

Universal Solar Pump Controller (USPC)

INSTALLATION, OPERATION AND MAINTENANCE MANUAL



181 W. Huntington Drive, Suite 202 – Monrovia, California 91016 – U.S.A.
Telephone (626) 357-9983 – FAX (626) 357-0326 – sales@avinc.com

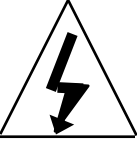


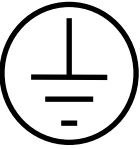
Important Safety Instructions

Read these instructions completely before installation.

NOTE: During installation, if conflict arises between this manual and local or national electrical codes, the applicable local or national electrical codes should prevail. If a conflict of codes seems to cause improper installation or operation, contact the distributor.

Save these instructions in a safe place.

This manual contains important instructions that should be followed during installation and maintenance of this unit.

	<p>This symbol is intended to warn users that parts inside the USPC are high voltage and are potential shock hazards.</p>
	<p>This symbol is intended to warn users that the part may be hot and could be a burn hazard. Allow the part to cool before handling.</p>
	<p>This symbol represents a ground connection point. Removing wire(s) from this point may disconnect other devices from earth ground and potentially create unsafe conditions.</p>
	<p>This symbol represents the main ground connection point to the attached device. Only one wire should be connected to this point. Removing the wire from this point will disconnect this device from earth ground and create unsafe conditions.</p>

WARNING

HIGH VOLTAGES PRESENT

Voltages capable of causing severe injury or death by electrical shock are present in this unit. This unit should only be installed or serviced by an AeroVironment-authorized dealer or supplier.

To safely service the USPC, the following procedure must be used:

1. Securely cover the array with a completely opaque tarp.
2. The external DC switch must be in the “OFF” position.
3. Set the mode switch to “DISABLE” and then lift the cover.
4. Remove the internal isolation disconnect device and put it in a safe place.
5. Wait 15 seconds after removing power from the unit before servicing.

SERVICE INFORMATION

Contact the supplier or dealer of this unit for any service requirements or warranty claims.

NOTICE TO INSTALLERS

The registration card enclosed with this unit must be completed and sent to AeroVironment’s Customer Service Department to validate the warranty. Refer to **Section 13** in this manual for instructions.

We strongly recommend that the installation data be recorded into **Section 11** of the small User’s Manual that accompanies the unit. The User’s Manual should remain with the unit.

Warranty

AeroVironment USPC Limited Warranty

Products manufactured by Seller are warranted to the original user to be free of defects in material and workmanship for a period of 18 months from date of installation, but not more than 24 months from date of purchase if installed, used and maintained according to Seller's product manual.

Seller's liability under this warranty shall be limited to repairing or replacing defective material, at Seller's option, F.O.B. Seller's factory or authorized service station. Seller will not be liable for any costs of removal, installation, transportation, or any other charges which may arise in connection with a warranty claim. This warranty shall be voided by damage or wear to products caused by abnormal operating conditions, accident, abuse, misuse, unauthorized alteration or repair, or if the product was not installed in accordance with Seller's printed installation and operating instructions.

To obtain service under this warranty, the defective product must be returned to the distributor or dealer from whom it was purchased together with proof of purchase and installation date, failure date, and supporting installation data. Any defective product to be returned must be sent freight prepaid with documentation supporting the warranty claim and/or a Return Material Authorization must be included if so instructed.

SELLER SHALL NOT BE LIABLE FOR ANY INCIDENTAL OR CONSEQUENTIAL DAMAGES, LOSSES, OR EXPENSES ARISING FROM INSTALLATION, USE OR ANY OTHER CAUSES. THERE ARE NO EXPRESS OR IMPLIED WARRANTIES, INCLUDING MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE, WHICH EXTEND BEYOND THE WARRANTY DESCRIBED ABOVE.

Table of Contents

Safety Instructions	2
High Voltage Warning.....	3
Warranty	4
1.0 Introduction.....	7
2.0 Product Description	8
2.1 General Description	8
2.2 Product Qualification	9
2.3 Features	10
2.3.1 Universal Pump Motor Interface	10
2.3.2 Universal Photovoltaic Array Interface	10
2.3.3 Optimized Operation in Marginal Weather	10
2.3.4 Underload & Overload Protection	10
2.3.5 Overdrive Feature	11
2.3.6 Selectable Minimum Motor Operating Speed	11
2.3.7 Input Protection.....	11
2.3.8 Smart Restart.....	11
2.3.9 Internal Isolation Disconnect Device.....	11
2.3.10 External Reset Switch	12
2.3.11 Thermal Protection.....	12
2.3.12 Remote or Float Switch	12
3.0 Product Specification.....	13
4.0 USPC External Configuration.....	14
5.0 USPC Internal Configuration.....	15
5.1 Internal Isolation Disconnect Device.....	15
5.2 Remote Shutoff Switch Connector	15
5.3 System Configuration Switch Blocks	16
5.4 DC Power Terminal	16
5.5 AC Power Connections.....	16
5.6 Ground Terminals	16
6.0 System Sizing.....	17
7.0 Handling, Inspection & Storage	18
7.1 Handling & Inspection.....	18
7.2 Storage	18
8.0 Configuring the System	19
8.1 Switch Block 1 (SW1)	19
8.1.1 Motor Phase (SW1-1 & SW1-2).....	19
8.1.2 Nominal Motor Speed Selection (SW1-3).....	20
8.1.3 Maximum Speed Limit (Overdrive) (SW1-4)	20
8.1.4 Minimum Motor Operating Speed (SW1-5 & SW1-6)	20
8.1.5 Output Voltage (SW1-7 & SW1-8)	20
8.2 Switch Block 2 (SW2)	20
8.2.1 Memory Reset (SW2-1).....	21
8.2.2 Fault Detection Margin (SW2-5).....	21

8.2.3 Fault Detection (SW2-6).....21

8.2.4 System Disable (SW2-8).....21

9.0 Installation.....23

9.1 Installation Preparation & Requirements.....23

9.1.1 Site Requirements23

9.1.2 Installation Recommendations.....24

9.1.3 Equipment Needed.....24

9.2 Physical Installation25

9.3 Electrical Installation26

9.3.1 External Disconnect Switch.....27

9.3.2 Internal Wiring.....27

9.3.3 Grounding Methods – Do’s & Don’ts28

9.3.4 DC Wire Connections.....29

9.3.5 Pre-Power Polarity Check.....31

9.3.6 Low Power Logic Test.....32

9.3.7 AC Wire Connections.....32

9.3.8 Overflow / Shutoff Switch Wiring.....34

9.3.9 Fusing Requirements34

9.4 Start-Up.....35

9.5 USPC Reset Procedure35

10.0 Operation.....36

10.1 General Start-Up & Operation.....36

10.2 Submersible Pump Operation37

10.3 High Open Circuit Voltage.....37

10.4 Heat Dissipation.....38

10.5 Turning Off the Unit.....38

11.0 Maintenance39

12.0 Troubleshooting40

Appendix A – System Sizing Tutorial / Worksheet42

Appendix B – Installation Notes.....47

Appendix C – Wire Selection48

Appendix D – Replacement of Microprocessor Chip.....49

Appendix E – AC Submersible Pump Motor Power Rating.....51

Appendix F – USPC Installation Checklist53

1.0 Introduction

AeroVironment's ("AV") Universal Solar Pump Controller ("USPC") is a versatile, high performance, variable speed motor controller for solar powered pumping applications. The USPC provides water to regions with little or no electricity for:

- Livestock watering
- Community and village water supply
- Small scale irrigation of fields
- Water purification
- Other applications requiring water pumping in remote locations.

This inverter has been used for other solar motor driven applications, such as refrigeration/ freezers and blowers. It can also be used for driving ice making machines, grain mills, and many different pumping applications (reverse osmosis, surface pumping, oil, etc.).

2.0 Product Description

2.1 General Description

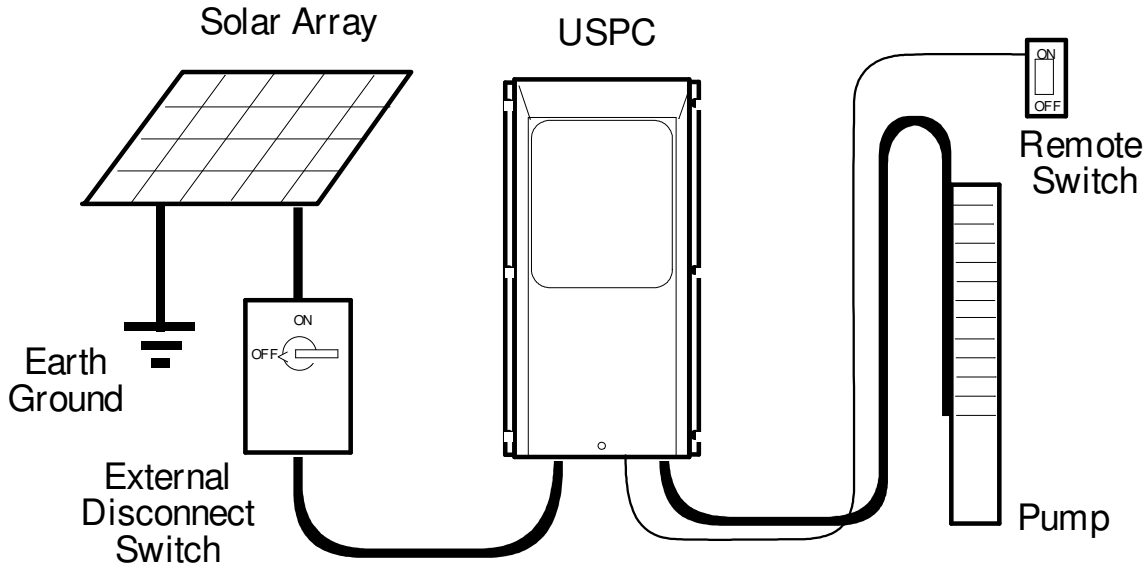


Figure 2.1 – System Block Diagram

AeroVironment's USPC converts high voltage, direct current (VDC) from a photovoltaic (PV) array into highly controlled, single or three-phase PWM (pulse width modulated) alternating current (VAC) to run standard AC water pump motors. The USPC is capable of controlling 115, 208 or 230 VAC single or three-phase motors. AV's proprietary microprocessor design tightly controls performance parameters, resulting in increased reliability since there are fewer individual parts to fail.

The USPC continuously monitors system performance and incorporates a number of features for pump system protection. In the event of a fault detection, the USPC will indicate the type of fault through LED indicators. For most fault modes, the USPC will periodically attempt restart. The microprocessor technology gives the USPC the capability to monitor the system and automatically shut down in the event of:

- Full reservoir
- Underload from a dry well or dry pump
- Overload from a bad pump motor (internal electrical short or bad bearing) or fouled pump
- Low input power detection (using minimum motor speed selection).

