

FARALLON DE PAJAROS

MAUG ISLANDS

# A PHOTOVOLTAIC SEAWATER PUMPING SYSTEM FOR GIANT CLAM MARICULTURE

ASUNCION

M  
A  
R  
I  
A  
N  
A  
  
I  
S  
L  
A  
N  
D  
S

PAGAN

*Stephen J. Winter*

ALAMAGAN *Gerald A. Heslinga*

GUGUAN *Larry D. McCleary*

SARIGUAN

*Water and Energy Research  
Institute  
of the  
Western Pacific*

ANATAHAN

FARALLON DE MEDINILLA

SAIPAN

TINIAN

AGUIJAN

UNIVERSITY OF GUAM

ROTA

*Technical Report No. 61*

*September, 1985*

A PHOTOVOLTAIC SEAWATER PUMPING SYSTEM

FOR

GIANT CLAM MARICULTURE

by

Stephen J. Winter

Gerald A. Heslinga

Larry D. McCleary

*Water and Energy Research Institute  
of the  
Western Pacific*

UNIVERSITY OF GUAM

Technical Report No. 61

September, 1985

Completion Report  
for  
Contract No. C50175

Office of Capital Improvement Programs  
Trust Territory of the Pacific Islands

## TABLE OF CONTENTS

	Page
LIST OF FIGURES.....	iv
LIST OF TABLES.....	v
INTRODUCTION.....	1
The Resource.....	1
The MMDC-PFDF Program.....	1
Pumping Needs for Giant Clam Culture.....	1
Solar Pumping.....	4
OBJECTIVES.....	4
DESIGN.....	4
INSTALLATION.....	5
TESTING.....	8
CONCLUSIONS.....	8
LITERATURE CITED.....	12
APPENDIX.....	13

## LIST OF FIGURES

	Page
1. Two and one half year old clams in the MMDC underwater nursery.....	2
2. Giant clam seed 4 to 6 months old produced at the MMDC.	3
3. The completed project showing relationship to wharf....	6
4. The Maximum Power Controller and pump/motor set.....	6
5. The completed project showing piping arrangement and relationship to clam growing tanks.....	7
6. The completed project showing pump suction line extending into lagoon.....	7

## LIST OF TABLES

	Page
1. Pump test data (August 3, 1985).....	9
2. Pump test data (August 4, 1985).....	10
3. Pump test data (August 17, 1985).....	11

## INTRODUCTION

### The Resource

The giant tridacnid clams have been an important traditional seafood resource in many Asian and Pacific nations, including those of Micronesia. The clams are large, regularly growing to more than a meter in length, and they live on shallow coral reefs easily accessible to fishermen. An unusual feature of the tridacnids is their symbiotic association with unicellular algae called zooxanthellae. These tiny plants capture sunlight and, via the process of photosynthesis, produce virtually all of the food required by the clams (Munro and Heslinga, 1983).

As a result of harvesting for commercial and subsistence purposes, giant clam populations have experienced a serious and in some cases spectacular decline throughout their range in the tropical Pacific. Indeed, on many reefs in Micronesia (e.g., Guam, Yap, Pohnpei, Truk, and Kosrae) the larger giant clam species are now extinct (Heslinga et al., 1984; Heslinga, in press).

### The MMDC-PFDF Program

For more than a decade, marine scientists working in the Pacific have attempted to breed giant clams in the laboratory, with the dual objectives of reversing the trend toward extinction and developing an economical method for food production through marine farming, or mariculture. The staff of the Micronesian Mariculture Demonstration Center (MMDC) in Palau has been at the forefront of this work (Figure 1) and in recent years has shown conclusively that it is feasible to produce hundreds of thousands of "seed" clams (Figure 2) each year in a simple coastal hatchery (Heslinga and Watson, in press). The seed clams can be sold to marine farmers or planted on the seabottom locally for growout to harvestable size. Personnel from Micronesia and throughout the Pacific basin have been trained in giant clam culture techniques and an innovative program of international clam re-introductions has met with initial success. This work has been funded by the Pacific Fisheries Development Foundation (PFDF). Efforts are now underway in at least six Pacific countries to establish giant clam culture programs based on the MMDC example.

### Pumping Needs for Giant Clam Culture

In order to function efficiently, giant clam hatcheries require a reliable source of power for pumping seawater. During daylight hours, when the algal cells residing in the clams are photosynthesizing, clean, unfiltered lagoon water must be pumped through the hatchery tanks at a rate sufficient to supply nutrients, remove wastes, and prevent overheating. At night, pumping is unnecessary because the photosynthetic process is shut down and the clams are quiescent; moreover, there is no danger of a potentially lethal heat buildup. In past years, conventional power sources such as diesel generators and direct-drive diesel pumps have been used to supply seawater to the MMDC hatchery. Despite being relatively inexpensive at the outset, diesel-based systems embody a number of well-known disadvantages; they are heavy, noisy, dirty and generally limited to an overhaul lifespan of only 4,000 hours or so.



Figure 1. Two and one half year old clams in the MMDC underwater nursery.

