Introduction

360° has been retained to conduct performance testing of three "brand" products, as shown to the right and listed below:

- Switch-1 (SW-1) Condensate Switch
- "New" Pump-1 (P-1) Small Condensate Pump
- Pump-1 (P-1) Small Split Slender Condensate Pump

Both of the pumps are rated to operate on 120 – 240VAC 50 or 60 Hz, while the Switch-1 (SW-1) is rated for use at 18 - 250VAC. The Small Split Slender pump uses a reed type float switch, while the "New" P-1- Small uses an electronic switch with bare probes, both inside a small plastic water tank. The Switch-1 (SW-1) Switch has an electronic moisture sensor as a separate, but attached (hardwired) module. The Switch-1 (SW-1) switches are covered later, beginning on page 6 of this report.

The condensate pumps and their attached tanks with internal float and probe switches were analyzed and tested for the following characteristics:

- PCB Build Quality Review
  - Schematic / physical layout review
  - Potential failure, anomalies and /or defects
  - General component overview +/- related calculation of sufficiency
- Power Fluctuation
  - Voltage supplied (i.e., 120/150/180/210/240 VAC; 50 & 60Hz)
  - Maximum current draw

Five of each pump model was provided; each sample was then randomly labelled 1 through 5 by 360° for further identification, as shown below.

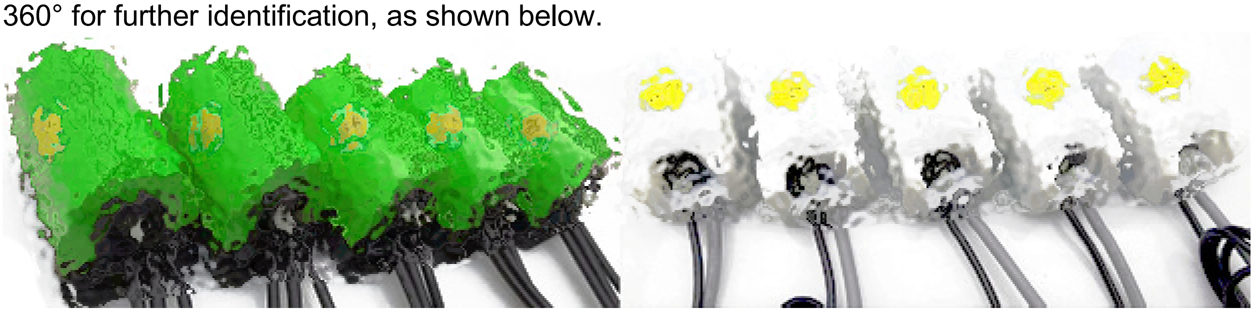


Figure 1: "New" P-1-Small pumps to the left, Small Split Slender pumps to the right. Each model of pump was randomly numbered 1 through 5 for further identification by 360° Product Testing.

The following presents 360°' Product Testing's findings.

“New” P-1-Small Pump Physical and Operational Inspection:
All five “New” P-1-Small pumps and tanks appeared to perform properly. The tanks were positioned in water at various depths while it was noted when the green LED on the tank cover turned to yellow and the pump was energized. When the tank was flooded, the red LED illuminated until almost all of the water was evacuated. When the water level was low enough, the green LED then illuminated again and the pump shut off. The red LED also shut off, signaling the end of the alarm state.

“New” P-1-Small pumps run on a cycle of 8 seconds-on, 16 seconds-off, which persisted until the water level in the tanks was lowered and the pumps switched into the “Normal” state. This cycle did not begin until several minutes after power was applied to the pump.

Engineers also monitored the normally-closed relay contacts for proper operation, finding that the contact would be closed when power was off to signify a possible alarm state by which the pump would be inoperative due to lack of power. When power was applied and with little or no water in the tank, the green LED would illuminate and the relay was energized, opening the alarm circuit.

The relay switched to alarm state when sufficient water filled the tank as to cause an alarm state. The contact would remain closed until water was drained from the tank sufficiently as to allow the green LED to turn on again as the pump stopped. At this time, the contact would open, removing the alarm state.

Relay contact resistance was measured at between 1.0 and 0.25 ohms on all five of the “New” P-1-Small pumps.

Small Split Slender Pump Physical and Operational Inspection:
While examining the Small Split Slender’s sample PC board (un-potted), engineers noticed that although a copyright notice stating version 13 has been silkscreened onto the board, an earlier copyright notice stating version 11 was still on the edge of the board; see Figure 2. The V13 notice was not found on the provided layouts of the PC board.

Engineers also noticed that most resistors and capacitors installed on the board appear to be larger than the pads placed on the board for that purpose; engineers believe that the larger components were used for handling/convenience reasons since the board was hand-assembled.

The PC boards installed in the provided Small Split Slender pumps were all potted with the same hard black plastic-looking potting compound as used in the “New” P-1-Small pumps; thus, engineers were unable to examine the pump PC boards directly. The tank reed relay board was already mounted within the tank cover, so similarly, it could not be examined.

Four of five Small Split Slender pumps and tanks performed properly. Unlike the “New” P-1-Small pump and tank, there are no LEDs on the Small Split Slender product to indicate state. Before applying power, the alarm relay contacts are closed due to the alarm wires being wired to normally-closed contacts. With power applied, the alarm relay contacts opened to indicate the tank had not been flooded.

