Model K63

Hotplate® Total Precipitation Gauge

Operation & Maintenance Manual

by

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1. Background

This report documents the installation, operating and maintenance procedures for the Hotplate® Total Precipitation Gauge, Pond Engineering Model Number K63. Information contained in this manual is proprietary to Pond Engineering and is provided for use by the purchaser exclusively for instructional and maintenance purposes; any other use is prohibited.

2. General Information and Operating Principles

This state-of-the-art precipitation gauge utilizes a solid-state precipitation sensing head with an integrated microprocessor-based control system to accurately measure and report precipitation events. When properly used, the system is capable of reporting frozen, freezing, and liquid precipitation at rates of up to 25mm/hr (liquid equivalent).

Designed and developed in conjunction with NCAR, the Model K63 Hotplate® Total Precipitation Gauge is based on patented technology licensed exclusively to Pond Engineering by UCAR. Utilizing a state-of-the-art single board microcontroller together with Pond Engineering's ultra-high precision temperature control technology, it independently controls the temperature of two thermally isolated plates in the solid-state sensing head. The upper plate, exposed to incident precipitation, is the sensor plate. The lower plate, which is substantially shielded from falling precipitation, is the reference plate. Precise temperature control and calibration of the temperature sensors on each plate to within ±0.3°C assures accurate and repeatable measurements. Precision power measurement circuitry and individual system calibration (uncertainty ±1.2W) together with data provided by an environmental sensor allows calculation of highly accurate liquid equivalent precipitation rates of rain or snow, as well as 24-hour accumulation totals.

Unlike traditional precipitation measurement systems, the Hotplate® system provides data with very low latency, reporting precipitation events as short as 1 minute in duration. Any incident precipitation is quickly evaporated and measured, allowing the system to quantify events that may have been missed by legacy precipitation measurement systems.

Figure 1 shows the general configuration of the Hotplate® Total Precipitation Gauge to provide the reader a better visualization of its appearance, as well as a point of reference for location and use of the controls and service points discussed later in this manual.

Figure 1 - System General Layout

3. System Installation & Commissioning

3.1 Site Selection & Preparation

When selecting a site for the Model K63, there are several factors that must be considered in order to ensure maximum data integrity and safety. This section contains information to be considered when selecting and preparing a site for this system.

3.1.1 Wind Obstacles/Turbulence

Turbulent air flow over the sensor head can cause variations in thermal load for the sensor and reference plates respectively. These variations can cause the system to over- or under-report precipitation rates. To ensure accurate measurement of precipitation and wind speed, the system should be installed in a relatively large, flat area with few obstructions (i.e. structures, other instruments or met towers).

3.1.2 Ground Vegetation

During operation, the sensing head of the Model K63 is electrically heated and controlled at an elevated temperature (between 70°C and 90°C). Because of fire risks associated with an electrically heated apparatus, it is highly recommended that the ground immediately surrounding the system be cleared of any and all vegetation. As a guideline, all vegetation within 1.25x the installed height of the system (see **Figure 2** for reference) should be cleared and maintained clear or covered with a fireproof material.

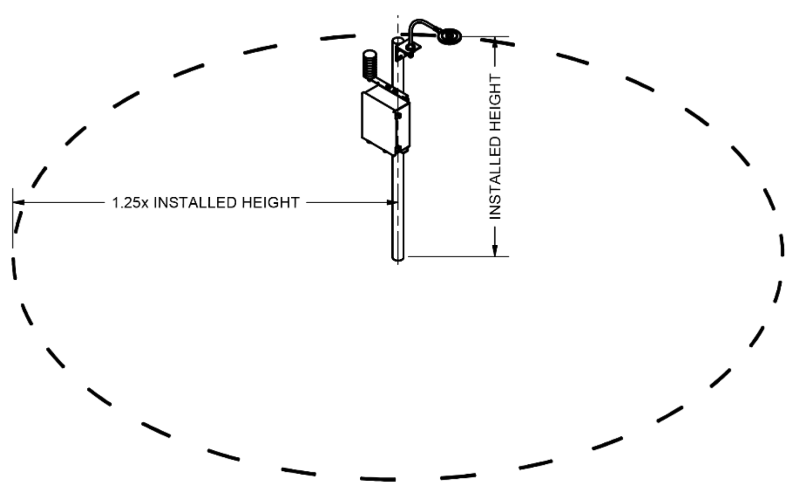

Figure 2 - Fire Risk Area

3.1.3 Wildlife/Animal Interaction

One advantage of the heated nature of this system is that birds, small rodents, and insects will tend not to nest and/or roost on or near the sensing head. This minimizes the need for small-animal deterrents, as well as cleaning/removal of nests, spider webs, etc.

