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TECHNOLOGY REVIEW FOR FIELD TEST #10
WIND POWERED DESALINATION SYSTEM

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FOREWORD
TECHNOLOGY REVIEW

The Egyptian Electricity Authority (EEA), 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 4-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 those renewable energy technologies which have proven successful, are available for widespread use in Egypt.

Each of the project field tests contain 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. Three of the eleven potential field test demonstration projects are wind energy system applications. The Technology Review for one of these three field tests, a wind powered desalination plant, is presented in this document.

The system consists of one or more wind generators, some battery storage and a diesel generator, operating as a hybrid system isolated from the local electric grid to supply power to a 50 m^3 per day desalination plant. The candidate site chosen for this demonstration project is the Hurghada Marine Institute located in Hurghada, a village along the Red Sea Coast approximately 450 kilometers from Cairo.

This Technology Review provides information regarding the technical maturity of all required hardware for the successful installation and operation of the system. The Review also provides information on a representative selection of manufacturers and products.

This document is Subtask 3.10.2 of the field test requirements under Contract AID 263-123C-00-4069-00, Task Area 3. The recommendations made in this document are based on the maturity of all technologies involved and with consideration of any perceived site-specific constraints existing at Hurghada. The results from Task 2.1, Economic/Market Assessment address other factors such as economics, market size and social/institutional aspects that may impact the potential for widespread implementation of wind powered desalination plants in Egypt. The Task 2.1 results will be provided in a separate document.

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1.0 EXECUTIVE SUMMARY

1.1 Project Objectives

The purpose of this field test is to demonstrate the use of wind system generated electricity to power a sea water desalination plant on the Red Sea Coast. The proposed location for the system is the Marine Biological Station in Hurghada, approximately 450 kilometers from Cairo. Data collected during the November 1985 site visit indicate that a stand-alone power system, consisting of wind turbines, a diesel generator and some battery storage, can be demonstrated at this location. The system sizing and specific location for this field test is based on a preliminary assessment of regions in Egypt where (1) current and future demand for potable water falls short of supply, (2) future regional growth and development is dependent upon adequate supplies of potable water, (3) the wind resources appear to be adequate to support such a demonstration, and (4) the infrastructure of the host organization appears to be adequate to support system operation and maintenance.

1.2 Intent of the Technology Review

There are five major factors in assessing the viability of this field test demonstration:

(1) The adequacy of the wind resource;

(2) User requirements and site specific characteristics;

(3) User capability for system, operation and maintenance;

(4) Social, economic and institutional aspects; and

(5) Maturity of the necessary technologies.

This document, the Technology Review, provides a review and evaluation of relevant technology in order to support decisions and information requirements of the conceptual design task, the preparation of a Statement-of-Work for a Tender Document, and the evaluation of field test contractor's proposals.

1.3 Technology Perspective

Field test #10 will evaluate the technologies of desalination, wind energy, 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 desalination equipment will also be evaluated.

The technologies considered for desalting sea water (reverse osmosis, electrodialysis and vapor compression distillation) are technically sound. Hardware is commercially available for reverse osmosis and vapor compression distillation processes. Sea water electrodialysis equipment is only available on a demonstration basis. The application of commercially available wind energy systems to each of the technologies is technically feasible and consistent with project objectives, but has yet to be commercially proven.

Diesel powered electricity generation (diesel generator) for remote power applications is a 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.

Lead-acid and nickel-cadmium storage batteries, best suited for wind 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.

As electricity prices in the United States began to increase in the 1970's and 1980's applications for wind generators also began to increase. Stand-alone applications for wind generators increased mainly in response to

increased electricity prices and the growing need for remote power sources. Currently, there are numerous stand-alone applications for wind generators on farms and in remote areas. However, the primary application for wind energy today, and the one for which the majority of wind generators are designed and manufactured, is for the production of grid connected electric power; i.e., wind farms. Wind farms have been in operation in the United States since the early 1980's and have developed mainly in response to tax credits. The U.S. wind turbine industry at the end of 1984 included 30 turbine manufacturers with commercial sales (about 15 manufacturers produce turbines in significant quantities), 96 equipment manufacturers, 15 siting service companies, 25 wind monitoring equipment suppliers, and more than 100 private wind power development or management companies. Since the expiration of the tax credits at the end of 1985 many companies in the wind industry have been reorganizing to streamline their operations. The massive industry shakeout predicted to result from the expiration of the tax credits, however, has not yet happened.

Each of the component technologies involved with this field test has been proven independently. The operating characteristics of the separate technologies are complimentary. Therefore, depending on the specific application and component sizing, the combination of these technologies for "hybrid" power systems (wind, diesels and batteries) can result in higher reliability and lower delivered energy costs than any of the individual technologies operating in a stand-alone mode. In the last five years, the attention given to wind/diesel hybrid (W/D) systems by industry and universities world-wide has increased substantially. Numerous studies are now being conducted in over 15 countries to analyze system behavior, predict performance, and define critical research needs. Testing and demonstration programs plus actual system implementation projects are a prime focus.

1.4 Review of Field Test Hardware

Desalination System

Based upon the proposed application at Hurghada, it appears that a reverse osmosis (RO) system is the most practical and cost-effective desalination alternative. Electrodialysis (ED) systems for sea water applications are not commercially available. Hence, their application for a demonstration project is not recommended. Vapor compression distillation (VCD), on the other hand, is a well proven commercially available technology for desalting sea water. However, such systems have traditionally proven economical only for large applications (i.e., greater than 1800 cubic meters per day), and are only marginally cost effective for applications in the size range proposed for this field test.

Wind Turbines

Wind turbines consist of four basic components: rotor, transmission, generator, and sensors and controls. These components are normally "pre-designed" into a wind turbine - i.e., when purchasing a wind turbine one does not request a specific rotor, generator, transmission or sensors/controls. Wind turbines are designed for specific wind speed ranges and applications and all equipment has already been optimally selected.

Rotor - Major performance variations in turbine output generally will involve rotor design. Popular materials for blade construction are wood, fiberglass and aluminum. Numerous manufacturers make rotors that are proven in operation over the past 5-years. Wooden or fiberglass blades appear to be most suitable for Hurghada.

Transmission - Almost all currently operating wind generators contain a step-up gearbox between the rotor and generator. Most wind turbines use helical or planetary gearboxes, with gear ratios ranging from 14:1 to 25:1. Gearbox technology is well understood and used in operational wind generators. Both helical and planetary gearboxes are appropriate for the proposed system at Hurghada.

Generators - Generators used in stand-alone wind turbine applications are one of four standard types - DC shunt, permanent magnet AC, standard AC, and self-excited induction. Generators are standard systems in use throughout the world, in wind generators and other applications for the generation of electricity. Any of the four types could be used at Hurghada.

Controls - Turbine controls are an important component for optimizing system performance. Turbine control prevents rotor overspeed in high winds and allows turbine operation during cut-in and cut-out wind speeds. Control methods currently used are blade pitch angle control, turbine yaw control and rotor braking. Rotor braking appears to be the simplest and most practical for application at Hurghada.

Diesel Generators

Self-contained diesel engine/generator sets for remote AC power are commercially available in 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.

Inverters/Rectifiers

The use of inverters and rectifiers may be required for system operation. 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. There are a number of suppliers of commercial inverters and rectifiers.

Batteries

The two most common batteries used for wind energy 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 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. 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.

Power System Controller

The type and level of sophistication of the power system controller (PSC) depends on the type of desalination and power system used. An ED and VCD desalina-

tion system, with no battery storage or diesel engine, requires a relatively simple PSC, while the hybrid system required for RO needs a fairly complex controller capable of:

1) Regulating power production from both the diesel and wind generators;

2) Protecting batteries from service extremes;

3) Managing power use to maximize wind energy production; and

4) Continuously displaying system operating parameters.

The PSC for this field test demonstration will most likely be a custom design that must be evaluated on a case-by-case basis.

1.5 Conclusions and Recommendations

The findings in this Technology Review support the recommendation to proceed with Field Test #10 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 wind/diesel power systems, this review indicates that there should be no insurmountable technical problems associated with this demonstration project. This review supports the following conclusions:

1. Hybrid wind/diesel power systems are a logical development step for future remote power system applications where the wind resource is adequate.

2. Individual subsystem component technologies for this field test are proven, reliable and commercially available. As long as all power system components are operating in a hybrid mode, supplying constant power to the desalination plant, no unusual system maintenance problems should result.

3. Wind/diesel power systems in a size compatible with the desalination loads of this field test should have 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 wind/diesel

hybrid powered desalination system should not be designed, purchased and installed at Hurghada.

2.0 FIELD TEST OBJECTIVES AND DESCRIPTION

2.1 Project Objectives

The Egyptian Electricity Authority (EEA), the U.S. Agency for International Development (USAID/Cairo), and a group of U.S. consultants form a team responsible for conducting field test demonstration projects of eleven renewable energy applications in Egypt.

The three general tasks being conducted are:

(1) Field Tests - To assess some selected renewable energy system/applications which could be suitable for commercial use in Egypt; develop detailed engineering design hardware specifications and system performance requirements; prepare RFP packages for procuring equipment; supervise the work of hardware contractors; and collect and evaluate data generated from the field tests.

(2) Supporting Analysis - Conduct technical, social, financial, economic, and market analyses of renewable systems related to the field tests. Develop a computer based Renewable Energy Information System (REIS).

(3) Training - Improve the skills of the Government of Egypt (GOE) and the private sector in evaluating renewable technologies, applications, economics and markets and provide technical assistance in system design, installation, operation and maintenance.

Three of the eleven potential field test demonstration projects are wind energy system applications:

- Village Power - A number of small wind turbines (4kWp to 25kWp) and/or wind turbine/diesel/battery hybrid systems will be designed as stand-alone systems or interconnected with existing power distribution systems.

- Desalination - A single turbine or a small cluster of wind turbines will supply power for a 50 m^3 per day desalination system near the Hurghada Marine Institute on the Red Sea.

- Grid Electricity - A 250 kWp wind farm will be built near Ras Ghareb on the Red Sea. The system will operate in a fuel-saver mode for an existing power station and provide electricity to an existing transmission grid.

The proposed desalination application is based on (1) the belief that future regional growth and the potential for dispersed development throughout the Red Sea coastal region is dependent upon adequate fresh water supplies and

(2) the value of a wind energy demonstration to be sited where the strengthening of Egyptian technical and institutional capabilities for widespread development of this technology can be maximized.

A visit was made to the proposed field test demonstration site on November 10-12, 1985 by personnel from the EEA and the U.S. Project Team[1] for field data collection and interviews with local personnel from the Canal Distribution Company (EEA), the Hurghada Marine Institute and the Red Sea Governorate.

The application of a wind/diesel/battery power system ("hybrid" power system) for desalination at the Hurghada Marine Institute will serve as a demonstration of the capability of these technologies to reliably supply significant amounts of power in locations where electric utility grid power is not available, or where supplies are inadequate or unreliable. It is important that this field test be designed to distinguish between the performance of the energy conversion system, the desalination equipment and other related equipment such as instrumentation and water treatment. The field test will also provide valuable data on the field performance of diesel generators in comparison to wind turbines under similar levels of operation and maintenance.

2.2 Description of the Field Test

The purpose of this field test is to demonstrate the use of wind system generated electricity to power a sea water desalination plant on the Red Sea Coast. The proposed location for the system is the Marine Biological Station in Hurghada, approximately 450 kilometers from Cairo. Data collected during

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[1] In attendance for the U.S. Project Team were Peter Borgo and Robert Russo of Meridian Corporation, and Bruce Watson, a consultant to Meridian. In attendance for the EEA were Eng. Mohamed Mitwally El-Sayed and Eng. Essam El-Din Abu-Zeid. Discussions were held with Dr. Salah and Dr. Fahmy El-Gammal of the Hurghada Marine Institute and Aly Yorsy, General Secretary of the Red Sea Governorate.

the November 1985 site visit indicate that a stand-alone power system, consisting of wind turbines, a diesel generator and some battery storage, can be demonstrated at this location.

The system sizing and specific location for this field test is based on a preliminary assessment of regions in Egypt where (1) current and future demand for potable water falls short of supply, (2) future regional growth and development is dependent upon adequate supplies of potable water, (3) the wind resources appear to be adequate to support such a demonstration, and (4) the infrastructure of the host organization appears to be adequate to support system operation and maintenance. In all towns along the Red Sea, water supply currently falls short of demand. Plans are being implemented to augment existing water supplies with additional desalination plants and pipline improvements. However, demand will continue to outpace supply for the foreseeable future. The 50 cubic meter per day desalination plant proposed for this field test will supplement the potable water supply currently supplied by a 220 kilometer pipeline from the Nile River through Saffaga. The specific location for the demonstration project (the Hurghada Marine Institute) was chosen based on its (1) immediate needs for potable water, (2) plans for future expansion, and (3) competent personnel technically skilled in water chemistry that are available to operate and maintain the system.

2.3 Purpose of the Technology Review

There are five major factors that will be considered specifically for this field test; (1) the adequacy of the wind resource, (2) the user requirements and site specific civil works and infrastructure characterisitics that could affect the installation, (3) the ability of the user to operate and maintain the system, (4) the social, economic and institutional aspects of the application, and (5) the maturity of the necessary technologies (wind turbines, diesel generators,

batteries, and dealination system), i.e. the availability of proven, reliable and commercially available hardware.

This document, the Technology Review, provides a review and evaluation of relevant technology in order to support decisions and information requirements of the conceptual design task, the preparation of a Statement-of-Work for a Tender Document, and evaluation of field test contractor's proposals.

There are certain issues that must be considered in using this document:

(1) There are few reliable methods for comparing wind turbine unit price and performance. Manufacturer specifications have not been developed from a consistent set of assumptions or operating conditions.

(2) Diesel engines and batteries have traditionally been used in steady state applications. However, when used in a wind/diesel hybrid configuration, diesel generator sets and batteries are subject to very cyclical, non-steady state operation. Under these extreme operating conditions certain phenomena or characteristics are not well understood, such as diesel wear, which may lead to high maintenance and a shorter lifetime.

(3) The various technologies required for the field test are "moving targets," as new developments substantially change the technology base, and as each manufacturer makes incremental design improvements to their products.

3.0 HISTORICAL PERSPECTIVE OF COMPONENT TECHNOLOGIES

Field test #10 will evaluate the technologies of desalination, wind energy 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 desalination equipment will also be evaluated.

A perspective on the past and current performance of each technology is provided in this section.

3.1 Desalination

In all desalination methods currently available, salt and water, or relatively pure water and the more salty water from which it originated, are separated by one means or another into their two distinct phases. Common methods used are: electrodialysis, reverse osmosis, distillation, freezing, and solar evaporation.

Electrodialysis (ED) plants have had successful operating histories for brackish water. Currently, there are no commercially available ED systems for seawater, although a few demonstration plants have been built. By its nature, the ED process is well suited to a direct current electrical generating system. Technology development in electrodialysis desalination has involved a process known as electrodialysis reversal (EDR). The system uses electrical polarity to continually control membrane scaling and fouling. Another development is a new anion membrane, which inhibits organic fouling, a problem associated with conventional membranes.

Reverse osmosis applications have increased dramatically over the past ten years, as membrane technology has improved. The process is most suitable for a constant power wind/diesel hybrid system, or wind with the electric grid

as a back-up. Technology development in reverse osmosis desalination has involved the development of energy recovery devices and new membrane designs. Energy recovery devices can reduce process energy requirements by 30% to 40%. The types of systems which have been most successful are the (a) Pelton Wheel Impulse Turbine; (b) the Multistage Vertical Reaction Turbine; and (c) the Horizontal Reaction Turbine. These turbines are connected to the brine discharge to capture some of the high pressure energy associated with the reject flow. Membrane development has centered around the design of thin film composites which have high product flow and salt rejection capabilities. Such membranes will allow lower operating pressures and, hence, reduced energy consumption.

Conventional distillation, the most widely used desalting process, requires significant amounts of thermal energy to effect the separation of salt and water and, hence, is not cost-effective for an electrical energy power supply. Vapor compression distillation (VCD), which operates on a heat pump cycle to evaporate water at atmospheric temperature, requires little or no thermal energy input. Hence, it is a candidate for a wind or wind/diesel hybrid power system. Currently there are over 160 installations of VCD systems throughout the world.

Desalination by freezing is a process with great potential. Although the concepts are proven, the process has not had many applications. As a result, it will not be considered for this field test.

Solar evaporation is a substitute for conventional distillation where adequate solar resources exist. It requires little electrical power (primarily for operating pumps) and, hence, is a poor application for a wind energy demonstration project.

Although the technologies which will be examined for this field test (VCD, RO and ED) are technically sound for desalting sea water, their use with wind generators has yet to be commercially proven. Currently, there are no sea water

VCD, RO or ED desalination systems powered by wind generators or wind/diesel hybrids.

3.2 Diesel Generators

Diesel powered electricity generation (diesel generator) for remote power applications is a 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.

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 wind energy technology and the trend toward lower costs for wind generators, diesel generator technology is being systematically replaced in certain remote power applications such as communications.

A recently published membership list of the trade association EGSA (Electrical Generating Systems Association) contains over 100 manufacturers of diesel generator systems and components. This demonstrates that there is a highly developed technology base for diesel generators.

3.3 Batteries

Lead-acid and nickel-cadmium storage batteries, best suited for wind 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 wind 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 require higher maintenance levels, their use in wind systems is expected to steadily increase.

3.4 Wind Generators

Denmark was the first country to use wind for the generation of electricity. By 1890 the Danes were using a 23 meter diameter wind turbine to generate electricity. By 1910, several hundred units with capacities of 5 to 25 kW were operating in Denmark. About 1925, commercial wind-electric plants using two- and three-bladed propellers came into use in America. These early systems were small in comparison to todays machines, ranging in size from 200 watts to 3 kW, and were used primarily on farms to charge batteries. With the widespread use of inexpensive and reliable utility generated electricity in the U.S. during the 1940's, stand-alone applications for wind generators rapidly decreased. As electricity prices in the United States began to increase in the 1970's and 1980's applications for wind generators also began to increase. Currently, there are numerous stand-alone applications for wind generators on farms and in

remote areas. However, the primary application for wind energy today, and the one for which the majority of wind generators are designed and manufactured, is for the production of grid connected electric power; i.e., wind farms, which have been in operation in the United States since about 1981.

Progress of wind energy technology has been rapid over the past 4-years. It consists of three general phases:

(1) Solving gross reliability problems (mostly structural),

(2) Concentrating on improved reliability through better maintenance and reducing operating and maintenance costs,

(3) Increasing energy production by more efficient control algorithms and by better siting.

There is no doubt however, that the interest and investment in wind energy systems since 1978 has produced a mature, commercially available technology for the generation of electricity in both grid-connected and stand-alone applications throughout the world.

The U.S. wind turbine industry at the end of 1984 included 30 turbine manufacturers with commercial sales (about 15 manufacturers produce turbines in significant quantities), 96 equipment manufacturers, 15 siting service companies, 25 wind monitoring equipment suppliers, and more than 100 private wind power development or management companies. The massive industry shakeout, which was predicted to result from the expiration of the tax credits, has not yet occured. The majority of changes in the wind industry have primarily involved corporate restructuring.

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, depending on the specific application and component sizing, the combination of these technologies for "hybrid" power systems (wind,

diesels and batteries) can result in higher reliability and lower delivered energy costs than any of the individual technologies operating in a stand-alone mode.

In the last five years, the attention given to wind/diesel (W/D) systems by industry and universities world-wide has increased substantially. Numerous studies are now being conducted in over 15 countries to analyze system behavior, predict performance, and define critical research needs. Testing and demonstration programs plus actual system implementation projects are a prime focus. In the United States, new interest has developed in W/D applications as stand-alone power sources for island communities. In addition, wind farm developers are considering adding diesel power sources to their wind power grid, thereby improving the system power "quality" to firm-power status (i.e., 100% availability). Growth in the small, highly reliable W/D system for telecommunication and military applications, in which U.S. manufacturers have played a significant role, is expected to continue.

The aggressive efforts in W/D technology primarily result from increased pressure to provide low-cost energy for remote applications and the economic potential of the W/D combination. Many recent market studies[2] predict that remote power applications will increase significantly over the next 10 years, with electrification expected to grow 20% per year. The studies indicate that W/D hybrids have the greatest potential for this market.

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2 Schroeder, M.P. and Henein, N.A., "State-of-the-Art Assessment on the Development and Engineering Analysis of Hybrid Wind/Diesel Systems," a paper presented at the Wind Power'85 Conference, San Francisco, CA, August 27-30, 1985.

4.0 POWER SYSTEM TECHNOLOGY

4.1 Power System Options

The power technologies specifically under evaluation in this field test are wind generated electricity, and wind in parallel with diesel generators. As background, a brief perspective is provided on competing remote power technologies in this section. Three basic "stand-alone" energy technologies are considered as power for sea water desalination at the Marine Biological Institute at Hurghada. These are diesel, wind and hybrid power.

Diesel Generators

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% back-up and operation of the load during diesel maintenance periods.

Of the three stand-alone energy technologies, diesel generators have the lowest capital cost for a particular application. However, as a result of fuel consumption requirements, their overall cost-of-electricity generation is relatively high.

Wind

In good wind regimes, wind power is usually cost competitive with diesel generators. Although wind turbine capital cost is high, wind turbines produce electricity at a cost competitive rate, over their lifetime, since they have no fuel requirements.

The wind resource at Hurghada appears to be adequate for consideration of a wind turbine to power a desalination plant. The variations in wind speed and, hence, turbine power output, on an hourly, daily and seasonal basis, would result in the need for a very "over designed" stand-alone wind only system

to provide power during low wind speeds. During periods of high wind speeds much energy would be wasted. Since the desalination plant requires a stable power supply, the variability of power output from a wind only system will necessitate the need for a stable back-up power source, such as the electric grid. Thus, if a stand-alone wind system is used, it is more practical to size the wind turbines for high wind speed months and rely on the electric grid to supply additional power requirements.

Wind/Diesel "Hybrid" Power Systems

A hybrid power system - the combination of a wind and diesel generator operating in parallel, and storage batteries - uses the benefits of the three technologies and reduces the disadvantages associated with each individually. The presence of a diesel generator eliminates the need to oversize the wind and battery system. The use of wind generators and batteries permits the diesel to operate at its rated capacity and therefore maximizes its efficiency. It also reduced maintenance and extends the life of the diesel generator.

A hybrid power system can offer improved energy availability at lower life cycle costs than a stand-alone diesel or conventional wind/battery system. 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 wind and battery.

4.2 Operating Strategies

The intermittent nature of the wind, combined with the continuous power needs of an RO desalination system may require a hybrid power generation system consisting of wind generators, a diesel generator and batteries. There are a number of possible operating strategies using various percentages of wind energy, diesel power and batteries to meet the system load and minimize system

operating costs. However, regardless of the operating strategy, the diesel generator should be sized to meet 100% of the system load. This is necessary to assure an adequate supply of fresh water during periods of low wind speeds and high states of battery discharge. A battery system is required to minimize the number of start/stop cycles of the diesel, and to allow the diesel to run close to full load when it is needed (diesel generators run most efficiently and have fewer maintenance problems when operating close to their rated capacity). The battery sub-system will minimize diesel run-time, increase diesel operating efficiency (by allowing it to run near full load), and reduce diesel maintenance (by decreasing the number of start/stop cycles).

A cost effective hybrid power system can only result if all of the power system components operate to minimize overall system operating costs. These components, are outlined below:

- Renewable energy system (wind energy conversion system)
- Fossil fuel based energy system (diesel generator set)
- Battery storage system (including inverters and rectifiers)
- Fuel storage and delivery system
- System controls and sensors.

The diesel generator set operates most efficiently in a cycle charge mode. In this case the generator is activated when the station battery reaches a preset state-of-charge and the generator operates at full load to run the desalination unit until the batteries are fully charged by the wind turbines. Operating the diesel generator in the cycle charge mode has two main advantages; (1) significant fuel savings in that the diesel is only operated at full load, and (2) reduced maintenance costs by fewer on/off cycles.

Early hybrid energy systems used battery voltage as the primary control parameter for system control. Experience has shown that battery voltage can be misleading, especially in a renewable energy system. This is due to the potential

for erroneous readings due to momentary changes in the bus voltage resulting from sudden wind gusts. These conditions may cause unnecessary cycling of the diesel generator. A more advanced method of control is obtained through the use of a battery state-of-charge accumulator. This device is preset for the battery capacity and efficiency and corrected for temperature variations. All of the current supplied to the load from the battery bank is accumulated and displayed as a percent-of-charge of the battery. Simple relay logic then provides start and stop signals for the diesel generator based upon battery state-of-charge. This state-of-charge indicator can also be used to activate or shed auxiliary or non-priority loads, sound alarms or, in extreme cases, disconnected the load entirely to save the expensive station battery from damage due to deep discharge. In most cases, low voltage sensing is also provided for redundancy as an additional safety factor.

4.3 Component Sizing

The most significant design question of a wind/diesel hybrid power system is the sizing of the wind, diesel and battery sub-systems. The wind turbines and diesel generator can be sized for one power source to contribute from 0 to 100 percent of the demand. If a 100% diesel system is chosen, no battery storage is needed. However, when wind energy is required as part of the power mix, batteries must be included and sized to minimize diesel run-time and on/off cycles. The selected size of the sub-system components is a function of their relative life cycle costs.

For a cost effective wind/diesel hybrid system, wind power must be a large component of the overall system power generation. The reason is the high initial cost and low-operating cost of wind turbines relative to diesels. High initial cost must be compensated for by maximizing wind turbine operation (low operating cost) and minimizing diesel operation (high operating cost).

Diesel-generators have generally been used as principal sources in small power systems. Engineering of diesel-generator sets has, therefore, always been based on high penetration, i.e. diesel-generators are designed to function as autonomous sources. On the other hand, wind-turbine generators have been considered small contributors to large power systems. This is particularly true in the United States, where the wind turbine market is largely driven by the California wind farms. These farms are connected to 10,000-20,000 MW power systems, which in turn are interconnected with other larger systems. As a result, engineering of wind turbine generators has generally ignored technical issues peculiar to high penetration.

Based upon the particular application loads, the wind energy system is sized to take maximum advantage of the available wind resource throughout the year. This requires that the system be sized to maximize wind energy output during low wind resource months, which means that there will be an excess energy production during high wind resource months. Batteries are sized for the worst wind resource month to minimize diesel run-time and number of on/off cycles. The diesel generator must be sized to meet 100% of the load for periods of low/no wind and high states of battery discharge.

4.4 AC Versus DC System Designs

An important design issue for the wind or wind/diesel power system and desalination plant is one of an AC or DC system. If electrodialysis is chosen a DC system is preferred to meet process requirements. If RO or VCD is chosen the choice between AC or DC Power becomes more difficult. Both RO and VCD systems, since they ultimately rely on mechanical shaft power for pressurization and/or vacuumization (pumps or compressor), can be designed for either AC or DC power. All commercially available systems however, are currently designed for AC applications. Wind generators are primarily designed for AC applications.

However, there are some commerically available small DC wind generators (< 10 KW).

Electrodialysis[3]

Electrodialysis is a DC process, producing fresh water in proportion to available current. Hence, the power variability from a wind turbine should not be a problem. In addition, since constant power requirements are not necessary, there is no need for battery storage or diesel generators. There will, however, be a need for large amounts of water storage for periods of low wind speed. The power system for this application could consist of DC wind generators or AC wind generators plus a rectifier. The final design choice should be based on cost and performance since all components are proven in the field.

Vapor Compression Distillation

VCD requires the application of shaft power to operate a vapor compression system, a vacuum pump and numerous circulation pumps. This shaft power can be supplied from either on AC or DC motor.

Although a constant power supply is not essential, it is recommended for efficient system operation. Hence, a battery storage or diesel generator should be used to moderate variable power output from the wind turbine. The wind turbine used can be either DC or AC. The AC vs. DC design options for VCD plant are the same as for an RO plant, and are detailed below.

Reverse Osmosis

The RO process requires a fairly constant pressure to operate properly. Therefore, a system with a constant power output is required. The pressure can be produced by either an AC or DC motor running a pump. The power generation system[4]

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[3] Electrodialysis systems are currently only available on a demonstration basis for sea water applications. Since the application is technically feasible, the design options are presented.

[4] Wind and diesel generators are considered as the power generation system, as opposed to batteries which are only storage services. Diesel and wind generators can be either AC or DC; while batteries are always DC.

will consist of both AC and DC components. The basic choice which must be made is whether the wind and diesel generators, and pump motors, are AC or DC.

There are four basic design configurations for the RO system powered by a hybrid system (Exhibit 1). First, a DC wind generator connected to a battery and a DC drive motor, and a DC diesel generator connected to the DC drive motor can be used. Second, an AC wind generator connected to a battery (via rectifier) and DC drive motor, and a DC diesel generator can be used. Third, a DC wind generator connected to a battery and AC motor (via inverter), and an AC diesel gen set can be used. Finally, an AC wind generator connected to a battery (via rectifier) and an AC motor (via inverter), and an AC diesel generator can be used.

Each of the design choices has advantages and disadvantages, as outlined below:

Option 1:

- o DC wind and diesel generators are more expensive than the same size AC generator
- o DC generators (both wind & diesel) are available in limited sizes
- o Standard DC motors contain bushes which require continuous maintenance
- o DC motors are more expensive than the same size AC motor
- o No inverter is required, thus improving system efficiency and reliability
- o Conventional RO systems will have to be redesigned for DC motor applications.

Option 2: (in addition to relevant statements above)

- o AC wind generators are available in a wide range of sizes

Option 3: (in addition to relevant statements above)

- o AC diesel generators are available in a wide range of sizes
- o Inverter adds inefficiency and unreliability to system
- o AC motors are more reliable and readily available than DC motors
- o Conventional packaged desalination plants can be used.

Option 4: (in addition to relevant statements above)

- o Requirement for rectifier and inverter further complicates system and increases the probability for reliability and maintenance problems.

For a remote application, especially a demonstration project, installed

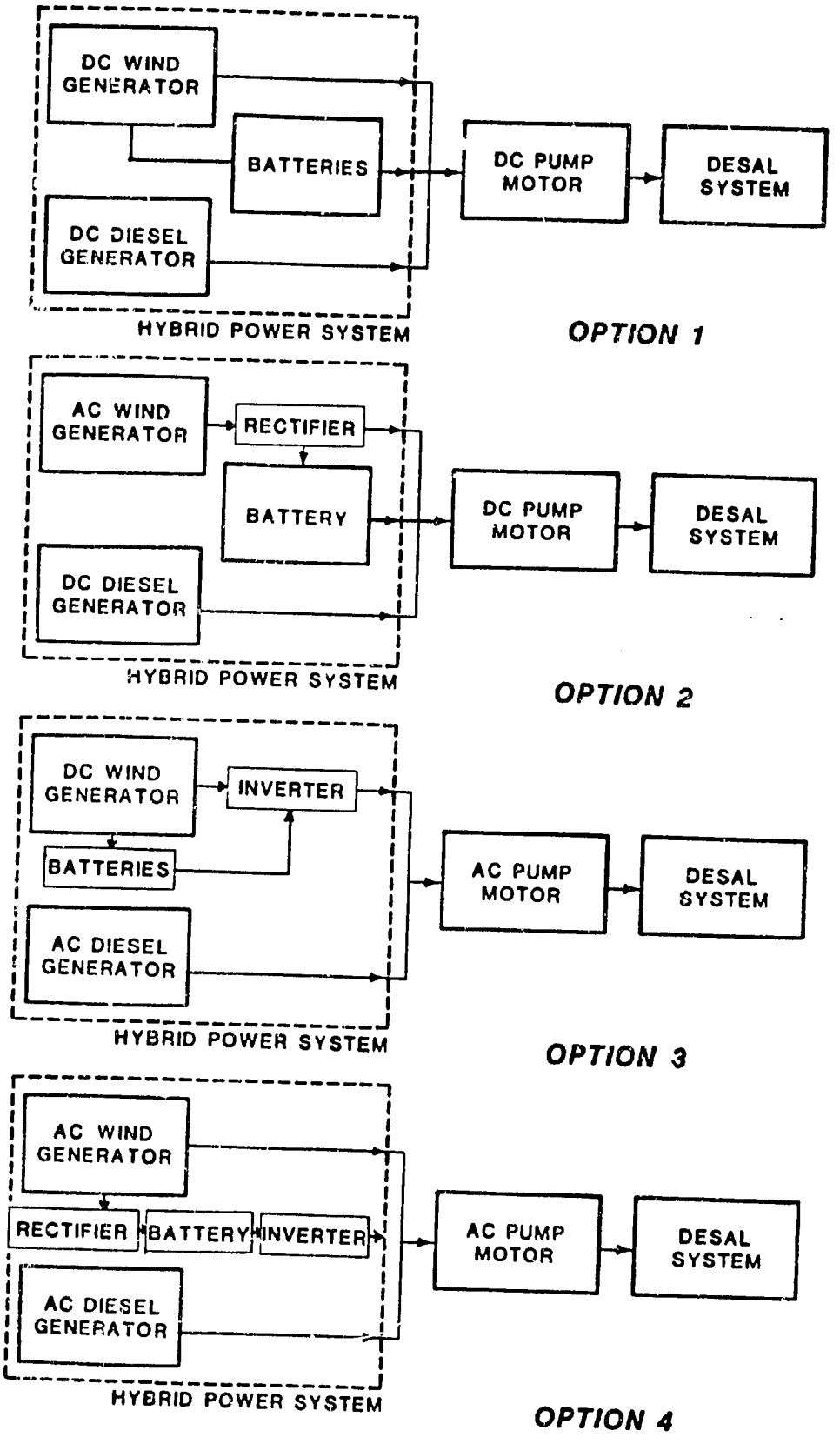

Exhibit 1.

DESIGN CONFIGURATIONS FOR HYBRID POWER SYSTEMS

hardware should be well proven. Systems with DC motors and inverters introduce additional reliability problems. When priority is given to least cost, efficiency and reliability is sacrificed.

5.0 REVIEW OF FIELD TEST HARDWARE

A discussion of the technology of wind generators, structures, batteries, and controllers is provided in the Wind Technology Reference Notebook published in June 1985. This section summarizes that discussion and describes in more detail the specific additional equipment technologies for this field test, including desalination equipment and diesel generators.

5.1 Desalination[5]

The operating principles of reverse osmosis, electrodialysis and vapor compression distillation systems are well understood. This section will discuss these principles and describe all required subsystem components.

Reverse Osmosis

The Osmosis-Reverse Osmosis Process described in Exhibit 2(a), (b), and (c) shows a chamber divided by a semi-permeable membrane, with a pure water solution on one side and on the other a solution of concentrated salts. The pure water passes through the membrane into the chamber containing the concentrated solution in an effort to bring the system to equilibrium.

In Exhibit 2(c), with the application of pressure to the concentrated solution, the pure water is driven back across the membrane, leaving behind the concentrated salts and creating once again a chamber with high purity water. Exhibit 2(c) represents the fundamental operating principles of Reverse Osmosis.

In Exhibit 3 we have a simplified Reverse Osmosis process flow diagram. A salt solution is pumped into a vessel containing a semi-permeable membrane. As pure water is passed through the membrane, the salt solution becomes increasingly concentrated and is passed from the system through a flow regulating valve. The regulating valve maintains the pressure required within the container, while the pump provides the necessary flow. The purified water that has crossed the mem-

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5 Information on reverse osmosis and electrodialysis desalination processes is excerpted from the "Report on Task 2 - Technology Review: Field Test #8 and #10," prepared by Bruce Watson, Watson Desalination, December, 1985.

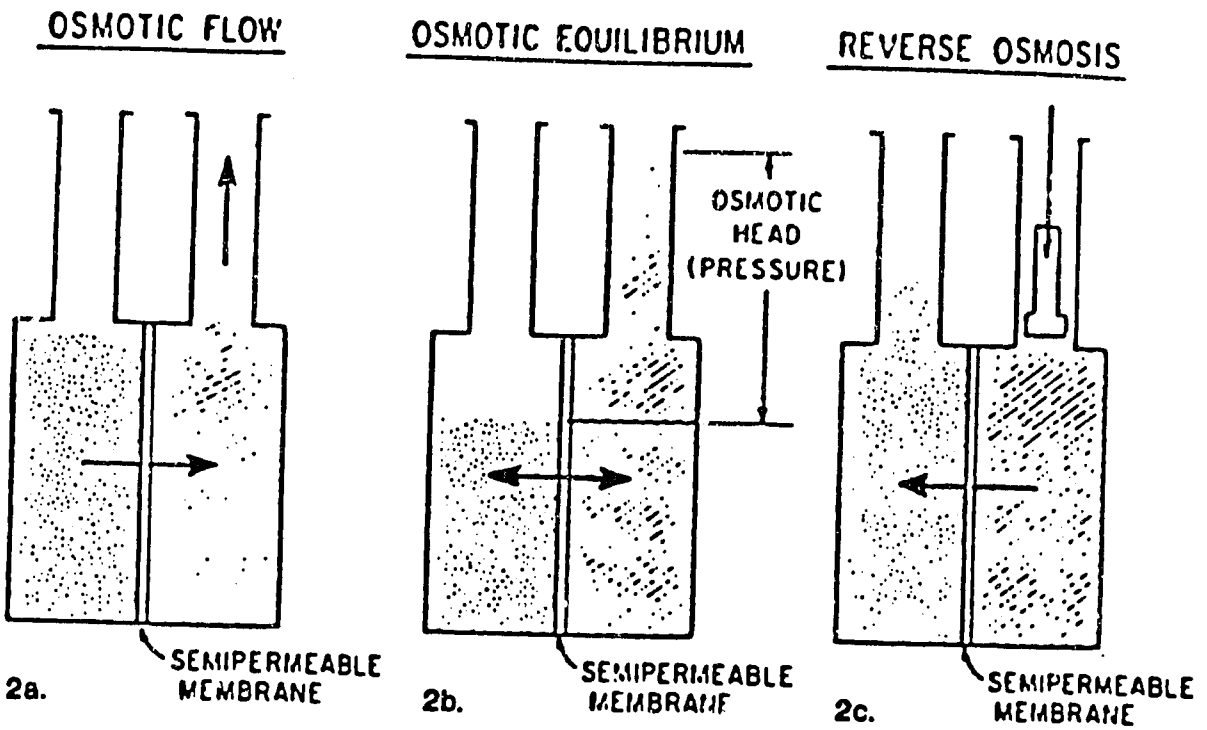


Exhibit 2.

OSMOSIS-REVERSE OSMOSIS PROCESS

SOURCE: Quinn, Robert M., "Designing the Reverse Osmosis System," RQ Associates, Inc.

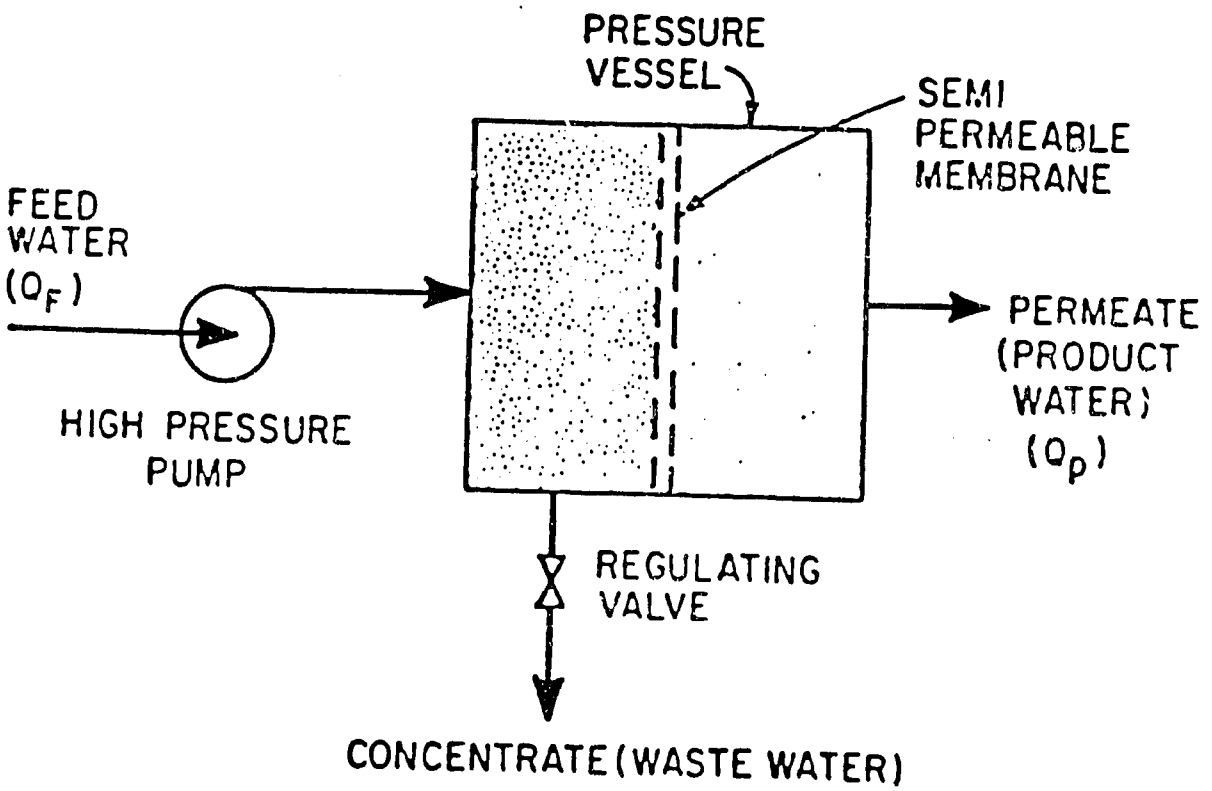


Exhibit 3.

SIMPLIFIED RO FLOW DIAGRAM

SOURCE: Quinn, Robert M., "Designing the Reverse Osmosis System," RQ Associates, Inc.

brane is collected in the permeate or product water chamber.

The membranes used in the reverse osmosis process are of two standard designs, hollow fiber and spiral round. Exhibit 4 describes the physical configuration of the Hollow Fiber permeators. The membrane is a fine fiber and many thousands are assembled parallel to each other in a fiber bundle. The bundled fibers are secured at each end in epoxy tube sheets. Typically these fibers have an inside diameter of approximately 42 microns, an outside diameter of approximately 85 microns, and a length of approximately 76.2 cm (30 inches). The feedwater enters the perforated tube, which is at the center of the fiber bundle, and water passes through the bundle and out the concentrate port. As the water travels across the outer surface of the fibers, the purified water passes through the fiber wall. The salts are retained in the vessel and discharged out the concentrate port. The purified water travels down the center of the fiber and is collected at the product end of the permeator vessel.

Exhibit 5 describes the physical configuration of the spiral wound elements. The spiral wound elements are produced from sheet membrane. Two membrane sheets are glued back to back to form an envelope. When water, under pressure, is passed over the surface of the sheet, pure water passes through the membrane, while the salts are held back on the outer surface of the envelope. The membrane envelopes are separated by mesh spacers and rolled into the spiral configuration. The spiral element is secured in a fiberglass outer wrap, and a brine seal or gasket is assembled on the outside of each element. As shown in Exhibit 6, the elements are assembled in series in a vessel containing a maximum of six (6) spiral elements. This assembly of spiral elements is similar to the hollow fiber permeators.

The spiral elements come in 10.2 cm (4 inch) and 20.4 cm (8 inch) diameter sizes for the larger industrial and municipal applications. The feedwater enters the pressure vessel (which measures in excess of 6.1 meters (20 feet)

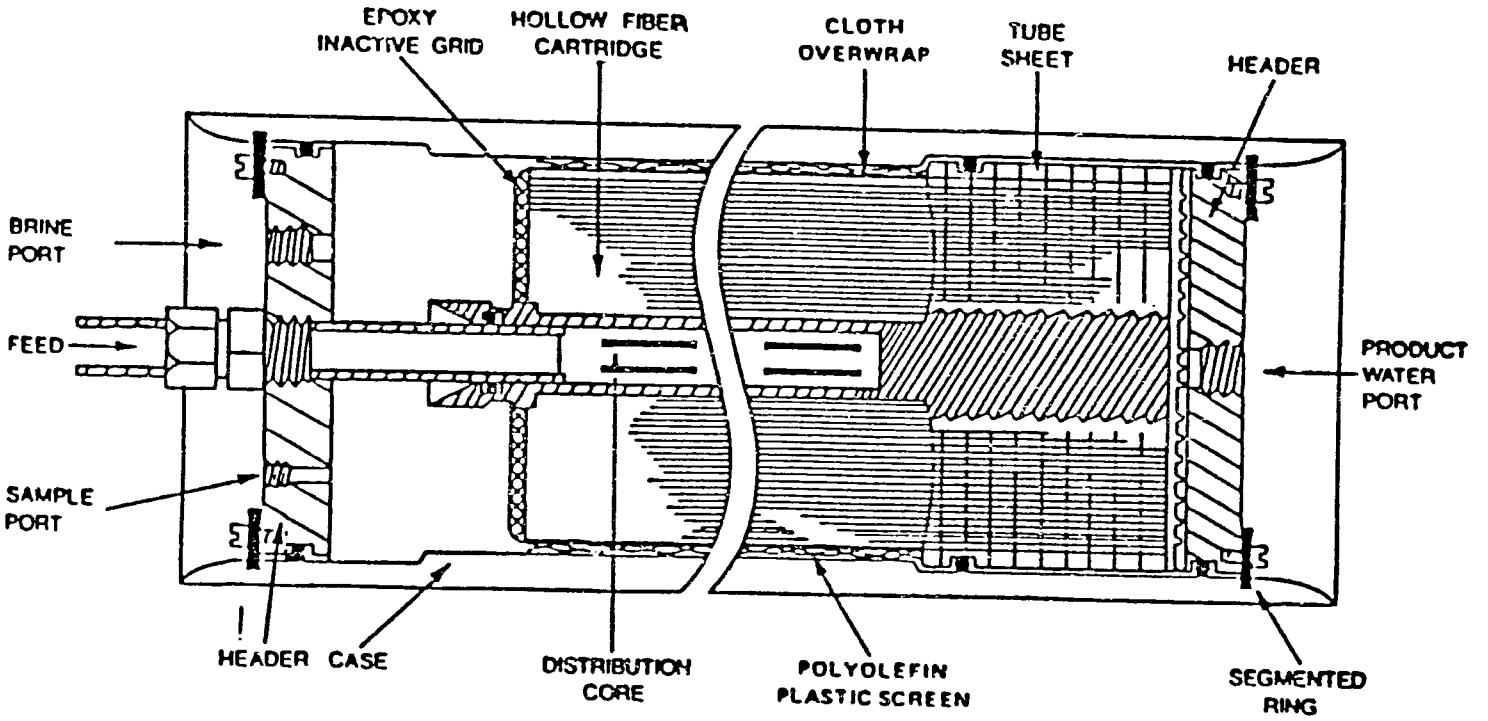


Exhibit 4.

REVERSE OSMOSIS PERMEATOR

SOURCE: Quinn, Robert M., "Designing the Reverse Osmosis System," RQ Associates, Inc.

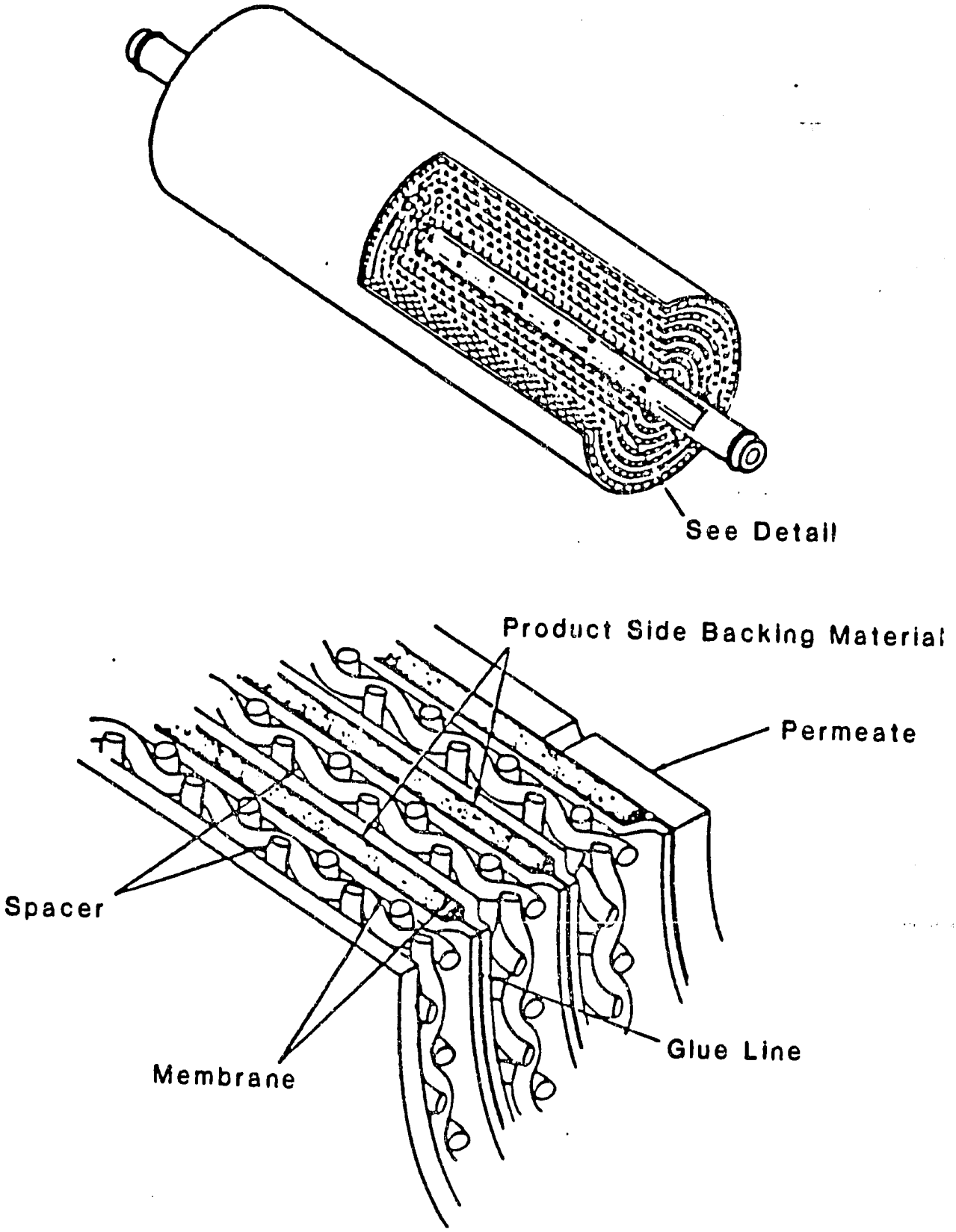


Exhibit 5.

DETAILS OF SPIRAL WOUND MODULE CONSTRUCTION

SOURCE: Quinn, Robert M., "Designing the Reverse Osmosis System," RQ Associates, Inc.

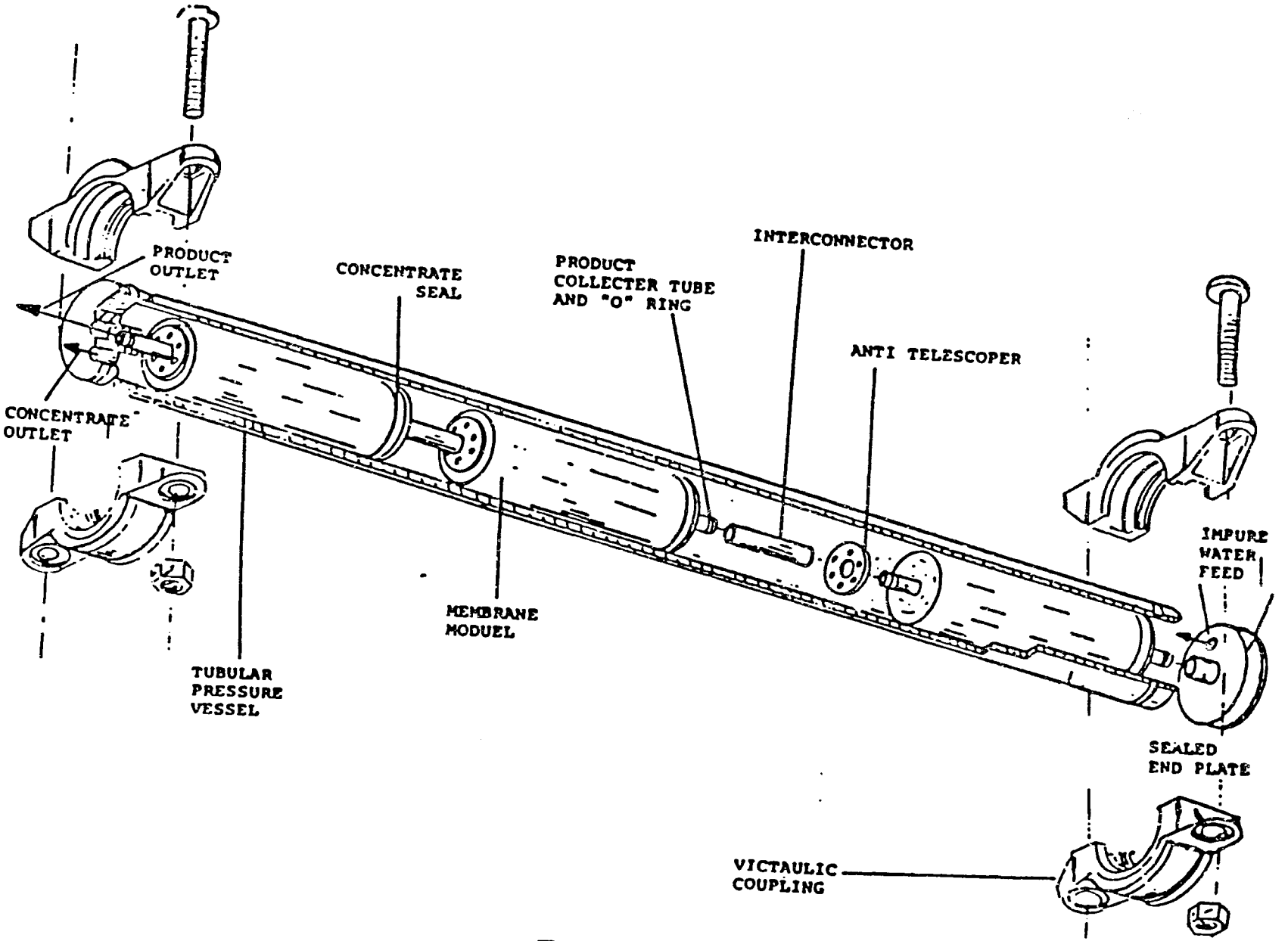


Exhibit 6.
SPIRAL WOUND MEMBRANE VESSEL

SOURCE: Quinn, Robert M., "Designing the Reverse Osmosis System," RQ Associates, Inc.

with a six-element assembly) and passes down through the space between the membrane sheets, exiting at the opposite end of the 6.1 meter (20 foot) container. The purified water passing through the membrane sheets is collected inside the envelope. It spirals down to the product tube, which collects the purified water and allows it to be transported out of the pressure vessel on either end. The pressure vessels, like the permeators, are assembled in parallel arrangements and piped to headers.

In general, the spiral wound and hollow fiber units are competitive both from a technical and cost standpoint, and the selection of one versus another depends very much on the quality of the feedwater, the desired effluent quality, and the general environment in which the systems must operate.

The following summary outlines the primary characteristics of the Spiral Wound and Hollow Fiber Membranes.

	Spiral Wound			Hollow Fiber			
	Brackish		Sea Water	Brackish		Sea Water	
	CA	TFC	TFC	CTA	Aramid	CTA	Aramid
Capacity - GPD							
4"	1000 to 1600	1800	1500	5000 to 7000	4200		1200 to 1600
8"	4000 to 8000	7500	6000	21000 to 26000	16000	3168 to 9240	6300 to 10000
10"					25000		
Salt -% Rejection	95-98	98-98.9		95-98	>90%		
Operating Pressure - psi	400 to 600	225 to 600	800 to 1000	250 to 400	400	Max. 850	800 to 1200
Operating - °C Temperature	Max. 30°C	Max. 45°C	Max. 45°C	Max. 35°C	Max. 35°C	Max. 40°C	Max. 35°C
pH Range	5 to 6	2 to 11	2 to 11	5 to 7	4 to 11	5 to 7	4 to 9
Maximum Chlorine -mg/l	1.0	0	0	1.0	0	1.0	0
Fouling Sensitivity	Moderate	Moderate	Moderate	High	High	High	High
Cleanability	Fair	Good	Good	Poor	Poor	Poor	Poor
Chemical Resistance	Poor	Good	Good	Fair	Good	Fair	Good

The Spiral Wound devices, as described in Exhibit 5 and 6 come in two forms, namely, Cellulose Acetate (CA) and Thin Film Composite (TFC).

The Hollow fiber devices, as described in Figure 4 come in two forms, namely Cellulose Triacetate (CTA) and Aramid (An aromatic polyamide produced only by E.I. DuPont).

The spiral wound elements are assembled as indicated in Figure 6. The pressure vessel containing a maximum of six elements is comparable to the single permeators described in Figure 4.

The pressure vessel and permeators are assembled in a similar manner as described in Figure 6. The CA and CTA membranes are similar and are limited in their operating pH range and maximum operating temperatures. The TFC and Aramid elements have significantly better pH, temperature, and operating pressure characteristics.

The major difference is the ability of the Spiral Wound to resist fouling. When this is combined with TFC membranes, which have good cleanability and chemical resistance, the spiral configuration is superior when used in an environment where there may be fouling components in the feed water.

The CA and CTA elements, having very limited pH ranges and poor chemical resistance, are least desirable for use in a fouling environment.

Electrodialysis

In the context of the membrane processes, electrodialysis (ED) is a process that removes the smaller component of a saline solution, salt, from the larger component, water, by means of direct current electricity and ion selective membranes. Electrodialysis is an electrochemical separations process in which ions are transferred through membranes from a less concentrated to a more concentrated solution as a result of the flow of direct electric current.

To understand this process more clearly, let us asssume a rectangular

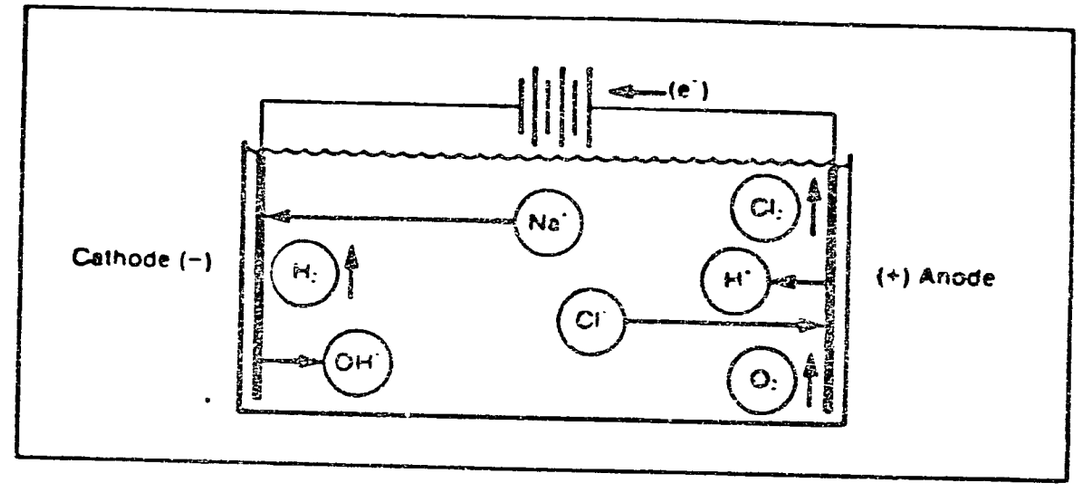


Exhibit 7.

ELECTODIALYSIS PROCESS

SOURCE: Quinn, Robert M., "Designing the Reverse Osmosis System," RQ Associates, Inc.

tank with an electrode at either end and filled with a sodium chloride (NaCl) solution (Exhibit 7). When a DC potential is applied across the electrodes, the following occurs:

1. Cations (Na^+) are attracted to the negative electrode.
2. Anions (Cl^-) are attracted to the positive electrode.
3. The water dissociation reduction reaction occurs at the cathode.

$$2H_2O + 2e \dashrightarrow 2(OH)^- + H_2$$

4. The water dissociation oxidation reaction occurs at the anode.

$$2H_2O \dashrightarrow 4H^+ \quad O_x \quad + \quad 4e^-$$

5. A reaction involving the formation of chlorine gas may also occur at the anode.

$$2Cl^- \dashrightarrow Cl_2 \quad + \quad 2e^-$$

To control the movement of ions in the tank containing the ionic solution and electrodes, several membranes can be added to form water-tight compartments as shown in Exhibit 8. Two types of membranes are shown.

1. Anion Transfer Membrane: Allows only the passage of negatively charged anions (Labeled A in Exhibit 8)

2. Cation Transfer Membrane: Allows only the passage of positively charged cations (Labeled C in Exhibit 8)

When a DC potential is applied across the electrodes the following happens:

Compartments 1 and 6: These compartments contain the metal electrodes. Chlorine gas and H^+ ions are produced at the anode, while hydrogen gas and OH^- ions are produced at the cathode.

Compartment 2:
1) Cl^- ions pass through ion anion membranes (A) into compartment 3.
2) Na^+ ions pass through cation membrane (C) into compartment 1.

Compartment 3:
1) The Na^+ ions cannot pass through the anion membrane and remain in compartment 3.
2) The Cl^- ions cannot pass through the cation membrane and remain in compartment 3.

Compartment 4:
1) Cl^- ions pass through the anion membrane into compartment 5.
2) Na^+ ions pass through the cation membrane into compartment 5.

Compartment 5:

1) The Na^+ ions cannot pass through the anion membrane and remain in compartment 5.
2) The Cl^- ions cannot pass through the cation membrane and remain in compartment 5.

The overall effect shows that compartments 2 and 4 have been depleted of ions and the ions have concentrated in compartments 3 and 5.

ED membranes have ion selectivity (anion/cation) and electrical conductivity. The selectivity of cation and anion membranes is generally about 90% for solutions less than 0.5 to 0.7 N, but decreases at higher ion concentrations. Membranes having low electrical resistance consume less energy, thus increasing the efficiency of the ED system. Resistance of membranes decreases as the solution concentration increases. Also, electrical resistance of membrane systems changes with temperature.

As shown in Exhibit 8, alternating compartments of demineralized solutions and concentrated solutions are formed in this membrane cell when a DC potential is applied across the electrodes. When properly manifolded, this unit will yield two major and separate streams; demineralized and concentrate waters, and two minor streams from the electrode compartments. In normal applications several hundred of these demineralizing and concentrating compartments are assembled into a "membrane stack" to obtain the desired water flow rate. These membrane stacks are the heart of the ED system.

The basic building block of an ED system is the membrane stack. A repeating section within the stack is called a "cell pair" and consists of a:

- Cation transfer membrane
- Demineralized water flow spacer
- Anion transfer membrane
- Concentrate water flow spacer

A typical membrane stack may contain from 300 to 500 cell pairs representing the same number of parallel hydraulic flow paths.

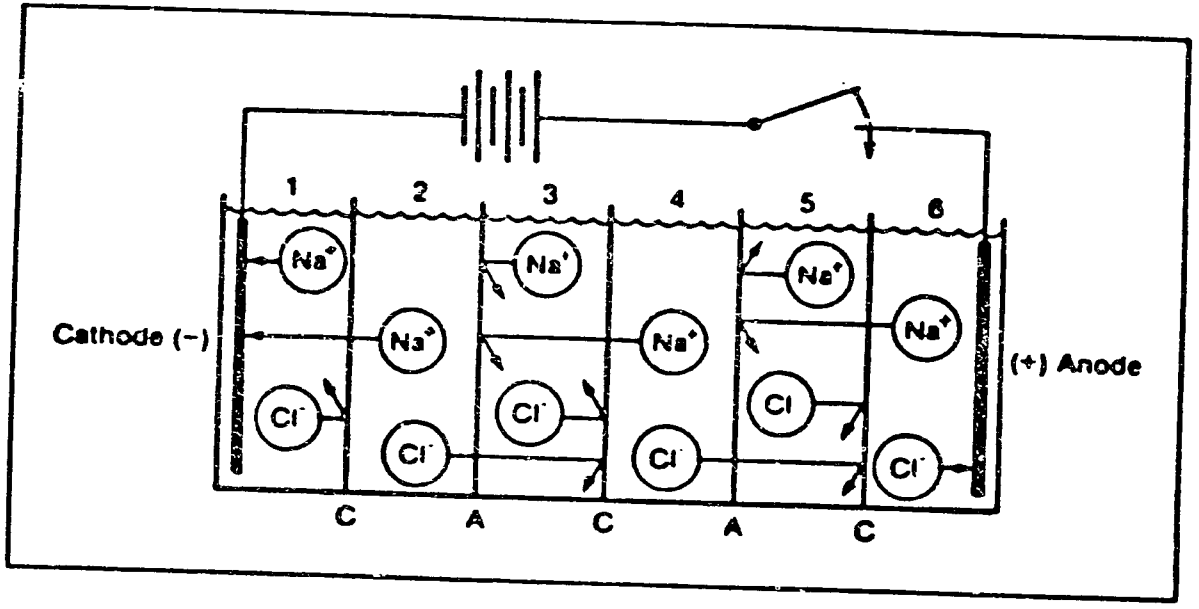


Exhibit 8.

ELECTRODIALYSIS MEMBRANE ARRANGEMENT

SOURCE: Quinn, Robert M., "Designing the Reverse Osmosis System," RQ Associates, Inc.

The capacity of the system, that is the quantity of treated water needed, determines the number of cell pairs, and the size of the pumps and piping. The fraction of the salt to be removed determines the configuration of the membrane stack array.

Vapor Compression Distillation

Vapor Compression Distillation (VCD) is inherently the most efficient distillation process. It achieves its high efficiency in a simple manner, without the need for a complex design based on a large number of stages or effects, by application of the "heat pump" principle to continuously recycle and keep within the system the latent heat exchanged in the evaporation-condensation process. In this scheme the heat required to evaporate part of the processed feed, which flows on one side of a heat transfer surface, is supplied through the simultaneous condensation of the distillate-producing vapor on the other side of the surface.

The driving force for this heat transfer, plus the energy required to separate the solution and overcome dynamic pressure drop losses and other irreversibilities are provided through the work of a compressor, which acts as the "heat pump," pumping the vapor generated from the solution to the higher pressure-enthalpy level required on the condensing side.

Benefits of the vapor compression process are:

- Low energy requirements, due to "heat pump" principle.
- Simplicity. Plant is an efficient distiller requiring only a tube nest, a compressor, a feed heat exchanger and pumps.
- Easy operation. Few controls required to achieve complete automation, allowing long term unattended operation.
- Easy regulation of capacity through one controller adjustment. Power consumption directly proportional to production rate.
- Small saline water supply system, since no cooling water is required. Feed rate is only 2 to 2.5 times product rate. Simple shallow well by sea is sufficient, eliminating expensive civil engineering for jetties, trash racks and filters and saving in feed pumping power consumption.

The basic operating principles of the VCD process as shown in Exhibit 9. The incoming saline feed is pretreated with a minute dose of scale inhibiting additive and passed through a heat exchanger, where the heat in the discharged brine and product streams is recuperated. The heat is generated in the unit itself, and is a converted form of the mechanical energy supplied to compress and circulate the fluids. Consequently, no separate make-up heat source is needed.

By simple preset of an automatic controller, which regulates heat exchanger flows, the unit's operating temperature, and hence production rate, may be easily adjusted. These temperatures are always below 65°C (150°F) to minimize scaling and corrosion.

The feed is mixed with recirculated brine and sprayed on the outside of a bundle of horizontal heat transfer tubes, at a rate just sufficient to create thin, continuous liquid films.

A centrifugal compressor provides, through its suction, a pressure lower than the equilibrium pressure of the brine. As a result, part of the brine is converted into vapor.

After passing through a demister, to remove droplet carryover, the vapor is compressed and discharged to the inside of the tubes. There it condenses, supplying the latent heat required for the flashing process.

The condensate, which is the salt free product, and the rejected brine are pumped out, after exchanging heat with the feed.

Non-condensible gases are first concentrated in an auxilliary condenser and then exhausted by means of a mechanical vacuum pump, which also serves to create an initial vacuum.

For a sea water application, regardless of the desalination process, a beach well should be used, as opposed to an open sea intake, to ensure clarity of the feedwater. Depending on the amount of particulate matter present, the

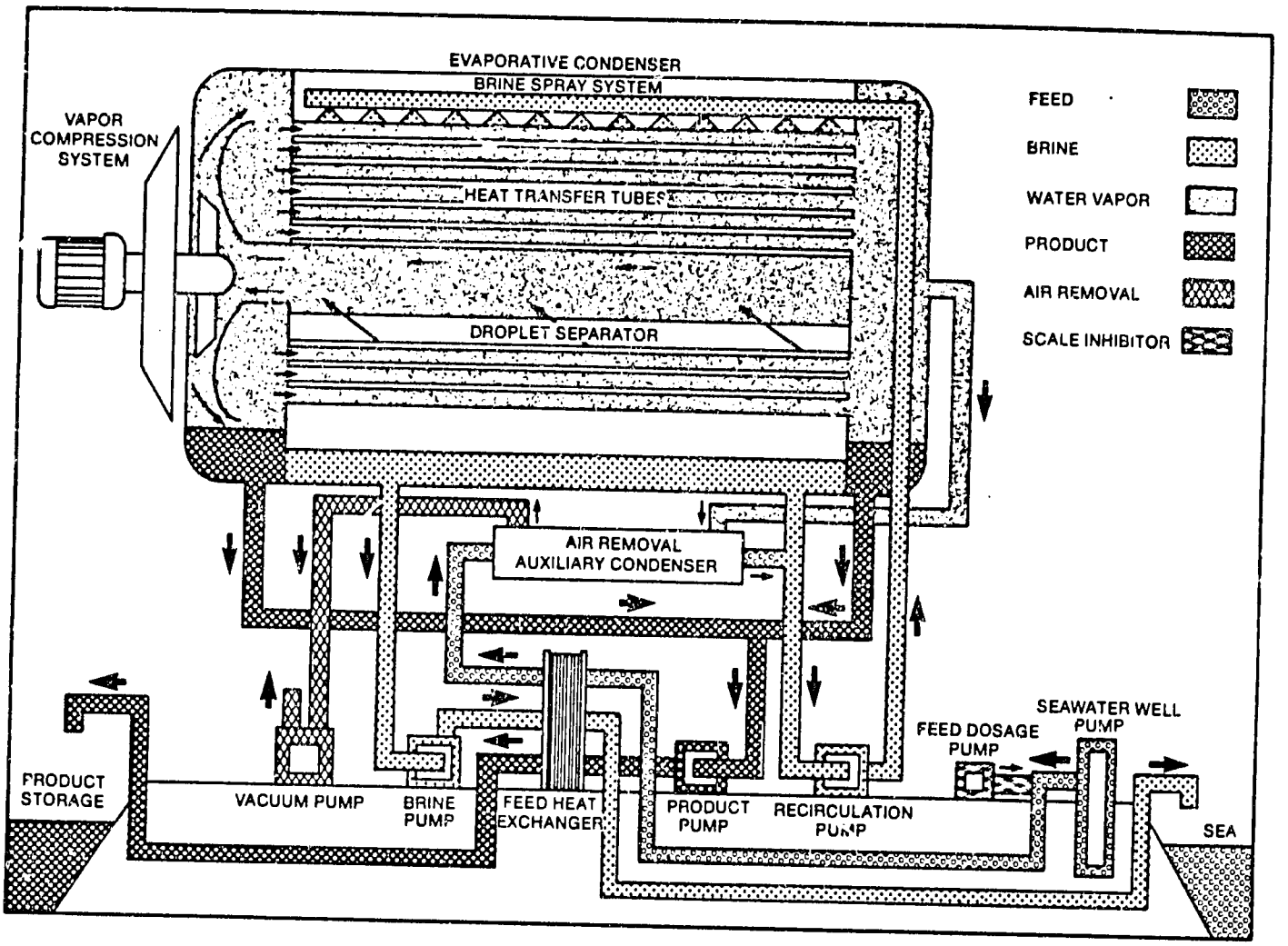


Exhibit 9.

VAPOR COMPRESSION DISTILLATION FLOW DIAGRAM

SOURCE: Israel Desalination Engineering Ltd.

feedwater may have to be pumped from the well to a settling tank to allow time for some of the heavier-than-water particles to settle. An alternate method for removing large particles would be with a filter. Depending on conditions of the feedwater, it may be necessary to add acid to balance the pH to prevent scale build-up. Chemicals may be added to coagulate other impurities or to treat biological impurities. There may be a need for filters to mechanically separate those impurities from the water.

There must be a pump or gravity feed to get this water to the desalination system. After separation into concentrate and product water, there must be a provision for transportation of two different types of water to storage areas. The concentrate water (brine) must be disposed of either in an open-air evaporation area or it may have to piped to sea. How this is done is site specific.

Based upon the proposed application at Hurghada, it appears as if a reverse osmosis system is the most practical and cost-effective desalination alternative. As previously mentioned, electrodialysis systems for sea water applications are not commercially available. Hence, their application for a demonstration project is not recommended. Vapor compression distillation, on the other hand, is a well proven commercially available technology for desalting sea water. However, such systems have traditionally proven economical only for large applications (i.e., greater than 1800 cubic meters per day), and are only marginally cost effective for applications in the size range proposed for this field test.

The primary piece of equipment for an RO system other than the membranes are the high pressure pumps. In this proposed application, the pumps will be Multiplunger positive displacement pumps. This is because of the high power efficiency of this type pump. This type of pump is readily available from a number of U.S. and European suppliers.

The instruments required are conventional flow meters, pressure gauges,

and conductivity and pH measuring devices.

The high pressure piping will be 316 SS and will employ readily available valves and fittings. The low pressure piping will be made of PVC (Polyvinyl-chloride) plastic material.

The conceptual design will most likely include the Spiral Wound-TFC elements. There are three major manufacturers of this type element in the United States: Dow/FilmTec, Fluid Systems, and Rohm and Haas (Hydranautics).

The specifications that will be part of the Request for Proposal should state that all equipment and membranes must be commercially available, with demonstrated experience in Reverse Osmosis applications. The Reverse Osmosis process is firmly established with a number of suppliers that assure a good competititve situation and reliable future sources of supply.

5.2 Wind Generators

Wind turbines for stand-alone and grid connected applications consist of four basic components as shown in Exhibit 10 rotor, transmission, generator, and sensors and controls. These components are normally "pre-designed" into a wind turbine - i.e., when purchasing a wind turbine one does not request a specific rotor, generaor, transmission or power conditioner. Wind turbines are designed for specific wind speed ranges and applications and all equipment has already been optimally selected. Since wind turbines are sold as "packaged units" and individual components are not specified in a bid, this section will discuss components of the wind turbine section in general terms.

Rotor

Major performance variations in wind machines generally will involve blade design. These diagrams (Exhibit 11), and discussion that follows, apply to both horizontal axis and vertical axis machines.

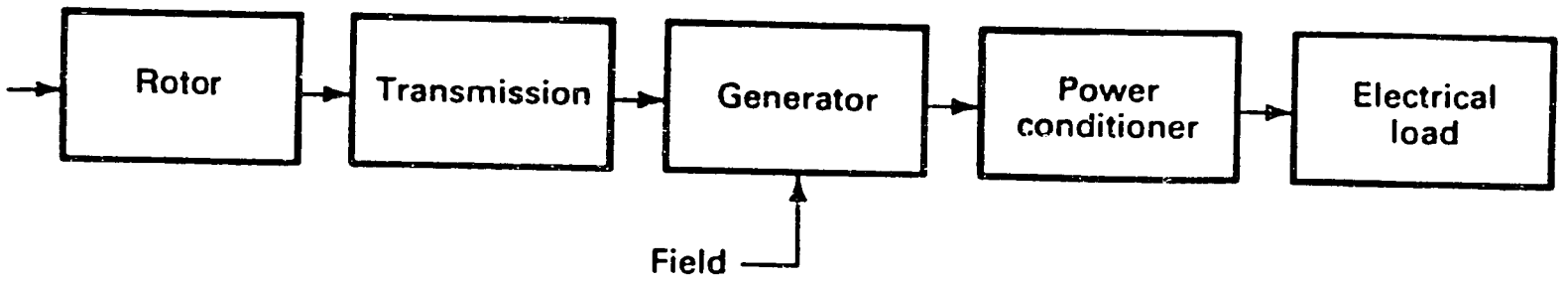


Exhibit 10.

BLOCK DIAGRAM OF A WIND GENERATOR

The extruded hollow aluminum blade was first installed on a wind turbine in the early 1950's. This blade construction is being used again, especially for the Darrieus (vertical axis) machines.

Built-up fiberglass blades with honeycomb or foam cores, or hollow cores (except for a tubular structural spar), are also being used, as are built-up sheet aluminum blades. All these methods of construction have a history of long service life in wind energy, as well as in many aerospace, applications.

One popular blade material is wood, either laminated or solid, with or without fiberglass coatings. Uncoated wooden blades usually have a copper or other metal leading edge cover for protection against erosion by sand, rain, and other environmental factors. Wood offers many advantages over other blade materials as follows:

1. Good resistance to fatigue loading.

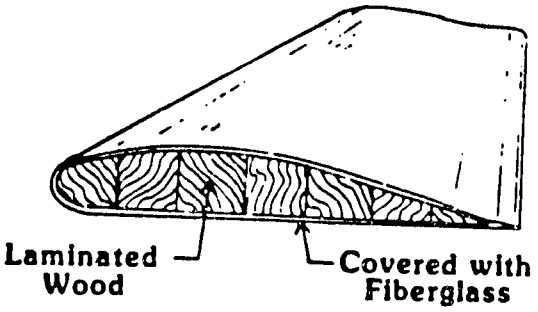
2. High strength-to-weight ratio -- wood is one of the strongest material per unit of weight. Because of heavy blade loadings aggravated by blade weight, the weight of the rotor is a concern.

3. Superior damping characteristics - Wood damps vibration better than most other structural materials (steel and aluminum for example). This is important because various excitation functions are always present in wind generating systems and it is desireable that the system itself serve to dampen these excitations.

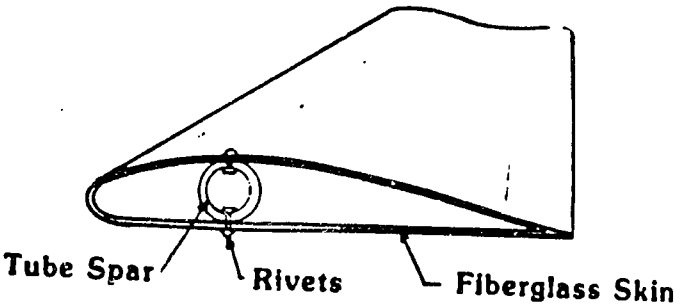
4. Minimal Electromagnetic Interference - Rotating turbine blades reflect electromagnetic signals in such a way as to cause periodically constructive and destructive interference between the reflected and transmitted signals. Poor siting of wind turbines could cause unacceptable interference with television, radio, VOR and DVOR navigational systems, microwave links, and other radio frequency equipment. Such interference is minimal with wooden blades in comparison to other materials.

These four factors provide strong incentives for using wooden rotors, either laminated or solid, with or without fiberglass coatings, at Hurghada. An additional factor influencing the choice of wooden blades is the corrosive environment present at Hurhada. Aluminum blades, whether hollow or built-up, are much more susceptible to corrosion damage than wood. Blade corrosion could

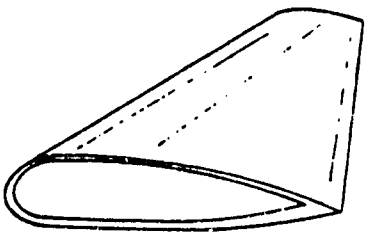
Exhibit 11.
DIFFERENT BLADE CONSTRUCTION METHODS



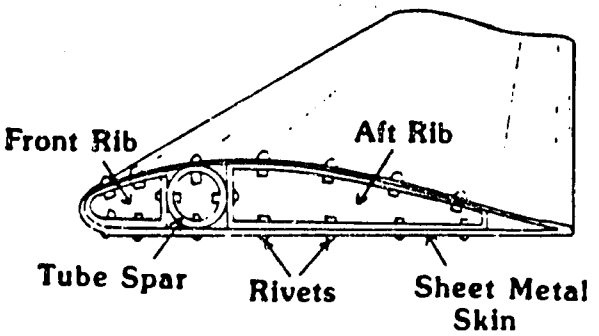
SOLID WOOD BLADE



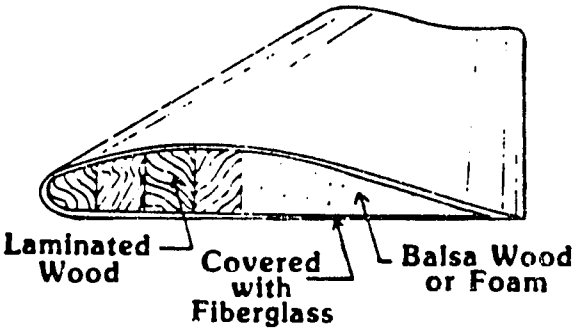
TUBULAR SPAR, WITH MOLDED FIBERGLASS SKIN



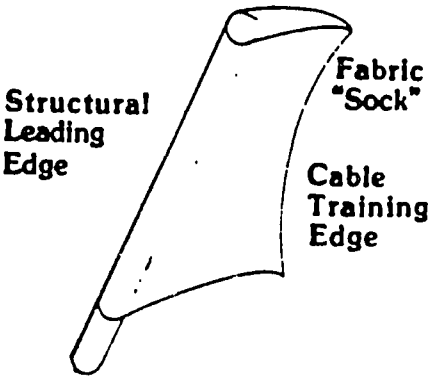
EXTRUDED HOLLOW METAL BLADES



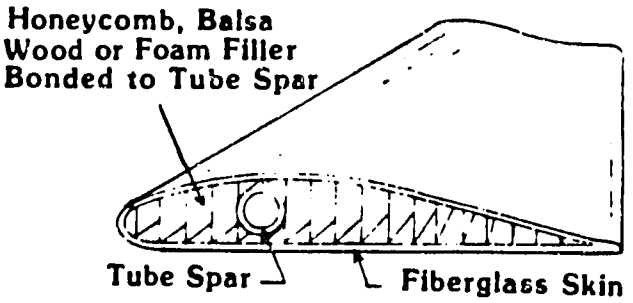
TUBULAR SPAR, WITH METAL RIBS AND SKIN



PARTIALLY SOLID BLADE



SAILWING CONSTRUCTION



COMPOSITE BLADE CONSTRUCTION

SOURCE: PARK, Jack and Schwind, Dick. Wind Power for Farms, Homes, and Small Industry. Nielsen Engineering & Research, Inc., Mountain View, CA., Department of Energy Contract E(04-3)-1270, September, 1978.

cause increased maintenance problems, decrease system performance or lead to catastrophic failure (i.e., blade throwing).

Turbine rotors can be either fixed or variable pitch. The fixed pitch rotor represents the simplest and most reliable rotor design option. Typically, in a machine with a variable pitch rotor, the pitching mechanism and associated controls represent the most complicated part of the system. Pitch actuation generally requires hydraulic, electrical or mechanical rotary connections to the blades. Statistically, this has always been a major source of failure in wind machines.

Some designers of wind turbines justify the additional complexity of a variable-pitch rotor by its theoretically higher efficiency and its ability to operate with variable-speed generators. Recent studies, however, have indicated that this theoretical advantage is largely lost in real-world situations because of the affects of wind gustiness. The fixed-pitch, constant-speed machines can react more quickly to gusts and extract power from them while the variable-pitch, variable-speed machine cannot change its speed rapidly enough to respond. The net effect is that as much energy can be extracted by the much simpler fixed pitch, constant speed machine.

One of the important design criteria for the wind powered desalination system at Hurghada is simplicity. Simple designs will result in fewer maintenance problems. Hurghada is subject to a lot of wind blown sand and salt spray. Such environmental conditions can only compound the maintenance problems associated with variable pitch rotors - i.e., the rotor pitch bearings are exposed to salt spray or sand. Since performance differences between fixed and variable pitch rotors appear minimal, it seems that a fixed pitch machine is more suitable at Hurghada.

Transmission

Early trade off studies have shown that medium size wind machines benefit from a step-up in speed between the rotor and generator. Although it is theoretically possible to custom-build a generator which will operate directly at the rotor speed (direct drive), this has always proven unsatisfactory and very expensive in practice. A much more practical approach is to use a step-up gearbox to increase the rotor speed to a common generator speed and benefit from the millions of hours of operating experience available with "standard" generators. Typical gearboxes have gear ratios ranging from 14:1 to 25:1.

The type of gearboxes which have been used in wind machines are generally of the helical, planetary, hypoid, or circulute design. Of these four, helical and planetary types are the most widely used. Planetary gearboxes offer large power capacities in small packages and in-line design, which make their use in windpower systems appropriate. Helical gearboxes are somewhat large for a given power capacity and are also available in the in-line configuration.

