iTPC LV Power Failures
Analysis, Cause & Corrective Action

- **Anderson Power-Pole connection failures (slides 2 – 10)**
- **iRDO FEE power open fuses (slide 11)**

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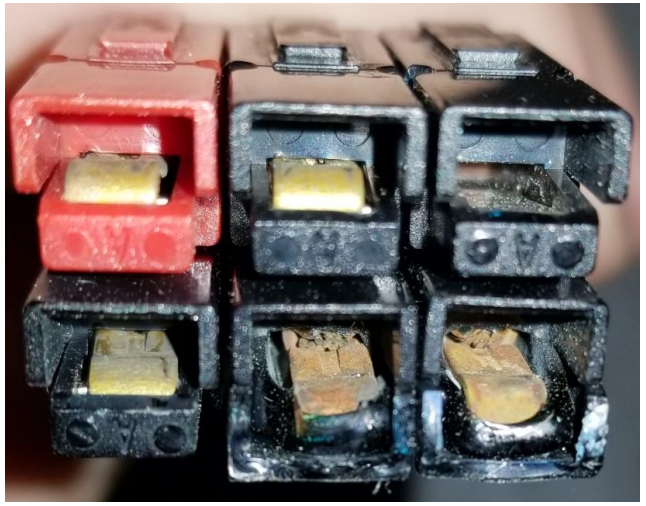


Typical overheated Anderson Power-Pole connector & contacts (iTPC LV power cable interconnect)

Contact housing & connector removal for typical repair of LV interconnect (parts removed from 4x sectors shown)

Background…

The power issues for the iTPC RDO + Front End electronics were found to be from degraded connections at the power feed at the detector side extension cables (**slide #3, fig 1**). The power feeds from the rack-mount power supplies are run to each clock position of the fringe of the outer TPC segments. Three-foot extension cables (**fig.1**) are then used to carry the power to each inner RDO or in the case of the TPX sectors a wye adapter cable is used to bring power to 2x RDO's. In total, there are five Anderson disconnects to each RDO.

The connections are made with Anderson Power-Pole family spring type contacts and housing assemblies (PN 1330).
The contacts & housing are rated for 30A with 12AWG wiring. With a 45 amp load each contact should typically see ~ 15ADC current with a V_{DROP} / contact of 10mV (~400mW / contact). The connector Voltage drop is derived from the manufacturers contact mating resistance.

Under the assumption that only a negligible imbalance exist between connections and that each connection is solid (within the rated mating resistance specs)…The connections should be well within the rated temperature for the contacts & housing assembly (i.e. within the current rating of the contacts). However, there is a condition that is causing excessive heating on one or more of the contacts of the connector. The excessive heating is melting the polycarbonate contact housing (**slides 3-4, fig.3,4,5**). Once the housing becomes distorted, the connection will become totally degraded. Significant pitting is also noted on the contact plating which is either a sign of overheating or possibly galvanic corrosion (**slide#8, fig.9**).

I have also noted that the cable jacket & wiring shows signs of over-heating as well. This indicates the wire & jacket are exceeding the 75° operating rating (**slide#3 fig. 2 & slide#4 fig.5**).

