263-0123.02

PN-AAV-128

Ian 45906

RENEWABLE ENERGY RESOURCES
FIELD TESTING

12 MAY 1986

# TECHNOLOGY REVIEW FOR FIELD TEST #6

# PV/DIESEL POWERED ICE MAKING PLANT AT WADI EL RAIYAN

MAY 1986

FINAL

Prepared for

Egyptian Electricity Authority
Cairo, Egypt

U.S. Agency for International Development
USAID Mission: Cairo, Egypt

Submitted to

Louis Berger International, Inc.
Washington, D.C.
(Contract AID 263-0123C-00-4069-00)
(Meridian Task No. MC-173-396)

Prepared by

Meridian Corporation
Falls Church, Virginia

## FOREWORD
## TECHNOLOGY REVIEW

The Egyptian Electricity Authority (EEA), the United States Agency for International Development (USAID/Cairo), and a group of U.S. consultants, form a team responsible for conducting field test demonstration projects for eleven renewable energy applications in Egypt. These demonstration projects include the use of photovoltaic, wind and solar thermal systems for water pumping, ice making, desalination, industrial process heat and grid connected electricity generation. The specific objectives of the four-year program are: (1) to demonstrate the viability of renewable energy technologies in Egypt, (2) to comprehensively strengthen Egyptian technical and institutional capabilities in the full spectrum of renewable energy planning and decision making, and (3) to establish the infrastructure necessary to ensure that renewable energy technologies, which have proven successful, are available for widespread use in Egypt.

Each field test contains seven generic tasks: Technology Review, Application Review, Conceptual Design, Preparation of a Statement-of-Work for a Tender Document, Proposal Evaluation, Supervision of Hardware Installation and Performance Evaluation. The Technology Review for one of these field tests, a PV/Diesel Powered Ice Making Plant, is presented in this document.

The PV/Diesel Powered Ice Making Plant being evaluated in this field test consists of two basic systems; the PV/diesel power system and the ice making equipment. The performance evaluation of the PV/diesel power system is the key element of this field test since it will assist in assessing the viability of this "hybrid" renewable energy technology for other applications in Egypt.

This Technology Review assesses the component and system technologies of this field test and provides a representative selection of manufacturers and

system integrating contractors, hardware system specifications and examples of field experience with other PV/diesel power system applications.

This document is subtask 3.6.2 to the field test requirements under Contract AID 263-123C-00-4069-00, Task Area 3.

PV/DIESEL POWERED ICE MAKING PLANT
TECHNOLOGY REVIEW
TASK 3.6.2
FIELD TEST #6

TABLE OF CONTENTS


| SECTION | | PAGE |
|---|---|---|
| 1.0 | EXECUTIVE SUMMARY | 1 |
| 1.1 | Project Objectives | 1 |
| 1.2 | Intent of the Technology Reivew | 1 |
| 1.3 | Technology Perspective | 2 |
| 1.4 | Manufactures and Hardware Systems | 4 |
| 1.5 | Conclusion and Recommendation | 5 |
| 2.0 | FIELD TEST OBJECTIVES AND DESCRIPTIONS | 6 |
| 2.1 | Project Objectives | 6 |
| 2.2 | Description of the Field Test | 7 |
| 3.0 | HISTORICAL PERSPECTIVES OF COMPONENT TECHNOLOGIES | 9 |
| 3.1 | Ice Making Equipment | 9 |
| 3.2 | Diesel Generators | 9 |
| 3.3 | Batteries | 10 |
| 3.4 | Photovoltaics | 11 |
| 3.5 | Hybrid Systems | 11 |
| 4.0 | PV/DIESEL POWER SYSTEM TECHNOLOGY | 15 |
| 4.1 | Power System Options | 15 |
| 4.2 | Operating Concept of PV/Diesel Power Systems | 18 |
| 4.3 | PV and Bettery Sizing | 20 |
| 4.4 | AC Versus DC System Design | 23 |
| 4.5 | Technology Maturity of PV/Diesel Power Systems | 26 |
| 5.0 | REVIEW OF FIELD TEST SYSTEM HARDWARE | 29 |
| 5.1 | Ice Making | 29 |
| 5.2 | Photovoltaic | 32 |
| 5.3 | Structures | 32 |
| 5.4 | Batteries | 33 |
| 5.5 | Power System Controllers | 34 |
| 5.6 | Diesel Generators | 35 |
| 5.7 | Inverters/Rectifiers | 35 |
| 5.8 | System Monitoring and Instrumentation | 36 |

TABLE OF CONTENTS (Continued)


| SECTION | PAGE |
|---|---|
| 6.0 MANUFACTURER PROFILES | 37 |
| 6.1 Photovoltaic Module Manufacturers | 37 |
| 6.2 Ice Making Equipment Companies | 40 |
| 6.3 Battery Manufacturers | 41 |
| 6.4 Inverters/Rectifiers | 43 |
| 6.5 Controllers | 44 |
| 6.6 Diesel Generator Manufacturers | 46 |
| 6.7 Integrating Contractors | 47 |
| 7.0 EQUIPMENT/PRODUCT SPECIFICATIONS | 51 |
| 8.0 PV/DIESEL RELEVENT PROJECTS EXPERIENCE | 57 |
| 9.0 CONCLUSION | 62 |
| BIBLIOGRAPHY | 63 |
| APPENDICES | |
| A. Product Literature | A-1 |
| B. Jet Propulsion Laboratory - PV Module Block V Specification | B-1 |
| C. Instrumentation Data Requirements | C-1 |

## LIST OF EXHIBITS


| FIGURE | | PAGE |
|---|---|---|
| 3-1 | Worldwide Photovoltaic Market Projections..... | 12 |
| 3-2 | Worldwide PV/Diesel Hybrid Market Projections..... | 14 |
| 4-1 | Wind Velocity Frequency Curve..... | 16 |
| 4-2 | PV/Diesel Idealized Operating Curve..... | 19 |
| 4-3 | Array Sizing Options..... | 22 |
| 4-4 | PV/Diesel AC Power System..... | 24 |
| 4-5 | PV/Diesel DC Power System..... | 24 |
| 4-6 | DC versus AC Decision Parameters..... | 25 |
| 7-1 | Equipment Data Base..... | 52-56 |
| 8-1 | Block Diagram - Natural Bridge National Monument..... | 58 |
| 8-2 | PV/Diesel Hybrid Power System for Zambia..... (confidential; Integrated Power Corporation) | 60 |

## 1.0 EXECUTIVE SUMMARY

### 1.1 Project Objectives

The primary objective of this field test is to provide EEA with practical working experience in the design, operation and evaluation of photovoltaic and diesel hybrid energy systems. This field test will accomplish this objective by the demonstration and evaluation of a photovoltaic and diesel powered ice making plant at Wadi El Raiyan, Egypt. The field test will also provide information on the technical, institutional and financial performance of PV/diesel power systems for assessing the viability of similar power systems for other applications throughout Egypt.

### 1.2 Intent of the Technology Review

There are a number of key factors that provide the context for Technology Reviews and support the evaluation of the desirability to proceed with a particular field test. The first factor is the degree to which the field test contributes to the objectives of the overall REFT Project. The Project has broad objectives to investigate selected renewable energy options:

1. Comprehensively strengthen Egyptian technical and institutional capabilities in the full spectrum of renewable energy planning and decision-making for technologies and applications;

2. Develop and sustain an Egyptian renewable energy infrastructure through establishment of data bases, information systems and organizations that effectively serve both the public and private sectors;

3. Design, realize and evaluate the performance of a series of field tests which utilize commercially available technologies in applications having potential for widespread use in Egypt.

4. Complete formal managerial and technical training, both on-the-job and specialized, and an intensive information dissemination program.

An assessment of the contribution of this specific field test to the REFT project objectives must consider the criteria necessary for a successful demonstration of a PV/diesel power system. The Technology Review is primarily concerned with the evaluation of commercially available hardware and systems

required for the successful design, installation and operation of the power system and the necessary ice making hardware. The criteria used to evaluate technologies are listed below, although not necessarily in the order of importance.

1. Commercial availability of hardware systems
2. Hardware performance/system reliability
3. Capital cost and cost of energy
4. Operation and maintenance costs
5. Potential for widespread development in Egypt.

A review of the component and system technologies involved with this field test has been performed to support a decision of whether or not to proceed with this demonstration. A representative selection of manufacturers system integrating contractors, and hardware specifications has been provided. Finally, available design and application experience with PV/diesel power systems are included.

## 1.3 Technology Perspective

The field test of a PV/diesel powered ice making plant involves the integration of four major technologies: photovoltaics, battery, diesel generator and ice making. Each of these technologies has been proven to be reliable and commercially viable for specific applications throughout the world under harsh conditions.

The power system technologies of photovoltaics, diesel generators and batteries have application specific limits indicative of either the specific technology or its cost. For example, diesel generators require a reliable fuel supply and proper maintenance. PV/battery energy systems, which require no fuel and very simple maintenance, must be oversized to provide for reliable operation during periods of reduced insolation or increased load. However, the

combination of photovoltaics and diesel technologies into what is refered to as a PV/diesel, or more generically a "hybrid" power system, maximizes the advantages of each technology and minimizes the disadvantages. A PV/diesel power system reduces fuel requirements, optimizes diesel operating efficiency thereby reducing maintenance, improves the capacity use factor of PV and battery equipment and improves power reliability. It is for these reasons that PV/diesel power system technology, although a relatively recent development, has been well received in the commercial telecommunications industry. Projections indicate an increasing number of applications within the next 5 to 10 years as PV costs decline.

The most critical technical areas in the application of a PV/diesel hybrid power system is the design choice of an alternating current (AC) or direct current (DC) system and the reliability and efficiency of the power system controller. For an AC system design, standard AC loads and off-the-shelf AC diesel generators are used. An AC design requires an inverter to convert DC power from the array and battery to AC power for the loads. The poor field performance record of stand-alone inverters, the efficiency penalty and the additional purchase price, encourages system designers toward a DC system design and toward modifying loads from AC to DC, in order to use power directly from the PV array and batteries.

A DC system requires that the diesel generator be capable of delivering DC power to the loads and the battery. This can be accomplished by means of a custom manufactured DC diesel generator or a separate rectifier. A DC power system design is more efficient than an AC system primarily because of the absence of inverter losses.

The decision to use an AC or DC system should be based on the risks of inverter failure compared to the required modification to the loads from conventional AC to DC power. Such modified loads may be difficult to replicate or maintain. This design choice and its full justification should be left up to the bidding contractor. It should be noted, however, that a DC system has been used for the conceptual design described in this Technology Review.

The availability of control systems specifically for PV/diesel power systems is currently limited. There are approximately 4 companies that have developed and will warrant hybrid power controllers. While hybrid power system controllers, per se, are relatively new, the electronic components are proven. Technology development is occuring primarily in the use of microprocessor control of the power systems and loads. The use of microprocessor controls in PV/diesel systems permits complex logic management of the power and loads to optimize component operation toward a lowest overall cost of delivered energy. The design and testing of the power system controls and related equipment components is a critical area for proposal review.

## 1.4 Manufacturers and Hardware Systems

A selection of manufacturers, integrating contractors and hardware system specifications are provided in Sections 6 and 7 of this document. It is likely that no single company will have the broad capabilities needed to respond to the tender document. Therefore, it is probable that an integrating contractor, who may or may not be a PV system manufacturer, will coordinate the design, equipment selection, testing, procurement, shipping, installing, start-up, and training among a bidding team of companies.

## 1.5 Conclusions and Recommendation

The findings in this Technology Review support the recommendation to proceed with Field Test #6 from the point of view of the potential for widespread use of the technology in Egypt, and based on the growing commercial availability of proven hardware.

Although experience is limited with PV/diesel power systems in sizes required for this field test this review indicates that there should be no insurmountable technical problems associated with this demonstration project. This review supports the following conclusions:

1. Hybrid PV/diesel power systems are a logical development step for future remote power system applications both technically and financially.

2. Individual subsystem component technologies for this field test are proven, reliable and commercially available.

3. PV/diesel power systems in a size compatible with the modular ice maker loads of this field test are an emerging technology with a significant promise of a widespread market.

4. The two most important technical considerations for this field test are the design choice of an AC or DC system and the design and performance of the power control system.

Based on these conclusions, there is no apparent reason why a PV/diesel powered ice making system should not be designed, purchased and installed at Wadi El Raiyan. The system should be sized and designed for maximum flexibility in operation and subsystem performance evaluation. The system should also be of modular design for ease of replicability in other remote power system applications throughout Egypt.

## 2.0 FIELD TEST OBJECTIVES AND DESCRIPTION

### 2.1 Project Objectives

The primary objectives of this field test are to provide EEA with practical working experience with photovoltaic energy systems, and to provide system design and operational training for Egyptian engineers for the purpose of assessing and implementing similar projects throughout Egypt. Specifically this field test will evaluate the performance of photovoltaic (PV) energy systems and PV in combination with diesel energy systems for ice making, through the demonstration of a "PV/diesel" powered ice making plant. PV/diesel refers to the integrated or "hybrid" operation of photovoltaics, diesel generator and battery power system technology.[1]

The application of a PV/diesel power system for ice making at Wadi El Raiyan will serve as a demonstration of the capability of the combined technology of PV and diesel to reliably supply significant amounts of power in remote locations. It is therefore important that this field test be designed to distinguish between the performance of the PV/diesel power system and the performance of the ice making equipment and other related equipment such as instrumentation and water treatment so that the PV/diesel power system can be evaluated for other applications. Other applications that are expected to have similar load levels and characteristics are communications and centralized village electrification. This field test will also provide valuable data on the field performance of diesel generators in comparison to PV under similar levels of maintenance and operational support.

This Technology Review is supplimented by the technical information provided in the PV System Technology Reference Notebook which was published in April 1985. This Technology Review provides a detailed review of the specific equipment

---

[1] The terms PV/diesel and hybrid are synonomous in this report and include the use of a compliment of battery storage.

technologies to be employed in this field test, i.e. PV/diesel power systems, ice making and diesel generation equipment. Recommendations are provided, pertaining to the commercial availability of equipment and the capabilities of contractors, to support a decision on whether or not to proceed with this field test.

## 2.2 Description of the Field Test

The site chosen for this field test demonstration of a PV/diesel powered ice making plant is Wadi El Raiyan, an area 140 kilometers south-west of Cairo near El Faiyum. Wadi El Raiyan consists of two joined man-made lakes, currently totaling about 10,000 acres, being formed by the discharge of an agricultural canal flowing from the El-Faiyum area. The lakes are managed by the Fish Resource and Development Authority (FRDA) as a source of fresh fish for El Faiyum, Cairo and neighboring market areas.

Fishing is regulated by the FRDA. The season may extend from September through April with daily catches ranging from 40 tonnes per day occuring in the early part of the season and tapering off toward the spring to as little as .2 tonnes per day. No fishing is permitted during the summer months of June, July and August because of the spawning season. Based on discussions with FRDA personnel and an evaluation of the limited data available, average daily catch throughout the season is estimated to be between 6 and 10 tonnes per day.

Currently fish are packed in ice, brought from El Faiyum at the lake location. The fish are then transported to markets in El Faiyum, Cairo and as far as Alexandria. The ice/fish ratio at Wadi El-Raiyan ranges from 1/2:1 to 2:1 depending on the market locations and the quality of ice used. Therefore, the average season daily ice demand for fish preservation over the fishing season may range from 3 tonnes per day to 20 tonnes per day.

In addition to the ice demand for fish preservation, there is a steady

ice demand in the El-Faiyum area for home refrigeration. Information collected for the market/economic analysis indicates that the current demand for ice in the El Faiyum area is significantly greater than the ice making capacity. Therefore, full capacity utilization of the PV/diesel ice making plant is possible if ice can be sold to non-fish specific markets. This will significantly improve the economics of the facility by maximizing the use of the capital intensive PV power system and ice making equipment.

An ice making capacity of 6 tons/day[2] has been selected as a candidate sizing. This sizing capacity will meet a significant portion of the average daily demand for ice. It also is a reasonable size for demonstrating the design, operation, maintenance of a PV/diesel power system and for evaluating system performance. A 6 ton/day capacity PV/diesel power ice plant is considered to be a "modular" design because of the modularity inherent in the purchase of photovoltaic arrays (power modules) and the fact that ice making capacity is often purchased on a modular basis to achieve high capacity (usage) factors.

An evaluation of the energy required for ice making was performed and is presented in the field test Application Review (Task 3.6.1) for this field test. A value of 70 kwh/ton per day of ice was determined based on manufacturer supplied information and discussions with refrigeration equipment suppliers. Multiplying 6 tons/day by 70 kwh/ton results in a total daily energy demand estimate of 420 kwh/day. This Technology Review contains an evaluation of the equipment components capable of meeting this estimated daily energy demand.

---

2 U.S. ice making capacities are expressed in ton (2000 pounds) as distinct from tonnes (2200 pounds).

## 3.0 HISTORICAL PERSPECTIVE ON COMPONENT TECHNOLOGIES

Field test #6 will evaluate the technologies of ice making, photovoltaics, diesel generators, and batteries at both an individual component level and as an integrated power and load system. During this field test each hardware component will be tested on a technical, institutional and economic basis. The integrated performance of the power system components, together with the ice making equipment will also be evaluated.

A perspective on the past and current performance of each technology is provided in this section to identify possible areas of concern for this field test.

### 3.1 Ice Making Equipment

Ice making is a mature technology. The fundamental technology of ice making, thermodynamic refrigeration, has been tested and proven for many years in a variety of environments. There are numerous reputable manufacturers around the world who design, manufacture, install and operate commercial ice production equipment. A selection of manufacturers and equipment are provided in Sections 6 and 7 of this Technology Review. A 6 ton/day ice making plant is a commercially available size from most manufacturers.

### 3.2 Diesel Generators

Diesel powered electricity generation (diesel generator) for remote power applications is another proven technology. Diesel generators have been installed in remote areas throughout the world for the past 30 years. Diesel generator technology development over the years has concentrated on increasing power density (more power per unit weight) and toward producing higher efficiency engines and generators that require less maintenance.

The usefulness of diesel generators and their counterpart, gasoline generators, is based on the availability of fuel and maintenance which represent the

bulk of the cost of delivered energy. A decision to employ diesel generators is not based on the technology, but on the reliable supply and associated costs of fuel and maintenance. Maintenance time and costs can be substantial in remote areas where parts are difficult to obtain or the environment is harsh.

Until about the mid-1970's there were few alternatives to diesel or gasoline powered generator technology for meeting remote demands for electricity. With the advent of photovoltaic energy technology and the trend toward lower costs for PV modules, diesel generator technology is being systematically replaced in certain remote power applications such as communications.

### 3.3 Batteries

Lead-acid and nickel-cadmium storage batteries, best suited for photovoltaic power system applications, are proven technologies. Lead-acid storage batteries have been produced on a commercial scale for over 75 years. Nickel-cadmium batteries, first developed around 1900, did not come into common use until after 1945. Both lead-acid and nickel-cadmium batteries are available worldwide.

Development in battery technology is directed at lowering cost, increasing life, reducing maintenance requirements and increasing efficiency. Progress toward these objectives is expected to occur slowly but steadily.

An important development in battery storage technology for PV systems is the commercial availability of deep cycle, sealed lead-acid batteries that use recombination battery technology. Recombination battery technology virtually eliminates water consumption by designing the battery cells to recombine any generated hydrogen and oxygen into water. This permits the battery to be sealed and results in a relatively maintenance free battery. Although the cost of these batteries is higher than "vented" lead-acid batteries, which required higher maintenance levels, their use in photovoltaic systems is expected to steadily increase. The effect of high temperature battery operation, as can

be expected in Egypt, is an important consideration in the selection of a specific type of battery.

### 3.4 Photovoltaics

The development and growth of terrestrial photovoltaics has been impressive over the past 20 years. The cost of photovolatic equipment has dropped dramatically while performance has steadily increased. The reliability of today's photovoltaic modules is virtually 100% according to reports NASA-Lewis Research Center based on their extensive PV application and evaluation experience. Related application experience worldwide supports this view. The productive life of photovoltaic modules is currently expected to be approximately 20 to 30 years. Ten year performance warrantees from manufacturers are now available.

The market for photovoltaics is expanding as the relative cost photovoltaics compared to conventional energy sources decreases for specific applications. Projections made by Photovoltaic Energy Systems Incorporated (PV ESI) show that the worldwide market for photovoltaics will reach over 300 megawatts by 1995 (Figure 3-1).

### 3.5 Hybrid Systems

Each of the component technologies involved with this field test have been proven independently. The operating characteristics of the separate technologies are complimentary. Therefore, the combination of these technologies for "hybrid" power systems (PV, diesels and batteries) results in higher reliability and lower delivered energy costs than any of the technologies alone. PV/diesel power systems are rapidly developing as an attractive remote power technology for a growing number of applications.

As the cost of photovoltaics declines over the next 5 to 10 years the number of installations of PV/diesel hybrid power systems will increase significantly.

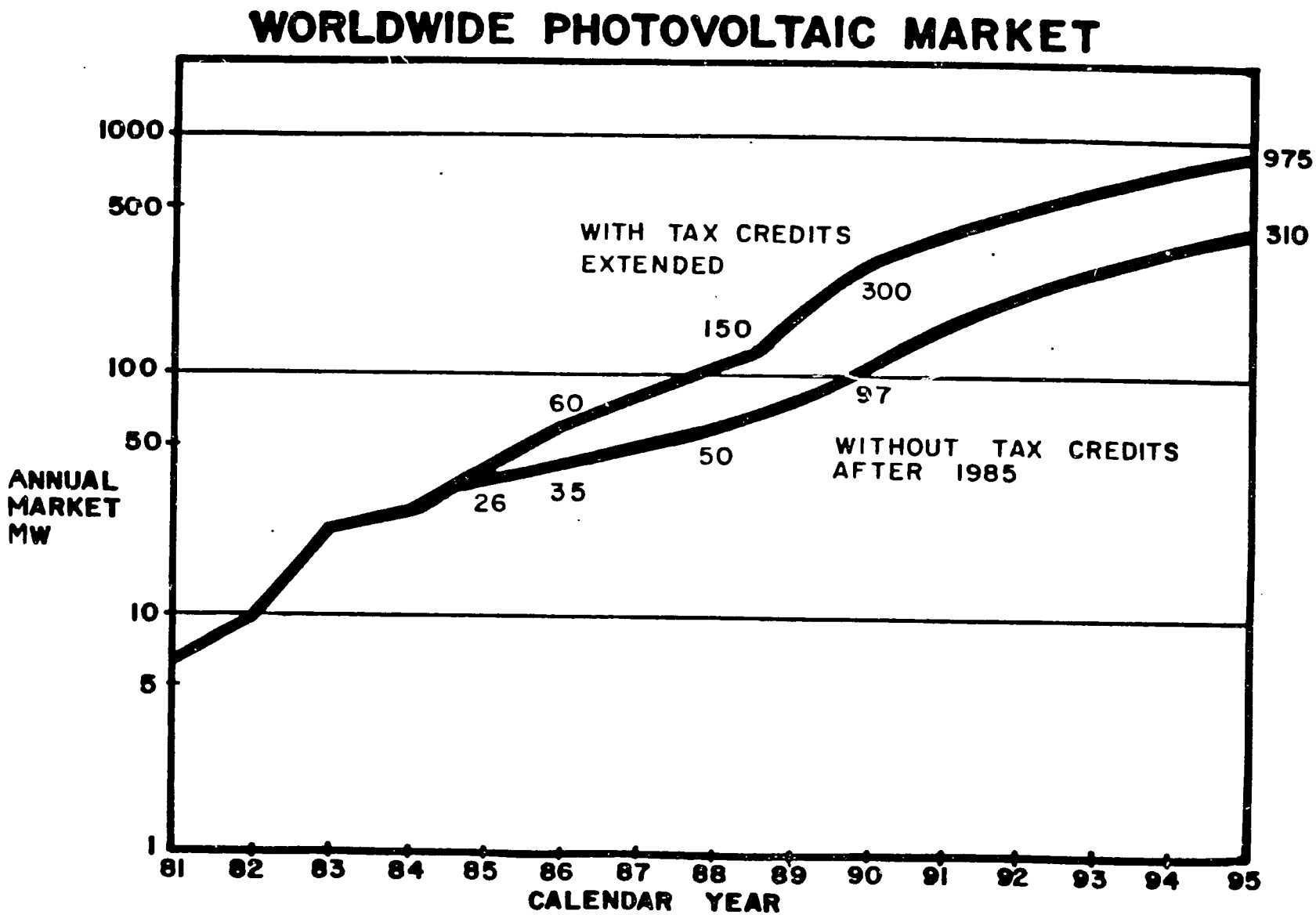



Figure 3-1 Worldwide Photovoltaic Market Projections
(Photovoltaic Energy Systems Inc., Nov. 1985)

A specific projection by PV ESI of the market potential for PV/diesel hybrid power systems is provided in Figure 3-2. A market equivalent to 100 megawatts is expected to exist for PV/diesel hybrid power systems in the 1990 timeframe.

PV/diesel power technology is a relatively new technology, even though each of the component technologies have many years of proven performance. Two areas of concentration for the design and operation of the PV/diesel system are the choice of an alternating current (AC) or direct current (DC) design and the performance reliability of the power system control electronics.

The next section of this report reviews in detail these technical issues and the design and performance characteristics of PV/diesel power system technology.

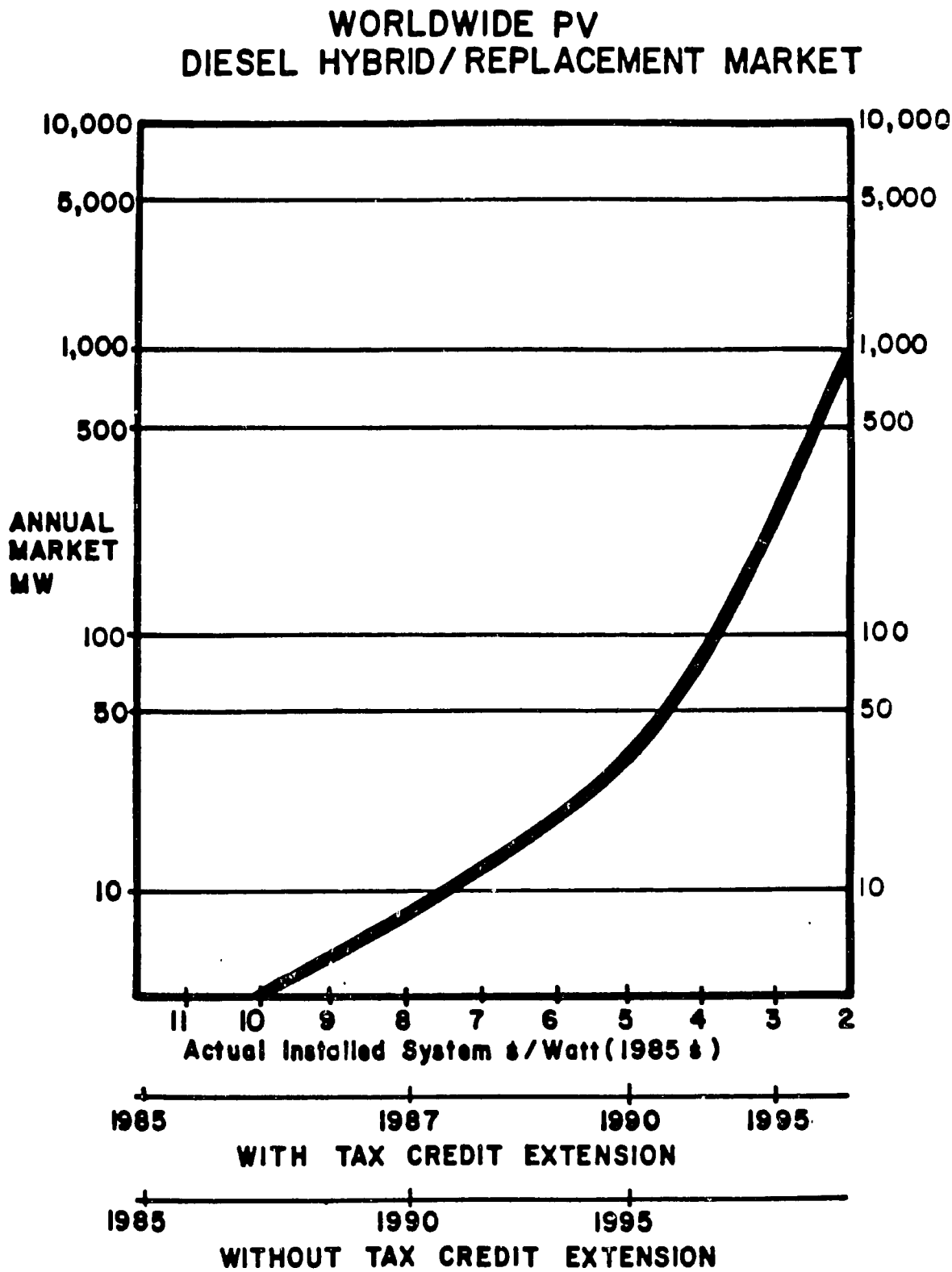



Figure 3-2 Worldwide PV/Diesel Hybrid Market Projections
(Photovoltaic Energy Systems Inc., Nov. 1985)

## 4.0 PV/DIESEL POWER SYSTEM TECHNOLOGY

### 4.1 Power System Options

The power technology specifically under evaluation in this field test is photovoltaics and photovoltaics in combination with diesel generators. As background, a brief perspective is provided on competing remote power technologies in this section. Four basic "stand-alone" energy technologies are considered as power for refrigeration and specifically ice making at Wadi El-Raiyan. These are diesel, wind, photovoltaics, and hybrid power. PV/diesel hybrid power system technology is evaluated in detail starting in Section 4.2.

