Global LEAP SWP Test Method

Version 1

December 13, 2019

Contents

1 Scope

This document defines methods to evaluate the quality and performance of off-grid solar water pumps (SWP).

The test method consists of the following major components:

- Overall **product quality** inspection both internal and external as well as an evaluation of the user manual and manufacturer provided information
- Evaluation of **performance**

The following international test procedures have been referenced in the preparation of this document:

- IEC 62253: 2011: Photovoltaic pumping systems – Design qualification and performance measurements
- IEC 62257-9-5: 2018 Integrated systems – Laboratory evaluation of stand-alone renewable energy products for rural electrification

2 Testing and evaluation definitions

2.1 Centrifugal Pump

A pump whose motor powers its impellers to rotate, which forms a suction to move fluid.

2.2 Positive Displacement Pump

A pump that traps water in cavities and uses decreasing pressure on the discharge side and increasing pressure on the intake side to move a fluid.

2.3 Maximum Power Point Tracking (MPPT)

A charge controller algorithm searches for the maximum power point along the PV array's I-V curve in order to maximize the power utilized from the PV array.

2.4 Inverter

A mechanism that transforms DC (direct current) into AC (alternating current).

2.5 Charge Controller

A device that controls the power (either current or voltage) going into a pump from a power source. Most charge controllers can detect operational faults and signal this to the user.

2.6 PV Array

Multiple PV modules that are connected in parallel or series.

2.7 Standard Testing Conditions (STC)

Testing conditions for PV modules and is defined as a cell temperature of 25 °C at 1000 W/m^2 and an airmass of 1.5. This is a standard in the solar industry to compare PV modules to one another.

2.8 Solar Array Simulator

Power supply that simulates an I-V curve, which allows a SWP charge controller to operate anywhere along that curve based off of the charge controlling algorithm.

2.9 Temperature Coefficient of V_{OC}

Quantifies the inverse relationship between temperature and voltage of a PV module.

2.10 Float Switch

Mechanism used for sensing water level that works by either opening or closing a circuit by the movement of some kind of instrument within, like a metal ball, being lifted or dropped by water level.

2.11 Head

The vertical distance water may be lifted by a pump, usually specified in meters.

2.12 Solar Irradiance

Amount of solar power available per m^2 of area at a given time.

2.13 Hydraulic Power (W)

Power converted by a motor to the movement of a liquid.

2.14 Hydraulic Energy (Wh)

Hydraulic power over time.

2.15 Wire to Water Efficiency

Hydraulic power generated by a pump divided by the measured input power.

2.16 Solar Day (hr)

Time over a day where there is solar irradiance above 0 W/m^2. Details on each simulated solar day and their assumptions can be found in the Volume Moved over Three Different Solar Days Test Method.

2.17 Testing Solar Irradiance

During the Dry Run Test, Full Tank Test, and Useful Operating Head Range Test, 700 W/m^2 is used as the irradiance set point, which is the highest irradiance seen during the Average Irradiance Day.

3 Test procedures

3.1 Visual Screening

The purpose of this section is to guide the Visual Screening process. Each of the following sub-sections (#1-8) correspond to physical components for a SWP apparatus/system. For each component, follow the provided guidance to describe a record each of the listed features in the test report. The information gathered here will also help inform the **Qualitative Assessment**. This procedure draws from IEC 62257-9-5: 2018, Annex F, Visual Screening.

1) External Photographs

   a) A photograph shall be taken of the controller, pump component, PV module and all included items that have been received by the test lab. This photograph should be representative of what a customer would expect to receive upon purchase.
   b) During the Visual Screening, photographs shall only be taken of the exterior of the controller, pump component along with any included accessories, the PV module, the product packaging, and the user manual/ warranty card (if applicable). These photographs should capture each side of the pump and its accessories as well as any ratings or product information. A more invasive, in-depth internal inspection shall be done once testing has been completed. Should there be any defects noted, high-resolution photographs shall be taken, and the defect documented.

2) General Information

For each SWP apparatus/system describe the following (if applicable):

   a) Company[1]
   b) Manufacturer[2]
   c) Submitting Entity[3]
   d) Product Name

[1] This is the branded entity on the product that will service any warranty-related issues. It could be the actual manufacturer or an entity that rebrands another product.
[2] This is the entity that actually manufactures the SWP apparatus/system
[3] This is the entity that submitted the product to be included in the competition and can be the company, manufacturer, or another entity like a distributor.

e) Model #[4]