iTPC damaged LV power connectors

LV Power cable diagram

Fig2. cable jack shows indications of overheating

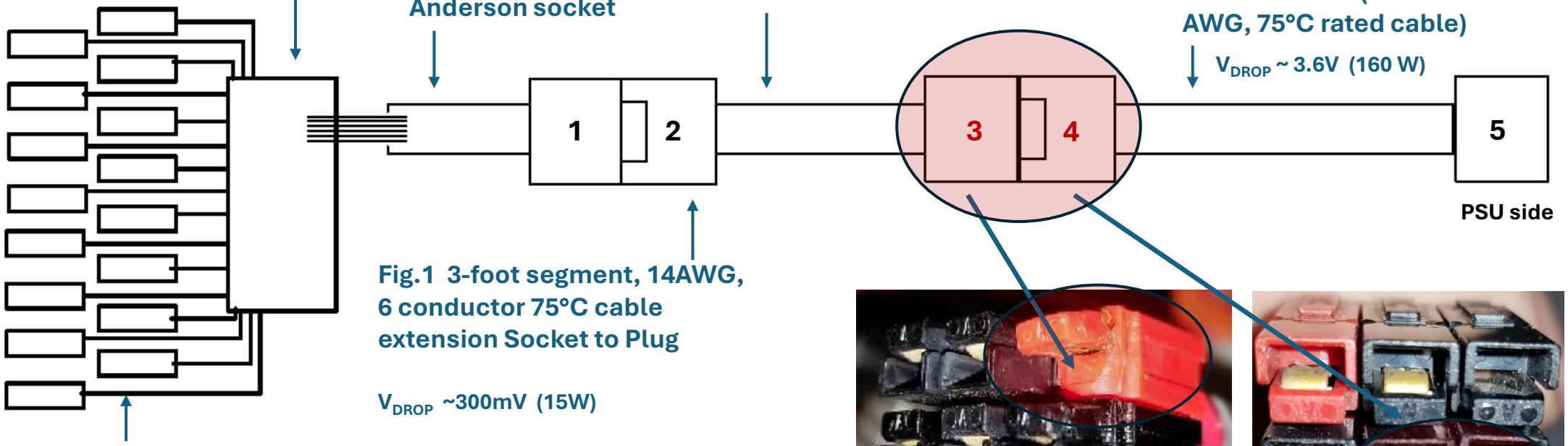


Fig.3 Socket & plug ends of 3-foot extension cable & feed cable ends
Melted pin housing & overheated contacts

Anderson power-pole connector housing & wire damage from excessive heating

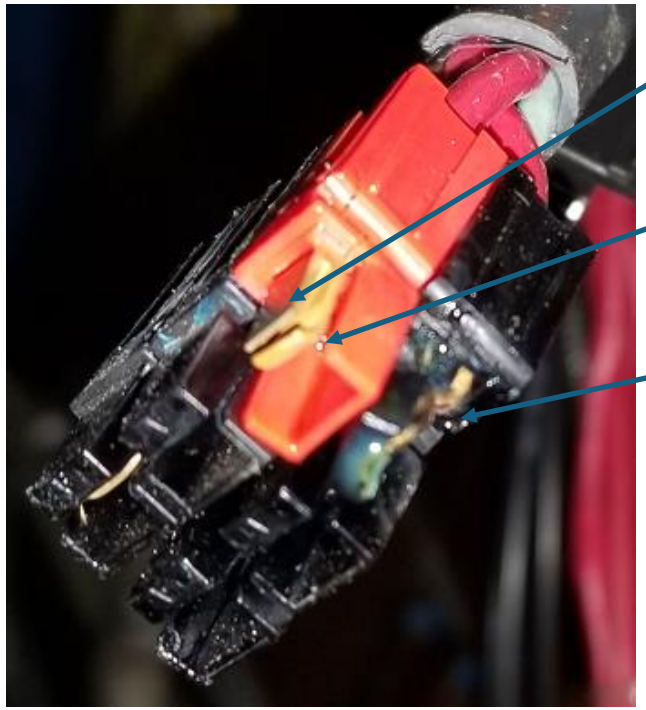


Fig.4 Metal spring for contact mating retention
Note: *part of contact housing broken off*

Contact

Damaged housing and contact from excessive amperage caused by heating effects
Housing is rated for 105°C

Corrective Action: Replace connectors 3 & 4 (slide #3) with 14 to 12 AWG Butt-Splices

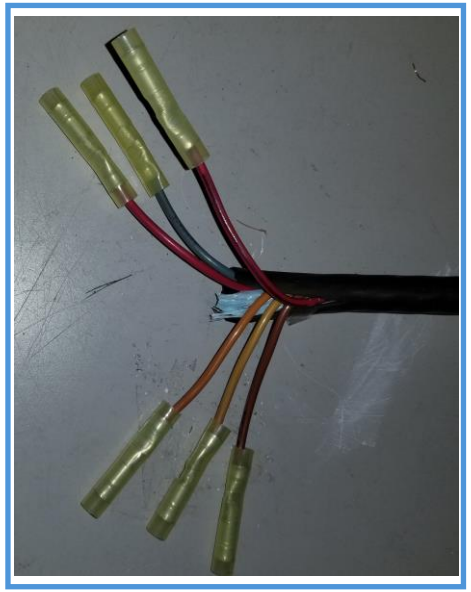


Fig.5 Burnt contacts and part of housing broke off due to excessive heat

Burnt wiring found on both the 12AWG feed and 14AWG extension
Wire & cable jacket is 75°C rated

=> There are a few circumstances that can cause the issues we are seeing here, and are also noted by the manufacturer.

REFERENCE

1. **Dirty Connectors**
   When engaged and disengaged, the contact surfaces of Anderson™ flat wiping connectors "over wipe," thus providing self cleaning action. To ensure the continued benefit of this feature, clean the contact surfaces and lubricate the connectors. Use a "white" lithium grease, which may be obtained from hardware stores and automotive parts suppliers.