Turbine manufacturers select gearboxes to suit specific requirements such as weight, size, gear ratio and rotational speeds. It is not a significant concern of wind turbine owners or operators as to which type of gearbox is used, so long as it performs efficiently and with minimum maintenance. Although helical and planetary gearboxes are the most widely used in current wind energy applications there is no overriding factors which would make their use at Hurghada better or worse than hypoid or circulute designs. Hence, it appears that any type of gearbox would be appropriate at Hurghada.

Generators

Most of the commercially available wind turbines are designed to be interconnected with a utility grid; i.e., their generators are synchronized with the electrical grid. There are a number of advantages to synchronized

operation in that frequency and voltage are controlled by the utility, reactive power for induction generators is available and storage requirements are minimal to non-existent. On the other hand, stand-alone wind electric applications, often called asynchronous loads, require the use of asynchronous generators. The various types of asynchronous generators used in stand-alone wind energy applications are; (1) DC shunt generator, (2) Permanent-magnet AC generator, (3) AC generator, and (4) Self-excited induction generator.

DC Shunt Generators

DC shunt generators are very simplistic in design and operation. They consist of a rotor (armature) and stator. The stator contains a field winding. Current is produced when the armature rotates in the stator. The current is brought out of the generator by brushes that press against the commutator, a set of electrical contacts at one end of the armature. The mode of operation of the generator is referred to as a self-excited mode. The residual magnetism of the generator produces a small flux, which causes a voltage to appear across the field windings when the armature is rotated. This small induced voltage in turn produces a small field current which helps to increase the electromotive force (EMF) in the generator. This larger EMF produces a still larger field current, which produces a still larger EMF, until equilibrium is reached.

Permanent-Magnet Generator

A permanent-magnet (PM) generator is like the synchronous or ac generator used in grid-connected applications except that the rotor field is produced by permanent magnets rather than current in a coil of wire. This means that no field supply is needed, which reduces costs. It also means that there is no I^2R power loss in the field, which helps to increase the efficiency. One disadvantage is that the reactive power flow cannot be controlled if the PM generator is connected to the utility network. This is of little concern in an asynchronous

mode, of course.

The rating of the PM generator is directly proportional to its rotational speed. The rated current is related to the winding conductor size, which is fixed for a given generator, so the output power will vary with the rotational speed. The resistance of the rotor field has to be varied with the rotational speed to maintain a constant current. This means that a generator rated at 5kW at 1800 r/min would be rated at 10kW at 3600 r/min because the voltage has doubled for the same current, thus doubling the power. The limitations to this increase in rating are the mechanical limitations of rotor and bearings, and the electrical limitations of the insulation.

Wide fluctuations of voltage and frequency will be obtained from the PM generator if the wind turbine does not have a rather sophisticated speed control system. The PM generator must therefore be connected to loads that can accept such voltage and frequency variations.

AC Generator

The AC generator (alternator) that is normally used for supplying synchronous power to an electric utility can also be used in an asynchronous mode. These generators produce an AC voltage at a frequency that is proportional to shaft speed. Even with rotor speed regulation (variable pitch blades) there will still be enough of a variation in frequency and phase to prevent connection of the generator directly to the load. To compensate for these variations, the alternator is allowed to turn at different speeds, producing a variable-frequency output. The alternator output is then rectified, converting it to DC. The DC is fed to a synchronous inverter, at a line frequency output that can be connected directly to the load.

Self-Excited Induction Generator

An induction generator requires an excitation current to operate. In grid

connected applications this current is supplied by the grid. If the excitation current, sometimes called field or magnetizing current, is removed the induction generator will stop. If an induction generator is to be used in a stand-alone application, this excitation current cannot be supplied by the gird. However, the generator can be made to operate as an isolated AC generator by supplying the necessary magnetizing current from capacitors connected across the terminals of the machine.

In selecting a wind turbine with a self-excited induction generator, the magnetizing current necessary to produce rated voltage should be as small as possible. If two machines from different manufacturers are otherwise equal, the one with the smaller magnetizing current should be chosen. This will allow operation with less capacitance and therefore less cost. It may also allow more flexible operation in terms of the operating ranges of load resistance and frequency.

Each of the above methods for generating power have proven technically successful in numerous stand-alone and grid connected wind electric applications. Since there is no definitive proof as to the costs and benefits associated with each method, a recommendation for a specific method for the proposed wind powered desalination project cannot be made. Bidder's designs should be evaluated on a case-by-case basis.

Sensors and Controls

Wind turbines require sensors primarily for monitoring rotor speed and wind speed. For machines which do not freely yaw into the wind a sensor for wind direction and rotor blade orientation are required. The most important sensors, however, are those for monitoring wind speed and rotor RPM. These sensors are connected to the turbine braking control mechanism, which controls turbine operation during cut-in and cut-out windspeeds and prevents overspeed

during high wind conditions. The sensors used in wind turbines are standard solid state devices which are relatively trouble free. They are selected by turbine manufacturers to meet specific control needs of a turbine and are normally not specified as part of a statement-of-work. Specific requirements for wind turbine sensors in Hurghada may be influenced by the heat and salt-spray in the area.

Three primary methods exist for preventing rotor overspeed: (1) yawing the rotor out of excessive winds, (2) changing the pitch angle (feathering) to lower the load; and (3) activating the machine's braking mechanism. The first method is used only on horizontal axis machines with mechanically controlled yawing. The second method is used only on machines with a variable pitch rotor. The third method can be implemented on most types of machines, and is the primary control mechanism for fixed pitch, free yawing machines and vertical axis turbines. Braking systems are extremely important for safe wind turbine operation, and are primarily required to prevent rotor overspeed. The most common types of braking system are a mechanically or hydraulically actuated disk brake.

In designing a braking system for a wind generator it is important to ensure that there will be adequate torque available to stop a machine, even at the point of maximum power output (in high winds). In addition, because braking loads the gearbox (the rotor inertia acts as a load during breaking), it is important that this torque not be so high as to damage or reduce the life of the gearbox. The best combination of reliability, low maintenance and torque characteristics have been found in a two-stage electrodynamic braking systems. In such an arrangement the first stage consists of an alternating current dynamic brake, which lowers the frequency, thereby forcing the generator to slow the rotor and convert rotational energy to electrical energy. The second stage is a disc parking brake which engages shortly after the dynamic brake, bringing the rotor to a complete stop. This type of braking system is not available for turbines

with a DC generator. Although relatively new, this braking system has proven successful in a number of commercially available wind generators.

A number of turbine manufacturers are designing their machines with a backup breaking system, since brake failures are unacceptable during unscheduled utility power outages. The most common such design feature are tip speed brakes which, as their name implies, are located at the tips of each of the rotor blades. Each of the brakes operate independently, being triggered mechanically by the centrifugal forces associated with an overspeed. The deployment of any one of the brakes serves to limit rotor speed to safe limits. The tip speed brakes serve as an emergency back-up protection device and deploy only as a result of a failure of the primary braking system.

The type of braking system used at Hurghada should contain a mechanically or hydraulically actuated disk brake and tip speed brakes, at a minimum. The alternating current dynamic braking system described above would be a nice feature, since it would decrease maintenance and proling the life of the disk braking system, but is not essential for successful wind turbine operation.

5.3 Structures

Tower

It is beneficial to support a wind system, be it vertical-axis or horizontal axis, to capture the higher winds above the ground and to be well above the nearest trees and buildings. Towers are subjected to two types of loads: weight, which compresses the tower downward, and drag, which tries to bend the tower downwind.

Towers are made in two basic configurations: guy-wire supported, and cantilever or unsupported (sometimes called freestanding). Given these two basic structural configurations, towers can be constructed using wood poles (primarily for small turbines), steel or concrete pole structures as well as a

lattice framework of pipe or steel.

The selection of a specific type of tower for Hurghada is an important consideration for system installation and maintenance. Guy-wire supported towers are usually the easiest to install since they can be tilted up, requiring minimum equipment or personnel. Tilt up towers also allow for ease of maintenance, since the tower can be tilted down and all maintenance performed on the ground. Appropriate tower types for Hurghada appear to be either steel or concrete pole, or steel or pipe lattice framework structures. These towers are resistant to the corrosive elements present at Hurghada. Steel, the most common tower material, should only be used with corrosion protection and a preventative maintenance program which includes regular tower inspections and repairs.

Regardless of which tower design is selected, the overriding consideration is the selection of a tower that can support the wind turbine in the highest wind possible at a particular site. The load that causes many towers to fail is a combination of turbine weight and tower drag. Tower failure is sometimes accelerated when destructive harmonics are established between a tower's natural frequencies and turbine rotor RPM characteristics.

Corrosion protection is an important part of preventative and periodic maintenance of a steel tower. It is difficult to specifically identify the causes of corrosion at a given site. There are a number of interrelated (and synergistic) factors. Besides humidity, the presence of hydrogen sulfide, sulfur dioxide, and chlorides can greatly accelerate corrosion. Hurghada has a high atmospheric salt content, as would be expected given its coastal location. Protection for structural steel in such a corrosive environment is usually done with some type of coating. Adequate surface pretreatment is important because any moisture or unremoved rust below the surface of the paint will eventually blister its. Paint surfaces will also need regular maintenance, especially in regions with atmospheric sulphides. The use of galvanized steel

(steel dipped in zinc) protects the structure by using the zinc coating as a sacrificial anode. Its protective capability would last only until it was completely corroded away. The use of stainless steel to inhibit corrosion is fairly successful in the atmosphere, even in the presence of sulphur oxides. The disadvantages with stainless steel are its high price and its susceptibility to corrosion in the presence of chlorides, which are relatively common in coastal areas.

To determine the best method of controlling corrosion at a specific site, long term corrosion coupon testing is a simple low-cost technique. Coupons of exposed steel, galvanize steel, various stainless steel alloys, and coupons with various protective coatings should be left exposed at the site for periods of 6 to 12 months. By evaluating the corrosion of these coupons, the applicability of the different possibilities can be evaluated.

Foundation

Conventional engineering design practices are used to determine the type and size of a foundation for each particular application based on soil conditions, tower and turbine weight, and wind loads. Local, national and international building codes will detail the basis for foundation design. A professional structural engineer should be consulted to review/design a foundation for a particular application.

5.4 Batteries

The two most common batteries used for wind energy 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 battereis can be fitted with "recombination caps" which greatly reduce the loss of electrolyte due to over-charging 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 type and level of sophistication of the power system controller (PSC) depends on the type of desalination and power system used. An ED or VCD desalination system, with no battery storage or diesel engine, requires a relatively simple PSC, while the hybrid system required for RO needs a fairly complex PSC.

For a wind only system the PSC would consist of a microcomputer which accepts inputs such as wind speed and direction, turbine speed, load requirements and the voltage and frequency being delivered to the load. The microcomputer sends signals to the turbine to establish proper yaw (direction control) and blade pitch, depending on the type of machine, and to set the brakes in high winds. It sends signals to the generator to change the output voltage if the generator has a separate field. It may turn off noncritical loads in times of light winds and it may turn on optional loads in strong winds. It may adjust the power conditioner to change the load voltage and frequency. Most importantly, however, the PSC maintains a constant power output from the wind turbines and electric grid. The microcomputer and the necessary sensors tend to have a fixed cost regardless of the size of turbine.

The hybrid system required for RO desalination requires a fairly sophisticated PSC. In addition to performing the function of the wind only PSC, it must be capable of:

1) Regulating power production from both the diesel and wind generators.
2) Protecting batteries from service extremes.
3) Managing power use to maximize wind energy production.
4) Continuously displaying system operating parameters.

5.6 Diesel Generators

Self-contained diesel engine/generator sets for remote AC power are commercially available in 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 percent for new engines operating at rated load. It may drop to as low as 15 percent under partial load and/or poor maintenance practices.

5.7 Inverters/Rectifiers

The use of inverters and rectifiers was outlined in Section 4.4. 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. 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 institutional 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.

A specific instrumentation data requirements list was prepared. The list is provided (Appendix A) as the recommended performance data requirements for this field test.

6.0 MANUFACTURER PROFILES

A brief overview of the major U.S. manufacturers of wind electric generating systems, desalination equipment, batteries, inverters, controllers and diesel generation equipment is provided in this section. Wind related product literature from these companies is included in the Technology Reference Notebook (TRN) (previously submitted under Task 2.1.1). A selection of product specifications are provided in Section 7. Information not included in the TRN, as well as product literature for diesel generators and desalination systems, is included in Appendix B.

6.1 Wind Turbines

The U.S. wind system industry at the end of 1984 consisted of approximately 30 manufacturers of wind turbines. Of these, approximately fifteen manufacturers had sold a significant number of turbines in 1984 ranging in size from a few hundred watts to hundreds of kilowatts. Two U.S. comapnies sold Darrieus (vertical axis) wind turbines of about 200 kilowatts peak power, the remaining companies manufactured horizontal axis turbines, both upwind and downwind.

The following paragraphs are brief corporate profiles of a range of companies, representative of the U.S. wind industry technology, that are very active in sales in the U.S. Points-of-contact for these companies are provided whenever possible. Data for these summaries are taken from manufacturer's product literature, the American Wind Energy Association Membership Directory for 1985, and the Wind Energy Directory for 1984, a special issue of the Wind Power Digest magazine.

<u>Bergey Windpower Company Inc.</u>

Mailing Address:	2001 Priestley Ave. Norman, OK 73069
Telephone:	405-374-4212
Chief Executive:	Karl Bergey
Sales Contact:	Michael Bergey
Purchaing Contact:	Beverly Binns

Bergey Windpower manufacturers and distributes wind turbine generators with power outputs in the range of 1.0 kW to 10.0 kW peak. All units incorporate direct drive low speed permanent magnet alternators, passive overspeed controls, and high strength composite rotor blades. Units are available in both battery-charging and utility-interconnect versions. Bergey sells most of their wind turbines for rural, agricultural applications in Texas and Oklahoma. Bergey has sold hundreds of the BWC Excel-10, their largest turbine at 10 kW peak power. The company has been in business for seven years.

Earth Energy Systems, Incorporated.

Mailing Address:	250 Prairie Center Dr., #390 Eden Prairie, MN 55344
Telephone:	612-829-1933
Chief Executive:	Robert D. Schmidt
Sales Contact:	Emil E. Ebner
Purchasing Contact:	Russell Skoglund

Earth Energy Systems manufacturers wind turbines and hybrid systems consisting of wind turbines, photovoltaics arrays, batteries, diesel generators and microprocessor controllers. Earth Energy Systems was previously known as Jacobs Wind Electric Company. The firm has been manufacturing wind turbines since the mid-1920's. Recently the company acquired the Windcharger Corporation, a manufacturer of stand-alone diesel generators for industrial, construction, consumer and agricultural markets since 1935. Earth Energy Systems manufactures 17.5 kW and 20 kW wind turbines. They have recently developed a hybrid power plant that consists of a 10 kW wind turbine, a 500 watt PV panel and a custom-sized battery system, all controlled by a power management system for remote, stand-alone operation. Earth Energy Systems has wind farms in California and Hawaii.

Carter Wind Systems

Mailing Address: Rt. 1 Box 405-A
Burkburnett, TX 76354
Telephone: 817-569-2238

Chief Executive: J.W. Carter, Jr.
Sales Contact: Leslie Kemp
Purchasing Contact: Horatio L. Urioste, Jr.

Carter Wind Systems was formed in 1976. From 1976 to 1979, Carter worked on development of a 25 kW system. To date over 500 of these machines are in operation. In 1981 development of a 250 kW machine began. To date over 22 of these turbines have been sold and installed. Carter recently upgraded the machine to 300 kW peak power. By the end of 1985, Carter will have installed 21 of the 300 kW model and plans to have sold 100 more of the 25 kW model.

Enercech Corporation

Mailing Address: P.O. Box 420
Norwich, VT
Telephone: 603-448-5550

Chief Executive: Emile Coulon
Purchasing Contact: John Robichaud

Manufacturers 60, 40, 25, 5, and 1.8 kW induction generator wind systems. A 300 kW system will be available in mid-1985. Enertech sells to wind farm developers direct. They can provide turn-key wind farm installations, monitoring systems, service/maintenance, and operations management. Enertech has been manufacturing wind systems since 1978, with over 1800 turbines now in operation. Enertech turbines are used in numerous wind farms in California, Massachusetts and elsewhere.

Wind Power Systems, Incorporated

Mailing Address: 9279 Cabot Dr.
San Diego, CA 91216

Telephone: 619-566-1806
Chief Executive: Edmund Salter

Wind Power Systems is a dealer/distributor of wind farm/commercial and residential/farm wind energy systems. The company is also a wind farm project developer. They have been in business for nearly 10 years. Since 1977 Wind Power Systems has produced the Storm Master Model 12, a 60 kw peak power turbine for turn key wind farm sales. Over 260 Storm Masters are installed in California wind farms in Tehachapi and Altamont Pass. A total of over 425 turbines are installed throughout California.

International Turbine Manufacturing

Mailing Address: 6591 Sierra Way
Dublin, CA 94568
Telephone: 415-833-0400

International Turbine Manufacturing (ITM) is the successor to Energy Sciences, Inc. (ESI). ITM/ESI has been manufacturing wind turbines for about 5 years for wind farm applications. For three separate developers in the Altamont Pass in California, ITM/ESI has provided 108, 75 kW turbines; 202, 80 kW turbines and one 250 kW turbine as of January 1985. On January 10, 1986 ITM filed for protection from creditors under Chapter 11 of the U.S. Bankruptcy Code while they reorganize.

North Wind Power Company

Mailing Address: P.O. Box 556
Moretown, VT 05660
Telephone: 802-496-2955

Chief Executive: Alvin Duskin
Sales Contact: Joseph Jankowski
Purchasing Contact: Steve Hamblin

North Wind Power specializes in high reliability wind turbines and hybrid renewable energy systems for remote power applications. They currently manufacture three wind turbines models; the HR1, a 1 kW, 3 meter machine; the HR2 a 3 kw, 5 meter machine; and the MB916 a 16 kW, 9 meter machine. They also

manufacture two hybrid power system controllers, the SC374 and the SC351. A 100 kW, 17 meter wind turbine that will be introduced in 1986 is currently under field test.

VAWTPOWER, Incorporated

Mailing Address:	134 Rio Rancho Dr. Rio Rancho, NM 87124
Telephone:	505-892-9463
Chief Executive:	Paul N. Vosburgh
Sales Contact:	Kimberly L. Southard
Purchasing Contact:	Diane K. Norris

The VAWTPOWER 185 is 200 kW capacity vertical axis wind turbine for windfarm, utility and agribusiness applications. The VAWTPOWER 055 is 50 kW capacity VAWT for agribusiness, extractive resource, municipality and export applications. The company has been in business for approximately 3 years. Twenty-four VAWTPOWER 185 wind turbines were installed in San Gorgonio Pass near Palm Springs, CA in 1984 for a total of 38 in the area. The company planned to produce over 60 turbines in 1985.

FloWind Corporation

Mailing Address:	1183 Quarry Lane Pleasanton, CA 12054
Telephone:	415-484-3300
Chief Executive:	Yi Hao (Michael) Pao
Sales Contact:	Hugh Rose

FloWind Corporation, an integrated wind energy company, designs, engineers, sites, finances, installs and operates its own turbines and windfarms. It had approximately 350 vertical axis 17 meter and 19 meter turbines operating commercially by mid-1985. This is the largest number of Darrieus turbines in the world. FloWind also produces wind-diesel and other hybrid systems, and advanced energy storage facilities. As of January 1985, FloWind had installed

128, 170 kW turbines and 21, 250 kW turbines in Altamont Pass. The company has been in business since 1982.

Micon Wind Turbines, Incorporated

Mailing Address: 9595 Wilshire Blvd.
Beverly Hills, CA 94550
Telephone: 213-273-0993

Chief Executive: Erling Moerup
Sales Contact: Peter Jensen

Manufacturer of a complete line of wind turbine generators including: 22 kW, 65 kW and 108 kW models for wind farms, as well as stand alone installation. Standard features include a lockable tubular tower and a microprocessor based control panel with a standard RS-232 interface which can be linked via modem to an optional Micon computer management system. Micon is a Danish firm that has recently opened a U.S. manufacturing facility. Over 100 Micon turbines currently installed in California were manufactured in the U.S. Micon has 212, 60 kW turbines installed in a wind farm in Altamont Pass.

Windtech, Incorporated

Mailing Address: 155 Sycamore Street
P.O. Box 837
Glastonbury, CT 06033
Telephone: 203-659-3786

Chief Executive: M.C. Chenery

WINDTECH was formed in 1981 to manufacture a wind turbine using a composite bearingless rotor concept developed for Sikorsky Aircraft Corp. WINDTECH manufacturers three models of wind turbines; 20 kW, 50 kW and 75 kW. In 1983, 156 of the 75 kW units were installed in the Tehachapi Valley near Los Angeles, CA.

U.S. Wind Power

Mailing Address: 500 Sansome St. #600
San Francisco, CA 94111
Telephone: 415-455-6012

Chief Executive: Gerald Alderson
Sales Contact: Robert T. Boyd

Windfarm/commercial WECS; project developer. The company manufacturers its own 50 kW and 100 kW turbines and installs them on its own financed and developed wind farms. As of January 1985, U.S. Windpower had installed 735, 50 kW turbines and 601, 100 kW turbines in the Altamont Pass.

Fayette Manufacturing Company

Office Address: 15885-B Altamont Pass Rd.
Mailing Address: P.O. Box 1149
Tracy, CA 95376
Telephone: 415-443-2929

Chief Executive: John E. Eckland
Sales Contact: Dick Hall

Windfarm/commercial WECS, project developer. The company manufactures its own 75 kW, 95 kW and 400 kW wind turbines and either installs them on its own wind farms or sells to other developers. As of January 1985, Fayette had installed 247, 75 kW turbines; 1,178, 95 kW turbines and 34, 400 kW turbines in the Altamont Pass.

6.2 Desalination Systems

Water Services of America
P.O. Box 23848
Milwaukee, WI 53223-0848
414-354-6470

Water services of America (WSA) has had a successful history of designing, installing and operating modular RO plants (both brackish and sea water). Their plants are installed throughout the world, with many of them in the Middle East. To service this market area, WSA has a distributor located in Al-Khobar,

Saudi Arabia.

Ionics, Incorporated

Head Office
Water Systems Division
65 Grove Street
Watertown, MA 02172, USA
617-926-2500

Ionics specializes in electrodialysis desalination equipment and is the only American company which manufactures such equipment. Ionics has had installations worldwide. One of its most publicized in a desert environment is in Libya where it is reported that an installation capable of producing 159 cubic meters of water per day (brackish water system) has been functioning since 1977. In addition there are two 200 cubic meter per day brackish water units installed at Mowah, Egypt.

Aquatron
Route 1, Box 638 Rosethorne Rd.
Marrero, Louisana 70072
504-689-2024

Aquatron manufactures reverse osmosis equipment. It's client base has primarily been with the oil industry and the U.S. Navy. It has sold some units to several localities in Saudi Arabia.

Sweet Water
A Subsidiary of Marland Evironmental Systems Inc.
P.O. Box 501
Great Falls, Virginia 22066, USA

Sweet Water deals in reverse osmosis systems. It makes three different types of equipment, one primarily designed for sea water, one for brackish water, and one for water fouled with contaminants. It custom designs each unit using an advanced computer-based design approach. Sweet Water has sales and services representatives throughout the world including Cairo, Amman, Jeddah, Qatar, and Abu Dhabi.

Culligan USA
1 Culligan Parkway
Northbrook, Illinois 60062
312-498-2000

Culligan is the best known water treatment company in the U.S. In addition to a wide range of water treatment products, it manufactures a line of reverse osmosis desalination products. Culligan has sales and service representatives in 90 different countries throughout the world. International offices are in Italy, France, and Spain.

Israel Desalination Engineering
P.O. Box 18041
Tel Aviv 61 180, Israel
(052) 557333

P.O. Box 45 0488
Miami, Florida 33145
(305) 856-8664

Israel Desalination Engineering (IDE) is one of the few manufacturers of VCD systems in the world. There line of VCD systems consists of packaged, fully automatic desalination plants, designed for continuous or on-off operation, at constant or variable output. Over 160 VCD systems have been installed by IDE throughout the world since their development in 1967.

6.3 Batteries

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

GNB Battery Company is a well established leader in the manufacture of industrial grade, deep cycle batteries. GNB manufactures the "Absolyte" battery: a sealed, maintenance free, deep cycle lead-acid battery which recombines hydrogen and oxygen. The Absolyte battery has been well received by wind system companies for use 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 wind system applications around the world. The principal battery model used in wind systems is a vented, deep cycle lead-acid battery. Exide offers the option of 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. 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 1[illegible]0 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 wind industry. Abacus makes inverters in a number of sizes capable of being used in this field test.

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. All NOVA products 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.

6.5 Controllers

North Wind Power Co.
P.O. Box 556
Moretown, Vermont 05660
802-496-2955

North Wind Power specializes in high reliability wind turbines and hybrid renewable energy systems for remote power applications. In addition, they manufacture two controllers; the SC374 and SC351. The SC351 is a system controller offering complete metering, protection and control capability for small battery based power systems. The SC347 is a hybrid system controller for integrating renewable energy sources into new or existing battery charging systems.

Earth Energy Systems, Inc.
250 Prairie Center Dr. #390
Eden Prairie, MN 55344
(612) 829-1933

Earth Energy Systems manufactures wind turbines, including hybrid systems. Recently the company developed a 10 kW continuous hybrid power plant consisting of a wind turbine, batteries, photovoltaic panels and diesel generator. A sophisticated power system controller developed for the system is the "brains" of the hybrid plant.

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

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

6.6 Diesel Generators

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

Onan is a principal 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 1563
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 renowned 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.

7.0 EQUIPMENT/PRODUCT SPECIFICATIONS

The U.S. wind industry offers a wide variety of equipment including: small, medium and large scale wind generator systems, both AC and DC; towers; rotors; controllers, inverters and rectifiers; and mechanical and electrical end-use equipment. Individual components can be obtained from respective manufacturers, or their distributors; turn-key systems can be purchased through systems integrators and some turbine manufacturers. Several of the major manufacturers also supply packaged systems for certain applications.

This chapter organizes U.S. manufacturers' products required for stand-alone and grid-connected wind energy applications. Information is summarized in matrix format by component, as follows:

- Wind Turbines (Exhibit 12)
- Towers (Exhibit 13)
- Batteries (Exhibit 14)
- Regulators/Controllers (Exhibit 15)
- Power Conditioning/Inverters (Exhibit 16)
- Diesel Generators (Exhibit 17)
- Desalination Equipment (Exhibit 18)

The information presented is based on product literature obtained through catelogues, directories and mailings to U.S. manufactures. Much of this literature is included in the Wind System Technology Reference Notebook (WSTRN). Manufacturers and products for which sufficient information is available are included in these summary matrices. As more information becomes available the matrices will be updated and product literature will be added to the WSTRN.

Appendix C contains a selection of manufacturer brochures for desalination equipment, wind generator 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.

FEATURE / MANUFACTURER	RATED OUTPUT (kW)							RATED WIND SPEED (meters/second)						CUT-IN WIND SPEED (m/s)		CUT-OUT WIND SPEED (m/s)			ELECTRICAL OUTPUT	
	≤10	11-20	21-35	36-50	50-100	101-200	>200	<10	10-12	13-14	15-16	17	>18	2-3	4-5	17-19	20-23	>23	AC	DC
ADVANCED ENERGY		●							●						●				●	
AEOLIAN ENERGY INC.	●													●		←	none	→	●	
ASTRAL WILCON		●									●				●	←	none	→	●	
BERGEY WINDPOWER	●								●					●		←	none	→	●	●
CARTER WIND SYSTEMS			●				●		●				●	●	●	←	none	→	●	
EARTH ENERGY SYSTEMS	●	●	●					●	●					●			●		●	●
ESI					●				●						●			●	●	
ENERTECH		●	●	●				●	●	●					●		●	●	●	
FAYETTE MFG. CORP.					●		●							●			●		●	
FLOWIND					●	●						●			●		●		●	
HUMMINGBIRD WIND POWER	●													●				●	●	
INTERNATIONAL DYNERGY								●	●	●					●		●	●	●	
KW CONTROL SYSTEMS			●						●						●	●			●	
LAKESTATE SYSTEMS															●		●		●	
MICON			●		●	●				●	●				●	←	none	→	●	
NORTH WIND POWER	●	●				●		●				●		●				●	●	●
PRODUCT DEVELOMENT	●								●						●		●		●	
U.S. WINDPOWER					●					●					●		●		●	
VAWTPOWER					●						●				●		●		●	
WHIRLWIND POWER	●								●					●		●			●	
WIND-POWER INC.	●														●	←	none	→	●	
WIND POWER SYSTEMS INC.					●							●			●			●	●	
WINPOWER	●								●						●	←	none	→	●	
WINDTECH		●			●						●				●	←	none	→	●	
WIND TECHNOLOGIES		●							●						●	←	none	→	●	

Exhibit 12. WIND TURBINES

FEATURES / MANUFACTURER	TYPE		TOWER SUPPORT		HEIGHT						
	POLE	LATTICED	GUYED	FREE-STANDING	<15 METERS	15-17 METERS	18-23 METERS	24-29 METERS	30-35 METERS	35 METERS	>35 METERS
BERGEY WINDPOWER	●		●					●	●	●	
CARTER WIND SYSTEMS	●		●				●	●			●
EARTH ENERGY SYSTEMS		●		●			●	●	●	●	●
ENERTECH		●		●				●			
ITM/ESI		●		●				●			
INTERNATIONAL DYNERGY	●		●	●		●	●				●
KW CONTROL SYSTEMS	●		●				●				
LAKE STATE SYSTEMS	●	●		●				●	●		
NORTH WIND POWER		●	●	●	●						
PRODUCT DEVELOPMENT					●		●	●	●		
ROHN*		●	●	●	●	●	●	●	●	●	●
WHIRLWIND	●	●	●	●	●	●	●	●	●		
WIND POWER SYSTEMS		●		●			●				
WINDTECH	●			●		●					

*Towers not part of total wind system

Exhibit 13. TOWERS

MANU-FACTURER \ FEATURE	Lead-Antimony (Lead-Acid)	Lead-Calcium (Lead-Acid)	Pure Lead (Lead-Acid)	Nickel-Cadmium	Sealed	Vented
C&D		●			●	●
CHLORIDE			●		●	
DELCO		●			●	
EXIDE			●			●
GNB	●	●			●	
GLOBE			●		●	
NIFE				●		●
SURRETTE	●					●
TIDELAND			●			●

Exhibit 14. BATTERIES

Exhibit 15.
REGULATORS/CONTROLLERS

FEATURE / MANUFACTURER	Characteristics		Nominal Voltage Input (Volts)						
	Shunt Regulation	Series Regulation	6	12	24	36	48	120	240
ADVANCED ENERGY	●							●	
BOSS	●	●	●	●	●	●	●	●	
HELIOTROPE GENERAL	●	●		●	●				
NORTH WIND POWER CO.				●	●		●	●	
SPECIALTY CONCEPTS	●	●	●	●	●	●	●	●	
TIDELAND					●				
WIND TECHNOLOGIES								●	

FEATURE / MANUFACTURER	Available Components						Inverter Characteristics								Inverter Power Output (kVA)			
	Inverter	Frequency Converter	Uninterruptable Power Supply	DC/DC Converter	Rectifier (AC/DC Converter)	AC Regulator	Line-Commutated	Self-Commutated	Stand-Alone Only	Maximum Power Tracking	Single-Phase	Three-Phase	Quasi-Sine Wave Output	Sine Wave Output	<1	1-15	15+-75	>75
ABACUS	●	●	●	●				●		●	●	●		●	●	●	●	
ACHEVAL	●						●				●	●	●			●	●	
ADVANCED ENERGY	●					●								●		●		
AMERICAN POWER CONVERSION	●						●			●	●			●		●		
BOSS				●														
BEST	●		●						●		●		●	●	●	●		
GNB					●													
HEART INTERFACE	●								●		●		●		●	●		
HELIONETICS	●	●					●	●		●	●	●		●	●	●	●	●
NOVA ELECTRIC	●	●	●					●			●	●		●	●	●	●	
POWERMARK	●	●	●			●			●				●	●	●	●		
TESLACO	●									●				●		●		
TRIPPLITE	●								●		●		●		●	●		
WINDWORKS	●						●			●	●	●	●			●	●	●
BERGEY WINDPOWER	●				●							●						
WHIRLWIND	●			●										●		●		
DYTEK	●					●							●					

Exhibit 16. POWER CONDITIONING/INVERTERS

SPECIFICATION / MANUFACTURER	RATED OUTPUT AT 50HZ (kW)							
	< 10	10-25	25-50	50-75	75-100	> 100	AC	DC
ALLIS-CHAMERS		●					●	
CATERPILLAR				●			●	
FERMONT	●	●	●	●	●	●	●	
KATO ENGINEERING		●	●					●
KOHLER	●	●	●	●	●	●	●	
LISTER		●	●				●	
ONAN		●	●				●	
WAUKESHA				●	●	●	●	
WINCO	●						●	●

Exhibit 17. DIESEL GENERATORS

MANUFACTURER	REVERSE OSMOSIS	ELECTRODIALYSIS	VAPOR COMPRESSION DISTILLATION
AQUATRON	●		
CULLIGAN	●		
IONICS		●	
ISRAEL DESALINATION ENGINEERS			●
SWEETWATER	●		
WATER OF AMERICA	●		

Exhibit 18. DESALINATION EQUIPMENT

8.0 CONCLUSIONS

Wind power for desalination in Egypt involves the use of four proven technologies; desalination, diesel generators, battery, and wind power. The integration of the power technologies of wind turbines, 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 other loads such as communications and village electrification.

The application experience with wind/diesel hybrid power systems is very limited. However, several manufacturers now offer or are developing equipment products for wind/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 is commercial equipment available in these technical areas but careful review is necessary to determine reliability risks, maintenance and replicability issues.

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

APPENDIX A

INSTRUMENTATION SYSTEM SPECIFICATIONS AND DATA REQUIREMENTS FOR FIELD TEST #10

SPECIFICATIONS FOR A FIELD TEST INSTRUMENTATION SYSTEM

The Renewable Energy Field Test instrumentation system will be used to monitor IPH, PV and wind energy system installations at urban and remote desert locations in Egypt. These energy systems include main power sources (solar collectors, PV arrays and wind turbines) as well as ancillary subsystems depending on specific field test applications. These sub-systems include ice-making equipment, desalination systems, and a variety of load characteristics ranging from small DC loads to grid-connected applications and back-up power systems (diesel engines and batteries).

The instrumentation system must be a stand-alone system. Failure of the instrumentation system must not affect the performance of the field test system that is being monitored. The instrumentation system must have an on-site data storage system that is non-volatile and capable of easy physical removal and transport to another location for data removal and long-term storage. One form of non-volatile storage system must be a microchip/EPROM or CMOSRAM - Type system that can be "milked" on site easily and without danger of loss of data.

The instrumentation system must be a microcomputer based data logger with programmable input channels and output formats. The user must have control over sampling frequency and output period for each channel. Primary design objectives for the instrumentation system should be reliability, simplicity, small size, low power and the ability to operate in enviornmental extremes (especially high temperature, sand/dust and tropical/sea coast). The unit must be capable of stand-alone battery operation for a period of at least two monts.

The following minimum specifications are required for the instrumentation system. If an exception must be taken to one or more of these requirements, the exception shall be noted and a clear explaination given as to why the

bidder believes that the exception should be acceptable to the purchaser.

Physical Specifications

- o Small, stand-alonge, self-contained system in an environmental enclosure
- o Desired weight: less than 10 pounds
- o Desired size: less than 10 inches x 10 inches x 6 inches

System Power Requirements

- o Capable of operation using self-contained batteries
- o Capability for the use of an external power source to allow continued data collection while changing batteries or the use of a non-battery external power source is desirable.
- o Capable of transient protection from spurious electrical charges or lighting.

Environmental Specifications

- o Ambient Temperature: -25 deg. C to +50 deg. C
- o Relative Humidity: 0 to 90 percent non-condensing
- o Impervious to a tropical, oceanside environment with occasional high airborne sand/dust and/or sulphur levels

Analog Inputs

Number of Channels: At least 16 channels with 20 channels desirable

Volatage Measurement Types: Differential or single-ended

Accuracy of Measurements: at least ± 0.5 percent

Range and Resolution: Selectable for any input channel from microvolts to several volts full scale

Sample Rates: At lease once per second for each channel

Pulse Inputs

Number of Pulse Counter Channels: at least 4 channels with 6 channels desired

Analog and Digital Control Outputs: a total of three resettable channels each is desired with a range of 0 to ± 5 volts with a 0.5 volt resolution

Output Signal Interface

Memory: Capable of storing at least 3000 data points per day for a period of one month (two months desirable)

Display: A visual display of stored data is required on-site for data verification before data removal

Peripheral Interface: Downloading of data at the site should be by physical removal of the data storage device or simple, reliable data downloading to a non-volatile storage device. Storage data files shall be IBM-PC compatible on floppy disc either directly from the data logger or through a simple, fast, reformatting technique.

Wind Powered Desalination at Hurghada (Field Test #10)
Data Requirements

Item	Channel Type*	Sampling Frequency	Output Interval	Priority Want	Priority Must
Conductivity of feed-water	(Manual)	Weekly	None	x	
Conductivity of Product water	(Manual)	Daily	Daily		x
Feedwater flow rate					
- Instantaneous	P	10 min	hourly		x
- Integrated	(Manual)	Daily/Weekly	none	x	
Feedwater Pressure	A	10 min	hourly		x
- Low pressure alarm		none	none		x
High pressure pump pressure	A	10 min	hourly		x
Brine outlet pressure	A	10 min	hourly		x
Brine flow	P				
- Instantaneous		10 min	hourly	x	
- Integrated	(Manual)	Daily/weekly	none	x	
Product flow rate					
- instantaneous	P	10 min	hourly		x
- integrated	(Manual)	daily/weekly	none	x	
pH of feedwater	(Manual)	weekly	none		x
Feedwater temp	(Manual)	weekly	none		x
Power consumption	A	minute	10 min	x	
Wind speed/direction	A	minute	10 min		x
Power output (turbine)	A	minute	10 min		x
Frequency (turbine)	A	minute	10		x
Power factor	A	minute	10 min		x
Voltage (turbine)	A	minute	10 min		x
On-off cycles (turbine)	P	monthly	none	x	
On-off cycles (Diesel)	P	monthly	none		
Power output (Diesel)	A	10 min	10 min		x
Output voltage (Diesel)	A	10 min	10 min	x	
Fuel used (Diesel)	(manual)	weekly	none		x
AMPS in (Battery)	A	10 min	10 min	x	
AMPS out (Battery)	A	10 min	10 min		x
Temperature (Battery)	A	10 min	10 min	x	
Voltage (Battery)	A	10 min	10 min		x

8 ("musts") x 8 samples x 24 hours = 1536
5 ("musts") x 24 hours = 120
1 ("musts") x 1 day = 1
Time Mark (6 x 24) = 144

Total = 1801 data points per day

14 channels

- o 3 pulse
- o 11 analog

(Plus 5 channels per additional turbine)

- o 1 pulse
- o 4 analog

* A = Analog
P = Pulse

RENEWABLE ENERGY RESOURCES
FIELD TESTING

18 AUG 1986

APPENDIX B
PRODUCT LITERATURE

TECHNOLOGY REVIEW FOR FIELD TEST #10
WIND POWERED DESALINATION SYSTEM

MAY 1986
DRAFT FOR COMMENT

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)

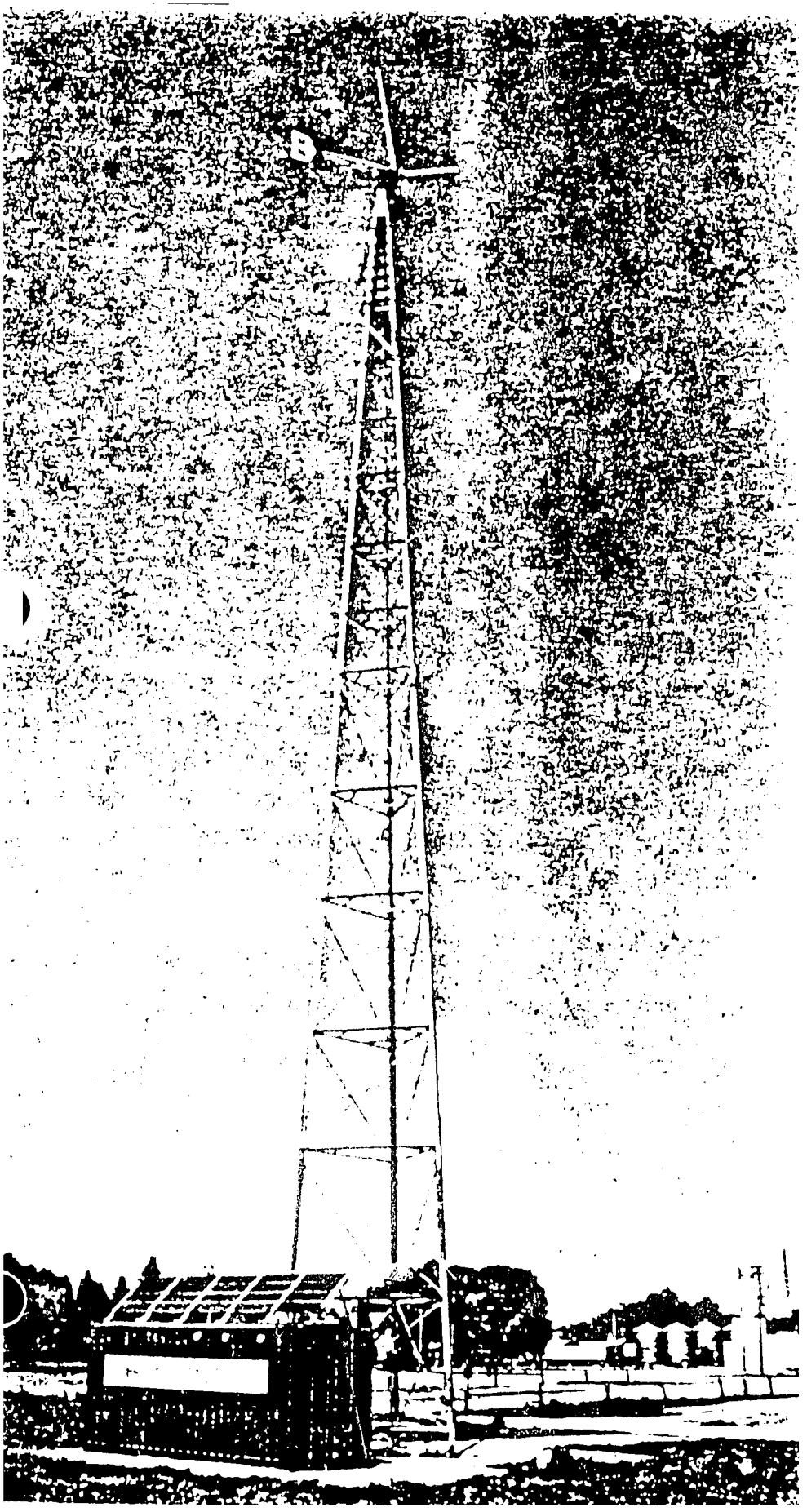
Prepared by

Meridian Corporation
Falls Church, Virginia

APPENDIX B

PRODUCT LITERATURE

A selection of manufacturer's product literature for desalination equipment, wind generators 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.



Earth Energy Systems Inc.

Hybrid Power Plant

Class A
Up To 10 kw Continuous

Earth Energy Systems Inc.

HYBRID POWER PLANT CLASS A UP TO 10 KW CONTINUOUS

Features

- Fully automatic unattended operation
- Factory engineered systems
- Compatible components
- Modularity/flexibility
- Simplified installation
- Industrial grade components
- Operational display/diagnostics
- Redundant safety provisions

Benefits

- Cost-effective electric power for remote applications
- Improved reliability from multiple sources
- Efficient operation over the complete power range
- Increased system life

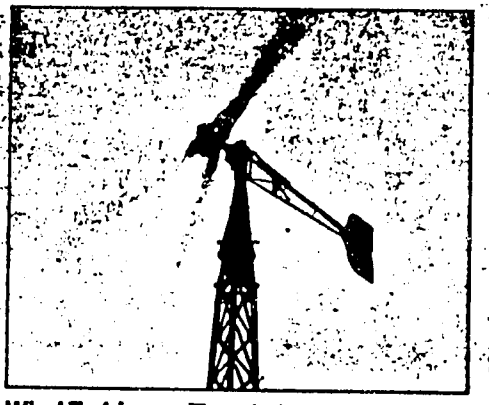
Introduction

The EESI class A hybrid power plant combines wind, solar, and engine power with a battery to supply electricity to remote areas. Locations that have relied on conventional fuels may now take advantage of natural energy to save or eliminate the use of fuel while improving reliability, efficiency and performance, and the life of their power system. Regions that have been denied electric power may now take advantage of the economy of a hybrid system utilizing the available wind and solar energy.

Definition

The EESI class A hybrid power plant is a complete electric power supply system that can be easily configured to meet a broad range of remote power needs. There are three basic elements to the system — the power sources, the battery, and the power management center. The power sources may be wind turbines, engine generators, or solar arrays. Any combination of up to three power sources may be specified, including multiples of any one source. The battery allows autonomous operation by compensating for the difference between power production and use. The Energy-Minder™ power management center regulates power production from each of the sources, controls power use by classifying loads, and protects the battery from service extremes. Additionally, the system includes a conventional electric load center with main and branch circuit breaker protection for the safe and convenient application of the power produced.

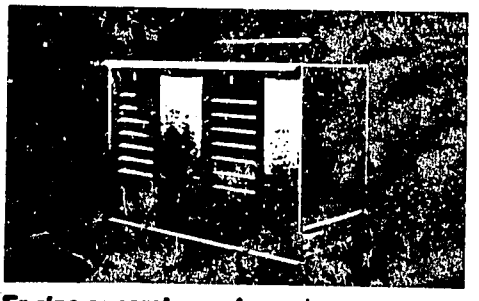
POWER SOURCES



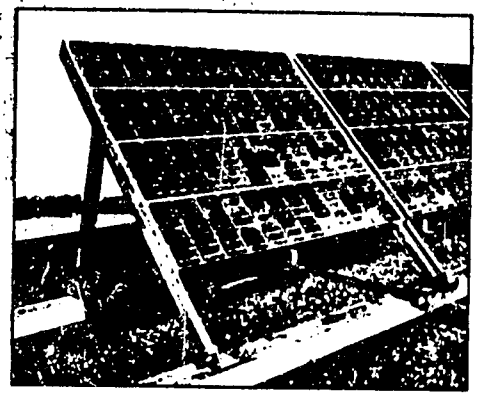
Wind Turbine — The wind turbine converts the kinetic energy in the wind to electric power and thus serves as the primary source for most applications. The EESI class A hybrid power plant uses the Jacobs wind electric turbine which was designed to standards of performance and dependability that have made Jacobs the leader and most respected name in wind energy for the past 60 years.

The smooth, efficient, 3-blade, upwind rotor drives a brushless 3-phase alternator mounted within the tower by way of a patented hypoid gear drive system. The wind turbine has a rated maximum output of 10 kw and is available with 23, 24 and 26 foot diameter rotors. The larger rotors have a lower rated windspeed and produce more power at all wind speeds. The turbine speed is limited by the proven Jacobs pitch control governor. The hypoid gear drive and dualfold tailvane act to turn the turbine out of the wind under violent wind conditions allowing unattended operation in the harshest environments.

The quiet performance turbine, clean simple design, and soft gray color blend in well with all surroundings. The wind turbine is supported in the smooth flowing wind by a strong and weatherproof freestanding tower that is easy to assemble and erect. Normal soil foundation anchors and tilt up/down hinges are available.

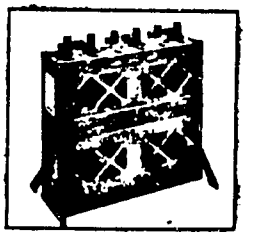


Engine generator — An engine generator is used to insure a continuous supply of electric power under all conditions where conventional fuels are available. When specified, a dependable Winco engine generator may be used to supply up to 10 kw of prime power on command from the Energy-Minder.™ When started, the engine operates at its optimum level to supply power to the load and recharge the battery. A rugged two cylinder liquid cooled diesel drives a brushless alternator at 1800 rpm to ensure long life, especially when operated on an intermittent basis in a hybrid power application. A complete selection of the most popular accessories are available.



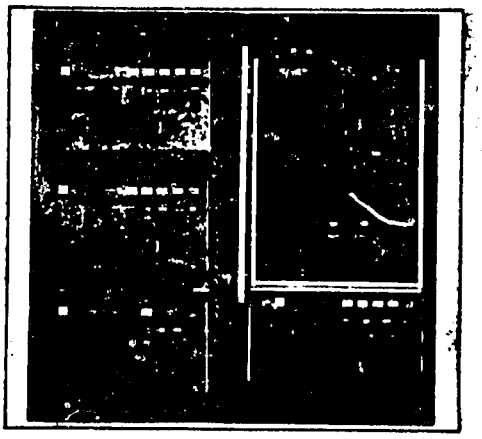
Solar Array — In many areas, the sun and wind complement each other on a daily and seasonal basis. Where practical, a solar array may be specified to regularly add power. A solar array may consist of up to six solar panels. Each solar panel contains 20 premium quality photovoltaic modules and is capable of producing 600 watts of peak power. Each sealed module provides weatherproof protection for the efficient single-crystal silicon cells that convert the sunlight to electricity. The long life expectancy of the modules make solar power an attractive alternative.

BATTERY



A lead-acid stationary battery is an essential component of every EESI class A hybrid power plant. The battery allows autonomous operation by compensating for the difference between power production and use, contributes to system stability, and supplies power for control information. EESI can provide a premium deep-cycle battery that is sized to the sources and to the specific power requirements of the application. A complete selection of accessory hardware can be supplied for their efficient and safe operation.

SYSTEM CONTROL



The EESI Energy-Minder™ power management system is the center of the EESI class A hybrid power plant. Several functions are provided:

- Regulates power production from each of the sources
- Protects the battery from service extremes
- Manages power usage to optimize natural energy production
- Facilitates the safe and convenient application of the power produced
- Continuously displays power production, use, and operational status

The Energy-Minder™ control system may be used with one, two, or three power sources. Each source requires a dedicated controller to connect it to the battery. Each controller has been designed to optimize power production and take full advantage of the battery storage capacity while protecting it from excessive charge rates and over charging. The power produced is distributed to the user through the electric load control center. The electric load control center is similar to a conventional service center which contains main and branch circuit breakers. Control sensors and relays are provided to maximize wind and solar power production and protect the battery from excessive discharge. Electric loads are grouped into three categories and controlled as follows:

Essential — Electric loads that must be satisfied at all times under normal operating conditions. The essential loads are served by a 100 amp main breaker with up to six branch circuits.

Interrupt — Electric loads that can be turned off for short periods when the battery is at a low state of charge. This makes best use of the wind and solar energy, reduces engine generator operating time, and promotes a quick efficient recharge. A single circuit breaker serves up to 50 amps of interruptible loads.

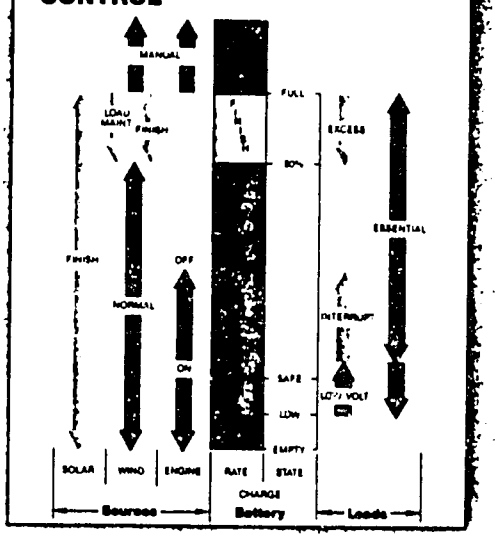
Excess — Electric loads that can be turned on for short periods when the battery is full. This also makes best use of the wind and solar energy while reducing service stress on these sources. A single circuit breaker serves up to 50 amps of excess loads.

A low voltage control signal is also provided if the battery is discharged to a minimum safe level because of a source failure, lack of fuel, or service excess. This signal can terminate all loads, switch to an auxiliary or emergency power supply, or provide an alarm until the battery state-of-charge has been raised to an acceptable level.

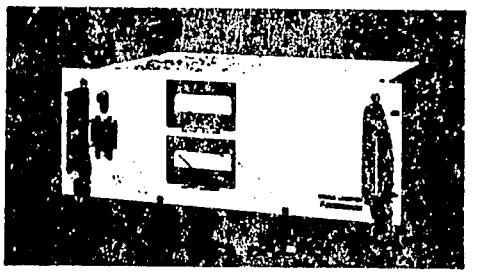
The Energy-Minder™ control system provides continuous power display meters, control event status annunciators with provisions for recording or remote monitoring, and built-in diagnostic capabilities.

The Energy-Minder™ power management center simplifies system design, installation, and application. The only additional equipment normally required is the electrical wiring and hardware to interconnect the components.

FULLY AUTOMATIC POWER CONTROL

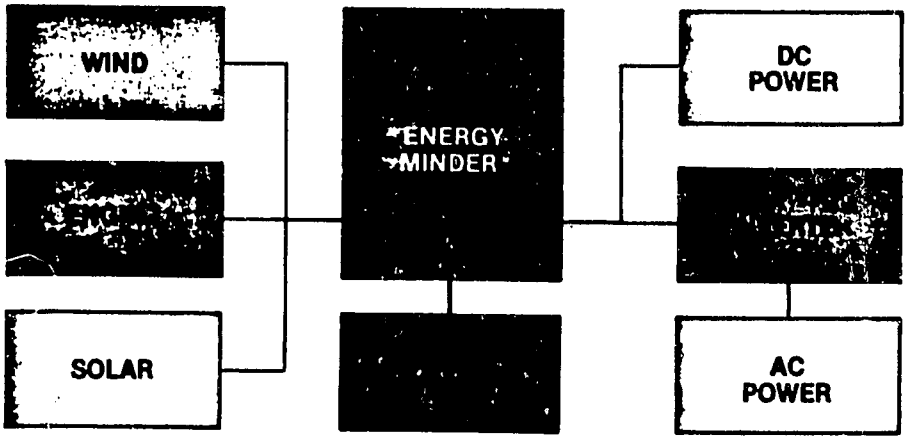


POWER SUPPLY



The EESI class A hybrid power plant supplies 120 volt (nominal) D.C. electrical power. Many electric loads, such as lights, resistance heaters, and some types of motors can be operated on D.C. power. If A.C. power is required an inverter is used to convert from D.C. to A.C. EESI offers a range of inverters available in most popular voltages and frequencies.

CLASS A SYSTEM DIAGRAM



Bringing power to your world

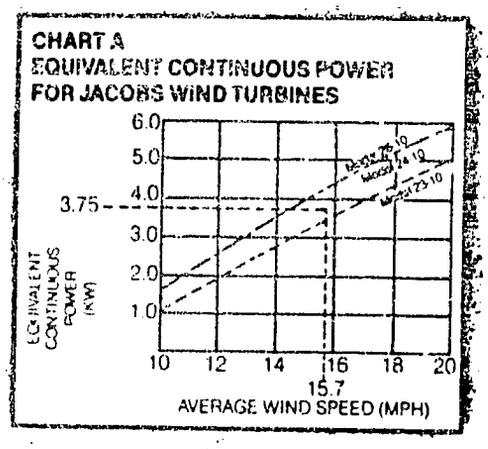
GUIDE TO DESIGNING YOUR REMOTE POWER PLANT

The EESI class A hybrid power plant has been designed to supply up to 10 kw of continuous electrical power and has a total peak power capability of 24 kw—12 kw essential, 6 kw interrupt, and 6 kw excess. This procedure for designing a hybrid power plant has been developed to determine the equipment required to satisfy a given electric power need. It is based on the concept of "equivalent continuous power" (ECP). "ECP" is the amount of power that would have to be continuously produced to satisfy the power requirements for a given application.

There are two methods to determine the ECP. Method 1: when the amount of power required in a given time period is known, divide the power required by the hours in the time period. For example, a remote telecommunications station requires 44000 kwhrs of electricity annually. Dividing 44000 kwhrs by 8760 hours/year yields an ECP of 5.0 kw. Method 2: when the electrical equipment to be operated is known, multiply the power rating for each item by the percent of the time that it operates to determine the ECP for that item. Add the individual ECP's to determine the total ECP. For example, an isolated village would like to operate a large refrigerator for food and medicine and a community water pump. The 4.0 kw refrigerator operates 15 minutes each hour and thus has an ECP of 1.0 kw. The 2.1 kw water pump operates 8 hours per day and thus has an ECP of 0.7 kw. Therefore, the total ECP for the village is 1.7 kw.

To determine the components required for a hybrid power plant to satisfy a given ECP, use steps 1 through 3 below to select a combination of power sources capable of producing 125% of the required ECP. The extra margin is to allow for future growth, power losses, and a safety factor. Use steps 4 through 6 to determine the Energy-Minder™ components, battery size, and inverters required for the system.

Step 1: The wind turbines should be considered the primary source of power for most remote



applications as they produce cost competitive power and require the least amount of maintenance and support. Use chart A to determine the "ECP" for each of the wind turbines at the average wind speed for the site under consideration. For example: the telecommunications station above is located in an area that has an annual average wind speed of 15.7 mph. A Jacobs wind turbine with a 24 foot dia. rotor will produce 3.75 kw of "ECP" at this site. Now, choose a tower 35 feet higher than obstructions to support the wind turbine in the smooth flowing wind.

Step 2: An engine generator is used to insure a continuous supply of power under all circumstances. Since the Winco engine generator is rated at 10 kw continuous, the "ECP" is proportional to the percent of the time that it is operated. The engine generator operating 25% of the time will have an ECP of 2.5 kw or an application requiring an ECP of 2.5 kw means that the engine generator will operate 25% of the time.

(Conclusion: A Jacobs wind turbine with a 24 foot dia. rotor and the Winco 10 kw engine generator operating 25% of the time can supply the power needed by the remote telecommunications station in the example above.)

Step 3: The cost of solar electric power requires that its use be carefully considered. Generally, solar power becomes more attractive in areas of limited access and high insolation. The "ECP" of a solar array can be estimated by dividing the peak power rating by 5. For example, a solar array with 5 panels and a peak power rating of 4.0 kw will have an "ECP" of approximately 0.8 kw.

Step 4: The Energy-Minder™ components are determined by the sources selected for the system. Each power source utilizes a dedicated controller while the electric load control center is required for every hybrid system.

Step 5: The battery size is primarily determined by the number of power sources selected and the "ECP" of the electric load to be served. Use chart B to select the proper battery size.

Step 6: The standard power output of the system is 120 volts D.C. Electrical equipment capable of operating with this power directly represents the most efficient and cost effective way to use the power produced and should be specified when practical. For electrical equipment requiring A.C. power, a range of D.C. to A.C. power inverters can be specified in the most popular voltages and frequencies from chart C. Inverters should be selected to serve a dedicated load or group of loads with care being used not to exceed either the continuous or surge power capabilities of the inverter.

CHART B BATTERY SIZE GUIDE

Number of Power Sources	Equivalent Continuous Power Required		
	Less Than 3 kw	3 kw to 6 kw	More Than 6 kw
1	A	B	C
2	B	C	D
3	C	D	E

CHART C COMPONENT TABLE

STEP 1		STEP 2	STEP 3		STEP 4	STEP 5		STEP 6	
WIND TURBINE		ENGINE GENERATOR	SOLAR ARRAY		ENERGY-MINDER™	BATTERY SIZE		DC-AC INVERTER RATED POWER	
ROTOR DIA.	TOWER HGT.		PANELS	PEAK POWER RATING		CODE	CAPACITY (APPROXIMATE)	60 HERTZ	50 HERTZ
23 feet 24 feet 26 feet	60 feet 80 feet 100 feet 120 feet	Standard: 11.5 kw peak 10.0 kw continuous 120/240 volt, 60 hertz, 1 phase Optional: 9.5 kw peak 8.5 kw continuous 100/200 volt, 50 hertz, 1 phase	1	800 watts	Source Controls: • Wind turbine • Engine/generator • Solar array Electric load control/center (required)	A	425-500 amp-hours	250 watts 500 watts 1000 watts 2.5 kw 5.0 kw 10.0 kw	200 watts 400 watts 800 watts 2.0 kw 4.0 kw 8.0 kw
			2	1600 watts		B	500-575 amp-hours		
			3	2400 watts		C	575-650 amp-hours		
			4	3200 watts		D	650-725 amp-hours		
			5	4000 watts		E	725-800 amp-hours		
			6	4800 watts					

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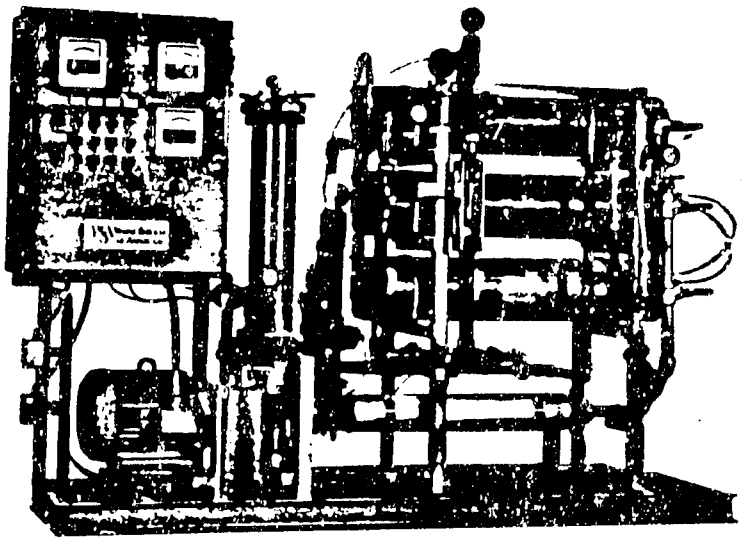
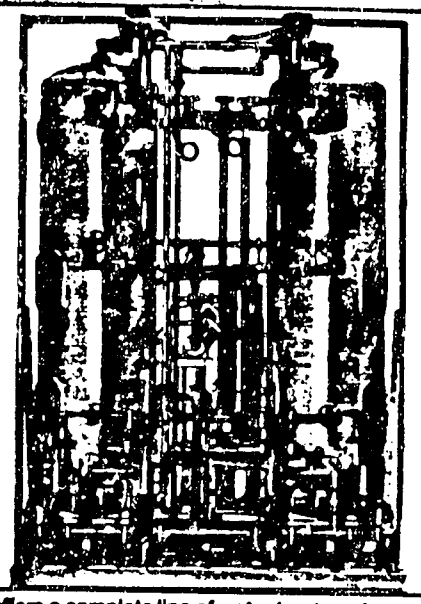
DESALINATION

WSA's Reverse Osmosis Systems purify sea and brackish water for the world.

WSA's Reverse Osmosis technology keeps pace economically with increased water demands.



Standard packaged RO units are designed and constructed using the highest quality corrosion resistant materials and state of the art controls and other proprietary design features which reduce operation and maintenance costs and provide long equipment life.



WSA offers a complete line of water treatment equipment for single source responsibility. Accessory equipment can be designed and built to complement and complete both standard and custom designed systems to meet various water quality requirements.

Our professional engineering staff and experienced field service group routinely take projects from concept to completion. This capability assures product uniformity and improvement, short term project completion, and customer satisfaction.

The Earth's supply of water is finite. The demand for potable water increases each year. Pollution becomes more serious and harder to control while industry requires higher purity water. The challenge is clear. Total cost effective energy efficient systems for pollution control, potable, process, and high purity water for municipalities, private water systems, resorts, offshore, and industrial installations are available from WSA.

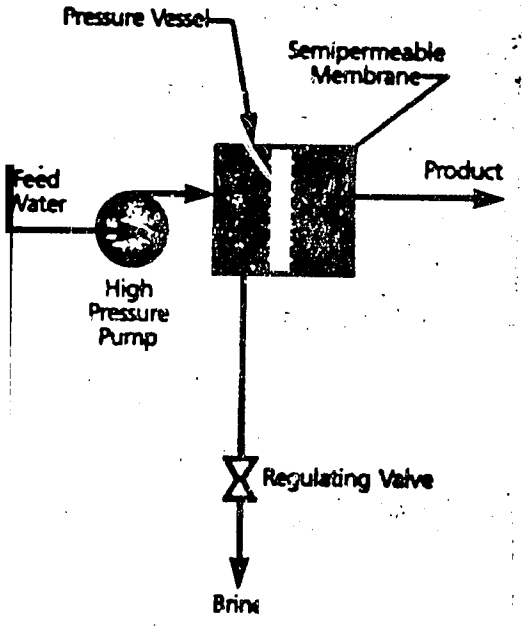
With proven technology and experience, WSA can provide solutions to your particular pure water requirements. Large or small, packaged or custom water treatment plants are designed, built, operated and maintained by WSA, a leader in the RO industry.

Learn more about the indisputable advantages of WSA's Reverse Osmosis technology. Please write for technical data sheets, and more detailed information on WSA RO installations.

WATER SERVICES OF AMERICA, INC.

Where technology is measured in payback.

P.O. Box 23848, Milwaukee, WI 53223 • Telephone (414) 354-6470 • TWX 910-262-3354 WSA MIL



SIMPLIFIED RO FLOW DIAGRAM

The world looks to Water Services of America for the latest application of Reverse Osmosis technology to meet the accelerating demand for fresh water. The need for fresh wate on this planet grows at the rate of 10 to 15% per year. The source is finite. To accommodate population increases and to permit industry and agriculture to expand, the world looks to engineers and scientists to ensure that our water requirements will be met. We can only achieve this formidable task by practicing the best known conservation methods, by improving the yield from traditional sources, and by using an imp tant new source of fresh water — seawater and brackish water that has undergone thorough, cost-effective desalination.

Over the years, three primary systems have been developed for seawater desalination. Of these three systems, two (vapor compression and flash distillation) are relatively effective, but they use two to six times as much energy as the third: Reverse Osmosis (RO).

At Water Services of America, we've refined the RO process to its most efficient state-of-the-art. Our units are modular; installations can be expanded incrementally to fill growing requirements. Components are constructed of inert materials, corrosion-resistant plastics, and stainless steels. And with the WSA RO systems, no heat is required. The process runs at ambient temperatures.

Where will you find WSA Reverse Osmosis systems? Standard WSA systems are in use throughout the world providing fresh, safe drinking water for use in hotels, apartment buildings, condominiums, and resorts. Large, custom-designed WSA RO plants provide fresh, safe drinking water for municipalities from the U.S.A. to the Middle East.

Industrial process water is provided by WSA RO systems for use in boiler feed, printed circuit board manufacturing, electroplating and food and drug manufacturing. WSA offers a complete line of industrial water treatment equipment for use in conjunction with RO systems when ultrapure water is required.

WSA also custom designs systems, using standard components, for use in wastewater recovery and chemical reclaiming operations. These systems are typically used to reduce wastewater volume, recover valuable chemicals and to provide process makeup water from wastewater.

What is Reverse Osmosis, and how does it work for you? The principl of osmosis is found throughout nature. O mosis enables our body's cells to receive nourishment and plants to obtain water from the soil. Simply stated, it is nature's effort to equalize liquids of varying salinity separated by a semipermeable membrane water with fewer impurities will flow through a membrane to dilute the higher salinity water on the other side.

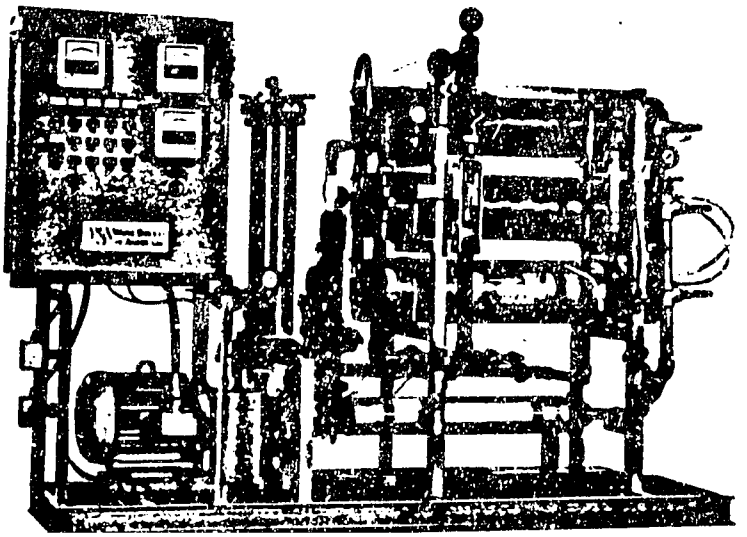
WSA engineers reverse this process by applying pressure to the high salinity wate forcing pure product water through the specially designed membranes. The conce trated solids left behind are flushed away from the membrane surface in the reject stream.

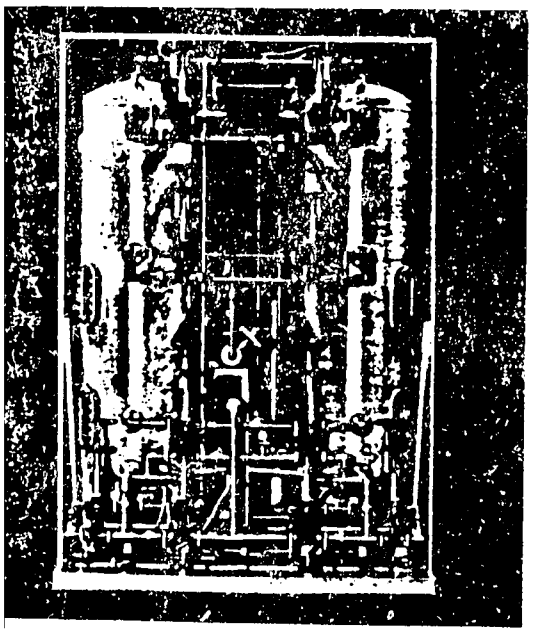
The system can produce fresh water — that is, containing fewer than 500 parts pe million TDS (total dissolved solids) — from seawater in a single pass.

The membranes, like the walls of plant and animal cells, are microscopic, hair-like, hollow tubes or flat sheets assembled in a cylindrical module to provide the maximun membrane surface area for highest possibl water productivity. A variety of membrane is available. WSA engineers analyze the fee stream to determine which type of membrane should be specified to provide the most efficient RO system.

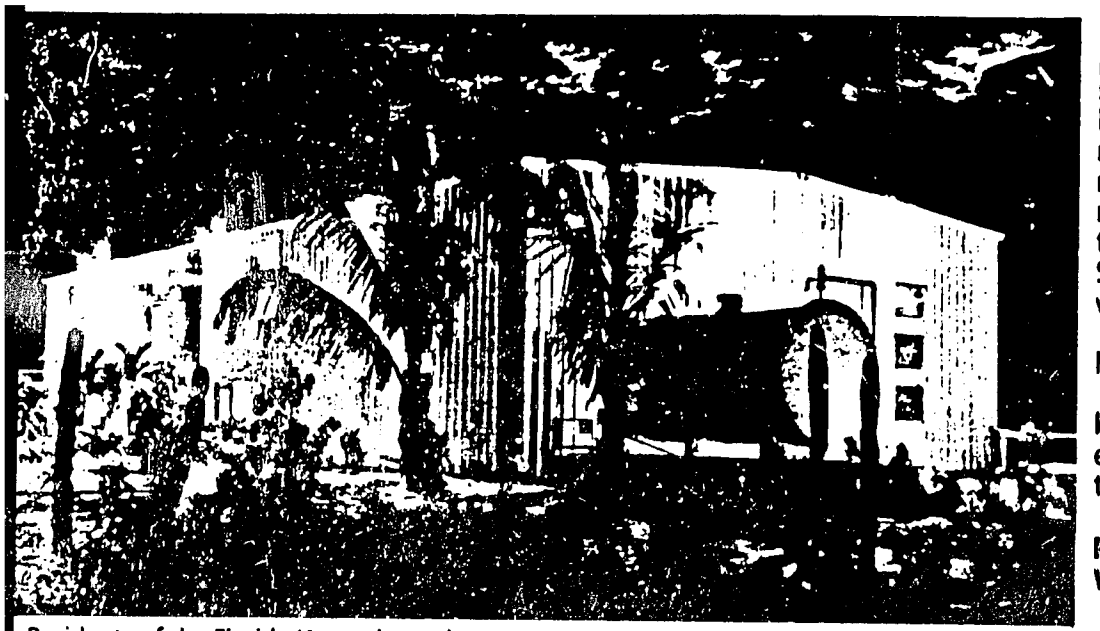
WSA offers standard Reverse Osmosis systems in a variety of sizes. Units are preassembled and factory-tested.

The type of membrane, membrane array, and operating conditions are determined for each application by WSA engineers, working with computer assistance in their own freshwater research laboratory.





Auxiliary systems for filtration, degasification, deionization, ultrafiltration, clarification, softening, and other treatment processes are also available from WSA either "off the shelf" or custom-engineered for specific use.



Residents of the Florida Keys rely on the 3.0 million gallon per day production of is self-contained RO plant, (the first major awater RO plant in the Western emisphere for production of potable ater). The entire installation was put on e in seven-and-one-half months. The stem is modularly designed and uses icroprocessor controls that enable plant perators to tailor plant output to meet emand at the touch of a button.

Water Services of America has strategically located sales and service offices to serve the world market. Their experience and technical expertise make them indispensable to government and industry. Together with the WSA laboratory and engineering support group (located in the Milwaukee headquarters) the problem of supplying clean water for any purpose can be quickly and efficiently solved at the lowest initial cost and the lowest operating cost.

earn more about the indisputable advantages of nature's own system for water purification, enhanced by WSA engineers. We have a number of technical data sheets, and more detailed information and case histo ries on actual Reverse Osmosis installations, designed and engineered by Water Services of America, the experts in Reverse Osmosis.

Call one of our regional offices, or ou headquarters in Milwaukee.

The world needs clean water. We know how to get it — faster, with less energy. In water purification, WSA has th track record the world depends on.

PARTIAL LIST OF WSA RO INSTALLATIONS

Isle Arena, Colombia, South America: Oldest operating seawater RO system.

Jeddah, Saudi Arabia: World's first solar energy seawater RO plant.

Baku on Caspian Sea: World's first major seawater RO installation, 3.3 million gallons per day.

Corps of Engineers, Fort Irwin, California: First major fluoride removal plan utilizing RO.

Key West, Florida: First major seawater RO plant in the western hemisphere.

Cape Coral, Florida: Major brackish water RO plant in U.S.A.

Indian River County, Vero Beach, Florida: Municipal water system, 2.0 million gallons per day.

Makkah, Saudi Arabia: A WSA 4.0 million gallons per day RO system to supply water needs for the Holy City.

Trans Saudi Oil Pipeline: 10 WSA plants supply all the water needs for the pipeline system.

Qatar State Water Department at Ras Abu Samra: First major RO facility i Qatar.

IBM Research Triangle Park, Nortl Carolina: Major ultrapure water facility for the electronics industry.

WATER SERVICES OF AMERICA

EDR

ElectroDialysis Reversal

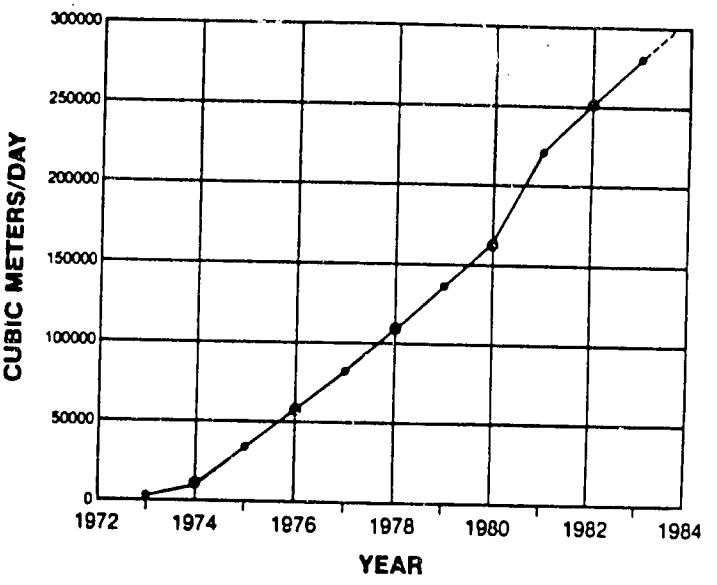
INTRODUCTION

The EDR process was developed in the early 1970s to solve operating and maintenance problems in unidirectional membrane based demineralizing systems. EDR is the only membrane process which is symmetrically reversible. Reversal inhibits the formation of scale and fouling films on the surface of membranes without addition of chemicals to the feed water, minimizes pretreatment and maximizes recovery of difficult to treat waters.

The EDR process removes ionized salts and minerals from water and concentrates them in a smaller volume of water by means of direct current electricity. The DC electricity moves ions from a demineralizing compartment through selective ion transfer membranes into adjoining concentrating compartments. At periodic intervals the direction of ion movement through the membranes and the identity of the concentrating and demineralizing compartments is reversed. (See process discussion that follows.) Reversing the direction of ion flow and interchanging concentrating and demineralizing compartments in the EDR process keeps the surfaces of the membranes clean and free of the scale and slime that occur in unidirectional membrane processes. Cleaner membrane surfaces keep EDR performance efficient and stable.

The practical result of EDR's reversal feature is that the process is more tolerant than other membrane processes of a wide range of troublesome organic, inorganic, colloidal, and biological contaminants in water. EDR is less dependent on chemical conditioning (such as pH correction, softening, or inhibitor feed), and is more forgiving of the physical and chemical upsets which affect real water supplies. A recent study on the state of the art of desalination technology, prepared by a leading engineering firm, gave EDR the highest technical evaluation among membrane processes The high ranking is based on such factors as state of development, stability under design conditions, flexibility and reliability.

FIGURE 1
GROWTH OF EDR CAPACITY
INSTALLED OR UNDER CONSTRUCTION



EDR has been applied to a wide variety of real water situations which has led to a rapid growth in use since the process was first introduced in the early 1970s (see Figure 1). In 1972, there was virtually no EDR capacity in operation or under construction; in 1973, there was less than 5000 cubic meters/day; by 1978, there was about 100,000 cubic meters/day; and by early 1984, there was 300,000 cubic meters/day (80 million gallons).

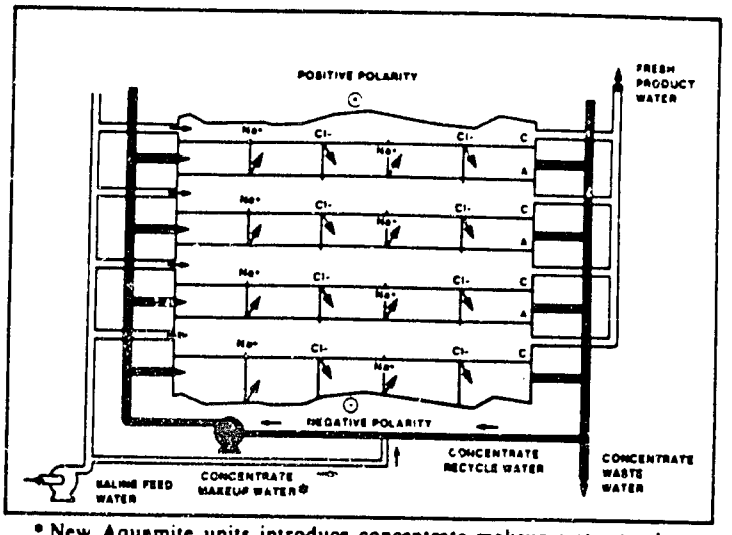
The major application of EDR for much of the 1970s was the demineralization of brackish waters of several thousands parts per million (ppm) of salts to potable levels below 500 ppm for municipalities, oil and construction camps, hospitals, schools, hotels, military bases, bottlers of beverages and purveyors of bottled water. Ionics' EDR AQUAMITE® systems have found great favor in remote locations and village water supply applications, where limited operator skills and availability of chemicals make other processes less attractive.

Starting in the late 1970s and accelerating into the 1980s, an increasing portion of new EDR capacity installed was used to produce high purity industrial process water from "fresh" industrial feed waters containing from a few hundred to over 1000 ppm total dissolved solids. In these cases, the EDR system replaced ion exchange systems or served as a "roughing demineralizer" ahead of an ion exchange "polishing" unit. Increased costs of regeneration chemicals for ion exchange systems and problems with the disposal of associated chemical wastes have facilitated the shift to EDR. Capital cost payback periods, based on chemical savings alone, range from under one year to about three years, depending upon the quality of the raw feed water (higher TDS feeds equal shorter payback periods).

Today, the EDR process is in use in 25 countries around the world, supplying quality drinking water and specified purity industrial process water to over 500 installations, the largest with a capacity of 24,000 cubic meters/day (6 million gallons). Typical industrial users of EDR include power plants, semiconductor manufacturers, the pharmaceutical industry, metals processors, cement plants, the petrochemical industry, food processors, textile manufacturers, and poultry and dairy applications.

ELECTRODIALYSIS (ED)

FIGURE 2
EDR CIRCULATION DIAGRAM



* New Aquamite units introduce concentrate makeup water to the discharge side of the recirculation pump.

The mechanism of operation of unidirectional electrodialysis is reviewed here as a basis for the understanding of EDR.

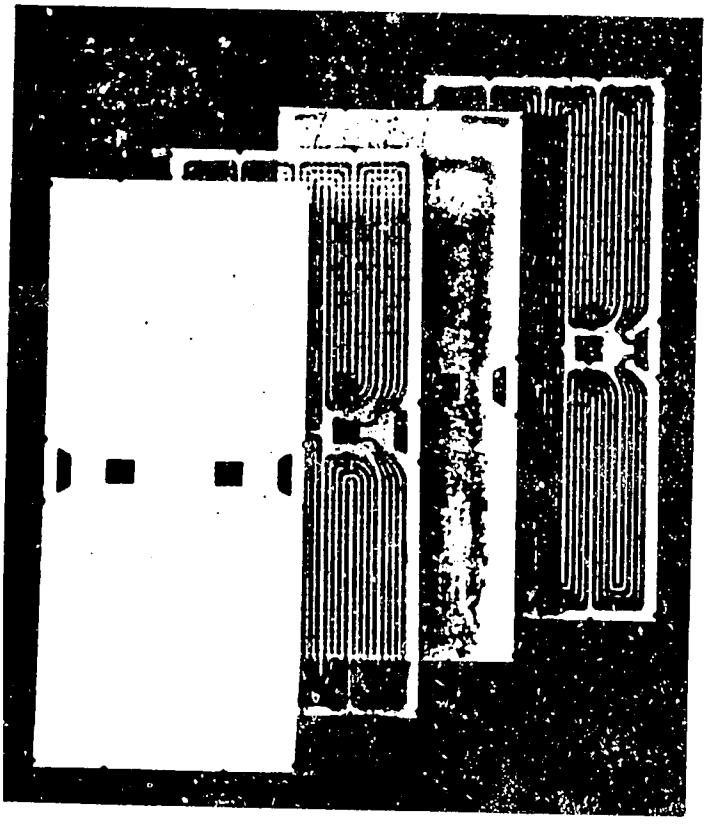
When salts and minerals dissolve in water, they break apart to form ions. Ions are particles of atomic or molecular size bearing positive or negative electrical charges. For example, common salt—sodium chloride—is ionized into a positively-charged sodium ion called a cation, and a negatively-charged chloride ion called an anion. These ions will migrate in a DC electrical field with the positively-charged sodium cations moving toward the negative pole (or cathode) and the negatively-charged chloride anions moving toward the positive pole or anode (Figure 2).

Ion transfer membranes, used to control ion movement in an ED unit, are made from either cationic or anionic ion exchange resins in sheet form. These are called, respectively, cation membranes and anion membranes.

Cation membranes, like cation exchange resin, have mobile or exchangeable cations (e.g., sodium, calcium, or magnesium) within their structure. As a result, cation membranes (marked "C" in Figure 2) will transfer cations—but exclude anions. Conversely, anion membranes, like anion exchange resin, have mobile or exchangeable anions (e.g., chloride, sulfate, or bicarbonate) within their structure. As a result, anion membranes (marked "A" in Figure 2) will transfer anions, but exclude cations.

Figure 2 depicts the operation of a classical ED array or "stack"—in which the elements described above, namely, dissolved ions, selective cation and anion membranes, and a DC electric field are combined to achieve both demineralization of water and concentration of removed ions in a waste stream.

FIGURE 3
EDR
ONE CELL PAIR
TWO MEMBRANES & TWO SPACERS



In the membrane stack, water containing dissolved ions is pumped between a cation and an anion membrane through a cut-out polyethylene spacer of about 1.0 mm thickness (Figure 3). The membranes are typically 0.5 mm thick. Each of the two membranes is bounded by another 1 mm liquid flow spacer, then a membrane of the alternate type, etc.

