Alberta Farm Machinery Research Centre

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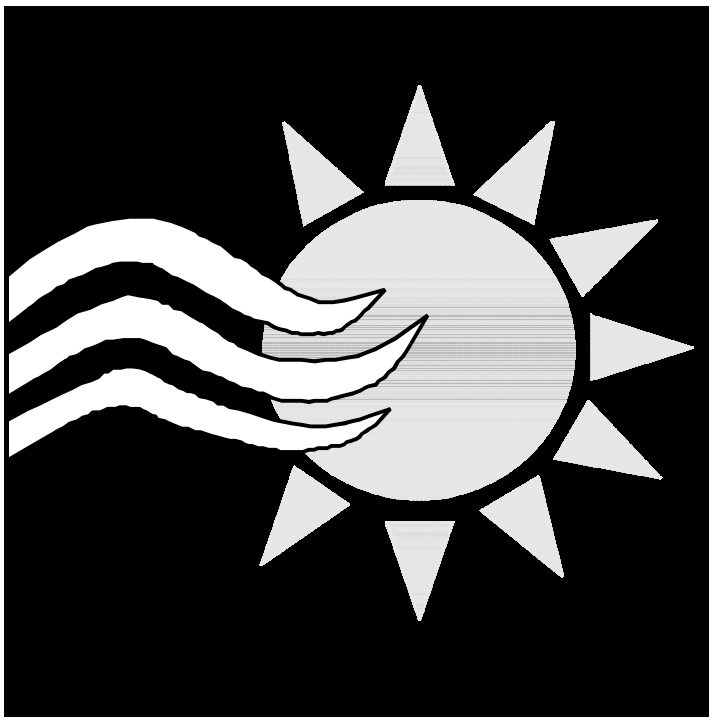
Summary Report 737



Alberta Renewable Energy Test Site

Summary of Wind and Solar Powered Pumping Units (1993-1996 Test Season)

A Co-operative Program Between

ALBERTA FARM MACHINERY RESEARCH CENTRE

PAMI
PRAIRIE AGRICULTURAL MACHINERY INSTITUTE

Summary of Wind and Solar Pumping System Tests (1993-1996)

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Wind Systems

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- Aermotor

Dutch Industries Ltd.
- Dutch Junior (Water)
- Dutch Junior (Aerator)
- Delta 16A

Wind Powered Equipment
- Breeze - 1 various configurations

Koenders Mfg. Co. Ltd.
- Koenders (Aeration) various configurations
- Koenders (Water) various configurations

Maverick Wind Energy Ltd.
- Windmotor

Solar Systems

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- CAP 448TRU Solar Pump
- CAP 448SF5 Solar Pump
- CAP 348SF5 Solar Pump
- CAP 348SRU Solar Pump
- CAP 175SM3 Solar Pump
- CAP 348SM5 Solar Pump
- CAP 448SM5 Solar Pump
- Grundfos SunSub 400

Kelln Consulting Ltd.
- Single Module Aeration System
- 6 Module Water System (Parallel)
- 6 Module Water System (Parallel/Series)
- 6 Module Water System (Parallel/Series)
- Pump Jack Solar System
- 3 Module Aeration System

Renewable Energy Pumping Systems

Renewable energy pumping systems are typically used in locations removed from an electric power source. In these instances, the cost of the pumping system is often less than the cost of extending the power lines from the nearest source. In Canada, the most common agricultural applications of these systems are livestock watering and sub-surface drainage. Livestock watering generally consists of pumping from a dugout or stream to a watering trough to eliminate water source contamination. These systems can also be used to pump to pastures for livestock use as part of a grazing management system. Sub-surface drainage is installed to lower water tables or intercept discharge areas such as sidehill saline seeps or seepage from irrigation canals. The drains gravity feed to a central sump which is then emptied with a pumping system. Both livestock watering and sub-surface drainage are typically low lift applications of less than 20 ft (6 m).

Test Results

The following results have been extracted from the Alberta Renewable Energy Test Site (ARETS) reports for the 1993-1996 test seasons. The ARETS has been in operation from 1982 and is managed by the Alberta Farm Machinery Research Centre (AFMRC). The site is located at Pincher Creek, Alberta.

The summary condenses the latest available information so direct comparisons can be made among the various makes and models of the systems tested. This, in turn, will aid in the selection process of the right pumping system for a given application.

Scope of Test

The wind pumping system's tests were performed in accordance with the Canadian Standards Association (CSA) Standard F417-M91 "Wind Energy Conversion Systems (WECS) - Performance". The solar pumping system tests also followed this standard in respect to instrumentation accuracy, sampling speed, averaging intervals and minimum data base requirements. Utilization of the above standard for the solar tests was required as no CSA field test standard has been prepared for solar pumping systems. Use of this standard also ensures uniformity of performance reporting. The Standard requires sampling input energy (wind speed or incident solar radiation) and performance variables of the pumping system at one sample per second and calculating 10 minute averages. Each 10 minute average is then grouped into a range of wind speeds or a range of solar radiation intensities. These ranges are, in turn, averaged, resulting in the final performance curve. The probability of these averages occurring are calculated to determine if they meet the Standard's minimum requirements.

A performance page has been prepared for each system in this summary report. The performance page consists of a picture of the unit, a physical description of the system, reliability reporting and performance graphs. In the case of wind systems, a graph of the expected pumping volume as a function of monthly mean wind speed has been produced. The performance graphs of the solar systems present the current draw of the pump and voltage supplied by the solar panels. They also present the power draw of the pump and the resulting water flow (pumping rate).

Notes

For commercial configurations, performance curves of previous configurations are contained in specific ARETS annual reports.

All performance graphs show the latest configuration of specific systems.

AERMOTOR

Manufacturer and Distributor:
Tensigrity Systems Limited
RR1
Metcalfe, Ontario, Canada
K0A 2P0
(613) 821-4420

Test years: 1992 - 1996

Performance:

Testing Period:	602 days
Period Operational:	602 days
Percent Availability:	100 %

Installed: June 18,1992

Figure 1. Aermotor Turbine.

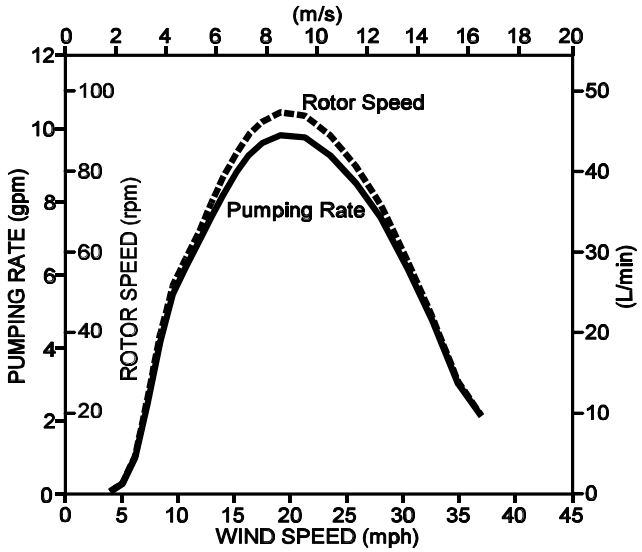

Figure 2. Pumping Rate and Rotor Speed versus Wind Speed for an 18 ft (5.5 m) Lift.

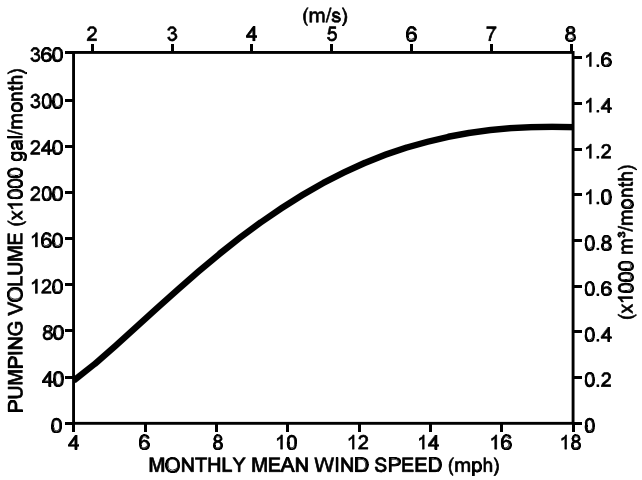

Figure 3. Pumping Volume versus Monthly Mean Wind Speed Based on 100% Availability, Rayleigh Distribution of Wind Speeds and a 30 Day Month.

Physical Description:

Turbine Type: upwind
Axis: horizontal
Rotor Diameter: 8 ft (2.4 m)
Swept Area: 50.3 ft² (4.7 m²)
Number of Blades: 18
Blade Design: torque aerofoil
Blade Material: galvanized steel
Hub Height: 25 ft (7.6 m)
Transmission: mechanical gearing
Gear Ratio: 3.29:1
Pump Type: reciprocating piston
Pump Size: 4 in (102 mm) dia.
Stroke: 7.3 in (18.5 cm)
Pumping System Description:
reciprocating rod connected to positive displacement pump.

DUTCH JUNIOR (Water)

Manufacturer and Distributor:

Dutch Industries Ltd.
705 - 1st Avenue
Regina, Saskatchewan, Canada
S4N 4M4
(306) 949-9522

Test years: 1996

Performance:

Testing Period:	37 days
Period Operational:	37 days
Percent Availability:	100%

Installed: August 7, 1996

Figure 1. Dutch Junior Turbine.

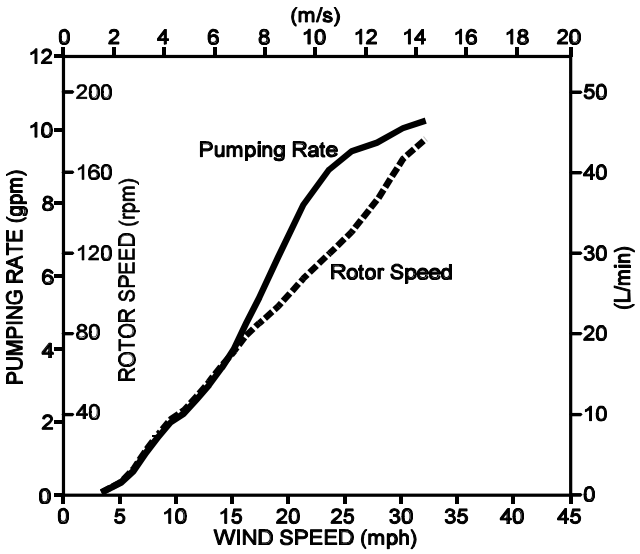

Figure 2. Pumping Rate and Rotor Speed versus Wind Speed for a 18 ft (5.5 m) Lift.

Physical Description:

Turbine Type: upwind
Axis: horizontal
Rotor Diameter: 8 ft (2.4 m)
Swept Area: 28 ft² (2.6 m²)
Number of Blades: 24
Blade Design: Delta Wing
Blade Material: mild steel (20 GA)
Hub Height: 12 ft (3.7 m)
Transmission: direct drive
Gear Ratio: 1:1
Pump Type: reciprocating piston
Pump Size: 2.3 in (57 mm) dia.
Stroke: 4 in (102 mm)
Pumping System Description:
reciprocating rod connected to positive displacement pump

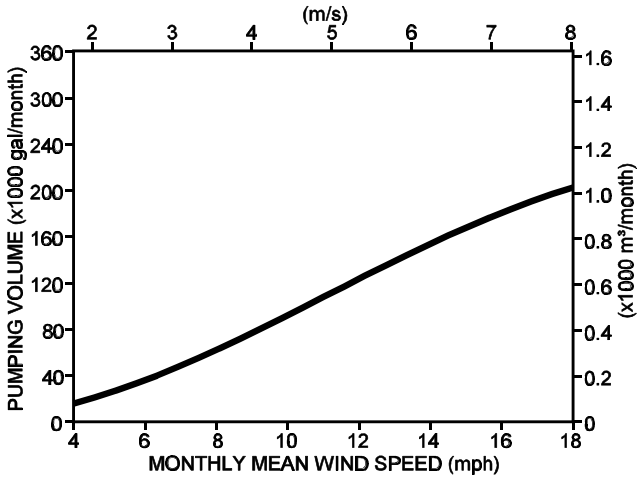

Figure 3. Pumping Volume versus Monthly Mean Wind Speed Based on 100% Availability, Rayleigh Distribution of Wind Speeds and a 30 Day Month.

DUTCH JUNIOR (Aerator)

Manufacturer and Distributor:

Dutch Industries Ltd.
705 - 1st Avenue
Regina, Saskatchewan, Canada
S4N 4M4
(306) 949-9522

Test years: 1996

Performance:

Testing Period:	34 days
Period Operational:	31 days
Percent Availability:	91%

Installed: June 28, 1996

Figure 1. Dutch Junior Turbine.

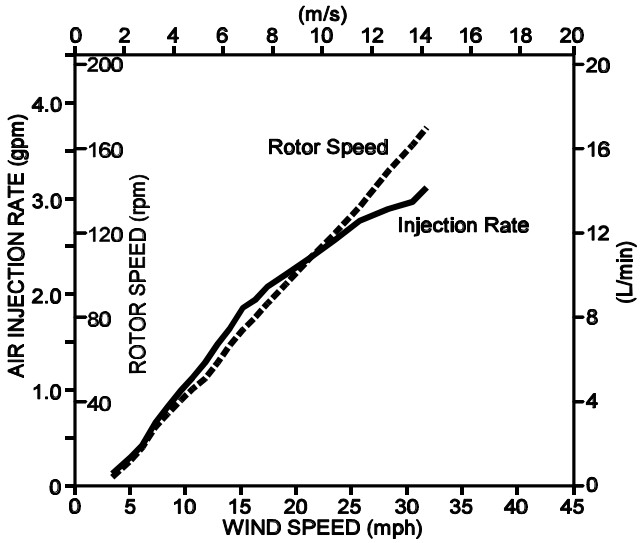

Figure 2. Air Injection Rate and Rotor Speed versus Wind Speed for a 12.5 ft (3.8 m) Submergence.

Physical Description:

Turbine Type: upwind
Axis: horizontal
Rotor Diameter: 8 ft (2.4 m)
Swept Area: 28 ft² (2.6 m²)
Number of Blades: 24
Blade Design: Delta Wing
Blade Material: mild steel (20 GA)
Hub Height: 12 ft (3.7 m)
Transmission: direct drive
Gear Ratio: 1:1
Pump Type: reciprocating piston
Pumping System Description:
reciprocating rod connected to diaphragm pump

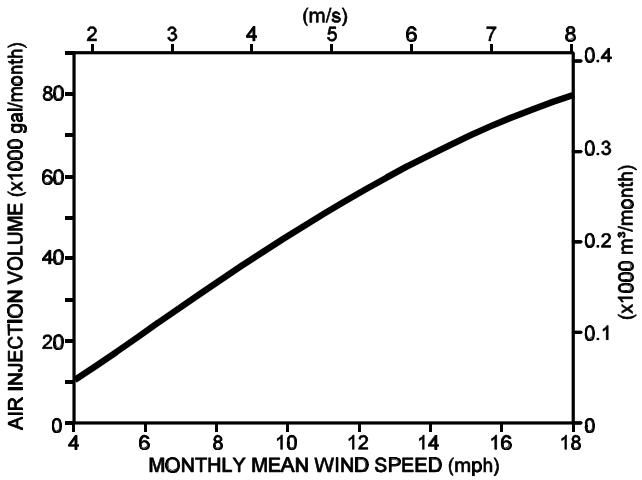

Figure 3. Air Injection Volume versus Monthly Mean Wind Speed Based on 100% Availability, Rayleigh Distribution of Wind Speeds and a 30 Day Month.