3) Controller

For each controller or inverter describe the following (if applicable) and note the source (user manual, product packaging, engraving on component, metal plate fastened on component, easily removable sticker on component, or manufacturer provided documentation) of the information:

a) Inverter or charge controller
b) MPPT or PWM
c) Dimensions [length x width x height]
d) Minimum input voltage
e) Maximum input voltage
f) Maximum input current
g) Minimum input power
h) Maximum input power
i) Minimum wire gauge input
j) Maximum wire gauge input
k) Type of conductor connection
l) Ingress protection (IP) rating
m) Remote monitoring present?
n) Indicators
o) Battery
a) Chemistry
b) Pack type
c) Nominal voltage
d) Capacity [Ah]
e) Overvoltage protection [V]
f) Low voltage disconnects [V]
g) Manufacturer
h) Safety or balancing circuit present?
i) Battery safety certifications
j) Encasing material
p) Ports
    i. Receptacle type
    ii. Number of identical ports
    iii. Nominal port voltage
    iv. Is the port intended to be used for charging mobile devices?

[4] Not every product may have a model #.

v. Port name
vi. Receptacle type

4) Pump component

For each pump describe the following and note the source (user manual, product packaging, engraving on component, metal plate fastened on component, easily removable sticker on component, or manufacturer provided documentation) of the information:

a) Submersible or surface
b) Pump type (centrifugal, helical rotor, etc.)
c) Motor type
d) Materials used
e) IP rating
f) Dimensions [length x width x height]
g) Minimum voltage input
h) Maximum voltage input
i) Minimum current input
j) Maximum current input
k) Minimum power input
l) Maximum power input
m) Average power
n) Wire gauge
o) Maximum flow rate
p) Maximum head
q) Head range
r) Hours of operation
s) Volume of water moved per day
t) Type of pipe included
u) Length of pipe provided
v) Diameter of included pipe
w) Indicators

5) PV Module

For each pump describe the following and note the source (user manual, product packaging, engraving on component, metal plate fastened on component, easily removable sticker on component, or manufacturer provided documentation) of the information:

a) Maximum power P_{mpp}
b) Open circuit voltage V_{oc}
c) Short-circuit current I_{sc}
d) Voltage at maximum power point V_{mpp}
e) Current at maximum power point I_{mpp}
f) Temperature coefficients
g) Dimensions [length x width x height]
h) Cable length
i) Outdoor cable rating/certifications
j) Active solar material
k) Encasing material

6) Documentation

For the provided documentation describe the following:

a) Company information
    i. Address
    ii. Phone number
    iii. Website
b) Manufacturer information
    i. Address
    ii. Phone number
    iii. Website
c) Submitting Entity Information
    i. Address
    ii. Phone number
    iii. Website
d) Operation manual provided?
e) Operation manual languages
f) Any warning labels?
g) Any certifications listed?

7) User or Operation Manual

For the user or operation manual, note if the following is included:

a) PV operation

    i. keep PV module surface clean
    ii. how to connect PV module to unit

iii. maximum distance between PV array and controller or pump
iv. face PV module surface toward the sun

b) Installation
   i. any required pre-use steps described (fully charge battery, insert supplied fuse, if applicable)
   ii. instructions on how to prime the pump before use (if applicable)
   iii. instructions for wire termination or connection during installation, if applicable
   iv. how to make all required permanent connections
   v. keep away from fire
   vi. install securely
   vii. controller location requirements
   viii. install by company that sells the DUT and/or trained technicians (and if so, if technician training documentation or other detailed installation
   ix. temperature restrictions
   x. instructions regarding wire or cable connections (e.g. warnings to prevent shorting connections, directions on stripping the wires and instructions to securely screw down the wires
   xi. dry run warnings
   xii. other warnings
   xiii. minimum water level above the pump
   xiv. minimum water level above the bottom of the borehole
   xv. liquid requirements
   xvi. pump placement or orientation
   xvii. instructions on how to set up remote monitoring

c) Product operation
   i. how to connect all advertised appliances
   ii. battery state-of-charge instructions
   iii. display instructions, if display is included
   iv. warning not to cut or heat cable

d) Maintenance
    i. warning to keep PV module surface clean
    ii. specifications for components that may require replacement (fuses, lights, PV, batteries)
    iii. instructions for replacing components that may require replacement (fuses, lights, PV, batteries)
    iv. battery state-of-charge directions for long-term storage
    v. disposal instructions

8) Warranty

Describe the following and note the source of the information (user manual, product packaging, documented on component, or manufacturer provided documentation):

a) if a warranty is included
b) duration of warranty
c) how to access the warranty
d) if it is consumer-facing
e) warranty source
f) special warranty stipulations
g) other features

