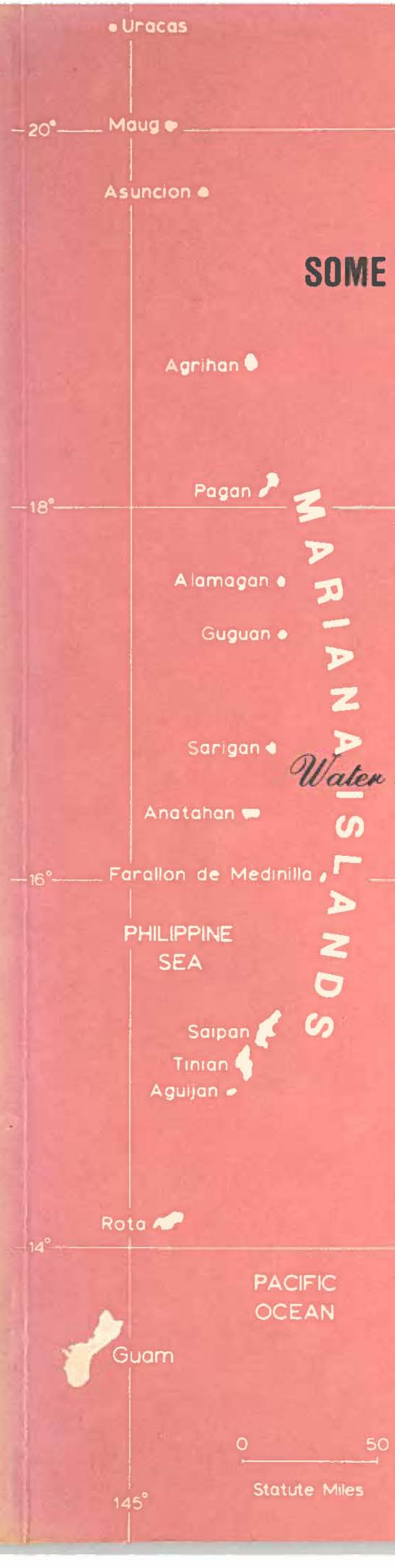

SOME IMPROVEMENTS IN THE DESIGN OF THE WERI WELL

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Technical Report No. 54

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INTRODUCTION

A previous report (Winter, McCleary, and Watters, 1983) described the development, design, and installation procedures for a small shallow well, affectionately dubbed the "WERI Well". These wells were developed as part of a program to improve fresh water supplies in rural areas of Truk. They were designed for use on atoll islands or on low flat sandy coastal areas of high islands. Efforts were made to keep the design of the well extremely simple both to minimize the need for maintenance and to simplify the installation.

The wells utilize a small submersible marine bilge pump that is connected directly to two 30 watt solar modules. No batteries are used. The design pumping rate is one gallon per minute at 16 ft head (from water table to top of storage tank). The construction details of the well are given in Figure 1. A list of material is given in Table 1.

Within the past year approximately 50 wells of this design have been installed throughout the islands of Truk. In general, the wells have performed satisfactorily. However, three problems have occurred that are considered to be significant:

1. Many pumps have failed, sometimes as soon as three months after installation.

2. The well is relatively expensive, primarily because two solar modules were required in order to achieve the desired head.

3. Installation sometimes took considerable time because of difficulty in obtaining the required amount of aggregate for backfilling the well.

OBJECTIVE

In an effort to find solutions to the foregoing problems, a program of laboratory and field testing was undertaken. The objective of this report is to describe the results of these tests and to utilize them to make recommendations for improvements in the design of the well.

TEST METHODS AND RESULTS

Pump Head Test

In an effort to quickly ascertain which small (less than 500 gal/hr) commercially available marine bilge pumps would be suitable for use in the WERI Well, a one-time test of head delivered at 1 gpm was made for three sizes of solar modules. A hoped-for result of this test was to find a pump that would deliver greater head than the existing Rule pump. The results

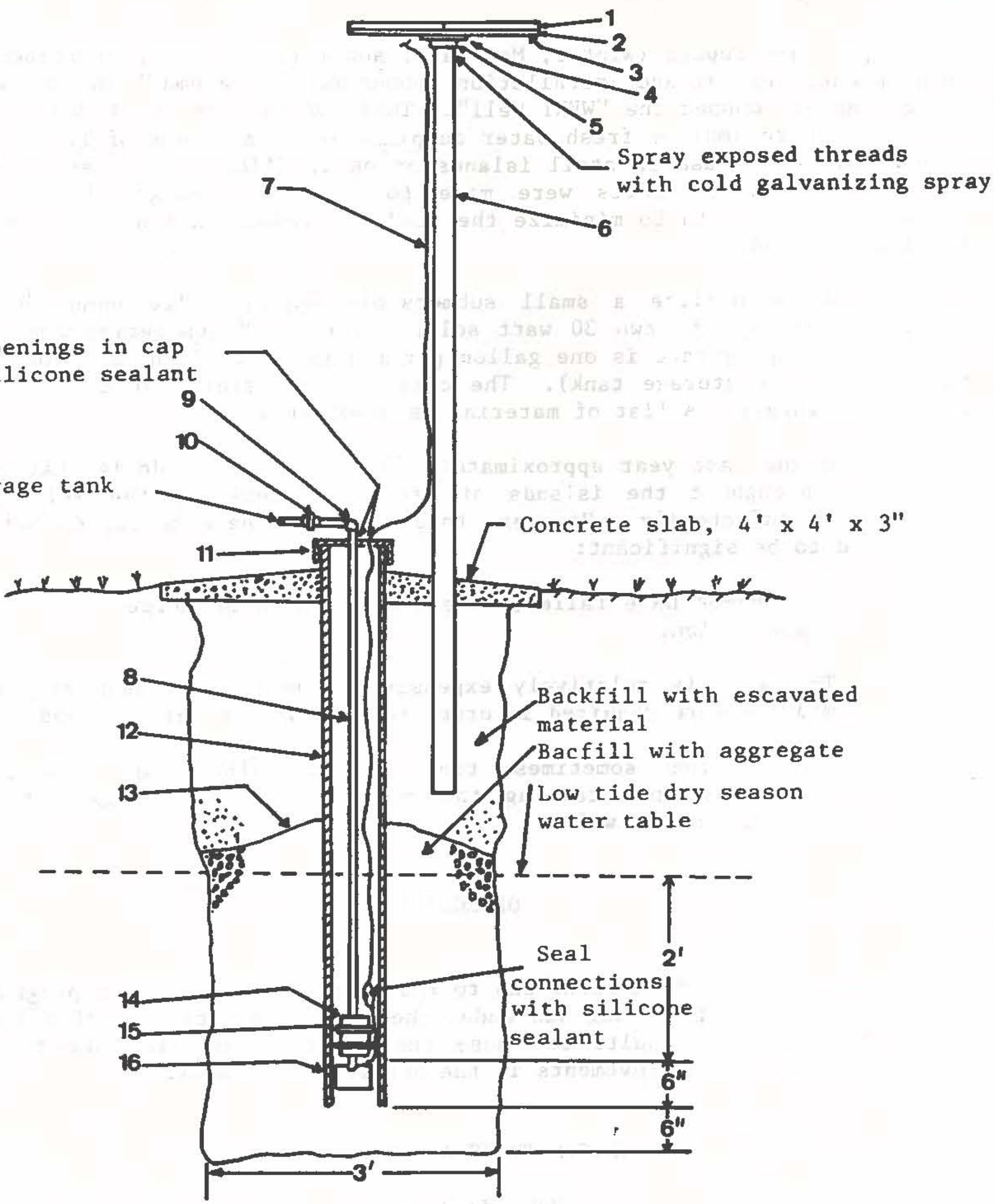


Figure 1. Assembly drawing of the "WERI Well" (not to scale). Refer to Table 1 for a descriptional of parts of the well.