Diesel Generators

Diesel generators are considered to be the existing technology and as such PV and wind are considered viable if they are economically competitive to it. Diesel generators are available in a wide range of sizes from 2 kW up to several hundred kW rating. They operate with a thermal-to-electricity fuel conversion efficiency of 15-30% depending on capacity factor and the quality of maintenance. For a stand-alone application, two diesel generator sets are normally required to provide for 100% backup and operation of the load during diesel maintenance periods.

Wind

In good wind regimes, wind power is usually cost competitive with diesel. Wind energy was considered on the basis of resource availability. The nearest available wind data for Wadi El Raiyan is from El Faiyum (Figure 4-1). If the wind resource data recorded at El-Faiyum is similar to Wadi El Raiyan, it does not appear to be significant enough to warrant consideration of wind energy technologies for ice making at this location.[3] In addition, wind energy technology for ice making is being evaluated as a separate project at Abu

[3] A minimum acceptable average wind speed is approximately 5 m/sec. El Faiyum data indicates 3 m/sec. average wind speed.

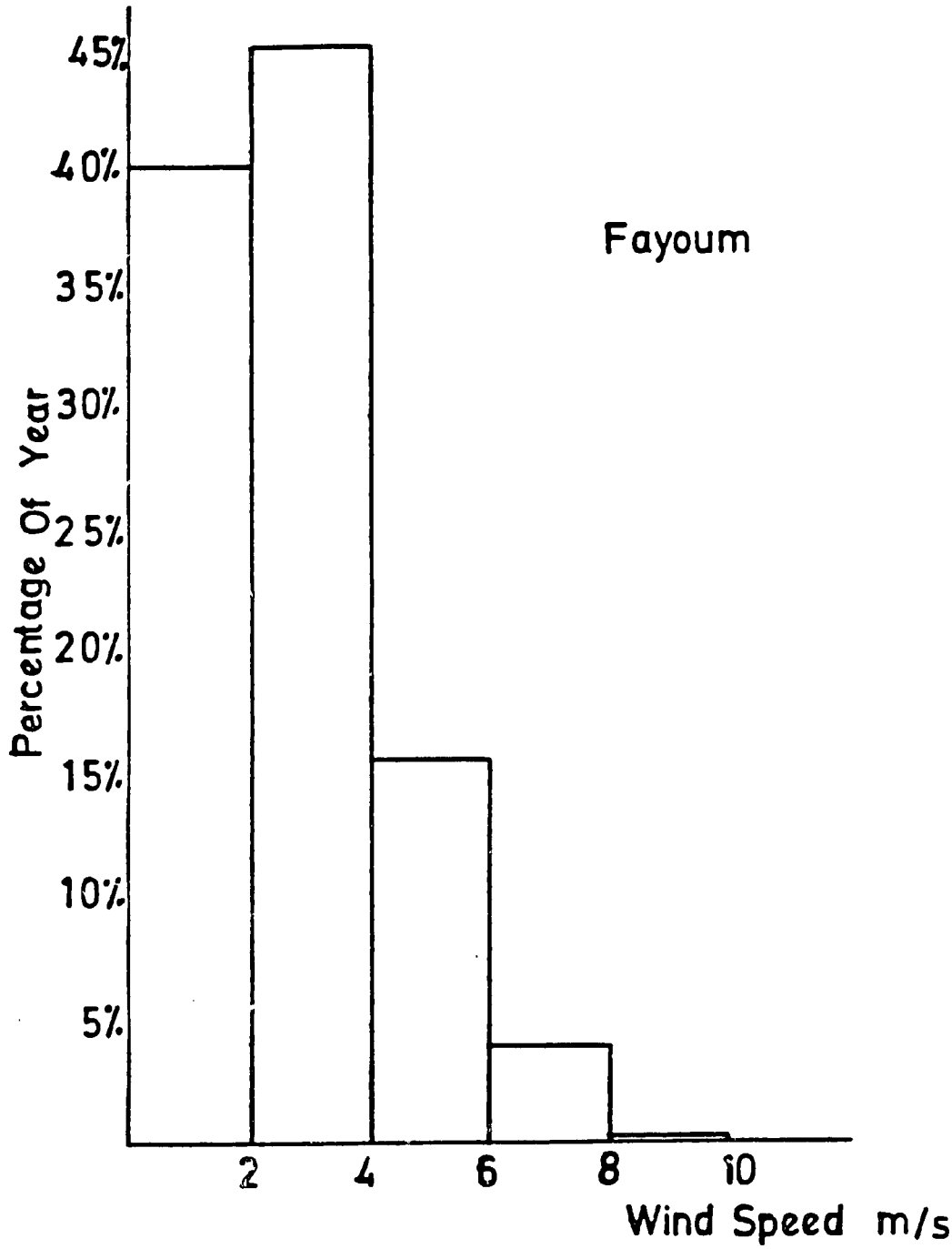



Figure 4-1. Wind Velocity Frequency Curve (Reference: first progress report on contract "Development of Wind-Solar Power Generation System for Rural Areas in Egypt", Prof. Dr. Ing. A. Mobarak.

Gossoun, Egypt, through funding from the United Nations Development Program. This project is being implemented by the Ministry of Electricity and Energy of the Arab Republic of Egypt and is in the hardware procurement phase.

Photovoltaic

Photovoltaic energy system technology is the primary technology under consideration in this field test. Photovoltaics has been technically proven to be more reliable and require less maintenance than diesel systems for remote power supply. Photovoltaic energy however, is currently competitive to diesel generators only at low daily load levels, generally below 10 kWh/day. The cost of photovoltaic energy is projected to drop over the next 10 years to a level where it will be competitive with PV for numerous remote power applications. This is discussed in detail in the Application Review.

The use of a photovoltaic power system to supply 100% of the load requires that the PV array, and a compliment of battery storage be over-sized to account for seasonal and daily fluctuations of solar insolation and load. A reduction in PV array and battery storage size, resulting in higher effective equipment capacity factors and lower delivered energy costs, is possible if PV is used in conjunction with a diesel generator. This is commonly refered to as a PV/diesel "hybrid" power system.

PV/Diesel "Hybrid" Power Systems

A hybrid power system - the combination of a PV and diesel generator power system - uses the benefits of both technologies and reduces the disadvantages. The presence of a diesel generator eliminates the need to oversize the PV array and battery system. The use of a PV array and battery permits the diesel to operate at its rated capacity and therefore maximizes the efficiency. It also reduces maintenance and extends the life of the diesel generator. A PV/ diesel hybrid power system can offer improved energy availability at lower life

cycle costs than a conventional diesel or stand-alone photovoltaic/battery systems. Some specific advantages of the hybrid system over either technology alone are:

1. Increased reliability
2. Reduced diesel fuel consumption
3. Reduced maintenance
4. Increased diesel component life
5. Higher diesel operating efficiency
6. Higher capacity factors for PV and battery.

## 4.2 Operating Concept of a PV/Diesel Power System

The operating concept of a PV/diesel power system is to operate each power system at its highest efficiency compatible with producing the lowest levelized energy cost. This means using a minimum battery capacity and operating the diesel at not less than 40 percent of its rated capacity to achieve good efficiency and to minimize maintenance requirements.

Figure 4-2 is a graphical representation of the operation of a PV/diesel power system supplying a twenty-four daily load. In general, the photovoltaic array operates the load during the day and the diesel operates the load during the night. Points "a" and "b" represent changes in the principal power supply source; from diesel to PV/battery in the morning as array output increases, and from PV/battery to diesel in the evening as array power decreases. The change in power supply can be gradual by "integrating" or combining PV, battery and diesel power to supply the total load, or it can be distinct by effectively operating the equipment as separate power supplies PV/battery and diesel. Both are reasonable operating methods.

A fully "integrated" power system provides for the maximum flexibility in operating the system. It requires a "smart" power system controller which can identify and compare various operating parameters relative to the PV, battery and diesel generator equipment and determine when to start the diesel, at what power level it should operate, and what is the optimum use of PV power at a given point in time. "Smart" controllers often incorporate microprocessor

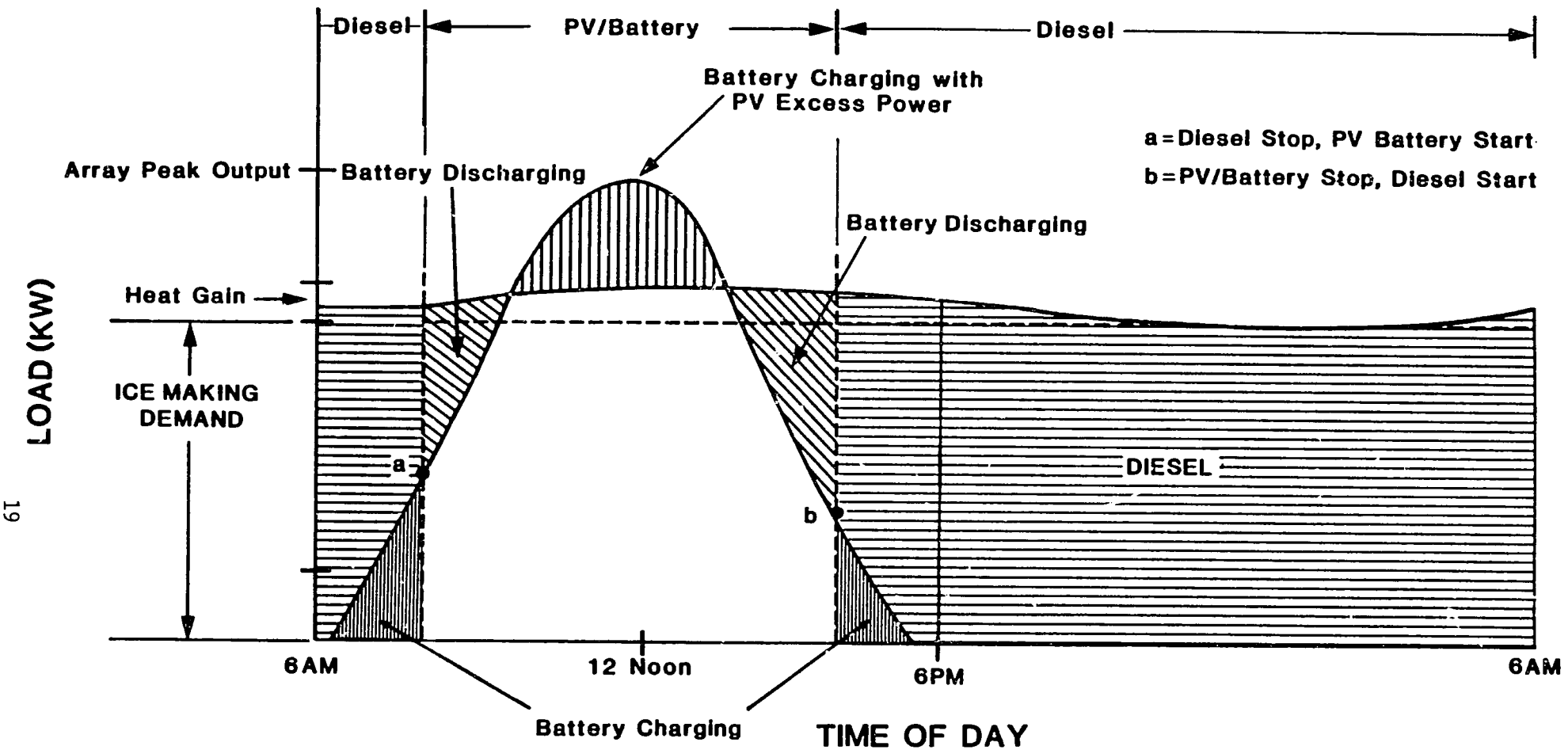



*Figure 4-2*

***PV/DIESEL IDEALIZED OPERATING CURVE***

logic controls which are a relatively recent development in the design of power control systems in the PV industry.

A simpler control method is to operate the PV, battery and diesel as independent power systems. The PV array and battery provide power to the loads for a specific time interval or until a certain battery charge level is reached at which point the diesel starts and takes over the ice making load. Any remaining array power is used to recharge the battery bank. Diesel power is dedicated to the ice making load and does not concurrently charge the battery system. Power supply is switched by power relays and can be specified to be manual or automated, to prevent load operation interruption. Commercially available controllers can perform as a "basic" power system controller with the addition of time, current, or voltage sensors and a "remote start" relay.

The Power Control System must be rugged and reliable. Further, it should be designed to be maintainable. The Operations and Maintenance manual must be clear on trouble shooting procedures. A common practice that makes these guidelines practical is to replace facility items at the "card" level. (A card is defined as a circuit board which contains a set of electronic components).

A redundant controller is not considered necessary or desirable. Most U.S. companies have an arrangement whereby they will consult with the client on trouble-shooting procedures. An individual or company may be retained for additional cost.

Issues such as proven reliability, efficiency, cost and maintainability should be considered when evaluating the power system controller design. In addition, it is useful to simulate typical daily power curves to clarify operational concepts specific to the control design.

## 4.3 PV and Battery Sizing With PV/Diesel Hybrid System

The most significant design question of a PV/diesel power system is the

sizing of the PV array and battery system. The PV array and battery can be sized to contribute from 0 to 100 percent of the demand. The selected size of the array and battery is a function of the relative life cycle costs of the PV, battery and diesel energy. To explore this sizing relationship, three different array sizing options are considered as shown in Figure 4-3.

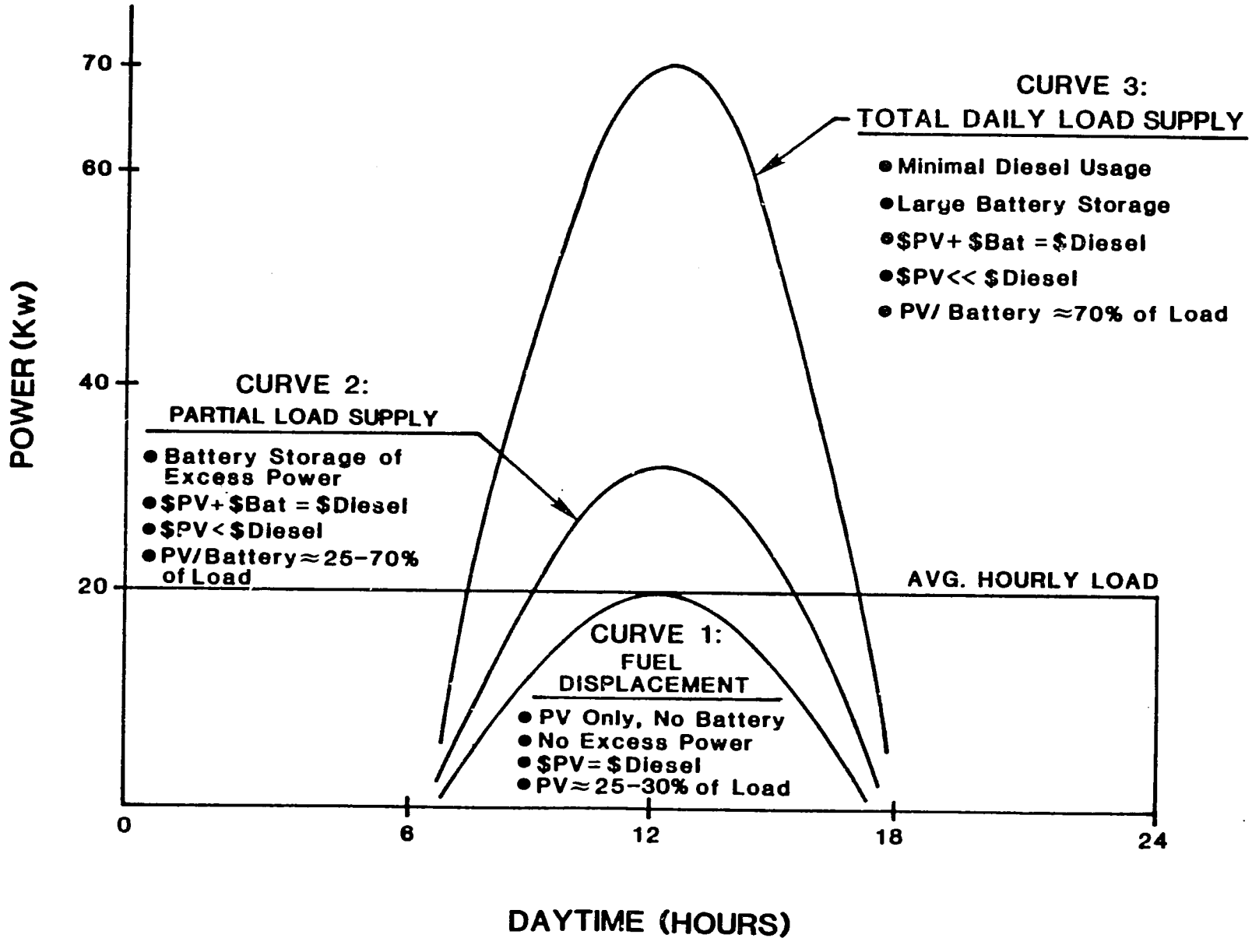
The first array sizing option is Curve 1 in Figure 4-3, labeled "Fuel Displacement." In this sizing, photovoltaic energy serves only to displace diesel fuel when the sun shines. No battery storage is used because on the average, no excess energy is produced. The maximum size for a PV array in this instance is when peak array output at midday equals average power demand at that period. If the cost of PV produced energy equals the cost of diesel energy, this "PV only" sizing is justified as a diesel fuel displacement design. PV energy will represent about 25-30 percent of the total daily energy demand assuming 24 hour continuous loading.

The second array sizing level is shown as Curve 2 and is labeled as "Partial Load Supply." The PV array produces excess energy during the day which is stored in a battery system and returned to the load during periods when the PV array output is less than the load. At night the diesel provides power to the ice loads. PV energy costs, in this case, must be less than diesel because battery energy costs are higher than diesel costs on a life cycle cost basis. Therefore, a PV array and battery storage size is justified to a point at which the marginal cost due to battery storage results in total PV/battery life cycle energy cost equal to diesel.

The third sizing level is where the PV/battery system is sized to supply the total daily load during the year and is shown as Curve 3 labeled "Total Daily Load Supply." In all cases, the combined life cycle cost of PV and battery must be equal to or less than diesel. Because of the relatively large battery storage cost, PV energy costs must be significantly less than diesel.

*Figure 4-3*

***ARRAY SIZING OPTIONS***



Sizing of the array to supply the total energy demand can greatly effect financial performance of the system. If the sizing is performed based on December insolation (to assure reliable power supply during months with low insolation), significant amounts of PV power will be "dumped" during the summer because of excess production. The amount of wasted energy is a function of the change in insolation from winter to summer and any seasonal load fluctuations. Designing for the average daily insolation over the year results in a smaller surplus in the summer but an energy deficit in the winter. Energy deficits would be supplied by a backup diesel because the battery capacity required to carry summer surplus to winter deficits would be unrealistically large. A value of approximately 70 percent has been seen as a reasonable limit of the proportion of PV to diesel[4]. Diesel makes up the 30 percent deficit over the year, to a greater extent in winter and to a lesser extent in summer.

The principle conclusion regarding sizing options for the PV array is that if PV energy costs (without battery) are less than diesel, then some battery storage is justified and the PV/battery system can be sized to provide from 25 percent to 70 percent of the total yearly energy demand. The optimum percentage is a function driven by the economics of the system components, primarily the PV array, battery and diesel life cycle costs.

## 4.4 AC Versus DC System Designs

The predominant design issue for the PV/diesel power system and ice making plant is one of an AC or DC system. A block diagram of an AC and DC power system are provided in Figures 4-4 and 4-5 respectively.

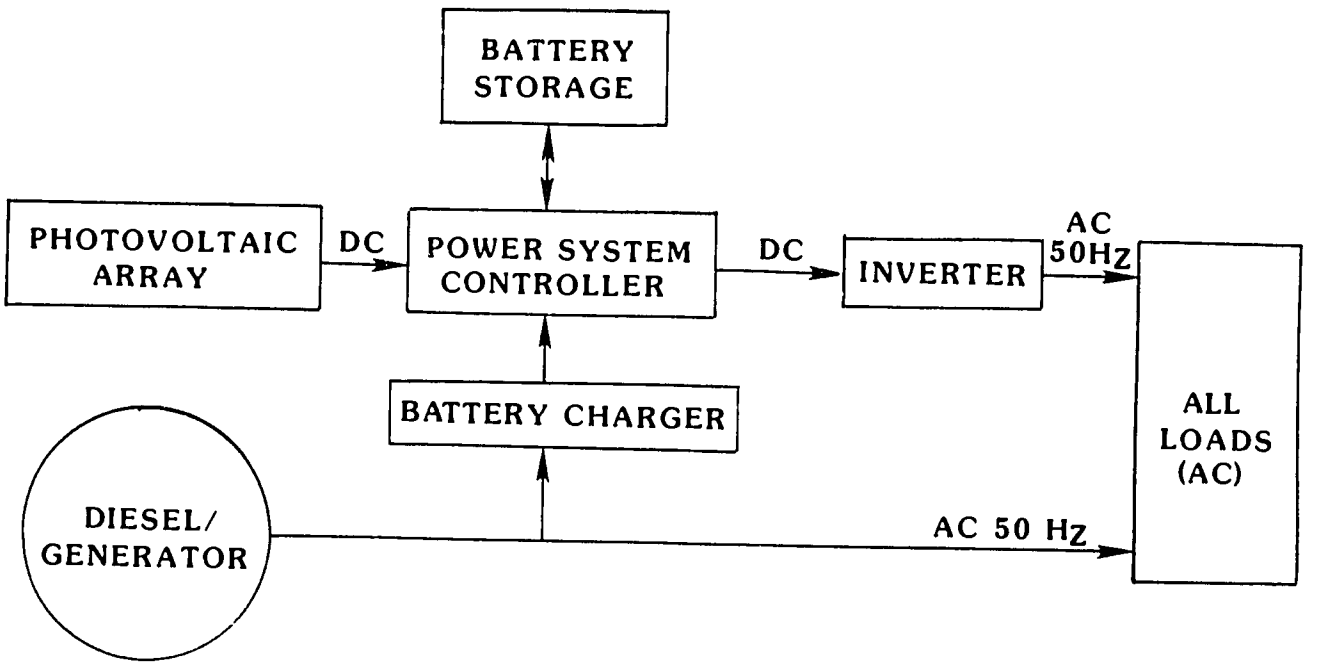
An AC PV/diesel power system uses a conventional ice maker, diesel/generator (AC), and ancillary AC loads. Because PV and battery are DC power technologies but the loads are AC, an inverter which converts DC power to AC

---

4 Conversation with Integrated Power Corporation

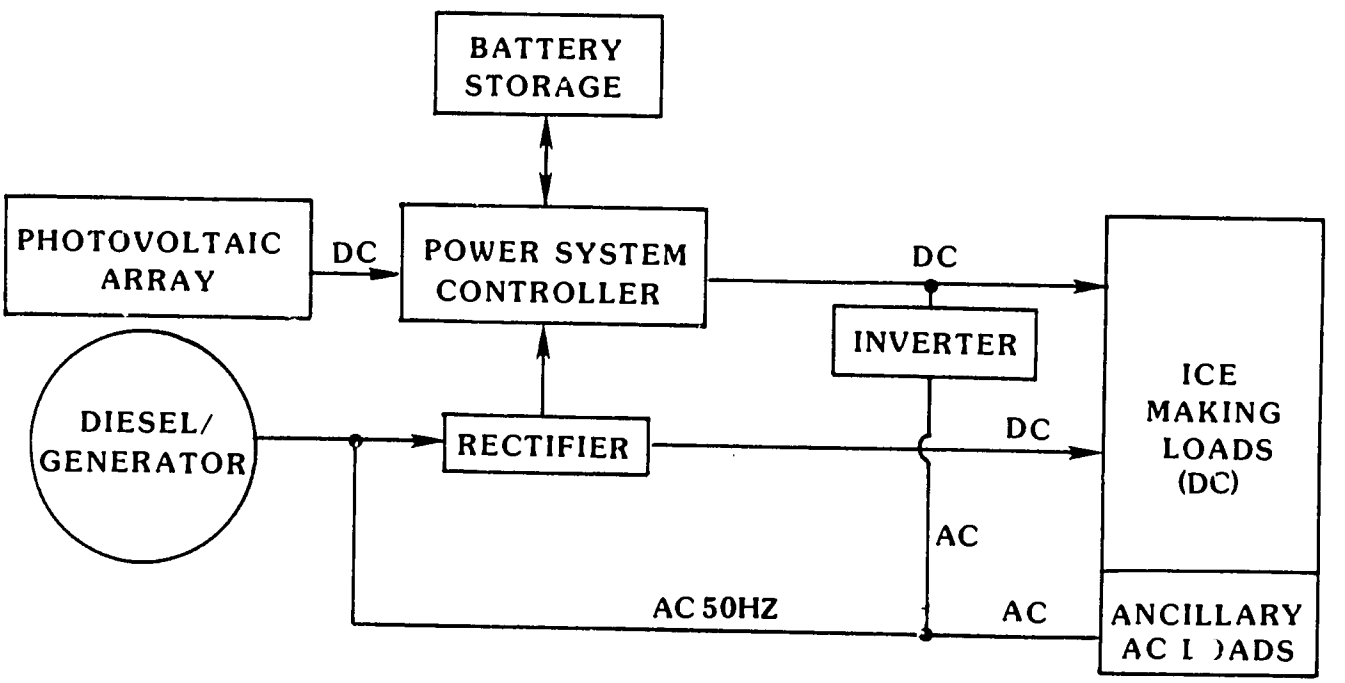
## Figure 4-4

## PV/DIESEL AC POWER SYSTEM




## Figure 4-5

## PV/DIESEL DC POWER SYSTEM



power is required. Large stand-alone inverters (>5kW) installed in developing countries have had poor performance reliability records. Most inverter failures result in a total loss of PV power because they are a critical link between the PV power and the load. Additionally, inverters are at best 90% efficient. PV system designers often consider modifying loads to use DC power directly from the array and battery whenever possible.

A DC power system, requiring a DC motor driven ice maker, has been evaluated as an alternative design choice. A DC load and power system eliminates the need for a stand-alone inverter and thus the associated inefficiency and apparent unreliability of this equipment. A DC design will require, a change of load drive motors from AC to DC and a rectifier to convert diesel generator AC output to DC output. Figure 4-5 shows a PV/diesel power system which provides DC power for the primary energy demand, ice making, and a small amount of AC power for ancillary loads such as lighting, pumping, etc. using a small inverter. Decision parameters for choosing a DC system versus AC systems are provided in Figure 4-6.

FIGURE 4-6 DC vs AC DECISION PARAMETERS

| DC SYSTEM | AC SYSTEM |
|---|---|
| Higher Reliability [1] | Conventional AC Loads |
| Lower Cost [2] | Safety [4] |
| Higher System Efficiency [3] | |

1 Critical inverter link is eliminated with DC system.
2 No inverter cost
3 No inverter losses
4 AC power is generally considered safer than DC power of the same voltage

The choice of AC vs DC motors to run the compressor is influenced by the following considerations.

- o Size of Motor
- o Availability of Hardware
- o Cost

The compressor motor for this application is approximately 20-25 horsepower. For this size of motor the practical choice of motors dictated by availability is between a DC wound-field motor with brushes and an AC 3-phase motor. In both cases it is mandatory that the electronics in the control system and the motor be carefully matched.

Brushless motors have come into usage the last few years for photovoltaic powered pumping applications and the response has been mixed. When there are breakdowns in remote locations, replacments are difficult to obtain. A U.S. company has recently gone back to recommending motors with brushes. Their reasoning is that it is better to train local people on the maintenance of brushes than to risk long periods of downtime of the motor due to an immature technology. Within the last year or so, there has been a newer generation of lower-cost brushless motors introduced that may hold promise.