3.2 Qualitative Assessment

Provide a rating (good, satisfactory, needs improvement, poor) for the following categories:

a) External Inspection
    i. Test the functionality of all buttons, ports, and indicators
    ii. Note any safety, functionality, or workmanship deficiencies
    iii. Rating scale:
        1. Good – No workmanship or functionality deficiencies were observed
        2. Satisfactory – Small workmanship deficiencies were observed such as scratches, missing screws, or small deformities, but these issues did not affect functionality of the product
        3. Needs improvement – Many workmanship issues were observed such as scratches, missing screws, or small deformities, that did not affect the overall functionality of the product or small functionality issues were observed such as broken indicator lights

4. Poor – Many workmanship issues were observed that affected the overall functionality of the product

b) Overall Safety

i. Note any external safety deficiencies.

ii. Rating scale:

1. Good – No safety deficiencies were observed
2. Satisfactory – One or two deficiencies such as sharp edges or deformed metal that could cut a consumer were observed
3. Needs improvement – Many small safety deficiencies such as sharp edges or deformed metal that could cut a consumer were observed
4. Poor – Serious safety issues such as exposed wires that could severely injure a consumer were observed.

c) Internal Inspection

i. After the testing is done, the pump shall be opened up, and photographs taken of the interior parts, such as any wiring, the impeller, the inside of the casing, the motor (bearing assembly, seal, shaft, etc.) The following shall be documented:

(1) Bearing type
(2) Rust or corrosion
(3) Wire connection

ii. Note any safety, functionality, or workmanship deficiencies

iii. Rating scale:

1. Good – No deficiencies were observed
2. Satisfactory – One or two small workmanship deficiencies were observed such as missing screws or small deformities that do not affect functionality of the product
3. Needs improvement – Many small workmanship deficiencies were observed such as missing screws or small deformities that do not affect functionality of the product or small amounts of rust were observed that may affect the long-term functionality of the product
4. Poor – Many issues such as large amounts of rust or loose wires were observed that affected the overall functionality of the product or pose safety concerns

d) User Manual

i. Note any deficiencies
ii. Rating scale:
  1. Good – All the necessary information is clearly provided so that the consumer can set up and use the product based on the provided information
  2. Satisfactory – Some information may reference older products or other information may be missing or confusing, but the consumer can set up the product based on the provided information
  3. Needs improvement – Additional information is required in order for a consumer to set the product.
  4. Poor – There is no user manual, or the user manual provided references a completely different product

e) Warranty

i. Note any deficiencies
ii. Rating scale:
  1. Good – What is covered by the warranty, the length of the warranty, and how to access the warranty provided.
  2. Satisfactory – What is covered by the warranty and the length of the warranty are explained, but how to access the warranty is missing.
  3. Needs improvement – A warranty is provided, but there is conflicting information on either what is covered by the warranty, the length of the warranty, and how to access the warranty provided.
  4. Poor – There is no warranty information provided.

3.3 Test Station Description and Layout

The test station design draws from IEC 62253: 2011.

a) A general layout of the test station can be seen in Figure 1, and accuracy recommendations can be found in Table 1.

b) Because many SWPs utilize MPPT controllers, when supplying power to the SWP, a solar array simulator must be used. We are still determining what the minimum specifications are for the solar array simulator in order to ensure that the interaction between the controller and the solar array simulator is representative of what would be seen in the real world. Right now, we are recommending a programming response rate of no more than 30 ms, but this will be confirmed with additional testing and research on solar array simulators.

c) It is assumed that over the normal operating range of the pump, the pressure drop due to frictional losses between the pump outlet and the pressure sensor will be negligible.

d) Any pressure sustaining device can be used such as a ball valve which creates backpressure by restricting flow.

e) The discharge pipe should be beneath the water surface to prevent splashing to prevent air bubbles from entering the pump inlet and affecting performance. If this setup is not possible, a vertical baffle shall be installed between the pump intake and the return pipe so that the water can pass under the baffle