When a DC field is imposed on this array, all of the cations will move toward the negative pole. If the first membrane a cation encounters is a cation membrane, it will pass to the next water compartment, thus leaving behind a partly-demineralized cell. If the first membrane the cation encounters is an anion membrane, that ion will not pass. It is trapped in its original compartment, which becomes a concentrating compartment.

As can be seen from Figure 2, the anions undergo similar movements and restrictions in the opposite direction as they are attracted to the positive pole.

In an ED array, with alternating cation and anion membranes, each ion can move either not at all or one compartment at most before being blocked by an opposite membrane.

The net result of these membrane-controlled DC-induced ion movements is that one set of water-containing compartments becomes demineralized and the alternate set becomes concentrated.

The system described is classical or unidirectional ED. The term unidirectional refers to the fact that the polarity of the DC field is unchanging, the ions always move in the same direction, and the identity of the alternating water compartments remains unchanged; that is, a demineralizing compartment always remains a demineralizing compartment, and a concentrating compartment always remains a concentrating compartment.

Classical unidirectional ED was, the first of the membrane processes to be developed. It dominated membrane desalting in the 1950s and 1960s—although the total market was, by today's standards, quite small.

Classical unidirectional ED was a major historical advance over the thermal processes of evaporation or distillation which were used to desalt water prior to its development. However, unidirectional ED suffers from a number of limitations which are shared in varying degrees by other unidirectional membrane processes such as reverse osmosis (RO).

1) It is generally necessary to add acid and/or complexing agents such as SHMP (sodium hexametaphosphate) or to presoften the water to be treated to achieve stable operation—even over a matter of hours. This preconditioning requirement results from the presence of small amounts of calcium carbonate, calcium, strontium, or barium sulfate, or iron in the water, all of which tend to precipitate at the membrane interface and degrade performance as concentration takes place.

2) Non-mineral substances in the water—organic and inorganic colloids, microbiological entities, or dissolved organics, tend to foul the membrane surface with no in-process means for their removal. Customarily, if the build-up of these substances can be tolerated for a week or a month, the process is stopped at such intervals for cleaning—which is more or less effective.

3) Even with the addition of complexing agents, uni-directional units show marked deterioration of performance in the presence of calcium sulfate saturation or organics over a period of a few months.

ELECTRODIALYSIS REVERSAL (EDR)

The mechanism of electrodialysis reversal differs from that of unidirectional ED in a very simple, but profound way. If one operates a unidirectional electrodialysis array—as shown in Figure 2—for a fixed limited period of time (e.g., 15 minutes) and then reverses the polarity of the applied DC field by an automatic switching mechanism and operates for an equal period of time in the reverse direction—and then continues in this manner of reversing operation indefinitely—one is operating an EDR system.

One can see by reference to Figure 2 that a compartment which was formerly a demineralizing compartment becomes a concentrating compartment when the current reverses (and vice versa). So, it is necessary to switch valves which feed and collect these two streams, shortly after the current is reversed. It is also necessary to divert both streams at the time of polarity reversal for a period of 0.75 to 1.5 minutes to purge both compartments before the demineralizing stream returns to making specified product.

Electrodialysis reversal, therefore, is achieved by symmetrical equal-time operation in alternating directions so that insoluble or sparingly-soluble substances which would otherwise coat the membranes will, during the reversed polarity period, tend to be removed.

EDR is unique among desalting processes in being capable of a reversal of this type because of two inherent characteristics: a) EDR membranes are symmetrical; they operate in the same way in both directions, and b) EDR stacks have a symmetrical configuration with the concentrating and diluting compartments being hydraulically and dimensionally identical.

An operating EDR unit requires a supply of pressurized feed water—in the range of 70 to 90 psi, a reversing DC power supply, and an array of demineralization stages in a membrane stack or stacks.

In order to conserve water, a concentrate recirculation pump is used to recirculate most of the water to the concentrating compartments. The actual waste concentrate flow is then simply regulated by a control valve in the feed line which controls the makeup to the recirculating concentrate loop and forces an equal amount of water out to waste (Figure 2).

EDR CAPABILITIES

Water Recovery: 90 to 95% of the feed water can be recovered as purified product by means of controlled recycle of the concentrate stream and other in-process steps. Simple recycle of the concentrate stream gives recoveries of 70 to 85%.

Electrical Energy: Energy consumption can be approximated by using 0.5 kwhr per cubic meter of product for pumping, plus 0.5 kwhr per cubic meter per 1000 ppm salts removed for ion transfer.

Pretreatment: Presoftening and cooling are generally not required. EDR systems can treat waters with a Langelier Index of plus 2.2 and temperatures to 45°C without special steps. Pretreatment is recommended when iron exceeds 0.3 ppm, and manganese and hydrogen sulfide exceed 0.1 ppm. Silica does not interfere with the process, and therefore, does not require removal or limit water recovery. EDR units are capable of long-term operation on waters having 5 minute SDI's of approximately 15—thereby minimizing filter use.

Chemical Additions: *No chemicals* are required for normal operation of an EDR system. Special, high recovery situations (see calcium sulfate, below) and periodic stack cleaning require minimal chemical use.

Stack Cleaning: Membrane stacks may be cleaned in three ways: 1) continually by means of reversal, 2) periodical chemical flushing, and 3) disassembly and scrubbing of membranes if plant upsets occur. EDR is the only system that allows periodic inspection of individual membranes, which results in lower membrane replacement.

Calcium Sulfate: Calcium sulfate saturation in the concentrate stream up to 175% can be tolerated with no chemical feeds to the EDR system. Addition of SHMP and/or acid, to the recirculating concentrate stream only, allows calcium sulfate saturations up to 400% resulting in high recoveries of difficult to treat waters.

EDR Membranes: Homogeneous, reinforced sheets of polymer, 0.5 mm thick, with fixed anion or cation transfer sites have excellent chemical and temperature stability. Continuous exposure to pH 1 to 10 and free chlorine to 0.3 ppm, and greater extemes for short-term cleaning is standard. Membranes can operate at temperatures above 55°C.

To summarize, the EDR process and system components are capable of long-term stable operation on waters containing a wide variety of mineral, colloidal, or microbiological constituents. The self-cleaning feature of reversal and the stability of the membranes combine to give long life and trouble-free service.

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IONICS, INCORPORATED

STATE-OF-THE-ART OF THE ELECTRODIALYSIS REVERSAL (EDR) PROCESS IN 1983

by
William E. Katz

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State-of-the-Art of the Electrodialysis Reversal (EDR) Process In 1983

William E. Katz

Ionics, Incorporated

INTRODUCTION

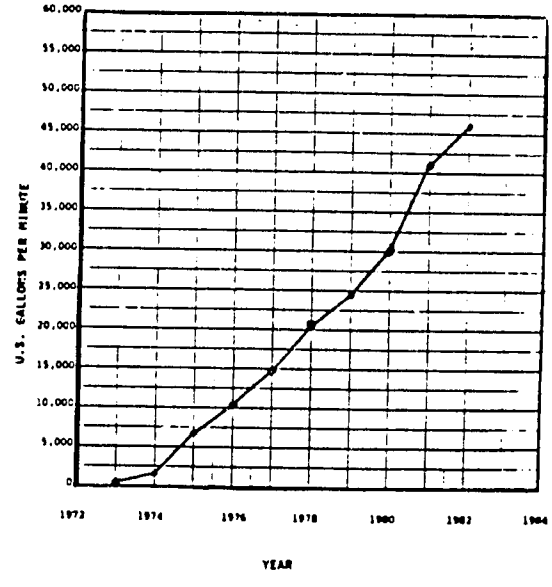
The Electrodialysis Reversal Process (abbreviated "EDR") removes ionized salts and minerals from water and concentrates them in smaller volumes of water by means of direct current electricity. The D.C. electricity moves ions from a demineralizing or diluting compartment through selective ion exchange membranes into an adjoining concentrating compartment.

EDR is the first commercially available membrane process which is symmetrically reversible, i.e., the direction of ion movement through the membranes and the identity of the concentrating and demineralizing compartments are reversed at equal periodic intervals, for example, every twenty minutes.[1] The reversal of direction of ion flow and the interchange of concentrating and diluting compartments in the EDR process keep the surfaces of the ion exchange membranes much cleaner than is possible in unidirectional membrane processes. Cleaner membrane surfaces keep EDR performance relatively stable in the presence of relatively high levels of colloidal and slightly soluble constituents.

The practical result of the symmetrically reversible characteristic of EDR is that the process is more tolerant than other commercially available membrane processes of a wide range of troublesome organic, inorganic, colloidal, and biological contaminants in water. EDR is less dependent on chemical conditioning (e.g. pH correction, softening, or inhibitor feed), requires less pretreatment, and is more forgiving of the physical and chemical upsets and excursions which affect most real water supplies. A recent study on the state-of-the-art of desalination technology, prepared by a leading engineering firm, gave the EDR process the highest technical evaluation among membrane processes based on such factors as state of development, pretreatment requirements, necessary skill of operators, maintenance requirement, stability under design conditions, flexibility and reliability.[2]

The applicability of EDR to a wide variety of real water situations has led to a rapid growth of practical usage since the process was first introduced in the early 1970's (see Figure 1). In 1972, there was virtually no EDR capacity in operation or under construction. In 1973 the was less than 1,000 gallons per minute, by 1978 there was 20,000 gallons per minute, and by the end of 1983 there will be about 50,000 gallons per minute.

FIGURE 1
GROWTH OF EDR CAPACITY
INSTALLED OR UNDER CONSTRUCTION
(U.S. Gallons Per Minute)



The predominant application of EDR for much of the 1970's was the demineralization of brackish waters of several thousand parts per million total dissolved solids to potable levels of a few hundred parts per million for municipalities, oil and construction camps, hospitals, hotels, military bases, bottlers of beverages and purveyors of bottled water. However, starting in the late 1970's and accelerating into the 1980's an increasing fraction of EDR capacity has been utilized to produce industrial water or partially demineralized water from "fresh" industrial feed waters containing from a few hundred parts per million to perhaps 1000 parts per million. Such waters are typical of those used for industrial purposes in many parts of the world.

By mid-1983 five public utility steam-electric generating stations with an aggregate capacity of 4000 MW had chosen EDR to pretreat boiler feed water prior to ion exchange demineralization. EDR units were also in operation or under construction to provide pre-demineralization or direct process water for a major oil refinery, several smaller refineries, one of the world's largest natural gas processing plants, a major copper refinery, a major petrochemical complex, half a dozen cement plants, a modern mini steel mill, several electronics and semiconductor facilities, several food processing plants, a large truck manufacturing complex, a pharmaceutical plant, and a number of miscellaneous industrial installations.

Most of the EDR capacity to date has been for use overseas - primarily in the Middle East, Africa, and Southern Europe. Installations in the U.S.A. currently represent less than 10% of the total, but the U.S.A. market is showing accelerating growth as industrial applications increase.

INDUSTRIAL APPLICATIONS AND CHARACTERISTICS/SUMMARY

The following applications and characteristics of EDR in industrial water treatment are worthy of note and several will be discussed in more detail in this paper:

A. EDR is capable of controlled roughing demineralization of brackish feed waters of any salinity, and of "fresh" feed waters in the range of 20 to 1000 ppm total dissolved solids. Percentage EDR demineralization can be controlled from 50% to 99% by the number of ED stages utilized, the temperature of the water and other design variables. Electrical energy consumption can be approximated by 2.5 kw-hr per thousand gallons (for pumping at normal systems pressures of 70 to 90 psig) plus 0.25 kw-hr per thousand gallons per 100 ppm as $CaCO_3$ removed, in the range below 3000 ppm. Thus a typical mid-Western river or well water with 300 ppm as $CaCO_3$ would require 2.5 + (2.7 X 0.25) or 3.2 kw-hr per 1000 gallons for 90% demineralization.

B. On most natural brackish or fresh waters, EDR is capable of operating at typical water recoveries (ratios of product to feed water) of 65 to 80% *without any chemical feeds or conditioning* (e.g. pH correction, inhibitor feed, or presoftening). EDR is also capable of water recoveries up to 95%, with the addition of very small quantities of acid and/or inhibitors to the brine stream.[3] Control of water recovery in EDR units is simply accomplished over the range of 50% to 95% by adjustment of a single brine make-up valve.[4]

C. EDR has been shown capable of stable operation on feed waters with 5 minute silt density indices (SDI's) as high as 15. Such waters are typical of some untreated surface waters and can occur in treated surface waters with less than optimal pretreatment. Since a high percentage of industrial feed waters are surface waters, this capability of EDR is critical to its use for many industrial applications.[2]

D. EDR is capable of long-term stable operation demineralizing high calcium sulfate waters with relatively high recoveries up to calcium sulfate saturation levels in the brine stream of at least 400%.[3] Experiments are currently underway to determine an upper limit to calcium sulfate saturation in EDR units. Such a limit appears to be greater than 400%. Thus EDR is capable of demineralizing high calcium sulfate waters with little or no pre-softening - a major economic and operational advantage over processes requiring pre-softening.[5]

E. EDR has been shown capable of concentrating minerals and salts to levels of about 100,000 parts per million in the brine.[6] An experimental unit to concentrate 20,000 to 40,000 parts per million waste water to 120,000 parts per million is about to be tested by a major state water agency as part of a long-range agricultural waste water disposal and recycle study project.[7]

F. EDR is capable of stable operation on waters with barium, strontium, or high (up to 200 ppm) silica contents.[8]

G. In view of its stability in the face of high SDI's, trace constituents, and high $CaSO_4$, EDR is a candidate for use in concentration of cooling tower blowdown from large thermal power stations. Encouraging results have been obtained from small and medium scale pilot work on an actual cooling tower circuit slipstream with conventional clarification over the past year, and such work is continuing.

H. In view of a new chlorine resistant anion membrane, EDR is now capable of sustaining long-term continuous chlorine residuals of at least 0.3 ppm plus weekly cleanings with levels up to 20 ppm free chlorine, thus enhancing its ability to operate in biologically contaminated waters.

I. In common with older ED equipment, EDR units are capable of continuous operation at temperatures up to 45 degrees C, continuous pH range of 1 to 10, cleaning pH range of 0 to 13 - thus enabling use of a wide variety of cleaning agents.

J. Average membrane life in most EDR applications is in the 5 to 10 year range.

K. Modern EDR stacks require little if any manual disassembly for cleaning although the option for disassembly exists if necessary to deal with disasters such as sand, carbon, or other media migration into the stacks, gross dirt or mud loads, etc.

BASIC PRINCIPLES FOR ED AND EDR

A. Classical Undirectional Electrodialysis ("ED")

The mechanism of operation of unidirectional electrodialysis (abbreviated "ED") has been described many times but will be reviewed here as a basis for the understanding of EDR.

When salts and minerals dissolve in water, they break apart to form ions, for example, sodium chloride ionizes to form a positively-charged sodium ion and a negatively-charged chloride ion. These ions will migrate in a D.C. electrical field - with the positively-charged sodium cations moving toward the negative pole (or cathode) and the negatively-charged chloride anions moving toward the positive pole or anode. (Figure 2).

Ion exchange membranes can be made from either cationic or anionic ion exchange resins in sheet form. These are called, respectively, cation membranes and anion membranes.

Cation membranes, in common with any cation exchange resin, have mobile or exchangeable charged cations (e.g., sodium, calcium, or magnesium) within their structure. As a result, cation membranes (marked "cation" in Figure 2) will "pass" cations - but exclude anions. Conversely, anion membranes, in common with any anion exchange resin, have mobile or exchangeable anions (e.g., chloride, sulfate, or bicarbonate) within their structure. As a result, anion membranes (marked "anion" in Figure 2) will "pass" anions, but exclude cations.

FIGURE 2
BASIC ION MOVEMENT
ED/EDR

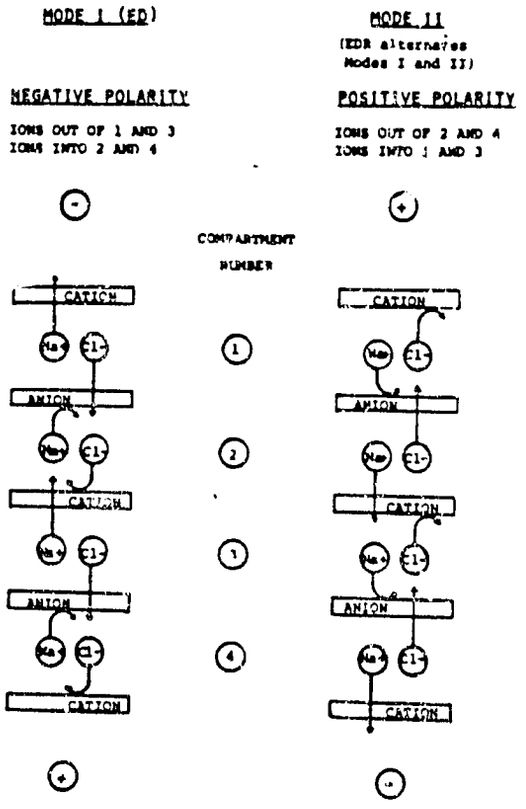


Figure 2 depicts under Mode I on the left hand side the operation of a classical electrodialysis array or "stack" - in which the elements described above, namely dissolved ions, selective cation and anion membranes, and a D.C. electric field are combined to achieve both demineralization or deionization of water and concentration of removed ions in a waste or brine stream of higher concentration.

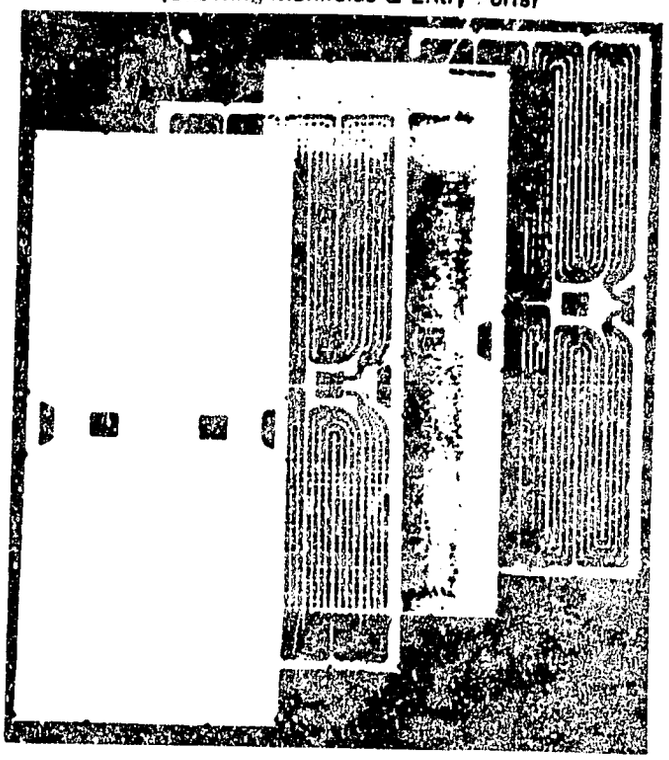
In the membrane stack, water containing dissolved ions is pumped between a cation and an anion membrane separated by a cut-out polyethylene spacer of about 1.0 mm thickness (Figure 3). The membranes are typically 0.5 mm thick. Each of the two membranes is bounded by another 1 mm liquid space, then a membrane of the alternate type, etc.

When a D.C. field is imposed on this array, all of the cations will move toward the negative pole. If the first membrane a cation encounters is a cation membrane, it will pass to the next water compartment, thus leaving behind a partly-deionized or "diluting" compartment. If the first membrane the cation encounters is an anion membrane, that ion will not pass. It is trapped in its original compartment, which becomes a "concentrating" compartment.

As can be seen from Figure 2, the anions undergo similar movements and restrictions in the opposite direction as they are attracted to the positive pole.

The net result of these membrane-controlled D.C.-induced ion movements is that one alternate set of water-containing compartments (e.g., the odd-numbered set) becomes demineralized and the other alternate set (e.g., the even-numbered set) becomes concentrated.

FIGURE 3
EDR
ONE CELL PAIR
TWO MEMBRANES & TWO SPACERS
(Showing Manifolds & Entry Ports)



The array or stack as described above depicts classical or unidirectional electrodialysis "ED". The term unidirectional refers to the fact that the polarity of the D.C. field is unchanging, hence the ions always move in the same direction, and the identity of the alternating water compartments remains unchanged, that is, a diluting compartment always remains a diluting compartment, and a concentrating compartment always remains a concentrating compartment.

Classical unidirectional electrodialysis ("ED") was, historically, the first of the membrane processes to be developed. It dominated membrane desalting in the 1950's, 1960's, and early 1970's, although the total market was - by today's standards - quite small.

Classical unidirectional electrodialysis was a major historical advance in that it was the first commercial process developed to desalt or demineralize water by use of membranes. However, unidirectional electrodialysis suffers from a number of limitations which are shared in varying degrees by other unidirectional membrane processes.

1. It is generally necessary to add acid and/or complexing agents such as SHMP (sodium hexametaphosphate) or to pre-soften the water to be treated to achieve stable operation - even over a matter of hours. The pre-softening requirement results from the presence of small amounts of calcium carbonate, calcium, strontium, or barium sulfate, or iron in the water, all of which tend to precipitate at the membrane interface or in the concentrating compartments and degrade performance as concentration takes place.

2. Non-mineral substances in the water - organic and inorganic colloids, microbiological entities, or polymeric organics tend to deposit on the membrane surface, with no-in-process means for their removal. Customarily, if the build-up of these substances can be tolerated for a week or a month, the process is stopped at such intervals for cleaning - which is more or less effective.

3. Even with the addition of complexing agents, unidirectional ED units showed marked deterioration of performance in the presence of calcium sulfate saturation over a period of a few months.[1]

B. Electrodialysis Reversal ("EDR")

The mechanism of electrodialysis reversal "EDR" differs from that of unidirectional electrodialysis "ED" in a very simple - but profound way. If one (1) operates a unidirectional electrodialysis array - as shown in Figure 2, Mode I - for a fixed limited period of time (e.g., 20 minutes) and (2) then reverses the polarity of the applied D.C. field by an automatic switching mechanism and operates for an equal period of time in the reverse direction (Figure 2, Mode II) - and (3) then continues this manner of reversing operation indefinitely - one is operating an "EDR" system.

One can see by reference to Figure 2 that a compartment which was formerly a diluting compartment becomes a concentrating compartment when the current reverses (and vice versa) so it is necessary to switch valves which feed and collect these two streams, shortly after the current is reversed. It is also necessary to divert both streams at the time of polarity reversal for a period of 0.5 to 1.5 minutes to purge both compartments before the diluting stream returns to making specified product.

Electrodialysis reversal therefore is achieved by symmetrical equal-time operation in alternating directions - so that insoluble or slightly soluble substances which would tend to coat the membranes or deposit in the concentrating compartments will tend - during the reversed polarity period - to be removed.

EDR is unique among desalting processes in being capable of a reversal of this type because of two inherent characteristics: a) EDR membranes are symmetrical; they operate in the same way in both directions, and b) EDR stacks have a symmetrical configuration with the concentrating and diluting compartments being hydraulically and dimensionally identical.

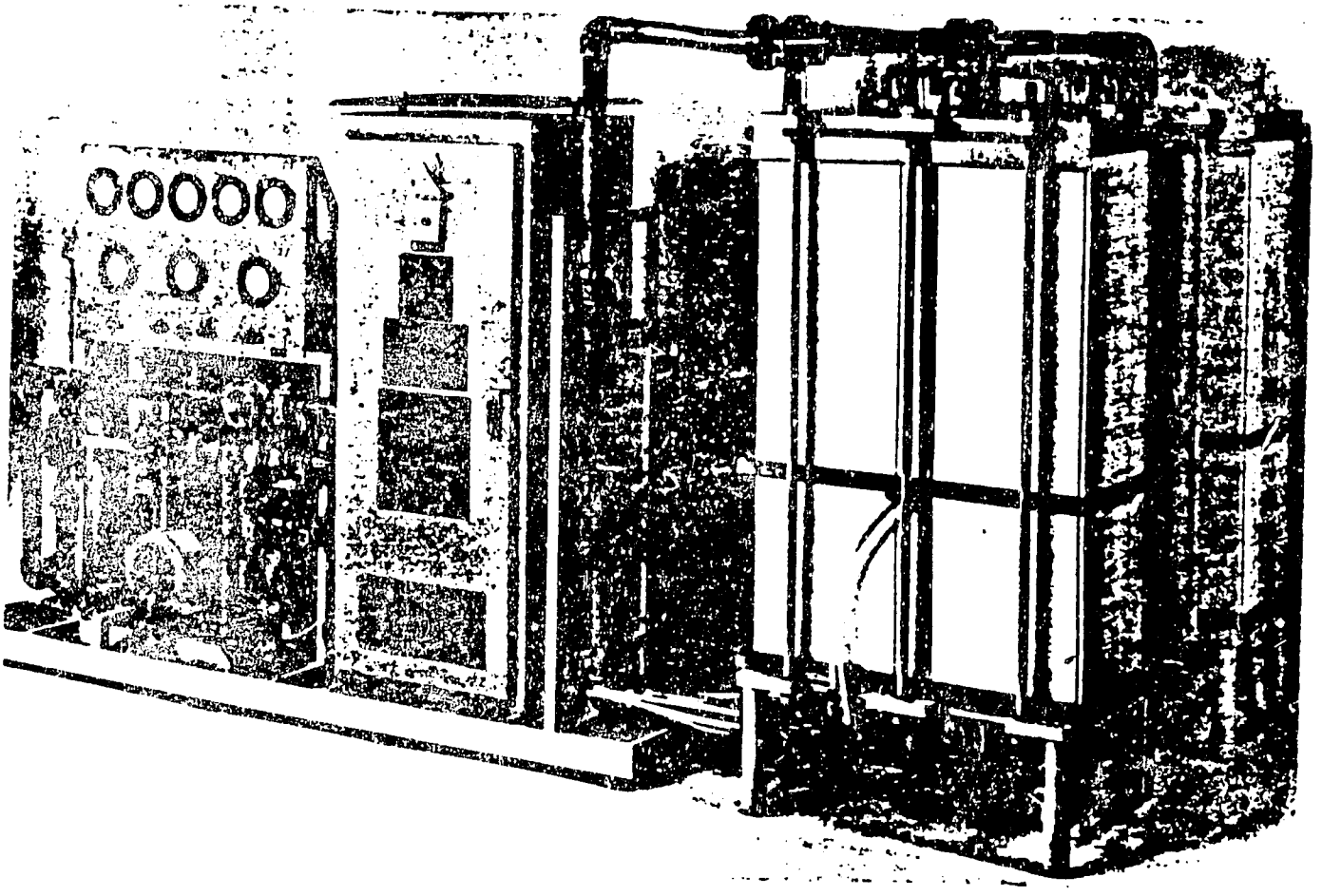
C. EDR Stacks, Stages, and Equipment

EDR stacks, stages, and equipment have been described in detail in the literature.[1] We will briefly review the main points so that the data below can be better understood.

As described above, the alternating diluting or concentrating compartments are bounded by alternating cationic and anionic membranes of 0.5 mm thickness. This repeating assembly of four elements (cation membrane, spacer/compartment, anion membrane, space/compartment) is called a "cell pair." The compartment itself is composed of the cut-out portion of a polyethylene spacer of 1.0 mm thickness, sandwiched between the pair of membranes. The concentrating and diluting spacers alternate, and are differentiated only by the entry ports or channels which connect the cut-out portion (in which the water flows) to the appropriate manifold. There are four manifolds which pass through the membrane-spacer sandwich carrying feed water in, demineralized water out, brine water in, and brine water out. The standard large EDR membranes have 18 by 40 inch dimensions and the spacers are of the same size. (Figure 3)

To form a membrane stack, hundreds of cell pairs are compressed between two platinized electrodes which alternate as anodes and cathodes as reversal takes place. The whole assembly (Figure 4) is compressed between steel end plates by metal tie rods to contain the liquids in the stack. Typically, membrane stacks have between 300 and 600 cell pairs. (Figure 4)

FIGURE 4
70 GPM PACKAGED EDR PLANT
WITH TWO MEMBRANE STACKS



A single pass through a membrane stack results (for waters below about 4000 ppm) in a partial percentage demineralization which depends upon temperature, ion composition, level of entering total dissolved solids, flow rate, and applied voltage. A typical range of partial demineralization per pass or "stage" is 30 to 60%. Higher temperatures, higher sodium chloride percentages, lower inlet total dissolved solids, lower flows, and higher applied voltages favor higher demineralizations per pass.

Since desired practical demineralizations are often in the range of 75 to 99%, it is necessary to use several stages of EDR demineralization. Practical numbers of stages vary from one or two to as many as 18 or 20 on sea water. For a partial demineralization of 50% per pass or "stage," one stage gives 50%, two stages 75%, four stages 93.8%, six stages 98.4%, eight stages 99.6%, etc.

Typical flows for a 500 cell pair single stage stack are in the range of 100 to 130 gallons per minute and typical pressure drops per stage are in the range of 7 psi to 11 psi in this flow rate range. Design pressure (for stacks) is usually kept at around 50 psig into the first stage of a multi-stage stack array. For units requiring more than 4 to 7 stages, further flow reductions below 100 to 130 gpm are necessary.

For EDR plants, where the desired output flow is in the range of 100 gpm or more, a single stack or group of parallel stacks is used as a single stage. However, for units with desired output flows of less than 100 gpm, several stages are contained in the same stack. In a single stage stack, all of the hundreds of alternating compartments flow in parallel off the manifolds. However, in multi-stage stacks, groups of cells flow in parallel to form one stage and the outputs of this group are collected and fed to another group within the same stack to form a separate stage. Groups of cells between any pair of electrodes constitute one "electrical stage." If two or more stages are grouped within a stack between one pair of electrodes these are called "hydraulic stages."

Figure 4 shows two multi-stage stacks comprising part of a packaged EDR unit of 70 gallons per minute net product output. The two stacks each contain 450 cell pairs and each have a net capacity of 35 gpm. They are identical to each other and arranged in parallel. Each stack has three hydraulic and two electrical stages. The two electrical stages are separated by a thick PVC block which is clearly visible about two-thirds of the way down from the top of each stack. The larger top section of each stack has two hydraulic stages within a single electrical stage defined between the top pair of electrodes. The smaller section at the bottom is a single hydraulic stage and also a single electrical stage defined between the bottom pair of electrodes.

An operating EDR unit requires a supply of pressurized feed water - generally in the range of 70 to 90 psi, a reversing D.C. power supply, and an array of demineralization stages in a membrane stack or stacks. The flow in the concentrating compartments within the stack is kept just slightly lower than the flow in the diluting compartments, since these compartments are identical in configuration, and one wishes to keep the pressure in the concentrating compartments just slightly lower than the pressure in the diluting compartments. In order to conserve brine water, a brine recirculation pump is used to recirculate most of the water to the concentrating compartments. The actual waste brine flow is then simply controlled by a control valve off the feed line which controls the makeup to the recirculating brine loop and forces an equal amount of water out to waste.

Water recovery - defined as the ratio of product water to feed water - can be simply controlled in this manner in EDR plants in the range of about 50 to 95%. There are some natural losses of water from the diluting to the concentrating compartments by endosmotic water transfer and intercompartmental leakage which place an upper limit on recovery. However, development work both on membranes and spacers is underway to raise the recovery limit and to allow even higher concentrations by EDR.

In Figure 4 one can see the major components of an EDR system with the two multi-stage stacks at the right and the skid at the left. The skid contains a feed pump, brine pump, cartridge filter, reversing and control valves, D.C. power supply and control cabinet, and hydraulic instruments.

ROUGHING DEMINERALIZATION

EDR plants are now in operation or under construction for use as roughing demineralizers ahead of ion exchange demineralizers in California, Arizona, Texas, Florida, New Jersey, Ohio, Wyoming, and a number of African and Middle Eastern countries. Capacities of individual installations currently in operation range from 25 gallons per minute to one thousand gallons per minute. Many of these EDR units have been retrofitted ahead of existing demineralizers in operating installations to adjust to changed operating conditions, for example, (1) increased salinity of the feed source, (2) a need for increased capacity, or (3) increases in waste disposal problems and costs.

Pre-demineralization by EDR leads to large reductions in frequency of regeneration of the downstream ion exchange demineralizer along with corresponding decreases in chemical consumption, waste disposal, and monitoring supervision, and a significant increase in demineralizer availability and capacity. The economics of EDR roughing demineralization will depend on many local factors, such as design of the ion exchange unit, water analysis, treatment objectives, waste disposal problems, local prices for chemicals and power, etc. However, the attraction of EDR pretreatment for ion exchange demineralizers is the simplicity, reliability and low operating cost of the EDR unit. In many cases where EDR units have been chosen, the performance stability of EDR on the water in question was first demonstrated by a pilot unit.

Results of demineralization by EDR at one installation in the Southwestern U.S.A. are given in Table I and Table II. Table I shows a 95% overall demineralization with individual ions varying from about 89% for bicarbonate to almost 97% for calcium, magnesium, and chloride.

One limitation of EDR in demineralization is that it removes only ionized substances so that silica is not removed. On the other hand, EDR units are not scaled by high silica waters (up to at least 200 parts per million) so that high recovery concentrations or demineralizations can be carried out by EDR in high silica waters.

Table II shows the detailed performance data for the packaged EDR unit which produced the demineralization in Table I. The unit has now been on line well over three years and performance has been stable. There is no chemical conditioning or feed to the unit. The unit has a diluting stream

TABLE I
30 GPM EDR DEMINERALIZATION
RESULTS AFTER THREE YEARS
(ppm as $CaCO_3$)

	Feed	Product	% Demineralization
Sodium	329	22	93.3%
Calcium	120	4	96.7%
Magnesium	117	2	96.7%
Total Cations	566	28	95.1%
Chloride	432	14	96.7%
Bicarbonate	80	9	88.8%
Sulfate	44	4	90.9%
Total Anions	556	27	95.1%
Conductivity (25°C)	1246	59	95.2%
pH	7.3	6.9	

Feed Water Temperature - 30°C

TABLE II
PERFORMANCE DATA
30 GPM EDR AFTER 3 YEARS

FEED Sum of Ions — 561 ppm as $CaCO_3$
PRODUCT Sum of Ions — 28 ppm as $CaCO_3$

PRODUCT FLOW — 30 GPM (10% Off-Spec)
BRINE MAKE-UP — 5 GPM

DC INPUT	VOLTS	AMPS	WATTS
Electrical Stage 1	183	7.3	1330
Electrical Stage 2	183	2.0	366
TOTAL	183	9.3	1696

TOTAL DC ENERGY — 1.15 kwhr/1000 gallons[1]

[1] Assuming 90% Rectifier Efficiency

flow of 30 gallons per minute, a brine makeup of 5 gallons per minute, and a fifteen minute EDR cycle with 1.5 minutes or 10% off-spec time at the time of reversals. Thus its net output is 1620 gallons per hour. Since the overall removal is 95%, the average removal for each of the four hydraulic stages is 53%, and for each of the two electrical stages is 78%.

One can see clearly in Table II how the two electrical stages of this unit are working with a total rectifier output of only 1696 watts D.C. The first electrical stage requires 7.3 amperes at 183 volts, while the second stage (with 78% fewer ions) requires only 2.0 amperes. The ratio of amperes is approximately the same - as it should be - as the ratio of ions removed.

The unit is equipped with a single 450 cell pair 18 by 40 inch EDR stack with two electrical and four hydraulic stages. Overall mineral removal is from an average of 561 ppm to 28 ppm as $CaCO_3$ or 533 ppm as $CaCO_3$ removed. The D.C. energy used (allowing for a 90% rectifier efficiency) is 1.15 kw-hr per thousand gallons or 0.215 kw-hr per thousand gallons per 100 ppm as $CaCO_3$ removed. To this must be added pumping power, which in this small unit runs around 5 kw-hr/1000 gallons. On units of the 100 gpm and greater size, the D.C. power would be the same, but the pumping power would be roughly cut in half.

EDR is attracting increasing attention and usage in roughing demineralization because it is a stable, durable process with very attractive total energy efficiency. For waters of 100 to 1000 ppm as $CaCO_3$ or below (and this range covers most industrial waters in the U.S.A.) total pumping plus D.C. energy consulmptions of 2.8 to 5.0 kw-hr/1000 gallons are realistic and sustainable over long periods. *This means that a 200 gpm unit requires an electric supply of 35 to 60 kilowatts and can save from hundreds to thousands of tons of chemicals annually.*

OPERATING ON HIGH CALCIUM SULFATE

Calcium sulfate is one of the most common minerals found in natural waters. Important rivers in the Southwestern U.S.A. such as the Red River, Washita, Canadian, and Colorado have significant calcium sulfate components. Perhaps one-third to one-half of the mineralized ground water in the U.S.A. is of a calcium sulfate or gypsum character. Gypsum is a major contaminant of well waters on the West Coast of Florida and in many parts of the Middle East and North Africa.

If a raw water is more than 25% saturated in calcium sulfate, and one wishes to demineralize it with a recovery of 75 to 90%, one must create a waste stream which is saturated or supersaturated in calcium sulfate. Unidirectional membrane processes must be designed with care - and often with pre-softening - to avoid damaging and sometimes catastrophic precipitations of gypsum in operating units on feed waters with even modest calcium sulfate contents. In fact, calcium sulfate is an important limiting design contaminant in evaporation and ion exchange demineralizer design, as well as in unidirectional membrane processes.

Through a series of developments in EDR, which were demonstrated at the Roswell Test Center of the former Office of Water Research and Technology (OWRT), the ability of the EDR process to handle calcium sulfate concentrations in the waste stream to the 350 to 400% range of calcium sulfate has now been established. Table III shows the feed water used in this work, and a highly concentrated waste water.[3]

Prior to the Roswell tests, it had been demonstrated in commercial EDR installations at Dell City, Texas, and Junius Ponds, New York, that EDR units were capable of long term stable operation with calcium sulfate saturations in the waste stream up to about 150% with no chemical addition.[1] However, the range above 150% had not been explored. At Roswell it was decided to explore the limits on calcium sulfate concentration and Langelier Index for EDR units operating with no chemical feeds, and then to determine if addition of acid or inhibitors, such as "SHMP" (sodium hexametaphosphate), to the waste stream of an EDR would extend the useful range.

TABLE III
HIGH $CaSO_4$ EDR PERFORMANCE
94.1% Water Recovery
424.6% $CaSO_4$ Saturation*
ROSWELL TEST CENTER - OWRT

	FEED	BRINE	PRODUCT
Sodium as Na	303 ppm	3300 ppm	50 ppm
Calcium as Ca	190	3609	12
Magnesium as Mg	64	1192	5
Potassium as K	1	26	—
Chloride as Cl	560	7374	62
Sulfate as SO_4	413	8075	22
Bicarbonate as HCO	198	2416	56
Sum of Ions	1729	25,992	207
pH	7.20	7.05	6.30
Conductivity	2740	28,230	350
Langelier Index		+2.16	

* Marshall & Slusher

The conclusions from the first parametric tests were as follows:

1. The Langelier Index limit for EDR systems with zero chemical feed appears to be approximately +2.4, where carbonate scale formation occurs on both system piping and membranes.

2. The calcium sulfate saturation limit for EDR with zero chemical feed or with sulfuric acid addition appears to be between 220 and 250%. At roughly 250% calcium sulfate saturation, gypsum deposition on the brine piping becomes intolerable and some gypsum scale deposition occurs on the membranes.

3. Using acid addition to a Langelier Index of +2.0 in the brine stream and sodium hexametaphosphate addition, trouble-free operation was demonstrated to an average 440% calcium sulfate saturation for 300 hours. Higher levels of supersaturation may be obtainable, but are as yet uncertain."

It was then decided to determine if SHMP alone would inhibit all precipitation without the addition of acid, and these tests were positive. Finally a successful long term test at a water recovery of 90% (equal to 350% $CaSO_4$ saturation) on a calcium sulfate water of 1800 ppm was carried out on a full-size EDR package unit for 5000 hours, using only small amounts of SHMP in the brine.

These tests have established the ability of EDR to deal with high calcium sulfate water - without lime, lime soda, or ion exchange pre-softening. Further work is underway on application of this equipment to cooling tower blowdowns with high calcium sulfate.

OTHER APPLICATIONS

A great deal of additional data has been collected on the other industrial applications of EDR listed in the summary above. Several papers are contemplated by users of EDR equipment for future conferences. This paper has been conceived as an introduction or reintroduction of EDR to the industrial water treatment community. Symmetrically reversible EDR is being used with increasing frequency for industrial water treatment applications because of its durability, energy efficiency, and stability of operation when treating a wide variety of ground and surface water.

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Discussion

by

Dr. Robert Kunin, Consultant

on

State-of-the-Art of the Electrodialysis Reversal (EDR) Process In 1983

It is indeed a pleasure for me to comment on the very interesting paper and presentation of William Katz on the subject of electrodialysis (ED). The subject of electrodialysis has virtually been ignored by the International Water Conference and the **State-of-The-Art** presentation of William Katz is indeed a welcome one. The last paper on ED was delivered at the 1970 International Water Conference by Bill Katz of Ionics, Inc. During this 13-year interval, several large ED plants have been operating successfully around the world and much experience has been accumulated.

In some ways, I have looked upon electrodialysis as a natural extension of ion exchange technology whereby one is able to extend the practical total dissolved solids (TDS) limitations of ion exchange by the substitution of electrical energy for chemical energy. The development of new and improved ion exchange resins and ion exchange resin techniques and equipment have extended the practical limits of ion exchange *resin* technology in terms of total dissolved solids. For example, counter-current systems and the expanded use of weak electrolyte ion exchange resins in seperate units or as stratified beds with the appropriate strong electrolyte ion exchange resins have extended the practical limits of conventional ion exchange resin technology. The advances in electrodialysis noted by Mr. Katz now permit one to combine ED with conventional ion exchange resin technology in a most effective and reliable manner. The ED can be used most effectively in lowering the TDS of high TDS levels to a point where the ion exchange resin systems can operate most effectively.

The EDR Process described by Mr. Katz apparently solves or effectively minimizes the fouling, poisoning and scaling problems which have plagued previous electrodialysis systems. The reversal of the electrode polarity prevents the accumulation of the $CaSO_4$ and $BaSO_4$ scale and minimizes the organic matter fouling of the anion exchange membranes to the extent that a membrane life of at least five years is routinely attained. It also appears that the old electrode problems associated with the ED have also been resolved. Further, it is also of interest to note that during the past thirteen years ion exchange resin technology has been improved to the extent that one can now effectively remove organic matter from surface water supplies without being seriously fouled. In fact, we now look at ion exchange technology as a means of removing organic matter.

It is quite reasonable to conclude that the EDR process could be competitive with RO as a "roughing" demineralizer, particularly for high TDS waters, prior to the ion exchange resin system. It is difficult, of course, to set forth firm limits of TDS which point to where each technology is *the* optimum technique. Much depends, of course, upon such factors as water composition, desired treated water quality, local availability and cost of chemicals, flow rate, power costs, etc. Mr. Katz may wish to discuss these items more fully.

It has been argued that one of the major advantages of RO as a "roughing demineralizer" is that, since the treated water passes through the membrane, colloidal matter is removed. In essence, it functions as an ultrafilter. However, by functioning as an ultrafiler, the RO membranes lose flux and their useful life is decreased. Using RO as an ultrafiler is not consistent with the silting index requirements for RO systems. The fact that ED does not have UF capabilities is not a disadvantage. It is best that the removal of colloidal matter be left to the primary clarification process or to post-demineralization with ultrafiltration.

The subject of electrodialysis further suggests employing ion exchange membranes electrochemically for producing the high purity caustic (NaOH) required by those employing ion exchange demineralizers. With the concern over mercury cells, the availability of caustic low in chlorides and chlorates may become a problem for many industries. It would appear that one could employ these electrolytic ion exchange membrane cells for producing high purity caustic at the site of the demineralizers. Perhaps Mr. Katz would like to comment on this matter.

ELECTRODIALYSIS REVERSAL FOR RELIABILITY IN WATER TREATMENT

Ionics, "The Water Company", manufactures and supplies a comprehensive line of water and wastewater treatment systems and instruments featuring unique technology developed in the Company's laboratories.

Ionics began in the water business with the invention of the ion transfer membrane in 1943 which resulted in the development of the classical ED (electrodialysis) process. In 1954, the ED process was introduced commercially to demineralize brackish waters in Saudi Arabia.

The New EDR (electrodialysis reversal) process was developed in the early 1970's to solve operating and maintenance difficulties encountered when injecting acids and chemicals into the system to control scaling. The elimination of chemical feeds and low-cost automatic operation earned rapid acceptance for the EDR process.

Today, hundreds of EDR systems, the largest with a capacity of 24,000 cubic meters per day (6 million gallons), demineralize water for industrial and municipal applications in over 25 countries around the world.

IONICS' AQUAMITE® EDR UNITS

The AQUAMITE units are packaged plants for Water Demineralization employing the proven process of electrodialysis reversal (EDR) to provide up to 4,000 cubic meters per day of fresh water from brackish water, or very pure industrial process water from normal water supplies. The AQUAMITE plant is tailored to each individual application while maximizing standard design components.

IONICS

IONICS, INCORPORATED

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Head Office
IONICS, INCORPORATED
65 Grove Street, Watertown, Massachusetts 02172
Telephone: (617) 926-2500 Telex: 922473

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INTERNATIONAL, INC.

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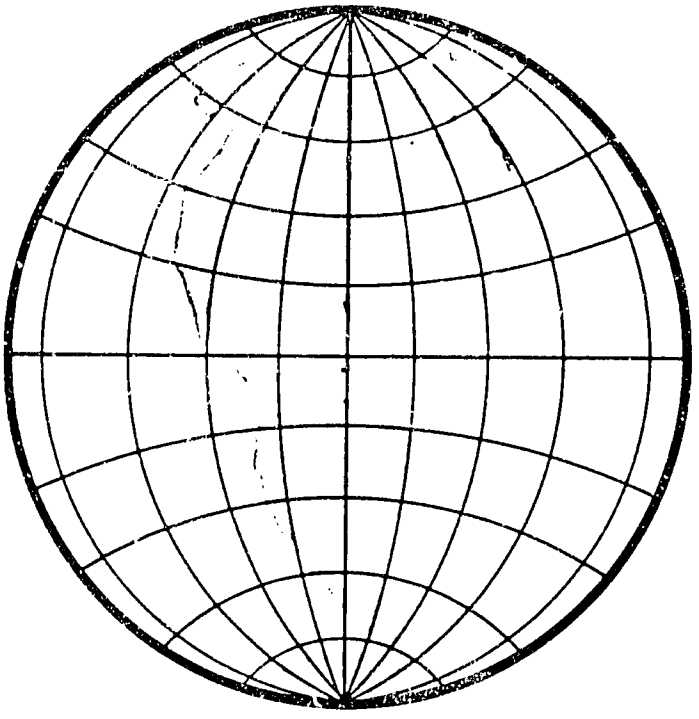
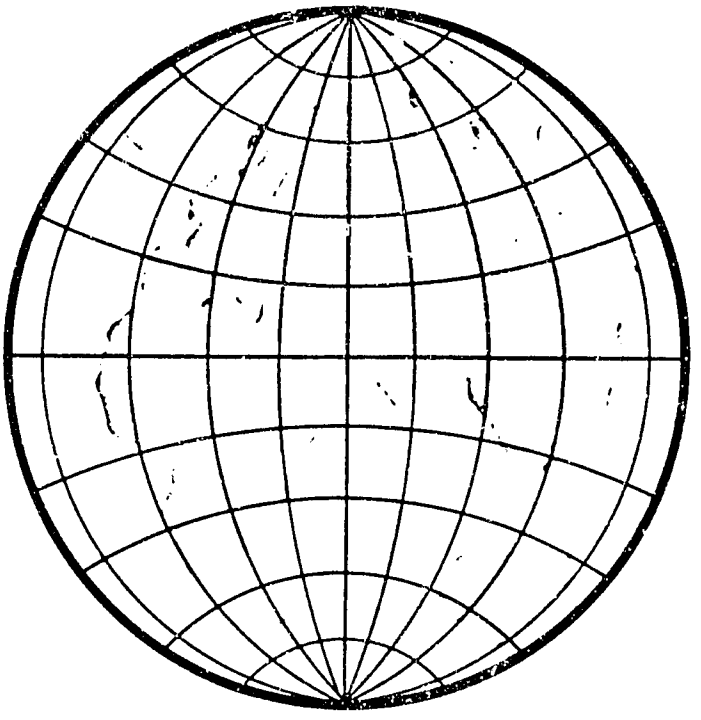
AQUATRON IS INTERNATIONAL IN SCOPE





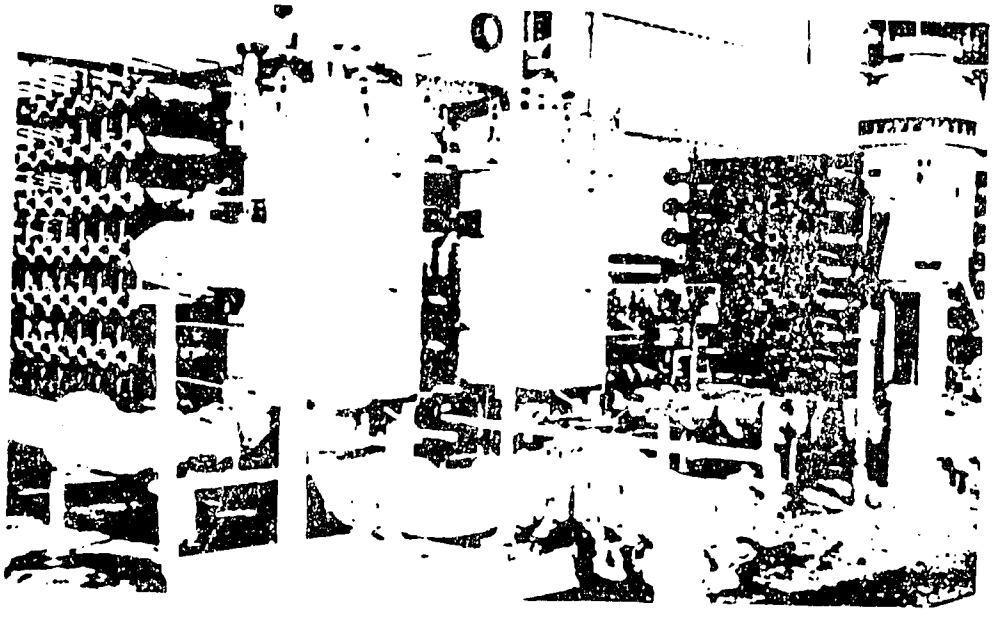
AQUATRON PRODUCTS are sold in the U.S.A. and many countries throughout the world

TO USERS SUCH AS:

★ Major oil companies, offshore and overseas ★ Hotels, motels, and condominiums ★ Hospitals and laboratories ★ Sea going vessels ★ Industrial sites ★ Sea side communities ★ Power generating plants (nuclear and fossil) ★ Chemical refineries ★ Paper mills

If you are thinking of *reverse osmosis* large or small, think *Aquatron International, Inc.*

We make *reverse osmosis* systems, from small eight gallons per day home and laboratory units



...to over 1,000,000 gallons per day packaged *reverse osmosis* systems

simple, low cost systems for water purification

WHAT IT DOES

AQUATRON - REVERSE OSMOSIS equipment simply and inexpensively purifies salty and bacterially contaminated water. By removing up to 99% of the dissolved minerals and virtually 100% of the bacteria, these systems provide drinking water from brackish or sea water sources.

HOW IT'S DONE

Source water, after pre-treatment, is pumped through a semi-permeable membrane material. This material permits the pure water to pass while rejecting the majority of the impurities; the rejected contaminants are continuously flushed from the membrane to drain.

What is *reverse osmosis?*

Nature has provided man with an abundance of water with over 70% of the earth's surface being covered with water. Unfortunately, only a small portion of it is suitable for human consumption. Of this portion, much of it contains various dissolved minerals (dissolved solids) and suspended solids. In addition to these natural solids, man has polluted his water with chemical and industrial wastes. These solids and chemicals, in sufficient concentrations, can render a water supply unacceptable for commercial application and unfit for human consumption.

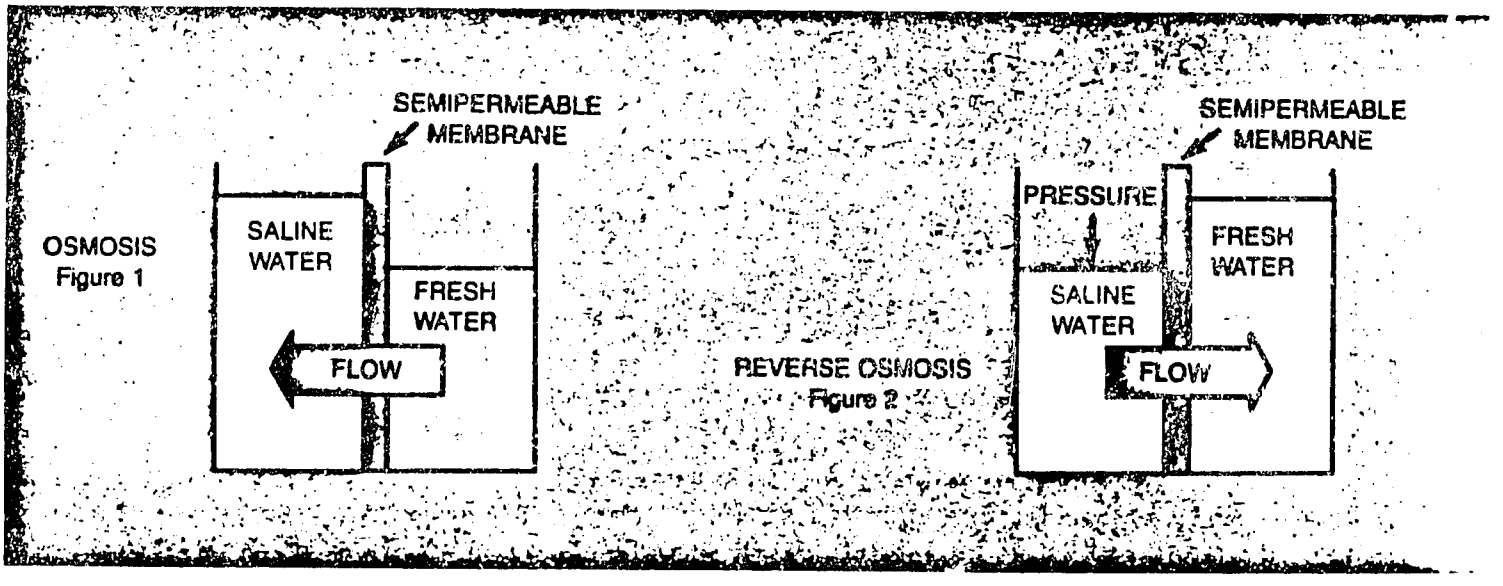
Working with a process known as reverse osmosis, scientists have been able to develop an osmotic membrane which will remove the dissolved solids from water. AQUATRON INT., INC. employs such an osmotic membrane and utilizes the process of reverse osmosis in their R.O. SYSTEMS. In order to understand the operation of the R.O. SYSTEM, it will be necessary to understand the process of osmosis and reverse osmosis. Osmosis is a phenomenon found in nature and is the process by which plant life absorbs minerals and nutrients from the soil. In figure 1, we have an example of osmosis.

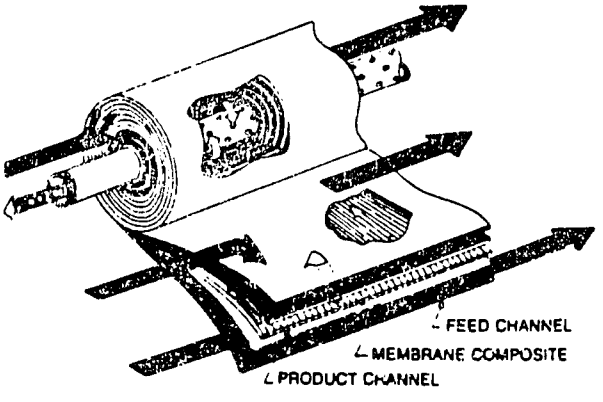
A container is divided by a membrane. On one side of the membrane is a highly concentrated solution of water and chemical salts. In the drawing we call this solution "saline water".

On the other side of the membrane, we introduce a high quality water, or water which contains little or no chemical salts. In the drawing this solution is referred to as "fresh water".

If we allow the container to remain in this condition for a period of time, sampling and analyzing the water in both halves would reveal that the fresh water is passing through the membrane and diluting the saline water. This is nature's way of correcting the imbalance between the two solutions. Scientists refer to this process as "osmosis". (Figure 1.)

It is also possible for the process of osmosis to be reversed. Scientists have found that they can create an imbalance in the other direction by applying pressure to the saline side of the container. The pressure creates an artificial imbalance and water will flow in the other direction in an attempt to reach an equilibrium. Figure 2 illustrates the reverse osmosis process. Note that the membrane allows only fresh water to pass through it in this direction.

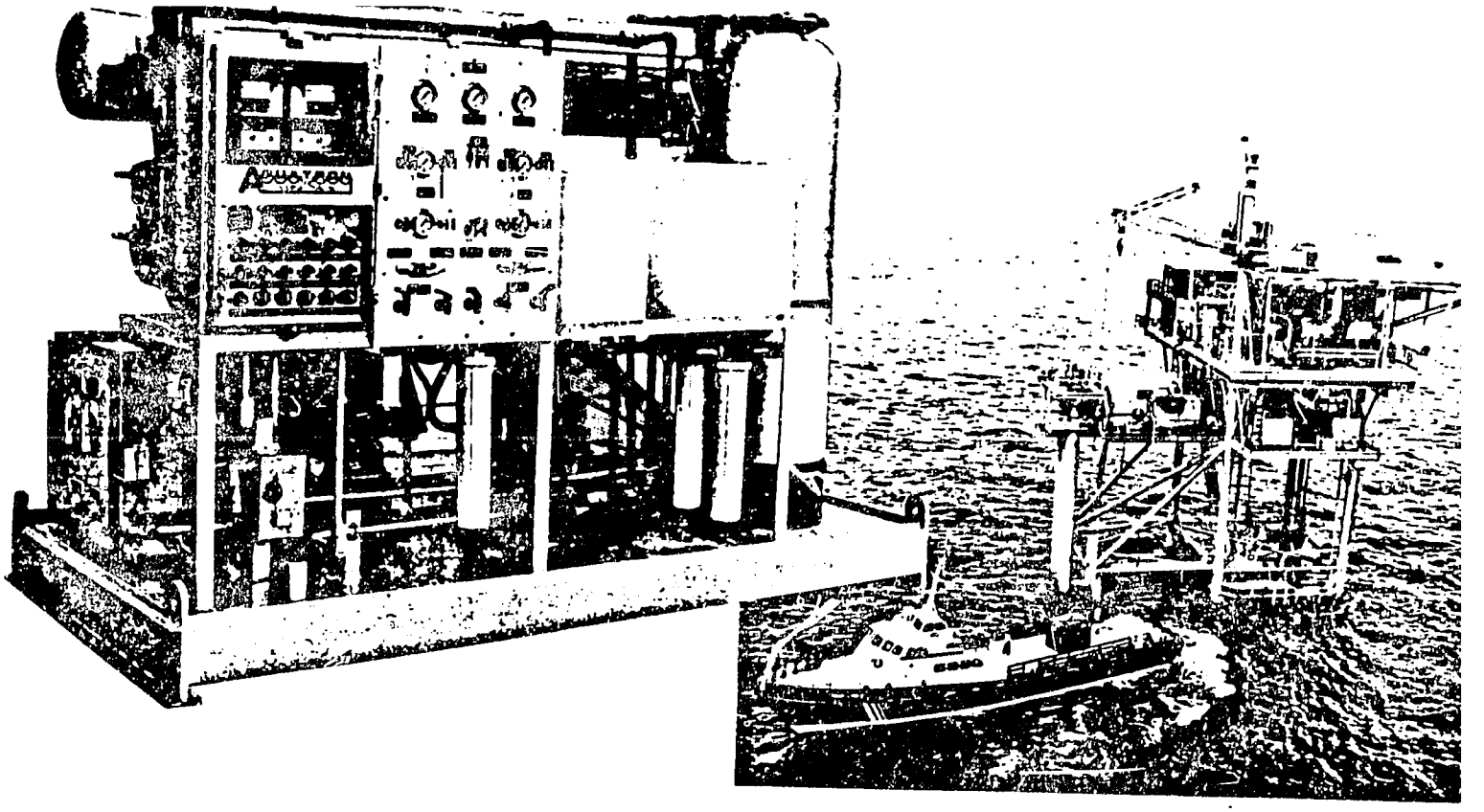




DESIGN FEATURES

AQUATRON INTL., INC. designs and manufactures systems employing various types of membranes. Selection is determined by the specific application and an analysis of the water. Water salinity, temperature and chemical composition are considered to assure an optimum membrane/application fit.

A spirally-wrapped sandwich of two membrane sheets is glued along a common edge and separated by porous backing materials. Pressurized feedwater passes longitudinally through the spiral package along a mesh separating the sandwiched layers. Permeate travels spirally through the material into a central perforating tube.



AQUATRON INTERNATIONAL, INC.

has serviced the offshore industry since 1975 by converting seawater to drinking water by *reverse osmosis.*

DESIGN FEATURES

Operation

Produces potable water from seawater, utilizing single-pass Reverse Osmosis technology.

Single control switch for instant start-up/stop of entire system.

Operation and maintenance are relatively simple - requiring daily check and routine maintenance.

Centralized instrument and control panel. All important operating parameters can be monitored and controlled from this panel.

Automatic shut-down when major fault occurs, with annunciation and visual display of cause.

Single chemical addition for control of scale. No acid addition is required.

No thermal or high salinity brine disposal problems. System capacity can be increased easily in the field. Multiple units can be interconnected to give larger capacities.

Installation

All standard systems are supplied on welded steel skids. These skids are sandblasted and epoxy-painted to a marine specification. Skids are easily moved by forklift.

Installation requires only skid placement and connection of electrical and water lines.

All systems are factory-operated in an eight-hour test run to insure reliable performance of all components.

Corrosion Resistance

All high pressure manifolding, valves, tubing and fittings are constructed of 316 stainless steel. High velocities are maintained to avoid pitting and crevice corrosion.

Aluminum bronze is used in the fluid end of the high pressure pump. This alloy gives excellent service in seawater application.

All wetted surfaces of the system are automatically flushed with fresh water upon shut-down.

All filtration equipment and membrane pressure vessels are constructed from Fiberglass Reinforced Plastic which is impervious to seawater corrosion.

All low pressure piping, valves and fittings are constructed from Sch. 80 PVC.

Stainless steel clamps and bolts are used throughout.

Maintenance

Designed-in accessibility of all components for ease of maintenance.

Easy-to-use system for cleaning the membranes.

Unattended operation - requires only daily check and log-taking.

Operating manuals contain easy to follow maintenance program and trouble-shooting chart.

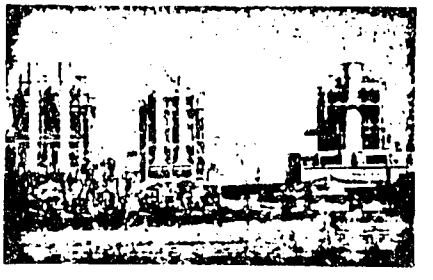
Chemical and power generating industry has called upon *Aquatron International, Inc.* to provide pure water by *reverse osmosis.*

Louisiana Power and Light Company has installed an Aquatron R.O. system ahead of their existing Demineralization units at their Taft, Louisiana generating plant.

The results have been better than expected.

Before installation of the R.O. system, the D.I. units had to be regenerated every 50,000 gallons of feedwater throughput.

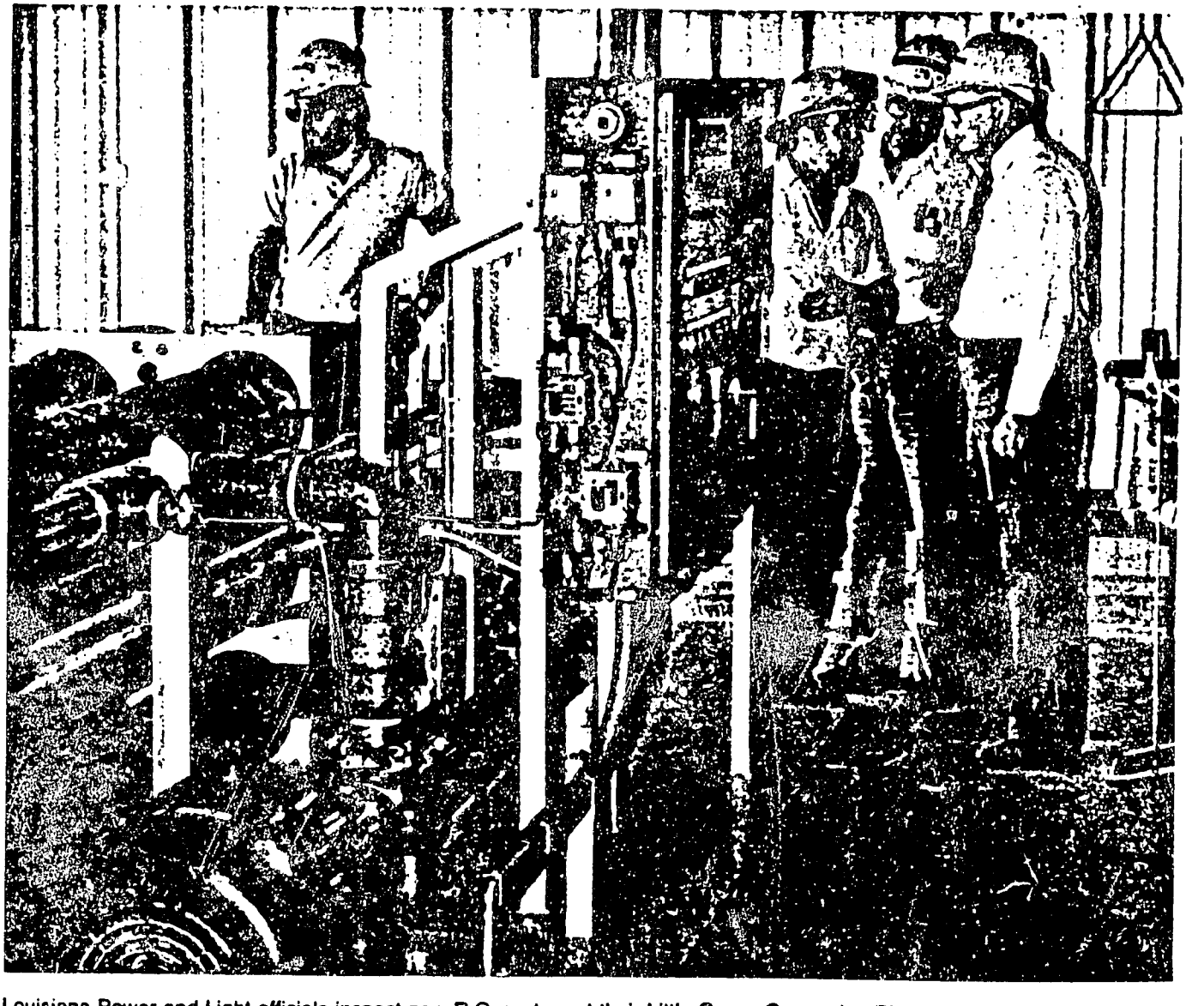
Not only was regeneration of the D.I. units costly and time consuming, but disposal of the caustic soda and sulfuric acid used in regeneration creates a severe environmental disposal problem.



Louisiana Power and Light's Little Gypsy Generating Plant.

After installation of the Aquatron R.O. system ahead of the D.I. units, regeneration has been extended from 50,000 gallons to over 2,000,000 gallons.

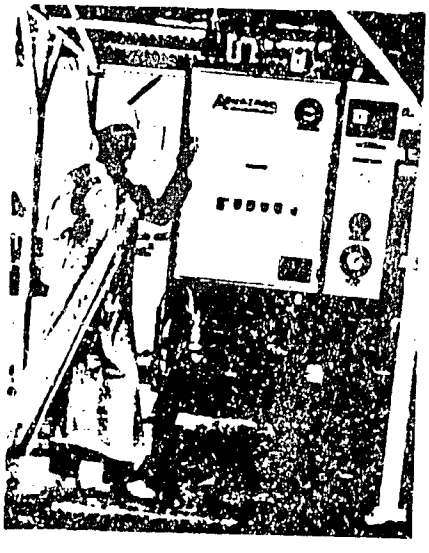
Needless to say LP&L is very pleased.

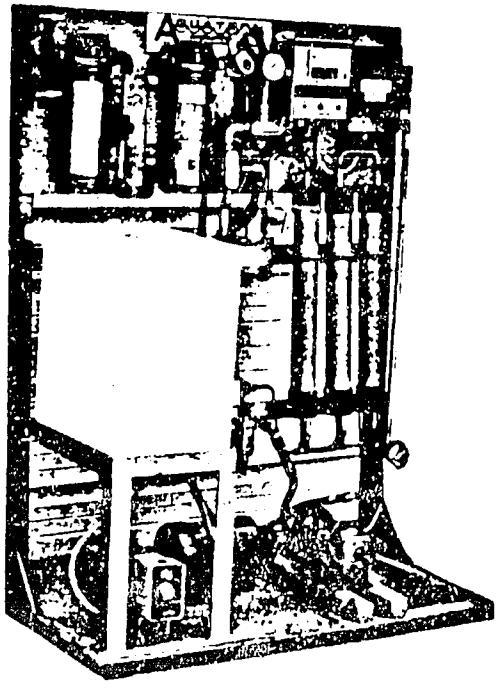


Louisiana Power and Light officials inspect new R.O. system at their Little Gypsy Generating Plant.

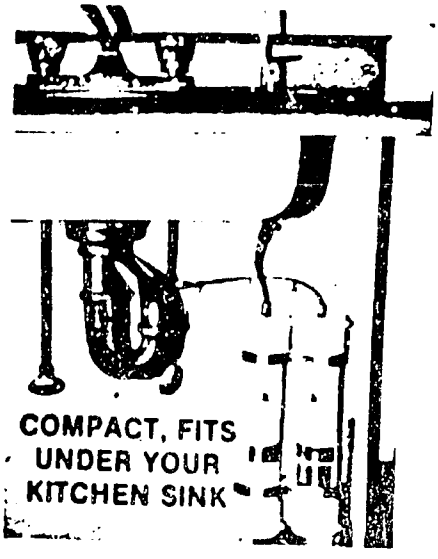
AQUATRON INTERNATIONAL, INC. manufactures wate for practicall

Brackish water systems capable of producing 120,000 gallons per day of potable water



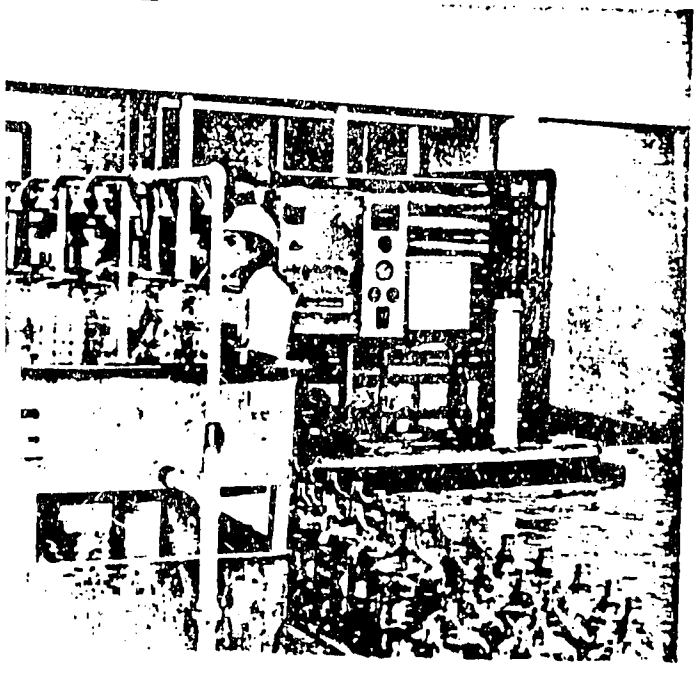


Small sea water R.O. SYSTEMS for boats and sea side homes

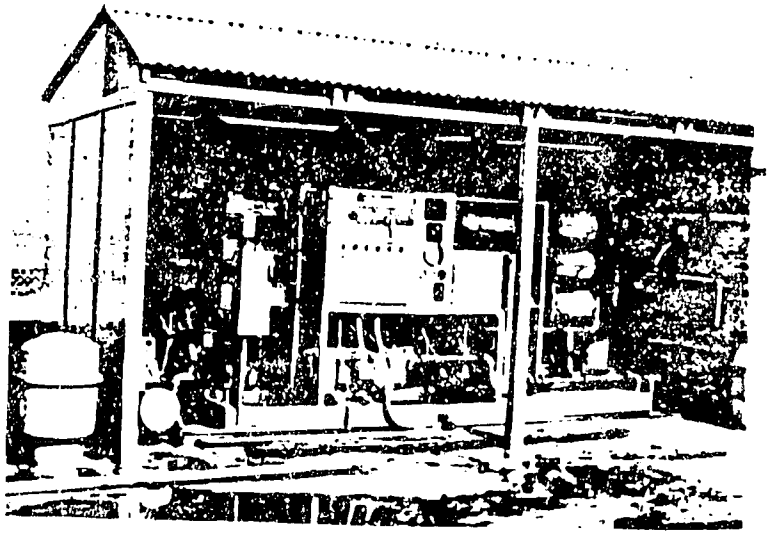


Under the sink water purifiers for home and businesses. Converts bad-tasting tap water into safer, delicious tasting bottled quality water. (U.S. Gov't. tested and registered.)

Bottled water plants, such as this system located in Ecuador, produces 20,000 gallons per day of ultra pure drinking water



65-K GPD brackish water reverse osmosis located in Saudi Arabia



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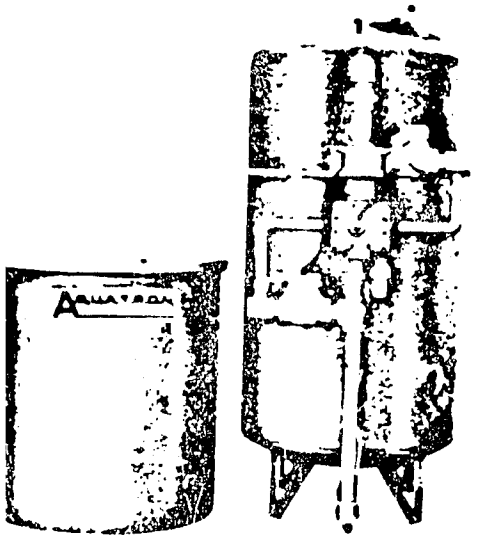
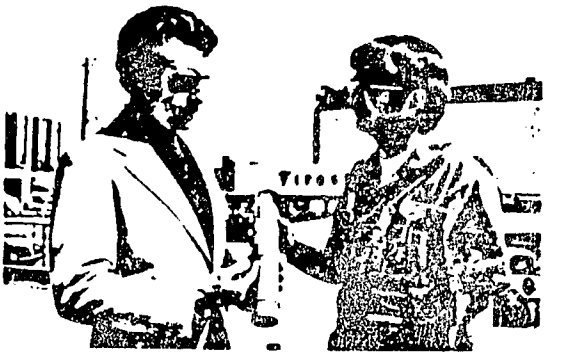
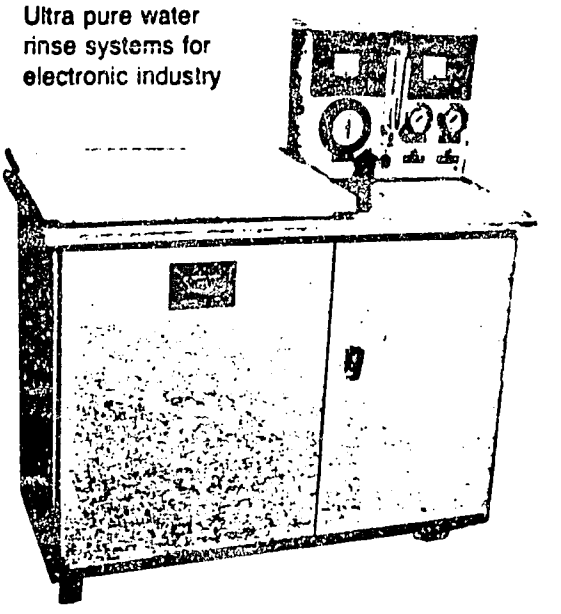


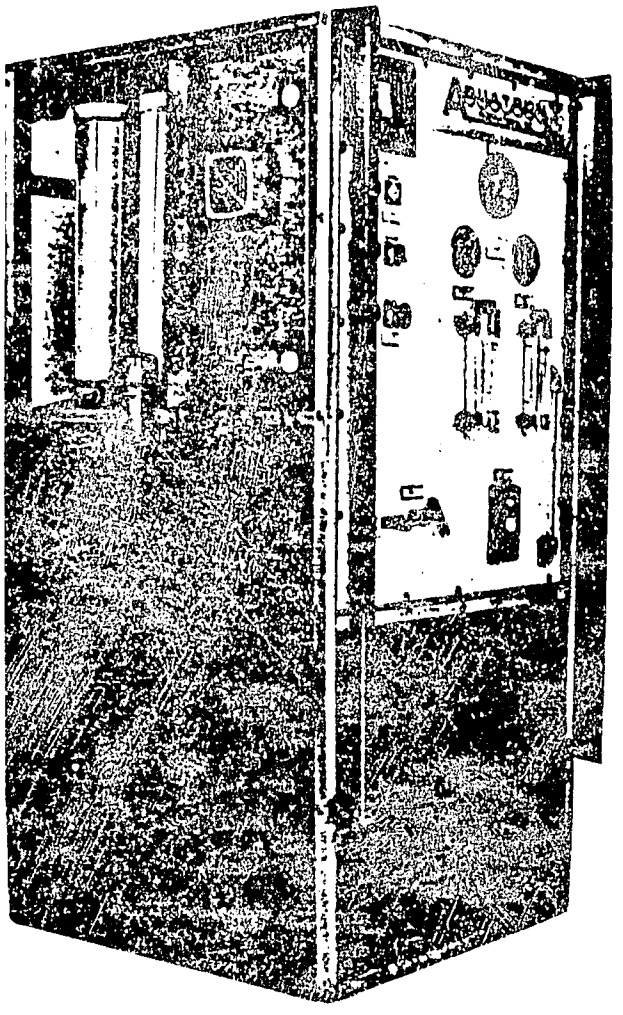


Hand held water purification units for travelers or emergency use

mmercial and industrial filters and water softeners

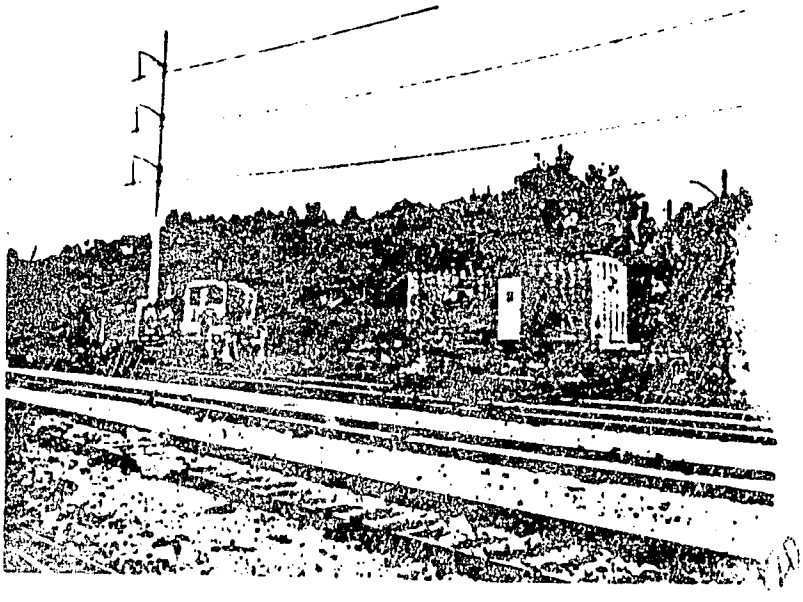
Ultra pure water rinse systems for electronic industry





Compact R.O. SYSTEMS for hospitals and laboratories

Self-contained water purification systems of various sizes

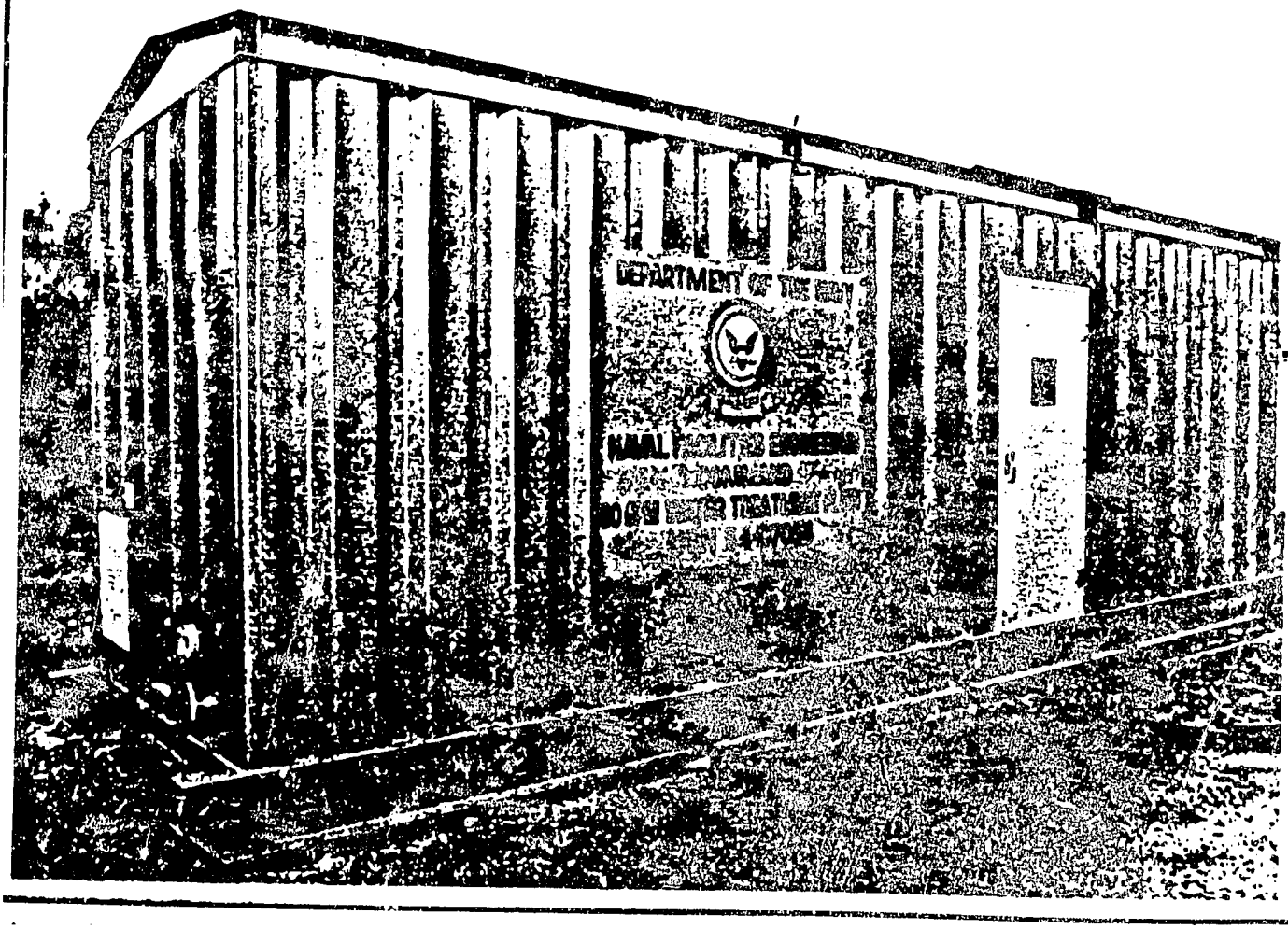


AQUATRON INTERNATIONAL, INC. technology is helping U.S. Navy...

Aquatron International, Inc. is providing the U.S. Navy with sophisticated two pass R.O. SYSTEMS capable of producing 90,000 gallons per day of ultra pure water.

These systems utilize the most advanced technology and engineering techniques in the industry today.

These systems will be deployed at naval support stations located around the world to provide ultra pure water for such uses on nuclear carriers and submarines.



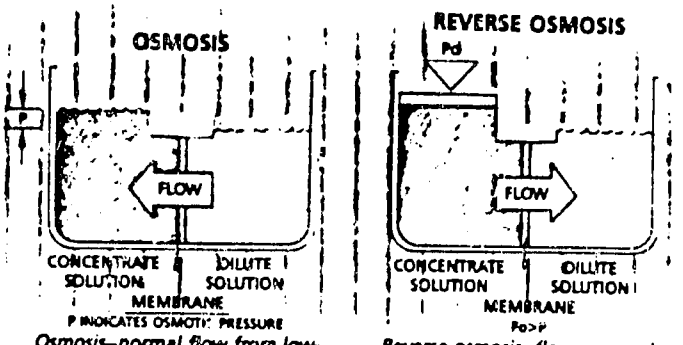
SweetWater®

DESIGNED REVERSE OSMOSIS WATER PRODUCTION SYSTEMS

The Osmotic Process

When freshwater and saltwater are allowed to stand side by side, separated only by a semi-permeable membrane, the natural tendency is for the freshwater to flow through the membrane into the saltwater. In nature this equalization is called osmosis.

