Advanced Training:

Inverter/Charger Systems

May 3, 2013
Port-Au-Prince, Haiti

Christopher Freitas

cfreitas@sunepi.org

Advanced Training:

Inverter/Charger Systems

Note: all photos from this presentation are from installations at Haitian hospitals which were installed between 2009 and 2013.

The goal of this presentation is to review the problems found and come up with ways to avoid these types of problems in future installations.

Inverter/Charger Systems

Past System Configurations and Components

- **Original installations used Trace Engr. DR and SW inverters**
  - DR is not a sinewave and SW was large, heavy and expensive
  - Both no longer made and are hard to get parts or have repaired

- **Not NEC compliant – very few safety components**
  - No DC disconnects or even any fusing was included
  - Used non-UL listed open type AC bypass switches – unsafe
  - Poor installation locations – batteries in front or under inverters, difficult access to inverters in many sites – under stairs etc.

- **One inverter/charger powered everything**
  - Sensitive loads were connected to the generator or grid resulting in failure of medical equipment and computers, etc.

Inverter/Charger Systems

Switched to OutBack FX and VFX inverters

- Better protected (screens/air filter etc) – sealed and vented versions
- Smaller / lighter and available in lower power levels vs Trace SW
- Additional components available (MATEs, FNDCs, AC & DC disc)

- Didn’t use Xantrex XW because it was 120/240vac and would not work with 120/208VAC three phase power sources or 127/230 VAC sources

- Didn’t use Magnum as they didn’t have sinewave inverter when we started or any Balance Of System (BOS) components (disconnects, controllers etc.)

- Didn’t use SMA Sunny Island – it was very expensive at that time / no BOS

  - *All are good products and options to consider but its good to have a consistent product to enable training and experience to build up*

- Eventually switched to all vented VFX inverter/chargers due to hot temperature issues and to get higher charging rates.

Inverter/Charger Systems

Contact Inverter/Charger & No-Contact Inverter

- **Contact inverter/charger connects to generator or grid and charges**
- **No-Contact inverter only powers sensitive loads – never charges**
  - » *Terminology originated in Haiti – not used in the US*
- **Used same inverter model is used for both the contact and no-contact in order to make the ordering & servicing easier**
  - **No-Contact inverter is often very lightly loaded – which is ok**
    - » *Used to power laboratory and computer server typically*
  - **Contact inverters work harder as they also battery charge**
    - » *Also power security lights and other hospital loads*

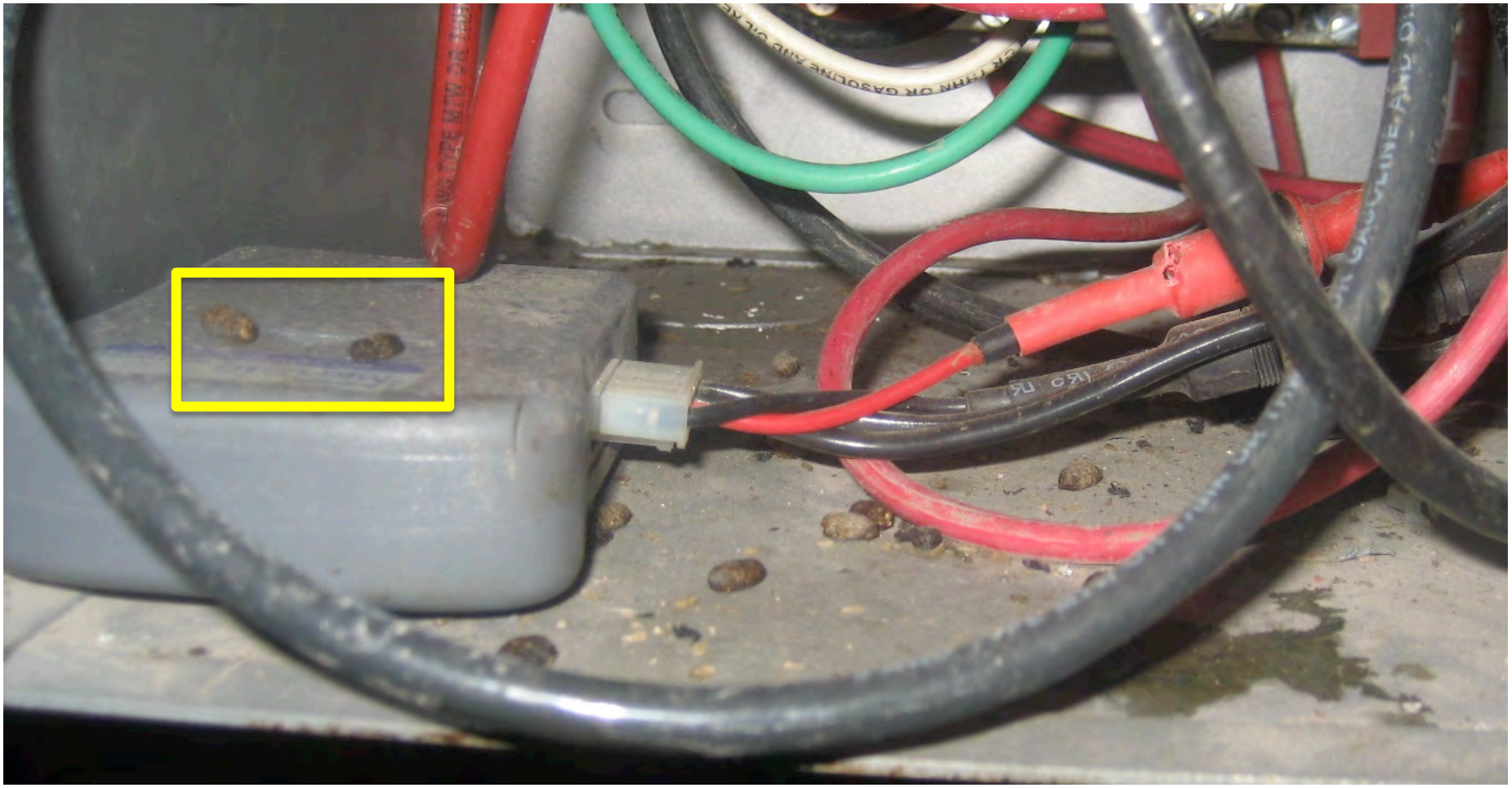
Inverter/Charger Systems

Problems We Have Been Having

- Biggest issue has been battery performance & lack of regular maintenance
- Inverter failures have occurred
    - **Problems caused by rats**
        - » Nesting on top of inverters – warmth?
        - » Chewing on wires – especially the battery temp sensor
    - **Internal cooling fan failures**
    - **Internal temperature sensor failures**

Inverter/Charger Systems

Signs of rats inside of enclosures



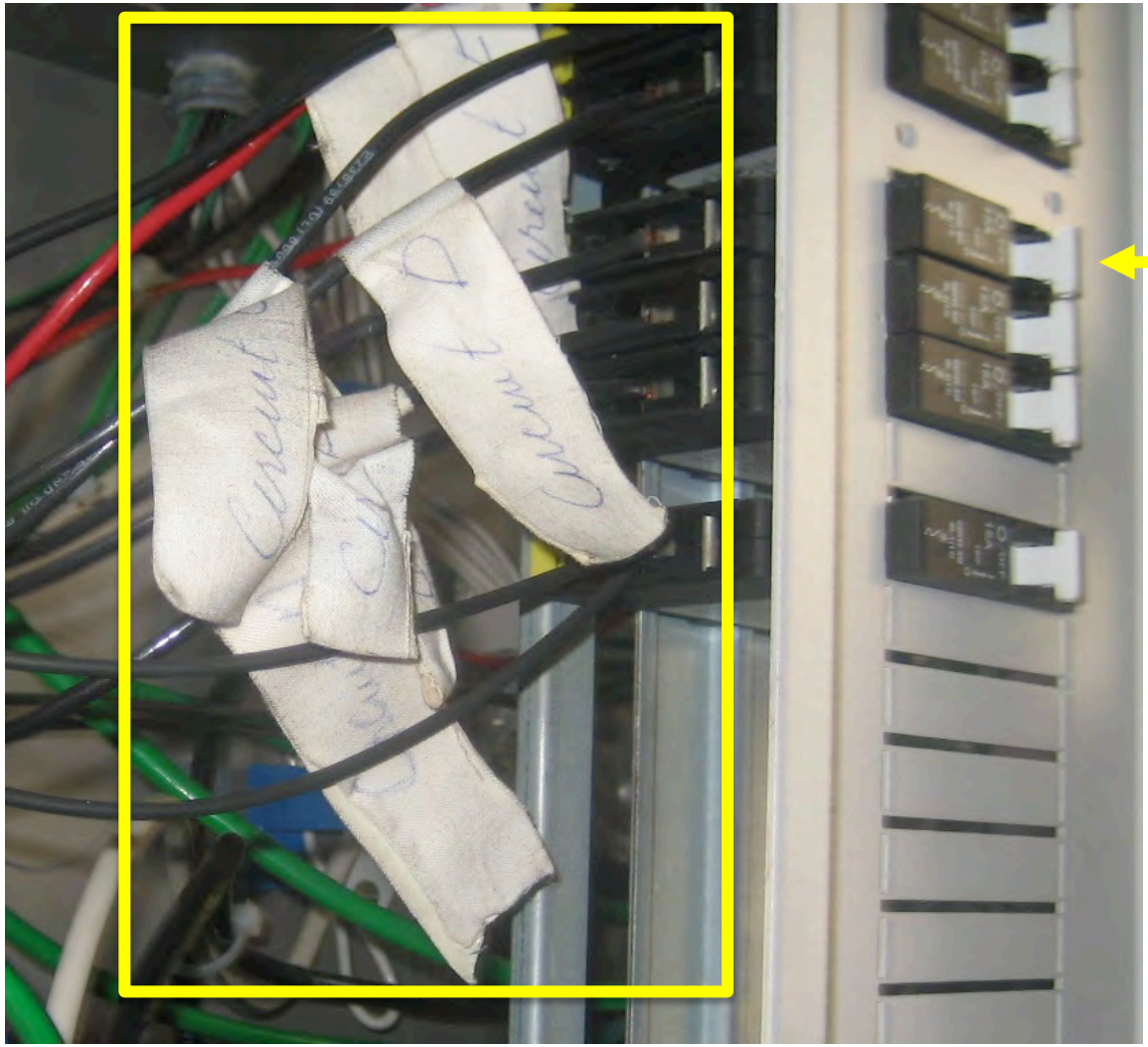
Inverter/Charger Systems

Installation quality issues

- **Lack of labeling of inverters, breakers and terminal busbars**
  - » *Makes testing & maintenance difficult*
- **Incorrect wire colors**
  - » *Makes following wires difficult*
- **Incorrect placement of washers & hardware materials**
  - » *Washers between battery terminals and cable lugs*
  - » *Non-stainless steel hardware being used with batteries*
- **General installation issues**
  - » *Conduit, wiring neatness, battery corrosion etc.*

Inverter/Charger Systems

Labeling Breakers



Breakers are not labeled on the outside of the enclosure

Wire labels where only visible when the screwed on cover is removed

Inverter/Charger Systems

Breaker and Fuse Mounting

Fuse laying at bottom of DC enclosure

Inverter/Charger Systems

National Electrical Code (NEC) Compliance:

- Can be challenging but has a big impact on safety and performance of the system
- Although it may not be required in Haiti – it is a good thing to do
- Important for applications such as hospitals and schools
- The standard in the USA

Inverter/Charger Systems

Conduit Installation

- ***Improper installation of conduit***
  - » *Conduits with gaps between lengths*
  - » *Not attached to enclosures*
  - » *No access for pulling wires*
  - » *Lack of grounding bushings on conduit*

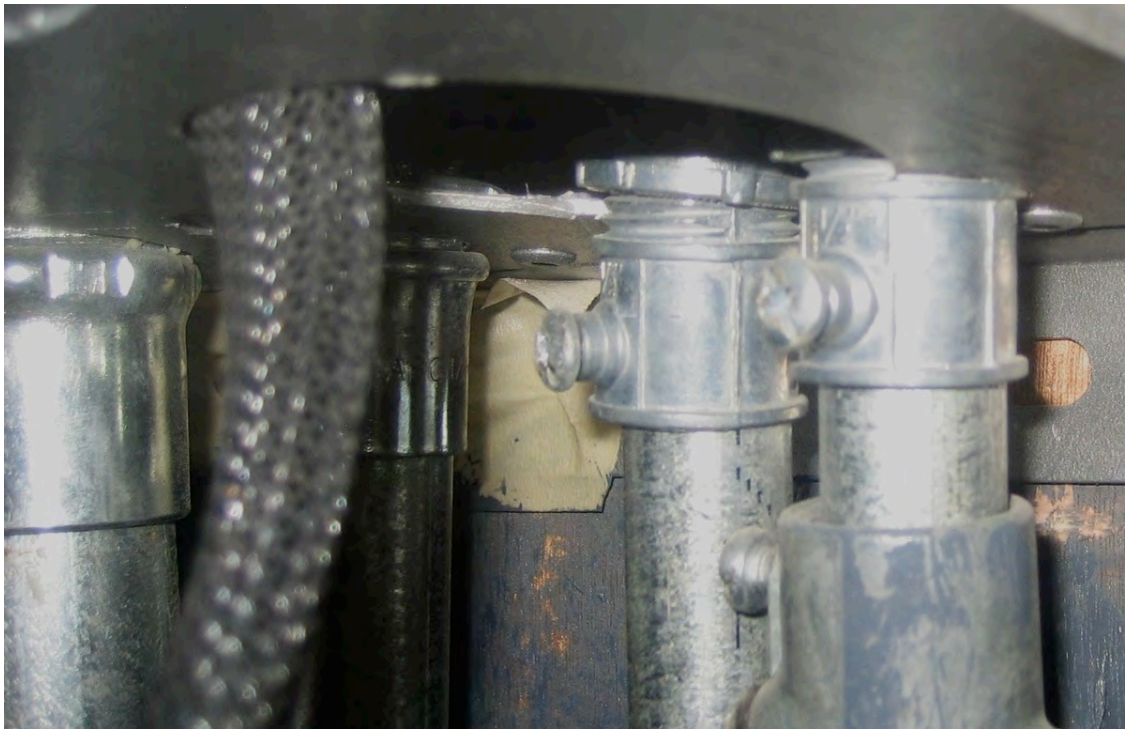
- ***Incorrect sized holes in the enclosure for conduit***
  - » *Conduit is not securely attached to enclosure*

- ***Open holes left in the enclosures***
  - » *allows rats / lizards / insects to get inside*

Inverter/Charger Systems

Conduit Installation

- *Do not leave openings in enclosures*
- *Use correct hole size for connector*
- *Use lock washers to provide grounding*

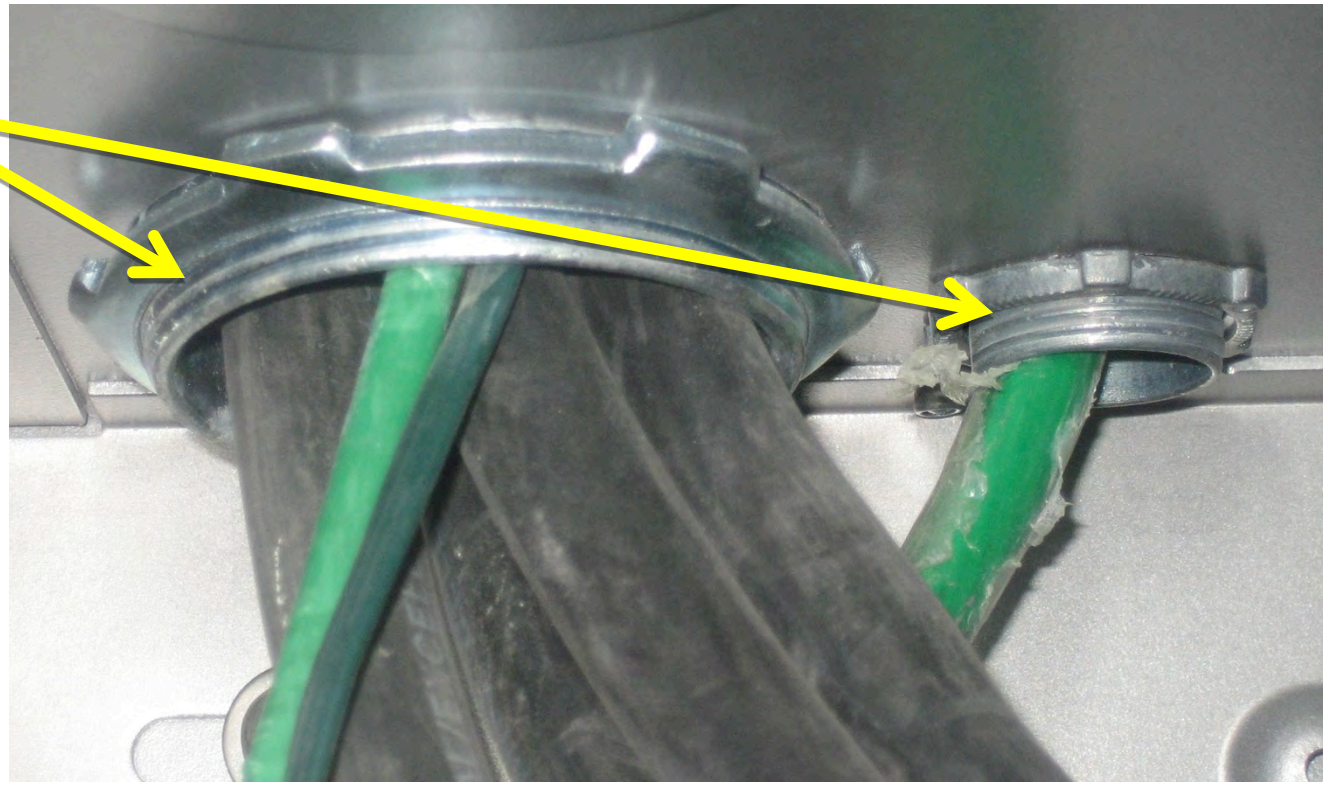


Inverter/Charger Systems

Conduit Installation

Battery cables too tight against the conduit adapter – a plastic bushing would protect the cable