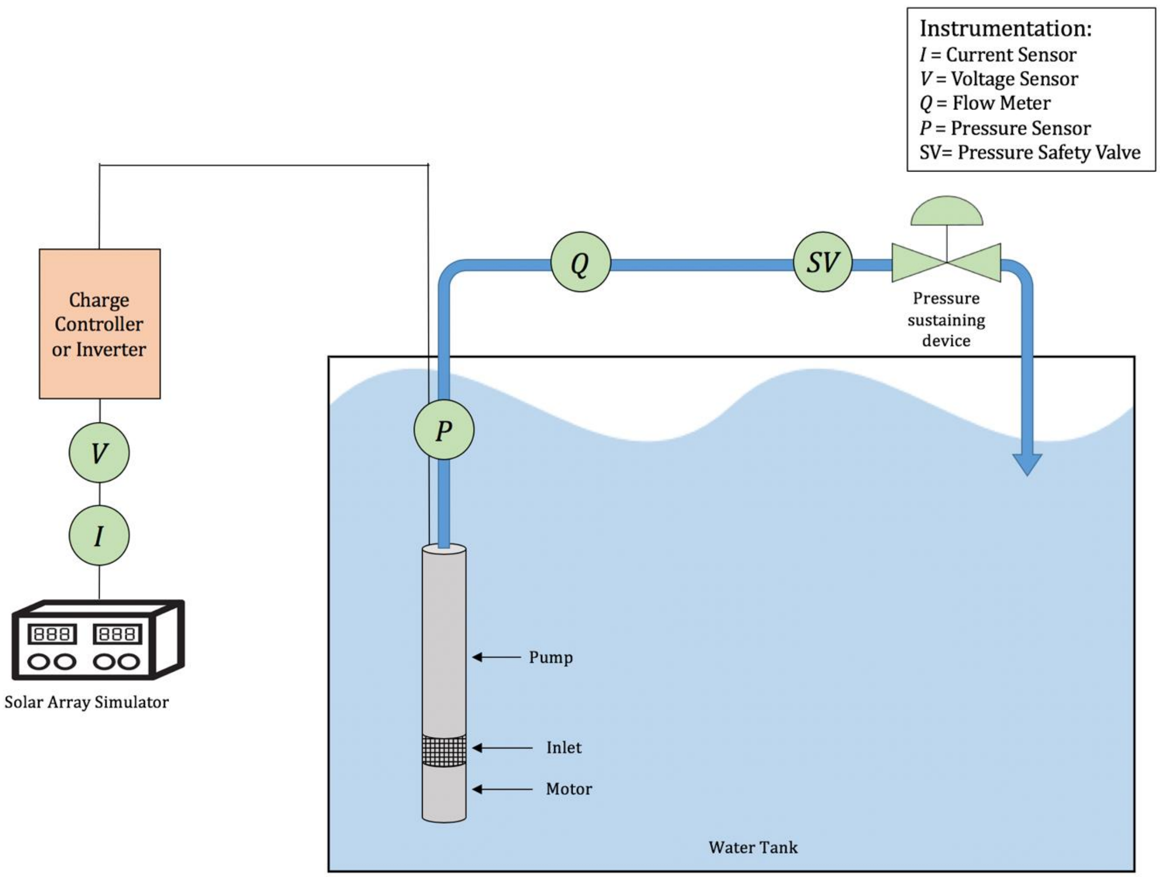

Figure 1: Test station diagram

3.4 PV Array Simulation

This section details how to determine the power settings for the solar array simulators. All PV arrays are simulated at a 50° C cell temperature.

a. Procedure

i. Determine the recommended PV array size (W) and PV module material from the submitting entity. If the submitting entity does not specify the material, the PV modules are assumed to be polycrystalline PV modules.
ii. From the PV array size and manufacturer guidance, determine the STC V_{mp} and I_{mp} values of the array. For many the solar array simulator software, the V_{mp} and I_{mp} are the required inputs to generate an IV curve used for testing.
iii. Unless the manufacturer specifies a temperature coefficient, -0.43 %/°C is used monocrystalline PV modules, and -0.35 %/°C is used for polycrystalline PV modules.
iv. For simulation purposes, the effect of temperature on the current is considered negligible. Therefore, when determining $I_{mp,50°C}$, the $I_{mp,STC}$ is equal to the $I_{mp,50°C}$.
v. To determine $V_{mp,50°C}$, use the following equation:

$$V_{mp,50°C} = V_{mp,STC}\left[1 + T_{C,Voc}(T - T_{STC})\right]$$

where

V_{stc}	is the PV module's voltage at STC, in volts (V);
V_{mp}	is the PV STC rated Vmp, in volts (V);
$T_{c,VOC}$	is the PV module's temperature coefficient for the voltage, per degree Celsius (1/°C);
T_{stc}	is the cell temperature at STC, 25 °C;
T	is the simulated cell temperature, 50 °C.

vi. The $V_{mp,50°C}$ and the $I_{mp,50°C}$ are then put into the solar array simulator software to generate an IV curve for the recommended PV array.

3.5 Dry Run Test

Determine if the pump has protection against a low water level or dry well situation. If no guidance is provided by the submitting entity or if the product comes with product dry run sensor perform the test below. However, some products may have innovative dry run protection that will need to be assessed on a case by case basis.

a) Procedure
   i. Simulate a 0 m of head or as close to 0 m of head as possible with the testing station.
   ii. Using the steps outlined in **3.4 PV Array Simulation** to determine the correct PV array, simulate 700 W/m^2 with the solar array simulator power supplies.
   iii. Once the pump has turned on and wait for the pump to stabilize. The pump is considered to be stabilized if over a five-minute period, the flow rate in not fluctuating by more than 5%.