Automatic shutdown protects the pump and motor from damage during unattended operation.

In the morning, the USPC begins monitoring power from the PV array. When there is enough power to operate the system (based on the pre-selected conditions), the USPC delivers power to the pump motor while monitoring the motor power requirements. If the motor requirements are not too low (dry well) or too high (locked rotor), the system continues to provide power to the pump throughout the day in proportion to the amount of power received from the PV array. Power is always limited to the maximum power specified for the pump motor.

Proportional power delivered from the PV array allows the system to run at variable speed. Variable speed operation means there is no in-rush or surge of energy during the pump motor start-up, helping to eliminate wear on the motor and pumping system. One of the main causes of pump motor failure is the stress applied to motors during a full voltage start-up. The USPC variable speed operation ramps up the speed smoothly, which eliminates starting stress. This should allow the pump motor to last longer. There is no starter box or motor starter to purchase, maintain or have fail. The start winding is controlled by the USPC and the USPC provides motor overload protection.

The microprocessor-controlled converter has customized settings of minimum motor speed, allowing the motor to run more efficiently and maximize the amount of water pumped during a solar day. Proper minimum motor speed settings ensure each pump site will obtain the maximum amount of water possible during marginal solar intensity conditions, like hazy or overcast days.

The USPC requires virtually no maintenance. Once the system is installed, the only periodic maintenance required is to ensure that the site remains free from small animals, insect and debris. Occasional washing of the PV array will ensure maximum performance of the USPC system. See **Section 11** for instructions on conducting preventative maintenance.

2.2 Product Qualification

The USPC product line has met stringent product qualification requirements, demonstrating the safety and reliability of the product. The USPC meets the requirements of UL Standard 1741 (power conditioning units for use in residential photovoltaic power systems) and all requirements of the National Electric Code (NEC), including Article 690.

2.3 Features

The USPC offers many operational features, as described below.

2.3.1 Universal Pump Motor Interface

The USPC works with most commonly available AC pump motors, and is able to be incorporated with an already existing installed pump. The USPC characterizes the pump motor operation automatically, so there is no need for special programming. Motors may use three-phase (3 or 4 wire + ground) or single-phase (start and run windings + ground) and 208-230 VAC or 115/230/240 VAC, 50/60 Hz. Section 3 identifies the wide range of specific voltages, phases and horsepowers that can be accommodated.

2.3.2 Universal Photovoltaic Array Interface

The USPC works with most commonly available photovoltaic (PV) arrays. The USPC tracks peak power from PV arrays, regardless of the PV material type – though all the PV modules used must be made from the same material (you cannot mix and match material types). Any manufacturing process for producing PV arrays is acceptable, including single or poly-crystalline silicon or thin-film technology. This flexibility in PV array technology allows you to use PV modules that are on hand or locally available.

2.3.3 Optimized Operation in Marginal Weather

AeroVironment's proprietary fast foldback algorithm allows the USPC to be highly tolerant of varying light intensity caused by changing weather conditions. Rapid changes in light, like the passing of a cloud, have a negative effect on the power from the PV array. The USPC compensates for the rapid change in power with minimum interruption, which maximizes the water output of the system during marginal weather conditions. This standard feature is automatic and requires no user adjustment.

2.3.4 Underload & Overload Protection

The USPC incorporates user-selectable underload and overload protection. Underload protection can prevent damage in the event of a dry well, dry pump, or a decoupled pump and motor. Overload protection shuts down the system when there is evidence of a fouled pump or motor, electrical short, bad motor or improper connection to the motor. Adjustable sensitivity fault detection

allows the user to minimize nuisance fault conditions. Refer to **Section 8.2.3** for details on setting the underload/overload protection.

2.3.5 Overdrive Feature

The overdrive feature pushes the pump motor to drive at a speed 5 Hz over the nominal motor frequency. Overdrive results in additional water flow when the PV array can deliver the power. Consult your pump supplier before selecting this option. Refer to **Section 8.1.3** for instructions on setting this parameter.

2.3.6 Selectable Minimum Motor Operating Speed

Users can select minimum motor operating speed settings as low as 10 Hz to maximize the flow of water when the PV array is producing minimal power due to the angle of the sun or during marginal weather conditions. Setting a motor minimum frequency to a value near that required to achieve flow will minimize the motor and pump wear. If uncertain, use 30 Hz. Consult your pump supplier before selecting 10 Hz. Refer to **Section 8.1.4** for details on selecting minimum motor operating speeds.

2.3.7 Input Protection

The USPC offers high PV array DC voltage input protection via a clamp circuit that protects internal circuit components from over voltage and maintains the input maximum voltage at 400 V when connected to the PV array. This standard feature is automatic and requires no user adjustment.

2.3.8 Smart Restart

The USPC's "smart" restart plan allows the system to achieve maximum water output while minimizing wear on the motor and pump components, as follows:

- *Schedule A* – for low input power, underload faults
- *Schedule B* – for overload and system faults
- *Schedule C* – for low input power before achieving minimal speed set by the user.

2.3.9 Internal Isolation Disconnect Device

This device disconnects the DC input power for added safety protection during installation and servicing of the unit.

2.3.10 External Reset Switch

The USPC is equipped with an external reset switch. The reset switch will clear the memory and begin the system start-up sequence. See **Figure 4-1** for the location of the reset switch.

2.3.11 Thermal Protection

The USPC automatically limits the maximum power to the pump motor when the ambient temperature is high. Lower power results in a lower internal temperature of the USPC unit, allowing the pump motor operation to continue at a reduced level, even on very hot days. This standard feature is automatic and requires no user adjustment.

2.3.12 Remote or Float Switch

A remote on/off switch and a float switch can be wired to the unit for manual or automatic system shutdown. Multiple switches can be wired in series for system shutdown if any switch is opened.

3.0 Product Specifications

The electrical, physical and performance specifications for the USPC product line are provided below for your reference. All specifications are subject to change without notice.

Performance Specifications		USPC-2000	USPC-5000
Input Parameters			
Maximum PV Array Open Circuit Voltage		600VDC	
Maximum Input Operating Voltage		400 VDC	
Minimum Starting Voltage		150 VDC	
Minimum Operating Voltage		70 VDC	
PV Array Optimal Operating Voltage			
115 V 1Φ Motor		210 VDC	
230 V 1Φ Motor		385 VDC	
230 V 3Φ Motor		380 VDC	
Maximum Input Power		2.2 kW	5.5 kW
Maximum PV Array Short Circuit Current		8 A	20 A
Output Parameters			
Selectable Minimum Frequency		10,20,30,40 Hz	
Selectable Motor Frequency*		50,60 Hz	
+5 Hz Overdrive Feature*		55,65 Hz	
Output Wave Form		Sine Weighted PWM	
Maximum Output Current		13 A pk/0.5 Arms	32 A pk/25 Arms
Two-Wire 1Φ Motor		The USPC will not operate motors that have internal electronics or centrifugal switches.	
Three-Wire 1Φ Motor** (full Power rating)	115 V	0.75 HP	0.75 HP
	208 V / 230 V	1 HP	2 HP
Three-Wire 3Φ Motor**		2 HP	5 HP
Inverter Efficiency	1Φ Motor	95% Maximum	
	3Φ Motor	97% Maximum	
Serial Communication		RS-232C	
Environmental Conditions			
Temperature		-20° to 60 °C	
Humidity		>95% (Non-Condensing)	
Noise		No Audible Noise	
Vibration, Humidity & Corrosion		MIL-STD-883 & MIL-STD-202F	
Starter Box		None Required	
Unit Dimensions		18" x 9" x 6" (46cm x 23cm x16cm)	
Shipping Dimensions		20" x 12" x 10" (51cm x 31cm x 26cm)	
Weight		17 lbs (8 kg)	18 lbs (8.4 kg)
*Maximum speed limited by array voltage and maximum frequency selected			
**Connecting a motor rated higher than indicated will give reduced performance due to input power limitations			

4.0 USPC External Configuration

Figure 4-1 below displays the exterior of the USPC. This drawing is provided to show location only. To safely operate and/or service the USPC, be sure to follow the procedures in **Section 9** for **Installation**, **Section 10** for **Operation**, **Section 11** for **Maintenance** and **Section 12** for **Troubleshooting**.

The USPC enclosure is NEMA 3 compliant, proving a long life expectancy for the enclosed electronics. The cover can be removed by unscrewing the two screws located at the bottom of each side. The enclosure can be securely locked with a standard lock that had a bolt diameter up to 5/16”.

The LEDs on the front cover indicate fault conditions (when present). For further information on the fault indications, refer to **Section 12 – Troubleshooting**.

The mode switch, RS-232 port and wiring access are located on the bottom of the unit. The unit model and serial numbers are provided on a label on the side of the heat sink. This information is required for warranty repair requests.

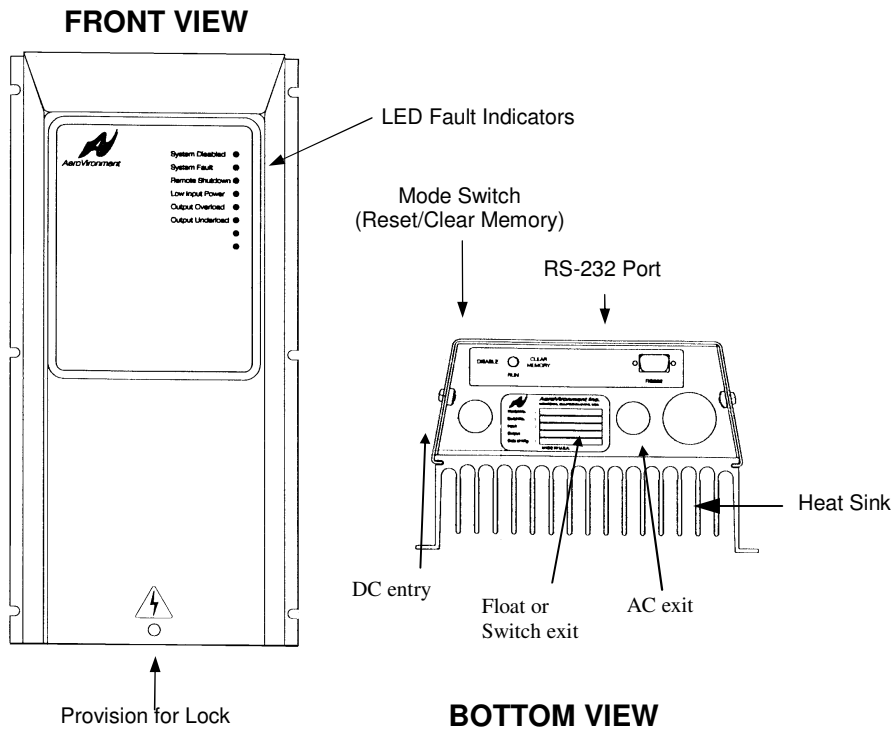


Figure 4.1 – USPC External Configuration View

5.0 USPC Internal Configuration

Figure 5.1 shows the internal contents of the USPC unit. The figure is provided to show location only. To safely service the USPC, be sure to follow the procedures in **Section 9** for **Installation**, **Section 10** for **Operation**, **Section 11** for **Maintenance** and **Section 12** for **Troubleshooting**.