To reverse this natural tendency, pressure can be applied to the saltier side which forces freshwater through the membrane out of the concentrated saltwater. This process is called REVERSE OSMOSIS (RO) and is the basic reason why SweetWater is able to make good tasting drinkable water from the sea.



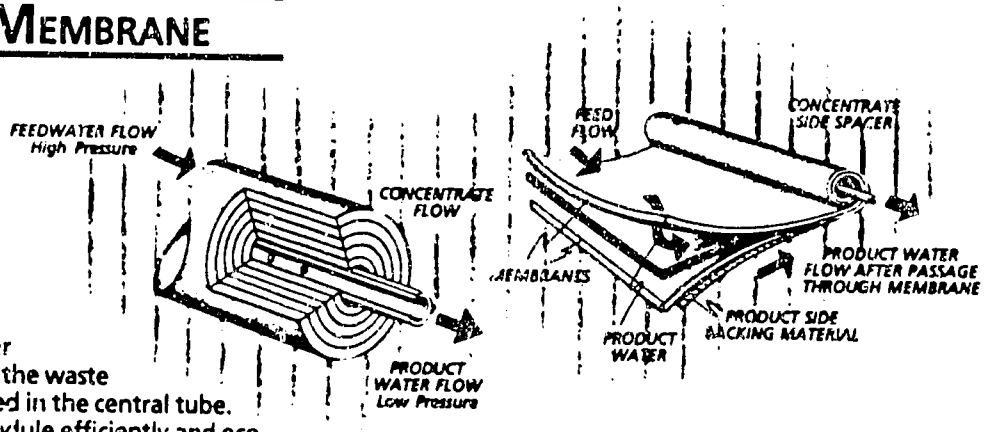
Osmosis–normal flow from low-concentration solution to high-concentration solution.

Reverse osmosis–flow reversed by application of pressure (Po) to high-concentration solution.

The SweetWater Membrane

The SweetWater module uses a spiral wound design as illustrated to the right. In this type of RO module, the pressurized sea water is constantly flowing past the many membrane surfaces. It is helpful to visualize the module as a unique filter where fresh water passes through the filter (spiral wound membranes), keeping the salts behind in the unfiltered portion of water which are continuously discharged with the waste water. The fresh product water is collected in the central tube.

The SweetWater spiral wound module efficiently and economically reduces high concentration of dissolved minerals and salts.



Sample RO Test Results

The chart shows the content of seawater before and after the RO process.

Comparison of Seawater–Before and After

ELEMENTS	RESULTS BEFORE	RESULTS AFTER	ELEMENTS	RESULTS BEFORE	RESULTS AFTER
TDS at 18°C (mg/l)	36,073	250	Conductivity (michromhos)	45,000	<550
Chloride (mg/l)	17,600	183	pH (units)	7.7	7.4
Sodium (mg/l)	11,000	105	Iron (mg/l)	0.3	<0.1
Calcium (mg/l)	315	0.8	Manganese (mg/l)	<0.1	<0.1
Magnesium (mg/l)	1,300	2.6	Strontium (mg/l)	13.8	0.4
Potassium (mg/l)	418	6.4	Nitrate (mg/l)	<2.0	<2.0
Sulfate (mg/l)	2,346	2.3	Silicon as SiO_2 (mg/l)	10.7	<5.0
Bicarbonate (mg/l)	63	4.9	Turbidity (FTU)	0.29	0.13
Carbonate (mg/l)	None	None	Boron (mg/l)	4.0	0.4
Hydroxide (mg/l)	None	None	Ammonia (mg/l)	None	None
Hardness as $CaCO_3$ (mg/l)	6,140	28	Bromide (mg/l)	85	0.85
P-alkalinity as $CaCO_3$ (mg/l)	0	0	Fluoride (mg/l)	0.8	<0.1
T-alkalinity as $CaCO_3$ (mg/l)	104	8	Total Sulfides (mg/l)	<0.1	<0.1

Note: Mg/l is the same as ppm
Salinities above 45,000 mg/l require special configurations

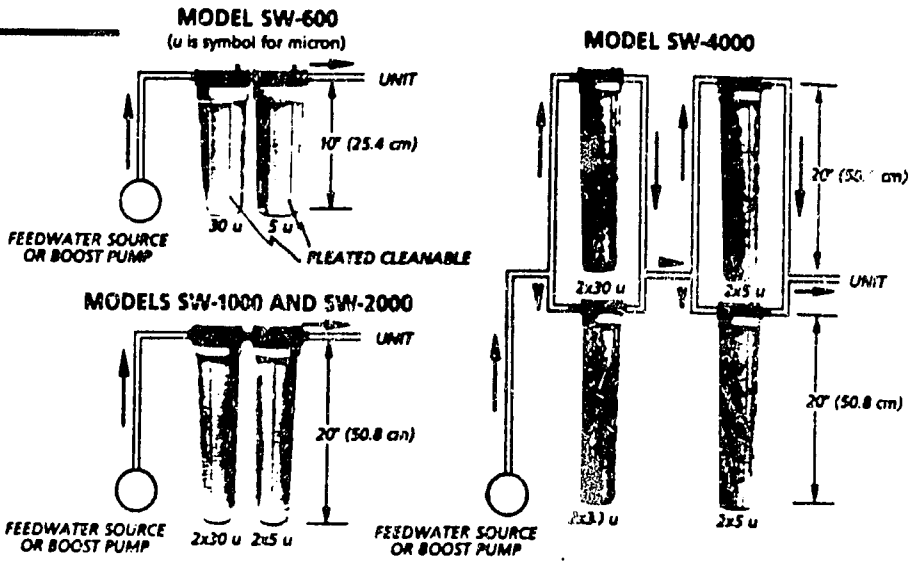
Operation And Maintenance

SweetWater systems require no special knowledge whatsoever to start and operate. Thanks to their simple, yet advanced design, routine maintenance is extremely simple.

Economy is one of SweetWater's strongest points. 1000 gallons (3785 liters) of water, produced by a SweetWater unit would cost U.S. $4.30. In comparison, the same amount of water produced by distillation would cost U.S. $6.65. (Documentation available upon request.)

Standard Packages

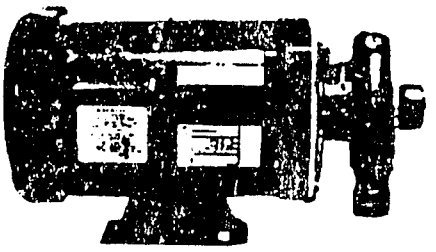
For any reverse osmosis system to function to manufacturer's design standards, the heart of the system (the membranes) must pass water which has been cleaned (filtered) to pre-set standards. All SweetWater systems are equipped with pre-filtration systems that are designed for operating areas where the feedwater contains only minor amounts of contaminants. This presumes the unit will be operating with salt or brackish water where there is low solid material suspended in the feedwater plus *no* oil contamination and *no* chlorine. Shown are the Standard Filtration arrangements shipped with SweetWater RO Systems.



Optional Packages

BOOST PUMPS

Boost pumps are available from SweetWater to match the flow requirements of your unit. They may also be purchased locally. When adding additional pre-filtration one must take into account the additional pump requirements caused by the pressure drop across the standard filters and any additional pre-filtration that is added. Consult SweetWater for your unit's specific pump requirements.

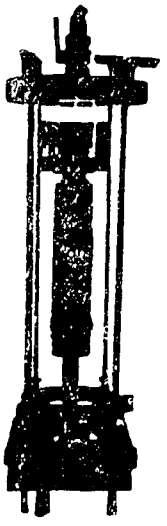


Available in various sizes matched to flow rate of unit. Consult SweetWater for size required. Only centrifugal pumps may be used as feedwater pumps.

Pre-Treatment Options

OIL PRE-FILTRATION

Oil, if present in feedwater, will coat the membrane and cause a decrease in system effectiveness. The system as shipped will not effectively prevent oil from entering the system. If the SweetWater system is to be used in harbors, or other areas known to contain oil in the feedwater, an oil filtration package must be added.



Available in various sizes matched to flow rate of unit. Consult SweetWater for size required.

BACKWASH MEDIA FILTER*

SweetWater's RO water makers will from time to time, be required to operate in adverse conditions which will require other than standard pre-filtration. High suspended solids in many areas will force the use of additional filtration to keep the system in best operating condition. When operating in a high solids area such as river basins where there is high concentration of sand and silt, or in tropical waters where high algae content may be present, a backwash media filter unit is required. The operation of this filter unit is similar to a water softener. To keep it operating efficiently, it must be backflushed periodically. Installation of a backwash media filter option is in the line between the feedwater pump and the filtration package supplied with the SweetWater system.

Available in various size matched to flow rate of unit. Consult SweetWat for size required.

*If the optional backwash media filter is used, the 30 micron filter becomes redundant and will not be supplied.

CHLORINE PRE-FILTERS

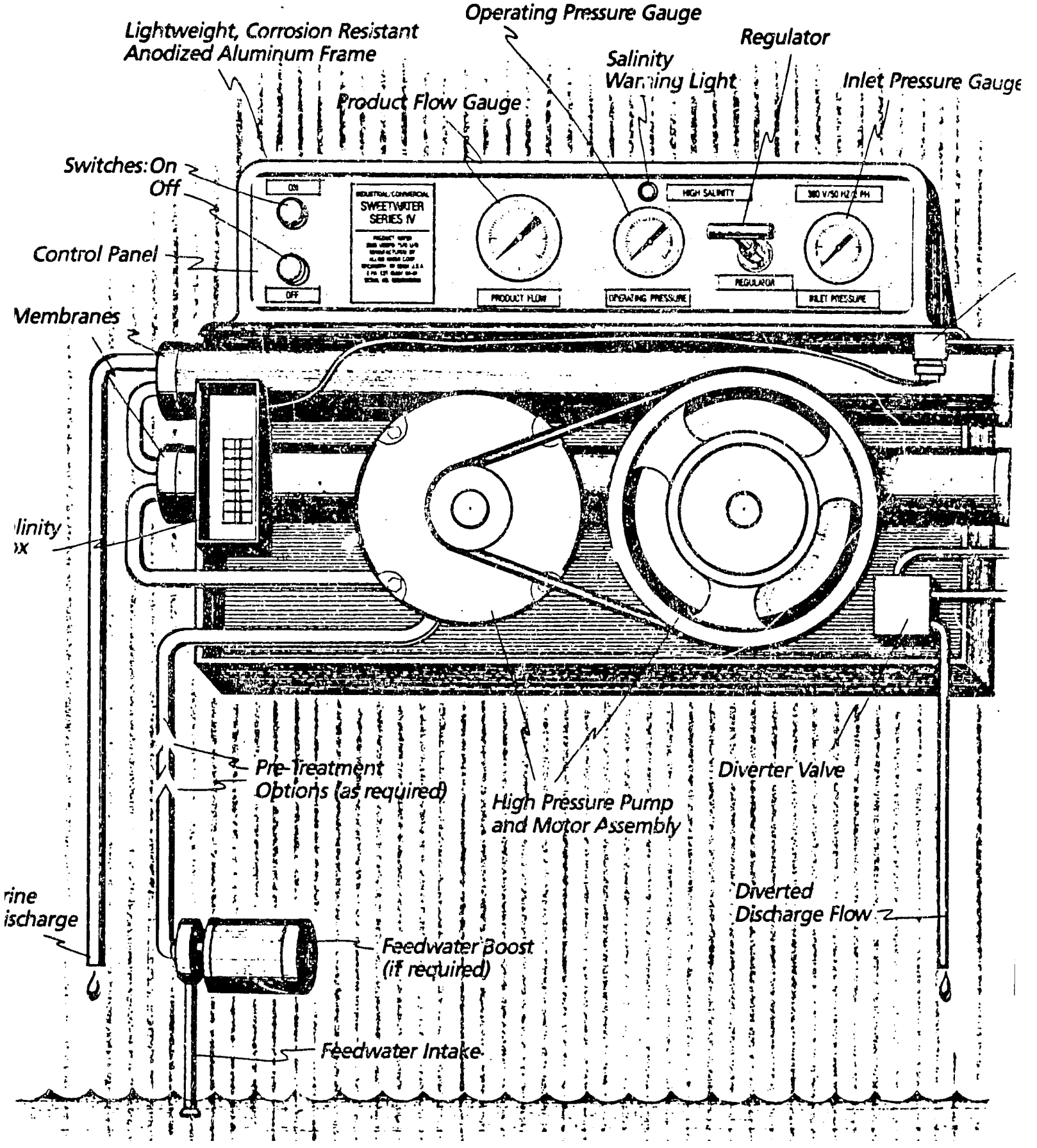
When operating a SweetWater unit where chlorine is present in the water, a chlorine filter must be used. Chlorine will permanently damage the membranes. Consult SweetWater if chlorine is present in the feedwater.

IRON (RUST) PRE-FILTER

Iron (rust) in the feedwater is detrimental to the membranes and to the operation of a reverse osmosis system. Therefore, any iron in the feedwater must be removed.

If it is impractical to use stainless steel, copper, Cu-Ni or plastics in the feedwater pumps or piping, or if a sea chest is used, an iron pre-filter or a Green Sand Filter must be used. SweetWater makes them available in various sizes to suit your specific need. Contact your local distributor or the factory for further information.

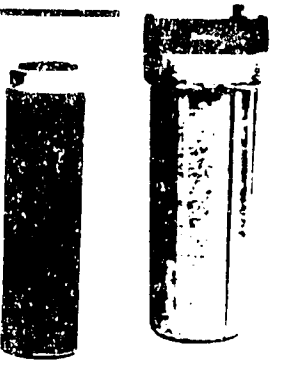
TYPICAL FLOW DIAGRAM



POST-TREATMENT OPTIONS

POST CARBON FILTER

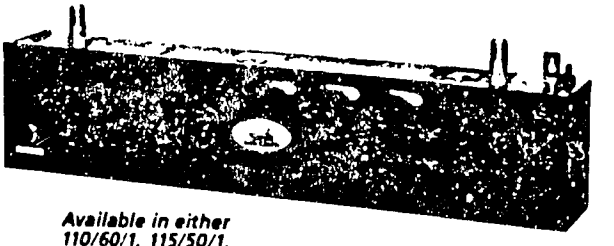
In extreme cases, water which has passed through a SweetWater system may still contain odor or taste from the original feedwater source. While this is a harmless condition, the use of a charcoal filter will help to eliminate this problem. A charcoal filter is placed in the product water line after the storage tank.



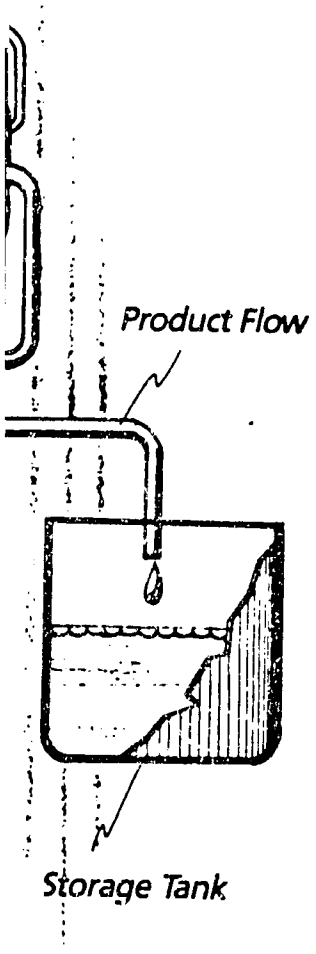
Available in various sizes matched to flow rate of unit. Consult SweetWater for size required.

ULTRAVIOLET UNIT

SweetWater RO systems produce safe, pure potable water, however, the water may be contaminated in the storage tank. To insure cleanliness an ultraviolet system may be added to the discharge line from the storage tank beyond the carbon filter. SweetWater offers one size capable of processing 3-10 gpm (11-38 lpm).

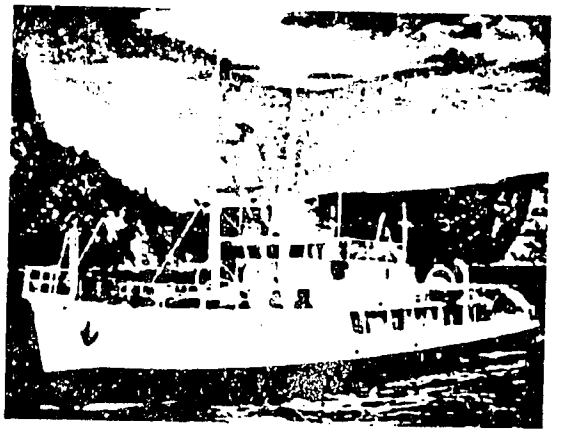


Available in either 110/60/1, 115/50/1, 220/50/1 or 230/60/1.



ON BOARD COUSTEAU'S R/V CALYPSO

SweetWater systems, standard or custom, deliver a continuous supply of pure, clean water from any ocean in the world. Starting and maintenance require no special knowledge whatsoever. Advice, answers and service are always available from SweetWater's dependable, worldwide sales/service network.

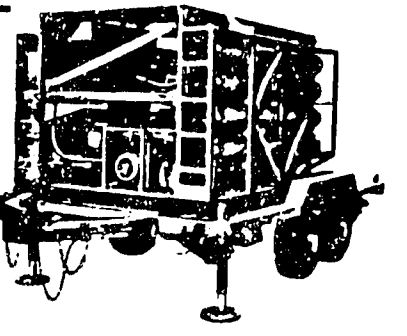


R/V Calypso
© Cousteau Society, Inc.

SWEETWATER MIL-SPEC SERIES

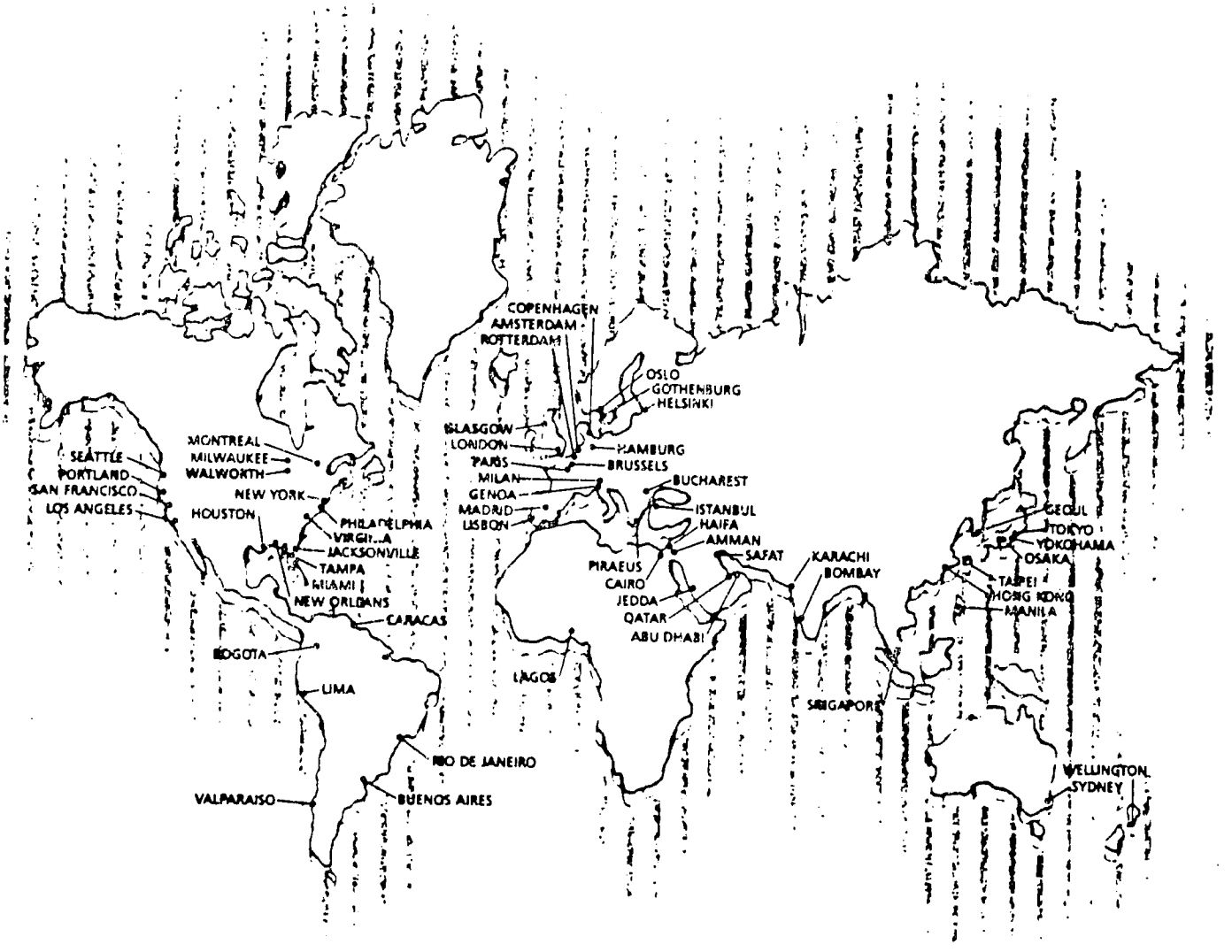
SweetWater's engineering expertise is available to the world's military markets with NBC (Nuclear, Biological, Chemical), Anti-Mag (Naval), heavy duty and lightweight, military-style, trailer-mount systems.

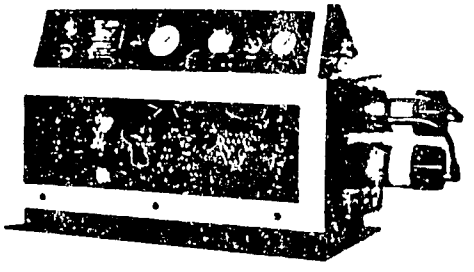
Built and certified to military specifications, they are field deployable, mobile, self contained, rugged, reliable and can withstand aerial drops. Call or write for additional free literature.



SweetWater. Superior RO systems that back you up every step of the way.

WORLDWIDE SALES AND SERVICE





SweetWater®

Manufactured by Allied Water Corp.

A subsidiary of MARLAND Environmental Systems, Inc.

P.O. Box 501, Great Falls, Virginia 22066 U.S.A.
Telephone: (703) 759-5244 • Telex: 287014 MARL UR

© MARLAND — 10M/1084

SweetWater Features

STANDARD

- Lightweight fiberglass enclosure (SW100–SW4000)
- Corrosion resistant, anodized aluminum frame
- Corrosion resistant gauges: low pressure gauge, operating pressure gauge and product flow gauge
- Energy efficient TEFC motors
- Pre-filter package
- Adjustable pressure regulator
- Low pressure and high pressure safety devices
- Water quality sensor (salinity monitor and diverter valve)
- Chemical injection package (Brackish Models)

OPTIONS

- Ultraviolet sterilizer with monitor
- Carbon pre-filter for chlorine removal
- Carbon post-filtration for taste and odor
- Feedwater boost pumps
- Additional pre-filtration packages for virtually all feedwater conditions
- Pre-filter package–custom designed
- SweetWater 4000 seawater unit is available in an Intrinsically Safe version
- Chemical injection package

Feedwater Flow Rates*

Models	Nominal
SW-600	3.0 gpm (11 lpm) @ 35 psi
SW-1000	7.0 gpm (26 lpm) @ 35 psi
SW-2000	10.0 gpm (38 lpm) @ 35 psi
SW-4000	20.0 gpm (76 lpm) @ 35 psi
SW-6500	28.0 gpm (106 lpm) @ 35 psi
SW-13500	56.0 gpm (212 lpm) @ 35 psi

*The flow rates indicated are rated prior to standard pre-filters.

Control Box Dimension*

SW600, SW1000, SW2000, SW4000:
14.5" L x 12.5" W x 7.6" H–8.5 lbs.
36.8 cm x 31.8 cm x 19.3 cm–3.9 kg.
SW6500, SW13500
(Integral – Built in)

*All control boxes are prewired to the units with 9' (2.7m) of cable.

Standard Capacities* (Seawater)

Model No.	Gallons per day	Liters per day	Tons per day
SW-600	600	2,271	2.27
SW-1000	1,000	3,785	3.79
SW-2000	2,000	7,570	7.57
SW-4000**	4,000	15,140	15.14
SW-6500	6,600	24,983	25.00
SW-13500	13,500	51,102	50.00

*Rated flow ± 15% capacities @ 25°C – 35,000 mg/l seawater. Larger capacities on request. Designed to order.
**SweetWater 4000 Seawater Unit is available in an Intrinsically Safe version, SWE-4000. Other capacities in this configuration available on request.

Standard Capacities* (Brackish Water)

Model No.	Gallons per day	Liters per day
SWB-600	600	2,271
SWB-1000	1,000	3,785
SWB-2000	3,640	13,777
SWB-4000	7,200	27,252
SWB-6500	11,000	41,635
SWB-13500	23,000	87,055

*Rated flow ± 15% capacities @ 25°C – 10,000 mg/l seawater. Larger capacities on request. Designed to order.

Dimensions And Weights*

SW600	51" L x 25" D x 23" H 130 cm x 63.5 cm x 58.4 cm	255 lbs. 116 kg
SW1000	51" L x 27" D x 23" H 130 cm x 69 cm x 58.4 cm	265 lbs. 120.5 kg
SW2000	53" L x 27" D x 23" H 135 cm x 69 cm x 58.4 cm	340 lbs. 154.5 kg
SW4000	59" L x 41" D x 24.5" H 150 cm x 104 cm x 62 cm	610 lbs. 277.3 kg
SW6500	90" L x 48" D x 66" H 228.6 cm x 121.9 cm x 167.6 cm	1500 lbs. 680.4 kg
SW13500	96" L x 60" D x 66" H 243.8 cm x 152.4 cm x 167.6 cm	2500 lbs. 1134 kg

*Add 10% for shipping weights.
Above are all dry weights.

Water Connections

Models	Feed Inlet	Product Outlet	Brine Outlet	Product to drain
SW-600	1" FNPT (2.54 cm)	¼" FNPT (.635 cm)	½" FNPT (1.27 cm)	¼" FNPT (.635 cm)
SW-1000	1" FNPT (2.54 cm)	¼" FNPT (.635 cm)	¾" FNPT (1.9 cm)	¼" FNPT (.635 cm)
SW-2000	1" FNPT (2.54 cm)	⅜" FNPT (.95 cm)	¾" FNPT (1.9 cm)	⅜" FNPT (.95 cm)
SW-4000	1½" FNPT (3.81 cm)	½" FNPT (1.27 cm)	1" FNPT (2.54 cm)	½" FNPT (1.27 cm)
SW-6500	2" FNPT (5.08 cm)	¾" FNPT (1.9 cm)	1½" FNPT (3.81 cm)	¾" FNPT (1.9 cm)
SW-13500	3" FNPT (7.62 cm)	1" FNPT (2.54 cm)	2" FNPT (5.08 cm)	1" FNPT (2.54 cm)

Above FNPT specifications will accommodate standard piping.

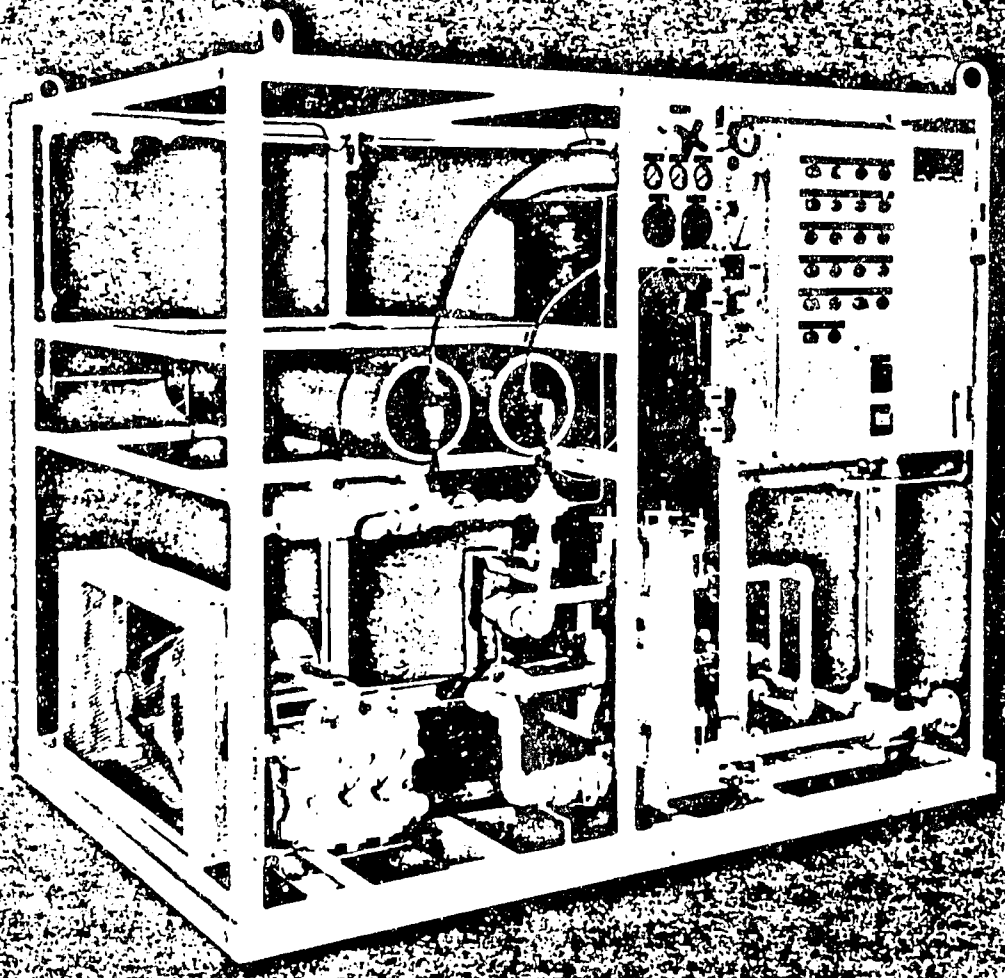
All specifications are subject to change without notice.

Culligan.

aqua-cleer®

SERIES SWL
SEAWATER CONVERSION SYSTEMS

FRESH WATER FROM SEAWATER



DESIGNED TO MEET EVERY APPLICATION

WATER TREATMENT WORLDWIDE™

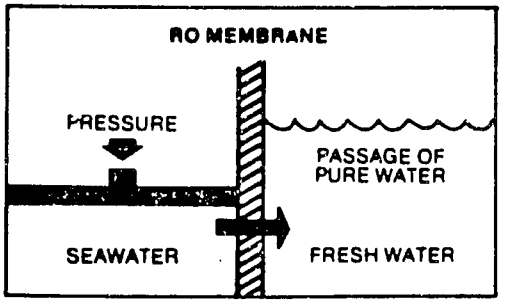
Culligan aqua-cleer® SERIES SWL SEAWATER CONVERSION BY REVERSE OSMOSIS

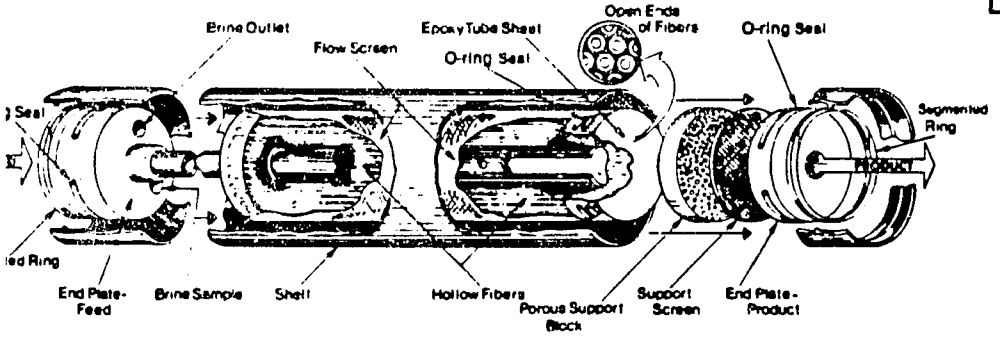
PRODUCT FEATURES

- Compact pre-engineered sizes from 1,600 to 72,000 gallons per day available. Units can be duplexed for larger capacities.
- Designed for simple operation and easy access for servicing.
- All controls and instrumentation conveniently located on front.
- Built-in failsafe features for system protection.
- Individual visual and audible alarms for ease of system monitoring.
- High efficiency positive displacement type pump.
- Optional energy recovery available.
- Complete with module maintenance equipment.
- Rugged construction. Heavy steel frame is blasted, primed and epoxy coated. Suitable for single point lift.

HOW REVERSE OSMOSIS WORKS

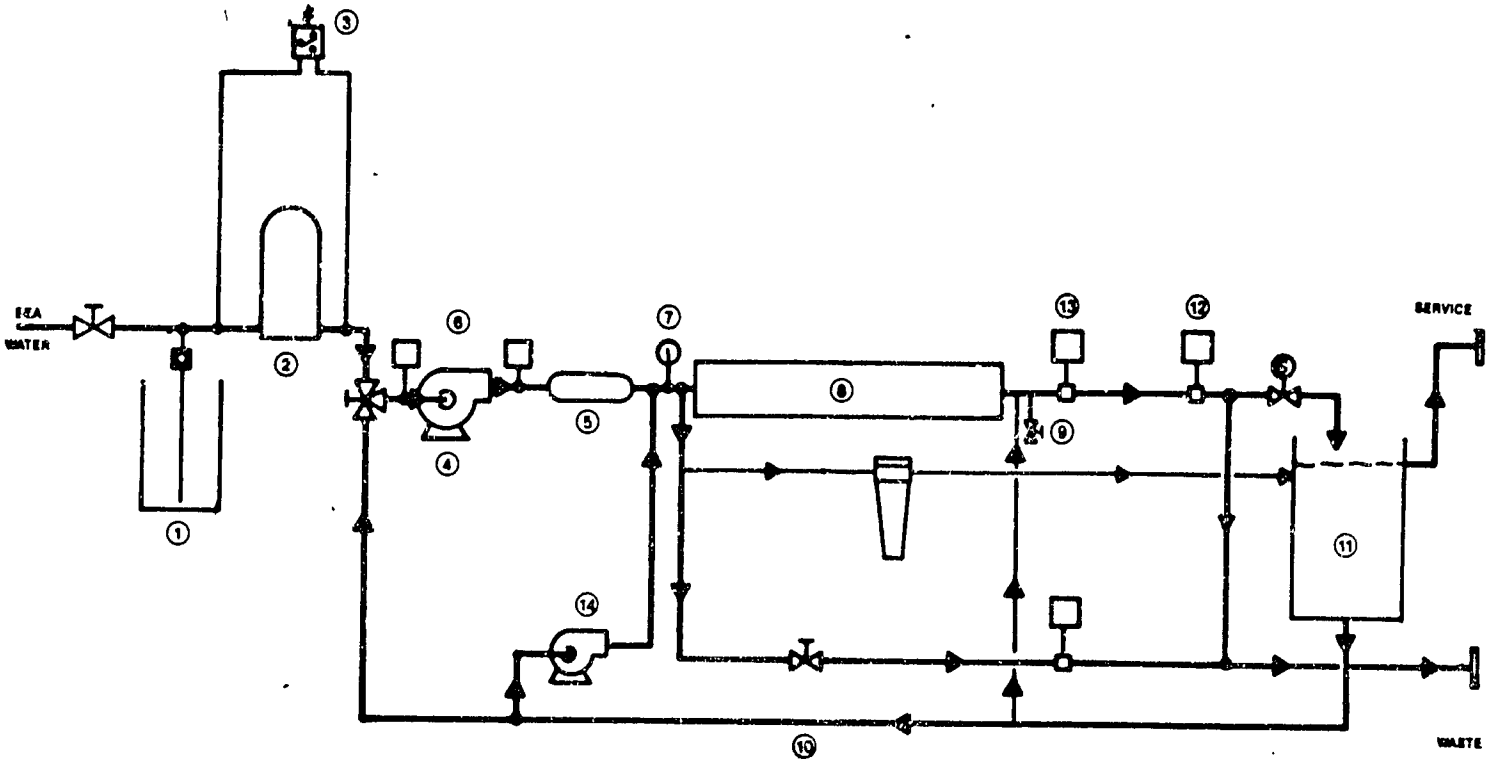
Reverse osmosis is the reverse of the osmosis process that occurs in plants and animals in nature. Pressure is used to force a flow of pure water through a semi-permeable membrane. Using a reverse osmosis system, pure water is forced from concentrated seawater to make fresh water, with the salts and other impurities being rejected to waste and over-board.





DuPont® hollow fiber modules are used in our system. The simplicity of design, operation and long life of this module is your assurance of high quality water with minimum operating difficulties.

SYSTEM OPERATION



1. Automatic pH control system.

2. Cartridge-type polishing filter. All-plastic housing with replaceable elements ensures particle removal.

3. Differential pressure switch senses when filters need changing and sends alarm.

4. High pressure pump boosts seawater to 800-1000 psi for efficient mineral removal.

5. Flow through pulse dampener provides smooth operation.

6. Pressure switches monitor pump suction and discharge. Both high or low pressure will cause system shutdown and activate alarms.

7. Panel mounted 316 SS liquid filled pressure gauges allow operator to easily monitor system operation.

8. DuPont B-10 hollow fiber modules reject 98.5% of all dissolved minerals.

9. Sample valves are provided on the product water side of each module. Permits checking state of individual modules.

10. Product water flush of wetted parts minimizes corrosion during system shut down.

11. Flush/Clean tank stores product water for system flush, module maintenance and to prevent module dehydration in case of power failure.

12. Water quality monitor and divert valve system. Monitor automatically diverts low quality water to waste. . . allows only high quality water to service.

13. Direct reading flow meters show product and waste flows at a glance.

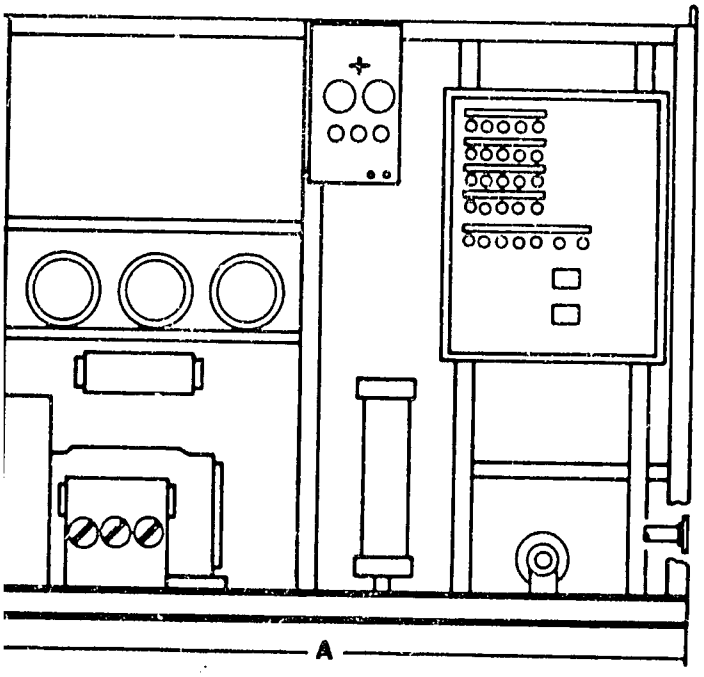
14. Module maintenance system allows simple periodic membrane treatment. Circulation of conditioning solution maintains high salt rejection capability.

Culligan® aqua-cleer® REVERSE OSMOSIS

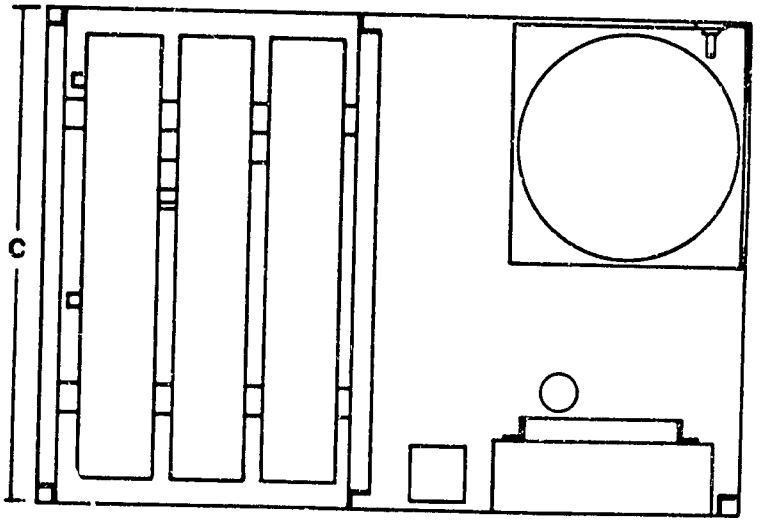
SYSTEM SPECIFICATIONS

MODEL		SWL SERIES														
		041	042	043	081	082	083	084	085	086	087	088	089	810	811	812
Nominal Design Capacity	GPD	1600	3200	4800	6000	12000	18000	24000	30000	36000	42000	48000	54000	60000	66000	72000
	m³/d	6.1	12.1	18.2	22.7	45.4	68.1	90.8	113.6	136.2	159.0	181.7	204.4	227.1	249.8	275.2
Operating Seawater Flow	GPM	8	15	22	13	24	36	48	60	72	84	96	108	120	132	144
	m³/h	1.8	3.4	5.0	3.0	5.5	8.2	11.0	13.6	16.4	19.1	21.8	24.5	27.3	30.0	32.7
No. of DuPont B-10 Modules		1-4"	2-4"	3-4"	1-8"	2-8"	3-8"	4-8"	5-8"	6-8"	7-8"	8-8"	9-8"	10-8"	11-8"	12-8"
Motor Horsepower		7.5	10	15	10	20	30	40	50	50	60	75	75	75	100	100
Average Power	KW	3.7	7.2	10.4	6.3	11.2	16.7	22	27	31	36	41	46	51	56	61
Length A	ft	4'-10"	→	→	6'-8"	→	→	8'-0"	→	→	→	→	→	→	→	→
	m	1.47			2.03			2.44								
Height B	ft	4'-7"	→	→	6'-0"	→	→	6'-8"	→	→	→	→	→	7'-6"	→	→
	m	1.4			1.8			2.03						2.35		
Depth C	ft	2'-9"	→	→	4'-6"	→	→	6'-0"	→	→	→	→	→	→	→	→
	m	.84			1.4			1.83								
Dry Weight	lb	1220	1300	1450	2450	2850	3100	5100	5470	6100	6650	7300	7950	8225	8900	10700
	kg	550	590	660	1110	1290	1410	2310	2475	2760	3010	3300	3600	3720	4030	4840

Note: Nominal rated capacity is based on standard seawater of 35000 PPM TDS at 77°F temperature. Capacity will vary with temperature and operating pressure.



FRONT VIEW



TOP VIEW

Culligan®

WORLDWIDE SERVICE CAPABILITY

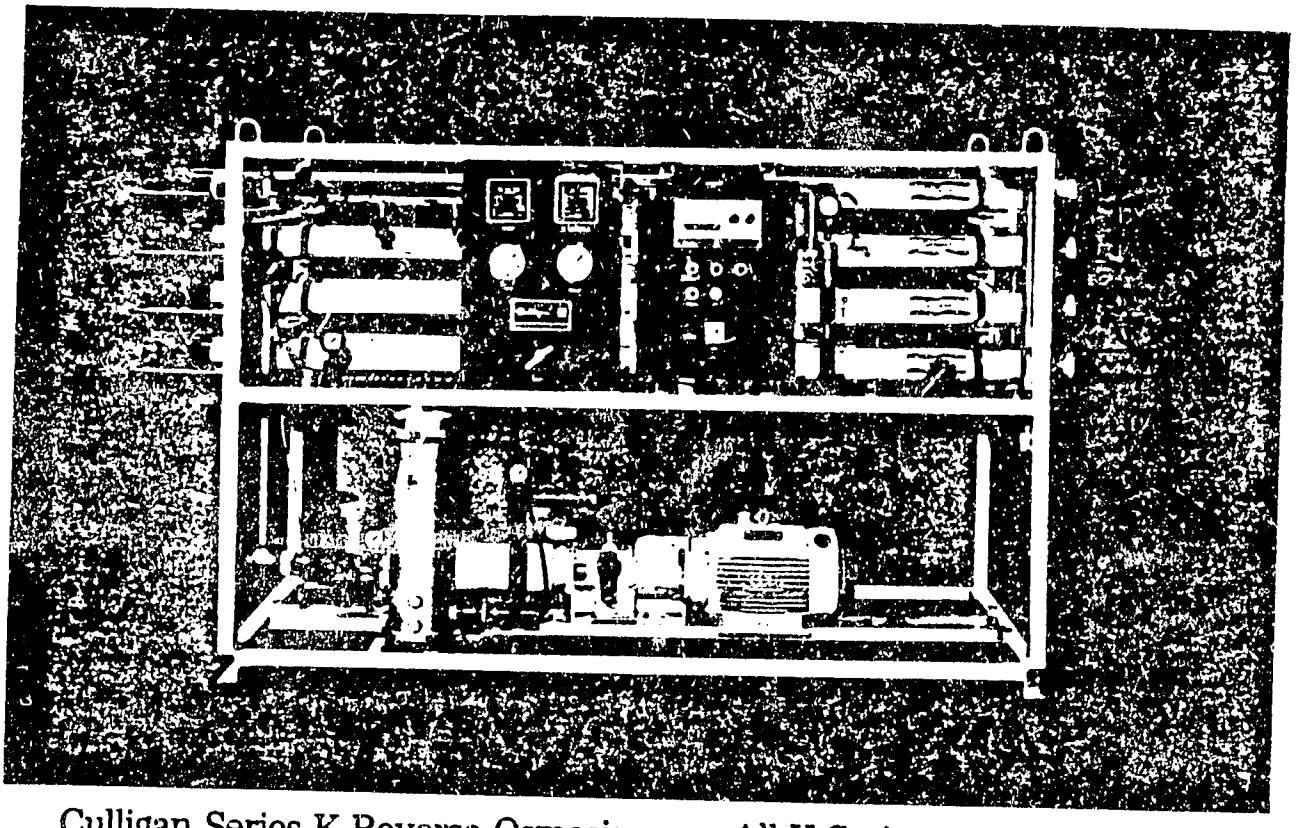
For the right answer to your water treatment problems, turn to the people who offer the efficient, dependable systems approach. Technical service is available worldwide. Call or telex Northbrook for dispatch of serviceman nearest your location.

Culligan USA
1 Culligan Parkway
Northbrook, IL 60062
Tel: 312-498-2000
Telex: 910-686-0005
Cable: Culliinc

6/82 Printed in U.S.A.

THE FUTURE CALLS FOR
Culligan.

SERIES K
REVERSE OSMOSIS SYSTEMS



Culligan Series K Reverse Osmosis Systems are designed for rugged industrial duty to offer the utmost in performance, durability and reliability. Standard models are available to provide water that is nearly free of dissolved solids, bacteria, virus and pyrogenic contaminants in quantities of from 26,000 to over 100,000 gallons per day.

K Series models are available with a choice of membranes and module configurations. The KS models use the conventional spiral wound cellulose acetate modules, the KP models have spiral wound thin-film composite membrane modules, while the KD models incorporate the DuPont hollow fiber modules. This choice allows for the best selection of module configuration and membrane type for the characteristics of the incoming water and operating parameter.

All K Series systems come with standard features that include a prefiltration system with replaceable elements to remove turbidity to extend component life; panel mounted flow meters, in-line temperature and pressure gauges to monitor system performance; conductivity monitor with selector switch for constant product/feed water TDS or percent rejection readings; and low feed water pressure shutdown control to protect the stainless steel pumping system. A full range of optional components and custom capacity designs are available to tailor the K Series to your exact requirements today, or allow for future expansion needs.

The Culligan K Series Reverse Osmosis systems represent the highest level of design, engineering excellence and performance available today.

Product Applications

- Electronics—Rinse Waters Low in Colloidal, Organic & Ionic Impurities
- Pharmaceutical—Water for Still Pre-Treatment
- Manufacturing—Process & Make-Up Water Treatment
- Food & Beverage—Reduced Sodium Process Water
- Cosmetics—Production of USP Water
- Boilers—Reduced Scaling & Improved Energy Efficiency
- Laboratories—Water for Reagent Make-Up & Glassware Washing
- Plating—Spot-Free Rinse & Solution Make-Up Water
- Drinking Water—Reduced TDS & Improved Taste
- Humidification—Reduced Scaling & Dusting
- Ice Production—Improved Taste & Clarity
- Floriculture—Reduced Leaf Spotting & Mineral Build-Up in Planting Soils

Model Descriptions

Model	Nominal Capacity GPD	Module Type	Element Qty. & Size	Approx. Recovery %	Max. Operating Temp.	Pipe Size (in) Feed	Pipe Size (in) Product	Pipe Size (in) Waste	Motor HP	Approx. Operating Wt.
KS-27	27,000	Spiral C.A.	15-4x40	75	104°F	1½	1½	¾	25	2150
KS-38	37,800	Spiral C.A.	21-4x40	75	104°F	2	1½	¾	25	2200
KS-43	43,000	Spiral C.A.	24-4x40	75	104°F	2	1½	¾	30	2450
KS-54	54,000	Spiral C.A.	30-4x40	75	104°F	2	1½	¾	30	2750
KS-65	64,800	Spiral C.A.	36-4x40	75	104°F	2½	2	1	40	2900
KS-76	75,600	Spiral C.A.	42-4x40	75	104°F	2½	2	1	40	3100
KS-86	86,400	Spiral C.A.	48-4x40	75	104°F	2½	2	1	40	3250
KS-97	97,200	Spiral C.A.	54-4x40	75	104°F	2½	2	1½	40	3500
KP-27	27,000	Spiral TFC	15-4x40	75	110°F	1½	1½	¾	15	2150
KP-38	37,800	Spiral TFC	21-4x40	75	110°F	2	1½	¾	25	2200
KP-43	43,000	Spiral TFC	24-4x40	75	110°F	2	1½	¾	25	2450
KP-54	54,000	Spiral TFC	30-4x40	75	110°F	2	1½	¾	25	2750
KP-65	64,800	Spiral TFC	36-4x40	75	110°F	2½	2	1	30	2900
KP-76	75,600	Spiral TFC	42-4x40	75	110°F	2½	2	1	30	3100
KP-86	86,400	Spiral TFC	48-4x40	75	110°F	2½	2	1	30	3250
KP-97	97,200	Spiral TFC	54-4x40	75	110°F	2½	2	1½	30	3500
KD-26*	26,000	DuPont B-9	2-9½x48	75	95°F	1½	1½	¾	25	1350
KD-39*	39,000	DuPont B-9	3-9½x48	75	95°F	2	1½	1	25	2200
KD-52*	52,000	DuPont B-9	4-9½x48	75	95°F	2	1½	1	30	2500
KD-65*	65,000	DuPont B-9	5-9½x48	75	95°F	2½	2	1½	30	2750
KD-78*	78,000	DuPont B-9	6-9½x48	75	95°F	2½	2	1½	40	3000
KD-91*	91,000	DuPont B-9	7-9½x48	75	95°F	2½	2	1½	40	3250
KD-104*	104,000	DuPont B-9	8-9½x48	75	95°F	2½	2	1½	40	3500

*DuPont moduled systems not recommended for medical or surgical applications.

System Specifications

Nominal Capacity
Approximate initial capacity based on properly pretreated feed water of 1500 PPM TDS as $CaCO_3$ & 77° F, plus operating pressure of 400 psi (225 psi-KP Series)

Operating Conditions
Feed Pressure: 20 psi min (flowing)/75 psi max
Max. Pump Pressure: KS 500 psi
KP 300 psi
KD 400 psi

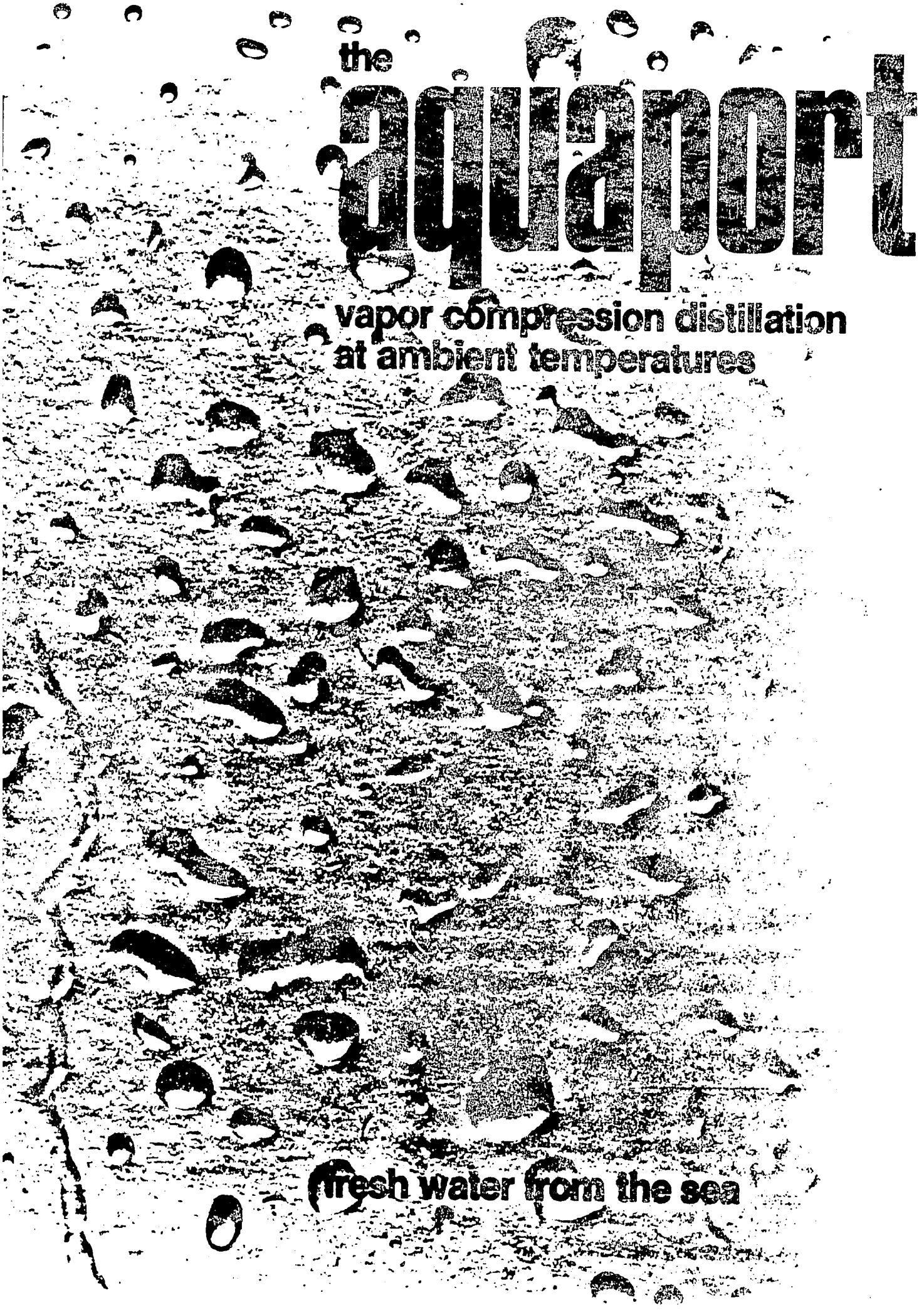
THE FUTURE CALLS FOR Culligan®

Power Requirements
460 VOLT/3 PHASE/60 HZ

Overall Dimensions
Depth 48" Width 169" Height 72"

Available Options
Feedwater pH Monitor/Control System
Chemical Feed System
Alternate Electrical Voltage & Controls
High Temperature Shutdown with Alarm
Product Water Relief/Control System
Alternate Capacities

NOTE: This product produces high quality water which can be contaminated by or corrode the plumbing system following the unit. The purchaser is responsible to supply system components of inert material that are compatible with the application.


the
aquaport
vapor compression distillation
at ambient temperatures
fresh water from the sea

the aquaport®

vapor compression distillation at ambient temperatures

Israel Desalination Engineering (Zarchin Process) Ltd., IDE, is recognized internationally as a leader in the development, engineering and production of advanced desalination systems.

Relying on a nucleus of highly skilled scientists, engineers and technicians, some of whom have been with the company since its establishment in 1958, IDE has maintained steadily one of the highest sales growth rates in the industry.

Behind this remarkable growth lies the fact that all IDE products are unique, based on original, self-developed processes and designs, with distinct advantages and features.

To the cost conscious operator or the profit minded businessman involved in the production of desalinated water these features mean a substantial and real saving of money, lower annual costs, larger profit margins.

The professional engineer will recognize and appreciate the beauty of a simple yet sophisticated design which assures long term trouble-free operation and superior performance.

The Aquaport Ambient Temperature Vapor Compression distillation plants described in this brochure represent IDE's successful solution for small, medium and large capacity desalination applications.

They are clearly in a class by themselves.

® registered trade name

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Water for Development and Progress

The Aquaports are packaged, fully automatic desalination plants, designed for continuous or on-off operation, at constant or variable outputs. They are capable of producing pure distilled water from almost any saline feed, sea water or brackish, at any rate up to 2500 tons per day with a single unit, and up to 20,000 tons per day in a multi-unit installation.

Over 160 Aquaports have been sold throughout the world since 1967, when the first commercial model was delivered to a hotel in Spain. Many of these are repeat orders from satisfied clients.

This is the best indication possible of their growing reputation and acceptance as an economic and dependable source of fresh water.

The plants sold to date have contributed decisively to the development of underdeveloped areas, to the defense of isolated but militarily strategic sites and to the profitable operation of many commercial enterprises.

Aquaport owners include: government departments concerned with raising living standards in remote communities and attracting and holding new residents and service personnel; regional authorities and investors interested in the initiation of new ventures based on local advantages such as low cost land or labor, excellent weather conditions, beautiful beaches or untapped natural resources; private businessmen and industries seeking a self sufficient and reliable water supply, free of uncertain quantity and price regulation according to distribution priorities and pricing policies beyond their control.

Typical applications are hotels, tourist centers, real estate developments, villages, municipalities, military camps, construction camps, off-shore oil rigs, fisheries, refrigeration plants and various industries. The high quality of the Aquaports' distillate allows their use also in the food processing, pharmaceutical and electronic industries and as boiler feed make-up for power utilities.

Distillate quality being independent of feed concentration, the Aquaports are ideal where feed salinity is variable or deteriorating with time.

Falling film evaporative condenser consisting of:

Main vessel: Welded pressure vessel. Design based on international standards. Mild steel, coated with six layers of epoxy-resin, with pinhole detection quality control to ensure effective corrosion resistance.

Heat transfer tubes: Of special corrosion resistant aluminium alloy suitable for sea water applications.

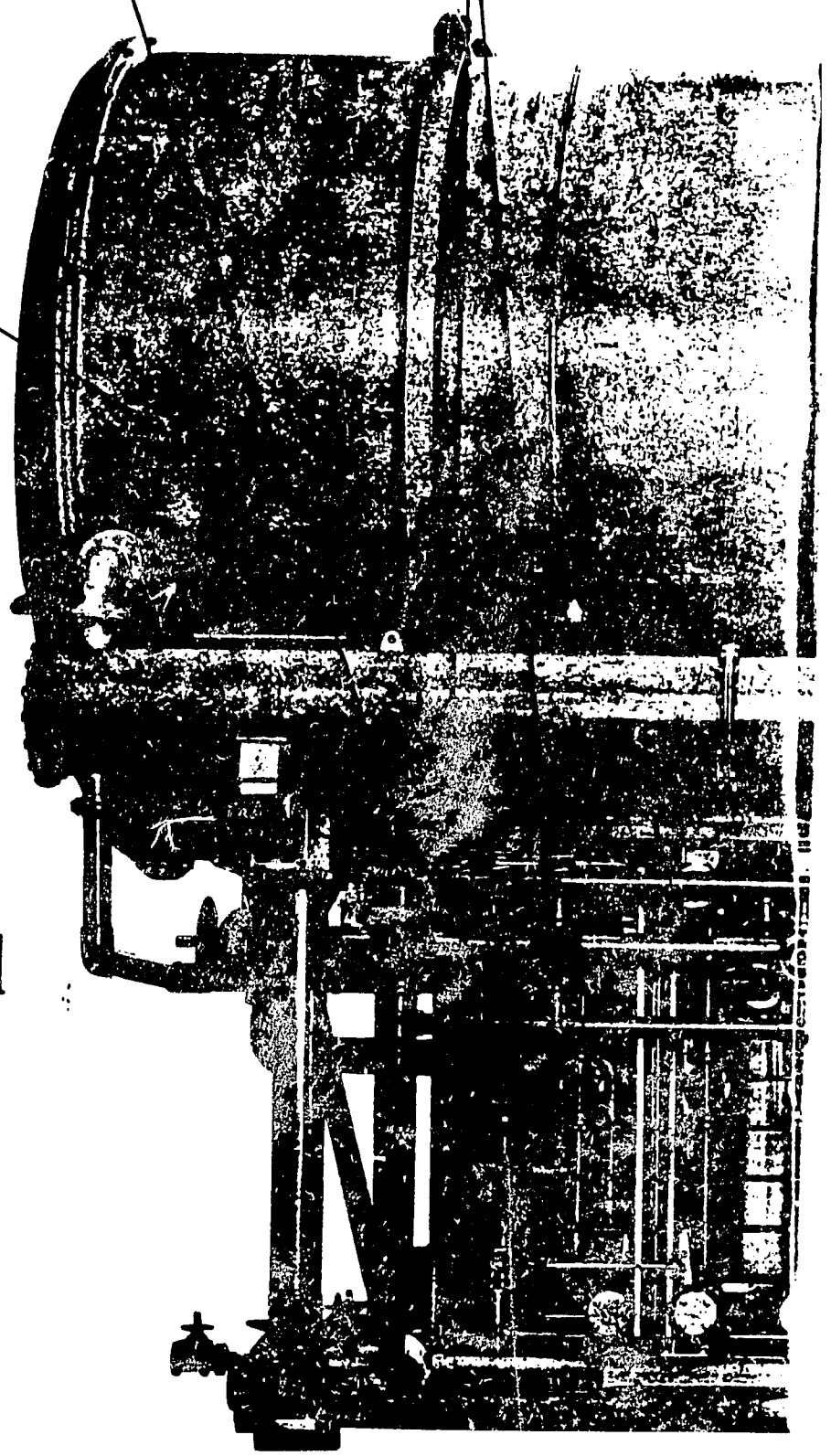
Droplet separator: High performance demister for efficient elimination of brine carryover, ensuring high product purity with a negligible vapor pressure drop.

Brine spray system: Efficient, non-clogging, corrosion-proof ebonite spray nozzles.

Pumps: Centrifugal low-suction head back pullout type to A.N.S.I. standards for easy maintenance. Double mechanical seals. Materials and characteristics specified to ensure trouble-free, high-efficiency service. 316 stainless steel casings, impellers and shafts for brine and sea water service.

Valves: Diaphragm type to ensure leak-tightness. Plastic, with neoprene diaphragms, totally immune to corrosion.

Piping: Plastic, clean and smooth, totally immune to corrosion.



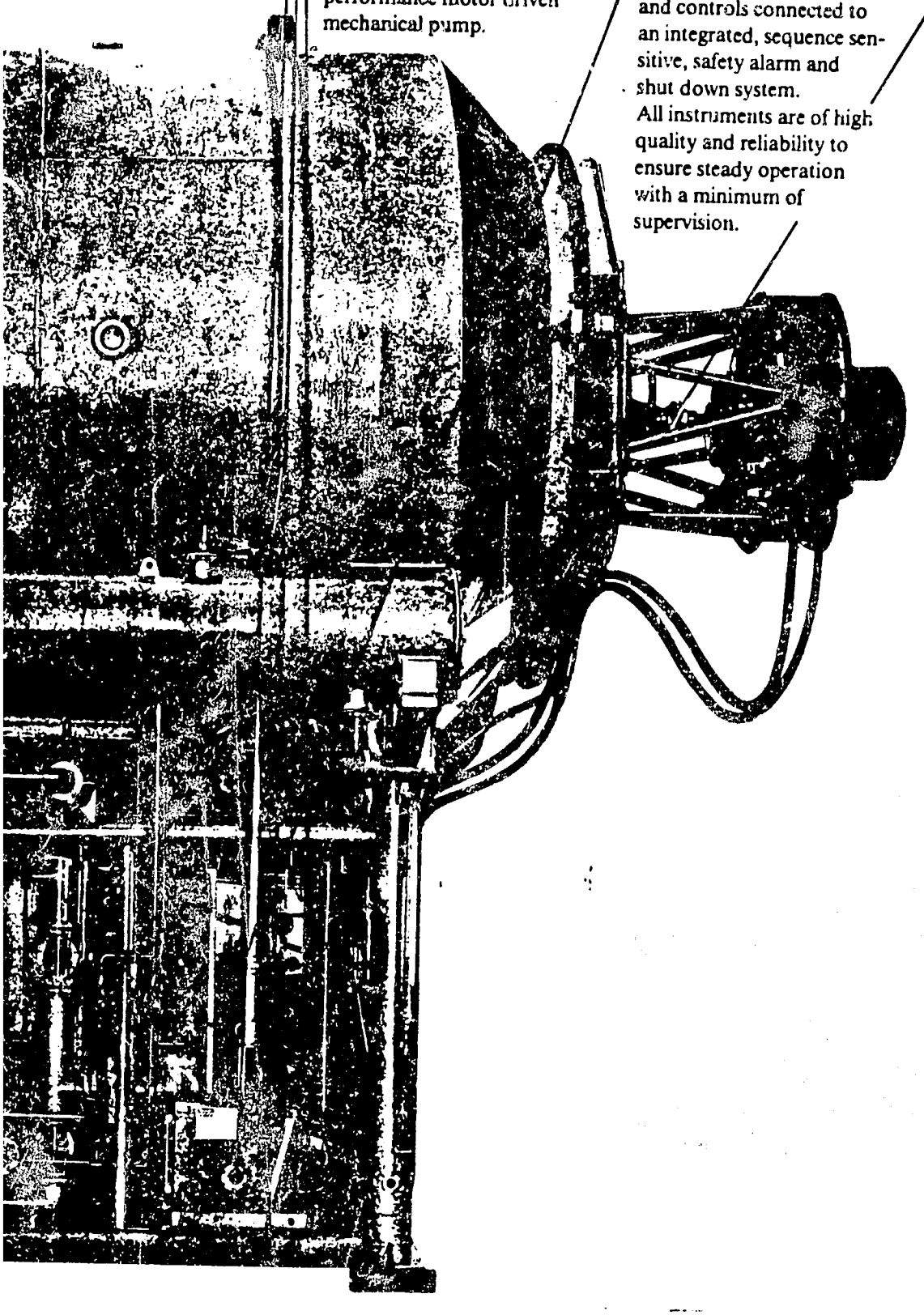
The Plant- A Compact and Elegant Design

proven in over 15 years of field operation refined through experience with over 160 units

Feed heat exchangers: Counter current flow, plate type, for efficient heat transfer. Compact and easy to service.

Air removal condenser: Design for efficient concentration of non-condensible gases and concurrent feed deaeration.

- **Pump motors:** Totally enclosed, fan cooled, to ensure trouble-free outdoor operation.
- **Skid base:** A steel frame uniting the main vessel support structure, all pumps, motors, piping and the central instrumentation, controls and elec. cabinet.
- **Vacuum pump:** High performance motor driven mechanical pump.
- **Central controls, instrumentation and electrical panel:** Drip-proof cabinet. Easily accessible. Containing complete electrical system, push-button motor starters and controls. A central display of all instrumentation and controls allows easy supervision of plant operation. Instrumentation and controls connected to an integrated, sequence sensitive, safety alarm and shut down system. All instruments are of high quality and reliability to ensure steady operation with a minimum of supervision.
- **Compression system:** Patented lightweight, radial blade centrifugal compressor. Rotor of special low density and fatigue-resistant materials. SAE 4340 steel shaft. Force-lubricated top quality bearings. Mechanical seal. Simple direct-drive power transmission.



Installation and Commissioning

quick and practical

As all Aquaport plants are assembled initially in the factory and tested to satisfaction on a special test stand, installation and commissioning on site is a simple and quick procedure.

For ease in handling and transportation, each plant is packed in three major sub-assemblies:

1) The skid base and its mounted equipment.

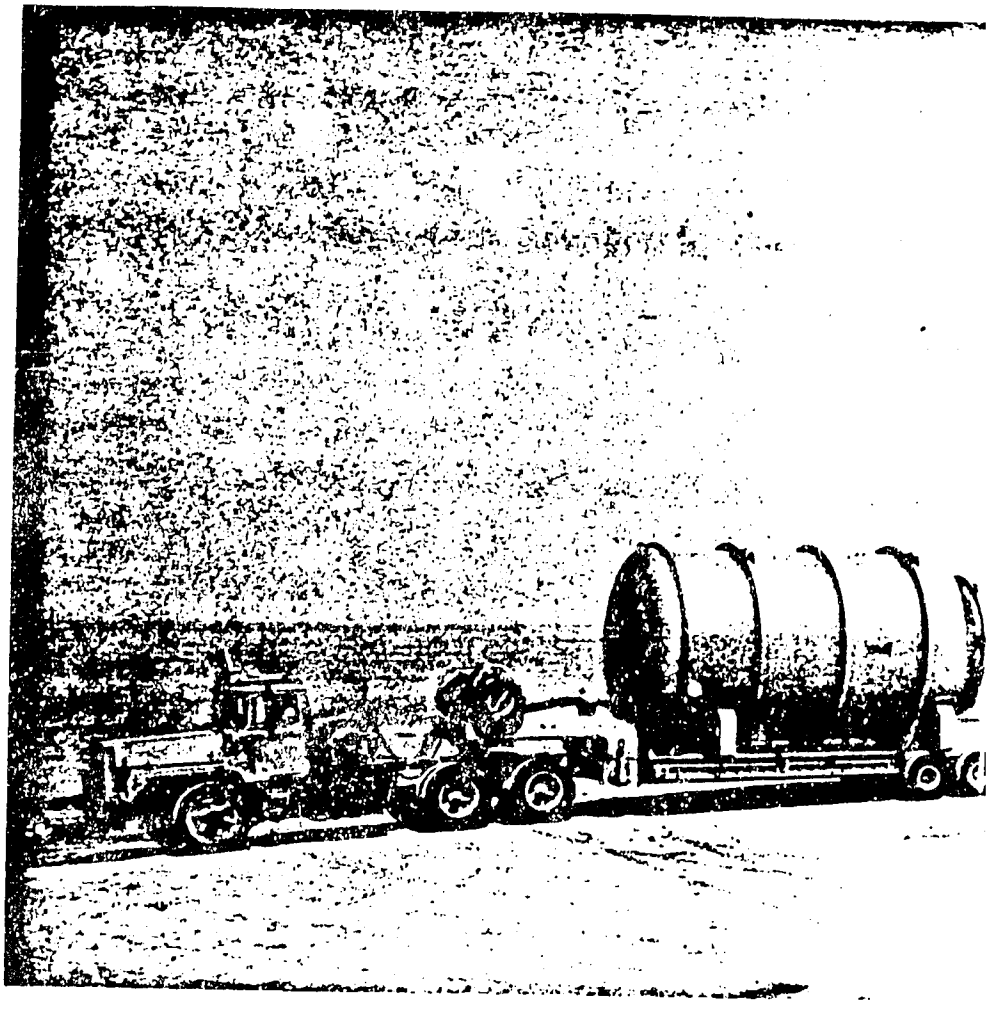
2) The evaporative-condenser main vessel, internals and rear dome.

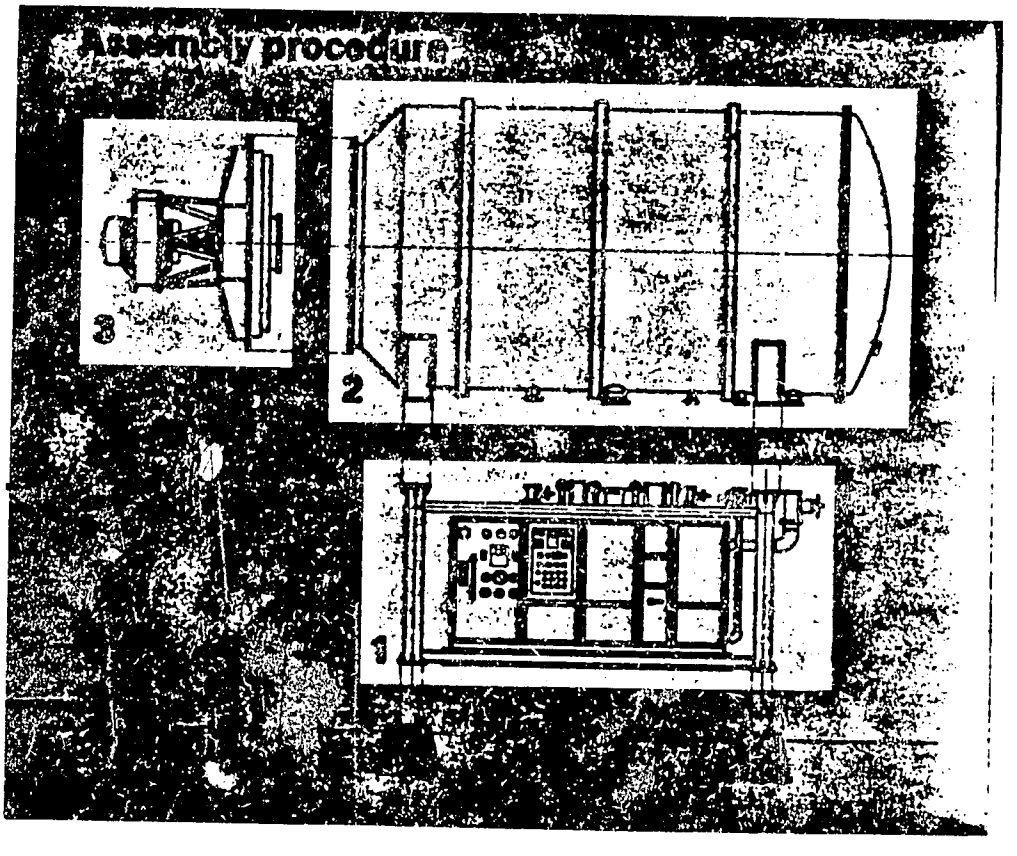
3) The vapor compressor dome and motor sub-assembly.

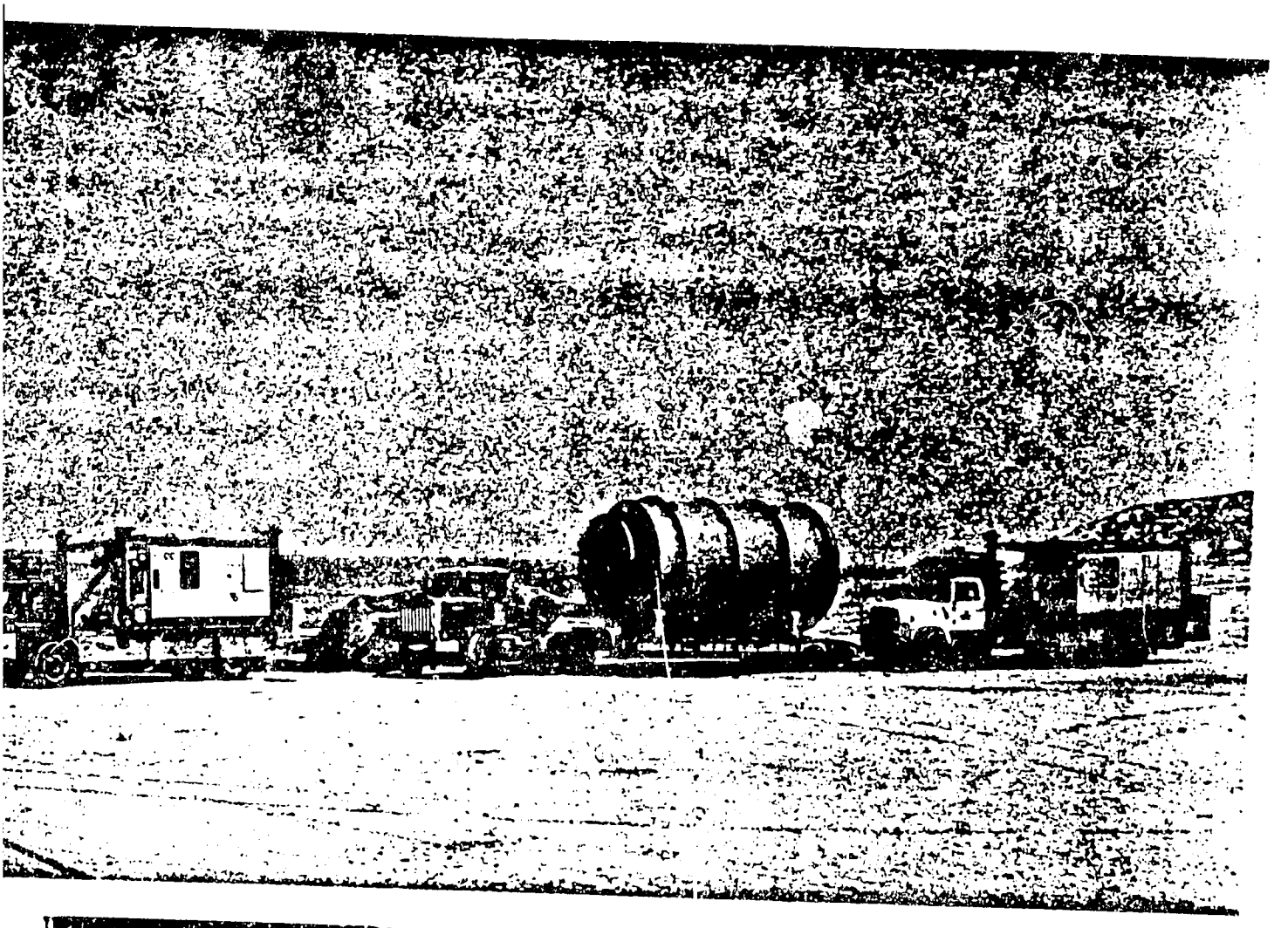
These are reassembled on site, by local technicians, under supervision of our commissioning engineer. As soon as the power and water lines are connected, the plant is ready for operation.

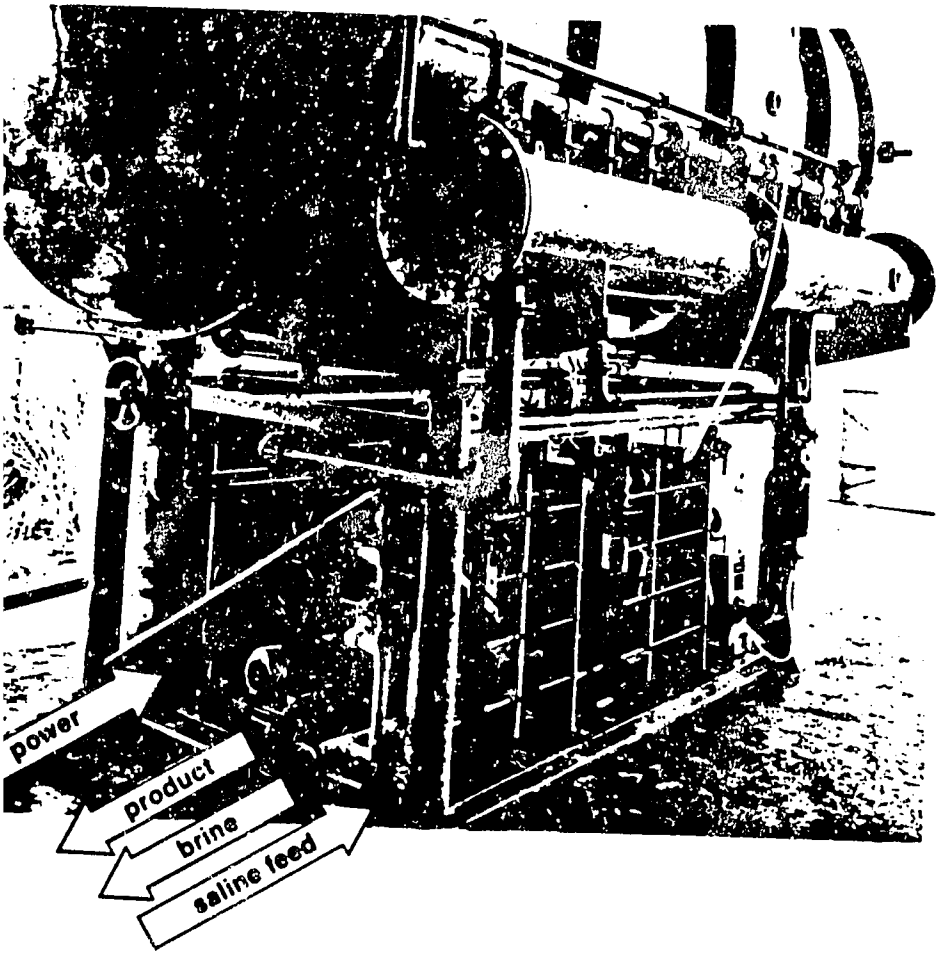
If all site facilities have been provided on time, the unit should be producing water within two weeks after arrival on site.

IDE commissioning service includes: supervision of installation, initial start-up of the unit, checking the general performance of the unit and instructing the operator in proper operation and maintenance procedures.









Plant connections

In - saline feed: Usually 2.4 times product rate at 2.0 atm.g. for sea water feed. Lesser feed rates for lower salinity feeds. Standard flanged connection.

In - power: Three phase cable to bus-bar terminals in electrical panel. Voltage and frequency to suit client.

Out - product: At 0.5-1.0 atm.g. to daily storage tank and, if necessary, to post treatment to neutralize the normal acidity of distilled water. Standard flanged connection.

Out - brine: Usually 1.4 times product rate at 0.5-1.0 atm.g. for sea water feed. Lesser flows for lower salinity feeds or where plant is operated as a feed concentrator. Standard flanged connection.

Plant Operation

push button start-up unattended running

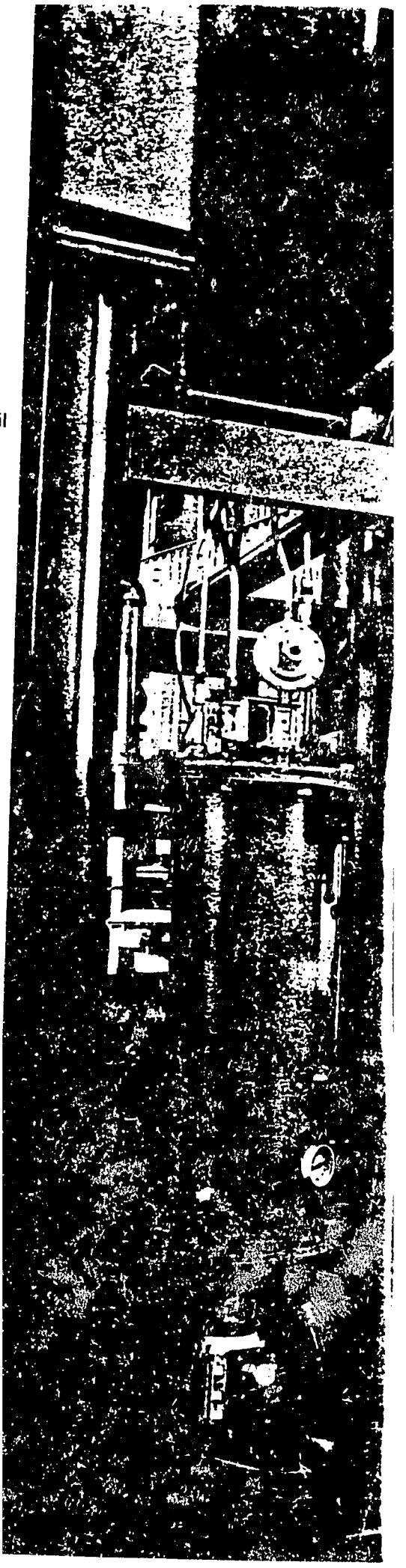
Plant start-up is easy, requiring no more than activation of a few motor starter switches and adjustment of one valve.