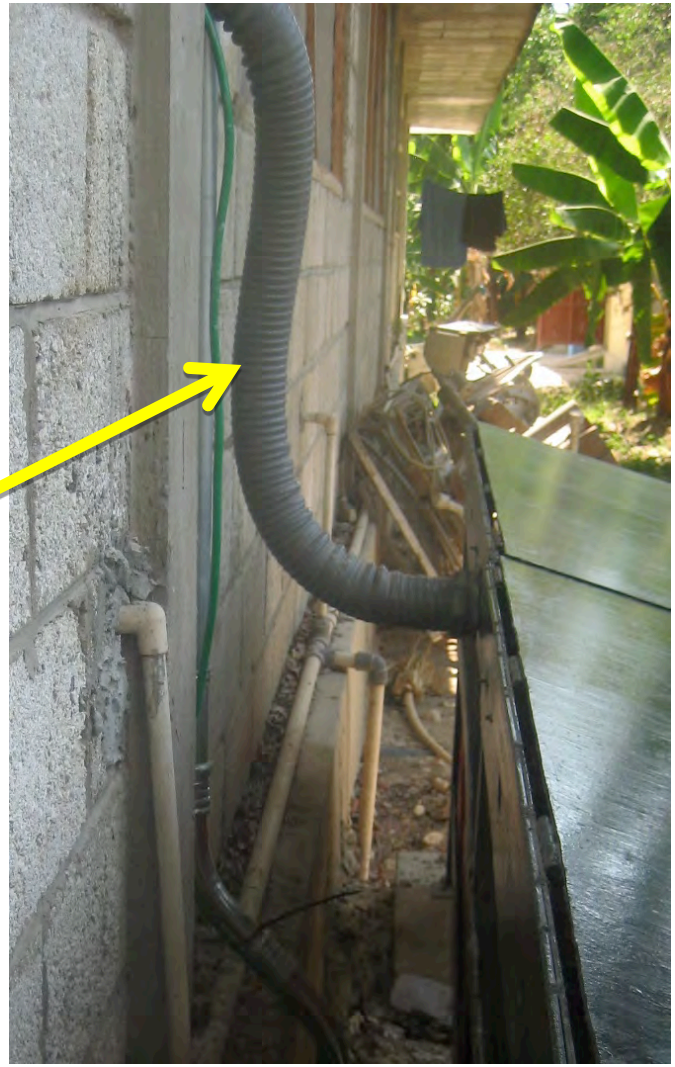
No Plastic Bushing



Inverter/Charger Systems

Conduit Installation

No conduit straps



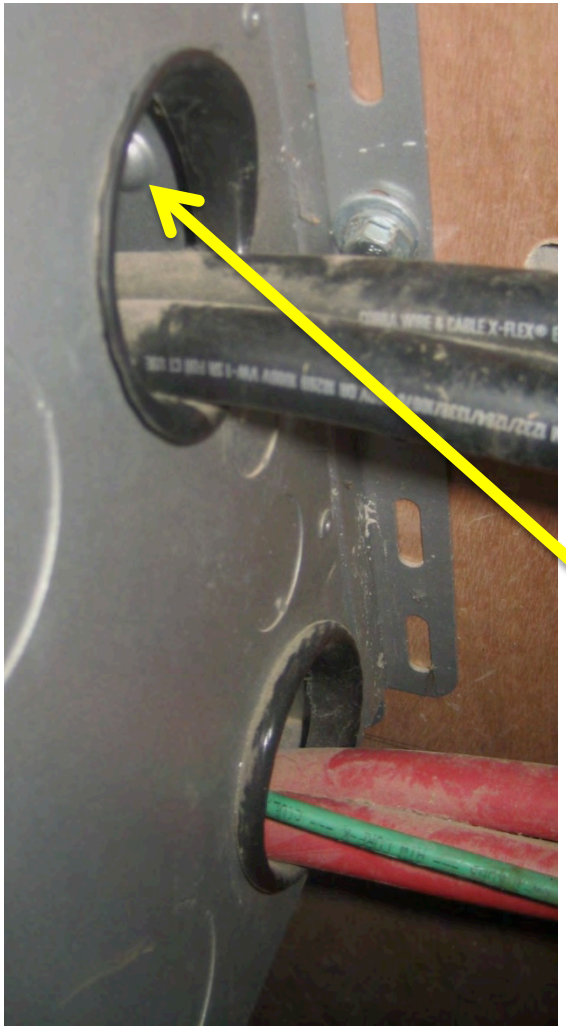
Inverter/Charger Systems

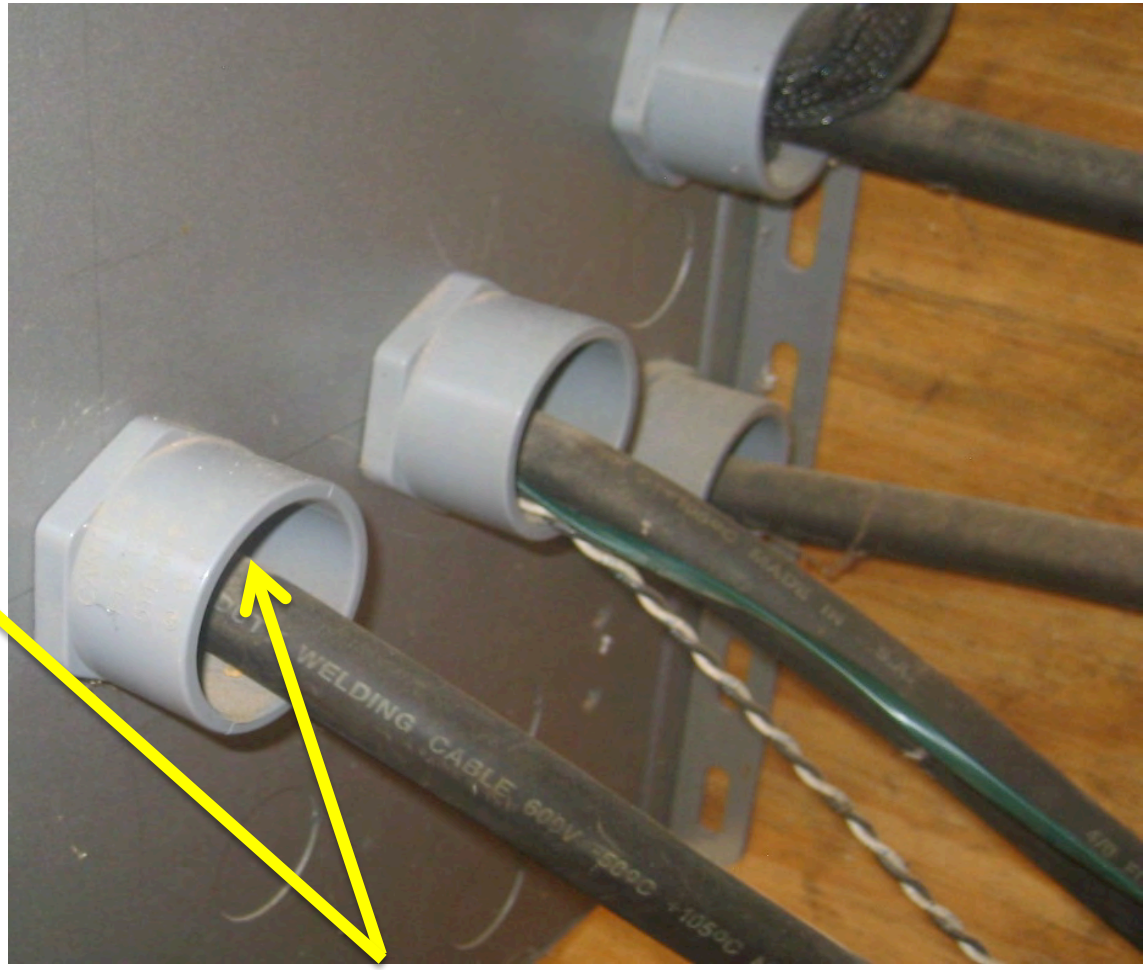
Lack of Conduits and Strain Relief

This is not code compliant! All exposed live terminals need to be mounted in enclosures with wiring protected by conduit

Inverter/Charger Systems

All wiring needs to be protected with conduit and no openings should be left in the enclosures for animals, lizards or insect to enter



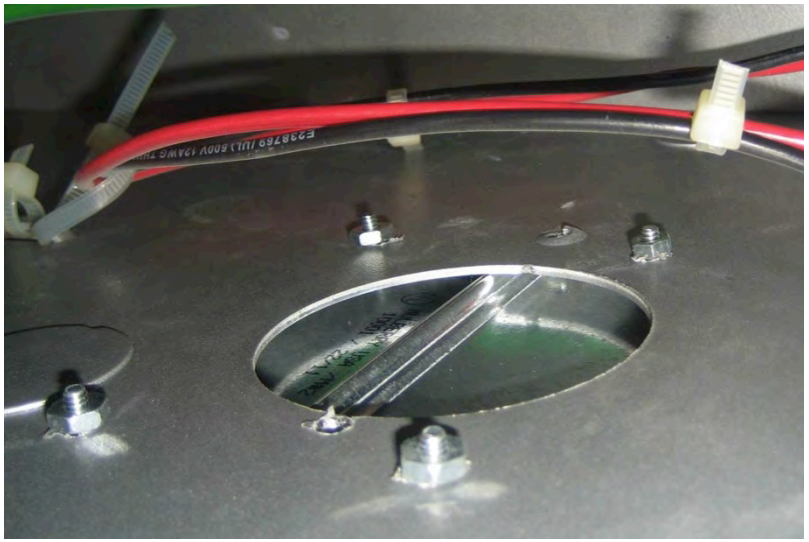


Exposed holes for animals to enter

Inverter/Charger Systems

Unused knock-out holes must be covered

Exposed wires through opening

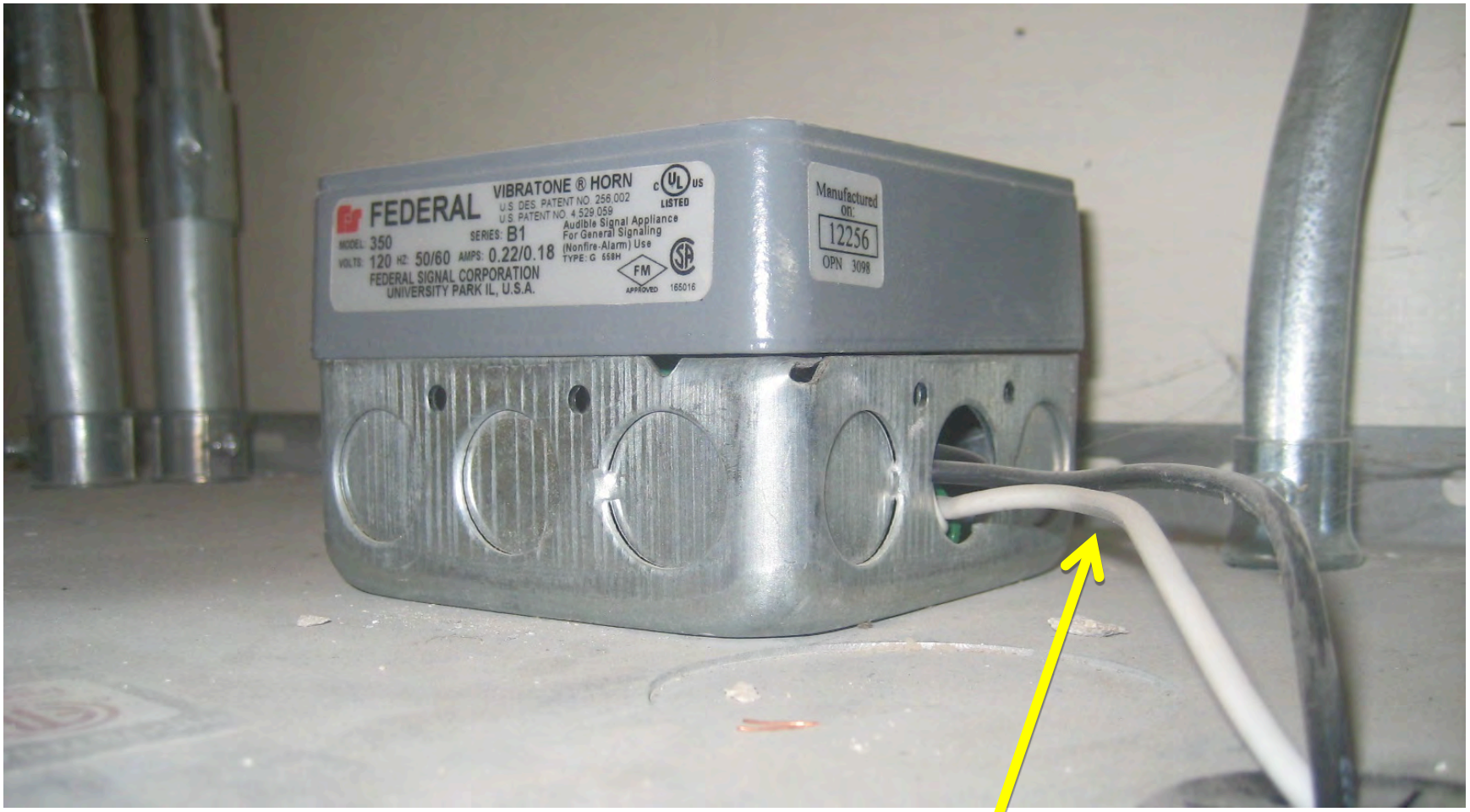


Inverter/Charger Systems

Wire Pull Boxes

Wire pull box's cover is not accessible – it would be very hard to remove and to access the wires inside

Inverter/Charger Systems



Cable exposed - no conduit

Inverter/Charger Systems

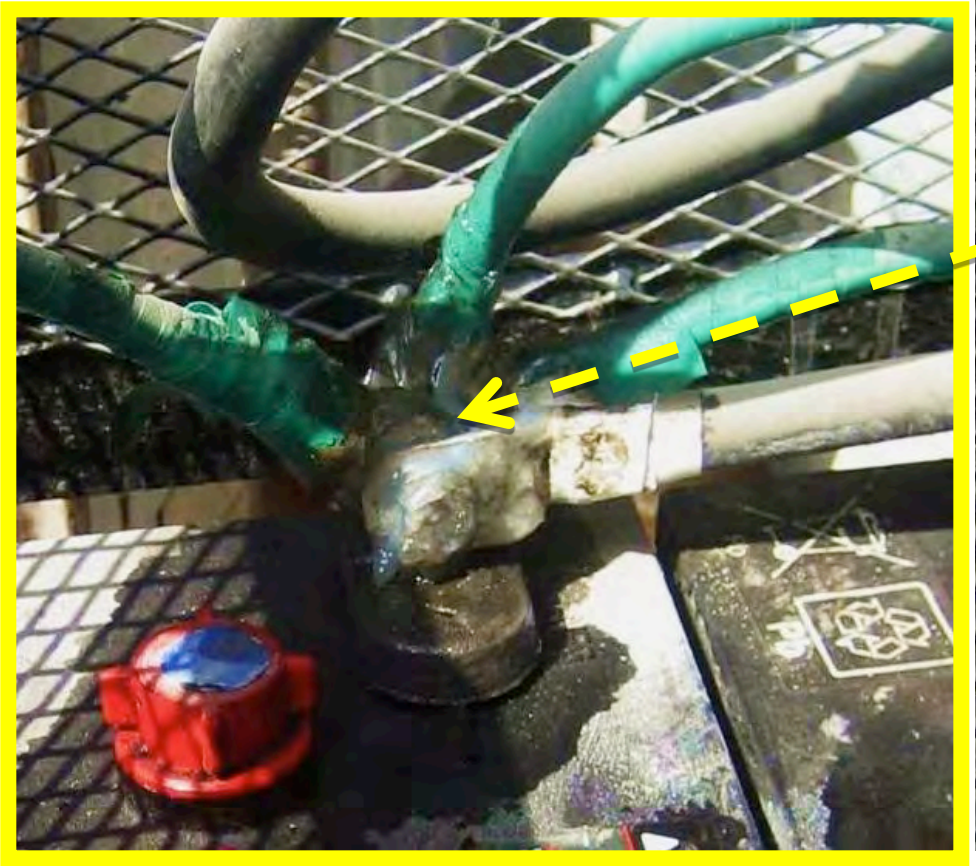
DC System Grounding

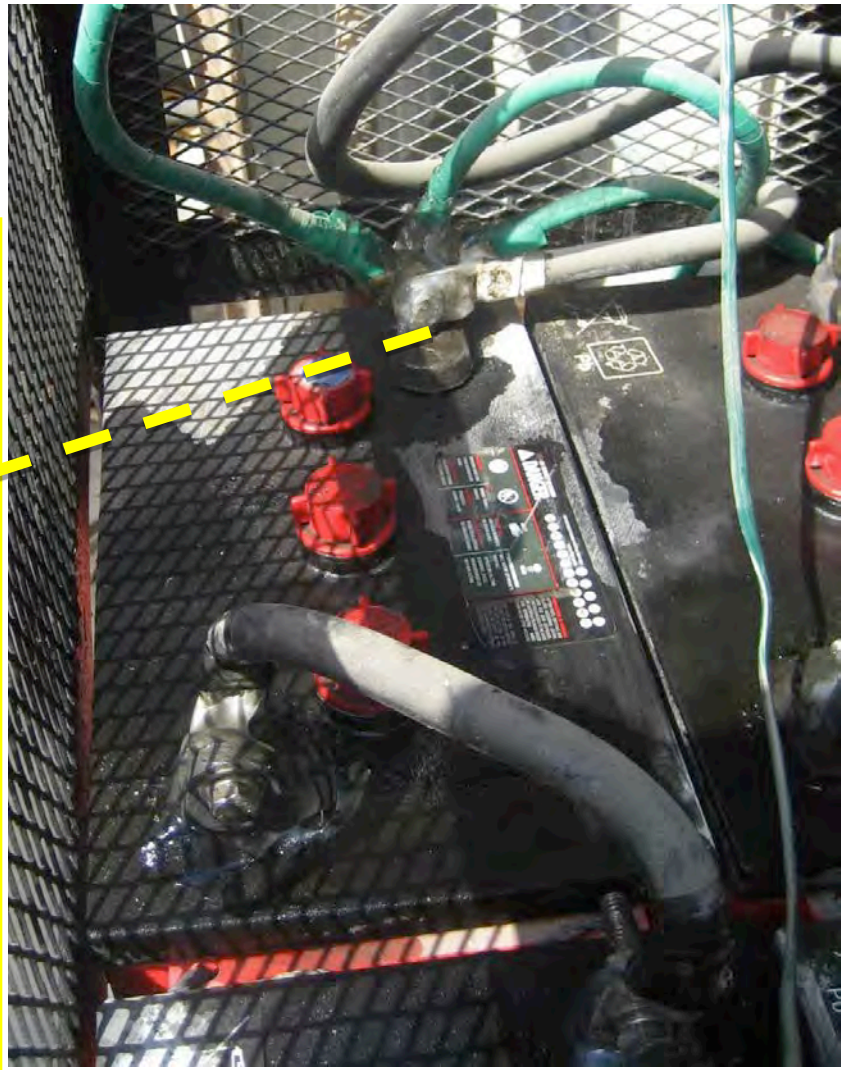
- *Intentional connection of the DC negative and grounding system*
- *Only made at a single location in the DC system*
- *Best to do it INSIDE of the DC enclosure*
- *Doing it at the battery is not recommended as it can become corroded or removed when servicing the battery*
- *Done by the GFDI device if solar panels are installed*

Inverter/Charger Systems

Negative to Ground Bond

Should not be made at the battery terminals!