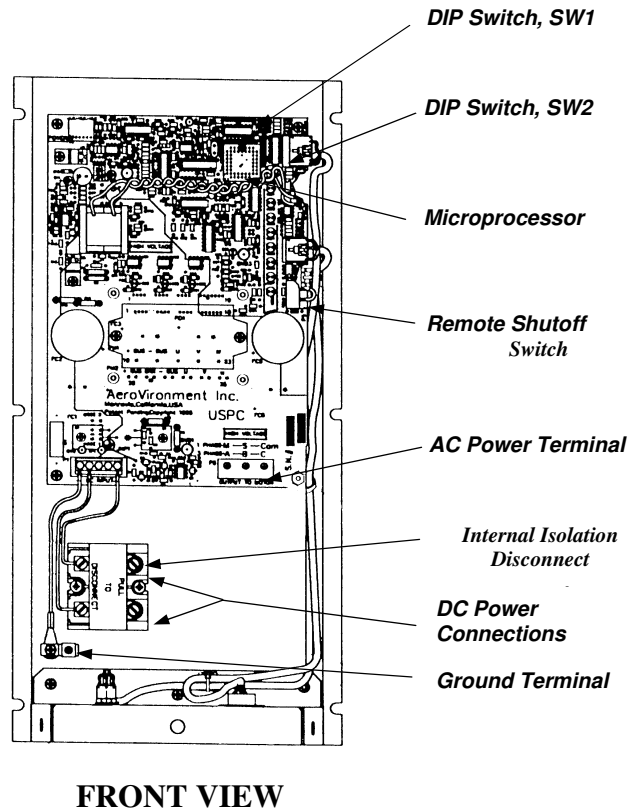


Figure 5.1 – USPC Internal Configuration

5.1 Internal Isolation Disconnect Device

This device is located in the lower left corner of the unit and is provided for safety isolation during service only. It is not meant to be used as a power switching device. After power to the USPC is removed, the internal isolation disconnect device can be removed and stored in a clean, safe location prior to installing or servicing the unit.

5.2 Remote Shutoff Switch Connector

This connector is used to hook up the system to a remote disconnect switch or switches. When this connection is open, the USPC will not run and will display the SHUTDOWN indicator. One application of this feature

is to connect it to a float switch what will open up if a water tank is at its full capacity. Multiple switches can be connected in series for other shutdown methods.

5.3 System Configuration Switch Blocks

The USPC must be configured by setting the two “DIP” switches, which are located in the upper right hand corner of the circuit board. See Section 8 for more details on setting the DIP switches.

5.4 DC Power Terminal

The solar array power is connected to the USPC at this terminal.

5.5 AC Power Connections

The pump motor is connected to the USPC at this location.

5.6 Ground Terminals

This is the main ground for the USPC. It must be connected to a good safe ground point. Refer to **Section 9 – Installation** for more information.

6.0 System Sizing

In order to obtain optimized performance from your USPC system, it is important to configure the system to meet the needs of the site and to fit the performance of the hardware available. It is recommended that the system configuration be performed by an AeroVironment-authorized supplier or dealer familiar with sizing solar pumping applications. AeroVironment can also help with system sizing directly. Having accurate information from the site, especially in regards to the Total Dynamic Head, is essential to get the most performance from the solar array and pump being used.

The best method for sizing the USPC system is to use the tutorial, worksheet and charts found in **Appendix A** of this manual.

7.0 Handling, Inspection & Storage

7.1 Handling & Inspection

Upon receiving the USPC unit, inspect it for any shipping damage. The unit should have no scratches on it, and the front cover and back heat sink should have no bends.

To inspect the interior of the unit for damages, unscrew the two screws at the bottom of the enclosure and lift off the cover. There should be no loose parts.

If the USPC was damaged during shipment, keep the shipping container and packing material from the carrier or distributor and file a claim for shipping damage immediately.

7.2 Storage

If the USPC equipment is not to be immediately installed, repack it in the original shipping carton and store it in a location that has temperatures between -30 to 70°C (-22 to 158°F) at all times. Do not allow the unit to be immersed in water.

8.0 Configuring the System

Configuring the USPC DIP Switches

The USPC DIP switches must be set prior to installation and operation. These switches enable the selection of the motor type, motor voltage, motor frequency and other operating parameters. Each DIP switch has eight (8) positions, which represent different operating parameters. The setting options for each switch are described below.

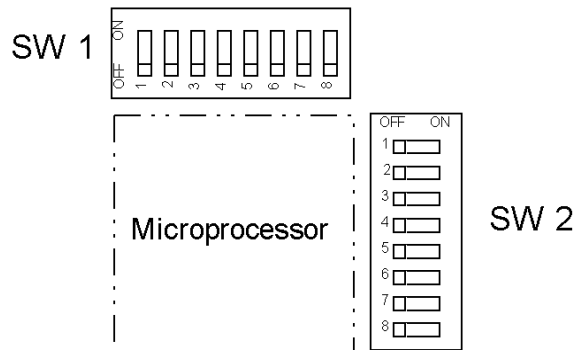


Figure 8.1 – USPC Switch Blocks

8.1 Switch Block 1 (SW1)

Switches are ON when UP and Off when DOWN.

Switch block 1 is identified as SW1. References to individual switches in the DIP switch block are referred to as SW1-#, where # refers to the numbered switch in the block. Switch #1 is the left-most switch and Switch #8 is the right-most switch.

8.1.1 Motor Phase (SW1-1 & SW1-2)

The pump motor can be either single- or three-phase. Check the motor nameplate to verify its configuration. Both switches, SW1-1 and SW1-2, must be in the SAME direction.

- *Single-Phase*: SW1-1 to OFF and SW1-2 to OFF (DOWN)
- *Three-Phase*: SW1-1 to ON and SW1-2 to ON (UP)

8.1.2 Nominal Motor Speed Selection (SW1-3)

The nominal pump motor speed (or nominal frequency) is either 50 Hz or 60 Hz. Refer to the pump motor nameplate to determine the proper setting.

- *60 Hz*: set SW1-3 to ON (UP)
- *50 Hz*: set SW1-3 to OFF (DOWN)

8.1.3 Maximum Speed Limit (Overdrive) (SW1-4)

The overdrive feature (also called maximum speed limit) allows the pump to drive at a speed 5 Hz over the nominal motor speed when sufficient power is available. Consult the pump supplier before selecting this option to avoid any damage to the motor or pump.

- *+5 Hz Over Nominal Motor Speed*: set SW1-4 to ON (UP)
- *Limit to Nominal Motor Speed*: set SW1-4 to OFF (DOWN)

8.1.4 Minimum Motor Operating Speed (SW1-5 & SW1-6)

Setting the minimum motor operating speed (or minimum frequency) to a value near that required to achieve flow will minimize the pump and motor wear. Refer to the sizing charts in Appendix A to determine an appropriate value. If uncertain, use 30 Hz. Consult the pump supplier before selecting 10 Hz to avoid causing damage to your pump or motor.

- *45 Hz*: set Sw1-5 to ON and SW1-6 to On (UP) (UP)
- *40 Hz*: set SW1-5 to OFF and SW1-6 to ON (DOWN) (UP)
- *30 Hz*: set SW1-5 to ON and SW1-6 to OFF (UP) (DOWN)
- *10 Hz*: set SW1-5 to OFF and SW1-6 to OFF (DOWN) (DOWN)

8.1.5 Output Voltage (SW1-7 & SW1-8)

The output voltage must be set to the correct value or damage may be caused to the motor. Refer to the pump motor nameplate to select the proper setting.

- *230 VAC*: set SW1-7 to ON and SW1-8 to ON (UP) (UP)
- *208 VAC*: set SW1-7 to OFF and SW1-8 to ON (DOWN) (UP)
- *115 VAC*: set SW1-7 to OFF and SW1-8 to OFF (DOWN) (DOWN)

8.2 Switch Block 2 (SW2)

Switches are ON when RIGHT and OFF when LEFT.

Switch block 2 is identified as SW2. References to individual switches in the DIP switch block will be referred to as SW2-#, where # refers to the numbered switch in the block. Switch #1 is the top-most switch and switch #8 is the bottom-most switch. Positions #2, #3, #4 and #7 are not used and should be switched to the OFF (LEFT) position. Settings for the remaining switches are as follows.

8.2.1 Memory Reset (SW2-1)

This switch is wired in parallel to the external MEMORY CLEAR switch and should be left in the OFF (LEFT) position. The system protection features will not work correctly if this switch is left in the ON position.

8.2.2 Fault Detection Margin (SW2-5)

This switch allows selection between two levels of error margins for overload and underload sensing. A wide margin will not trip as easily as a narrow margin but may provide less protection for your pump. AV recommends using the narrower margin unless it is determined that too many nuisance shutdowns may occur. Refer to **Section 12 – Troubleshooting** for additional information.

- *Narrow Margin*: set SW2-5 to OFF (LEFT)
- *Wide Margin*: set SW2-5 to ON (RIGHT)

8.2.3 Fault Detection (SW2-6)

This switch allows motor-based overload and underload shutdowns to be disabled. This setting should normally be enabled. If the switch is set to the disable position, the motor does not have as much protection and could be damaged by dry-well or locked rotor conditions. If significant nuisance tripping occurs and a wider margin doesn't help, this switch would allow system operation in an emergency. It should be noted that this feature does not disable the system-based overloads, which function at the system-based limits.

- *Enable Faults*: set SW2-6 to OFF (LEFT)
- *Disable Faults*: set SW2-6 to ON (RIGHT)

8.2.4 System Disable (SW2-8)

This switch is wired in parallel to the external DISABLE switch and should be left in the OFF (LEFT) position. The switch allows the system to be functionally disabled regardless of power being available and any other switch setting. When this switch is ON (RIGHT), power may still be present in the system, making this an unsafe mode to service the system in or open the enclosure.

- *Enable System:* set SW2-8 to OFF (LEFT)
- *Disable System:* set SW2-8 to ON (RIGHT)

9.0 Installation

READ THESE INSTRUCTIONS COMPLETELY BEFORE INSTALLATION.

Note: During installation, if a conflict arises between this manual and local or national electrical codes, the applicable local or national electrical codes should prevail.

- If a conflict of codes seems to cause improper operation, contact the distributor.
- The life expectancy and efficiency of the USPC may be adversely affected by improper installation.
- Installation not in accordance with this manual will void the warranty.
- The PV array structure, modules and wiring harness must be properly assembled according to the manufacturer's installation instructions before installing the USPC.
- AV recommends that the pump and motor are tested above ground with the USPC before installing the system in a well or other location.

