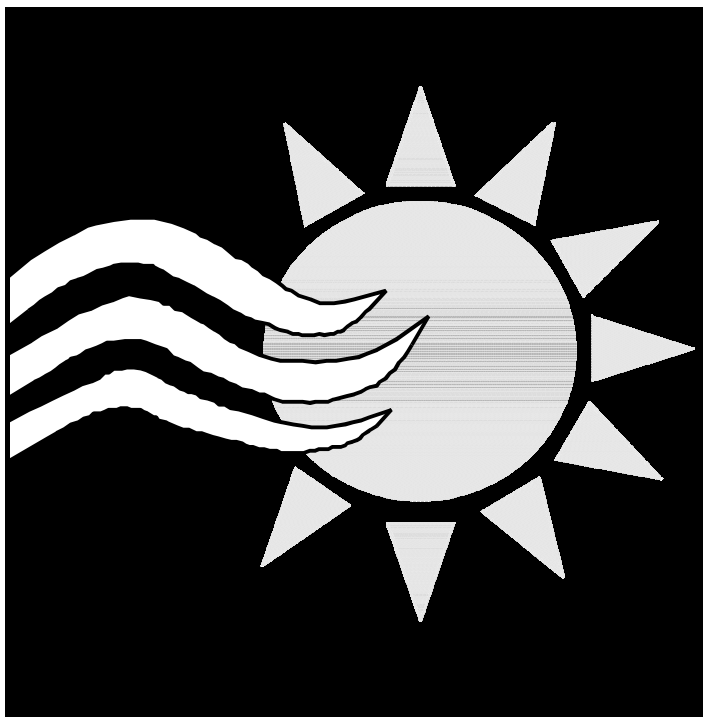


Summary Report 737



Alberta Renewable Energy Test Site

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

A Co-operative Program Between



PRAIRIE AGRICULTURAL MACHINERY INSTITUTE

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

Table of Contents

Performance results, appearing in alphabetical order, are given for the following solar and wind water pumping systems.

Wind Systems

Tensigrity Systems Ltd.

- 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

Canadian Agtechnology Partners International Inc.

- CAP 348SF5 Solar Pump
- 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

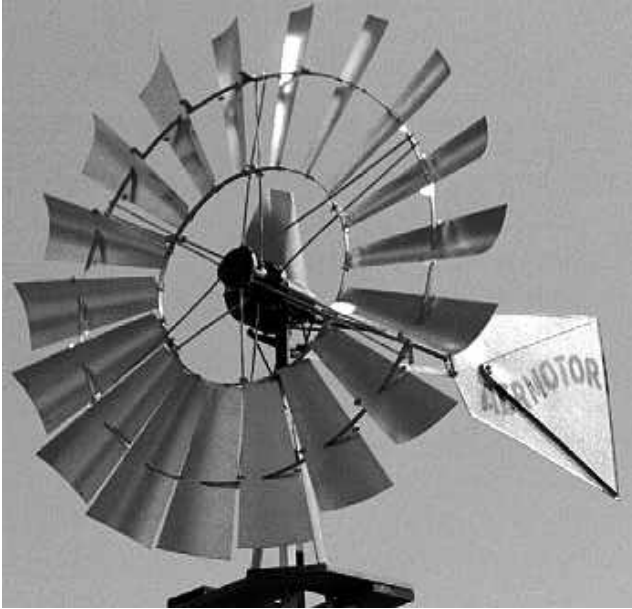


Figure 1. Aermotor Turbine.

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.

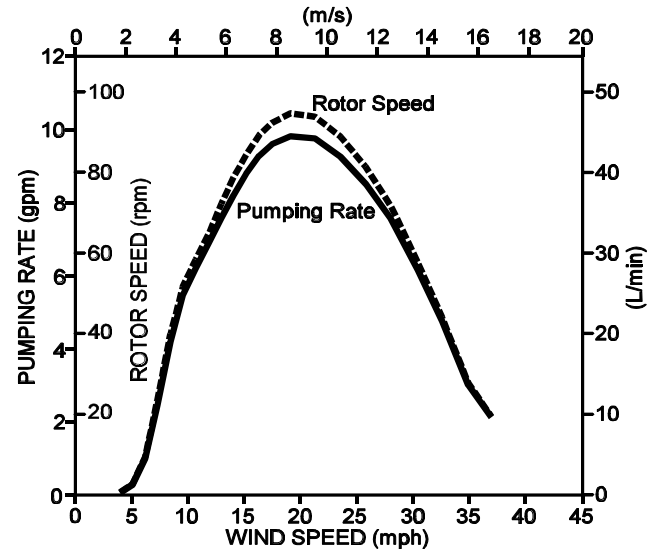


Figure 2. Pumping Rate and Rotor Speed versus Wind Speed for an 18 ft (5.5 m) Lift.

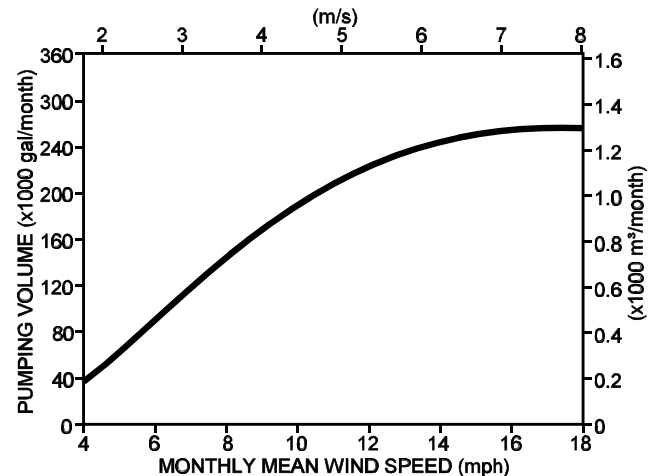


Figure 3. Pumping Volume versus Monthly Mean Wind Speed Based on 100% Availability, Rayleigh Distribution of Wind Speeds and a 30 Day Month.

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

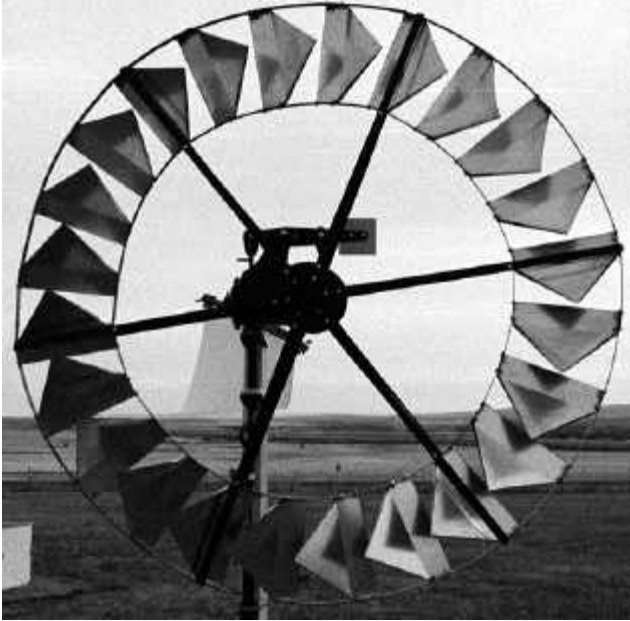


Figure 1. Dutch Junior Turbine.

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

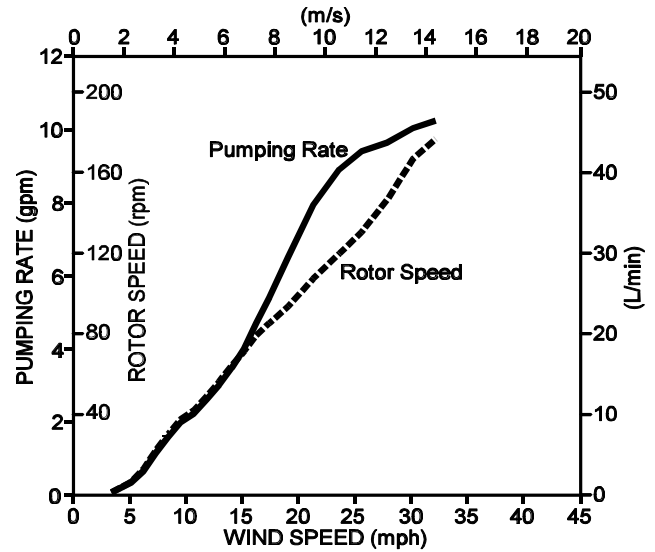


Figure 2. Pumping Rate and Rotor Speed versus Wind Speed for a 18 ft (5.5 m) Lift.

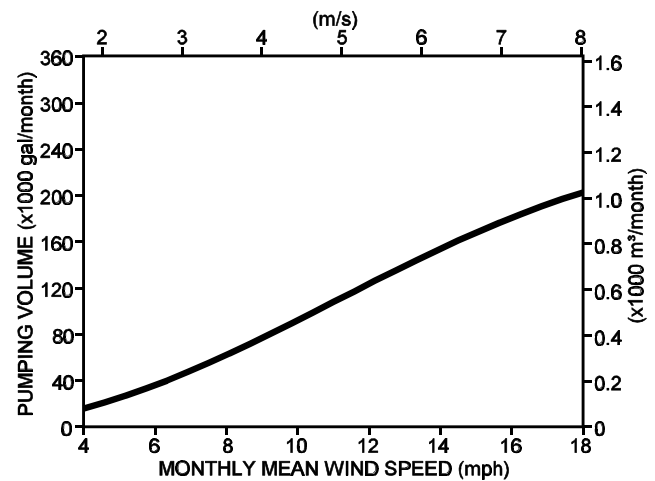


Figure 3. Pumping Volume versus Monthly Mean Wind Speed Based on 100% Availability, Rayleigh Distribution of Wind Speeds and a 30 Day Month.

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

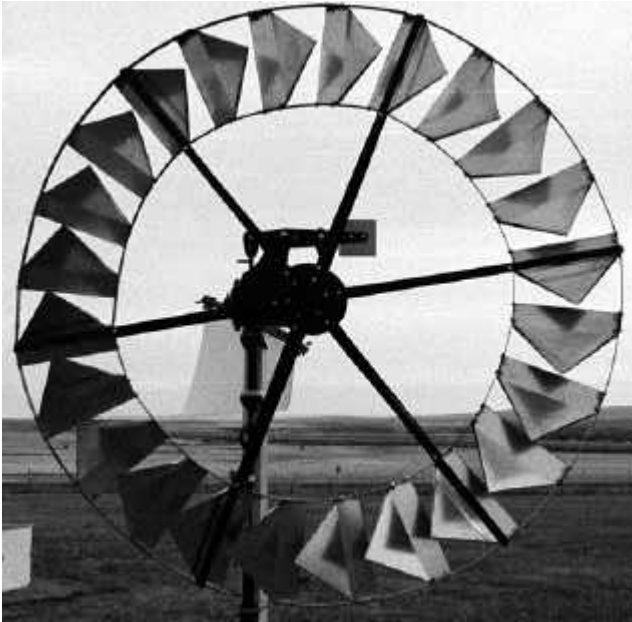


Figure 1. Dutch Junior Turbine.

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

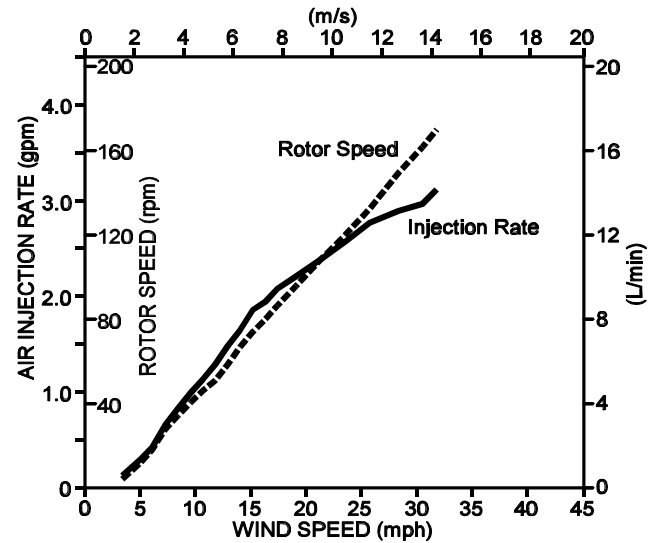


Figure 2. Air Injection Rate and Rotor Speed versus Wind Speed for a 12.5 ft (3.8 m) Submergence.