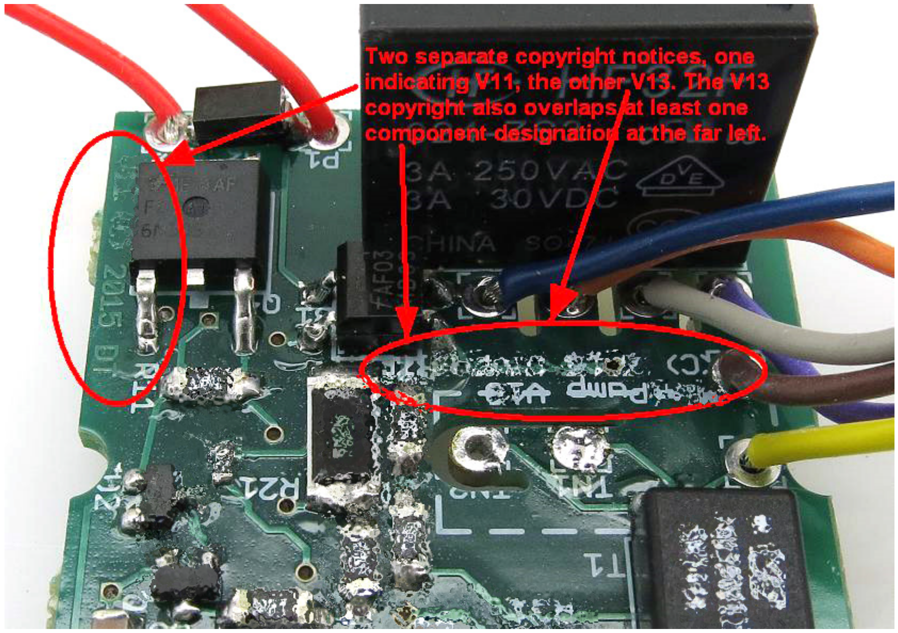


Figure 2: Notice the two copyright notices, one indicating V11, the other indicating V13. The V13 notice seems to have been silkscreened onto the PC board after component designations were silkscreened, as the copyright notice overlaps at least one such designation.

The tanks were submerged in water until the pump energized. When the tank was flooded, the alarm relay contact opened and the pump began running. When the tank’s water level was lowered, the pump shut off and the alarm contact opened again. Small Split Slender pumps were found to run on a 120-seconds-on, 60-seconds-off cycle when continuously in the alarm state. This is the reverse of the “New” P-1-Small run-pattern which is 8 seconds-on, 16 seconds-off.

A fifth Small Split Slender pump would not turn on the pump, apparently due to a known production issue regarding the value of resistor R13. According to the schematic and BOM[1], R13 is supposed to be 100 ohms; however, 360° has been informed that the installed resistor might be 10K ohms, which would prevent MOSFET Q4, which controls the pump, from turning on. This issue does not affect the operation of the relay, however, which uses a separate driver transistor, Q6.

Relay contact resistance was measured between about 0.5 and 0.25 ohms on three of the Small Split Slender pumps; however, one measured around 10 ohms in the alarm state, and another about 15 ohms. It is believed these resistances will most likely drop into the fractions-of-ohm region if a small amount of current were flowing through the relay contacts.

[1] Please reference the 360° included and linked: “Reviewed_BOM.xlsx”

Power "Fluctuation":
"New" P-1-Small and Small Split Slender pumps

Power was supplied by a YK-BP8102 frequency converter, while current was measured from the front panel of the converter; see the following image.

Figure 3: A "New" P-1-Small pump under test at 240VAC. Current of the Small pumps tended to fluctuate somewhat; the current observed after several minutes was recorded below in Table 1.

The following table shows the measured current draw and power factor of each pump when running after several minutes before the alarm-state on/off cycle begins. A power factor of 1.0 is considered “perfect”, and is desirable. Due to the low current-draw of either pump relative to larger equipment on the same AC power line, the relatively-poor power factor is unlikely to be a concern.

E (VAC)	“New” P-1-Small Pumps									
	Freq. = 50 Hz									
	1		2		3		4		5	
	I	PF	I	PF	I	PF	I	PF	I	PF
120	0.142	0.603	0.161	0.642	0.142	0.610	0.163	0.682	0.142	0.617
150	0.130	0.500	0.116	0.460	0.125	0.508	0.127	0.476	0.122	0.508
180	0.132	0.430	0.111	0.417	0.116	0.447	0.114	0.442	0.116	0.462
210	0.109	0.400	0.111	0.399	0.111	0.399	0.105	0.418	0.112	0.412
240	0.114	0.360	0.119	0.375	0.108	0.370	0.116	0.375	0.108	0.382

E (VAC)	Freq. = 60 Hz									
	1		2		3		4		5	
	I	PF	I	PF	I	PF	I	PF	I	PF
120	0.148	0.660	0.128	0.622	0.150	0.650	0.175	0.738	0.148	0.647
150	0.133	0.527	0.125	0.527	0.130	0.541	0.145	0.577	0.130	0.541
180	0.125	0.473	0.114	0.453	0.120	0.472	0.116	0.472	0.119	0.476
210	0.125	0.420	0.111	0.424	0.120	0.439	0.125	0.439	0.117	0.432
240	0.122	0.410	0.123	0.400	0.114	0.417	0.108	0.402	0.114	0.406

E (VAC)	Small Split Slender pumps									
	Freq. = 50 Hz									
	1		2		3		4		5	
	I	PF	I	PF	I	PF	I	PF	I	PF
120	0.100	0.781	0.101	0.775	0.106	0.826	0.101	0.710	-----	-----
150	0.108	0.664	0.111	0.644	0.111	0.632	0.106	0.660	-----	-----
180	0.109	0.535	0.108	0.541	0.112	0.522	0.108	0.538	-----	-----
210	0.095	0.512	0.094	0.456	0.098	0.497	0.094	0.456	-----	-----
240	0.095	0.394	0.094	0.400	0.097	0.400	0.094	0.400	-----	-----

E (VAC)	Freq. = 60 Hz									
	1		2		3		4		5	
	I	PF	I	PF	I	PF	I	PF	I	PF
120	0.117	0.864	0.119	0.813	0.131	0.833	0.111	0.789	-----	-----
150	0.109	0.760	0.123	0.706	0.120	0.730	0.116	0.747	-----	-----
180	0.120	0.643	0.123	0.601	0.127	0.666	0.122	0.675	-----	-----
210	0.117	0.530	0.116	0.534	0.117	0.530	0.114	0.553	-----	-----
240	0.123	0.484	0.120	0.494	0.125	0.481	0.122	0.486	-----	-----

Table 1: Current Draw and Power Factor at varying voltages and frequencies

Switch-1 (SW-1) Switch:
Physical and Operational Inspection

The provided condensate switches were unlabeled; therefore, the specifications of previously-tested switches were assumed [18 - 250VAC for power and up to a 2 (alarm) or 5 (run) amp load].

The condensate switch changes the state of a mechanical relay when moisture is detected by the attached sensor. The relay state can also be changed by a "Test" button on the device. The encapsulated printed wire board is encased within a glued plastic housing.