Table 1. List of material for the "WERI Well".

Item No.	Quantity	Description	Function
1	2	28 watt solar module, SPC LG160-12	generates 12v electricity from sunlight
2	1	2'x4'x½" marine plywood, treated & painted	mounting for solar modules
3	8	1/4" x 20 x 1" long, aluminum hex head cap screws, nuts, and washers	fastens solar modules to plywood mounting
4	5	1/4" x 20 x 1½" long glavanized carriage bolts, nuts, and washers	fastens plywood mounting to flange
5	1	2" galvanized steel floor flange	connects 2" pipe to solar module assembly
6	10' provided	2" galvanized steel water pipe (threaded on one end)	support for solar module assembly
7	20' provided	16-2 stranded wire	connects pump and solar module
8	40' provided	½" PVC water pipe	connects pump to storage tank (not shown)
9	6 provided	½" PVC elbow (socket ends)	provides for changes in pipe direction
10	1	½" PVC union (socket ends)	permits easy assembly and disassembly of well
11	1	6" PVC end cap	protects well from contamination
12	10' provided	6" PVC pipe	well casing
13	1	plastic sheet	prevents sand from entering aggregate
14	1	1" diameter x 6" long rubber hose	connects pump to ½" PVC pipe
15	2	1" stainless steel hose clamp	clamps hose to pipe and pump
16	1	Rule 400 gph pump	pumps water from well

of this test are shown in Table 2 and indicate that only the Teel pump delivers greater head than the Rule, 20.6 ft vs. 14.8 ft for the 35 watt module. Consequently, the other pumps that were tested were not considered further.

It was noted in this test that pump output was essentially the same using the 35 and 40 watt solar modules. This effect was also observed in the pump characteric curve tests described later. Possibly this effect was the result of an under rated 35 watt module and/or an over rated 40 watt module.

This test and later tests to develop pump characteristic curves were performed on the same apparatus. It is shown in Figure 2 and consists of a square container (holding approximately 30 gallons) and a panel on which two Dwyer flow meters and a U.S. Gage 0 to 10 psi pressure gage are mounted. The pump to be tested is connected by means of a 4 inch length of hose to a pipe submerged in the water container. Head is regulated by valves in the flow meters and measured with the pressure gage which is installed upstream of the meters. One meter measures flow from 0 to 1 gpm and the other from 1 to 10 gpm. Water discharges from the rear of the meters into the container.

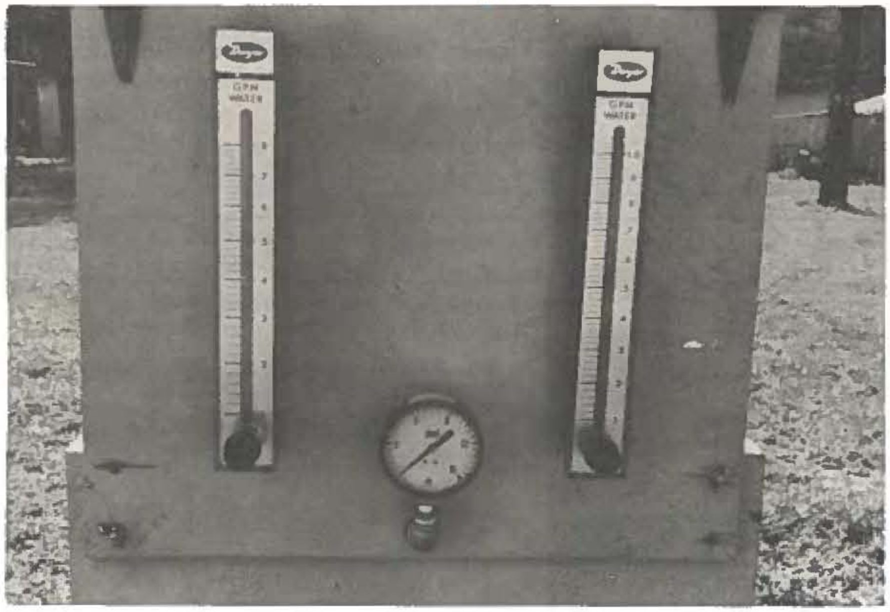
Pump Accelerated Life Test

An estimate of the life-expectancy of the Rule and Teel pumps was made by continuous running of the pumps with a 12 volt power supply. Assuming that field operation is for 6 hours per day (9 am to 3 pm --- the hours of bright sun), 1 day of laboratory operation is equivalent to 4 days of field operation.

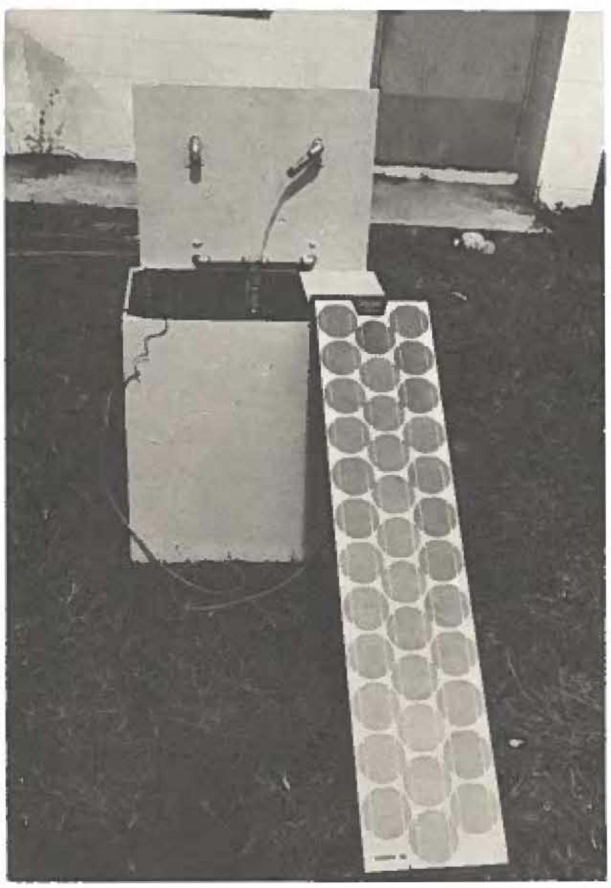
Four Teel pumps and two Rule pumps were tested. The results of the tests are given in Table 3. The Rule pumps failed after 31 and 45 days, equivalent to 124 and 180 days of field operation (4 and 6 months). This agrees very well with field observations where pumps typically fail within 3 to 9 months. The larger variation in the field is probably due to shading and/or weather conditions.

