr each)	7,000	"
Fans and motors (12 at 1.5 hp each)	54,000	"
Lights (7,500 watts)	25,000	"
People (2 at 1,000 each)	2,000	"
	584,000	btu/hr
Add 10%	58,400	"
Total	642,400	btu/hr

This is approximately equivalent to 54 tons of refrigeration. Infiltration heat load might be more or less depending upon number of opened doors and frequency of movement into and out of storage.

Calculated refrigeration heat loads for the new section are:

Respiration	300,000 btu/hr
Conduction	86,000 "
Infiltration	180,000 "
Fork trucks (2 at 3,500 each)	7,000 "
Fans and motors (12 at 1.5 hp)	54,000 "
Lights (7,500 watts)	25,000 "
People (2 at 1,000 each)	2,000 "
	654,000 btu/hr
Add 10%	65,400 "
Total	719,400 btu/hr

This is approximately equivalent to 60 tons of refrigeration. The total combined refrigeration requirement for the two sections is thus 114 tons. Precooling or room cooling would require extra refrigeration. The amount would depend upon cooling time and quantity of product to be cooled. Cooling 40,000 pounds of a product, 60°F in two hours would require approximately 100 tons of refrigeration. Cooling the same product in 24 hours takes only 10 tons of refrigeration.

<u>Refrigeration Equipment</u>:

Both the old and the new sections are presently served by three ammonia compressors with capacity for 60 tons refrigeration each at a suction temperature of 14°F. A fourth compressor, with about one-third more capacity than the existing ones, is presently being installed. Air coolers in each storage room are fed by a central ammonia surge system.

<u>General Observations and Conclusions</u>:

This is a well built facility with an adequate but not surplus refrigerating capacity. The available refrigeration system has the capacity to hold all existing rooms full of cooled product with extra capacity to reduce the temperature of 800,000 pounds of product, 60°F, in a 24 hour period.

The primary problem is that, not being equipped with specialized precooling facilities, sometimes the product is not properly cooled before loading out. The chief reason is that the cartons are not adequatly ventilated. The absence of precooling facilities adds to the problem.

Another problem is attributable to handling practices. As previously noted, shipboard refrigeration and cooling equipment is not adequate to do significant cooling. Therefore the product should be cooled before loading on board. During loading, the product is often held for several hours without refrigeration. Heat gained during this time negates much of the value of cooling that may have been accomplished previously. Partial correction of these problems can be accomplished by: (1) Provide special precooling facility to be incorporated as an integral component of the refrigerated storages; (2) provide adequate ventilation in cartons and through the stack for effective cooling; (3) avoid use of master container overwrap until product has been cooled; (4) provide, as much as practical, protection of the product from heat gain during load out; (5) consider refrigerated loading deck for loading out of storage; and (6) consider semi-enclosure for loading deck.

CITRUS MARKETING BOARD

Facility:

Centralized precooling plant and refrigerated storage for preparation for shipment and terminal warehousing of fresh citrus fruit.

Transport:

Citrus is transported to the European Common Market, Japan and the United State by non refrigerated, ventilated ships. Ventilation is manually controlled, depending upon ambient temperature. Some, but not all, of the fruit is precooled before loading on shipboard. Transport time to Europe ranges from 8 to 14 days.

Handling:

Fruit packed in 44 pound fibreboard containers is received at the centralized precooling facility, stacked on palletized frames to facilitate handling into and out of the precooler. The incoming frame, containing 8 pallets of 48 cartons each, is drawn into the cooler through an overhead door and mounted onto a track where it is positioned for cooling. The same method is used for load out, thus the entire operation is mechanized.

After cooling, pallet loads of fruit are loaded onto a flat bed truck for transfer to the shipping deck. At the shipping deck, the fruit is either held on the flat bed truck, or it is set off onto the ground, awaiting loading onto shipboard. Under this procedure, fruit is exposed to ambient temperatures and solar radiation for as much as an hour or more before loading.

It is then loaded into non-refrigerated ships holds where further warm-up occurs. After several hours under these conditions, any value gained from precooling is nullified.

Precooling and Refrigerated Storage:

The facility is designed to combine precooling with refrigerated storage. Air, at an initial velocity of 4,300 feet per minute, discharges downward from ceiling jets onto the top of the stacked cartons. This initial force is suppose to cause air to be circulated through the stacks and the cartons for reasonably fast precooling. The precooler has a total capacity of 181 tons of packed fruit. It is designed to cool this amount of fruit from 77°F to 41°F in 24 hours with a volume rate of airflow of approximately 2.5 cfm per pound.