Figure 4: "Switch-1" (SW-1) Condensate Switch

Upon arrival, the switches were labeled to uniquely identify each switch and then the basic functionality of the switches was verified.

Power Fluctuation

The Switch-1 (SW-1) switches were powered with 4 voltages from 18 to 48 volts (18, 24, 36 and 48), six voltages from 90 to 140 volts (90, 100, 110, 120, 130 and 140) and five voltages from 210 to 250 volts (210, 220, 230, 240 and 250) at both 50Hz and 60 Hz.

Power was supplied by a YK-BP8102 frequency converter, current was measured by a HP/Agilent 3457A digital multi-meter, and relay state was monitored with a HP/Agilent 3468A digital multi-meter.

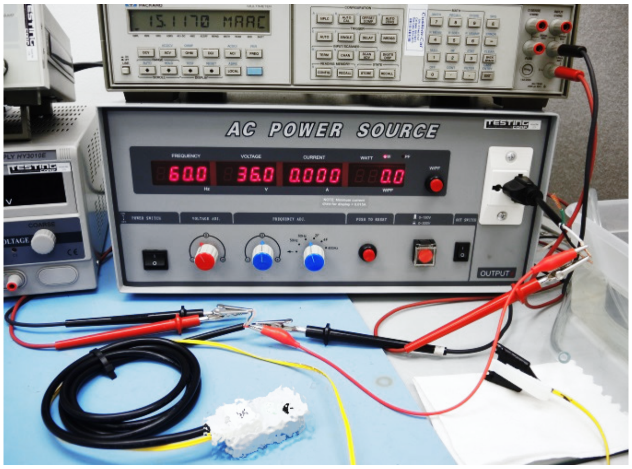


Figure 5: 36VAC / 60Hz

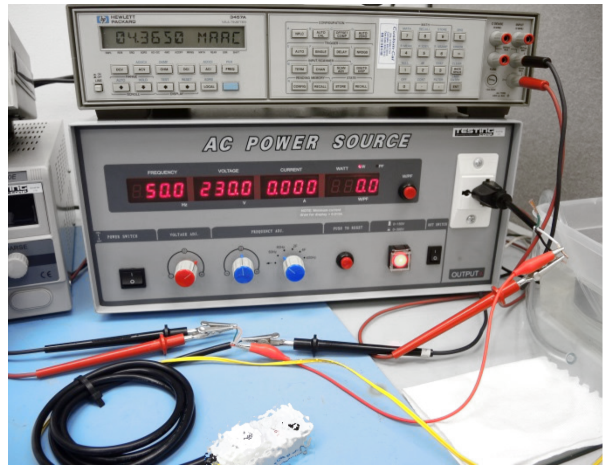


Figure 6: 230VAC / 50Hz

Power consumption at 60Hz was slightly higher than 50Hz at all voltages. The maximum current draw was found to occur when the relay was energized; i.e., the “run” state. In the “run” state, the power consumption varied from a high of approximately 10 mA @ 250VAC (2.5 watts) to a low of approximately 13.1 mA @ 18VAC (0.24 watts). In the “alarm” state, the power consumed was significantly lower, ranging from a high of approximately 4.5 mA @ 250VAC (1.13 watts) to a low of approximately 3.0 mA @ 18VAC (0.05 watts).

Firmware Functionality

Firmware functionality was investigated by powering the Switch-1es (SW-1) with 18VAC @ 60Hz supplied by a YK-BP8102 frequency converter. Moisture stimulus was provided by immersing the sensor into a container of tap water.

When power is first applied, the red LED flashes once, then the green LED flashes for approximately 3 - 4 seconds. The relay is then switched from the alarm state to the run state and the green LED is lit continuously.

When the test button is pressed, there is an approximately-one-second delay after which the red and green LEDs begin flashing alternately and the relay is switched to the “alarm” state. After twenty seconds, the LEDs stop flashing, the red LED is extinguished, the green LED is lit continuously, and the relay switches back to the “run” state.

Approximately 3 - 4 seconds after the sensor is wetted, the green LED is extinguished and the red LED begins flashing. 10 to 11 seconds later, the relay is switched from the run state to the alarm state and the red LED is lit continuously. Approximately six seconds after the sensor is no longer wetted, the red LED extinguishes and the green LED begins flashing. Approximately 16 seconds later, the green LED is illuminated continuously and the relay switches to the “run” state.

Temperature Sensitivity
The Switch-1 (SW-1) Switches were placed within a YTH-225-70-1P environmental chamber for determination of temperature sensitivity. The leads of each Switch-1 (SW-1) were passed through the chamber wall where power was applied, moisture stimulus provided, and relay function verified.

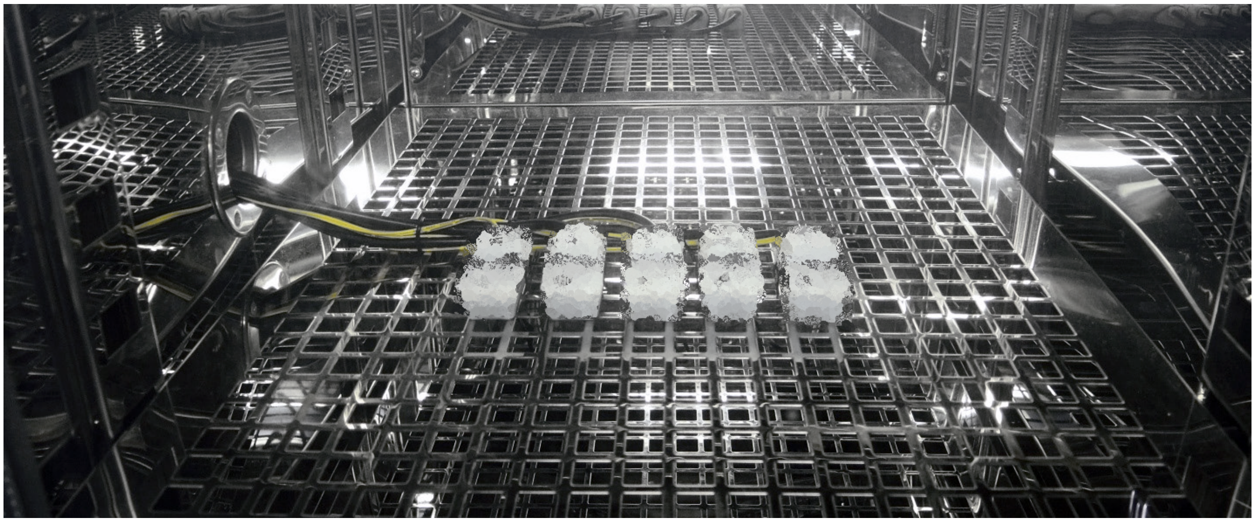


Figure 2: Switch-1es (SW-1) fixtured within an environmental chamber ("A"-"E", left to right)

Power was applied to the switches by a conventional 120VAC 60Hz electrical receptacle and the environment in the thermal chamber was lowered to 0°C (32°F). The chamber environment was maintained at 0°C for one hour before functionality of the switches was tested. The Switch-1es (SW-1), except for "C" & "E", operated normally when a moisture stimulus was applied.