Inverter/Charger Systems

Grounding

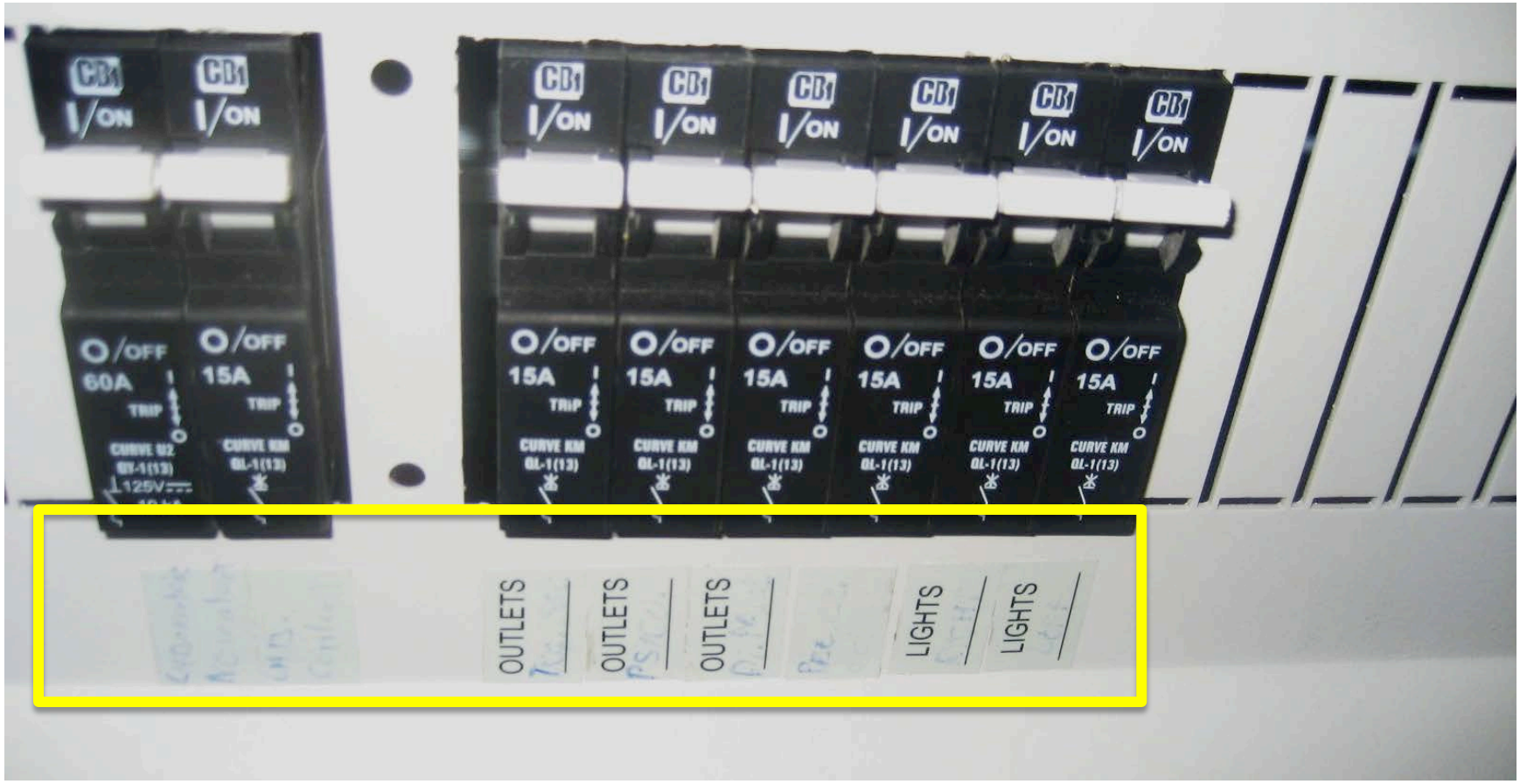
- **The metal battery enclosures should also be grounded**
  - » *Can be difficult to do as steel will rust*
  - » *Should use stainless steel bolt for connection*

- **Grounding bushings should be used on metallic conduit**
  - » *Ensures that the conduit can carry enough fault current to cause the circuit breaker or fuse to blow when a problem occurs*

Inverter/Charger Systems

Labeling

Use of non-permanent pens on labels is not acceptable



Inverter/Charger Systems

Labeling

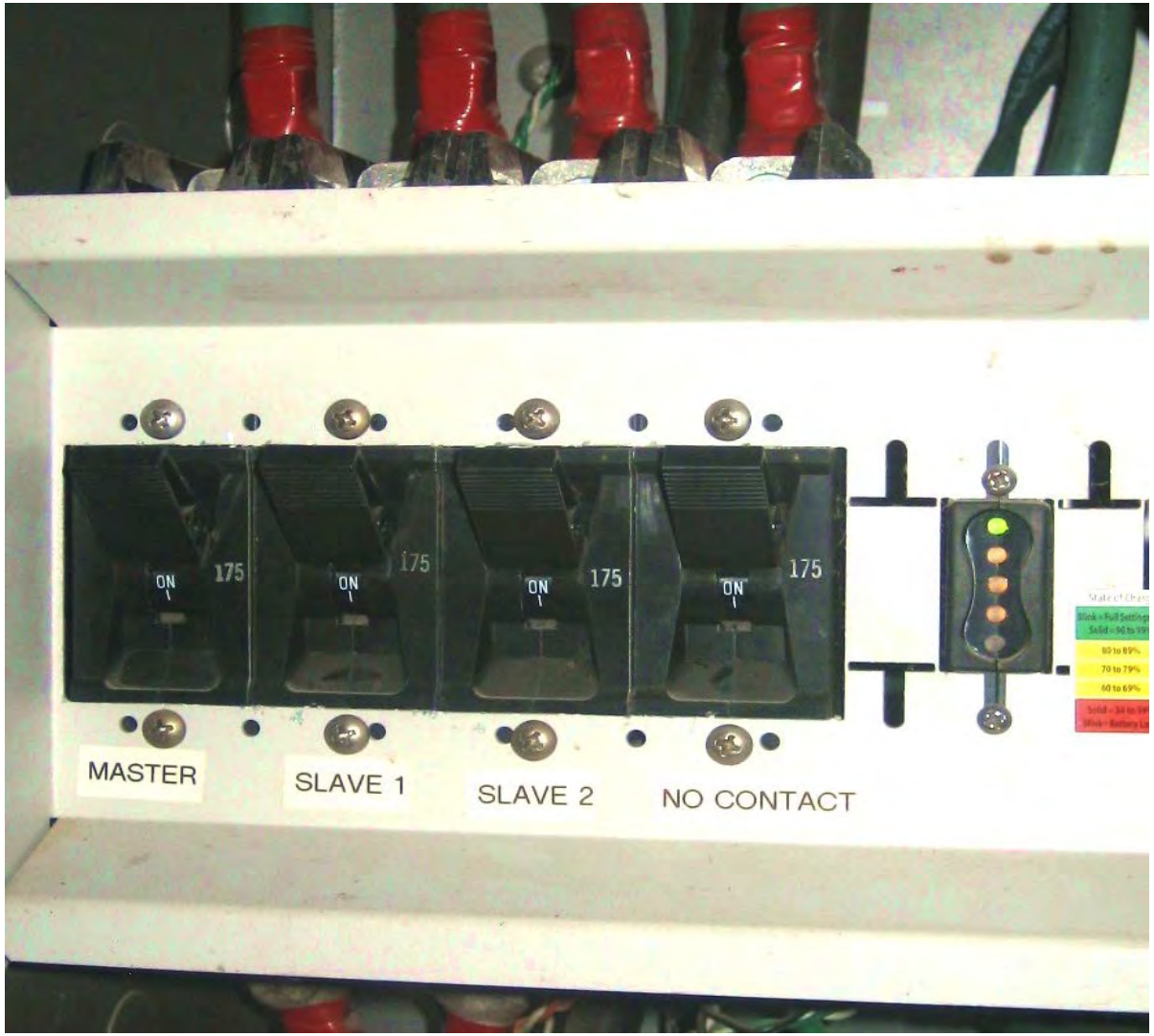
- **All DC and AC breakers should be labeled as to function**
  - » *No-Contact Inverter Output*
  - » *Contact Inverter Output*
  - » *Contact Charger Input*

- **All TBBs (Terminal Bus Bars) should be labeled**
  - » *Contact AC Hot In L1*
  - » *No-Contact AC Hot Out L1*
  - » *AC Neutral*

- **Inverters need to be labeled as well – ideally not on a removable part of the inverter – not on the AC or DC covers**
  - » *Master – Slave L1 – Slave L2 etc.*

Inverter/Charger Systems

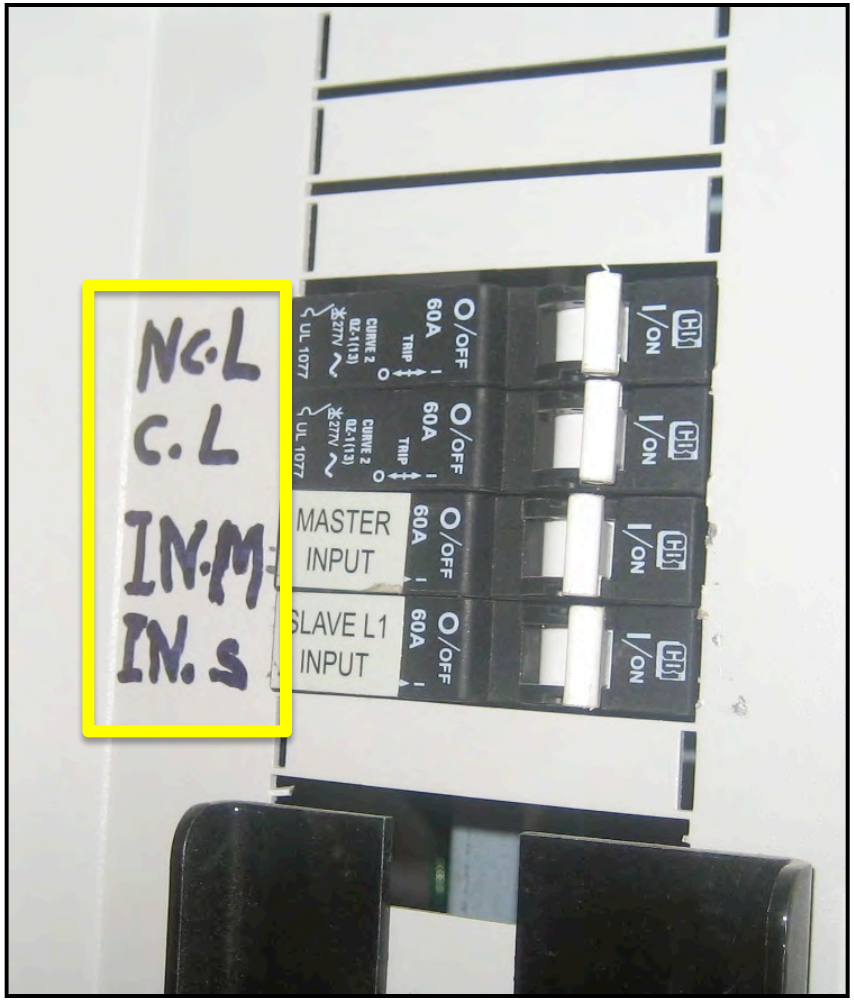
DC Breaker Labels



Inverter/Charger Systems

Labeling Breakers and Inverters

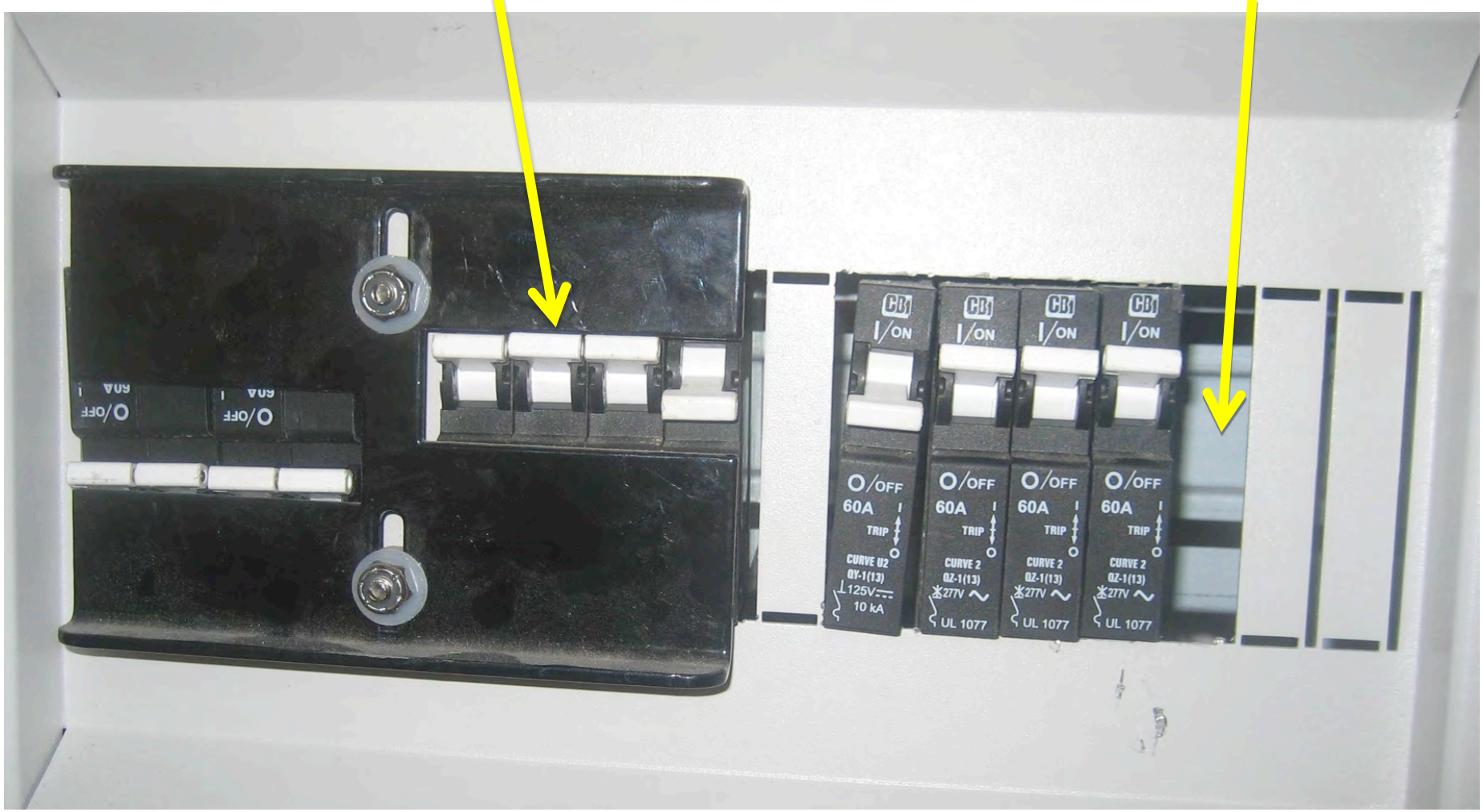
Not ideal…



Inverter/Charger Systems

Breakers not labeled

Open space needs to be covered



Inverter/Charger Systems

Wire Colors

- **Need to use the correct wire colors:**
  - » *AC Hots & DC Positives – Black, Red or Blue*
  - » *AC Neutrals & DC Negatives – White*
  - » *Ground – Green or Bare (no insulation)*
- **Wires can be "phase taped" on the ends with colored tape but this is only is allowed by the NEC for wires larger than #4 AWG**

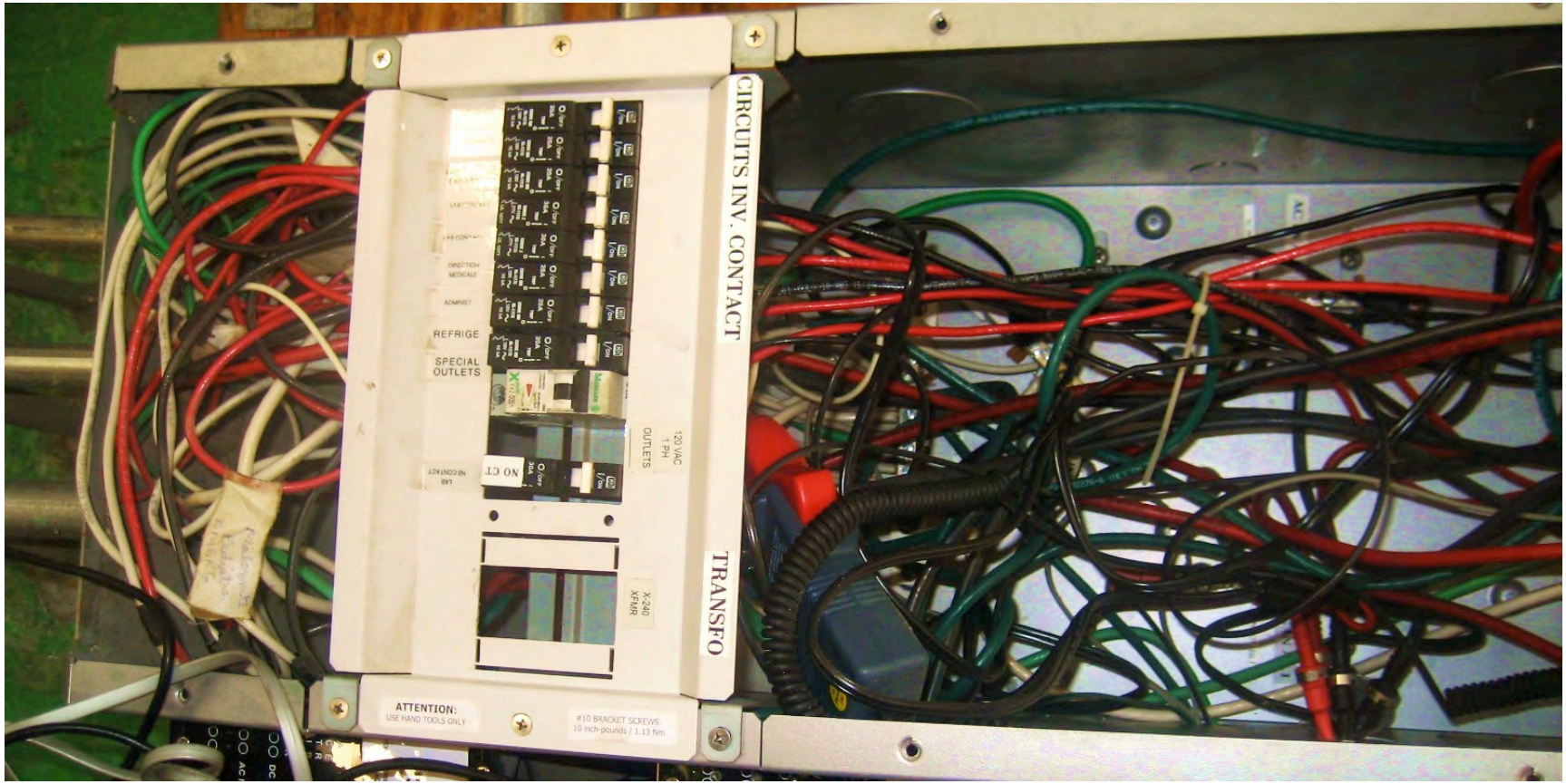
Inverter/Charger Systems

Wire Management

- **Grouping wiring to help with troubleshooting**
  - » Keep AC input wiring separate from AC output
  - » Use wire colors or tags to help identify wires
  - » Label TBBs to make wire identification easier

