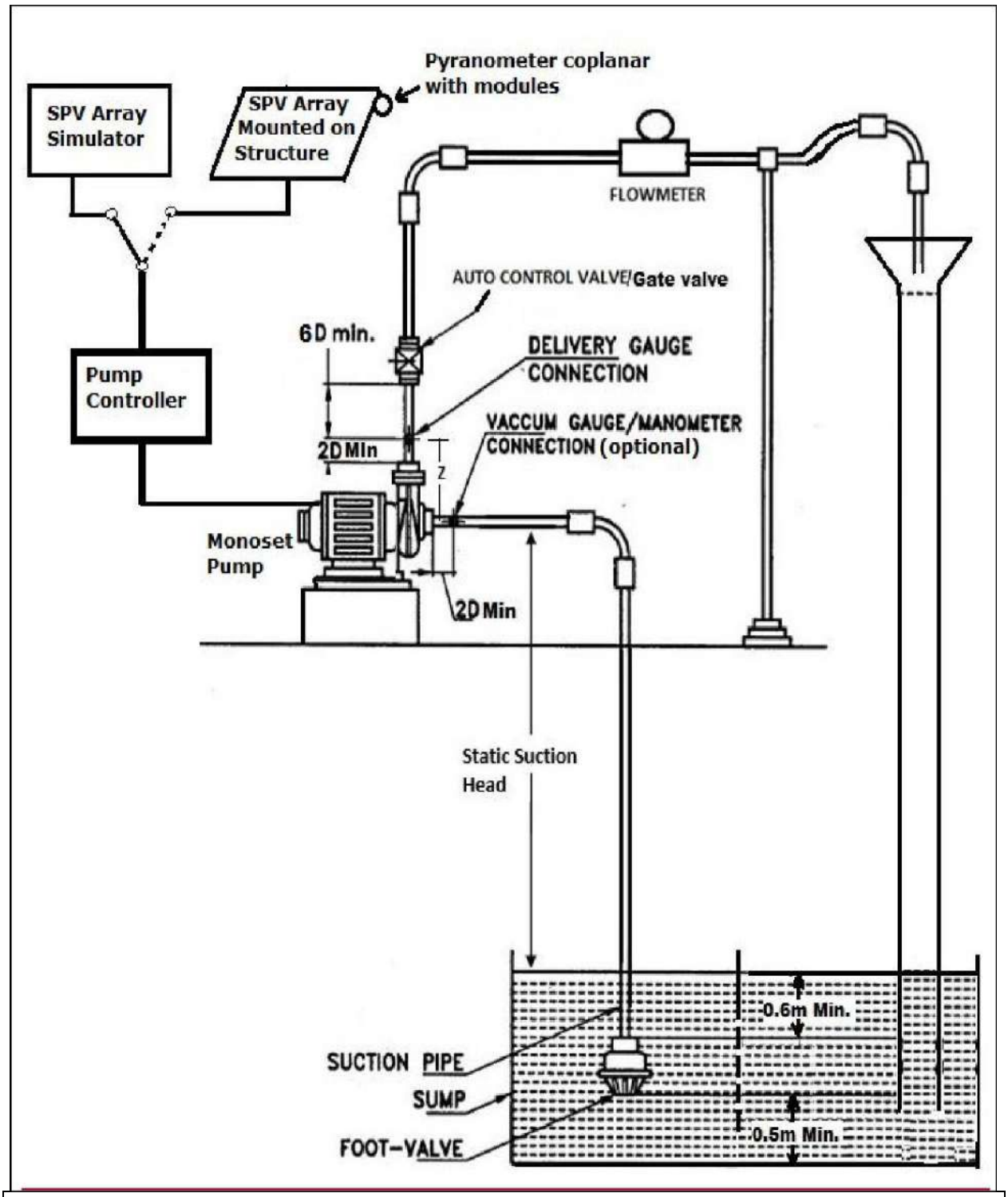


FIGURE 2 - TYPICAL TEST SET-UP FOR SPV SURFACE/MONO-BLOCK WATER PUMP SET

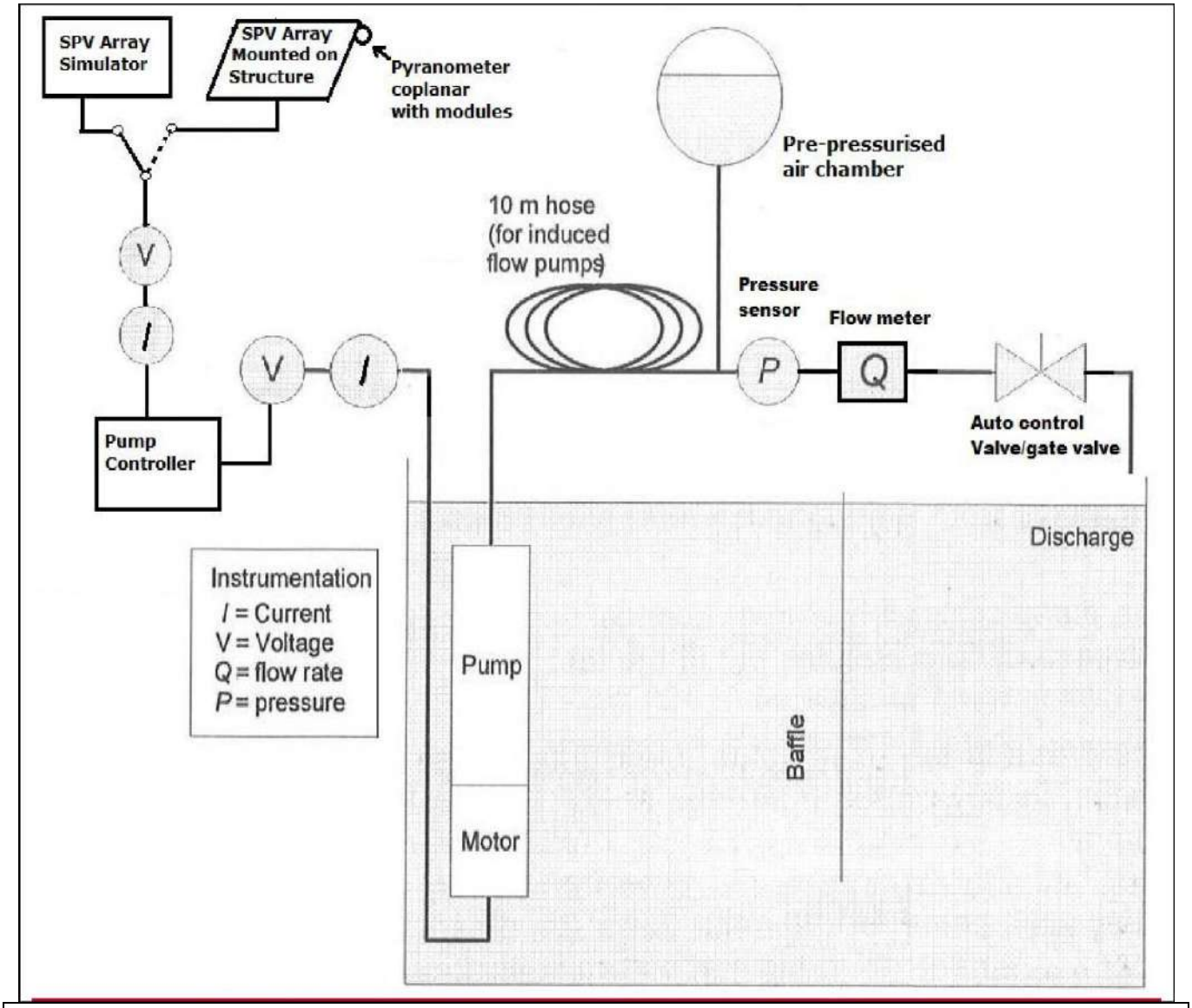


FIGURE 3 - BLOCK DIAGRAM OF TEST SETUP FOR SUBMERSIBLE PUMP-SET

5.0 Test Procedure for Performance Evaluation of SPV Pumping System:

There are three major profiles to be completed for comprehensive certification and qualification of a sample SPV water pump as per this standard. Two steps correspond to two simulation profiles, Hot & Cold. The third step corresponds to actual outdoor conditions testing using natural sun radiation. The SPV water pump sample should attain or exceed the qualification bench marks set by MNRE for the specified model & design, in all the three profiles. Before executing the three profiles testing, it is necessary to conduct the following protections test on the sample:

1. **Dry running:** System must shut down within one minute/manufacturer specification in dry running condition (when water level goes below pump inlet).
2. **Open circuit:** System should not operate if any phase become open circuited, the controller shall be tripped within one minute/manufacturer specified time.
3. **Short circuit:** System should not operate if any two or all three-phase short circuited.