2. **Melting Connectors**
   Connector housings overheat and melt for many reasons. To prevent this:

   A. Examine the crimp between cable and contact. Ensure the crimp tooling recommended by Anderson™ has been used. Improper crimping, corrosion, and broken wires result in unnecessary resistance causing the contact to heat up.

   B. Check contact surfaces for signs of "pitting" caused by dirt or disengaging connectors under load. One badly pitted contact, particularly in a connector attached to a battery charger, can lead to pitting on surfaces of other contacts. If not corrected, this can result in an epidemic of bad connectors throughout a fleet of electric vehicles and in chargers and batteries.

   C. Check to see if batteries are being disconnected while the charger is still on. This causes the contacts to arc at the tips, resulting in progressive pitting and silver removal from tip to crown. If this practice is occurring, it should be discontinued to avoid major repairs in the future.

I have noted in some instances several post crimped pins that were distorted most likely by an improper crimp method. In these cases, the pins are bent in such a way that causing decreases mating force.

In other cases (although rare in the case of TPX and iTPC) an improper crimp was noted in that the wire pulled out of the contact with a force well below the rated pull test.

3. Other Conditions

If any of the following conditions exist, the connector housing, contact and / or cable should be replaced immediately.

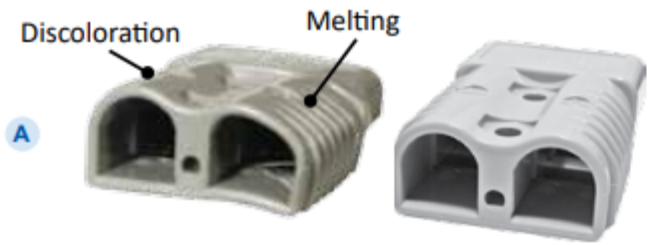
A. Housing - Cracks, missing pieces, evidence of excessive heat, discoloration. You may consider replacing the existing housing with a Chemical Resistant equivalent for improved durability against UV rays and common solvents and hydrocarbons.

B. Contacts - Pitting, burns, corrosion, excessive wear and cracked crimp barrels, as shown in image “B”.

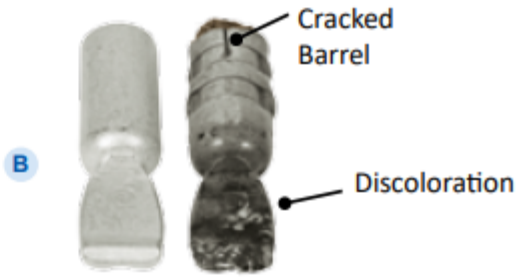
C. Cable - Exposed copper near housing, cracked cable, peeling or frayed insulation.

D. Handles - Loose attachment and signs of damage as missing or loose hardware and cracked or broken plastic (Handles should be used for connectors that are hard to reach or move).

E. Cable Clamps - Loose attachments, signs of abraded cable jacket, missing or loose hardware. (Cable clamps should be used to relieve strain on unmounted cable).