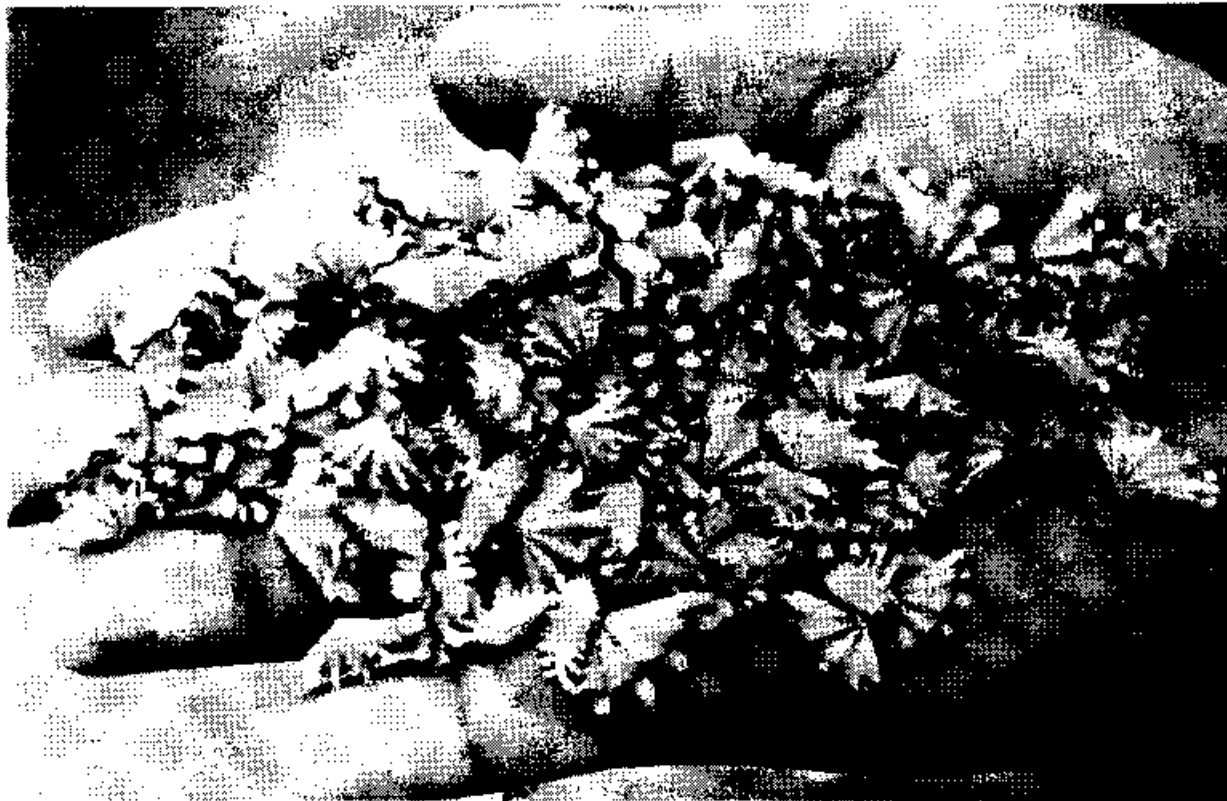


Figure 2. Giant clam seed 4 to 6 months old produced at the MMDC.



## Solar Pumping

Solar photovoltaic pumping of groundwater for remote island water supplies has been demonstrated to be feasible in Micronesia (Winter, McCleary, and Watters, 1983; Winter and McCleary, 1984; and Winter and McCleary, 1985). It is logical to consider the use of solar powered seawater pumps as an alternative to diesel engines. In the case of giant clam culture where the output of a solar module parallels the need of a clam for circulating seawater, solar power is especially appealing. In order to determine the compatibility of photovoltaic technology and giant clam mariculture, the MMDC approached the U.S. Department of Energy in 1983 with a proposal to construct a prototype clam rearing system based on solar power.

### OBJECTIVES

The objective of this project was to design and construct a solar photovoltaic seawater pumping system for use at the MMDC giant clam culture facility and to evaluate its performance from technical and economic points of view.

### DESIGN

Since the need for circulating seawater for giant clam culture is proportional to sunlight intensity and there is no need for circulation at night, it was decided that battery storage would not be necessary. Thus, the primary components of the pumping system were anticipated to be an array of solar modules directly connected to a suitable pump/motor set. This simple system would provide circulating seawater at a rate roughly proportional to sunlight intensity.

Previous experience with a similar (flow rates and heads) groundwater pumping system (Winter and McCleary, 1985) indicated that such systems (without battery storage) experience difficulty when pumping at low levels of sunlight because the current generated becomes corresponding low and is insufficient to cause the motor to turn. The problem arises because the speed of a direct current motor is essentially proportional to voltage, assuming adequate current is provided. Consequently, it was decided to use a power controller that would "manufacture" essentially constant current regardless of the level of sunlight.

The components of the pumping system were designed/selected using the following criteria:

1. maximum lift of 18 feet (vertical distance from lowest tide level to top of holding tank).
2. 20 gpm pumping rate at maximum lift; more flow desirable.
3. ability of system to pump for 6 to 8 hours per day. Pumping at less than design pumping rate acceptable early and late in the day.

4. resistance to seawater corrosion.
5. high reliability.
6. low maintenance.

The Chronar TriSolar Corporation of Bedford, Massachusetts, selected the major hardware items. These are:

1. 8 Arco M53 43 watt photovoltaic modules.
2. a "Maximum Power Controller" (MPC).
3. a pump/motor set.

Manufacturers' Literature for each of these items is given in the Appendix. Chronar TriSolar also supplied a mounting frame for the pump/motor set, a stainless housing for the motor, a suction hose, and miscellaneous fittings.

The M53 modules were wired in series to produce a nominal 138 volts and 2.49 amps at load. Array output was connected to the MPC, a proprietary device manufactured by Chronar TriSolar. It serves two functions:

1. provides a pulse of current to initially start a motor.
2. provides essentially constant current output regardless of current input (sunlight intensity).

Output from the MPC was connected to a Baldor Electric Co. 3/4 horsepower, 90 volt D.C. motor. It drove a Robbins and Moyns SP Series 300, Model 35604 pump. This is a positive displacement screw pump with a stainless steel body and rotor and a NBR (nitrile) rubber stator.

#### INSTALLATION

The array was mounted approximately 20 feet inland of the wharf at the MMDC in order to protect it and other system components from seawater spray during windy periods (Figure 3). It was tilted 15° to the horizontal and oriented 10° east of south (in order to be parallel with the edge of the wharf). The MPC was mounted on one of the legs supporting the array and the pump/motor set was mounted on a concrete slab which was also placed under the array (Figure 4). The resulting arrangement was compact and utilized the array to provide a degree of weather protection for the other components (Figure 5). A 2 inch suction line was used and was routed through a large drain pipe to the edge of the wharf. A flexible hose was attached to the suction line and anchored to the bottom of the lagoon (Figure 6). A screened ball check valve was attached to the end to the hose and served as a foot valve. The total length of suction line was 47 feet. The suction lift to the top of the wharf varied from around 3 feet at high tide to around 9 feet at low tide. A 1½ inch discharge line was



Figure 3. The completed project showing relationship to wharf.