The refrigeration heat load on this facility is calculated as follows:

Product (362,000 lbs., 36°F T.R.) - - - - - - - - - - - - -	543,000	btu/hr
Respiration (181 tons at 4,000 btu/ton - 24 hours) - - - -	30,200	"
Transmission (40,200 sq. ft. at 3.6 btu/sq.ft) - - - - - -	145,000	"
Infiltration (382,500 cu.ft. at one air change/24 hours) -	231,000	"
Fans and motors (16-20 hp. 3,000 btu/hr each) - - - - -	960,000	"
Miscellaneous (equipment, workers, etc.) - - - - - - - - - -	50,000	
T o t a l - - -	1,959,000	btu/hr

This heat lead is equivalent to approximately 164 tons of refrigeration.

Refrigeration Equipment:

Two R-22 screw corpressors, having a combined total of 550 tons of refrigerating capacity at design conditions, serve 8 direct expansion evaporator coils. Each coil has two 60 inch diameter vane axial fans with design capacity to deliver 53,000 cfm against a static pressure of 1.5 inches water gauge. The fans are driven by 20 hp motors. The evaporator coils operate at suction temperatures from 21 to 25 °F. Air leaves the coils at approximately 30°F.

General Observations and Conclusions:

The Citrus marketing Board Precooling Plant is a modern facility with highly efficient handling and structural design featnes. The refrigeration plant is more than adequate to satisfy the design requirements, yet cannot achieve the design cooling rate because of poor air distribution both among and through the cartons. This attributable both to improper air system design and inadequately ventilated cartons.

A thorough and comprehensive research study on the cooling effectiveness of this facility, showed a significant variation in air velocity, and hence product temperature, among the various containers. In early tests, cooling time ranged from 56 to 260 hours. After some modification cooling times was reduced to 35 to 232 hours. The researchers observed that the precooling plant exceeded, "by a factor of 2", the specified requirement for reducing product temperature. figures in this report show this to be an accurate, if not somewhat modest, observation. For example, airflow at 0.5 cfm per pound could accomplish the required product temperature reduction in 24 hours if it were distributed through adequately ventilated cartons. Energy needed to move the air would be much less.

RESEARCH NEEDS AND APPROACHES

The research problems, and thus areas of approach, can be broken down into three main categories, namely; (1) Precooling, (2) Handling, and (3) Transport. Many of the problems are similar across commodity lines. Background research can therefore effectively deal with the problem area rather than the commodity in relation to its particular handling procedure. This particularly applies to precooling. In some cases, however, background research needs to be dealt with on a commodity basis. The Division of Environmental Engineering of the Agricultural Engineering Institute has a staff of well trained, competent researchers working in all of these problem areas. Under its Central Refrigeration Research Laboratory project, and in work plans growing out of this project, many of the problems have been delineated. Solutions to some have been achieved. Results leading toward solutions have been obtained for others. The current research program is on target and is making good progress. Obviously progress would be better with a larger staff. More support personnel (technicians, aids, etc.) are especially needed. On of the chronic difficulties is that the wide diversity of agricultural enterprises creates problems in practically the entire spectrum of agricultural activities. Yet, because of the small scale, concentrated research efforts cannot be justified in any one area. Consequently, research personnel are "spread thin" and often, efforts are frustrated because of pressing problems needing immediate solutions taking priority over the recognized need for more background, or basic, research.

Research needs and approaches outlined in the following envision a long range, stepwise research program carried out by three or four professionals and several support personnel. Some that are cited are currently underway. Breakdown is by main problem area.

PRECOOLING

Carton Effects:

Conduct a series of tests to evaluate cooling rate in relation to airflow, air distribution and pressure drop through individual cartons employing existing cartons, modifications of existing cartons and new cartons with completely new design criteria. A strong research effort, already underway on this problem, has yielded substantial background information and has produced a number of effective apprаches for the solution of specific problems regarding size, number, shape and location of vent holes to provde maximum cooling rate possible with the available system. This research should be continued in the direction it is going with a strong emphasis placed on development of new criteria for carton design with respect to cooling requirements.

Stacking Patterns:

Conduct tests to evaluate cooling rate in relation to quantity and direction of airflow and pressure drop through stacks of fruit in cartons involving various stacking patterns and carton designs. Carton design criteria derived from individual tests would be employed. The primary objective of this research would be to obtain maximum cooling effectiveness with the least air movement possible. This research would be most effectively carried out in specially equipped facilities of the Agricultural Engineering Institute. Follow-up tests with select stacking patterns, vent hole alignments, etc. would be carried out in commercial facilities.

Methods or Techniques:

(1) Conduct a feasibility study to determine the value of packinghouse precooling as compared to centralized precooling at the terminal warehouse.

(2) Investigate new methods for precooling, either at the packinghouse or at the centralized precooler with a view towards utilizing maximum refrigerating effectiveness in relation to product requirements.