Damaged Housing **Good Condition**



Uncrimped Good Contact **Damaged Contact**

Your Best Connection™

2020-0055 Preventative Maintenance REV C7

Proper Vs Improper post-crimped pins

Contact mating force spring

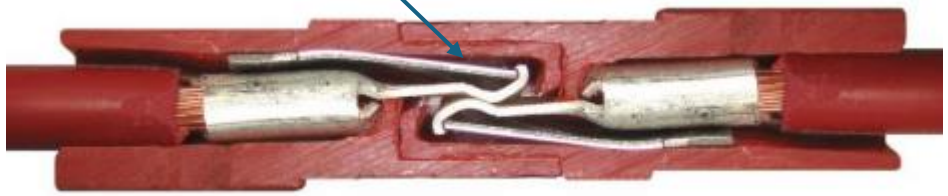


Fig. 6 Cutaway view of correct mating position of contacts inside of housing

Distorted contacts bent during crimping process

Crimp bent upwards causing insufficient mating contact

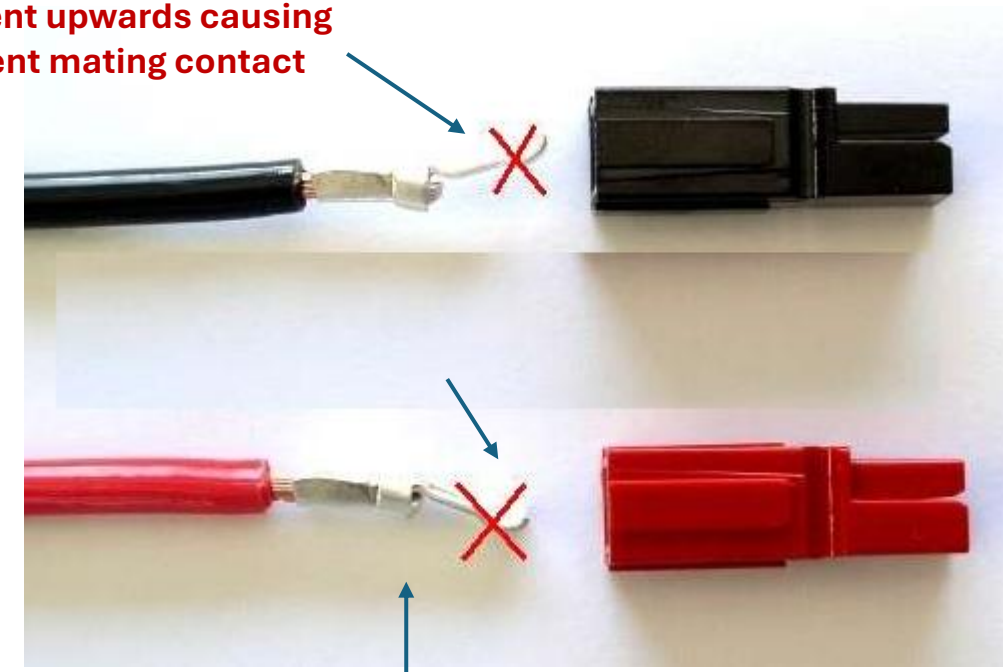


Fig. 7 Crimp bent downwards causing contact not locking into place. This causes the contact to recede too far in & will cause insufficient mating contact.