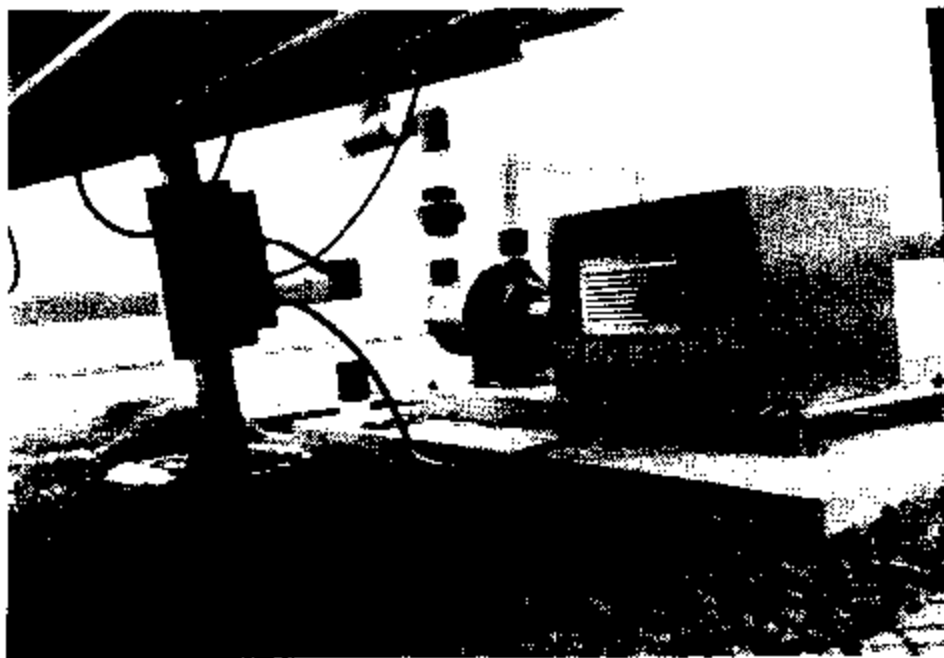


Figure 4. The Maximum Power Controller and pump/motor set.



Figure 5. The completed project showing piping arrangement and relationship to clam growing tanks.



Figure 6. The completed project showing pump suction line extending into lagoon.

used to deliver water to a holding tank approximately 9 feet above the level of the surface of the wharf. The total length of discharge line was 95 feet. Water was discharged to a temporary location at the same elevation as the probable final location in order to facilitate pumping tests. PVC piping was used for both suction and discharge lines.

#### TESTING

The system was tested on three days, August 3, 4, and 17, 1985. The first test was preliminary and provided only flow and head data. The second and third tests were more comprehensive and provided electrical data as well. Test results are given in Tables 1, 2, and 3.

Unfortunately, the test data are limited. However, it is still possible to draw some general conclusions concerning system performance. These should be regarded as tentative and subject to verification by subsequent tests. At noon, at nearly low tide and in clear weather, the system delivers between 20 and 25 gpm (Tables 1 and 3). This performance should occur for at least the 2 hour period from 1100 to 1300. At around 1500, under roughly the same conditions, the flow rate drops to around 12 or 13 gpm (Table 1). Thus, in clear weather, it could be concluded that a flow of at least 10 gpm could be delivered for 6 to 8 hours at low tide. Under hazy conditions at the same tides, the flow is slightly less (Figure 2). Likewise, at high tide, under clear or hazy skies, it can be expected that flow will be correspondingly greater, perhaps up to 30 gpm at optimum conditions.

The test data also reveal the operating characteristics of the MPC. It is seen that, under all cloud conditions, current delivered to the motor is essentially constant. However, the voltage delivered to the motor varies considerably. This occurs while array voltage is essentially constant and array current is varying (proportional to sunlight). Thus, the MPC serves the purpose of changing a constant voltage, varying current source to one with a varying voltage and constant current. This is, of course, what a D.C. motor requires.

The MPC provides another feature. This is a high pulse of current for starting the motor. When the system is turned on, the motor will not turn for around 20 seconds. It will then start and turn fast for 30 seconds or so and will ultimately seek a speed proportional to the available sunlight. This may only be a few rpm in very low light conditions.

It is seen that the use of an MPC or similar device significantly increases the pumping time per day as it permits the pump to turn under all conditions of sunlight, even those when it will turn so slowly that no water will be delivered. In these situations it is recommended that the system be shut down to prolong motor life.

#### CONCLUSIONS

Based on limited testing and observation of the pumping system, it appears to fulfill the design criteria set forth at the beginning of the report. The pump delivers slightly more than the required flow at the

Table 1. Pump test data (August 3, 1985).

Time of Day	Flow Rate (gpm)	Distance to Water	Open Circuit Array Voltage	Array Voltage	Motor Voltage	Motor Current (amps)	Cloud Cover
1200	25.3	7'-0" (estimate)	155			2.5	clear
1445	12.7	8'-8"					clear
1515	10.8	8'-9"					slight haze
1545	5.1	8'-8"					slight haze
1600	no flow	8'-8" (estimate)					haze

Table 2. Pump test data (August 4, 1985).

Time of Day	Flow Rate (gpm)	Distance to Water	Open Circuit Array Voltage	Array Voltage	Motor Voltage	Motor Current (amps)	Cloud Cover
1015	12.3	4'-1"	152	116-126	50	2.2	overcast
1045	8.7	4'-7"	150	116-126	42	2.2	overcast
1115	8.4	5'-1"	153	113-126	43	2.3	heavy overcast
1145	10.6	5'-8"	155	117-129	50	2.4	overcast
1215	14.9	6'-2"	155	117-128	62	2.6	haze
1245	13.7	6'-7"	155	114-128	60	2.6	haze
1315	9.6	7'-2"	154	116-128	48	2.4	heavy haze
1345	11.3	7'-6"	155	118-128	53	2.5	haze
1415	5.7	7'-10"	153	116-129	37	2.5	overcast
1445	no flow	8'-3"	150	116-122	22	2.0	heavy overcast
1515	no flow	8'-5"	151	116-122	22	2.0	heavy overcast

Table 3. Pump test data (August 17, 1985).

Time of Day	Flow Rate (gpm)	Distance to Water	Open Circuit Array Voltage	Array Voltage	Motor Voltage	Motor Current (amps)	Cloud Cover
1210	23.0	7'-6"	151	118-120	79-80	3.3*	clear

\*@80 m W/cm<sup>2</sup>@95 m W/cm<sup>2</sup>, motor current = 3.4 amps



design head and should be able to pump at a reduced rate for 6 to 8 hours per day. The major components of the system do not experience seawater corrosion. Only the motor shaft and flexible coupling showed some sign of rust. However, they will be protected by a stainless steel housing. The only maintenance required is periodic inspection of the motor brushes for wear and their possible replacement. It is expected that the system should be extremely reliable. The MPC, which is the most complex component, has a good track record in installations in undeveloped countries.