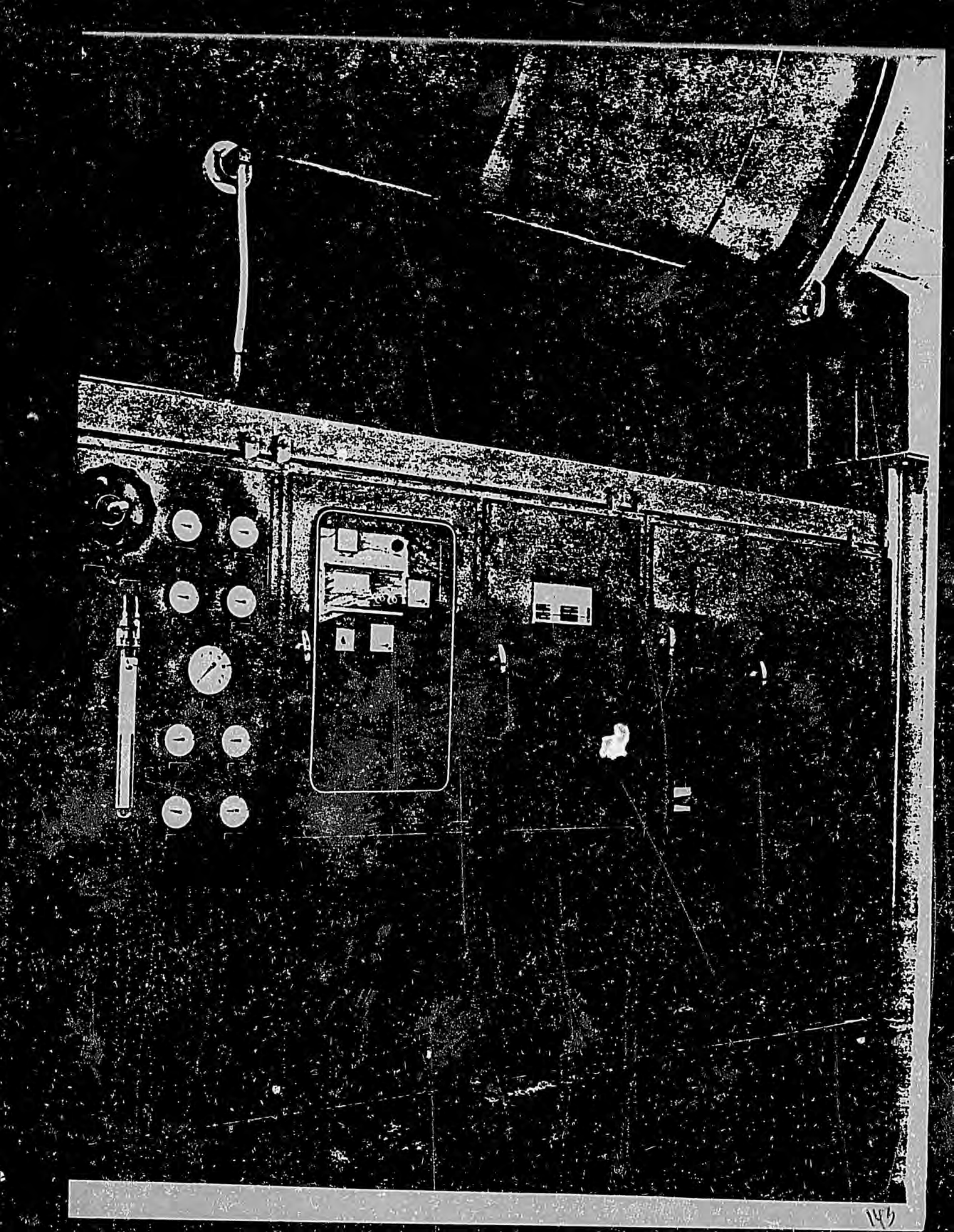
The unit's automatic controls ensure steady operation from the start and as soon as the operator turns the auto-manual switch to "automatic" the unit can be left unattended with the protective shut down and alarm system ensuring fail-safe operation.

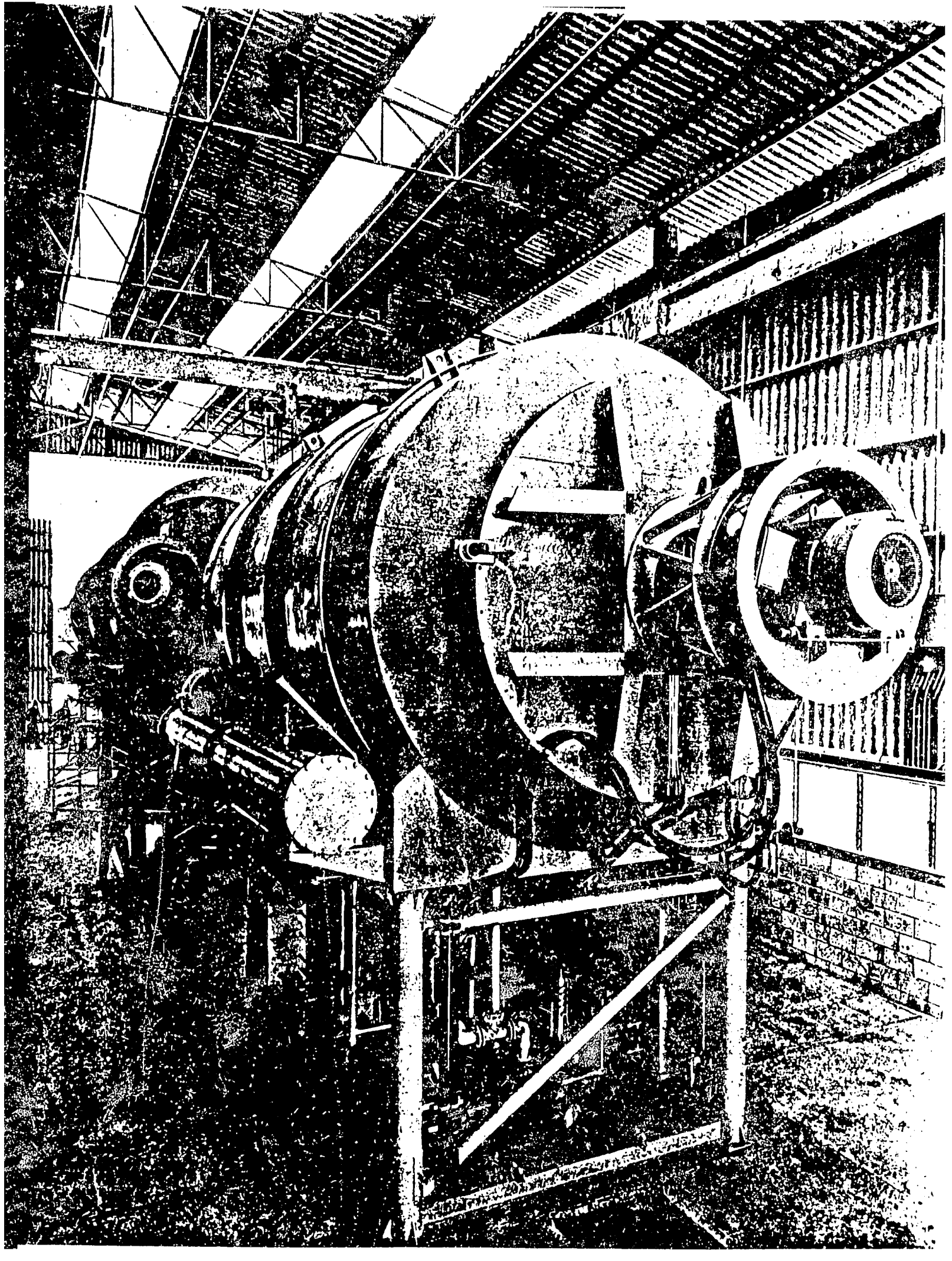
The automatic shut down system consists of sensing devices for detecting any possible fault. Off-normal conditions will activate a relay holding network, removing power from all motors and the feed line solenoid valve.

The entire unit is then safely shut down and cannot be restarted or operated with the "auto" setting until the malfunction is remedied. The source of the malfunction will be identified by a visual indicator which will remain lit.

The voluntary shut down of the unit under "auto" control can be effected simply by shutting any one of the unit's motors.







Models and Specifications

a wide range of options

A wide range of standard and non-standard Aquaports is available today to meet the specific requirements of any project. These include the standard all-electric models whose basic specifications are shown here, and the following variants:

1. Direct diesel drive versions of all plants, suitable for locations where costs of purchased power is excessive and where self-generation of power by a diesel-generator set is prohibited by law. The direct diesel drive units require 10 to 15 percent less power than their all-electric equivalents, through elimination of generator and electric motor efficiency losses. However, the direct drive units lose the versatility of the diesel-generator plus all-electric Aquaport scheme, which allows use of the power plant for generating power, at a marginal cost, to other consumers or as a standby emergency set for grid supplied power.

2. Variable speed versions of all plants, suitable for applications where it is contemplated that operation at partial load will be on a regular basis. The variable speed versions, which include a compressor RPM regulator, will decrease power consumption not merely proportionately to reduced production rate, as with standards Aquaports, but to an even larger extent. This results in specific energy consumptions at low outputs approaching values achieved in the LE models.

3. Concentrator models, suitable for concentration of effluents, polluted industrial discharge waters, cooling tower blowdown and recovery from solution of valuable chemicals. These models contain modified vapor compression and liquid recirculation systems.

4. Special materials models, suitable for low temperature concentration of highly corrosive solutions, beverages, juices and other food products and by-products. Evaporator-condenser tubes and feed heat exchanger plates constructed of copper-nickel alloys, stainless steel, aluminum-brass, titanium or any heat-transfer material specified by client.

IDE will be pleased to discuss and present detailed descriptions and specifications for any model or variant following receipt of information on the nature of the project, including the following data:

Saline feed: composition (complete chemical analysis) and temperatures (min, max and average).

Power supply: voltage, frequency and unit cost.

Diesel fuel: cost.

Product: rate (nominal and seasonal variations, if any), desired purity and pH level.

Notes on electrical models specifications

1. All models are supplied with electricals to suit client's power supply voltage and frequency.
2. Compressor motor includes star-delta reduced voltage starters. Pump motors are designed to withstand momentary 25 percent voltage drops.
3. Minimum power supply rating shown is the smallest diesel generator capable of meeting compressor motor start-up current surge (10-15 seconds) with a voltage drop of less than 20 percent. In sizing power plant for multi-unit Aquaport installations peak power allowance for start-up should be made for one unit only. The allowance for other units should be equal to their nominal power consumptions.

The Aquaport's assembly line and preshipment test stands.

The Mobile Series up to 100 tons / day

instant water on a temporary basis

The Mobile Series answers the need for portable desalination plants capable of rapid deployment and immediate production.

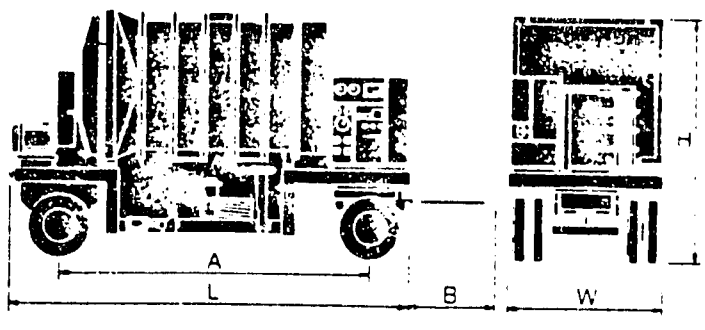
The plants are supplied with an auxiliary feed intake system, complete with feed pump, the filter end of which can be inserted into any brackish water bore or submerged in the sea. Standard flexible feed line length is 15m., but longer lines may be supplied upon request.

Power is provided from any external source, e.g., a stationary or portable diesel generator set. A 10m long power cable connection is provided as standard equipment.

Typical applications are military logistic support, civil emergency sets for disaster areas, oil drilling and other temporary work camps, nomadic sheep or cattle raising herds, which shift from one water bore and grazing ground to the next.

Where storage capacity is available, one mobile unit can be rotated and operated periodically, serving several small communities spread out over a large area whose small water requirements do not justify installation of a fixed plant with fixed personnel.

Model No.	AQ25M	AQ50M	AQ75M	AQ100M
nominal capacity (tons/day)	25	50	75	100
saline feed rate (tons/hr)	2.5	5.0	7.5	10.0
specific energy consumption (kwh/ton)	21	16.5	16.5	16.5
nominal power consumption (kw)	22	35	52	69
KVA for start-up	61	102	142	195
dimensions (m) L	5.0	6.5	6.5	9.0
W	2.5	3.0	3.0	3.2
H	5.5	5.5	5.5	6.0
A	4.0	5.3	5.3	7.5
B	1.0	1.4	1.4	1.4
transport weight (tons)	16	20	20	30
shipping volume (m^3)	75	115	115	190



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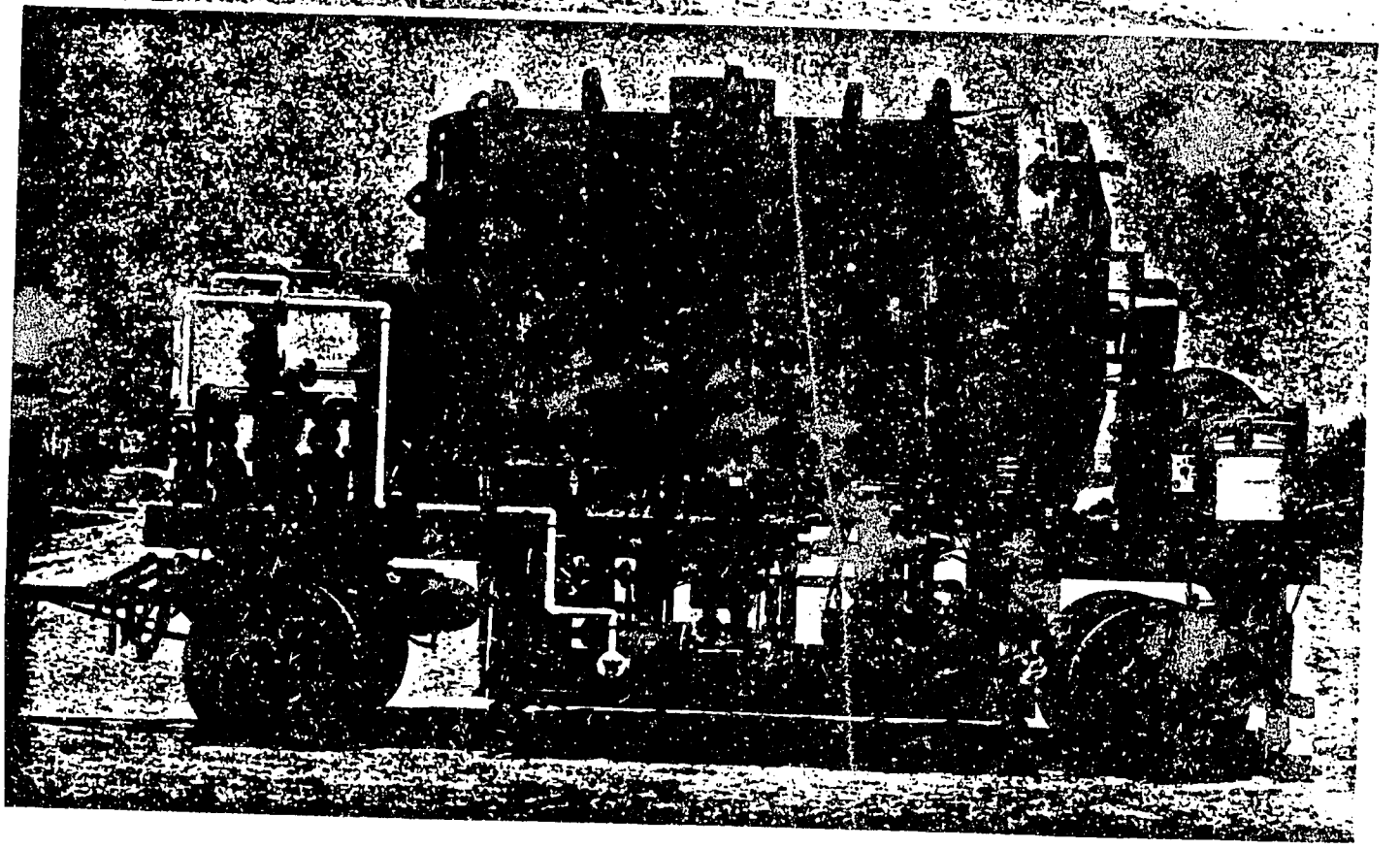
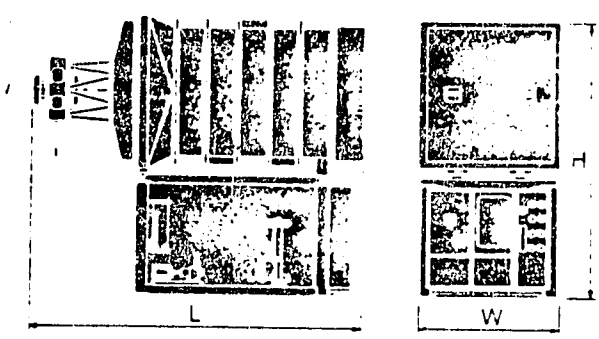


The Mini-Aquaport Series up to 100 tons/day

dependable small scale solution

The Mini-Aquaports are the skid-based version of the Mobile Series units. They have found their application on the factory and small community level, where the overriding consideration is long term, trouble free operation. Typical uses are fish canneries situated close to fishing villages or fishing grounds, refrigeration plants, remote radar sites and other military installations, off-shore drilling rigs, small islands, towns or villages, where the local population is on the order of hundreds, and various industries which require pure distillate for processing or boiler feed.

Model No.	AQ25M	AQ50M	AQ75M	AQ100M
nominal capacity (tons/day)	25	50	75	100
saline feed rate (tons/hr)	2.5	5.0	7.5	10.0
specific energy consumption (kwh/ton)	21	16.5	16.5	16.5
nominal power consumption (kw)	22	35	52	69
KVA for start-up	61	102	142	195
dimensions (m) L	4.0	5.2	5.2	8.0
W	2.5	3.0	3.0	3.2
H	5.5	5.5	5.5	6.0
transport weight (tons)	11	15	15	22
shipping volume (m^3)	60	90	90	170



mapport
75

The Mid-Range Series 100 to 500 tons/day

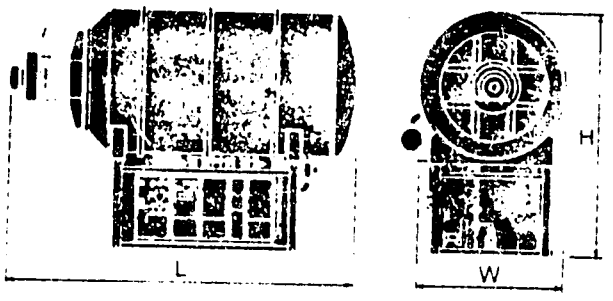
the classic models

The Mid-Range Aquaports are the reliable and simple solution for hotels, tourist development centers, real estate developments, military bases, power stations and moderate size municipalities.

The operational requirements for this range have been considerably reduced to offset the general increase in manpower and energy prices.

Over the past fifteen years more Aquaports have been sold in this capacity range than any other distillation plant of comparable size.

Model No.	AQ150	AQ200	AQ250	AQ300	AQ350	AQ400	AQ450	AQ500
nominal capacity (tons/day)	150	200	250	300	350	400	450	500
saline feed rate (tons/hr)	15	20	25	30	35	40	45	50
specific energy consumption (kwh/ton)	16.5	16.5	16.5	16.5	16.5	16.5	16.5	16.5
nominal power consumption (kw)	103	137	172	206	240	275	309	343
KVA for start-up	276	331	468	578	655	783	789	789
dimensions (m) L	8.0	8.0	8.0	8.9	8.9	8.9	9.0	9.0
W	3.2	3.2	3.2	3.8	3.8	3.8	4.0	4.0
H	6.0	6.0	6.0	6.5	6.5	6.5	6.5	6.5
shipping weight (tons)	22	25	25	28	30	30	32	32
shipping volume (m^3)	170	170	170	230	230	230	230	240



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The Low Energy (LE) Series

lowest energy consumption of any distillation plant

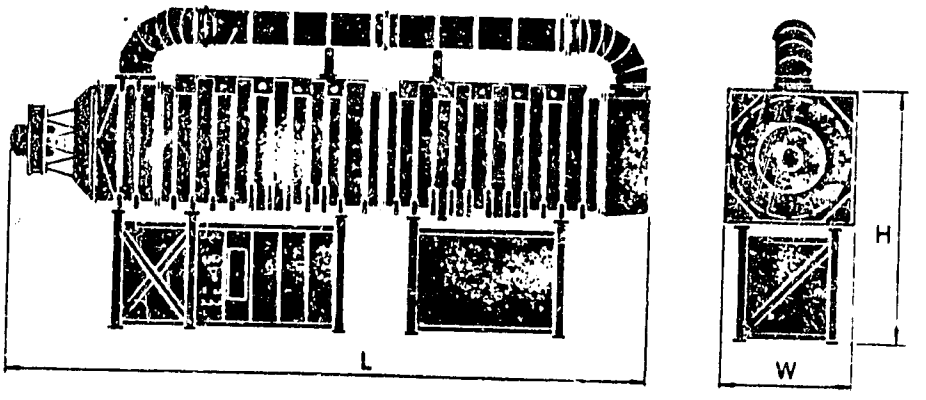
The fourfold increase in fuel prices since 1973 has magnified the energy cost component in desalinated water costs and provided an incentive to design plants in which the trade-off point between capital and energy costs is shifted in favour of lower energy consumption.

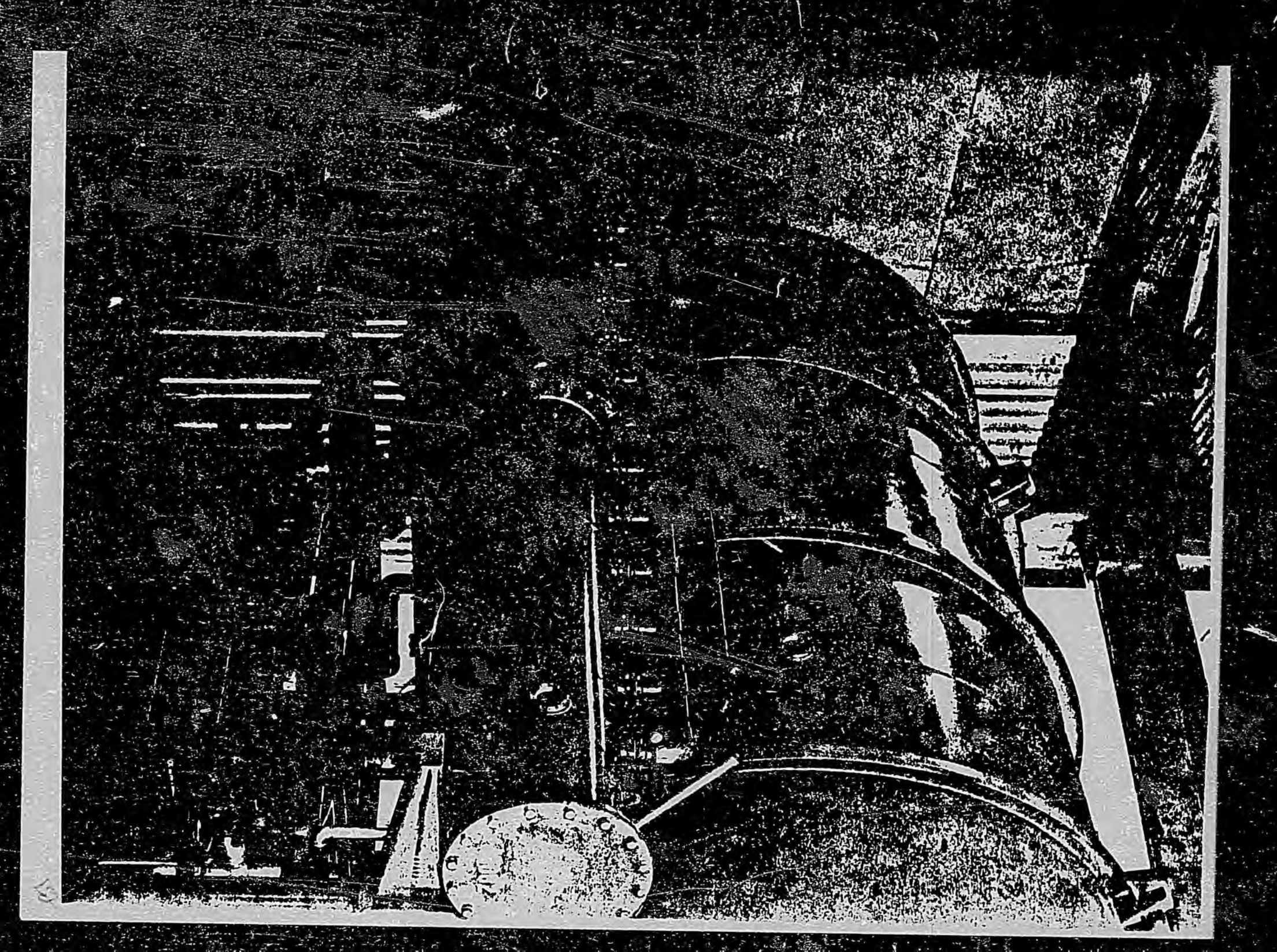
The LE series of Aquaports has been developed along this line, incorporating larger heat transfer surfaces and more efficient vapor compressors. They require only 8 to 12 kwh/ton product (30 to 45 kwh/1000 gallons).

To gain greater economy, the LE plants can be designed to utilize waste heat from the power supply diesel or from any other low grade heat source.

Scale-up has been achieved without losing the easy handling and installation features of the smaller sized Aquaports. The Low Energy Aquaports are, similarly, skid based, packaged units.

Model No.	AQ500	AQ600	AQ700	AQ800	AQ900	AQ1000	AQ1500
nominal capacity (tons/day)	500	600	700	800	900	1000	1500
saline feed rate (tons/hr)	50	60	70	80	90	100	150
specific energy consumption (kwh/ton)	9.0	11	12	10	10.5	11	8.5
nominal power consumption (kw)	188	275	350	333	394	458	532
KVA for start-up	580	750	800	800	1000	1100	1250
dimensions (m) L	16.5	17.5	17.5	20	20	20	26
W	3.4	3.4	3.4	3.8	3.8	3.8	3.8
H	8.8	8.8	8.8	8.8	8.8	8.8	8.8
shipping weight (tons)	54	57	57	67	67	67	97
shipping volume (m^3)	340	350	350	400	400	400	550





2806

Multi-Unit Installations up to 20,000 tons/day

a versatile systems concept

The inherent efficiency of the Aquaports and their low installation and auxiliaries costs make them competitive on a strict water cost basis, even in multi-unit installations, with larger MSF or VTE type distillation plants of up to 20,000 tons per day.

The multi-unit scheme is ideal for gradual development of a water supply system. Rather than invest in a large plant designed to cover future requirements, it is preferable to install one or two smaller Aquaports to meet present needs, and add other plants, in a modular fashion, as the demand increases.

The installation of each additional Aquaport can be done with a minimum of disturbance to the normal activities of any resort, military camp or industrial facility. The Aquaports, arriving pre-tested, pre-assembled and self-contained, will be erected rapidly with no noise or messy construction work.

The multiple unit concept itself provides the water supply system with added flexibility and reliability. Any number of units may be operated, covering a wide range of capacities, and a continuous supply of water will always be assured, even in the case of an involuntary shut down or the servicing of any single unit.

A battery of Aquaports serving a regional water supply scheme may be combined also with the local power generating plant into a central, dual purpose station, sharing common facilities and personnel. The Aquaports will allow design for any water to power ratio, unlike steam consuming distillation plants which require matching outputs to steam flows available from the power plant at a given load. Both water and power plants can thus be sized to meet actual requirements rather than some compromised balance.

The Aquaports will function independently of the power plant and its load, serving as a desirable client for marginally produced power (increasing the plant's utilization factor) rather than as a burdensome steam demanding adjunct which hampers the generation of lowest cost power.

They can be operated at a fixed output rate, serving as a steady base load, or, where power supply is limited, output may be regulated periodically. The load can be reduced during peak demand hours to make more power available for other consumers, and increased during off-peak, night time hours when electric rates are normally lower.

This feature may be applied also to those very large dual purpose stations which can be based only on large steam consuming desalination plants. The huge distillers can then serve for base load water production, while a battery of Aquaports, incorporated on site, will be operated variably to balance the system and maintain the proper ratios of steam, power and water at all hours of the day, irrespective of variations in power demand.

The issue of this publication does not constitute an offer and the right is reserved to alter designs and/or specifications at any time without notice.

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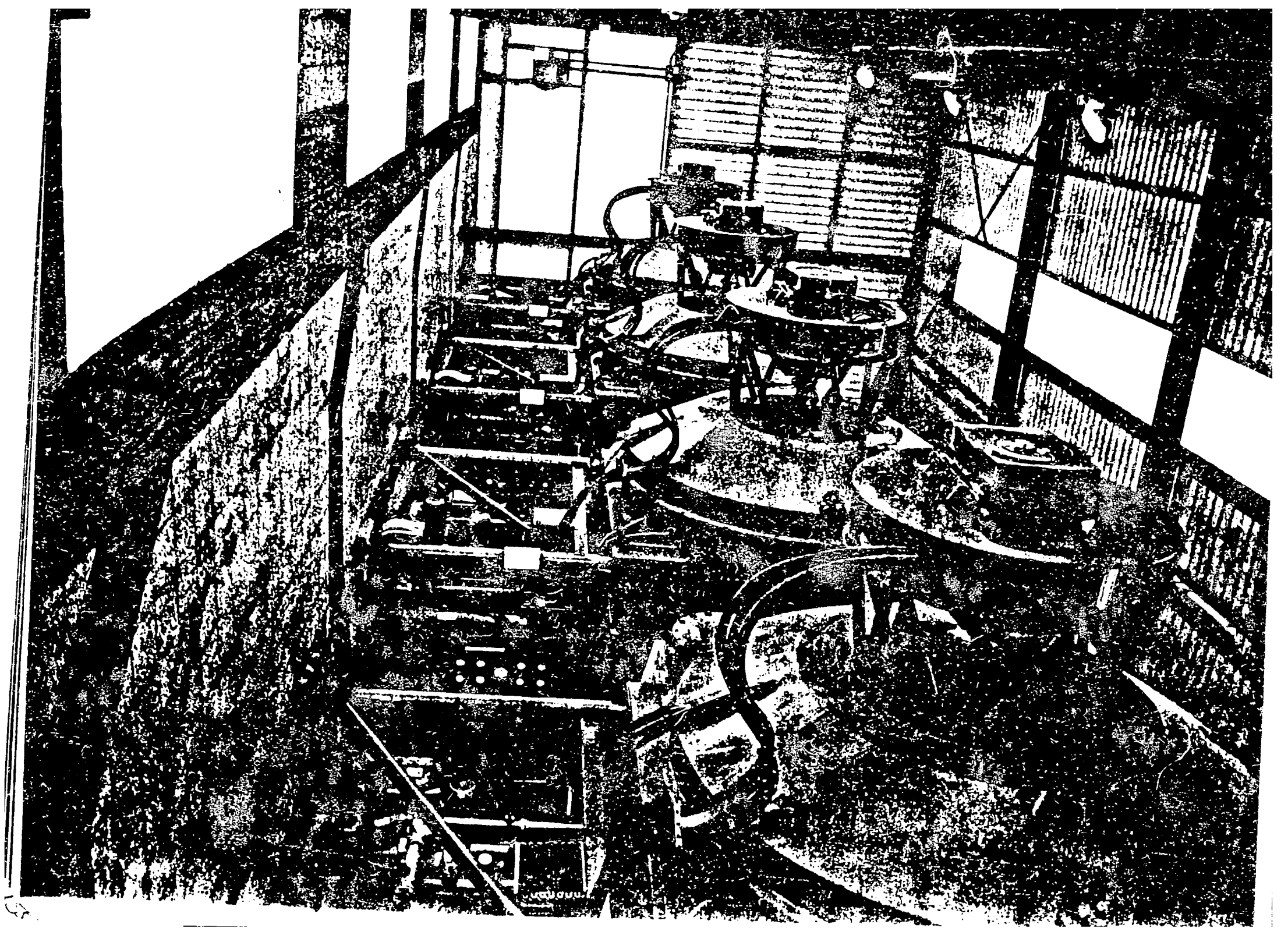
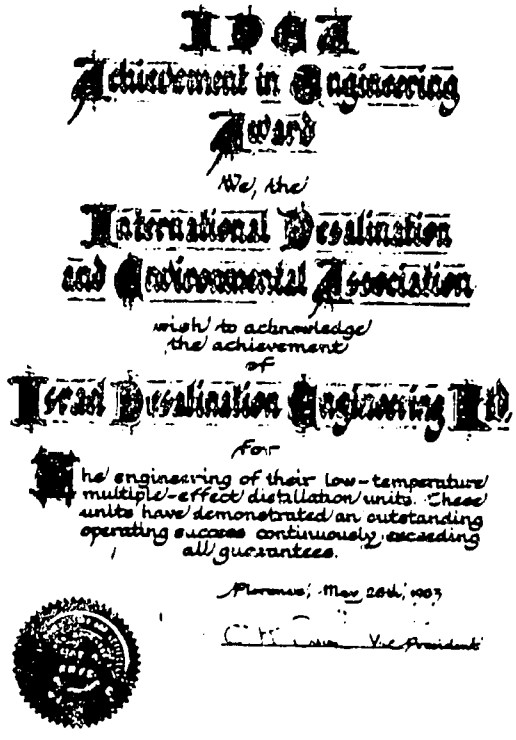


I.D.E. Services include

- consultation, assessment and problem identification
- definition of project parameters
- laboratory testing and process analysis
- site evaluation and power source optimization
- complete plant and system design and engineering
- manufacture and supply of evaporators and all principal items of equipment, with full one-year guarantee
- on-site assembly, commissioning and running-in
- your choice of service arrangements;

long-term service contract covering parts and labor for repairs, as well as supervision of plant operation. On-call, pay-as-you-go service arrangement with periodic check-up and preventive maintenance if desired.

All I.D.E.'s services are available on an optional basis: you decide your requirements - and I.D.E. will follow through. Samples of service contracts and a list of clients are available upon request.


IDEA
Achievement in Engineering
Award
We, the
International Desalination
and Environmental Association
wish to acknowledge
the achievement
of
Israel Desalination Engineering Ltd.
for
the engineering of their low-temperature multiple-effect distillation units. These units have demonstrated an outstanding operating success continuously exceeding all guarantees.
Florence, May 28th, 1983
Vice President

Israel Desalination Engineering
(Zarchin Process) Ltd.

P.O. Box 12041 Tel Aviv 61180, Israel. Telephone (052) 557333
Telex 33590, Cables: Hatpala Tel Aviv

Member of IDE Group

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DESALINATION
ENGINEERING
(ZARCHIN PROCESS)
LTD.

DESALINATION PLANT REFERENCE LIST

During the past sixteen years, over 160 AQUAPORT Vapour Compression and Multi-Effect Distillation units, ranging in capacity from 30 to 18,000 M3/day each, have been sold throughout the world, in countries like Spain, Venezuela, Mexico, Ecuador, Colombia, Peru, United States, South Africa and Israel. Details of the type and capacity of most of the units in the different locations are given in the following list.

OWNER	LOCATION	TYPE - SIZE OF UNITS (CUBIC M./DAY)
Rocamar	Kadaces, Spain	VC* 60
Maxorata	Fuerteventura, Canary Islands, Spain	VC 125
Govertment of Egypt	Sharm-el-Sheik, Egypt	Four units VC 450 each
Imperial Iranian Air Force	Bushire, Iran	Three units VC 300 each
TMI	Linosa, Italy	VC 50
TMI	Bari, Italy	VFVC* 450
Imperial Iranian Air Force	Kish, Iran	Five units VC 200 ea.
Hocasa - Hotel San Antonio	Lanzarote, Canary Islands, Spain	Three units VC 200 each
TMI	Lampeduza, Italy	VC 500
Terra-Sol	Fuerteventura, Canary Islands, Spain	VC 350
Imperial Iranian Air Force	Bushire, Iran	Ten units VC 250 each
Garavilla	Lanzarote, Canary Islands, Spain	VC 150

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OWNER	LOCATION	TYPE - SIZE OF UNITS (CUBIC M/DAY)
Edisa	Formentera, Baleare Islands, Spain	VC 250
Cabildo de Lanzarote	Lanzarote, Canary Islands, Spain	VC 350
La Santa - Caja Insular de Ahorros de Gran Canaria	Lanzarote, Canary Islands, Spain	VC 400
Imperial Iranian Air Force	Kharg, Iran	Two units VC 50M* each
Imperial Iranian Air Force	Jask, Iran	Six units VC 250 each
Hadish	Kharg, Iran	VC 200
Mekoroth, Water Co.	Eilat, Israel	MED* 4000
Jandia Playa Hotel	Fuerteventura, Canary Islands Spain	VC 450
Rio Tinto	Lanzarote, Canary Islands, Spain	Two units VC 450 each
TMI	Bandar Abbas, Iran	Four units VC 450 each
Dead Sea Works	Sdom, Israel	VC 450
Imperial Iranian Air Force	Kharg, Iran	Ten units VC 250 each
Kish Island Develop. Organization	Kish, Iran	Five units MED 2000 each
La Aldea de San Nicolas Tolentino	Gran Canaria, Canary Islands, Spain	VC 250
Pajara	Fuerteventura, Canary Islands, Spain	VC 250

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OWNER	LOCATION	TYPE - SIZE OF UNITS (CUBIC M./DAY)
Instituto Nacional de Obras Sanitarias	Los Roques, Venezuela	VC 75
TMI - SAMIFI	Jask, Dayer & Konorak, Iran	Three units VC 50 each
Imperial Iranian Air Force	Kish, Iran	Ten units VC 250 each
Imperial Govertment of Iran	Bandar Langeh, Iran	Two units VC 500 each
Tuineje, Gran Tarajal	Fuerteventura, Canary Islands, Spain	VC 250
Israel Defense Force	ZAHAL, Israel	VC 75 M
Cabildo de Fuerte-ventura, Puerto del Rosario	Fuerteventura, Canary Islands, Spain	Eight units VC 500 each
Hierro Peru	San Nicolas, Peru	Four units VC 500 each
Imperial Iranian Navy	Bandar Abbas, Iran	MED 2000
Inpesca	Guayaquil, Ecuador	VC 550
Industrias Ales, C.A.	Manta, Ecuador	VC 500
Mekoroth, Water Co.	Ovda, Israel	RO* 600
Mekoroth, Water Co.	Eilat, Israel	RO 4300
Solmat	Sdom, Israel	Solar plant 20
Virgin Islands Water & Power Authority	St. Thomas, Virgin Islands, U.S.A.	Two units MED 5000 each
		One unit MED 2200
Virgin Islands Water & Power Authority	St. Croix, Virgin Islands, U.S.A.	One unit - MED 5000
		Two units - MED 2000 ea.

OWNER	LOCATION	TYPE - SIZE OF UNITS (CUBIC M./DAY)
Negocios Industriales Real	Guayaquil, Ecuador	VC 350
Neckerman	Fuerteventura, Canary Islands, Spain	VC 200
Digaases	Bahia Tortugas, Mexico	VC 200
Karbochem - Afprene Project	Newcastle, So. Africa	Two concentrators VCC* 550 and VCC 200
Miluot -Miloumor Cotton seed processing plant	Haifa Bay, Israel	VC concentrator 1
Hotel Tres Islas	Fuerteventura, Canary Islands Spain	VC 400
Demarco	Posorja, Ecuador	VC 150
Cerrejon Coal Mines	Guajira, Colombia	Four units - three VC 645 and one VC 570
Kadmar	Lanzarote, Canary Islands, Spain	VC 500
Gadot - Petrochemical Industries	Haifa Bay, Israel	VC Concentrator 2
Electricity Corp.	Ashdod, Israel	MED 18000
ESCOM - Electricity Supply Commission of South Africa	Tutuka, Standerton, So. Africa	Two concentrators VCC 650 each
ESCOM - Electricity Supply Commission of South Africa	Lethabo, Sasolburg, South Africa	Two concentrators VCC 650 each
Pancontinental Gold Mining Areas (Pty) Ltd.	Australia	VC Concentrator

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VC	Vapour Compression
VFVC	Vacuum Freeze Vapor Compression
M	Mobile
MED	Multi-Effect Distillation
RO	Reverse Osmosis
VCC	Vapor Compression Concentrator

9/6/84

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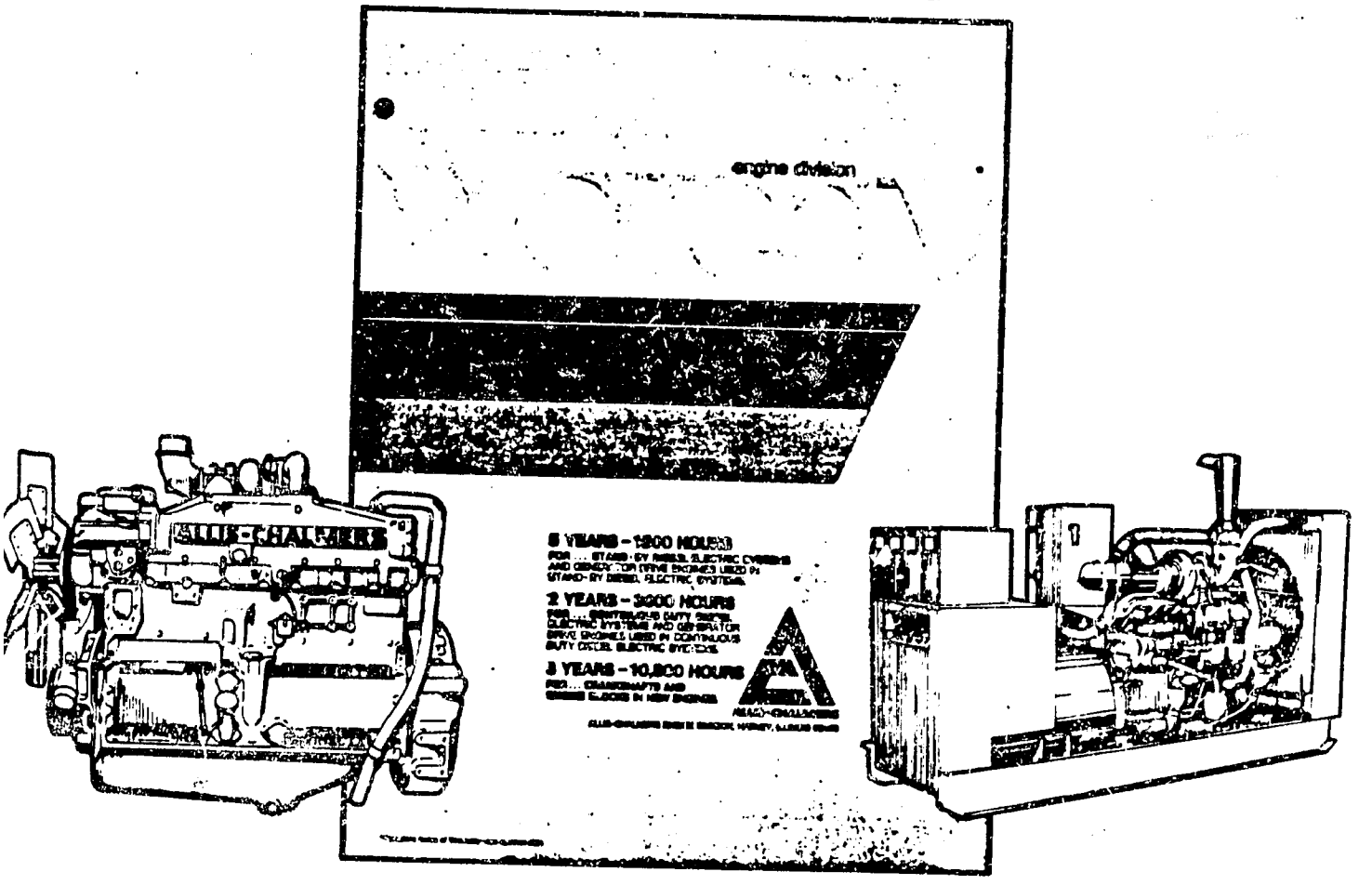
ALLIS-CHALMERS

Diesel Engines & Generator Sets

Backed by the Best Warranty in the Industry!



5 YEARS—1500 HOURS

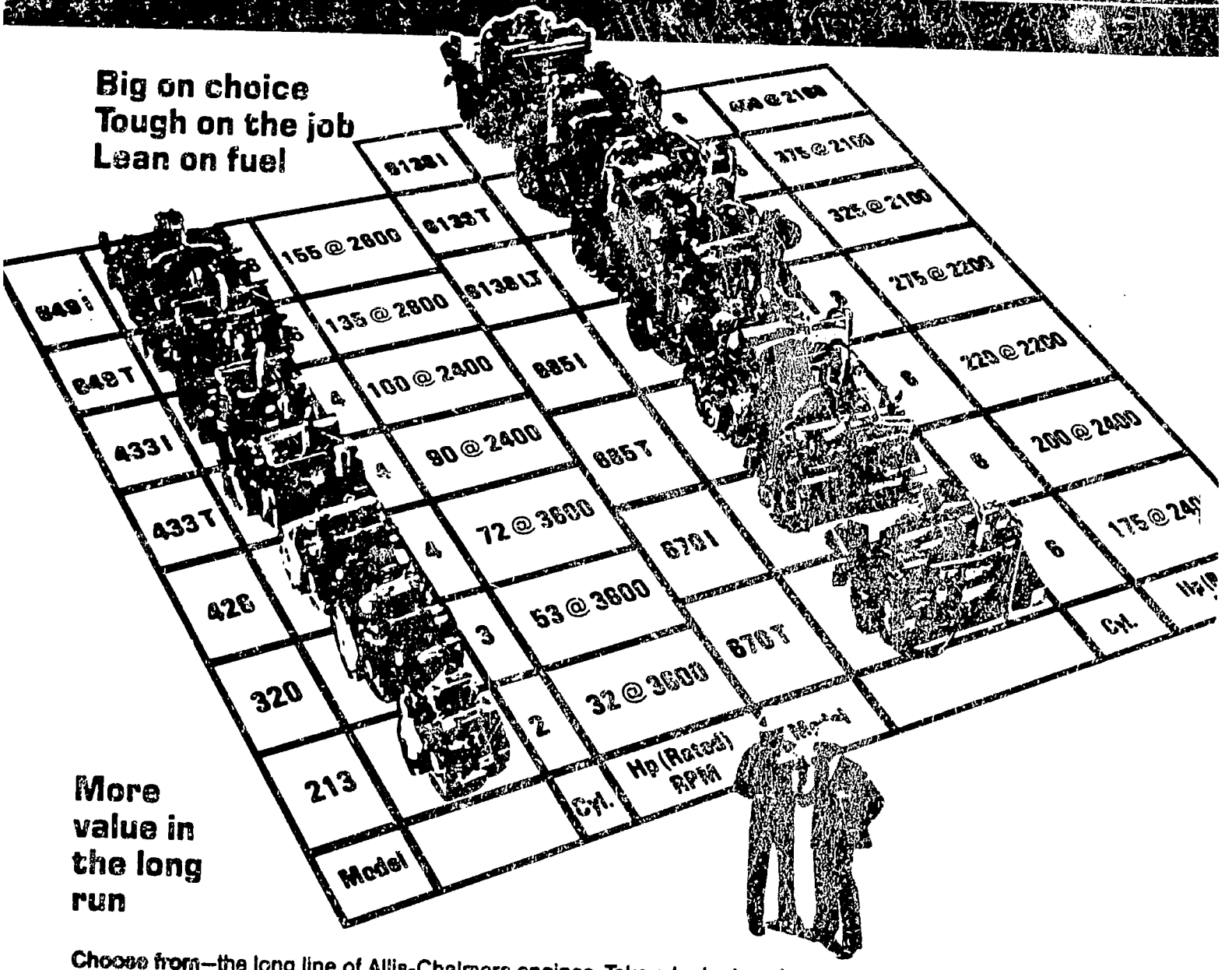
FOR...ALLIS-CHALMERS STANDBY DIESEL ELECTRIC SYSTEMS AND FOR ALLIS-CHALMERS GENERATOR DRIVE ENGINES USED IN ANY STANDBY DIESEL ELECTRIC SYSTEM.

2 YEARS—3600 HOURS

FOR...ALLIS-CHALMERS CONTINUOUS DUTY DIESEL ELECTRIC SYSTEMS AND FOR ALLIS-CHALMERS GENERATOR DRIVE ENGINES USED IN ANY CONTINUOUS DUTY DIESEL ELECTRIC SYSTEM.

Diesel Engines

Big on choice
Tough on the job
Lean on fuel



Model	Cyl.	Hp (Rated) RPM
213	2	32 @ 3600
320	3	53 @ 3600
426	4	72 @ 3600
433T	4	90 @ 2400
433I	4	100 @ 2400
848T	6	135 @ 2800
848I	6	155 @ 2800
6138I	6	[illegible]
6138T	6	[illegible]
6138LX	6	275 @ 2100
6851	6	325 @ 2100
6851T	6	275 @ 2200
6701	6	220 @ 2200
670T	6	200 @ 2400
	6	175 @ 24[illegible]

More value in the long run

Choose from—the long line of Allis-Chalmers engines. Take a look at performance curves that provide superior fuel efficiency, long-term reliability. Controlled Turbulence direct injection combustion mixes fuel and air completely to wring out every drop of power... turbocharging and intercooling contribute to cleaner burning, less smoke, less sludge, less noise, less waste heat—and low maintenance.

Features like these help explain, too, why A-C engines can perform beautifully in high altitudes without derating. Available in two, three, four and six cylinder models, ranging from 15 to 450 horsepower, there's a compact Allis-Chalmers engine readily adaptable to virtually any OEM application.

Choose back-up—from Allis-Chalmers worldwide service and support facilities... more reasons why A-C engines offer greater long-run values to assure customer satisfaction. For more information, write for our free Fuel Performance Map booklet and engine catalog. Allis-Chalmers, Engine Division, P.O. Box 1563, Harvey, Illinois 60426.

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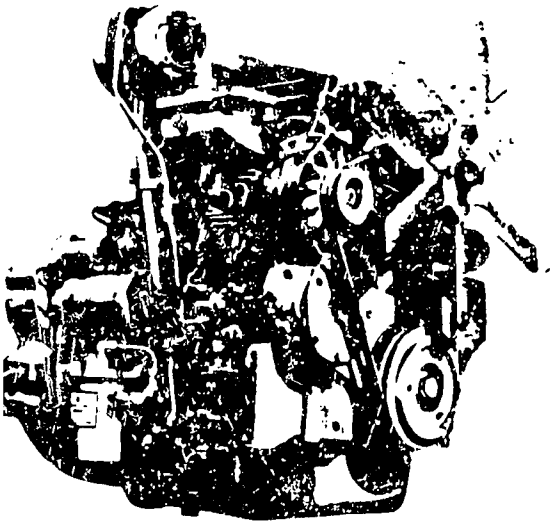
Industrial Application Ratings



Curve 1 Represents the power available at full throttle for applications in which the engine will operate under highly variable conditions of load and speed. Factory approval required.

Curve 2 Recommended power for variable load applications where full throttle operation might be required for extended periods... followed by equal periods of operation at reduced loads.

Curve 3 Recommended power to be used for driving sustained loads for continuous-duty operation.

213 Diesel	26 @ 2500 32 @ 3600	24 @ 2500 27 @ 3000	24 @ 2500 27 @ 3000	397 lbs. (180 kg)	21.57 in. (54.8 cm)	21.18 in. (53.8 cm)	27.95 in. (71.0 cm)
320 Diesel	38 @ 2500 53 @ 3600	36 @ 2500 49 @ 3600	35 @ 2500 40 @ 3000	507 lbs. (229 kg)	26.29 in. (66.8 cm)	20.11 in. (51.1 cm)	28.34 in. (72.0 cm)
426 Diesel	55 @ 2500 72 @ 3600	52 @ 2500 67 @ 3600	48 @ 2500 55 @ 3000	595 lbs. (270 kg)	30.80 in. (78.3 cm)	20.11 in. (51.1 cm)	28.34 in. (72.0 cm)
433 T Diesel	90 @ 2400	80 @ 2400	67 @ 2200	796 lbs. (361 kg)	33.40 in. (84.8 cm)	23.22 in. (59.0 cm)	34.12 in. (86.7 cm)
433 I Diesel	100 @ 2400	89 @ 2400	74 @ 2200	808 lbs. (367 kg)	33.40 in. (84.8 cm)	24.88 in. (63.5 cm)	34.12 in. (86.7 cm)
649 T Diesel	135 @ 2600	118 @ 2400	100 @ 2400	1100 lbs. (499 kg)	44.75 in. (113.7 cm)	22.75 in. (57.8 cm)	36.90 in. (93.7 cm)
649 I Diesel	155 @ 2600	139 @ 2400	121 @ 2400	1025 lbs. (465 kg)	42.90 in. (109.0 cm)	24.10 in. (61.2 cm)	29.56 in. (91.6 cm)
670 T Diesel	175 @ 2400	158 @ 2400	136 @ 2200	1425 lbs. (646 kg)	41.00 in. (104.1 cm)	29.50 in. (74.9 cm)	41.00 in. (104.1 cm)
670 I Diesel	200 @ 2400	180 @ 2400	158 @ 2200	1465 lbs. (665 kg)	41.00 in. (104.1 cm)	29.50 in. (74.9 cm)	41.00 in. (104.1 cm)
685 T Diesel	220 @ 2200	190 @ 2000	169 @ 2000	2300 lbs. (1043 kg)	51.78 in. (131.5 cm)	29.50 in. (74.9 cm)	48.72 in. (123.7 cm)
685 I Diesel	275 @ 2200	250 @ 2200	219 @ 2000	2320 lbs. (1052 kg)	54.01 in. (137.2 cm)	29.50 in. (74.9 cm)	48.69 in. (123.7 cm)
6138 LT Diesel	325 @ 2100	290 @ 2000	240 @ 1800	3275 lbs. (1486 kg)	62.37 in. (158.4 cm)	36.81 in. (93.5 cm)	51.94 in. (131.9 cm)
6138 T Diesel	375 @ 2100	325 @ 2000	280 @ 1800	3285 lbs. (1490 kg)	62.37 in. (158.4 cm)	36.81 in. (93.5 cm)	51.94 in. (131.9 cm)
6138 I Diesel	450 @ 2100	376 @ 2000	320 @ 1800	3330 lbs. (1510 kg)	62.37 in. (158.4 cm)	36.62 in. (93.0 cm)	53.25 in. (135.3 cm)

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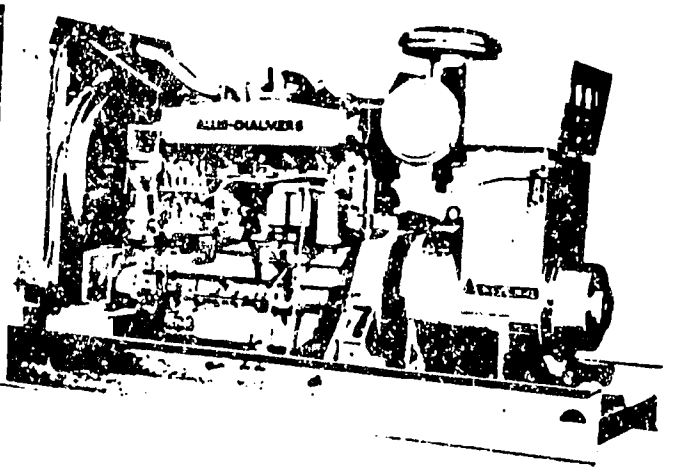
Generator Drive Ratings



Standby Power Rating—the power output at which an engine may operate for the duration of a commercial power outage.

Prime Power Rating—the power output at which an engine normally operates, with an overload capability for operating at a power output of up to the standby rating for intermittent periods.

60 Hertz

3600 RPM

Standby Rating 60 Hz	32 HP (24 KW)	53 HP (40 KW)	72 HP (53.7 KW)
Prime Rating 60 Hz	29 HP (22 KW)	50 HP (37 KW)	67 HP (50 KW)

1800 RPM

Standby Rating 60 Hz	19 HP (14 KW)	28 HP (21 KW)	39 HP (29 KW)	.75 HP (56 KW)	84 HP (63 KW)	113 HP (84 KW)	130 HP (97 KW)	162 HP (121 KW)	210 HP (157 KW)	249 HP (186 KW)	310 HP (231 KW)	390 HP (291 KW)	454 HP (339 KW)
Prime Rating 60 Hz	16 HP (12 KW)	26 HP (19 KW)	37 HP (28 KW)	67 HP (50 KW)	74 HP (55 KW)	100 HP (75 KW)	116 HP (87 KW)	133 HP (99 KW)	177 HP (132 KW)	212 HP (158 KW)	272 HP (203 KW)	335 HP (250 KW)	374 HP (279 KW)

50 Hertz

3000 RPM

Standby Rating 50 Hz	30 HP (22 KW)	48 HP (35 KW)	65 HP (48 KW)
Prime Rating 50 Hz	27 HP (20 KW)	45 HP (34 KW)	60 HP (45 KW)

1500 RPM

Standby Rating 50 Hz	16 HP (12 KW)	23 HP (17 KW)	[illegible] HP ([illegible] KW)	63 HP (47 KW)	70 HP (52 KW)	94 HP (70 KW)	110 HP (82 KW)	135 HP (101 KW)	175 HP (131 KW)	205 HP (153 KW)	260 HP (193 KW)	325 HP (242 KW)	378 HP (282 KW)
Prime Rating 50 Hz	14.5 HP (11 KW)	21 HP (16 KW)	30.5 HP (23 KW)	56 HP (42 KW)	62 HP (46 KW)	82 HP (61 KW)	97 HP (72 KW)	110 HP (82 KW)	150 HP (112 KW)	174 HP (130 KW)	226 HP (169 KW)	290 HP (216 KW)	325 HP (242 KW)

The information contained herein is general in nature and is not intended for specific application purposes. Allis-Chalmers reserves the right to make changes in specifications shown herein or add improvements at any time without notice or obligation.

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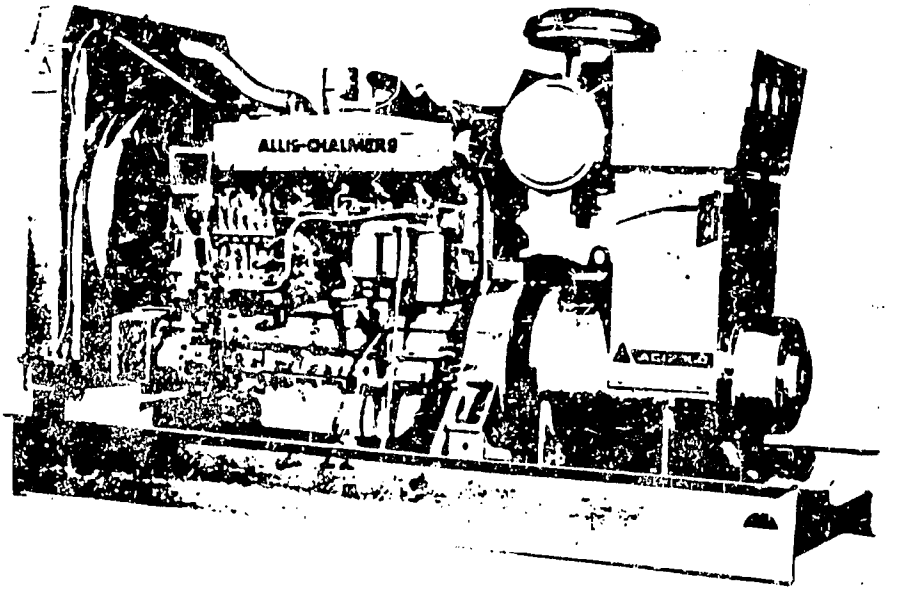
Generator Sets



Standby Power Rating:
The power at which the unit can operate continuously for the duration of a commercial power outage and is the maximum intermittent overload rating for continuous duty applications.

Prime Power Rating:
The power at which the unit can operate for continuous application with normal load factors with an overload capability up to the standby rating for intermittent periods.

All units are broad range generators with twelve leads brought out; the set can be reconnected to either high or low voltage range. Other voltages: consult factory.

Voltage Range		Low Range Voltage	High Range Voltage
60 cycle	3 wire	208 to 240	416 to 480
	4 wire	120/208 to 139/240	240/416 to 277/480
	Single Phase	120/240	–
50 cycle	3 wire	173 to 200	346 to 400
	4 wire	100/173 to 115/200	200/346 to 230/400
	Single Phase	100/200	–

11 models from 10 KW to 300 KW

1800 RPM–60 HERTZ–3Φ–.8 PF

Standby Rating KW	11.5	17.5	25	50	80	100	135	160	200	250	300
Prime Rating KW	10	15.5	22	45	75	75	108	130	175	200	250

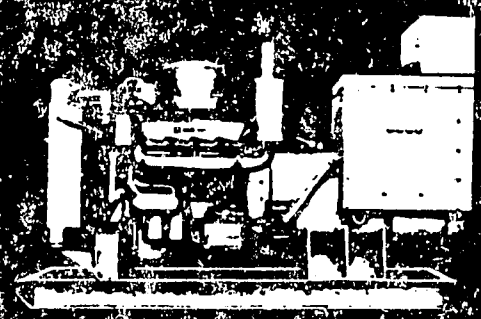
1500 RPM–50 HERTZ–3Φ–.8 PF

Standby Rating KW	9.5	14.5	20.5	41.6	66.6	83	112	130	165	208	250
Prime Rating KW	8.5	12.5	16	37.5	62.5	70	90	110	145	178	208

Note: The ACG 11.5, 17.5 & 25 models incorporate oversized alternators to provide the same rating at single phase and unity power factor as they have at three phase and .8 power factor.

Caterpillar Selection Guide for Diesel Standby and Prime Power

50kW 52kW 60kW 62kW 64kW 70kW 75kW 78k
W 80kW 83kW 84kW 85kW 100kW 102kW 103kW
105kW 107kW 110kW 11 W 120k
W 125kW 127kW 131kW 6kW 14
0kW 145kW 150kW 154k W 160k
W 165kW 170kW 175kW kW 185
kW 190kW 200kW 205k 220kW
225kW 230kW 235kW 240kW 250kW 255kW 260
kW 265kW 275kW 280kW 285kW 300kW 305kW
310kW 315kW 320kW 325kW 330kW 345kW 350
kW 355kW 360kW 365kW 370kW 375kW 385kW
390kW 395kW 400kW 415kW 420kW 430kW 440
kW 450kW 455kW 460kW 470kW 480kW 485kW
495kW 500kW 505kW 525kW 530kW 540kW 555
kW 560kW 565kW 575kW 600kW 605kW 630kW
650kW 675kW 685kW 700kW 730kW 735kW 750
kW 760kW 775kW 785kW 800kW 820kW 830kW
840kW 850kW 900kW 935kW 950kW 985kW 100
0kW 1050kW 1100kW 1200kW 1235kW 1400kW

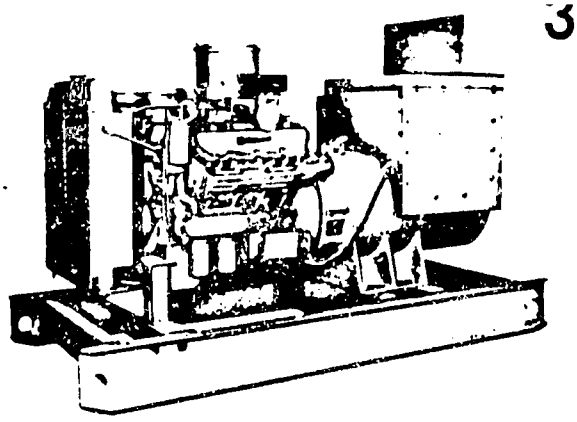


Brief Specifications

This catalog provides a convenient guide to the range of Cat Generator Sets for your standby or prime power applications.

Cat Generator Sets are proven economical and dependable prime power sources in thousands of installations worldwide. And, they are widely applied where high quality, reliable standby power is desired.

Note: Weights and dimensions are for diesel engines, consult your Caterpillar Dealer for natural gas specifications.



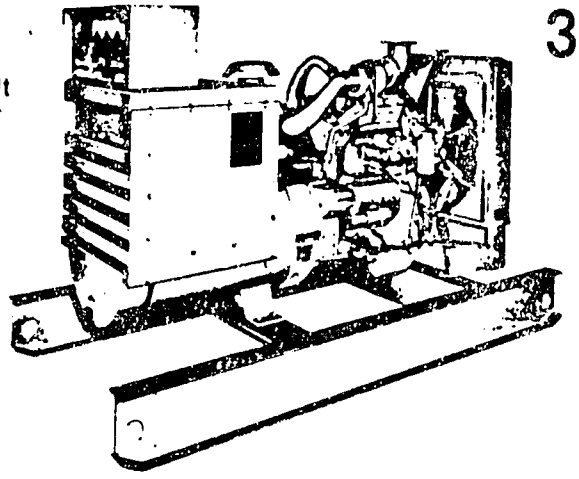
3208

GENERATOR SET DATA

Output range: 60 to 154 kW
Weight (dry): 3400 to 3700 lb (1543 to 1680 kg)
Dimensions (L x W x H)
without radiator: 77.18 x 34.81 x 60.15 in (1960 x 884 x 1528 mm)
with radiator: 87.33 x 34.81 x 60.15 in (2218 x 884 x 1528 mm)

ENGINE DATA

V8 1800 or 1500 rpm
Bore: 4.5 in (114 mm)
Stroke: 5.0 in (127 mm)
Displacement: 636 cu in (10.4 liter)
Aspiration: Naturally Aspirated or Turbocharge



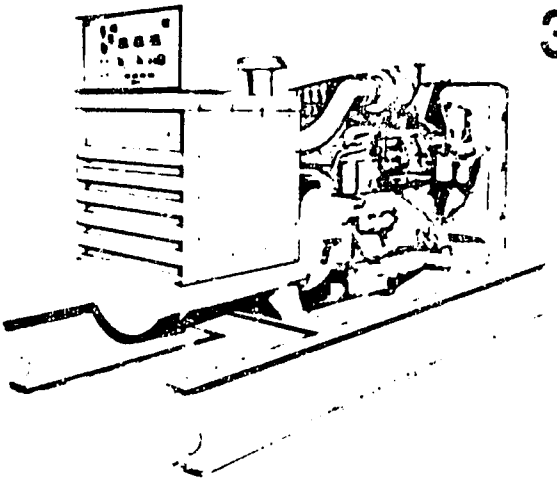
3304B

GENERATOR SET DATA

Output range: 50 to 130 kW
Weight (dry): 3350 to 3740 lb (1520 to 1696 kg)
Dimensions (L x W x H)
without radiator: 77.2 x 30.7 x 45.9 in (1962 x 781 x 1166 mm)
with radiator: 100.6 x 48.0 x 61.0 in (2555 x 1220 x 1550 mm)

ENGINE DATA

In-line 4 1800 or 1500 rpm
Bore: 4.75 in (121 mm)
Stroke: 6.0 in (153 mm)
Displacement: 425 cu in (7.0 liter)
Aspiration: Naturally Aspirated or Turbocharge



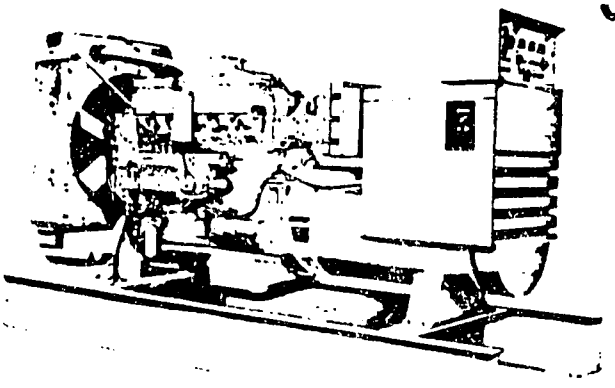
3306B

GENERATOR SET DATA

Output range: Diesel 115 to 206 kW
Natural Gas 70 to 150 kW
Weight (dry): 4350 to 4750 lb (1969 to 2155 kg)
Dimensions (L x W x H)
without radiator: 92.7 x 30.8 x 46.8 in (2355 x 783 x 1188 mm)
with radiator: 121.7 x 48.0 x 63.0 in (3090 x 1220 x 1600 mm)

ENGINE DATA

In-line 6 1800 or 1500 rpm
Bore: 4.75 in (121 mm)
Stroke: 6.0 in (153 mm)
Displacement: 638 cu in (10.5 liter)
Aspiration: Turbocharged or Turbocharged Aftercooled



3406B

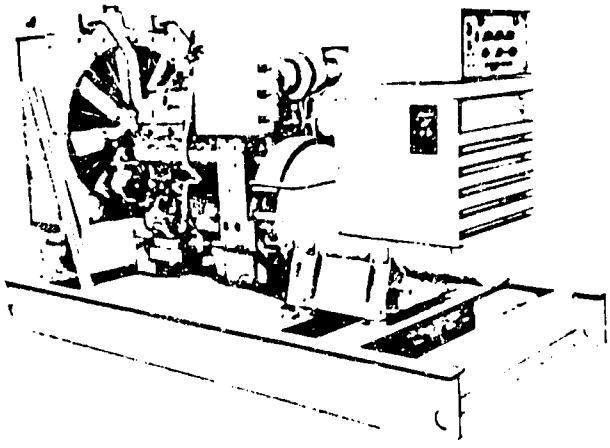
GENERATOR SET DATA

Output range: 160 to 315 kW
Weight (dry): 5700 to 5915 lb (2586 to 2682 kg)
Dimensions (L x W x H)
without radiator: 106.0 x 35.5 x 52.6 in (2692 x 902 x 1335 mm)
with radiator: 133.5 x 48.0 x 71.4 in (3390 x 1220 x 1815 mm)

ENGINE DATA

In-line 6 1800 or 1500 rpm
Bore: 5.4 in (137 mm)
Stroke: 6.5 in (165 mm)
Displacement: 893 cu in (14.6 liter)
Aspiration: Turbocharged or Turbocharged Aftercooled

170



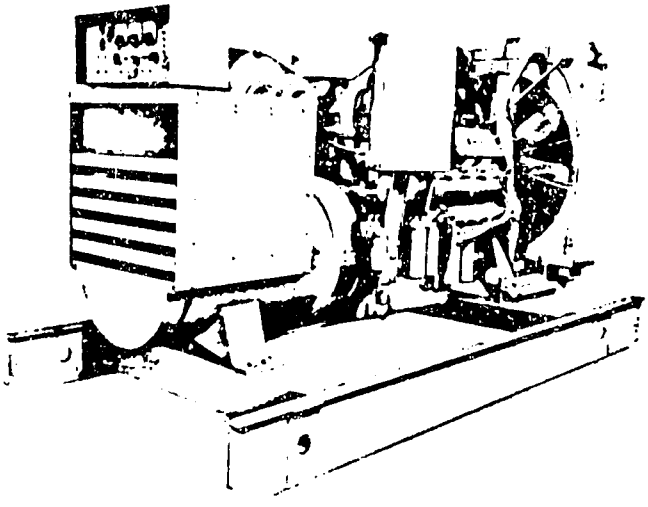
3408B

GENERATOR SET DATA

Output range: 230 to 410 kW
Weight (dry): 7665 to 8085 lb
(3476 to 3667 kg)
Dimensions (L x W x H)
without radiator: 101.8 x 48.5 x 54.0 in
(2585 x 1231 x 1371 mm)
with radiator: 132.4 x 61.4 x 80.1 in
(3365 x 1560 x 2035 mm)

ENGINE DATA

V8 1800 or 1500 rpm
Bore: 5.4 in (137 mm)
Stroke: 6.0 in (153 mm)
Displacement: 1099 cu in (18.0 liter)
Aspiration: Turbocharged or Turbocharged Aftercooled



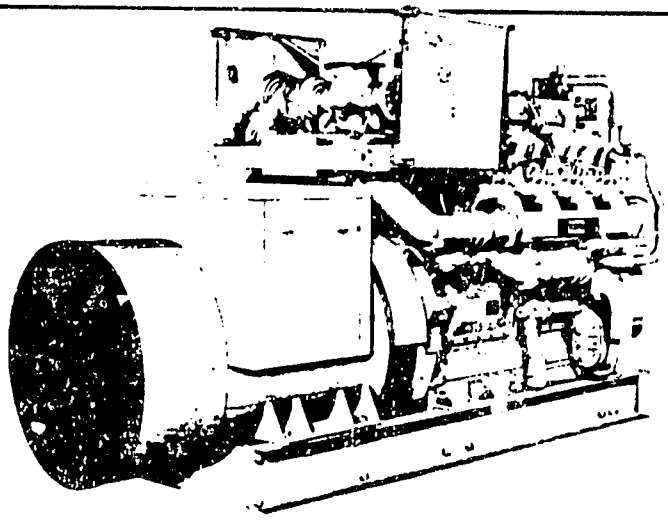
3412

GENERATOR SET DATA

Output range: 280 to 620 kW
Weight (dry): 7060 to 9610 lb
(3202 to 4358 kg)
Dimensions (L x W x H)
without radiator: 119.4 x 58.0 x 58.9 in
(3033 x 1483 x 1495 mm)
with radiator: 150.6 x 70.0 x 82.0 in
(3825 x 1780 x 2085 mm)

ENGINE DATA

V12 1800 or 1500 rpm
1200 or 1000 rpm (slow speed)
Bore: 5.4 in (137 mm)
Stroke: 6.0 in (153 mm)
Displacement: 1649 cu in (27.0 liter)
Aspiration: Turbocharged or Turbocharged Aftercooled



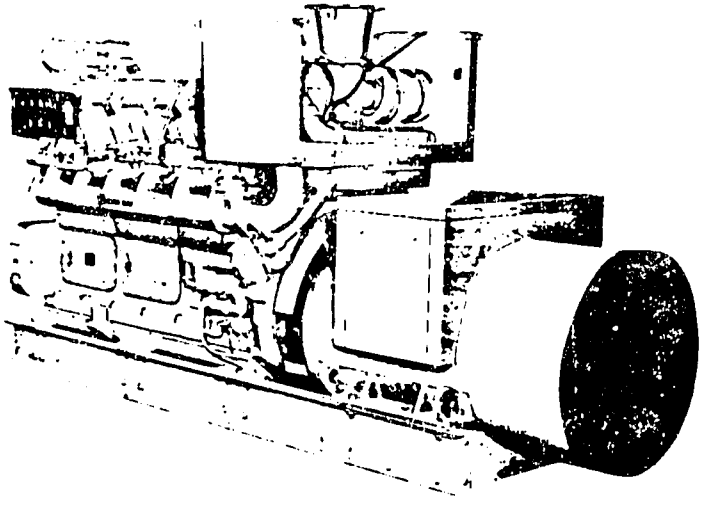
D379

GENERATOR SET DATA

Output range: Diesel 315 to 450 kW
Natural Gas 170 to 325 kW
Weight without radiator (dry): 13,200 lb
(5990 kg)
Dimensions (L x W x H)
without radiator: 120.4 x 59.3 x 75.4 in
(3060 x 1505 x 1915 mm)
with radiator: 143.7 x 62.0 x 84.6 in
(3650 x 1575 x 2150 mm)

ENGINE DATA

V8 1200 or 1000 rpm
Bore: 6.25 in (159 mm)
Stroke: 8.0 in (203 mm)
Displacement: 1964 cu in (32.2 liter)
Aspiration: Turbocharged Aftercooled



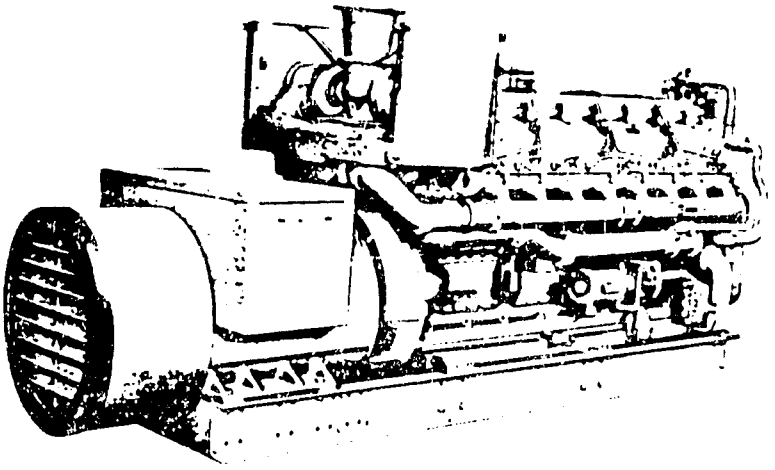
D398

GENERATOR SET DATA

Output range: Diesel 480 to 675 kW
Natural Gas 260 to 500 kW
Weight without radiator (dry): 17,985 lb
(8158 kg)
Dimensions (L x W x H)
without radiator: 157.4 x 60.5 x 78.8 in
(3710 x 1505 x 2000 mm)
with radiator: 189.7 x 73.0 x 86.7 in
(4820 x 1855 x 2200 mm)

ENGINE DATA

V12 1200 or 1000 rpm
Bore: 6.25 in (159 mm)
Stroke: 8.0 in (203 mm)
Displacement: 2946 cu in (48.3 liter)
Aspiration: Turbocharged Aftercooled



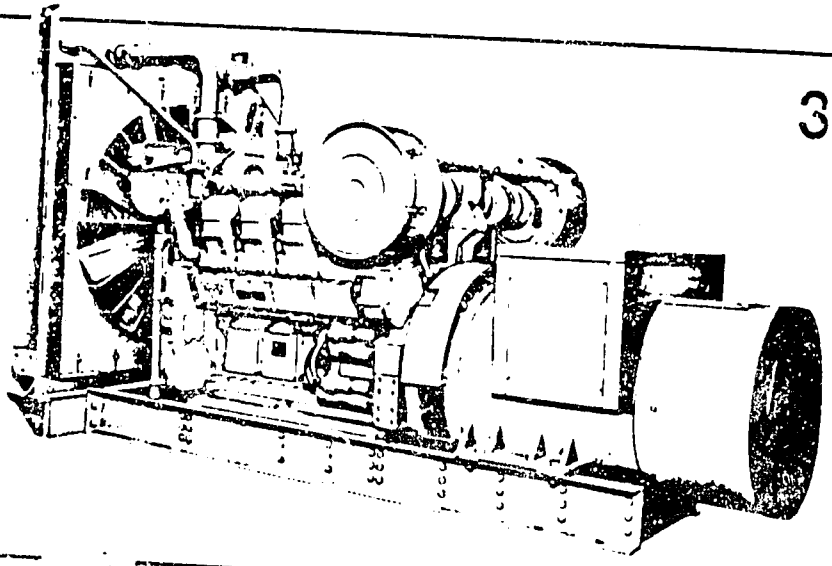
D399

GENERATOR SET DATA

Output range Diesel 685 to 930 kW
Natural Gas 345 to 650 kW
Weight without radiator (dry) 22,700 lb (10 297 kg)
Dimensions (L x W x H)
without radiator 175 0 x 59 3 x 78 8 in (4445 x 1505 x 2000 mm)
with radiator. 217 8 x 87 5 x 100 5 in (5530 x 2223 x 2553 mm)

ENGINE DATA

V16 1200 or 1000 rpm
Bore. 6 25 in (159 mm)
Stroke 8 0 in (203 mm)
Displacement 3928 cu in (64 4 liter)
Aspiration. Turbocharged Aftercooled



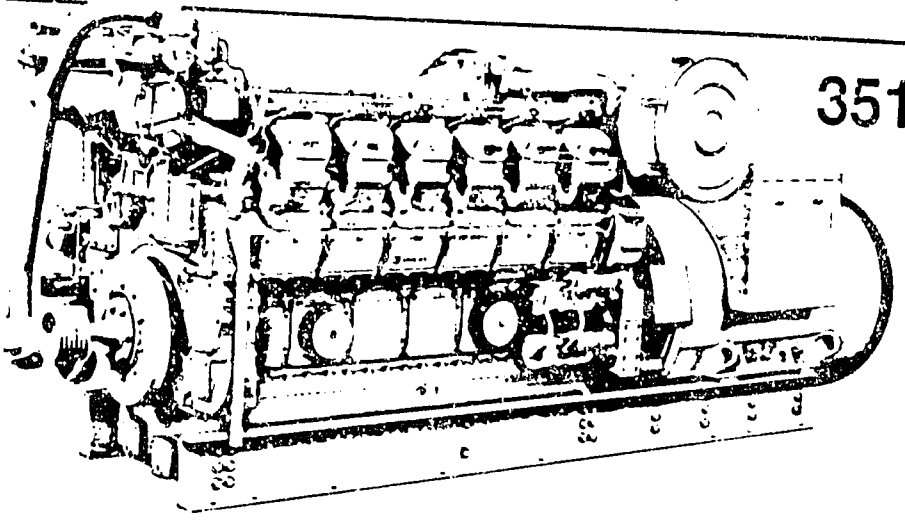
3508

GENERATOR SET DATA

Output range 400 to 765 kW
Weight without radiator (dry) 15,500 lb (7031 kg)
Dimensions (L x W x H)
without radiator 138 1 x 67 0 x 67.7 in (3509 x 1703 x 1720 mm)
with radiator. 177.2 x 73.0 x 90 2 in (4500 x 1854 x 2291 mm)

ENGINE DATA

V8 1800 or 1500 rpm
1200 or 1000 rpm (slow speed)
Bore. 6.7 in (170 mm)
Stroke. 7 5 in (190 mm)
Displacement 2105 cu in (34 5 liter)
Aspiration. Turbocharged Aftercooled



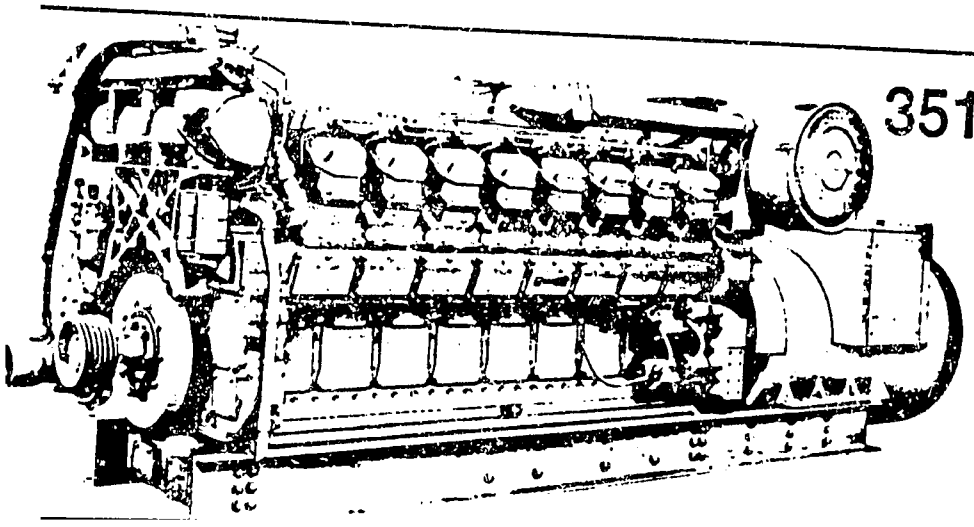
3512

GENERATOR SET DATA

Output range 600 to 1085 kW
Weight without radiator (dry): 20,610 lb (9347 kg)
Dimensions (L x W x H)
without radiator: 157 2 x 67 1 x 67 7 in (3995 x 1705 x 1720 mm)
with radiator: 196 3 x 87 5 x 100 6 in (4985 x 2223 x 2555 mm)

ENGINE DATA

V12 1800 or 1500 rpm
1200 or 1000 rpm (slow speed)
Bore: 6.7 in (170 mm)
Stroke: 7.5 in (190 mm)
Displacement. 3158 cu in (51 8 liter)
Aspiration. Turbocharged Aftercooled



3516

GENERATOR SET DATA

Output range. 700 to 1400 kW
Weight without radiator (dry). 23,400 lb (10 200 kg)
Dimensions (L x W x H)
without radiator: 187 5 x 67 0 x 73 9 in (4761 x 1703 x 1876 mm)
with radiator: 230 3 x 87.5 x 100 5 in (5846 x 2223 x 2553 mm)

ENGINE DATA

V16 1800 or 1500 rpm
1200 or 1000 rpm (slow speed)
Bore. 6.7 in (170 mm)
Stroke: 7 5 in (190 mm)
Displacement: 4210 cu in (69 1 liter)

Caterpillar Diesel Generator Set Ratings

Ratings Without Fan					Ratings With Fan				Available Voltages	
60 Hz kW		50 Hz kW			60 Hz kW		50 Hz kW			
Standby	Prime	Standby	Prime	Model	Standby	Prime	Standby	Prime	60 Hz	50 Hz
64	64	55	55	3304B NA	60	60	50	50	2,4,5	1,4
77	68	62	—	3304B T	75	68	60	—	—	1,4
95	84	75	62	3304B T	95	80	72	60	2,4,5	1,4
103	78	82	62	3208 NA	100	75	80	60	2,4,5	1,4
130	105	103	87	3304B T	125	100	100	80	2,4,5	1,4
128	103	107	82	3208 T	125	100	105	80	2,4,5	1,4
155	131	122	115	3306B T	150	125	120	115	2,4,5	1,4
182	156	148	138	3306B T	175	150	144	130	2,4,5	1,4
154	119	128	103	3208 T	150	115	125	100	2,4,5	1,4
—	—	—	141	3306B T	—	—	—	138	2,4,5	1,4
206	183	167	154	3306B TA	200	175	160	150	2,4,5	1,4
250	210	180	165	3406B T	240	200	175	160	2,4,5	1,4
260	220	205	185	3406B T	250	210	200	180	2,4,5	1,4
350	265	280	235	3408B T	350	255	280	230	2,4,5	1,4
315	260	250	210	3406B TA	300	250	240	200	2,4,5	1,4
410	320	325	290	3408B TA	400	310	320	285	2,4,5	1,4
—	330	—	285	3412 TA*	—	325	—	280	4,5	1,4
—	365	—	—	3412 T	—	355	—	—	2,4,5	1,4
450	420	390	330	D379 TA†	430	400	375	315	4,5	1,4
460	365	370	330	3412 T	450	355	360	320	2,4,5	1,4
480	440	425	410	3508 TA*	485	425	420	400	4,5	1,4
520	409	410	370	3412 T	500	400	400	360	2,4,5	1,4
520	468	—	—	3412 TA	500	455	—	—	2,4,5	—
620	468	480	420	3412 TA	600	455	480	410	2,4,5	1,4
665	610	540	500	3508 TA	665	600	540	500	4,5	1,4
765	610	615	500	3508 TA	750	600	600	500	4,5	1,4
675	600	560	500	D398 TA†	650	575	540	480	4,5	1,4
730	680	655	610	3512 TA*	700	650	650	600	4,5	1,4
965	775	800	715	3512 TA	955	750	800	700	4,5	1,4
830	850	775	700	D399 TA†	900	820	760	685	3,7,8	1,6,7
1005	930	790	730	3516 TA*	975	900	760	700	7,8	6,7
1085	935	980	880	3512 TA	1050	900	950	850	7,8	6,7
1220	1100	1150	1030	3516 TA	1220	1100	1120	1000	—	—
1400	1265	1305	1135	3516 TA	1400	1250	1280	1100	7,8	6,7

RATING CONDITIONS
Ratings are based on SAE J1349 standard conditions. Also applies at ISO 3046/1, DIN 6271 and BS 5514 standard conditions.

kW = kilowatts
Hz = Hertz or cycles per second
NA = naturally aspirated
T = turbocharged
TA = turbocharged and aftercooled

DEFINITIONS
Standby power — for continuous electrical service during interruption of normal power
Prime power — for continuous electrical service with 10% overload capability except where noted with †
kV•A ratings are 1.25 times kW ratings listed

Available Voltages (all adjustable ± 5%; some models ± 10%)

1 115/200 — 230/400
2 120/208 — 240/416
3 133/230 — 266/460
4 139/240 — 277/480
5 173/300 — 346/600
6 230/400
7 277/480
8 346/600

*Low speed version

Materials and specifications are subject to change without notice

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CATERPILLAR

Worldwide support for Cat Generator Sets

More than 1100 Caterpillar Dealer outlets worldwide provide a variety of services to help you select and maintain Cat Diesel and Natural Gas Generator Sets. These CAT PLUS services include:

- **Prepurchase consultation** to help fit the installation package precisely to your special needs and specifications.
- **Start-up inspection and orientation,** upon request, to assure proper operation from day one.
- **Operator and service training** classes to help you get highest productivity and efficiency out of your Cat Generator Set.
- **Preventive maintenance services** offered by many dealerships include Scheduled Oil Sampling to anticipate potential trouble spots. Allows you to schedule preventive repairs when most convenient.
- **A service contract** with your dealer to help control owning and operating costs.
- **The Cat Dealer's extensive parts inventory** to help keep your Cat Engine, Generator and Controls operating properly and profitably. Backed by 24 strategically located Cat parts facilities.
- **Parts and component exchange** service to allow replacement of worn components with rebuilt instead of new ones at your option. Saves time and money.
- **Caterpillar-qualified servicemen** staff Cat Dealer service shops and provide fast, expert service.