It is recommended that the design choice and justification of an AC or DC system be the responsibility of the bidding contractor and that the RFP clearly indicate the concerns raised in this section. All bids should be evaluated for the risk associated with DC to AC inverters and the potential problems associated with the maintenance and replacement of non-standard load equipment as would be required for a DC system.

## 4.5 Technology Maturity of PV/Diesel Systems

PV/diesel power systems have been used for remote communication applications

such as repeater stations and satellite receiver stations. There is a growing interest in the use of these hybrid power systems for other application such as village electrification and irrigation. Several companies now offer PV/diesel packaged power systems.

One major diesel manufacturer, Hawker-Siddeley has teamed with a photovoltaic systems company, Solapak (British firm) in offering turn-key PV/diesel power systems for remote power applications. Their systems include a diesel generator, fuel storage tank, battery and system controls enclosed in a "controlled" space which is actually an air cooled shipping container. The photovoltaic array, available up to 5kW, is designed to be mounted on top of the shipping container. The use of a shipping container serves to protect equipment during transport, simplify the installation, and help control the overall quality of the operation of the system.

There are two constraints to the application of PV/diesel power systems: the cost of photovoltaics and the scarcity of publicized performance data on PV/diesel systems. The current costs of photovoltaics compared with diesel fuel, limit the use of PV/diesel power systems to daily load levels below 10-20 kWh/day depending on the site location, insolation, and load characteristics. As the cost of photovoltaics declines, the size range and number of applications will expand. Projected life-cycle comparative costs indicate that PV/diesel power system for loads above 20 kWh/day will become financially justified around a 1995 time frame.

The market reception of PV/diesel hybrid power systems for applications other than communications also depends on the performance experienced with current systems. The most critical technical factor is the performance reliability of the power control or switching equipment. Several companies offer sophisticated controllers whose operating principles have been proven on

stand-alone PV system installations. The design, operation, and guarantee of the PV/diesel power system controller performance should be carefully reviewed for this field test.

## 5.0 REVIEW OF FIELD TEST HARDWARE

A discussion of the technology of photovoltaic modules, structures, batteries, and controllers is provided in the PV Technology Reference Notebook published in April 1985. This section summarizes that discussion and describes the specific equipment component technologies to be used in this field test including ice making and diesel generators.

### 5.1 Ice Making

There are four basic ice production technologies: block, plate, flake and tube.

Block ice is the ice making technology currently used in the El Faiyum and Wadi El Raiyan area. Block ice is manufactured by immersing water filled rectangular cans into a tank of refrigerated brine. The brine, which is cooled by the refrigeration process, extracts heat from the water and produces blocks of ice within the cans. Block ice making is the most energy intensive of the ice making processes because the heat transfer must occur through the block as it solidifies. Block ice must be crushed for use in fish preservation, however it is the best form for storage and transport because the small surface to weight ratio reduces melting. It is the preferred choice for "in-home" refrigeration.

Plate ice is formed by running water over a vertical refrigerated surface. A plate of ice builds up to a specified thickness at which point it is separated from the forming surface by a defrost cycle and falls into a collection bin. Plate ice is broken into small pieces by a mechanical breaker. The thickness of ice can be varied by varying the length of the refrigeration/defrost cycle. Ice is usually produced in 10-15 mm thickness as an optimum thickness because thinner ice increases the number of cycles while thicker ice requires heat to be transferred through the ice plate and therefore progressively reduces the

ice forming rate. The advantages of plate ice are that it is a more efficient process than block ice making and ice thickness can be varied to meet specific product requirements. Plate ice as a final product can also be formed into "solid" blocks by use of commercial "block presses" to produce block ice with properties reported to be identical to block produced ice. This is a particularly important aspect for this field test because it greatly increases the capabilities of the ice plant and permits full usage of the capital equipment year-round by making "block-like" ice available for commercial sale. The principle disadvantage is that plate ice production is a cyclic process. It therefore requires that the diesel generator and battery storage be sized for the peak power requirements.

Flake ice is the most desirable form of ice for fish preservation because it has the highest surface to weight ratio. This enables the fish to be cooled rapidly avoiding spoilage. In addition, the flake thickness, usually 1.5 to 2.5 mm, will not cause physical damage to the fish. Flake ice is produced by spraying water on a refrigerated drum surface and shaving it off by a rotating blade. On some machinery, the blade is stationary and the drum rotates. The flake ice process results in a relatively stable or continuous load. Flake ice making is the most energy efficient ice production technology.

Tube ice is formed by passing water down the inside of verticle tubes which are cooled by circulated refrigerant on the outer surface. In the same fashion as plate ice, a defrost cycle is used, which cause the hollow ice tubes to slide down the forming tube where a rotating blade cuts the tube into pieces. The geometric shape of tube ice is highly desirable in the commercial beverage industry.

A reliable supply of potable water is required for ice making. For a 6 ton/day capacity ice maker, approximately 6 $m^3$/day of water or 1600 gallons/day is required. An additional amount of water is required as a heat exchanger

working fluid to extract heat from the refrigeration process. A water supply of 20 $m^3$/day is estimated[5] for condenser cooling assuming an evaporative heat exchanger is used. Although "potable" water may not be required for condenser cooling, some water treatment is usually necessary to minimize scale formation and related maintenance.

Lake water at Wadi El Raiyan is available for the ice making and condenser cooling, however, initial water quality analyses indicate that water treatment for hazardous pollutants will be necessary. An evaluation of the water quality analysis conducted during the October 1985 site visit is provided as Appendix B of the Application Review. Additional analyses have been requested and are currently being performed. For purposes of this Technology Review it is assumed that potable water is available.

Additional related design issues for the ice making equipment are the amount of ice handling and the design of the ice storage containment.

Most commercial ice makers offer an automated system of moving ice from the ice maker into the storage and finally to the end user. Mechanical screws and "ice rakes" are used. These are powered by small (2-3 hp) motors and operate on demand. They add the complexity of more moving parts to the process, but they simplify the ice handling. Of primary concern should be reliability, energy consumption and the required maintenance of any ice handling equipment.

The storage facility may or may not be cooled. Long term ice storage must be maintained below freezing because ice will tend to form into a solid mass if left too long. Ice rakes can be employed to keep ice broken up. In applications such as this field test, where it is anticipated that the ice storage will be emptied on a daily basis, a non-cooled ice storage is often used.

---

5 Based on discussions with engineering staff of BACU Refrigeration Equipment Company.

Designs should be encouraged which permit gravity flow of ice from the ice maker to the storage and minimize the need for ice handling equipment.

## 5.2 Photovoltaics

Photovoltaic modules are available worldwide. They have been proven in numerous applications and under harsh conditions. Most field experience exists with single crystalline, poly-crystalline, and ribbon technology flat plate photovoltaic modules. The term "flat plate" refers to the direct use of the sun's energy (i.e., there is no enhancement or concentration of the sun's energy). Although concentrating photovoltaic modules are available, they have limited operating experience in developing countries. In addition to crystalline silicon PV technology, the technology of amorphous silicon has received much attention over the past few years and projections are that it will someday replace all other photovoltaic technologies as the least cost option. However, for the most part, amorphous silicon is being utilized on very small applications (square centimeters in size) such as calculators and watches. All photovoltaic technologies are highly reliable, virtually 100 percent based on NASA-Lewis Research Center extensive worldwide installation experience.

## 5.3 Structures

Fixed and adjustable tilt array mounting structures are commercially available. Fixed structures are constructed of galvanized pipe, aluminum or galvanized steel angle, and wood and concrete. Adjustable tilt structures permit manual adjustment of the tilt of panels (groups of modules) or sub-arrays. Adjustable tilt structures can be designed using the same basic materials and configuration as a fixed structure. Consideration needs to be given for the operation and maintenance requirement for tilting and for wind loading specifications.

## 5.4 Batteries

Performance characteristics of batteries, such as capacity, efficiency and discharge rate capability improve as temperature goes up (cold weather is considered a more hostile environment for batteries). However, the increased performance is at the expense of lifetime. Most battery manufacturers caution against extended operation at elevated temperatures above 32°C (it should be noted that in addition to the environment, battery temperatures rise during rapid charging and discharging cycles).

The most dominant maintenance item connected with battery banks is the periodic addition of water to the electrolyte. For this reason the physical arrangement of the battery bank should be carefully considered so that this water addition can be done in a safe manner without unduly exposing maintenance workers to high currents or high voltages.

The enclosure for the batteries must be vented so that any hydrogen which is generated will not accummulate and cause an explosive hazard.

One comparatively recent innovation to reduce maintenance is the sealed battery which is especially designed for deep cycle operation such as that required for FT #6. The hydrogen and oxygen is recombined before it leaves the battery to form water. In this way water from the outside does not have to be added.

The two most common batteries used for PV applications are lead-acid and nickel cadmium. Lead-acid batteries are the preferred choice over nickel-cadmium primarily because of lower cost. Lead-acid batteries are sometimes referred to by the type of electrode used; for example, lead-antimony, pure lead, or lead-calcium. Lead-acid batteries are manufactured in sealed and vented configurations. For remote applications and sandy areas, sealed batteries are often preferred over vented batteries because the loss of electrolyte and

potential for contamination is greatly reduced. Sealed batteries are however more expensive than vented batteries. Vented batteries can be fitted with "recombination caps" which greatly reduce the loss of electrolyte due to overcharging and evaporation. The decision parameters for selecting a battery system should be life cycle cost, maintenance, and reliability. It is recommended that lead acid, sealed or vented batteries be selected for this application. Vented batteries must contain provisions for minimizing electrolyte and water loss.

## 5.5 Power System Controller

The power system controller (PSC) is defined as the equipment components which determine the source of power and its level relative to the load demand. The power sources in this application are the PV array the diesel generator and the battery. The loads are predominantly ice making equipment however, the battery can behave as a power source or as a load. The PSC may also contain a PV array maximum power tracker, voltage regulators and other power regulation equipment, however, our definition is limited to considering the PSC by its primary function of power source management and regulation. The PSC may provide for the following functions depending on the sophistication level of the design.

1. Efficient management of PV array, PV/diesel and battery power.
2. Regulation of charge and discharge rates of the battery system.
3. Protection of battery system against low and high states of charge.
4. Diesel start and stop functions.

As described in Section 4, there are two types of PSC commercially available; one which can optimize the operation of the power system and battery toward minimizing the total cost of delivered energy, and one which simply starts and stops the diesel generator as a function of battery voltage. The design, testing and guarantee of the power system controller is an important area for evaluation in this field test.

## 5.6 Diesel Generators

Self-contained diesel engine/generator sets for remote AC power are commercially available over a wide range of sizes from many manufacturers. Diesel/generator sets which produce DC power are also commercially available but generally only on a special order basis. A method of obtaining DC power is to use a conventional AC diesel generator in conjunction with an AC to DC rectifier. A listing of companies which supply DC diesel generators and AC to DC rectifiers is provided in Section 6 of this Technology Review.

The operating efficiency of a diesel/generator set refers to the fuel-to-electricity conversion efficiency. Typically it is 30% for new engines operating at rated load. It may drop to as low as 15% under partial load and/or poor maintenance practices.

The diesel/generator set requires that a fuel storage tank be specified together with a full range of protection and monitoring equipment.

## 5.7 Inverters/Rectifiers

The use of an inverter in this application would be to convert DC power from the PV/battery side of the power system to AC power compatable with the load and with the diesel engine generator. A rectifier rather than an inverter is required if the loads are to be DC. A rectifier will convert AC produced power from a conventional diesel/generator to DC power for DC load operation and battery charging.

The performance record of stand-alone inverters in developing countries has been poor. In addition, there are efficiency penalties and added costs for their use. The alternative system, DC power and DC loads, would require either an integrated or separate rectifier in the form of a "battery charger." There are a number of suppliers of commercial inverters and rectifiers. A selection is provided in Section 6 and 7.

## 5.8 System Monitoring and Instrumentation

There are two levels of instrumentation required for this field test: Monitoring and Troubleshooting/Repair. The purposes of each level of instrumentation are as follows:

| Level | Purpose |
|---|---|
| Monitoring | To provide system and component performance information for evaluating long term technical, financial and institution performance. |
| Troubleshooting/ Repair | To determine system and component performance on site, over short intervals, in sufficient detail to identify faults, make repairs or perform modifications. |

It is recommended that monitoring instrumentation be automated for data collection and transmission (by physical or automatic means) and that the troubleshooting/repair level of instrumentation be provided by procuring portable site usable instrumentation. Accessible locations in the system wiring must be part of the design of the system to provide for IV curve tracing of the array and subarrays and similar levels of testing and evaluation.

A specific instrumentation data requirements list was prepared following a sub-contractors meeting held on December 10, 1985, at Meridian Corporation. The list is provided as Appendix C as the recommended performance data requirements for this field test.

## 6.0 MANUFACTURER PROFILES

A brief overview of the major manufacturers of PV systems, ice making equipment, batteries, inverters, controllers and diesel generation equipment is provided in this section. Also provided are a representative selection of integrating contractors that have PV system application experience. PV related product literature from these companies is included in the Technology Reference Notebook (previously submitted under Task 2.1.1). A selection of product specifications are provided in Section 7.

### 6.1 Photovoltaic Module Manufacturers

ARCO Solar, Inc.
21011 Warner Center Lane
Woodland Hills, CA
800-ARCO-SOL

ARCO is the world's leading volume manufacturer of photovoltaics. ARCO Solar has a world-wide distribution network.

ARCO has built its photovoltaic business by manufacturing single-crystalline modules. Typical efficiencies (using the entire module surface area) are about 10 percent. Recently, ARCO has claimed a significant increase in efficiency, to 12.5% by an improved manufacturing process and a better module packing factor. Cells are made using screen-printed silver metallization. Encapsulant is ethylene vinyl acetate (EVA) with a tough white tedlar backing.

ARCO modules have passed the Jet Propulsion Laboratory (JPL)-sponsored Block V environmental tests and some models have passed the Underwriters Laboratory tests for certification[6]. Standard modules are available in 30, 40, and 43 watt sizes. ARCO is the only company, world-wide, to offer 10 year module performance warranty.

---

6 Summary specifications of the JPL tests are provided in Appendix B.

Solarex Corporation
1335 Piccard Drive
Rockville, Maryland 20850
301-948-0202

Solarex is the second largest PV manufacturer (by sales volume) in the world and has modules installed world-wide. Solarex advertizes itself as a systems company and unlike ARCO has traditionally bid directly on PV system projects around the world rather than through representative companies.

Solarex uses polycrystalline silicon for their standard modules. This type of silicon is made by a cast process in which the silicon is cast in a near-square shape. Proponents of this type of technology maintain that this process is inherently less expensive and has less waste than single crystal silicon because less silicon is sawed off the ingot. Solarex module efficiencies are typically about 9-10 percent on a module area basis though modules for selected projects have achieved nearly 12 percent. Solarex modules have also passed the JPL-Block V environmental tests. Standard Solarex modules come in 36, 42, 46, and 140 watt sizes. Encapsulant is EVA with a tough white tedlar backing.

Mobil Solar Energy Corporation
16 Hickory Drive
Waltham, Massachusetts 02254
617-890-1180

Mobil Solar is the leading producer of "ribbon" silicon photovoltaic modules in the U.S.

Mobil Solar modules are made from "ribbon" silicon, which refers to the way it is manufactured. Proponents of this process feel that it is a very good approach toward manufacturing low cost silicon solar cells because it avoids the losses associated with sawing silicon made from single crystal or polycrystalline cast silicon ingots. The silicon manufacturing process is being developed to make it more efficient and less costly. Typical module efficiencies are of the order of 8.4 percent.

Modules are manufactured in 40 and 180 watt modules. They have also passed the JPL - Block V environmental tests.

Mobil has made a concentrated effort to develop a market in the Middle East. There are two functioning desalination installations in Jeddah, Saudi Arabia and Doha, Qatar which are powered by Mobil Solar modules. Additionally there is a street lighting project in Riyadh, Saudi Arabia.

Mobil has long maintained the policy to perfect the ribbon technology before going into full volume production. Mobil has however commercially offered modules for several years. Mobil has sufficient field performance experience to support its guarantees for the reliability and performance of its "ribbon" technology.

<u>Solavolt International</u>
P.O. Box 2934
Phoenix, Arizona 85062
Telex 249901

Solavolt modules are polycrystalline silicon. Their prime module for sale is one which produces 40 watts at standard conditions. It has passed the JPL - Block V environmental tests.

Solavolt is a joint venture formed from the former photovoltaics units of Motorola and Shell Oil company. Solavolt is reputed to be working on a proprietary process known as the "ribbon-to-ribbon" technology, which is yet to be introduced commercially. Solavolt currently uses polycrystalline modules for its commercial projects in the near future.

Solavolt has been very active in setting up distributorships world-wide. Solavolt (and its predecessor Motorola) have modules installed in many locations including Gabon, Africa, pumping/irrigation sites in the U.S. southwest, and the Southwest Residential Experiment Station in New Mexico.

## 6.2 Ice Making Equipment Companies

North Star Ice Equipment Corporation
4511 Shilshole Avenue N.W.
Seattle, Washington 98107
206-784-4500

North Star makes flake ice manufacturing equipment. The company has been in operation since 1940 and operates in more than 86 countries. North Star claims that more industrial flake ice is made and distributed with North Star equipment than with any other line of equipment in the world. North Star sells its equipment on a non-exclusive basis through refrigeration contractors or firms with strong backgrounds in the field of industrial refrigeration.

North Star makes ice making equipment in capacities ranging from 3 tons per day to more than 400 tons per day. North Star offers ice makers, storage bins, ice rakes and packaged ice plants. North Star flake ice making equipment is installed in a cement plant in Alexandria, Egypt and efforts are being made by the company to introduce equipment throughout the middle east.

Turbo Refrigeration Company
P.O. Box 386
Denton, Texas 76201
817-387-4301

Turbo is a leading plate ice making equipment manufacturing company in the U.S. and around the world. Turbo has been in business since 1952 and offers plate ice makers, ice storage systems, block ice makers and related products. Through an associated company, Turbo Marine Corporation (TMC), a diesel powered 5 ton/day capacity packaged ice making plant is available. Turbo also offers a "block ice maker" which makes block ice with the plate ice and waste products produced from their standard plate ice making equipment.

Turbo is represented by distributors and engineering companies in the ice making industry.

Henry Vogt Machine Company

P.O. Box 1918
Louisville, Kentucky 40201
502-634-1511

Vogt makes tube-ice making machinery. Vogt has been in business since 1880. Machinery ice making capacity ranges from 3 ton per day to 80 ton per day. Vogt has installations worldwide and is represented by dedicated distributors, refrigeration equipment supply and engineering companies throughout the U.S. Vogt offers design, installation and servicing for their equipment.

BACU Refrigeration Supply Company
35 High Street
Poughkeepsie, New York 12601
914-454-3500

BACU is a refrigeration engineering and supply company representing Turbo Refrigeration Company for ice making and other companies for related equipment. BACU also deals in water treatment equipment as related to refrigeration and ice making.

Vivian of St. Louis, Inc.
1525 Ocello Drive
Fenton, Missouri 63026
314-343-1220

Vivian is a refrigeration system and equipment supply company which produces its own ice making equipment and also represents other manufacturers such as Turbo and Vogt. Vivian handles installation and servicing and also conducts a training course entitled "Repair and Maintenance Seminar" in February each year which is highly recommended by refrigeration professionals.

## 6.3 Battery Manufacturers

GNB Batteries Inc.
2010 Cabot Boulevard West
Longhorne, Pennsylvania 19047
215-750-2600

GNB Battery Company is a well established leader in the manufacture of industrial grade, deep cycle batteries. GNB manufacturers the "Absolyte"

battery: a sealed, maintenance free, deep cycle lead-acid battery using recombination battery technology. The Absolyte battery has been well received by PV system companies for use in PV power systems in remote harsh environments. Sealed batteries in general are more expensive than vented batteries. The initial capital cost, in dollars per kilowatt-hour of rated capacity, for an Absolyte is approximately fifty percent more than an equivalent rated vented battery.

Exide
101 Gibraltar Road
Horsham, Pennsylvania 19044
215-674-9500

Exide is another reputable manufacturer of lead-acid batteries. They have been used in numerous photovoltaic system applications around the world. The principle battery model used in photovoltaic systems is a vented, deep cycle lead-acid battery. Exide offers gas recombination caps to reduce electrolyte and water loss, minimize contamination and improve operating safety.

Allied C&D Power Systems
3043 Walton Road
Plymouth Meeting, Pennsylvania 19462

C & D is the largest manufacturer of industrial batteries, chargers and associated power equipment in the world, according to their company literature. C & D states that they manufacture fully integrated power systems. C & D provides installation service and maintenance for its energy systems through more than 75 sales and service organizations in the U.S. and Canada.

Chloride Group PLV
P.O. Box 305
North Haven, Connecticut 06473
203-777-0037

Chloride is a leading manufacturer of lead-acid batteries. A London based company, Chloride has distributors around the world. A manufacturing plant is located near Cairo, Egypt.

Chloride makes sealed and vented batteries. The POWERSTORE model battery is a sealed, maintenance free recombination electrolyte battery. Chloride distributor Simpler Solar Systems in Florida indicates that the POWERSTORE is available in cell sizes up to 2 volts and 240 ampere-hours at a 20 hour discharge rate. Larger lead-acid vented batteries are available up to 1000 amp-hours.

## 6.4 Inverters/Rectifiers

Abacus Controls Inc.
P.O. Box 893
Somerville, NJ 08876
201-526-6010

Abacus is a major supplier of inverters to the photovoltaic industry. Solarex has used Abacus inverters on several stand-alone photovoltaic systems installed in South America and on one relevant project at East Oweinat, Egypt. Abacus makes inverters in a number of sizes capable of being used in this field test (35 kW total capacity).

Helionetics Inc.
17312 Eastman Street
Irvine, California 92714
800-421-7915

Helionetics is a manufacturer of electronic power-conversion equipment and systems for military and commerical use. The DECC division of Helionetics designs and manufacturers power conditioning and conversion equipment (inverters) for the PV industry. Helionetics has been in business since 1970.

Helionetics supplied two 500 kW inverters to ARCO for use in the 1 - MW PV array at Hesperia, California built for Southern California Edison in 1982. Helionetics makes commercial stand-alone inverters up to 40 kW.

Heart Interface Corporation
1626 S. 341st Place
Federal Way, Washington 98003
800-732-3201

Heart Interface is a manufacturer of small inverters for remote power

commerical and private applications. Heart Interface makes stand-alone inverters up to 5 kW capacity.

Best Energy Systems Inc.
P.O. Box 280
Necedah, Wisconsin 54646

Best is another company that manufactures stand-alone inverters. Inverters are commercially offered in sizes up to 10 kW for stand-alone, hybrid power systems and utility interface.

NOVA Electric Manufactering Company
263 Hillside Avenue
Nutley, New Jersey 07110
201-661-3434

NOVA is an electronics company, founded in 1966, which designs and manufactures inverters and rectifiers. NOVA products all feature modular designs with easily replaceable subassemblies. This results in a MTTR (Mean Time to Repair) of approximately 30 minutes. NOVA claims that its power conditioning equipment achieves better than 20,000 hours as a Mean Time Between Failure. The PV power system at Sadat City, Egypt, uses a 10 kW NOVA inverter and reports good operational performance.

## 6.5 Controllers

Chronar/Tri-Solar
10 DeAngelo Drive
Bedford, Massachusetts 01730
617-275-1200

Chronar/Tri-Solar Company is a company formed by the merging of Chronar and Tri-Solar. Chronar designs and sells manufacturing plants for the production of amorphous silicon technology photovoltaic modules. Tri-Solar is an established PV systems company specializing in PV pumping systems and controller development. Chronar/Tri-Solar manufacturers a "smart" microprocessor controlled programmable controller, developed under contract to NASA-Lewis Research Center (U.S. National Aeronautics and Space Administration Lewis Research Center), which may be used for the operation and monitoring of PV/diesel power systems. The controller

is microprocessor based and includes power tracking. Field experience with this controller is limited but approximately 20 were installed in a middle-eastern country in 1985. Performance data relative to this equipment will be important to evaluating similar equipment that may be offered.

Solarex Corporation
1335 Piccard Drive
Rockville, Maryland 20850
301-948-0202

Solarex, as a PV systems company, designs, manufacturers and sells PV system controllers. Solarex offers a limited function series regulator, SR model and a full function controller identified as the ACR model. The ACR model controller has been used in numerous PV applications around the world ranging from health centers to irrigation systems. Development of the ACR controller has been continuous since the first units were manufactured around 1981. The standard ACR controller can be customized with voltage sensing relays which can be used for starting a diesel generator, sounding an alarm or performing other functions. The ACR controller is regarded as a "basic" controller which can be modified for use as a power system controller for use in PV/diesel power systems.

Balance of Systems Specialists (BOSS)
7745 East Redfield Road
Scottsdale, Arizona 85260
602-948-9809

BOSS designs and manufactures PV system controllers. BOSS offers full engineering and support services and can customize its controllers to meet the requirements of this project.

## 6.6 Diesel Generator Manufacturers

Onan
1400 73rd Avenue, NW
Minneapolis, Minnesota 55432
612-574-5000

Onan is a principle manufacturer and distributor of gasoline and diesel engine generators. Diesel generator packaged power systems are available in sizes ranging from 3 to 1000 kW and 50 or 60 Hertz AC.

Allis-Chalmers
P.O. Box 1565
Harvey, Illinois 60426
312-339-3300

Allis-Chalmers is a reputable established manufacturer of diesel engines and generators. Standard units are available in sizes ranging from 10 to 300 kW, 50 or 60 Hz. Allis-Chalmers offers limited warrantees of up to 3 years or 10800 hours. A two year or 3600 hour warrantee is offered on "continuous" duty diesel applications covering the electrical systems and the diesel engine.

Caterpillar (Representative)
Alban Engine Company
1401 Cherry Hill Road
Baltimore, Maryland 21225
301-355-6700

Caterpillar is a world renown manufacturer of medium to large diesel engine generators. They have a strong technical and parts support network throughout the world. Packaged power systems are available in sizes starting at 50 kW.

Lister Diesels Inc. (Representative)
555 E. 56 Highway
Olathe, Kansas 66061
913-764-3512

Lister is a division of Hawker-Siddeley, an English company incorporated in the U.S. Lister makes packaged diesel generator power systems in sizes ranging from 3 to 130 kW. Lister/Hawker-Siddeley supplies electrical and mechanical equipment and service for their equipment throughout the world.

Kurtz and Root Company
P.O. Box 1119
Appleton, Wisconsin 54912
414-739-9441

Kurtz and Root Company is a manufacturer of AC and DC generators, DC motors, motor generator sets and engine generator sets. Kurtz and Root offer standard AC generators in sizes from 10 - 250 kW. They also offer DC generators on a customized basis, matched to the load and the drive engine.

Kato Engineering
P.O. Box 47
Mankato, Minnesota 56001
507-625-4011

Kato engineering manufacturers AC and DC generators in sizes form 1 kW to 3 megawatts. Kato was contacted about the availability of DC generators for the PV/diesel power system. Delivery would be 150 - 180 days.

## 6.7 Integrating Contractors

In an effort to identify possible contracting companies who would act as the prime (or integrating contractor) a number of organizations are listed below. These companies have acted as the integrating contractors on photovoltaic projects in the past.

Chronar/Tri-Solar
10 DeAngelo Drive
Bedford, Massachusetts 01730
617-275-1200

Tri-Solar acquired by Chronar in 1985 has been an integrating contractor since its inception. Chronar/Tri-Solar has performed as the integrating contractor on many international PV-powered projects. Two of the most notable application areas are PV pumping and village electrification. Chronar/Tri-Solar is currently involved in a major PV lighting systems project in Saudi Arabia.

BDM International Inc.
7915 Jones Branch Drive
McLean, Virginia 22043
703-821-5000

BDM's renewable energy division is based in Albuquerque, New Mexico. They have been the integrating contractor for a number of projects both in the United States and internationally. These include:

- A one Megawatt grid interactive, tracking flat plate PV power system at Hisperia, California
- A 35 Kw installation at McClellan Air Force Base near Sacramento, California
- A demonstration installation in Taipai
- A residential demonstration project at the Southwest Residential Experiments station in Las Cruces, New Mexico

Hughes Aircraft Company
P.O. Box 9399
Long Beach, California 90810
213-513-3487

Hughes is based in Long Beach, California and over a period of about five years has been the integrating contractor for a number of PV-powered installations. These include:

- Communications and village power applications in Indonesia and the Marshall Islands for NASA-Lewis Research Center.
- Design studies and a demonstration project to illustrate low-cost construction methods for Sandia National Laboratories
- Acted as the integrating contractor for a number of remote power applications for the U.S. Navy at China Lake, California.
- Georgetown University intercultural Center, a 320 kW Grid-interactive installation in which the PV models are integrated into the roof of the building.