The cost of the system, including development and design time but excluding installation time, is approximately \$7,000. The value of the system hardware alone is approximately \$5,000. This is considerably higher than the first cost of a diesel engine with similar performance characteristics. However, the solar system has no operating costs and almost no maintenance. The life span of the solar modules should be in the neighborhood of 20 years, perhaps 4 times the life of a comparable diesel engine. Finally, the aesthetic appeal of the solar system deserves note. It is quiet, clean, and smoke free.

Serious consideration should be given to the use of solar power for seawater pumping systems elsewhere in Micronesia.

#### LITERATURE CITED

- Munro, J. L. and G. A. Heslinga. 1983. Prospects for the commercial cultivation of giant clams (*Bivalvia: Tridacnidae*). *Proceedings of the Gulf and Caribbean Fisheries Institutes*, 35:122-134.
- Heslinga, G. A., O. Orak and F. E. Perron. 1984. Mass culture of giant clams (family *Tridacnidae*) in Palau. *Aquaculture* 39:197-215.
- Heslinga, G. A. In press. Biology and culture of the giant clam. In: Manzi, J., and M. Castagna (eds.), *Clam Culture in North America*. Elsevier, Netherlands.
- Heslinga, G. A. and T. C. Watson. In press. Recent advances in giant clam mariculture. *Proceedings of the Fifth International Coral Reef Congress*.
- Winter, S. J., L. D. McCleary, and R. D. Watters. 1983. The WERI Well on Truk: A solar photovoltaic pumping project. Univ. of Guam, WERI, Tech. Rept. No. 39. v + 27 p.
- Winter, S. J. and L. D. McCleary. 1984. Some improvements in the design of the WERI Well. Univ. of Guam, WERI, Tech. Rept. No. 54. v + 29 p.
- Winter, S. J. and L. D. McCleary. 1985. Solar-powered wells for atoll island water supplies. Univ. of Guam, WERI, Tech. Rept. No. 60. v + 13 p.

## APPENDIX

### Manufacturers' Literature

### Maximum Power Control for Water Pumping

Photovoltaic (PV) power sources and pumping loads are easily mated with the proper electronics. All TriSolar Corp (TSC) pumping systems include a Maximum Power Controller (MPC) which matches the load of the pumpset to varying power available from the solar array. This eliminates the need for batteries, economizes on the array size and provides an efficient, low-maintenance system. The MPC improves motor-starting capability and ensures that the system will yield the maximum amount of water with whatever sunlight is available. Within a broad range, the MPC allows the PV/pump system to be self-optimizing to local conditions of insolation, temperature and head, thus eliminating the need for separate site adjustments.

The MPC automatically down converts the available array voltage from the array maximum-power voltage to a voltage that is proportional to the insolation, while stepping up the current. Thus, the rotational speed of a centrifugal pump or the reciprocating frequency of a jack pump will vary as the sunlight varies, with the result that the current available to the motor remains above the "stall current." This voltage modulation by the MPC allows the pumpset to run as a variable flow-rate system.

#### MPC Functions

For DC motors, the most efficient method of voltage modulation is to use a DC-DC downconverter with a full-load voltage of approximately two-thirds the nominal array maximum-power-point voltage. This allows the one power stage of the MPC to perform five separate functions. The MPC provides:

- 1) Increased starting current at low speed and low insolation when the solar array could not otherwise start the motor;
- 2) Maximum power tracking to maximize motor speed and fluid flow under normal conditions, under varying insolation, head and temperature; as well as
- 3) Current limiting to avoid damage to motor, electronics or other components under stall or jam conditions;
- 4) Over-speed protection in case of broken power train elements; and
- 5) Variable speed cyclic operation at low speeds to match the array to a volumetric pump when a static match would be impossible.

All these functions require three control algorithms in the Maximum Power Controller.

First, a maximum power tracking algorithm to vary the output voltage and motor speed in response to insolation changes and other operating point variations. The algorithm used for the max-power tracking function is realized by one control stage.

Second, a current limiting algorithm which overrides the maximum power tracking when called upon.

Third, an output voltage limiting algorithm which overrides the max-power tracking but may be slower-responding than the current limit.

### Power Stage

The series switching transistor driven at high frequency (20 KHZ) by a pulse width modulator (PWM). This basic power stage has very high efficiency which depends mainly on output voltage level. This is the reason why high system voltages - typically 90 to 150 volts - are chosen. Maximum system voltages are limited by the cost and availability of PV modules and semi conductor switching elements. In general, a separate power stage is used for each array series string.

### MPC Motor Drive

Operation of the Maximum Power Controller as a motor drive is based on two factors:

1. A DC-to-DC downconverter acts as a DC transformer between input and output. Input and output voltages and currents are related as follows (neglecting efficiency factors):

$$V_{out} = DV_{in}$$

$$I_{out} = \frac{I}{D} \underline{in}$$

where D is the duty cycle of the downconverter. Varying the duty cycle gives an impedance transformation between the array and the load.

2. Current output from the downconverter is related to the power drawn from the array by

$$I_{out} = \frac{P}{V} \frac{\underline{array}}{\underline{load}}$$

Since the load voltage is effectively constant for periods of fractions of seconds, the output current is proportional to the array output power over such an interval.

In the TriSolar Corp Maximum Power Controller circuit parameters are set so that, over all array insolation and temperature conditions, the array operates on the short circuit side of the maximum power point for duty cycle near unity and on the open circuit side for duty cycle near zero. Hence, varying the duty cycle from a low to a high value or vice versa will sweep array power and therefore output current through a maximum.

In this design, duty cycle is constantly changing in a linear fashion, and output current is sampled every 80msec. If a sample is larger than its predecessor, the direction of duty cycle change is correct for increasing power and no action is taken. If a sample is less than its predecessor, power from the array has decreased. Upon detecting this occurrence, the duty cycle direction is reversed.

The net consequence of the operation is a smaller dither about the array maximum power point. Since operation for the most part is seldom exactly at the maximum power point, a small loss (less than 1%) is incurred; this loss is more than offset by the increased overall energy output resulting from tracking the maximum power point under all operating conditions. Performance is optimized at all times, particularly during critical winter months.

The physical configuration of TriSolar Corp's electronics is modular, facilitating rapid fault diagnosis and repair. All electronics are packaged in standard weather tight NEMA-4 type enclosures suitable for outdoor installation.

**Power Specifications**

1000 w/m<sup>2</sup>  
AM 1.5 spectrum  
and 25°C (±0.5°C)  
cell temperature

Open Circuit Voltage/Typical	21.7 Volts
Short Circuit Current/Typical	2.7 Amps
Voltage/Typical at Load	17.3 Volts
Current/Typical at Load	2.49 Amps
Module Efficiency/Typical	11.5%
Average Power/Typical Watts @ Test, ±10%	43 Watts/P. Max.