4. **Reverse polarity:** System should not malfunction if polarity of input power is reverse.

5.**Under Voltage**: System shall not operate if terminal voltage goes below limit specified by manufacturer.

6.**Surge Protection:** Surge protection device (SPD) shall be installed on both the inputs and outputs side.

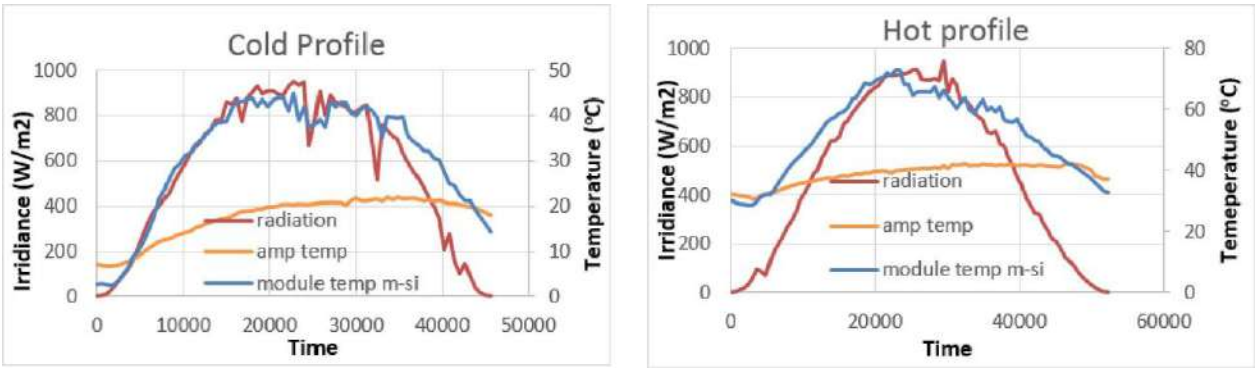
The performance testing of SPV Pumping System for the three procedures are discussed in following sections:

5.1 Simulator Methods:

Simulation methods are the easiest and fastest way of estimating SPV pump performance. However, in these methods actual PV array is not used, instead a PV array simulator is used. Here, a Programmable SPV array simulator capable of generating power output equal to actual SPV array under the given radiation and temperature conditions for given SPV array configuration (i.e. the number of modules, the type and the series / parallel combination) will be used. Although any radiation & temperature can be created, for the purpose of testing, two conditions one Hot summer day conditions (hot profile) and the other Winter day conditions (cold profile) shall be used.

Hot & Cold Profiles:

The typical Hot & Cold day profiles are shown Figure 4. These profiles of full day Solar irradiance and temperature shall be loaded in PV array simulator, sequentially one after the other. The simulator output is connected to the motor & pump through the pump controller and the profiles



are run-on real-time basis. The performance parameters as given in table 2 are collected every minute for the entire duration of run time (per day). The total water output and output in liters /watt STC/ day can be estimated at desired constant head / dynamic head for complete duration of profiles.

FIGURE 4 . TYPICAL SOLAR RADIATION HOT AND COLD PROFILE

Note: Per second data for hot and cold profile may be downloaded from MNRE/NISE website using the following link: -https://nise.res.in/public-information/technical-reports-resources/

5.2 Outdoor Condition using sun radiation:

To operate the motor-pump set using actual PV array, an array as per the Motor-pump set HP capacity to be designed. The STC wattage of all the PV modules is measured first, as per IEC 60904-1/ IS 12762-1 or clause number 11.6 of IEC 61215/ clause number 10.6 IS1 4286. The modules will then be installed on the structures, both in series and parallel combinations, as required, are connected and designed PV module array is created. The array output is connected to Motor & Pump through pump controller.