Integrated Power Corporation
7624 Airpack Road
Gaithersburg, Maryland 20879

Integrated Power is based in Gaithersburg, Maryland. It was formed in 1983 and specializes in engineering and installation of stand-alone PV-battery systems. They have also done significant development engineering of PV/diesel

hybrid power systems.

Mobil Solar Power Corporation
16 Hickory Drive
Waltham, Massachusetts 02254
617-890-1180

Mobil Solar is based in Waltham, MA, near Boston. Mobil has had a systems integration capability since about 1981. Mobil has a representative in Saudi Arabia who is an engineer specializing in PV systems design and applications.

Mobil has concentrated in developing PV-powered desalination. Two installations have been built and are operating --one in Jeddah, Saudi Arabia and one in Qatar. In addition, Mobil has a cooperative venture with the University of New South Wales in Australia for a brackish water desalting experimental program. Other installations include:

- Street lighting project in Dubai, United Arab Emerates
- Impact 2000, a PV-powered residence demonstration project in the Boston area designed to publicize PV.

Simpler Solar Systems Inc.
1217 Walton Drive
Tallahassee, Florida 32312
904-385-5686

Simpler Solar Systems is based in Tallahassee, Florida. It has been in business as a company since 1980. The company designs, tests, and installs PV-powered systems and has specialized in stand-alone systems in remote areas. Projects include:

- Medical Facility (Bulape Hospital) in Zaire
- PV powered water pumping for irrigation in the Bahamas
- Recreational homes in Florida
- Projects for church-sponsored groups in Caribbean

Solarex Corporation
1335 Piccard Drive
Rockville, Maryland 20850
301-948-0202

Solarex is based in Rockville, Maryland and has been integrating systems primarily with its own modules for about ten years. Projects include:

- The General Petroleum Company project in East Oweinat
- PV-powered portable communications units for the Egyptian military in Egypt
- A grid-independent solar powered manufacturing facility in Frederick, Maryland.
- A 22 kW stand-alone rural hospital power system in Guyana, South America.

Solarex has a distributor in Cairo.

Solavolt
P.O. Box 2934
Phoenix, Arizona 85062
Telex 249901

Solavolt is another photovoltaic company which performs as a "systems" company. Solavolt has participated as a system integrating contractor on a number of projects.

- A NASA-Lewis Research Center project for water pumping and village power in Gabon, Africa
- Numerous irrigation and other pumping applications around the world

Stone and Webster Incorporated
1875 Eye Street, N.W.
Washington, DC 20006
202-466-7415

Stone and Webster, based in Boston, MA, is a large international construction, architectural and engineering company. It has a group within the company which is very active in photovoltaics engineering projects. Included in the projects it has engineered are:

- Beverly, MA High School grid-interactive 100KW installation
- 50 kW grid interactive demonstration project for Virginia Power (a utility) near Richmond, Virginia
- A 300 kW grid interactive installation for Austin Power and Light in Austin, Texas (under conot reaction in 1986)

## 7.0 EQUIPMENT/PRODUCT SPECIFICATIONS

A selected number of components and basic specifications are provided in Figure 7-1.

Appendix A contains a selection of manufacturer brochures for ice making equipment and diesel generators. These data on equipment are provided to show representative equipment specifications that may be received from bidders in response to the RFP. This listing of equipment is not intended to support any manufacturers or products.

FIGURE 7-1 EQUIPMENT DATA BASE

| Component | Manufacturer | Equipment Offered | Operating Efficiency | Other Relevant Specifications | Notes |
|---|---|---|---|---|---|
| Ice Making Machinery | North Star Ice Equipment Corp., Seattle, WA "Flake Ice" | M10WC 7.5 (2.7 ton/day) M10WC15 (3.7 ton/day) M10AC15 (3.7 ton/day) M20WC30 (8.6 ton/day) | 55-62 kwh/ton (COP 1.8, based on 60 kwh/ton, 75°F water) | o Continuous power demand relative to other ice making technologies<br>o Ice thickness 1.5-2.5 mm<br>o Price/ton-day range: ($6800-11600) | o High surface to weight ratio<br>o Commonly used in fish processing<br>o Egyptian installations in Alexandria - chemical industry |
| | Turbo Refrigerating Company, Denton, Texas "Plate Ice" | CF2R (1ton/day) CF4R (2ton/day) CF6R (3ton/day) CF12R(6ton/day) | 75-85 kwh/ton (COP 1.4, 80kwh/ton, based on 75° F water) | o Cyclic loading<br>o Block ice making capability<br>o Variable ice thickness<br>o Price/ton-day range: ($4700-11600) | o Middle-east experience |
| | Henry Vogt Machine Co., Louisville, KY "Tube-Ice" | Mod. 6000 (2.3 tons/day) Mod. 9000 (3.3 tons/day) | 72 kwh/ton<br>96 kwh/ton (COP 1.3, based on 84 kwh/ton, 75°F water) | o Cyclic loading<br>o Crushed ice making capability | o High quality ice good clarity |
| | BACU Refrigeration Supply Co. Poughkeepsie, NY | Manufacturer Representative for Turbo | | o Design, service, install services<br>o Water Treatment Equipment | o 7000/ton (10 ton/day capacity) |
| | Vivian of St. Louis Fenton, Missouri | Manufacturer representative for Turbo, Vogt and others. | | o Offers training program in design, operated and service in February at plant. | |

FIGURE 7-1 EQUIPMENT DATA BASE (Continued)

| Component | Manufacturer | Equipment Offered | Operating Efficiency | Other Relevant Specifications | Notes |
|---|---|---|---|---|---|
| Photovoltaic Modules | ARCO Solar, Inc. Chatsworth, CA | M53, 43 watts 17.3 Vpp M63, 30 watts 14.8 Vpp M73, 40 watts 164Vpp | 11.5% | 10 year performance guarantee, ± 10% | o Single crystal silicon o Largest manufacturer in the world o American Univ., Sadat City project o Egyptian representative |
| | Solarex Corp. Rockville, MD | SX-146, 47 watts 18 Vpp SX-42, 42W 16.5Vpp PL-300, 135W 17.5Vpp | 9.9% | 5 year min. performance guarantee | o Polycrystalline silicon o Second largest manufacturer in the U.S. o Egyptian representative o East Oweinat 10kw project |
| | Solavolt International Phoenix, AZ | MSVN-4010 MSP43E, 36W 18.8 Vpp | 8.7% | | o Uses Wacker and Crystal Systems polycrystal silicon o Gabon, West Africa community power system project |
| | Mobil Solar Power Corp. Waltham, MA | Ra-40 Ra-180, 180 watts-48volt | 8.4% | | o Ribbon technology o Numerous installations in Arab countries |

FIGURE 7-1 EQUIPMENT DATA BASE (Continued)

| Component | Manufacturer | Equipment Offered | Operating Efficiency | Other Relevant Specifications | Notes |
|---|---|---|---|---|---|
| Photovoltaic Modules (cont.) | Chronar/Tri Solar Princeton, NJ | | <5% | Development modules | o Amorphous silicon modules |
| Battery Storage | GNB-Batteries, Inc. "Absolyte" Longhorne, PA | 35A21-397 AH<br>45A21-510 AH<br>75A21-850 AH<br>(12 hour discharge rate) | 65-80% | 50% DOD, 2800 cycles | o Recombination battery technology<br>o Egyptian distributor |
| | EXIDE Worminster, PA | 6E 120-13-750AH<br>3E-120-27-1652AH | 65-80% | | o Recombination caps offered<br>o East Oweinat project |
| | Allied C&D Plymouth Meeting, PA | CP75E13-450 AH<br>CP75-25-900 AH<br>CP125-1500 AH | 65-80% | Metallic casing | |
| | Chloride London, Eng. | 6V-720 AH | 65-80% | Special battery design for PV applications | o American and Egyptian distributors |
| Power System Controller | Chronar/Tri-Solar Bedford, MA | Microprocessor Based Controller | 92-97% | Series regulated ampere hour recording battery SOC | o 23 placed in service 1985, Saudi Arabia<br>o "Smart" controller |
| | Solarex Rockville, MD | ACR-6, modified | 90-95% | Shunt regulated voltage sensing battery SOC | o Primarily PV battery controller but can be equiped with diesel remote start relay. |

FIGURE 7-1 EQUIPMENT DATA BASE (Continued)

| Component | Manufacturer | Equipment Offered | Operating Efficiency | Other Relevant Specifications | Notes |
|---|---|---|---|---|---|
| | BOSS<br>Scottsdale, AZ | Modular units<br>Customized units | 90-95% | No off-the-shelf models available | o Services a wide variety of markets in U.S. |
| Inverters | Abacus<br>Somerville, NJ | 743C-3-200<br>783C-4-200 | 90% | | o Inverters for GPC E. Oweinat installation |
| | Helionetics<br>Irvine, CA | Inverters<br>61300-3500W<br>61340-1600 KVA | | 2.5-40 KVA units in stock | |
| | Heart Interface<br>Federal Way, WA | Inverters | 92-95% | 300-5000 watt inverters in standard product line | |
| | BEST Energy Systems<br>Necedah, WI | M Series<br>M 120-6000<br>M 120-12000 | 90% | Load demand switch engine-6en set start transfer switch | o Wide experience in variety of applications<br>o Standard models up to 12 kW capacity. |
| | NOVA Electric<br>Nutley, NJ | 3.7 KVA<br>Inverter 240<br>VDC Input | 89%<br>(FOB) | 50 Hz, sinewave, 3 phase | o Also supplies rectifiers<br>o Egypt experience: Sadat City. 10 KVA inverter |
| Diesel Gensets | Onan<br>Minneapolis, MN | 25DL6-25KW<br>30DL6-30KW | .40 liters/kwh<br>(23% efficient)<br>.32 liters/<br>(29% efficient) | | |

FIGURE 7-1 EQUIPMENT DATA BASE (Continued)

| Component | Manufacturer | Equipment Offered | Operating Efficiency | Other Relevant Specifications | Notes |
|---|---|---|---|---|---|
| | Allis-Chalmers Harvey, IL | AC6 25 | 0.34 ltrs. kwhr (27% efficient) | 5 yr.-1500 hr warranty | o Standard Model prices, FOB factory<br>o Large range of capability |
| | Caterpillar Peoria, IL | Model 3304 NA 50 KW | 0.30 liters/ kwh (31% effic.) | Trailer or skid mounted | o World-wide tribution & s vice reps. |
| | Lister, England | HR-3-25kw<br>HL-4-34kW | | Air-cooled engines on some models | o American distr. Witchita, Kansas |
| D-C Generator | Kato Engineering Mankato, MN | 20 kw-250V output<br>25 kw-250V output<br>30 kw-250V output | | | |
| | Kurz & Root Appleton, WI | Custom jobs | | | No recent experience |

## 8.0 PV/DIESEL RELEVANT PROJECTS

There are very few applications of PV/diesel power systems in sizes similar to that proposed for this field test. Available details on some similarly sized applications are provided in this section.

Natural Bridges National Monument, Utah

A photovoltaic array and diesel power system was designed, installed and put in operation at Natural Bridges National Monument in 1981. The system consisted of 100 kW of photovoltaic array, 600 kWh of battery storage capacity, an inverter and two 40 kW diesel generators. The diesel generator is designed to provide backup power to the load and to suppliment the array/battery energy output. The diesel generator also provides for periodic battery equalization, using a battery charger. The battery is cycled daily, charged from the PV array and discharged into the load through the main inverter. Figure 8-1 is a block diagram of the system conceptual design.

An automated microprocessor control system was programmed to start the diesel at specified intervals for battery equalization. Battery charging and voltage control were accomplished by array shedding. Maximum power tracking control of the array was not utilized because the battery storage capacity was large enough to maintain the array at reasonably efficient voltage and current levels. Additionally, the added cost and complexity of maximum power tracking were not justified (Note 1981 time period of design).

ARCO, Motorola and Spectrolab PV modules, and C & D batteries were used. Problems were experienced with some PV modules and the inverter. PV module failures involved hot spots, shorting and open circuiting of array strings and similar problems related to early module designs at that time. Inverter problems consisted primarily of blown fuses due to surge currents by the loads. Since the time of this project, Motorola and Spectrolab have left the commercial photovoltaic business.

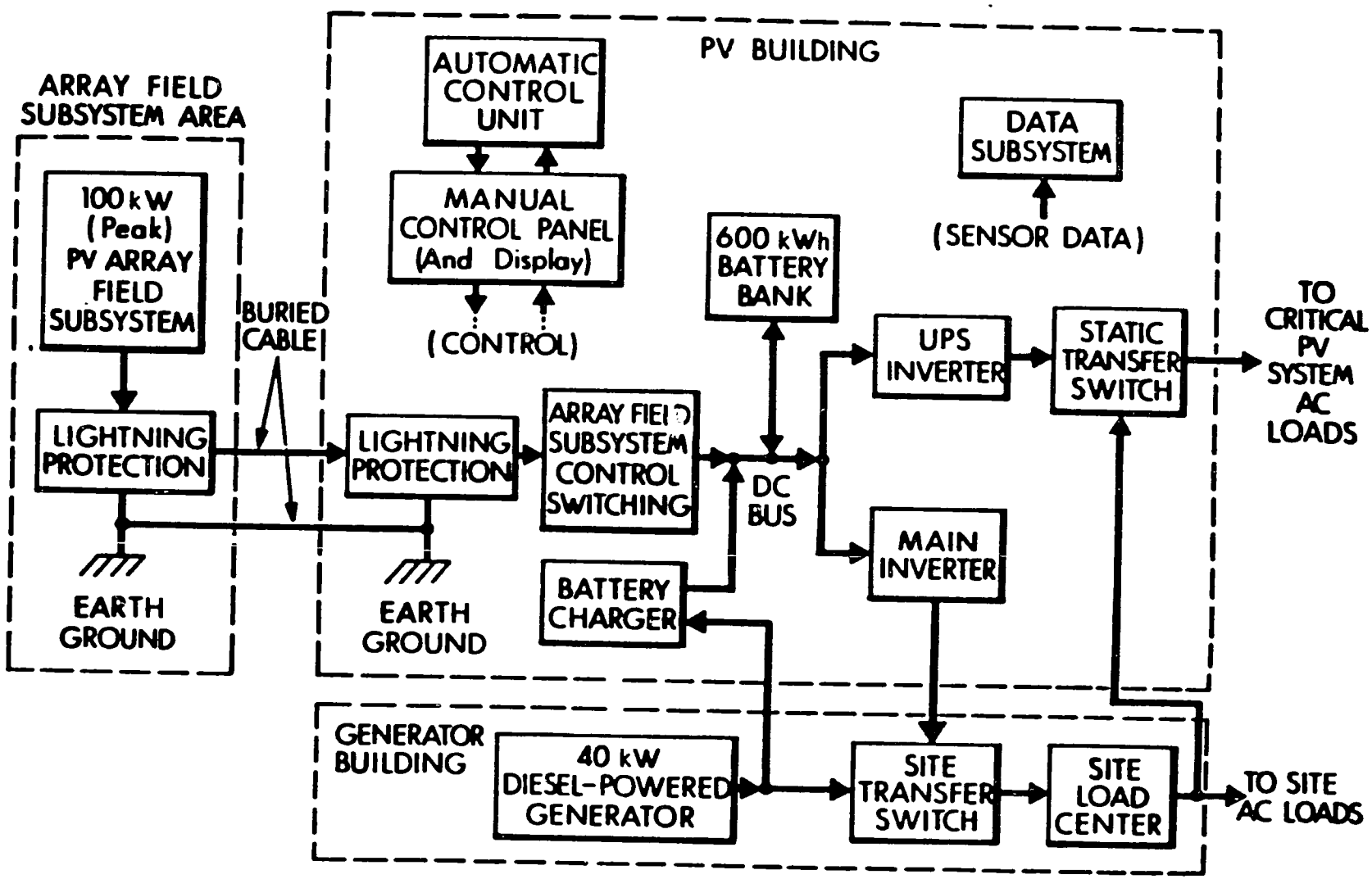



Figure 8-1. **BLOCK DIAGRAM — NATURAL BRIDGES NATIONAL MONUMENT PHOTOVOLTAIC POWER SYSTEM**

32 PV/Diesel Hybrid Power Systems, The Zambia, (confidential)

A request for proposals was recently issued by Nippon Electric Company of Japan for 32 PV power systems and related control equipment to power micro-wave repeater stations in Zambia, Africa. PV power systems are required to be retro-fitted to existing 12.5 kVA diesel generators at each micro-wave repeater stations. The continuous daily loads range from 3.5 kWh/day to 30 kWh/day at the locations. Operating difficulties with the diesels such as unreliable fuel delivery and high levels of maintenance dictated that PV be utilized as a primary energy supply.

Integrated Power Incorporated has produced a hardware and software design to integrate the PV array and diesel generator at the sites (Figure 8-2). The design is based on unattended system operation and therefore reduces diesel maintenance from a weekly basis to every six months. The power system controller design is microprocessor based and provides for regular cycling of the diesels, battery charge equalization and control, and efficient management of diesel and PV energy sources and battery system to achieve maximum life.

Installation of this equipment is expected to occur in 1986.

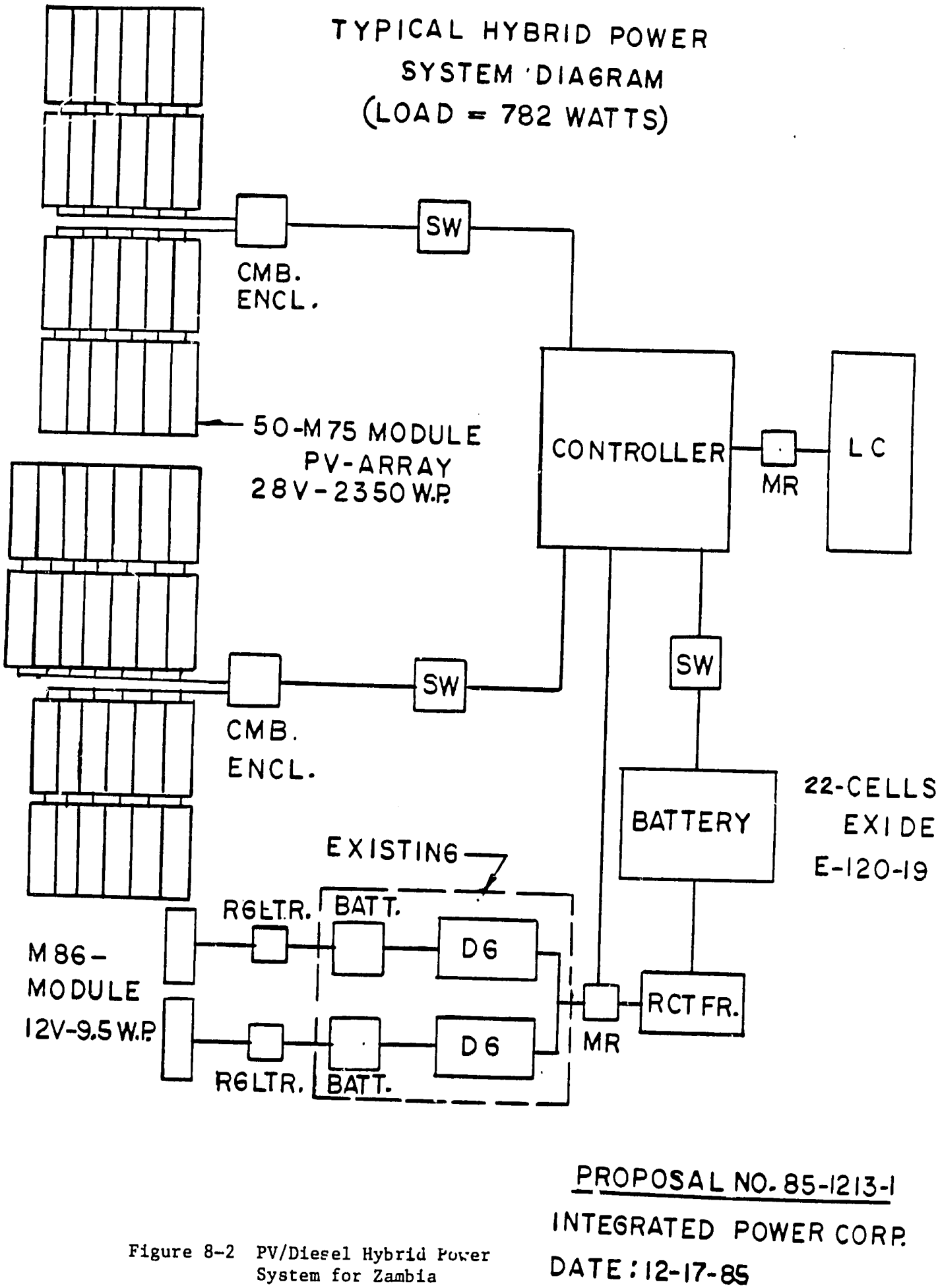



Figure 8-2 PV/Diesel Hybrid Power System for Zambia

## 3 PV-Diesel Hybrid Power Systems - Highway Maintenance Facilities

Photron, of Willits, CA, is completing work on three PV-diesel electric generating systems for the California Department of Transportation (CalTrans). The project involves the design, installation and maintenance of an advanced series of stand-alone hybrid PV power systems for remote highway maintenance facilities.

Each of the three systems is intended to provide 100% of the electricity and 90% of the thermal energy need of the maintenance facilities. The designs include a total of 90 kilowatts of Arco Solar's new large-scale "integrated panels," which measure 10 x 17.5 feet and have a peak output of over 2kW each. DC power from the PV-diesel systems is stored in batteries and then converted to AC by large inverters. Waste heat from the diesel generators will be recovered and stored on-site for space conditioning and domestic hot water. The PV array structure consists of passive single-axis tracking mounts made by Robbins Engineering.

The system incorporates an advanced microprocessor for the control and monitoring of all operating parameters. Fifty channels of information are logged and linked to computers by telephone, permiting remote monitoring and operation of the systems.

This commercial project was made possible in part because of U.S. State and Federal Business Energy and Investment Tax Credits. Photron reports that they have calculated that systems of this scale can be financed through conventional means without tax credits when 12% efficient PV modules are available in quantity, at approximately $3.00/Wp (in 1985 dollars). This should occur about 1988-1990.

## 9.0 CONCLUSION

Photovoltaics for ice making in Egypt involves the use of four proven technologies; ice making, diesel generators, battery, and photovoltaics. The integration of the power technologies of photovoltaics, diesel generators and batteries as a hybrid power system offers the potential for a useful reliable remote power system for Egypt which can be replicated to power loads such as ice making, communications and village electrification.

The application experience with PV/diesel power systems is very limited. However, it is expected to increase worldwide over the next 5 to 10 years as the price of photovoltaics drops. Several manufacturers now offer or are developing equipment products for PV/diesel hybrid power systems.

The most critical technical areas for this field test are the basic electrical design of the system, AC or DC, and the reliable and efficient performance of the power control system. There are commercial equipment available in these technical areas but careful review needs to occur determine reliability risks, maintenance and replicability issues.

Finally, the performance of PV/diesel hybrid power systems for use in Egypt can only be evaluated through the design, installation and testing of a PV/diesel power system in Egypt.

# BIBLIOGRAPHY

Conversations with Paul Maycock, Photovoltaic Energy Systems, Inc., Nov. 1985.

Conversations with various engineers at BACU Refrigeration Equipment Company, Poughkeepsie, New York, Jan-Feb, 1986.

Conversations with various engineers at Integrated Power Corporation, Gaithersburg, MD, Jan-Feb, 1986.

Mobarak, Prof. Dr. Ing. A., Development of Wind-Solar Power Generation System for Rural Areas in Egypt.

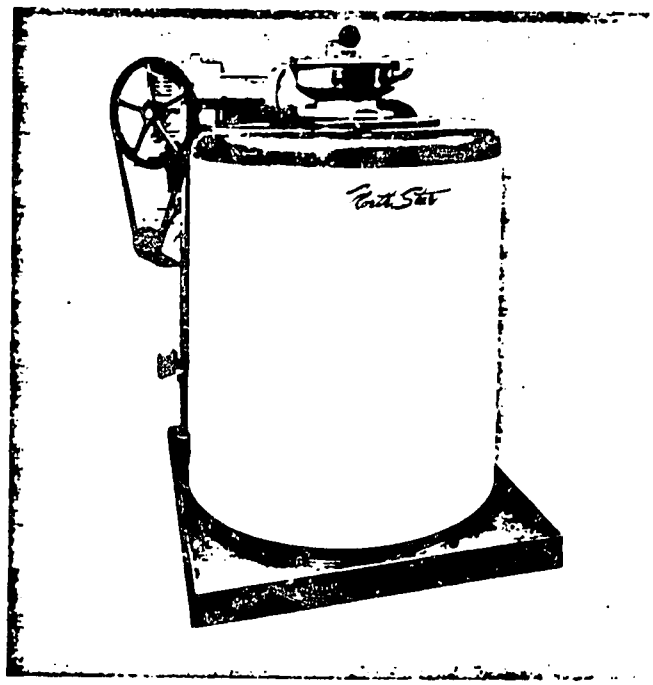
Photovoltaic F-Chart Energy Analysis Software, F-Chart Software, Middleton, WI.

# APPENDIX A

## PRODUCT LITERATURE

A selection of manufacturer's product literature for ice making equipment and diesel generators is provided in this Appendix. Additional manufacturer's product literature is available in the Technology Reference Notebook previously submitted under Task 2.2.4.

North Star®




**The Recognized Leader In**
**Ice Making Equipment,**
**Ice Distribution Systems,**
**& Automated Ice Plants**

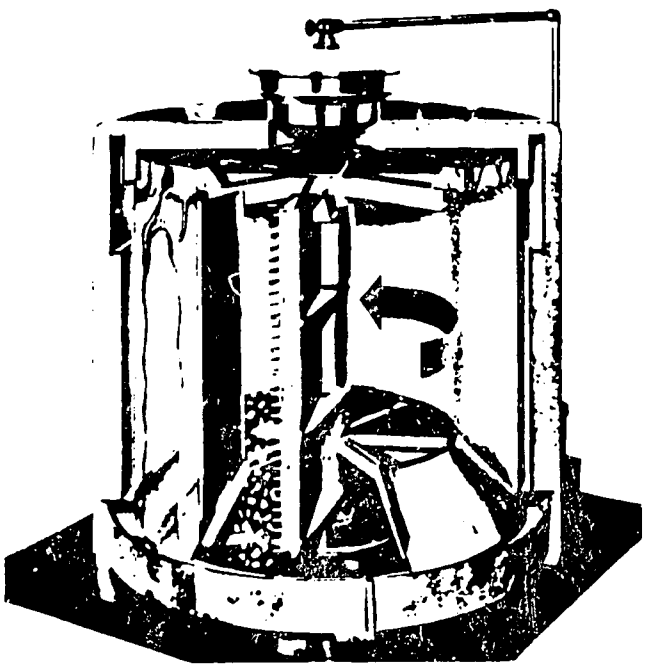
**ON EVERY CONTINENT...ON EVERY OCEAN!**

© Copyright North Star Ice 1981

# NORTH STAR LEADS

## Proven Performance!

North Star industrial Ice Makers are built for rugged, reliable service, are simple to operate, and are very versatile. The compact size requires a minimum of space and is easy to install, even without factory supervision. These Ice Makers will efficiently produce more ice per BHP applied, or more ice from the same compressor, than any other ice maker: 1.3 tons of refrigeration per ton of ice from incoming water at 60°F. (4.34 KCAL/KG at 16°C)



Each ton of dry, sub-cooled ice provides the equivalent of more than 17,000 square feet (1580 square meters) of cooling surface to chill and cool perishable and critical products.

The ice surface is always dry and cold — ice temperatures of 0°F. (-18°C.) or below are possible.

**ADDITIONAL FEATURES INCLUDE:**

- Totally enclosed and well-insulated housing to reduce refrigeration loss.
- Uses standard refrigerants or glycol or brine; either flooded or pumped systems.
- Stationary evaporator, thus no refrigerant seals to leak!
- No water loss - all water is converted to ice.
- Continuous production - no defrosting cycles at any time.
- Freezes other liquids such as blood plasma, fruit juices, and seawater, into sub-cooled flakes.
- Accepted by U.S. Department of Agriculture for installation in food plants.

### CAPACITY RANGE

The capacity range is based on evaporator temperatures from +5°F to −30°F. reasonably oil-free ammonia, 60°F makeup water with less than 100 PPM total hardness, an average ice temperature of 25°F, an ice thickness between 1.5 and 2.0mm, and a carbon steel freezing surface. A change in any of the above conditions will affect capacity. Consult a North Star distributor or the factory for capacities under specific operating conditions.