The Teel pumps did not perform well, two of the four pumps failing after only a few days because of improperly installed "O" rings. The other two Teel pumps failed after 12 and 18 days, significantly quicker than the Rules. Consequently, even though the Teel delivers a greater head, its lower life expectancy renders it unsatisfactory for normal use in the WERI Well.

The test apparatus for the accelerated life test consists of a long waterproof box (approximately 6 ft long x 1 ft wide x 1 1/2 ft deep) with provision for testing 6 pumps simultaneously. The pumps being tested are mounted such that they draw water from near the bottom of the box and



front view showing gages



rear view showing piping
and module being tested

Figure 2. Characteristic curve test apparatus.

Table 2. Results of the head test (feet of head delivered at 1 gallon per minute).

		Solar Module		
		SPC* 30 watt	SPC 35 watt	SPC 40 watt
Pump	Rule 400	12.2	14.8	14.8
	Teel #1P811A	16.2	20.6	21.0
	Atwood 360	4.2	--	4.9
	Atwood 500	4.2	7.9	7.9
	1st Mate #1250	9.7	12.7	12.7

*Solar Power Corporation

Table 3. Results of the accelerated life test.

Pump	Date test began	Date pump failed	Days of operation	Cause of failure
Rule 400	5-23-84	7-7-84	45	1 brush worn out
"	6-6-84	7-7-84	31	"
Teel #1P811A	5-23-84	6-4-84	12	brushes worn out/ leakage
"	6-5-84	6-6-84	1	leakage at "O" ring
"	"	6-7-84	2	"
"	"	6-23-84	18	brushes worn out

discharge it above the water level. In this manner, it is easy to visually ascertain when a pump has failed. Power for the pumps is supplied by a VHF Engineering Model PS 25M 12 volt power supply. The apparatus is shown in Figure 3.

Characteristic Curve Tests

Pump characteristic curve tests were conducted in an effort to gain a thorough understanding of the performance of the Rule pump. The tests were performed using 30, 35, and 40 watt modules. Five sets of tests were performed for these modules on separate days between the hours of 11 am and 1 pm. There was no obvious correlation between the time of day and module output or pump performance.

Each test resulted in a pump characteristic curve (head vs. flow) and a performance curve (current vs. voltage) for the module. The results of each test are given in the Appendix. The averages of the test results for each module are given in Tables 4 and 5. The pump characteristic curves resulting from the average values are given in Figure 4 and the module performance curves for the average values are given in Figure 5. As previously noted, there is no significant difference between the results for the 35 and 40 watt modules.

Data for current and voltage were also recorded during the characteristic curve tests. These data were superimposed on the portion of the module performance curve the pump was operating at. In all tests, the pump operated on the "knee" of the curve, indicating a good match between module and pump motor characteristics. This information is shown on the module performance curves given in Figure 5.

The pump characteristic curves confirm the information given in the pump head tests. At one gpm, a 30 watt module can provide approximately 13 ft of head, a 35 watt module 15 ft, and a 40 watt module also 15 ft. At greater flow rates, the heads delivered decrease.

Well Casing Test

In an attempt to reduce installation time, a well casing was designed such that the hole for the well could be filled with excavated material rather than aggregate. A well using the modified casing was constructed and the drawdown and recovery of the well measured by means of a field test.

A 2 ft diameter hole was dug in the center of a small (6 acre) coralline island situated in the Truk lagoon. The water table was reached at an approximate depth of 6 ft below the ground surface. The hole was dug further to an additional 2 ft below the water table.

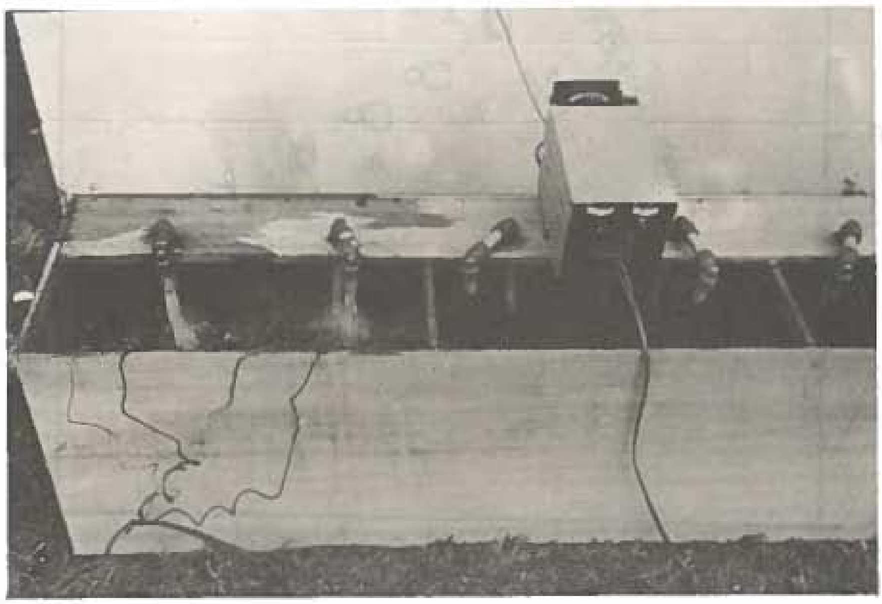


Figure 3. Accelerated life test apparatus.