**Module Characteristics**

Electrically matched single-crystal silicon solar cells.

Fault tolerant, multiple redundant contacts on each cell for circuit reliability.

Nominal operating cell temperature (NOCT) 47°C/50°C (black version).

Service Temperature conditions of -40°C to +90°C, 0 to 100 percent humidity.

Computer designed cell grid pattern for high conductivity.

Cells chemically textured for anti-reflection enhancement.

Two by-pass diodes. Each by-passes 24 cells, with 12 cell overlap.

Tempered anti-reflective glass front.

Specular reflection by inside of front glass.

Efficient conversion of both direct and diffuse light.

Polymeric encapsulant.

Multiple-layer protective coating behind cells.

Interlocking aluminum side rails—(black anodized optional).

External grounding screw.

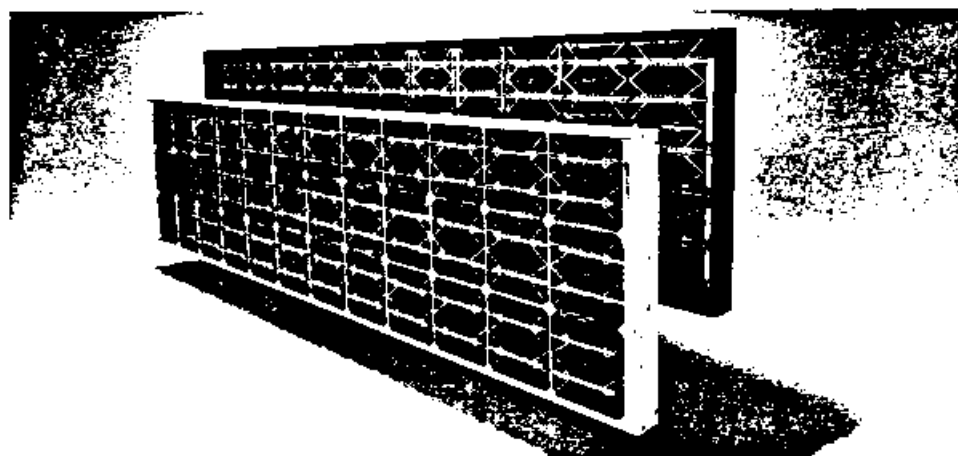
Module surface promotes self-cleaning by natural processes (rain, wind, etc.)

Junction boxes designed for easy wiring access.

Module leakage current of less than 50µA at 3000 VDC.

Ground continuity of less than 1 ohm for all metallic surfaces.

# M53 Photovoltaic Module



148 in./121.9 cm  
12 in./30.5 cm  
C Depth: 1.5 in./3.8 cm  
2.4 in./6.1 cm including  
Junction Box



## New High Efficiency Square Cells

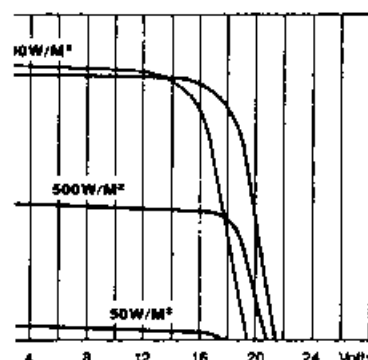
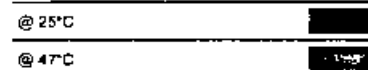
The ARCO Solar M53 is a nominal 43 watt photovoltaic (solar electric) module; it is the first ARCO Solar module to utilize our high efficiency single-crystal silicon square cells. The M53 continues to maintain the quality and features that have established ARCO Solar modules as an industry standard, and also incorporates many new features. These innovations make it an even more efficient, reliable and durable solar module well suited for a wide variety of applications—large and small.

The M53 is available either with regular aluminum frame and white backing, or with black anodized aluminum frame and black backing. The M53 is physically and electrically compatible with existing ARCO Solar systems.

Each of the M53's 36 series-connected solar cells produces over 2.4 amps\*. Overall module efficiency is greater than 11.5% due to the denser packing allowed by the square cells. Multiple redundant connections on the front and back of each cell help assure module circuit reliability, and by using single-crystal silicon cells, the module can produce power in as little as 5% of noon sun. Two by-pass diodes are wired into each module to reduce potential power loss from partial shading of a single module within an array.

## Module Characteristics

The (current vs. voltage) below demonstrates typical response to various light levels at 25°C cell temperature and at the NOCT (Nominal Cell Operating Temperature), 47°C.



## Specialized Construction

The M53 utilizes our highest standard of glass laminate construction. This enables it to withstand some of the harshest environments and continue to perform efficiently. This same standard of construction has allowed other ARCO Solar modules to meet the design, performance and durability requirements of the U.S. Department of Energy and pass additional, more stringent, ARCO Solar tests. Solar cells are permanently laminated between special anti-reflective tempered glass and EVA, backed by multiple layers of polymeric protection. This weather-proof package is then sealed by a neoprene edge-gasket and supported by a rugged lightweight aluminum frame.

There are two environmentally sealed junction boxes on each module, one for positive and one for negative termination. Each junction box contains dual terminations, a wired-in by-pass diode and two additional non-active termination posts. Designed for easy wiring access, the junction boxes accept standard 3/4" flexible conduit or our Standard Interconnect Wire (SIW) and grommets. Junction boxes are securely attached to the module frame with screws and to the module backing with adhesive.

## D. C. MOTOR INSTALLATION AND MAINTENANCE

**INSPECTION:** Examine the motor for possible damage in shipment. Check the brush springs to see that they bear properly on the brush pressure plate, and be sure the shaft turns freely by hand. Check the nameplate voltage to be sure it agrees with power supply.

**INSTALLATION:** Motor should be mounted on a firm foundation. If foundation is not flat, shims should be used to prevent strains when tightening hold-down bolts. All Baldor motors are equipped with ball bearings and may be operated in any position, however, shaft-up mounting should be avoided when possible. Location should be dry, clean and well ventilated for most satisfactory service. Be sure possibility of oil seepage into the motor is prevented. Commutator end of motor should be accessible so that brushes can be conveniently inspected.

**ALIGNMENT:** Shafts should be carefully aligned with a straight edge before tightening any couplings. Remove paint, dirt and burrs from shaft. If necessary use file or reamer for proper fit. Pulley or coupling should be carefully fitted so as to easily slip on shaft. Self-aligning couplings are recommended. Do not hammer on shaft, pulley or coupling.