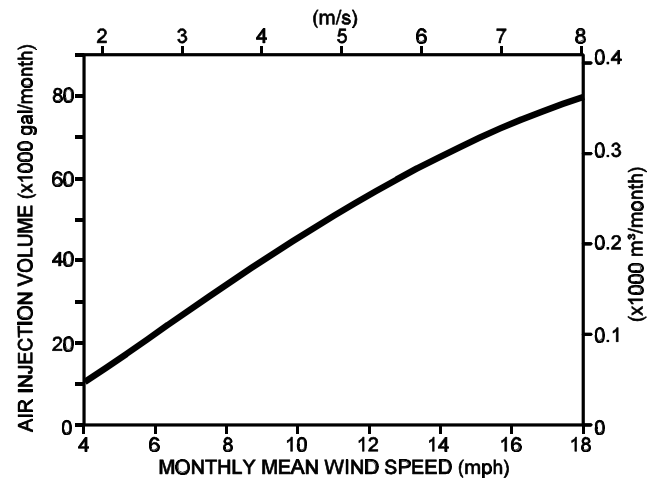


Figure 3. Air Injection Volume versus Monthly Mean Wind Speed Based on 100% Availability, Rayleigh Distribution of Wind Speeds and a 30 Day Month.

DELTA 16A

Manufacturer and Distributor:

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

Test years: 1992 - 1995

Performance:

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

Installed: October 1, 1992



Figure 1. Delta 16A Turbine.

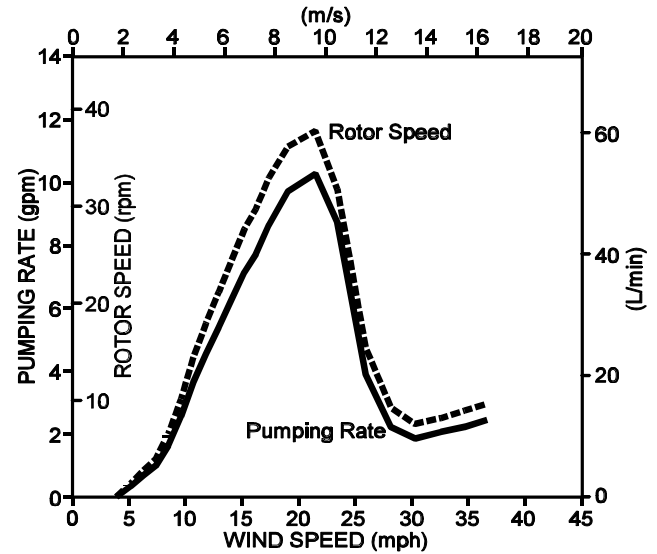


Figure 2. Pumping Rate and Rotor Speed versus Wind Speed for a 98 ft (30 m) Lift.

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

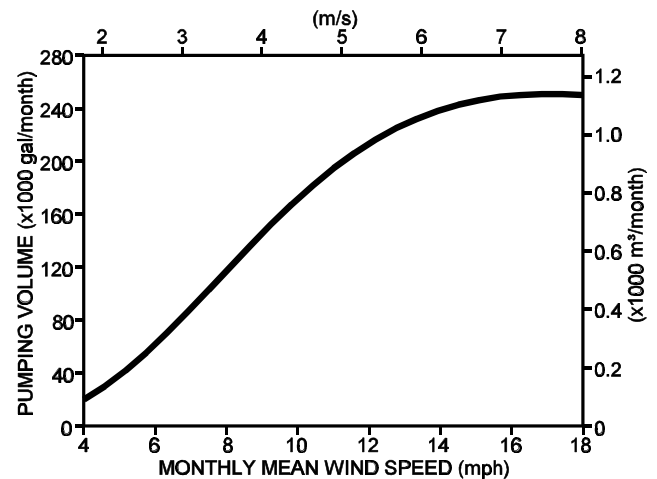


Figure 3. Pumping Volume versus Monthly Mean Wind Speed Based on 100% Availability, Rayleigh Distribution of Wind Speeds and a 30 Day Month.

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.

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

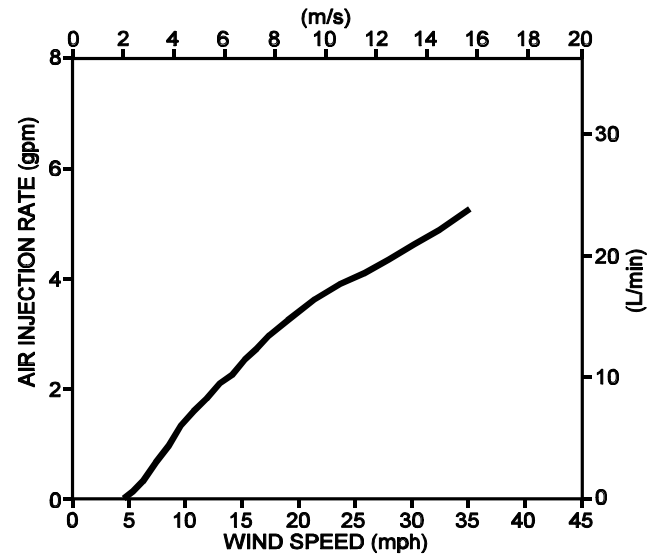


Figure 2. Air Injection Rate versus Wind Speed for 12.5 ft (3.8 m) Submergence.

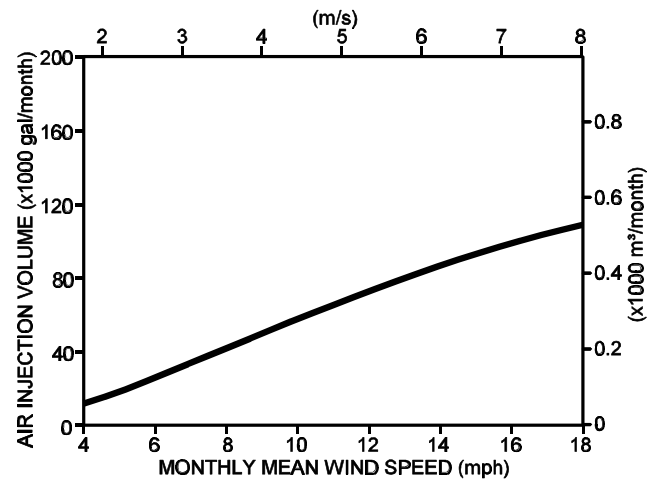


Figure 3. Air Injection Volume versus Monthly Mean Wind Speed Based on 100% Availability, Rayleigh Distribution of Wind Speeds and a 30 Day Month.

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

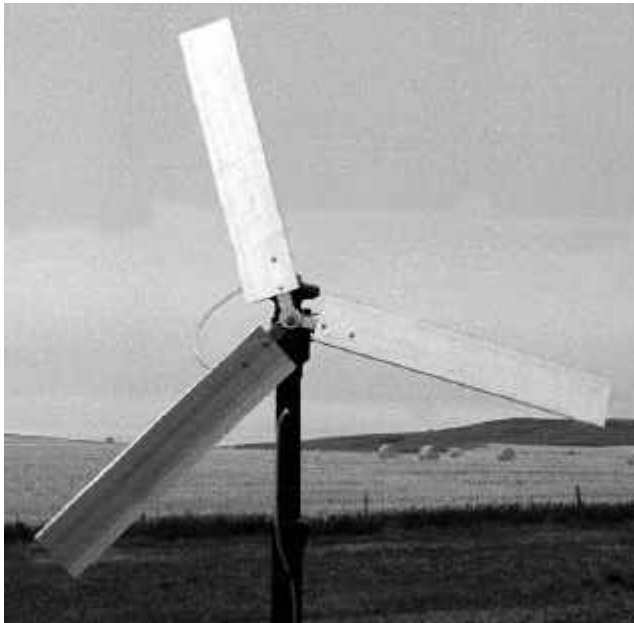


Figure 1. Breeze-1 Aeration Turbine.

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

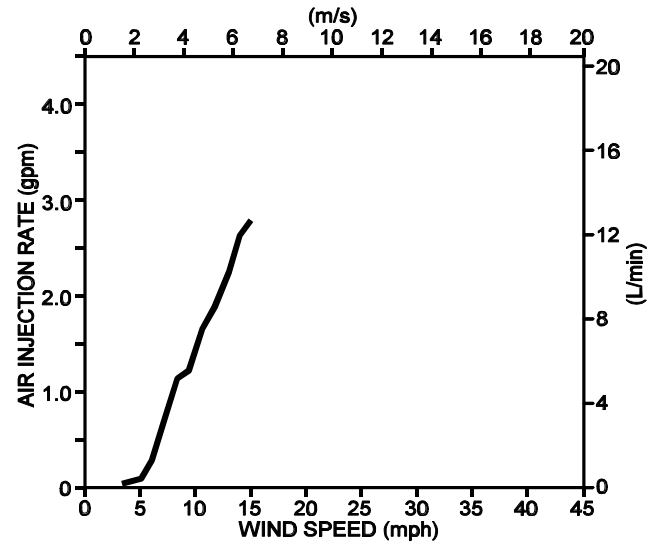


Figure 2. Air Injection Rate versus Wind Speed for 8 ft (2.4 m) Submergence.

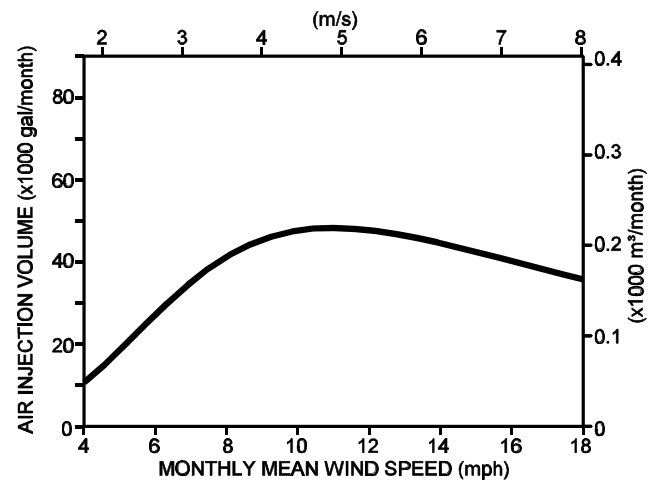


Figure 3. Air Injection Volume versus Monthly Mean Wind Speed Based on 100% Availability, Rayleigh Distribution of Wind Speeds and a 30 Day Month.

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

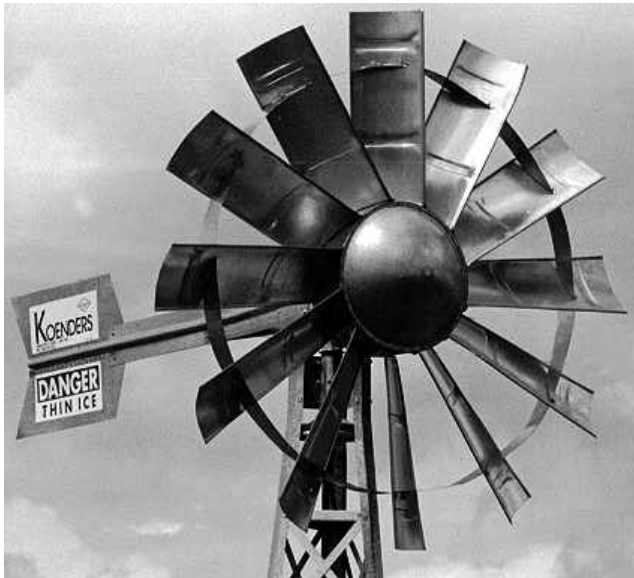


Figure 1. Koenders Aeration Turbine.

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

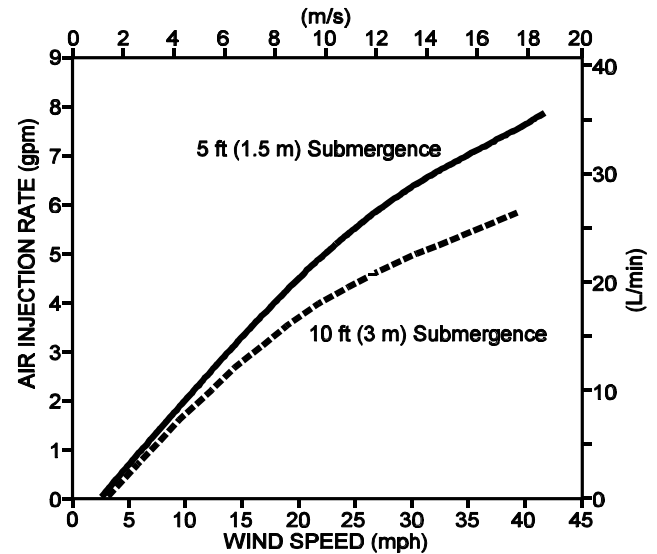


Figure 2. Air Injection Rate versus Wind Speed for a 5 and 10 ft (1.5 and 3.0 m) Submergence.