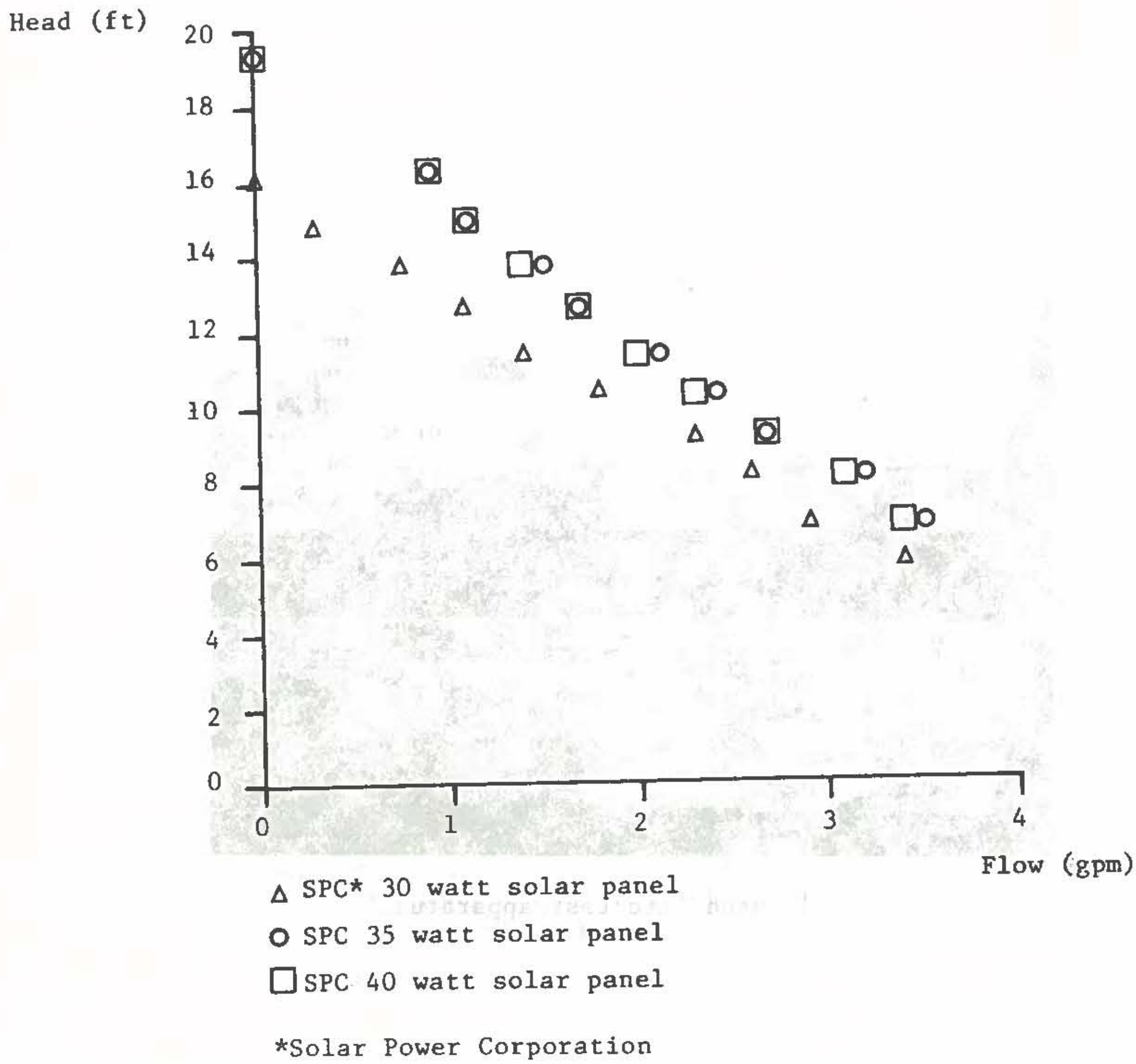


Figure 4. Average pump characteristic curves for the Rule 400 pump.

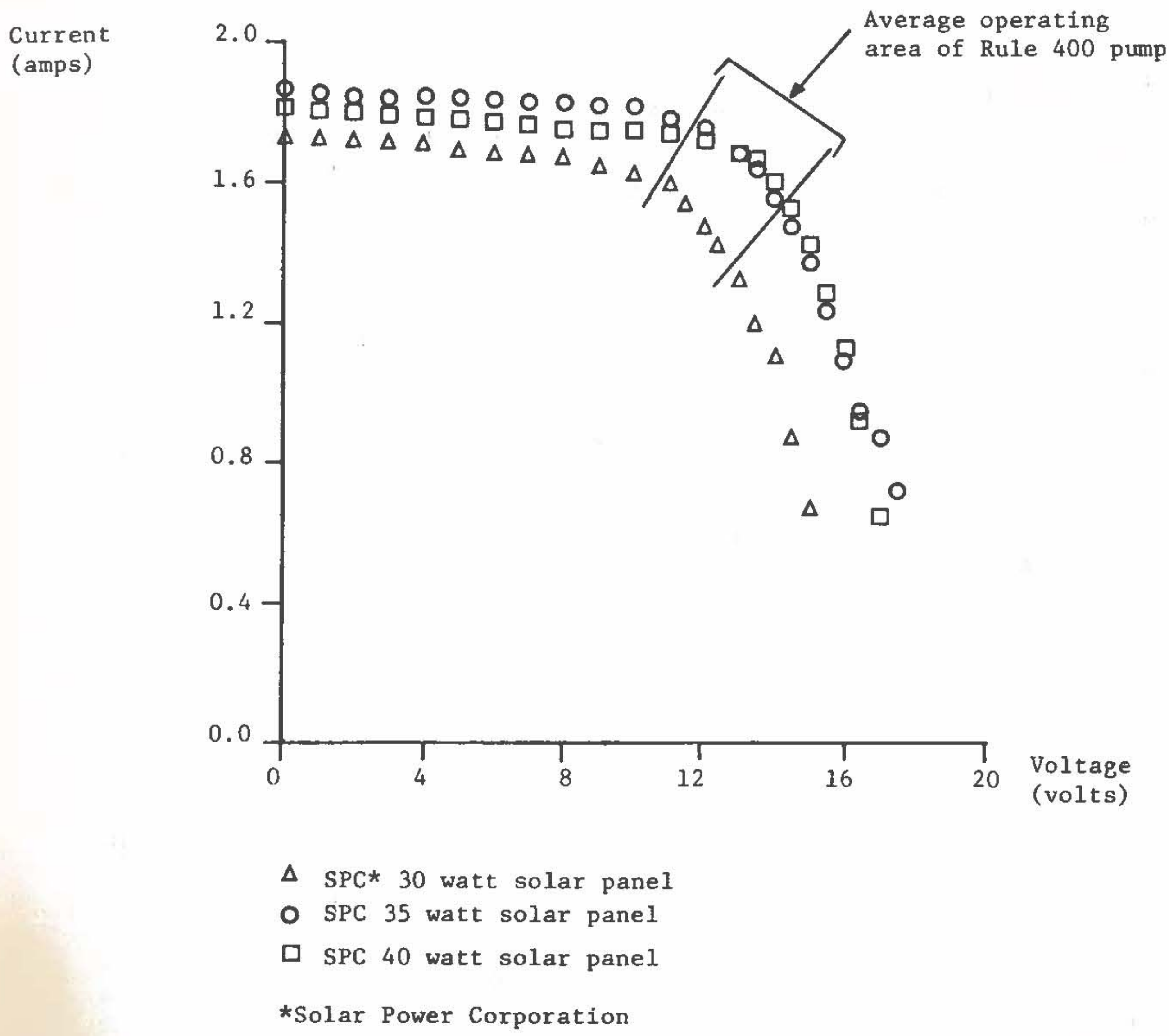


Figure 5. Average solar module performance curves.

Table 4. Average results of the characteristic curve test results for the Rule 400 pump.