### HORSEPOWER & CAPACITY RANGE

| MODEL | MOTOR H.P. | | CAPACITY RANGE |
|---|---|---|---|
| | DRIVE | PUMP | U.S. TONS/DAY |
| 10 | ⅓ | 1/20 | 2.5 to 5.5 |
| 20 | ½ | ⅛ | 6.0 to 14.0 |
| 40 | ¾ | ⅛ | 9.0 to 23.0 |
| 60 | 1 | ⅛ | 14.0 to 40.0 |
| 90 | 1½ | ⅛ | 20.0 to 56.0 |

### DIMENSIONS AND WEIGHTS OF ICE MAKERS

| MODEL | OVERALL HEIGHT | | OVERALL WIDTH | | OVERALL LENGTH | | DOMESTIC | EXPORT | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | WEIGHT | WEIGHT | VOLUME |
| | INCH | MM | INCH | MM | INCH | MM | (lbs.) | (lbs.) | cu. ft. |
| 10 | 45 | 1143 | 32 | 813 | 48 | 1219 | 1350 | 1500 | 70 |
| 20 | 51 | 1295 | 56 | 1422 | 83 | 2108 | 3800 | 4000 | 240 |
| 40 | 75 | 1905 | 58 | 1422 | 83 | 2108 | 5200 | 5700 | 326 |
| 60 | 81 | 2057 | 76 | 1930 | 107 | 2718 | 8100 | 8500 | 510 |
| 90 | 105 | 2667 | 76 | 1930 | 109 | 2769 | 10500 | 11200 | 645 |



66

# THE WAY IN ICE MAKERS

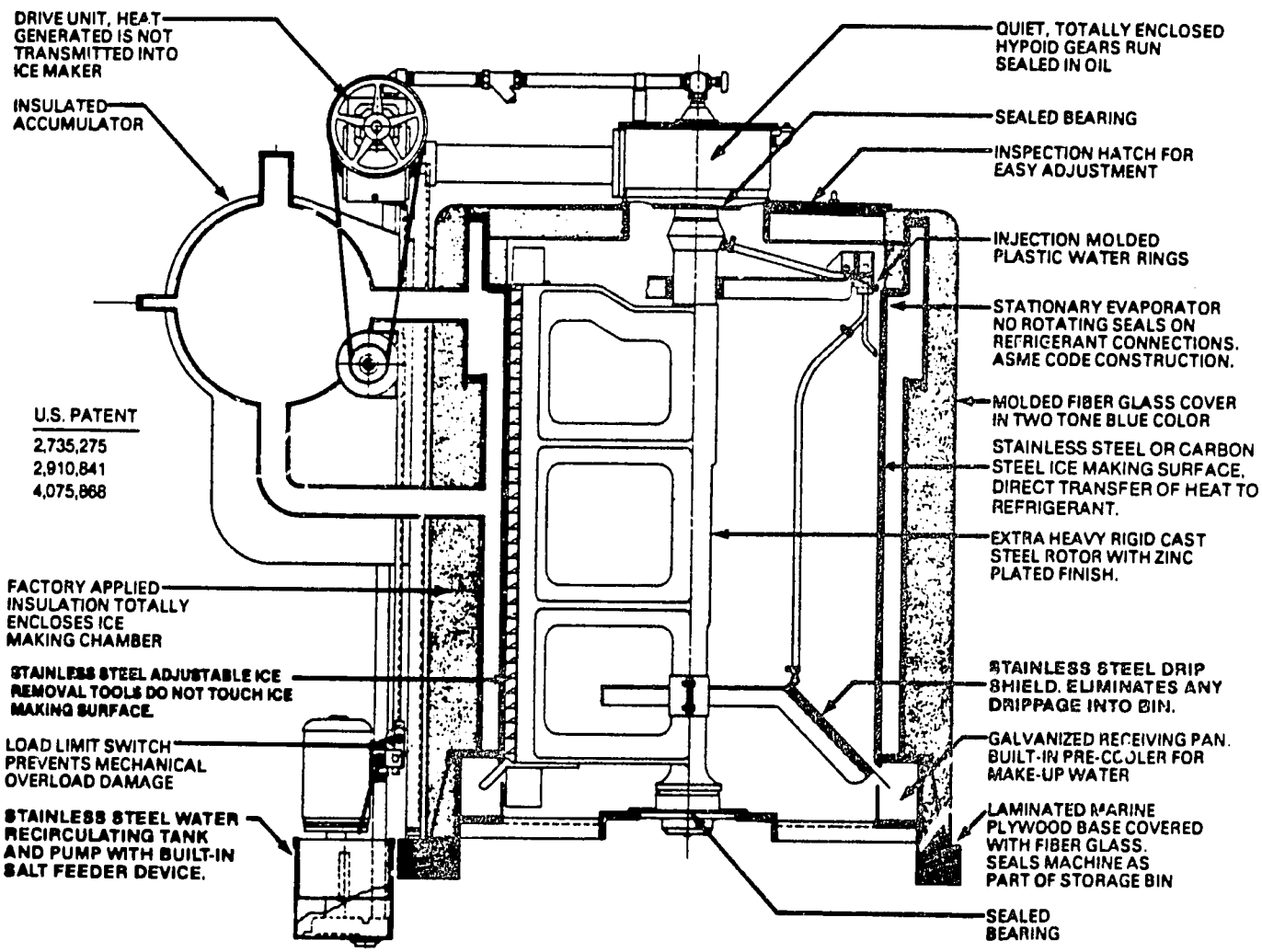
## Description of Operation

The North Star Ice Maker is a stationary, double walled, rigid cylinder mounted in a vertical position. Water is pumped into the top of the hollow central rotating shaft and distributed over the stainless steel or carbon steel inner cylindrical surface in a continuous water curtain, except for the narrow arc of the circle in which ice removal takes place. The low temperature refrigerant between the cylinder walls freezes the water. Excess water is deflected back into the receiving pan at the bottom of the freezing surface and is recirculated.

The rotating central shaft carries an arm with a series of stainless steel ice removal tools which shear the ice from the freezing surface without actually touching the wall. The ice falls out the bottom of the machine. No water is delivered with the ice.

Ice temperature is adjustable by varying the arc of the drying area allowing temperatures of 0°F (−18°C) or lower. The ice thickness is adjustable by changing the speed of the rotating shaft. Ice production can be continuous, even on a 24 hour basis without an attendant. No freeze ups. In case of a power failure, all water drains.

**FIVE MODELS — FROM 2.5 TO 56 U.S. TONS PER DAY**




**SECTION THRU ICE MAKER**

© Copyright North Star Ice 1981



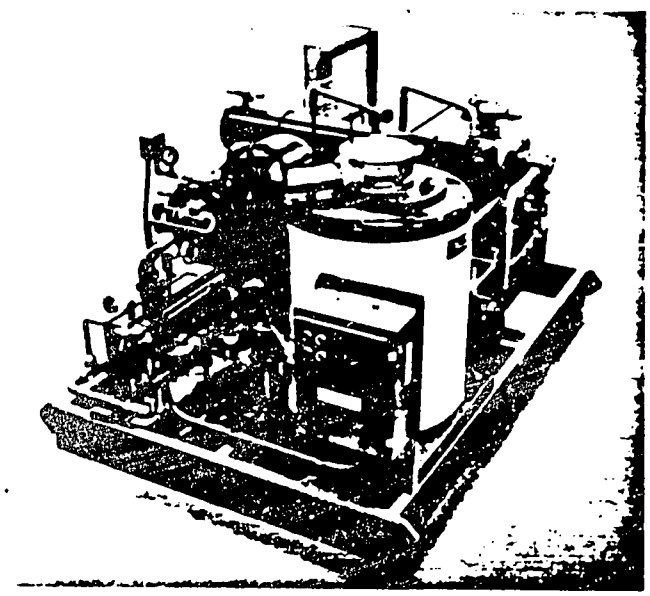
67

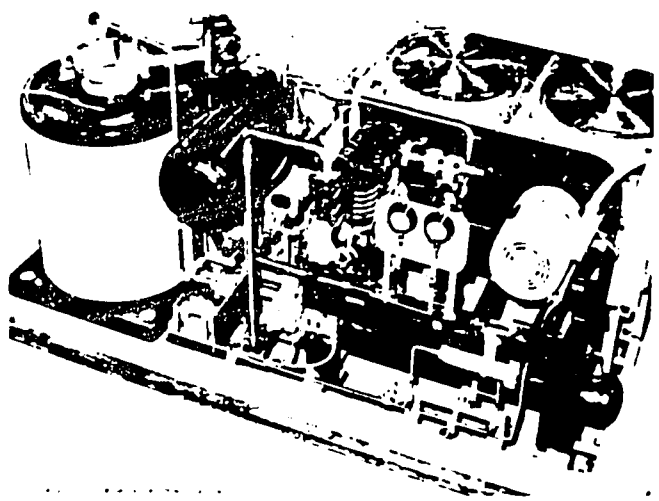
# NORTH STAR LEADS THE WAY IN PACKAGED ICE MAKERS

Primarily for export and remote locations, North Star packaged ice makers are designed to the optimum operating conditions of the locale and the specific requirements of the customer. In the integral units, where the condensing unit and ice maker are on a common base, the only field requirements are to connect the main electrical leads to the control panel, pipe the water supply to the unit, add the refrigerant charge, and add oil per instructions supplied.

The weight and size of the larger packaged units sometimes makes it preferable to separate the ice maker and condensing unit. Then, only the ice maker has to be supported over the top of the storage bin and the condensing unit can be located in a more convenient place. The inter-connecting piping and fittings are supplied, making the field assembly work very simple with the drawings and instructions supplied.

North Star will also engineer and design special ice maker packaged units to meet your exact requirements when unusual operating conditions exist. Specifications of the standard packaged units are shown below.





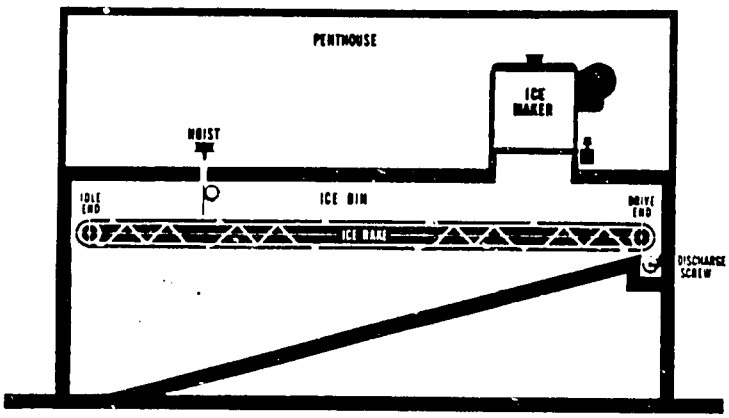
| STANDARD MODEL | CAPACITY | MOTOR | DIMENSIONS (Approx.) | | | SHIPPING | |
|---|---|---|---|---|---|---|---|
| | | | | | | WT. | SIZE |
| | (U.S. tons) | H.P. | L./ft. | W/ft. | H/ft. | (lbs.) | (cu. ft.) |
| M10WC7.5 | 2.5 | 7.5 | 9 1/2 | 3 1/3 | 4 1/2 | 3,400 | 213 |
| M10WC15 | 4.0 | 15.0 | 9 1/2 | 3 1/4 | 4 1/2 | 4,100 | 213 |
| M10AC15 | 4.0 | 15.0 | 9 1/2 | 6 | 4 1/2 | 5,400 | 452 |
| M20WC30 | 9.0 | 30.0 | 13 1/2 | 4 3/4 | 7 1/2 | 9,600 | 745 |
| M40WC30 | 12.0 | 30.0 | 13 1/2 | 4 3/4 | 7 1/2 | 10,500 | 745 |
| M40WC50 | 16.0 | 50.0 | 15 | 4 3/4 | 7 1/2 | 12,900 | 800 |
| M60WC60 | 20.0 | 60.0 | 17 | 6 1/2 | 8 1/2 | 16,900 | 910 |

**NOTES:**

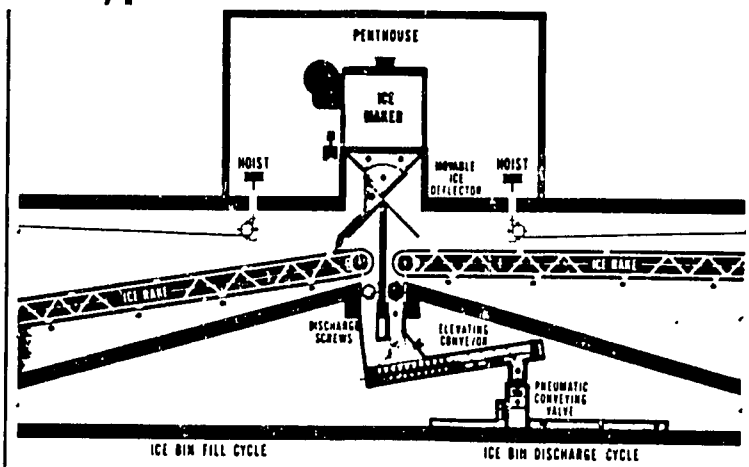
1. Available for 50 Hertz or 60 Hertz operation.
2. Standard unit includes across-the-line starting. Reduced voltage starters can be provided.
3. Standard unit refrigerant is R-12. Also available for use with R-22 and R-502.
4. Sea water units available.
5. Nominal ratings based on 60°F make-up water and 105°F condensing temperature.

# NORTH STAR ICE STORAGE BINS

## Triangular Type




TRIANGULAR ICE BIN

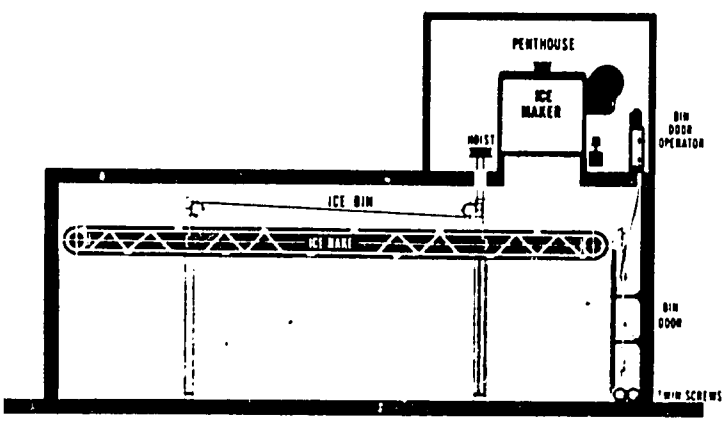



DOUBLE TRIANGULAR ICE BINS

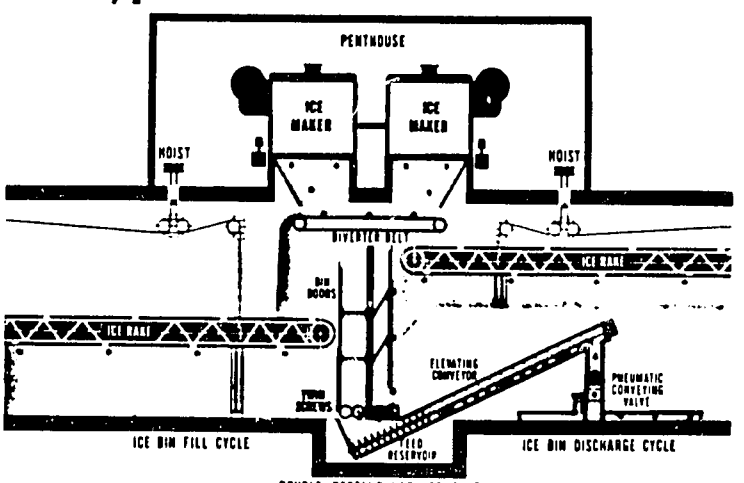
| RAKE Size/in. | DIMENSIONS L/ft. | W/ft. | H/ft. | STORAGE CAPACITY* |
|---|---|---|---|---|
| 15 | 30 | 14 | 14 | 35 tons |
| 17 | 42 | 16 | 14 | 55 tons |

| RAKE Size/in. | DIMENSIONS L/ft. | W/ft. | H/ft. | STORAGE CAPACITY* |
|---|---|---|---|---|
| 2-15 | 60 | 14 | 4 | 70 tons |
| 2-17 | 84 | 16 | 14 | 110 tons |

## Rectangular Type




RECTANGULAR ICE BIN




DOUBLE RECTANGULAR ICE BINS

| RAKE Size/in. | DIMENSIONS L./ft. | W/ft. | H/ft. | STORAGE CAPACITY* |
|---|---|---|---|---|
| 15 | 36 | 18 | 14 | 100 tons |
| 17 | 52 | 20 | 14 | 165 tons |
| 17S | 57 | 22 | 14 | 200 tons |
| 17SD | 62 | 25 | 14 | 250 tons |

| RAKE Size/in. | DIMENSIONS L./ft. | W/ft. | H/ft. | STORAGE CAPACITY* |
|---|---|---|---|---|
| 2-15 | 72 | 18 | 14 | 200 tons |
| 2-17 | 104 | 20 | 14 | 330 tons |
| 2-17S | 114 | 22 | 14 | 400 tons |
| 2-17SD | 124 | 25 | 14 | 500 tons |

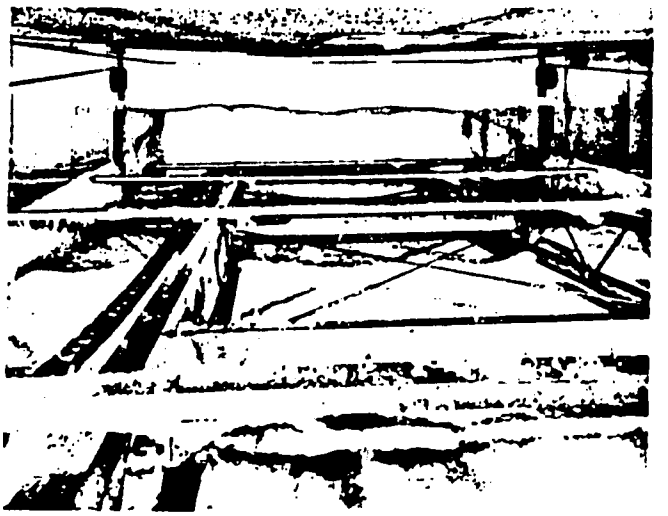
These are Maximum Dimensions, based on inside bin dimensions.
*These are Maximum Storage Capacities based on ten-foot ice depth and shown in U.S. Tons (1 ton = 2000 lbs. or 60 cu. ft. of ice.)

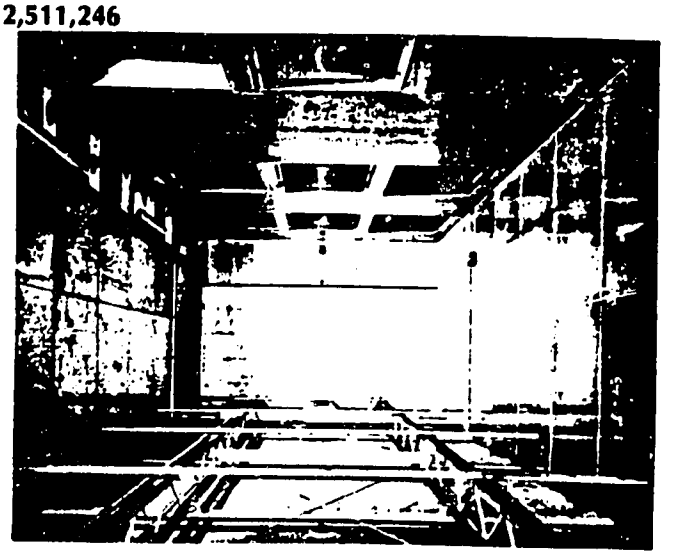


69

# ICE RAKES

**U.S. Patent 2,511,246**





The patented North Star ice rake systems are used to **automatically** store and discharge ice. Rakes can be furnished painted, hot-dip galvanized or plated for acceptance in food plants inspected by the U.S. Department of Agriculture.

The **Triangular Rake System** is ideally suited for small automatic plants, or large plants where the demand for ice is fairly constant around the clock and in which the storage capacity can be relatively small. Chemical plants and medium-sized concrete cooling projects fit into this category. This design provides direct discharge of ice from either one side or both sides of the bin at an elevated point.

The **Rectangular Rake System** is usually recommended for installations which require larger storage capacities. The storage capacity of a rectangular system is about twice the amount of a triangular bin of the same dimensions. Wherever quantity demands for ice vary widely, such as the fishing and various food industries, the rectangular system is usually preferred.

Either system is easily adapted to a conveying system beyond the bin.

# DELIVERY SYSTEMS

The discharge of ice from the bin can be controlled automatically from remote stations, and volumetrically metered and recorded within ±2% accuracy.

A **Screw Conveyor System** is usually less expensive where the total distance is less than 125 feet (40 meters). Intermediate in-line discharge points can be provided utilizing manually operated, or automatically operated, curved slide gates. Conveyors are available painted, galvanized, or in stainless steel, and pre-assembled with factory applied insulation.

The **Pneumatic Conveying System** is more economical when conveying over long distances or when the ice has to be greatly elevated. Conveying is through small diameter (4 to 8 inch) lightweight tubing, placed vertically or horizontally. Multiple delivery points are served utilizing manual or automatic diverter valves. Ice can also be gravity fed by use of cyclone receivers. The high-velocity discharge system is ideally suited for discharging ice into the hold of a boat, a rail car, or a truck.

# NORTH STAR LEADS THE WAY IN ICE PLANTS

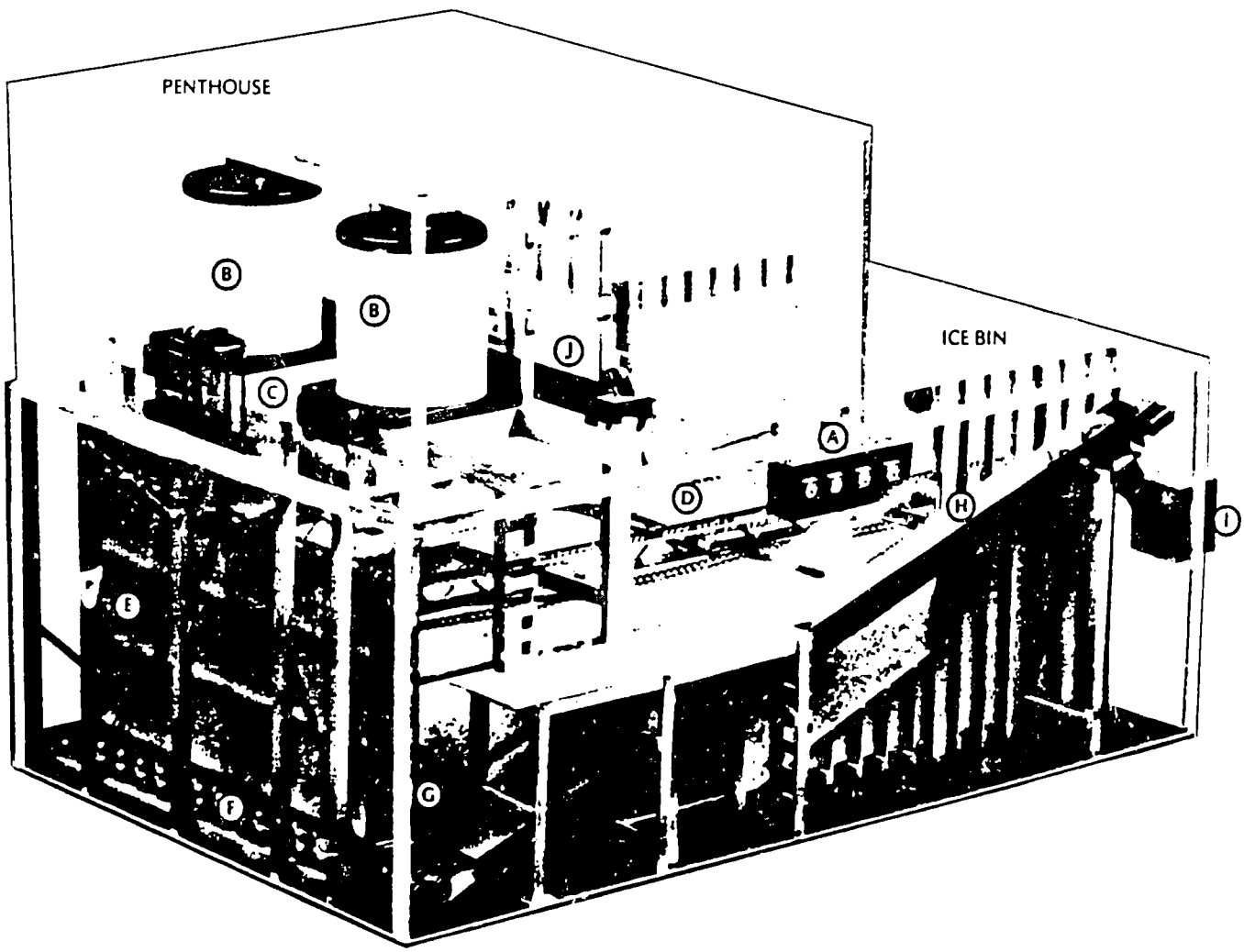
**Companies which**

- **—are using 5 tons or more of ice daily,**
- **—want to slash ice bills and labor costs,**
- **—want a turnkey operation,**
- **—want the very best in engineering, workmanship, and performance,**

...should consider construction of their own ice plant, designed and manufactured by North Star Ice Equipment Corporation to meet their exact requirements. To supplement the handling of North Star ice we also manufacture automatic ice dispensers, intermediate storage bins (day-tank) and ice slingers.

Custom service is the hallmark of quality of North Star. This service is available for plants anywhere in the world and includes equipment which will be compatible with your present or future refrigeration requirements. We would be pleased to tell you about North Star ice plants in your area — for your industry.

**TYPICAL SINGLE RECTANGULAR ICE STORAGE AND HANDLING SYSTEM**




**LEGEND**

**A.** Bin cooling unit
**B.** Ice maker-model and number as required to meet daily ice demand
**C.** Motorized ice bin door operator
**D.** Ice rake
**E.** Bin door
**F.** Twin screws
**G.** Feed reservoir
**H.** Elevating screw conveyor
**I.** Motorized ice discharge door-screw conveyors beyond as required
**J.** Ice rake hoist

# LEADERSHIP BASED UPON QUALITY–EFFICIENCY–RELIABILITY ...THAT'S NORTH STAR!

No company can maintain a world-wide reputation without the highest standards of manufacturing excellence, plus the "built-in" assurance of proven performance under the most severe climatic or environmental conditions. North Star's original Ice Equipment, built in the late 1940's, is still operating properly and profitably in more than 86 countries around the world!

Today North Star equipment can be seen in many fish, poultry, meat, dairy and food processing plants, in chemical processing plants, and for pre-cooling concrete.

Many ice plants in Alaska, Iceland, Newfoundland, Singapore, Pakistan, Guiana, Brazil and Chile continue to rely exclusively on North Star equipment for quality control.

North Star has not only been a pioneer in its industry, but today is still the leader: more industrial flake ice is made and distributed with North Star equipment than with any other line of equipment in the entire world! New marketing efforts are opening opportunities for us to introduce our equipment in Russia, the Arab nations, and the Orient. All in all it is a responsibility we do not assume lightly nor accept without gratitude and determination.

North Star Ice Equipment Corporation has been devoted exclusively to the manufacture of industrial ice makers and ice handling systems for more than 25 years. Whatever your flake ice requirements, from three tons per day to 400+ tons per day, North Star's vast experience and ingenuity are available to solve **your** problem. Send us your requirements and we will gladly provide a detailed proposal - anything from a single ice maker to a completely automatic turn-key operation.