LECQ4232
Supersedes LECQ3547

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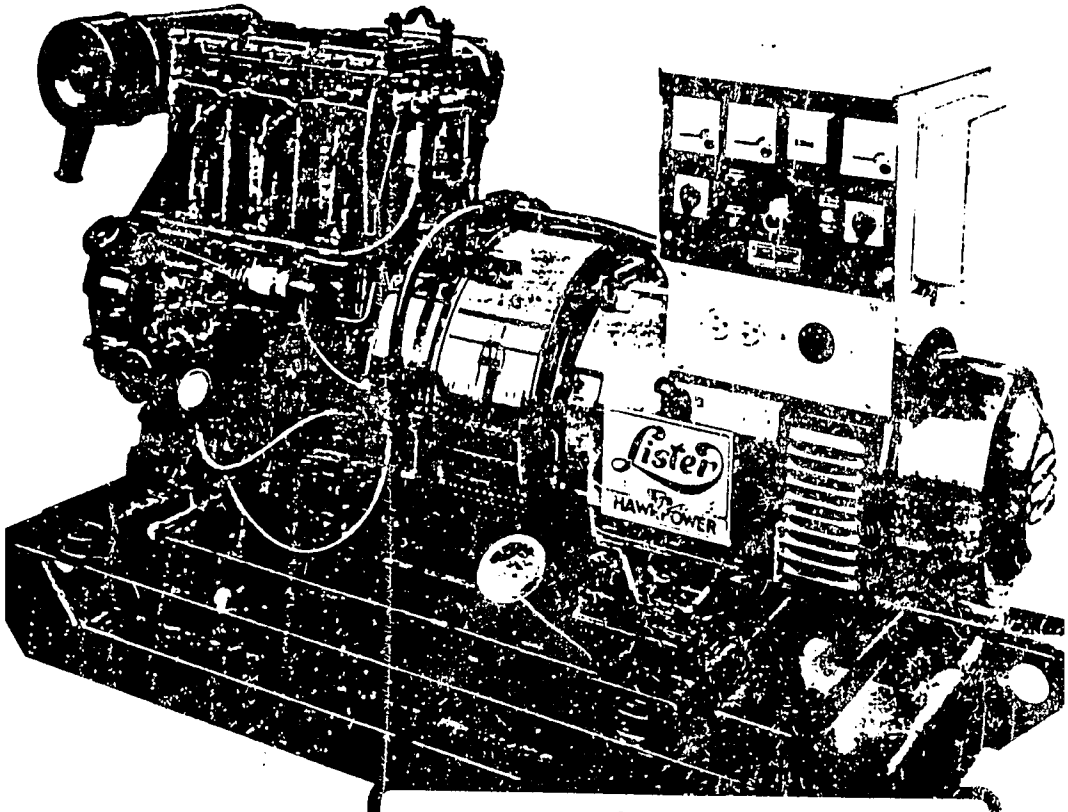


Lister

HAWKPOWER®

A new name from a name you know

An entirely new concept in Generating Sets from Lister Diesels Inc. The combination of modular design coupled with the legendary ruggedness and reliability of Lister Diesels has resulted in a range of Generating Sets which may be individually customized to suit virtually any user requirements.

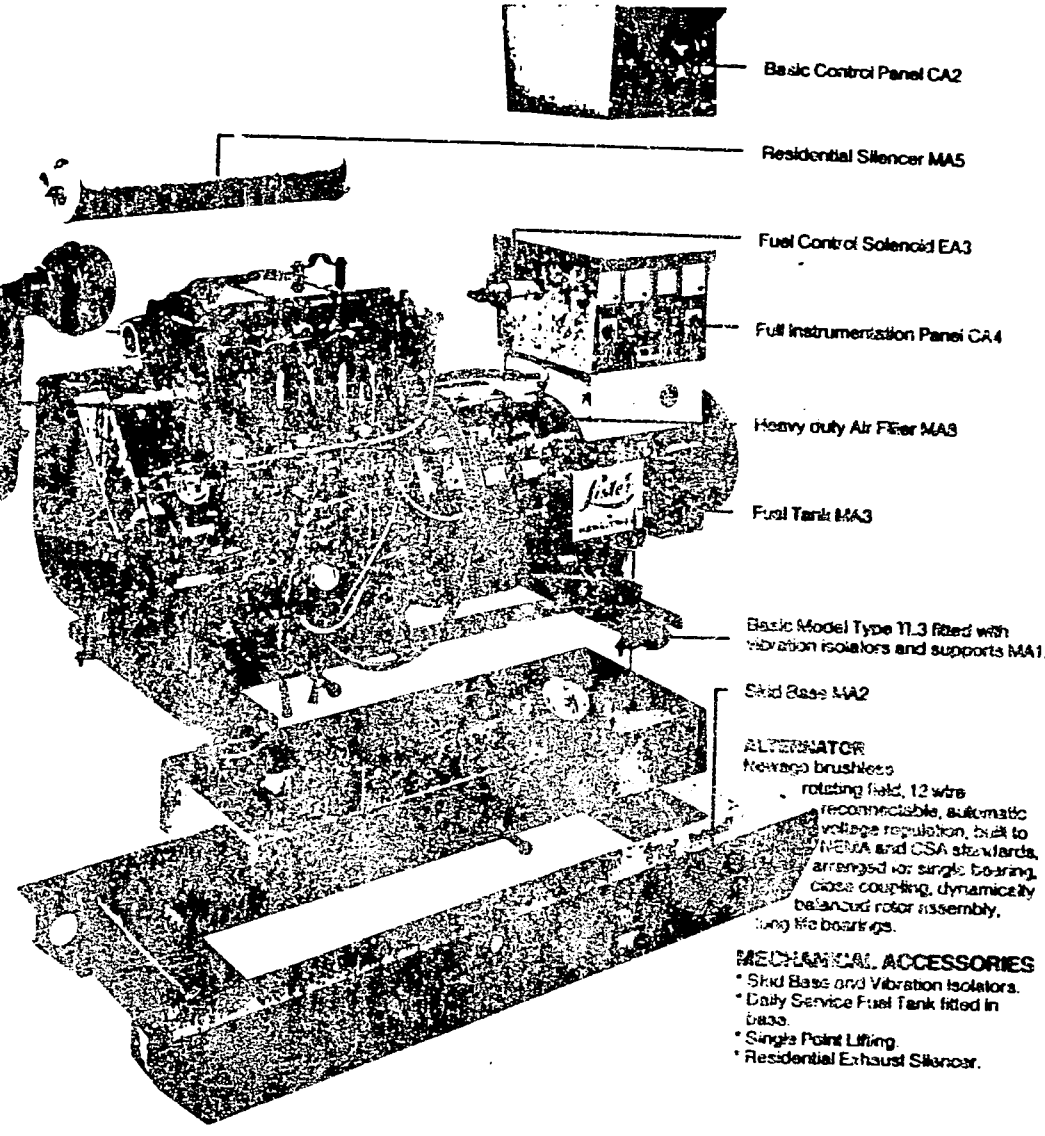
TAILE POWER OUTPUT:
Any of the world-proven Lister ranges of air-cooled diesels can be incorporated into your unit to deliver power from 2kw to 130kw.

TAILE ADAPTABILITY:
Off-the-shelf, a wide range of specially added components can be fitted by your distributor to provide you with a customized unit quickly, efficiently, and economically.
If you need a mobile power source, you can opt for trailer mounting instead of base-plate mounting.
The fuel tank can be built into the skid base or located remotely. Control panels of various degrees of sophistication are available and there's a choice of automatic or key-start.

TAILE APPLICATIONS:
HAWKPOWER® Generating Sets can be configured to suit virtually any industrial, agricultural or commercial application; in hospitals to keep vital equipment running in a brown out; in computer installations to maintain essential data; in process industries to keep lines operational; on construction sites in remote locations requiring base load such as telecommunications or cathodic protection; in food stores and to prevent panic when mains power fails; in the gas and oil industries; and even in the home.
In fact, wherever a totally reliable power source is required.
Over 60 years of success in the field makes a Lister Generating Set the first choice, whether the unit needs to run non-stop for six months without attention, or be idle for six months then start immediately.
Every HAWKPOWER® Generating Set is delivered with a full warranty, and is backed by the nationwide Lister parts and service organisation. A full advisory service is available to ensure that customers can derive maximum benefits from HAWKPOWER®'s modular design.
Whatever climatic or environmental conditions you operate in, any unit from the HAWKPOWER® range can be guaranteed to give you outstanding reliability, low fuel consumption, minimum maintenance and long life.

SPECIFICATION
The units are designed around a modular construction enabling a basic close coupled diesel engine and 12 wire single bearing alternator to be customized into a multitude of configurations meeting a wide range of applications.

ENGINE
The world renowned Lister air-cooled industrial diesel arranged for 12 volt electric start, with replaceable element fuel and oil filters (spin on 4 – 13kw), cold starting facility, air cleaner, direct injection, exhaust muffler.



MECHANICAL ACCESSORIES
- Skid Base and Vibration Isolators.
- Daily Service Fuel Tank fitted in base.
- Single Point Lifting.
- Residential Exhaust Silencer.
- Extended Long Running Lub Oil System.
- Air Ducting Flange.
- Heavy Duty Air Filter.
- Weather Protective Canopy.
- Road Towing Trailer.

ELECTRICAL ACCESSORIES
- Oil Pressure Failure Protection Switch.
- High Engine Temperature Protection Switch.
- Energised to Run Fuel Control Solenoid.
- 12 volt Starter Battery.
- Set Mounted Battery Rack and Leads.
- Rotary Switch for Selecting Alternator Configurations.

CONTROL PANEL OPTIONS
A multitude of control panel options are available with a standard mounting frame fitted to the alternator to receive any one of the many options offered, with vibration isolators fitted between the mounting frame and control panel.

CONTROL PANEL VARIATIONS AVAILABLE

Battery Charging
Up to and including HR3 solid state charger in control panel – HL4 and above charging alternator.

Meters
Ammeter, Voltmeter and selection switches, Frequency Meter, Running Hour Recorder.

Lamp Indication
For Charger Failure, Oil Pressure Failure, Excess Engine Temperature.

Circuit Breakers
Standard to U.S. specification also CSA and Ground Fault Protection available.

Auto Transfer Panel
With full Instrumentation Variable Voltage Level Detection and Mechanical and Electrical Interlocked Change-Over-Contactors.

Receptacles
Cubicle Support will receive a variety of Twist Lock and Duplex Switches.

Technical Specification

BASIC MODEL TYPES

MODEL TYPE	PHASE	KILOWATTS
LT1	1Ø	4.1
	3Ø	TBA
ST1	1Ø	3.9
	3Ø	4.3
LV2	1Ø	6.3
	3Ø	6.8
TS2	1Ø	7.9
	3Ø	9
TS3	1Ø	12.1
	3Ø	13.7
TL3	1Ø	15.7
	3Ø	17.1
HR2	1Ø	15.4
	3Ø	17.1
HR3	3Ø	25.5
HL4	3Ø	34.0
HL6	3Ø	51.8
HLT6	3Ø	75.6
JA6	3Ø	93.9
JAS6	3Ø	128.4

MECHANICAL ACCESSORIES

DESCRIPTION	CODE
Vibration Isolators and Support	MA1
Skid Base	MA2
Fuel Tank in Base	MA3
Single Point Lifting	MA4
Residential Silencer	MA5
Long Running Oil System	MA6
Air Duct Adaptor	MA7
Heavy Duty Air Filter	MA8
Weather Protective Canopy	MA9
Road Towing Trailer	MA10
Oil Pressure Gauge	MA11
Fuel Lift Pump	MA12
Export Packing	MA13
Delivery FOB UK Port	MA14

ELECTRICAL ACCESSORIES

DESCRIPTION	CODE
Oil Pressure Switch	EA1
Engine Temperature Switch	EA2
Fuel Control Solenoid	EA3
Starter Battery	EA4
Battery Rack and Leads	EA5
12 Wire Rotary Switch	EA6

CONTROL PANEL OPTIONS

	CONTROL PANEL OPTIONS										
Components Included in Control Panels	CA2	CA3	CA4	CA5	CA6	CA7	CA8	CA9	CA10	CA11	CA12
Single action key start switch	*	*	*	*	*	*	*	*			
Terminal block	*			*	*						
Solid state battery charger and lamp	*	*	*	*	*	*	*	*		*	*
Circuit breaker		*	*			*	*	*		*	
Oil pressure protection switch and lamp			*	*	*	*	*	*		*	*
Engine temp. protection switch and lamp					*		*	*		*	*
Ammeter and ammeter selector switch			*					*		*	
Voltmeter and voltmeter selector switch			*					*		*	
Frequency meters			*					*		*	
Hours run recorder			*					*		*	
Auto transfer switch								*			
Auto start stop									*		

TECHNICAL DATA

60 Cycle SINGLE PHASE. 3 WIRE. 240/120 VOLT. 0.8 PF.

Model	Kw	Fuel Consumption Full Load U.S. Gall/Hour	Dimensions* L	W	H	Weight* Nett lb
HP1 ST1	3.9	0.423	54	24	35	715
HP1 LT1	4.1	0.587	34	20	26	350
LV2	6.3	0.682	39.5	20	28	475
HP1 TS2	7.9	0.86	48	24	35	975
HP1 TS3	12.1	1.28	55	24	35	110
HP1 TL3	15.7	1.55	55	24	35	1200

60 Cycle THREE PHASE. FOUR WIRE. 208/120 and 480/277 VOLT 0.8 PF.

HP3 ST1	4.3	0.423	54	24	35	715
LV2	6.8	0.682	39.5	20	28	475
HP3 TS2	9.0	0.86	48	24	35	975
HP3 TS3	13.7	1.28	55	24	35	110
HP3 HR2	17.1	1.64	59	32	45	1716
HP3 TL3	17.1	1.55	55	24	35	1200
HP3 HR3	25.5	2.4	68	32	45	1760
HP3 HL4	34.0	3.13	80	32	45	2530
HP3 HL6	51.8	4.62	88	32	53	2860
HP3 HLT6*	75.6	6.4	88	32	53	2880
HP3 JA6	93.9	7.55	125	40	57	3650
HP3 JAS6*	128.4	10.4	125	40	61	3650

RPM: All sets 1,800 RPM except LT1, 3,600 RPM

DERATING

The outputs shown above should be derated for the following environmental conditions.

Altitude
Derate 3.5% (turbo charged engines – 2½%) for every 1000ft above 500ft above sea level.

Temperature
Derate 2% for every 10°F above 85°F.

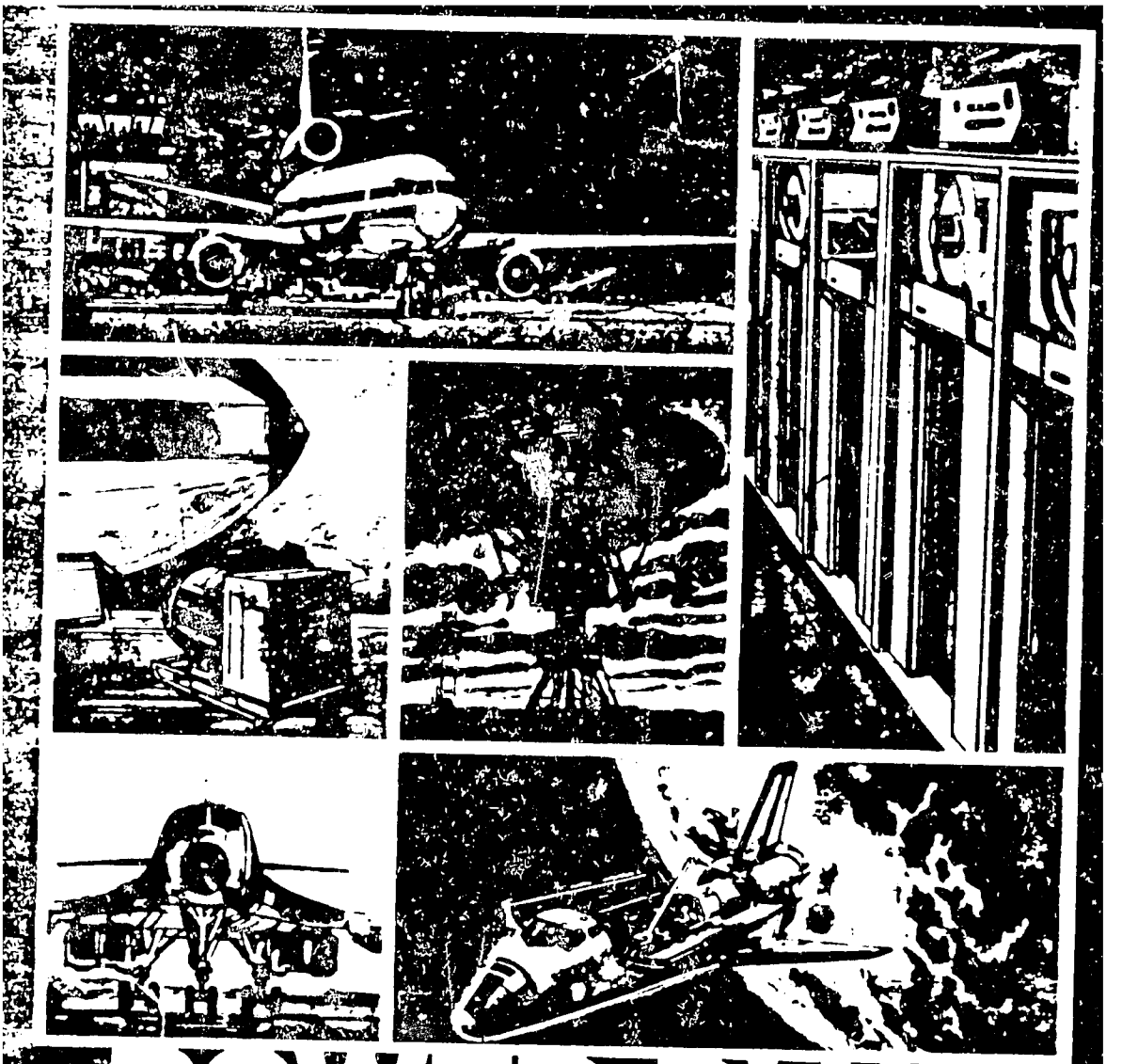
Humidity
Derate up to a maximum of 6%.

** The weights and dimensions assume a basic set complete with base plate, fuel tank, control range and vibration isolators.*

HAWKER SIDDELEY
LISTER DIESELS INC.
555 EAST 56 HIWAY, OLATHE, KANSAS, 66061
TELE: (913) 764-3512 TELEX: 42-6262

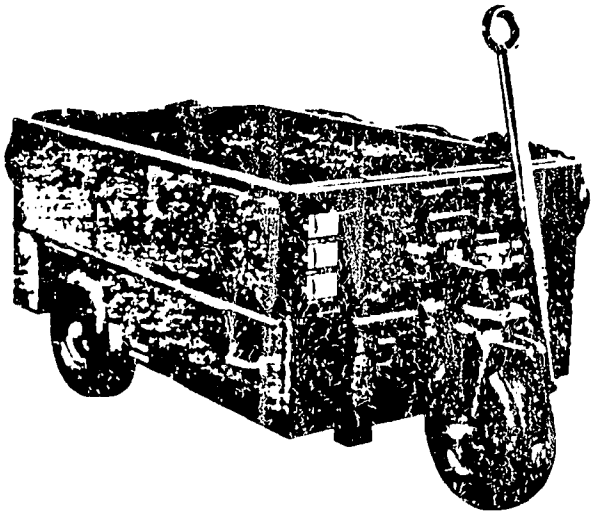
Hawker Siddeley Group supplies electrical and mechanical equipment with world-wide sales and service.

KR

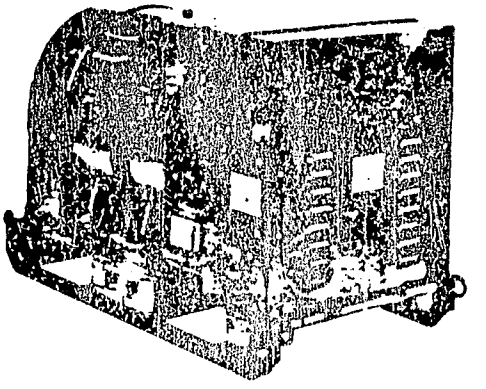


POWER-PLUS
MOTOR GENERATOR SETS

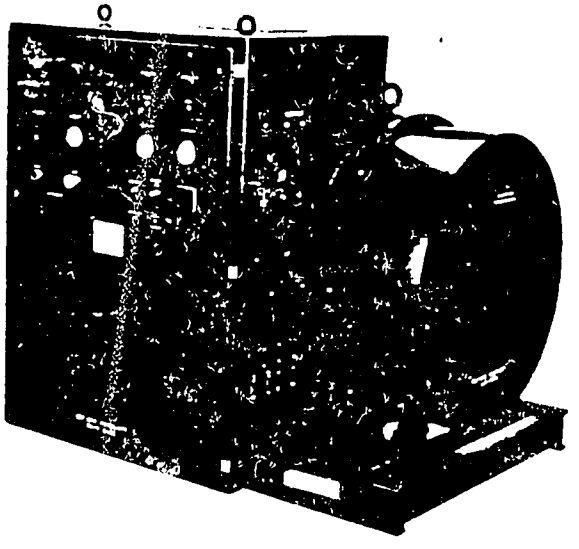
15-250 kW



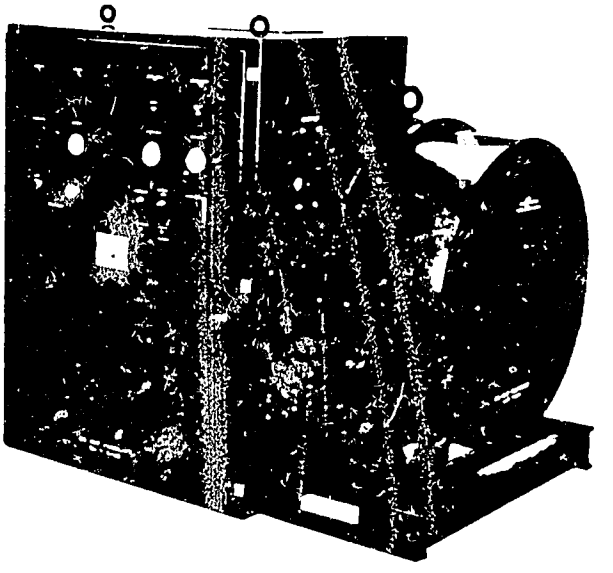
MC1-A
60 Hz—400 Hz
30 kW 3-Phase Output
500 Amp 28 Volts DC Output



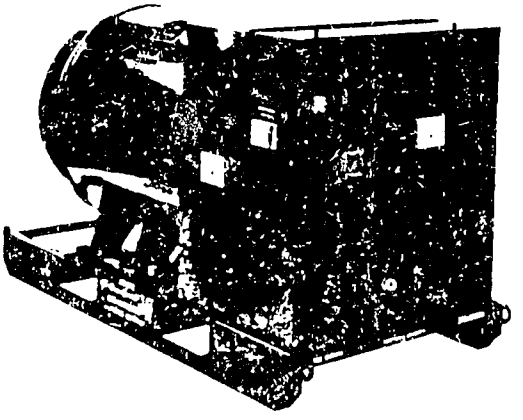
MD-2
60 Hz—400 Hz
15 kW 3-Phase Output
10 kW Single-Phase Output



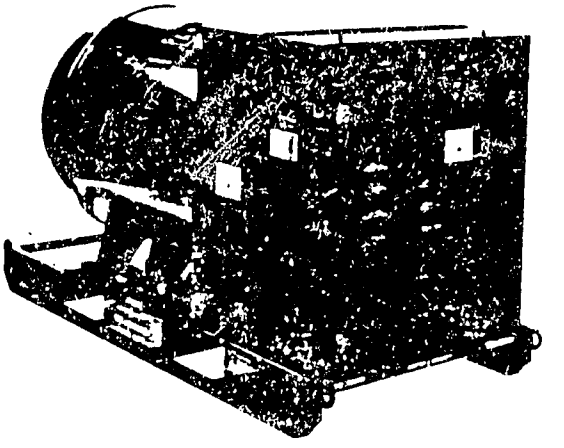
35-1-400
60 Hz—400 Hz
100 kW 3-Phase Output
65 kW Single-Phase Output



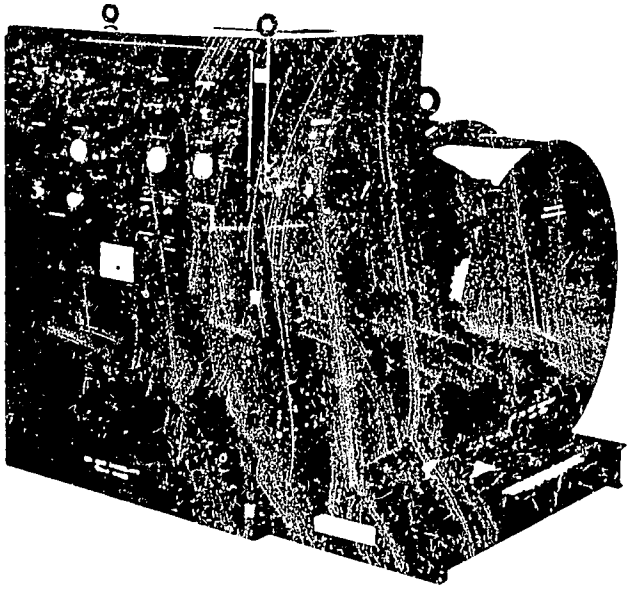
35-2-400
60 Hz—400 Hz
125 kW 3-Phase Output
80 kW Single-Phase Output



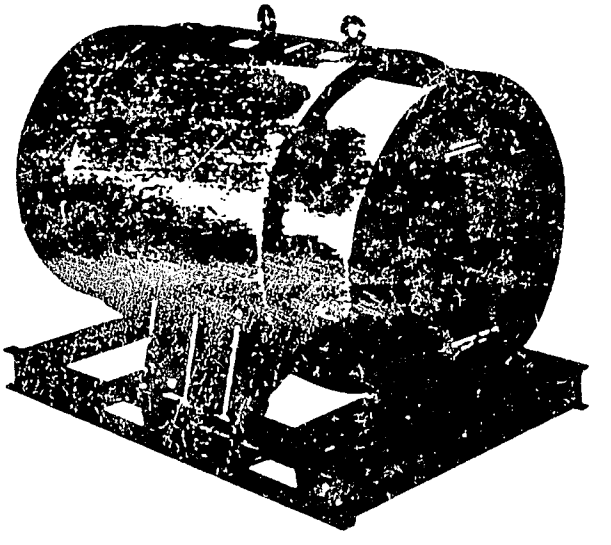
MD-3
60 Hz—400 Hz
30 kW 3-Phase Output
20 kW Single-Phase Output



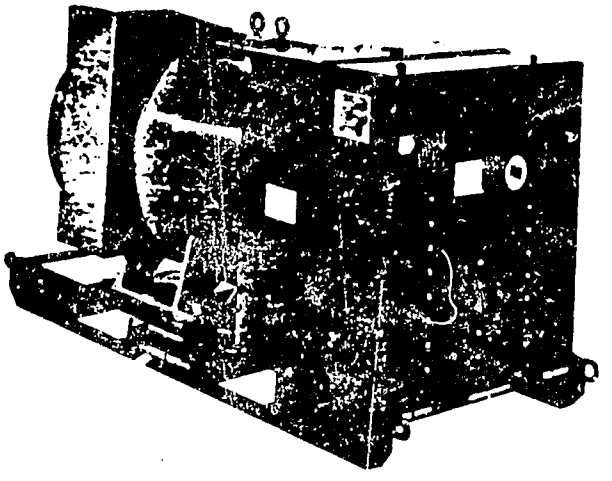
MD-4
60 Hz—400 Hz
60 kW 3-Phase Output
50 kW Single-Phase Output



35-3-400
60 Hz—400 Hz
150 kW 3-Phase Output
100 kW Single-Phase Output

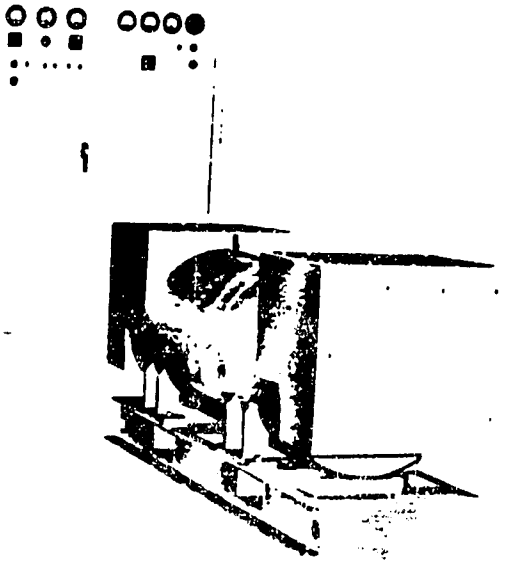


35-4-400
60 Hz—400 Hz
200 kW 3-Phase Output
135 kW Single-Phase Output



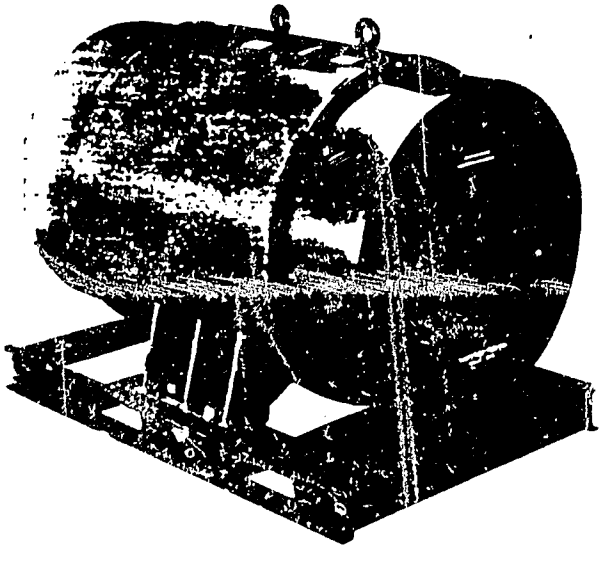
MD-4 UNISYNC

60 Hz—400 Hz
60 kW 3-Phase Output
50 kW Single-Phase Output
(For Applications Requiring Parallel Operation)



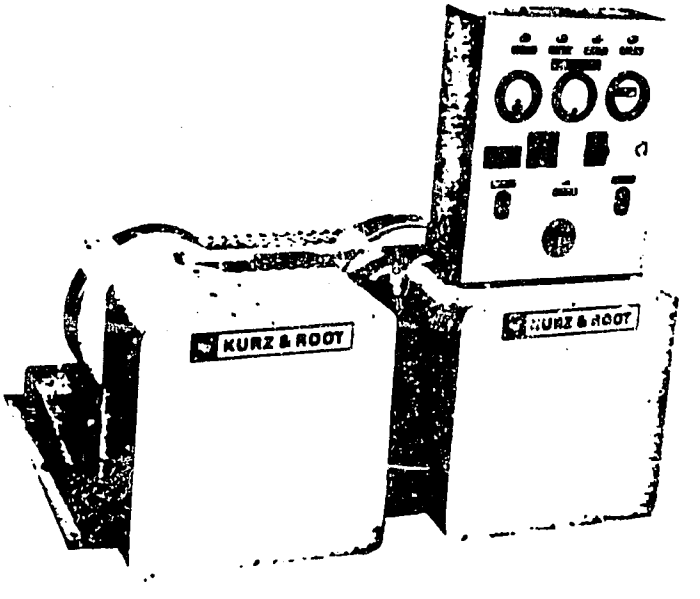
60 Hz—60 Hz ISOLATORS

25—150 kW



35-5-400

60 Hz—400 Hz
250 kW 3-Phase Output
165 kW Single-Phase Output



60 Hz—50 Hz CONVERTORS

10—200 kW

POWER-PLUS MOTOR GENERATOR FEATURES

- 6-pole synchronous motor in a common frame with a 40-pole synchronous generator.
- Stator and rotor coils triple dipped-and-baked with fungus-resistant modified polyester epoxy varnish to meet NEMA Class F insulation standards.
- Heavy-duty, permanently lubricated, double-shielded cartridge bearings.
- Dynamically balanced rotor.
- Independent brushless rotating exciters.
- Oversized rotating rectifiers capable of handling up to 300% of normal exciter output.
- Large capacity cast aluminum blower.
- Static regulator providing 0.5% voltage regulation.

KURZ & ROOT ENGINEERING CAPABILITIES

- Power ratings from 15 to 250 kW.
- Operating voltages from 200 to 575 VAC, 50 or 60 Hz.
- Motor starting methods to suit any power distribution system.
- Control circuitry tailored to the application.
- Free-standing or unit-mounted control cabinets to meet all operating requirements.
- Enclosure options for every operating environment.
- Synchronizing capability available for applications requiring parallel operation.

A RECORD OF PERFORMANCE

Kurz & Root's POWER-PLUS motor generator sets are engineered for long, reliable service and ease of maintenance. They've been proven in military and commercial applications throughout the world, and they're backed by Kurz & Root's 85 year tradition of quality and service.

A CONCERN FOR YOUR NEEDS

When you're ready to talk about motor generators, give us a call. We'll be happy to discuss your requirements, review your specifications and recommend a POWER-PLUS product to meet your needs.

For immediate assistance, contact your local POWER-PLUS distributor or call Kurz & Root's Motor Generator Answer Line at 414/739-9441.

POWER-PLUS PRODUCTS

"Custom Engineered... Performance Proven"

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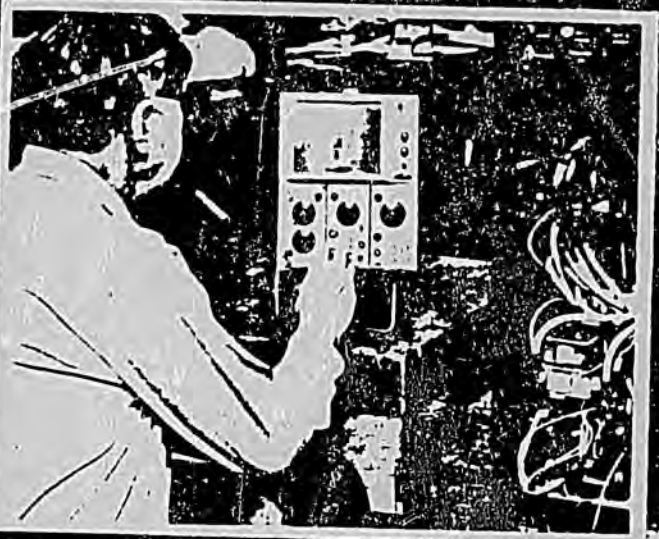
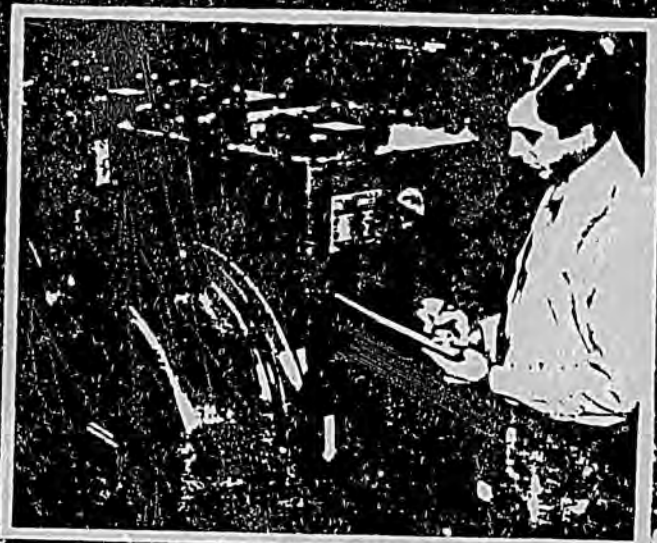
KR

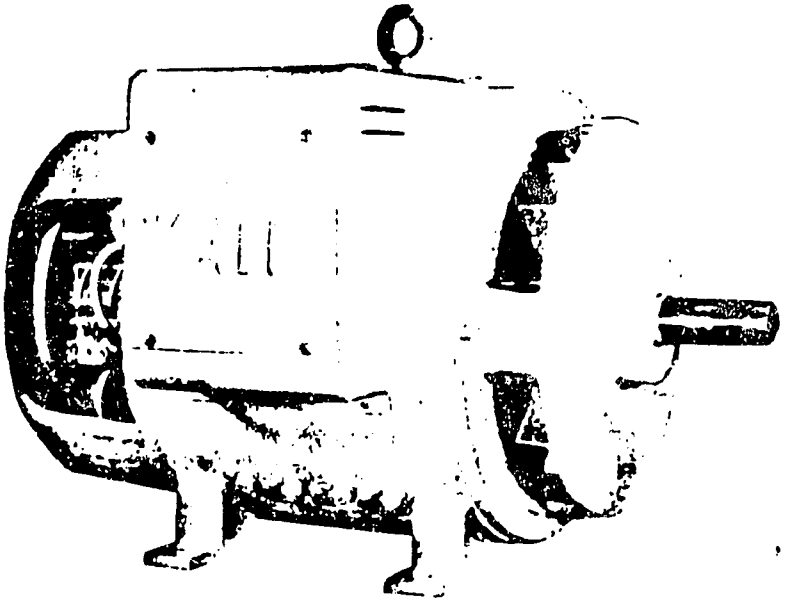
Kurz & Root [illegible]
reliability [illegible]
motor [illegible]
The Company's [illegible]
includes resident [illegible]
ensures that quality [illegible]
the entire production [illegible] from design [illegible] review and inspection.





Represented By:

D.C. GENERATOR



SIZES AVAILABLE

KW	RPM	VOLTAGE	KW	RPM	VOLTAGE
.5	1800	75, 125 or 220	7.5	1200	125
.5	1200	75, or 125	7.5	1500	125
1	1800	28, 75, 125 or 220	7.5	1800	125 or 250
1	1200	75 or 125	10	1800	28, 125 or 220
2	1800	32 or 125	10	1800	250
2	1200	125	12	1200	125 or 250
3	1800	28, 125 or 230	12	1800	125 or 250
3	1200	125	16	1200	250
5	1800	28 or 125	16	1500	125 or 250
5	1200	32 or 125	16	1800	28
5	1800	125 or 230	20	1200	250
6	1200	32 or 125	20	1800	28, 125 or 250
6	1800	28 or 125	40	1800	125 or 250
			50	1800	125 or 250

Kato DC generators are now available in sizes ranging from 500 watts to 50 KW with various voltages throughout the line. Fifty-two standard models are offered. Other models are available on special order.

The generator illustrated, typical of quality constructed units throughout the line, has four commutating poles in addition to the field poles. Commutation is improved as constant location of the commutating zone is maintained regardless of load changes. Brush sparking is greatly reduced and overall generator performance is improved. These units are being used in heavy duty magnet service and battery charging

Only highest quality materials and workmanship standards go into the construction of Kato direct current generators. Simplicity of frame and endbell design affords convenient accessibility to all component parts and ease of maintenance.

Both shunt and compound wound units are available throughout the range of sizes, enabling the generators to be used for a wide range of applications, including battery charging, testing and operating DC appliances.

Both two bearing design and single bearing design for direct connection to engines is available.

KATO

KATO ENGINEERING COMPANY
1415 FIRST AVENUE – MANKATO, MINN. 56001

300(

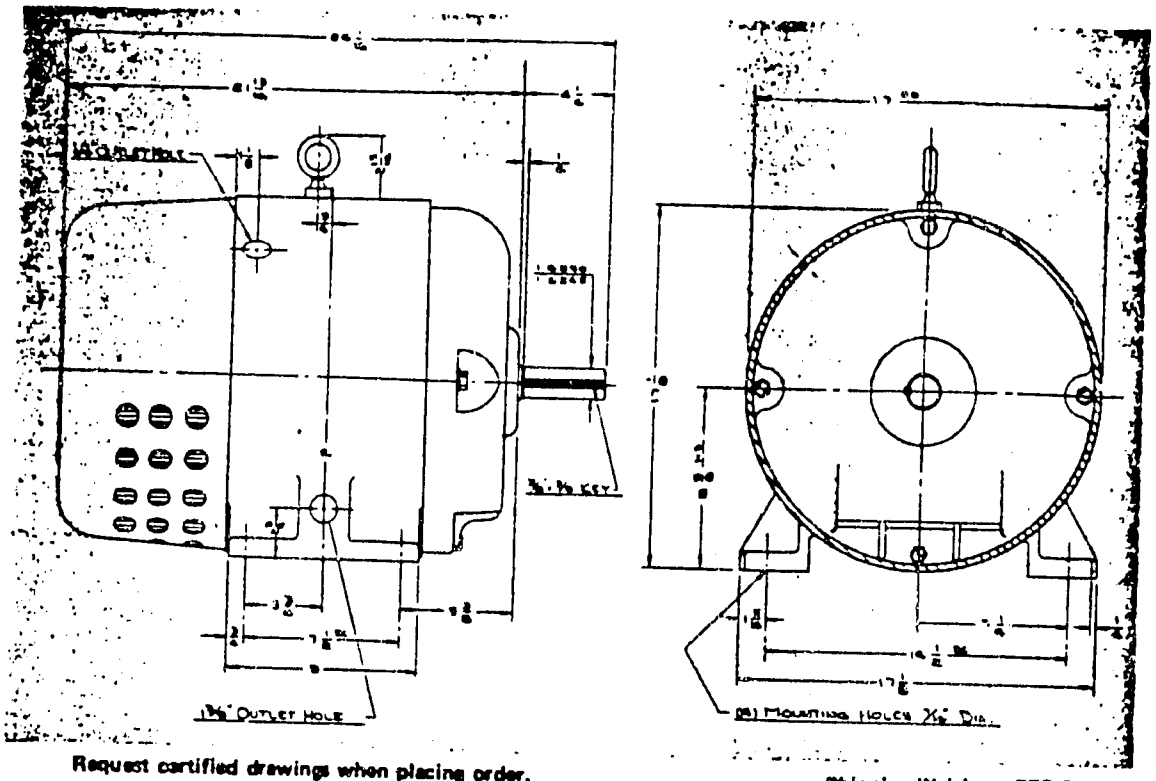
RANG
500
WATTS
thru
50 KV

RPM
1200
to
1800

VOLTA(
up to
250

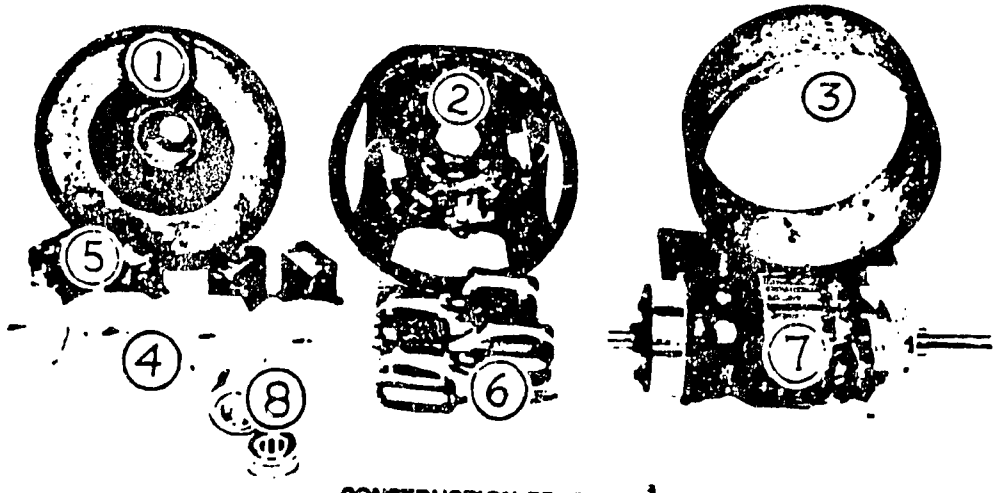
Form No
DC-37

DIMENSIONS



Request certified drawings when placing order.
Dimensions shown pertain to the machine illustrated only.

Shipping Weight — 570 Pounds



CONSTRUCTION FEATURES:

1. **DRIVE ENDBELL:** Cast endbells contribute to the overall rigidity of the machine. Machining, grinding and drilling of frame and endbells are held to even closer tolerances than required for good engineering, contributing to accurate bearing and shaft alignment.

2. **BRUSH RING ASSEMBLY:** Brush holders are mounted on a single insulation ring which is easily removed, reassembled and aligned. Exclusive Kato brush holder design offers even spring tension throughout the life of the brushes.

3. **FRAME:** Frames are jig machined and drilled. Pole pieces are easily removed. Misalignment problems present with light weight fabricated construction are eliminated.

4. **FIELD COILS:** Individual field coils are form wound and easily removable. Coils and armature windings alike are dipped in high bonding quality thermosetting varnish and backed in electronically controlled ovens as required, making one thoroughly impregnated, homogeneous mass.

5. **FIELD POLES:** Individual laminated pole pieces contribute to well proportioned field strength and are designed to hold the field coils firmly in place when bolted to the frame.

6. **COMMUTATING POLES:** Constant location of the commutating zone is insured regardless of load changes.

7. **ARMATURE ASSEMBLY:** Electrical steel laminations are punched from highest quality electrical steels. High current carrying capacity wire used in all windings and well designed cooling fan contribute to low temperature rise and excellent generator performance. Kato DC generator windings have more circular mills per ampere than do most competitive makes of equal rating. Commutators of most models are of hard drawn, single segment construction. When dipping, baking and commutator machining is completed, armature assemblies are statically and dynamically balanced.

8. **BEARINGS:** Heavy-duty, pre-lubricated, grease-sealed ball bearings are used, eliminating entry of foreign material to insure maximum bearing life.

KATO

KATO ENGINEERING COMPANY
1415 FIRST AVENUE – MANKATO, MINN. 56001

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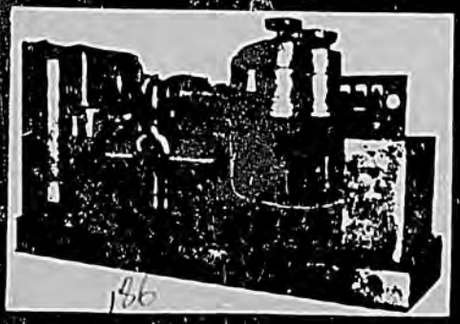
Fermont

Special, custom built generator sets at standard prices.



c power for transmit-
operation as well as
eral utilities including
ts, air conditioning
heating, assuring
adcasting capability in
s of emergency.

Guarantee of power so critical for ongoing computer function including conventional business applications as well as commercial ticket control centers and central freight operations.

Electrical energy for general household and commercial needs widespread in developing nations with applications generally involving alternate use of generator sets on twelve hour shifts.

Police communications and headquarters illumination, fire station warning alarms and general communications, automatic toll booth coin collectors, general lighting and heating.

Continuing hospital operating room function ing, life support systems, environmental controls, special power equipment.

very Fermont generator set produced is cus-
ized to perfectly match the particular require-
nts of the installation for which it's intended.
cial? Certainly. High priced? Absolutely not.
ermont generator sets cover all the popular
ngs and are available with over fifty options.
ose among cycle cranking, engine coolant
ters, manual or automatic paralleling, equip-
nt with reconnection panels to provide multiple
ages, monitoring panels, weather resistant
osures, panels for unattended operation of
tiple unit installations, and more.
ermont generator sets are water cooled types
lable in ratings from 10KW to 1050KW, 50 or
cycle, designed for the widest possible range of applications involving a need for reliable prime or standby power. Voltage options include 50 or 60 Hz service, 3 or 4 -wire generators with voltages for all single and three phase NEMA standard outputs through 4800 VAC. Each Fermont set is a completely self-contained power package including a radiator, fan to flywheel engine, AC generator and control panel all compactly mounted on a rugged steel skid base. Engines are two and four cycle, heavy duty industrial types available for operation on either diesel, gasoline, LP gas or natural gas fuels.

All Fermont generator sets include 3 or 4 lead brushless, reconnectable generators providing ±1% voltage regulation, no load to full load, excellent motor starting capacity, to 250% rated KVA, and, rapid recovery time, to 97% of voltage in 300 milliseconds. Fermont diesel generator sets are recommended for those situations where elaborate safety precautions required for highly volatile fuels cannot be taken. Low volatile diesel fuels are more easily handled and stored.

The gas driven type of Fermont generator set with spark fired engines offer a choice of fuel selection including gasoline, LP gas or natural gas. A gasoline carburetor is offered with automatic choke, antidieseling solenoid and fuel pump. An LP gas carburetor is available for LP vapor, secondary regulator and solenoid operated shut off valve. A natural gas carburetor is designed for 8 ounce inlet pressure with solenoid shut off valve and gas strainer.

ation of electric
ors for driving feeders,
oolers, fans, screens and
eyors as well as neces-
outdoor lighting and
hing equipment.

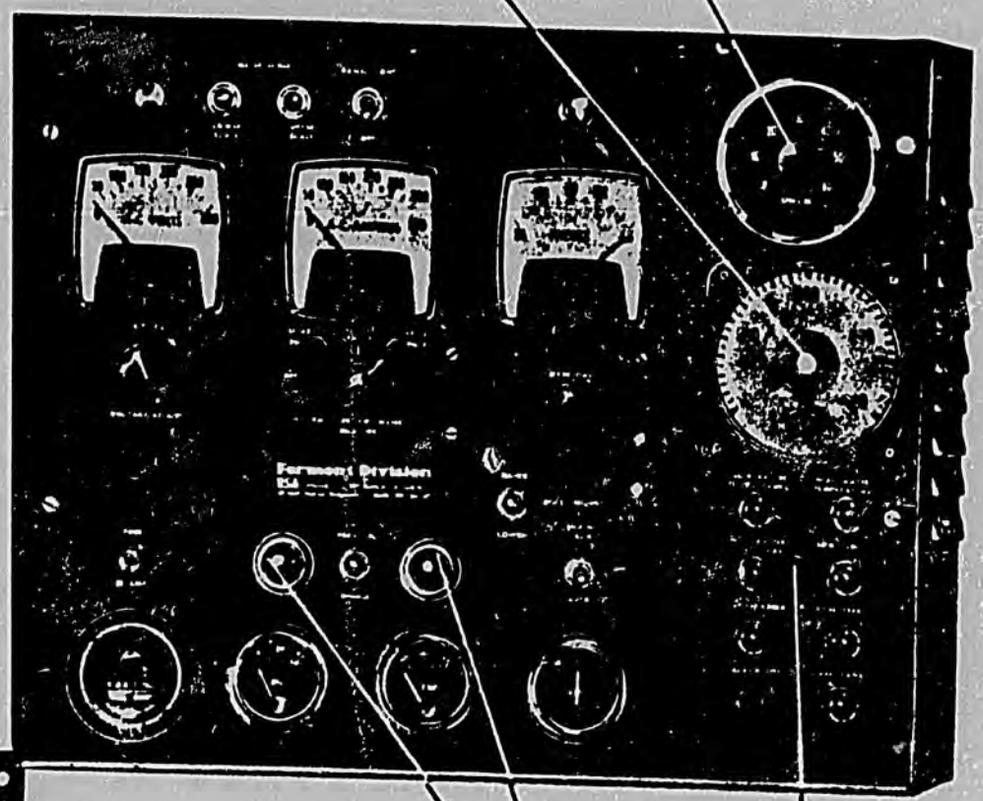
Energy for environmental control systems and illumination for greenhouses, animal shelters, hatcheries, refrigerating and freezing installations, milking machines, and silo dryers.

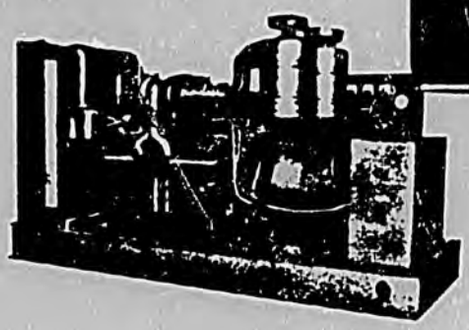
Support of all electrically operated facilities including heating and cooling, elevators, lighting, plumbing and signage for the complete maintenance of guests' comfort in hotels, motels and convalescent homes.

Runway landing light operation, taxi lights, battery charging equipment, plus support of control tower functions.

Operation of process pumps and vacuum filter drums for process treatment of raw sewage for primary and second water pollution wat control.

A few of the over 50 options which permit complete custom-ization.





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Standard Generator Set Equipment List

Cooling: unit radiator, pusher fan driver water pump, fan guard, thermostat and bypass.

Engine: fan to flywheel power. Gasoline, natural gas, liquified petroleum gas or diesel fuel type. Oil sump, gear pump pressure lubrication and filter. Fuel pump and filters, 3% governor, intake manifold and dry type air filter. Electric starter, battery charging alternator and engine. Dry type exhaust manifold.

Generator: brushless single bearing AC generator. Brushless exciter. Steel housing, [illegible] coupling. Current [illegible] voltage [illegible] voltage [illegible] 60 Hertz, [illegible] NEMA MG 1-22.40 [illegible] speed voltage.

Control Box: generator and engine gauges, shock mounted. AC voltmeter, AC ammeter, frequency meter. Voltage adjusting rheostat. AM and VM selector switch. Parallel and engine selector switch. Start-stop automatic [illegible] pressure, water temperature, battery [illegible] Fermont voltage [illegible] operating [illegible] Fermont [illegible] Control [illegible]

Safety Shutdown: complete [illegible] shut down [illegible] and safety shutdown.

Optional Equipment and Controls

Class I: cycle crank, 8 periods.
Class II: visual display of shut down from overcrank, overspeed, low oil pressure, high cooling temperature, push to test lamps, and one common alarm contact.
Class IV: [illegible] and incorporates all items of Class II and meets requirements of NFPA 76 A. Remote Annunciator panel for Class II or IV system.

Cooling: heat exchanger, [illegible] water cooling, temperature [illegible] radiator, water control valve, thermostatic [illegible] discharge duct adapter, [illegible] engine heaters.

Governors: [illegible] electronic [illegible], remote throttle.

Exhaust: [illegible] residential [illegible] exhaust [illegible] gas.

Fuel System: day tank system, flexible fuel connectors, electric fuel pumps, float tank systems.

Installation: vibration isolators, pad and spring types, weather protective metal housing.

Starting System: starting battery, battery racks, battery chargers, lead acid or nickel cadmium batteries, automatic battery chargers, battery cables, other starting aids. Consult factory for other options available including factory training school, literature translations, parts and service.

Model No.	Diesel Engine Driven Generator Sets							
	Standby 130° C Rise				Continuous 105° C Rise			
	60 Hz		50 Hz		60 Hz		50 Hz	
	KW	KVA (.8PF)	KW	KVA (.8PF)	KW	KVA (.8PF)	KW	KVA (.8PF)
15DH	15	18	10	12	13	16	10	12
20DH	20	25	12	15	19	24	12	15
25DH	25	31	16	20	23	28	16	20
30DH	34	42	29	36	29	36	25	31
40DH	41	51	34	42	36	45	31	38
50DH	50	62	42	52	45	56	37	46
60DH	63	78	52	65	54	67	45	56
75DH	72	90	59	73	62	77	52	65
100DH	100	125	86	107	90	112	77	96
110DH	117	146	95	118	95	118	77	96
125DH	132	165	106	132	119	148	97	121
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
400DA	[illegible]	[illegible]	37	[illegible]	37	46	34	42
500DA	[illegible]	[illegible]	43	53	42	52	38	47
[illegible]	[illegible]	[illegible]	[illegible]	67	[illegible]	73	50	62
[illegible]	[illegible]	[illegible]	[illegible]	73	59	73	53	66
750DA	81	101	54	62	67	83	61	76
1000DA	100	125	[illegible]	105	81	101	66	84
1250DA	136	169	112	140	105	131	90	112
1500DA	[illegible]	308	140	175	155	193	125	156
2000DA	206	257	174	217	180	225	150	187
2500DA	260	325	220	275	207	258	183	228
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	297	[illegible]	[illegible]

Model No.	Diesel Engine Driven Generator Sets							
	Standby 130° C Rise				Continuous 105° C Rise			
	60 Hz		50 Hz		60 Hz		50 Hz	
	KW	KVA (.8PF)	KW	KVA (.8PF)	KW	KVA (.8PF)	KW	KVA (.8PF)
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
350DC	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	340	300	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	166
450DC	271	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	170	223
500DC	317	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
550DC	363	478	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	425	531	340	425	375	[illegible]	[illegible]	375
650DC	485	561	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	437
700DC	582	[illegible]	[illegible]	575	475	[illegible]	430	525
800DC	617	771	518	647	[illegible]	[illegible]	[illegible]	[illegible]
750DC	787	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	225
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
140DG	136	163	115	143	90	112	79	98
160DG	180	225	140	175	134	167	117	146
200DG	210	262	160	200	137	171	120	150
275DG	270	337	235	293	176	220	157	196
300DG	318	397	280	350	238	297	210	262
375DG	400	500	350	437	284	355	236	295
400DG	423	528	361	451	284	355	236	295
450DG	500	625	405	506	373	466	310	287
500DG	565	706	475	593	374	467	326	407
600DG	655	818	570	712	494	617	430	537
775DG	765	956	665	831	530	662	470	587
1050DG	1049	1311	850	1062	728	910	637	796

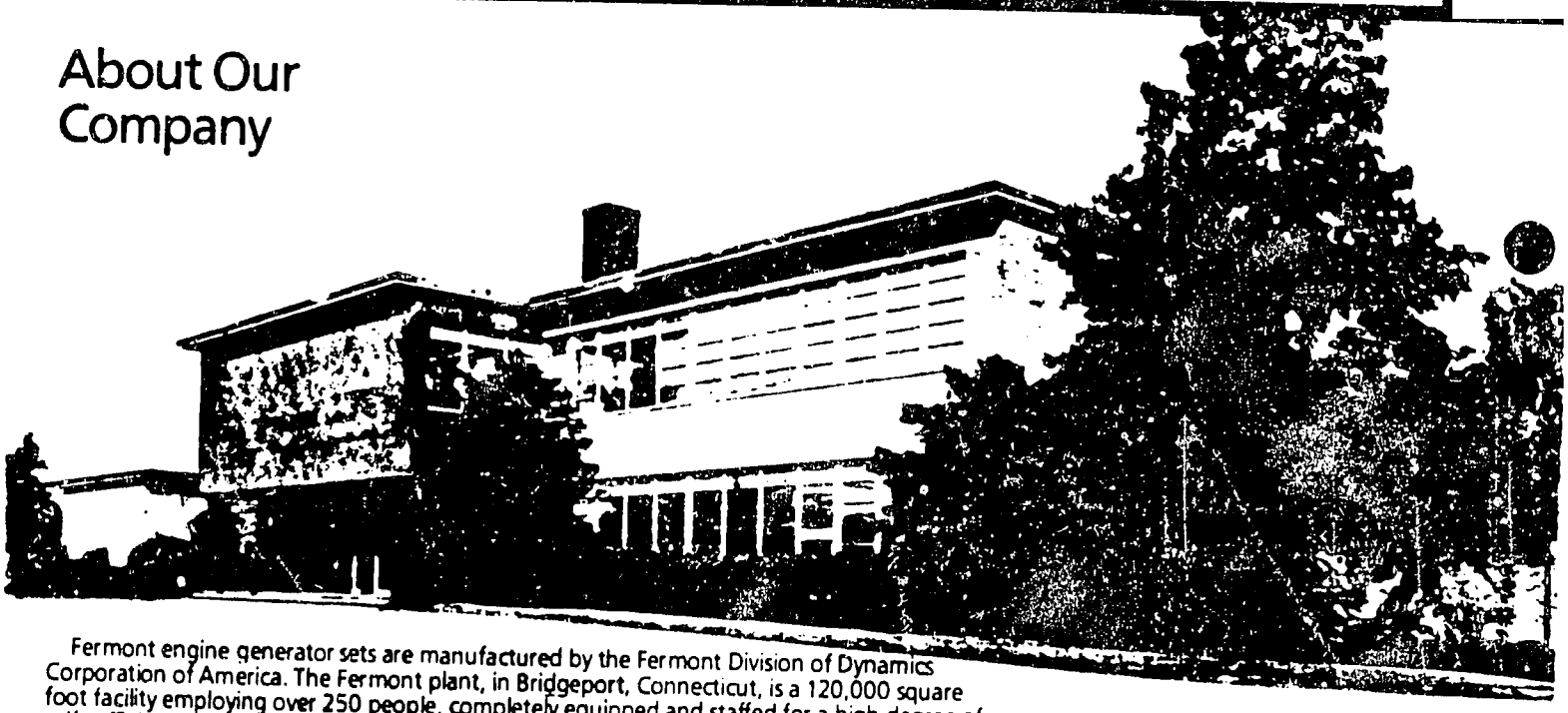
Model No.	Gas Engine Driven Generator Sets							
	Standby 130° C Rise				Continuous 105° C Rise			
	60 Hz		50 Hz		60 Hz		50 Hz	
	KW	KVA (.8PF)	KW	KVA (.8PF)	KW	KVA (.8PF)	KW	KVA (.8PF)
15GH	15	18	10	12	13	16	10	12
20GH	20	25	12	15	19	23	12	15
25GH	25	31	16	20	23	28	16	20

All sets available in single and three phase NEMA Standard voltages through 480 VAC

Model No.	Gas Engine Driven Generator Sets							
	Standby 130° C Rise				Continuous 105° C Rise			
	60 Hz		50 Hz		60 Hz		50 Hz	
	KW	KVA (.8PF)	KW	KVA (.8PF)	KW	KVA (.8PF)	KW	KVA (.8PF)
35GH	37	46	30	37	33	41	27	34
45GH	55	68	42	52	45	56	40	50
55GH	58	72	49	61	51	63	43	53

KW Ratings are maximum ratings based on engine manufacturers current published HP rating ± 5%

About Our Company



Fermont engine generator sets are manufactured by the Fermont Division of Dynamics Corporation of America. The Fermont plant, in Bridgeport, Connecticut, is a 120,000 square foot facility employing over 250 people, completely equipped and staffed for a high degree of self sufficiency in design, engineering and manufacturing. Fermont pioneered the concept of solid state electronic engine generator controls. Engine generator set skids, frames, switchboard panels, special mountings, complete housings, harness assemblies, control panels, are all Fermont produced. Special facilities include environmentally controlled dust free areas for assembly and testing of delicate electronic elements.

Fermont is currently the largest single producer of engine generator sets to the Department of Defense with standardized units having been accepted by the Army, Navy, Marines and Air Force and has established an effective marketing and service organization in support of its commercial sales representatives and customers throughout the world.

Since 1945, Fermont has been responsible for producing over 50,000,000 KW of reliable power in standby and prime sets at the same time building a reputation throughout the world for the highest possible quality, competitive pricing and unmatched service.

EGSMA

Fermont Division
DYNAMICS CORPORATION OF AMERICA
141 North Avenue Bridgeport CT 06606 (203) 366-5211 telex 964365

Form No 60177

Printed in U.S.A.

KOHLER GENERATORS

4 KW

ac air-cooled diesel generator set

60 HERTZ MODELS

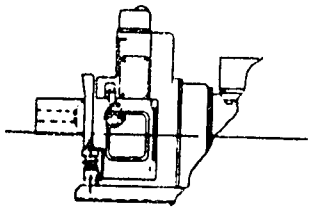
Model	Voltages	Phase	Starting	Amperes	KW	KVA	Governed RPM
4RMO21	120	1	Remote	33.3	4	4	1800
4CMO21	120	1	Push button	33.3	4	4	1800
4RMO61	120/240	1	Remote	16.6	4	4	1800
4CMO61	120/240	1	Push button	16.6	4	4	1800

50 HERTZ MODELS

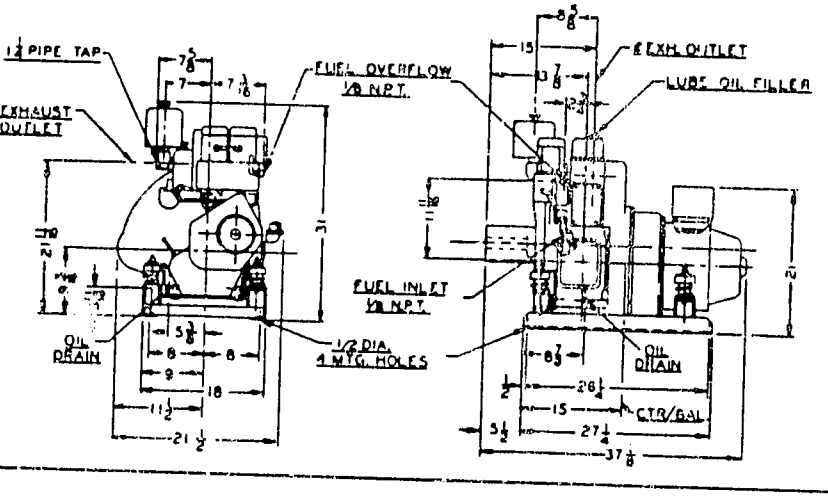
Model	Voltages	Phase	Starting	Amperes	KW	KVA	Governed RPM
4RFMO21	110	1	Remote	31.8	3.5	3.5	1500
4CFMO21	110	1	Push button	31.8	3.5	3.5	1500
4RFMO61	110/220	1	Remote	15.9	3.5	3.5	1500
4CFMO61	110/220	1	Push button	15.9	3.5	3.5	1500

Ratings at 1.0 power factor. Derate approximately 3% per 1000 ft (300 m.) above 500 ft (150 m.) above sea level. Derate 2% for every 10° F (5½° C) above 85° F (30° C).
RATINGS: All models are continuous standby rated. Unit will operate at this rating for the duration of any power outage.

Availability is subject to change without notice. Kohler Co. reserves the right to change the design or specifications without notice and without any obligation or liability whatsoever. Availability can be determined by contacting your local Kohler Co. Distributor.

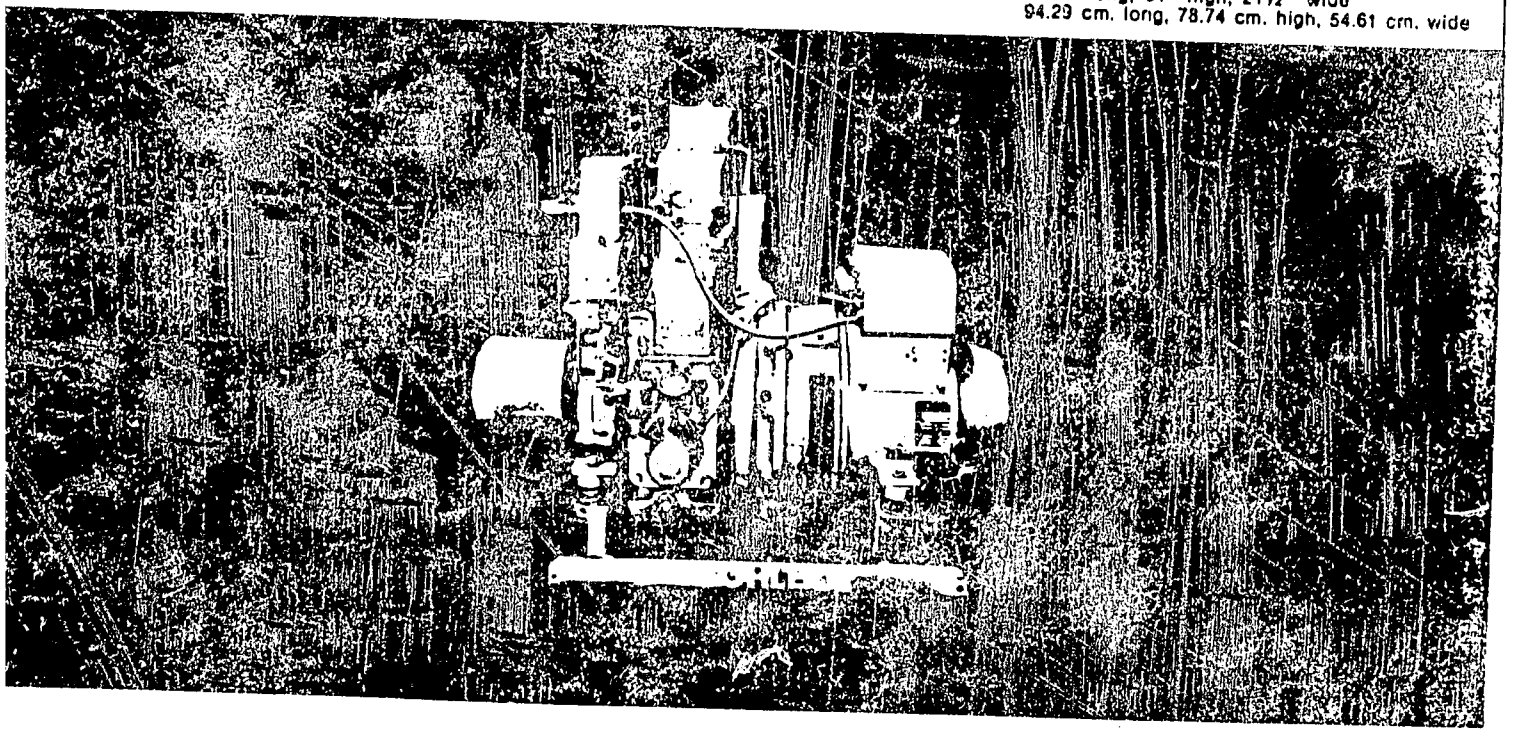


PUSH BUTTON VERSION



Approximate net weight: 505 lbs.
229.06 kg.

Nominal dimensions: 37⅛" long, 31" high, 21½" wide
94.29 cm. long, 78.74 cm. high, 54.61 cm. wide



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APPLICATION DATA

DIESEL ENGINE

SPECIFICATIONS	60 Hertz	50 Hertz
Manufacturer	Lister	
Model	ST-1	
Type	4 cycle	
Displacement cu. in. (cc)	38.7 (634)	
Bore and stroke in. (mm)	3.75 x 3.50 (95 x 89)	
Compression ratio	16.8 to 1	
Piston speed ft/min. (m/min.)	1050 (320)	875 (267)
Horsepower @ 1800 RPM and @ 1500 RPM HP (KW)	8.2 (6.1)	6.6 (4.9)
Number of cylinders	1	
Number of main bearings	2	
Governor, make model	Lister centrifugal	
regulation % frequency no load to full load	5	
steady state regulation ± % frequency	.5	

ENGINE COOLING SYSTEM

Cooling air CFM (m³/min)	442 (12.5)	375 (10.6)
Maximum air restriction in. water (KPa)	.5 (.12)	

ENGINE FUEL SYSTEM

Suction @ transfer pump — clean — recommended in. Hg. (KPa)	3.00 (10.2)

FUEL CONSUMPTION

100% load (gal/hr) (ltr/hr)	.40 (1.5)	.36 (1.4)
75% load (gal/hr) (ltr/hr)	.32 (1.2)	.29 (1.1)
50% load (gal/hr) (ltr/hr)	.26 (.98)	.24 (.91)
25% load (gal/hr) (ltr/hr)	.21 (.79)	.19 (.79)

FUEL SYSTEM ACCESSORIES

- ☐ Flexible fuel line
- ☐ 6 or 10 gallon fuel tank
- ☐ 8 or 20 gallon fuel transfer tank with pump

ENGINE EXHAUST SYSTEM

Exhaust temperature @ rated BHP °F (°C)	932 (500)	842 (450)
Exhaust gas flow @ rated BHP CFM (m³/min)	43.8 (1.2)	34.6 (.98)
Maximum exhaust back pressure allowable in Hg. (KPa)	2.9 (9.96)	

EXHAUST SYSTEM ACCESSORIES

- ☐ Flexible exhaust connector (steel)
- ☐ Flexible exhaust connector (stainless steel)
- ☐ Residential exhaust silencer

INTAKE AIR REQUIREMENTS

Combustion CFM (m³/min)	16 (.45)

SPECIFICATIONS	60 Hertz	50 Hertz
ENGINE LUBE OIL SYSTEM		
Oil pan capacity qts. (ltrs)	2 (1.9)	
Lube oil filter	full flow	
ENGINE ELECTRICAL SYSTEM		
Voltage DC	12 volt	
Battery recommendation	55 ampere	
Rolling current @ 30°F (amperes)	190	
Breakaway current	525	
RPM	325	

ENGINE ELECTRICAL SYSTEM — ACCESSORIES

- ☐ 12 volt, 55 ampere battery
- ☐ Battery chargers

STANDARD ENGINE FEATURES

- Mounting base
- Vibromounts (spring isolators)
- Fuel lift pump
- Muffler
- Compression release
- Fuel cut-off solenoid for remote start models
- Dry air cleaner
- Battery cables
- Hand crank
- Oil pressure gauge

GENERATOR

SPECIFICATIONS

Make	Kohler
Insulation	class B
Number of bearings	1
Rotor balancing	dynamic
Exciter type	rotating
Generator efficiency — % @ full load	85
Wave form deviation factor — no load — full load	NEMA MG1-22.42
Telephone influence factor — TIF	NEMA MG1-22.43

STANDARD FEATURES

- Motor starting capability ½ HP per KW of rating
- Direct connected

CONTROLLER

Controllers are vibro-mounted to the generator frame. An automatic 10 ampere maximum, two-step battery charging circuit is standard.

Push Button Model — Provides electric starting by manually depressing a momentary starter switch.

Remote Model — Provides electric starting by means of a start/stop switch located on the controller or by two-wire remote control. Overcranking protection arranged to open the cranking circuit after 30-90 seconds. Includes overcranking reset button and alarm circuit contacts.

CONTROLLER ACCESSORIES

- ☐ Running time meter
- ☐ Battery charging ammeter
- ☐ Single receptacle
- ☐ AC voltmeter
- ☐ AC ammeter

ADDITIONAL ENGINE AND GENERATOR ACCESSORIES

- ☐ Air-vent cooling
- ☐ High temperature and low oil pressure cut-out
- ☐ CSA listing
- ☐ Export boxing
- ☐ 2-wheel trailer
- ☐ Engine crankcase heater (250 watt)
- ☐ Automatic load control panel for automatic starting on load demand for remote start models

KOHLER CO., KOHLER, WISCONSIN 53044 PHONE 414 565-3381 TELEX 26888 TWX 910 264 3877

G05-011
Printed in U.S.A.

KOHLER GENERATORS

KOHLER
GENERATORS

4 KW Diesel
Air-Cooled

SAMPLE SPECIFICATIONS

EMERGENCY STANDBY ELECTRICAL SYSTEMS: The standby generator set shall be installed by the contractor at the location shown on the plans and drawings, and as specified herein; with all accessories and transfer switch(es) as required.

All equipment shall be new and of current production of a National firm, who manufactures the alternator and control panel and assembles the standby generator set as a matched unit, having a service and parts organization within a reasonable distance of this project, backed up by a natural sales and service organization.

The generator set shall be rated 4 KW*, 4KVA, Units P.F., ____Volts, ____Phase, ____Wire, ____Amps., 60 Hertz, A.C., as KOHLER Model 4RMO Series, with a direct injection Diesel fuel system.

*VOLTAGE COMBINATIONS AVAILABLE (SELECT ONE)

(120 volt, 1 phase, 2 wire, 33.3 amps.)

(120/240 volt, 1 phase, 3 wire, 16.6 amps.)

ALTERNATOR: The alternator shall be four pole, rotating armature, of drip proof construction, with built-in exciter. It shall be self-ventilated, with constant tension brush springs.

Radio interference suppression meeting commercial standards shall be supplied.

Temperature rise shall be within NEMA, IEEE, and ANSI standards for continuous duty temperature rise limits at all output ratings.

The alternator, having a single, maintenance free, bearing, shall be direct connected to the engine.

CONTROLLER AND INSTRUMENT PANEL: Plant mounted controller shall be vibration isolated on the alternator frame. It shall include the following; factory installed, wired and tested by the manufacturer:

Complete standby 2 wire start/stop control which shall operate on activation of a remote contact.
Overcranking protection designed to open the cranking circuit if engine does not start after 30-90 seconds, with cranking reset button.
Line circuit breaker - Battery charging ammeter.
Alarm circuit - Duplex receptacle.

METER KITS AVAILABLE (SELECT ONE)

(1 phase, 2 wire - voltmeter, ammeter, and current transformer)
(1 phase, 3 wire - voltmeter, 2 ammeters, and current transformers)

ENGINE: The naturally aspirated engine shall be Diesel fueled, 1 cylinder, 4 cycle, including Air-vent cooling system, with not less than 38.7 cubic inch displacement and deliver a minimum of 8.2 H.P., at a governed speed of 1800 RPM.

Engine speed shall be governed by a gear driven centrifugal governor to maintain alternator frequency within 3 cycles from no load to full load alternator output. Belt driven governors will not be considered.

Starting shall be accomplished by a 12 volt exciter cranking.

Engine shall be equipped with the following:

Lube oil filter - Oil bath air cleaner.
Radio suppression.
Engine crankcase heater with thermostat, 120 volt.
Critical silencer, to be installed by contractor.
Electric solenoid fuel shut-off valve.
Gas proof seamless, stainless steel, flexible exhaust connection.
Flexible fuel connection.
Automatic solenoid operated compression release.
High temperature and low oil pressure cutouts.

PLANT MOUNTING: The standby plant shall be equipped with factory installed vibration isolators mounted between the plant and fabricated steel skid base to prevent distortion of alignment between alternator and engine when installed. Mount on I-beams or concrete pedestals as shown on plans and drawings.

ACCESSORIES: 12 volt, 55 ampere hour battery and battery cables. Kohler 20 ampere automatic float battery charger Model A269214 with the following features: Constant voltage regulation; current limiting; temperature compensated; voltmeter and ammeter, for conduit installation.

INFORMATION REQUIRED FOR SPECIFIED STANDBY SYSTEMS:

Certified final factory test report shall be provided to the architect, certifying this units full power rating, stability, voltage and frequency regulation.
Detailed specification sheets.
Complete operating instruction and maintenance manual with parts list.
A factory trained representative shall consult with the contractor during installation and start-up. He shall fully instruct the owner's personnel as to correct operating and testing procedure.

AUTOMATIC TRANSFER SWITCH:

See specification sheets.

WEATHER PROTECTIVE HOUSING:

See specification sheets.