Per day water output test to be performed at desired constant dynamic head for complete day from dawn to dusk (sunrise to sunset). Irradiance shall be measured at coplanar to modules. Tracking may be done manually or automatically. Total flow shall be corrected at reference Average Daily Solar Radiation of 7.15 kWh/m^2 on the surface of SPV array (i.e. coplanar with the SPV Modules). Results of the SPV pumping system obtained under outdoor condition shall be compared with data supplied by the applicant and also from the results obtained through simulator testing to assess the performance of the system.

NOTE: -

- Handle PV modules carefully during installation.
- PV modules to be free from dirt (sand, bird droppings etc.,) during test.
- Install PV modules in shadow free access-controlled area.
- Tracking shall be minimum three time in a day for maximum performance
- Pyrono-meter should be mounted co-planer with SPV modules.

Recoding, measurement & logging of flow for the period of hot profile, cold Profile and Realistic condition need to be done.

5.3 Remote Monitoring System Verification

Provision for remote monitoring of the installed pumps must be made in the controllers through an integral arrangement and it should be capable of providing live status/parameters through online portal.

6 MEASUREMENTS AND APPARATUS

6.1 Solar Radiation Measurement

Solar radiation at coplanar with Module surface shall be measured using pyranometer. Response time of pyranometer should not be more than 15 seconds. Interval between two readings should not be more than one minute for the calculation of average daily solar radiation.

6.2 Measurement of Head

6.2.1 *Delivery Head*

Digital pressure gauge/sensor shall be used, also a data logging system must be used for calculation of average head through day. Interval between two readings should not be more than one minutes for the calculation of average head. Accuracy for pressure sensor shall be within ± 0.5 percent.

6.2.2 *Suction Lift*

Suction head shall be kept constant by mean of vertical distance from sump water level to centre of pump impeller. Correction in head shall be applied as per atmospheric pressure at the testing place.

Distance measuring scale or laser based sensors may also be used for suction head measurement.

6.3 Measurement of Rate of Flow

A good quality Magnetic flow-meter of minimum 0.5% accuracy class shall be used for flow measurement, data logging system shall be used for calculation of cumulative water volume throughout the day. The maximum flow rate of flowmeters should be at least 1.5 times the maximum flow rate of pumps. Instrument can be selected as per 3.2 of IS 11346. Interval between two readings should not be more than one minutes for the calculation of cumulative flow. Accuracy for flowmeters shall be within ± 0.5 percent.

7 CALIBRATION OF APPARATUS

All measuring instruments are to be calibrated periodically as per requirement.

8 STEP-WISE TEST PROCEDURE

8.1 Per Day Water Flow Test of Submersible Pumps

a) Install the Pump-set as per Figure 1.

b) Connect Pump-set with controller as per manufacturer instruction

c) Use Solar PV Array Simulator Or actual output from SPV array, for testing of pump-set at given profile.

d) Connect controller with PV array Simulator or with actual SPV array output as per requirement of profile

e) Input STC performance data of each module in the array, into simulator and invoke the desired profile and run the same.

f) For realistic condition test, make array by mounting all SPV modules on structure(s) by connecting modules in series or parallel as per requirement.

g) Start controller after connecting it with array or array simulator.

h) Use head control valve or pre-pressurize tank to keep constant desired dynamic head.

j) Record parameters as given in table 2 recording interval shall be ≤ 1 minute.

8.2 Per Day Water Flow Test of Surface Pumps

a) Install pumps as per Figure 2

b) Maintain height to get desirable static suction head as per requirement

c) Install of foot valve or non-return valve as per manufacturer instructions; and

d) Follow steps (b) to (j) of para-No. 8.1

9 OBSERVATIONS

The following observations of complete day profile shall be recorded in a test record sheet.