iv. After the five-minute waiting period, simulate a dry well situation by either pulling the water level sensor out of the water, removing the intake house from the water, or another method to achieve a dry well situation.
v. As soon as the dry well situation has been initiated, start a timer and stop the timer once the pump has come to a complete stop. Run this test for two minutes, and if the pump continues to run after this waiting period, it determined that the pump does not have any dry run protection.

b) Report
   i. Simulated irradiance (W/m^2)
   ii. Time taken for pump to turn off (s)
   iii. Description of how the pump stops

3.6 Full Tank Test

This procedure determines if the pump has the ability to stop pumping water once its storage tank is full.

a) Procedure
   i. Simulate 0 m of head or as close to 0 m of head as possible with the testing station.
   ii. Using the steps outlined in **3.4 PV Array Simulation** to determine the correct PV array, simulate 700 W/m2 with the solar array simulator power supplies.
   iii. Once the pump has turned on, wait five minutes for the pump to stabilize.
   iv. After the five-minute waiting period, simulate a full tank situation. For example, many water pumps utilize a float switch which signals to the pump to stop once it starts floating on top of water. For pumps with this mechanism, simulating a full tank situation can be achieved by setting the float switch in a small tank of water or simply turning the float switch in a position that is representative of what the float switch would experience when exposed to water.
   v. As soon as the full-tank situation has been initiated, start a timer and stop the timer once the pump has come to a complete stop. Run this test for two minutes, and if the pump continues to run after this waiting period, it determined that the pump does not have any full-tank protection.

b) Report
   i. Simulated irradiance (W/m^2)
   ii. Time taken for pump to turn off (s)
   iii. Description of how the pump stops

3.7 Cold Start Test

This procedure determines the minimum irradiance needed to start the pump and references IEC 62253: Start-up power measurements (5.3.4)

a) Procedure

i. Using the steps outlined in **3.4 PV Array Simulation** to determine the correct PV array.
ii. Simulate 0 m of head or as close to 0 m of head as possible with the testing station.
iii. Starting at 50 W/m^2, increase the irradiance by 50 W/m^2 increments until the pump starts and runs for two minutes without turning off. If the pump turns off, there is not enough power for the pump to run for a sustained period of time, and the next step must be tested. When the two-minute mark is met, this is the minimum irradiance required to start the pump.

b) Report

i. Simulated irradiance (W/m^2)
ii. Measured flow at minimum PV power (lpm)

3.8 Head Range Test

This procedure references IEC 62253: H-Q characterization (5.3.3).

a) Procedure

i. Using the steps outlined in **3.4 PV Array Simulation** to determine the correct PV array, simulate 700 W/m^2 with the solar array simulator. All measurements for this test will be taken at 700 W/m^2.
ii. Simulate 0 m of head or as close to 0 m of head as possible with the testing station.
iii. Once the pump has stabilized, average and record the PV voltage, PV current, head, and flow over a two-minute period.
iv. Slowly ramp up the pressure until the pump can no longer provide flow. This is pressure is the highest head value for the pump's head range.
v. Repeat Step iii at 25%, 50%, and 75% of the maximum head value for a minimum of 5 number of measurements over the head range. Additional measurements are encouraged.

b) Calculate

i. Wire to water efficiency (hydraulic power output divided by the PV power input) for each head tested:

$$\eta = \frac{\rho g H Q}{IV}$$

where

η	is the efficiency (%);
ρ	is density (kg/m^3);
G	is gravity (m/s^2)
H	is flow (l/s);
I	PV current (I);
V	PV voltage (V).

ii. Maximum efficiency
   1. With a spreadsheet or program, use a non-linear minimization technique to minimize the sum of the squared residuals (SSR) between measured efficiency and simulated efficiency by altering the input variables.
   2. From the resulting equation, calculate the efficiency in 0.1 m increments, and determine the maximum efficiency and resulting head.

iii. Useful Operating Head Range

   This calculation is only performed for surface pumps.

   1. With a spreadsheet or program, use a non-linear minimization technique to minimize the sum of the squared residuals (SSR) between measured flow and simulated head by altering the input variables.
   2. From the resulting equation, calculate the head where the flow rate is 50% of the maximum flow rate.

c) Report

i. Simulated irradiance (W/m^2)
ii. Measured PV power (W)
iii. Simulated heads (m)
iv. Measured flows (lpm)
v. Calculated efficiency (%)
vi. Maximum efficiency (%)
vii. H-Q graph (Figure 2)
viii. Useful operating head range (surface pumps only)