SPC* 30 watt					SPC 35 watt					SPC 40 watt				
Head Psi	Flow ft.	Flow gpm	Current amps	Voltage volts	Head Psi	Flow ft.	Flow gpm	Current amps	Voltage volts	Head Psi	Flow ft.	Flow gpm	Current amps	Voltage volts
7.0	16.2	0	1.39	12.9	8.3	19.2	0	1.54	14.1	8.3	19.2	0	1.57	14.1
6.5	15.0	.43	1.41	12.6	7.0	16.2	.88	1.60	13.7	7.0	16.2	.86	1.62	13.8
6.0	13.8	.78	1.44	12.4	6.5	15.0	1.1	1.61	13.6	6.5	15.0	1.1	1.63	13.6
5.5	12.7	1.1	1.46	12.3	6.0	13.8	1.5	1.63	13.4	6.0	13.8	1.4	1.65	13.5
5.0	11.5	1.4	1.48	12.2	5.5	12.7	1.7	1.65	13.3	5.5	12.7	1.7	1.67	13.3
4.5	10.4	1.8	1.50	12.0	5.0	11.5	2.1	1.66	13.1	5.0	11.5	2.0	1.67	13.1
4.0	9.2	2.1	1.52	11.8	4.5	10.4	2.4	1.68	12.9	4.5	10.4	2.3	1.69	13.0
3.5	8.1	2.6	1.53	11.6	4.0	9.2	2.7	1.70	12.7	4.0	9.2	2.7	1.70	12.7
3.0	6.9	2.9	1.55	11.5	3.5	8.1	3.2	1.71	12.6	3.5	8.1	3.1	1.71	12.5
2.5	5.8	3.4	1.57	11.3	3.0	6.9	3.5	1.72	12.4	3.0	6.9	3.4	1.71	12.4

*Solar Power Corporation

Table 5. Average results of the solar module performance test.

SPC* 30 watt		SPC 35 watt		SPC 40 watt	
Current amps	Voltage volts	Current amps	Voltage volts	Current amps	Voltage volts
0	16.4	0	18.4	0	18.2
.68	15.0	.72	17.5	.66	17.0
.87	14.5	.88	17.0	.93	16.5
1.05	14.0	.95	16.5	1.12	16.0
1.19	13.5	1.10	16.0	1.29	15.5
1.31	13.0	1.25	15.5	1.42	15.0
1.41	12.5	1.38	15.0	1.52	14.5
1.48	12.0	1.48	14.5	1.60	14.0
1.54	11.5	1.56	14.0	1.66	13.5
1.58	11.0	1.63	13.5	1.69	13.0
1.63	10.0	1.69	13.0	1.73	12.0
1.65	9.0	1.76	12.0	1.75	11.0
1.68	8.0	1.79	11.0	1.76	10.0
1.68	7.0	1.81	10.0	1.76	9.0
1.69	6.0	1.81	9.0	1.76	8.0
1.70	5.0	1.82	8.0	1.77	7.0
1.71	4.0	1.83	7.0	1.78	6.0
1.71	3.0	1.83	6.0	1.78	5.0
1.71	2.0	1.84	5.0	1.79	4.0
1.72	1.0	1.85	4.0	1.79	3.0
1.72	0	1.85	3.0	1.80	2.0
		1.86	2.0	1.80	1.0
		1.86	1.0	1.81	0
		1.86	0		

*Solar Power Corporation

After passing the root zone (approximately 3 ft below the ground surface), the sand was very clean. The sand below the water table was coarser than the sand above.

A piece of 6 in PVC pipe was perforated by drilling 1/4 in diameter holes approximately 1 in apart in the portion of the pipe between 6 in and 1 ft from its bottom (Figure 6). A pipe cap was forced onto the end of the pipe (gluing was not necessary as the fit was very tight) and six layers of fiberglass window screen were wrapped around the perforated portion of the pipe and held in place with copper wire (Figure 7). The well casing pipe was placed in the bottom of the hole and the hole backfilled, making an effort to replace the excavated sand in the same strata it was obtained from and taking care not to damage the fiberglass screen with rocks.

A Rule 400 pump powered by a single Solar Power Corporation 30 watt module was used for the perforated casing tests (Figure 8). The pump was run continuously for at least 30 minutes before each recovery measurement in an effort to insure that the water had reached an equilibrium level in the well casing. The depth of water in the well casing was measured initially while the pump was on and then at 5 minute intervals after the pump was turned off. For the three tests conducted, drawdown varied from 1/2 in to 1 5/8 in, with complete recovery to the initial depth after 5 minutes (Table 5).

There appears to be no problem with sand entering the well casing through the screen. Some fine particles of sand were observed in the G.I. cans into which water was pumped. These either passed through the pump or were in the cans initially. It is expected that any sand particles that pass through the 6 layers of screen will be small and light enough to pass through the pump.

Water level was measured by marking on a long slender rod lowered into the well and by subsequently measuring from the end of the rod to the marks. Flow rates were measured by noting the time to fill a bucket of known volume (1 7/8 gal).

DISCUSSION AND RECOMMENDATIONS

Only two pumps, the Rule and the Teel, produce heads that are usable. Perhaps the 1st Mate might have application in a low head situation. The Teel pump has very poor life expectancy, leaving only the Rule as a serious candidate for consideration for use in the WERI Well. The Teel pump might have application in a high head application where only occasional use is called for.

Since the Rule is the pump that is presently used and its failure rate is already too high, additional methods of increasing its life expectancy

Figure 6. Perforated portion of well casing.

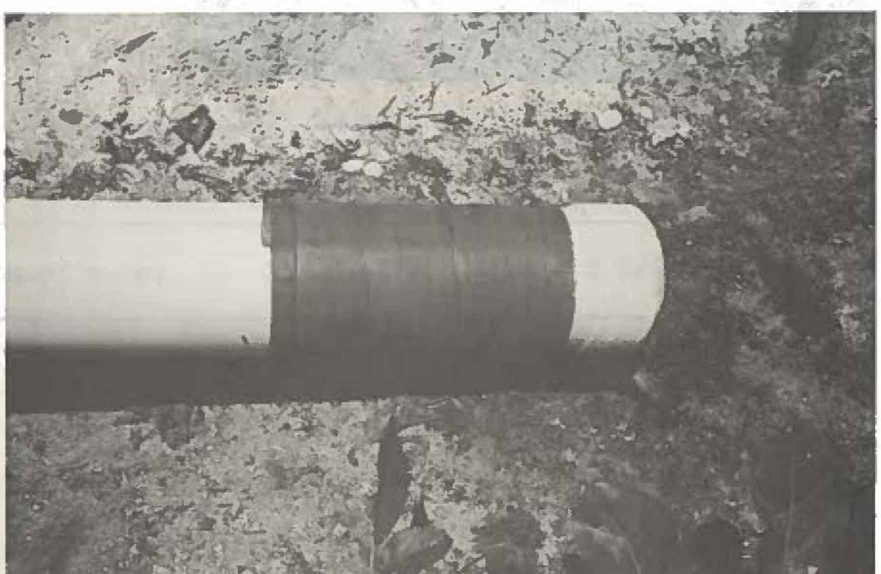


Figure 7. Pipe cap and fiberglass window screen in place on bottom end of well casing.

Figure 8. Set up for perforated casing test.

Table 6. Results of perforated casing test.