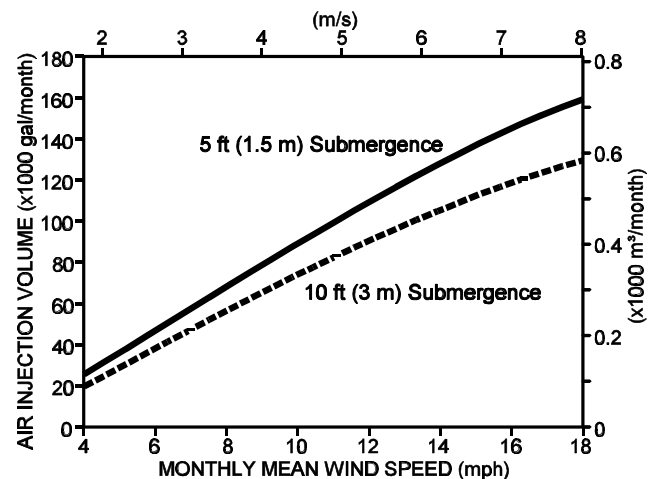


Figure 3. Air Injection Volume versus Monthly Mean Wind Speed Based on 100% Availability, Rayleigh Distribution of Wind Speeds and a 30 Day Month.

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

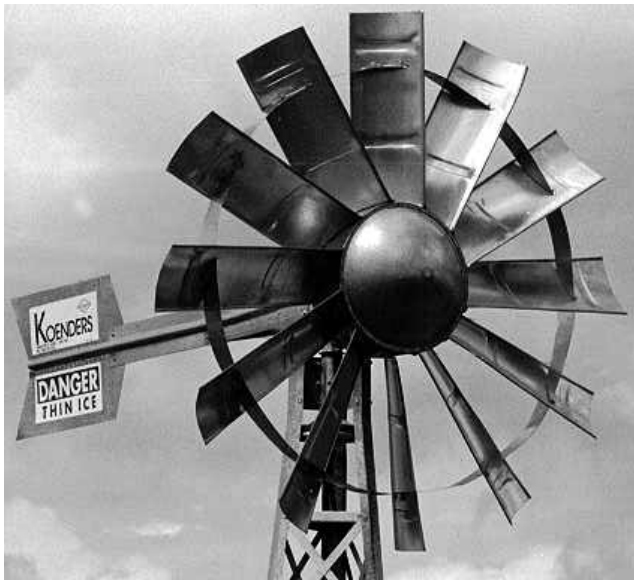


Figure 1. Koenders Aeration Turbine.

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

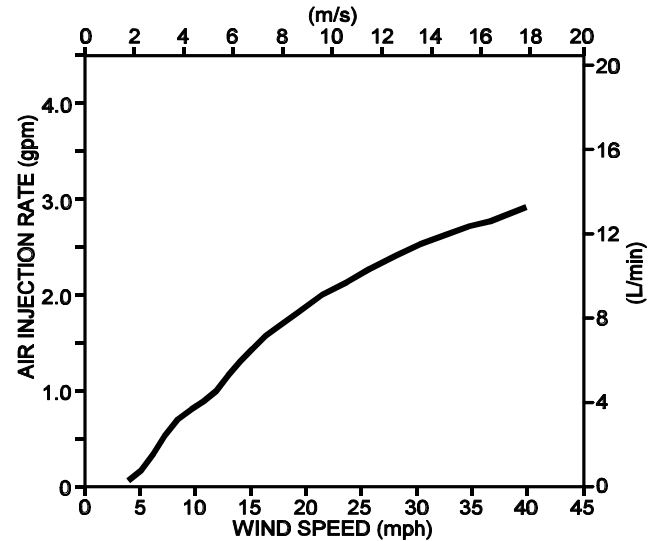


Figure 2. Air Injection Rate versus Wind Speed for an 18 ft (5.5 m) Lift.

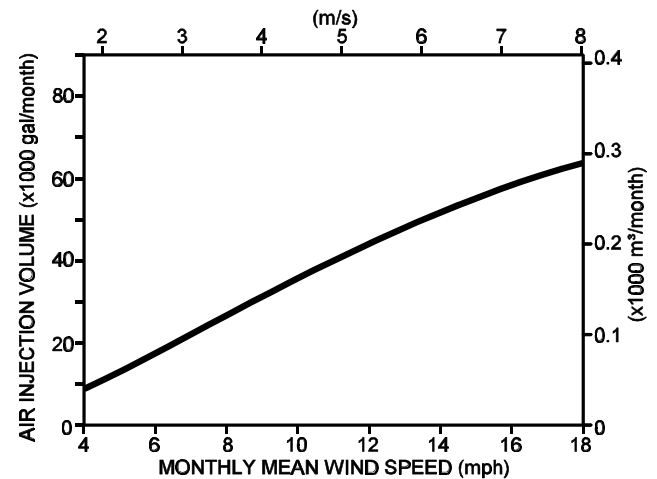


Figure 3. Air Injection Volume versus Monthly Mean Wind Speed Based on 100% Availability, Rayleigh Distribution of Wind Speeds and a 30 Day Month.

KOENDERS TURBINE

Manufacturer and Distributor:

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

Test years: 1992 - 1993

Performance:

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

Installed: June 24, 1992

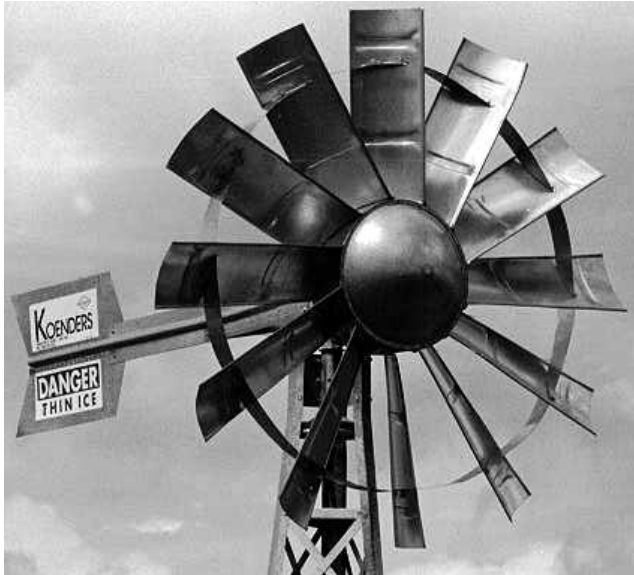


Figure 1. Koenders Wind Turbine.

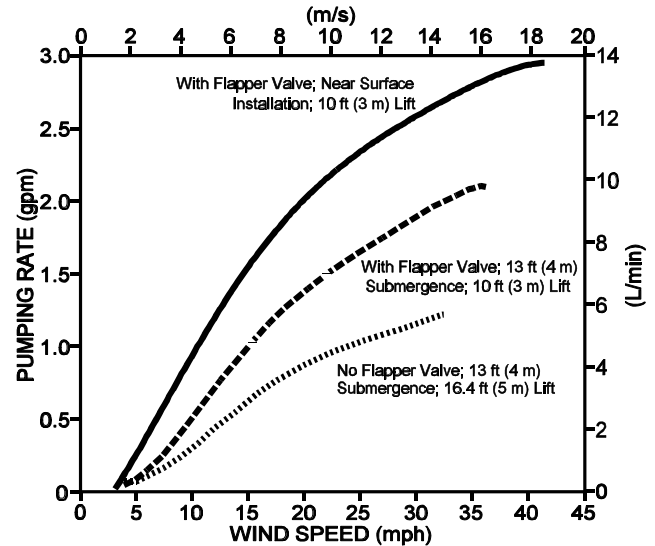


Figure 2. Pumping Rate versus Wind Speed for Various Configurations

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:
 diaphragm injects air into
 pump

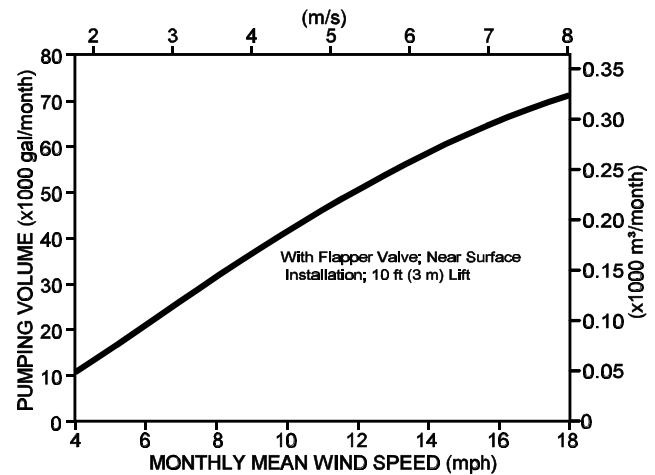


Figure 3. Pumping Volume versus Monthly Mean Wind Speed Based on 100% Availability, Rayleigh Distribution of Wind Speeds and a 30 Day Month.

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

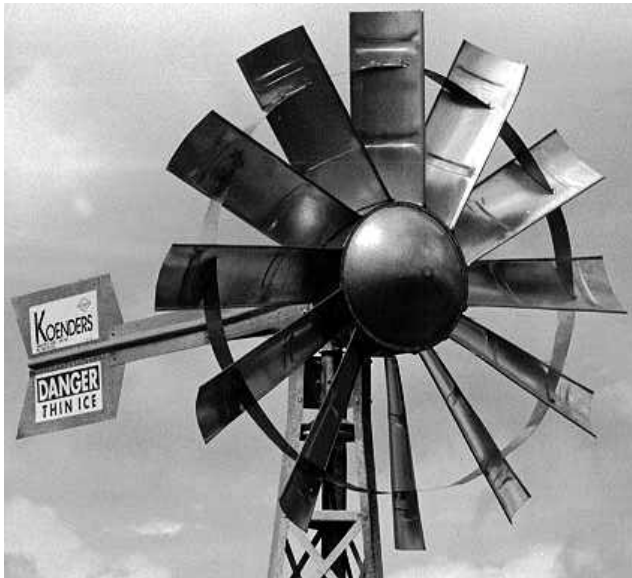


Figure 1. Koenders Turbine.

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

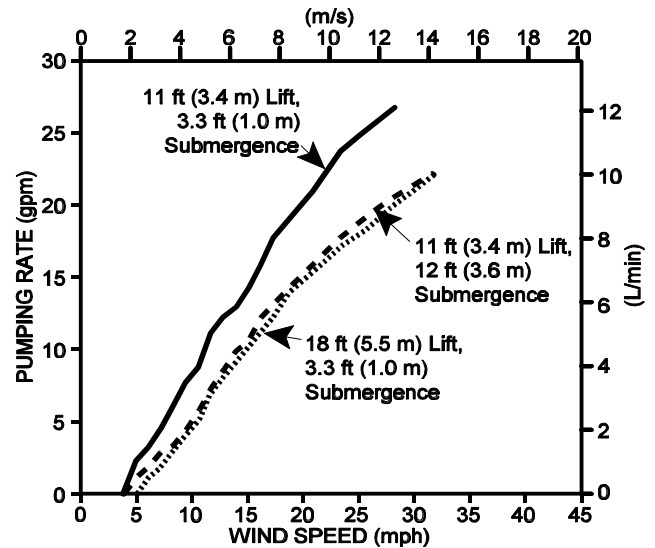


Figure 2. Pumping Rate versus Wind Speed for Various Configurations.

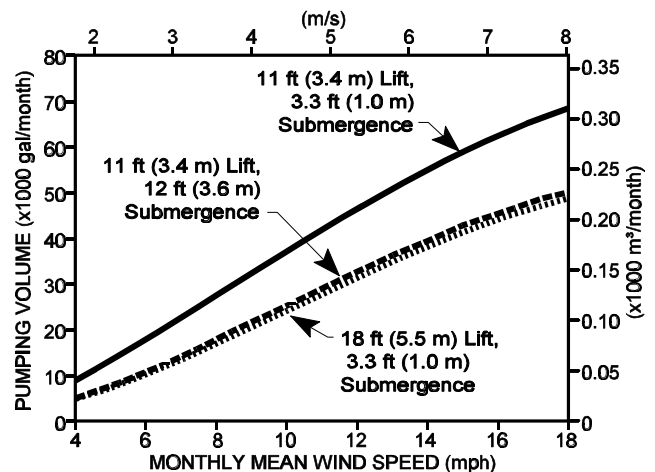


Figure 3. Pumping Volume versus Monthly Mean Wind Speed Based on 100% Availability, Rayleigh Distribution of Wind Speeds and a 30 Day Month.