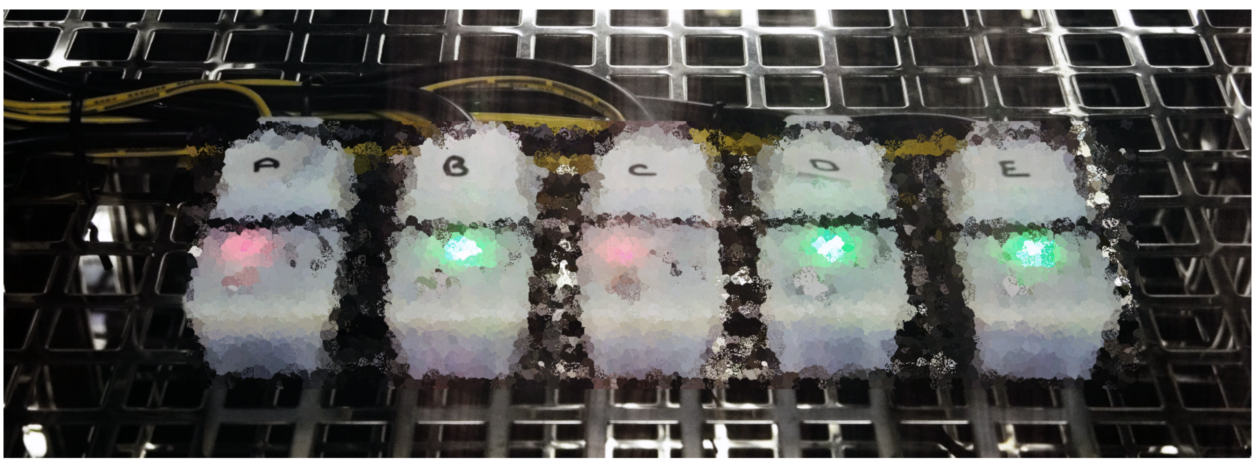


Figure 3: Moisture stimulus applied to switch "A" only, yet switch "C" is also in the "alarm" state.

At 0°C, even when not stimulated, switch "E" would occasionally flash the red LED, and switch "C" often flashed the red LED and also occasionally switched its relay to the "alarm" state. Note that in Figure 9 above, Switch-1 (SW-1) Switch "A" is shown with a red LED; but this is because "A" is being stimulated by dipping its sensor into water.

When the chamber temperature was raised to 4°C (39°F), both switches continued to occasionally flash the red LED, but less often, and neither switched to the “alarm” state.

Figure 4: Thermal chamber @ 0°C

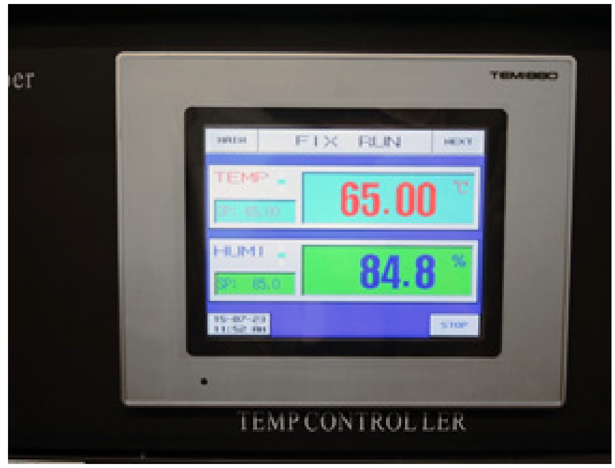


Figure 5: Thermal chamber @ 65°C, 85% RH

The environment in the chamber was then raised to +65°C (149°F) @ 85% relative humidity that was maintained for one hour before testing the functionality of the Switch-1es (SW-1). In this environment, all of the switches properly responded to a moisture stimulus and switched to the “alarm” state where they remained until the moisture stimulus was removed.

Detailed PCB, Schematic and BOM Reviews:

<u>The electronic design of either pump, and of the Switch-1 (SW-1) switches, do not incorporate any transient protection at the AC line input. This might be considered important</u> since these devices would normally be used on circuits with large electric motors, pumps or compressors, which can easily generate significant electrical transients.

The Small Split Slender schematic appears to be missing two connection points, at the top of C6, a 47 μF/25V electrolytic capacitor, and another at the top of the relay K1 and diode D5, which should show a connection to 24V. At present, there is no apparent connection to 24V although there is text above the relay and diode on an earlier version of the schematic indicating they should connect to 24V. For comparison, various other points within the schematic do show connections to V++ (rectified AC line voltage).

In addition, engineers noted that the specified relays, which include the brand-2 type PART#, appear to be rated differently in the catalog versus the current rating stamped onto the relay body. The relay body clearly shows 3A at either 250VAC or 30VDC, but the catalog picture shows 10A @ 125VAC and 5A @ 250VAC or 30VDC on the body of the relay. The following image illustrates the differences.