(3) Conduct analysis on the cost of facilities, refrigeration and handling where precooling is carried out as a seperate operation from the refrigerated storage compared to precooling as a function of the storage system.

Results from these studies would provide factual information for industry to use in making management decisions regarding effective but economical methods and for design engineers in making design recommendations. This kind of information is not normally available and is often helpful in designing a new plant or modifying an existing one.

Systems:

(1) Evaluate existing systems to determine (a) cooling rate in relation to system design criteria; (b) cooling capability in relation to product needs; (c) performance, in terms of the ratio of product heat removed per unit of time to refrigerating capacity; and (d) performance in terms of the ability of the system to provide design air temperatures. Some valuable research results have already been obtained in this area.

(2) Develop engineering design criteria for potential commercial systems, utilizing results of small scale tests. Where plans, specifications or recommendations are adopted by industry, conduct follow-up tests to evaluate the system as it is applied on a commercial scale.

Product Quality:

All of this work should be carried out in close collaboration with the Division of Fruit and Vegetable Storage of the Institute of Food Technology and Storage, A.R.O., to evaluate effects of the various treatments on product quality. Research on quality effects of precooled Vs. non-precooled citrus during simulated transport has already produced valuable information. This work whould be continued, jointly with the engineering studies, in both simulated and actual transport investigations. Findings to date point out problem areas that need to be pursued.

HANDLING

Existing Methods:

Conduct a formal study to document specific handling procedures that are detrimentat from the standpoint of temperature management. Research data collected would include: (1) magnitude and distribution of temperature rise during transfer from cold storage to ships hold; (2) temperature distribution and rise within cargo after loaded on board; (3) incidence of decay, deterioration or other physiological and pathological responses as a result of inadequate temperature management. This would entail monitoring select loads of product from the precooler, throughout the handling and transport, to arrival at destination.

Transfer From Precooler To Ship:

One of the primary problems is heat gain to the product during transfer from precooler to ships hold, and even within the non-refrigerated hold. Research is needed to develop procedures and designs for a practial handling system that will enable maintenance of product temperature during transfer. Research would entail studies to investigate the feasibility of refrigerated loading docks, sealed, or protected, transport vehicles, and procedures to minimize exposure time from transfer vehicles to ships hold. Where necessary, entirely new concepts is product handling might be investigated.

Containerized Handling:

Investigate the application and utilization of various types of shipping and transport containers for both air and sea transport that will protect the product from the precooler to arrival at destination. Various types of containers ranging from low cost disposable to expensive refrigerated containers might be investigated. Research would entail cost analyses, compatability with handling and transport proceduresand vehicles, adaptability to existing systems and effectiveness in maintaining product temperature and hence product quality.

TRANSPORT

Existing Methods:

Conduct detailed shipboard study of environmental conditions during transit to include: (1) observations on distribution and history of fruit and air temperature during transit for both refrigerated and non-refrigerated vessels; (2) air temperature in ships hold when not ventilating and during ventilating; (3) ventilating schedules and procedures; (4) operation of refrigeration equipment in refrigerated vessels; and (5) observations on product condition at terminal point in relation to transit environment.

Ventilating Techniques For Non-Rfrigerated Ships:

Research is needed to establish design and operating criteria for ventilating and non-refrigerated ships. The following is suggested: (1) Conduct studies to determine the minimum quantity of air needed, in relation to air and fruit temperature, to provide required product environment during transport; (2) Evaluate the effectiveness of various ventilating techniques employing automatically controlled dampers and fans to regulate quantity and temperature of ventilating air and to control periods and duration of ventilation; and (3) Develop design criteria for such systems.

Air Distribution In Refrigerated Ships:

Research is needed to establish design criteria for air ducts, fans and stacking patterns in refrigerated ships. The following is suggested: (1) Determine the pressure drop across the stacks and the fans in ships compartments as affected by stacking patterns, carton design, duct design and quantity of air flow; (2) Evaluate effectiveness of various rates of airflow to determine optimum rate with respect to product requirements; and (3) Develop criteria for fan selection, air temperature and rate of flow, air duct design, stacking patterns and operation of refrigeration system.

RECOMMENDATIONS

Examination and analysis of the facilities, equipment and handling methods and procedures used by industrial companies dealing with precooling, storing and transporting of perishables for export show that every effort is made to provide the system needed to do the job. Often, this is done at the expense of overdesign. Some aspects of the total operation of preparing the product for transport are highly efficient. Attention is given to packaging and handling at the expense of precooling, with the result that precooling is either not accomplished effectively, is grossly inefficient or is wasted.

Researchers are engaged in studies that will provide solutions to some of the problems thus generated. But the task is large for a small staff. A program whereby research personnel, consulting and design engineers and industry personnel could learn from the experience of others with similar problems in more developed countries should be of substantial benefit. Also the diversity of enterprises makes it impossible for the small research staff to adequately address itself to all the problems. The following recommendations are thus aimed at alleviating these difficulties.