DELTA 16A

Manufacturer and Distributor:

Dutch Industries Ltd.
705 - 1st Avenue
Regina, Saskatchewan, Canada
S4N 4M4
(306) 949-9522

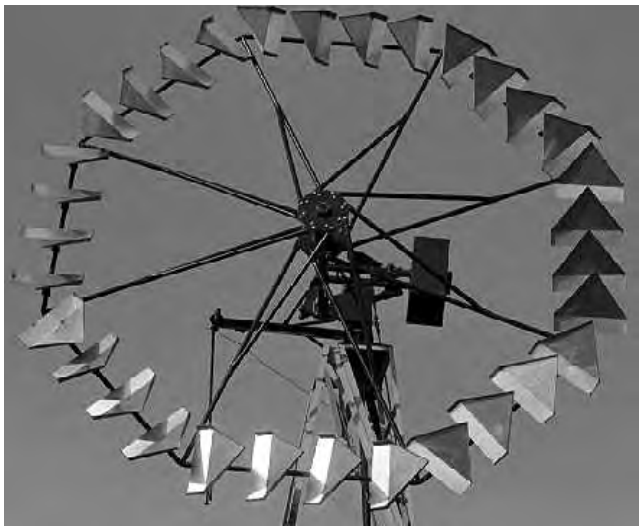

Figure 1. Delta 16A Turbine.

Physical Description:

Turbine Type: upwind
Axis: horizontal
Rotor Diameter: 15.8 ft (4.8 m)
Swept Area: 80.5 ft² (7.5 m²)
Number of Blades: 32
Blade Design: Delta Wing
Blade Material: mild steel (20 GA)
Hub Height: 27 ft (8.3 m)
Transmission: direct drive
Gear Ratio: 1:1
Pump Type: reciprocating piston
Pump Size: 4 in (101.6 mm) dia.
Stroke: 6.5 in (165 mm)
Pumping System Description:
reciprocating rod connected to positive displacement pump

Test years: 1992 - 1995

Performance:

Testing Period:	263 days
Period Operational:	245 days
Percent Availability:	93%

Installed: October 1, 1992

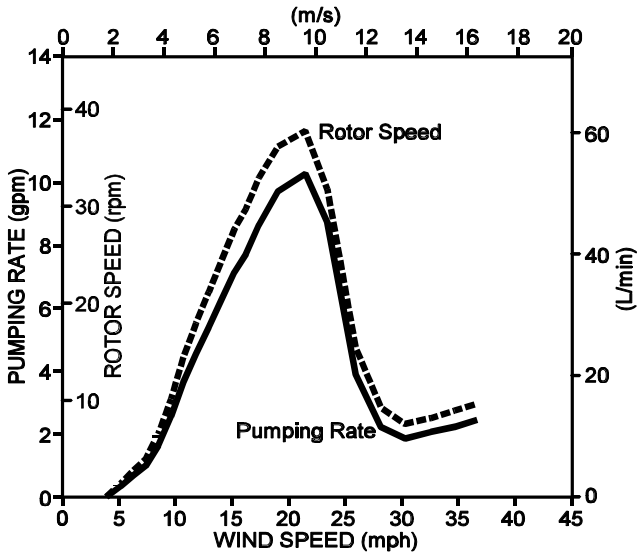

Figure 2. Pumping Rate and Rotor Speed versus Wind Speed for a 98 ft (30 m) Lift.

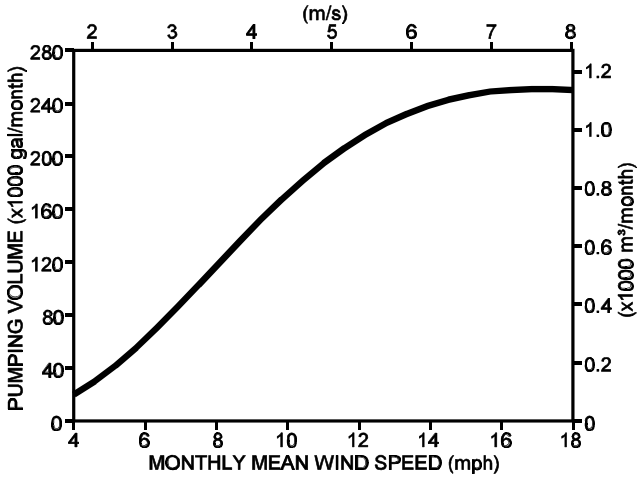

Figure 3. Pumping Volume versus Monthly Mean Wind Speed Based on 100% Availability, Rayleigh Distribution of Wind Speeds and a 30 Day Month.

BREEZE - 1 AERATION TURBINE

Manufacturer and Distributor:

Wind Powered Equipment
Box 416
Manning, Alberta, Canada
T0H 2M0
(403) 836-3907
FAX: (403) 836-3022

Test years: 1993 - 1995

Performance:

Testing Period:	287 days
Period Operational:	200 days
Percent Availability:	70 %

Installed: May 31, 1993

Figure 1. Breeze-1 Aeration Turbine.

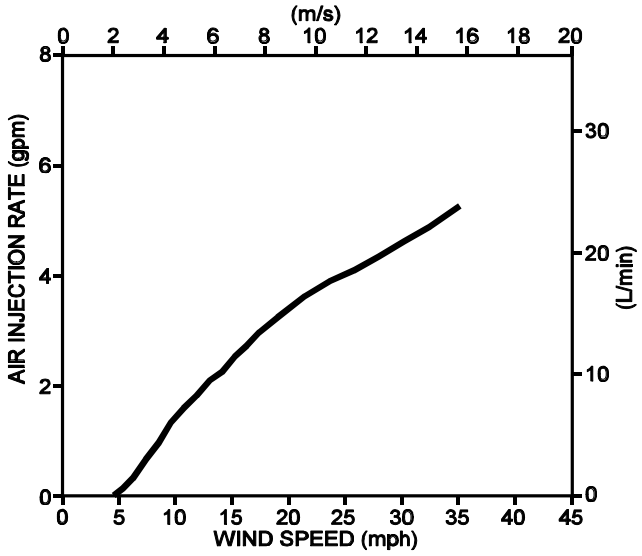

Figure 2. Air Injection Rate versus Wind Speed for 12.5 ft (3.8 m) Submergence.

Physical Description:

Turbine Type: upwind
Axis: horizontal
Rotor Diameter: 7 ft. (2.1 m)
Swept Area: 38.4 ft² (3.6 m²)
Number of Blades: 3
Blade Design: airfoil
Blade Material: wood
Hub Height: 10.8 ft (3.3 m)
Transmission: direct drive
Gear Ratio: 1:1
Pump Type: diaphragm
Pump Size: diaphragm size = 5.9 in (150 mm)
Stroke: 0.7, 0.9 or 1 in (18, 22 or 25 mm)
Pumping System Description:
diaphragm pump injects air into water

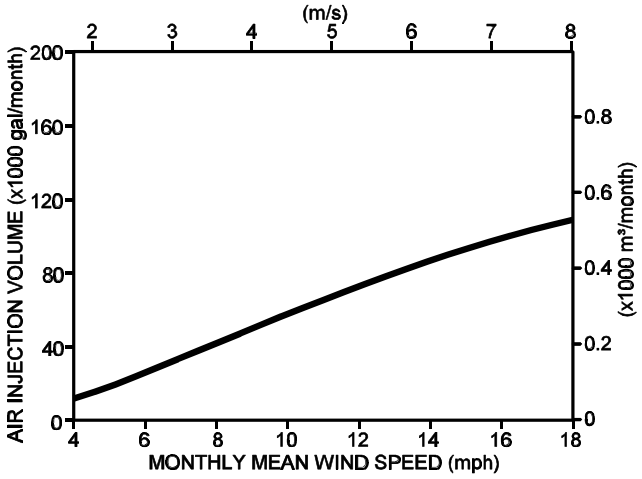

Figure 3. Air Injection Volume versus Monthly Mean Wind Speed Based on 100% Availability, Rayleigh Distribution of Wind Speeds and a 30 Day Month.

BREEZE - 1 AERATION TURBINE

Manufacturer and Distributor:

Wind Powered Equipment
Box 416
Manning, Alberta, Canada
T0H 2M0
(403) 836-3907
FAX: (403) 836-3022

Test years: 1996

Performance:

Testing Period:	49 days
Period Operational:	31 days
Percent Availability:	63%

Installed: July 25, 1996

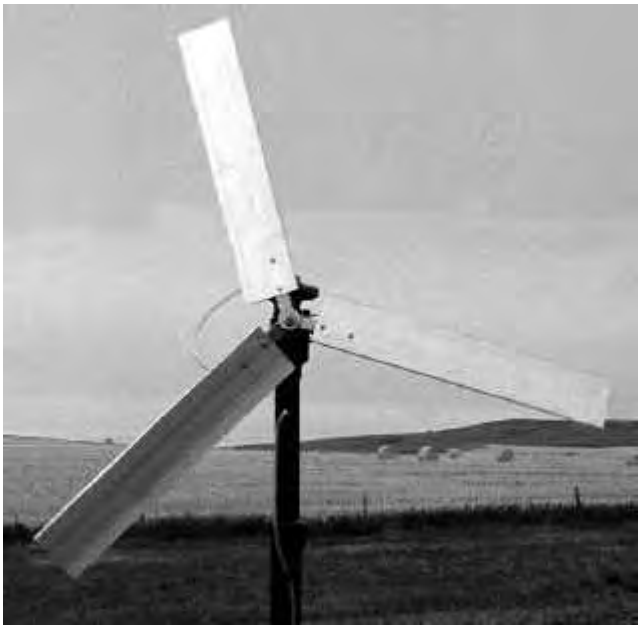

Figure 1. Breeze-1 Aeration Turbine.

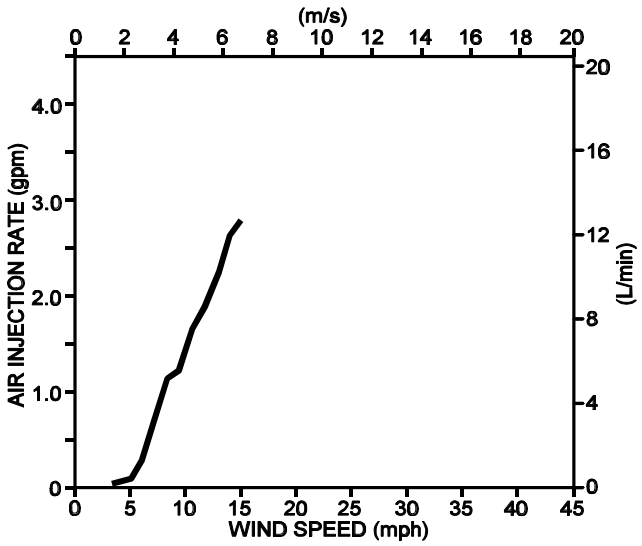

Figure 2. Air Injection Rate versus Wind Speed for 8 ft (2.4 m) Submergence.

Physical Description:

Turbine Type: upwind
Axis: horizontal
Rotor Diameter: 7 ft (2.1 m)
Swept Area: 38.5 ft² (3.6 m²)
Number of Blades: 3
Blade Design: airfoil
Blade Material: aluminum
Hub Height: 11 ft (3.3 m)
Transmission: direct drive
Gear Ratio: 1:1
Pump Type: diaphragm
Pump Size: diaphragm size = 6 in (150 mm)
Stroke: 0.7, 0.9 or 1 in (18, 22 or 25 mm)
Pumping System Description:
diaphragm pump injects air into water

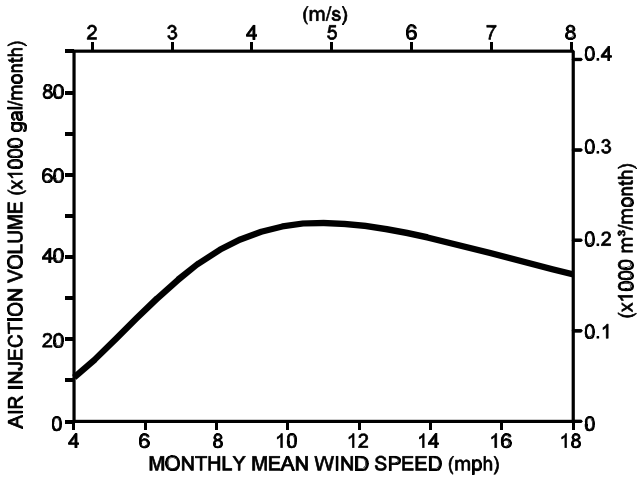

Figure 3. Air Injection Volume versus Monthly Mean Wind Speed Based on 100% Availability, Rayleigh Distribution of Wind Speeds and a 30 Day Month.

KOENDERS AERATION TURBINE

Manufacturer and Distributor:
Koenders Mfg. Co. Ltd.
P.O. Box 171
Englefield, Saskatchewan, Canada
S0K 1N0
(306) 287-3139

Test years: 1993

Performance:

Testing Period:	128 days
Period Operational:	128 days
Percent Availability:	100 %

Installed: June 3, 1993

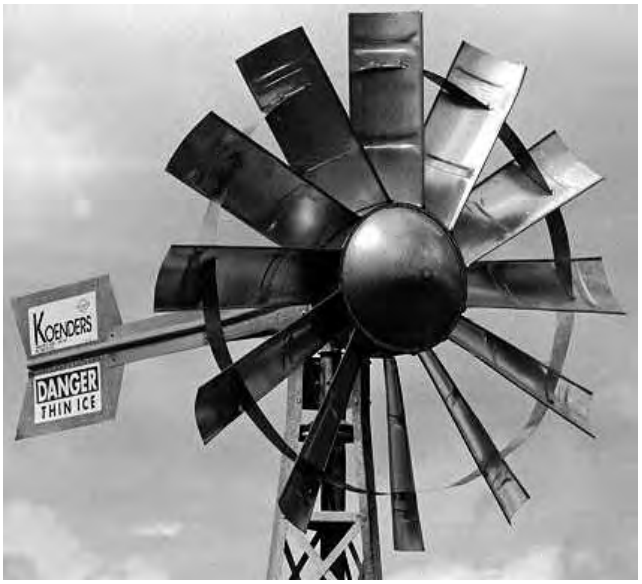

Figure 1. Koenders Aeration Turbine.