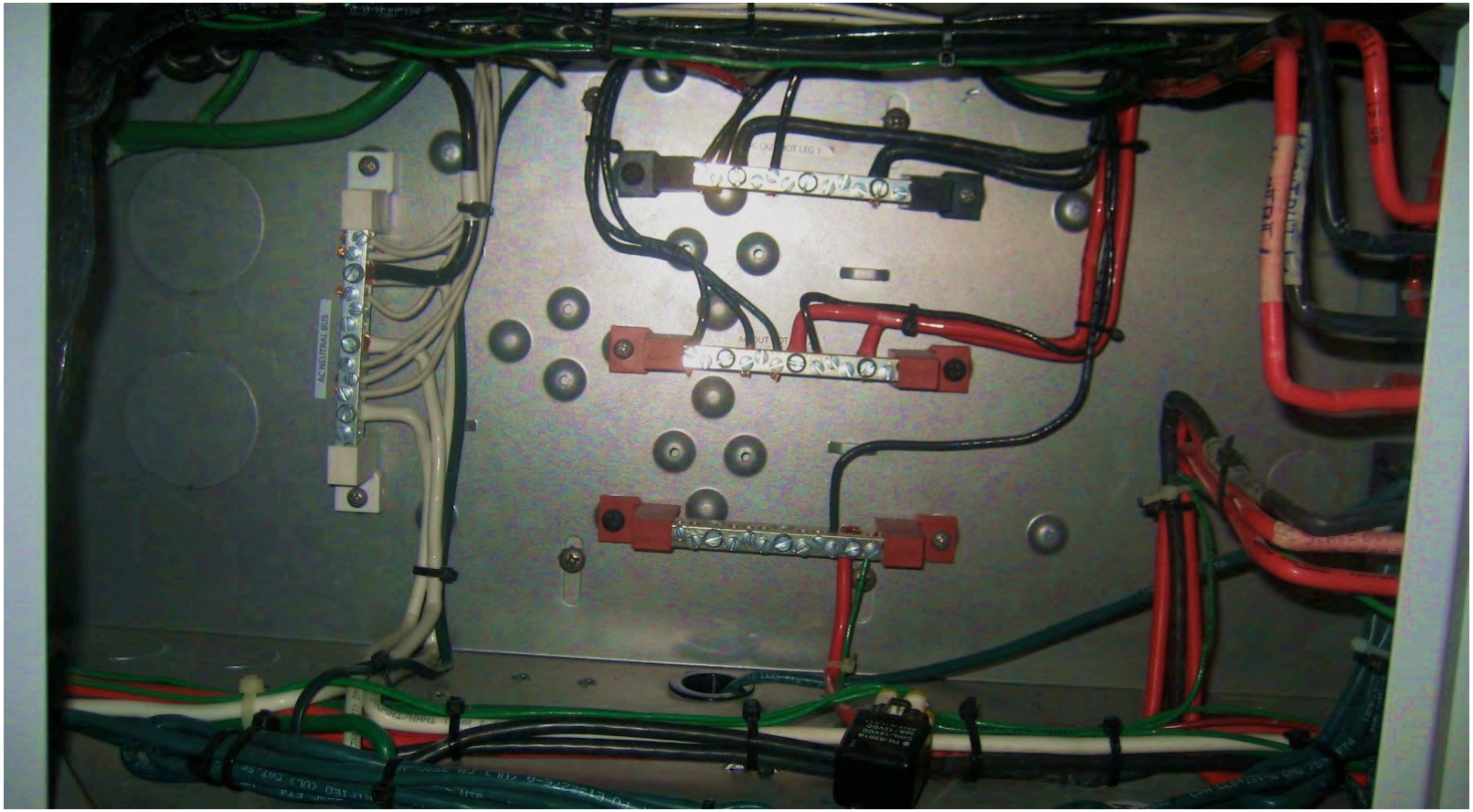
Inverter/Charger Systems

Wire Management – *what a mess!*



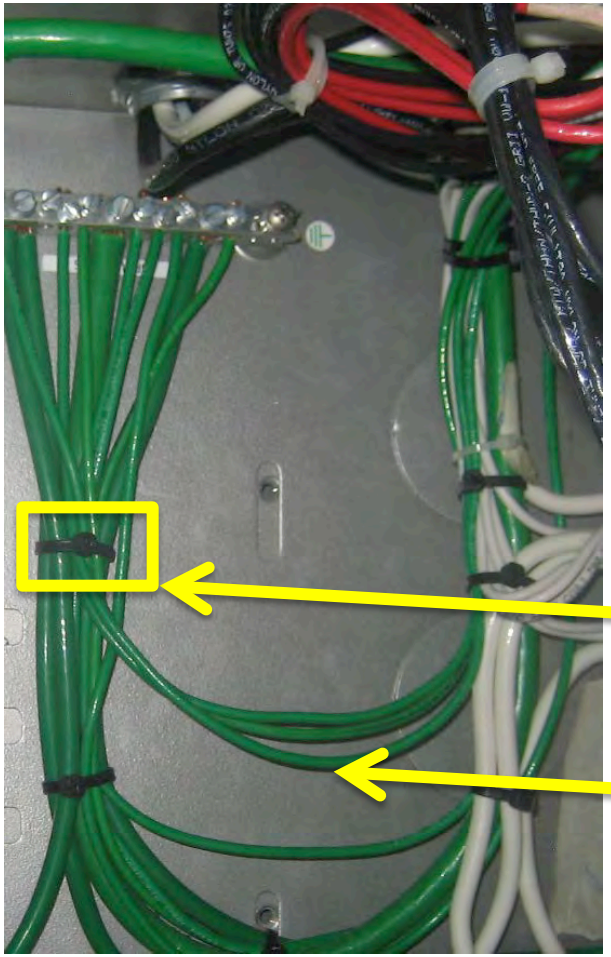
Inverter/Charger Systems

Wire Management – *Each of the TBBs must be labeled*



Inverter/Charger Systems

Good Wire Management



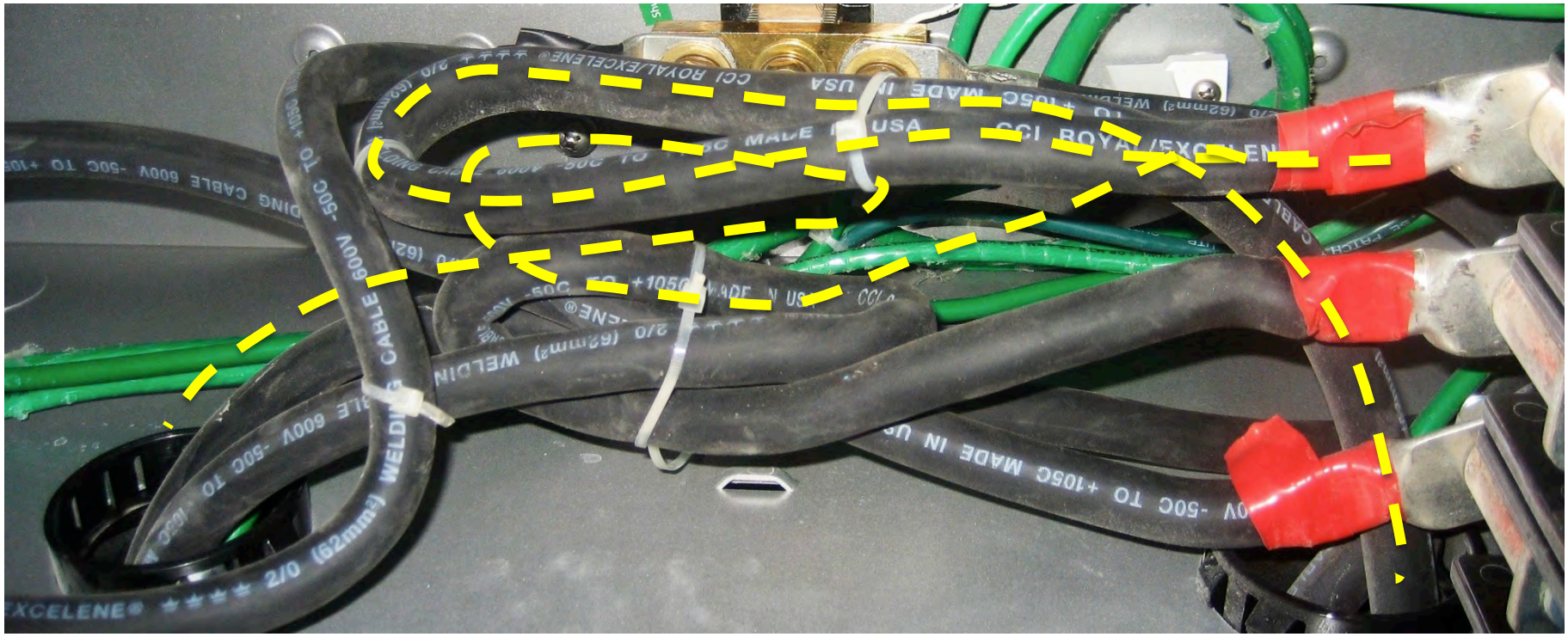
Zip ties

Bending radius

Inverter/Charger Systems

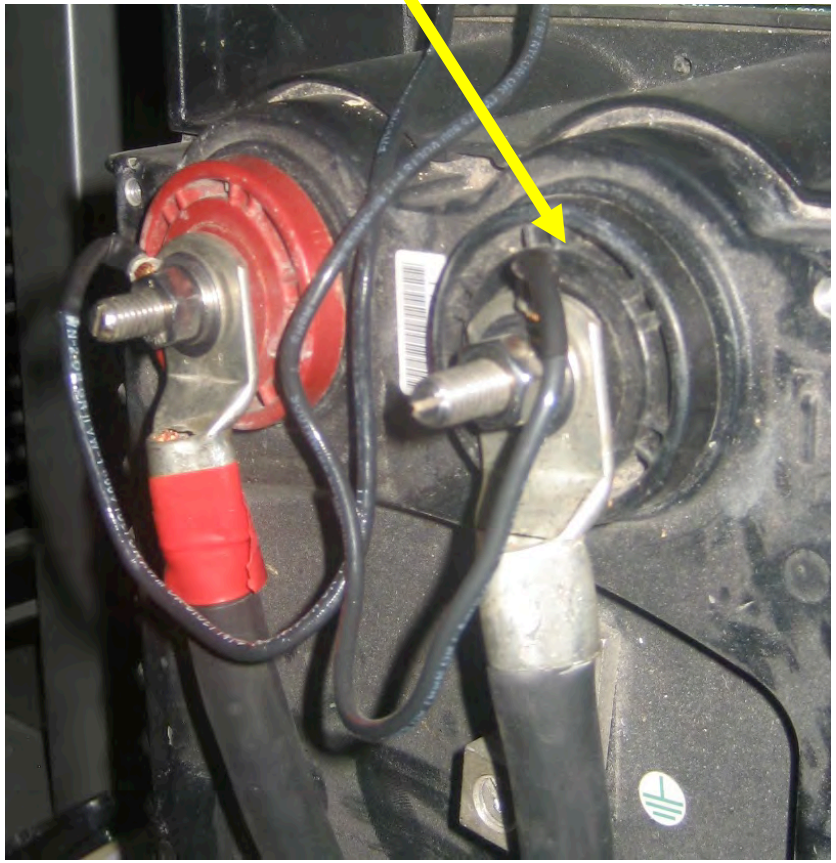
Wire routing and minimum bending radius

Example of insufficient bending radius and excess cable lengths

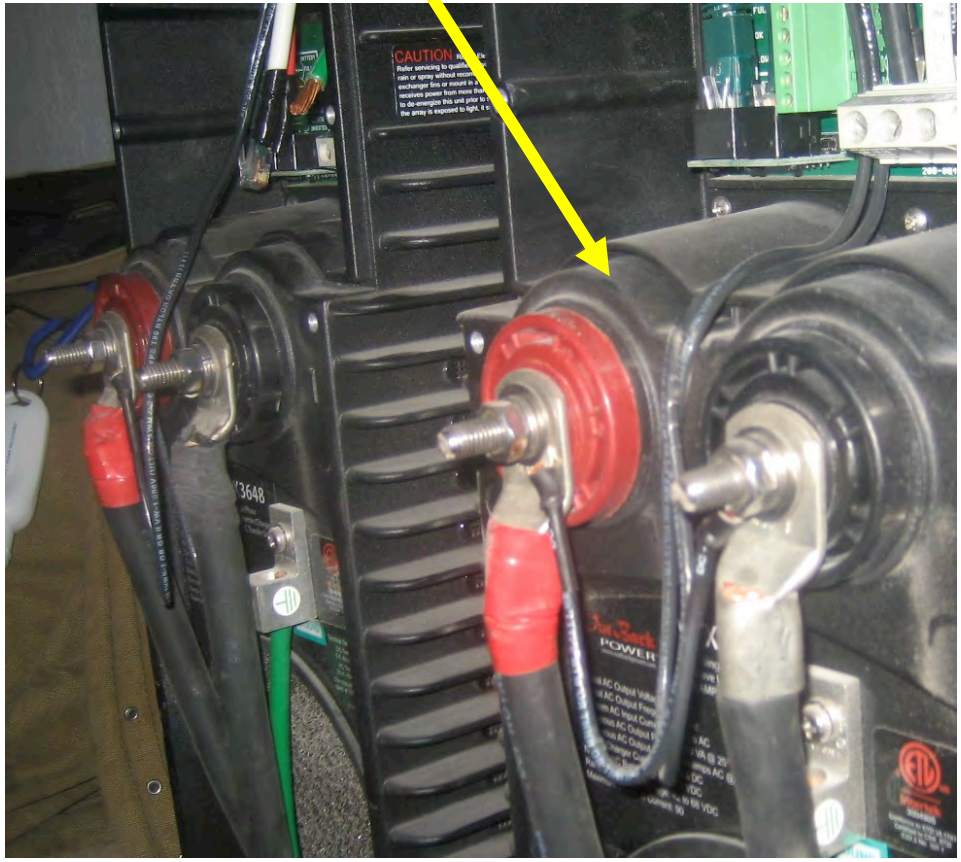


Inverter/Charger Systems

Poor wire routing and to tight of wire bending radius

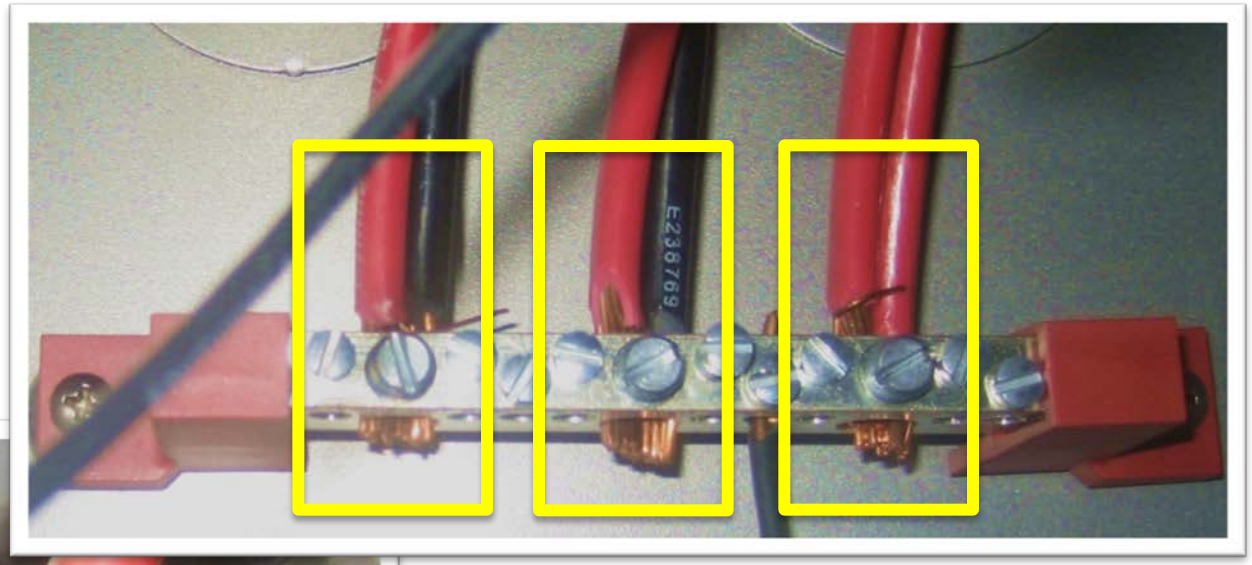


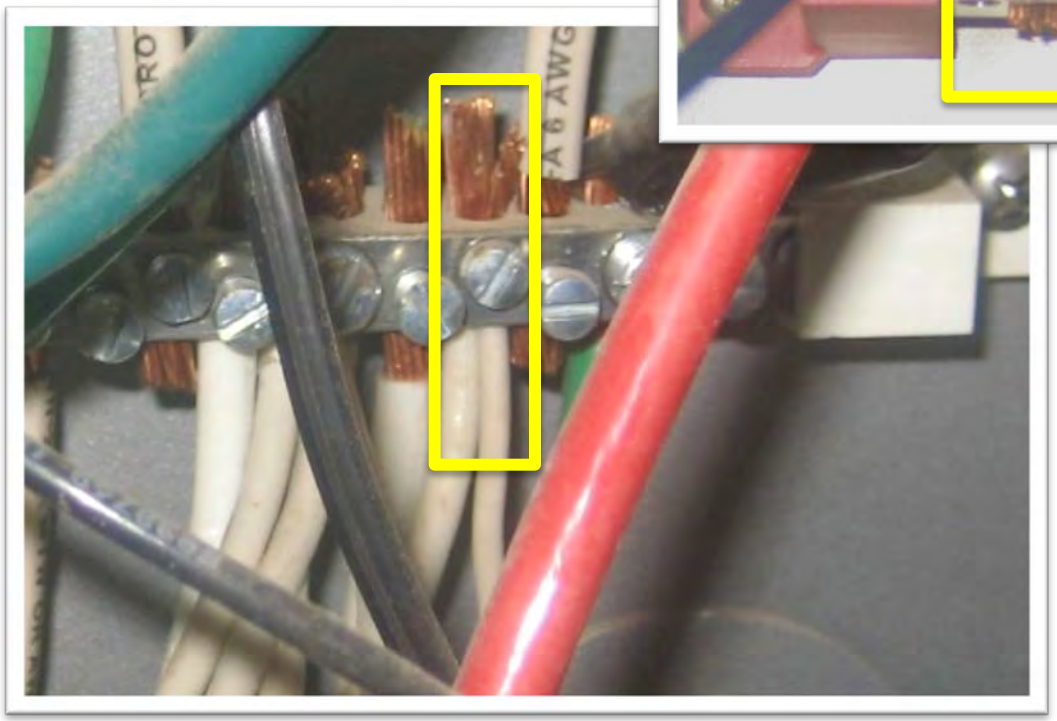
Good wire routing and wire bending radius