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

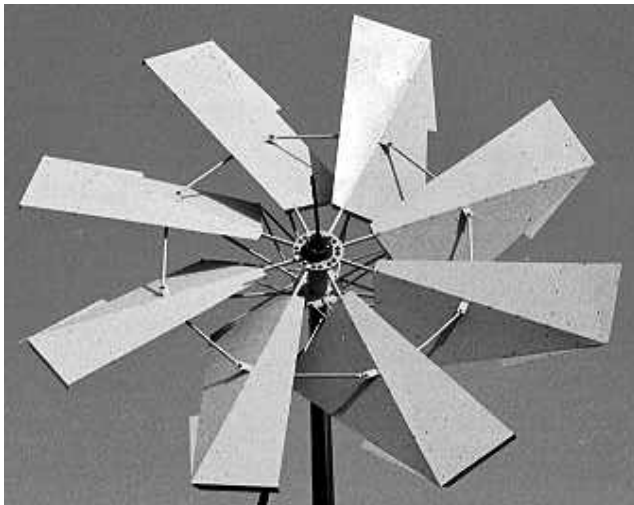


Figure 1. Maverick Windmotor Turbine.

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

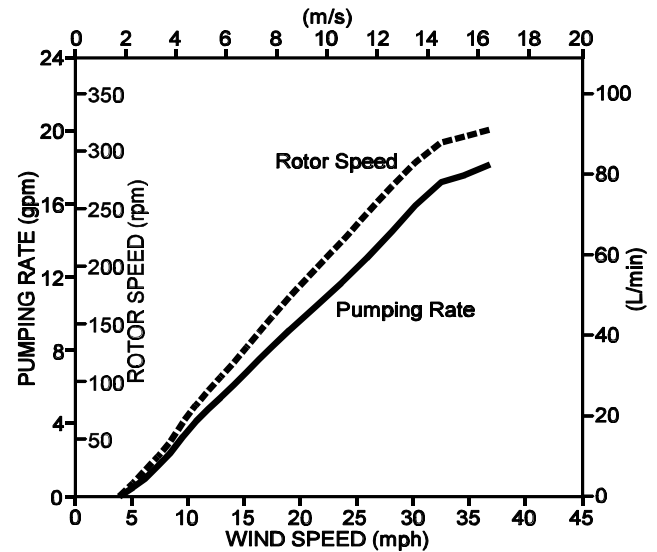


Figure 2. Pumping Rate and Rotor Speed versus Wind Speed for an 18 ft (5.5 m) Lift.

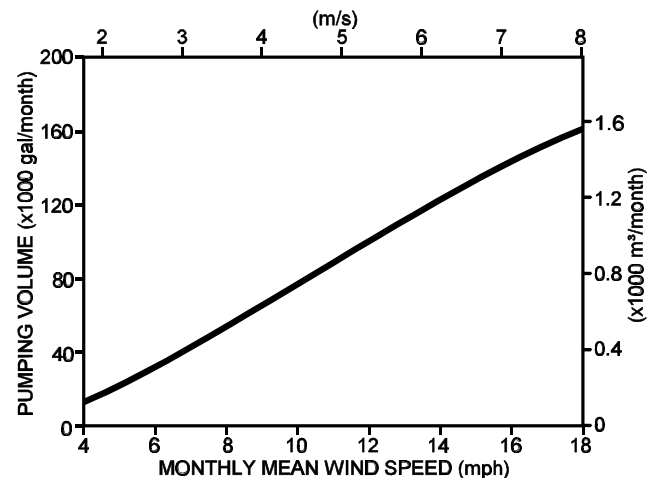


Figure 3. Pumping Volume versus Monthly Mean Wind Speed Based on 100% Availability, Rayleigh Distribution of Wind Speeds and a 30 Day Month.

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

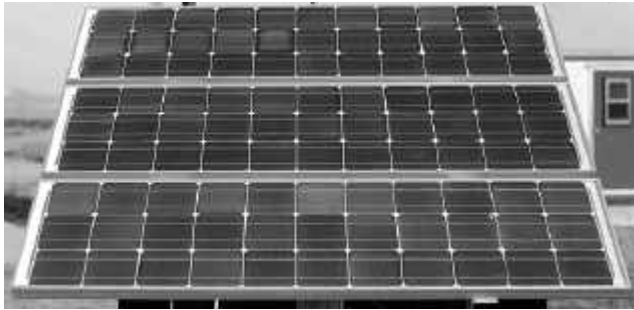


Figure 1. CAP 348SF5 Solar System.

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

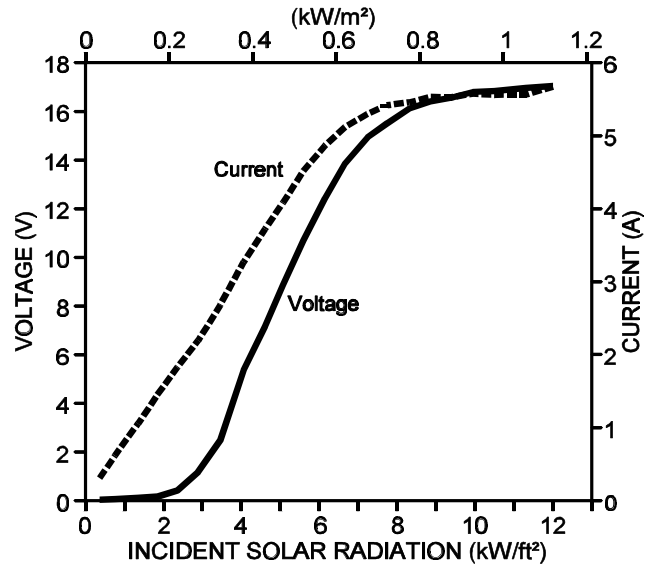


Figure 2. Voltage and Current versus Incident Solar Radiation for an 18 ft (5.5 m) Lift.

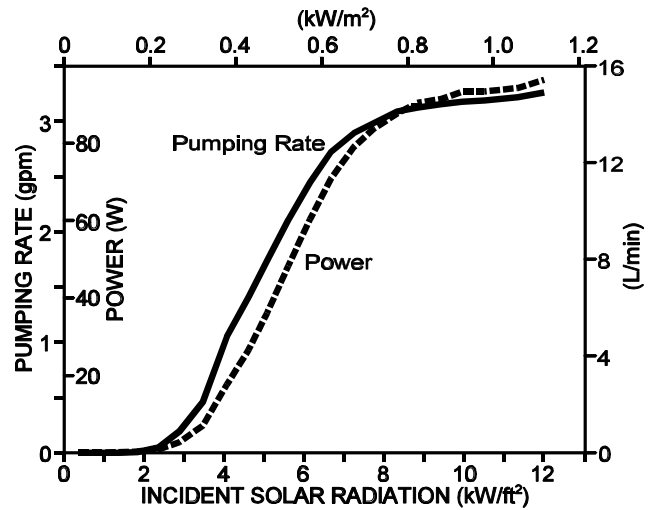


Figure 3. Pumping Rate and Power versus Incident Solar Radiation for an 18 ft (5.5 m) Lift.

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

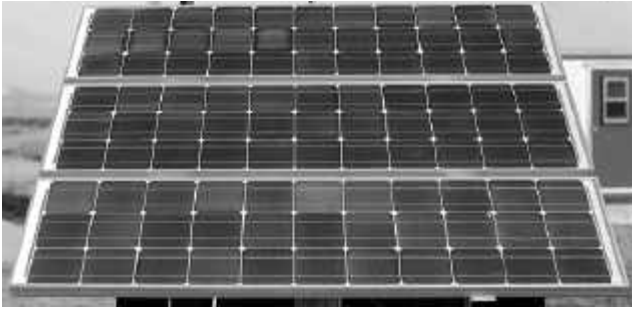


Figure 1. CAP 448TRU Solar System.

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)

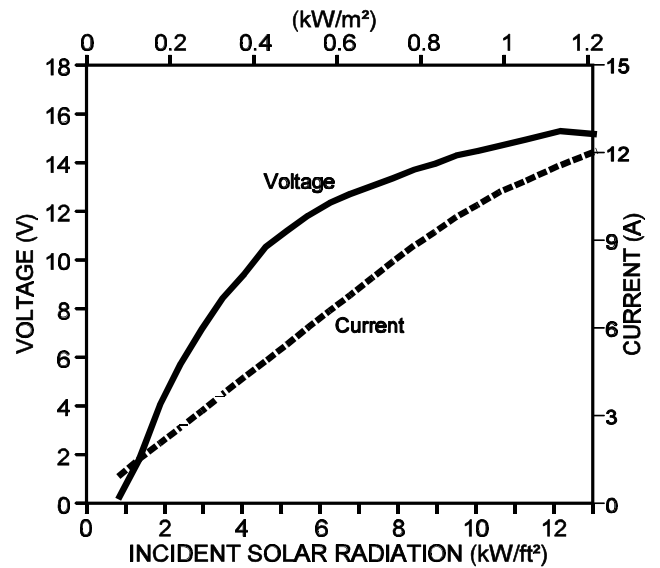


Figure 2. Voltage and Current versus Incident Solar Radiation for an 18 ft (5.5 m) Lift.

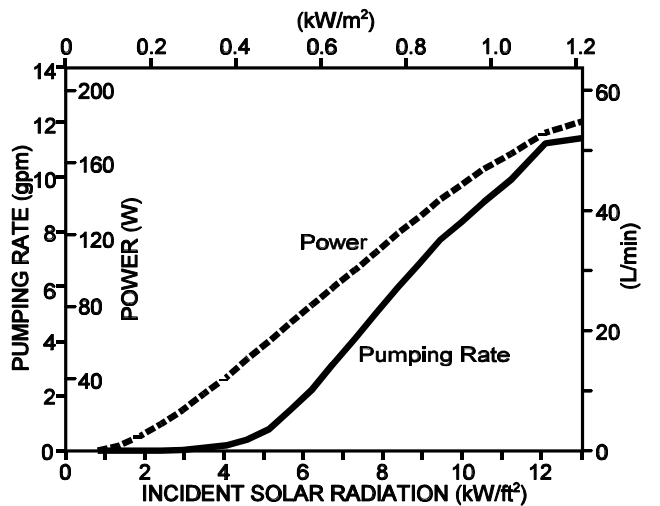


Figure 3. Pumping Rate and Power versus Incident Solar Radiation for an 18 ft (5.5 m) Lift.

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

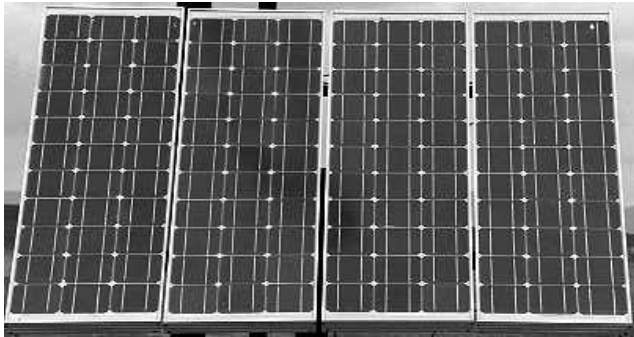


Figure 1. CAP 448SF5 Solar System.

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)

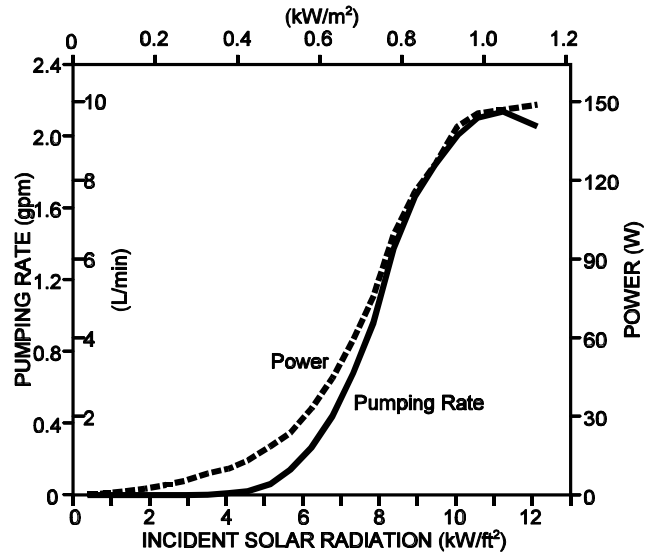


Figure 2. Power and Pumping Rate versus Incident Solar Radiation for a 98 ft (30 m) Lift.

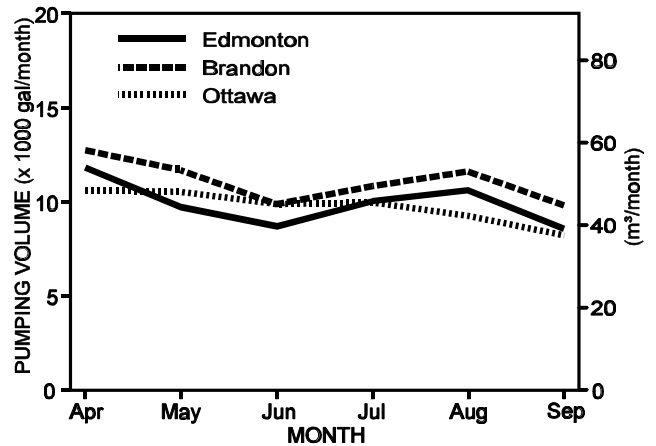


Figure 3. Simulated Pump Yields in Canada when Modules are Tilted at Latitude -5° from Horizontal and Pumping Against a 98 ft (30 m) Lift.