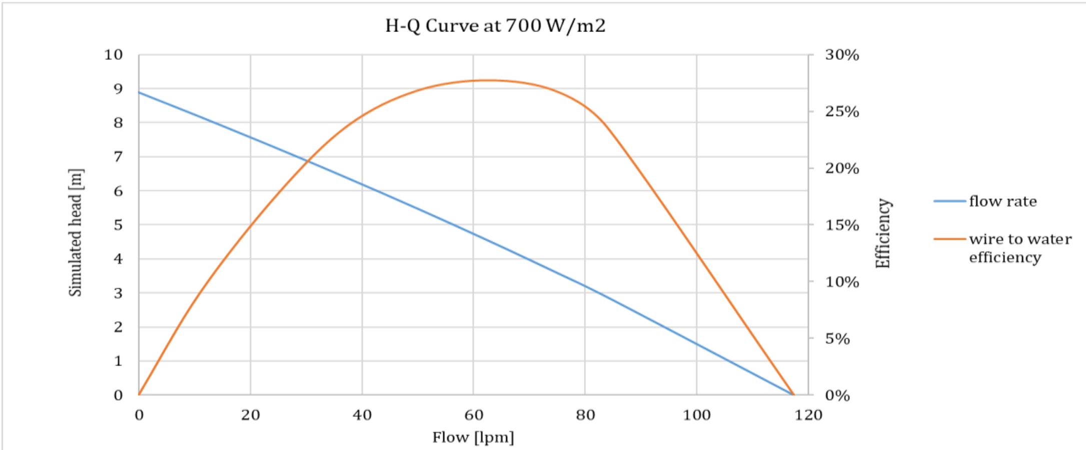

Figure 2: H-Q Curve

3.9 Volume Moved over Three Different Solar Days

This procedure references IEC 62253: P-Q characterization (5.3.2).

a) Procedure

i. Use the steps outlined in **3.4 PV Array Simulation** to determine the correct PV array inputs.

ii. Which head value to use for this section is dependent on how these test methods are being used evaluate a product:

1. If this evaluation is for a competition, the head value should be determined by the administrators running the program in conjunction with the entity submitting the product for testing.
2. If this is a private evaluation, the head value should be determined by the manufacturer or the entity submitting the product for testing.
3. If this is a randomly selected product from the market, this head value should be determined by how it's advertised use in that market.

iii. Ramp up the irradiance steps in 50 W/m2 intervals until the pump is able to provide a stable flow at the requested head for two minutes without tripping.

iv. As the irradiance is increased, the pressure sustaining device may need to be adjusted to maintain the requested head value.

v. Once the pump has stabilized, average and record PV voltage, PV current, head, and flow over a two-minute period.

vi. Repeat the measurement procedure so that there are least five measurements ranging from the lowest irradiance with flow to highest irradiance.

b) Calculations

i. Irradiance versus flow curve

1. With a spreadsheet or program, use a non-linear minimization technique to minimize the sum of the squared residuals (SSR) between measured flow and simulated flow by altering the input variables.
2. Graph this irradiance-flow curve based off of the equation determined in the previous step (Figure 3).

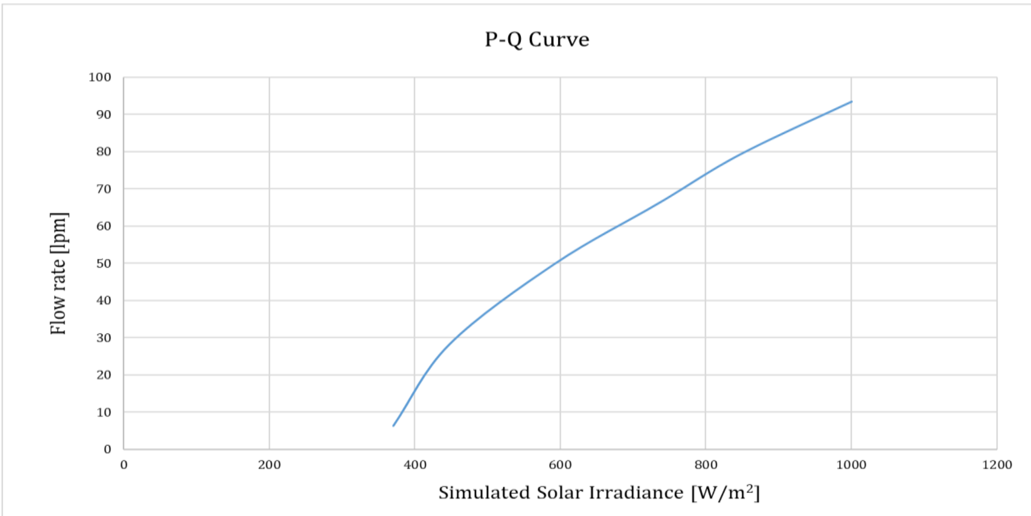

Figure 3: P-Q Curve

ii. Different irradiance days
   1. In assessing the pump performance over a full day, three different solar days are used. The solar day equations and approximate day parameters are listed below:
      a. High (max irradiance: 1000 W/m^2, 13.4 hours, 7.9 kWh)
         i. $y = 0.2403x^4 - 6.7085x^3 + 37.457x^2 + 130.5x - 41.541$
      b. Average (max irradiance: 700 W/m^2, 12 hours, 5 kWh)
         i. $y = 0.2894x^4 – 6.9456x^3 + 32.65x^2 + 108.29x +0.06244$
      c. Low (max irradiance: 500 W/m^2, 9.5 hours, 2.6 kWh)
         i. $y = 0.3329x^4 - 7.9895x^3 + 42.12x^2 + 70.359x - 163.5$