Inverter/Charger Systems

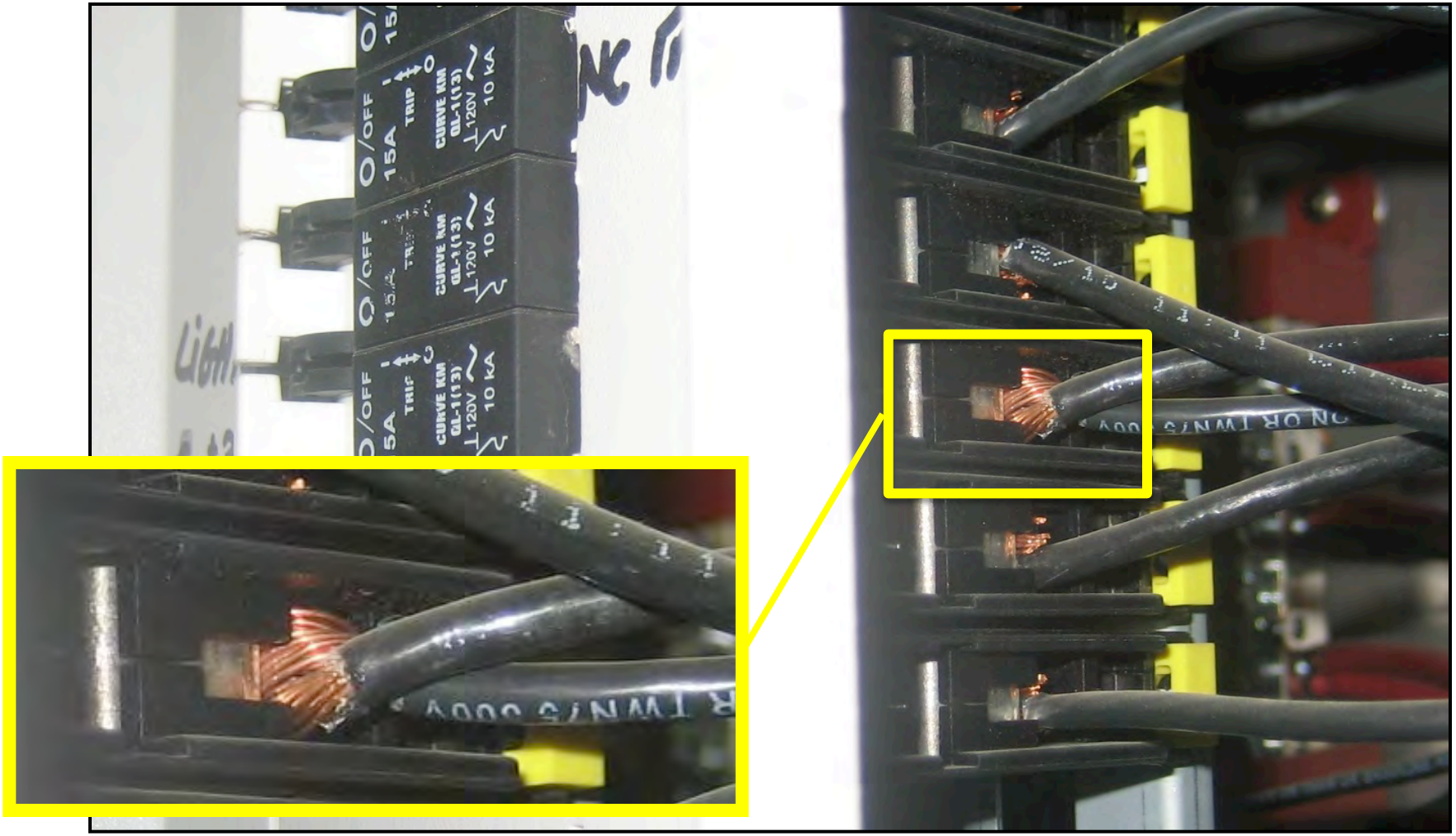
Multiple wires in a single terminal is not acceptable!





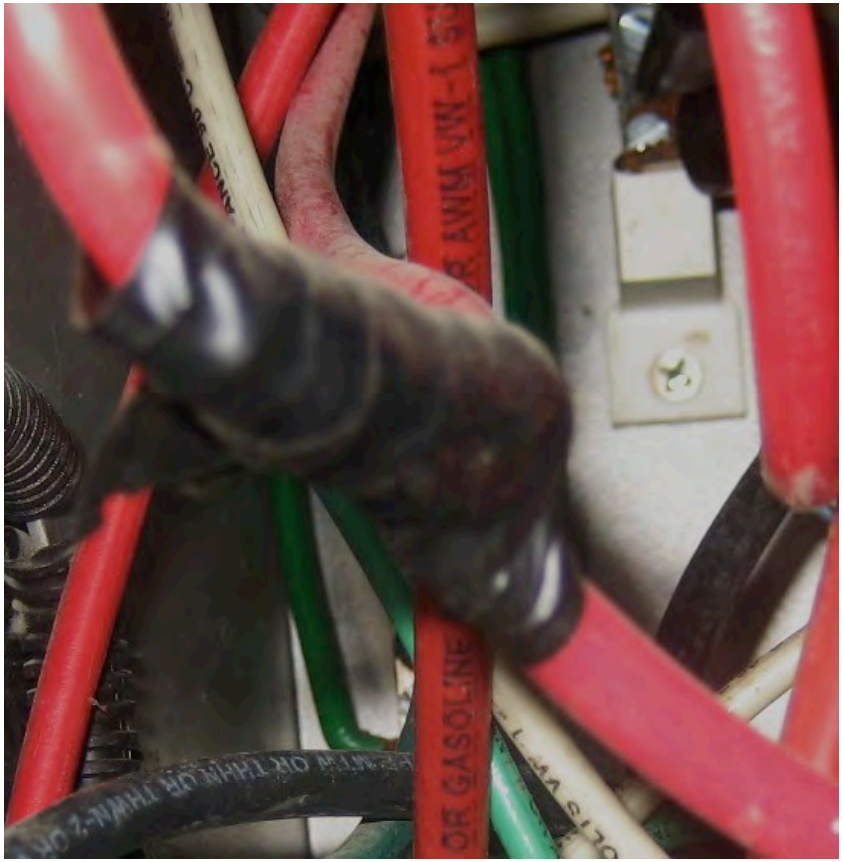
Inverter/Charger Systems

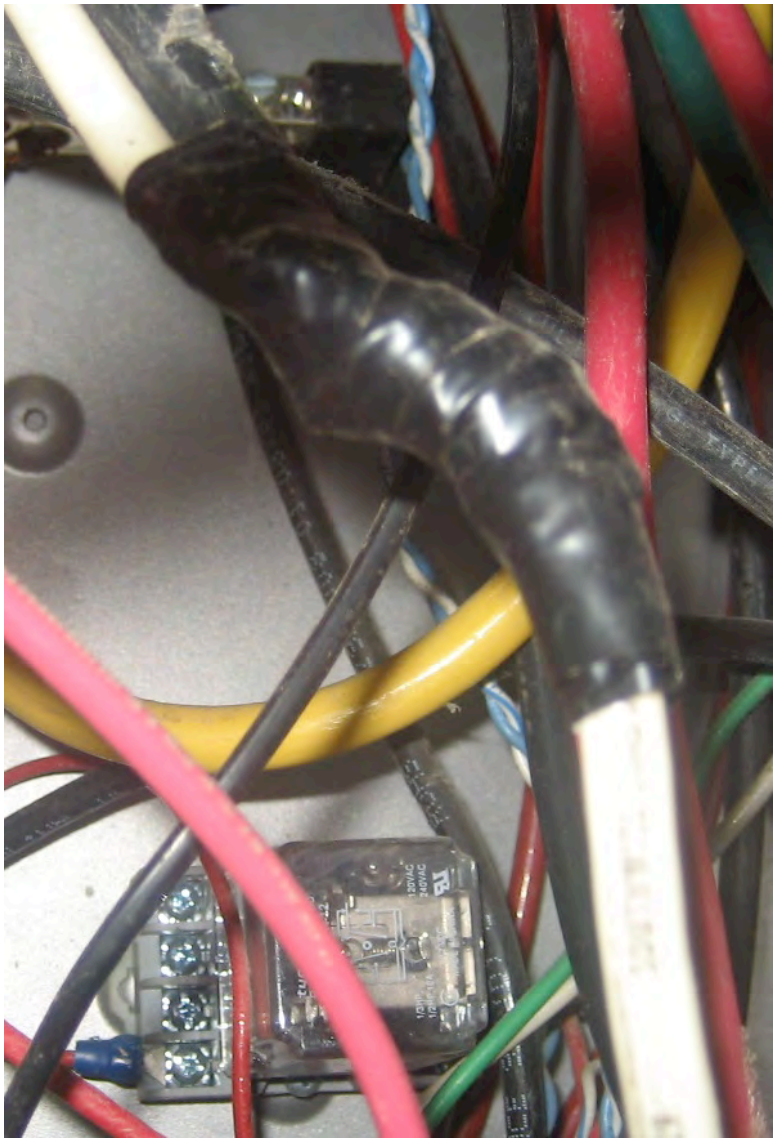
Two wires in one terminal of a breaker is not acceptable!