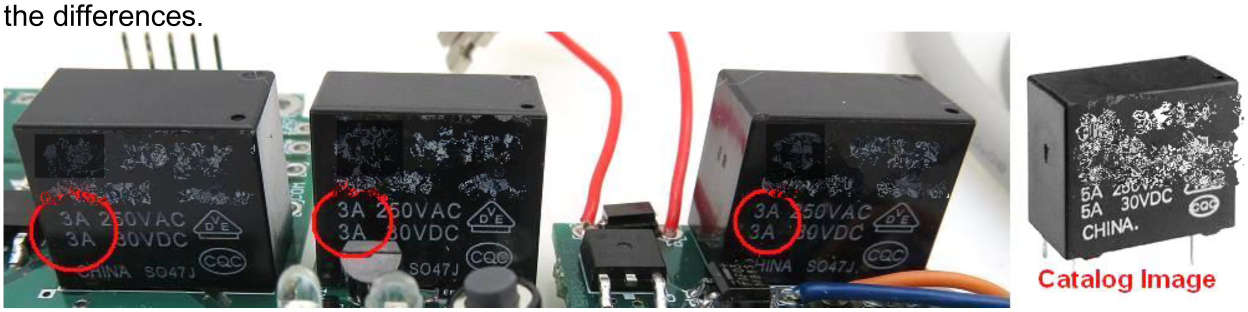


Figure 6: Left is the relay on a "New" P-1-Small Rev. 2C board; 2nd from the left is a Switch-1 (SW-1) relay; 3rd from the left is a Small Split Slender relay; and extreme right is a copy of the catalog image of the relay. Note the current rating differences at 250VAC between the left relays and the catalog relay.

However, further down in the catalog page, these differences are explained in a contact current ratings table:

Contact Rating:	1A	Standard:	H:5A 250VAC 5A 30VDC 10A 125VAC
		Sensitive:	HL:3A 250VAC 3A 30VDC、HLQ:8A 250VAC
	1C	Standard:	3A 250VAC、 3A 30VDC

Thus, the actual relay contact rating depends upon how the contacts are configured within the relay itself: as a 1A form contact wherein the contact is only a wiper and a single normally-open contact (SPST), the rating is 5A/250VAC. As a 1C form contact (wiper plus one normally-closed contact and one normally-open contact, also known as SPDT), the rating drops slightly to only 3A/250VAC. Since these particular relays are in the SPDT configuration, the correct current rating is 3 amperes at 250VAC or 30VDC.

Common Issues Found: BOM/Schematic Review

- In three provided schematics, the bridge rectifier (B1) should be marked as MB8S instead of MB1S. However, the BOM and the provided un-potted PCB have the correct part.

- The rated 250VAC/3A relay, K1 should be listed as having 3-ampere 1C contacts. Neither listed part number for K1, the Brand-2 PART# or the Brand-3 PART#, was found listed at either Mouser or Digi-key. The provided un-potted PCBs were built with Brand-2 PART#.

- Several listed Mouser product numbers (p/n) in the provided BOMs were actually the Digi-Key part numbers. 360° also attached the reviewed BOMs with each link of the part on Mouser.com or Digi-Key.com.
- Q1 (PART#) is not a Mouser p/n, while the Digi-Key p/n is .... The description of Q1 on the P-1-Small and Small Split BOM were incorrect in that it defines Q1 as a NPN bipolar transistor; Q1 is actually a MOSFET ... type and PART#.

"New" P-1-Small Pump & Tank, BOM/Schematic Review [2]

- The Tank probe socket, E, A, R, and Ant, appears to be listed twice with the same p/ns: once as the 6th item on the Tank Board BOM, and again as the 20th item. This could result in double-ordering of the required quantity.

- The schematic appears to be missing three connection points: at the top of C6, a 47 µF/25V electrolytic capacitor; at the top of the relay K1 and diode D5, which should show a connection to 24V; and the top junction of Q5 and R19 should show a connection to +24V. At present, there is no apparent connection to 24V. For comparison, various other points within the schematic do show connections to V++ (rectified AC line voltage).

- According to available part information, -40°C ~ +85°C would be the appropriate overall rated operating temperature range.

"New" P-1-Small Pump &Tank, PCB Build Quality Review - (the provided un-potted PCB sample)

No observed issue other than oversized parts seem to have been installed, apparently for ease of handling and soldering during hand-assembly.

Small Split Slender Pump / Reed Switch, BOM/Schematic Review [3]

- The brand p/n listed in the BOM for R11 is a 5% tolerance part instead of 1%, as the schematic and BOM descriptions both call for. The correct brand p/n for a 1% resistor would be PART#.

[2] Please reference the included and linked: "Reviewed_... BOM - Rev 2C.xlsx"
[3] Please reference the included and linked: "Reviewed_... BOM.xlsx"

- R7 (PART#) is a Digi-key p/n for a 2512 size component, not a Mouser p/n. In the BOM, R7 is apparently the equivalent part and is listed as a PART# (4.7K, SMD 1206 package).

- The worksheet page title of the provided BOM states "V10", the schematic states "V13" and the PC board layout states both "V11" and "V13".

- Similar to the P-1-Small Pump, the schematic appears to be missing two connection points: at the top of C6, a 47 μF/25V electrolytic capacitor, and another at the top of the relay K1 and diode D5, both of which should show a connection to 24V. At present, there is no apparent connection to 24V. For comparison, various other points within the schematic do show connections to V++ (rectified AC line voltage).

- As with the P-1-Small Pump, according to available part information, -40°C ~ +85°C would be the appropriate overall rated operating temperature range.

Small Split Slender Pump, PCB Build Quality Review - (the provided un-potted PCB sample)

- On the solder side of the provided sample PC board, the COM wire connection does not have sufficient solder.

- U2 was not soldered into position precisely, and excessive solder was found nearby.

- B1 is located immediately next to relay K1; in addition, the wire thru-holes are located on the PC board such that K1 might overlap them, causing difficulty in soldering either K1 or the wires. There should be at least a small amount of space between K1 and any other component or connection.

Switch-1 (SW-1) Switch, BOM/Schematic Review [4]

- The schematic lists D2 as a 3.9V zener diode, the BOM, however, lists the device as 5.1V, 0.35W zener diode with a Digi-Key p/n. 360° believes the correct voltage rating should be 3.9V as the schematic shows, which would make Vdd to the PIC microcontroller about 0.7 + 3.9 = 4.6V. If a 5.1V zener were used, Vdd would be a little higher than desired at around 5.8V. Engineers could not determine what device is actually installed on the un-potted sample board.

- Transistor PART#, which should be labelled Q4, is instead labelled T1 on both the schematic and BOM. T*n* is typically used to label transformers.