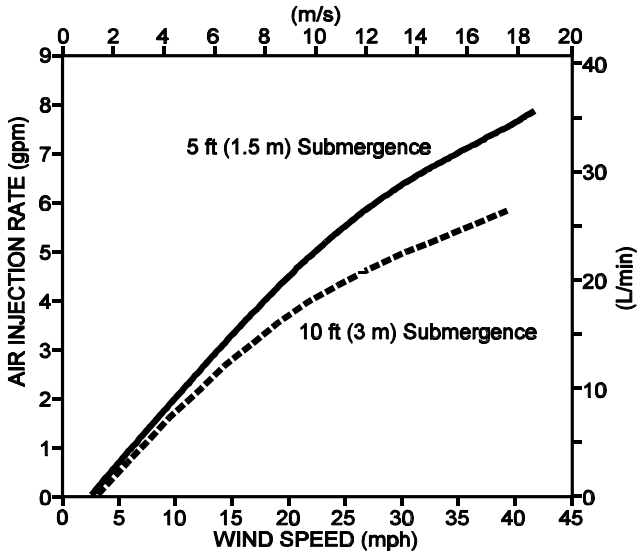

Figure 2. Air Injection Rate versus Wind Speed for a 5 and 10 ft (1.5 and 3.0 m) Submergence.

Physical Description:
Turbine Type: upwind
Axis: horizontal
Rotor Diameter: 5.1 ft (1.6 m)
Swept Area: 21 ft² (1.9 m²)
Number of Blades: 12
Blade Design: proprietary
Blade Material: galvanized steel
Hub Height: 12 ft (3.7 m)
Transmission: direct drive
Pump Type: diaphragm 128 days
Pump Size: diaphragm dia. 8 in (203 mm)
Stroke: 0.8 in (19.1 mm)
Pumping System Description:
diaphragm pump injects air into water

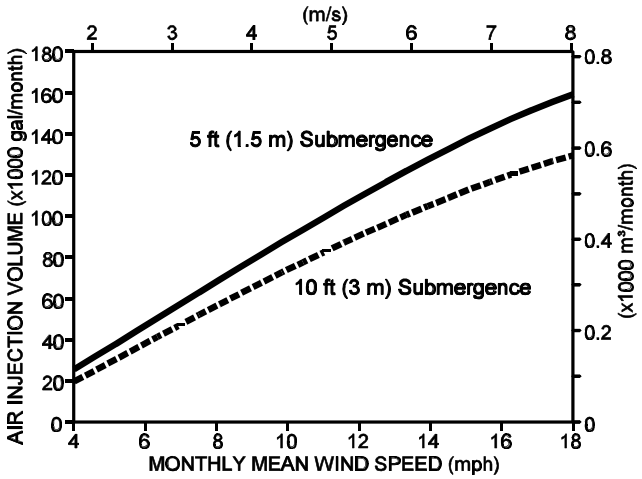

Figure 3. Air Injection Volume versus Monthly Mean Wind Speed Based on 100% Availability, Rayleigh Distribution of Wind Speeds and a 30 Day Month.

KOENDERS AERATION TURBINE

Manufacturer and Distributor:
Koenders Mfg. Co. Ltd.
P.O. Box 171
Englefield, Saskatchewan, Canada
S0K 1N0
(306) 287-3139

Test years: 1996

Performance:

Testing Period:	105 days
Period Operational:	105 days
Percent Availability:	100%

Installed: May 24, 1996

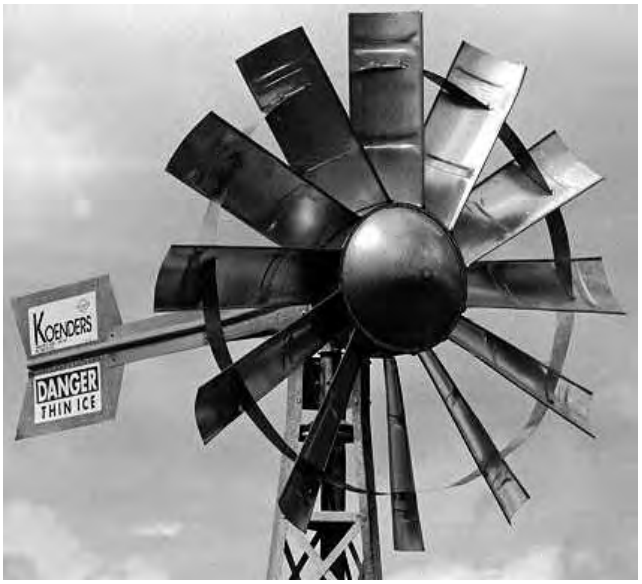

Figure 1. Koenders Aeration Turbine.

Physical Description:
Turbine Type: upwind
Axis: horizontal
Rotor Diameter: 5 ft (1.6 m)
Swept Area: 21 ft² (1.9 m²)
Number of Blades: 12
Blade Design: proprietary
Blade Material: galvanized steel
Hub Height: 12 ft (3.7 m)
Transmission: direct drive
Pump Type: air operated proprietary system
Pumping System Description:
diaphragm injects air into pump

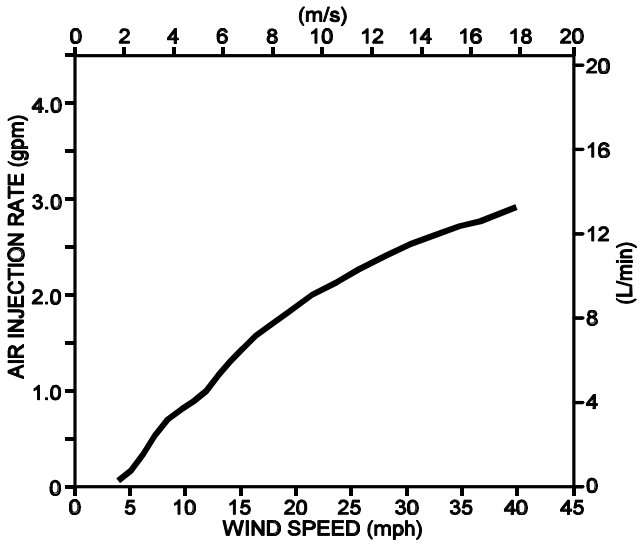

Figure 2. Air Injection Rate versus Wind Speed for an 18 ft (5.5 m) Lift.

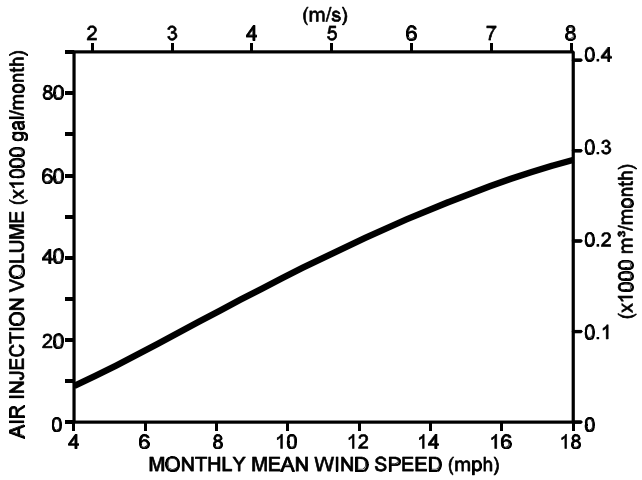

Figure 3. Air Injection Volume versus Monthly Mean Wind Speed Based on 100% Availability, Rayleigh Distribution of Wind Speeds and a 30 Day Month.

KOENDERS TURBINE

Manufacturer and Distributor:

Koenders Mfg. Co. Ltd.
P.O. Box 171
Englefield, Saskatchewan, Canada
S0K 1N0
(306) 287-3139

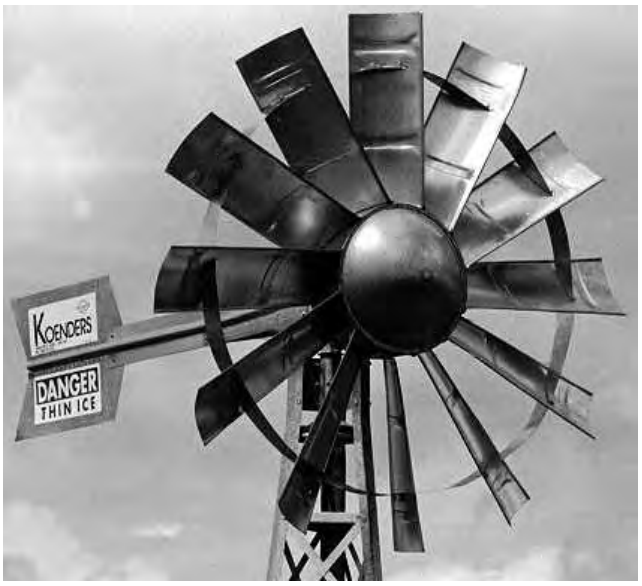

Figure 1. Koenders Wind Turbine.

Physical Description:

Turbine Type: upwind
Axis: horizontal
Rotor Diameter: 5.1 ft (1.6 m)
Swept Area: 21 ft² (1.9 m²)
Number of Blades: 12
Blade Design: proprietary
Blade Material: galvanized steel
Hub Height: 12 ft (3.7 m)
Transmission: direct drive
Pump Type: air operated proprietary system
Pumping System Description:
diaphragm injects air into pump

Test years: 1992 - 1993

Performance:

Testing Period:	242 days
Period Operational:	233 days
Percent Availability:	96 %

Installed: June 24, 1992

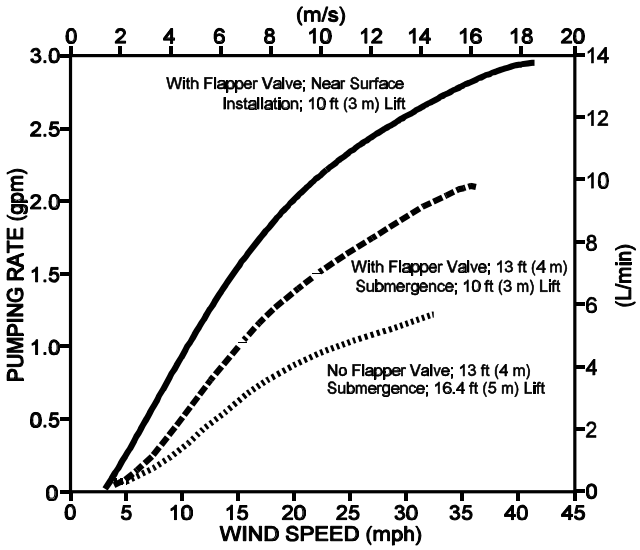

Figure 2. Pumping Rate versus Wind Speed for Various Configurations

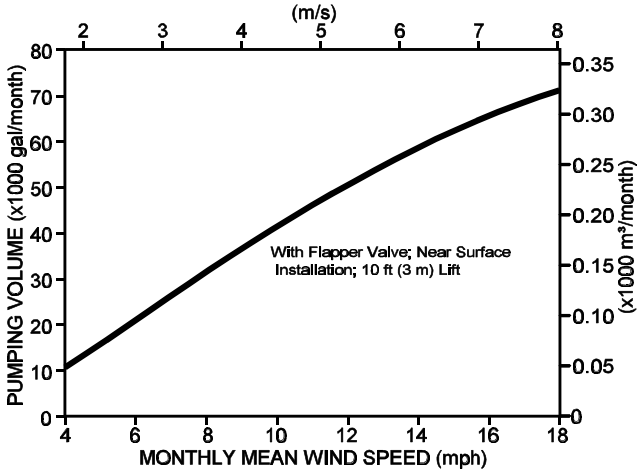

Figure 3. Pumping Volume versus Monthly Mean Wind Speed Based on 100% Availability, Rayleigh Distribution of Wind Speeds and a 30 Day Month.

KOENDERS TURBINE

Manufacturer and Distributor:
Koenders Mfg. Co. Ltd.
P.O. Box 171
Englefield, Saskatchewan, Canada
S0K 1N0
(306) 287-3139

Test years: 1992 - 1995

Performance:

Testing Period:	475 days
Period Operational:	460 days
Percent Availability:	97 %

Installed: June 24, 1992

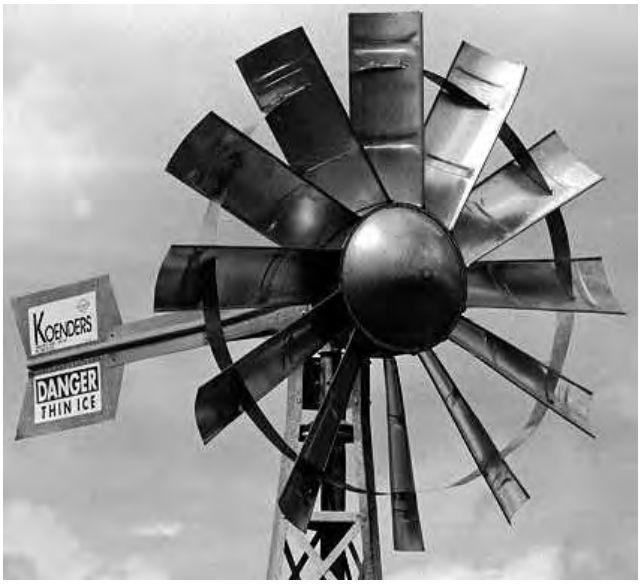

Figure 1. Koenders Turbine.

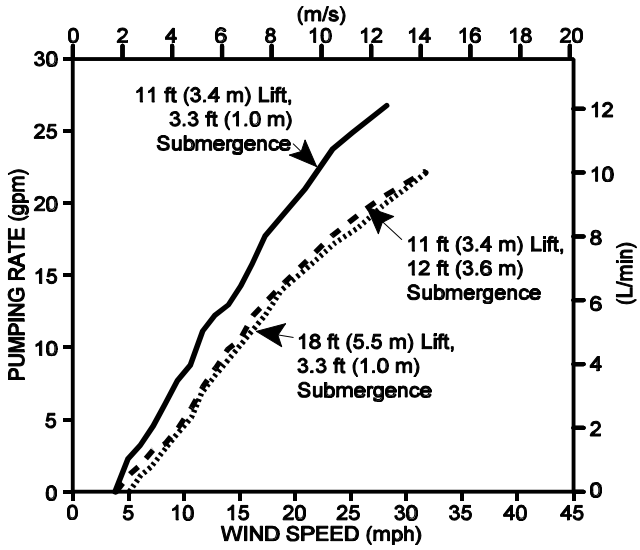

Figure 2. Pumping Rate versus Wind Speed for Various Configurations.