**CONNECTIONS:** If the motor is part of an SCR drive system, refer to the control manufacturer's diagrams and installation data. If the motor is shunt wound and not part of an SCR control system, a proper resistance starter should be used. For protection, use a fuse or circuit breaker rated at 125% of full load amperage on the nameplate. If the motor is a series or compound wound motor, refer to the connection data tag attached to the motor. If the motor is a component part of a piece of equipment, be sure to refer to the Original Equipment Manufacturer's electrical circuit information for proper connection.

**BEARINGS:** Baldor D. C. Motors have prelubricated and permanently sealed ball bearings. The lubrication is sufficient for the life of the bearing. When bearings become worn they will produce excessive noise, which is a warning that bearings should be replaced. They should be replaced in the following manner. Pull brushes out of brush holder. Remove pulley end bell withdrawing armature. While the motor is disassembled, take the opportunity to blow out brush dust residue. Pull off bearings by means of bearing puller, taking care not to mar center in end of shaft. The new bearing is pushed on the shaft gently by pressure on the Inner Race or by tapping gently on the Inner Race. See that no dirt enters the bearing housing. Reassemble motor, taking care that the bearing shims are properly assembled so that the brushes ride properly on the commutator.

**BRUSHES:** Periodically, the brushes should be inspected and the brush dust blown out of the motor. If the length has been worn down 1/2" from the original length shown on Page 11, the brushes should be replaced. If at this time the commutator is worn or rough, the armature should be removed. The commutator should be turned in a lathe, the mica recut, and commutator polished. Reassemble, and seat the new brushes using a brush seating stone. Be sure the rocker arm is set on the neutral mark.

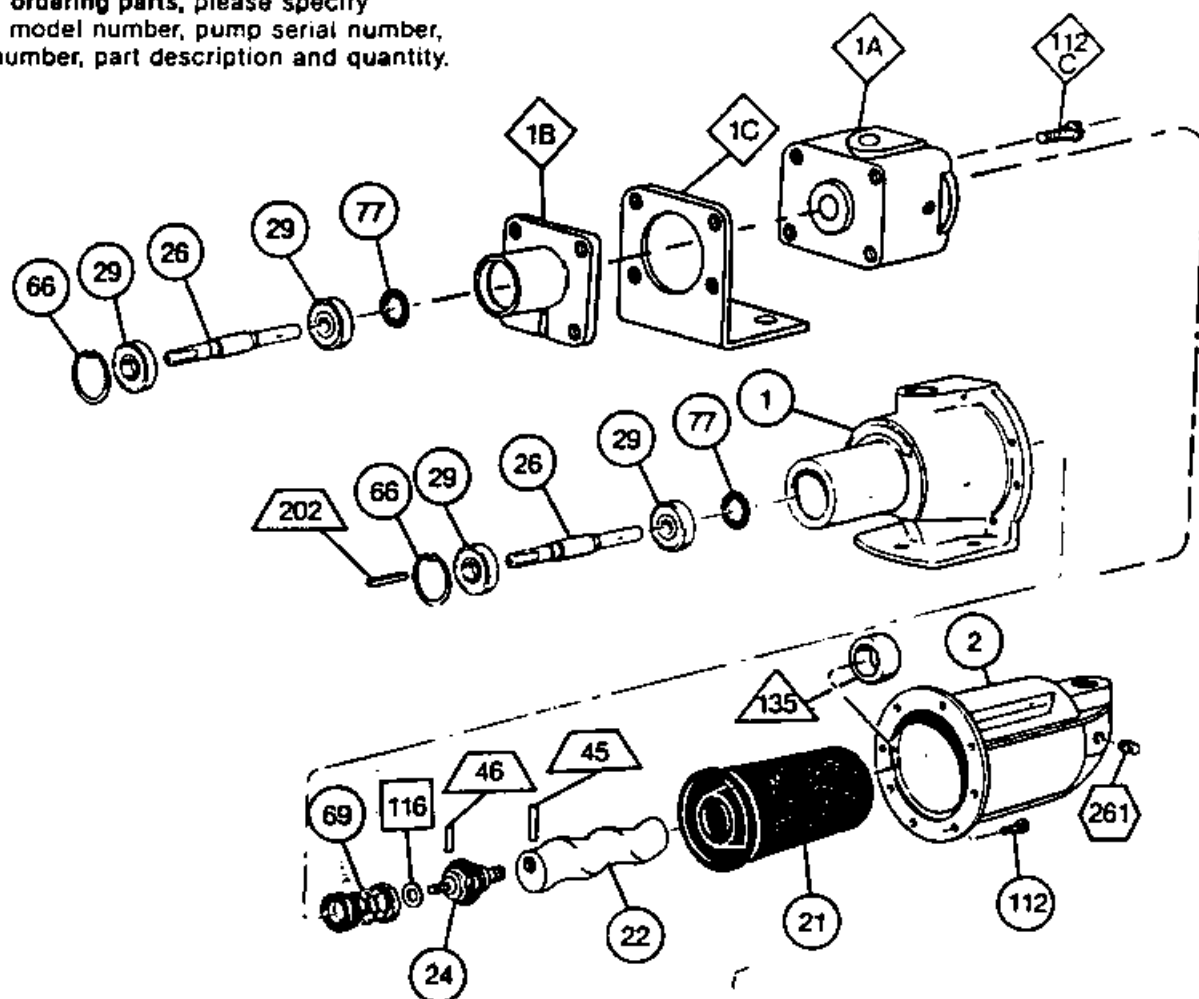
**REPAIRS:** Unless the maintenance man is properly qualified, it is advisable that the repair work be done at a qualified service station. When ordering replacement parts, give Complete Nameplate Data.