Date: 8-9-84
Cloud cover: slight haze
Initial pumping rate: 1 gpm (estimated)

Time	1:40 pm	1:45 pm	1:50 pm	1:55 pm
Depth of water	1' - 10"	1' - 10 1/2"	1' - 10 1/2"	1' - 10 1/2"

Date: 8-12-84
Cloud cover: clear
Initial pumping rate; 1.8 gpm

Time	11:45 am	11:50 am	11:55 am	12:00 am
Depth of water	2' - 0"	2' - 1 5/8"	2' - 1 5/8"	2' - 1 5/8"

Date: 8-14-84
Cloud cover: clear
Initial pumping rate: 1.8 gpm

Time	11:40 am	11:45 am	11:50 am	11:55 am
Depth of water	2' - 1 7/8"	2' - 2 3/4"	2' - 2 3/4"	2' - 2 3/4"

must be considered. One such method is to simply install a switch in the system so that, when water is not needed or when the storage tank is full, the system can be turned off.

The tests have definitely shown that it is possible to deliver sufficient head with only one module. Using a single 30 watt module, a head of around 13 feet can be obtained from a Rule pump at one gpm. A head of around 15 feet can be obtained with a 35 watt module. Thus, in order to minimize the expense of a well installation, a careful prior measurement should be made of the vertical distance from the water table to the top of the storage tank to which water will be pumped. A solar module should then be chosen that is adequate to suit this pumping requirement.

It is noted that, by pumping into the bottom of the storage tank, the pump will only have to pump against the maximum head when the tank is near full. This results in a "tuned" system wherein the pumping rate is maximum when the tank is empty and is low (or zero) when the tank is full. A check valve must be placed in the pump discharge line to prevent back flow from the tank to the well when the pump is off. A disadvantage of this system is that it is difficult to ascertain whether or not the pump is operating as water cannot be seen or heard entering the tank. This is the reason this approach was not used in the original well design.

The tests of the perforated well casing show that this is a satisfactory alternative to the procedure of utilizing aggregate backfill in the well. Thus, if limited time is anticipated in the field or if aggregate is unavailable, a perforated well casing could be prepared before hand and quickly installed at the site. The characteristics of each well site will dictate which is the more appropriate approach.

ACKNOWLEDGEMENTS

The writers wish to thank Mr. Nachsa Siren, Coordinator of the Rural Sanitation Program on Truk, for the use of a solar module and other supplies and for logistic support during the field testing phase of this study.

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APPENDIX

Table A1. Pump characteristic curve test results for the Rule 400 pump.

Date: 5/22/84
Time: 11:25 a.m. - 12:10 p.m.
Cloud cover: clear

SPC* 30 watt					SPC 35 watt					SPC 40 watt				
Head		Flow	Current	Voltage	Head		Flow	Current	Voltage	Head		Flow	Current	Voltage
psi	ft	gpm	amps	volts	psi	ft	gpm	amps	volts	psi	ft	gpm	amps	volts
7.8	18.0	0	1.50	13.5	8.5	19.6	0	1.59	14.5	8.2	18.9	0	1.62	14.3
7.5	17.3	.12	1.49	13.3	8.0	18.5	.32	1.59	14.0	7.5	17.3	.37	1.62	14.0
7.0	16.2	.34	1.48	13.0	7.5	17.3	.66	1.61	13.9	7.0	16.2	.68	1.62	13.8
6.5	15.0	.66	1.48	12.8	7.0	16.2	.96	1.62	13.8	6.5	15.0	1.0	1.64	13.6
6.0	13.8	.96	1.50	12.6	6.5	15.0	1.3	1.65	13.7	6.0	13.8	1.2	1.64	13.4
5.5	12.7	1.2	1.52	12.5	6.0	13.8	1.6	1.68	13.6	5.5	12.7	1.5	1.65	13.2
5.0	11.5	1.6	1.54	12.3	5.5	12.7	1.8	1.68	13.4	5.0	11.5	1.9	1.65	13.0
4.5	10.4	1.8	1.55	12.1	5.0	11.5	2.2	1.69	13.2	4.5	10.4	2.1	1.66	12.8
4.0	9.2	2.2	1.56	12.0	4.5	10.4	2.5	1.71	13.1	4.0	9.2	2.6	1.67	12.6
3.5	8.1	2.6	1.56	11.7	4.0	9.2	2.8	1.73	12.9	3.5	8.1	2.9	1.67	12.3
3.0	6.9	2.9	1.57	11.6	3.5	8.1	3.2	1.73	12.8	3.0	6.9	3.3	1.67	12.2
2.5	5.8	3.4	1.58	11.4	3.0	6.9	3.5	1.75	12.6	2.5	5.8	3.7	1.67	12.0

*Solar Power Corporation

Table A2. Pump characteristic curve test results for the Rule 400 pump.

Date: 6/8/84
Time: 11:50 a.m. - 12:35 p.m.
Cloud cover: clear

SPC* 30 watt					SPC 35 watt					SPC 40 watt				
Head		Flow	Current	Voltage	Head		Flow	Current	Voltage	Head		Flow	Current	Voltage
psi	ft	gpm	amps	volts	psi	ft	gpm	amps	volts	psi	ft	gpm	amps	volts
6.8	15.7	0	1.36	13.0	7.5	17.3	0	1.54	13.9	7.5	17.3	0	1.56	14.0
6.5	15.0	.28	1.39	12.9	7.0	16.2	.50	1.56	13.8	7.0	16.2	.47	1.59	13.8
6.0	13.8	.66	1.42	12.7	6.5	15.0	.91	1.57	13.7	6.5	15.0	.75	1.61	13.7
5.5	12.7	1.0	1.46	12.6	6.0	13.8	1.2	1.59	13.6	6.0	13.8	1.1	1.62	13.6
5.0	11.5	1.3	1.48	12.5	5.5	12.7	1.5	1.61	13.5	5.5	12.7	1.4	1.64	13.5
4.5	10.4	1.7	1.51	12.4	5.0	11.5	1.9	1.63	13.3	5.0	11.5	1.8	1.66	13.3
4.0	9.2	2.1	1.53	12.3	4.5	10.4	2.2	1.64	13.2	4.5	10.4	2.1	1.67	13.2
3.5	8.1	2.5	1.56	12.1	4.0	9.2	2.5	1.67	13.0	4.0	9.2	2.5	1.69	13.0
3.0	6.9	2.9	1.58	12.0	3.5	8.1	2.9	1.68	12.9	3.5	8.1	2.9	1.71	12.8
2.5	5.8	3.3	1.61	11.9	3.0	6.9	3.3	1.69	12.7	3.0	6.9	3.1	1.72	12.6
					2.5	5.8	3.7	1.71	12.6	2.5	5.8	3.6	1.73	12.5

*Solar Power Corporation

Table A3. Pump characteristic curve test results for the Rule 400 pump.