These observations shall be used to derive pump characteristics:

a) Instantaneous Solar irradiation (W/m^2), pyranometer reading
b) Delivery gauge/sensor readings
c) Suction gauge/sensor readings / Distance between water level to impeller eye, (if applicable)
d) Gauge distance correction factor, Z
e) Calculate cumulative daily solar radiation coplanar with solar modules (kWh/m^2),
f) Calculate total water discharge in a day at desirable constant head (Liters per Day)
g) Water output per day per watts peak (Liters/Wp)

10 COMPUTATION OF TEST READINGS

10.1 Computation of Total Head for Surface (Mono-set) Pumps

$$\text{Total Head } H = H_{SSL} + H_d + Z + ((V_d^2 - V_s^2) / 2g)$$

H_{SSL} = Total Static suction Lift in meters of water column (measured by calibrated measuring tape or any distance measuring sensors)

H_d = Delivery gauge/sensor reading in meters of water column

Z = Gauge distance correction factor for delivery gauge centre and inlet pipe centre in meters (refer figure 3). If the delivery gauge centre is below the inlet pipe centre, Z is subtracted from the delivery gauge reading and if the delivery gauge centre is above inlet pipe centre, Z is added to the delivery gauge reading; the gauge distance correction factor shall never be applied to the suction vacuum gauge or mercury manometer reading irrespective of their positions:

V_d = Velocity at delivery gauge/sensor connection, m/s;

V_s = Velocity at suction gauge/sensor connection, m/s; and
g = Acceleration due to gravity in m/s2.

The Total Static Suction Lift in surface pump (H_{SSL})

H_{SSL} = Height in meter from water level to impeller + Altitude correction in meter + water temperature correction in meter.

10.1.1 Correction for Altitude

Barometric pressure shall be recorded at test place. The difference between atmospheric pressure at the test place and 10.33 mWC (that is atmospheric pressure at MSL) shall be deducted from Static suction lift.

10.1.2 Correction for Water temperature

Static suction lift specified in below Table shall be increased or reduced as given below when water temperature is below or above 33°C.

Table 4 - Correction for water temperature

Hourly Average of Water Temperature °C	Vapour pressure mWC	Correction in Static suction lift above and below 33°C water temperature mWC
10	013	+ 0.39
15	0.18	+ 0.34
20	0.24	+ 0.28
25	0.33	+ 0.19
30	0.43	+ 0.09
33	0.52	0.00
35	0.58	- 0.06
40	0.76	- 0.24
45	1.00	- 0.48
50	1.28	- 0.76

Suction head shall be adjusted minimum 3 time in a day as per average water temperature and barometric pressure, by adjusting water level of tank.

Following formula can also be used on behalf of table 4

$$y = -0.0007\ x^2 + 0.0130\ x + 0.3079$$

Where
y = Correction in Static suction lift
x = Average of water temperature.

10.2 Computation of Total Head for Submersible Pump-sets

Total head $H = H_d + Z + ((V_d^2) / 2g)$

Where:

H_d = Delivery gauge/sensor reading in meters of water column;
Z = Gauge distance correction factor for delivery gauge. Distance between gauge/sensor center to tank water level (refer figure 1).
V_d = Velocity at delivery gauge/sensor connection in m/s;
g = Acceleration due to gravity in m/s^2.

10.3 Total Water Per-Day

Total per day water output shall be calculated by Integration (Sum) of flow rate with respect to time. Integration shall start from the time when pump set achieve desired constant head in morning time (start point refer figure 5) and end at the time when pump set unable to achieve desired constant head in evening time (End point refer figure 5).

In case if Average Daily Solar Radiation found less than requirement then test shall be performed on next sunny day.

10.4 Water Output Per Day Per Watt Peak

Water output per day per watts peak (ltr/Wp) = Water output (Liters) per day at specified head / Array STC power in watts-peak

10.5 Cumulative Daily Solar Radiation

Cumulative Solar Radiation (kWh/m^2) in a day= Average of instantaneous irradiance reading from Dawn to Dusk (kW/m^2) X period of time in hours.

This can be obtained through time weight summation of pyranometer readings.

Dawn = Time of sunrise when irradiance become positive from zero value.
Dusk = Time of sunset when irradiance become zero from positive value.

10.6 Mismatch in maximum power at STC among modules of array

The mismatch shall be calculated as under:

$$\%\,Power\ mismatch\ in\ array = \frac{(P\mathrm{Max} - PMin)}{(PMax + PMin)} x\,100$$

P_{Max} = Maximum power among modules in array
P_{Min} = Minimum power among modules in array