Large animals such as moose, elk, bears, and even cattle may try to use the system as a scratching post and may cause damage to the installation. While a wind shield or fence is not required for this system to operate accurately, fencing may be necessary in order to protect the system from any local wildlife or animals.

3.2 System Installation

With the site prepared as outlined above, the system can now be installed. The following sections outline the process for system installation.

3.2.1 Control Box

The control box comes fitted with two (2) 1-1/2” angle mounting brackets attached to it. These mounting brackets have features to accommodate U-bolts ranging from 1-1/4” to 2-1/2” (32-64mm) inside diameter. Straight fasteners may also be used if preferred. Fasteners can be up to 5/16” (8mm) in diameter. Care should be taken to ensure that the control box is level (±5°) when mounted.

3.2.2 Environmental Sensor

Once the control box is mounted, the environmental sensor can be attached. First, remove the 1/2” conduit nut from the base of the environmental sensor. With the nut removed, insert the cable through the slot in the upper mounting bracket on the control box. Slide the threaded boss into the machined hole, re-install and tighten the nut. Typically, the nut can be adequately tightened by turning the sensor body while holding the nut stationary.

Electrical connection of the environmental sensor is accomplished by removing the 1/2” conduit nut from the cable feed-thru and feeding the cable through the appropriate hole in the bottom of the control box (see **Section 6.1** for reference). The feed-thru is then inserted into the hole in the control box. With the feed-thru in place, thread the nut over the connector and cable then re-install and tighten the nut. Plug the sensor connector into the appropriate socket on the control board (there is only 1 mating socket on the board).

3.2.3 Sensor Head Mounting Bracket

A machined “L” bracket for mounting the sensor head is provided as part of the system. The sensor head is fitted with a 40” (1m) cable for connection to the control box. It is important that the sensor head mounting plate be positioned such that the sensor can be easily connected to the control box without resulting in unnecessary strain on the cable. The mounting bracket has features to accommodate mounting with U-bolts ranging from 1-1/4” to 2-1/2” (32-64mm) inside diameter. Straight fasteners may also be used if preferred. Fasteners can be up to 5/16” (8mm) in diameter. Typically, the plate is mounted with the vertical leg extending downward, but it can be used in either orientation. Care should be taken to ensure that the mounting plate is level (±5°) when mounted.

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3.2.4 Sensor Head

The sensor head mount is capable of providing ±5° of adjustability in both axes and comes pre-assembled with the necessary washers and mounting nut in place. When placing the sensor head mount on the mounting plate, ensure that the washers are in the correct locations, as shown in **Section 6.2**. Once in place, use a wrench to tighten the mounting nut to bring the washers into contact with each other. **DO NOT FULLY TIGHTEN AT THIS STAGE**. The sensor head should still be able to be adjusted and leveled at this point.

Orientation of the sensor head (i.e. which way it is “pointing”) can be adjusted to suit the installation setup. Care should be taken to avoid wind shadowing.

Various methods can be used to level the sensing head. It is convenient to place a torpedo level or sensitive bullseye level on the top of the sensing head during leveling, rotating the level 90° to check both planes as necessary. Once level (±1°), the mounting nut should be tightened to a torque of 60 to 120 in-lbs, locking the sensor in position.

Also available from Pond Engineering is a leveling tool. This tool utilizes 3 screws oriented around the base of the sensor head mount to allow for finer resolution and increased control when leveling the sensor head. The leveling tool can be temporarily attached either above or below the mounting plate for use, providing a slightly higher sensitivity when attached below the plate. See **Section 6.3** for mounting orientation & position.