Physical Description:
Turbine Type: upwind
Axis: horizontal
Rotor Diameter: 5.1 ft. (1.6 m)
Swept Area: 21 ft² (1.9 m²)
Number of Blades: 12
Blade Design: proprietary
Blade Material: galvanized steel
Hub Height: 12 ft (3.7 m)
Transmission: direct drive
Pump Type: air operated proprietary system
Pumping System Description:
diaphram injects air into pump

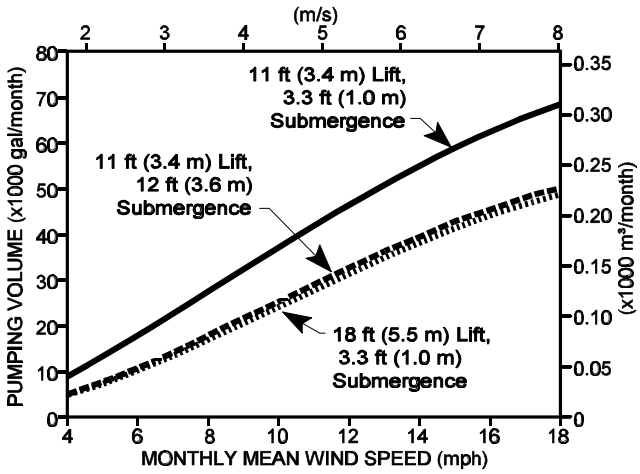

Figure 3. Pumping Volume versus Monthly Mean Wind Speed Based on 100% Availability, Rayleigh Distribution of Wind Speeds and a 30 Day Month.

MAVERICK WINDMOTOR

Manufacturer and Distributor:

Maverick Wind Energy Ltd.
P.O. Box 2707
Pincher Creek, Alberta, Canada
T0K 1W0
(403) 627-3630
(403) 627-3091

Test years: 1992 - 1995

Performance:

Testing Period:	376 days
Period Operational:	374 days
Percent Availability:	99 %

Installed: July 9, 1992

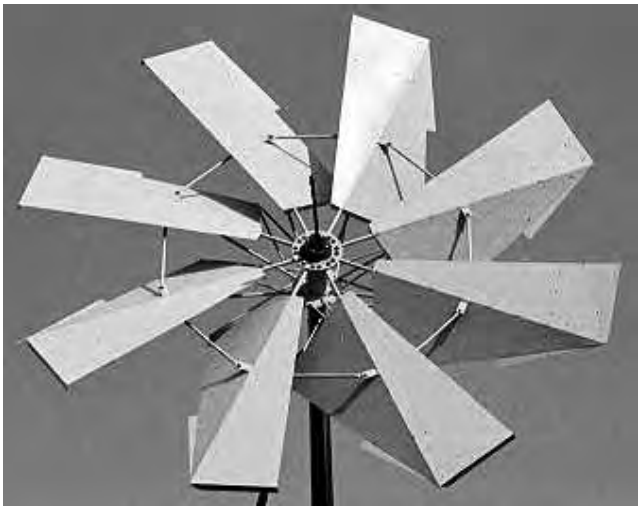

Figure 1. Maverick Windmotor Turbine.

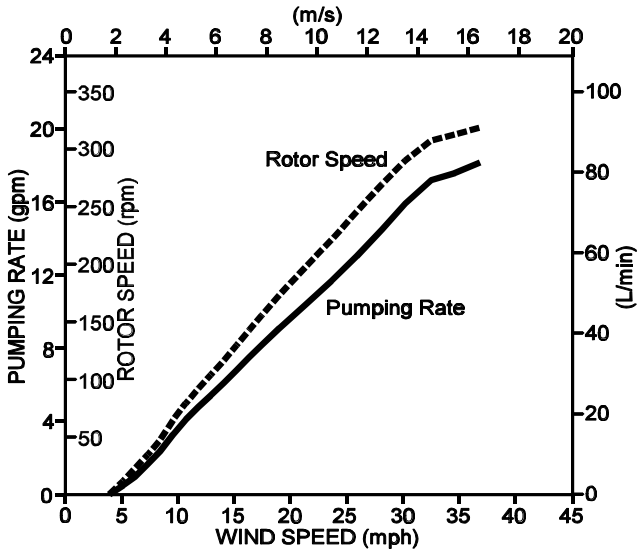

Figure 2. Pumping Rate and Rotor Speed versus Wind Speed for an 18 ft (5.5 m) Lift.

Physical Description:

Turbine Type: downwind
Axis: horizontal
Rotor Diameter: 8 ft (2.4 m)
Swept Area: 50.4 ft² (4.7 m²)
Number of Blades: 8
Blade Design: high speed delta
Blade Material: sheet metal
Hub Height: 25 ft (7.6 m)
Transmission: direct drive
Gear Ratio: 1:1
Pump Type: helical progressing cavity
Pump Size: 4.5 in (114.3 mm) dia.
Pumping System Description:
direct cable drive from rotor to pump

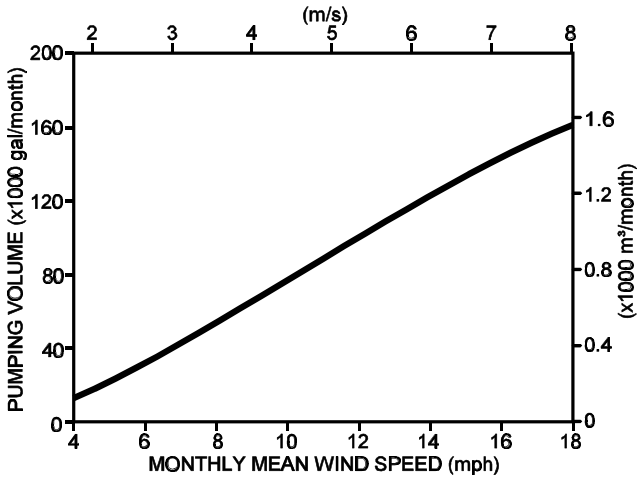

Figure 3. Pumping Volume versus Monthly Mean Wind Speed Based on 100% Availability, Rayleigh Distribution of Wind Speeds and a 30 Day Month.

CAP 348SF5 Solar Pump

Manufacturer and Distributor:

CAP International Inc.
#104, 5037 - 50th St.
Olds, Alberta, Canada
T4H 1R8
Phone: (403) 556-8779
Fax: (403) 556-7799

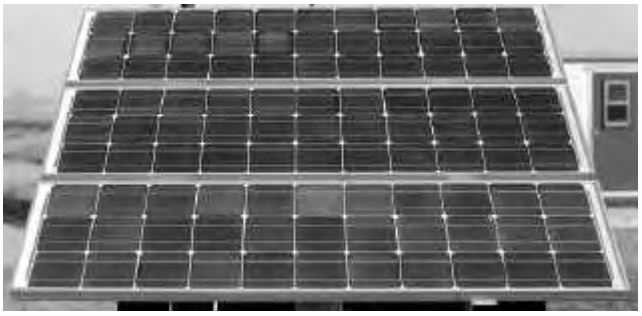

Figure 1. CAP 348SF5 Solar System.

Physical Description:

Number of Modules: 3
Module Manufacturer: Siemens
Power Rating @ 77°F (25°C) and 93 W/ft² - (1000 W/m²): 48 W/panel
Configuration: parallel
Mount: fixed
Pump Type: diaphragm submersible pump (F5)

Test years: 1992 - 1993

Performance:

Testing Period:	178 days
Period Operational:	153 days
Percent Availability:	86 %

Installed: June 26, 1992

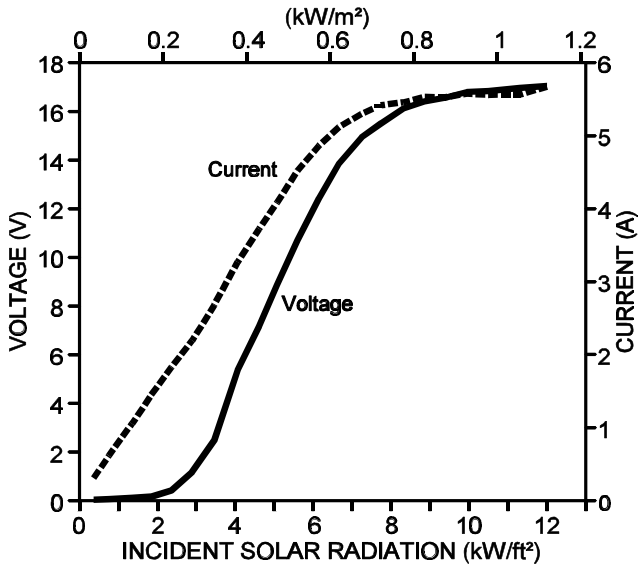

Figure 2. Voltage and Current versus Incident Solar Radiation for an 18 ft (5.5 m) Lift.

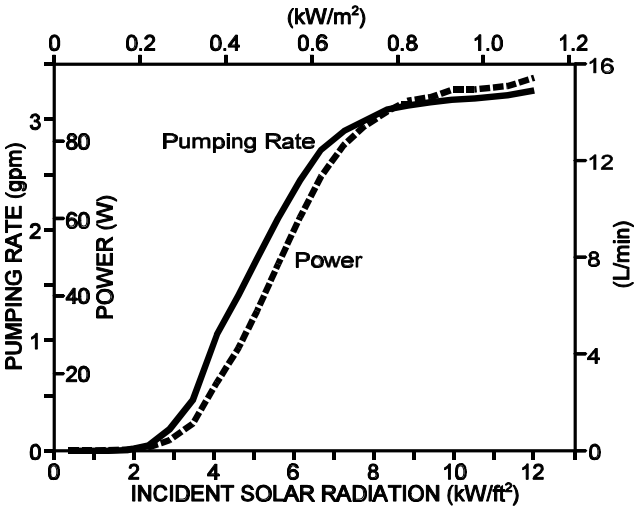

Figure 3. Pumping Rate and Power versus Incident Solar Radiation for an 18 ft (5.5 m) Lift.

CAP 448TRU SOLAR PUMP

Manufacturer and Distributor:

CAP International Inc.
#104, 5037 - 50th St.
Olds, Alberta, Canada
T4H 1R8
Phone: (403) 556-8779
Fax: (403) 556-7799

Test years: 1992 - 1993

Performance:

Testing Period:	188 days
Period Operational:	188 days
Percent Availability:	100 %

Installed: August 31, 1992

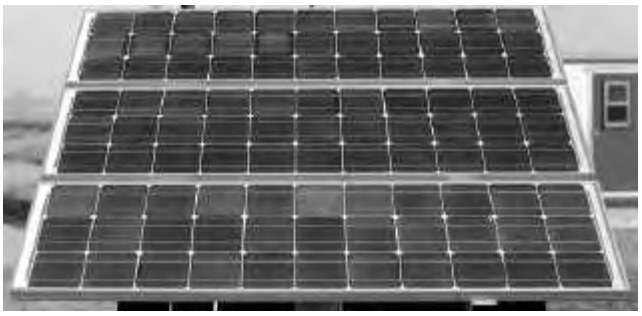

Figure 1. CAP 448TRU Solar System.

Physical Description:

Number of Modules: 4
Module Manufacturer: Siemens
Power Rating @ 77°F (25°C) and 93 W/ft² - (1000 W/m²) : 48 W/panel
Configuration: parallel
Mount: tracker
Pump Type: floating centrifugal (RU)

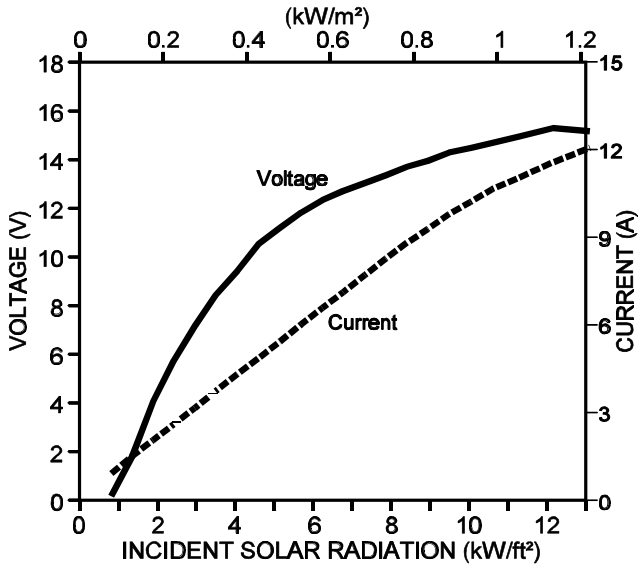

Figure 2. Voltage and Current versus Incident Solar Radiation for an 18 ft (5.5 m) Lift.

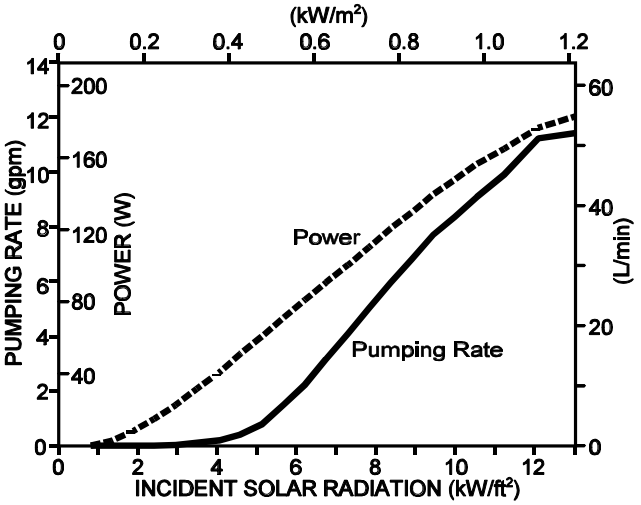

Figure 3. Pumping Rate and Power versus Incident Solar Radiation for an 18 ft (5.5 m) Lift.

CAP 448SF5 SOLAR PUMP

Manufacturer and Distributor:

CAP International Inc.
#104, 5037 - 50th St.
Olds, Alberta, Canada
T4H 1R8
Phone: (403) 556-8779
Fax: (403) 556-7799

Test years: 1994 - 1995

Performance:

Testing Period:	223 days
Period Operational:	203 days
Percent Availability:	91%

Installed: July 13, 1994

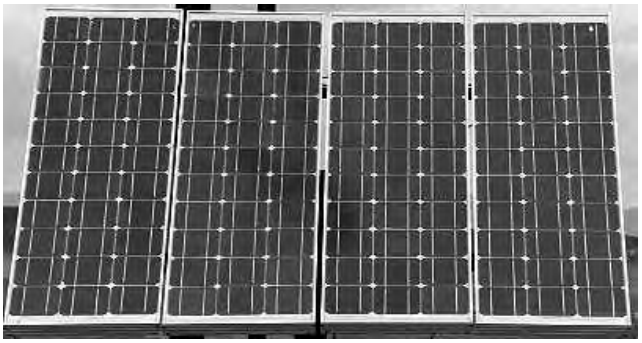

Figure 1. CAP 448SF5 Solar System.