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

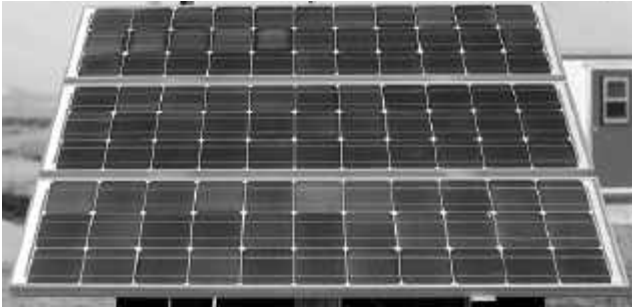


Figure 1. CAP 348SF5 Solar System.

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)

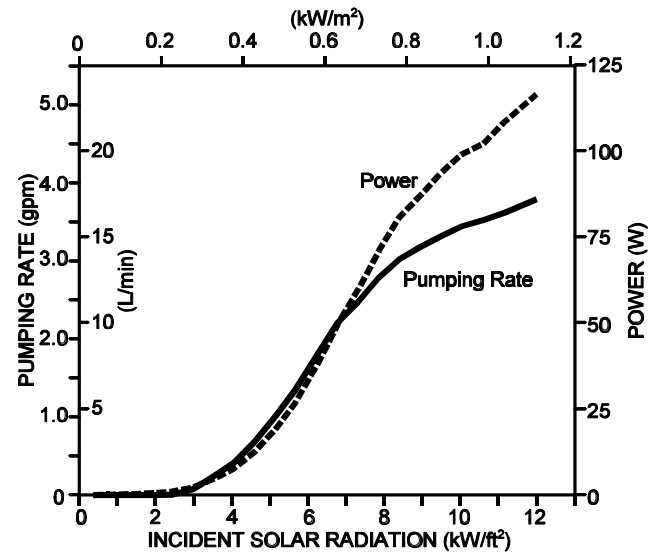


Figure 2. Power and Pumping Rate versus Incident Solar Radiation for a 18 ft (5.5 m) Lift.

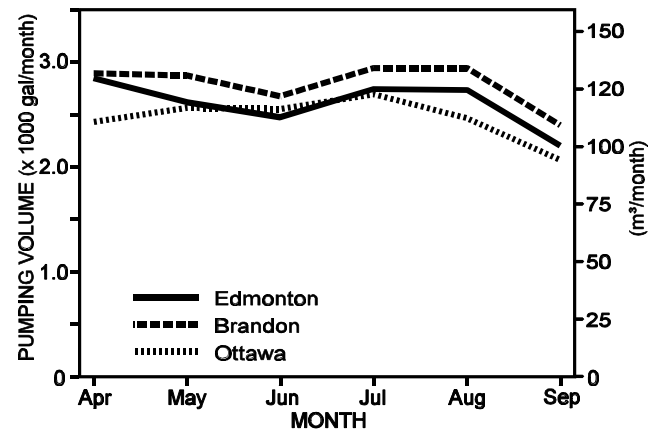


Figure 3. Simulated Pump Yields in Canada when Modules are Tilted at Latitude -5° from Horizontal and Pumping Against a 18 ft (5.5 m) Lift.

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

Test years: 1994 - 1995

Performance:

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

Installed: July 15, 1994

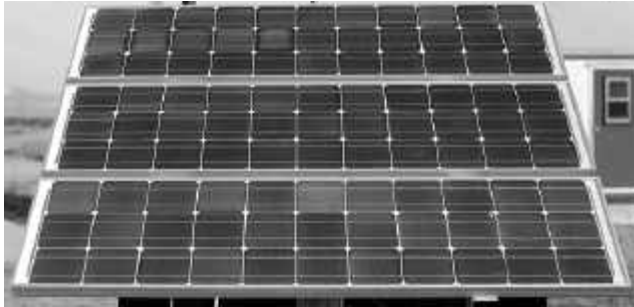


Figure 1. CAP 348SRU Solar System.

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)

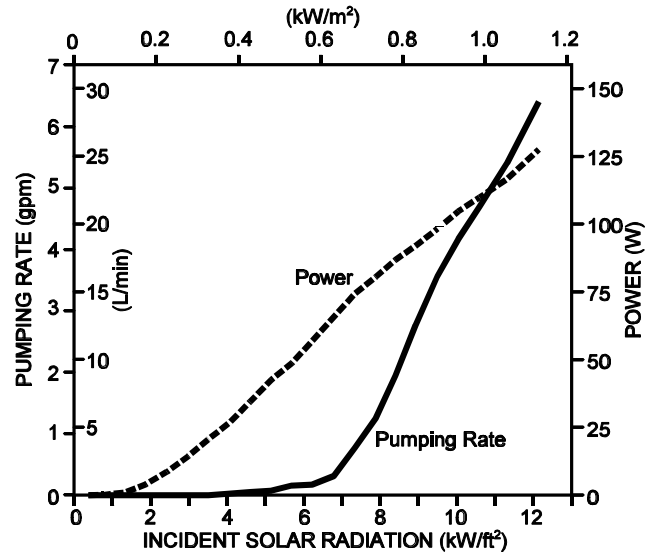


Figure 2. Power and Pumping Rate versus Incident Solar Radiation for a 18 ft (5.5 m) Lift.

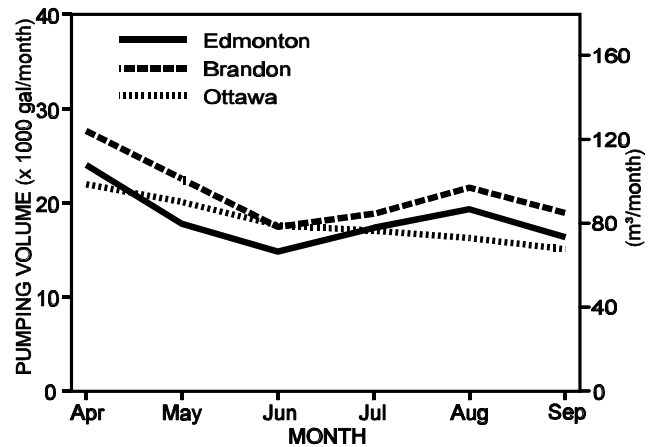


Figure 3. Simulated Pump Yields in Canada when Modules are Tilted at Latitude -5° from Horizontal and Pumping Against a 18 ft (5.5m) Lift.

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

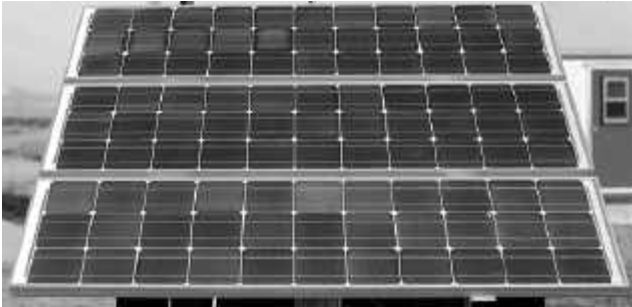


Figure 1. CAP348SRU Solar System.

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)

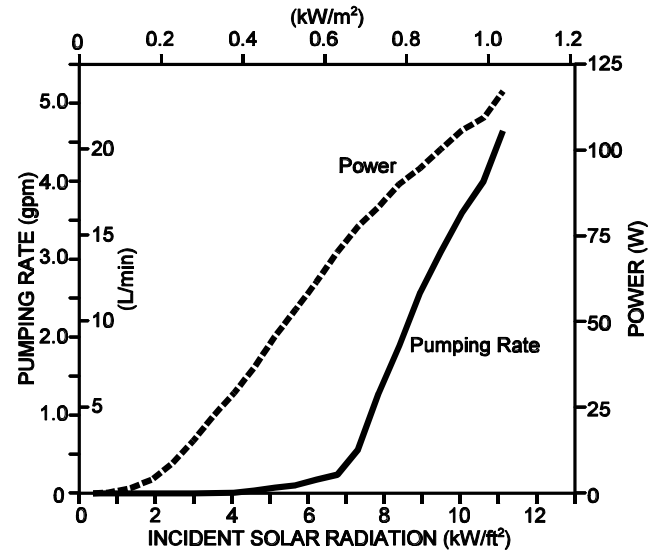


Figure 2. Power and Pumping Rate versus Incident Solar Radiation for a 18 ft (5.5 m) Lift.

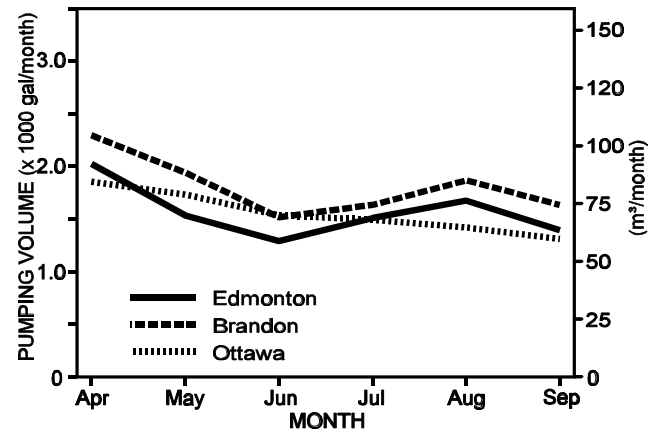


Figure 3. Simulated Pump Yields in Canada when Modules are Tilted at Latitude -5° from Horizontal and Pumping Against a 18 ft (5.5 m) Lift.

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

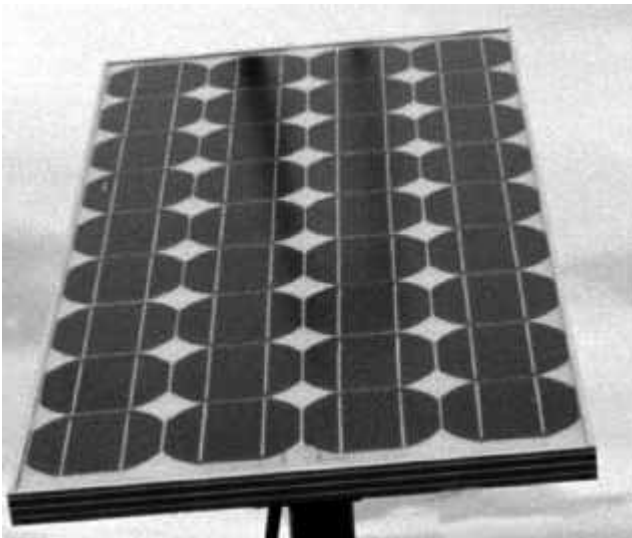


Figure 1. CAP 175SM3 Solar System.

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)

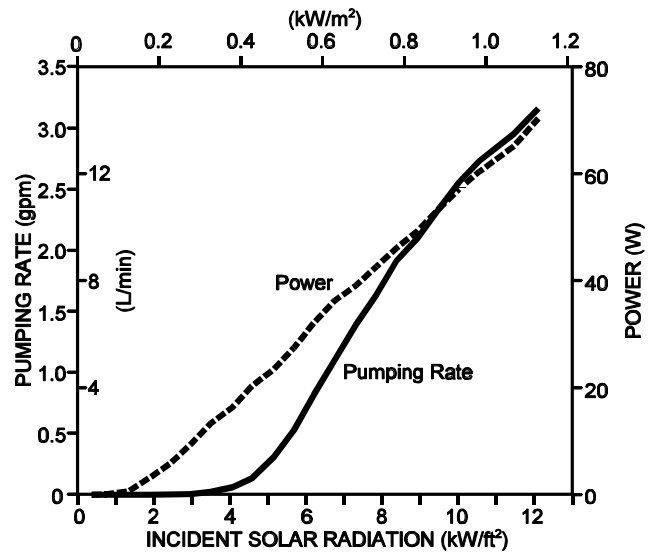


Figure 2. Power and Pumping Rate versus Incident Solar Radiation for a 18 ft (5.5 m) Lift.