iii. Calculations
   1. Using the equation for each solar day, create a spreadsheet that shows the irradiance for each minute over the solar day.
   2. Using the equation determined in irradiance-flow curve, calculate the flow for each minute over the solar day.
   3. Create a graph (Figure 4) displaying both the irradiance over the day and flow rate over the day. Repeat this for each solar day.

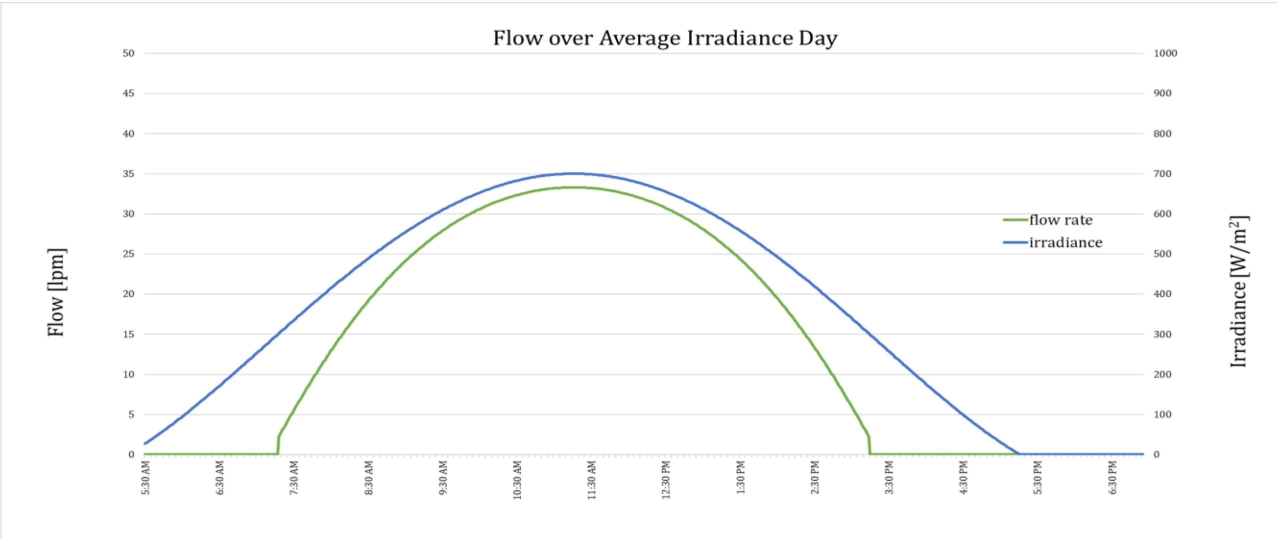

Figure 4. Flow over an average day

4. Total volume moved (m^3/day)
    i. Add all of the water moved at each minute interval for each solar day and convert to m^3/day to calculate the total volume moved over each solar day.
5. Hydraulic energy (Wh/day)
    i. Calculate the hydraulic energy at each minute interval and add this to determine the hydraulic energy for each solar day.

iv. Report
1. For each simulated irradiance day
    a. Flow (lpm) versus irradiance (W/m^2) graph
    b. Graphs irradiance (W/m^2), flow (lpm), time
    c. Total volume moved (m^3/day)
    d. Hydraulic energy for each day (Wh/d)

3.10 Mechanical Durability

This procedure references IEC 62257-9-5:2018, Annex W.

a) Procedure
    i. Confirm each switch/ button/ port works prior to testing.

ii. Press each type of switch/ button on the pump and/or charge controller (and/or inverter, if applicable) 1000 times, checking for functionality after each round of 100.
iii. If the product has any ports, test the ports by inserting and removing the correct plug to each port 1000 times, and check for functionality after each round of 100.

b) Report
   i. Any damage, functionality failures, or safety concerns
      1. If any are reported, also take photos and include them in the test report
   ii. The number of cycles achieved

3.11 Alternative Method

This procedure provides an alternative method to the testing if there are interaction issues between the solar water pump controller and the solar simulator. While this method appears to be a good alternative to using a solar array simulator, it has not been validated and is not recommended to be used until validation has occurred. The following equipment is required for the alternative method.