**THOSE WHO WANT THE VERY BEST IN ENGINEERING, WORKMANSHIP AND PROVEN PERFORMANCE SPECIFY:**

North Star®

## ICE EQUIPMENT CORPORATION

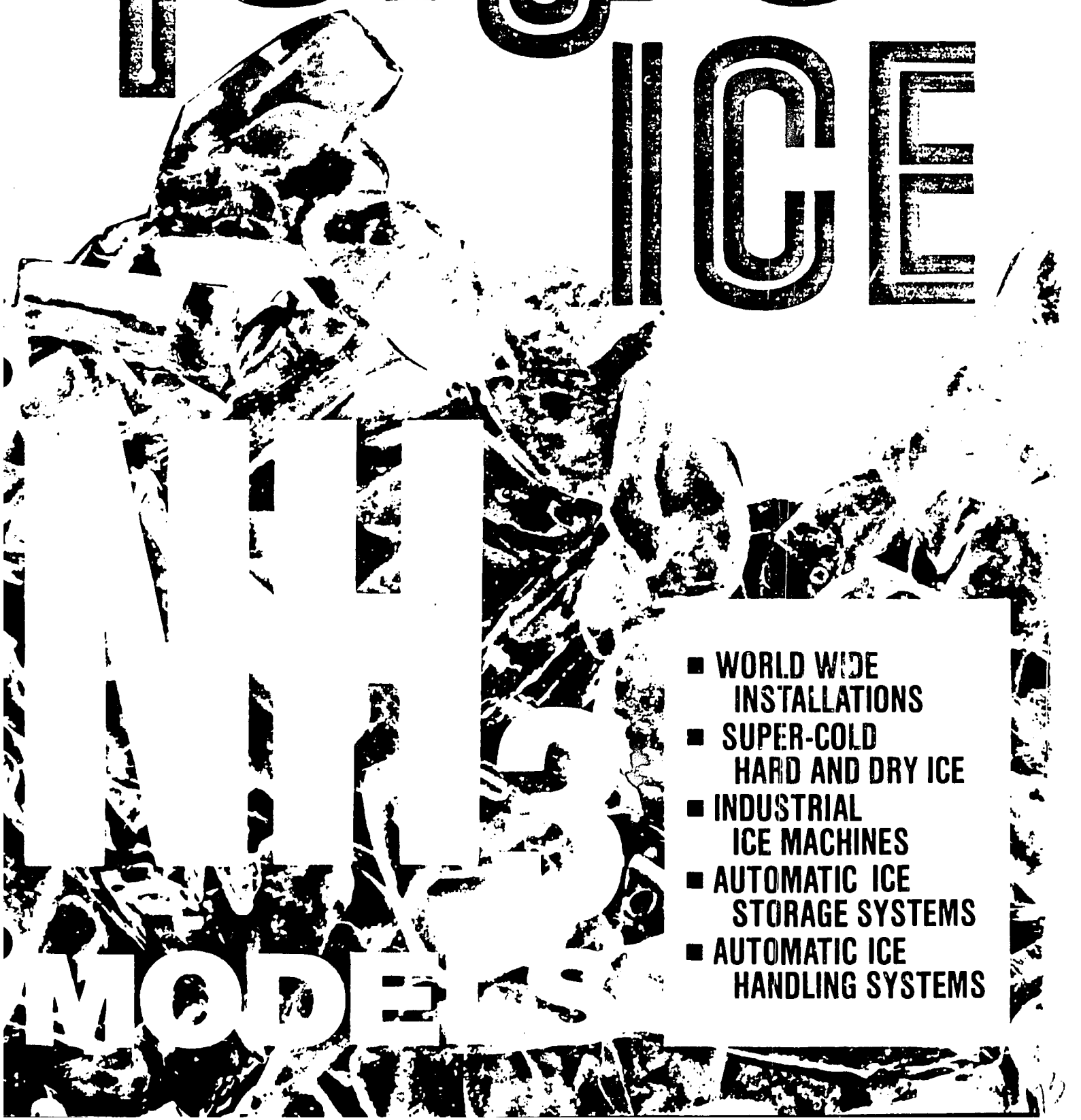
**P.O. Box 70668 or 4511 Shilshole Avenue N.W. Seattle, Washington 98107 U.S.A.**
**Telephone [206] 784-4500 Cable: NORSTAR SEATTLE Telex: 32-9470**

6/85 2M

72

A. I. A. No. 30F4

# TURBO ICE



- WORLD WIDE INSTALLATIONS
- SUPER-COLD HARD AND DRY ICE
- INDUSTRIAL ICE MACHINES
- AUTOMATIC ICE STORAGE SYSTEMS
- AUTOMATIC ICE HANDLING SYSTEMS

MODEL

# TURBO

## . . . THE *PROVEN* LEADER IN THE INDUSTRIAL ICE MACHINE INDUSTRY

. . . Offering the Largest Range of Ammonia Icemakers.

The right kind of ice is important to you and your customers . . . and because more TURBO ICE is sold in the industrial field than any other ice, TURBO is the proven leader.

This leadership is built upon these three reasons:

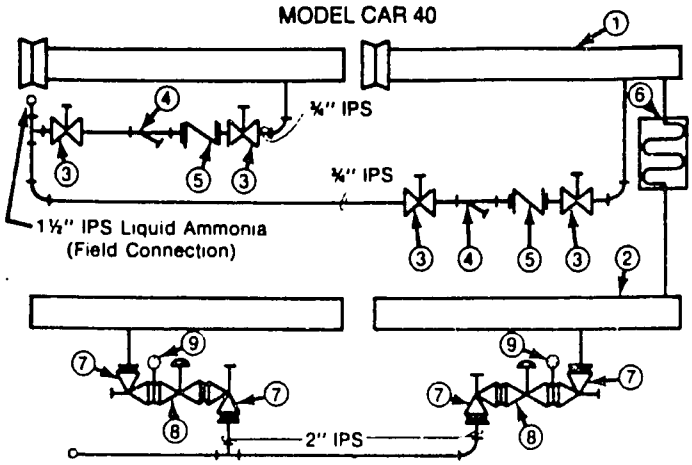
1. **SIMPLICITY**
   TURBO utilizes a simplicity of installation, simplicity of operation and simplicity of maintenance.

2. **VERSATILITY**
   TURBO ICE is available in the widest range of sizes: thick or thin . . . large or small . . . whatever the requirement, TURBO can make **exactly** the right kind of ice.

3. **HIGHEST QUALITY at a REASONABLE COST**
   Extensive use of 304 stainless steel in all critical areas is made possible by TURBO's high production and modern, efficient plant.

**REFRIGERANT PIPING**

MODEL CAR 40




3" IPS Ammonia Section (Field Connection)

① Orificed Liquid Ammonia Header
② Suction Header
③ Liquid Ammonia Stop Valve
④ Liquid Ammonia Strainer
⑤ Check Valve
⑥ Evaporators
⑦ Ammonia Suction Stop Valve
⑧ Suction Pressure Regulator
⑨ Pressure Gauge

# TURBO

## AMMONIA ICE MAKERS

Turbo Icemakers are particularly well suited for recirculated ammonia systems because of the inherent simplicity of the refrigerant piping.

Turbo Icemakers utilize a patented water defrost harvest system. Not only does this water harvest increase the efficiency of the system, but it greatly simplifies the refrigerant circuit.

Specifically the use of the water defrost has the following advantages:

1. Hot gas lines and controls are eliminated.
2. There is no transfer of large amounts of refrigerant from receiver to evaporator.
3. Heat for harvest is taken from the incoming fresh water thus reducing the temperature of the water to be frozen and actually continuing useful heat transfer during harvest period. Water usage is not increased by this method.

The use of a top feed liquid recirculating system prevents the lodging of oil in the evaporators by washing any oil out of the plate evaporators back to the recirculating drum to a central point for draining. Additionally, liquid recirculation adapts to the varying refrigerant load throughout the cycle. Finally, the operating ammonia charge is kept to a minimum.

# TURBO-ICE

## FILLS EVERY NEED

## PROCESSING, PACKING, SHIPPING

Quick-ice fish, fresh from the water, pack and ship poultry, dairy products and produce—there's a TURBO Plate Ice Maker that's just right for you. TURBO ice drops clean, hard and dry, with no slushing or soft ice that requires wasteful handling and mess. TURBO's fragmentary ice forms cellular structures for maximum chilling, air circulation and longer temperature control . . . protects poultry, produce, fish and other products longer and minimizes dehydration. For the best ice protection — use TURBO.

*"The unit is simple to operate and produces the best quality ice we have seen . . . happy to recommend this unit"*

*Gulf Coast Ice Plant*

## CONSUMER'S PACKAGED ICE

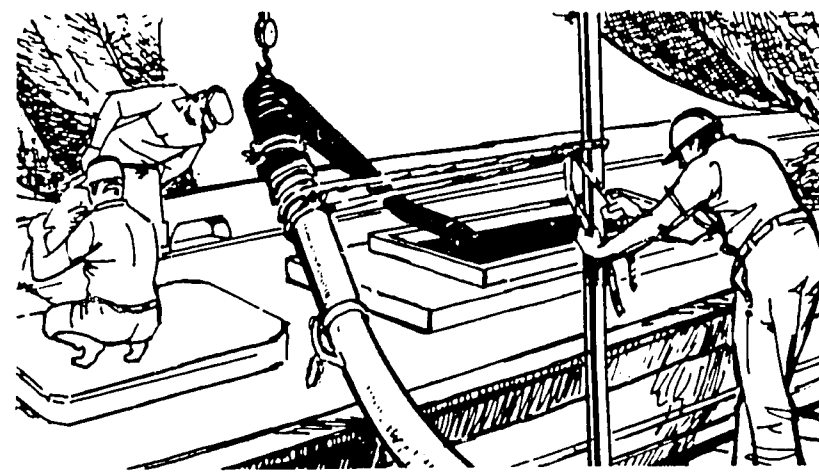
A package of consumer ice today must serve many varied needs. TURBO meets all the consumer's ice problems in one machine. Customer satisfaction is the big reason why TURBO ice is the called-for package and a universal repeat seller. You can manufacture clean, super-cold, sanitary, consumer-quality ice in a labor-saving, low-cost and most profitable method with a TURBO ice maker. Ice costs in the average installation are less than $2 a ton. Your business can grow — with a TURBO.

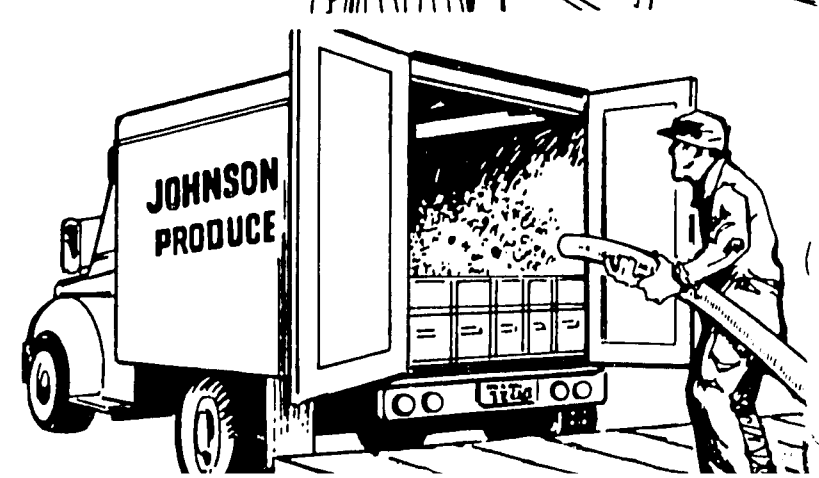
*"Turbo ice is highly acceptable to all of our customers who have previously used crushed ice"*

*Ice Company South Carolina*

## *TURBO ICE CAN SERVE YOU MORE PROFITABLY IN ANY ICE APPLICATION.*

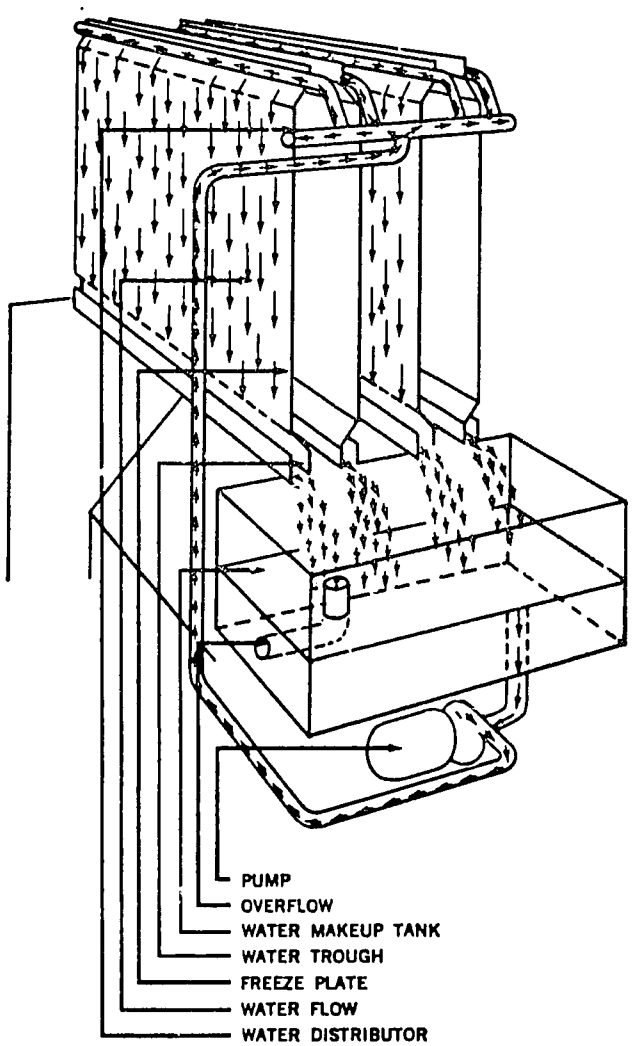
Fishing • Poultry Processing • Meat Packing • Dairy • Produce • Ice Plant • Hotel



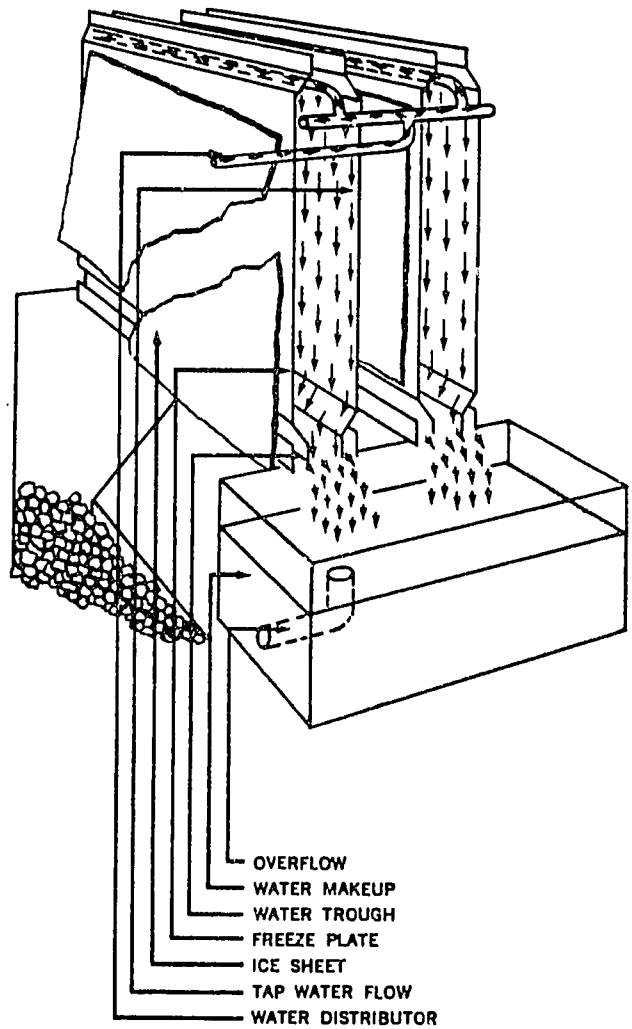


# THE TURBO PLATE ICE MAKER

ICE FREEZING CYCLE



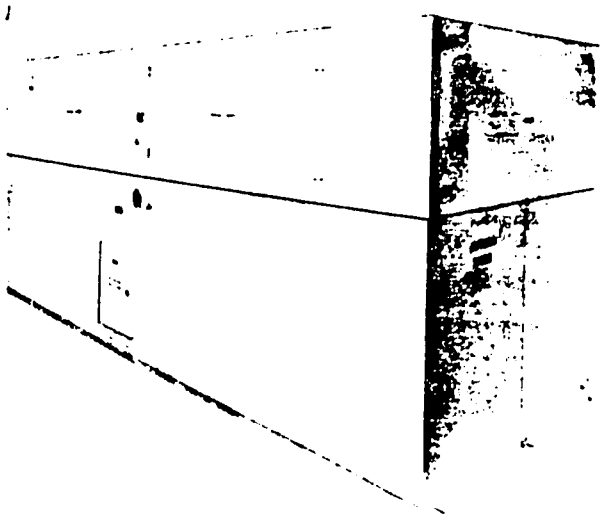

ICE HARVESTING CYCLE




Water is pumped above freezing plates and flows by gravity over plates in freezing cycle (lefthand drawing). For harvesting, gravity-fed tap water flows on back of plates, releasing ice which falls by gravity into crusher. Exclusive ice drying cycle is built in.

# DELIVERS THE PROVEN ICE AND PROD ES

## *A BETTER KIN JF ICE!*



MODEL CAR 80
40 TONS

### SIMPLE PRINCIPLES MAKE ICE PRODUCTION BETTER, FASTER, EASIER, MORE ECONOMICAL

The TURBO Ice Maker incorporates trouble-free designs and simple principles that make ice production better, faster, easier and more economical than ever. You'll wonder why someone hasn't thought of it before. But TURBO ice engineers did think of it, and designed a series of ice makers to fit every ice need. Operation of the TURBO ICE MAKER is as simple as the principle of refrigeration. It's product is a new and proven, notably better kind of ice.

### OPERATING PRINCIPLE

The heart of the TURBO Ice Maker is the icemaking cycle, stainless-steel ice freezing plates. Ice is formed on the outside of each icemaking plate. Thick, clear ice is released or harvested by the fresh water defrost flowing on the backside of the plates. Ice stays hard and dry, super-cold and drops by gravity, is cracked into perfect chunks, all in one operation. Harvest water is prechilled, recirculated and becomes your next batch of ice.

### SIMPLE CONTROLS

All TURBO units are controlled in operation sequence by a timer. This timer controls the time cycle of ice thickness. The ice making cycle and defrost cycle are actuated by this timer. Even the ice sizing or cutting bar is operated through this simple mechanism. TURBO units are all internally wired.

### FEWER MOVING PARTS

The liquid pump, water recirculating pump and crusher bar motor are the three moving components on all TURBO models.

### LARGE FREEZING SURFACE

The entire stainless-steel freezing plate is prime refrigerating surface — nearly 9 square feet per plate. High heat-transfer coefficient produces highly efficient sub-cooled low temperature ice.

### HIGH SPEED, NO-HEAT HARVESTING

Complete harvest normally is accomplished in less than two minutes. No artificial heat to melt the ice is applied. No liquid touches the ice. Ice is harvested hard, dry, ready to use, with no slush or melt.

### CAPACITY FOR EVERY NEED

TURBO Plate Ice Makers are available in completely packaged, self-contained or remote units of capacities from 5 to 72 ons per day. Future expansion is simple, too, with TURBO modular add-on design.

### THE ICE

TURBO MACHINES deliver super-cold fragmentary ice that does not melt together. The simple timer control lets you make the size of ice you need, for ¼" to ¾" average thickness. In addition the ice crusher is adjustable to fine, medium or coarse, making available a large variety of ice sizes from any one of the 15 models in the TURBO line.

### LOWER COST

Average cost per ton of TURBO ice — is less than $2.00. There are also substantial savings in space requirements, installation costs and maintenance.

### SIMPLE INSTALLATION

The TURBO Plate Ice Maker is compact. Installation is quick, easy and inexpensive. No special engineering or personnel are required. Your TURBO unit may be placed for maximum convenience or space-saving. The unit can be installed on the roof, requiring no building space at all. TURBO units are heavily insulated at the factory to work outdoors in hot or cold climates.

### MINIMUM MAINTENANCE

You won't need factory engineers to keep your TURBO unit operating at peak efficiency. There are no complicated or recurring adjustments. Simplicity of design and operation eliminates major problems, and routine maintenance can be performed without special skills.

For more detailed information and specifications, write or call the ice engineers at TURBO Refrigerating Company. P. O. Box 396, Denton, Texas 76201; area code 817/387-4301.

# GUIDE TO TURBO INDUSTRIAL MODEL SPECIFICATION

**NOMINAL CAPACITY IN TONS OF ICE IS BASED ON 70°F FRESH WATER AND 90°F AMBIENT AIR**

| Nominal Ice Capacity | Model No. | Overall Dims. (L x W x H) | Net Weight (Lbs.) | Shipg. Weight (Lbs.) | Feed Water Flow During Defrost | Feed Water Connection Size at Unit | Liquid Pump Motor | Oper. Ref. Charge (Lbs.) | S/S Freezing Plates | Water Pump | Crusher Bar | Connected Amps @ 220/3/60 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5 TON | CAR 8 | 78x44x 88 | 2,930 | 3,120 | 15 G.P.M. | 1¼" IPS | — | 48 | 10 | 60 G.P.M. | 1½ HP | 17.6 |
| | CAR 8 LR | 78x44x 88 | 3,250 | 3,440 | 15 G.P.M. | 1¼" IPS | ½ | 83 | 10 | ½ HP | 1½ HP | 19.6 |
| 7 TON | CAR 14 | 78x72x 92 | 4,762 | 5,020 | 22 G.P.M. | 1¼" IPS | — | 68 | 14 | 90 G.P.M. | 1½ HP | 18.4 |
| | CAR 14 LR | 78x72x 92 | 5,258 | 5,516 | 22 G.P.M. | 1¼" IPS | ¾ | 126 | 14 | ¾ HP | 1½ HP | 21.2 |
| 10 TON | CAR 16 | 78x72x 92 | 5,029 | 5,284 | 30 G.P.M. | 1½" IPS | — | 96 | 20 | 120 G.P.M. | 3 HP | 21.8 |
| | CAR 16 LR | 78x72x 92 | 5,525 | 5,780 | 30 G.P.M. | 1½" IPS | 1 | 154 | 20 | ¾ HP | 3 HP | 25.3 |
| 15 TON | CAR 28 | 96x94x108 | 7,319 | 7,670 | 22 G.P.M. | 2" IPS | — | 138 | 28 | 90 G.P.M. | 3 HP | 24.6 |
| | CAR 28 LR | 96x94x108 | 7,819 | 8,170 | 44 G.P.M. | 2" IPS | 1 | 234 | 28 | (2) ¾ HP | 3 HP | 28.1 |
| 20 TON | CAR 40 | 128x94x108 | 8,500 | 8,958 | 60 G.P.M. | 2" IPS | — | 193 | 40 | 120 G.P.M. | 3 HP | 24.6 |
| | CAR 40 LR | 128x94x108 | 8,802 | 9,260 | 60 G.P.M. | 2" IPS | 1½ | 317 | 40 | (2) ¾ HP | 3 HP | 30.2 |
| 30 TON | CAR 56 | 192x94x108 | 14,772 | 15,300 | 22 G.P.M. | 2" IPS | — | 275 | 56 | 120 G.P.M. | (2) 3 HP | 39.2 |
| | CAR 56 LR | 192x94x108 | 15,272 | 15,800 | 44 G.P.M. | 2" IPS | (2) 1 | 467 | 56 | (4) ¾ HP | (2) 3 HP | 46.2 |
| 40 TON | CAR 80 | 256x94x108 | 15,800 | 16,440 | 30 G.P.M. | 2" IPS | — | 384 | 80 | 120 G.P.M. | (2) 3 HP | 39.2 |
| | CAR 80 LR | 256x94x108 | 16,400 | 17,040 | 60 G.P.M. | 2" IPS | (2) 1½ | 632 | 80 | (4) ¾ HP | (2) 3 HP | 50.4 |
| 60 TON | CAR 120 | 384x94x119 | 23,185 | 23,865 | 30 G.P.M. | 2" IPS | — | 577 | 120 | (6) ¾ HP | (3) 3 HP | 54.6 |

# ICE PRODUCTION CAPACITIES

**SINGLE TURBO AMMONIA ICEMAKERS**

| MODEL | CYCLE TIME | TONS ICE/24 HRS. | COMP. CAPACITY @ 0°F (TONS REFR.) | AV. ICE THICKNESS |
|---|---|---|---|---|
| CAR 8<br>CAR 8 LR | 20 MIN. | 5.8 | 9.35 | .39" |
| | 25 MIN. | 5.7 | 9.35 | .50" |
| | 30 MIN. | 5.6 | 9.35 | .60" |
| CAR 14<br>CAR 14 LR | 20 MIN. | 8.7 | 14.0 | .42" |
| | 25 MIN. | 8.6 | 14.0 | .53" |
| | 30 MIN. | 8.5 | 14.0 | .63" |
| CAR 16<br>CAR 16 LR | 20 MIN. | 11.6 | 18.7 | .39" |
| | 25 MIN. | 11.4 | 18.7 | .50" |
| | 30 MIN. | 11.2 | 18.7 | .60" |
| CAR 28<br>CAR 28 LR | 20 MIN | 17.3 | 28.0 | .42" |
| | 25 MIN. | 17.1 | 28.0 | .53" |
| | 30 MIN. | 16.8 | 28.0 | .63" |
| CAR 40<br>CAR 40 LR | 20 MIN. | 23.2 | 37.4 | .39" |
| | 25 MIN. | 22.8 | 37.4 | .50" |
| | 30 MIN. | 22.5 | 37.4 | .60" |
| CAR 56<br>(4 HARVEST) | 20 MIN. | 35.5 | 56.1 | .43" |
| | 25 MIN. | 34.6 | 56.1 | .54" |
| | 30 MIN. | 33.7 | 56.1 | .63" |
| CAR 56 LR<br>(2 HARVEST) | 20 MIN. | 34.8 | 56.1 | .42" |
| | 25 MIN. | 34.4 | 56.1 | .53" |
| | 30 MIN. | 33.7 | 56.1 | .63" |
| CAR 80<br>(4 HARVEST) | 20 MIN. | 47.4 | 74.8 | .40" |
| | 25 MIN. | 46.3 | 74.8 | .50" |
| | 30 MIN. | 45.0 | 74.8 | .60" |
| CAR 80 LR<br>(2 HARVEST) | 20 MIN. | 46.9 | 74.8 | .39" |
| | 25 MIN. | 45.9 | 74.8 | .50" |
| | 30 MIN. | 45.0 | 74.8 | .60" |
| CAR 120 | 20 MIN. | 70.6 | 112.2 | .40" |
| | 25 MIN. | 69.1 | 112.2 | .50" |
| | 30 MIN. | 67.5 | 112.2 | .60" |

# UIDE TO TURBO INDUSTRIAL MODEL SPECIFICATIONS

**NOMINAL CAPACITY IN TONS OF ICE IS BASED ON 70°F FRESH WATER AND 90°F AMBIENT AIR.**

| Nominal e Capacity S. Tons/Day | Model No. | Overall Dimensions L x W x H (In.) | Net Weight (Lbs.) | Shipping Weight (Lbs.) | Feed Water Flow During Harvest G.P.M. | Feed Water Conn. IPS | Liquid Pump Motor | Oper. $NH_3$ Chg. (Lbs.) | S/S Freezing Plates | Water Pump GPM & HP | Breaker Bar H.P. | Connected Amps @ 230/3/60 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6 | CAR12 | 78 x 44 x 8[illegible] | 3,198 | 3,388 | 18 | 1¼ | — | 58 | 12 | 72 | 1½ | 17.6 |
| | CAR12LR | 78 x 44 x 88 | 3,518 | 3,708 | 18 | 1¼ | ½ | 100 | 12 | ½ | 1½ | 19.6 |
| 9 | CAR16 | 78 x 72 x 92 | 4,896 | 5,154 | 25 | 1¼ | — | 78 | 16 | 103 | 1½ | 18.4 |
| | CAR16LR | 78 x 72 x 92 | 5,392 | 5,650 | 25 | 1¼ | ¾ | 144 | 16 | ¾ | 1½ | 21.2 |
| 13 | CAR24 | 78 x 72 x 92 | 5,297 | 5,552 | 36 | 1½ | — | 115 | 24 | 144 | 3 | 22.6 |
| | CAR24LR | 78 x 72 x 92 | 5,793 | 6,048 | 36 | 1½ | 1 | 185 | 24 | 1 | 3 | 26.1 |
| 22 | CAR36 | 99 x 94 x 108 | 8,272 | 8,623 | 28 | 2 | — | 177 | 36 | 116 | 3 | 26.2 |
| | CAR36LR | 99 x 94 x 108 | 8,772 | 9,123 | 56 | 2 | 1 | 300 | 36 | (2)-1 | 3 | 29.7 |
| 27 | CAR48 | 128 x 94 x 108 | 10,004 | 10,462 | 36 | 2 | — | 232 | 48 | 144 | 3 | 26.2 |
| | CAR48LR | 128 x 94 x 108 | 10,306 | 10,764 | 72 | 2 | 1½ | 380 | 48 | (2)-1 | 3 | 31.8 |
| 44 | CAR72 | 198 x 94 x 108 | 16,477 | 17,005 | 28 | 2 | — | 354 | 72 | 116 | (2)-3 | 52.4 |
| | CAR72LR | 198 x 94 x 108 | 17,077 | 17,605 | 56 | 2 | (2)-1 | 600 | 72 | (4)-1 | (2)-3 | 59.4 |
| 55 | CAR96 | 256 x 94 x 108 | 18,008 | 18,648 | 36 | 2 | — | 464 | 96 | 144 | (2)-3 | 52.4 |
| | CAR96LR | 256 x 94 x 108 | 18,808 | 19,448 | 72 | 2 | (2)-1½ | 760 | 96 | (4)-1 | (2)-3 | 63.6 |
| 82 | CAR144 | 384 x 94 x 1[illegible]9 | 24,365 | 24,685 | 36 | 2 | — | 696 | 144 | 144 (6)-1 | (3)-3 | 78.6 |

# CE PRODUCTION CAPACITIES

**SINGLE TURBO AMMONIA ICEMAKERS**

| MODEL | CYCLE TIME | TONS ICE/24 HRS. | COMP. CAPACITY @ 0°F (TONS REFR.) | AV. ICE THICKNESS (IN.) |
|---|---|---|---|---|
| CAR 12 CAR 12 LR | 20 MIN. | 6.9 | 11.16 | .39 |
| | 25 MIN. | 6.8 | 11.16 | .50 |
| | 30 MIN. | 6.7 | 11.16 | .60 |
| CAR 16 CAR 16 LR | 20 MIN. | 9.9 | 18.6 | .42 |
| | 25 MIN. | 9.8 | 18.6 | .53 |
| | 30 MIN. | 9.7 | 18.6 | .63 |
| CAR 24 CAR 24 LR | 20 MIN. | 13.9 | 22.32 | .39 |
| | 25 MIN. | 13.7 | 22.32 | .50 |
| | 30 MIN. | 13.4 | 22.32 | .60 |
| CAR 36 2 HARVEST | 20 MIN. | 22.2 | 33.48 | .39 |
| | 25 MIN. | 22.0 | 33.48 | .50 |
| | 30 MIN. | 21.6 | 33.48 | .60 |
| CAR 36 LR 1 HARVEST | 20 MIN. | 22.2 | 33.48 | .39 |
| | 25 MIN. | 22.0 | 33.48 | .50 |
| | 30 MIN. | 21.6 | 33.48 | .60 |
| CAR 48 2 HARVEST | 20 MIN. | 27.8 | 44.64 | .39 |
| | 25 MIN. | 27.3 | 44.64 | .50 |
| | 30 MIN. | 27.0 | 44.64 | .60 |
| CAR 48 LR 1 HARVEST | 20 MIN. | 27.8 | 44.64 | .39 |
| | 25 MIN. | 27.3 | 44.64 | .50 |
| | 30 MIN. | 27.0 | 44.64 | .60 |
| CAR 72 4 HARVEST | 20 MIN. | 45.6 | 66.96 | .40 |
| | 25 MIN. | 44.4 | 66.96 | .50 |
| | 30 MIN. | 43.3 | 66.96 | .60 |
| CAR 72 LR 2 HARVEST | 20 MIN. | 44.7 | 66.96 | .39 |
| | 25 MIN. | 44.2 | 66.96 | .50 |
| | 30 MIN. | 43.3 | 66.96 | .60 |
| CAR 96 4 HARVEST | 20 MIN. | 56.8 | 89.28 | .40 |
| | 25 MIN. | 55.5 | 89.28 | .50 |
| | 30 MIN. | 54.0 | 89.28 | .60 |
| CAR 96 LR 2 HARVEST | 20 MIN. | 56.2 | 89.28 | .39 |
| | 25 MIN. | 55.0 | 89.28 | .50 |
| | 30 MIN. | 54.0 | 89.28 | .60 |
| CAR 144 6 HARVEST | 20 MIN. | 84.7 | 133.92 | .40 |
| | 25 MIN. | 82.9 | 133.92 | .50 |
| | 30 MIN. | 81.0 | 133.92 | .60 |

# CENTRAL SYSTEM PERFORMANCE

Multiple TURBO ice makers connected to a common central system can be timed so that harvest periods are equi-spaced. The result is that the suction pressure is essentially constant and ice production is increased.