- According to the available information, -25°C ~ +85°C would be the overall rated operating temperature range. <u>However, as noted earlier, the current Switch-1 (SW-1) Switch appears to become erratic and may randomly switch to alarm when close to 0°C.</u>

[4] Please reference the included and linked: "Review_ ... Final BOM.xlsx"

Switch-1 (SW-1) Switch, PCB Build Quality Review - (the provide uncoated PCB sample)

The only issue found was that Q3, a high voltage transistor, is located immediately next to relay K1; in addition, the wire thru-holes are located on the PC board such that K1 might overlap them, causing difficulty in soldering either K1 or the wires. Components should not be placed immediately next to K1.

Conclusion

Five each "New" P-1-Small and Small Split Slender pumps were inspected, evaluated, and current draw measured at a number of AC input voltages. All "New" P-1-Small and four of the five Small Split Slender pumps appeared to operate correctly; the one Small Split Slender pump that did not work appears to have a known production issue. However, the "alarm" state ON/OFF timing was found to be very different between the two models of pumps.

The Switch-1es (SW-1) performed well except at temperatures near freezing. Near freezing, two of the switches did not operate properly. However, since only two of the switches did not operate properly, a part tolerance or assembly issue may be at fault. Engineers suggest that troubleshooting of this operational issue might be considered.

The preceding reviews were based on all provided documents. Other than with the Switch-1 (SW-1) switches, 360° was not tasked by the Client to perform troubleshooting or circuit verification of each segment and performance analysis under different temperature conditions. Since the product applications are highly-dependent upon sensors that are interactive with water, 360° strongly recommend tests under different temperatures.

An e-mail was received from the Client on August 26, 2014:

From customer staffer on Aug 26th 20..,
"Some areas where we've had problems in the past ...."

360° is unaware what "..." might entail. Should more information be available and provided, 360° suggests investigations of those issues.

Appendix A

All ten pumps appear to have been hand-assembled and exhibited indications of the potting compound having been allowed to cure before the pump covers were installed. This caused the wire retainer/grommets not to fit properly on most pumps, which then resulted in the covers not fitting properly.

360° assumes the provided samples in white-plastic enclosures are 3D-printed, made for testing purpose only.

“New” P-1-Small Pump Mechanical Inspection:
All five of the “New” P-1-Small pumps showed signs of a poorly installed metal cover; see the following image.

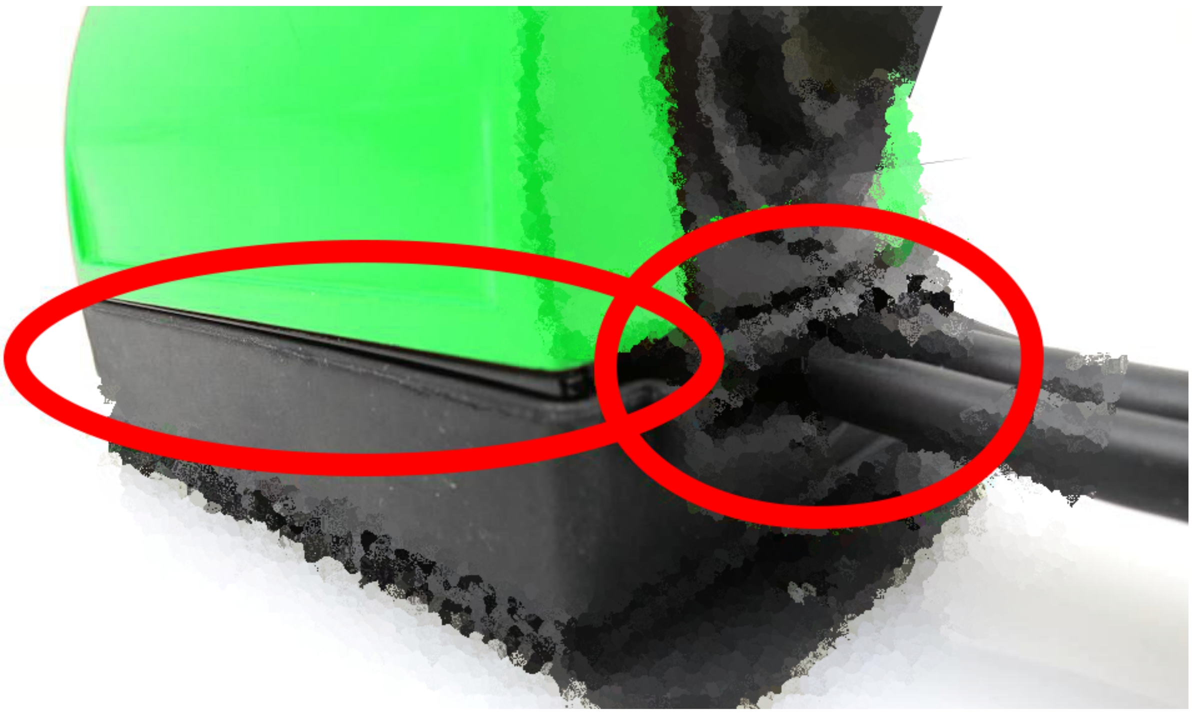


Figure 7: Poor fit of the cable restraint/grommet causes the outer cover to not fit into the base properly. The left red oval illustrates how the end of the cover is lifted compared to the rear, while the right red oval points out how the cables are not fully seated into the cable restrainer/grommet.

The cause of this appears to be the cable restrainer/grommet; the two outside cables are too large for the holes in the grommet, while the center hole is oblong but the cable is circular. The following image shows this cable – misfit, as well as a crack in the hard-plastic grommet over the center cable.

It appears as if the grommet is prevented from fitting tightly into the housing both due to the improper hole sizes for the cables as well as, perhaps, not being pressed down into the potting compound laid within the base housing until after the potting compound has cured. One end of the grommet was noticeably higher in the base than the other. It was found that this assembly problem existed on all five of the provided “New” P-1-Small pumps to varying degrees.