### BALDOR®

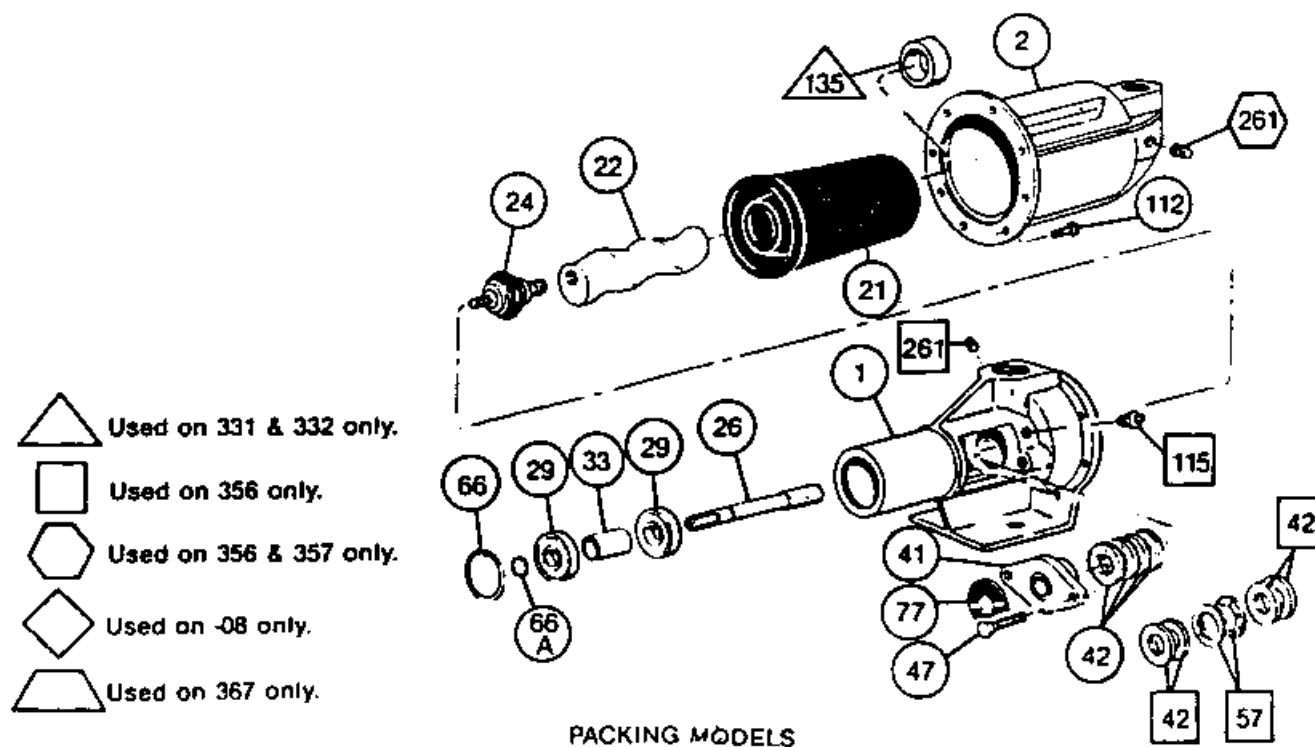
PHONE 501-648-4711  
TELEX 527425 - TWX 910-773-7850  
FORT SMITH, ARKANSAS 72902



When ordering parts, please specify pump model number, pump serial number, part number, part description and quantity.



### MECHANICAL SEAL MODELS



### PACKING MODELS

BALDOR MOTOR Model number: 34 5017 3662

3/4HP 90V 1750 RPM 7.0 Amps Fram 56 428p

Ser. F. 1.00 Class B

Rating 40°C amb-cont

Ser. no. W284

**Note:** When replacing bearings, always press on the inner race when assembling to shaft, and on the outer race when pressing bearings into the housings.

2. Press shaft assembly into pump body (1) securing with snap ring (66).
3. Install mechanical seal (69) using the following procedure:
  - a. Clean and oil sealing faces using a clean light oil (not grease).

**Caution:** Do not use oil on EPDM parts. Substitute glycerin or soap and water.

- b. Oil the outer surface of the seal seat, and push the assembly into the bore in the pump body (1), seating it firmly and squarely.
  - c. After cleaning and oiling the shaft, slide the seal body along the shaft until it meets the seal seat.
  - d. Install seal spring and spring retainer on shaft.
4. Thread flexible joint (24) into shaft (26) in a clockwise direction (RH thread). On Model 356, install seal spacer (69A) and washer (116) before threading flexible joint onto shaft in a clockwise direction. On Model 367, use shaft pin (46) to pin flexible joint (24) to shaft.
5. Thread rotor (22) onto flexible joint (24) in a clockwise direction (RH thread). On Model 367, pin rotor (22) to joint using rotor pin (45).
6. Slide stator (21) on rotor (22). On Models 331 and 332, insert rounded end of stator ring (135) into end of stator prior to installing stator on rotor.
7. Secure stator (21) and suction housing (2), with suction port vertically up, to pump body (1) using screws (112).
8. Proceed as in installation instructions.

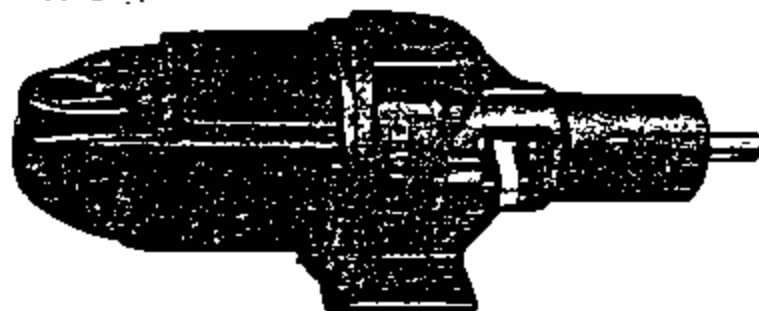
## SERVICE MANUAL

# MOYNO® SP PUMPS

### SERIES 300

DESIGN FEATURES	33101 34401 33201 35601 33301 36701	33104 34404 33204 35604 33304	33108 33308 33208 34408	34411 35611	35613
Housing:	Cast Iron	AISI 316 SS	Nylon	Cast Iron	AISI 316 SS
Pump Rotor:	Chrome plated 416 SS	Chrome plated 316 SS	Chrome plated 416 SS	Chrome plated 416 SS	Chrome plated 316 SS
Pump Stator:	NBR (Nitrile)	NBR (Nitrile)	NBR (Nitrile)	NBR (Nitrile)	NBR (Nitrile)
Shaft:	416 SS	316 SS	416 SS	416 SS	316 SS
Flexible Joint:	Carbon steel/ NBR	316 SS/ NBR	Carbon steel/ NBR	Carbon steel/ NBR	316 SS/ NBR
Bearings:	Ball (sealed)	Ball (sealed)	Ball (sealed)	Ball (sealed)	Ball (sealed)
Mechanical Seal:	Carbon-ceramic	Carbon-ceramic	Carbon-ceramic	---	---
Packing:	---	---	---	Graphite impregnated asbestos	Graphite impregnated asbestos

Note: Alternate elastomers available. Refer to Repair/Conversion kit numbers, pages 6 and 7.