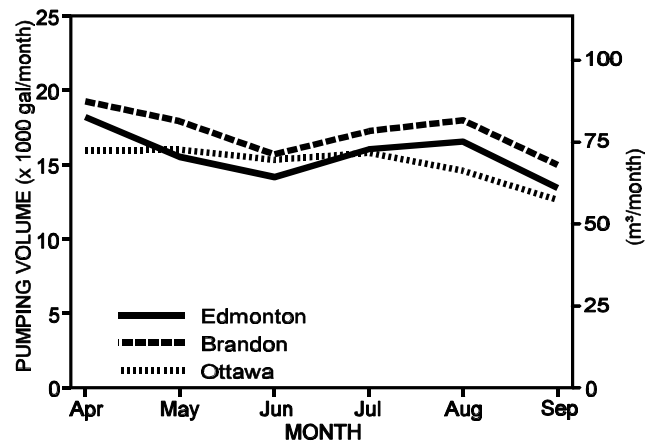


Figure 3. Simulated Pump Yields in Canada when Modules are Tilted at Latitude -5° from Horizontal and Pumping Against a 18 ft (5.5 m) Lift.

CAP 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

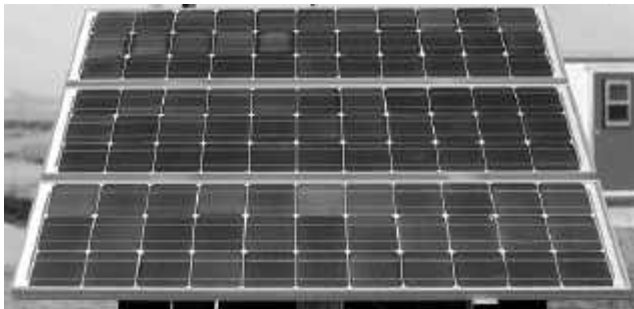


Figure 1. CAP 348SM5 Solar System.

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)

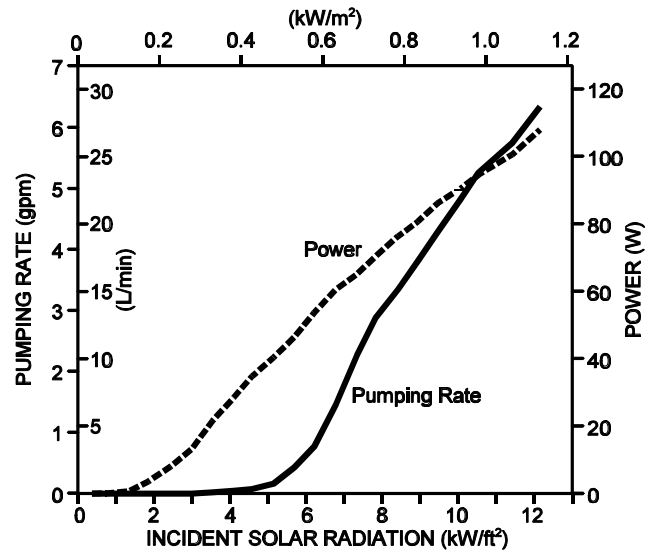


Figure 2. Power and Pumping Rate versus Incident Solar Radiation for a 18 ft (5.5 m) Lift.

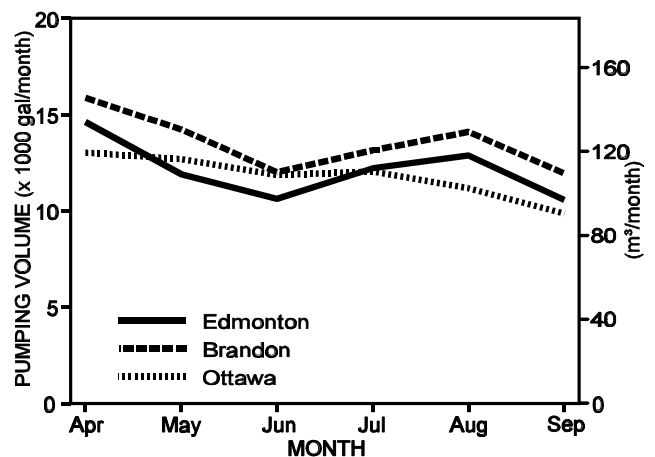


Figure 3. Simulated Pump Yields in Canada when Modules are Tilted at Latitude -5° from Horizontal and Pumping Against a 18 ft (5.5 m) Lift.

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

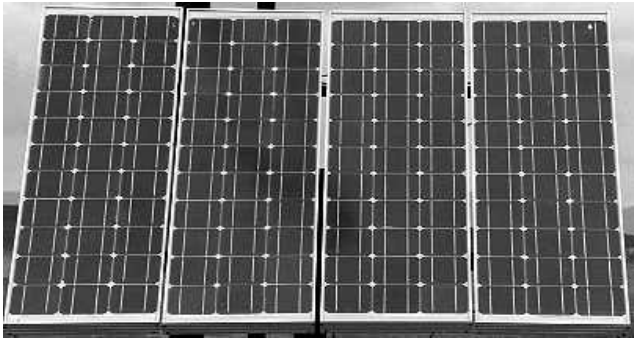


Figure 1. CAP 448SM5 Solar System.

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)

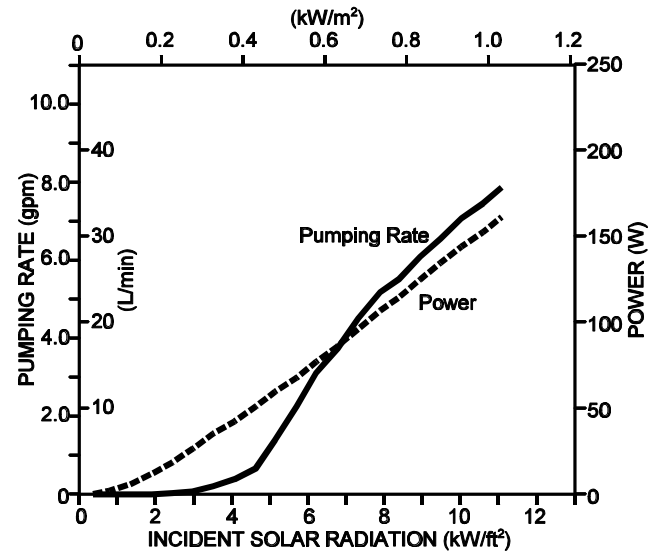


Figure 2. Power and Pumping Rate versus Incident Solar Radiation for a 18 ft (5.5 m) Lift.

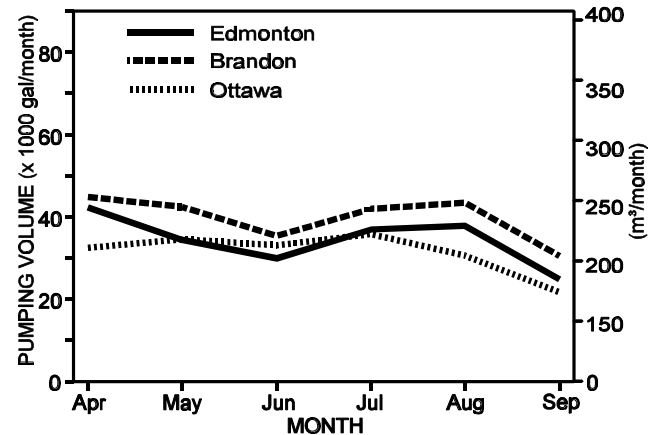


Figure 3. Simulated Pump Yields in Canada when Modules are Tilted at Latitude -5° from Horizontal and Pumping Against a 18 ft (5.5 m) Lift.

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

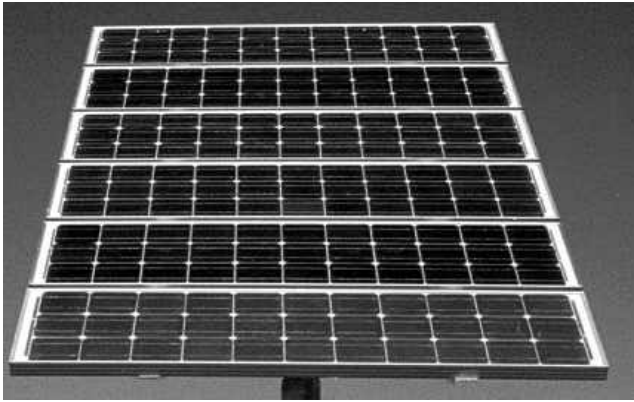


Figure 1. Grundfos SunSub 400 Siemens Modules.

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

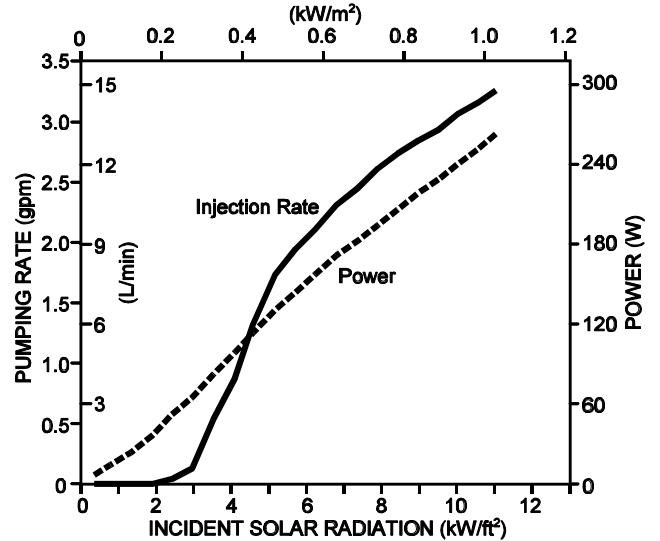


Figure 2. Power and Pumping Rate versus Incident Solar Radiation for an 59 ft (18 m) Lift.

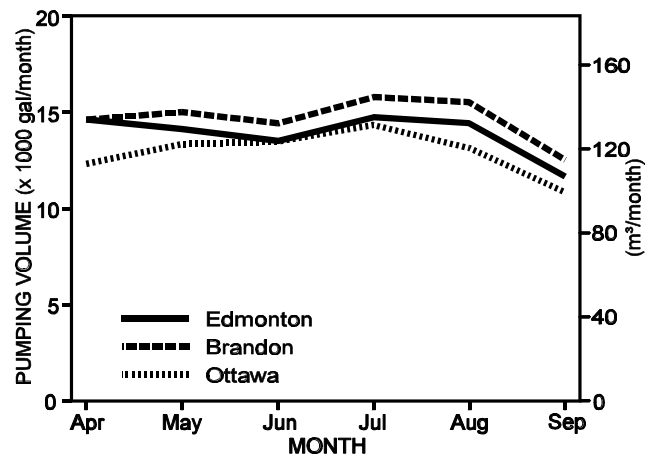


Figure 3. Simulated Pump Yields in Canada when Modules are Tilted at Latitude -5° from Horizontal and Pumping Against an 59 ft (18 m) Lift.

KELLN SINGLE MODULE AERATION SYSTEM

Manufacturer and Distributor:

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

Test years: 1993

Performance:

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

Installed: June 18, 1993

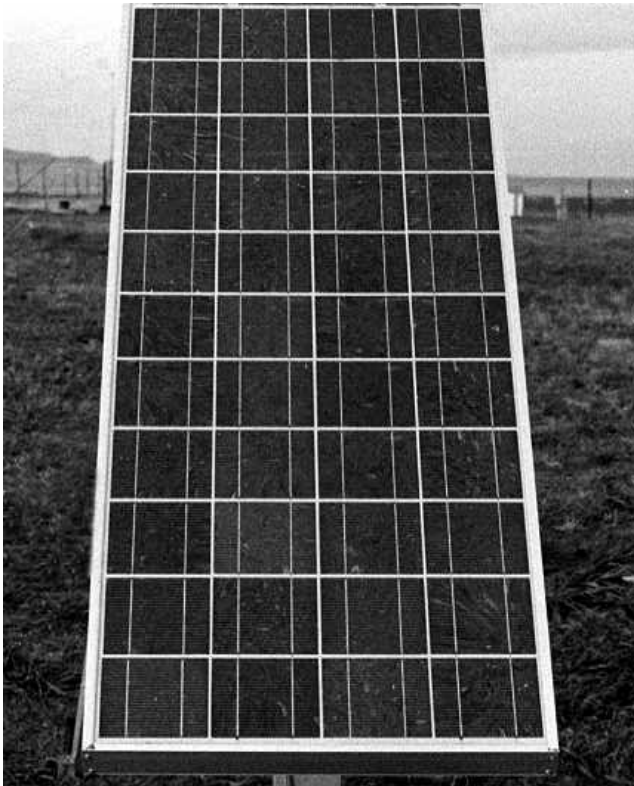


Figure 1. Kelln Single Module Aeration System.