KOHLER GENERATORS

8.5 KW

ac air-cooled diesel generator set

60 HERTZ MODELS

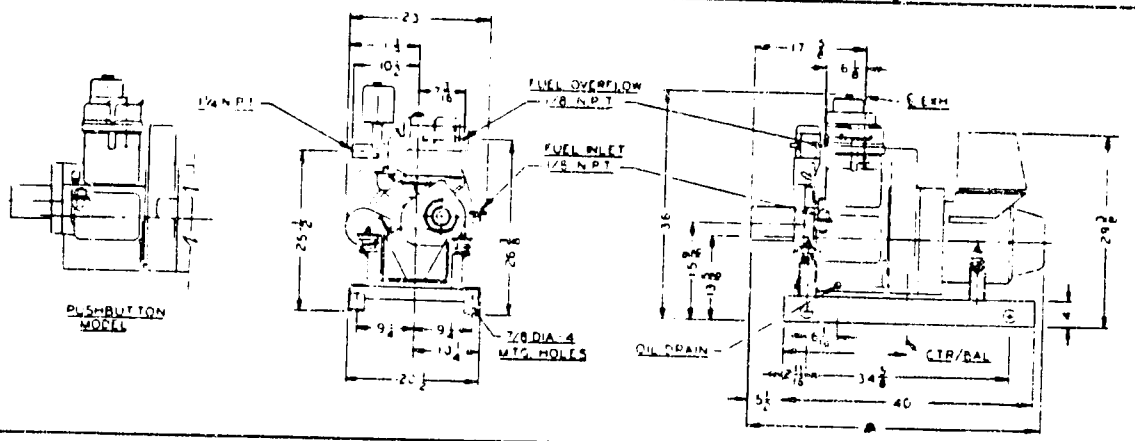
Model	Voltages	Phase	Starting	Amperes	KW	KVA	Governed RPM
8.5RMO21	120	1	Remote	70.8	8.5	8.5	1800
8.5CMO21	120	1	Push button	70.8	8.5	8.5	1800
8.5RMO51	240	3	Remote	22.5	7.5	9.4	1800
8.5CMO51	240	3	Push button	22.5	7.5	9.4	1800
8.5RMO61	120/240	1	Remote	35.4	8.5	8.5	1800
8.5CMO61	120/240	1	Push button	35.4	8.5	8.5	1800
8.5RMO81	120/208	3	Remote	29.5	8.5	10.6	1800
8.5CMO81	120/208	3	Push button	29.5	8.5	10.6	1800

50 HERTZ MODELS

Model	Voltages	Phase	Starting	Amperes	KW	KVA	Governed RPM
8.5RFMO21	110	1	Remote	63.6	7	7	1500
8.5CFMO21	110	1	Push button	63.6	7	7	1500
8.5RFMO51	220	3	Remote	19	5.8	7.25	1500
8.5CFMO51	220	3	Push button	19	5.8	7.25	1500
8.5RFMO61	110/220	1	Remote	31.8	7	7	1500
8.5CFMO61	110/220	1	Push button	31.8	7	7	1500
8.5RFMO81	120/208	3	Remote	24.2	7	8.75	1500
8.5CFMO81	120/208	3	Push button	24.2	7	8.75	1500

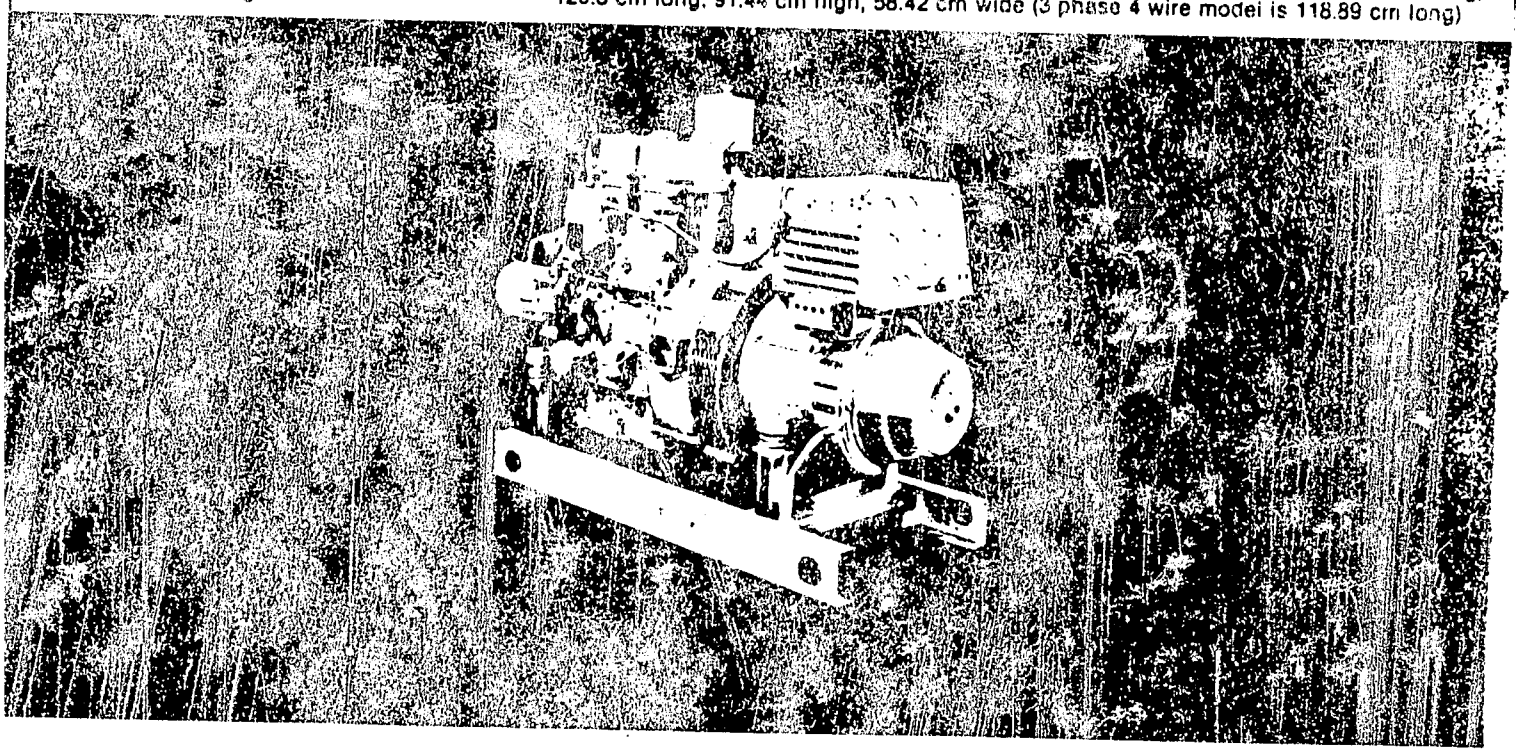
All single phase units are rated at 1.0 power factor. 3 phase units at 0.8 power factor. Derate approximately 3% per 1000 ft (300 m.) above 500 ft (150 m.) above sea level. Derate 2% for every 10° F (5½° C) above 85° F (30° C).
RATINGS: All models are continuous standby rated. Unit will operate at this rating for the duration of any power outage.

Availability is subject to change without notice. Kohler Co. reserves the right to change the design or specifications without notice and without any obligation or liability whatsoever. Availability can be determined by contacting your local Kohler Co. Distributor.



Approximate net weight: 800 lbs., 362.88 kg.

Nominal dimensions: 47 9/16" long, 36" high, 23" wide (3 phase 4 wire model is 46 13/16" long)
120.8 cm long, 91.44 cm high, 58.42 cm wide (3 phase 4 wire model is 118.89 cm long)



8.5 KW

APPLICATION DATA

DIESEL ENGINE

SPECIFICATIONS	60 Hertz	50 Hertz
Engine make	Lister	
Engine model	ST-2	
Engine type	4-cycle	
Displacement cu. in. (cc)	77.3 (1267)	
Bore and stroke in. (mm)	3.75 (95) x 3.5 (89)	
Compression ratio	16.8:1	
Piston speed ft/min (m/min)	1050 (320)	875 (267)
Horsepower @ 1800 RPM and @ 1500 RPM HP (KW)	16.5 (12.3)	13.4 (10)
Number cylinders	2	
Number main bearings	3	
Governor, make model	Lister mechanical	
regulation % frequency no load to full load	5	
steady state regulation ± % frequency	.33	

ENGINE COOLING SYSTEM

Cooling air CFM (m^3/min.)	950 (26.9)	808 (22.9)

ENGINE FUEL SYSTEM

Suction @ transfer pump — clean — recommended in. Hg. (KPa)	3 (10.2)

FUEL CONSUMPTION

100% load gal/hr (ltr/hr)	.8 (3.0)	.66 (2.5)
75% load gal/hr (ltr/hr)	.66 (2.5)	.55 (2.1)
50% load gal/hr (ltr/hr)	.55 (2.1)	.44 (1.7)
25% load gal/hr (ltr/hr)	.47 (1.8)	.36 (1.4)

FUEL SYSTEM ACCESSORIES

- ☐ Flexible fuel line
- ☐ 6 or 10 gallon fuel tank
- ☐ 8 or 20 gallon fuel transfer tank with pump

ENGINE EXHAUST SYSTEM

Exhaust temperature @ rated BHP °F (°C)	932 (500)	842 (450)
Exhaust gas flow @ rated BHP CFM (m^3/min)	87.6 (2.46)	74.5 (2.11)
Max. exhaust back pressure allowable in. Hg. (KPa)	3 (10.2)	

EXHAUST SYSTEM ACCESSORIES

- ☐ Flexible exhaust connector (steel)
- ☐ Flexible exhaust connector (stainless steel)
- ☐ Residential exhaust silencer.

INTAKE AIR REQUIREMENTS

Combustion air CFM (m^3/min)	32 (.9)	27 (.77)
Max. intake air restriction in. Hg. (KPa)	.3 (1.02)	

ENGINE LUBE OIL SYSTEM

Oil pan capacity qts. (ltr)	5.5 (5.2)
Lube oil filter	full flow

SPECIFICATIONS	60 Hertz	50 Hertz
ENGINE ELECTRICAL SYSTEM		
Voltage DC	12	
Battery recommended	90 ampere	
Starting system	exciter cranked	
Rolling current @ 30° (amps)	190	
Breakaway current	525	
RPM	325	

ENGINE ELECTRICAL SYSTEM — ACCESSORIES

- ☐ 12 volt, 90 ampere battery
- ☐ Battery chargers

STANDARD ENGINE FEATURES

- Mounting base
- Vibromounts (spring isolators)
- Fuel lift pump
- Muffler
- Oil pressure gauge
- Compression release
- Fuel cut-off solenoid for remote start models
- Dry air cleaner
- Battery cables
- Hand crank
- Operating instructions

GENERATOR

SPECIFICATIONS

Make	Kohler
Insulation	class F
Number of bearings	1
Rotor balancing	dynamic
Exciter type	rotating
Voltage regulator	Kohler stabilizer
no load to full load — ± %	5%
Generator efficiency — % @ full load	85
Wave form deviation factor — no load — full load	NEMA MG1-22.42
Telephone influence factor — TIF	NEMA MG1-22.43

STANDARD FEATURES

- Motor starting capability ½ HP per KW of rating
- Direct connected

CONTROLLER

Controllers are vibro-mounted to the generator frame. An automatic 6 ampere maximum, two-step battery charging circuit is standard.

Push Button Model — Provides electric starting by manually depressing a momentary starter switch.

Remote Model — Provides electric starting by means of a start/stop switch located on the controller or by two-wire remote control. Overcranking protection arranged to open the cranking circuit after 30-90 seconds. Includes overcranking reset button and alarm circuit contacts.

CONTROLLER ACCESSORIES

- ☐ Ammeter, voltmeter, selector switch
- ☐ Frequency meter
- ☐ Running time meter
- ☐ Battery charging ammeter
- ☐ Line circuit breaker
- ☐ Duplex receptacle
- ☐ Overfrequency relay

ADDITIONAL ENGINE AND GENERATOR ACCESSORIES

- ☐ Air-vent cooling
- ☐ High temperature and low oil pressure cut-out
- ☐ CSA listing
- ☐ Export boxing
- ☐ Weather housing
- ☐ Housing locking kit
- ☐ Engine crankcase heater (250 watt)
- ☐ Automatic load control panel for automatic starting on load demand for remote start models
- ☐ Two wheel trailer

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KOHLER GENERATORS

KOHLER GENERATORS

8.5 KW Diesel
Air-Cooled

SAMPLE SPECIFICATIONS

EMERGENCY STANDBY ELECTRICAL SYSTEMS: The standby generator set shall be installed by the contractor at the location shown on the plans and drawings, and as specified herein; with all accessories and transfer switch(es) as required.

All equipment shall be new and of current production of a National firm, who manufactures the alternator and control panel and assembles the standby generator set as a matched unit, having a service and parts organization within a reasonable distance of this project, backed up by a national sales and service organization.

The standby generator set shall be rated 8.5 KW*, _____KVA, _____P.F., ____Volts, ____Phase, ____Wire, ____Amps., 60 Hertz, A.C., as KOHLER Model 8.5RMO Series, with a direct injection Diesel fuel system.

*VOLTAGE COMBINATIONS AVAILABLE (SELECT ONE)

(8.5KVA	Unity P.F.	120 volt, 1 phase, 2 wire, 70.8 amps.)
(8.5KVA	Unity P.F.	120/240 volt, 1 phase, 3 wire, 35.4 amps.)
(9.4KVA	.8 P.F.	240 volt, 3 phase, 3 wire, 22.5 amps.)
(10.6KVA	.8 P.F.	120/208 volt, 3 phase, 4 wire, 29.5 amps.)

ALTERNATOR: The alternator shall be four pole, rotating armature, self-ventilated of drip proof construction, with built-in exciter.

Radio interference suppression meeting commercial standards shall be supplied. Voltage regulation shall be within plus or minus 5 percent of rated voltage, from no load to full load.

Temperature rise shall be within NEMA, IEEE, and ANSI standards for continuous duty temperature rise limits at all output ratings.

The alternator, having a single, maintenance free, bearing, shall be direct connected to the engine.

CONTROLLER AND INSTRUMENT PANEL: Plant mounted controller shall be vibration isolated on the alternator frame. It shall include the following; factory installed, wired and tested by the manufacturer:

Complete standby 2 wire start/stop control which shall operate on activation of a remote contact.
Overcranking protection designed to open the cranking circuit if engine does not start after 30-90 seconds, with cranking reset button.
Line circuit breaker - Panel light - Alarm circuit - Duplex receptacle.
Direct reading, frequency meter.

METER KITS AVAILABLE (SELECT ONE)

(1 phase, 2 wire - voltmeter, ammeter, and current transformer)
(1 phase, 3 wire - voltmeter, 2 ammeters, and current transformers)
(3 phase, 3 and 4 wire - voltmeter, ammeter, selector switch, and current transformers)

Controller mounted engine features shall include: running time meter, and battery charging ammeter.

ENGINE: The naturally aspirated engine shall be Diesel fueled, 2 cylinder, 4 cycle, including Air-vent cooling system, with not less than 77.3 cubic inch displacement and deliver a minimum of 16.5 H.P., at a governed speed of 1800 RPM.

Engine speed shall be governed by a gear driven centrifugal governor to maintain alternator frequency within 3 cycles from no load to full load alternator output. Belt driven governors will not be considered.

Starting shall be accomplished by a 12 volt exciter cranking.

Engine shall be equipped with the following:

Lube oil filter - Oil bath air cleaner - Radio suppression.
Engine crankcase heater with thermostat, 120 volt.
Critical silencer, to be installed by contractor.
Electric solenoid fuel shut-off valve.
Gas proof seamless, stainless steel, flexible exhaust connection.
Flexible fuel connection - Oil pressure gauge.
High temperature and low oil pressure cutouts.
Automatic solenoid operated compression release.

PLANT MOUNTING: The standby plant shall be equipped with factory installed vibration isolators mounted between the plant and fabricated steel skid base to prevent distortion of alignment between alternator and engine when installed. Mount on I-beams or concrete pedestals as shown on plans and drawings.

ACCESSORIES: 12 volt, 90 ampere hour battery and battery cables. Kohler 20 ampere automatic float battery charger Model A269214 with the following features: Constant voltage regulation; current limiting; temperature compensated; voltmeter and ammeter; for conduit installation.

INFORMATION REQUIRED FOR SPECIFIED STANDBY SYSTEMS:

Certified final factory test report shall be provided to the architect, certifying this units full power rating, stability, voltage and frequency regulation.
Detailed specification sheets
Complete operating instruction and maintenance manual with parts list.
A factory trained representative shall consult with the contractor during installation and start-up. He shall fully instruct the owner's personnel as to correct operating and testing procedures.

AUTOMATIC TRANSFER SWITCH:

See specification sheets.

WEATHER PROTECTIVE HOUSING:

See specification sheets.

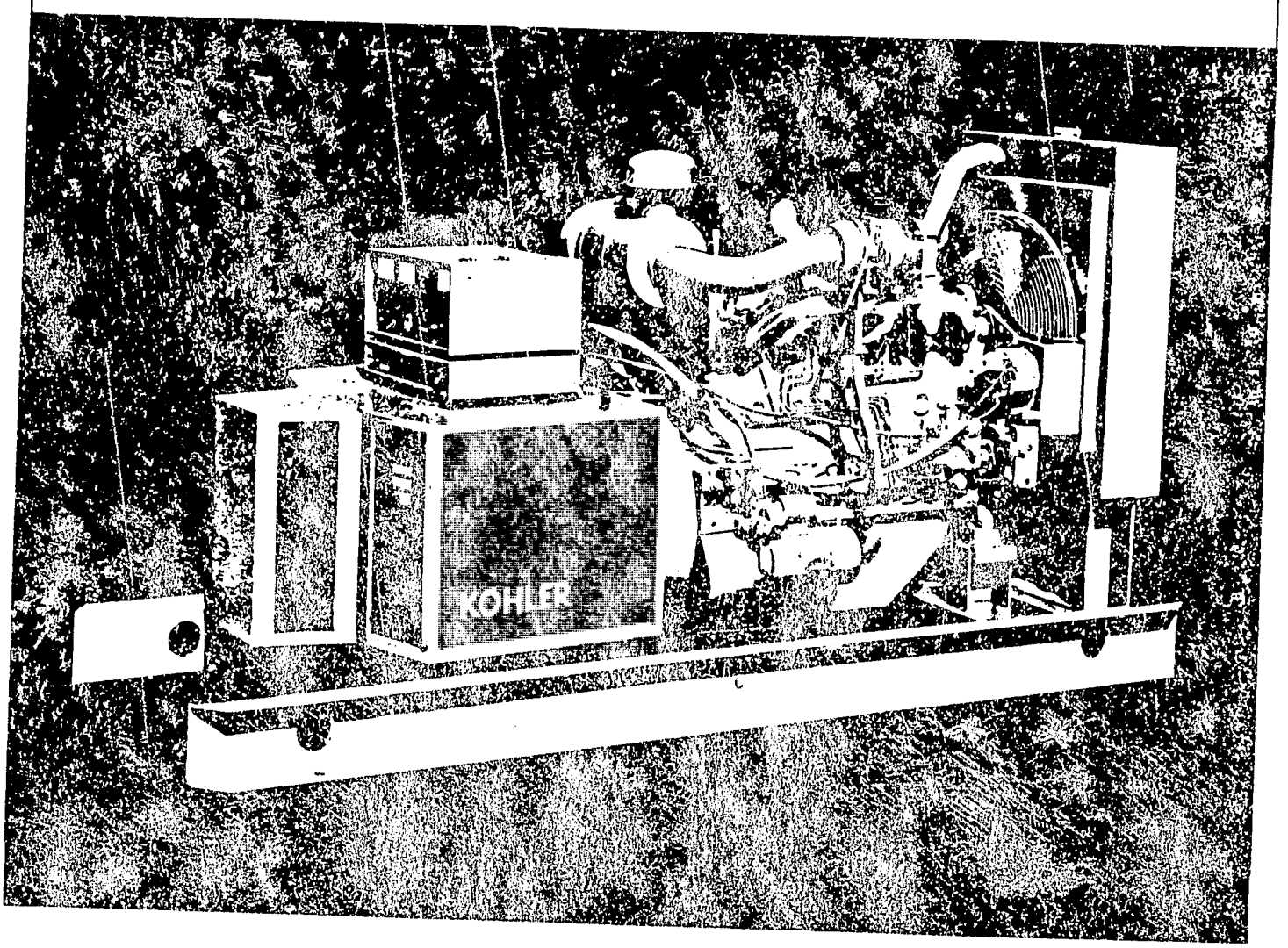
KOHLER GENERATORS

75 KW

ac liquid-cooled diesel

continuous standby generator set

- SUSTAINED SHORT CIRCUIT PROTECTION. Generator will not collapse. Sustains high short circuit current for selective tripping of normal sized branch circuit breakers.
- FAST RESPONSE TO LOAD CHANGES. Kohler-patented voltage regulation system provides full power to the main generator field within .05 seconds or less. Voltage dip on most 3-phase models, no load to specified load, is less than 15%.
- SAFEGUARD BREAKER. To prevent overloads, Kohler provides an AC line-sensing time delay circuit breaker as standard generator equipment. This breaker protects the generator from its own high current capability. Sufficient high current output time is allowed to trip a branch circuit breaker affected by a short.
- HARMONIC INTONATION. No high frequency spikes in output wave form.
- 12-LEAD RECONNECTIBLE TO COMMON VOLTAGES.
- POWER SCANNER* — A Light Emitting Diode monitoring system aids in service troubleshooting. Green light indicates power is available from the exciter, red light indicates that power is reaching the rotor according to load requirement. (* Patent Pending.)
- CONTROLLER — SOLID STATE *DECISION MAKER* MODEL. Accessories to meet NFPA-76A hospital code.
- GENERATOR ENCLOSURE. Serves as junction box, allows installation of conduit from either side.



APPLICATION DATA

DIESEL ENGINE

ENGINE SPECIFICATIONS	60 Hertz	50 Hertz
Manufacturer	White Engines	
Model	D-3400T	
Type air intake	turbocharged	
Cylinder arrangement (number, inline, V, etc.)	6 in-line	
Displacement in³ (cm³)	339 (5555)	
Bore and stroke in. (mm)	4 (102) x 4.5 (114)	
Compression ratio	16:1	
Piston speed ft/min (meters/sec.)	1350 (6.9)	1125 (5.7)
Bearings: mains, number	7	
connecting rods, number	6	
Rated RPM	1800	1500
Max. horsepower at rated RPM HP (KW)	128 (94)	97 (72)
BMEP at rated KW, standby psi (KPa)	156 (1072)	123 (846)
Fan horsepower HP (KW)	4 (3)	2.3 (1.8)
Cylinder head type and material	O.H.V. — cast iron	
Connecting rod type and material	forged steel	
Piston type and material	aluminum	
Crankshaft material	forged steel	
Valves, material	alloy forging	
Governor, make/model	Roosa-Master, DB	
regulation % frequency no load to full load	3% nominal, 5% maximum	
steady state regulation ± % frequency	± 0.33%	

ENGINE COOLING SYSTEM

Engine jacket water capacity gal. (litre)	3.1 (12)	
Engine jacket water flow GPM (LPM)	31 (117)	27 (102)
Heat rejected to cooling water (without fan) at rated KW — dry exh. BTU/sec (KW)	70 (74)	55 (53)
Water pump type	centrifugal	
Radiator system capacity (incl. engine) gal. (litre)	6.4 (24.4)	
Total inlet air requirement CFM (m³/min.)	5390 (153)	4407 (125)
Fan, blades	5	
dia. in. (mm)	18 (457)	
pitch in. (mm)	2.4 (60)	

ENGINE SPECIFICATIONS	60 Hertz	50 Hertz
OPTIONAL COOLING SYSTEMS		
☐ City water cooling system		
Heat exchanger mfgr/model	Young/F-502	
Exhaust manifold type	wet	
Connection sizes,		
Water inlet	.5" NPT	
Water outlet	1" NPT	
City water consumption, GPM (LPM)/at °F (°C)	9.5 (36)/80 (27)	
☐ Remote radiator system		
Exhaust manifold type	wet	
Cooling system capacity (incl. rad. & eng.) gal. (litre) (Based on Perfex DDV-35)	17.3 (66)	
Total inlet air requirement @ 25°F rise CFM (m³/min.) (Based on Perfex DDV-35)	4205 (119)	3324 (94)
Connection sizes		
engine; water inlet in. (mm)	2 (51) I.D. hose	
engine; water outlet in. (mm)	2.25 (57) I.D. hose	
remote radiator;		
top tank (inlet)	2" NPT	
bottom tank (outlet)	2" NPT	

COOLING SYSTEM ACCESSORIES

- ☐ Block heater — 1000 watt, 120 volt AC
- ☐ Radiator duct flange
- ☐ Remote radiator — vertical mount with 3 phase, 60 cycle motor DDV-35

FUEL SYSTEM

Fuel supply line, min. i.d. in. (mm)	.25 (6.5)	
Fuel return line, min. i.d. in. (mm)	.25 (6.5)	
Max. lift of engine driven fuel pump ft. (m)	6 (2)	
Fuel prime pump	manual	
Fuel oil filter	single stage	
Diesel fuel recommended	no. 2	

FUEL SYSTEM ACCESSORIES

- ☐ 8 gallon fuel transfer tank with pump
- ☐ 20 gallon fuel transfer tank with pump
- ☐ Fuel priming tank (1 qt.)
- ☐ Auxiliary fuel pump (12 volt)
- ☐ Flexible fuel lines

FUEL CONSUMPTION

100% load gal./hr. (liter/hr.)	6.6 (25)	5.1 (19)
75% load gal./hr. (liter/hr.)	5 (19)	3.8 (14)
50% load gal./hr. (liter/hr.)	3.7 (14)	2.8 (11)
25% load gal./hr. (liter/hr.)	2.8 (11)	2.1 (8)

60 HERTZ MODELS

Model	Voltage	Phase	Generator Model	Ampere	Continuous Standby KW/KVA
75ROZ01	120/240	3	4R6	210	70/87.5
75ROZ51	139/240	3	4R6	225	75/93.75
75ROZ61	120/240	1	4R6	250	60/60
75ROZ71	277/480	3	4R6	112	75/93.75
75ROZ81	120/208	3	4R6	260	75/93.75
75ROZ91	347/600	3	4R6	90	75/93.75

50 HERTZ MODELS

75RFOZ01	120/240	3	4R6	165	55/68.75
75RFOZ61	110/220	1	4R6	227	50/50
75RFOZ71	220/380	3	4R6	114	60/75
75RFOZ81	120/208	3	4R6	208	60/75

Note: All single phase units are rated at 1.0 power factor, 3 phase units at 0.8 power factor.
Ratings also apply to city and remote radiator cooling systems.
Ratings: All models are continuous standby rated. Unit will operate at this rating for the duration of any power outage.

APPLICATION DATA

ENGINE SPECIFICATIONS	60 Hertz	50 Hertz
EXHAUST SYSTEM		
Exhaust flow at rated KW CFM (m³/min.)	570 (16)	470 (13)
Exhaust temp. at rated KW, dry exhaust °F (°C)	1100 (593)	
Maximum allowable back pressure in. Hg. (KPa)	1.5 (5)	
Exhaust outlet size at hook-up in. (mm)	3" (76.2) NPT	

EXHAUST SYSTEM ACCESSORIES

- ☐ Flexible exhaust connector (stainless steel)
- ☐ Critical exhaust silencer
- ☐ Industrial exhaust silencer
- ☐ Residential exhaust silencer

AIR INDUCTION SYSTEM		
Combustion air at rated KW CFM (m³/min.)	245 (6.9)	204 (5.8)
Air cleaner type — all models	dry	

LUBRICATING SYSTEM	
Oil pan capacity gals. (liters)	2 (7.6)
Oil filter (quantity, type)	one, cartridge
Lube oil cooler (quantity, type)	one — oil/water

ENGINE ELECTRICAL SYSTEM	
Battery charging system ground (negative, positive)	negative
volts	12 DC
Starter motor rated voltage — volts	12 DC
Minimum recommended battery for 0°F (−18°C)	74 ampere
quantity	1
voltage — volts	12 DC

ENGINE ELECTRICAL SYSTEM — ACCESSORIES

- ☐ 12 volt, 90 ampere battery 1 required
- ☐ Battery rack (standard on housed units)
- ☐ Battery charger 12 volt trickle type with power cord and leads
- ☐ Battery cables
- ☐ Battery charger 12 volt, automatic float type

STANDARD FEATURES

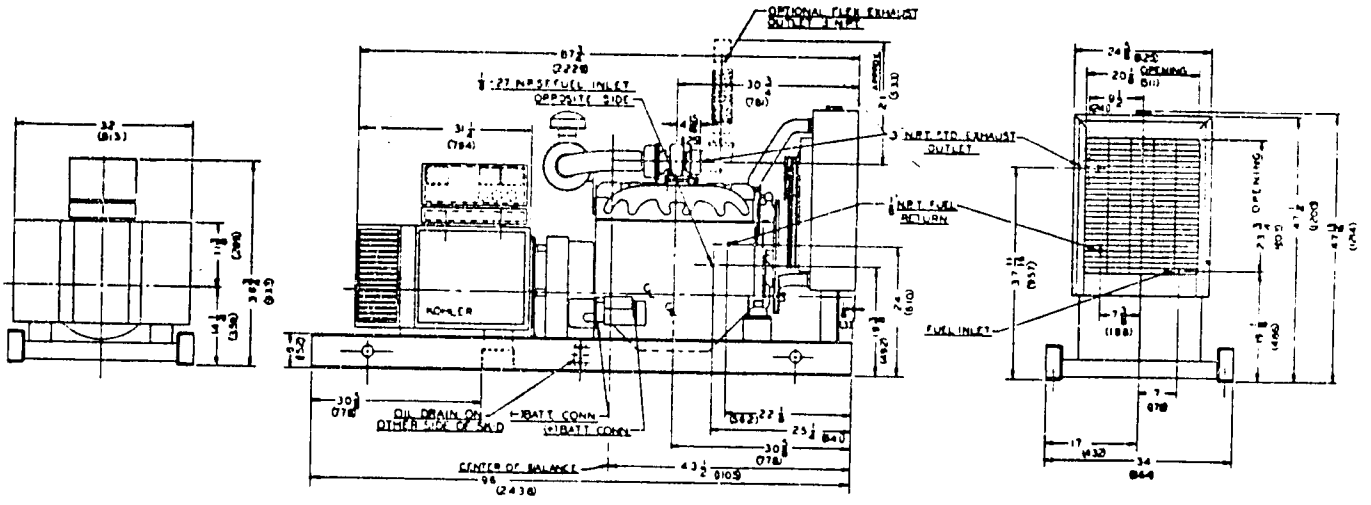
- Lube oil cooler
- Vibro-mounts
- Mounting base
- Operating instructions
- Low oil pressure cutout
- Automotive type starting
- High water temperature cutout
- Full flow lube oil filter

SPECIFICATIONS DERATION FACTORS	60 hertz	50 hertz
Maximum altitude before gen. set derating ft. (m)	500 (150)	
altitude deration factor — % per 1000 ft. (305 m)	3%	
Maximum intake air temp. before gen. set derating °F (°C)	85 (29)	
Temp. deration factor — % per 10°F (5.5°C)	1%	
Maximum mounting angle — front or rear up degrees	15°	

CONTINUOUS STANDBY 75ROZ

KOHLER
GENERATORS

DIMENSIONS SHOWN ARE APPROXIMATE AND ARE NOT TO BE USED FOR INSTALLATION. CONTACT FACTORY FOR CERTIFIED DIMENSION DRAWING. KOHLER CO. RESERVES THE RIGHT TO CHANGE DESIGN OR SPECIFICATIONS WITHOUT NOTICE.



WEIGHTS AND DIMENSIONS

Weight — Radiator Model; dry lb. (kg) 2100 (953)
Overall size: L x W x H in. (mm) 96 (2438) x 34 (864) x 47.8 (1214)

APPLICATION DATA

FAST-RESPONSE GENERATOR

SPECIFICATIONS	60 Hertz	50 Hertz
Manufacturer	Kohler	
Output reconnectible to	1Ø, wye and delta	
Number of leads	12	
Generator type	rotating field	
Excitation method	rotating exciter, brushless	
Voltage regulation method	Fast-Response	
Insulation — class, NEMA MG1-22.40	F	
Number of bearings	1	
Coupling	flexible disc	
Amortisseur windings	full	
Machine constants at (KW, volts)	75, 240 wye	60, 110 wye
Voltage regulation no load to rated load	± 2%	
Transient response no load to specified load (KW, % voltage dip)	70, 17%	
Recovery time — sec. (For above load)	.1	.13
Motor starting capacity, code F motor no load, 30% voltage dip, 60 Hz, 3 phase; no series boost — HP (KW)	45 (34)	

- Generator is designed and built within NEMA, IEEE and ANSI standards for temperature rise under continuous duty operation.
- Permanent magnet field rotating exciter.
- Skewed stator for smooth voltage wave form.
- Self-ventilated, drip-proof construction.
- Fungus resistant per MIL-E-4970A.
- Safeguard Breaker.

GENERATOR ACCESSORIES

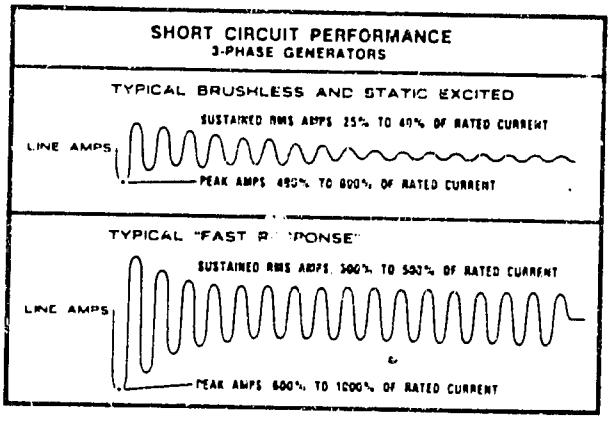
☐ Line circuit breakers.
- a. 139/240 volt (3 phase)
- b. 120/240 volt (1 phase)
- c. 277/480 volt (3 phase)
- d. 120/208 volt (3 phase)
- e. 347/600 volt (3 phase)

☐ Reactive droop compensator (3 phase)

ADDITIONAL ENGINE AND GENERATOR ACCESSORIES

☐ Accessories available to meet NFPA-76A.
- Block heater
- Low water temperature cutout
- Annunciator panel, remote, 16 lamp
- Alarm relay and horn
- All required indicator lamps (see controller description)

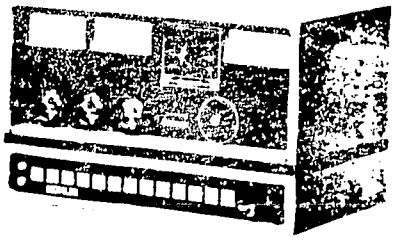
☐ CSA approval
☐ Weather housing
☐ Bosch electric governor
☐ Trailer
☐ Export boxing



SHORT CIRCUIT PROTECTION

Conventional generator current collapses under short circuit. FAST-RESPONSE generators continue to provide ample current to permit normal breaker tripping.

Vibro-mounted lower cabinet contains indicating lamps and solid state circuit boards. All instruments in upper cabinet are standard, as are six lamps in lower cabinet.



DECISION MAKER CONTROLLER

SPECIFICATIONS	
Manufacturer	Kohler
Type	solid state
Starting method	remote and local
Weight lbs. (kg)	33 (15)
Size — H x W x D in. (mm)	11.75 (298) x 18.25 (475) x 12.25 (311)
Power source	12 or 24 volt DC

STANDARD EQUIPMENT

- Wiring harness for electrical connections
- Lamp test switch
- Cyclic cranking
- Overcrank and starter unmesh protection
- Fault reset switch
- Overspeed control
- Two-wire remote start/stop termination
- Phase selector switch
- Voltage adjusting rheostat, front panel mounted
- DC circuit protection
- Engine start control selector switch
- Emergency stop switch
- Panel lamps (2)
- Shutdown time delay for engine cool off, adjustable 2 to 10 minutes

Instruments	Size in. (mm)	Accuracy % FS
AC voltmeter	3.5 (89)	2%
AC ammeter	3.5 (89)	2%
AC frequency meter	3.5 (89)	0.5%
Batt. charg. ammeter	2 (51)	2%
Engine H_2O temp.	2 (51)	2%
Engine oil pressure	2 (51)	2%
Running time meter	1.7 (43)	

Indicator Lamps

- Overcrank (red lamp)
- High water temperature (red lamp)
- Low oil pressure (red lamp)
- Overspeed (red lamp)
- Emergency stop (red lamp)
- Switch "off" (flashing red lamp) warns that engine start control selector switch has been left in the off position.

Mounting Capabilities

- Controller can be positioned so instruments face toward either side or toward rear of generator set.
- Either or both controller cabinets can be remote mounted as a monitoring aid.

ACCESSORIES

☐ Prealarm lamp group
- Anticipatory low oil pressure (yellow lamp)
- Anticipatory high water temperature (yellow lamp)
- Low water temperature (red lamp)

☐ Hospital lamp group required to meet NFPA-76A
- Anticipatory low oil pressure (yellow lamp)
- Anticipatory high water temperature (yellow lamp)
- High battery volts (red lamp)
- Low battery volts (red lamp)
- Low water temperature (red lamp)
- Low fuel (red lamp)
- "System ready" (green lamp) indicates no faults detected by monitoring system and that engine start control selector switch is in automatic position and ready for emergency start.

☐ Alarm relay plus horn
- Horn silence switch

☐ Decision Monitor — sixteen light remote annunciator panel.
☐ Fast-Check — diagnostic fault detector activates controller indicator circuits without operating engine/generator.
☐ Extension wiring harness for remote mounting of controller.
☐ Isolated alarm contact kit.

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Code: G05-001
Printed in U.S.A.

KOHLER GENERATORS

FASTRESPONSE

75KW Diesel
Liquid Cooled

SAMPLE SPECIFICATION

EMERGENCY STANDBY ELECTRICAL SYSTEM: The standby generator set shall be installed by the contractor at the location shown on the plans and drawings, and as specified herein; with all accessories and transfer switch(es) as required.

All equipment shall be new and of current production of a national firm, who manufactures the generator and control panel and transfer switch and assembles the standby generator set as a matched unit, having a service and parts organization within a reasonable distance of this project, backed up by a national sales and service organization.

The standby generator set shall be supplied to operate on #2 Diesel fuel.

The engine shall be liquid-cooled by means of a (select one) RADIATOR, CITY-WATER COOLING SYSTEM WITH HEAT EXCHANGER, REMOTE RADIATOR SYSTEM.

The standby generator set shall be rated continuous standby (defined as continuous for the duration of any power outage) *_____Volts_____Phase_____Wire _____Power Factor_____KW_____KVA_____Ampere at 500 feet altitude, 85 degrees F, as Kohler Model 75ROZ series.

*Ratings (select one)

NOTE: Ratings apply to radiator, city water, and remote radiator cooling systems.

Voltage	Phase	Wire	Power Factor	KW/KVA	Ampere
120/240	3	4	.8	70/87.5	210
139/240	3	3	.8	75/93.75	225
120/240	1	3	1.0	60/60	250
277/480	3	4	.8	75/93.75	112
120/208	3	4	.8	75/93.75	260
347/600	3	4	.8	75/93.75	90

ENGINE: The turbo-charged engine shall be Diesel fueled, 6 cylinder, 4-cycle, liquid-cooled, with not less than 339 cubic inch displacement and deliver a minimum of 126 HP, at a governed speed of 1800 RPM.

Engine speed shall be governed by a gear driven mechanical governor to maintain generator frequency within 3 cycles from no load to full load generator output. Belt driven governors will not be considered.

Engine shall be equipped with the following:

12 volt positive engagement solenoid shift starting motor.
40 ampere automatic battery charging alternator.
Lube oil filter - Dry-type air cleaner.
Electric solenoid fuel shut-off valve.
Gas-proof seamless, stainless steel, flexible exhaust connector.
Flexible fuel connection - oil drain extension.

GENERATOR: The generator shall be 4 pole, brushless, 12 lead reconnectable of drip-proof construction with amortisseur windings. Insulation shall be Class F with epoxy varnish. Generator field current shall be controlled by a rotating thyrister bridge module optically coupled to a firing circuit type voltage regulator. The exciter shall be 24 pole permanent magnet type. Generators controlled by wound field exciters will not be accepted unless they meet the following performance.

Radio-interference suppression meeting commercial standards shall be supplied. Voltage regulation shall be within plus or minus 2% of rated voltage, from no load to rated load.

Upon application of 90% rated load in one step voltage dip as measured by a light beam recorder or oscilloscope shall not exceed 17%, recovery to stable voltage shall occur within .1 second. Stable or steady state operation is defined as operation with terminal voltage remaining constant within plus or minus 1/2 of 1 percent of rated voltage. Voltage adjustment range shall be plus or minus or minus 5 percent of rated voltage. Temperature rise shall be within NEMA, IEEE, and ANSI standards.

KOHLER

If a line to neutral short circuit occurs, the generator shall support 300% rated current for 10 seconds without externally mounted devices.

A resettable line current sensing circuit breaker with inverse time vs. current response shall be furnished which protects the generator from damage due to overload. This breaker shall not trip within the 10 seconds specified above.

Separate visual diagnostic means shall be furnished on the generator rotor for determining that exciter voltage is being developed and that the excitation system is supplying current to the generator field according to load requirements.

The generator, having a single, maintenance free bearing, shall be direct connected to the flywheel housing, with a disc coupling between the rotor and the flywheel.

CONTROLLER: Set mounted controller facing right, left, rear (choose one) shall be vibration isolated on the generator enclosure. It shall be of solid state design. Relays will be acceptable only for high current circuits. Circuitry shall be of plug-in design for quick replacement. Controller shall be equipped to accept a plug-in device capable of allowing maintenance personnel to test controller performance without operating the engine. The controller shall include:

Fused DC circuits.

Complete 2-wire start/stop control which shall operate on activation of a remote contact.

Cranking period controller by a speed sensor which disengages the starting motor when the engine has started. Battery charging alternator or generator voltage may not be used for this signal.

The starting system shall be designed for restarting, in the event of a false engine start, by permitting the engine to completely stop and then re-engage the starter.

Cranking cycler with individually adjustable (2 to 20 seconds) ON and OFF cranking periods.

Overcranking protection designed to open the cranking circuit after 30-60 seconds if the engine fails to start.

Circuitry to shut down the engine when signal for high coolant temperature, low oil pressure or overspeed are received, with reset button.

Adjustable (2- to 10-minute) factory set at 5-minute time delay to permit unloaded running of the standby set after transfer of the load to normal.

Alarm horn.

Three-position (automatic-off-test) selector switch.

Emergency stop switch.

Indicating lights to signal:

Standard Equipment	Switch "off" (flashing red) Overcrank (red) Emergency stop (red) High coolant temperature (red) Overspeed (red) Low oil pressure (red)
Optional Anticipatory Group*	Anticipatory high coolant temperature (yellow) Anticipatory low oil pressure (yellow) Low coolant temperature (red)
Optional Hospital Group*	High battery voltage (red) Low battery voltage (red) Low fuel (red) System ready (green)

Test button for indicating lights.

Connections to the controller shall be by plug-in wiring harness.

*Required to meet NFPA-76A regulations.

INSTRUMENT PANEL: A set mounted instrument panel shall include:

Dual range voltmeter 3 1/2 inch ± 2% accuracy.

Dual range ammeter 3 1/2 inch ± 2% accuracy.

Voltmeter-Ammeter phase selector switch.

Lights to indicate high or low meter scale.

Direct reading pointer type frequency meter 3 1/2 inch ± .3 hz accuracy.

Panel illuminating light.

Battery charging ammeter.

Oil pressure gauge.

Coolant temperature gauge.

Running time meter.

Plug-in voltage regulator with front panel voltage adjusting rheostat.

AUTOMATIC TRANSFER SWITCH(ES) The automatic transfer switch shall be listed by Underwriters Laboratory under Std. UL 1008 for emergency systems and all classes of load, and be CSA approved. The ampere rating shall be at least equal to the total load being transferred. Control circuitry shall be solid state except for "OFF" timers and heavy current circuits. The transfer switch shall initiate transfer to the generator set when the voltage of any phase of the normal drops below 70% of rated. The transfer switch shall have closing, withstand and interrupting ratings equal to the available short circuit current on the normal supply. A minimum of .5 second delay must exist between the opening of the emergency and closing of the normal to allow induced voltages in the system to decay.

GENERATOR SET MOUNTING: The standby generator set shall be equipped with factory installed vibration isolators mounted between the set and fabricated steel base to prevent distortion of alignment between generator and engine when installed. Mount on concrete pad as shown on plans and drawings.

ACCESSORIES: Engine block heater, 1,000 watt, 120 volt.*

One, 90 ampere hour, 12 volt battery, battery rack, and battery cables.

20 ampere automatic float battery charger Model A-269214 with constant voltage regulation, current limiting capability, temperature compensated for ambients from -20°F, voltmeter and ammeter; equipped for conduit installation, as supplied by Kohler Co.

Engine exhaust silencer rated for (select one) Industrial, Residential, Critical application.

Remote annunciator panel* with visual indicators for:

Switch "off" (flashing red), Overcrank (red), Emergency stop (red), High coolant temperature (red), Overspeed (red), Low oil pressure (red), Anticipatory high coolant temperature (yellow), Anticipatory low oil pressure (yellow) Low coolant temperature (red), High battery voltage (red), Low battery voltage (red), Low fuel (red), System ready (green), Normal line power (yellow), Generator power (yellow), Alarm switch off (red), and an audible alarm with shut-off switch.

*Required to meet NFPA-76A regulations.

INFORMATION REQUIRED FOR SPECIFIED STANDBY SYSTEMS

1. Detailed specification sheets.

2. Certified final factory test report shall be provided to the architect, certifying this unit's full power rating, stability, voltage and frequency regulation.

3. Complete operating instruction and maintenance manual with parts list.

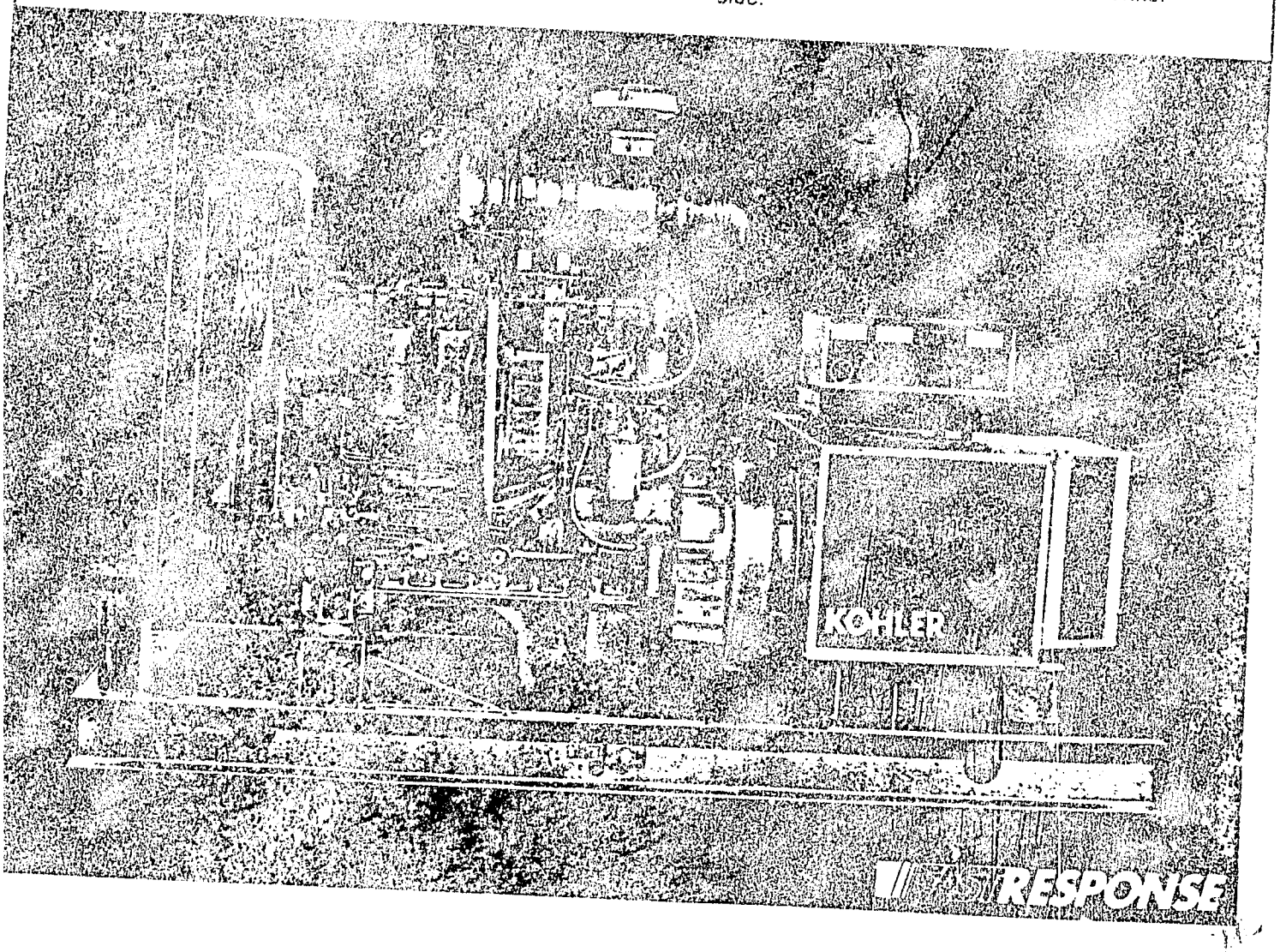
KOHLER GENERATORS

100 KW

ac liquid-cooled diese

continuous standby generator set

- SUSTAINED SHORT CIRCUIT PROTECTION. Generator will not collapse. Sustains high short circuit current for selective tripping of normal sized branch circuit breakers
- FAST RESPONSE TO LOAD CHANGES. Kohler-patented voltage regulation system provides full power to the main generator field within .05 seconds or less. Voltage dip on most 3-phase models, no load to specified load, is less than 15%.
- SAFEGUARD BREAKER. To prevent overloads, Kohler provides an AC line-sensing time delay circuit breaker as standard generator equipment. This breaker protects the generator from its own high current capability. Sufficient high current output time is allowed to trip a branch circuit breaker affected by a short.
- HARMONIC INTONATION. No high frequency spikes in output wave form.
- 12-LEAD RECONNECTIBLE TO COMMON VOLTAGES.
- POWER SCANNER* — A Light Emitting Diode monitoring system aids in service trouble-shooting. Green light indicates power is available from the exciter, red light indicates that power is reaching the rotor according to load requirement. (* Patent Pending.)
- CONTROLLER — SOLID STATE *DECISION MAKER* MODEL. Accessories to meet NFPA — 76A hospital code.
- GENERATOR ENCLOSURE. Serves as junction box, allows installation of conduit from either side.



APPLICATION DATA

DIESEL ENGINE

ENGINE SPECIFICATIONS	60 Hertz	50 Hertz
Manufacturer	White Engines, Inc.	
Model	D-4800T	
Type	4 cycle, turbocharged	
Cylinder arrangement (number, inline, V, etc.)	6 in-line	
Displacement in³ (cm³)	478 (7850)	
Bore and stroke in. (mm)	4.56 (116) x 4.88 (124)	
Compression ratio	18:1	
Piston speed ft/min (meters/sec.)	1464 (7.4)	1220 (6.2)
Bearings: mains, number	7	
connecting rods, number	6	
Rated RPM	1800	1500
Max. horsepower at rated RPM HP (KW)	180 (134)	147 (110)
Fan horsepower HP (KW)	3.4 (2.5)	2 (1.5)
Cylinder head type and material	O.H.V. — alloy casting	
Connecting rod type and material	forged steel	
Piston type and material	aluminum	
Crankshaft material	forged steel	
Valves, material	alloy forging	
Governor, make/model	Roosa Master/DB	
regulation % frequency no load to full load	3 nominal, 5 maximum	
steady state regulation ± % frequency	0.33	

ENGINE COOLING SYSTEM		
Engine jacket water capacity gal. (litre)	4 (15)	
Engine jacket water flow GPM (LPM)	60 (227)	50 (189)
Heat rejected to cooling water (without fan) at rated KW — dry exh. BTU/sec (KW)	81 (86)	69 (73)
Water pump type	centrifugal	
Radiator system capacity (incl. engine) gal. (litre)	9 (34)	
Total inlet air requirement CFM (m³/min.)	8645 (245)	7245 (205)
Fan, blades	6	
dia. in. (mm)	21.75 (552)	
pitch in. (mm)	2.25 (57)	

ENGINE SPECIFICATIONS	60 Hertz	50 Hertz
OPTIONAL COOLING SYSTEMS		
☐ City water cooling system with heat exchanger includes: pipe threaded water connections, water shut-off solenoid valve, thermostatically controlled water saver valve, surge tank		
Heat exchanger mfgr/model	Young/F-502	
Exhaust manifold type	dry	
Connection sizes, water inlet	.75" NPT	
water outlet	1" NPT	
City water consumption, GPM (LPM/at °F (°C)	12 (45)/90 (32)	
☐ Remote radiator system		
Exhaust manifold type	dry	
Cooling system capacity (incl. rad. & eng.) gal. (litre) (Based on Perfex DDV-35)	15 (57)	
Total inlet air requirement at 25°F rise CFM (m³/min.) (Based on Perfex DDV-35)	5335 (151)	
Connection sizes		
engine; water inlet in. (mm)	2.5 (63) I.D. hose	
engine; water outlet in. (mm)	2 (51) I.D. hose	
remote radiator; top tank (inlet)	2" NPT	
bottom tank (outlet)	2" NPT	

COOLING SYSTEM ACCESSORIES

- ☐ Block heater — 2500 watt, 120 volt AC.
- ☐ Radiator duct flange.
- ☐ Remote radiator — vertical mount with 3 phase, 60 cycle motor DDV-35.

FUEL SYSTEM	
Fuel supply line, min. I.D. in. (mm)	.25 (6)
Fuel return line, min. I.D. in. (mm)	.25 (6)
Max. lift of engine driven fuel pump ft. (m)	6 (2)
Fuel prime pump	electric
Fuel oil filter	single stage

FUEL SYSTEM ACCESSORIES

- ☐ Fuel priming tank (1 qt.)
- ☐ 8-gallon fuel transfer tank with pump.
- ☐ Flexible fuel line.
- ☐ 20-gallon fuel transfer tank with pump.
- ☐ Auxiliary fuel pump (24 volt).

FUEL CONSUMPTION	
100% load gal./hr. (liter/hr.)	8.1 (31)
75% load gal./hr. (liter/hr.)	6.1 (23)
50% load gal./hr. (liter/hr.)	4.4 (17)
25% load gal./hr. (liter/hr.)	3.0 (11)

60 HERTZ MODELS

Model	Voltage	Phase	Generator Model	Ampere	Continuous Standby KW/KVA
100ROZ01	120/240	3	4R8	270	90/112.5
100ROZ51	139/240	3	4R8	301	100/125
100ROZ61	120/240	1	4R8	375	90/90
100ROZ71	277/480	3	4R8	150.5	100/125
100ROZ81	120/208	3	4R8	347	100/125
200ROZ91	347/600	3	4R8	120	100/125

50 HERTZ MODELS

100RFOZ01	120/240	3	4R8	225.5	75/93.74
100RFOZ61	110/220	1	4R8	340	75/75
100RFOZ71	220/380	3	4R8	161.5	85/106.25
100RFOZ81	120/208	3	4R8	295	85/106.25

RATINGS: All models are continuous standby rated. Unit will operate at this rating for the duration of any power outage. Ratings also apply to city water and remote radiator cooling systems. All single phase units are rated at 1.0 power factor, 3 phase units at 0.8 power factor. Derate approximately 1.5% per 1000 ft. (305 m.) above 3300 ft. (1000m) elevation.

APPLICATION DATA

ENGINE SPECIFICATIONS	60 Hertz	50 Hertz
EXHAUST SYSTEM		
Exhaust flow at rated KW CFM (m^3/min.)	900 (25)	750 (21)
Exhaust temp. at rated KW, dry exhaust °F (°C)	1165 (627)	
Maximum allowable back pressure in. Hg. (KPa)	1.1 (3.7)	
Exhaust outlet size at hook-up	3" NPT	
EXHAUST SYSTEM ACCESSORIES		
☐ Flexible exhaust connector (stainless steel)	☐ Residential exhaust silencer	
☐ Industrial exhaust silencer	☐ Critical exhaust silencer	
AIR INDUCTION SYSTEM		
Combustion air at rated KW CFM (m^3/min.)	295 (8.3)	245 (6.9)
Air cleaner type — all models	dry	
LUBRICATING SYSTEM		
Oil pan capacity gals. (litres)	5.5 (21)	
Oil filter (quantity, type)	2 — full flow	
Lube oil cooler (quantity, type)	one — oil/water	
ENGINE ELECTRICAL SYSTEM		
Battery charging system ground (negative, positive)	negative	
volts	24 DC	
Starter motor rated voltage — volts	24 DC	
Minimum recommended battery for 0° F quantity	140 ampere	
voltage — volts		

ENGINE ELECTRICAL SYSTEM — ACCESSORIES

- ☐ 6 Volt, 160 ampere battery 4 required
- ☐ Battery charger 24 volt trickle type with power cord and leads.
- ☐ Battery cables.
- ☐ Battery charger 24 volt, automatic float type.
- ☐ Battery rack (standard on housed units).

STANDARD ENGINE FEATURES

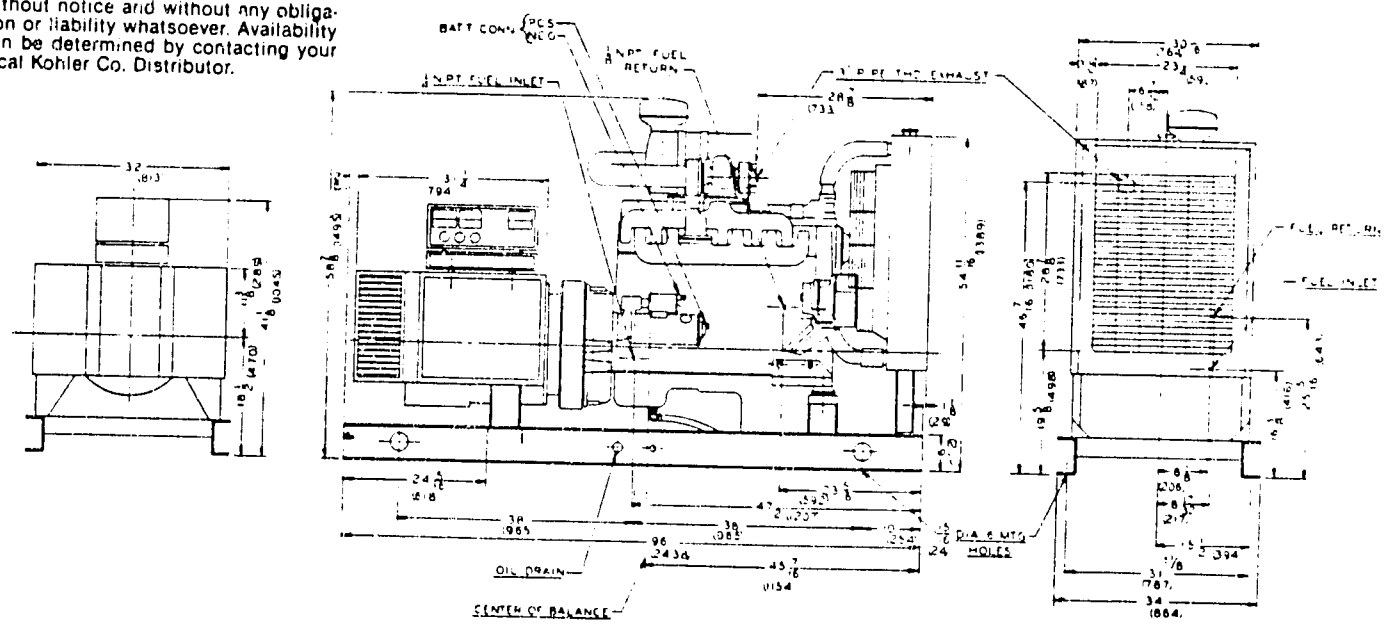
- Vibro-mounts
- High water temperature cut-out
- Lube oil cooler
- Mounting base
- Full flow lube oil filter
- Low oil pressure cut-out
- Automotive type starting
- Operating instructions

SPECIFICATIONS	60 Hertz	50 Hertz
DERATION FACTORS		
Maximum altitude before gen. set derating ft. (m)	3300 (1000)	
altitude deration factor — % per 1000 ft. (305 m)	1.5	
Maximum intake air temp. before gen. set derating °F (°C)	105 (40)	
temp. deration factor — % per 10°F (5.5°C)	2.7	
Maximum mounting angle — front or rear up degrees	30	

CONTINUOUS STANDBY 100ROZ

KOHLER
GENERATORS

Availability is subject to change without notice. Kohler Co. reserves the right to change the design or specifications without notice and without any obligation or liability whatsoever. Availability can be determined by contacting your local Kohler Co. Distributor.



WEIGHTS AND DIMENSIONS

Weight — approximately lb. (kg) 2985 (1356)

Overall Size: L x W x H in. (mm) 96.25 (2438) x 34 (864) x 58.87 (1495)

APPLICATION DATA

FAST-RESPONSE GENERATOR

SPECIFICATIONS	60 Hertz	50 Hertz
Manufacturer	Kohler	
Output reconnectible	1Ø, wye and delta	
Number of leads	12	
Generator type	rotating field	
Excitation method	rotating exciter, brushless	
Voltage regulation method	Fast-Response	
Insulation — class, NEMA MG1-22.40		
Number of bearings	1	
Coupling	flexible disc	
Amortisseur windings	full	
Voltage regulation steady state — no load to full load — %	2 maximum	
One step load acceptance % of rating	90	

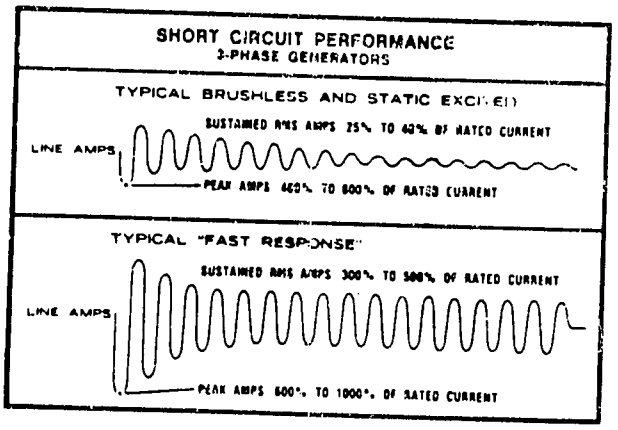
- Generator is designed and built within NEMA, IEEE and ANSI standards for temperature rise under continuous duty operation at all output ratings.
- Permanent magnet field rotating exciter.
- Skewed stator for smooth voltage wave form.
- Self-ventilated, drip-proof construction.
- Fungus resistant per MIL-E-4970A.
- Safeguard Breaker.

GENERATOR ACCESSORIES

- ☐ Line circuit breakers.
  - a. 240 volt (3 phase)
  - b. 120/240 volt (1 phase)
  - c. 277/480 volt (3 phase)
  - d. 120/208 volt (3 phase)
  - e. 347/600 volt (3 phase)
- ☐ Reactive droop compensator.

ADDITIONAL ENGINE AND GENERATOR ACCESSORIES

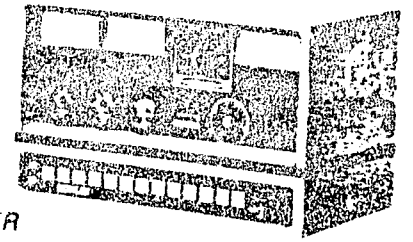
- ☐ Accessories available to meet NFPA-76A.
  - Block heater
  - Low water temperature cut-out
  - Annunciator panel, remote, 16 lamp
  - Alarm relay and horn
  - All required indicator lamps (see controller description)
- ☐ CSA approval.
- ☐ Weather housing.
- ☐ Bosch electric governor.
- ☐ Trailer.
- ☐ Export boxing.
- ☐ Generator strip heater.



SHORT CIRCUIT PROTECTION

Conventional generator current collapses under short circuit. FAST-RESPONSE generators continue to provide ample current to permit normal breaker tripping.

Vibro-mounted lower cabinet contains indicating lamps and solid state circuit boards. All instruments in upper cabinet are standard, as are six lamps in lower cabinet.



DECISION MAKER CONTROLLER

SPECIFICATIONS	
Manufacturer	Kohler
Type	solid state
Starting method	remote and local
Weight lbs. (kg)	33 (15)
Size — H x W x D in. (mm)	11.75 (298) x 18.25 (475) x 12.25 (311)
Power source	12 or 24 volt DC

STANDARD EQUIPMENT

- Wiring harness for electrical connections
- Lamp test switch
- Cyclic cranking
- Overcrank and starter unmesh protection
- Fault reset switch
- Overspeed control
- Two-wire remote start/stop termination
- Phase selector switch
- Voltage adjusting rheostat, front panel mounted
- DC circuit protection
- Engine start control selector switch
- Emergency stop switch
- Panel lamps (2)
- Shutdown time delay for engine cool off, adjustable 2 to 10 minutes

Instruments

	Size in. (mm)	Accuracy % FS
• AC voltmeter	3.5 (89)	2%
• AC ammeter	3.5 (89)	2%
• AC frequency meter	3.5 (89)	0.5%
• Batt. charg. ammeter	2 (51)	2%
• Engine H_2O temp.	2 (51)	2%
• Engine oil pressure	2 (51)	2%
• Running time meter	1.7 (43)	

Indicator Lamps

- Overcrank (red lamp)
- High water temperature (red lamp)
- Low oil pressure (red lamp)
- Overspeed (red lamp)
- Emergency stop (red lamp)
- Switch "off" (flashing red lamp) warns that engine start control selector switch has been left in the off position.

Mounting Capabilities

- Controller can be positioned so instruments face toward either side or toward rear of generator set.
- Either or both controller cabinets can be remote mounted as a monitoring aid.

ACCESSORIES

- ☐ Prealarm lamp group
  - Anticipatory low oil pressure (yellow lamp)
  - Anticipatory high water temperature (yellow lamp)
  - Low water temperature (red lamp)
- ☐ Hospital lamp group required to meet NFPA-76A
  - Anticipatory low oil pressure (yellow lamp)
  - Anticipatory high water temperature (yellow lamp)
  - High battery volts (red lamp)
  - Low battery volts (red lamp)
  - Low water temperature (red lamp)
  - Low fuel (red lamp)
  - "System ready" (green lamp) indicates no faults detected by monitoring system and that engine start control selector switch is in automatic position and ready for emergency start.
- ☐ Alarm relay plus horn
  - Horn silence switch
- ☐ Decision Monitor — sixteen light remote annunciator panel.
- ☐ Fast-Check — diagnostic fault detector activates controller indicator circuits without operating engine/generator.
- ☐ Extension wiring harness for remote mounting of controller.
- ☐ Isolated alarm contact kit.

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KOHLER GENERATORS

KOHLER GENERATORS

100 KW Diesel
Liquid Cooled

SAMPLE SPECIFICATION

EMERGENCY STANDBY ELECTRICAL SYSTEM: The standby generator set shall be installed by the contractor at the location shown on the plans and drawings, and as specified herein; with all accessories and transfer switch(es) as required.

All equipment shall be new and of current production of a national firm, who manufactures the generator and control panel and transfer switch and assembles the standby generator set as a matched unit, having a service and parts organization within a reasonable distance of this project, backed up by a national sales and service organization.

The standby generator set shall be supplied to operate on #2 Diesel fuel.

The engine shall be liquid-cooled by means of a (select one) RADIATOR, CITY-WATER COOLING SYSTEM WITH HEAT EXCHANGER, REMOTE RADIATOR SYSTEM.

The standby generator set shall be rated continuous standby (defined as continuous for the duration of any power outage) *_____Volts_____ Phase_____Wire_____Power Factor _____KW_____KVA_____Ampere at 3300 feet altitude, 85 degrees F, as Kohler Model 100ROZ series.

*Ratings (select one)

NOTE: Ratings apply to radiator, city water, and remote radiator cooling systems.

Voltage	Phase	Wire	Power Factor	KW/KVA	Ampere
120/240	3	4	.8	90/112.5	270
240	3	3	.8	100/125	301
120/240	1	3	1.0	90/90	375
277/480	3	4	.8	100/125	150.5
120/208	3	4	.8	100/125	347
347/600	3	4	.8	100/125	120

ENGINE: The turbo charged engine shall be Diesel fueled, 6 cylinder, 4-cycle, liquied cooled, with not less than 478 cubic inch displacement and deliver a minimum of 180 HP, at a governed speed of 1800 RPM.

Engine speed shall be governed by a gear driven mechanical governor to maintain generator frequency within 3 cycles from no load to full load generator output. Belt driven governors will not be considered.

Engine shall be equipped with the following:

24 volt positive engagement solenoid shift starting motor.
40 ampere automatic battery charging alternator.
Lube oil filter - Dry-type air cleaner.
Electric solenoid fuel shut-off valve.
Gas proof seamless, stainless steel, flexible exhaust connection.
Flexible fuel connection - Oil drain extension.

FASTRESPONSE

GENERATOR: The generator shall be four pole, brushless, 12 lead reconnectable of drip-proof construction with amortisseur windings. Insulation shall be Class F with epoxy varnish. Generator field current shall be controlled by a rotating thyrister bridge module optically coupled to a firing circuit type voltage regulator. The exciter shall be 24 pole permanent magnet type. Generators controlled by wound field exciters will not be accepted unless they meet the following performance.

Radio-interference suppression meeting commercial standards shall be supplied. Voltage regulation shall be within plus or minus 2% of rated voltage, from no load to rated load.

Upon application of 89% rated load in one step voltage dip as measured by a light beam recorder or oscilloscope shall not exceed 15%, recovery to stable voltage shall occur within .1 second. Stable or steady state operation is defined as operation with terminal voltage remaining constant within plus or minus 1/2 of one (1) percent of rated voltage. Voltage adjustment range shall be plus or minus 5 percent of rated voltage. Temperature rise shall be within NEMA, IEEE, and ANSI standards.

If a line to neutral short circuit occurs, the generator shall support 300% rated current for 10 seconds without externally mounted devices.

A resettable line current sensing circuit breaker with inverse time vs. current response shall be furnished which protects the generator from damage due to overload. This breaker shall not trip within the 10 seconds specified above.

Separate visual diagnostic means shall be furnished on the generator rotor for determining that exciter voltage is being developed and that the excitation system is supplying current to the generator field according to load requirements.

The generator, having a single, maintenance free bearing, shall be direct connected to the flywheel housing, with a disc coupling between the rotor and the flywheel.

CONTROLLER: Set mounted controller facing right, left, rear (choose one) shall be vibration isolated on the generator enclosure. It shall be of solid state design. Relays will be acceptable only for high current circuits. Circuitry shall be of plug-in design for quick replacement. Controller shall be equipped to accept a plug-in device capable of allowing maintenance personnel to test controller performance without operating the engine. The controller shall include:

Fused DC circuits.

Complete 2 wire start/stop control which shall operate on activation of a remote contact.

Cranking period controlled by a speed sensor which disengages the starting motor when the engine has started. Battery charging alternator or generator voltage may not be used for this signal.

The starting system shall be designed for restarting in the event of a false engine start, by permitting the engine to completely stop and then re-engage the starter.

Cranking cycler with individually adjustable (2 to 20 seconds) ON and OFF cranking periods.

Overcranking protection designed to open the cranking circuit after 30-90 seconds if the engine fails to start.

Circuitry to shut down the engine when signal for high coolant temperature, low oil pressure or overspeed are received, with reset button.

Adjustable (2 to 10 minute) factory set at 5 min. time delay to permit unloaded running of the standby set after transfer of the load to normal.

Alarm horn.

Three position (automatic-off-test) selector switch.

Emergency stop switch.

Indicating lights to signal -

Specifier's Note:		
	Standard Equip.	(Switch "off" (flashing red) (Overcrank (red) (Emergency stop (red) (High coolant temperature (red) (Overspeed (red) (Low oil pressure (red)
	Optional Anticipatory Group*	(Anticipatory high coolant (Temperature (yellow) (Anticipatory low oil pressure ((yellow)
	Optional Hospital Group*	(System ready (green) (High battery voltage (red) (Low battery voltage (red) (Low fuel (red)

Test button for indicating lights.

Connections to the controller shall be by plug-in wiring harnesses.

*Required to meet NFPA-76A Regulations.

<u>INSTRUMENT PANEL</u>: A set mounted instrument panel shall include:

Dual range voltmeter 3-1/2 inch ±2% accuracy.

Dual range ammeter 3-1/2 inch ±2% accuracy.

Voltmeter-Ammeter phase selector switch.

Lights to indicate high or low meter scale.

Direct reading pointer type frequency meter 3-1/2 inch ±.3 hz accuracy.

Panel illuminating light.

Battery charging ammeter.

Oil pressure gauge.

Coolant temperature gauge.

Running time meter.

Plug-in voltage regulator with front panel voltage adjusting rheostat.

AUTOMATIC TRANSFER SWITCH(ES): The automatic transfer switch shall be listed by Underwriters Laboratory under Std. UL 1008 for emergency systems and all classes of load, and be CSA approved. The ampere rating shall be at least equal to the total load being transferred. Control circuitry shall be solid state except for "OFF" timers and heavy current circuits. The transfer switch shall initiate transfer to the generator set when the voltage of any phase of the normal drops below 70% of rated. The transfer switch shall have closing, withstand and interrupting ratings equal to the available short circuit current on the normal supply. A minimum of .5 second delay must exist between the opening of the emergency and closing of the normal to allow induced voltages in the system to decay.

GENERATOR SET MOUNTING: The standby generator set shall be equipped with factory installed vibration isolators mounted between the set and fabricated steel base to prevent distortion of alignment between generator and engine when installed. Mount on concrete pad as shown on plans and drawings.

ACCESSORIES: Engine block heater, 2,500 watt, 120 volt.*

Four, 160 ampere hour, 6 volt batteries, battery rack, and battery cables.

15 ampere automatic float battery charger Model A269215 with constant voltage regulation, current limiting capability, temperature compensated for ambients from -20° F, voltmeter and ammeter; equipped for conduit installation, as supplied by Kohler Co.

Engine exhaust silencer rated for (select one) Industrial, Residential, Critical application.

Remote annunciator panel* with visual indicators for:

Switch "off" (flashing red), Overcrank (red), Emergency stop (red), High coolant temperature (red), Overspeed (red), Low oil pressure (red), Anticipatory high coolant temperature (yellow), Anticipatory low oil pressure (yellow), low coolant temperature (red), High battery voltage (red), Low battery voltage (red), Low fuel (red), System ready (green), Normal line power (yellow), Generator power (yellow), Alarm switch off (red), and an audible alarm with shut-off switch.

*Required to meet NFPA-76A Regulations.

INFORMATION REQUIRED FOR SPECIFIED STANDBY SYSTEMS

1. Detailed specification sheets.

2. Certified final factory test report shall be provided to the architect, certifying this unit's full power rating, stability, voltage and frequency regulation.

3. Complete operating instruction and maintenance manual with parts list.

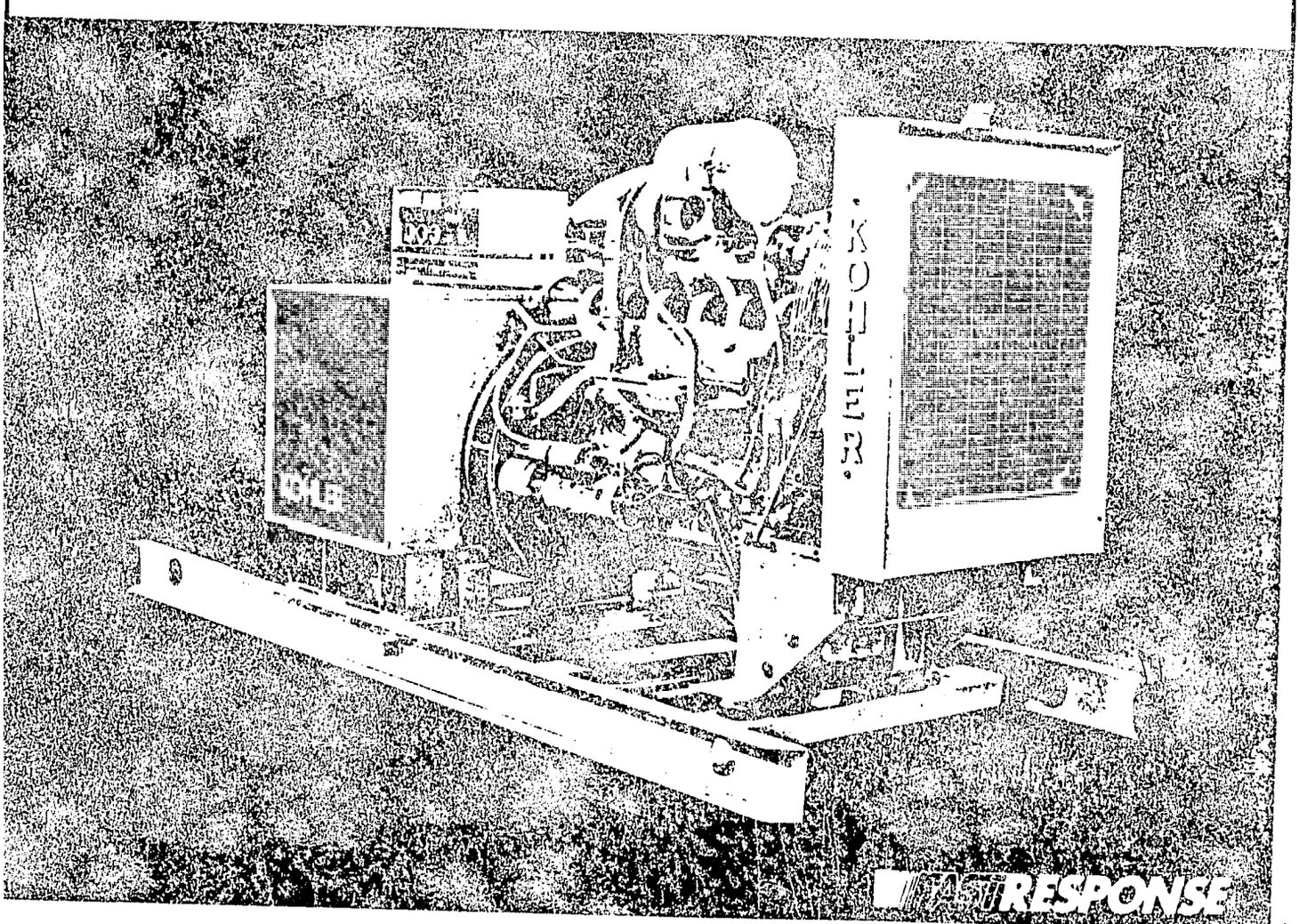
KOHLER GENERATORS

125 KW

ac liquid-cooled diesel

continuous standby generator set

- SUSTAINED SHORT CIRCUIT PROTECTION. Generator will not collapse. Sustains high short circuit current for selective tripping of normal sized branch circuit breakers.
- FAST RESPONSE TO LOAD CHANGES. Kohler-patented voltage regulation system provides full power to the main generator field within .05 seconds or less. Voltage dip on most 3-phase models, no load to specified load, is less than 15%.
- SAFEGUARD BREAKER. To prevent overloads, Kohler provides an AC line-sensing time delay circuit breaker as standard generator equipment. This breaker protects the generator from its own high current capability. Sufficient high current output time is allowed to trip a branch circuit breaker affected by a short.
- HARMONIC INTONATION. No high frequency spikes in output wave form.
- 12-LEAD RECONNECTIBLE TO COMMON VOLTAGES.
- POWER SCANNER* — A Light Emitting Diode monitoring system aids in service trouble-shooting. Green light indicates power is available from the exciter, red light indicates that power is reaching the rotor according to load requirement. (* Patent Pending.)
- CONTROLLER — SOLID STATE *DECISION MAKER* MODEL. Accessories to meet NFPA — 76A hospital code.
- GENERATOR ENCLOSURE. Serves as junction box, allows installation of conduit from either side.



APPLICATION DATA

DIESEL ENGINE

ENGINE SPECIFICATIONS	60 Hertz	50 Hertz
Manufacturer	White Engine, Inc.	
Model	D-4600TA	
Type air intake	turbocharged & after-cooled	
Cylinder arrangement (number, inline, V, etc.)	6 in-line	
Displacement in³ (cm³)	478 (7850)	
Bore and stroke in. (mm)	4.56 (116) x 4.88 (124)	
Compression ratio	18:1	
Piston speed ft/min. (meters/sec.)	1460 (7.4)	1220 (6.2)
Bearings: mains, number	7	
connecting rods, number	6	
Rated RPM	1800	1500
Max. horsepower at rated RPM HP (KW)	220 (164)	172 (128)
Fan horsepower HP (KW)	8.(5.4)	4.6 (3.1)
Cylinder head type and material	O.H.V. — alloy casting	
Connecting rod type and material	forged steel	
Piston type and material	aluminum	
Crankshaft material	forged steel	
Valves, material	alloy forging	
Governor, make/model	Roosa Master/DM	
regulation % frequency no load to full load	3% nominal, 5% maximum	
steady state regulation ± % frequency	± 0.33%	

ENGINE COOLING SYSTEM		
Engine jacket water capacity gal. (litre)	4 (15)	
Engine jacket water flow GPM (LPM)	60 (227)	50 (189)
Heat rejected to cooling water (without fan) at rated KW — dry exh. BTU/sec. (KW)	86 (91)	69 (73)
Water pump type	centrifugal	
Radiator system capacity (incl. engine) gal. (litre)	8 (30)	
Total inlet air requirement CFM (m³/min.)	8760 (248)	7335 (208)
Fan, blades	6	
dia. in. (mm)	25 (635)	
pitch in. (mm)	2.25 (57)	

ENGINE SPECIFICATIONS	60 Hertz	50 Hertz
OPTIONAL COOLING SYSTEMS		
☐ City water cooling system with heat exchanger includes: pipe threaded water connections, water shut-off solenoid valve, thermostatically controlled water saver valve.		
Heat exchanger mfgr/model	Young/F-502	
Exhaust manifold type	dry	
Connection sizes, water inlet	.75" NPT	
water outlet	1" NPT	
City water consumption, GPM (LPM/at °F (°C)	9 (34)/90 (32)	
☐ Remote radiator system		
Exhaust manifold type	dry	
Cooling system capacity (incl. rad. & eng.) gal. (litre) (Based on Perfex DDV-45)	18 (68)	
Total inlet air requirement @ 25°F rise CFM (m³/min.) (Based on Perfex DDV-45)	6140 (174)	3050 (171)
Connection sizes		
engine; water inlet in. (mm)	2.5 (63) I.D. hose	
engine; water outlet in. (mm)	2 (51) I.D. hose	
remote radiator; top tank (inlet)	3" NPT	
bottom tank (outlet)	3" NPT	

COOLING SYSTEM ACCESSORIES

- ☐ Block heater — 2500 watt, 120 volt AC.
- ☐ Radiator duct flange.
- ☐ Remote radiator — vertical mount with 3 phase, 60 cycle motor DDV-45.

FUEL SYSTEM	
Fuel supply line, min. I.D. in. (mm)	.38 (10)
Fuel return line, min. I.D. in. (mm)	.38 (10)
Max. lift of engine driven fuel pump ft. (m)	6 (2)
Fuel prime pump	electric
Fuel oil filter	single stage

FUEL SYSTEM ACCESSORIES

- ☐ 8-gallon fuel transfer tank with pump.
- ☐ Flexible fuel line.
- ☐ 20-gallon fuel transfer tank with pump.
- ☐ Auxiliary fuel pump (12 volt).

FUEL CONSUMPTION	60 Hertz	50 Hertz
100% load gal./hr. (litre/hr.)	10.2 (38.6)	8.2 (31)
75% load gal./hr. (litre/hr.)	7.9 (30)	6.2 (23.5)
50% load gal./hr. (litre/hr.)	5.8 (22)	4.5 (17)
25% load gal./hr. (litre/hr.)	3.9 (14.7)	2.9 (11)

60 HERTZ MODELS

Model	Voltage	Phase	Generator Model	Ampere	Continuous Standby KW/KVA
125ROZ01	120/240	3	4T5	376	125/156.25
125ROZ51	139/240	3	4T5	376	125/156.25
125ROZ71	277/480	3	4T5	188	125/156.25
125ROZ81	120/208	3	4T5	434	125/156.25
125ROZ91	347/600	3	4T5	150	125/156.25
Remote radiator and city water cooled		3Φ Wye	4T5		130
		3Φ Delta & 120/208 Wye			125

50 HERTZ MODELS

125RFOZ01	120/240	3	4T5	286	95/118.75
125RFOZ71	220/380	3	4T5	190	100/125
125RFOZ81	120/208	3	4T5	347	100/125
Remote radiator and city water cooled		3Φ Wye	4T5		103
		3Φ Delta			98

RATINGS: All models are continuous standby rated. Unit will operate at this rating for the duration of any power outage.
Note: Units rated at 0.8 power factor. Derate 3% per 1000 ft. (305m) above 1000 ft.

APPLICATION DATA

ENGINE SPECIFICATIONS	60 Hertz	50 Hertz
EXHAUST SYSTEM		
Exhaust flow at rated KW CFM (m³/min.)	900 (25)	750 (21)
Exhaust temp. at rated KW, dry exhaust °F (°C)	1100 (600)	1100 (600)
Maximum allowable back pressure in. hg. (KPa)	1.1 (3.7)	
Exhaust outlet size at hook-up	4" NPT	

EXHAUST SYSTEM ACCESSORIES

- ☐ Flexible exhaust connector (stainless steel)
- ☐ Industrial exhaust silencer
- ☐ Residential exhaust silencer
- ☐ Critical exhaust silencer

AIR INDUCTION SYSTEM		
Combustion air at rated KW CFM (m³/min.)	500 (14)	410 (12)
Air cleaner type — all models	dry	
LUBRICATING SYSTEM		
Oil pan capacity gals. (liters)	5.5 (21)	
Oil filter (quantity, type)	2 — element	
Lube oil cooler (quantity, type)	one — oil/water	
ENGINE ELECTRICAL SYSTEM		
Battery charging system ground (negative, positive)	negative	
volts	12 DC	
Starter motor rated voltage — volts	12 DC	
Minimum recommended battery for 0°F	220 ampere	
quantity	1	
voltage — volts	12	

ENGINE ELECTRICAL SYSTEM — ACCESSORIES

- ☐ 12 volt, 220 ampere battery 1 required
- ☐ Battery charger 12 volt trickle type with power cord and leads.
- ☐ Battery cables
- ☐ Battery charger 12 volt, automatic float type
- ☐ Battery rack (standard on housed units).