- PV stand that is able to be moved to follow the sun throughout the day
- calibrated pyranometer
- the recommended size of PV modules
- clear skies where the irradiance will reach 1000 W/ W/m^2

The test set up is identical, except, instead of using the solar array simulator to power the product under test, actual PV modules will be the source of power (Figure 5). Additionally, the reporting and calculations for each test is the same. Alterations to the procedures are outlined below.

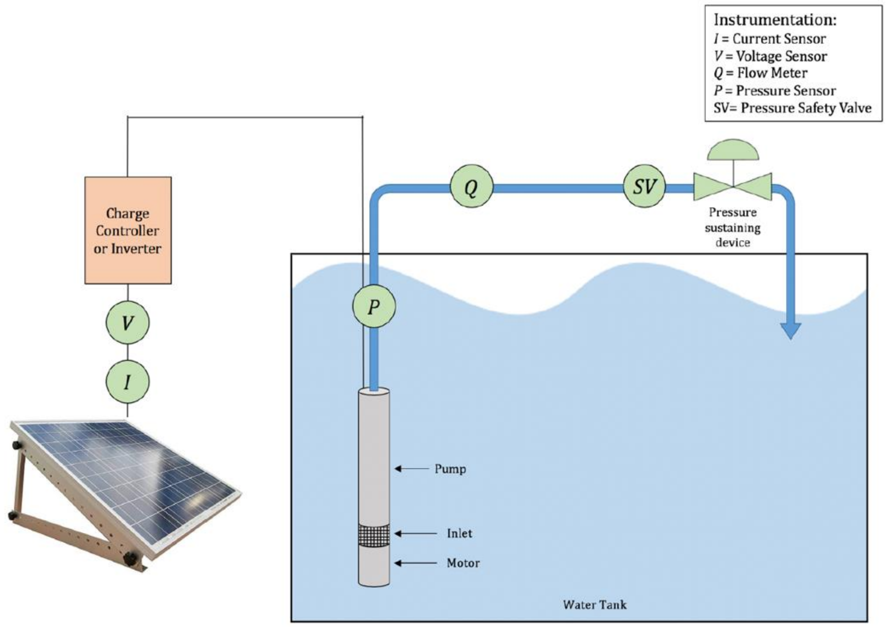

Figure 5: Alternative Test Set-Up

a) Alternative PV Array Simulation
   a. Instead of follow steps i-vi in **PV Array Simulation**, connect the actual PV modules sold with the product- or an array with equivalent wattage- to the product.
   b. When performing the tests using this method, a pyranometer must be placed in the same plane as the PV array to determine the irradiance that the PV array is exposed to.
   c. By slowly rotating the entire PV array and pyranometer, you can change the irradiance that the PV array is exposed to.
   d. Using this method requires two people to successfully complete the test. One person is operating the test station while the other person is monitoring the irradiance and adjusting the PV array stand accordingly.
   e. While following the stabilization and averaging in the normal test methods is recommended, because of quickly changing environmental conditions, point measurements without averaging are also acceptable for this method.

b) Dry run Test
   a. Procedure
      i. Follow Steps i-v of the **Dry Run Test** except instead of using Step ii to simulate the PV array, follow the Alternative PV Array Simulation to simulate 700 W/m^2 .

c) Full tank test
   a. Procedure
      i. Follow Steps i-v of the **Full Tank Test** except instead of using Step ii to simulate the PV array, follow the Alternative PV Array Simulation to simulate 700 W/m^2.

d) Cold start
    a. Procedure
        i. Follow Steps i-v of the **Cold Start TestDry Run Test**, and instead of using Step iii increase the irradiance in 50 W/m^2 increments using the Alternative PV Array Simulation.

e) Head Range
    a. Procedure
        i. Follow Steps i-v of the **Cold Start Test Full Tank Test** except instead of using Step ii to simulate the PV array, follow the Alternative PV Array Simulation to simulate 700 W/m^2.

f) Volume Moved Per Day
        i. Follow Steps i-vi of the **Volume Moved over Three Different Solar DaysFull Tank Test** except instead of using Step iii increase the irradiance in 50 W/m^2 increments using the Alternative PV Array Simulation.

3.12 Photo Appendix

This section will include all photos of the pump (interior and exterior) and all components listed in the Photos section of the Visual Screening. Some photos that may also be added to this section could include relevant photos taken during testing.

Annex A: Equipment Accuracy Recommendations

Table 1: Instrument Accuracy Recommendations

Parameter	Unit	Accuracy
PV Voltage	V	≤ 2%
PV Current	A	≤ 2%
Pressure	psi	≤2%
Flow	lpm	≤ 2%