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

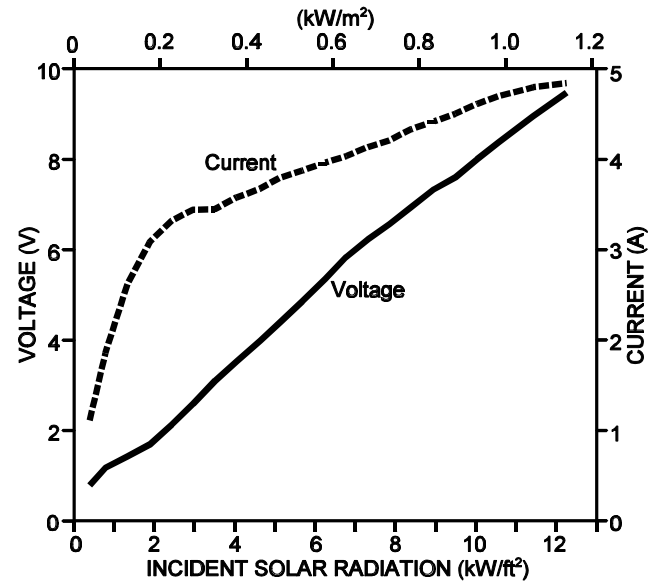


Figure 2. Voltage and Current versus Incident Solar Radiation for a 5 ft (1.5 m) Submergence.

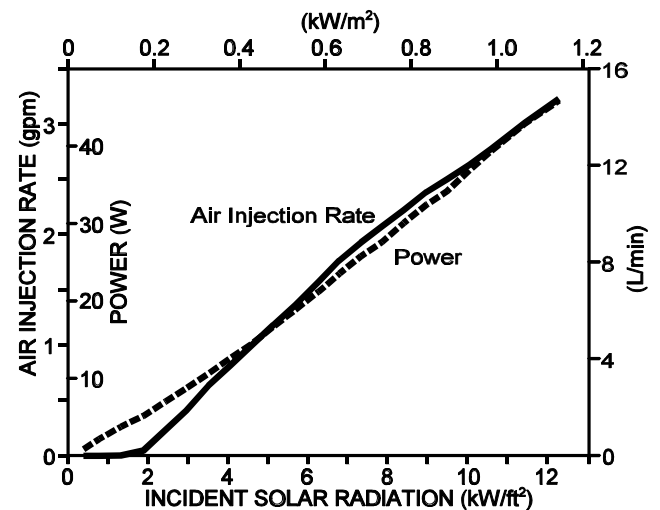


Figure 3. Air Injection Rate and Power versus Incident Solar Radiation for a 5 ft (1.5 m) Submergence

Test years: 1993

Performance:

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

Installed: June 18, 1993

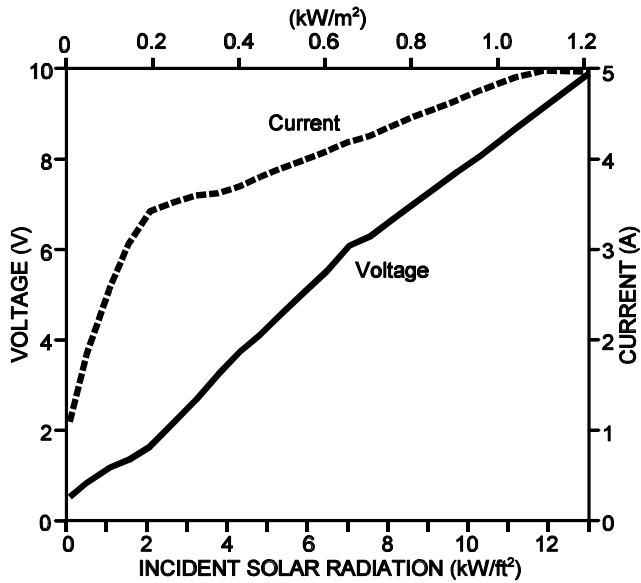


Figure 4. Voltage and Current versus Incident Radiation for a 10 ft (3 m) Submergence.

Test years: 1994-1995

Performance:

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

Installed: June 18, 1993

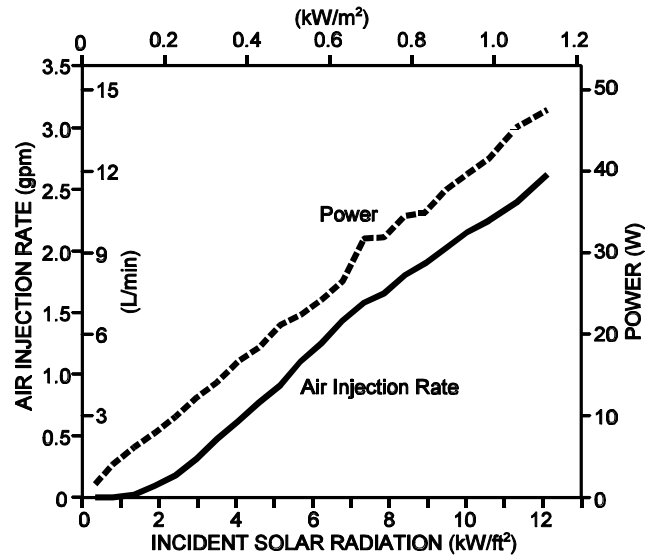


Figure 6. Power and Air Injection Rate versus Incident Solar Radiation for a 13 ft (4 m) Submergence.

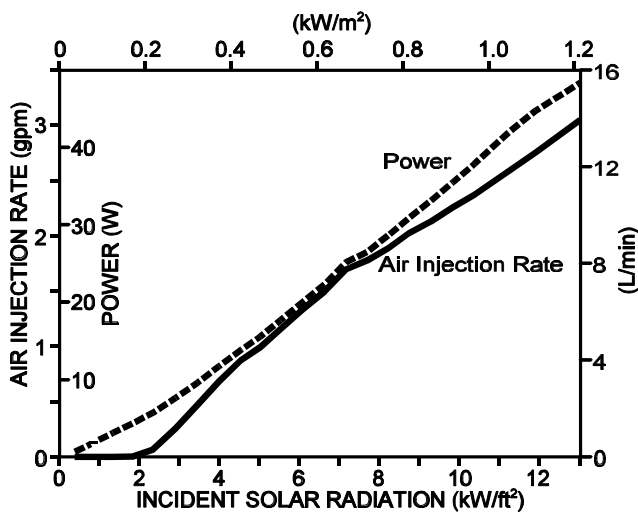


Figure 5. Air Injection Rate and Power versus Incident Solar Radiation for a 5 ft (1.5 m) Submergence

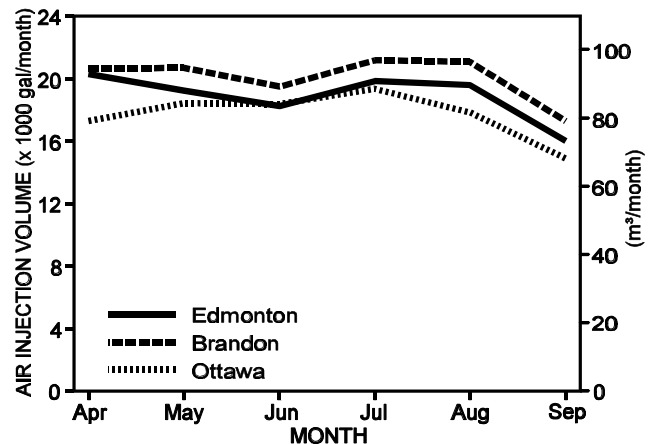


Figure 7. Simulated Air Injection Volumes in Canada when Modules are Tilted at Latitude -5° from Horizontal and Injecting Air at a Depth of 13 ft (4 m).

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

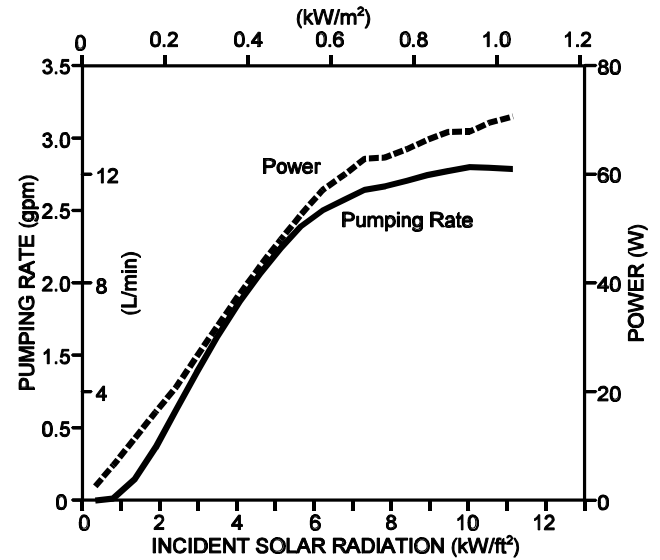


Figure 2. Voltage and Current versus Incident Solar Radiation for an 18 ft (5.5 m) Lift.

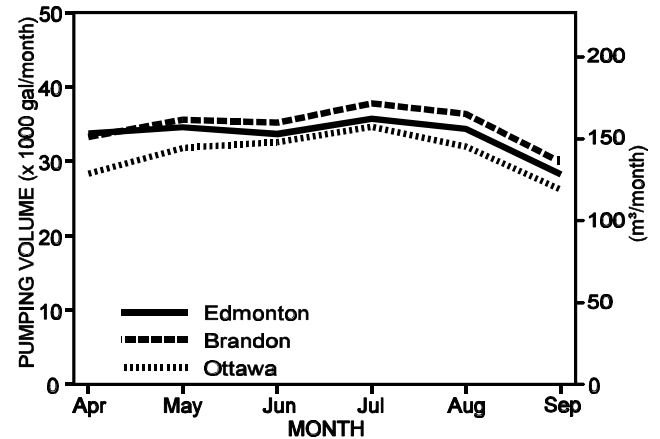


Figure 3. Simulated Pump Yields in Canada when Pumping Rate and Power versus Incident Solar Radiation for an 18 ft (5.5 m) Lift.

KELLN 6 MODULE WATER SYSTEM (Parallel/Series)

Manufacturer and Distributor:

Kelln Consulting Ltd.
 P.O. Box 94
 Lumsden, Saskatchewan, Canada
 SOG 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

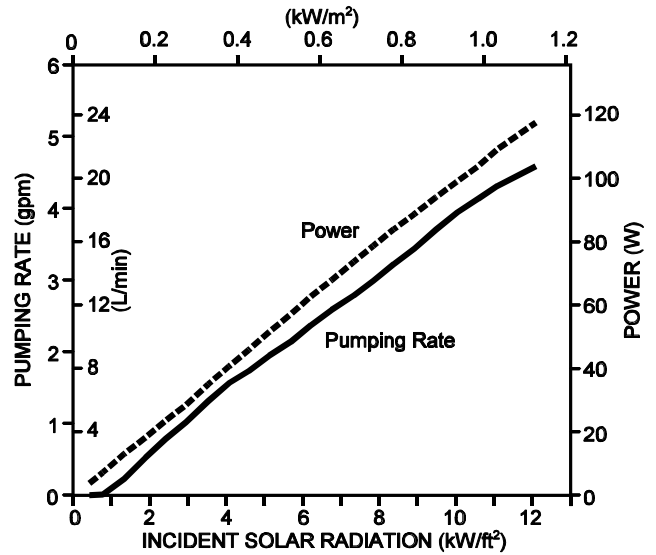


Figure 2. Power and Pumping Rate versus Incident Solar Radiation for a 18 ft (5.5 m) Lift.

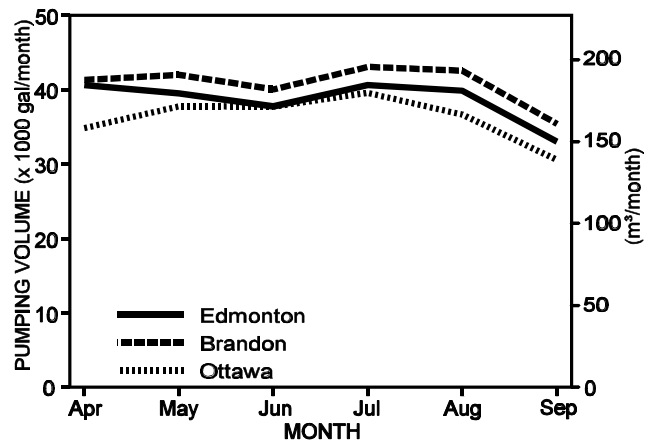


Figure 3. Simulated Pump Yields in Canada when Modules are Tilted at Latitude -5° from Horizontal and Pumping Against a 18 ft (5.5 m) Lift.