9.1 Installation Preparation & Requirements

9.1.1 Site Requirements

When installing the USPC, the following items should be noted and/or followed:

- High voltage is present in the USPC when powered on; proceed accordingly.
- Provide provisions to protect the safety of unauthorized persons in the vicinity of the USPC and the solar array.
- Cover the array with a completely opaque tarp while completing the wiring and assembly procedures (high voltages can be present with some tarps; verify voltage presence with a volt meter periodically).
- Either short the array output or break the array connection in two places to help protect against high voltages during assembly as installation codes permit.
- Keep all flammable materials away from the assembly site, including dry brush and vegetation.
- For optimal performance, any fencing or other barrier should not cast shadows on the solar array (if possible).
- Install the USPC out of direct sunlight (if possible) to minimize heating and exposure damage.
- Keep the USPC out of direct rainfall (if possible).
- Install the USPC away from external sources of heat and moisture.

- Keep the surrounding area clear of vegetation.
- Do not block airflow around the USPC's heat sink.
- Provide provisions to prevent damage, theft or vandalism.
- Try to limit access of animals to the system.
- Do not allow bird or rodent nests or insect infestations to occur around or on the system.
- Protect wires from rodent chewing or other such damage.
- Do not leave the site if live wires are exposed.

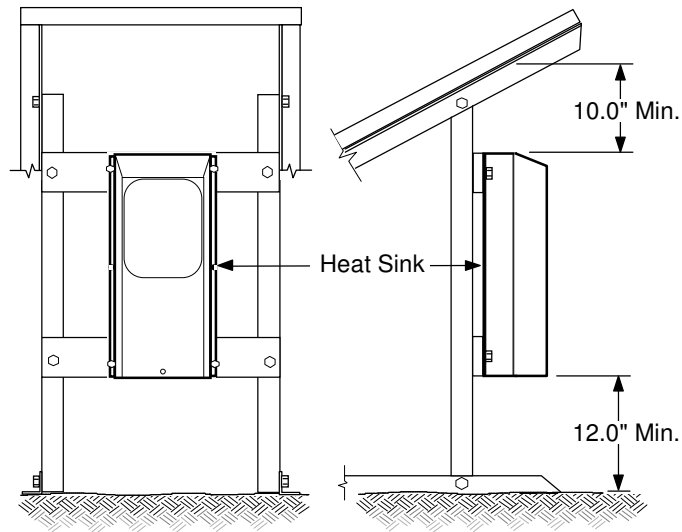


Figure 9.1 – Site Installation Diagram

9.1.2 Installation Recommendations

The best place for the USPC installation is under the PV array, as shown in **Figure 9.1**. This location helps minimize the effects of driving rain, sleet, snow and direct sunlight.

Wiring from the array to the USPC and from the USPC to the pump should be protected from weathering and abuse by use of a conduit. Additional protection can be achieved by burying the conduit in the ground.

9.1.3 Equipment Needed

Tools:

- Phillips-head screwdriver, medium size
- Flat-head screwdriver, 5/32" wide blade
- Flat-head screwdriver, 1/4" wide blade
- Wire cutters
- Wire stripper
- Tape measure
- Volt meter capable of reading 400 volts AC and DC

Mounting Hardware:

The hardware required to mount the USPC may vary due to site requirements and should be determined by the installer to obtain best results.

Installation:

- Completely opaque tarp

9.2 Physical Installation

Follow all local and national electric code requirements.

See **Section 9.1.1** for guidelines on locating the installation site. The USPC must be located out of the path of direct sunlight and away from any source of heat or moisture, in an area free of vegetation.

A good location for installing the USPC is on the solar array support structure closest to the array wire harness and near a good electrical ground.

The USPC must be mounted vertically, at a minimum of 12" (30 cm) above the ground; 3 ft to 4 ft (~1 meter) above ground is optimal. A minimum clearance of 10" (25 cm) must be maintained above the unit to allow the lid to rise for wire installation and allow airflow around the heat sink (very important). To completely remove the USPC cover, 19" (48 cm) clearance above the unit is required.

The mounting points on the USPC are located on the heat sink flange at the notched areas (three on each side). Use 1/4" diameter screws or bolts in each location, though four bolts or screws are sufficient to properly mount the USPC. During mounting, be careful not to bend or warp the heat sink.

9.3 Electrical Installation

WARNING: HIGH VOLTAGES PRESENT

Voltages capable of causing severe injury or death by electrical shock are present in this unit. This unit should only be installed or serviced by an AeroVironment-authorized dealer or supplier.

To safely service the USPC, the following procedure must be used:

- Securely cover the array with a completely opaque tarp.
- The external DC switch must be in the OFF position.
- Set the mode switch to DISABLE and then lift the cover.
- Remove the internal isolation disconnect device and put it in a safe place.
- Wait 15 seconds after removing power from the unit before servicing.

Note: During installation, if conflict arises between instructions in this manual and the local and national electrical codes, the local and electrical codes should be followed.

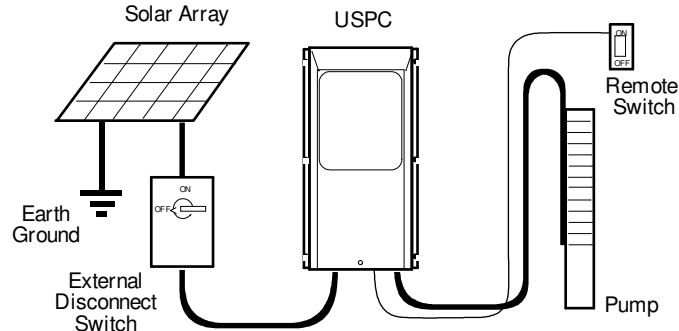


Figure 9.2 – Component Layout

The principal electrical elements of the installation are shown in **Figure 9.2**. They include 1) the USPC, 2) the solar array, 3) an external disconnect switch, 4) a pump and 5) a remote switch (optional). All electrical connections to the USPC are made through the holes at the bottom of the USPC. Be sure to follow local electrical codes and standards with respect to wiring and safety practices. AV recommends documenting the system configuration that you use, which can help with troubleshooting or servicing the unit at a later date.


9.3.1 External Disconnect Switch





Mount the external disconnect switch near the USPC. The purpose of this switch is to isolate the PV array from the USPC during installation or maintenance. AV recommends the disconnect switch also be mounted beneath the PV array. It should be easy to access in case of emergency.

Note: This disconnect switch must be mounted within the line of sight of the USPC to satisfy the NEC Code.

9.3.2 Internal Wiring

All of the USPC wiring is pre-assembled. The pre-installed wires are color coded and marked as shown in **Figure 9.4**. Do not change the location of the wires. This can cause damage to the equipment and will void the warranty.

RED	=	POSITIVE (+)
BLACK	=	NEGATIVE (-)
GREEN/YELLOW	=	GROUND (GND, )

TORQUE REQUIREMENTS			
	5.0 in-lb		0.54 Nm
	11 in-lb		1.20 Nm
	24 in-lb		2.61 Nm
	Ground Bar Torque Requirements		
	AWG	In-lb	Nm
	10-14	20	2.18
	8	25	2.73
	6	35	3.82
	(2) 12-14	25	2.73

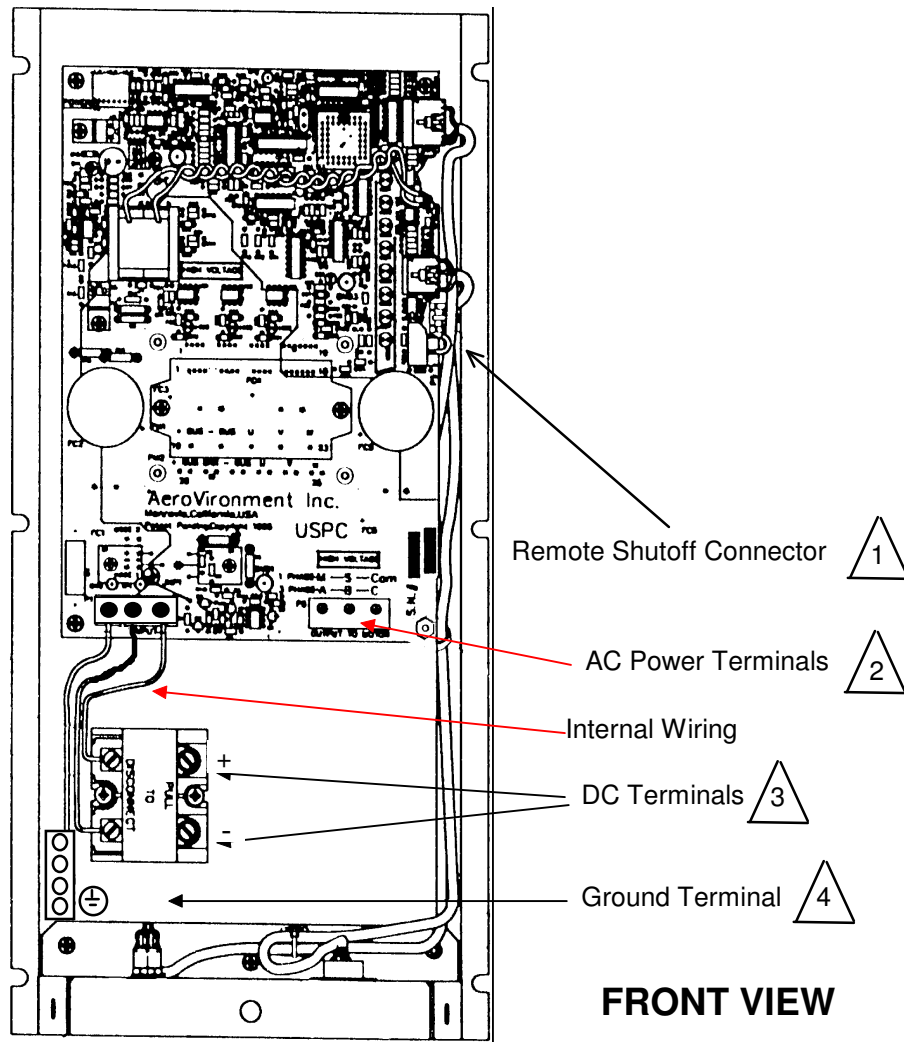


Figure 9.4 – Internal Wiring & Torque Values

9.3.3 Grounding Methods – Do’s & Don’ts

The purpose of grounding the USPC system is to provide protection for the systems as well as the user. A ground connection at all system components provides a low impedance return path (for fault current), which is easier for current to pass through than high impedance circuits or bodies. System components with exposed conductive surfaces must have these surfaces grounded to a common tie point so that a person or animal touching them will not provide the path through their body to ground. The solar array must have the structure and the solar panel frames grounded. NEC code also requires one power side of the array to be grounded, which in this case the negative side of the array will be the one that is grounded. The disconnect switch should have any

exposed conductive parts grounded. The USPC must have its enclosure grounded. The pump must have its casing grounded. All the grounds must be brought to one location through proper wiring, and that location must be tied to a good earth ground. Refer to local codes for a definition of what constitutes a “good” ground. Although the pump casing is immersed in water and seems to be a good ground, it cannot be used as such because if the well runs dry, the ground disappears and the system can become unsafe.