Electrical connection of the sensor head is accomplished by removing the 1” conduit nut from the cable feed-thru, threading the cable through the appropriate hole in the bottom of the control box (see **Section 6.1** for reference) and inserting the feed-thru into the hole. With the feed-thru in place, thread the nut over the connector and cable and re-install and tighten the nut. Plug the sensor into the appropriate socket on the control board (there is only 1 mating socket on the board).

It is possible that the plate powers will need to be balanced based on site-specific environmental conditions (wind patterns, etc.). See **Section 5.1.2** for additional information about this process.

3.2.5 Accumulation Jumper

By default, the K63 is configured to automatically reset the accumulation parameter at 00:00, based on the internal system clock. This feature can be disabled by reconfiguring a hardware jumper on the control circuit board as shown below. In either configuration, the accumulation can be reset manually via RS-232 command.

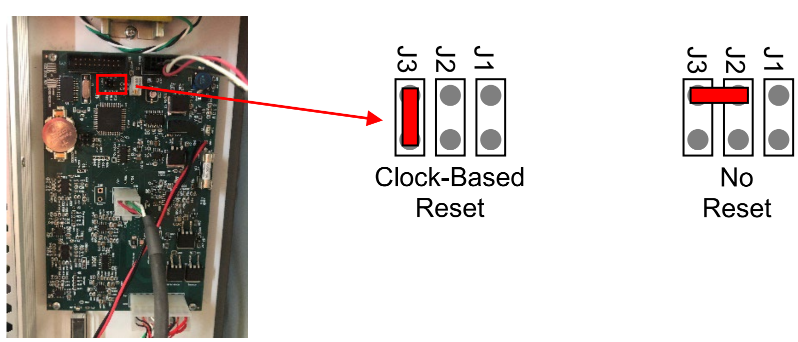


Figure 3 - Accumulation Jumper Positions

3.3 Communications

3.3.1 RS-232 Settings

The settings for RS-232 communications are as follows:

Baud Rate	9600
Data Bits	8
Parity	None
Stop Bits	1
Flow Control	None

3.3.2 RS-232 Command Set

The command set for the system is outlined in the following paragraphs. The commands are issued from the host computer which acts as the controller. Note that each command must be terminated with a CR (\r) for the command to be correctly received by the Model K63.

3.3.2.1 1-Minute Data Transmit

Data maintained in 1-minute running averages can be retrieved by sending “T1” to the system. On receiving this command, the system will respond with a string of 84 characters containing the following data:

Time Stamp, precip rate,24 hour accumulated precip, ambient temperature, 1-minute barometric pressure, 1-minute relative humidity, wind speed, system status, 1-minute Sensor Plate power, 1-minute Ref. Plate power*CRC-16

The syntax for the interpretation of this data is:

T1\r\nmm/dd/yyyy(sp)hh:mm:ss,dd.dd,dddd.dd,±dd.dd,dddd.d,ddd.d,dd.d,d,ddd.d,ddd.d*hhhh

Below is a sample response to the “T1” command:

T1\r\n**02/24/2020\s20:24:42,00.00,0000.01,+22.96,0844.1,016.6,00.1,1,008.3,007.7***3A27\r\n

The last 4 bytes of the data transmission are a 16-bit CRC performed on the data in the transmission. In the above example, the bold characters are used in the calculation of the CRC. The polynomial used to generate this CRC is $x^{16}+x^{15}+x^2+1$ (hex code 0x8005), and the CRC register starts at hex 0x00.

Pond Engineering recommends terminating the “read” operation after the appropriate number of characters. For the “T1” command, the response will contain 84 characters. Alternatively, the user can specify a line-feed character (\n or 0x0A) as a termination character. If this is done, each query must consist of a write followed by 2 reads.