Date: 7/17/84
Time: 11:10 a.m. - 11:40 a.m.
Cloud cover: clear

SPC* 30 watt					SPC 35 watt					SPC 40 watt				
Head		Flow	Current	Voltage	Head		Flow	Current	Voltage	Head		Flow	Current	Voltage
psi	ft	gpm	amps	volts	psi	ft	gpm	amps	volts	psi	ft	gpm	amps	volts
6.8	15.7	0	1.35	12.7	8.2	18.9	0	1.53	14.0	8.3	19.2	0	1.56	14.2
6.5	15.0	.37	1.39	12.4	7.5	17.3	.53	1.57	13.7	7.5	17.3	.51	1.60	13.9
6.0	13.8	.72	1.41	12.3	7.0	16.2	.86	1.60	13.5	7.0	16.2	.86	1.62	13.7
5.5	12.7	1.1	1.44	12.1	6.5	15.0	1.1	1.61	13.4	6.5	15.0	1.1	1.64	13.6
5.0	12.7	1.4	1.46	12.0	6.0	13.8	1.4	1.62	13.3	6.0	13.8	1.4	1.65	13.4
4.5	10.4	1.7	1.48	11.7	5.5	12.7	1.7	1.64	13.1	5.5	12.7	1.7	1.67	13.2
4.0	9.2	2.1	1.49	11.6	5.0	11.5	2.0	1.65	12.9	5.0	11.5	1.9	1.68	13.1
3.5	8.1	2.6	1.50	11.4	4.5	10.4	2.3	1.67	12.8	4.5	10.4	2.3	1.69	12.9
3.0	6.9	2.9	1.52	11.2	4.0	9.2	2.7	1.69	12.6	4.0	9.2	2.7	1.70	12.7
2.5	5.8	3.3	1.53	11.0	3.5	8.1	3.1	1.70	12.4	3.5	8.1	3.1	1.71	12.5
					3.0	6.9	3.5	1.71	12.3	3.0	6.9	3.5	1.72	12.3
					2.5	5.8	3.9	1.71	12.1	2.5	5.8	3.9	1.72	12.2

*Solar Power Corporation

Table A4. Pump characteristic curve test results for the Rule 400 pump.

Date: 7/18/84
Time: 11:20 a.m. - 12:00 p.m.
Cloud cover: clear

SPC* 30 watt					SPC 35 watt					SPC 40 watt				
Head		Flow	Current	Voltage	Head		Flow	Current	Voltage	Head		Flow	Current	Voltage
psi	ft	gpm	amps	volts	psi	ft	gpm	amps	volts	psi	ft	gpm	amps	volts
6.8	15.7	0	1.39	12.8	8.2	18.9	0	1.56	14.0	8.4	19.4	0	1.58	14.1
6.5	15.0	.35	1.42	12.7	7.5	17.3	.57	1.58	13.8	8.0	18.5	.40	1.59	14.1
6.0	13.8	.69	1.44	12.4	7.0	16.2	.90	1.61	13.6	7.5	17.3	.73	1.61	13.9
5.5	12.7	1.0	1.46	12.2	6.5	15.0	1.1	1.62	13.4	7.0	16.2	1.0	1.63	13.8
5.0	11.5	1.3	1.48	12.1	6.0	13.8	1.4	1.64	13.2	6.5	15.0	1.3	1.65	13.6
4.5	10.4	1.7	1.50	11.8	5.5	12.7	1.7	1.66	13.0	6.0	13.8	1.5	1.67	13.4
4.0	9.2	2.0	1.51	11.7	5.0	11.5	1.9	1.67	12.9	5.5	12.7	1.8	1.67	13.3
3.5	8.1	2.5	1.52	11.4	4.5	10.4	2.3	1.68	12.7	5.0	11.5	2.0	1.69	13.1
3.0	6.9	2.8	1.54	11.2	4.0	9.2	2.7	1.70	12.5	4.5	10.4	2.4	1.70	12.9
2.5	5.8	3.3	1.56	11.1	3.5	8.1	3.1	1.71	12.3	4.0	9.2	2.7	1.72	12.6
					3.0	6.9	3.5	1.72	12.2	3.5	8.1	3.1	1.73	12.5
					2.5	5.8	3.9	1.73	12.1	3.0	6.9	3.5	1.73	12.3
										2.5	5.8	3.9	1.73	12.1

*Solar Power Corporation

Table A5. Pump characteristic curve test results for the Rule 400 pump.

Date: 7/19/84
Time: 12:20 p.m. - 12:55 p.m.
Cloud cover: clear

SPC* 30 watt					SPC 35 watt					SPC 40 watt				
Head psi	Head ft	Flow gpm	Current amps	Voltage volts	Head psi	Head ft	Flow gpm	Current amps	Voltage volts	Head psi	Head ft	Flow gpm	Current amps	Voltage volts
7.0	16.2	0	1.33	12.5	9.0	20.8	0	1.50	14.3	9.0	20.8	0	1.52	14.3
6.5	15.0	.49	1.39	12.3	8.5	19.6	.39	1.52	14.1	8.5	19.6	.38	1.54	14.2
6.0	13.8	.85	1.41	12.2	8.0	18.5	.68	1.56	14.0	8.0	18.5	.67	1.57	14.1
5.5	12.7	1.2	1.43	12.0	7.5	17.3	.93	1.57	13.9	7.5	17.3	.99	1.61	13.9
5.0	11.5	1.5	1.45	11.9	7.0	16.2	1.2	1.59	13.7	7.0	16.2	1.3	1.62	13.7
4.5	10.4	1.9	1.47	11.8	6.5	15.0	1.5	1.61	13.6	6.5	15.0	1.5	1.63	13.7
4.0	9.2	2.3	1.50	11.6	6.0	13.8	1.7	1.63	13.5	6.0	13.8	1.7	1.65	13.6
3.5	8.1	2.7	1.51	11.4	5.5	12.7	2.0	1.65	13.3	5.5	12.7	1.9	1.67	13.4
3.0	6.9	3.1	1.53	11.3	5.0	11.5	2.3	1.67	13.1	5.0	11.5	2.3	1.69	13.2
2.5	5.8	3.6	1.55	11.1	4.5	10.4	2.7	1.69	12.9	4.5	10.4	2.7	1.71	13.0
					4.0	9.2	3.0	1.71	12.7	4.0	9.2	3.0	1.72	12.8
					3.5	8.1	3.5	1.72	12.5	3.5	8.1	3.5	1.73	12.6
					3.0	6.9	3.8	1.73	12.4	3.0	6.9	3.7	1.73	12.4

*Solar Power Corporation

Table A6. Solar module performance test results.

Date: 5/22/84
Cloud Cover: Clear

SPC* 30 watt		SPC 35 watt		SPC 40 watt	
Current amps	Voltage volts	Current amps	Voltage volts	Current amps	Voltage volts
0	18.4	0	18.6	0	18.6
.40	16.7	.55	17.5	.61	17.5
.55	15.9	.78	17.0	.84	17.0
.78	15.0	.99	16.5	1.10	16.5
.96	14.5	1.16	16.0	1.22	16.0
1.13	14.0	1.30	15.5	1.36	15.5
1.27	13.5	1.42	15.0	1.47	15.0
1.38	13.0	1.53	14.5	15.5	14.5
1.45	12.5	1.61	14.0	1.60	14.0
1.53	12.0	1.67	13.5	1.64	13.5
1.58	11.5	1.73	13.0	1.67	13.0
1.64	11.0	1.80	12.0	1.67	12.0
1.67	10.5	1.82	11.0	1.68	11.0
1.68	10.0	1.84	10.0	1.69	10.0
1.69	9.0	1.84	9.0	1.70	9.0
1.79	8.0	1.85	8.0	1.72	8.0
1.79	7.0	1.85	7.0	1.73	7.0
1.80	6.0	1.85	6.0		
1.82	5.0	1.86	5.0		
1.83	4.0	1.86	4.0		
1.83	3.0	1.86	3.0		
1.83	2.0	1.87	2.0		
1.83	1.0	1.87	1.0		
1.83	0	1.87	0		

*Solar Power Corporation

Table A7. Solar module performance test results.