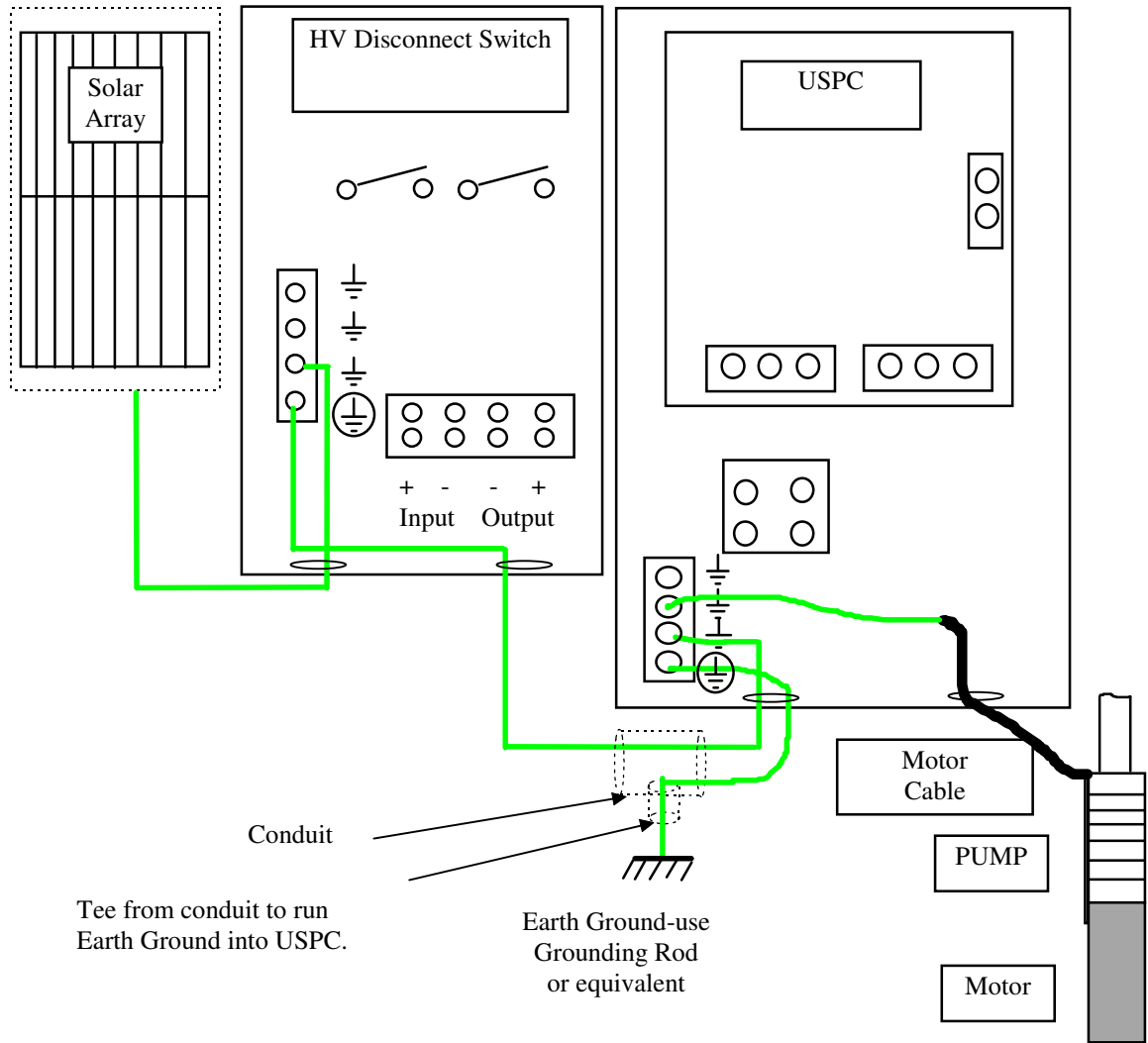


Figure 9.5 – Ground Wiring Diagram

9.3.4 DC Wire Connections

The power wires inside the USPC are color coded to show their function.

- Green is ground
- Black is the negative power connection (-)
- Red is the positive power connection (+)

If your DC cable selection matches these colors, make sure that all polarities are properly maintained throughout your system. If not, try to choose a connection plan that is not confusing. Improper connections can endanger safety and void the warranty should the system be damaged as a result. The ground wire must be connected to a good safe ground source. If you cannot locate such a source, do not proceed with the installation until one is provided.

To connect, first make sure that the disconnect switch is open. If the array is producing voltage, you must disable it before proceeding by covering it with a completely opaque tarp. The tarp must be secured so that it cannot accidentally come off during installation. If possible, open one or more of the array connecting wires to break any possible current path. Additional protection can be achieved by shorting out the array output with a jumper of sufficient size (i.e., able to conduct the worst case short circuit current that the array can produce). Whichever protection method is used, be careful because high voltages can be present on the wires.

Before installing the DC wiring:

- Follow the instructions noted above.
- Make sure that the external disconnect switch is off.
- Remove the USPC internal isolation disconnect device by pulling on the top of it and then set it aside in a clean area where you will not lose it.
- Connect the conduit or strain relief to the hole on the left after removing the hole cover by squeezing the rear part of the hole cover, which releases the locking tabs.
- Make sure that all the wires are properly identified and marked: 1) the cable from the PV to the external DC disconnect switch and 2) the cable from the external DC disconnect to the USPC.

Taking the DC cable that was selected for the PV array to the external DC disconnect switch, connect one end to the array and the other end to the primary side of the external disconnect switch. Connect the ground wire first, and then the negative and positive. The ground wire needs to be hard wired at the switch. Do not connect the ground through a switch (refer to **Figure 9.6** below). Next, install the DC cable from the external disconnect to the USPC

by connecting one end of the cable to the secondary side of the external disconnect switch and the other end to the USPC. Again, make sure to connect ground first, and then the negative and positive. The ground wire is connected to the terminal at the bottom left corner of the USPC. Connect the negative wire from the external disconnect switch to the terminal on the internal isolation disconnect device marked minus (-). Connect the positive wire from the external disconnect switch to the terminal on the internal isolation disconnect device marked plus (+) (refer to Figure 9.6 below). This completes the DC wiring.

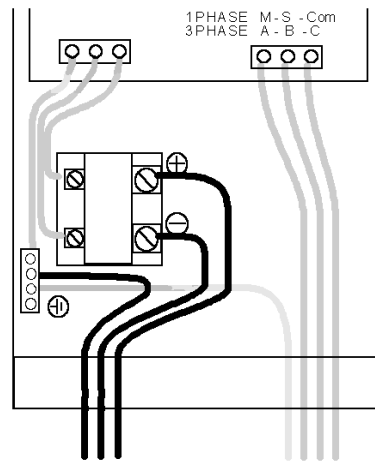


Figure 9.6 – DC Power Wiring

9.3.5 Pre-Power Polarity Check

It is now time to do a polarity correctness check before full power is applied to the system. With the external disconnect switch still open (OFF), remove the array output-shorting jumper (if it was used in the earlier steps) carefully, since high voltage arcing could occur. Next, reconnect any wire connections on the array that were previously opened for safety reasons during initial set-up. Connect a voltmeter set to read 600 VDC (or greater) to the primary terminals of the external disconnect switch, making sure that the meter lead polarity is properly connected (positive to positive and negative to negative). Due to the use of an opaque tarp, the voltmeter should show no voltage present. If the voltmeter does register voltage, the tarp that is being used is allowing light to pass, which is potentially dangerous. A completely opaque tarp should be obtained and used prior to proceeding.

Once the voltmeter is connected and zero voltage is indicated, fold over a small section of the tarp at a corner to allow some light to hit

the array. If the voltmeter shows voltage, verify that the polarity of the voltage is as expected. If the polarity isn't as expected, the array-to-disconnect wiring is most likely swapped and needs to be corrected. To do this, cover the array, verify that no voltage is present and swap the wires. Perform the polarity check again.

Next, move the voltmeter to the USPC internal isolation disconnect device input terminals. Connect positive to positive and negative to negative. Verify that the internal isolation disconnect device is still removed. With the external disconnect switch still open, again remove the array output-shortening jumper, if it had been applied, and reconnect any wire connections on the array that you opened for safety reasons. Fold over a small section of the tarp at a corner to allow some light to hit the array. Close the external disconnect switch and observe if the polarity of the voltage reading at the USPC is correct. If it is, then open the external disconnect switch. This test has verified that the array-to-USPC connections are at the proper polarity.

9.3.6 Low Power Logic Test

Before the pump is connected to the system, the following USPC low power logic test should be performed. First, close the external disconnect switch and observe the voltage applied to the USPC. If it is below 150 VDC, remove more of the tarp until at least 150 VDC is available. Open the external disconnect switch. Re-install the internal isolation disconnect device. Set the disable switch at the bottom of the USPC to DISABLE (LEFT position). The top LED indicator on the USPC should be showing DISABLED status. If this LED is not lit, following the troubleshooting procedure found in **Section 12**. If the LED is lit, switch the disable switch to ENABLE (MIDDLE position). The top LED should block one or three times and then the LEDs will start to blink from top to bottom. This sequence indicates that the system is operational and ready for the pump to be installed. Open the external disconnect switch to complete the test.

9.3.7 AC Wire Connections

USPC Output	Single-Phase Motors	Three-Phase Motors
1	Main Winding (BLACK)	Winding A (BLACK)
2	Start Winding (RED)	Winding B (YELLOW)
3	Neutral Winding (YELLOW)	Winding C (RED)
GND Terminal	Ground Wire (GREEN)	Ground Wire (GREEN)

Table 9.2 – Pump Wire Color Codes

Indications are marked above the output-to-motor connector as A-B-C and M-S-Com. The ground wire ties to the ground connector of the USPC in both motor configurations.

NOTE: Do not confuse the Com (Common) and GND (Ground) wires. They are not the same.

Do not connect a motor that has windings that are not clearly identified.

Follow the pump manufacturer’s specifications regarding line terminations and connections to the pump motor. To reduce resistive losses, a minimum cable length should be used. The induced current in the motor can be higher than the source current - and should be sized accordingly. The wire must be heavy enough to pass the pump motor’s service factor rating current. This is usually ~1.4 times the normal run current at full load. Keep in mind that with a larger wire, there is less of a voltage drop and less power lost in the wire, which offers more power to the motor. Since the DC voltage is passed through the USP to the motor, the voltage rating of the pump motor wiring should be the same as the DC wiring. Refer to the basic wiring notes in Appendix C for more information on wire selection.