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

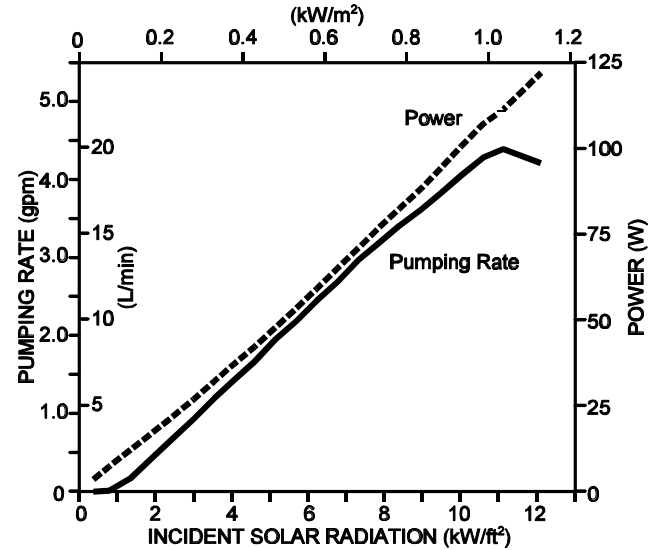


Figure 2. Power and Pumping Rate versus Incident Solar Radiation for a 18 ft (5.5 m) Lift.

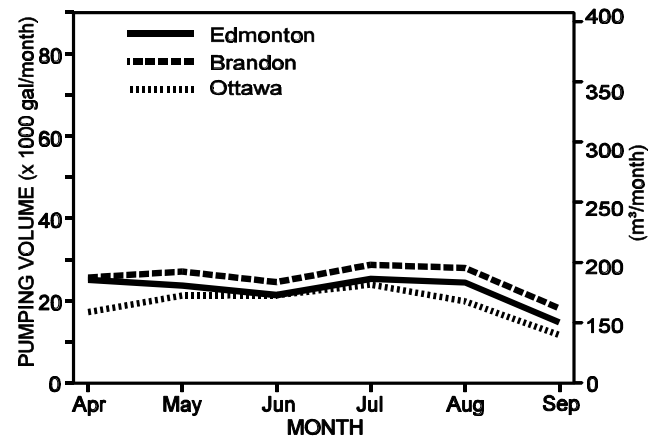


Figure 3. Simulated Pump Yields in Canada when Modules are Tilted at Latitude -5° from Horizontal and Pumping Against a 18 ft (5.5 m) Lift.

KELLN 6 MODULE WATER SYSTEM

Manufacturer and Distributor:

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



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

Test years: 1993

Performance:

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

Installed: May 6, 1993

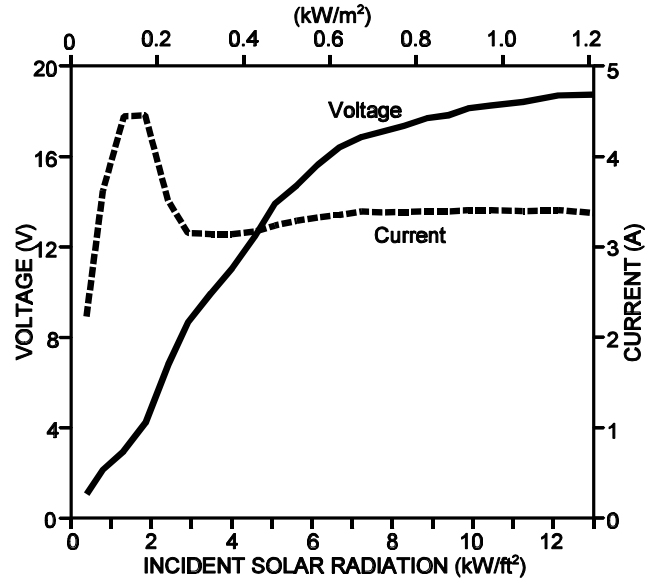


Figure 2. Voltage and Current versus Incident Solar Radiation for an 18 ft (5.5 m) Lift.

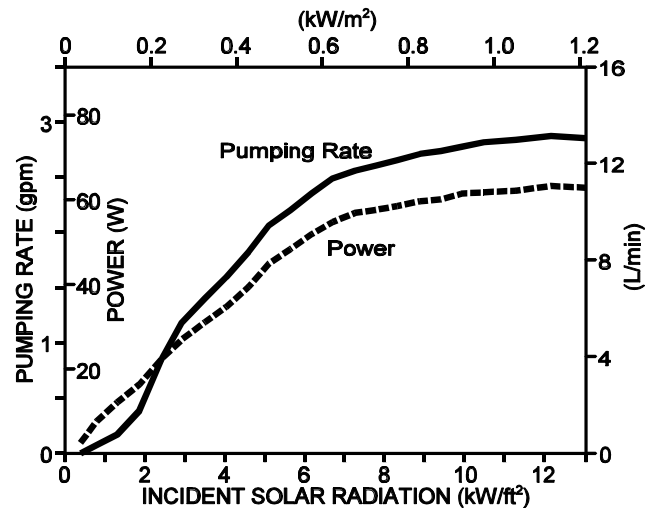


Figure 3. Pumping Rate and Power versus Incident Solar Radiation for an 18 ft (5.5 m) Lift.

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

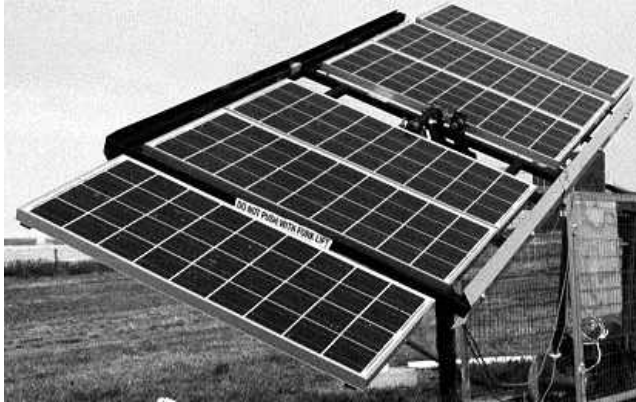


Figure 1. Kelln Pump Jack Solar System.

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

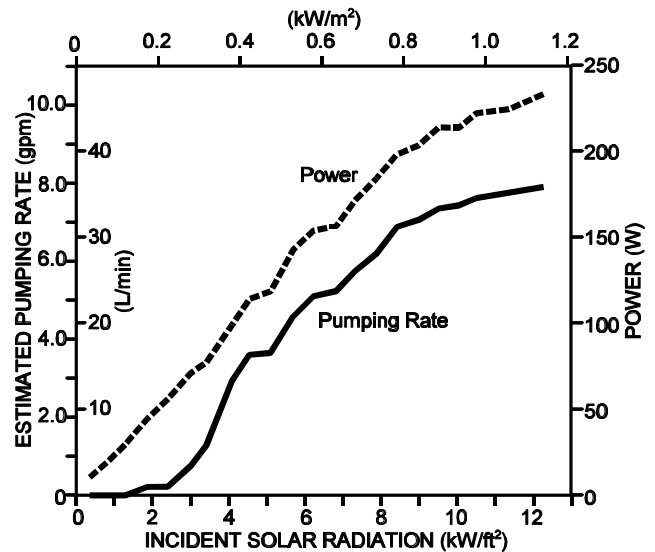


Figure 2. Power and Pumping Rate versus Incident Solar Radiation for a 115 ft (35 m) Lift.

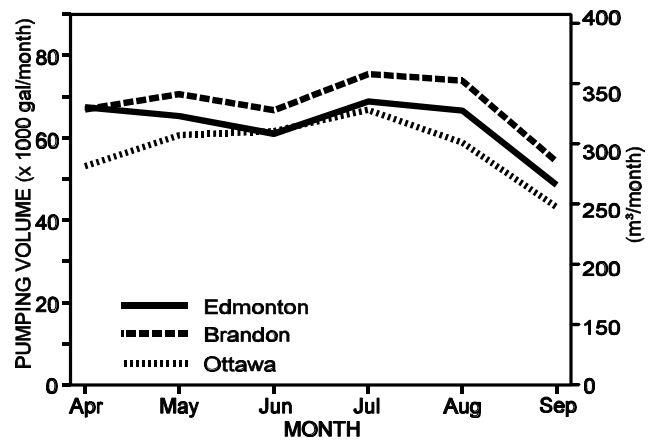


Figure 3. Simulated Pump Yields in Canada when Modules are Tilted at Latitude -5° from Horizontal and Pumping Against a 115 ft (35 m) Lift.

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

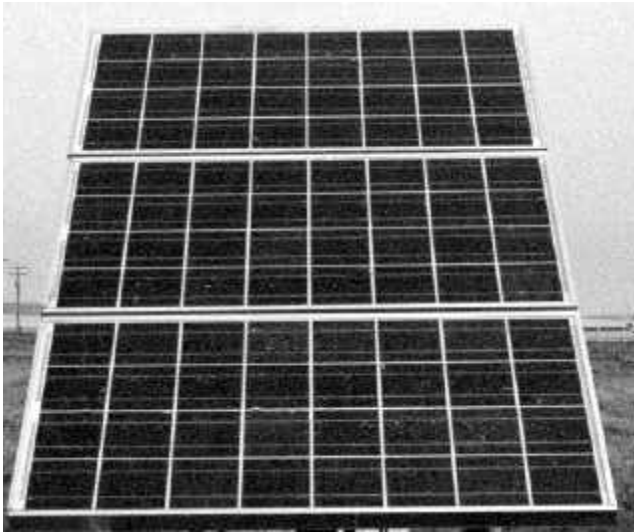


Figure 1. Kelln Three Module Aeration System.

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

Test years: 1996

Performance:

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

Installed: August 22, 1996

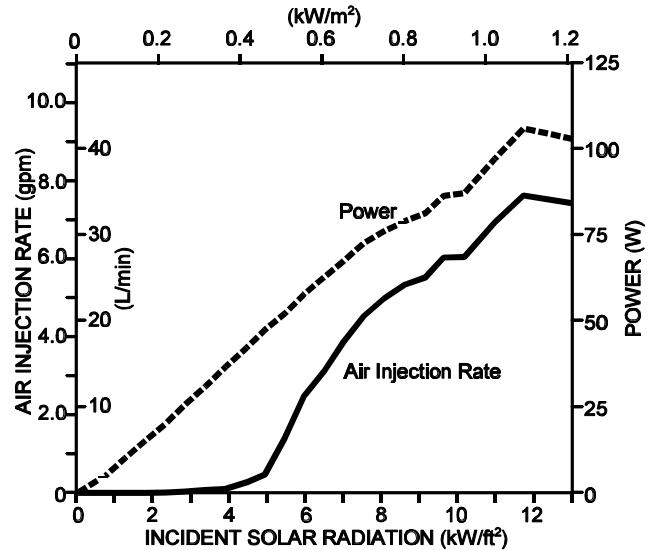


Figure 2. Power and Air Injection Rate versus Incident Solar Radiation for a 10 ft (3 m) Submergence.

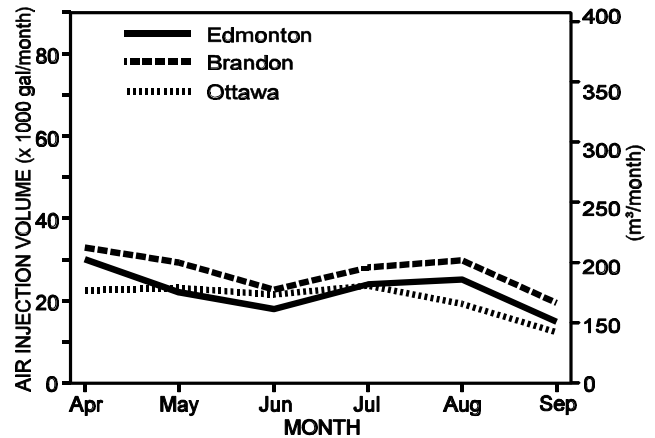


Figure 3. Simulated Air Injection Volumes in Canada when Modules are Tilted at Latitude -5° from Horizontal and Pumping Against a 10 ft (3.0 m) Lift.



**ALBERTA
FARM
MACHINERY
RESEARCH
CENTRE**

3000 College Drive South
Lethbridge, Alberta, Canada T1K 1L6
Telephone: (403) 329-1212
FAX: (403) 329-5562
[http://www.agric.gov.ab.ca/navigation/engineering/
afmrc/index.html](http://www.agric.gov.ab.ca/navigation/engineering/afmrc/index.html)

Prairie Agricultural Machinery Institute

Head Office: P.O. Box 1900, Humboldt, Saskatchewan, Canada S0K 2A0
Telephone: (306) 682-2555

Test Stations:
P.O. Box 1060
Portage la Prairie, Manitoba, Canada R1N 3C5
Telephone: (204) 239-5445
Fax: (204) 239-7124

P.O. Box 1150
Humboldt, Saskatchewan, Canada S0K 2A0
Telephone: (306) 682-5033
Fax: (306) 682-5080