3.3.2.2 5-Minute Data Transmit

Data maintained in 5-minute running averages can be retrieved by sending “T5” to the system. On receiving this command, the system will respond with a string of 75 characters containing the following data:

Time Stamp, 5-minute avg precip rate, 5-minute avg ambient temperature, 5-minute barometric pressure, 5-minute relative humidity, 5-minute avg wind speed, system status, SP_Pwr_5, RP_Pwr_5*CRC-16

The syntax for the interpretation of this data is:

T5\r\nmm/dd/yyyy(sp)hh:mm:ss,dd.dd,±dd.dd,dddd.d,ddd.d,dd.d,d,ddd.d,ddd.d*hhhh

Below is a sample response to the “T5” command:

T5\r\n**02/24/2020\s20:32:04,00.00,+22.96,0844.1,016.6,00.1,1,008.2,007.5***B316\r\n

As with the 1-minute data, the 5-minute data is terminated by a 16-bit CRC that can be used to verify data integrity. See **Section 3.3.2.1** for more details on the CRC implementation.

Pond Engineering recommends terminating the “read” operation after the appropriate number of characters. For the “T5” command, the response will contain 75 characters. Alternatively, the user can specify a line-feed character (\n or 0x0A) as a termination character. If this is done, each query must consist of a write followed by 2 reads.

3.3.2.3 Read Individual Parameter

The "READ" command, called by sending an "R" (upper or lower case) followed by the two-digit address of the variable, enables the user to read or interrogate the current values for system variables. The syntax for the read command is "Rxx", where xx is the address of the variable to interrogate. The address must be two digits in length, therefore addresses less than 10 MUST HAVE LEADING ZEROS. After receiving a read command, the system will wait to be addressed as a talker to return the data over the bus. The system has a one second write time-out, thus the controller in charge must read from the system within one second after sending the "R" command to receive data. For example: If the user wanted to see the value stored as the total accumulated precipitation, the user would send the character string: R01. The controller in charge would then wait for the data to be returned.

****Note: Control of the K63 remains the highest priority even when the system is in remote mode and may put off responding to remote commands for as long as 500ms.**

Continuing with the above example, as soon as it is not performing control functions the K63 will return the 23-byte text string R01\r\n+1.840000e+01\s01\r\n. This indicates that the value 18.4 (mm) is the current value for Variable 01 (the total accumulated precipitation). Values returned are always in the above scientific notation format followed by a space and address number for the given value.

****Note: If the system is not configured to do a clock-based reset of the accumulated precipitation (see Section 3.2.5), this value will count up to 9999.9 mm, and does not self-reset. In this case, the accumulation can be reset by issuing the command “W01,0.00”.**

The following is a list of commonly accessed system variables and their locations.

Vars Addr	Description	Units
0	Current Setpoint Temperature	°C
1	Current (or 24-hr) Precip. Accumulation (Jumper Selectable)	mm (liquid equiv)
2	Instantaneous Ambient Temperature	°C
3	1-Minute Average Precipitation Rate	mm/hr
4	Alarm Code	Unitless
64	Real-Time Clock Value – seconds	ss
65	Real-Time Clock Value – minutes	mm
66	Real-Time Clock Value – hours	hh
67	Real-Time Clock Value – day	dd
68	Real-Time Clock Value – month	mm
69	Real-Time Clock Value – year	yyyy
98	Plate Power Balancing Offset	Watts
99	POST result code	Unitless

Table 1 - Commonly Accessed Variables

3.3.3 Data Visualization Software

Available on request from Pond Engineering is a copy of the Model K63 Data Visualization Software. This software provides an intuitive interface for visualization of data as it is received from the instrument. While this software does not include data storage functionality, it provides a means to verify system functionality prior to implementing data collection and storage software. Custom software packages are also available to integrate the Model K63 as part of a more comprehensive met station or mesonet.

Installation

To begin the installation, open the *installer.exe* file received from Pond Engineering. From there, follow the prompts to install the software.

Usage

To start the software, go to Start – Program Files – Hotplate – K63 Data Visualizer. The screen should appear as shown in **Figure 4**. Be sure to set the "Resource Name" control to the appropriate COM port.