Typical failure analysis of over-heated Anderson Power-Pole connectors

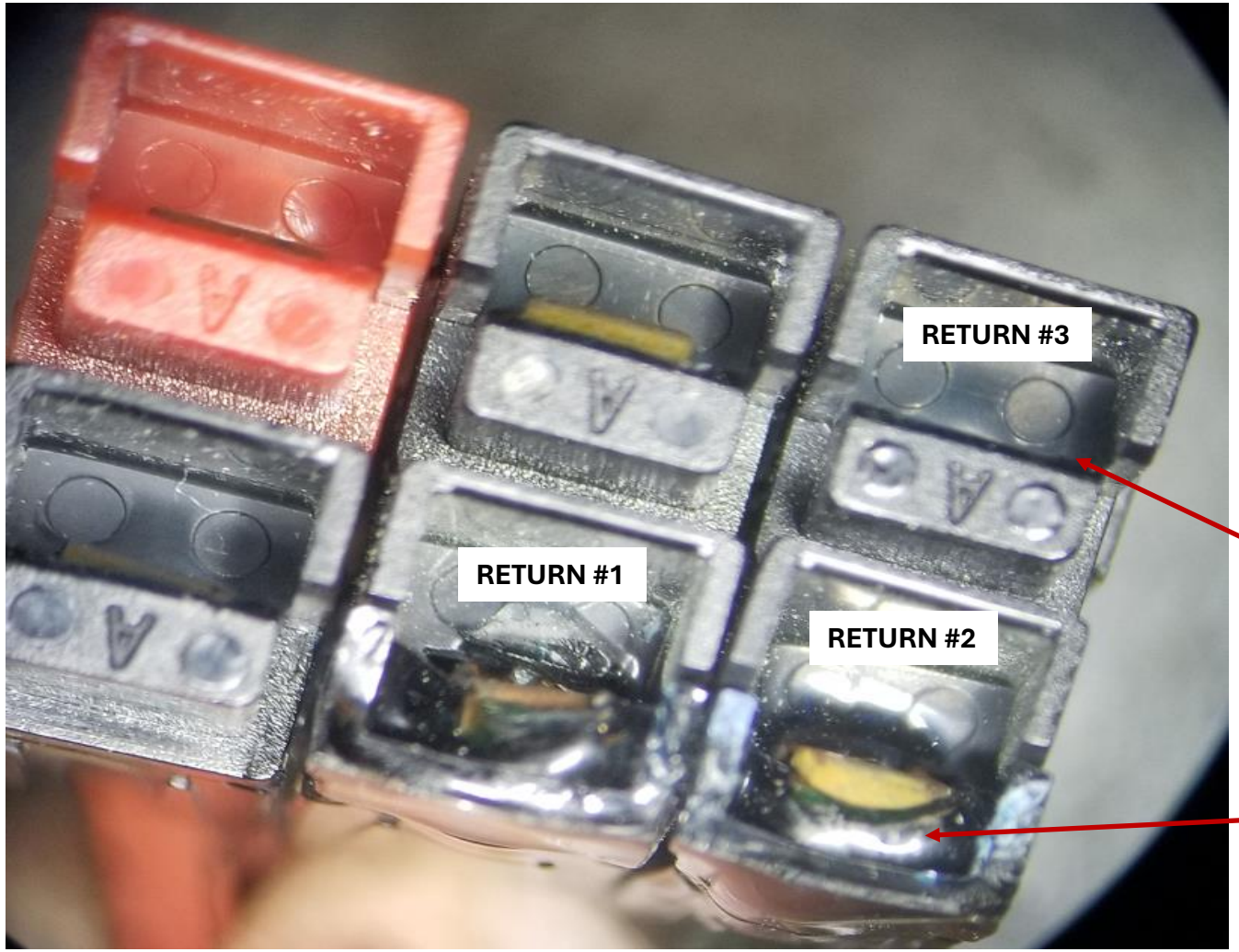


Fig.8 LV Return housing melted

Fig.9 New contact on top Vs contact removed from the field

Contact on bottom shows signs of pitting & excessive heating

Third return contact pulled out possibly due to distorted or bent crimp

Over-heated LV return connections either due to increased mating resistance or from third contact not seating correctly…causing these 2x pins to carry a 33% increase in load.

Conclusion

As we can see from **slide #5** from the manufacturer, there are several conditions or circumstances that could cause the contacts and connector housings to overheat.

If any one of the stated issues are present, then we could expect to have this condition occur. In other words, any small deviation in the assembly process could cause a compromised connection.

NOTE: For the repairs for Run24: ~44% were failures at the LV interconnect…

Improper Crimp:

I have noted in the case of Anderson Power-Pole connectors used in other detectors, that the condition of bent contacts (**slide 7, figure 7**) caused similar overheating. I am not 100% certain if this condition exist here for the TPC, but I have observed while removing the connector for the splice replacement…that a contact would fall out. On **slide #8 (figure 8)** we can see this condition where a contact pin for the LV return fell out (upper left corner pin) while the other contact pins remained intact.

Also, in other detectors that use the Power-Pole series, loose crimps were noted. This is where the crimping force on the conductor was not enough to properly crimp the contact to the wire. This was noted by the wires pulling out of the contact crimp when just pulling by hand. It should also be noted that too much crimping force or "over-crimping" can cause similar failure do to the mailability of copper wire and the contact. However, *I have not noted this issue with the TPC LV connections*.

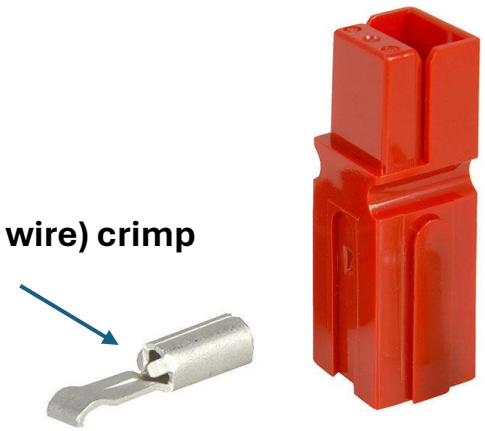
Dirty or pitted contacts (maybe galvanic corrosion?):

I have observed even looking at pins from housings that did not melt, that it appears that the contact finish was worn off. On **slide eight, figure** 9 I compare a new silver-plated contact on top with one removed from the field. It could be possible that the contacts used on the feed side Vs the three-foot extension side contacts use different plating (Tin Vs Silver). If this is true, then the discoloration and pitting on the contacts could be due to electrolysis caused by galvanic corrosion and would cause overheated connections over time.