Practice shows that this condition is achieved when there is 12½% or less of the evaporator sections harvested at one time.

## CENTRAL SYSTEM ICE PRODUCTION TABLE

APPLICABLE WHEN ⅛ OR LESS OF TOTAL EVAPORATORS HARVEST AT SAME TIME

| CYCLE TIME (MIN.) | | 12 | 15 | 17½ | 20 | 22½ | 25 | 30 | 35 | 40 | 45 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| AV. ICE THICKNESS (IN.) | | .26 | .32 | .37 | .42 | .47 | .51 | .60 | .67 | .74 | .79 |
| MODEL | TONS REF @ 0°F PER UNIT | | | | | | | | | | |
| CAR 12/CAR 12 LR | 11.16 | 7.5 | 7.4 | 7.3 | 7.2 | 7.1 | 6.9 | 6.6 | 6.4 | 6.3 | 6.0 |
| CAR 16/CAR 16 LR | 18.6 | 10.8 | 10.6 | 10.4 | 10.3 | 10.2 | 9.9 | 9.5 | 9.2 | 9.0 | 8.6 |
| CAR 24/CAR 24 LR | 22.32 | 15.2 | 14.9 | 14.6 | 14.5 | 14.3 | 14.0 | 13.4 | 13.0 | 12.7 | 12.1 |
| CAR 36/CAR 36 LR | 33.48 | 24.2 | 23.8 | 23.2 | 23.1 | 22.9 | 22.3 | 21.3 | 20.8 | 20.2 | 19.2 |
| CAR 48/CAR 48 LR | 44.64 | 30.4 | 29.9 | 29.2 | 29.0 | 28.7 | 28.0 | 26.8 | 26.1 | 25.4 | 24.2 |
| CAR 72/CAR 72 LR | 66.96 | 49.8 | 49.0 | 47.8 | 47.5 | 47.1 | 45.9 | 43.9 | 42.7 | 41.6 | 39.6 |
| CAR 96/CAR 96 LR | 89.28 | 62.1 | 61.1 | 59.6 | 59.2 | 58.7 | 57.2 | 54.8 | 53.3 | 51.8 | 49.4 |
| CAR 144 | 133.92 | 91.5 | 90.1 | 87.9 | 87.2 | 86.48 | 84.3 | 80.7 | 78.5 | 76.3 | 72.9 |

### TABLE NO. 1

| MODEL | CAR 12 | CAR 12 LR | CAR 16 | CAR 16 LR | CAR 24 | CAR 24 LR | CAR 36 | CAR 36 LR | CAR 48 | CAR 48 LR | CAR 72 | CAR 72 LR | CAR 96 | CAR 96 LR | CAR 144 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HARVEST/CYCLE | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 2 | 1 | 4 | 2 | 4 | 2 | 6 |

### TABLE NO. 2

## ENTERING WATER TEMPERATURE CAPACITY MULTIPLIERS

| WATER TEMP. | 65 | 70 | 75 | 80 | 85 | 90 |
|---|---|---|---|---|---|---|
| CAPACITY MULT. | 1.028 | 1.00 | 0.974 | 0.950 | 0.925 | 0.902 |

### TABLE NO. 3

## SUCTION PRESSURE CAPACITY MULTIPLIERS

| SUCTION TEMP. °F* | +5 | +4 | +3 | +2 | +1 | 0 | −1 | −2 | −3 | −4 | −5 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| CAP. MULT. | .84 | .87 | .90 | .93 | .96 | 1.00 | 1.03 | 1.06 | 1.09 | 1.12 | 1.15 |

*Refers to suction temp. at icemakers — no allowance for suction line losses!

### TABLE NO. 4

## LIQUID AMMONIA FLOW

(BASED ON 0°F LIQUID & 15 PSIG Δ P ACROSS ICEMAKER)

| MODEL | CAR 12 | CAR 16 | CAR 24 | CAR 36 | CAR 48 | CAR 72 | CAR 96 | CAR 144 |
|---|---|---|---|---|---|---|---|---|
| $NH_3$ GPM | 4.6 | 6.8 | 9.0 | 14 | 16 | 28 | 36 | 54 |

NOTE: ALL CAPACITIES ARE BASED ON OIL FREE AMMONIA REFRIGERANT.

# CENTRAL SYSTEM PERFORMANCE

Multiple TURBO ice makers connected to a common central system can be timed so that harvest periods are equi-spaced. The result is that the suction pressure is essentially constant. Practice shows that this condition is achieved when there is 12½% or less of the evaporator sections harvested at one time. This is the condition when two CAR56 or two CAR80 units are connected to a central system.

The constant suction pressure hastens greatly the initial freezing of ice with the result that a considerable increase in the production of thin ice occurs. Production of thick ice is not greatly affected because of the inhibiting effect of the thick ice sheet on heat transfer.

## CENTRAL SYSTEM ICE PRODUCTION TABLE

APPLICABLE WHEN 1/8 OR LESS OF TOTAL EVAPORATORS HARVEST AT SAME TIME

| CYCLE TIME (MIN.) | | 12 | 15 | 17½ | 20 | 22½ | 25 | 30 | 35 | 40 | 45 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| AV. ICE THICKNESS (IN.) | | .26 | .32 | .37 | .42 | .47 | .51 | .60 | .67 | .74 | .79 |
| **MODEL** | TONS REF. @ 0°F PER UNIT | | | | | | | | | | |
| CAR 16/CAR 16 LR | 18.7 | 12.7 | 12.4 | 12.2 | 12.1 | 12.0 | 11.7 | 11.2 | 10.9 | 10.6 | 10.1 |
| CAR 28/CAR 28 LR | 28.0 | 19.1 | 18.6 | 18.3 | 18.1 | 18.0 | 17.6 | 16.8 | 16.4 | 15.9 | 15.1 |
| CAR 40/CAR 40 LR | 37.4 | 25.5 | 24.9 | 24.5 | 24.2 | 24.0 | 23.5 | 22.5 | 21.9 | 21.2 | 20.2 |
| CAR 56/CAR 56 LR | 56.1 | 38.2 | 37.3 | 36.7 | 36.3 | 36.0 | 35.2 | 33.7 | 32.8 | 31.8 | 30.3 |
| CAR 80/CAR 80 LR | 74.8 | 51.0 | 49.8 | 49.0 | 48.5 | 48.1 | 47.0 | 45.0 | 43.8 | 42.5 | 40.5 |
| CAR 120 | 112.2 | 76.5 | 74.7 | 73.5 | 72.7 | 72.1 | 70.5 | 67.5 | 65.7 | 63.7 | 60.7 |

### TABLE NO. 1

| MODEL | CAR 16 | CAR 16 LR | CAR 28 | CAR 28 LR | CAR 40 | CAR 40 LR | CAR 56 | CAR 56 LR | CAR 80 | CAR 80 LR | CAR 120 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| HARVESTS/CYCLE | 1 | 1 | 2 | 1 | 2 | 1 | 4 | 2 | 4 | 2 | 6 |

### TABLE NO. 2

## ENTERING WATER TEMP. CAPACITY MULTIPLIERS

| WATER TEMP. | 65 | 70 | 75 | 80 | 85 | 90 |
|---|---|---|---|---|---|---|
| CAPACITY MULT. | 1.028 | 1.00 | 0.974 | 0.950 | 0.925 | 0.902 |

### TABLE NO. 3

## SUCTION PRESS CAPACITY MULTIPLIERS

| SUCTION TEMP. °F* | +5 | +4 | +3 | +2 | +1 | 0 | −1 | −2 | −3 | −4 | −5 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| CAP. MULT. | .84 | .87 | .90 | .93 | .96 | 1.00 | 1.03 | 1.06 | 1.09 | 1.12 | 1.15 |

* Refers to suction temp. at icemakers — no allowance for suction line losses!

### TABLE NO. 4

## LIQUID AMMONIA FLOW

(BASED ON 0°F LIQUID & 15 PSIG ΔP ACROSS ICE MAKER)

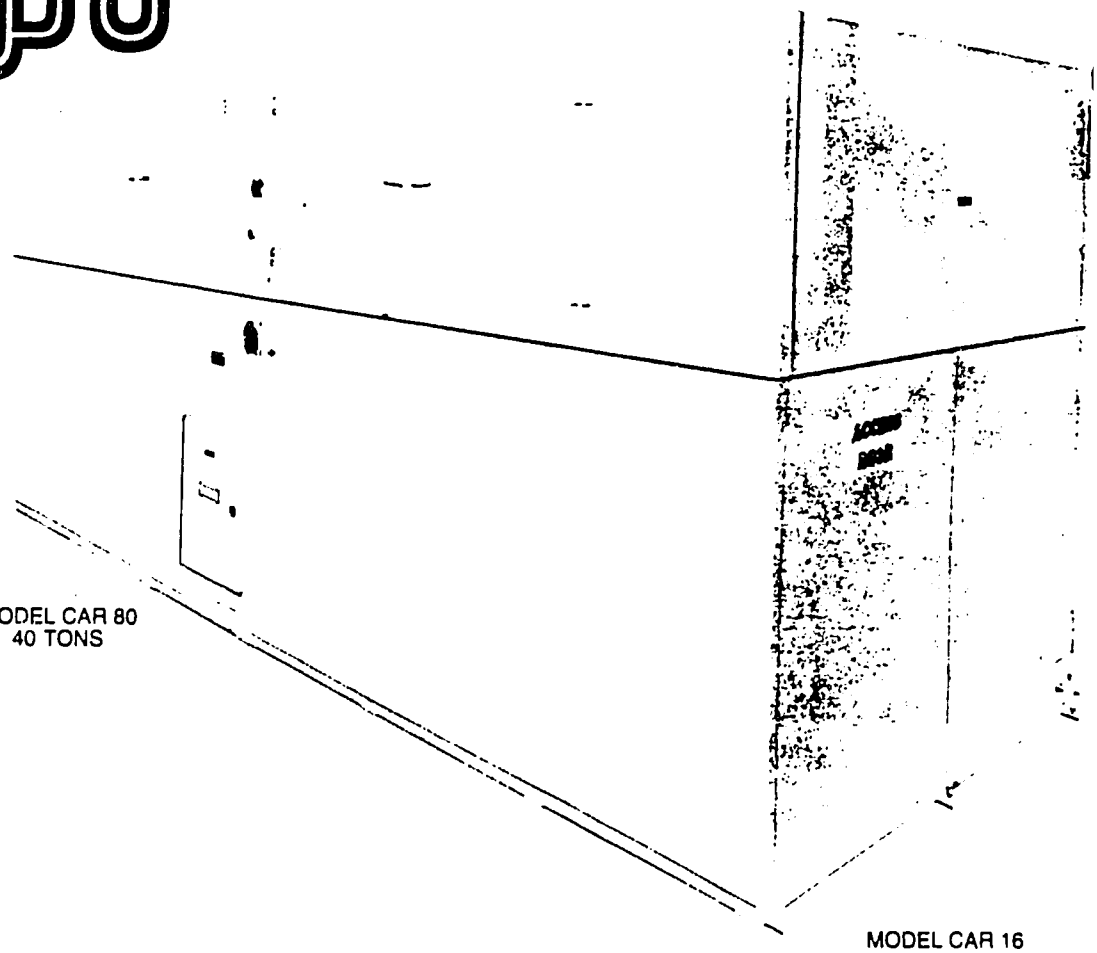
| MODEL | CAR 8 | CAR 14 | CAR 16 | CAR 28 | CAR 40 | CAR 56 | CAR 80 | CAR 120 |
|---|---|---|---|---|---|---|---|---|
| $NH_3$ GPM | 3.8 | 6 | 7.5 | 11 | 15 | 23 | 30 | 45 |

NOTE: All capacities are based on oil free ammonia refrigerant.

# TURBO

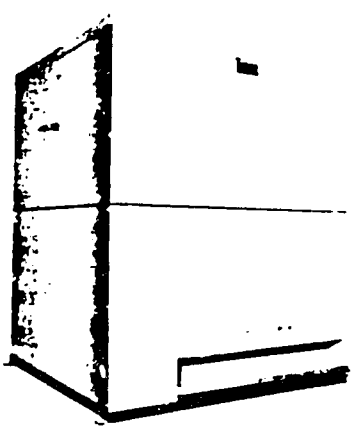
# AMMONIA PLATE ICE MAKERS

. . . are available in 15 models, producing up to 128,000 lbs. of super-cold diamond-hard ice.

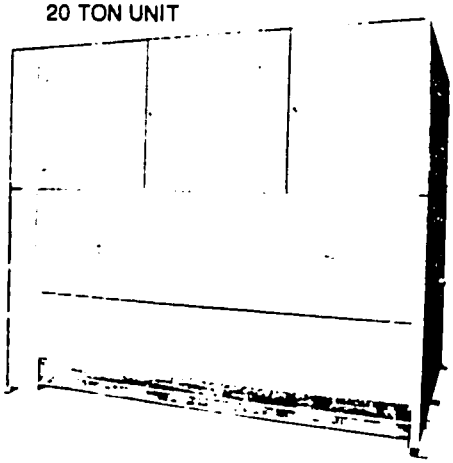


MODEL CAR 80
40 TONS

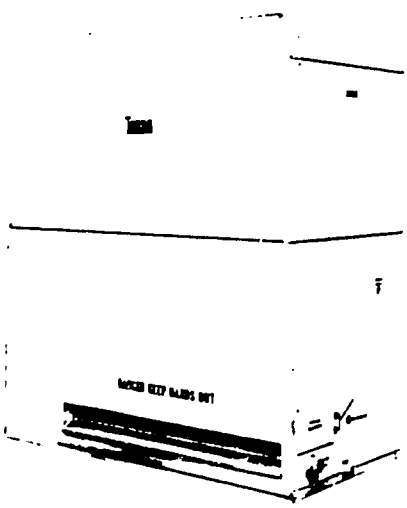
MODEL CAR 8
5 TON UNIT



MODEL CAR 40
20 TON UNIT



MODEL CAR 16
10 TON UNIT

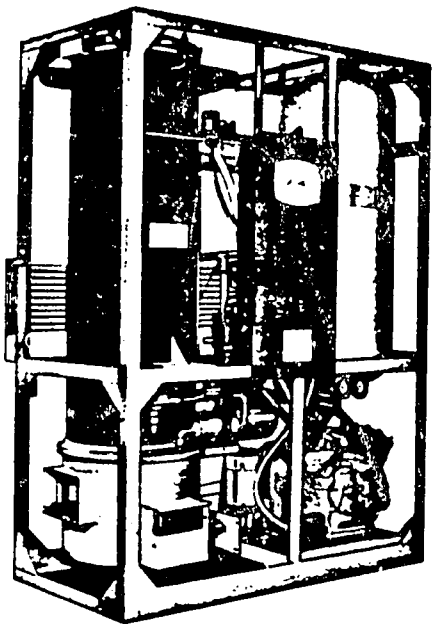


TURBO also manufactures Ice Makers available for refrigerants R12, R22 and R502 in remote and self-contained models, in 1 to 50 tons daily ice capacity. For detailed information on any of these models, contact TURBO REFRIGERATING CO. for illustrated brochures.

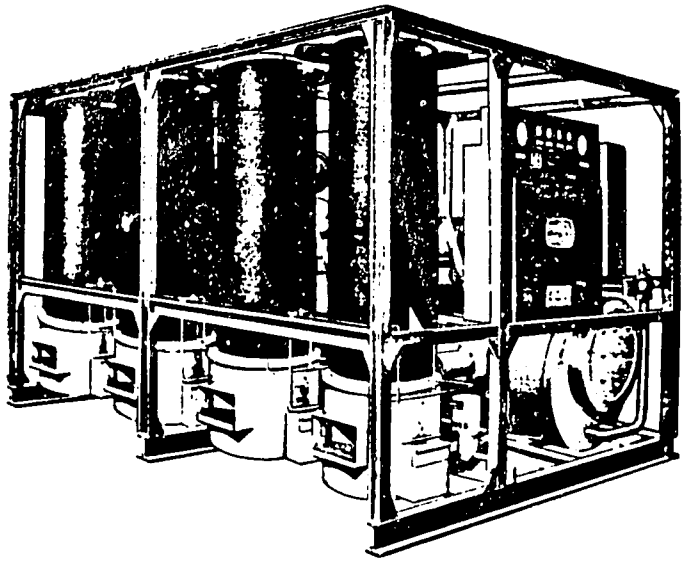
TURBO
REFRIGERATING
COMPANY

817/387-4301
P. O. BOX 396 / DENTON, TEXAS 76201

# *There's a* Vogt TUBE-ICE MACHINE



Models 6000-9000



Model P-418F

### Standard Cylinder

**MODEL 6000**

produces up to 6000 lbs. of ice in the standard size per day. 60" wide, 35" deep, 84" high. 2715 lbs. shipping weight.

### Mini-Tube Cylinder

**MODEL 9000**

produces up to 9250 lbs. of ice in the "Mini-Tube" size per day. 60" wide, 35" deep, 84" high. 3025 lbs. shipping weight.

**See pages 6 and 7**

### Mini-Tube Cylinder

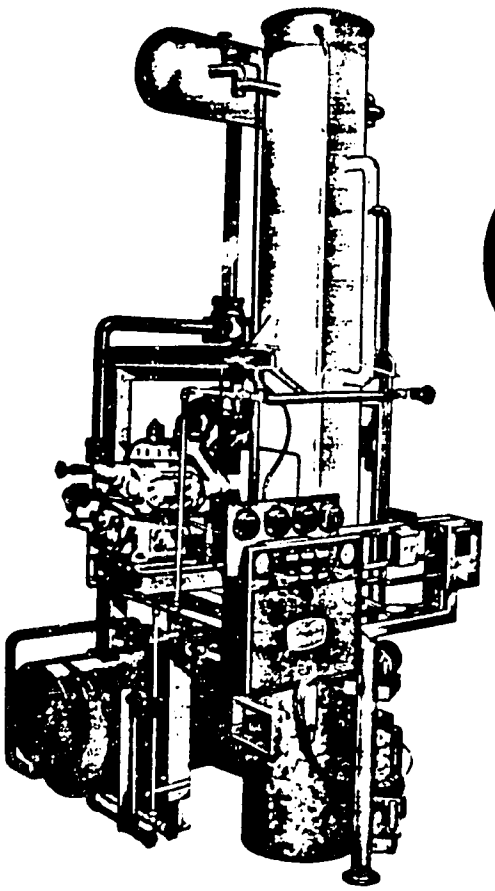
**MODEL P-418F**

produces up to 17 tons of ice in the "Mini-tube" size per day. 7'-8" wide, 10'-0" deep, 7'-8" high. 13500 lbs. shipping weight, 14500 lbs. operating weight.

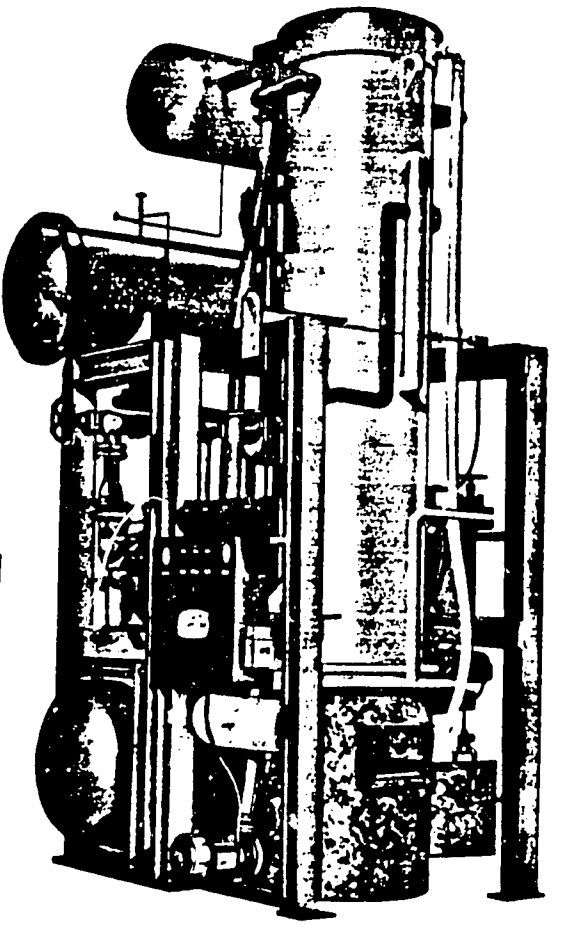
**See pages 8 and 9.**

**MODEL DIFFERENCES** are designated by a series of letters and numbers: **P-**, packaged (includes compressor, condenser and complete high side; **A**, ammonia; **F**, Refrigerant 12; **L**, low side only (does not include compressor, condenser or high side piping); **6000** and **9000**, approximate pounds of ice produced per day; **24**, **34**, and **48**, diameter of freezer."

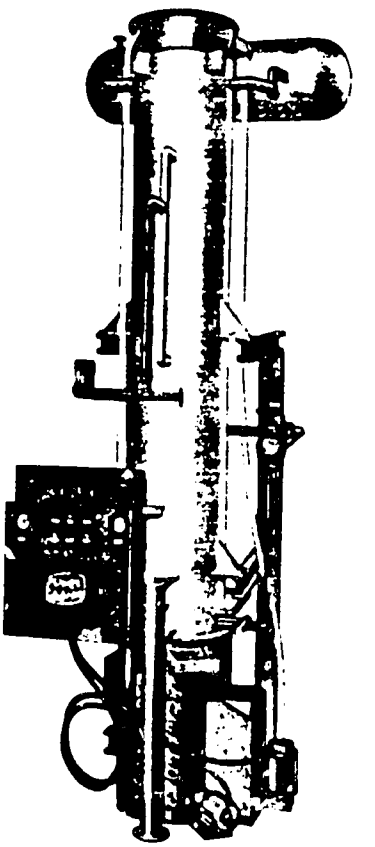
# *For every capacity and ice size requirement*



Model P-24A



Model P-34A



Model P-24AL

### Standard Cylinder

**MODEL P-24A**
produces up to 20 tons of ice in the standard size per day. 8' wide, 7'-6" deep, 16' high. 12,000 lbs. shipping weight, 14,000 lbs. operating weight.

**Model P-24F**
produces up to 15.5 tons of ice in the standard size per day. 8' wide, 7'-6" deep, 16' high. 12,000 lbs. shipping weight, 14,000 lbs. operating weight.

**See pages 10 and 11**

EXAMPLE:

P - 24 AL

Package — P

24" Dia. Freezer — 24

Ammonia Refrigerant — AL

Low Side Only — AL

### Standard Cylinder

**MODEL P-34A**
produces up to 39 tons of ice in the standard size per day. 8'-6" deep, 9'-2" wide, 16' high. 21,000 lbs. shipping weight, 23,000 lbs. operating weight.

**See pages 10 and 11**

### Standard Cylinder

**MODEL P-24AL**
low side unit (designed for existing refrigeration system) can produce up to 29.5 tons of ice in standard size cylinders or crushed per day. 5'-6" wide, 5'-6" deep, 16' high. 6000 lbs. shipping weight, 7500 lbs. operating weight.

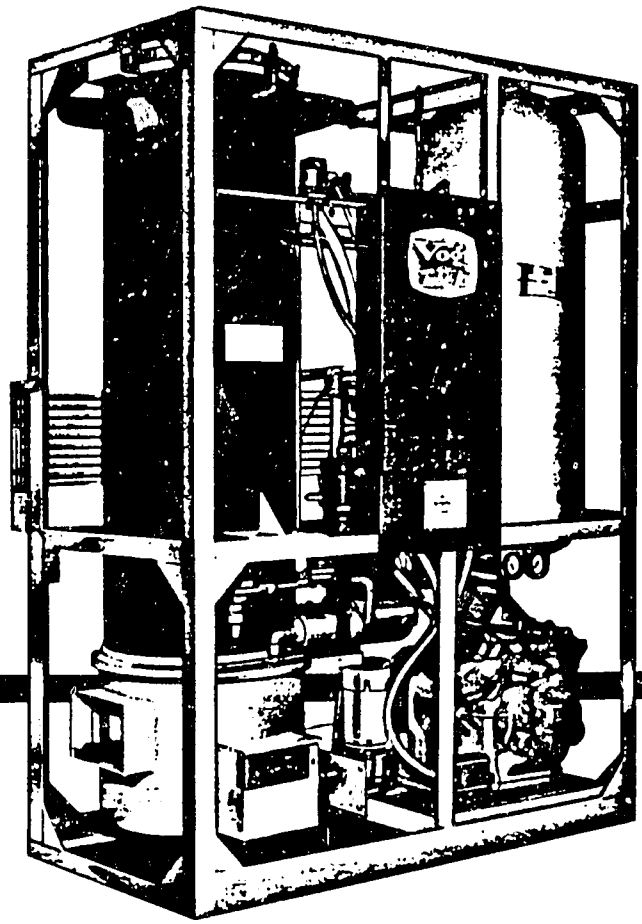
**MODEL P-34AL**
low side unit can produce up to 59 tons of ice in standard size cylinders or crushed per day. 7' wide, 7' deep, 16' high. 9,600 lbs. shipping weight, 11,000 lbs. operating weight.