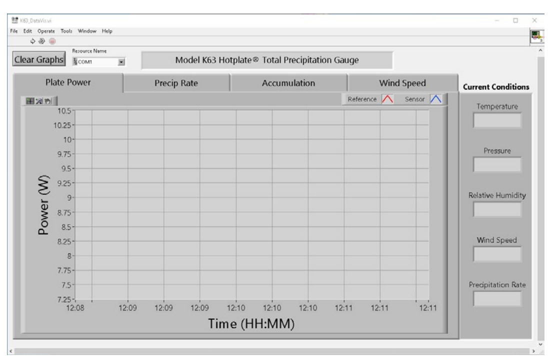


Figure 4 – K63 Data Visualizer Screen

4. Normal Operating Procedures

4.1 Initial Power-on and Warm-up

Once the K63 is connected to power, the controller will perform a power-on self-test (POST). During this test, the status LED will flash RED. The results of this test are saved and can be retrieved by querying the system for the value of variable 99. See **Section 5.1.5** for more information on the POST and its result code. Upon passing the POST, the sensing head will begin heating and the system will be operational. Typically, the system takes 2-4 minutes to stabilize at the setpoint. During this warm-up period, the status LED, located on the bottom surface of the control enclosure, will alternate red/green. Once stable at operating temperature, the status LED will change to solid green, with a brief off-period every second to indicate that the controller is active. A summary of LED patterns and their meanings can be found in **Section 5.1.3**. While the sensor will begin to gather precipitation data during the warm-up period, the data provided will be most accurate once the sensor is able to stabilize at the system setpoint.

During the onset of heavy precipitation, it is reasonable to expect the system to return to its warm-up state until it can re-establish control after compensating for the precipitation. As such, precipitation rates during the onset and termination of a significant precipitation event may be under- or over-reported.

4.2 Normal Operation

During normal operation, the system will perform a proof-of-life test on the watchdog circuitry to ensure that heater power can be disabled in the event of an alarm condition. During this test, the drive voltage to both plates is briefly disabled, and the system looks for a corresponding drop in the measured voltage on both sensor and reference plates, ensuring that the watchdog is properly functioning. By default, this test is performed once every hour, based on the internal system clock. This interval can be user-adjusted to as short as 1 minute. Please note that while a shorter interval would potentially allow the system to catch a watchdog issue earlier, the test does disrupt system stability and the system may be in its warm-up state for a greater percentage of its runtime.

5. Handling and Maintenance

5.1 System Maintenance

The Hotplate® Total Precipitation Gauge is designed and fabricated to require minimal periodic maintenance. The following information is provided to guide the user in maintaining the system.

5.1.1 Cleaning

In environments where there is significant mineral content in the water, a residue may accumulate on the sensor plate over time. While this residue should not influence system performance, it may be beneficial to remove the residue periodically. The system should be unplugged and allowed to cool before handling or cleaning the sensor head.

5.1.2 Balancing the Plate Powers

Each system is factory balanced to cause both channels to indicate the same power (±0.5 Watts) in the absence of precipitation, with a wind speed of 1.0 to 1.5 m/sec. It is recommended that zero-precipitation plate power agreement be verified at least annually to the same specification above.

Any necessary adjustments to the balancing offset can be made in the field. Please contact Pond Engineering for instructions on how to accomplish these adjustments. This offset should not exceed ±3 Watts. If an offset outside this range is required to balance the plate powers, it is recommended that the system be sent back to Pond Engineering for a full power calibration.

5.1.3 Status LED

The system status LED can provide a visual indication of the current state of the system controller. The following sections outline the various patterns and their meanings.

5.1.3.1 Flashing Red LED

Immediately after applying power to the system, a power-on self-test (POST) is performed. During this process, the LED will be RED, with a brief flash OFF every second. The POST should last approximately 15 seconds.

5.1.3.2 Alternating Red/Green LED

The system status LED will alternate between RED and GREEN when the system is in its warm-up state, indicating that the system is outside of the defined stability band. Data provided while the system is in this state is still valid but may be less accurate than data provided while stable.

5.1.3.3 Flashing Green LED

After the system is stable at its setpoint, the LED will transition to GREEN, with a brief flash OFF every second. This indicates that the system is providing the most accurate data it is capable of.

5.1.3.4 Solid Red LED

If an alarm condition is triggered, the LED will change to a solid RED, with no flashing behavior. This indicates that there is a problem with the system, and user action is required. Additional information on alarm conditions can be found in **Section 5.1.4**.

5.1.4 System Alarms

If at any time during operation, an alarm condition is met, the system will set an alarm and power delivery to the sensor head will be disabled. There are two different categories of system alarms – **primary** and **secondary**.