Physical Description:

Number of Modules: 4
Module Manufacturer: Siemens
Maximum Rated Module Power Output: 48 Watts
Wiring Configuration: Parallel
Mount: fixed
Pump Type: D.C. diaphragm submersible pump (F5)

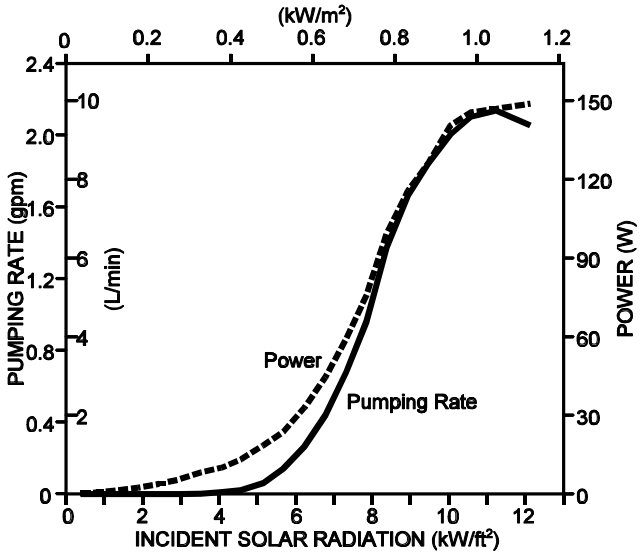

Figure 2. Power and Pumping Rate versus Incident Solar Radiation for a 98 ft (30 m) Lift.

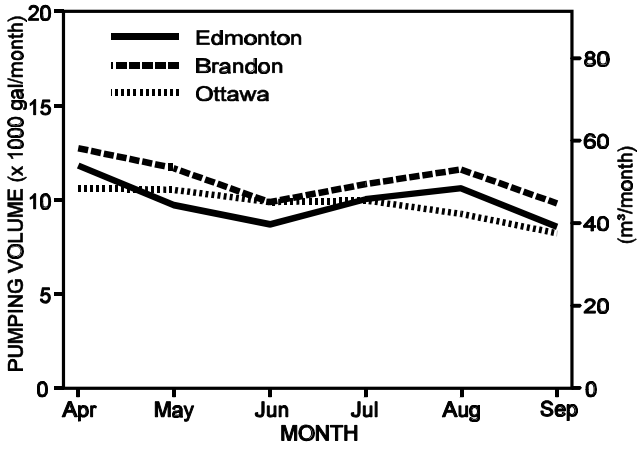

Figure 3. Simulated Pump Yields in Canada when Modules are Tilted at Latitude -5° from Horizontal and Pumping Against a 98 ft (30 m) Lift.

CAP 348SF5 SOLAR PUMP

Manufacturer and Distributor:

CAP International Inc.
#104, 5037 - 50th St.
Olds, Alberta, Canada
T4H 1R8
Phone: (403) 556-8779
Fax: (403) 556-7799

Test years: 1996

Performance:

Testing Period:	100 days
Period Operational:	100 days
Percent Availability:	100%

Installed: May 21, 1996

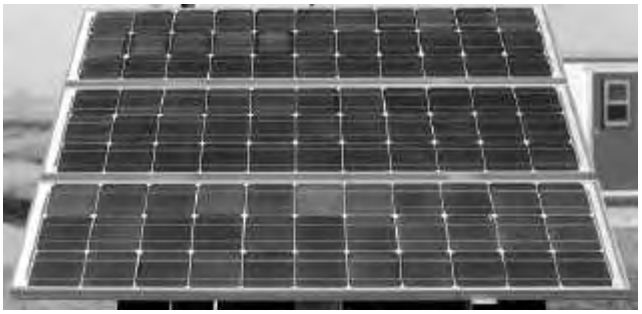

Figure 1. CAP 348SF5 Solar System.

Physical Description:

Number of Modules: 3
Module Manufacturer: Siemens
Wiring Configuration: parallel
Mount: fixed
Maximum Rated Module Power Output: 48 Watts
LCB: No
Pump Type: D.C. diaphragm submersible pump (F5)

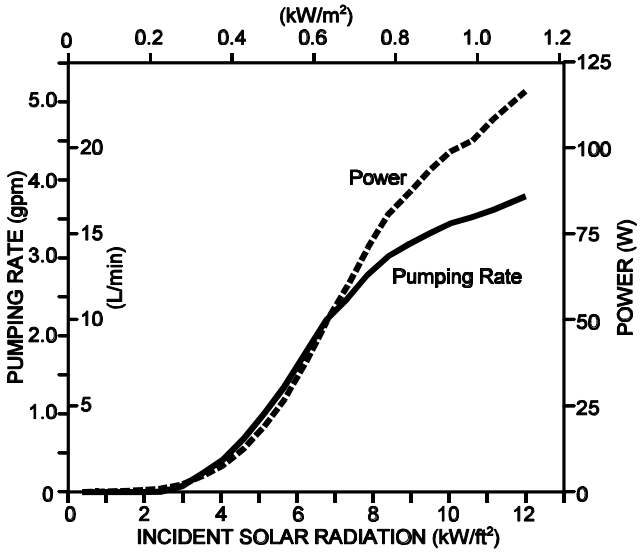

Figure 2. Power and Pumping Rate versus Incident Solar Radiation for a 18 ft (5.5 m) Lift.

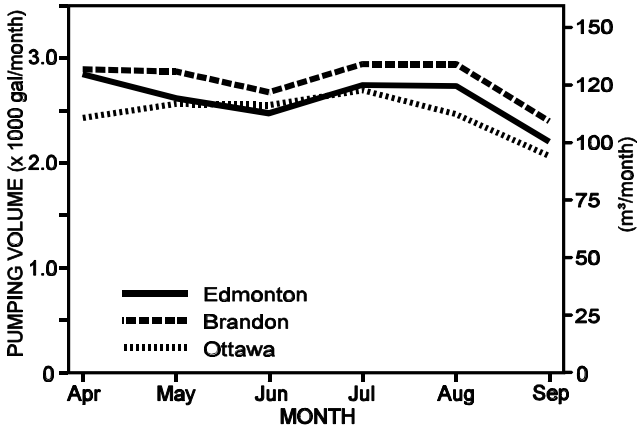

Figure 3. Simulated Pump Yields in Canada when Modules are Tilted at Latitude -5° from Horizontal and Pumping Against a 18 ft (5.5 m) Lift.

CAP 348SRU SOLAR PUMP

Manufacturer and Distributor:

CAP International Inc.
#104, 5037 - 50th St.
Olds, Alberta, Canada
T4H 1R8
Phone: (403) 556-8779
Fax: (403) 556-7799

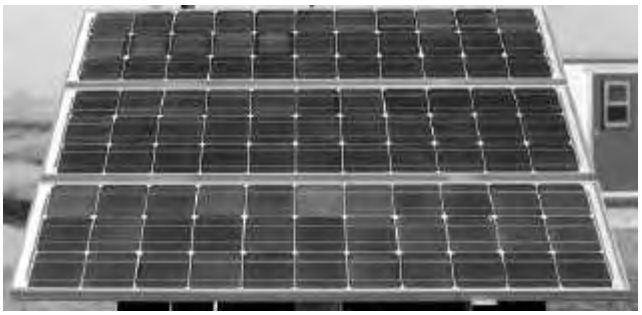

Figure 1. CAP 348SRU Solar System.

Physical Description:

Number of Modules: 3
Module Manufacturer: Siemens
Maximum Rated Module Power Output: 48 Watts
Wiring Configuration: parallel
Mount: fixed
Pump Type: floating D.C. centrifugal pump (RU)

.

Test years: 1994 - 1995

Performance:

Testing Period:	148 days
Period Operational:	148 days
Percent Availability:	100%

Installed: July 15, 1994

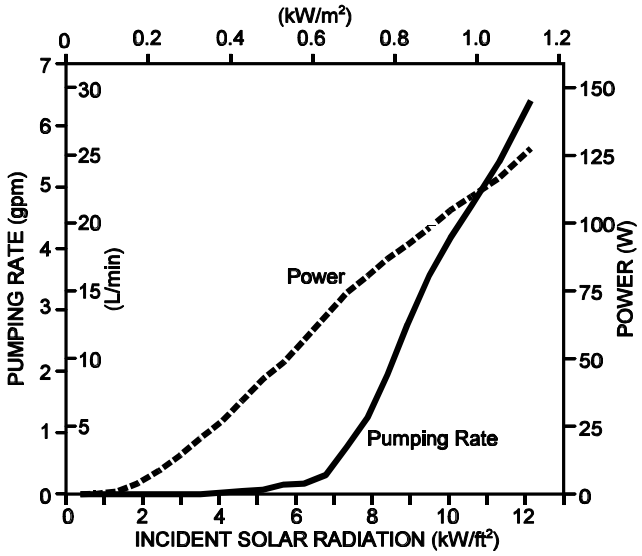

Figure 2. Power and Pumping Rate versus Incident Solar Radiation for a 18 ft (5.5 m) Lift.

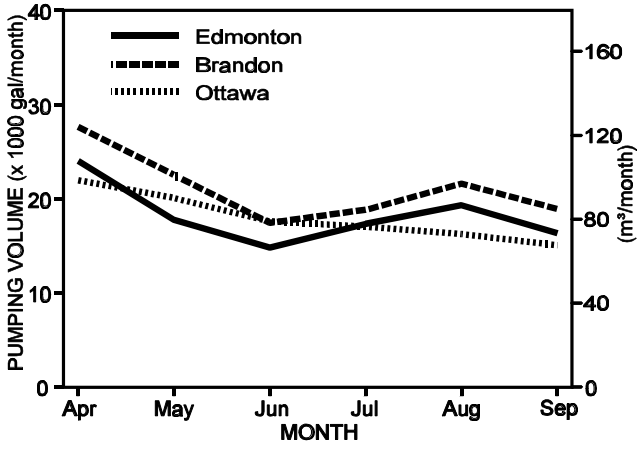

Figure 3. Simulated Pump Yields in Canada when Modules are Tilted at Latitude -5° from Horizontal and Pumping Against a 18 ft (5.5m) Lift.

MODEL 348SRU SOLAR PUMP

Manufacturer and Distributor:

CAP International Inc.
#104, 5037 - 50th St.
Olds, Alberta, Canada
T4H 1R8
Phone: (403) 556-8779
Fax: (403) 556-7799

Test years: 1996

Performance:

Testing Period:	118 days
Period Operational:	118 days
Percent Availability:	100%

Installed: May 17, 1996

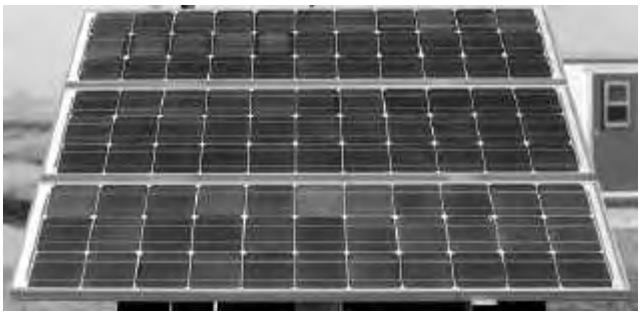

Figure 1. CAP348SRU Solar System.

Physical Description:

Number of Modules: 3
Module Manufacturer: Siemens
Maximum Rated Module Power Output: 48 Watts
Wiring Configuration: parallel
Mount: fixed
LCB: no
Pump Type: floating D.C. centrifugal pump (RU)

.

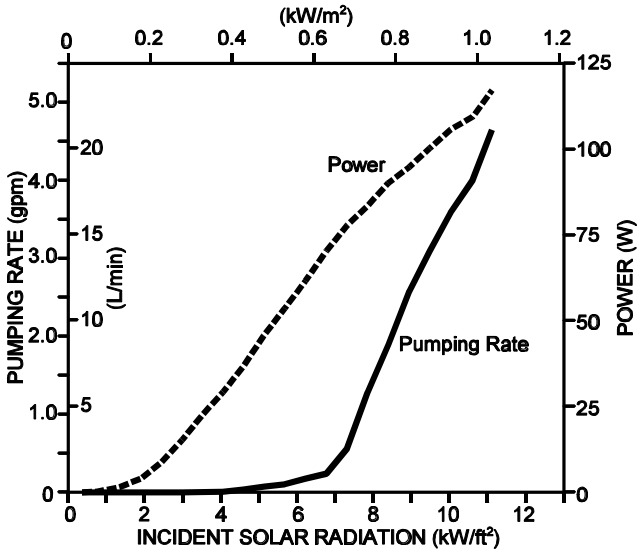

Figure 2. Power and Pumping Rate versus Incident Solar Radiation for a 18 ft (5.5 m) Lift.

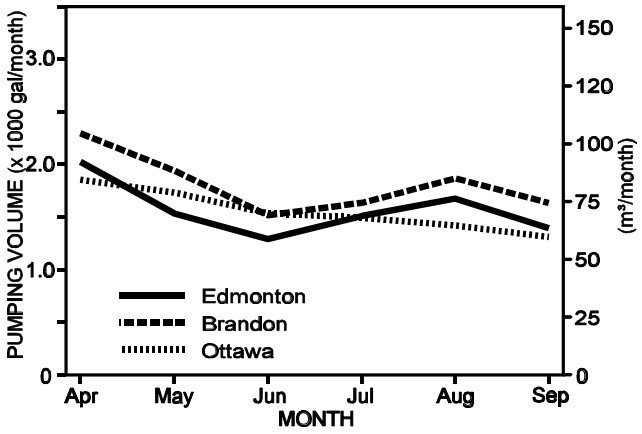

Figure 3. Simulated Pump Yields in Canada when Modules are Tilted at Latitude -5° from Horizontal and Pumping Against a 18 ft (5.5 m) Lift.

CAP 175SM3 SOLAR PUMP

Manufacturer and Distributor:

CAP International Inc.
#104, 5037 - 50th St.
Olds, Alberta, Canada
T4H 1R8
Phone: (403) 556-8779
Fax: (403) 556-7799

Test years: 1995

Performance:

Testing Period:	66 days
Period Operational:	66 days
Percent Availability:	100 %

Installed: July 10, 1995

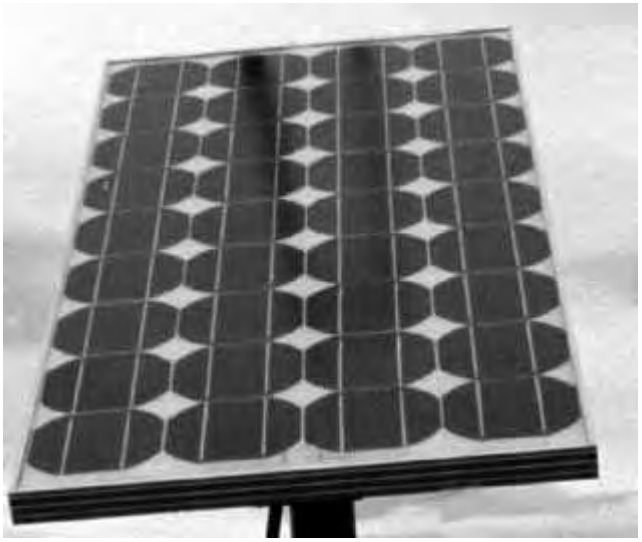

Figure 1. CAP 175SM3 Solar System.