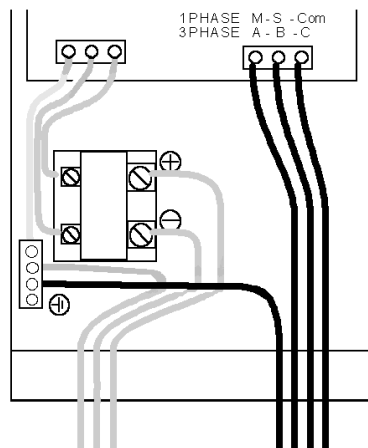


Figure 9.7 – AC Power Wiring

To proceed, remove the USPC internal isolation disconnect device and set it aside in a clean area. Remove the USPC hole cover found at the bottom right side of the enclosure (refer to **Figure 4.1** if needed) by squeezing the rear part of the hole cover to release the locking tabs. Connect the conduit from the well pump to the hole on the right side of the USPC and make sure that it is secured. The three power leads of the motor are to be attached to the USPC output terminals marked A, B and C, which are located at the lower right portion of the power electronics circuit board (see **Figure 9.7** above). The wiring guidelines outlined in **Table 9.2** above must be followed. The output connector is marked with phasing identification. Three-phase is A, B, C and single-phase is marked M (main), S (start) and C (common). The shield or conduit ground goes to the grounding connection. Connect the pump wires as outlined above and be sure to tighten them securely. Do not over torque any screws, and follow the torque guidelines outlined in **Figure 9.4**. The internal isolation disconnect can now be installed. This completes the installation of the AC pump wires.

9.3.8 Overflow / Shutoff Switch Wiring

The external shutoff switch is an optional, remotely located switch. This switch is typically installed on a storage tank to shut off the pump when the tank is full. The shutdown feature is engaged when the shut down switch is connection is opened. Additional switches may be installed at other locations if necessary to provide manual or safety shutoffs. Multiple shutoff switches must be wired in series using contacts that open when a shutdown is desired. Since the USPC requires a complete circuit in order to operate, any break in the circuit will cause the USPC to shut off (which includes broken or disconnected wires). The sense voltage on this shutdown circuit is very low (5 to 10 VDC) and fully isolated from the array voltage. The remote shutoff switch wires are connected to the connector shown in **Figure 9.4**, which is located on the right middle side inside the USPC. The shutoff switch wires must run through their own hole as shown in **Figure 4.1** and their own conduit – not in the same conduit as the AC pump wires or the DC wires.

9.3.9 Fusing Requirements

Fusing the DC circuit is not necessary, since all circuits are rated for full short circuit current from the array. A fuse in the DC path rated at or below the short circuit current of the array will fuse open during normal operation of the system, causing it to stop

functioning. A fuse rating above that of the maximum source current will most likely never be exceeded, thus making it redundant.

Fusing the AC circuit between the USPC and the pump is needed only when the array and pump are mismatched. This mismatch happens if you have an array that is used on different pumps (ie, the array is mounted on a trailer and moved to different locations – one being a small pump). Select a fuse that can handle the normal run current but will open when the over current value is exceeded. The voltage rating of the fuse should be 400 VDC or higher.

9.4 Start-Up

Install the internal isolation disconnect device and set the external mode switch to the DISABLE position. Enable the external disconnect switch. The USPC should now have power available and the top LED (System Disable) should be illuminated, indicating the system is ready. Move and hold the external mode switch to the CLEAR MEMORY position until the LEDs flash in a toggle manner, and then release the switch to the RUN position. When the array voltage is greater than 150 Volts, the USPC will power up itself. If a single-phase mode was selected, the LED will flash once in unison; if three-phase was selected, the LED will flash three times in unison. If the PV array has sufficient energy to pump water at the minimum frequency setting, it will immediately begin pumping water.

9.5 USPC Reset Procedure

Certain situations can cause the USPC to have to be reset. These include if conditions change for the pump, water levels drop, pumping changes to a higher site, etc.

To reset the USPC, using the toggle switch on the bottom left side of the USPC, hold the switch to the right until the top and bottom LEDs flash – and then let the switch come back to the middle. This action will reset the memory and the unit will automatically relearn the pump site characteristics. While the USPC is accelerating through various speeds, it is learning the pump/well/site characteristics.

10.0 Operation

In order for the USPC to run the pump, the follow conditions must be met:

- There must be enough light to power the array at a minimum level. This value will vary depending on the size of the array and the load.
- The system disconnect switch must be closed.
- The internal isolation disconnect device must be in place.
- The disable switch must be in the ENABLED position (MIDDLE), and the internal disable switch, SW2-8, must be to the LEFT (OFF).
- If implemented, the remote shutdown switch(es) must be closed.
- No fault conditions can be present.

10.1 General Start-Up & Operation

When the above criteria have been met and the DC voltage is greater than 150 VDC, the USPC will turn itself on and the top LED will flash to verify logic start-up. The USPC will then try to run the pump, which is indicated by the top to bottom sequencing of the LEDs. If the solar array cannot produce sufficient power to run the pump, then the USPC will shut down and the diagnostic LEDs will indicate *low input power*. The USPC will restart the pump at various intervals until the array delivers enough power to run the pump at its minimum speed. The USPC begins operation at 1 Hz and quickly (less than one second) accelerates the pump to its minimum operating speed as selected by the user. This may be 10, 20, 30 or 40 Hz. The power and speed required to produce water is dependent upon the pump size and the depth of the well (refer to the system sizing guidelines found in Appendix A). After the pump is successfully started, the USPC adjusts the motor speed up or down in an effort to operate at the maximum power level that the solar array can supply. This feature is called *Peak Power Tracking* (PPT). Operation at the peak power point ensures that the water pumping rate is always at its maximum possible level. The USPC continues operating in this manner until there is no longer enough sunlight to operate the pump. The fault that will occur in this situation is the *Low Input Power* fault.

The operational status of the USPC and pump is indicated by LEDs. The LEDs' functions are clearly labeled on the front of the USPC enclosure. A continuous sequencing of the LEDs from top to bottom indicates proper operation of the USPC. The speed of this sequencing is proportional to the motor speed. As the pump speed increases, the LED sequencing speed increases. If the system experiences a fault, the LED indicators will indicate what the failure was by blinking one particular LED. Refer to **Section 12 – Troubleshooting** for additional information on the diagnostics of the USPC.

10.2 Submersible Pump Operation

Water pumped from a well is replenished from the surrounding water table. The maximum flow rate the well can sustain is called its capacity. This capacity is dependent upon many diverse factors such as location, depth, well diameter and aquifer type. As the water in the well is pumped out, the water level may become lowered, which is known as draw down. The amount of draw down is dependent upon the pumping rate (water leaving the well) and the bore hole capacity (water entering the well).

When a pump is lowered into a well, it must be placed low enough below the water level to accommodate the draw down. If the water level drops too low, the pump will lose its priming and fill with air. This will cause the USPC to detect a dry well condition, *output underload*, and stop operation. If this fault occurs repeatedly, the well may be weak and not capable of supporting the pumping capacity of the system. It may be necessary to lower the pump further or limit the flow rate. For more information on this condition, refer to **Section 12 – Troubleshooting**. If you suspect that you have a weak well, consult a well drilling professional.

10.3 High Open Circuit Voltage

The USPC has a self-protection feature that keeps the internal voltage below 400 VDC when the USPC is connected to the array. When the voltage of the array tries to go above 400 VDC, this circuit is activated. The open circuit voltage must be below 600 VDC. In most cases, the array voltage should be below 400 VDC. Operating in a very cold environment can cause the rated voltage to be over 400 VDC.

The array is clamped through the power electronics to the internal secondary DC bus. *This feature will cause erroneous and random readings if the voltage of the array is read with a voltmeter.* This will only occur when the unit is connected and not running because little or no power is consumed. In a properly sized system, the voltage at which the unit normally operates is below this clamping voltage (less than 400 VDC) because of normal power draw from the array. In this mode, the voltmeter reading will be true.

NOTE: If the USPC is clamping the array and the DC internal isolation disconnect device is opened, the array voltage will jump to a much higher level (up to 600 VDC).

10.4 Heat Dissipation

The power electronics are activated and dissipating heat whenever the array is producing sufficient voltage for running. The heat sink needs to stay clear of weeds and other obstructions for proper cooling.

10.5 Turning Off the Unit

The disable switch can be engaged by turning off the unit, but the circuits will still have voltage present and be active. If no pumping is required for an extended period of time, AV recommends opening the internal isolation disconnect device to stop operation and maximize the life of the unit.

11.0 Maintenance

The USPC requires very little preventative or regular maintenance. To ensure proper operation, AV recommends the following.

- The cooling fins at the rear of the enclosure must be kept clear of debris and other obstructions that could inhibit proper cooling and thereby adversely impact the life expectancy and efficiency of the USPC. Failure to keep these fins clear of these blockages can void the warranty.
- The USPC's wiring and ground connections should be checked annually to make sure that they are in good condition.
- The unit should be checked at least once a year to make sure that no insect infestations have occurred.
- The area around the USPC and array should be kept clear of combustible materials, such a dry brush and other vegetation.

12.0 Troubleshooting

The USPC is constantly monitoring itself and the pump motor for possible faults. The LEDs on the front of the USPC enclosure will indicate if any faults have been detected. Refer to **Table 12.1** below for the LED listings, which are labeled on the USPC cover and the circuit board.

LED	Condition	Possible Causes	Corrective Action
1	System Disabled	Reset DIP switch or external disable switch engaged; or microprocessor defective.	Set the memory reset DIP switch to normal operation (SW2-1 to OFF) and the external switch to the RUN position.
2	System Fault	Over Current: motor winding shorted or connection shorted to case; pump may have lightning protection installed.	Check the motor and connections. Remove the lightning protection feature (these are only needed for utility connected systems).
		Over Temperature: unit may be in direct sunlight or the heat sink may be blocked.	Provide protection from direct sunlight and/or clean the heat sink area to ensure optimal cooling.
		Note: it is much more likely that a system fault has been caused by excessive current, rather than an over temperature fault.	Unit output may have been shorted or internal fault.
3	Remote Shutdown	The reservoir is full; the manual shut-off is enabled; or there is a broken/bad shut-off switch connection.	Check the integrity of the switches and connection.
4	Low Input Power	Insufficient solar radiation to operate the system (ie., early morning or evening, dark clouds or other blockage of light)	The USPC will automatically attempt to restart periodically; check for any blockage of light to the array or bad array.
5	Output Overload	Power too high for the motor speed (ie., electrical short, seized or bad motor, fouled pump or motor).	The USPC will shutdown until the reset button is pushed or power to the unit is interrupted. Disconnect power, inspect the system wiring, and the check the pump and motor.
6	Output Underload	Motor speed too high for power (ie., dry well, decoupled pump and motor).	The USPC will automatically attempt to restart periodically. Check the water level and height of the pump and the pump and motor coupling.