STANDARD ENGINE FEATURES

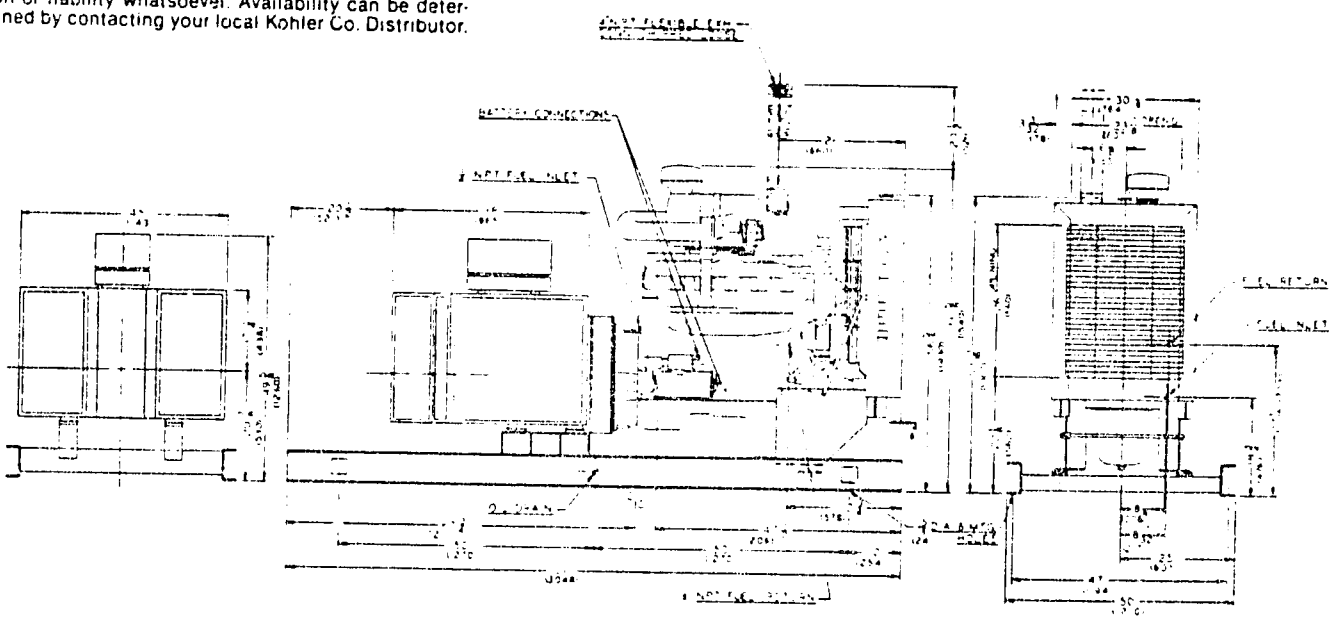
- Vibro-mounts
- High water temperature cut-out
- Lube oil cooler
- Mounting base
- Full flow lube oil filter
- Low oil pressure cut-out
- Automotive type starting
- Operating instructions

SPECIFICATIONS	60 Hertz	50 Hertz
DERATION FACTORS		
Maximum altitude before gen. set derating ft. (m)	1000 (305)	
altitude deration factor — % per 1000 ft. (305 m)	3%	
Maximum intake air temp. before gen. set derating °F (°C)	100 (38)	
temp. deration factor — % per 10°F (5.5°C)	2%	
Maximum mounting angle — front or rear up degrees	30°	

CONTINUOUS STANDBY 125ROZ

KOHLER GENERATORS

Availability is subject to change without notice. Kohler Co. reserves the right to change the design or specifications without notice and without any obligation or liability whatsoever. Availability can be determined by contacting your local Kohler Co. Distributor.



WEIGHTS AND DIMENSIONS

Approximate weight — radiator model; dry lb. (kg) 4000 (1814)

Nominal dimensions: L x W x H in. (mm) 120 (3048) x 50 (1270) x 60.6 (1540)

APPLICATION DATA

FAST-RESPONSE GENERATOR

SPECIFICATIONS	60 Hertz	50 Hertz
Manufacturer	Kohler	
Output reconnectible	wye and delta	
Number of leads	12	
Generator type	rotating field	
Excitation method	rotating exciter, brushless	
Voltage regulation method	Fast-Response	
Insulation — class, NEMA MG1-22.40	F	
Number of bearings	1	
Coupling	flexible disc	
Amortisseur windings	full	
Voltage regulation steady state — no load to full load — %	2% maximum	
One step load acceptance % of rating	90%	82%

- Generator is designed and built within NEMA, IEEE and ANSI standards for temperature rise.
- Permanent magnet field rotating exciter.
- Skewed stator for smooth voltage wave form.
- Self-ventilated, drip-proof construction.
- Fungus resistant per MIL-E-4970A.
- Safeguard Breaker.

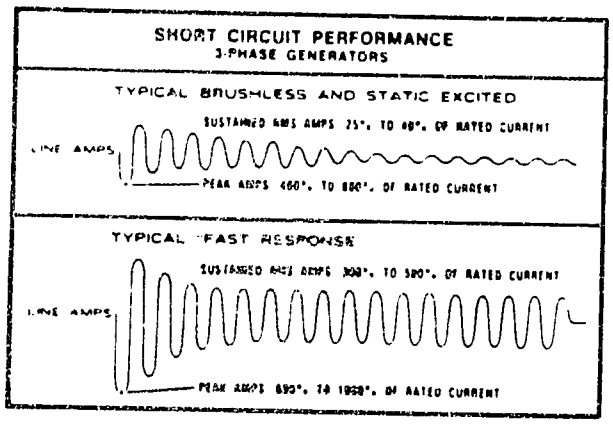
GENERATOR ACCESSORIES

☐ Line circuit breakers.
a. 240 volt (3 phase)
b. 277/480 volt (3 phase)
c. 120/208 volt (3 phase)
d. 347/600 volt (3 phase)

ADDITIONAL ENGINE AND GENERATOR ACCESSORIES

☐ Accessories available to meet NFPA-76A.
- Block heater
- Low water temperature cutout
- Annunciator panel, remote, 16 lamp
- Alarm relay and horn
- All required indicator lamps (see controller description)

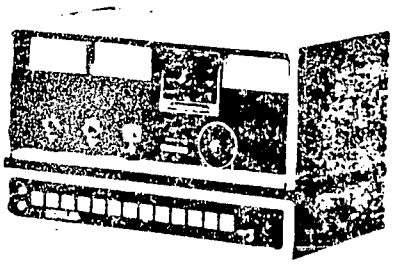
☐ CSA approval.
☐ Weather housing.
☐ Trailer.
☐ Export boxing.



SHORT CIRCUIT PROTECTION

Conventional generator current collapses under short circuit. FAST-RESPONSE generators continue to provide ample current to permit normal breaker tripping.

Vibro-mounted lower cabinet contains indicating lamps and solid state circuit boards. All instruments in upper cabinet are standard, as are six lamps in lower cabinet.



DECISION MAKER CONTROLLER

SPECIFICATIONS

Manufacturer	Kohler
Type	solid state
Starting method	remote and local
Weight lbs. (kg)	33 (15)
Size — H x W x D in. (mm)	11.75 (298) x 18.25 (475) x 12.25 (311)
Power source	12 or 24 volt DC

STANDARD EQUIPMENT

- Wiring harness for electrical connections
- Lamp test switch
- Cyclic cranking
- Overcrank and starter unmesh protection
- Fault reset switch
- Overspeed control
- Two-wire remote start/stop termination
- Phase selector switch
- Voltage adjusting rheostat, front panel mounted
- DC circuit protection
- Engine start control selector switch
- Emergency stop switch
- Panel lamps (2)
- Shutdown time delay for engine cool-off, adjustable 2 to 10 minutes

Instruments	Size in. (mm)	Accuracy % FS
AC voltmeter	3.5 (89)	2%
AC ammeter	3.5 (89)	2%
AC frequency meter	3.5 (89)	0.5%
Batt. charg. ammeter	2 (51)	2%
Engine H_2O temp.	2 (51)	2%
Engine oil pressure	2 (51)	2%
Running time meter	1.7 (43)	

Indicator Lamps
- Overcrank (red lamp)
- High water temperature (red lamp)
- Low oil pressure (red lamp)
- Overspeed (red lamp)
- Emergency stop (red lamp)
- Switch "off" (flashing red lamp) warns that engine start control selector switch has been left in off position.

Mounting Capabilities
- Controller can be positioned so instruments face toward either side or toward rear of generator set.
- Either or both controller cabinets can be remote mounted as a monitoring aid.

ACCESSORIES

☐ Prealarm lamp group
- Anticipatory low oil pressure (yellow lamp)
- Anticipatory high water temperature (yellow lamp)
- Low water temperature (red lamp)

☐ Hospital lamp group required to meet NFPA-76A
- Anticipatory low oil pressure (yellow lamp)
- Anticipatory high water temperature (yellow lamp)
- High battery volts (red lamp)
- Low battery volts (red lamp)
- Low water temperature (red lamp)
- Low fuel (red lamp)
- "System ready" (green lamp) indicates no faults detected by monitoring system and that engine start control selector switch is in automatic position and ready for emergency start.

☐ Alarm relay plus horn
- Horn silence switch

☐ Decision Monitor — sixteen light remote annunciator panel.
☐ Fast-Check — diagnostic fault detector activates controller indicator circuits without operating engine/generator.
☐ Extension wiring harness for remote mounting of controller.
☐ Isolated alarm contact kit.

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KOHLER GENERATORS

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KOHLER
GENERATORS

125 KW Diesel
Liquid-Cooled

SAMPLE SPECIFICATION

EMERGENCY STANDBY ELECTRICAL SYSTEM: The standby generator set shall be installed by the contractor at the location shown on the plans and drawings, and as specified herein; with all accessories and transfer switch(es) required.

All equipment shall be new and of current production of a national firm, who manufactures the generator and control panel and transfer switch and assembles the standby generator set as a matched unit, having a service and parts organization within a reasonable distance of this project, backed up by a national sales and service organization.

The standby generator set shall be supplied to operate on #2 Diesel fuel.

The engine shall be liquid-cooled by means of a (select one) RADIATOR, CITY-WATER COOLING SYSTEM WITH HEAT EXCHANGER, REMOTE RADIATOR SYSTEM.

The standby generator set shall be rated continuous standby (defined as continuous for the duration of any power outage *_____Volts, 3 Phase, 4 Wire, .8 Power Factor, 125KW, 156.25KVA, _____Ampere at 500 feet altitude, 85 degrees F, as Kohler Model 125ROZ series.

*Ratings (select one)

NOTE: Ratings apply to radiator, city water, and remote radiator cooling systems.

Voltage	Phase	Wire	Power Factor	KW/KVA	Ampere
120/240	3	4	.8	125/156.25	376
139/240	3	4	.8	125/156.25	376
277/480	3	4	.8	125/156.25	188
120/208	3	4	.8	125/156.25	434
347/600	3	4	.8	125/156.25	150

ENGINE: The turbo charged and aftercooled engine shall be Diesel fueled, 6 cylinder, 4-cycle, liquid-cooled, with not less than 478 cubic inch displacement and deliver a minimum of 220 HP, at a governed speed of 1800 RPM.

Engine speed shall be governed by a gear driven mechanical governor to maintain generator frequency within 3 cycles from no load to full load generator output. Belt driven governors will not be considered.

Engine shall be equipped with the following:

12 volt positive engagement solenoid shift starting motor.
35 ampere automatic battery charging alternator.
Lube oil filter - Dry-type air cleaner.
Electric solenoid fuel shut-off valve.
Gas proof seamless, stainless steel, flexible exhaust connection.
Flexible fuel connection - Oil drain extension.

FASTRESPONSE

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GENERATOR: The generator shall be four pole, brushless, 12 lead reconnectable of drip-proof construction with amortisseur windings. Insulation shall be Class F with epoxy varnish. Generator field current shall be controlled by a rotating thyrister bridge module optically coupled to a firing circuit type voltage regulator. The exciter shall be 24 pole permanent magnet type. Generators controlled by wound field exciters will not be accepted unless they meet the following performance.

Radio-interference suppression meeting commercial standards shall be supplied. Voltage regulation shall be within plus or minus 2% of rated voltag from no load to rated load.

Upon application of 92% rated load in one step voltage dip as measured by a light beam recorder or oscilloscope shall not exceed 15%, recovery to stable voltage shall occur within .1 second. Stable or steady state operation is defined as operation with terminal voltage remaining constant within plus or minus 1/2 of one (1) percent of rated voltage. Voltage adjustment range shall be plus or minus 5 percent of rated voltage. Temperature rise shall be within NEMA, IEEE, and ANSI standards.

If a line to neutral short circuit occurs, the generator shall support 300% rated current for 10 seconds without externally mounted devices.

A resettable line current sensing circuit breaker with inverse time vs. current response shall be furnished which protects the generator from damage due to overload. This breaker shall not trip within the 10 seconds specified above.

Separate visual diagnostic means shall be furnished on the generator rotor for determining that exciter voltage is being developed and that the excitation system is supplying current to the generator field according to load requirements.

The generator, having a single, maintenance free bearing, shall be direct connected to the flywheel housing, with a disc coupling between the rotor and the flywheel.

CONTROLLER: Se. mounted controller facing right, left, rear (choose one) shall be vibration isolated on the generator enclosure. It shall be of solid state design. Relays will be acceptable only for high current circuits. Circuitry shall be of plug-in design for quick replacement. Controller shall be equipped to accept a plug-in device capable of allowing maintenance personnel to test controller performance without operating the engine. The controller shall include:

Fused DC circuits.

Complete 2 wire start/stop control which shall operate on activation of a remote contact.

Cranking period controlled by a speed sensor which disengages the starting motor when the engine has started. Battery charging alternator or generator voltage may not be used for this signal.

The starting system shall be designed for restarting in the event of a false engine start, by permitting the engine to completely stop and then re-engage the starter.

Cranking cycler with individually adjustable (2 to 20 seconds) ON and OFF cranking periods.

Overcranking protection designed to open the cranking circuit after 60 seconds if the engine fails to start.

Circuitry to shut down the engine when signal for high coolant temperature, low oil pressure or overspeed are received, with reset button.

Adjustable (2 to 10 minute) factory set at 5 min. time delay to permit unloaded running of the standby set after transfer of the load to normal.

Alarm horn.

Three position (automatic-off-test) selector switch.

Emergency stop switch.

Indicating lights to signal -

Specifier's Note:		
	Standard Equip.	(Switch "off" (flashing red) (Overcrank (red) (Emergency stop (red) (High coolant temperature (red) (Overspeed (red) (Low oil pressure (red)
	Optional Anticipatory Group*	(Anticipatory high coolant (Temperature (yellow) (Anticipatory low oil pressure (yellow) (Low coolant temperature (red)
	Optional Hosipital Group*	(High battery voltage (red) (Low battery voltage (red) (Low fuel (red) (System ready (green)

Test button for indicating lights.

Connections to the controller shall be by plug-in wiring harnesses.

*Required to meet NFPA-76A Regulations.

<u>INSTRUMENT PANEL</u>: A set mounted instrument panel shall include:

Dual range voltmeter 3-1/2 inch ±2% accuracy.

Dual range ammeter 3-1/2 inch ±2% accuracy.

Voltmeter-Ammeter phase selector switch.

Lights to indicate high or low meter scale.

Direct reading pointer type frequency meter 3-1/2 inch ±.3 hz accuracy.

Panel illuminating light.

Battery charging ammeter.

Oil pressure gauge.

Coolant temperature gauge.

Running time meter.

Plug-in voltage regulator with front panel voltage adjusting rheostat.

AUTOMATIC TRANSFER SWITCH(ES): The automatic transfer switch shall be listed by Underwriters Laboratory under Std. UL 1008 for emergency systems and all classes of load, and be CSA approved. The ampere rating shall be at least solid state except for "OFF" timers and heavy current circuits. The switch shall initiate transfer to the generator set when the voltage of any phase of the normal drops below 70% of rated. The transfer switch shall have closing, withstand and interrupting ratings equal to the available short circuit current on the normal supply. A minimum of .5 second delay must exist between the opening of the emergency and closing of the normal to allow induced voltages in the system to decay.

GENERATOR SET MOUNTING: The standby generator set shall be equipped with factory installed vibration isolators mounted between the set and fabricated steel base to prevent distortion of alignment between generator and engine when installed. Mount on concrete pad as shown on plans and drawings.

ACCESSORIES: Engine block heater, 2,500 watt, 120 volt.*

220 ampere hour, 12 volt battery, battery rack, and battery cables.

20 ampere automatic float battery charger Model A269214 with automatic voltage regulation, current limiting capability, temperature compensated for ambients from -20° F, voltmeter and ammeter; equipped for conduit installation, as supplied by Kohler Co.

Engine exhaust silencer rated for (select one) Industrial, Residential, Critical application.

Remote annunciator panel* with visual indicators for:

Switch "off" (flashing red), Overcrank (red), Emergency stop (red), High coolant temperature (red), Overspeed (red), Low oil pressure (red), Anticipatory high coolant temperature (yellow), Anticipatory low oil pressure (yellow), low coolant temperature (red), System ready (green), Normal line power (yellow), Generator power (yellow), Alarm switch off (red), and an audible alarm with shut-off switch.

*Required to meet NFPA-76A Regulations.

INFORMATION REQUIRED FOR SPECIFIED STANDBY SYSTEMS

1. Detailed specification sheets.

2. Certified final factory test report shall be provided to the architect, certifying this unit's full power rating, stability, voltage and frequency regulation.

3. Complete operating instruction and maintenance manual with parts list.

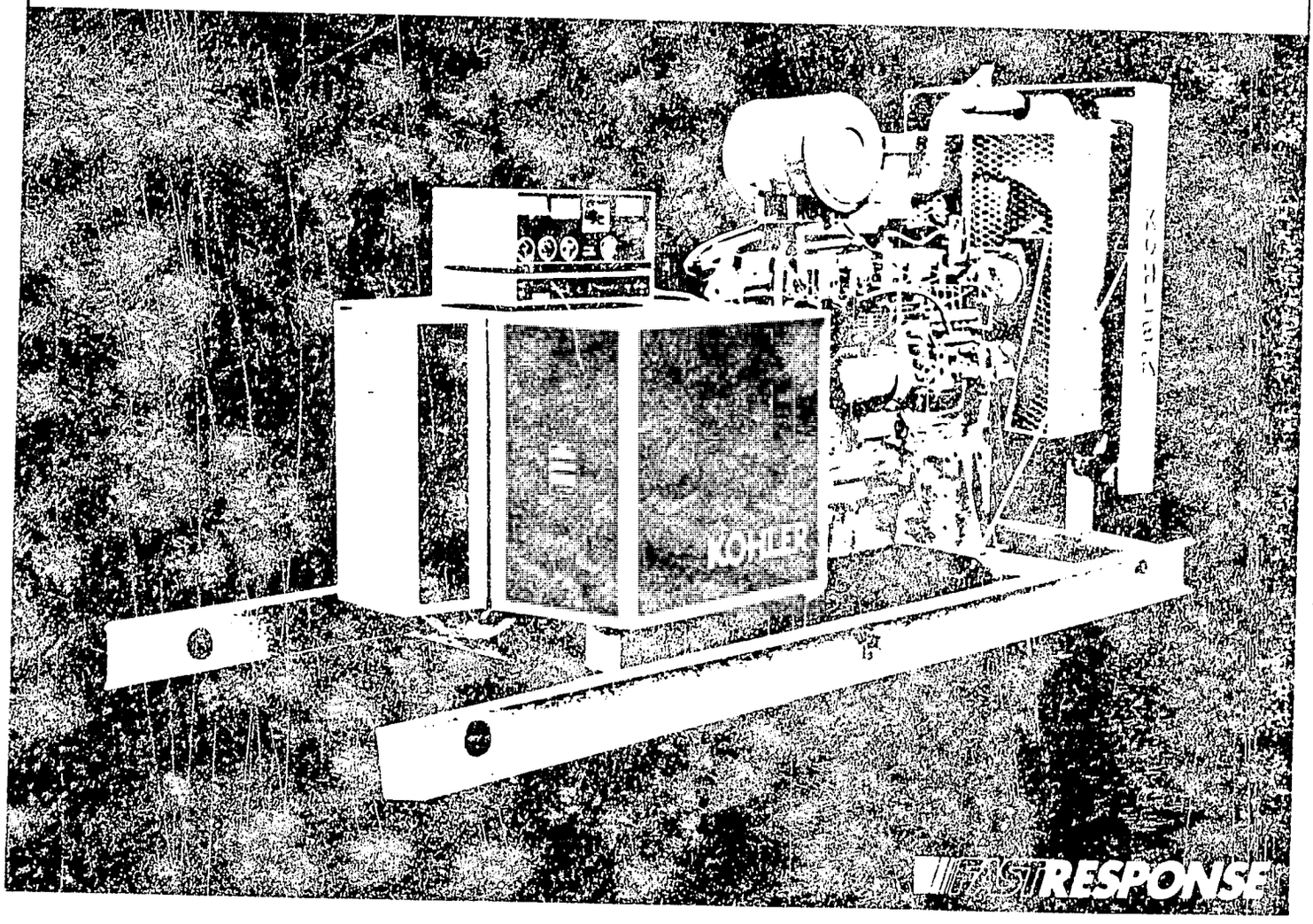
KOHLER GENERATORS

150 KW

ac liquid-cooled diesel

continuous standby generator set

- SUSTAINED SHORT CIRCUIT PROTECTION. Generator will not collapse. Sustains high short circuit current for selective tripping of normal sized branch circuit breakers.
- FAST RESPONSE TO LOAD CHANGES. Kohler-patented voltage regulation system provides full power to the main generator field within .05 seconds or less. Voltage dip on most 3-phase models, no load to specified load, is less than 15%.
- SAFEGUARD BREAKER. To prevent overloads, Kohler provides an AC line-sensing time delay circuit breaker as standard generator equipment. This breaker protects the generator from its own high current capability. Sufficient high current output time is allowed to trip a branch circuit breaker affected by a short.
- HARMONIC INTONATION. No high frequency spikes in output wave form.
- 12-LEAD RECONNECTIBLE TO COMMON VOLTAGES.
- POWER SCANNER* — A Light Emitting Diode monitoring system aids in service trouble-shooting. Green light indicates power is available from the exciter, red light indicates that power is reaching the rotor according to load requirement. (* Patent Pending.)
- CONTROLLER — SOLID STATE *DECISION MAKER* MODEL. Accessories to meet NFPA — 76A hospital code.
- GENERATOR ENCLOSURE. Serves as junction box, allows installation of conduit from either side.



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t motor starting winding, Full
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ssure shutdown.

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gral trailer, Croft coupler, pintle
n adapter, housing, residential
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e levels of controllers, Fast Link™
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ry type motor generator, 12 vdc
4 vdc input, 120 vac 60 Hz sine
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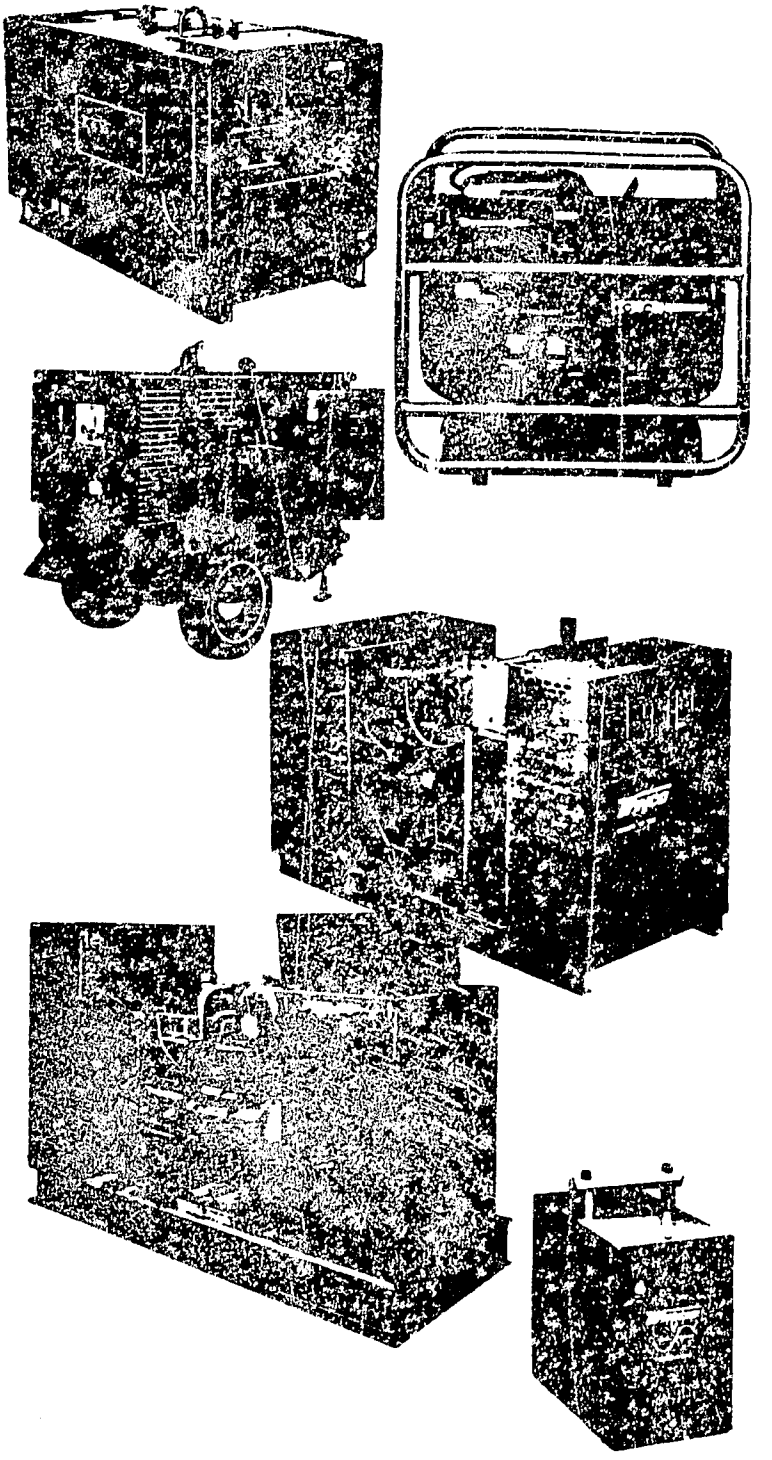

WINCO
Division of DYNA TECHNOLOGY, INC
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(612) 853-8400
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Dyna Tech MPS

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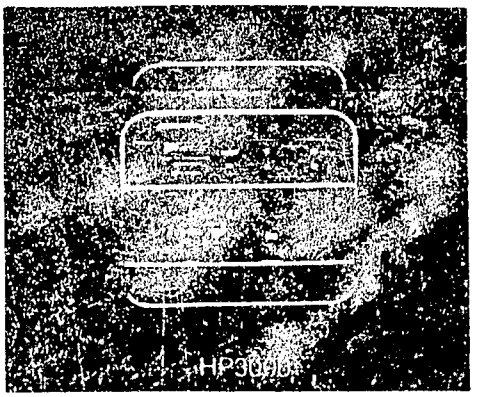
No 21-FL-084

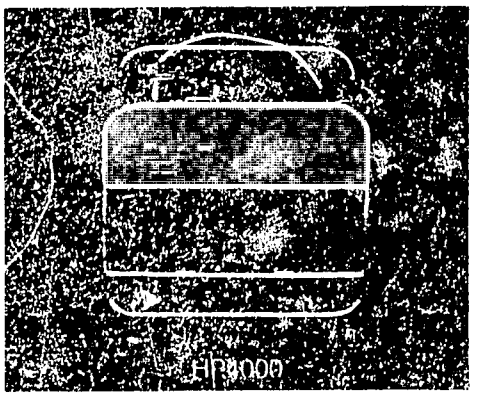
WINCO

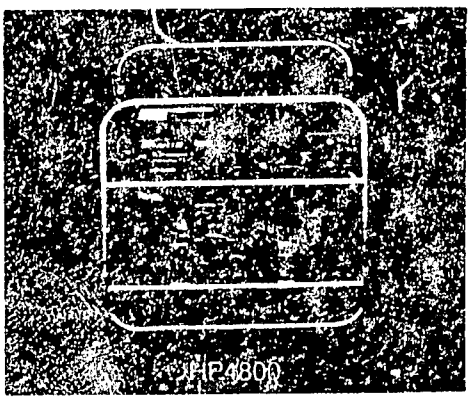
High Performance Generators *'The Quiet Ones'*

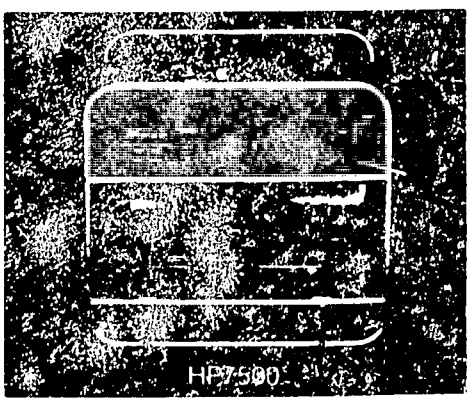
Surge rating	3000 watts	4000 watts	4800 watts	7500 watts
Continuous rating	2500 watts	3800 watts	4500 watts	7200 watts
Voltage	120 vac	120/240 vac	120/240 vac	120/240 vac
Full power	N/A	Standard	Standard	Standard
Phase	Single	Single	Single	Single
Frequency	60 Hz	60 Hz	60 Hz	60 Hz
Current (1.0 PF)	23 amps	32/16 amps	38/19 amps	60/30 amps
Simultaneous direct current	10 amp 12 vdc	10 amp 12 vdc	10 amp 12 vdc	10 amp 12 vdc
Max-watt motor starting ability (Code G capacitor start)	1 Hp	1½ Hp	3 Hp	4 Hp
Low oil level shutdown	Standard	N/A	Standard	N/A
Wrap around cradle	Standard	Standard	Standard	Standard
Vibration isolated control center	Standard	Standard	Standard	Standard
Start/stop switch	Stop only	Standard	Standard	Standard
Idle switch	Standard	Standard	Standard	Standard
Fast connect DC plug	Standard	Standard	Standard	Standard
DC charge rate ammeter	Standard	Standard	Standard	Standard
AC and DC power indicator lamps	Standard	Standard	Standard	Standard
Circuit breakers	Standard	Standard	Standard	Standard
Outlets				
NEMA 5-15R, 120v, 15A	2	2	2	2
NEMA L5-20R, 120v, 20A twistlock	1	2	2	2
NEMA 5-30R, 120v, 30A	1	N/A	N/A	N/A
NEMA L5-30R, 120v, 30A twistlock	N/A	1	1	1
NEMA L6-20R, 240v, 20A twistlock	N/A	1	1	1
NEMA 5-50R, 120v, 50A	N/A	1	1	1
NEMA 6-50R, 240v, 50A	N/A	N/A	N/A	1
Twistlock, 240v, 50A	N/A	N/A	N/A	N/A
Two wheel dolly	Optional	Optional	Optional	Optional
Instruction manual	Standard	Standard	Standard	Standard
Engine				
Type	Air-cooled 4-cycle	Air-cooled 4-cycle	Air-cooled 4-cycle	Air-cooled 4-cycle
Model	RA210D	I/C 195432	KF82DX	I/C 326432
Size	207cc	319cc	341cc	531cc
Fuel system	Gasoline	Gasoline	Gasoline	Gasoline
Fuel tank capacity	4 gal	5 gal	5 gal	5 gal
Operating duration, normal load	9 hrs	8 hrs	7 hrs	4 hrs
Starting system	Recoil	Recoil/12v electric	Recoil/12v electric	Recoil/12v electric
Starting battery	N/A	Optional	Optional	Optional
DC cables and cable storage box	Standard	Standard	Standard	Standard
Lubrication system	Splash	Splash	Splash	Splash
Oil capacity	1½ pts	2½ pts	2½ pts	4 pts
Air cleaner	Foam	Dual element	Dry	Dual element
Governor	Mechanical	Mechanical	Mechanical	Mechanical
Spark arresting muffler	Standard	Standard	Standard	Standard
Dimensions				
Length	24"	27"	27"	31"
Width	17½"	21½"	21½"	22½"
Height	20"	21½"	24½"	27"
Net weight	129 lbs	177 lbs	260 lbs	372 lbs
Shipping weight	160 lbs	225 lbs	308 lbs	440 lbs

WINCO continually improves its products and therefore reserves the right to change the design, materials and/or specifications without notice









APPLICATION DATA

DIESEL ENGINE

ENGINE SPECIFICATIONS	60 Hertz	50 Hertz
Manufacturer	John Deere	
Model	6466A	
Type air intake	turbocharged & intercooled	
Cylinder arrangement (number, inline, V, etc.)	6 in-line	
Displacement in³ (cm³)	466 (7636)	
Bore and stroke in. (mm)	4.56 (116) x 4.75 (121)	
Compression ratio	15.5:1	
Piston speed ft/min. (meters/sec.)	1425 (7.2)	1187 (6)
Bearings: mains, number	7	
connecting rods, number	6	
Rated RPM	1800	1500
Max. horsepower at rated RPM HP (KW)	240 (179)	210 (157)
Cylinder head type and material	cast iron	
Connecting rod type and material	I section forged steel	
Piston type and material	inserted aluminum	
Crankshaft material	forged steel	
Valves, material	alloy steel	
rotators	yes — all	
Governor, make/model	Bosch/mechanical	
regulation % frequency, no load to full load	5	
steady state regulation ± % frequency	0.33	

ENGINE COOLING SYSTEM		
Engine jacket water capacity gal. (litre)	3 (11.4)	
Engine jacket water flow GPM (LPM)	60 (227)	50 (189)
Heat rejected to cooling water (without fan) at rated KW — dry exh. BTU/sec. (KW)	91 (96)	
Water pump type	centrifugal	
Radiator system capacity (incl. engine) gal. (litre)	9.4 (36)	
Total inlet air requirement CFM	10,400 (294)	8300 (235)
Fan, blades	8	
dia. in. (mm)	28 (711)	
pitch in. (mm)	2.39 (61)	

ENGINE SPECIFICATIONS OPTIONAL COOLING SYSTEMS	60 Hertz	50 Hertz
☐ City water cooling system with heat exchanger includes: pipe threaded water connections, water shut-off solenoid valve, thermostatically controlled water saver valve.		
Heat exchanger mfgr/model	Young F-502	
Exhaust manifold type	dry	
Cooling system capacity gal. (litre)	11/42	
Connection sizes, water inlet in.	.75" NPT	
water outlet in.	1" NPT	
City water consumption, GPM (LPM/at °F (°C)	11 (42)/90 (32)	
☐ Remote radiator system		
Exhaust manifold type	dry	
Cooling system capacity (incl. rad. & eng.) gal. (litre) (Based on Perfex DDV-45)	17 (64)	
Total inlet air requirement at 25°F rise CFM (m³/min.) (Based on Perfex DDV-45)	7406 (210)	7315 (207)
Connection sizes		
engine; water inlet in. (mm)	2.38 (60) I.D. hose	
engine; water outlet in. (mm)	2.5 (64) I.D. hose	
remote radiator; top tank (inlet)	3" NPT	
bottom tank (outlet)	3" NPT	

COOLING SYSTEM ACCESSORIES

- ☐ Block heater — 2500 watt, 120 volt AC.
- ☐ Radiator duct flange.
- ☐ Remote radiator — vertical mount with 3 phase, 60 cycle motor DDV-45.

FUEL SYSTEM	
Fuel supply line, min. I.D. in. (mm)	.38 (10)
Fuel return line, min. I.D. in. (mm)	.38 (10)
Max. lift of engine driven fuel pump ft. (m)	3 (1)
Fuel prime pump	manual
Diesel fuel recommended	No. 2
Fuel oil filters	2 (primary & secondary)

FUEL SYSTEM ACCESSORIES

- ☐ Auxiliary fuel pump (24 volt).
- ☐ 8-gallon fuel transfer tank with pump (120 volt AC motor).
- ☐ 20-gallon fuel transfer tank with pump (120 volt AC motor).

FUEL CONSUMPTION

100% load	gal./hr. (liter/hr.)	11.8 (45)	9.9 (37)
75% load	gal./hr. (liter/hr.)	8.7 (33)	7.8 (30)
50% load	gal./hr. (liter/hr.)	6.2 (23)	5.6 (21)
25% load	gal./hr. (liter/hr.)	3.8 (14)	3.4 (13)

60 HERTZ MODELS

Model	Voltage	Phase	Generator Model	Ampere	Continuous Standby KW/KVA
150ROZ01	120/240	3	4T7.5	436	145/181
150ROZ51	139/240	3	4T7.5	452	150/187.5
150ROZ71	277/480	3	4T7.5	226	150/187.5
150ROZ81	120/208	3	4T7.5	521	150/187.5
150ROZ91	347/600	3	4T7.5	181	150/187.5
Remote radiator and city water cooled models			4T7.5		Add 5 KW (6.25 KVA) to above ratings.

50 HERTZ MODELS

150RFOZ01	120/240	3	4T7.5	331	125/156
150RFOZ71	220/380	3	4T7.5	218	130/162
150RFOZ81	120/208	3	4T7.5	399	130/162
Remote radiator and city water cooled models			4T7.5		Add 5 KW (6.25 KVA) to above ratings.

RATINGS: All models are continuous standby rated. Unit will operate at this rating for the duration of any power outage.
Note: Units are rated at 0.8 power factor. Derate 3% per 1000 ft. (305 m.) above 7500 ft. (3300 m.) elevation.

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APPLICATION DATA

ENGINE SPECIFICATIONS	60 Hertz	50 Hertz
EXHAUST SYSTEM		
Exhaust flow at rated KW CFM (m³/min.)	825 (23.6)	700 (20)
Exhaust temp. at rated KW, dry exhaust °F (°C)	1000 (540)	
Maximum allowable back pressure in. hg. (KPa)	2.9 (9.7)	
Exhaust outlet size at hook-up	4" NPT	

EXHAUST SYSTEM ACCESSORIES

- ☐ Industrial exhaust silencer.
- ☐ Residential exhaust silencer.
- ☐ Critical exhaust silencer.

AIR INDUCTION SYSTEM		
Combustion air at rated KW CFM (m³/min.)	566 (16)	475 (13.4)
Air cleaner type — all models	dry	
LUBRICATING SYSTEM		
Oil pan capacity gals. (liters)	5.5 (21)	
Oil filter (quantity, type)	one — replaceable element	
Lube oil cooler	one — oil to water	
ENGINE ELECTRICAL SYSTEM		
Battery charging system ground (negative, positive)	negative	
volts	12 DC	
ampere rating	35	
Starter motor rated voltage — volts	12 DC	
Minimum recommended battery for 0°F quantity	220 ampere hour	
voltage — volts	1	
	12	

ENGINE ELECTRICAL SYSTEM — ACCESSORIES

- ☐ 12 volt, 220 ampere battery
- ☐ Battery charger 12 volt, trickle type.
- ☐ Battery rack (standard on housed units.)
- ☐ Battery cables.
- ☐ Battery charger 12 volt, automatic float type.

STANDARD ENGINE FEATURES

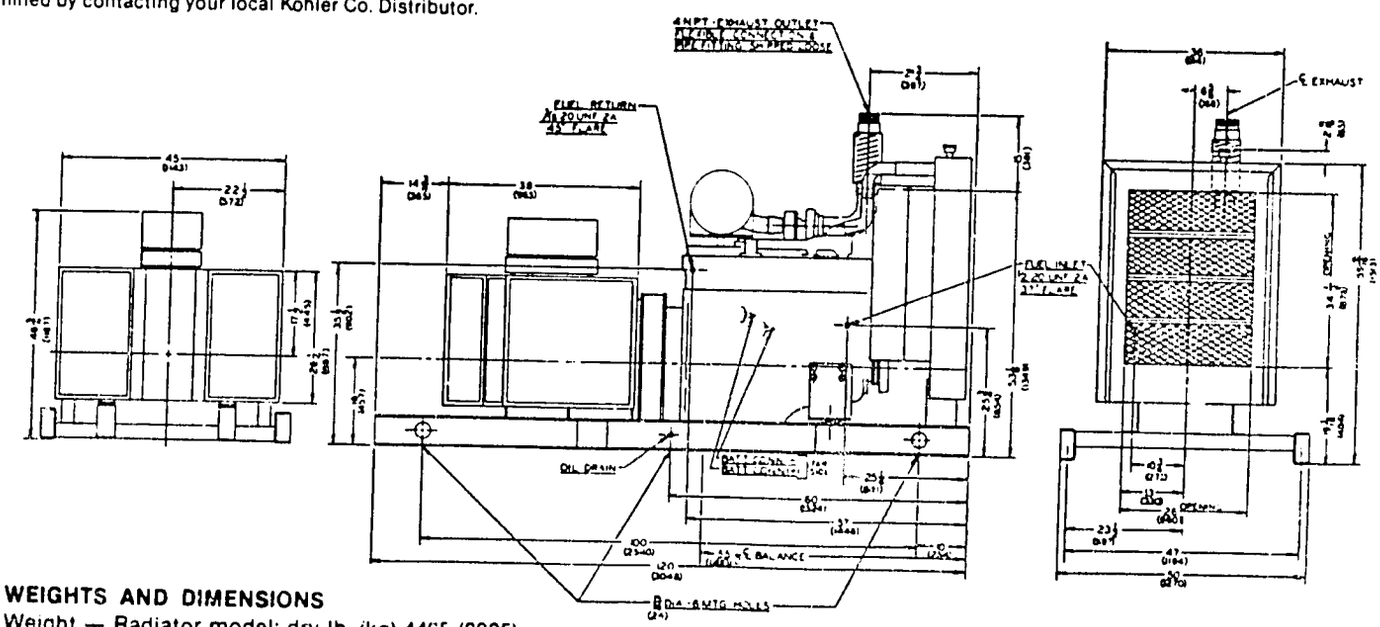
- Vibro-mounts
- High water temperature cut-out
- Flexible exhaust connection (stainless steel)
- Mounting base
- Lube oil cooler
- Low oil pressure cut-out
- Automotive type starting
- Operating instructions

SPECIFICATIONS DERATION FACTORS	60 Hertz	50 Hertz
Maximum altitude before gen. set derating ft. (m)	7500 (3300)	
altitude deration factor — % per 1000 ft. (305 m)	3	
Maximum intake air temp. before gen. set derating °F (°C)	85 (29)	
temp. deration factor — % per 10°F (5.5°C)	1	
Maximum mounting angle — front or rear up, degrees	30	

CONTINUOUS STANDBY 150ROZ

KOHLER
GENERATORS

Availability is subject to change without notice. Kohler Co. reserves the right to change the design or specifications without notice and without any obligation or liability whatsoever. Availability can be determined by contacting your local Kohler Co. Distributor.



WEIGHTS AND DIMENSIONS

Weight — Radiator model; dry lb. (kg) 4465 (2025)
Overall size: L x W x H in. (mm) 120 (3048) x 50 (1270) x 68.12 (1578)

APPLICATION DATA

FAST-RESPONSE GENERATOR

SPECIFICATIONS	60 Hertz	50 Hertz
Manufacturer	Kohler	
Output reconnectible	wye and delta	
Number of leads	12	
Generator type	rotating field	
Excitation method	rotating exciter, brushless	
Voltage regulation method	Fast-Response	
Insulation — class, NEMA MG1-22.40	F	
Number of bearings	1	
Coupling	flexible disc	
Amortisseur windings	full	
Voltage regulation steady state — no load to full load — %	2% maximum	
One step load acceptance % of rating	88	74

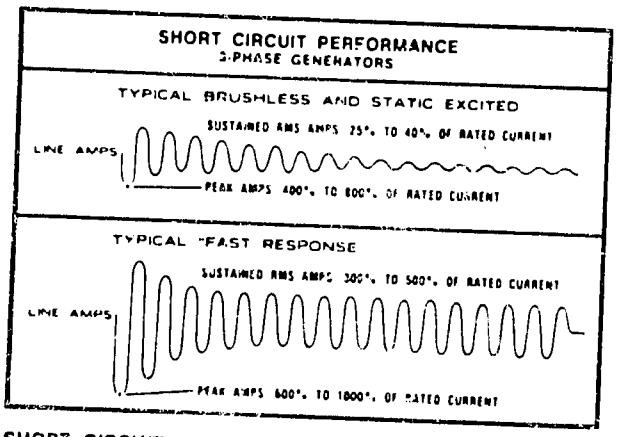
- Generator is designed and built within NEMA, IEEE and ANSI standards for temperature rise under continuous duty operation at all output ratings.
- Permanent magnet field rotating exciter.
- Skewed stator for smooth voltage wave form.
- Self-ventilated, drip-proof construction.
- Fungus resistant per MIL-E-4970A.
- Safeguard Breaker.

GENERATOR ACCESSORIES

- ☐ Line circuit breakers.
  - a. 240 volt (3 phase)
  - b. 277/480 volt (3 phase)
  - c. 120/208 volt (3 phase)
  - d. 347/600 volt (3 phase)
- ☐ Reactive droop compensator.

ADDITIONAL ENGINE AND GENERATOR ACCESSORIES

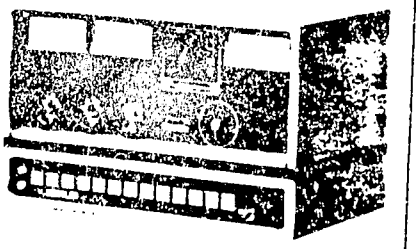
- ☐ Accessories available to meet NFPA-76A.
  - Block heater
  - Low water temperature cut-out
  - Annunciator panel, remote, 16 lamp
  - Alarm relay and horn
  - All required indicator lamps (see controller description, above)
- ☐ CSA approval.
- ☐ Weather housing.
- ☐ Trailer.
- ☐ Export boxing.
- ☐ Barber Coleman Dyna ! electric governor.
- ☐ Generator strip heater.



SHORT CIRCUIT PROTECTION

Conventional generator current collapses under short circuit FAST-RESPONSE generators continue to provide ample current to permit normal breaker tripping.

Vibro-mounted lower cabinet contains indicating lamps and solid state circuit boards. All instruments in upper cabinet are standard, as are six lamps in lower cabinet.



DECISION MAKER CONTROLLER

SPECIFICATIONS	
Manufacturer	Kohler
Type	solid state
Starting method	remote and local
Weight lbs. (kg)	33 (15)
Size — H x W x D in. (mm)	11.75 (298) x 18.25 (475) x 12.25 (311)
Power source	12 or 24 volt DC

STANDARD EQUIPMENT

- Wiring harness for electrical connections
- Lamp test switch
- Cyclic cranking
- Overcrank and starter unmesh protection
- Fault reset switch
- Overspeed control
- Two-wire remote start/stop termination
- Phase selector switch
- Voltage adjusting rheostat, front panel mounted
- DC circuit protection
- Engine start control selector switch
- Emergency stop switch
- Panel lamps (2)
- Shutdown time delay for engine cool-off, adjustable 2 to 10 minutes

Instruments	Size In. (mm)	Accuracy % FS
AC voltmeter	3.5 (89)	2%
AC ammeter	3.5 (89)	2%
AC frequency meter	3.5 (89)	0.5%
Batt. charg. ammeter	2 (51)	2%
Engine H_2O temp	2 (51)	2%
Engine oil pressure	2 (51)	2%
Running time meter	1.7 (43)	

Indicator Lamps

- Overcrank (red lamp)
- High water temperature (red lamp)
- Low oil pressure (red lamp)
- Overspeed (red lamp)
- Emergency stop (red lamp)
- Switch "off" (flashing red lamp) warns that engine start control selector switch has been left in off position.

Mounting Capabilities

- Controller can be positioned so instruments face toward either side or toward rear of generator set.
- Either or both controller cabinets can be remote mounted as a monitoring aid.

ACCESSORIES

- ☐ Prealarm lamp group
  - Anticipatory low oil pressure (yellow lamp)
  - Anticipatory high water temperature (yellow lamp)
  - Low water temperature (red lamp)
- ☐ Hospital lamp group required to meet NFPA-76A
  - Anticipatory low oil pressure (yellow lamp)
  - Anticipatory high water temperature (yellow lamp)
  - High battery volts (red lamp)
  - Low battery volts (red lamp)
  - Low water temperature (red lamp)
  - Low fuel (red lamp)
  - "System ready" (green lamp) indicates no faults detected by monitoring system and that engine start control selector switch is in automatic position and ready for emergency start.
- ☐ Alarm relay plus horn
  - Horn silence switch
- ☐ Decision Monitor — sixteen light remote annunciator panel.
- ☐ Fast-Check — diagnostic fault detector activates controller indicator circuits without operating engine/generator.
- ☐ Extension wiring harness for remote mounting of controller.
- ☐ Isolated alarm contact kit.

KOHLER CO., KOHLER, WISCONSIN 53044 PHONE 414 565-3381 TELEX 26888 TWX 910 264 3877

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KOHLER GENERATORS

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FAST RESPONSE

150 KW Diesel
Liquid Cooled

SAMPLE SPECIFICATION

EMERGENCY STANDBY ELECTRICAL SYSTEM: The standby generator set shall be installed by the contractor at the location shown on the plans and drawings, and as specified herein; with all accessories and transfer panel (s) as required.

All equipment shall be new and of current production of a national firm, who manufactures the generator and control panel and transfer panel and assembles the standby generator set as a matched unit, having a service and parts organization within a reasonable distance of this project, backed up by a national sales and service organization.

The standby generator set shall be supplied to operate on #2 Diesel fuel.

The engine shall be liquid-cooled by means of a (select one) RADIATOR, CITY-WATER COOLING SYSTEM WITH HEAT EXCHANGER, REMOTE RADIATOR SYSTEM.

The standby generator set shall be rated continuous standby (defined as continuous for the duration of any power outage) *_____Volts, 3 Phase, 4 Wire, .8 Power Factor,_____KW_____KVA_____Ampere at 500 feet altitude, 85 degrees F, as Kohler Model 150ROZ series.

*Ratings (select one)

NOTE: Ratings apply to radiator, city water, and remote radiator cooling systems.

Voltage	Phase	Wire	Power Factor	KW/KVA	Ampere
120/240	3	4	.8	145/181	437
139/240	3	4	.8	150/187.5	452
277/480	3	4	.8	150/187.5	226
120/208	3	4	.8	150/187.5	521
347/600	3	4	.8	150/187.5	181

ENGINE: The turbo charged and intercooled engine shall be Diesel fueled, 6 cylinder, 4-cycle, liquid-cooled, with not less than 466 cubic inch displacement and deliver a minimum of 240 HP, at a governed speed of 1800 RPM.

Engine speed shall be governed by a gear driven mechanical governor to maintain generator frequency within 3 cycles from no load to full load generator output. Belt driven governors will not be considered.

Engine shall be equipped with the following:

12 volt positive engagement solenoid shift starting motor.
35 ampere automatic battery charging alternator.
Lube oil filter - Dry-type air cleaner.
Electric solenoid fuel shut-off valve.
Gas proof seamless, stainless steel, flexible exhaust connection.
Flexible fuel connection - Oil drain extension.

KOHLER

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GENERATOR: The generator shall be four pole, brushless, 12 lead reconnectable of drip-proof construction with amortisseur windings. Insulation shall be Class F with epoxy varnish. Generator field current shall be controlled by a rotating thyrister bridge module optically coupled to a firing circuit type voltage regulator. The exciter shall be 24 pole permanent magnet type. Generators controlled by wound field exciters will not be accepted unless they meet the following performance.

Radio-interference suppression meeting commercial standards shall be supplied. Voltage regulation shall be within plus or minus 2% of rated voltage, from no load to rated load.

Upon application of 90% rated load in one step voltage dip as measured by a light beam recorder or oscilloscope shall not exceed 15%, recovery to stable voltage shall occur within .1 second. Stable or steady state operation is defined as operation with terminal voltage remaining constant within plus or minus 1/2 of one (1) percent of rated voltage. Voltage adjustment range shall be plus or minus 5 percent of rated voltage. Temperature rise shall be within NEMA, IEEE, and ANSI standards.

If a line to neutral short circuit occurs, the generator shall support 300% rated current for 10 seconds without externally mounted devices.

A resettable line current sensing circuit breaker with inverse time vs. current response shall be furnished which protects the generator from damage due to overload. This breaker shall not trip within the 10 seconds specified above.

Separate visual diagnostic means shall be furnished on the generator rotor for determining that exciter voltage is being developed and that the excitation system is supplying current to the generator field according to load requirements.

The generator, having a single, maintenance free bearing, shall be direct connected to the flywheel housing, with a disc coupling between the rotor and the flywheel.

CONTROLLER: Set mounted controller facing right, left, rear (choose one) shall be vibration isolated on the generator enclosure. It shall be of solid state design. Relays will be acceptable only for high current circuits. Circuitry shall be of plug-in design for quick replacement. Controller shall be equipped to accept a plug-in device capable of allowing maintenance personnel to test controller performance without operating the engine. The controller shall include:

Fused DC circuits.

Complete 2 wire start/stop control which shall operate on activation of a remote contact.

Cranking period controlled by a speed sensor which disengages the starting motor when the engine has started. Battery charging alternator or generator voltage may not be used for this signal.

The starting system shall be designed for restarting in the event of a false engine start, by permitting the engine to completely stop and then re-engage the starter.

Cranking cycler with individually adjustable (2 to 20 seconds) ON and OFF cranking periods.

Overcranking protection designed to open the cranking circuit after 60 seconds if the engine fails to start.

Circuitry to shut down the engine when signal for high coolant temperature, low oil pressure or overspeed are received, with reset button.

Adjustable (2 to 10 minute) factory set at 5 min. time delay to permit unloaded running of the standby set after transfer of the load to normal.

Alarm horn.

Three position (automatic-off-test) selector switch.

Emergency stop switch.

Indicating lights to signal -

Specifier's Note:		
	Standard Equip.	(Switch "off" (flashing red) (Overcrank (red) (Emergency stop (red) (High coolant temperature (red) (Overspeed (red) (Low oil pressure (red)
	Optional Anticipatory Group*	(Anticipatory high coolant (Temperature (yellow) (Anticipatory low oil pressure (yellow) (Low coolant temperature (red)
	Optional Hosipital Group*	(High battery voltage (red) (Low battery voltage (red) (Low fuel (red) (System ready (green)

Test button for indicating lights.

Connections to the controller shall be by plug-in wiring harnesses.

*Required to meet NFPA-76A Regulations.

INSTRUMENT PANEL: A set mounted instrument panel shall include:

Dual range voltmeter 3-1/2 inch ±2% accuracy.

Dual range ammeter 3-1/2 inch ±2% accuracy.

Voltmeter-Ammeter phase selector switch.

Lights to indicate high or low meter scale.

Direct reading pointer type frequency meter 3-1/2 inch ±.3 hz accuracy.

Panel illuminating light.

Battery charging ammeter.

Oil pressure gauge.

Coolant temperature gauge.

Running time meter.

Plug-in voltage regulator with front panel voltage adjusting rheostat.

AUTOMATIC TRANSFER PANEL (S): The automatic transfer panel shall be listed by Underwriters Laboratory under Std. UL 1008 for emergency systems and all classes of load, and be CSA approved. The ampere rating shall be at least equal to the total load being transferred. Control circuitry shall be solid state except for "OFF" timers and heavy current circuits. The transfer panel shall initiate transfer to the generator set when the voltage of any phase of the normal drops below 70% of rated. The transfer panel shall have closing, withstand and interrupting ratings equal to the available short circuit current on the normal supply. A minimum of .5 second delay must exist between the opening of the emergency and closing of the normal to allow induced voltages in the system to decay.

GENERATOR SET MOUNTING: The standby generator set shall be equipped with factory installed vibration isolators mounted between the set and fabricated steel base to prevent distortion of alignment between generator and engine when installed. Mount on concrete pad as shown on plans and drawings.

ACCESSORIES: Engine block heater, 2,000 watt, 120 volt.*

220 ampere hour, 12 volt battery, battery rack, and battery cables.

20 ampere automatic float battery charger Model A-269214 with automatic voltage regulation, current limiting capability, temperature compensated for ambients from -20° F, voltmeter and ammeter; equipped for conduit installation, as supplied by Kohler Co.

Engine exhaust silencer rated for (select one) Industrial, Residential, Critical application.

Remote annunciator panel* with visual indicators for:

Switch "off" (flashing red), Overcrank (red), Emergency stop (red), High coolant temperature (red), Overspeed (red), Low oil pressure (red), Anticipatory high coolant temperature (yellow), Anticipatory low oil pressure (yellow), low coolant temperature (red), High battery voltage (red), Low battery voltage (red), Low fuel (red), System ready (green), Normal line power (yellow), Generator power (yellow). Alarm switch off (red), and an audible alarm with shut-off switch.

*Required to meet NFPA-76A Regulations.

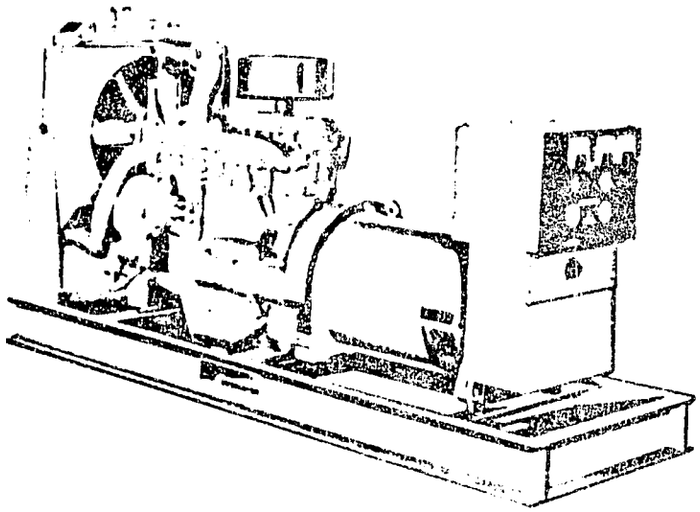
INFORMATION REQUIRED FOR SPECIFIED STANDBY SYSTEMS

1. Detailed specification sheets.

2. Certified final factory test report shall be provided to the architect, certifying this unit's full power rating, stability, voltage and frequency regulation.

3. Complete operating instruction and maintenance manual with parts list.

Waukesha VR 220/330
Diesel Enginator® Systems
24 to 69 Kilowatts
PRELIMINARY INFORMATION



VRD330 Enginator® with Engomatic® Controls

ENGINATOR® SPECIFICATIONS

AIR CLEANERS — Dry type.

BATTERY CHARGING ALTERNATOR — 12 volt D.C., 55 amp., negative ground, integral voltage regulator, mounting and drive. Near zero taper charge feature.

BEARINGS — Replaceable, precision type main and rod bearings.

CONNECTING RODS — Forged steel.

CRANKCASE — Single piece heavy duty, deep-skirted crankcase.

CRANKSHAFT — Forged steel, dynamically balanced and counterweighted with hardened journals. VRD220: Five (5) main bearings. VRD330: Seven (7) main bearings.

CYLINDERS — Centrifugally cast, replaceable wet liners. 3.875 inch bore x 4.665 inch stroke.
VRD 220/220S — 4 cylinders
VRD 330/330S — 6 cylinders

CYLINDER HEAD — Open combustion chamber. Overhead valves with replaceable valve guides. Cross flow design. One piece construction. Exhaust valve rotators and inserts.

EXHAUST — Vertical exhaust, (3.25" OD)

FUEL INJECTION SYSTEM — Distributor type fuel injection pump, speed advance and integral governor. Fuel supply pump. Fuel filter, 12 volt solenoid shut-off on injection pump.

GOVERNOR — Mechanical type; 5% regulation.

LUBRICATION SYSTEM — Full pressure lube oil system with full flow oil filter and gear-type lube oil pump.

OIL PAN — Automotive type. Rear sump. Capacity 8.0 quarts (7.6 litres) including filter (without cooler). Right hand dipstick.

PISTONS — Aluminum alloy 3-ring type with full floating pin. Rectangular top ring.

WATER CIRCULATING SYSTEM — Belt-driven water pump, 175° F. (79° C.) start-to-open thermostat. Positive bypass shut-off.

STARTING EQUIPMENT — Electric starting motor, 12 volt DC solenoid engagement.

TURBOCHARGER — On VRD 220S/330S only.

COOLING SYSTEM — Choice of unit mounted radiator (Pusher Fan), heat exchanger with surge tank, or connections for remote radiator cooling.

GENERATOR — Waukesha, direct connected, fan cooled, A.C. revolving field type, single bearing generator, with brushless exciter and damper windings. TIF and Deviation Factor within NEMA MG – 1.22 Voltage 480/277, 3 phase, 4 wire, Wye 60 Hz. and 400/231, 3 phase, 4 wire, Wye 50 Hz. Other voltages are available, consult factory. Insulation material NEMA Class F. Temperature rise within NEMA (105° C.) for prime power duty, within NEMA (130° C.) for continuous standby duty. All generators are rated at .8 Power Factor, are mounted on the engine flywheel housing and have multiple steel disc flexible coupling drive.

VOLTAGE REGULATOR — SCR static automatic type providing 1% regulation from no load to full load. Includes voltage adjustment rheostat and automatic subsychronous speed protection.

ENGINATOR BASE — Engine, generator, and radiator or heat exchanger are mounted and aligned on a channel steel base suitable for lifting.

ENGOMATIC CONTROL — Generator mounted. NEMA 1 for general indoor use.

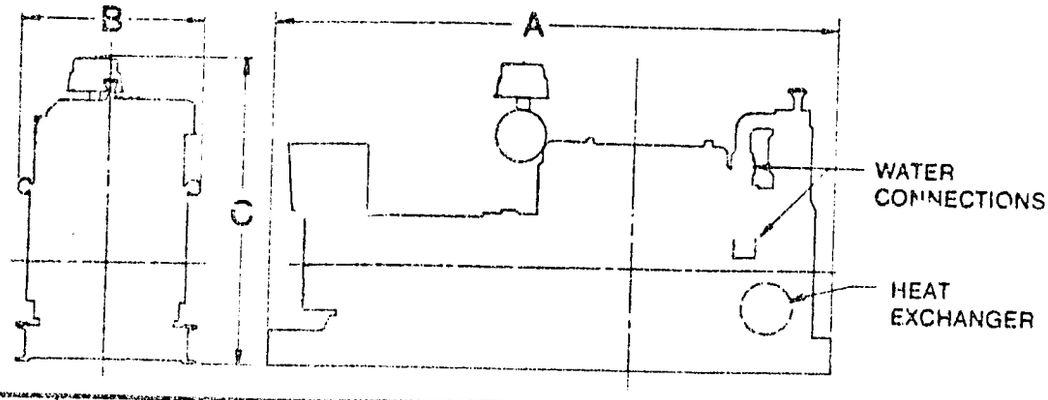
METERS — 3.5" (89 mm) panel type 2% accuracy, voltmeter, ammeter, dial type frequency meter, hourmeter and combination voltmeter/ammeter switch.

CONTROL SWITCH — Three position selector switch, off-run-start for manual operation.

SAFETY SHUTDOWN CIRCUITS — For low oil pressure and high water temperature, manual reset type with common indicator light.

RELAYS — Dust resistant, totally enclosed, plug-in type.

ENGINE INSTRUMENTS — 2" (51 mm) water temperature and oil pressure gauges, battery charging ammeter.



Model	Type of Cooling	A		B		C		Net Weight (Dry)	
		IN.	MM	IN.	MM	IN.	MM	LB.	KGS
220	Radiator	82	2083	30	762	48	1219	2000	909
220S	Radiator	82	2083	30	762	48	1219	2100	955
330	Radiator	94	2388	30	762	51	1295	2550	1159
330S	Radiator	94	2388	30	762	51	1295	3000	1364
220	Heat Ex.	82	2083	30	762	48	1219	2000	909
220S	Heat Ex.	82	2083	30	762	48	1219	2100	955
330	Heat Ex.	94	2388	30	762	51	1295	2550	1159
330S	Heat Ex.	94	2388	30	762	51	1295	3000	1364
220	Water Con.	82	2083	30	762	48	1219	1950	886
220S	Water Con.	82	2083	30	762	48	1219	2050	932
330	Water Con.	94	2388	30	762	51	1295	2500	1136
330S	Water Con.	94	2388	30	762	51	1295	2950	1341

	PRIME POWER RATINGS			CONTINUOUS RATINGS FOR STANDBY USE		
Cooling	Model	1800 RPM kW Rating	1500 RPM kW Rating	Model	1800 RPM kW Rating	1500 RPM kW Rating
Radiator	220	28	24	220	31	26
	220S	38	31	220S	43	34
	330	48	38	330	50	41
	330S	62	52	330S	67	55
Heat Exchanger	220	29	25	220	32	27
	220S	39	32	220S	44	35
	330	50	40	330	52	43
	330S	64	54	330S	69	57
Water Connection	220	29	25	220	32	27
	220S	39	32	220S	44	35
	330	50	40	330	52	43
	330S	64	54	330S	69	57

RATING DEDUCTIONS FOR ALTITUDE AND TEMPERATURE

Type of Engine	Deduction	Continuous Rating for Standby Power	Prime Power Ratings
Naturally Aspirated	Altitude – Deduct 3% for each 1000' (305m) above ...	500' (152m)	1500' (457m)
	Temperature – Deduct 1% for each 10°F (6°C) above ...	85°F (29°C)	100°F (38°C)
Turbocharged	Altitude – Deduct 2% for each 1000' (305m) above ...	500' (152m)	1500' (457m)
	Temperature – Deduct 1% for each 10°F (6°C) above ...	85°F (29°C)	85°F (29°C)

The manufacturer reserves the right to change or modify, without notice, the design, equipment specifications or ratings as herein set forth without incurring any obligation either with respect to engines previously sold or in the process of construction except where otherwise specifically guaranteed by the manufacturer.

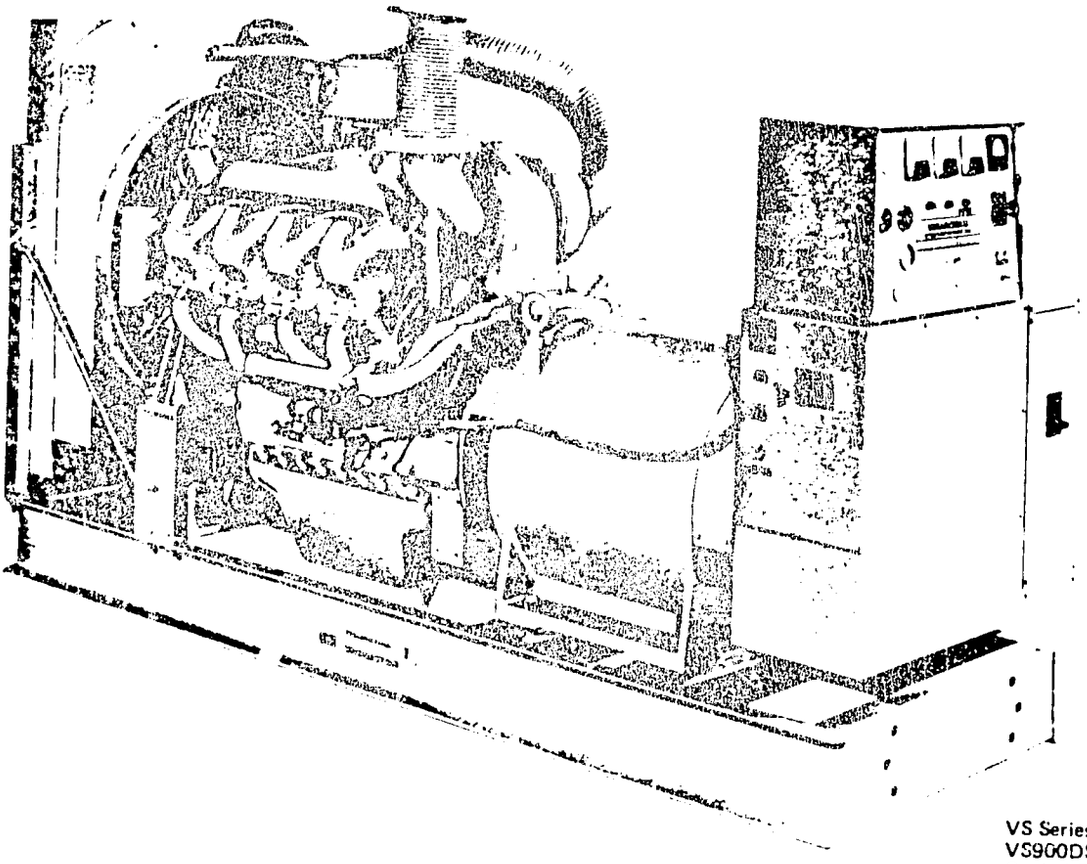
Waukesha DRESSER

Your Distributor

WAUKESHA ENGINE DIVISION
DRESSER INDUSTRIES INC.
WAUKESHA, WISCONSIN 53187
Bulletin 6214 10-81 Litho in U.S.A.

VS series

BULLETIN 6205A



VS Series Model VS900DS Radiator Cooled Diesel Enginator® System Rated 250 Kilowatts for Standby - Continuous Service

- WAUKESHA VS Diesel Engine
- WAUKESHA generator and regulator
- Factory load tested as a system
- Factory certified test report
- Torsionally tested and approved
- Industrial and Marine Sets

BASIC UNIT SPECIFICATIONS

Air Cleaners — Dry.

Battery Charging Alternator — 35 amps, belt driven, alternator charging ammeter in instrument panel.

Bearings — Heavy duty, replaceable, precision type.

Breather — Crankcase ventilating type, open.

Connecting Rods — Forged steel rifle drilled for pin lubrication.

Crankshaft — Forged steel, hardened journals, dynamically balanced.

Crankcase — Integral crankcase and cylinder frame.

Cylinders — Removable wet cylinder liners.

Cylinder Heads — Interchangeable valve-in-head type. Stellite intake and exhaust valves with chrome plated stems.

Fuel System — Multiple plunger injector pump, injector lines, fuel transfer pump, hand primer pump, flexible fuel lines.

Governor — Variable speed centrifugal 5% regulation.

Instrument Panel — Mounted on Engomatic control panel, includes 2" (51 mm) water temperature and oil pressure gauges.

Lubrication — Full pressure, positive displacement pump, centrifugal oil filter.

Manifolds — Air cooled exhaust. Single outlet.

Oil Cooler — Full flow shell and tube type.

Oil Pan — Automotive sump type.

Pistons — Aluminum with floating pin.

Safety Shutdown — Conditions of high water temperature or low oil pressure cause automatic fuel shutoff and shutdown.

Starting Equipment — Electric starting motor 24V DC, solenoid engagement.

Turbochargers — One on DS units.

Water Circulating System — Engine driven centrifugal water pump and bypass thermostat.

Cooling System — Thermostatically controlled. Choice of unit mounted radiator, heat exchanger with surge tank, or connections for remote radiator cooling.

Generator — Direct connected Waukesha AC revolving field type, single bearing, damper windings. TIF max. 150. Standard voltage 480/277, 3 phase, 4 wire, Wye 60 Hz or 400/231, 3 phase, 4 wire, Wye 50 Hz. Other voltages available, consult factory. Generators are mounted to engine flywheel housing, and have multiple steel disc, flexible coupling drive. All generators are 12 lead machines suitable for commercial lug and cable connections. The generators are built per NEMA standards.

Exciter — Brushless direct connected type with shaft mounted diodes and residual magnetism eliminating field flashing.

Ventilation — Shaft mounted fan for air flow from exciter end and exiting through drive end.

Voltage Regulator — SCR static automatic type providing 1% regulation from no load to full load. Includes voltage adjustment rheostat and automatic subsynchronous speed protection.

Enginator Base — Engine, generator, and radiator or heat exchanger are mounted and aligned on a channel steel base suitable for lifting.

Engomatic Control — Generator mounted.

Enclosure — NEMA I for general indoor use.

Meters — 3.5" (89 mm) panel type 2% accuracy, voltmeter, ammeter, dial type freq. meter, and combination voltmeter-ammeter switch.

Control Switch — 3 position selector switch, off-run-start for manual operation.

Safety Shutdown Circuits — For low oil pressure and high water temperature, with indicator light.

Relays — Dust resistant, totally enclosed, plug-in type.

Accessories — Consult Price Book for complete list of accessories and optional equipment.

The manufacturer reserves the right to change or modify, without notice, the design, equipment specifications, or ratings as herein set forth without incurring any obligation either with respect to systems previously sold or in the process of construction except where otherwise specifically guaranteed by the manufacturer.

VS SERIES KILOWATT RATINGS – Industrial Enginator® Systems

MODEL	TYPE OF COOLING	CONTINUOUS RATING FOR STANDBY USE		PRIME POWER RATING	
		KW 60 Hz & 480 V @ 1800 RPM	KW 50 Hz & 400 V @ 1500 RPM	KW 60 Hz & 480 V @ 1800 RPM	KW 50 Hz & 400 V @ 1500 RPM
VS900DS	Heat Exchanger	260	220	215	190
	Remote Radiatcr	260	220	215	190
	Radiator	250	215	205	185
VS700DS	Heat Exchanger	175	150	155	130
	Remote Radiator	175	150	155	130
	Radiator	170	150	155	130
VS500DS	Heat Exchanger	115	95	100	85
	Remote Radiator	115	95	100	85
	Radiator	110	95	100	85
VS500D	Heat Exchanger	80	68	72	60
	Remote Radiator	80	68	72	60
	Radiator	80	68	72	60

RATING DEDUCTIONS FOR ALTITUDE AND TEMPERATURE

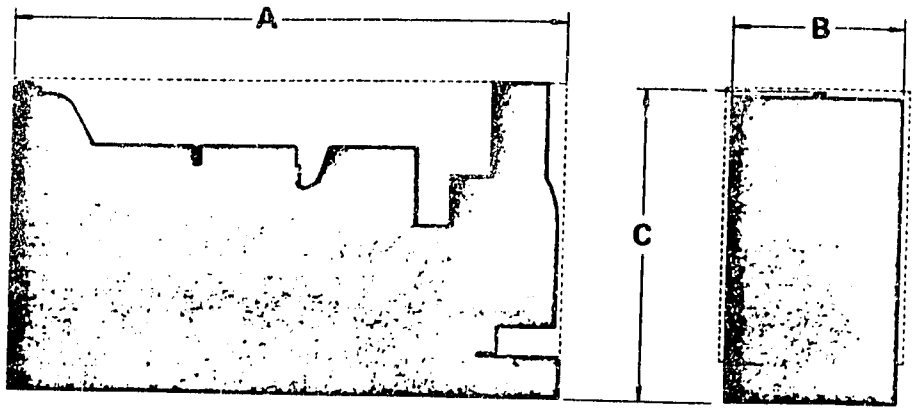
Type of Enginator	Continuous Rating for Standby Use	Prime Power Ratings
Naturally Aspirated	3% for each 1000' above 1000 altitude	3% for each 1000' above 2000' altitude
	1% for each 10° over 80° F.	1% for each 10° over 100° F.
Turbocharged	2% for each 1000' above 1500' altitude	2% for each 1000' above 3000' altitude
	1% for each 10° over 80° F.	1% for each 10° over 100° F.
Turbocharged Intercooled	2% for each 1000' above 1500' altitude	2% for each 1000' above 3000' altitude
	1% FOR EACH 10° OVER 100° F. AMBIENT TEMPERATURE	

Diesel Fuel Ratings based on ASTM D975 Classification No. 2D Cetane Rating 40 minimum.

VS SERIES KILOWATT RATINGS – Marine Enginator® Systems

MODEL ①	TYPE OF COOLING	PRIME POWER RATING SHIPS SERVICE GENERATOR SETS	
		60 Hz KW @ RPM	50 Hz KW @ RPM
VS900DSIM	Heat Exchanger	235 1800	200 1500
VS700DSIM	Heat Exchanger	200 1800	175 1500
VS700DSM		160 1800	140 1500
VS700DM		115 1800	100 1500
VS500DSM	Heat Exchanger	105 1800	90 1500
VS500DM		80 1800	70 1500

① All Enginator generator sets capable of 10% overload to meet classification society requirements.



VS SERIES OUTLINE DIMENSIONS

MODEL	TYPE OF COOLING	A		B		C		APPROXIMATE DRY WEIGHT	
		IN.	MM	IN.	MM	IN.	MM	LBS.	KGS
VS900DS	Heat Exchanger	114	2895	42	1067	56.5	1486	5675	2580
	Remote Radiator	114	2895	42	1067	56.5	1486	5600	2545
	Radiator	114	2895	42	1067	56.5	1486	6100	2773
VS700DS	Heat Exchanger	114	2895	36	914	60	1524	4850	2205
	Remote Radiator	114	2895	36	914	57.5	1460	4400	2000
	Radiator	114	2895	36	914	63	1600	4600	2091
VS500DS	Heat Exhanger	114	2895	36	914	57.5	1460	4300	1950
	Remote Radiator	114	2895	36	914	57.5	1460	4200	1905
	Radiator	114	2895	36	914	57.5	1460	4200	1905
VS500D	Heat Exchanger	114	2895	36	914	57.5	1460	3450	1565
	Remote Radiator	114	2895	36	914	57.5	1460	3450	1565
	Radiator	114	2895	36	914	57.5	1460	3450	1565

NOTE: Dimensions may vary with service and installation requirements and, therefore, are not guaranteed. Detailed prints available for layout work. Contact your Waukesha distributor.

Waukesha DRESSER
WAUKESHA ENGINE DIVISION
DRESSER INDUSTRIES INC.
WAUKESHA, WISCONSIN 53187

Your Distributor:

Bulletin 6205A 6-79 Litho in U.S.A.

plug in to high performance.

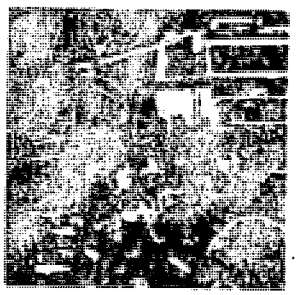
WINCO... YOUR ONE SOURCE FOR POWER

WINCO is the U.S.A.'s largest manufacturer of portable generators. The majority of our generators are built for the construction, industrial and agricultural markets. We have been manufacturing Power Systems since the 1930's.

The High Performance Series by WINCO is designed to be functional, easy-to-service, and powerful. In fact, we are so confident of the design integrity, all High Performance generators are warranted for one year even in construction, industrial, and rental applications.

Every WINCO generator undergoes numerous in-process inspections during manufacturing. After the generator system is assembled, and prior to shipment, it undergoes a final test run and inspection. Your High Performance generator will come with a report documenting its actual performance on its final test. WINCO manufactures a complete line of systems from 200 watts thru 300,000 watts including automatic, portable, tractor drive, and two-bearing generators powered by the wind or by diesel, gasoline, LPG, or natural gas engines.

Construction Power



Outdoor Power

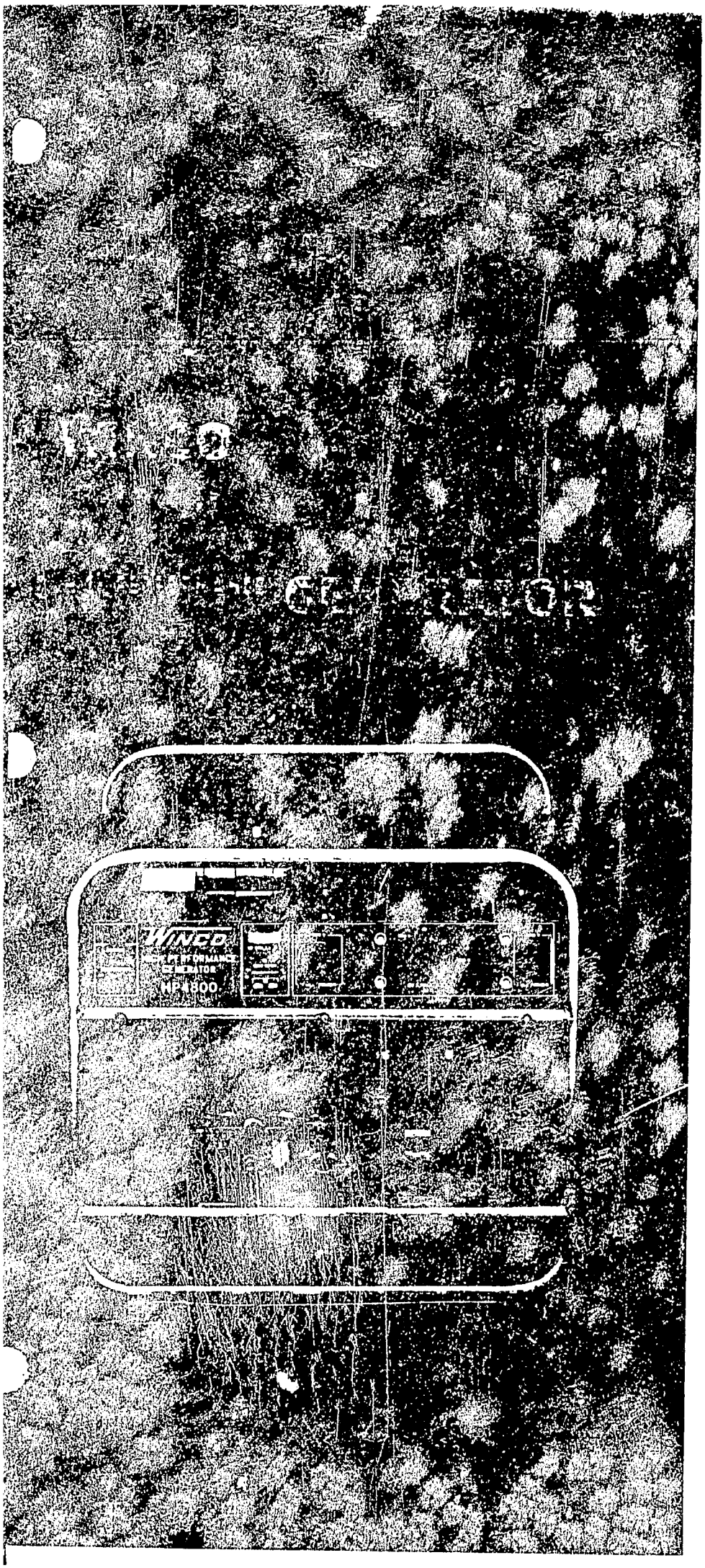
Emergency Power

If you want performance, WINCO has a generator for you. The High Performance models are designed for the demanding applications of construction, rental, or emergency power requirements.

The Power Systems in this series include top of the line features that live up to their name. These sets are designed to be quiet, powerful, dependable, and easy to maintain. Various models are equipped with the following features:
• A frame-mounted (vibration isolated) control panel that is well planned, well equipped, well marked and conveniently located. • An automatic engine idler that saves gasoline and lowers the sound level even farther when there is no load. • A Full Power circuit that allows the maximum rating to be taken from one receptacle – either 120 volt or 240 volt. • A Maxi-Watt winding for extra motor starting ability. • Convenient electric starting and easy manual starting. • A large fuel tank for long uninterrupted run times. Mounted below the set with a specially designed filler tube and fuel gauge. A steel plate below the tank is included for added protection. • Simultaneous AC and DC power, starting/battery cables and battery cable storage box. • A high quality, long life engine. • Compact size, light weight, maximum output. • Full WINCO warranty. • High Performance.

WINCO generators sets are easy-to-service. Did you ever try to replace a spark plug, change oil, or perform simple maintenance on a "pretty" generator? If so, you will appreciate the service accessibility on these generators. All routine maintenance can be done without removing any "sheet metal." There are factory authorized service centers throughout the nation and the world to keep it on the job. Compare WINCO with any other brand available and you'll see why the High Performance generators are such a terrific value.

WINCO's new High Performance Generator Systems are designed for heavy duty applications with the best motor starting in the industry for their size. WINCO, the leader in construction generators, has designed these units from the ground up to be quiet, powerful, dependable, and easy-to-maintain. The particular features for each model are described in more detail on the following pages.



FEATURES.

Vibration Isolated Control Center. Designed for maximum versatility and convenience. Standard features include: Stop/start switch • Switch for automatic idling or continuous full speed • Fast connect DC plug • DC charge rate ammeter • AC and DC power indicator lamps • Circuit breakers • Multiple twist-lock and straight blade receptacles.

Electronic Conserver. Built-in solid state idling control. Engine idles when power is not required, "revs" up to full engine speed instantly when load is switched on. No relays or moving parts. The module is encased in epoxy, eliminating any possibility of moisture or dust damage. Extends engine life, increases reliability, saves up to 60% on fuel costs.

Full Power. The full rated generator output is available from a single 120 volt outlet – or a single 240 volt outlet – or any combination of receptacles. Full Power is a patented heavy-winding built into the rotor, eliminating the need for any switches or reconnecting.

Maxi-Watt. An extra-heavy winding in the fields that provides extra power for heavier motor starting loads, reducing the size and weight of the generator required. The HP4800 will start a 3 horsepower Code G motor.

Two-Way Starting. Can be started electrically with the push of a button or manually with the recoil starter. The engine has an automatic compression release for easy pulling. The "fast spin" electric start spins the engine 2 or 3 times faster than a conventional type starter to aid starting under difficult conditions.

Five Gallon Fuel Tank. The large fuel tank is mounted underneath the generator set. The large slanted filler neck is designed for easy filling. If fuel is spilled while filling the tank, it drops to the ground, not on the hot engine. Operates over 7 hours under normal load. A steel plate below the tank is included for added protection.

Fuel Gauge.

Low Oil Level Shutdown.

USDA Approved Muffler. Super quiet spark arrestor type.

Wrap-Around Cradle. Heavy-duty, tubular steel construction for maximum protection.

Battery Cables. Use for both battery charging and engine starting.

Battery Cable Storage Box.

Long Life Engine. Kawasaki 4-cycle; air-cooled; cast-iron cylinder; 341 cc; CD ignition; balanced crankshaft with integral counter weights; ball bearing main bearings; stellite exhaust valve; maximum noise suppression.

Generator Specifications: 4800 surge watts • 4500 continuous watts • 120/240 volts • 38/19 amps • 60 hertz • 1 phase • 10-amp 12-volt DC • Simultaneous AC/DC power • Length 27" • Width 21½" • Height 24½" • Weight 260 lbs. • One Year Warranty.

Optional: Heavy duty two wheel pneumatic tire dolly.