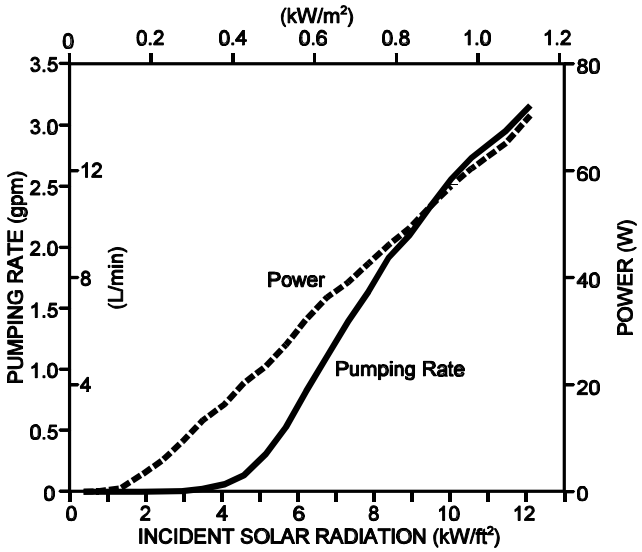

Figure 2. Power and Pumping Rate versus Incident Solar Radiation for a 18 ft (5.5 m) Lift.

Physical Description:

Number of Modules: 1
Module Manufacturer: Siemens
Maximum Rated Module Power Output: 75 Watts
Wiring Configuration: direct
Mount: fixed
Pump Type: floating D.C. centrifugal pump (M3)

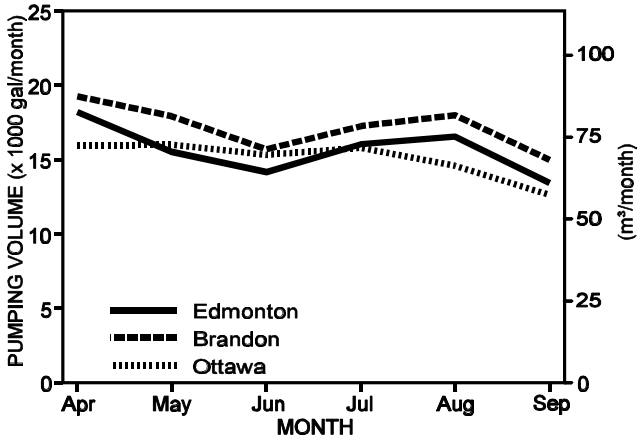

Figure 3. Simulated Pump Yields in Canada when Modules are Tilted at Latitude -5° from Horizontal and Pumping Against a 18 ft (5.5 m) Lift.

CAP 348SM5 SOLAR PUMP

Manufacturer and Distributor:

CAP International Inc.
#104, 5037 - 50th St.
Olds, Alberta, Canada
T4H 1R8
Phone: (403) 556-8779
Fax: (403) 556-7799

Test years: 1995

Performance:

Testing Period:	71 days
Period Operational:	71 days
Percent Availability:	100 %

Installed: July 10, 1995

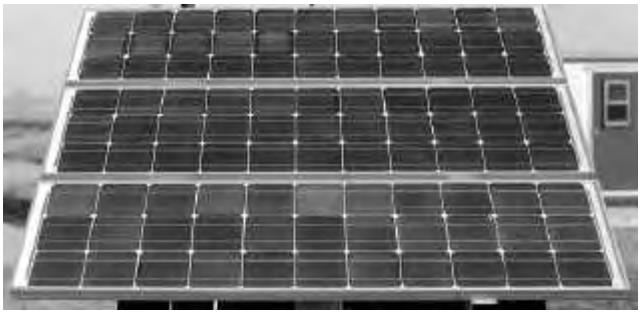

Figure 1. CAP 348SM5 Solar System.

Physical Description:

Number of Modules: 3
Module Manufacturer: Siemens
Maximum Rated Module Power Output: 48 Watts
Wiring Configuration: parallel
Mount: fixed
Pump Type: floating D.C. centrifugal pump (M5)

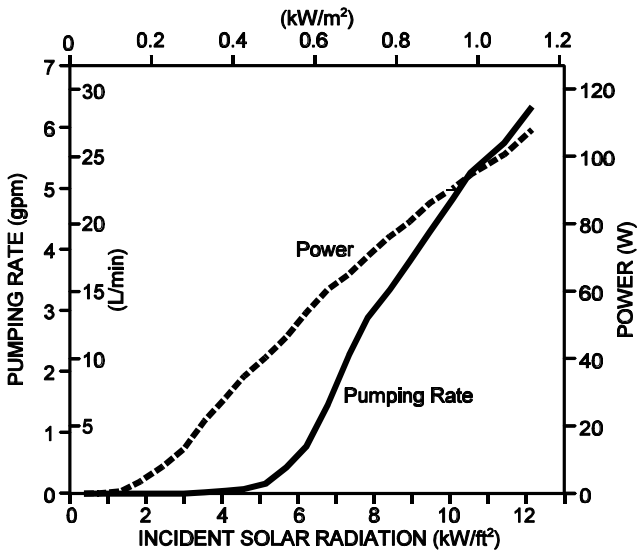

Figure 2. Power and Pumping Rate versus Incident Solar Radiation for a 18 ft (5.5 m) Lift.

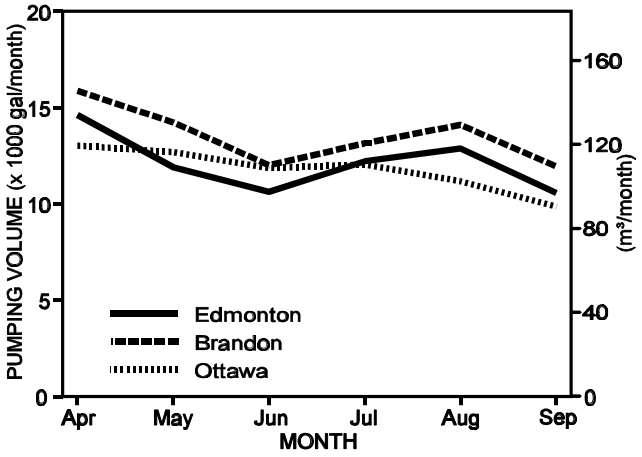

Figure 3. Simulated Pump Yields in Canada when Modules are Tilted at Latitude -5° from Horizontal and Pumping Against a 18 ft (5.5 m) Lift.

CAP 448SM5 SOLAR PUMP

Manufacturer and Distributor:

CAP International Inc.
#104, 5037 - 50th St.
Olds, Alberta, Canada
T4H 1R8
Phone: (403) 556-8779
Fax: (403) 556-7799

Test years: 1996

Performance:

Testing Period:	31 days
Period Operational:	31 days
Percent Availability:	100 %

Installed: August 13, 1996

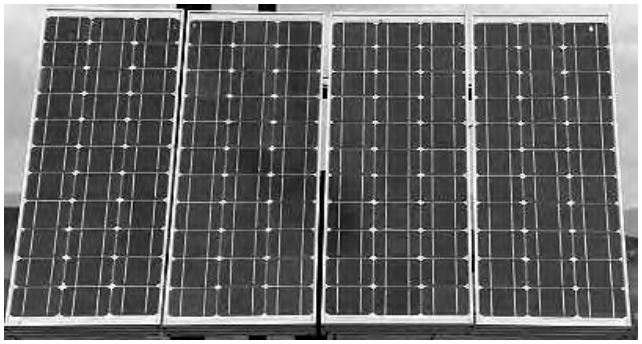

Figure 1. CAP 448SM5 Solar System.

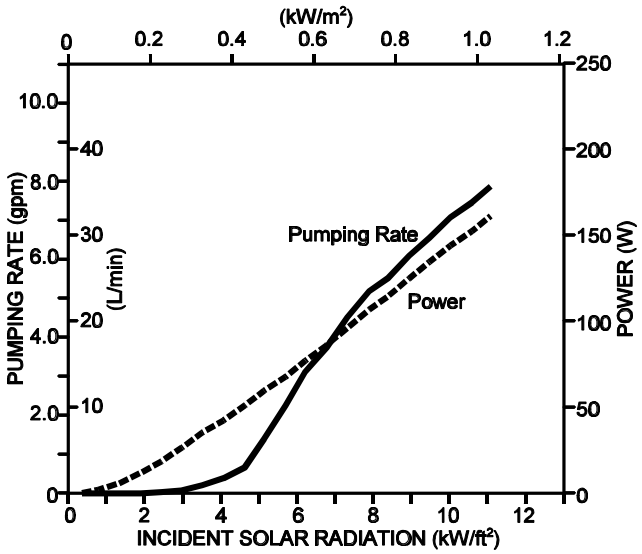

Figure 2. Power and Pumping Rate versus Incident Solar Radiation for a 18 ft (5.5 m) Lift.

Physical Description:

Number of Modules: 4
Module Manufacturer: Siemens
Wiring Configuration: parallel
Mount: fixed
Maximum Rated Module Power Output: 48 Watts
LCB: no
Pump Type: floating D.C. centrifugal pump (M5)

.

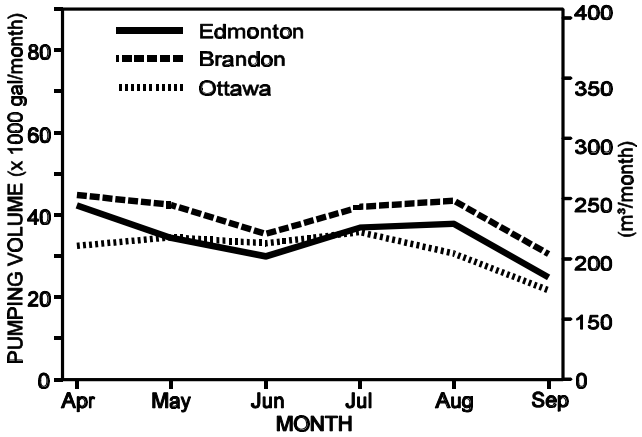

Figure 3. Simulated Pump Yields in Canada when Modules are Tilted at Latitude -5° from Horizontal and Pumping Against a 18 ft (5.5 m) Lift.

GRUNDFOS SUNSUB 400

Distributor:

CAP International Inc.
#104, 5037 - 50th St.
Olds, Alberta, Canada
T4H 1R8
Phone: (403) 556-8779
Fax: (403) 556-7799

Test years: 1995

Performance:

Testing Period:	28 days
Period Operational:	28 days
Percent Availability:	100 %

Installed: August 22, 1995

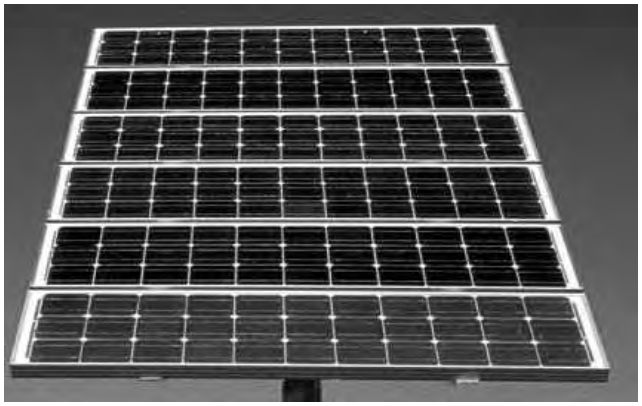

Figure 1. Grundfos SunSub 400 SiemensModules.

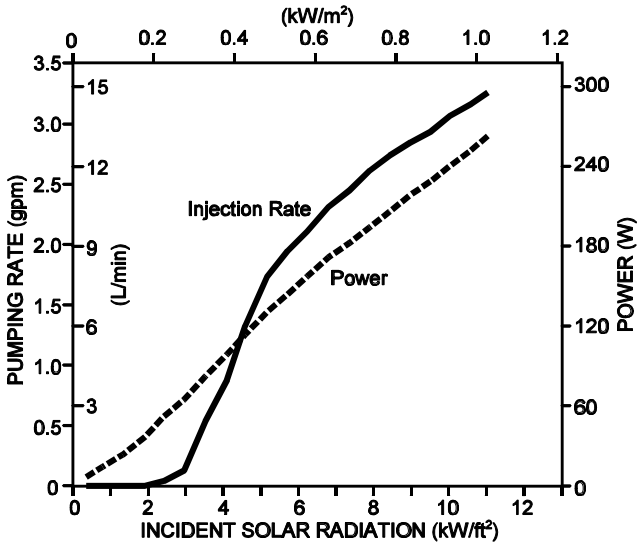

Figure 2. Power and Pumping Rate versus Incident Solar Radiation for an 59 ft (18 m) Lift.

Physical Description:

Number of Modules: 6
Module Manufacturer: Siemens
Maximum Rated Module Power Output: 48 Watts
Configuration: series
Mount: fixed
Pump Type: three phase A.C. multi-stage centrifugal submersible pump

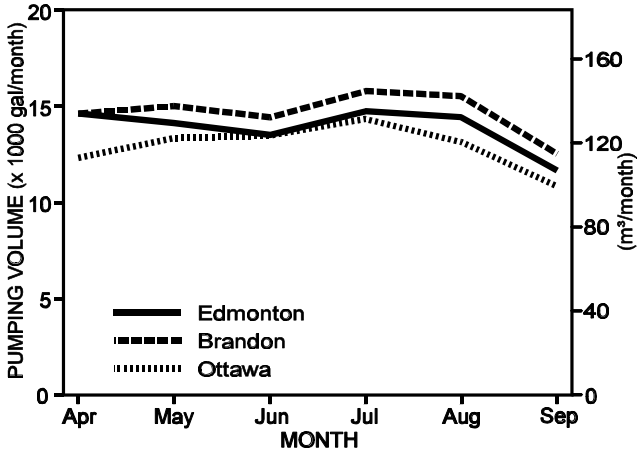

Figure 3. Simulated Pump Yields in Canada when Modules are Tilted at Latitude -5° from Horizontal and Pumping Against an 59 ft (18 m) Lift.