Inverter/Charger Systems

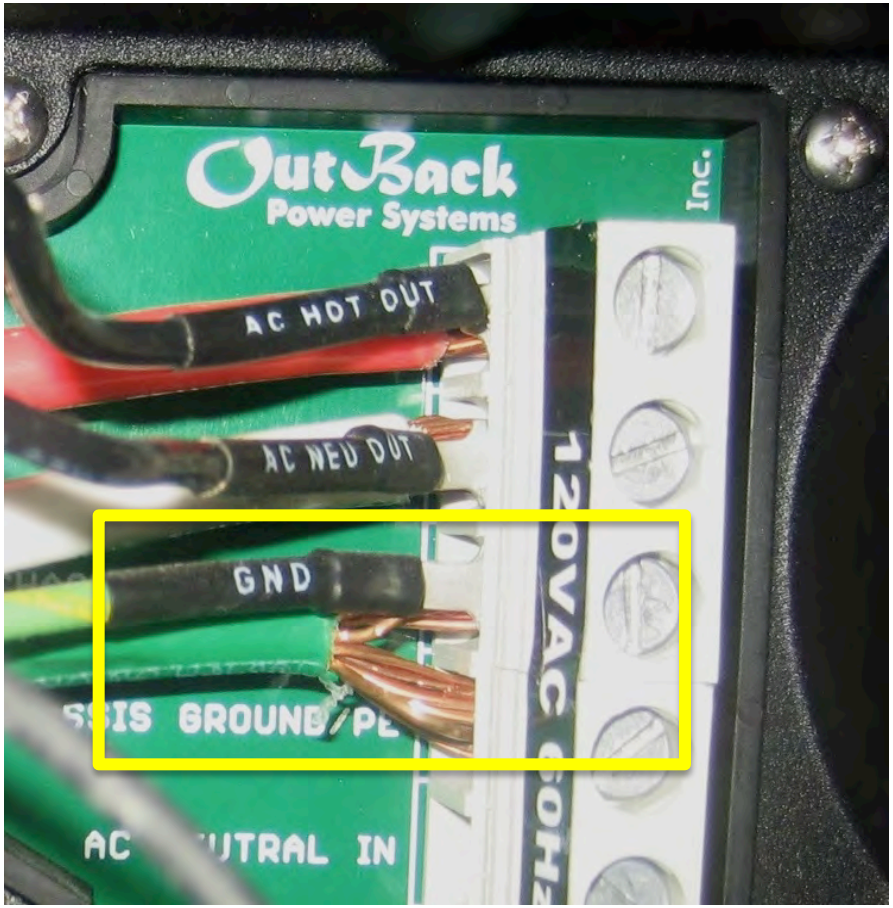
Improper Wire Splices

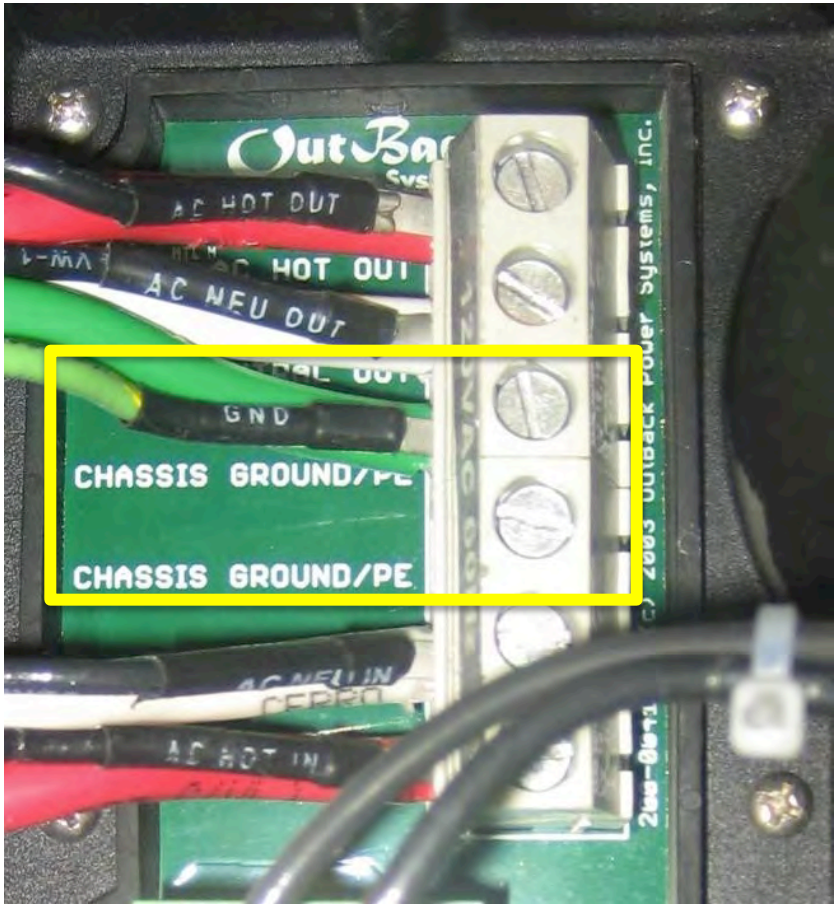




Inverter/Charger Systems

AC ground wire split between two terminals – not necessary or recommended



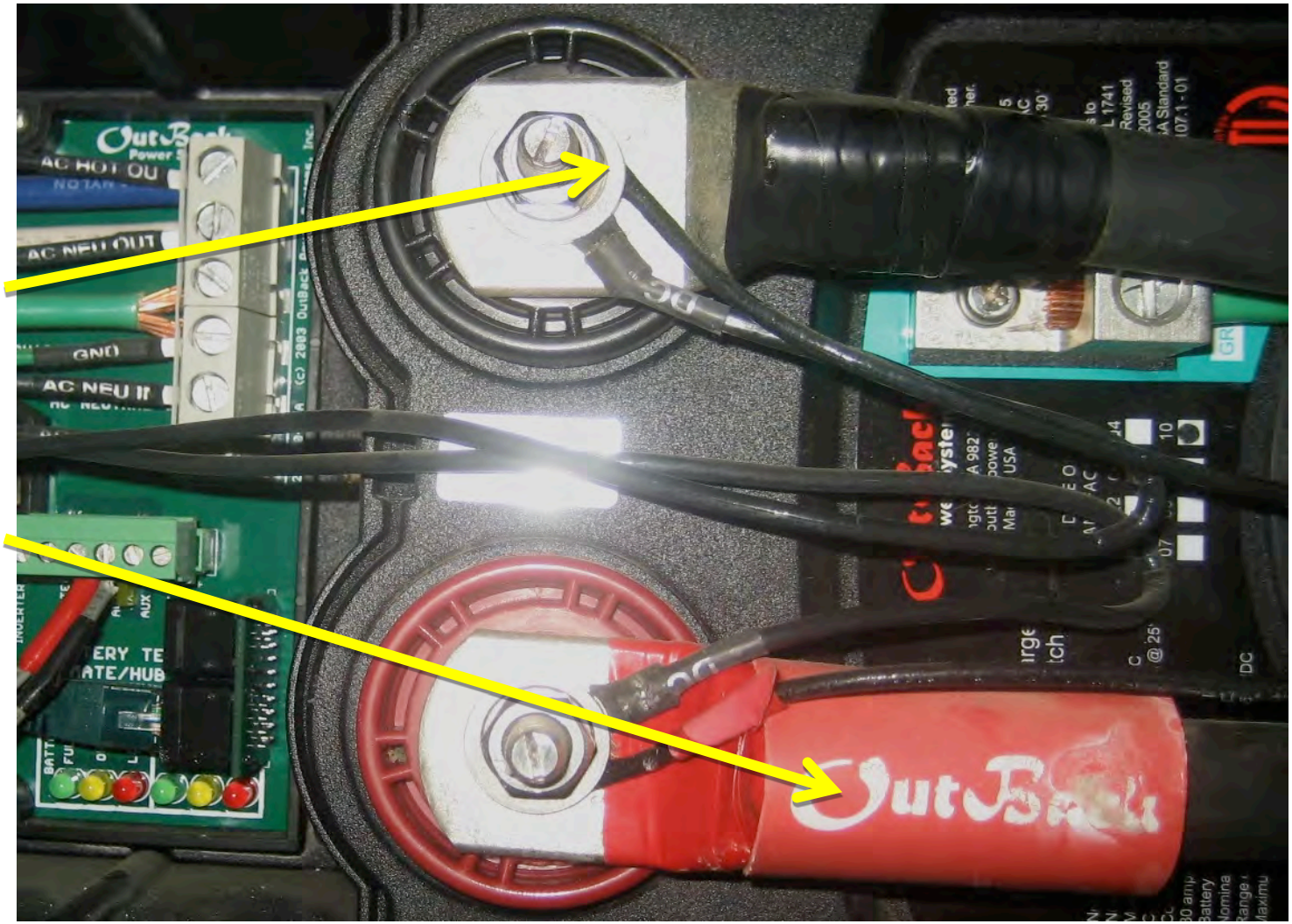


Inverter/Charger Systems

Incorrect Inverter Hardware Connections

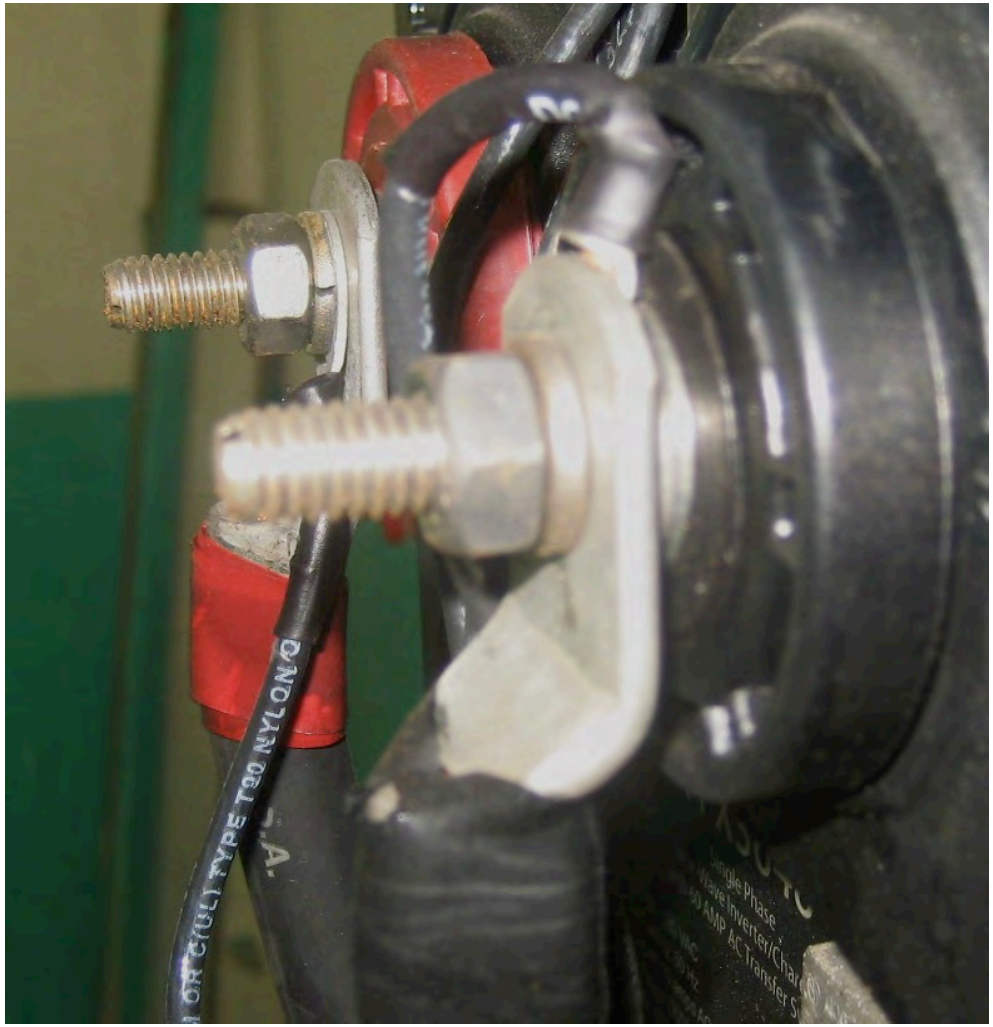
Insulation under washer

Heatshrink not heated

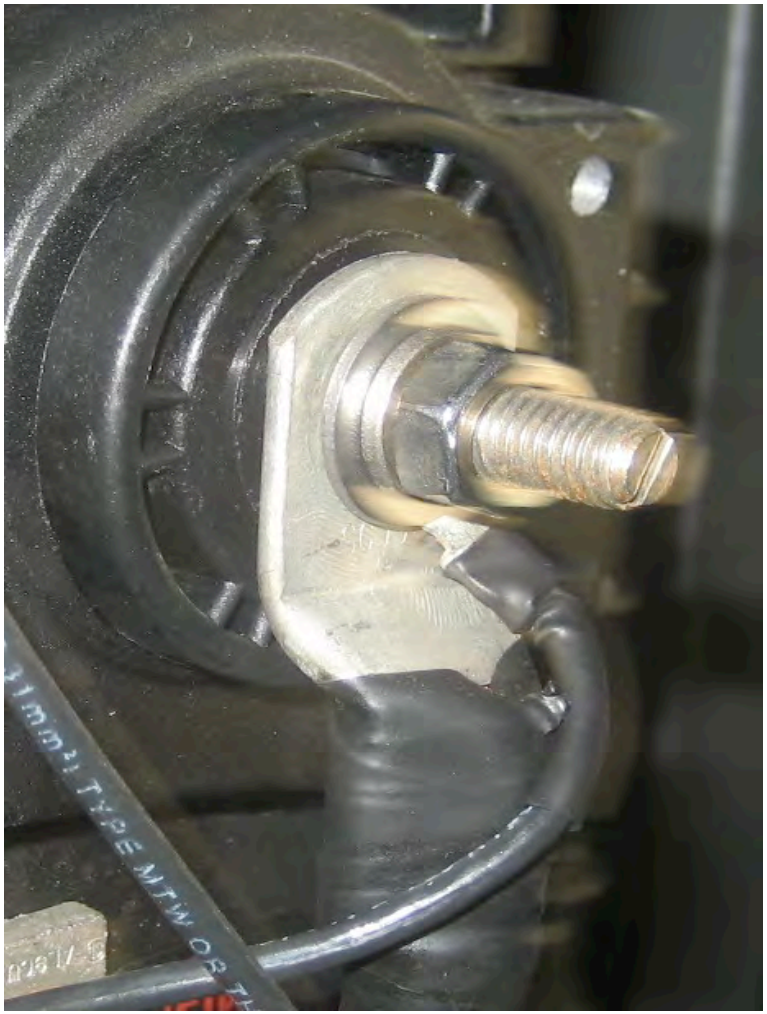


Inverter/Charger Systems

INCORRECT – The washer and surge protection ring terminal must be on top!



CORRECT – This the the proper method for connection



Inverter/Charger Systems

Inverter Cabling and Overcurrent Protection

- Washers MUST NOT BE located between the cable lug and the inverter's terminal.
  - » *Washer will get very hot and can melt the battery terminal*

- It can be better to use 125 amp DC breakers instead of 175 amp DC breakers to ensure the battery cables are not overloaded

  - » *When more than 3 cables are ran in a conduit – the ampacity of the conductors are reduced by 20%*

2/0 AWG then is limited to 140 amps

4/0 AWG then is limited to 184 amps

Inverter/Charger Systems

Battery & Inverter Cables

- **Use of non-UL listed welding cable**

Inverter/Charger Systems

Battery & Inverter Cables

- **Non-UL listed battery cable is not NEC compliant**
  - » *Temperature rating and insulation thickness may not be acceptable*
  - » *May not be acid resistant*
  - » *May not be sunlight resistant*
  - » *Fine strands can be hard to crimp into a lug*

Inverter/Charger Systems

Poorly Crimped Cable Lugs – *wire is able to be pulled out*

Inverter/Charger Systems

Poorly Crimped Lugs

- *On multiple hospital systems the cables were able to be pulled out from the poorly crimped lugs*
- *Need to use a proper crimping tool that is made to work with the size and type of lug being used*
- *Need to test the crimp's integrity by pulling on the cables – you should not be able to pull out the wire if the crimp is properly done*

Inverter/Charger Systems

Cable Lugs and Corrosion

- *Do not use "open end" type lugs on batteries terminals*
  - » *Corrosion can get inside the lug – it can't be cleaned out*
- *Heatshrink is needed to reduce corrosion problems – it wil seal the crimp connection – if it's the type with an adhesive in it (available from OutBack and battery suppliers)*
  - » *Electrical tape doesn't work as well – when its used apply more tape and do not "stretch" the tape when done – use a knife or sissors to cut it once done taping will keep it from unwrapping*

Inverter/Charger Systems

Bad Cable Lug Example:

Open type lug

- Corrosion can get in

Bare copper

- Corrodes more easily

No Heatshrink

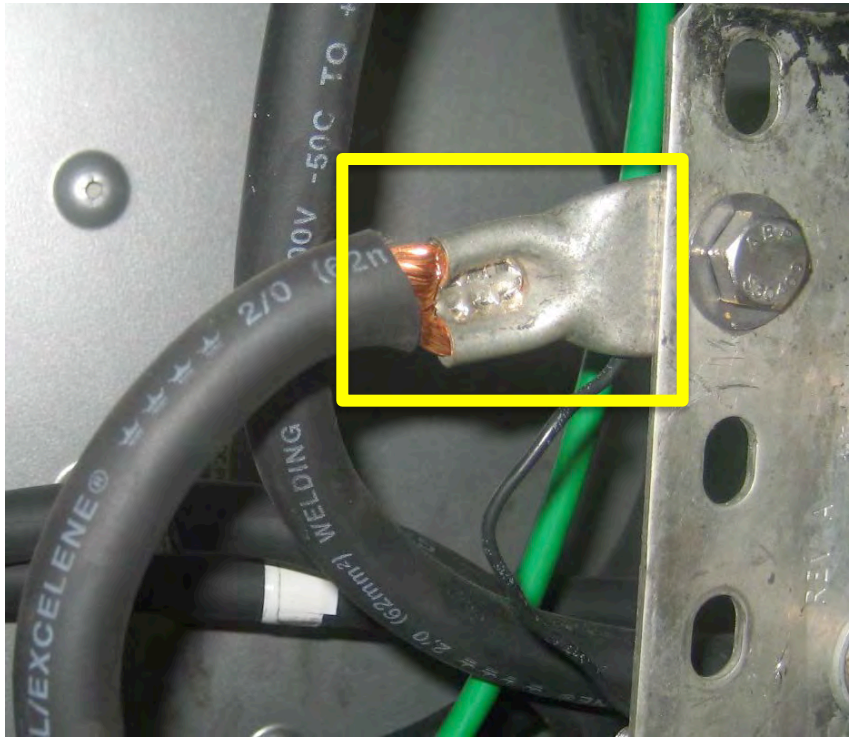
Flexing of cable may result in damage to connection over time

Inverter/Charger Systems

Heatshrink Examples:

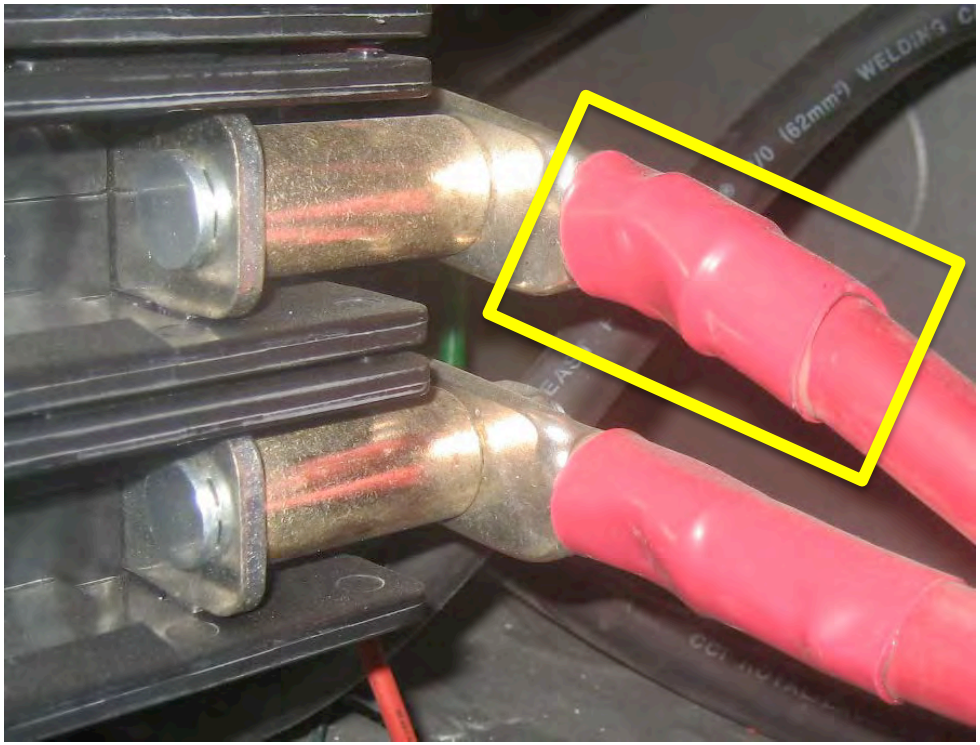
No heatshrink

Cable not Color Coded



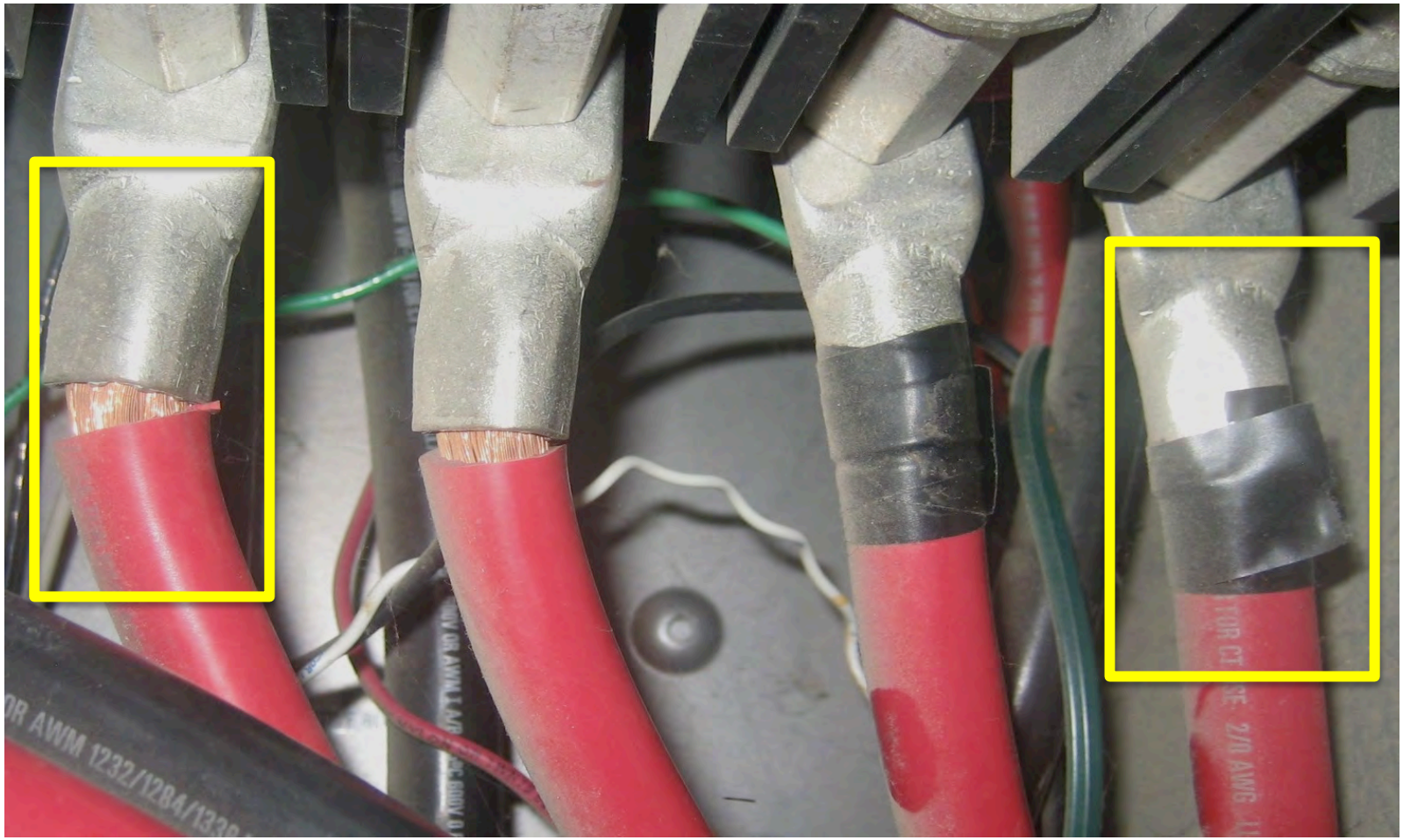
Proper Heatshrinking

Cable is color coded



Inverter/Charger Systems

All Cables need to be taped or heatshrinked and the proper color needs to be used



Inverter/Charger Systems

Cable Lugs

- **Prefer lugs which are plated (silver colored)**
  - » *Not bare / plain copper type if possible*
  - » *Corrode less and make longer lasting connection*

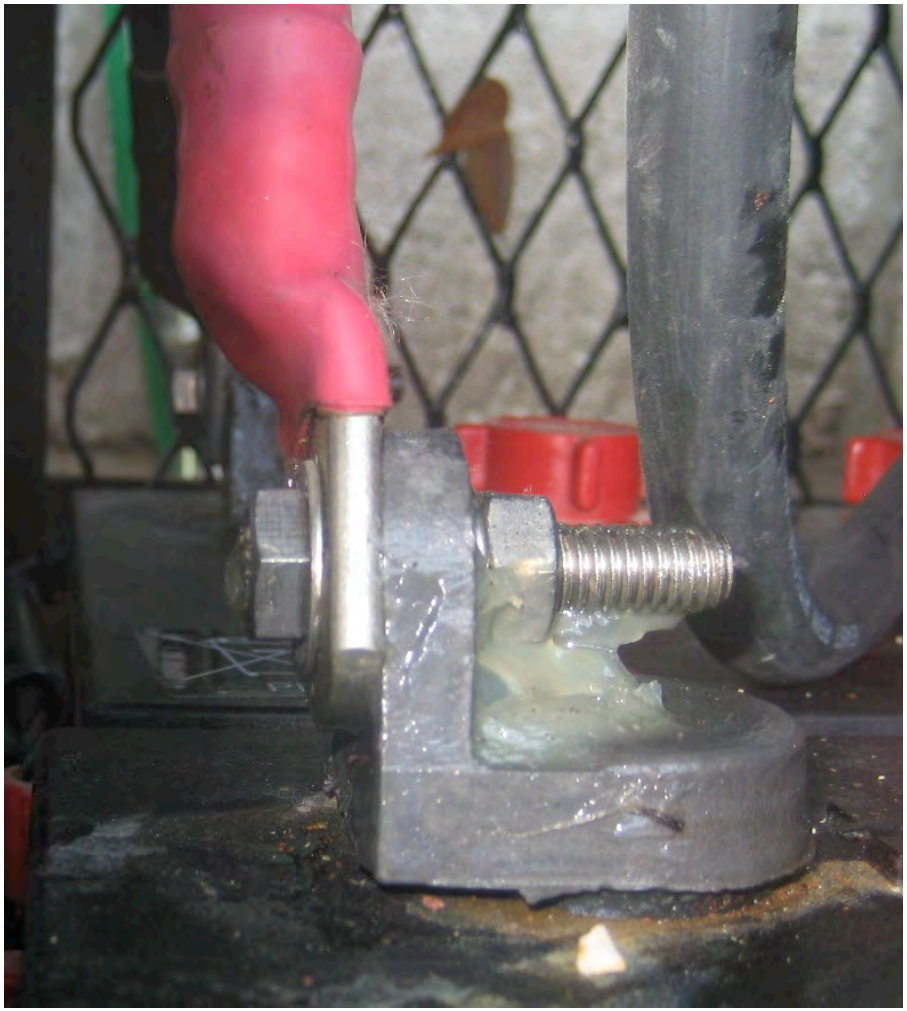
Inverter/Charger Systems

Battery Connections and Hardware

- All of the hardware needs to be stainless steel – not mixed
- Needs to include a split type lock washer AND 2 flat washers as the lead terminal on the battery is soft and connection will loosen over time if flat washers are not used to prevent bolt head from digging in
- The washers MUST NOT be installed between the lug and the terminal – it will cause the battery to not charge well and can get very hot and melt the battery's terminal.
- The terminal should be cleaned before making the connections with a wire brush to remove dull gray oxidized lead (similar to rusty steel)
- The battery terminal, all hardware and cable lug needs to be protected AFTERWARDS with a coating to prevent corrosion