A **primary** alarm will cause the system to stop heating the sensor head and will initiate a countdown that will allow the controller to self-restart ~2 minutes later. The purpose of this functionality is to allow the system to resume normal operation in the event that an alarm was triggered falsely (i.e. lightning strike or power glitch) If an alarm condition persists after the self-restart, the alarm will “stack”, and promote to **secondary**.

A **secondary** alarm will also cause the system to stop heating the sensor head, but the system will not be allowed to attempt a self-restart. In the event that a secondary alarm is set, it can only be cleared by a manual power-cycle of the controller. Repeated secondary alarms will also “stack”.

Once the system has experienced two “stacked” system alarms, it will lock out any further operation until any issues have been investigated and the alarm code is reset. **Figure 5** shows the possible alarm codes and their causes. When alarms are “stacked”, the first alarm will appear in the tens digit, and the second will be in the ones digit (For example: a failed POST followed by a failed watchdog proof-of-life test would create alarm code 14).

Alarm Code	Description	Alarm Type
0	No Alarm	-
1	System failed POST – see var 99 for details	See **Figure 6**
2	Sensed temperature out-of-bounds (< -70 or >130°C)	Primary
3	Calculated plate heater resistance exceeds limit	Primary
4	Watchdog proof-of-life test failure	Secondary

Figure 5 - System Alarm Codes

If the system behaves normally following a single alarm condition, the alarm code (variable 4) will clear itself after ~10 hours of operation without incident.

5.1.5 Power-on Self-test (POST)

Immediately after applying power to the system, a power-on self-test (POST) is performed. During the POST, the system evaluates the functionality of the following systems.

1. Temperature measurement
2. Watchdog circuitry
3. Individual plate power drive circuitry

Once completed, a POST result code is stored as variable 99 for later access. This code is the sum of individual sub-codes, associated with specific elements of the POST. For example, a POST result of 6 would be a combination of sub-codes 2 and 4, indicating that both plate drive MOSFETs are unable to provide power. This could also be the case if fuse F2 is open.

A POST result of “0” means no issues were detected, and the system is fully functional. **Figure 6** shows each sub-code, and its associated condition.

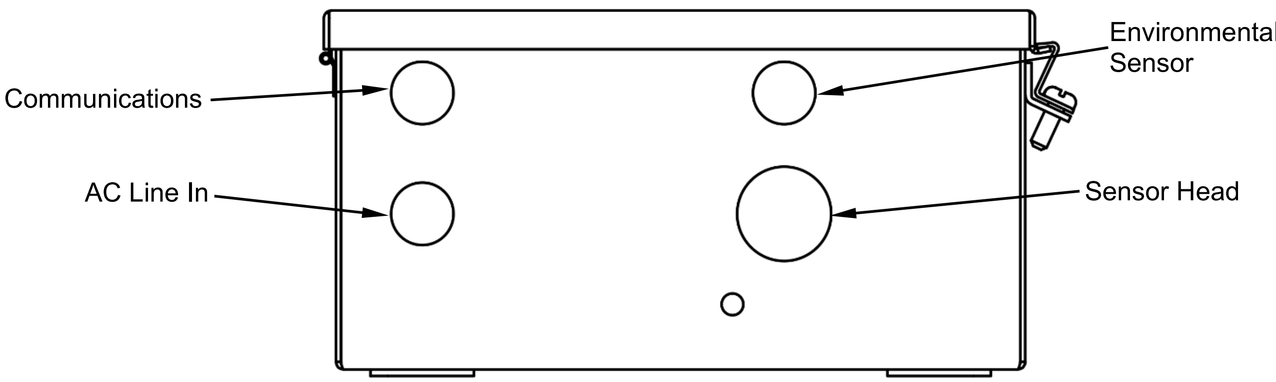
<table>
<tr><th>POST Sub-Code</th><th>Description</th><th>Alarm Type</th></tr>
<tr><td>1</td><td>Watchdog non-functional</td><td>Secondary</td></tr>
<tr><td>2</td><td>Ref. Plate drive MOSFET not providing power</td><td rowspan="6">Primary</td></tr>
<tr><td>4</td><td>Sensor Plate drive MOSFET not providing power</td></tr>
<tr><td>8</td><td>Ref. Plate drive MOSFET not shutting off power</td></tr>
<tr><td>16</td><td>Sensor Plate drive MOSFET not shutting off power</td></tr>
<tr><td>32</td><td>Ref. Plate temperature out-of-bounds (< -70 or >130°C)</td></tr>
<tr><td>64</td><td>Sensor Plate temperature out-of-bounds (< -70 or >130°C)</td></tr>
</table>