Anderson Power-Pole Connectors…mechanical specifications

Polycarbonate pin housing

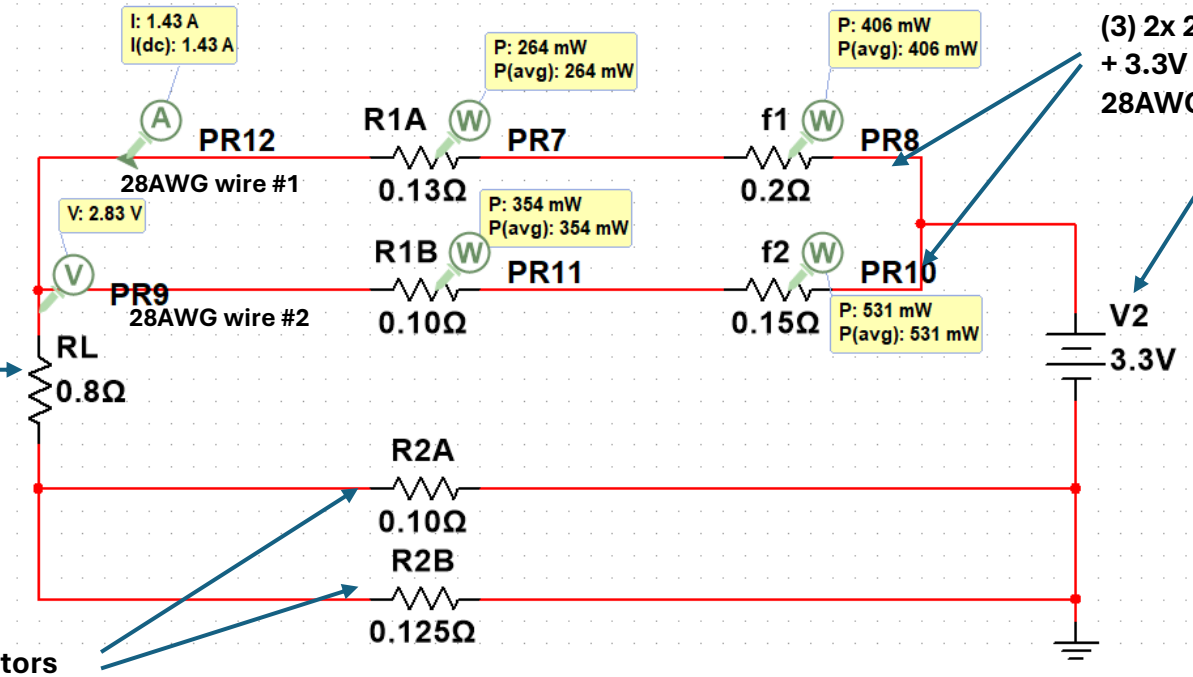
30AMP contact (12 AWG wire) crimp



Operating Temperature [2]	**°F**	**°C**
Powerpole® Housings & Powerpole® Pak Shells	-4° to 221°	-20° to 105°
Mating Cycles No Load by Plating	**Silver (Ag)**	**Tin (Sn)**
PCB to Wire	-	1,500
Wire to Wire	10,000	1,500
Avg. Mating / Unmating Force	**Lbf.**	**N**
Low Force Wire, High Force PCB, & Ground	3	13
High Force Wire	5	22
Low Force PCB	2	9
Min. Contact / Spring Retention Force	**Lbf.**	**N**
	20	90
Powerpole® Pak Latch Avg. Defeat Force	**Lbf.**	**N**
	150	667

Blown Fuse Condition…Loss of FEE power
iTPC RDO digital LV power distribution to FEE card (effects of parallel fusing)

Another issue exist where the fuses on the RDO that distribute power to the FEE cards are blowing. This condition occurs due to placing a separate fuse for each of the two LV positive wires from the SAS cable which essentially places the fuses in parallel…



(1) 1.3A Load from FEE card
RL = FEE digital load

(2) 2x 28AWG conductors from SAS cable 3.3V return power to FEE card

(3) 2x 28AWG conductors from SAS cable + 3.3V power to FEE card. Fuse 1 and 2 are inline w/ each 28AWG wire.

LV digital power from RDO

Fig. 1A RDO to FEE card SAS LV cable model simulation

(2) R1A, R1B, R2A, R2B includes cable resistance + contact mating resistance variations

Fuse & contact resistance can vary as much as 20%

In this example: Due to the imbalance caused by placing the fuses in parallel, f2 will see a greater power drop. This will cause a gradual but steady climb in operating temperature which can eventually cause the fuse to open.

Power on surge current can also cause this condition, due to in imbalance in voltage drop.

It is typically better & accepted to tie both connections at PCB and use a single fuse for both conductors.

Note: f1 and f2 are 1.0A rated fast blow fuse

Corrective action: Bridge connection at RDO PCB (left side of f1 & f2) & replace with single 2.5A fast fuse or 2A slow blow.