Inverter/Charger Systems

Corrosion Protection Coating and Heatshrink with Stainless Steel Hardware

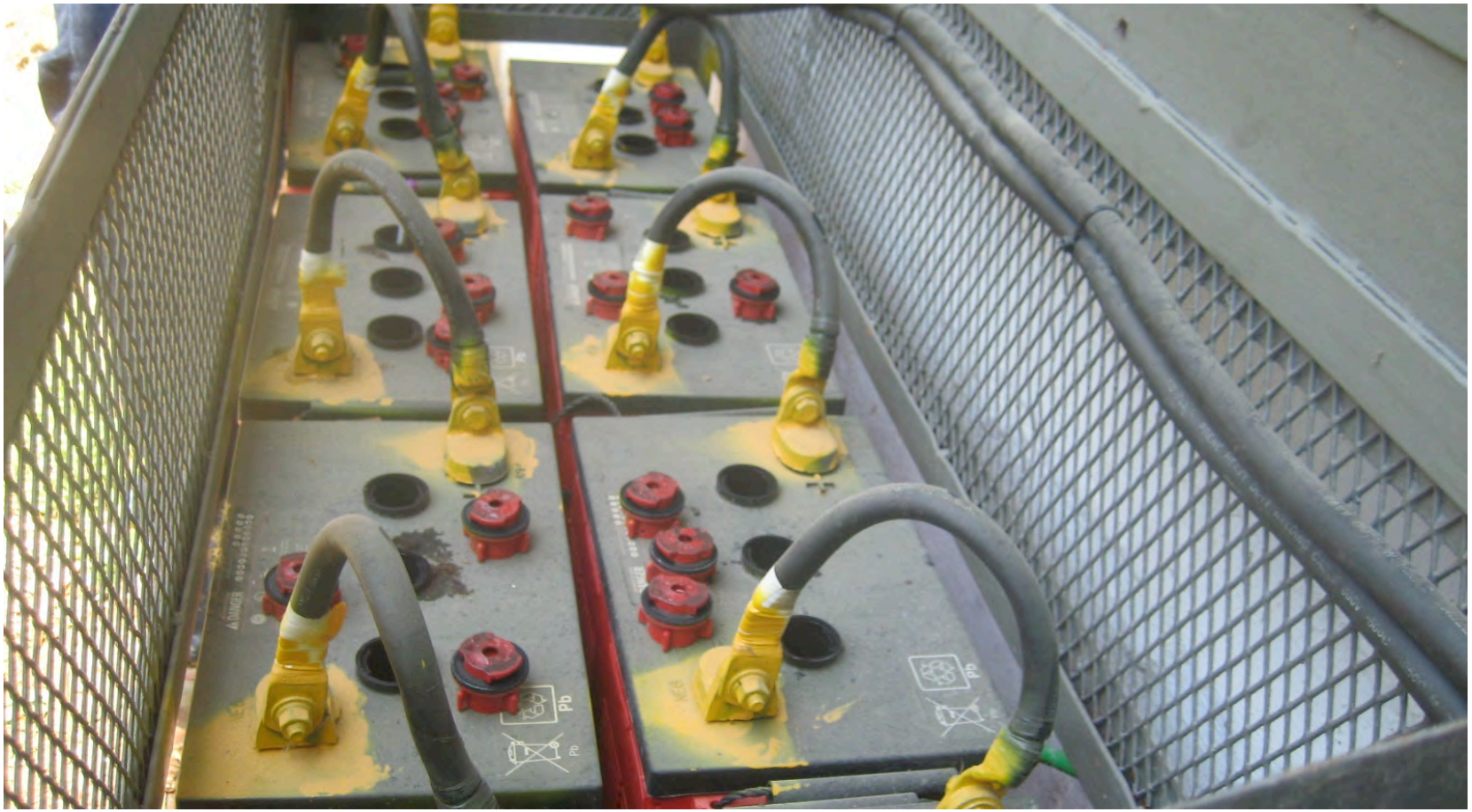


Inverter/Charger Systems

Corrosion Protection Spray with Poor Wrapping of Cable Lugs with Electrical Tape

Inverter/Charger Systems

Well Done Corrosion Protection and Heatshrink



Inverter/Charger Systems

Corrosion from the Battery Terminals to the Metal Battery Rack

- *Coating the battery terminals can reduce this problem*
- *More clearance should be provided in the metal rack to reduce the chances of this problem occuring*

Inverter/Charger Systems

Battery Enclosure and Location – *not in the sun!*

Inverter/Charger Systems

Battery Enclosure and Location

- Not exposed to sun's heat
  - » *Batteries will get hot and fail early*
  - » *Need to shade both the top and sides and provide enough ventilation*

- Need weather protection
  - » *Terminals get wet and corrode more*

- *Not hard to access – battery racks on "stilts"*

Inverter/Charger Systems

Battery Enclosure and Location

Inverter/Charger Systems

Battery Enclosure and Location

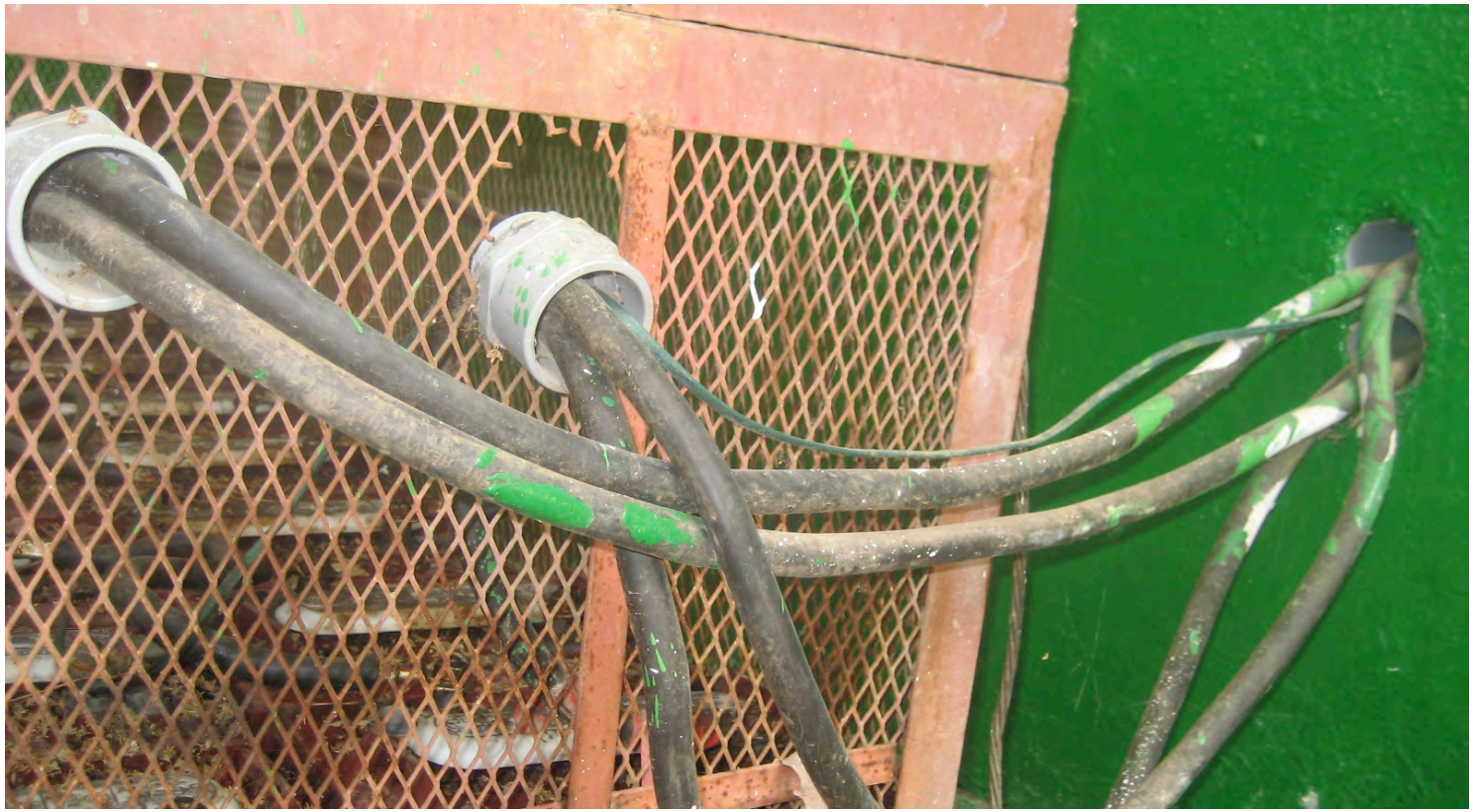
- Put in a location with good ventilation – don't exposes people to the fumes
- Inside a locked room or closet will cause battery to run hotter
- Solid top cover – needed to prevent material from falling onto batteries and potentially cause a problem or to get into the cell
- Conduit should go all the way into the battery enclosure to protect wiring

Inverter/Charger Systems

Battery Enclosure and Location

Inverter/Charger Systems

Battery Enclosure and Location

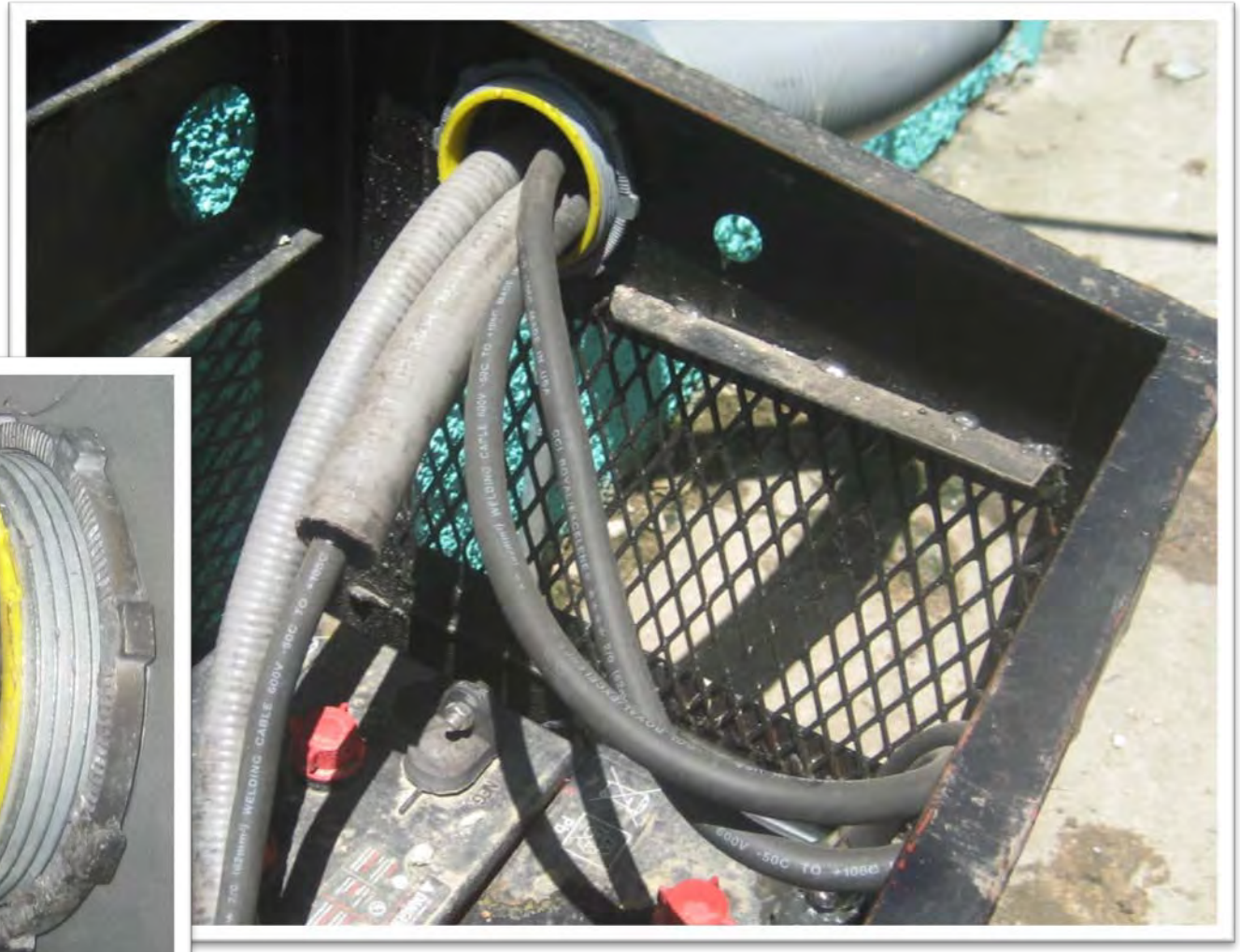


Inverter/Charger Systems

Battery Enclosure and Location – *nicely conduit!*

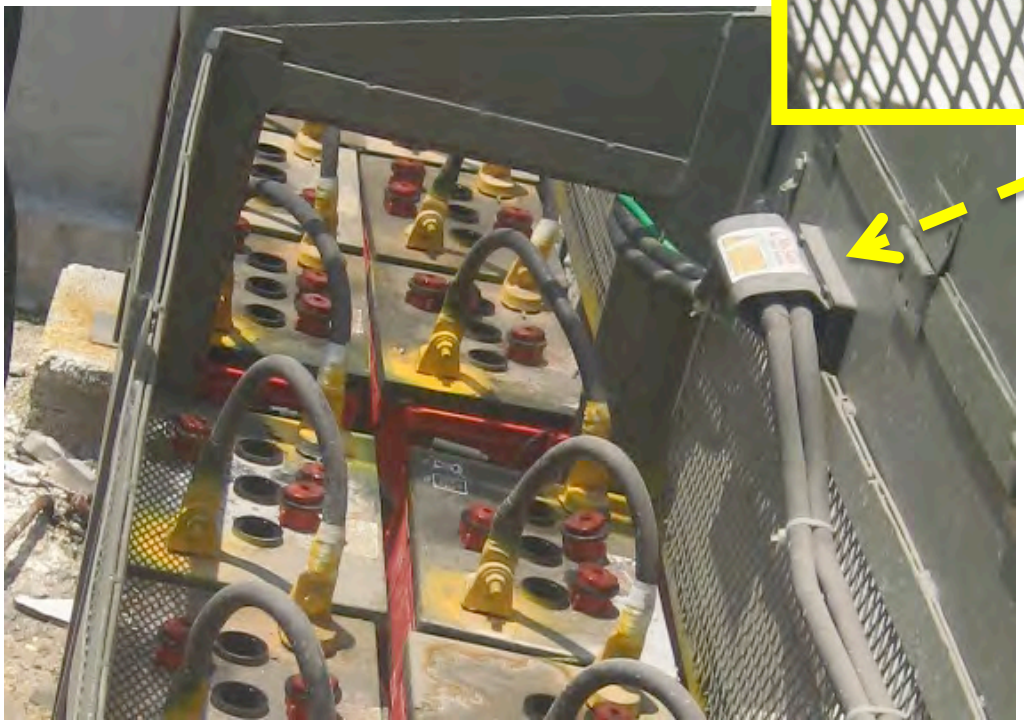
Inverter/Charger Systems

Conduit –in-Conduit?



Inverter/Charger Systems

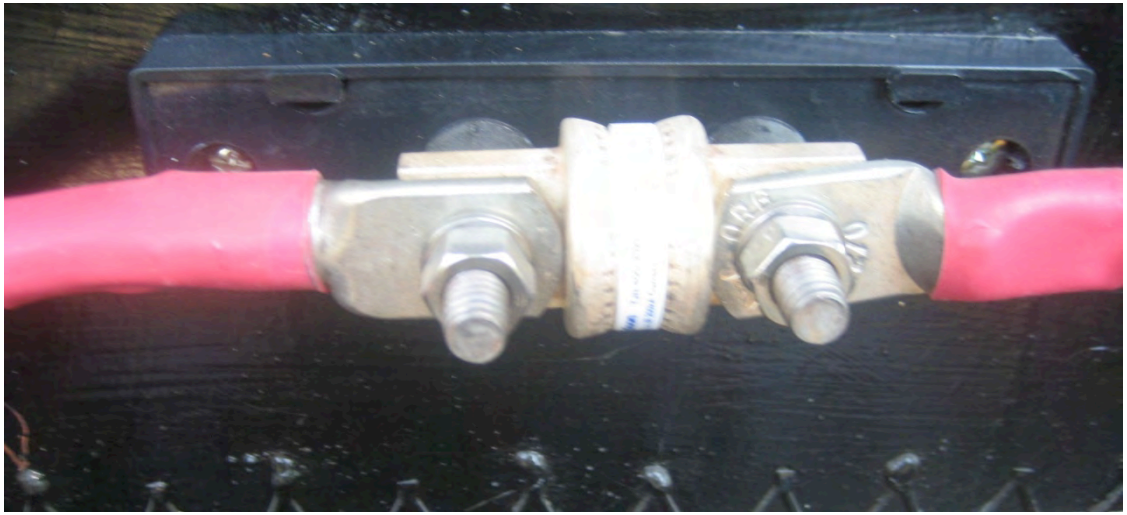
Battery Fusing



Inverter/Charger Systems

Battery Fusing

One Fuse per Cable - or two Cables per Fuse?