KELLN SINGLE MODULE AERATION SYSTEM

Manufacturer and Distributor:

Kelln Consulting Ltd.
P.O. Box 94
Lumsden, Saskatchewan, Canada
S0G 3C0
Phone: (306) 731-2224
Fax: (306) 731-2277

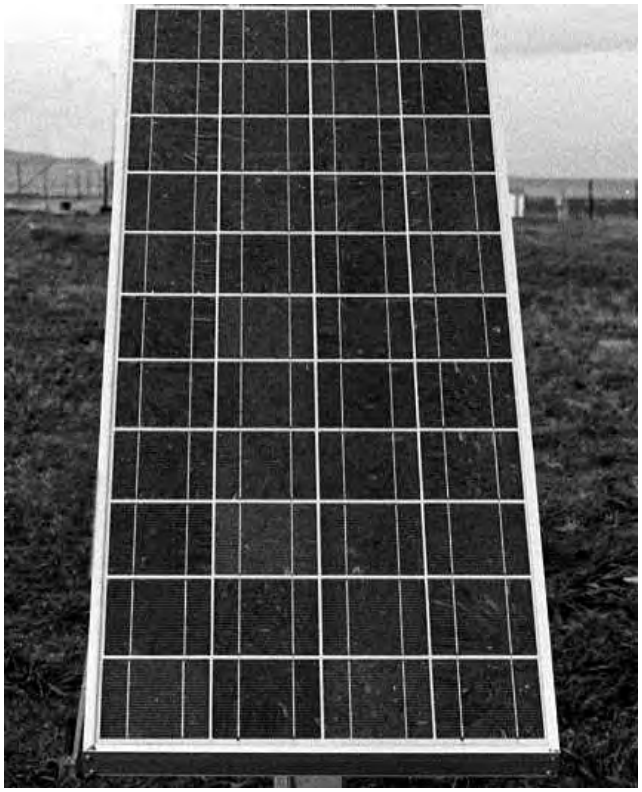

Figure 1. Kelln Single Module Aeration System.

Physical Description:

Number of Modules: 1
Module Manufacturer: Kyocera Corporation
Maximum Rated Module Power Output: 62.7 Watts
Wiring Configuration: wired direct to LCB,
LCB wired to pump
Mount: fixed
LCB: yes, 3M-T Sun Selector
Pump Type: 12V, piston air compressor

.

Test years: 1993

Performance:

Testing Period:	104 days
Period Operational:	104 days
Percent Availability:	100 %

Installed: June 18, 1993

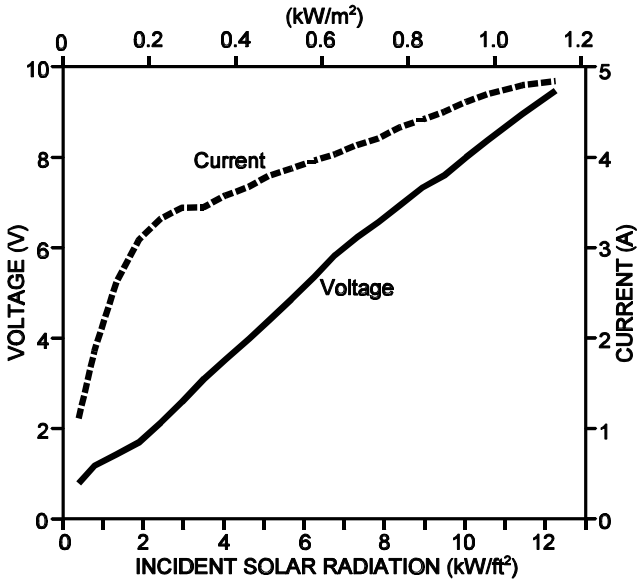

Figure 2. Voltage and Current versus Incident Solar Radiation for a 5 ft (1.5 m) Submergence.

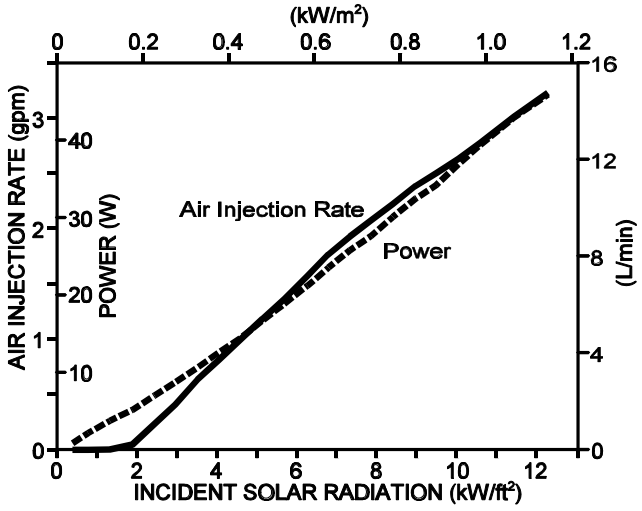

Figure 3. Air Injection Rate and Power versus Incident Solar Radiation for a 5 ft (1.5 m) Submergence

Test years: 1993

Performance:

Testing Period:	104 days
Period Operational:	104 days
Percent Availability:	100 %

Installed: June 18, 1993

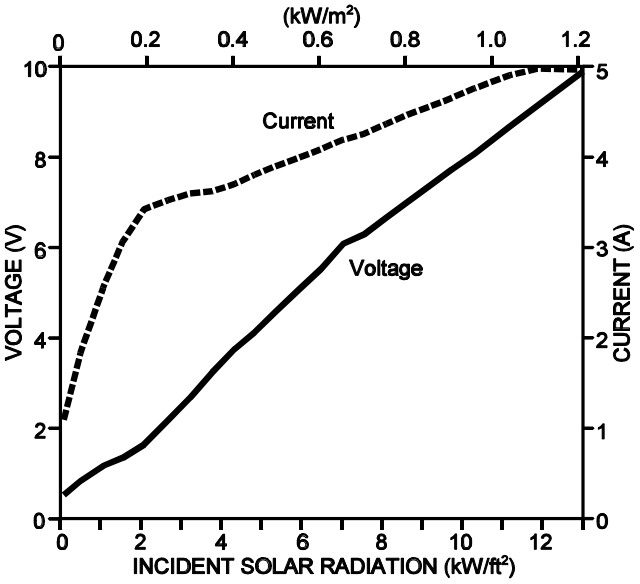

Figure 4. Voltage and Current versus Incident Radiation for a 10 ft (3 m) Submergence.

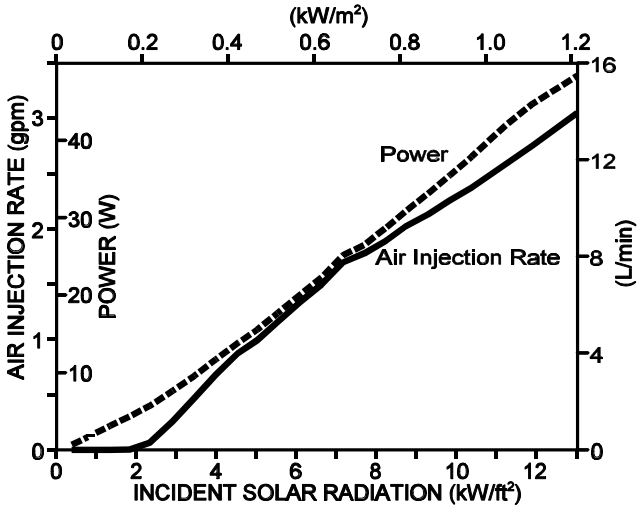

Figure 5. Air Injection Rate and Power versus Incident Solar Radiation for a 5 ft (1.5 m) Submergence

Test years: 1994-1995

Performance:

Testing Period:	165 days
Period Operational:	165 days
Percent Availability:	100 %

Installed: June 18, 1993

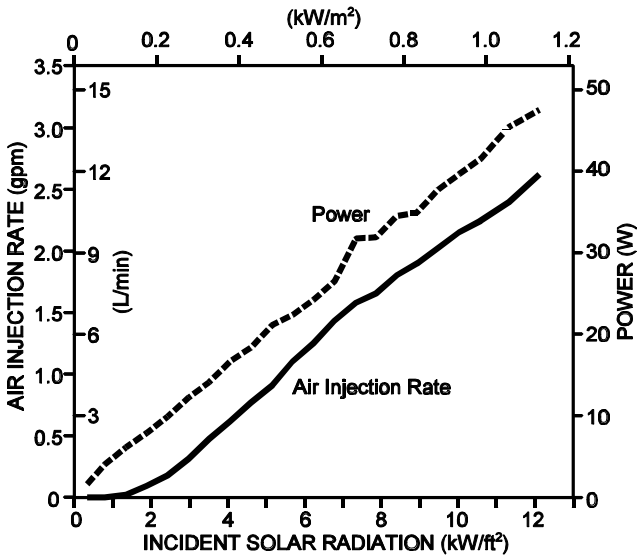

Figure 6. Power and Air Injection Rate versus Incident Solar Radiation for a 13 ft (4 m) Submergence.

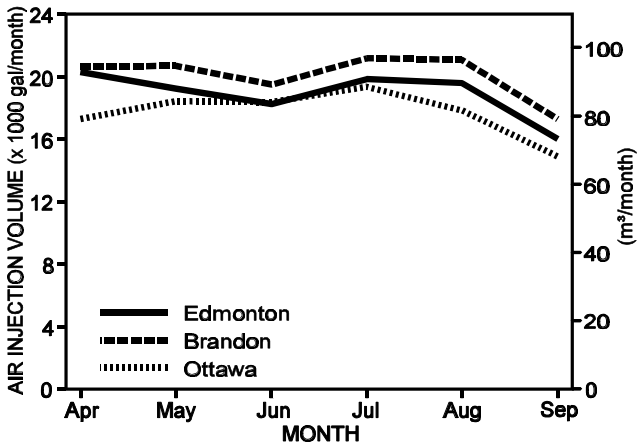

Figure 7. Simulated Air Injection Volumes in Canada when Modules are Tilted at Latitude -5° from Horizontal and Injecting Air at a Depth of 13 ft (4 m).

KELLN 6 MODULE WATER SYSTEM (Parallel)

Manufacturer and Distributor:

Kelln Consulting Ltd.
P.O. Box 94
Lumsden, Saskatchewan, Canada
S0G 3C0
Phone: (306) 731-2224
Fax: (306) 731-2277

Test years: 1993 - 1995

Performance:

Testing Period:	203 days
Period Operational:	203 days
Percent Availability:	100 %

Installed: May 6, 1993

Figure 1. Kelln 6-Panel Water System (Parallel).

Physical Description:

Number of Modules: 6
Module Manufacturer: United Solar Systems Corp.
Maximum Rated Module Power Output: 22 Watts
Wiring Configuration: parallel
Mount: fixed, South Facing
LCB: yes, LCB-20 Sun Selector
Pump Type: rotary vane

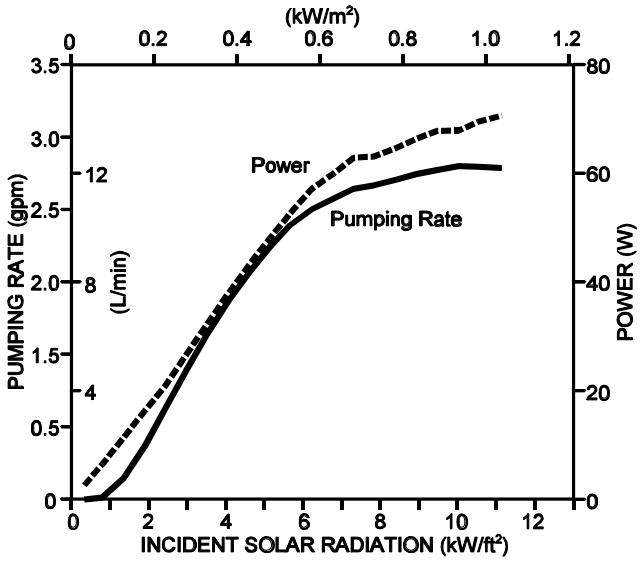

Figure 2. Voltage and Current versus Incident Solar Radiation for an 18 ft (5.5 m) Lift.

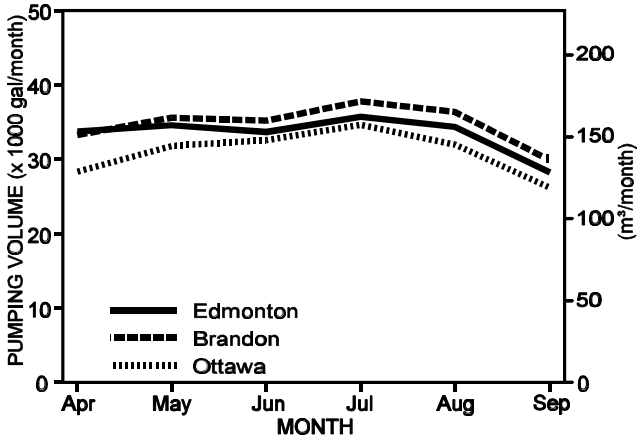

Figure 3. Simulated Pump Yields in Canada when Pumping Rate and Power versus Incident Solar Radiation for an 18 ft (5.5 m) Lift.

KELLN 6 MODULE WATER SYSTEM (Parallel/Series)

Manufacturer and Distributor:

Kelln Consulting Ltd.
P.O. Box 94
Lumsden, Saskatchewan, Canada
S0G 3C0
Phone: (306) 731-2224
Fax: (306) 731-2277

Test years: 1994 - 1995

Performance:

Testing Period:	153 days
Period Operational:	153 days
Percent Availability:	100 %

Installed: September 16, 1994

Figure 1. Kelln 6 Module Water System (Parallel/Series).

Physical Description:

Number of Modules: 6
Module Manufacturer: United Solar Systems Corp.
Maximum Rated Module Power Output: 22 Watts
Wiring Configuration: 3 Series x 2 Parallel
Mount: fixed, South Facing
LCB: yes, LCB-20 Sun Selector
Pump Type: rotary vane

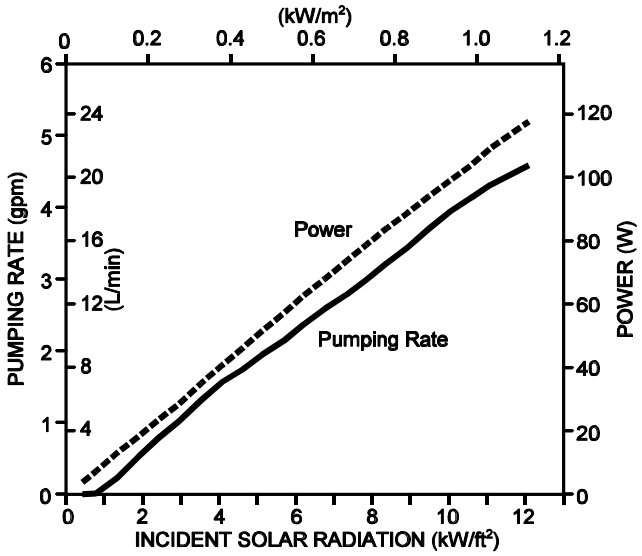

Figure 2. Power and Pumping Rate versus Incident Solar Radiation for a 18 ft (5.5 m) Lift.