Figure 6 - POST Result Codes

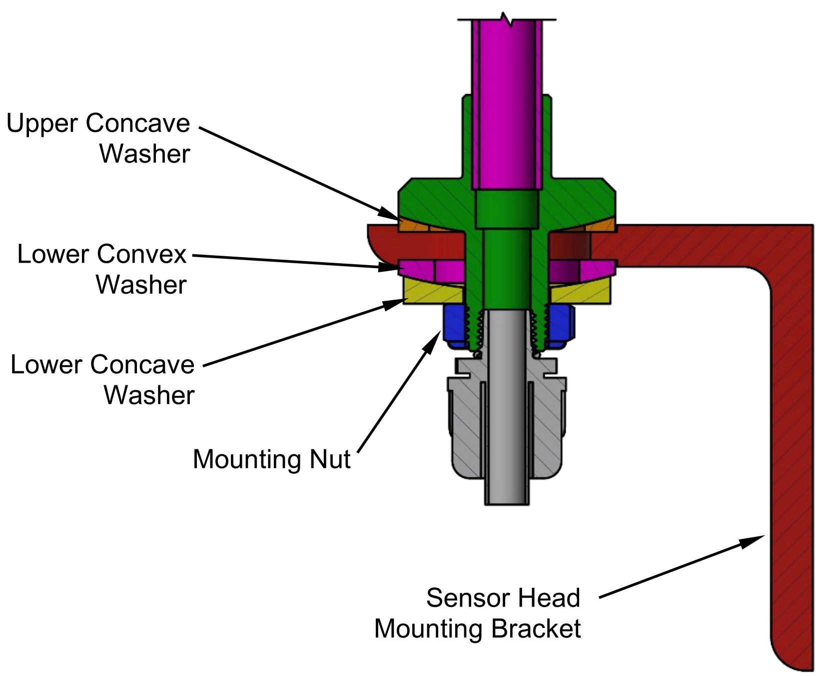
6. System Hardware Description

A brief description of system hardware is provided in this section as a reference to aid the user in periodic maintenance of the system. In the event significant maintenance or repair is required, it is recommended that Pond Engineering be contacted prior to replacing or modifying major system components.

6.1 Control Box – Bottom View



6.2 Sensor Head Mount



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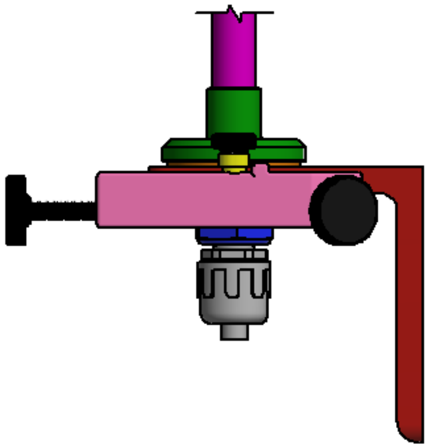
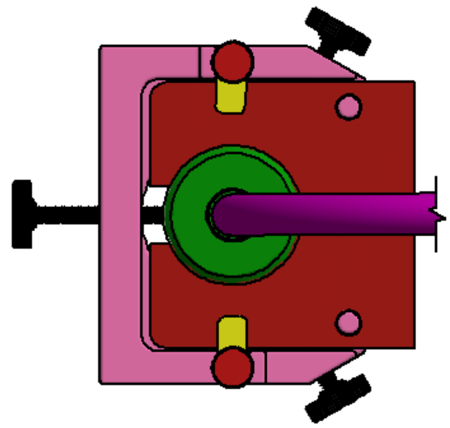
6.3 Optional Sensor Head Leveling Tool