## INSTALLATION

**Mounting Position.** Pump may be mounted in any position. When mounting vertically, it is necessary to repack bearings above seals to prevent possible seal leakage into bearings.

**Pre-Wetting.** Prior to connecting pump, wet pump elements and mechanical seal or packing by adding fluid to be pumped into suction and discharge ports. Turn shaft several times in a clockwise direction to work fluid into elements.

**Piping.** Piping to pump should be self-supporting to avoid excessive strain on pump housings. See Table 1 for suction and discharge port sizes of each pump model. Use pipe "dope" or tape to facilitate disassembly and to provide seal.

**Belt Driven Units.** On belt driven units, adjust belt tension to point non-slip. Do not overtighten.

**Direct Drive Units.** On direct drive units, coupling components should be aligned and spaced at least 1/16" apart.

**Rotation.** Pump rotation must be clockwise when facing shaft to prevent damage to pump. Check direction of rotation before startup.

**Flush of Packing (356 Models Only).** The packing may be either grease lubricated through a grease fitting in the stuffing box or have plumbing connected to the stuffing to allow a water flush.

Maximum speed is 1750 rpm.

When the material being pumped is abrasive in nature, it may be advantageous to flush the packing to prevent leakage under packing and excessive shaft wear.

Clean water can be injected through a 1/8" NPT tapped hole that normally houses the grease fitting for lubricating the packing. The water can be permitted to leak axially along the shaft in either direction or can be removed from the second tapped hole in the stuffing box. In both cases, the discharge from the stuffing box should be throttled slightly to maintain 10-15 PSI higher pressure in the stuffing box than is present in the suction housing.

Table 1. Pump Data

Pump Series	331	332	333	344	356	367
Suction Port (NPT)	3/4"	3/4"	3/4"	3/4"	1-1/2"	2"
Discharge Port (NPT)	3/4"	3/4"	3/4"	3/4"	1-1/4"	2"
Discharge Pressure (psig)	150	100	50	40	50	50

38 versions = 1" NPT

Table 2. Temperature Limits

Elastomer	Temperature Limits
*NBR	10°-160°F
*EPDM	10°-210°F
*FPM	10°-240°F

\*NBR = Nitrile

EPDM = Ethylene-Propylene-Diene Terpolymer

FPM = Fluoroelastomer

## OPERATION

**Self-Priming.** With wetted pumping elements, the pump is capable of 25 feet of suction lift when operating at 1750 rpm with pipe size equal to port size.

**DO NOT RUN DRY.** Unit depends on liquid pumped for lubrication. For proper lubrication, flow rate should be at least 10% of rated capacity.

**Pressure and Temperature Limits.** See Table 1 for maximum discharge pressure of each model. Unit is suitable for service at temperatures shown in Table 2.

**Storage.** Always drain pump for extended storage periods by removing suction housing bolts and loosening suction housing.

## TROUBLE SHOOTING

**WARNING:** Before making adjustments, disconnect power source and thoroughly bleed pressure from system. Failure to do so could result in electric shock or serious bodily harm.

### Failure To Pump.

1. Belt or coupling slip: Adjust belt tension or tighten set screw on coupling.
2. Stator torn; possibly excessive pressure: Replace stator, check pressure at discharge port.
3. Wrong rotation: Rotation must be clockwise when facing shaft.
4. Threads in rotor or on shaft stripped: Replace part. Check for proper rotation.
5. Excessive suction lift or vacuum.

### Pump Overloads.

1. Excessive discharge pressure: Check discharge pressure for maximum rating given in Table 1. Check for obstruction in discharge pipe.
2. Fluid viscosity too high: Limit fluid viscosity to 20,000 CP or 100,000 SSU.

Viscosity CP	Limit RPM
1-300	1750
300-1,000	1200
1,000-2,000	700
2,000-5,000	350
5,000-10,000	180
10,000-20,000	100

3. Insufficient motor HP: Check HP requirement.

### Noisy Operation.

1. Starved suction: Check fluid supply, length of suction line, and obstructions in pipe.
2. Bearings worn: Replace parts; check alignment, belt tension, pressure at discharge port.
3. Broken flexible joint: Replace part, check pressure at discharge port.
4. Insufficient mounting: Mount to be secure to firm base. Vibration induced noise can be reduced by using mount pads and short sections of hose on suction and discharge ports.

### Mechanical Seal Leakage (Mechanical Seal Models Only)

1. Leakage at startup: If leakage is slight, allow pump to run several hours to let faces run in.
2. Persistent seal leakage: Faces may be cracked if freezing or thermal shock. Replace seal.

### Pump Will Not Prime.

1. Air leak on suction side: Check pipe connections.

## MAINTENANCE

**General.** These pumps have been designed for minimum of maintenance, the extent of which is routine lubrication and adjustment of packing. The pump is of the easiest to work on in that the main elements are very accessible and require few tools to disassemble.

## PUMP ASSEMBLY

**To Assemble Mechanical Seal Models:**

1. Press bearings (29) on shaft (26), and locate slip ring (77) near bearing on threaded end of shaft.

## PUMP DISASSEMBLY

**WARNING:** Before disassembling pump, disconnect power source and thoroughly bleed pressure from system. Failure to do so could result in electric shock or serious bodily harm.

**To Disassemble Mechanical Seal Models:**

1. Disconnect suction and discharge piping.
2. Remove screws (112) holding suction housing (2) to pump body (1). Remove suction housing and stator (3).
3. Remove rotor (22) from flexible joint (24) by turn counter-clockwise (RH thread). Use 3/16 inch diameter punch to remove rotor pin (45) on Model 367.
4. Flexible joint (24) can be removed from shaft (26) using a 3/16 inch allen wrench in end of joint (1/4 inch wrench on Model 356) and turn counter-clockwise. Use 3/16 inch diameter punch to remove shaft pin (46) on Model 367.
5. Carefully slide mechanical seal (69) off shaft (26). Carefully pry seal seat out of pump body (1). If any parts of mechanical seal are worn or broken, the complete seal assembly should be replaced. Seal components are matched parts and are not interchangeable.
6. The bearings (29) and shaft (26) assembly can be removed from pump body (1) after snap ring (66) has been removed. To remove the assembly, lightly tap shaft at threaded end using a block of wood to protect the threads. The bearings may be pressed off shaft.