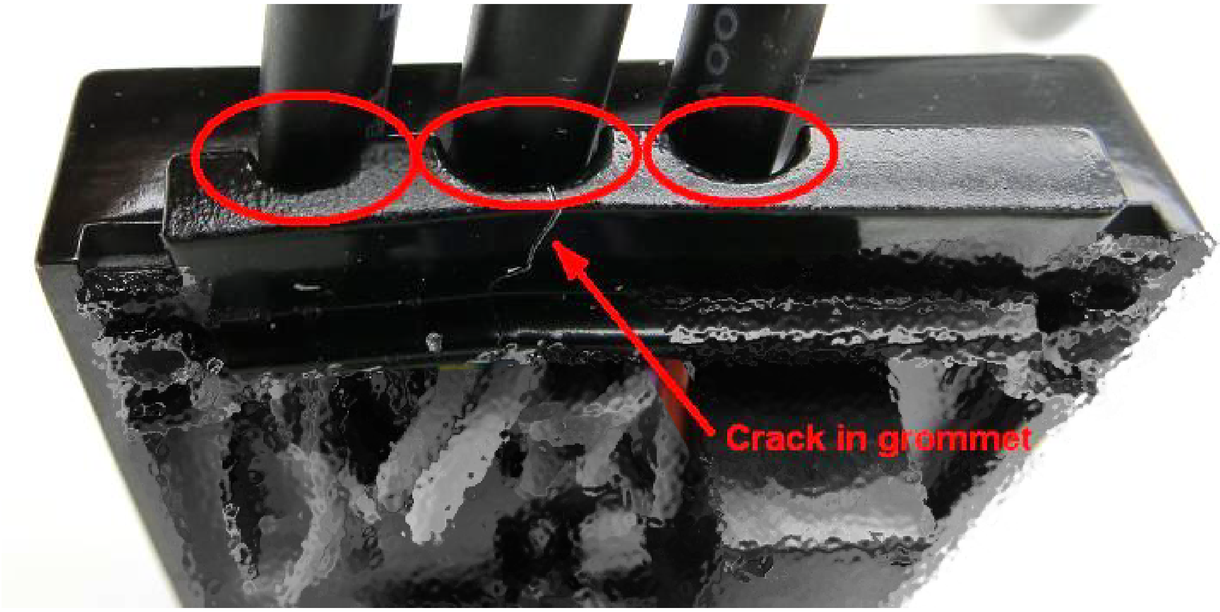


Figure 8: Close-up of the cable restrainer/grommet. The red ovals illustrate how the holes in the grommet do not fit the cables, while the red arrow shows a crack in the grommet caused by tightening the top cover over the grommet, which does not fully fit over the cables.

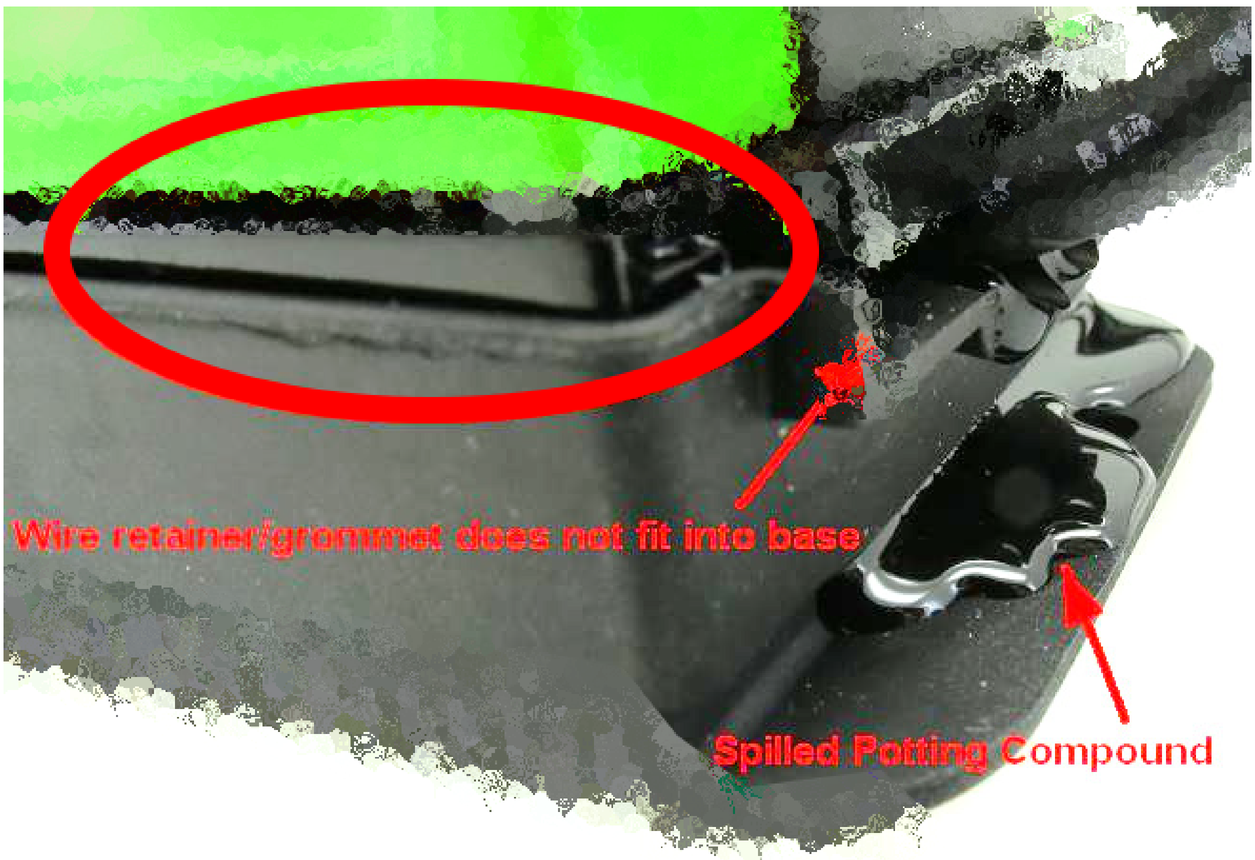


Figure 9: "New" P-1-Small pump #3. Note the spilled, hardened potting compound on the rubber base, as well as the poor fit of the wire retainer/grommet.