1. Fellowships For Travel and Training

The research personnel in the Division of Environmental Engineering of the Agricultural Engineering Institute have had excellent training in their respective fields and are academically equipped to conduct high level research. However, limitations stemming primarity from the physical size of the various operations, and hence financial support, preclude their gaining broad experience by contact with others engaged in similar activity. Fellowships for travel and training, both to observe commercial facilities and work with research personnel in countries with similar problems would be helpful.

2. Short Courses

One of the chief weakness in the field of postharvest handling of perishables is lack of experience. In this field, industry and research has accomplished much in a short time. However, in doing so, mistakes are made that can be prevented. A program of short courses carried out under the auspices of the Division of Environmental Engineering, Agric. Engi. Institute, would provide industry personnel and design engineers with information that should be of substantial value in decision making. The short courses should be balanced so as to get a well rounded, cross-section of experts from various countries over the world.

3. Research Equipment and Instrumentation

Equipment and instrumentation is needed to implement research programs proposed. Examples are laboratory equipment for heat and mass transfer studies in the laboratory, portable equipment for field studies, data acquisition and computer systems and small laboratory instruments for laboratory or field.

4. Technicians

Because of the broad program of research, a large staff of support personnel would greatly improve the efficiency of the professionals and therby enhance the broad effort.

5. Fellowships For Consulting Engineers

Consulting or design engineers often create problems, because of their lack of experience, that eventually fall upon the research personnel to correct. Some times the mistakes cannot be corrected. Always, it is better to prevent the mistake before it is made. Fellowships that would enable design engineers to observe, first hand, facilities that are successfully operating, and have contact with the engineers who designed them, would be of considerable value in illeviating the problem.

APPENDIX

I. Job Description

DP/ISR/73/014/11-01/06

Post title: Agricultural Engineer

Duration: Two and a half months

Date Required: November 1974

Duty Station: Institute of Agricultural Engineering, Agricultural Research Organization. The Volcani Center, Bet-Dagan.

Purpose of Project: To assist in improving refrigerated storage and transport of perishable products through applied research and introduction of modern equipment and methods.

Duties: The expert, working within the Division of Environmental Engineering of the Institute and in co-operation with the Division of Fruit and Vegetable Storage of the Institute of Technology and Storage of Agricultural Products, will be expected to:

1. lead local research staff in establishing engineering methods of work at the laboratory;
2. evaluate adaptability of new engineering practices in the field of refrigeration for local use in research and industry;
3. advise and assist local research and commercial organizations in improving refrigeration equipment, cold storage operations and refrigerated transport of perishables.

Qualifications: Highly qualified agricultural engineer with extensive practical experience in refrigeration and transport of agricultural products, heat and mass transfer, measurement and control methods and equipment.

II. <u>Project Counterparts</u>

Mr. G. Felsenstein

Deputy Director, Institute of Agricultural Engineering

Dr. Edo Chalutz

Cooperating Physiologist, Institute of Food Technology and Fruit and Vegetable Storage

Mrs. Elisa Haas

Research Engineer, Institute of Agricultural Engineering

Mr. O. Yekutieli,

Head, Environmental Engineering Research Group, Institute of Agricultural Engineering

III. <u>Fellowships</u>

Mr. G. Felsenstein and Dr. Edo Chalutz to become familiar with cold storage and refrigerated transport of perishables. Australia and Japan. April 25 through June 1, 1974.

IV. <u>Equipment</u>

1. Van type jewel mounted Anemometer
2. Miniature portable recording Thermograph
3. Fruit-spearing Thermometer
4. Standard mercury-in-glass thermometer
5. Hygrothermograph
6. Tong-test Amperometer
7. Multipoint temperature recorder
8. Polaroid 35D Land Camera and accessories
9. Metric Inflo Air Meter
10. N.I.A.E. Pattern Airflow Meter
11. Refrigeration truck

V. <u>Seminars Conducted</u>

1. Technion, Faculty and students of Departments of Agricultural and Mechanical Engineering, 35 participants, Janurary 3, 1975. Designing Precooling and Cold Storage Systems for Perishable Produce to Provide Maximum Effectiveness in Relation to Energy Use.

2. Institute of Food Technology and Fruit and Vegetable Storage, The Volcani Center. 25 participants, January 6, 1975. An Overview of Precooling Handling and Refrigerated Storage Systems for Perishable Produce in the United State.

VI. Acknowledgements

Appreciation is expressed to the officials of AGREXCO and The Citrus Marketing Board for making their facilities available for this study. Appreciation is also expressed to the captain and chief engineer of the transport vessel Vikfrost, who cooperated fully with us in the inspection of their ship.