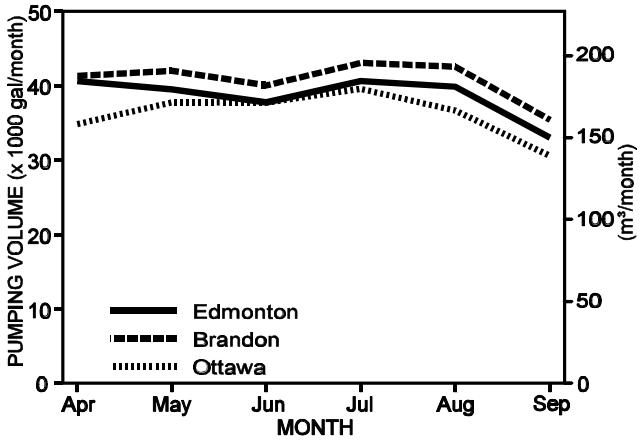

Figure 3. Simulated Pump Yields in Canada when Modules are Tilted at Latitude -5° from Horizontal and Pumping Against a 18 ft (5.5 m) Lift.

KELLN 6 MODULE WATER SYSTEM (PARALLEL/SERIES)

Manufacturer and Distributor:

Kelln Consulting Ltd.
P.O. Box 94
Lumsden, Saskatchewan, Canada
S0G 3C0
Phone: (306) 731-2224
Fax: (306) 731-2277

Test years: 1996

Performance:

Testing Period:	120 days
Period Operational:	120 days
Percent Availability:	100%

Installed: May 16, 1996

Figure 1. Kelln 6 Module Water System (Parallel/Series).

Physical Description:

Number of Modules: 6
Module Manufacturer: United Solar Systems Corp.
Maximum Rated Module Power Output: 22 Watts
Wiring Configuration: 2 Series X 3 Parallel
Mount: fixed
LCB: LCB-20 Sun Selector
Pump Type: rotary vane

.

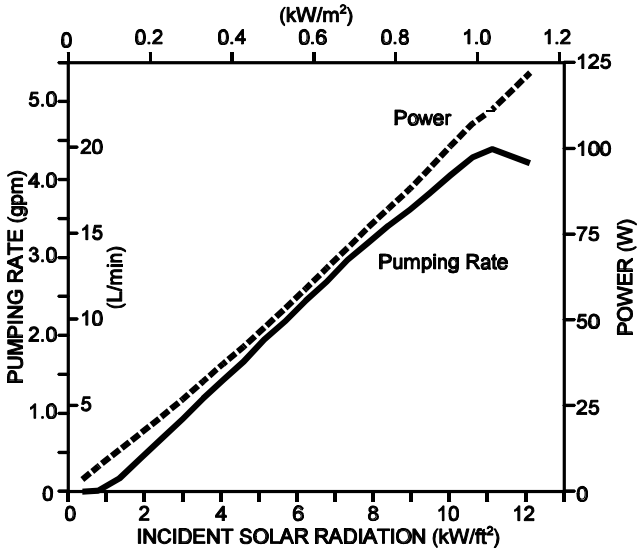

Figure 2. Power and Pumping Rate versus Incident Solar Radiation for a 18 ft (5.5 m) Lift.

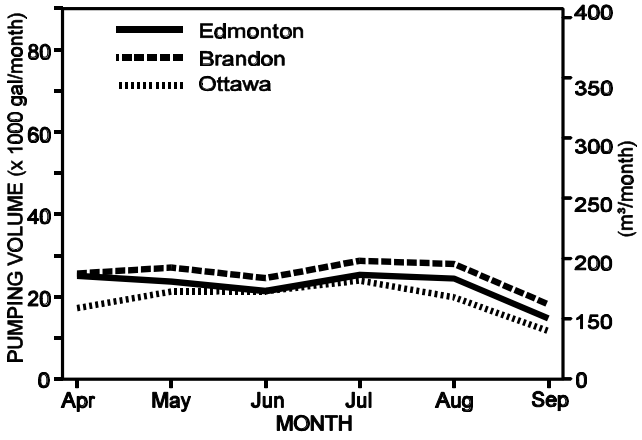

Figure 3. Simulated Pump Yields in Canada when Modules are Tilted at Latitude -5° from Horizontal and Pumping Against a 18 ft (5.5 m) Lift.

KELLN 6 MODULE WATER SYSTEM

Manufacturer and Distributor:

Kelln Consulting Ltd.
P.O. Box 94
Lumsden, Saskatchewan, Canada
S0G 3C0
Phone: (306) 731-2224
Fax: (306) 731-2277

Test years: 1993

Performance:

Testing Period:	140 days
Period Operational:	140 days
Percent Availability:	100 %

Installed: May 6, 1993

Figure 1. Kelln 6-Module Water System.

Physical Description:

Number of Modules: 6
Module Manufacturer: United Solar Systems Corp.
Maximum Rated Module Power Output: 22 Watts
Wiring Configuration: parallel
Mount: fixed, bi-directional (S.E. and S.W.)
LCB: yes, LCB-20 Sun Selector
Pump Type: rotary vane

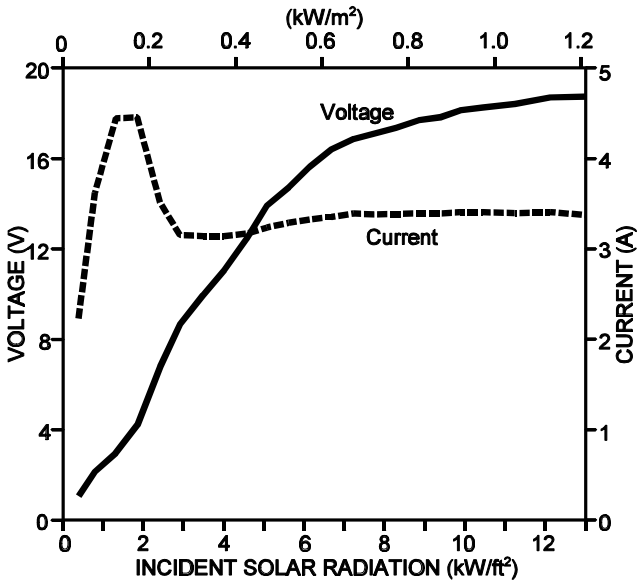

Figure 2. Voltage and Current versus Incident Solar Radiation for an 18 ft (5.5 m) Lift.

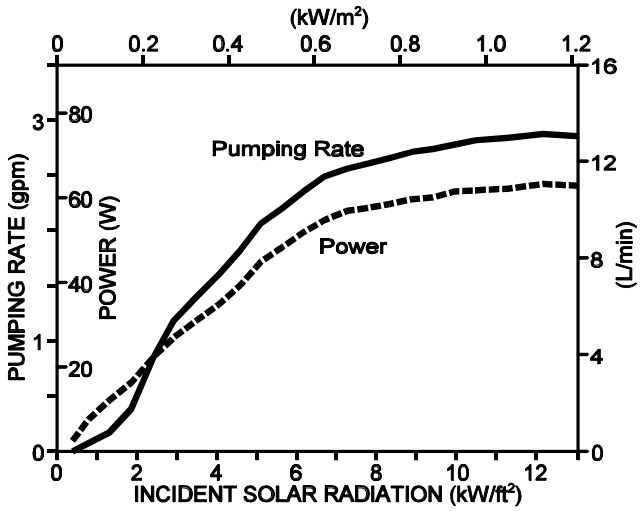

Figure 3. Pumping Rate and Power versus Incident Solar Radiation for an 18 ft (5.5 m) Lift.

KELLN PUMP JACK SOLAR SYSTEM

Manufacturer and Distributor:

Kelln Consulting Ltd.
P.O. Box 94
Lumsden, Saskatchewan, Canada
S0G 3C0
Phone: (306) 731-2224
Fax: (306) 731-2277

Figure 1. Kelln Pump Jack Solar System.

Physical Description:

Number of Modules: 6
Module Manufacturer: Kyocera Corporation
Maximum Rated Module Power Output: 45 Watts
Wiring Configuration: parallel
Mount: tracking
LCB: PCB10-90A Solar Jack
Pump Type: reciprocating, positive displacement

Test years: 1996

Performance:

Testing Period:	11 days
Period Operational:	11 days
Percent Availability:	100%

Installed: September 20, 1996

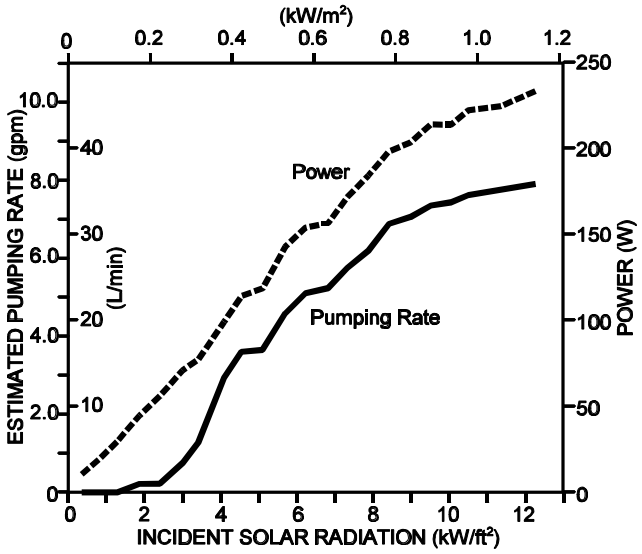

Figure 2. Power and Pumping Rate versus Incident Solar Radiation for a 115 ft (35 m) Lift.

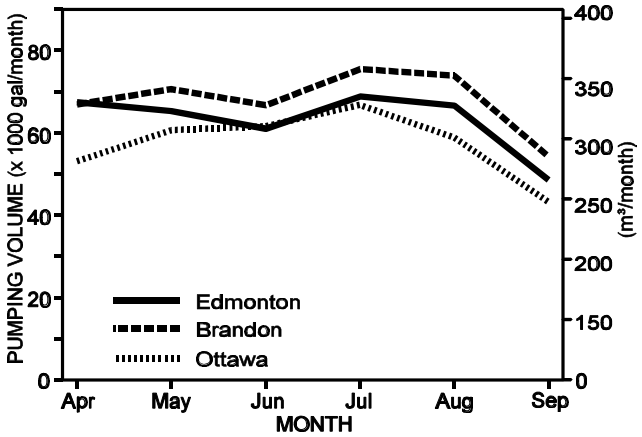

Figure 3. Simulated Pump Yields in Canada when Modules are Tilted at Latitude -5° from Horizontal and Pumping Against a 115 ft (35 m) Lift.

KELLN SOLAR AERATION SYSTEM

Manufacturer and Distributor:

Kelln Consulting Ltd.
P.O. Box 94
Lumsden, Saskatchewan, Canada
S0G 3C0
Phone: (306) 731-2224
Fax: (306) 731-2277

Test years: 1996

Performance:

Testing Period:	22 days
Period Operational:	22days
Percent Availability:	100%

Installed: August 22, 1996

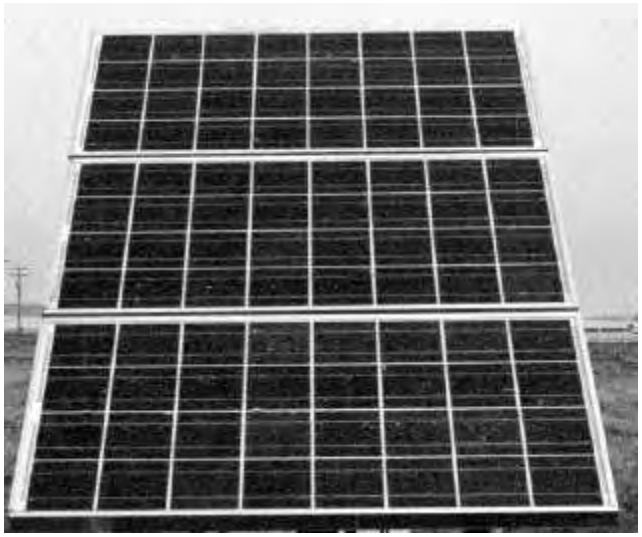

Figure 1. Kelln Three Module Aeration System.

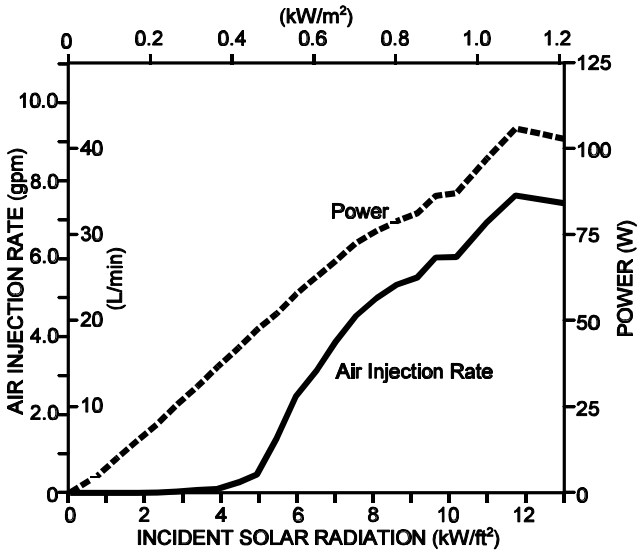

Figure 2. Power and Air Injection Rate versus Incident Solar Radiation for a 10 ft (3 m) Submergence.

Physical Description:

Number of Modules: 3
Module Manufacturer: Kyocera Corporation
Maximum Rated Module Power Output: 45 Watts
Wiring Configuration: parallel
Mount: fixed
LCB: 7M-14.5 Sun Selector
Pump Type: 12V, piston air compressor

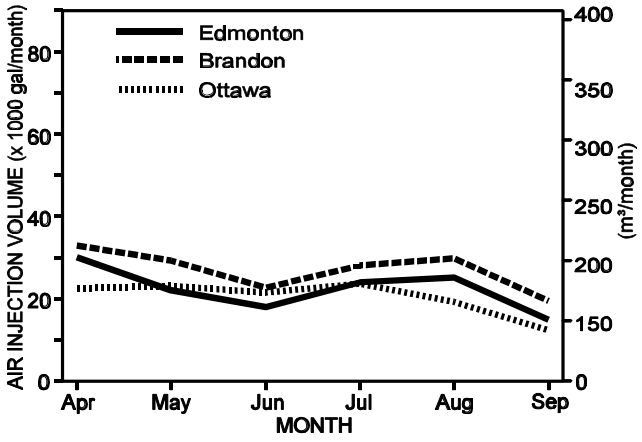

Figure 3. Simulated Air Injection Volumes in Canada when Modules are Tilted at Latitude -5° from Horizontal and Pumping Against a 10 ft (3.0 m) Lift.

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