Shown attached to mounting plate



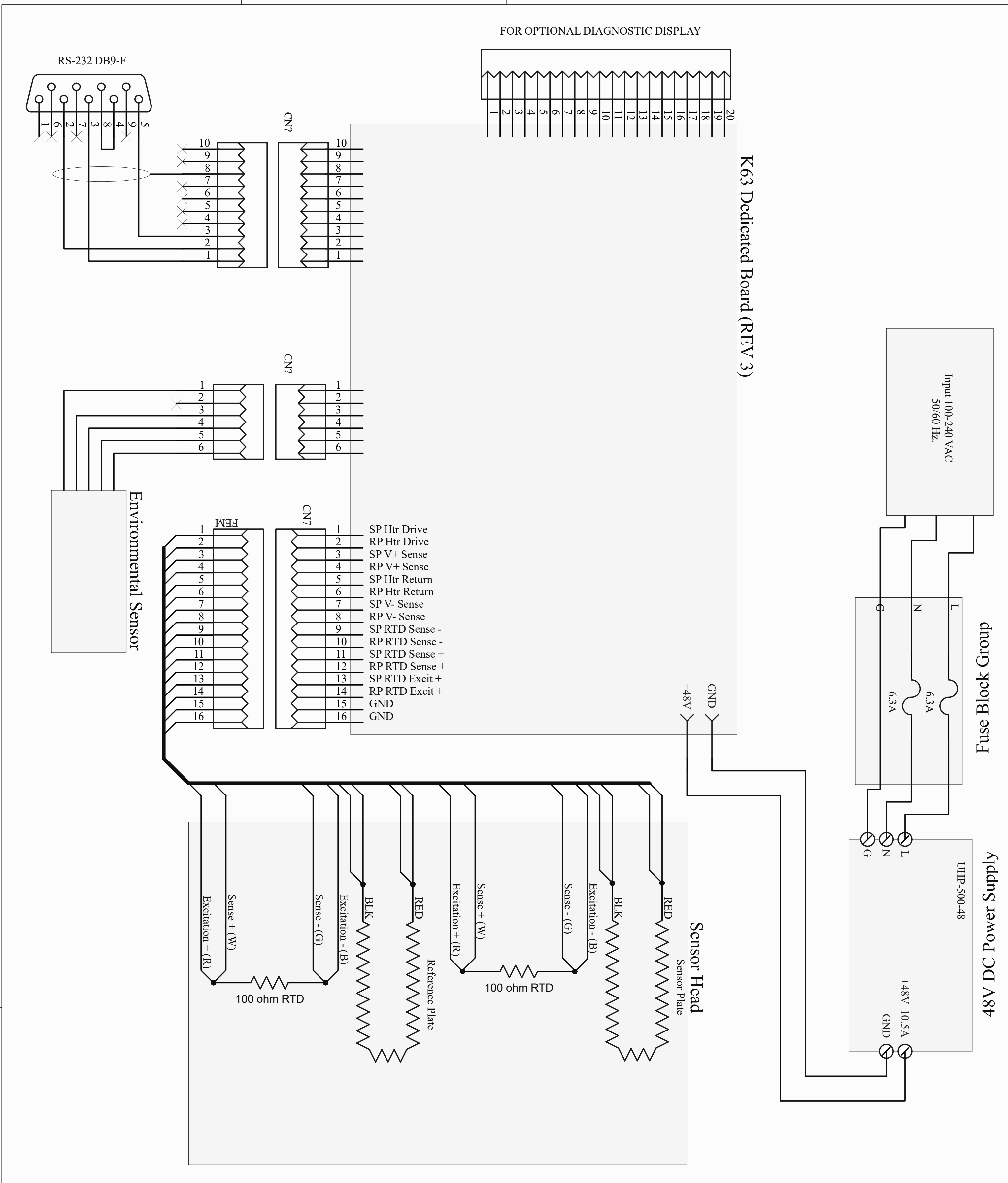
Side View



Top View

6.4 Top Level Schematic

This page is intentionally left blank. The following page contains a schematic diagram of the Model K63 electrical systems.



NAME: K63 Top Level Schematic

DRAWN BY: Michael Pond

DATE: 1/26/2023

NO. REQUIRED: *

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