NOTE: During initial installation and startup, the Underload or Overload fault may appear and the system may repeatedly shutdown before water begins to flow normally. This is due to inconsistent loading during the

priming process. The reset switch may be depressed immediately in order to avoid waiting for the USPC to restart automatically. Make sure that the memory is cleared once the system is primed so that it can learn the true load profile.

NOTE: Any time environmental factors cause a change in loading, the memory may need to be cleared to accommodate the new conditions after all other possible causes for the fault have been investigated. If a bad motor exists, the unit will learn a bad curve so it is necessary to ensure that the motor is good before learning the power curve.

Appendix A – System Sizing Tutorial / Worksheet

Introduction

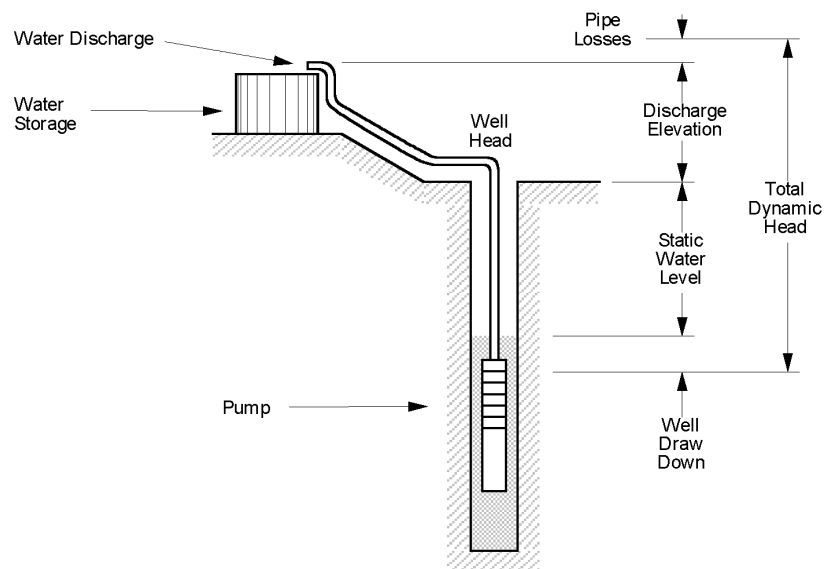
This guide is intended to supplement the attached *System Sizing Charts & Worksheet*. This document provides a description of the sizing process along with additional information that may be useful to the system integrator. Please note that the sizing tables published with this tutorial are relevant only to 4" submersible pumps and the conditions specified. Contact your distributor or AeroVironment's Customer Service Department directly for assistance if your system requirements fall outside these parameters.

1. Establishing System Requirements

The water requirement, also referred to as the system capacity, is usually specified by the customer in terms of gallons per day (GPD). This requirement is often given for both winter and summer. If the customer does not know his/her water needs, the following table can be used as a guide.

Each horse, dry cow or beef animal	12 GPD
Each milking cow	35 GPD
Each hog	4 GPD
Each sheep	2 GPD
Every 1000 chickens	4 GPD

The total dynamic head (TDH) is equal to the total amount of lift the pump must produce and is usually given in terms of feet. The TDH is equal to the sum of the static water level, discharge elevation, well drawn down, and friction losses in the pipe and fittings.



The static water level is the vertical distance from the water level in the well to the ground surface (often confused with the well depth or pump setting). This is the most important system sizing parameter, yet this value is often not known and even may change depending on the season. If uncertain, have a well driller or pump installer check the water level.

The discharge elevation is the vertical distance from the well head to the water discharge.

Well draw down is the vertical distance the water level in the well drops while pumping water. For most solar applications, the flow rates are sufficiently low that the draw down is not significant, unless the well is weak.

Friction losses in the pipe and fittings must be considered for installations where the pipe run is very long or the pipe diameter is small for the flow rates. This value is often very small compared with the vertical lift. **Tables 1 and 2** below can be used to estimate these losses.

Flow (US GPM)	PVC Plastic Pipe Diameter			15-Year-Old Iron Pipe	
	1"	1.5"	2"	3"	4"
5	1.75	0.20			
10	6.31	0.79	0.23	0.07	
15	13.00	1.70	0.50	0.15	
20		2.83	0.84	0.25	0.06
25		4.26	1.27	0.38	0.09
30		6.00	1.78	0.54	0.13
40		10.20	3.03	0.91	0.22
50		15.40	4.57	1.38	0.34
60			6.44	1.92	0.47
70			8.53	2.57	0.63
80			10.90	3.28	0.81
90			13.60	4.08	1.00
100				4.96	1.22

Table 1 – Friction Loss in Pipe (feet per 100 feet of pipe)

Type of Fitting	Nominal Size Fitting & Pipe				
	1"	1.5"	2"	3"	4"
Globe Value	26	44	55	80	110
Angle Value	15	22	28	42	58
Side Outlet of Tee	6	9	11	17	22
90° Elbow	3	4	5	8	11
45° Elbow	1	2	2	4	5

Table 2 – Friction Loss Through Fittings (feet of equivalent lengths of pipe)

The design insolation is a measure of the solar energy available usually given in terms of kilowatt-hours-per-square-meter-per-day (kWh/m²/day). This parameter is often presented for specific locations by season or month. Values are often given for various collector configurations; tracking, flat plate fixed horizontal, and tilted at various angles. Make certain that the correct assumptions and data are used. Tables and/or maps of solar insolation may be obtained from several government and industry sources. The solar insolation maps at the back of this tutorial are for fixed arrays, tilted at an angle equal to the latitude.

2. System Selection Using System Sizing Tables

The System Selection & Estimated Performance Tables are used to determine a suitable pump and solar array specification. There are several tables, each for a different pump motor type. Each of these tables is arranged with the total dynamic head on the vertical axis and the array rated power on the horizontal axis. Each cell in the table provides the necessary information to specify the system components and predict its performance.

Determining the pump motor specification is the first step in selecting appropriate system components. There are several electrical standards and the customer may have a preference based on locally availability or ability to use an existing generator as back-up. Three-phase motors are significantly more efficient than single-phase motors and should be used in most cases. High voltage motors are marginally more efficient than low voltage motors. Tables are provided for three common motor standards, which may be used for most situations.

Voltage Range	Phases	Frequency	Comments
230 (220 – 240)	3	50, 60 Hz	May be used for 208 VAC, 3 ph
230 (220 – 240)	1	50, 60 Hz	May be used for 208 VAC, 1 ph
115 (110 – 120)	1	50, 60 Hz	Typically available for less than 0.5 HP only

The pump model number and rating is determined from the system sizing tables for the specific requirement and pump motor specification. Use the following procedure:

- Select the row with a TDH most closely matching the design TDH. It is best to use a row identified with a TDH higher than the design requirement if there is no direct match.
- Then look toward the right for a cell most closely matching the desired pumping capacity. This will be the design configuration. It is best to select a design configuration that has a capacity slightly less than the design requirement. Record this value.
- Record the pump model number, rated horsepower and GPM rating from the table.
- Record the array minimum rated voltage from the row at the top of the table.

Important note for ordering submersible pumps:

Single-Phase Pumps – The power electronics used in the USPC are designed to provide the power for the start winding. This is how the high starting loads normally associated with standard AC pumps are avoided. The desired motor is typically referred to as a three or four wire single-phase motor. The wires are for the main, common and start windings, and there is often a ground wire. *Verify that the pump motor being ordered does not have an electronic or mechanically engaged starting capacitor.* This type of motor is usually called a two wire single-phase motor, although there are often three wires with the ground.

Three-Phase Pumps – Any three-phase motor will operate with the USPC.

Surge Suppressor Equipped Motors – Do not use motors equipped with surge suppressors. These devices are not normally designed for the type of PWM signal produced by the USPC electronics, and the motor will not operate. If additional protection is desired, contact AeroVironment's Customer Service Department for assistance in specifying the correct components.

3. PV Array Sizing

The array rated power specification from the selected design configuration must be corrected for the design insolation and capacity requirements. The following procedure should be used to determine the final array rated power and configuration:

- The array rated power is determined by multiplying the design configuration array rated power by correction factors for desired insolation and capacity. The correction for insolation is equal to 6.0 kWh/m²/day

divided by the design insolation in kWh/m²/day. The correction for the desired capacity is equal to the capacity required in GPD divided by the capacity from the sizing table.

- The minimum number of modules in series is determined by dividing the minimum array voltage specified in the sizing table by the nominal PV module operating voltage under normal ambient temperatures. The result is normally rounded up to the nearest whole number. Since the controller operates the induction motors on the basis of constant Volts / Hz, using a lower array voltage is likely to decrease system performance. A higher array voltage may increase performance in some cases, but will never decrease the performance as long as the peak power voltage point is at or below 400 VDC.
- The maximum number of modules in series is determined by dividing the maximum array operating voltage by the PV module nominal peak power voltage. The maximum array operating voltage is normally 400 VDC. Typically, the maximum number of standard modules in series is about 25. The maximum allowable open circuit voltage is 600 VDC.
- The PV module power rating is calculated by dividing the power required by the minimum number of modules in series. Select a PV module that has close to the required rating. Use more modules in series to achieve the desired array rating, if necessary.

NOTE: The assumptions used in the sizing tables include roughly 20 percent module degradation for aging, soiling, mismatching and temperature effects.

Appendix B – Installation Notes

The following reference information must be noted during installation. Proper and complete registration is the responsibility of the installer.

Date Installed:	
USPC Serial No. (Bottom Label):	
USPC PC Board Serial No.:	
Installer:	
Address:	
Phone:	
Location of Installation:	
Pump Manufacturer / Model No.:	
Motor:	
Make:	
HP:	
VAC:	
PH:	
Well Depth (m, ft):	
Pumping Rate Required (lpd, gpd):	
Solar Module Manufacturer:	
Module Model Number:	
No. Modules in Series / Parallel:	
Tilt Angle:	
Weather During Installation:	
Comments:	

Appendix C – Wire Selection

Select the DC Power Wiring from the Array

- Select the appropriate wire size from **Table C-1** for the DC cable connection from the solar array to the USPC

AC Pump to Pump Motor

- Consult your pump distributor or pump installation manual for the suitable power cable connection size from the USPC to the pump.
- If a recommendation from the pump distributor or pump installer is unavailable, the recommended pump power cable may be selected using Table C-1 below. This table lists the maximum recommended motor cable length for each motor horsepower rating and copper wire size. This recommendation is relevant only to copper wire, 230V, three-phase systems. For single-phase applications, use 0.6 as a multiplier of the value listed under *Wire Length (feet)* to determine the correct size.