**MODEL P-48AL**
low side unit can produce up to 80 tons of ice in standard size cylinders or crushed per day. 8'-6" wide, 11'-6" deep, 22' high, 18,500 lbs. shipping weight, 22,000 lbs. operating weight.

**See pages 12 and 13**

# Vogt TUBE-ICE MACHINES
## MODEL 6000—*Standard cylinder ice*
## MODEL 9000—*Mini-Tube cylinder ice*

STANDARD CYLINDER
(ACTUAL SIZE)
MODEL 6000



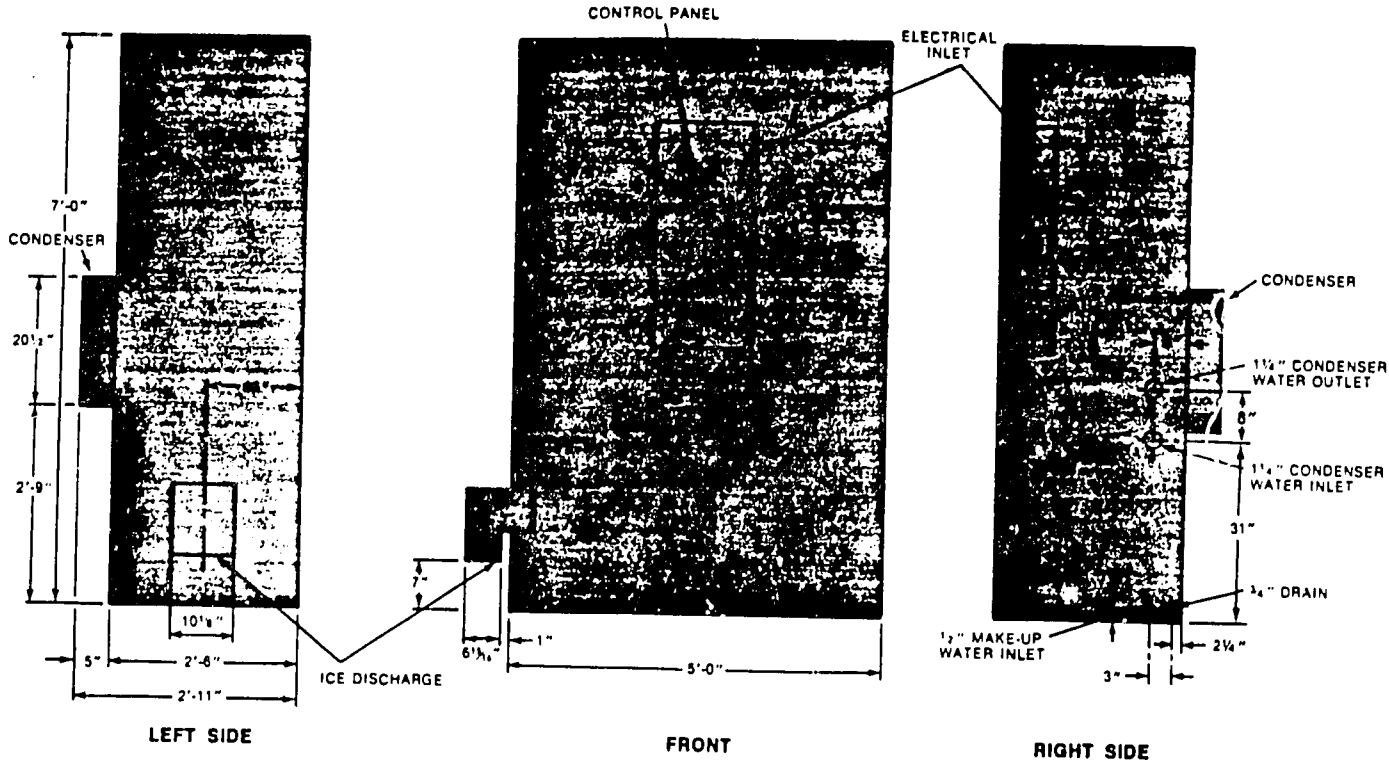
MINI-TUBE CYLINDER
(ACTUAL SIZE)
MODEL 9000

These models are ideally suited for quality ice production to meet the requirements of hotels, marinas, amusement parks, ice plants and other large capacity requirements.

The model 6000 produces the standard size ice cylinder (approximately 1¼" diameter x 1" long). The Model 9000 produces the "Mini-Tube" size ice cylinder (approximately ⅞" diameter x ¾" long). Cylinder ice lengths up to 1½" are possible with a field adjustment.

CYLINDER OR CRUSHED ICE ... a selector switch can be set for either cylinder or crushed ice exclusively, or when set on automatic, both types will be produced. Cylinder ice is produced until a bin level control is actuated, automatically switching the controls for the next cycle to produce crushed ice. When the divided storage bin is full of both types of ice the unit shuts off. When ice is removed the automatic cycle resumes.

These units are readily adaptable to a variety of ice handling arrangements and custom storage bins.




## SPECIFICATIONS

| | MODEL 6000 | | | | | | MODEL 9000 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Capacity Lbs. Per 24 Hr. | | KWH Per 100 Lbs. | | Water Requirements | | Capacity Lbs. Per 24 Hr. | | KWH Per 100 Lbs. | | Water Requirements | |
| Water Temperature | Hertz 60 | Hertz 50 | Cylinder | Crushed | Ice Making GPH | Condenser GPM | Hertz 60 | Hertz 50 | Cylinder | Crushed | Ice Making GPH | Condenser GPM |
| 85° | 4600 | 3820 | 3.60 | 4.00 | 23.0 | 13.4 | 6600 | 5500 | 4.80 | 5.30 | 33.0 | 18.3 |
| 75° | 5100 | 4235 | 3.50 | 3.90 | 25.5 | 7.0 | 7300 | 6050 | 4.30 | 4.70 | 36.5 | 9.5 |
| 65° | 5500 | 4565 | 3.40 | 3.80 | 27.5 | 4.7 | 7950 | 6610 | 3.95 | 4.40 | 39.8 | 6.4 |
| 55° | 5800 | 4815 | 3.25 | 3.65 | 29.0 | 4.4 | 8600 | 7170 | 3.65 | 4.05 | 43.0 | 6.0 |
| 45° | 6000 | 4980 | 3.10 | 3.60 | 30.0 | 4.1 | 9250 | 7730 | 3.35 | 3.75 | 48.3 | 5.6 |
| **Weight** | Net: 2500 lbs. — Shipping: 2715 lbs. | | | | | | Net: 2800 lbs. — Shipping: 3025 lbs. | | | | | |
| **Standard Electrical Requirements** | 50 ampere service | | | | | | 100 ampere service | | | | | |
| | Eith[illegible]08 volt, 3 phase, 60 hertz, or 230 volt, 3 phase, 60 hertz. (Optional electrical arrangements on request.) | | | | | | | | | | | |
| **Standard Condensing Unit** | 10 hp rating | | | | | | 15 hp rating | | | | | |
| | Refrigerant 12 with accessible hermetic compressor and water cooled tube-within-a-tube condenser. Remote air cooled condenser available as optional extra. | | | | | | | | | | | |
| **Ice Size** | M-6000 Cylinder: 1¼" diameter x 1" long (adjustable to 1½"). Crushed: 3/16" - ¼" thick.<br>M-9000 Cylinder: ⅞" diameter x ¾" long (adjustable to 1½"). Crushed: 3/16" - ¼" thick. | | | | | | | | | | | |

NOTE Capacity based on Ambient (Air) Temperature 90° F
Water and KWH based on 60 Hertz operation
Water requirement for Ice Making does not include Blowdown
Refrigerant charge included

*Over Half a Century Better*

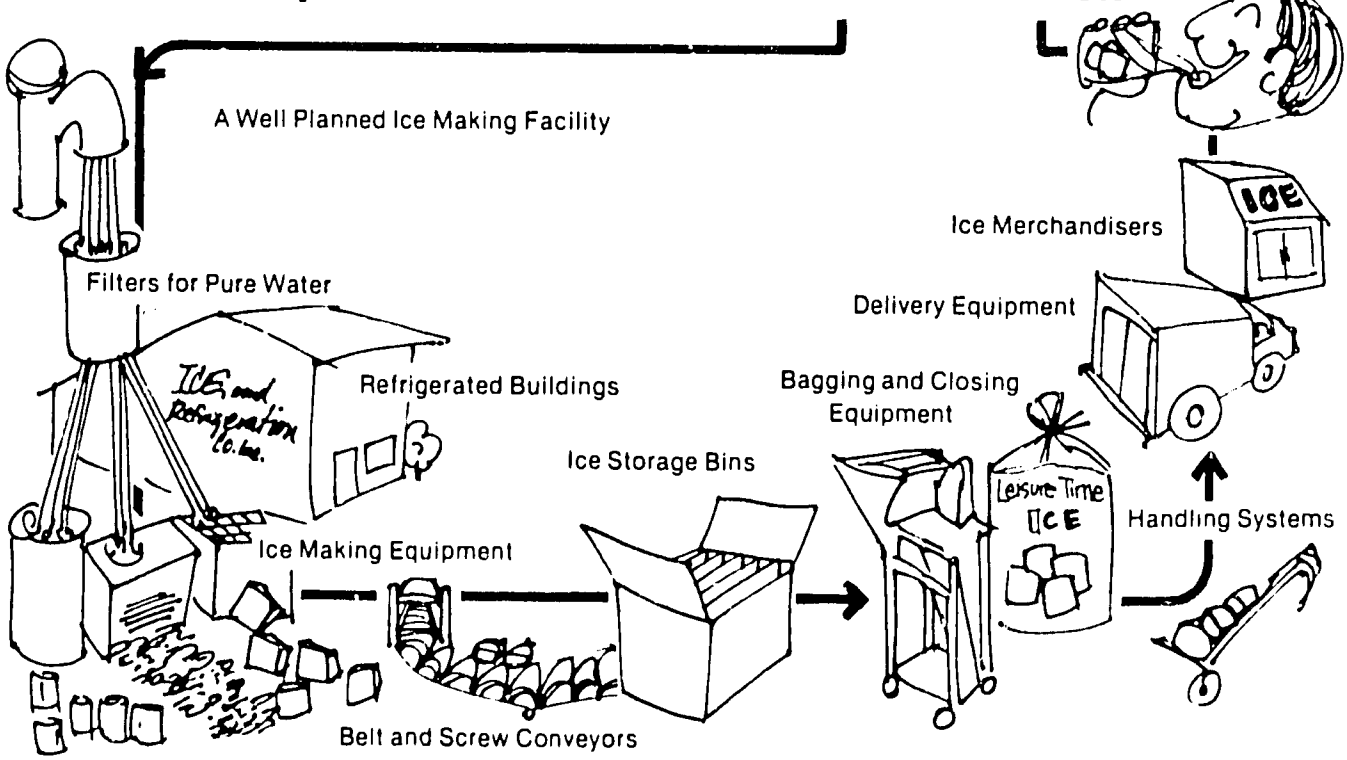
# BACU

## REFRIGERATION COMPANY

## SUPPLYING, SERVICING, INSTALLING, DESIGNING, and ENGINEERING

## All and Anything for Today's Ice Industry Needs

***You Can Depend on BACU from Start to Finish***



# Time Tested Loyalty

For more than fourty years now, we've offered realistic, often unique, solutions to an immense variety of ice related and water treatment problems. In this time, we've proudly designed many ice plants. We properly place and choose all equipment with one thing in mind—Your on-going business and profit.

We continue to expertly service and install all types of ice making equipment, from the simplest commercial bagging equipment to the largest industrial evaporative condensors. BACU still offers the Ice Industry many complete lines of the best ice making supplies and equipment available anywhere. We are committed to quality and to competitive prices—making the best in the industry available to you at the best possible price. Now, when You want the best for Your business, call the best in the industry. We give you our best. We're BACU Refrigeration Supply Company.

# Profitable Ice Production Depends on Solid, Efficient Ice Equipment

BACU's highly skilled engineers and technicians draw upon the finest equipment available to the ice industry today when designing efficient, economical ice manufacturing facilities for you.

The people at BACU understand the industry's constant problems of labor efficiency, equipment up-keep, performance and profit. They understand all facets of the refrigeration business. The innovative creative BACU team can help you solve any seemingly difficult production problem. Experience counts when down time means dwindling profits. BACU has an abundance of practical problem solving experience. We can design and engineer an entire ice making facility or install a simple modern conveying system. All will fit your space requirements and most importantly, your finances. **These quality manufacturers are part of the great BACU problem solving force.**

- **MYCOM** Refrigeration Equipment
- **KASTEN** Bins
- **HANCO** Truck Bodies
- **PLAS-TIES** Bag Closers
- **BACU-PROMAR** Automatic Packaging Systems
- **MOBIL**
- **UNION CAMP** Bags
- **STRETCH GARD MINI-WRAPPER** Panel Wrap Film
- **K.G. BROWN**
- **ROBERTS ENGINEERING**
- **POLAR** Block Ice Systems
- **NEW JERSEY** Wire Stitchers
- **KWIK LOC**
- **HAMER** Bag Closers
- **MASTER-BILT** Refrigerated Buildings
- **WILSON/MSA** Safety Equipment
- **WELD LOC** Poly Strappers
- **FILTERITE** Water Filters
- **LEER**
- **STAR**
- **STARRETT**
- **BILOFF** Ice Merchandisers
- **BALTIMORE AIR COIL (B.A.C.)**
- **EVAPCO**
- **MARLEY** Evaporative Condensors and Cooling Towers
- **HYTROL**
- **LILLY** Conveyors, Ice Handling Equipment
- **PERFECTION**
- **MATTHIESON** Baggers, Conveyors, Ice Handling Equipment
- **VOGT** Tube Ice Makers
- **ROLL-ER-CARY** Merchandiser Movers
- **ICE PLANT**
- **MORRIS** Ice Makers
- **TURBO** Production, Storage and Distribution Systems
- **SEMCO** Ice Handling Equipment
- **BACU-MATIC** Non-Chemical Fluids Conditioners
- **LAKOS** Separators
- **INSTA-FOAM** Insulation Kits
- **FRICK**
- **VILTER**
- **YORK**
- **SULLAIR** Compressors and Refrigeration Accessories
- **AMAR** Poly Sealers
- **NIECO**
- **CURTRON** Strip Doors

# The BEST-Just a Call away and TOLL FREE

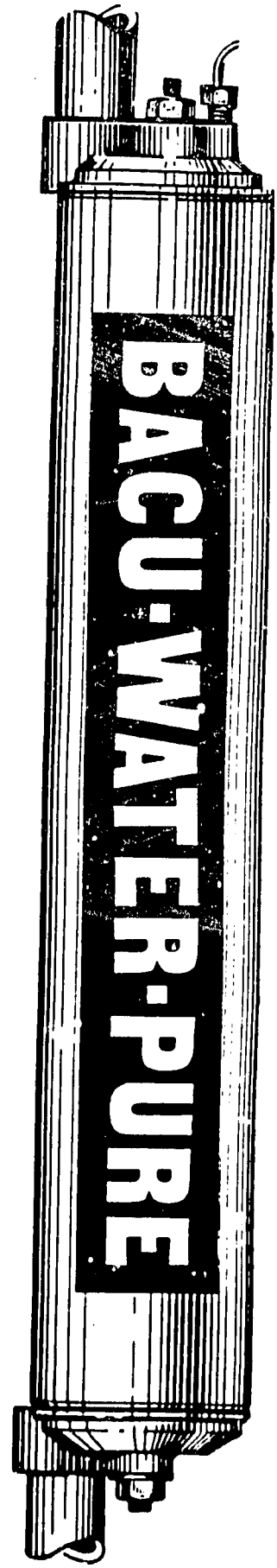
**NATIONWIDE CALL: 1 • 800 • 431-5000** In New York State Call 1•914•454-3500
P.O. Box 63, 35 High Street, Poughkeepsie, New York 12602

Member Associated Builders and Contractors, Inc. · Packaged Ice Association · National Concrete Masonry Association · Approved by International Association of Plumbing and Mechanical Officials

# BacuWaterPure

## Reverse Osmosis Drinking Water System

WaterPure's unique "full-flow" module design makes installation on the main water supply line or on the discharge side of a water conditioner possible. This eliminates any need for in-line, cartridge-type prefilters that ultimately reduce system pressure. WaterPure modules are available in five and ten gallon per day sizes and can be manifolded for higher outputs.




## *It's the Product America NEEDS and WANTS...*

### The WaterPure® Advantage

- **AUTOMATIC:** The WaterPure system is completely automatic — no solenoids or special equipment to fail. When the storage tank is full, the system automatically stops working. When water is drawn from the storage tank, it automatically starts to work again.
- **BACTERIAL & pH RESISTANT:** The cast-in-place triacetate membrane is very resistant to bacteria and high pH's. The feed water can be chlorinated or unchlorinated.
- **DRAINFREE:** The WaterPure R.O. is installed on the main line and does not require a drain, thus eliminating both wasted water and the many problems relating to drain systems.
- **EASY INSTALLATION:** The simple installation instructions make for trouble-free installation and service.
- **HARD OR SOFT WATER:** These units can be installed on hard or soft water. By following the simple instructions, they will treat some waters up to 3000 ppm, and, by following special instructions, can even be operated up to 200 pounds of pressure.
- **NO PREFILTERS:** The in-line installation means that no prefilters are needed. Having to change prefilters at other than membrane change time can be a serious and costly problem with other R.O.
- **SELF-CLEANING:** The self-cleaning action of continued turbulent flows of water over the 18 membrane element surfaces ensures long life.
- **PRICED RIGHT:** WaterPure reverse osmosis drinking water systems are competitively priced, and after 6½ years of field service by water conditioning dealers, they have proven to be profitable and trouble-free for both rentals and sales.

**BACU** FLUIDS CONDITIONING COMPANY

DESIGN
ENGINEERING
INSTALLATION
SERVICE

A Division of BACU INDUSTRIES, INC.

BACU Fluids Conditioning Company P.O. Box 63, 35 High Street, Poughkeepsie, New York 12602 1•914•454-3500 **TOLL FREE 1•800•431-5000**

# INTRODUCING A NEW GENERATION OF ICE MAKERS ENGINEERED SPECIFICALLY FOR PROFITABILITY

VIVCO ICE MACHINES

**VIVCO** will easily double the capacity now produced by the next best machine at virtually the same set-up cost, while substantially reducing maintenance headaches and overhead operating costs.

## Highly advanced refrigeration concepts deliver 30% + increased efficiency factor - 40% less fines!

We determined that the whole ice maker should be used rather than allow the top 20 to 30% to clog the bins with wet, unusable fines. **VIVCO'S** innovative circulating system freezes all the way to the top with constant quality saleable ice. Refrigerant goes where it's supposed to and profit stealing waste heat goes where it should.

We determined that higher profitability could be achieved if efficient condensing means were used. Rather than locate heat exchangers on the machine **VIVCO** incorporates evaporative condensers in a remote (preferably outside) location. You get lower overall operating temperatures resulting in as much as 30% more efficient use of kwh per ton! Further cost savings.

## State of the art, fully programmable electronics controls.

You can forget about fluxuations in conditions. Forget about mechanical timers and pressure switches. Give your control people something more profitable to do!

**VIVCO** control constantly monitors and adjusts to optimum performance specs as outside conditions and temperatures demand. Now! Not after coffee break. More specifically, these efficiency adjustments are made simultaneous as fluxuations occur.

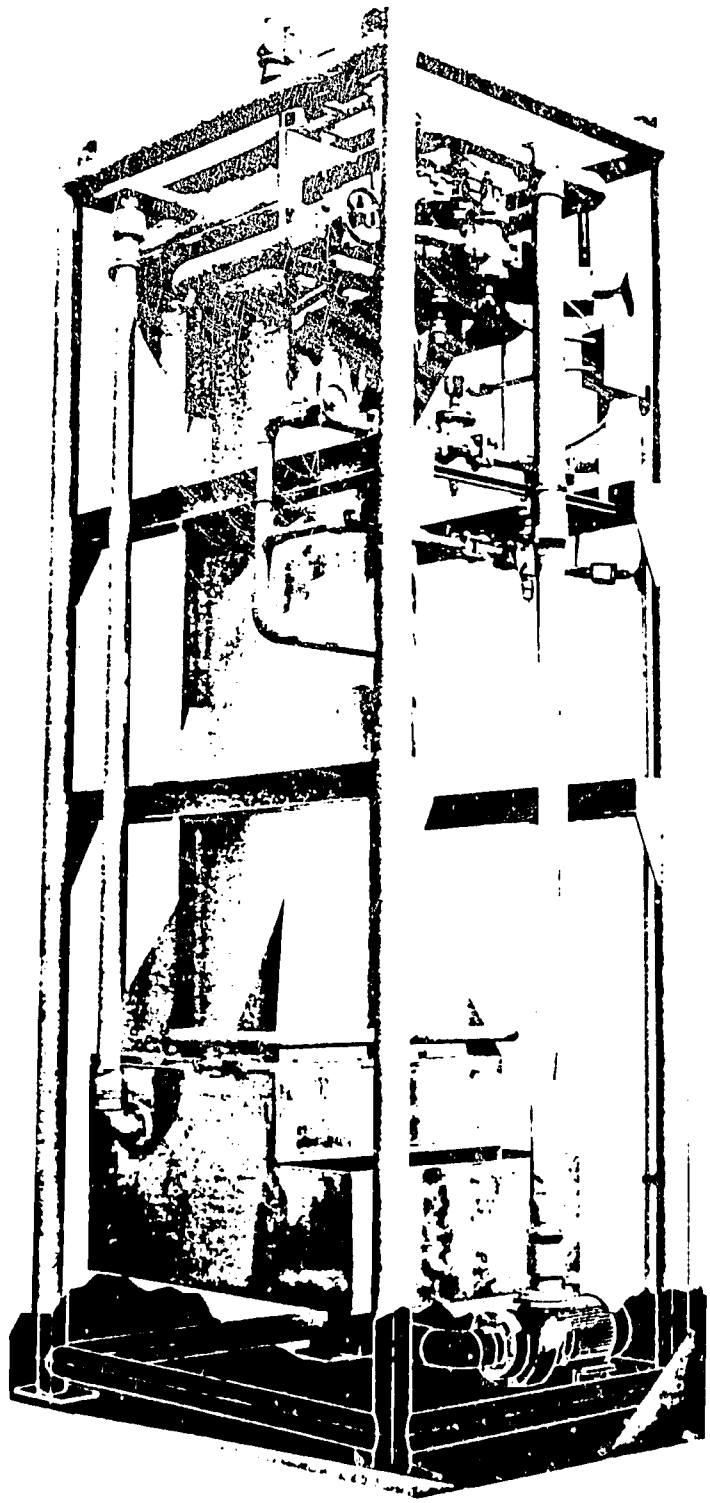
**Results?** Excellent Q.C. Unheard of uniformity in product. Absolute optimum harvest times. Less overhead and man power costs. Reliable bagging volume and reduced bagging, weighing and stacking adjustments. Much more saleable product. Higher profitability.

## Self protection is built in.

Our built in "jam" circuit can eliminate many headaches too. If an emergency arises, our **VIVCO** control command center knows what to do. It will hold, shut down, or automatically harvest depending on conditions and save you a shaft, motor or more!

## VIVCO easy to buy.

Just talk with one of our sales/tech representatives.



# VIVCO ICE MACHINES

## VIVCO is built to take care of itself.

**The only wear part in the whole machine can be held in the palm of your hand and completely replaced at your local machine shop for 10 bucks.**

This is the lowest maintenance system known. Motors are instantly accessible. No bearings in water, no belts, no rack and gear drives. The cutter shaft is engineered for self protection and is easily removed. No gears to wear or replace.

All stress parts and fittings are shelf items at the local hardware or plumbing supply. All "wet" parts are stainless steel, plastic or brass. Motors are sealed and strategically located for cool operation.

## VIVCO becomes your slave.

Since our control command center is fully programmable it can be slaved with other operations. Communicate with other **VIVCO** machines to synchronize harvest cycles. Operate security warning systems. Drive or control other support machines. Operate to automatic timers. Turn on lights. Remote monitor and management capabilities abound. It will even turn on, make ice, harvest, turn off, tell you it's doing so and await further instructions.

## VIVCO easy profitability.

Easy to install. Standard electrical and plumbing hook ups. Highly adaptable to a wide variety of plant layouts and physical requirements - will occupy half the floor space of other machines of comparable production capacity.

## WHAT VIVCO OWNERS HAVE TO SAY

"We are very pleased with the performance of the **VIVCO**."

"The personal touch we received from Vivian went a long way in our decision to purchase a **VIVCO**."

"1,000 lbs of 7/8" ice every 17 minutes...the most capacity at a price we like very much."

"I'm quite amazed to see **VIVCO's** computer adjust to temperatures instantaneously."

| Ice Type | VIVCO | | | VIVCO | | | VIVCO | | |
|---|---|---|---|---|---|---|---|---|---|
| FREEZER DIAMETER | 20 inch | 24 inch | 36 inch | 20 inch | 24 inch | 36 inch | 20 inch | 24 inch | 36 inch |
| Ice Size (Dia. Inches) | 1 3/8" | | | 1 1/8" | | | 7/8" | | |
| Capacity (Tons) | 5 | 17 | 39 | 6.5 | 17.5 | 40 | 7 | 18 | 42 |
| Electrical Requirement | 440 or 220 Volt, 3 phase, 60 Hertz (Whole Machine) | | | | | | | | |
| Water Connection | 3/4" FPT | | | | | | | | |
| Height | 9'2" | 16'6" | 16'6" | 9'2" | 16'6" | 16'6" | 9'2" | 16'6" | 16'6" |
| Depth | 6'0" | 5'0" | 6'8" | 6'0" | 5'0" | 6'8" | 6'0" | 5'0" | 6'8" |
| Width | 4'0" | 3'6" | 4'8" | 4'0" | 3'6" | 4'8" | 4'0" | 3'6" | 4'8" |
| Shipping Weight (Lbs.) | 3900 | 4230 | 8300 | 3900 | 4230 | 8300 | 3900 | 4230 | 8300 |
| Operating Weight (Lbs.) | 6130 | 5915 | 12,500 | 6130 | 5915 | 12,500 | 6130 | 5915 | 12,500 |

Ammonia or Freon Units Available! Self Contained or Low Side Only!

# "SERV-ICE" EVENTS AND SERVICES

## VIVIAN "SERV-ICE" SEMINAR

The Vivian "Serv-Ice" Repair and Maintenance Seminar is an annual event which takes place in February. This seminar has become the industry's standard by which similar seminars are judged, covering all aspects of preventive maintenance and repair in all sizes and types of ice makers, ice handling and packaging equipment, and ice merchandisers.

Watch for more specific information and dates in *Refrigeration* magazine and plan to attend this comprehensive learning experience this year. Remember, maintenance doesn't cost . . . it pays.

## USED EQUIPMENT PROGRAM

The next time you trip over that piece of equipment that you've outgrown or retired, consider this: With new equipment costs rising steadily, there is a large demand for used and reconditioned items. Vivian's new cooperative program allows you to find a market for this "junk" equipment. Call us, tell us what you have, ship it prepaid to our warehouse, and we will totally rebuild it, charge the purchaser for parts, labor and 15% profit, and send you a check for the remainder when it's sold.

Arrangements must be made with Vivian prior to shipping any items.


Member

PACKAGED ICE ASSOCIATION

If you are in the ice business, you should be in the PIA.
As a businessman, you must know your industry. You must understand governmental regulations and how they affect your business. You must be aware of economic factors that affect your firm's growth and profitability. You must keep abreast of developments in technology and marketing.
If you are not in the PIA, you are not doing all you can do for your industry. It's as simple as that.
We invite you to ask any PIA member about the value of PIA. Or, call us, we'll do our best to answer all your questions.

For complete membership information, call or write our national headquarters:
PACKAGED ICE ASSOCIATION
111 E. WACKER DRIVE — CHICAGO, ILLINOIS 60601
312/ 644-6610

REFRIGERATION

National News, Merchandising and Technical Publication for Ice and Allied Industries.

Keeps you informed on what's happening throughout the industry!
— New Products
— Convention Information
— Classified Advertisements help find that item you're looking for or sell what you no longer need.

To subscribe, write:
REFRIGERATION
P.O. BOX 7368
ATLANTA, GA. 30357