P-1-Small #3's cover fit so poorly that daylight can be seen underneath the orange cover, all the way through the pump:

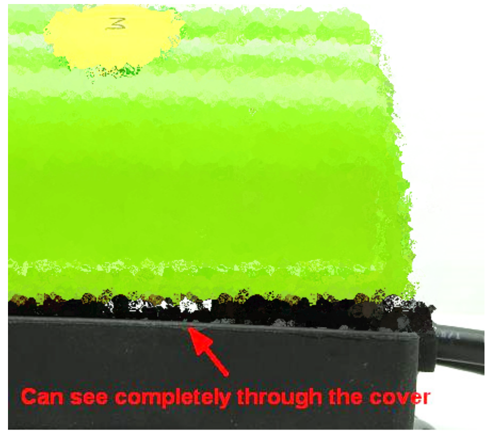


Figure 10: Daylight can be seen between the orange cover and the black baseplate of "New" P-1-Small #3.

The following image shows the internal construction of the "New" P-1-Small pump, including the potted PC board. The potting compound appears to be a hard-setting black plastic.

Figure 11: Internal construction of "New" P-1-Small pump. A rubber grommet has been removed from the right side of the pump during disassembly.

P-1 Small Split Slender Pump Mechanical Inspection:
Construction quality of the Small Split Slender pumps was similar to that of the "New" P-1-Small pumps in that the cases do not fit tightly together due to the wire retainer/grommet improperly fitting over the cables and, in at least one instance, excess potting compound; see below.

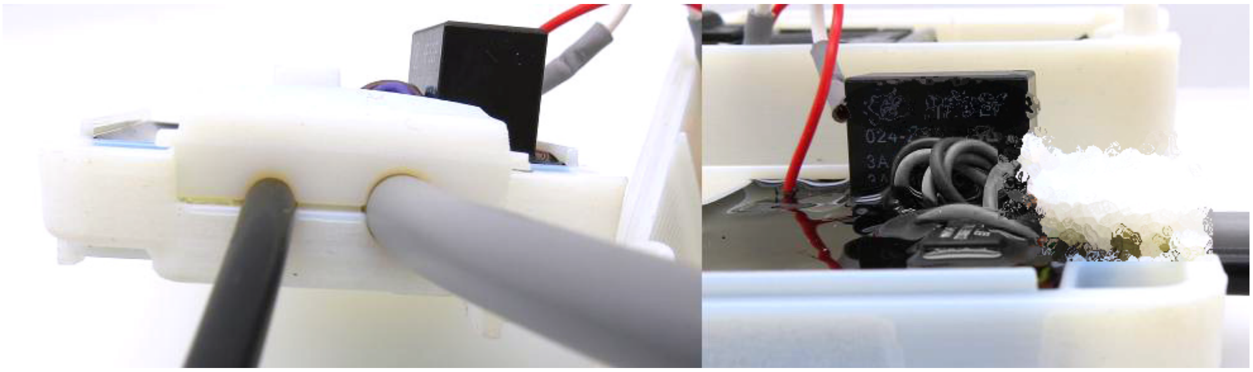


Figure 12: Left: Although the holes in the cable retainer appear to be the correct size, the retainer does not fit quite properly, and does not allow the case to fully close.

Right: Note how the inside edge of the retainer is tilted up; this higher edge butts against a lip in the upper case and prevents the case from closing entirely. The top case half sits on the outer edges of this retainer and is thus not able to press the retainer down due to the hardened potting compound underneath the retainer.

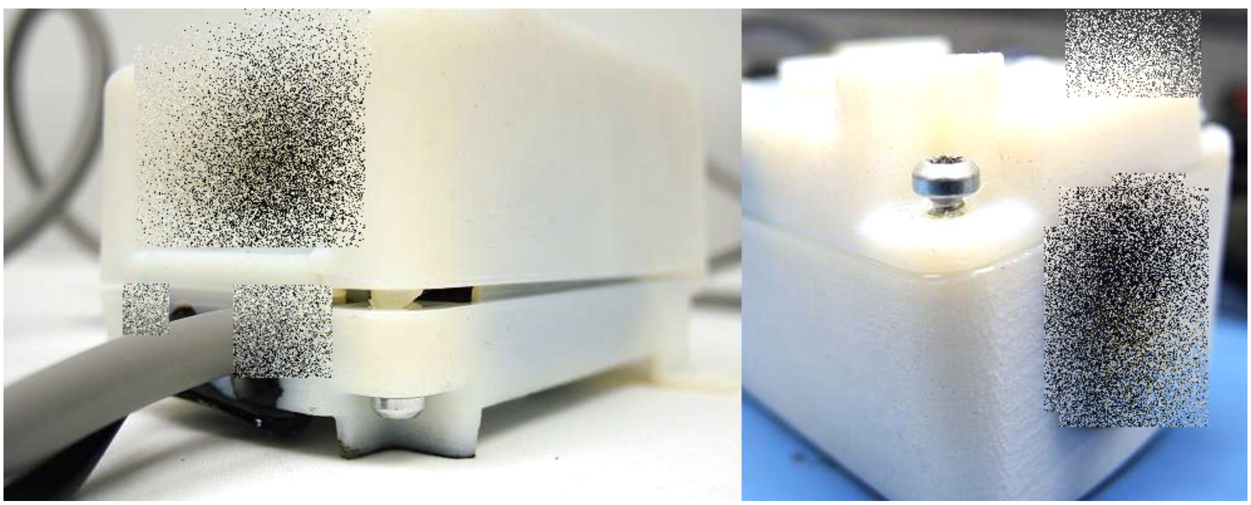
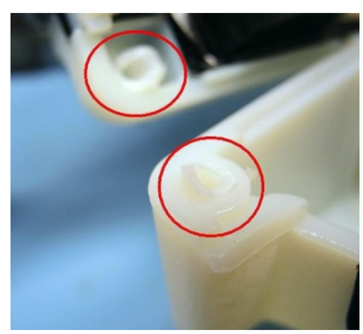


Figure 13: Left: Excess potting compound is preventing the cable retainer from fitting properly.
Right: Several Slender pumps arrived with loose case screws as shown.

One Small Split Slender pump was received with an internal case-securing screw mounting tang broken off, as seen below in Figure 19. This appears to have happened when the screw was overtightened in an effort to close up a gap in the case. Another of the Small Split Slender pumps had one of the two outer mounting "ears" broken off when received (as shown on the right).



Reviewed by: PDM, SMH, ZJH, CRW