Motor Power 3-Phase		Recommended Wire Size				
HP	KW	14	12	10	8	6
1.2 – 1.5	1.0	90'	145'	230'	360'	-
2.0	1.5	70'	110'	175'	275'	435'
2.5	2.0	50'	85'	135'	215'	335'
3.0	3.4	70'	110'	175'	275'	435'
3.5	1.5	70'	110'	175'	275'	435'
4.0	1.5	70'	110'	175'	275'	435'
4.5	1.5	70'	110'	175'	275'	435'
5.0	5.5	70'	110'	175'	275'	435'
		Wire Length (feet)				

Table C-1 – AC Power Wiring Selection Chart

Example:

If motor horsepower is HP = 1.2 – 1.5 and wires size is AWG = 14, under three-phase conditions, the acceptable maximum wire length is 90 feet.

For single-phase, 54 feet is the maximum length (90 ft x 0.6).

Appendix D – Replacement of Microprocessor Chip

The microprocessor can be easily replaced in the field for software upgrades.

READ ALL INSTRUCTIONS BEFORE ATTEMPTING TO REPLACE THE CHIP.

WARNING: All service performed on the USPC should be done at a static-free workstation. Static electricity can damage the PC board components.




The USPC operates from a program stored inside the processor chip U11. This program may need to be replaced as features are added or for software upgrades. Care must be taken during replacement to avoid damaging the processor part. U11 is a static sensitive part, which means that static voltage can damage the part. It is necessary to be statically grounded when replacing the part. It is also important to install the part in the correct position, not backwards or upside down. To replace the processor, make sure you have the following tools and follow all instructions carefully.

Required Tools:

- Ink marker
- 52-pin PLCC – IC extractor (or two small eyeglass-size screwdrivers)
- Replacement processor chip

Procedure:

- Make sure that all power is removed from the USPC. The part cannot be removed if power is still present.
- Wait **five minutes** after power is turned off before working on the USPC. All LED indicators should be off. 
- Open the USPC by removing the two screws at the base of the cover and sliding the cover up and off the unit. Set the cover to the side.
- For an added safety measure, pull out the internal isolation disconnect device and set to to the side.
- U11 is the processor chip and is located near the top right side of the unit. The chip is installed in a ~1” square socket. The chip should be oriented with the small dot up (the small dot is located midway on the edge of the chip). Mark the chip surface with the ink marker to identify it and distinguish it from the replacement chip.
- To remove the chip properly, use an IC extractor. This tool is used to remove 52-pin PLCC Ics from 52-pin PLCC sockets. The IC extractor looks like a large pair of tweezers with hooks on the two tongs. Insert the two hooks into the IC socket at opposite corners from where you see the two slots. The hooks grab the IC corners and pops out as you compress the handles. This removal should be done evenly and slowly. The chip should remain in the tool until you release the pressure on the handle.

If you are unable to obtain an IC extractor, it is possible to remove the chip by using two small rods (such as eyeglass screwdrivers). Pry the chip out slowly from each of the two slotted corners of the socket. Insert the two small rods into the corner slots so that they go part way under the chip's corners. The chip must be pried out *slowly and evenly*, so that it remains flat. Once removed, place the chip on a grounded clean surface or into a clean static-free container.

- Inspect the socket to make sure that no damage has occurred. All the pins inside the socket should look the same – even and straight. If any pins are damaged, the new chip may not install properly or work correctly.
- Remove the new chip from its container. Position the part so that it will go into the socket in the same direction as the one that was previously removed, with the dot on the chip facing up. Use the dot on the chip's edge as the proper alignment indicator, not the printed label.

Make sure the chip's pins are properly aligned with the socket's pin slots along all four edges.

Apply pressure to the chip evenly with your thumbs so that it snaps into the socket and lays flat and properly aligned. If it looks off, remove the chip and try again. The pins can be straightened slightly if accidentally bent.

- Put the old chip into the now empty container and dispose of properly.
- Reinstall the internal isolation disconnect device.
- Slide the cover back onto the unit and reinstall the cover screws.
- Follow the instructions in this manual for re-installation.

Appendix E – AC Submersible Pump Motor Power Ratings

- The shaft power produced from a submersible pump motor is higher than the rated power.
- A pump motor service factor rating is a good estimate of the input power required.

The solar industry is accustomed to working in measurements of Watts (w). Solar panels are rated in Watts, as are power electronics. Pump manufacturers typically rate their pumps to reflect the design shaft horsepower (HP) rating of the motor used (1 HP = 746 Watts).

To the solar system integrator, a HP rating for a pump might imply that the power consumed by the pump is roughly equal to the power rating of the motor divided by the motor efficiency. Three-phase 4” submersible pump motor efficiencies are typically near 70 percent, so the required input power for a 1.0 HP pump would be:

$$Power = 1.0 \text{ HP} \times 746 \text{ Watts/HP} / 0.7 = 1066 \text{ Watts}$$

However, the actual power consumed by a 1.0 HP pump is typically near 1400 Watts.

Example:	Pump Manufacturer	Grundfos
	Pump Model Number	16S10-10
	Pump HP Rating	1 HP
	Motor Rated Input Power	1070 Watts
	Design Point	16 GPM @ 205 feet head
	Measured Power @ 60 Hz	1430 Watts

The reason for this discrepancy is that submersible pump manufacturers tend to load the motor at close to the rated service factor of a motor. This operating point represents the usable margin for the motor and may be 15 percent to 40 percent higher than the rated input. The pump manufacturers have sufficient control over the design load to use this available margin. The rated load and service factor ratings for Franklin three-phase submersible pump motors are given as an example.

Example:	<u>HP</u>	<u>Rated Input (W)</u>	<u>S.F. Load (W)</u>
	0.50	585	860
	0.75	810	1150
	1.00	1070	1440
	1.50	1460	1890
	2.00	2150	2700
	3.00	2980	3420
	5.00	5050	5810

To check this, the expected pump performance for the example shown above may be calculated from the power in the water output of the pump at the design point.

$$\text{Power in Water (Watts)} = 0.180532 \times \text{Flow (GPM)} \times \text{Head (Feet)} = 592 \text{ Watts}$$

For the example case, a 4" centrifugal pump typically has a peak efficiency of about 60 percent. Using a motor efficiency of 70 percent, the combined pump and motor efficiency should be about 42 percent. The power required to operate the pump is then:

$$\text{Power Required (Watts)} = 592 \text{ Watts} / 0.42 = 1410 \text{ Watts}$$

This result agrees well with the service factor rating for a 1.0 HP pump motor and the example measured performance. Most submersible pumps seem to tend to be loaded near the rated service factor for the motor. However, the actual input power can vary between manufacturers and even within make and model of the same manufacturer.

As a conservative estimate, the pump motor service factor rating may be used for the input power required at the design speed. When selecting a pump, always ask for the power required to drive the pump or the motor.

Appendix F – USPC Installation Checklist

Unit Model Number:
 USPC Serial Number:
 PCBA Serial Number:

Date:
 Installer:

Instructions:

The following checklist should be used when setting the DIP switches and again to verify the installation before start-up in the field. This checklist should be retained for your records.

Preparation:

Item	Setting	Verify
------	---------	--------

Unpack the USPC from its shipping container. Remove the two screws at the bottom of the enclosure and lift off the cover. Inspect the unit for damages.

1. Configure the USPC – DIP Switch SW1.		SW1			
2a. Set Motor Phase					
<i>Single-Phase</i>	1 = off	2 = off	1 =	on	off
<i>Three-Phase</i>	1 = on	2 = on	2 =	on	off
2b. Set Motor Frequency					
50 Hz	3 = off		3 =	on	off
60 Hz	3 = on				
2c. Set Maximum Frequency Increase					
<i>Nominal</i>	4 = off		4 =	on	off
<i>Nominal + 5 Hz</i>	4 = on				
2d. Set Motor Minimum Frequency					
10 Hz	5 = off	6 = off	5 =	on	off
20 Hz	5 = on	6 = off			
30 Hz	5 = off	6 = on	6 =	on	off
40 Hz	5 = on	6 = on			
2e. Set Output Voltage					
115 Vac	7 = off	8 = off	7 =	on	off
208 Vac	7 = off	8 = on	8 =	on	off
230 Vac	7 = on	8 = on			

3. Configure the USPC – DIP Switch SW2					SW2
3a. Set Switches 1 – 4 to Off					1 – 4 = off
3b. Set Fault Detection Margin					
<i>Wide Margin</i>	5 = on		5 =	on	off
<i>Normal Margin</i>	5 = off	← (std)			
3c. Set Fault Detection					
<i>Disabled</i>	6 = on		6 =	on	off
<i>Enabled</i>	6 = off	← (std)			
3d. Set Modulation Limit					
<i>Disabled</i>	7 = on		7 =	on	off
<i>Enabled</i>	7 = off	← (std)			
3e. Set System					
<i>Disabled</i>	8 = on		8 =	on	off
<i>Enabled</i>	8 = off	← (std)			

Installation:

Item **Verify**

1. Location: The USPC should be located out of direct sunlight, away from any source of heat or moisture, and in an area that is free of vegetation.

2. Mounting: The USPC should be mounted at least 12" (30 cm) above the ground, with a minimum clearance of 10" (25 cm) above the unit, and without obstruction to air flow around the heat sink.

3. Electrical: The electrical installation should conform to all local electrical codes and standards.

4. DC Power from PV Array:

4a. *V_{oc}* The PV array open circuit voltage should not exceed 600 VDC.

The PV array is configured to provide adequate voltage for the motor.

4b. *V_p* -115 VAC motor requires a minimum peak power voltage = 210 VDC

-230 VAC, one-phase motors require a peak power voltage = 385 VDC

-230 VAC, three-phase motors require a peak power voltage = 340 VDC

4c. *I_{sc}* The short circuit current for the array should not exceed the spec.
 -8 Amps maximum, USPC-2000
 -18 Amps maximum, USPC-5000

5. AC Power Wiring to Motor (verify with motor/pump documentation)

<i>Output</i>	Single-Phase	Three-Phase
<i>A</i>	Main Winding (Black)	Winding A (Black)
<i>B</i>	Start Winding (Red)	Winding B (Yellow)
<i>C</i>	Neutral Winding (Yellow)	Winding C (Red)
<i>GND</i>	Ground Wire (Green)	Ground Wire (Green)

Initial Startup:

Item **Verify**

1. Install the internal safety isolation disconnect and set the external mode switch to the DISABLE position.

2. Enable the external disconnect switch. The USPC should now have power available and the top LED, *System Disabled*, should be illuminated, indicating that the system is ready.

- Move and hold the external mode switch to the CLEAR MEMORY position until the LEDs flash in a toggle manner, then release the switch to the RUN position. If
3. there is sufficient power available, the LEDs will cycle from top to bottom indicating that the USPC is operating. The USPC should slowly increase motor speed while calibrating to the new installation.

 4. Observe the system operation to ensure that there are no indications of any faults or problems with the installation. Refer to Section 12 – Troubleshooting if there appears to be any problems.

####