Date: 6/8/84
Cloud Cover: Clear

SPC* 30 watt		SPC 35 watt		SPC 40 watt	
Current amps	Voltage volts	Current amps	Voltage volts	Current amps	Voltage volts
0	16.1	0	18.2	0	17.9
.54	15.0	.53	17.5	.54	17.0
.77	14.5	.63	17.0	.81	16.5
.97	14.0	.84	16.5	1.02	16.0
1.12	13.5	1.05	16.0	1.22	15.5
1.26	13.0	1.20	15.5	1.36	15.0
1.39	12.5	1.32	15.0	1.48	14.5
1.47	12.0	1.45	14.5	1.48	14.0
1.56	11.5	1.52	14.0	1.65	13.5
1.61	11.0	1.60	13.5	1.69	13.0
1.65	10.5	1.67	13.0	1.73	12.5
1.67	10.0	1.73	12.5	1.76	11.5
1.69	9.5	1.75	12.0	1.77	11.0
1.70	9.0	1.78	11.5	1.78	10.0
1.71	8.0	1.79	11.0	1.78	9.0
1.71	7.0	1.81	10.5	1.79	8.0
1.72	6.0	1.82	10.0	1.79	7.0
1.73	5.0	1.82	9.0	1.79	6.0
1.73	4.0	1.83	8.0	1.79	5.0
1.73	3.0	1.84	7.0	1.79	4.0
1.73	2.0	1.84	6.0	1.80	3.0
1.73	1.0	1.85	5.0	1.81	2.0
1.73	0	1.86	4.0	1.81	1.0
		1.86	3.0	1.81	0
		1.87	2.0		
		1.87	1.0		
		1.87	0		

*Solar Power Corporation

Table A8. Solar module performance test results.

Date: 7/17/84
Cloud Cover: Clear

SPC* 30 watt		SPC 35 watt		SPC 40 watt	
Current amps	Voltage volts	Current amps	Voltage volts	Current amps	Voltage volts
0	16.4	0	18.5	0	18.2
.40	15.6	.52	17.5	.44	17.4
.69	15.0	.75	17.0	.68	17.0
.88	14.5	.94	16.5	.94	16.5
1.05	14.0	1.09	16.0	1.13	16.0
1.17	13.5	1.27	15.5	1.31	15.5
1.30	13.0	1.38	15.0	1.43	15.0
1.39	12.5	1.48	14.5	1.52	14.5
1.45	12.0	1.56	14.0	1.59	14.0
1.50	11.5	1.62	13.5	1.67	13.5
1.54	11.0	1.67	13.0	1.69	13.0
1.58	10.0	1.70	12.5	1.73	12.5
1.60	9.0	1.73	12.0	1.73	12.0
1.61	8.0	1.76	11.0	1.74	11.0
1.62	7.0	1.77	11.5	1.75	10.0
1.62	6.0	1.78	10.0	1.76	9.0
1.63	5.0	1.79	9.0	1.76	8.0
1.64	4.0	1.79	8.0	1.76	7.0
1.65	3.0	1.81	7.0	1.77	6.0
1.65	2.0	1.82	6.0	1.77	5.0
1.65	1.0	1.83	5.0	1.78	4.0
1.66	0	1.83	4.0	1.78	3.0
		1.84	3.0	1.79	2.0
		1.84	2.0	1.79	1.0
		1.84	1.0	1.79	0
		1.84	0		

*Solar Power Corporation

Table A9. Solar module performance test results.

Date: 7/18/84
Cloud Cover: Clear

SPC* 30 watt		SPC 35 watt		SPC 40 watt	
Current amps	Voltage volts	Current amps	Voltage volts	Current amps	Voltage volts
0	16.7	0	18.5	0	18.3
.57	15.5	.53	17.5	.44	17.5
.80	15.0	.75	17.0	.61	17.0
.97	14.5	.94	16.5	.94	16.5
1.11	14.0	1.10	16.0	1.14	16.0
1.24	13.5	1.25	15.5	1.30	15.5
1.33	13.0	1.39	15.0	1.44	15.0
1.43	12.5	1.48	14.5	1.52	14.5
1.48	12.0	1.56	14.0	1.60	14.0
1.52	11.5	1.62	13.5	1.67	13.5
1.55	11.0	1.67	13.0	1.73	12.0
1.59	10.0	1.74	12.0	1.75	12.5
1.60	9.0	1.77	11.0	1.76	11.0
1.62	8.0	1.79	10.0	1.77	10.0
1.62	7.0	1.79	9.0	1.77	9.0
1.63	6.0	1.80	8.0	1.77	8.0
1.64	5.0	1.81	7.0	1.78	7.0
1.65	4.0	1.82	6.0	1.78	6.0
1.65	3.0	1.83	5.0	1.78	5.0
1.65	2.0	1.83	4.0	1.78	4.0
1.66	1.0	1.83	3.0	1.79	3.0
1.66	0	1.84	2.0	1.79	2.0
		1.84	1.0	1.79	1.0
		1.84	0	1.80	0

*Solar Power Corporation

Table A10. Solar module performance test results.

Date: 7/19/84
Cloud Cover: Clear

SPC* 30 watt		SPC 35 watt		SPC 40 watt	
Current amps	Voltage volts	Current amps	Voltage volts	Current amps	Voltage volts
0	16.2	0	18.4	0	18.0
.59	15.0	.48	17.5	.62	17.0
.79	14.5	.71	17.0	.87	16.5
.99	14.0	.91	16.5	1.10	16.0
1.14	13.5	1.10	16.0	1.26	15.5
1.27	13.0	1.24	15.5	1.41	15.0
1.39	12.5	1.38	15.0	1.52	14.5
1.47	12.0	1.48	14.5	1.61	14.0
1.52	11.5	1.57	14.0	1.67	13.5
1.56	11.0	1.64	13.5	1.72	13.0
1.63	10.0	1.69	13.0	1.74	12.5
1.65	9.0	1.77	12.0	1.77	12.0
1.67	8.0	1.80	11.0	1.78	11.0
1.67	7.0	1.81	10.0	1.79	10.0
1.68	6.0	1.82	9.0	1.79	9.0
1.69	5.0	1.83	8.0	1.79	8.0
1.70	4.0	1.84	7.0	1.79	7.0
1.70	3.0	1.84	6.0	1.79	6.0
1.71	2.0	1.85	5.0	1.79	5.0
1.71	1.0	1.85	4.0	1.80	4.0
1.71	0	1.86	3.0	1.80	3.0
		1.87	2.0	1.81	2.0
		1.87	1.0	1.81	1.0
		1.87	0	1.82	0

*Solar Power Corporation