Inverter/Charger Systems

Battery/Inverter Cables and Catastrophic Fuses

- **Do not use a 400 amp fuse with 2/0 AWG cable**
  - » *2/0 AWG cable is rated by NEC for 175 amps in conduit*
  - » *4/0 AWG cable is rated by NEC for 230 amps in conduit*
  - » *OK to use a larger fuse for "catastrophic protection"*
    - → *but not 2.25 times larger*

Inverter/Charger Systems

Battery/Inverter Cables and Catastrophic Fuses

Recommendations:

For "Catastrophic" fusing when cables are in conduit

- *2/0 AWG with 200 amp fuses*
- *4/0 AWG with 300 amp fuses*
- *Use 125 amp DC breakers for 48V inverter/chargers (instead of the usual 175 amp DC breakers)*

Battery Connections and Cabling

- Only one cable should be connected on each side of a battery terminal – it is better to use more battery cables and a separate bus plate than to make multiple connections on a single terminal

- Care needs to be done to ensure that all paralleled strings of batteries has the same total cable length to enable them to share the load and charging equally

- It is better to not parallel the individual battery strings together at the battery rack but to instead run individual positive and negative cables for each string separately to the DC enclosure where they are then paralleled together at the breaker bus plate (for positive cables) and at the current shunt assembly (for negative cables)

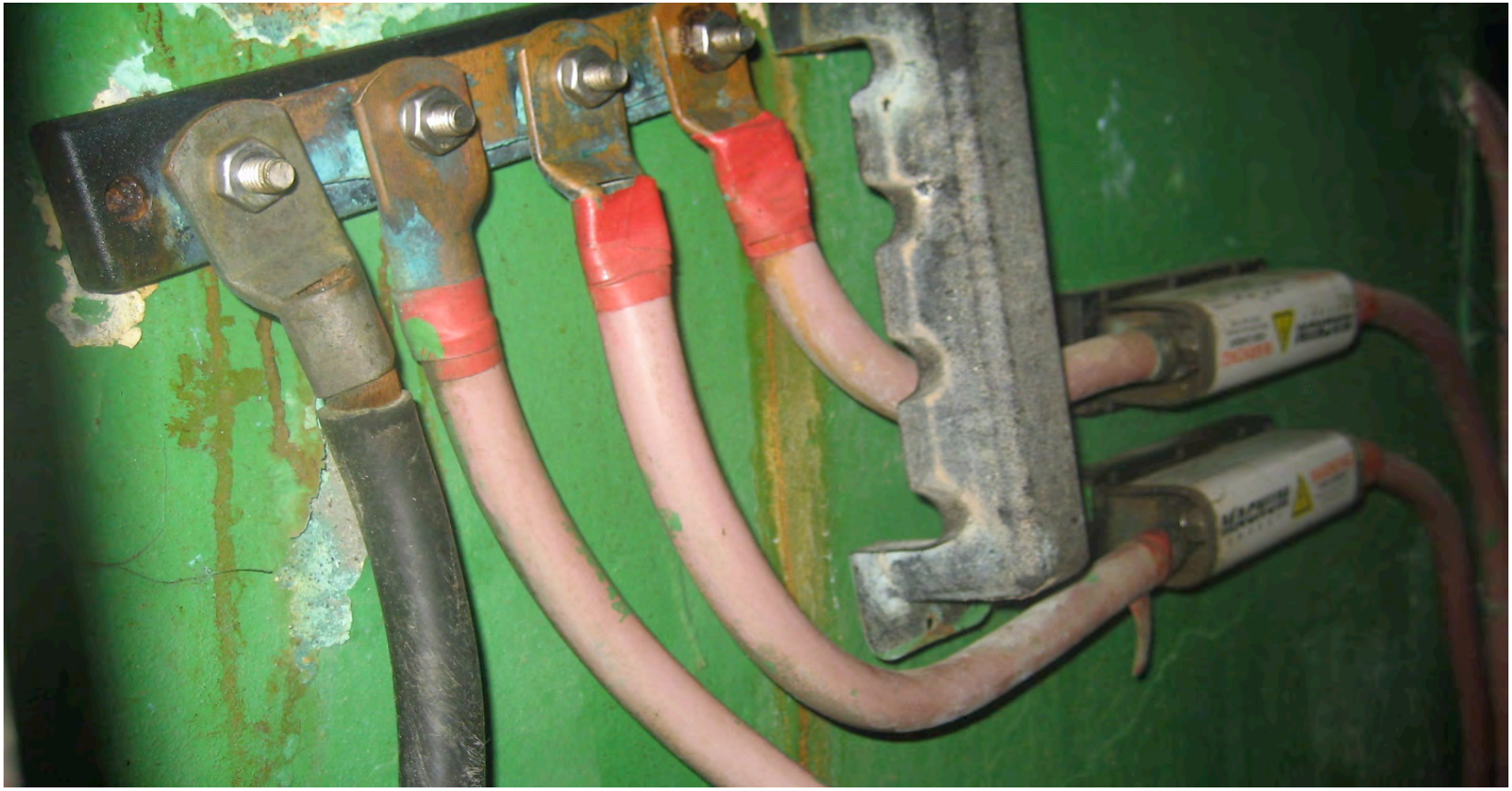
Inverter/Charger Systems

Avoid paralleled cables if possible

- *Problems if one cable comes loose / poor crimped lug – other cable will end up carrying all the current and will overheat*
- *Use a separate fuse for each positive cable and for each string of batteries*
- *Make all of the parallel connections of multiple battery strings in the DC enclosure instead of at the batteries themselves*

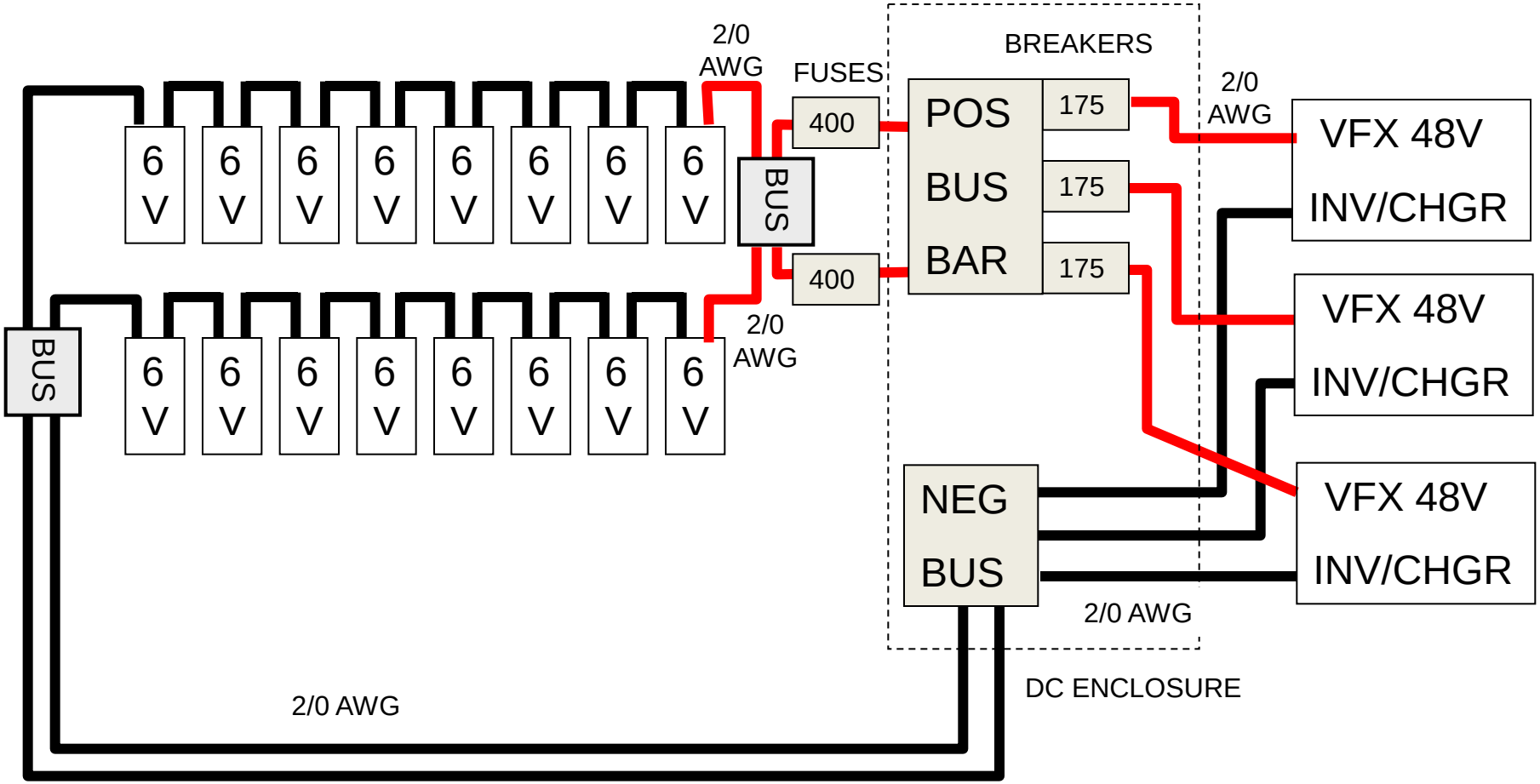
Inverter/Charger Systems

Battery Paralleling and Fusing – ***example of old method using a wall mounted bus to connect the positive and negative cables together***



Inverter/Charger Systems

Battery Paralleling and Fusing – *Example of the old method for a system with two strings of batteries using 4/0 AWG cable with 200 amp fuses and 175 DC breakers with the parallel connection being done outside of the DC enclosure*



Inverter/Charger Systems

Battery Fusing – *new recommendations*

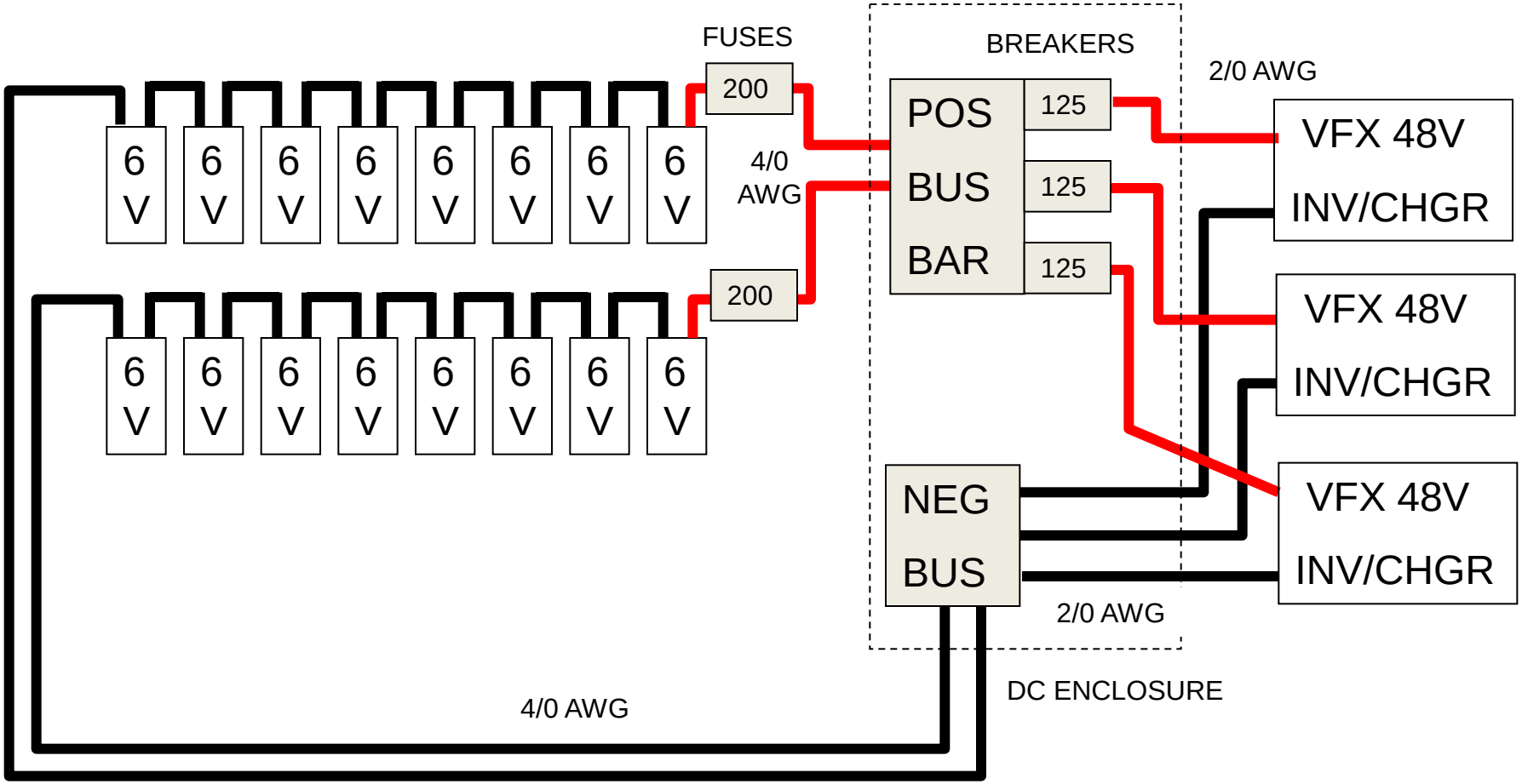
- Best practice is to install one fuse per battery string
- Should be mounted near battery but with safe access
- Needs to be matched to battery cable size
- Can be wall or mounted inside of battery enclosure
- Must be very secure – strong attachment to allow fuse replacement

Inverter Cabling and Overcurrent Protection

- It might also be better to run separate cables from each of the battery strings individually to the bus in the DC breaker enclosure – each protected with a separate fuse
    - The individual battery strings are not paralleled at the battery bank end of the cables
    - The resistance of each cable run will help to balance the amount of current pulled from each battery string

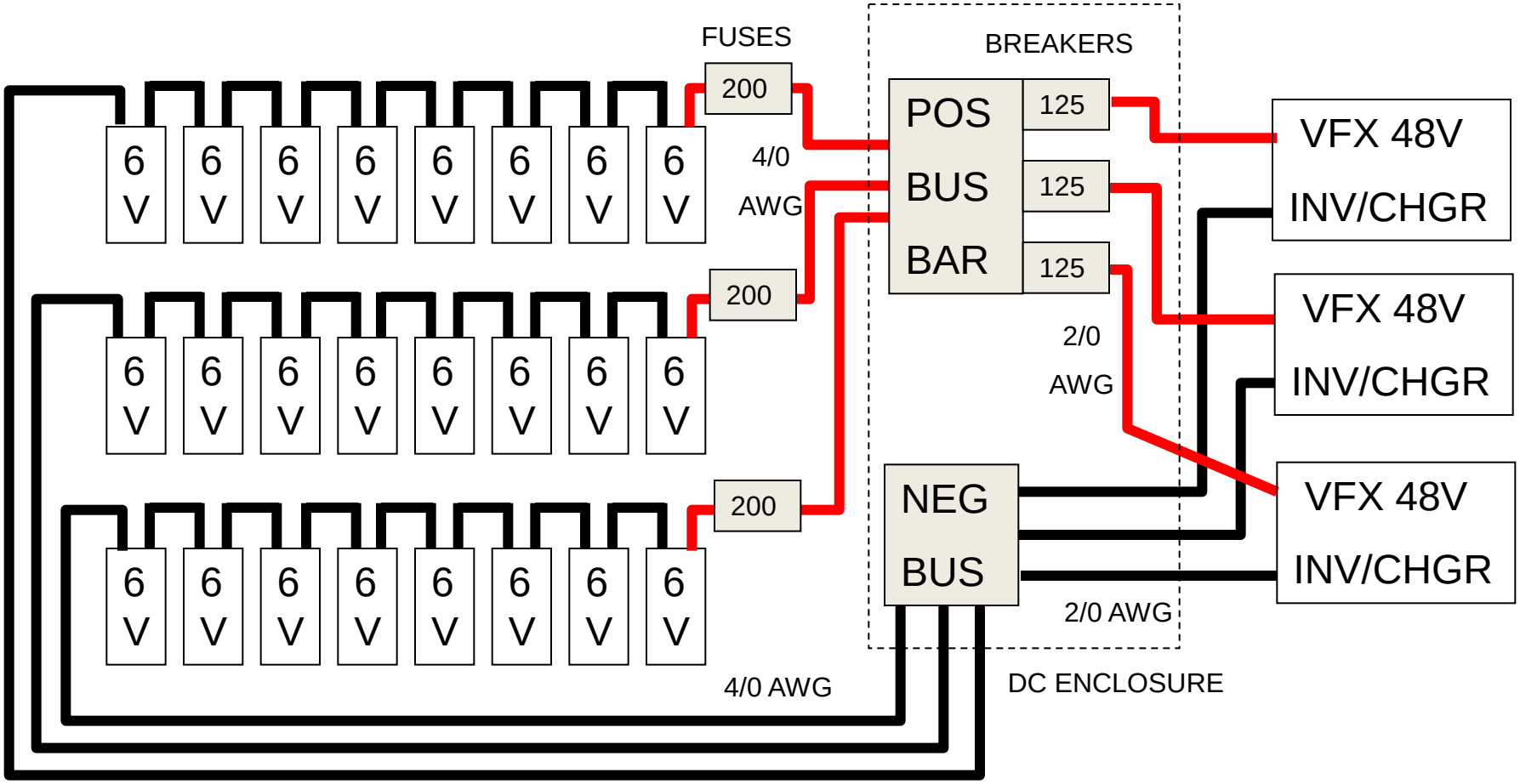
Inverter/Charger Systems

Battery Paralleling and Fusing – *Example of new method for a system with two strings of batteries using 4/0 AWG cable with 200 amp fuses and 125 DC breakers with the parallel connection being done inside of the DC enclosure*



Inverter/Charger Systems

Battery Paralleling and Fusing – *Example of new method for a system with three strings of batteries using 4/0 AWG cable with 200 amp fuses and 125 DC breakers with the parallel connection being done inside of the DC enclosure*



Inverter/Charger Systems

Inverter Cabling and Overcurrent Protection

- With this method, a failure of a crimp lug connection or bolted connection will not result in a fire or overload of the remaining cables (the fuses my blow if large loads where operated)

- Can allow use of 2/0 cable since currents per cable are lower

- Works better when the individual inverter DC breakers are 125 amp instead of the usual 175 amp DC breakers in order to not require very large cables

  » *The 125 amp DC breakers are also less expensive*

Inverter/Charger Systems

Breaker and Fuse Sizing and Coordination with Cable Ampacity

- One system had a fire occur on the battery cables and fuse holder
- Cables where in metal conduit – may not have been well grounded
- Current did not get high enough to blow the 400 amp fuse
- Cables overheated – was it the cause or result of the problem?

Inverter/Charger Systems

Breaker and Fuse Sizing and Coordination with Cable Ampacity

- The fuse size needs to be better coordinated with the size of the cables – 200 amp fuse for 2/0 AWG and 300 amp fuse for 4/0 AWG
- Use of dual 2/0 cables on one 400 amp fuse should be avoided if possible
- Metal Conduit needs to be well grounded – use a grounding bushing
- A better option is to use non-metalic conduit instead

Inverter/Charger Systems

DC and AC Enclosure Mounting and Location

- One site had entire system flipped upside-down to make DC on left
  - » *Inverters are not approved for being mounted upside-down*
- Would have been better to rotate the entire system 90 degrees with the AC and DC enclosures mounted horizontally to allow easy DC access from either end of the enclosure
  - » *Better for cooling of the inverters*
  - » *Less issues with rats*
  - » *Makes conduit connections easier*
- AC enclosure are then across the top / DC across the bottom

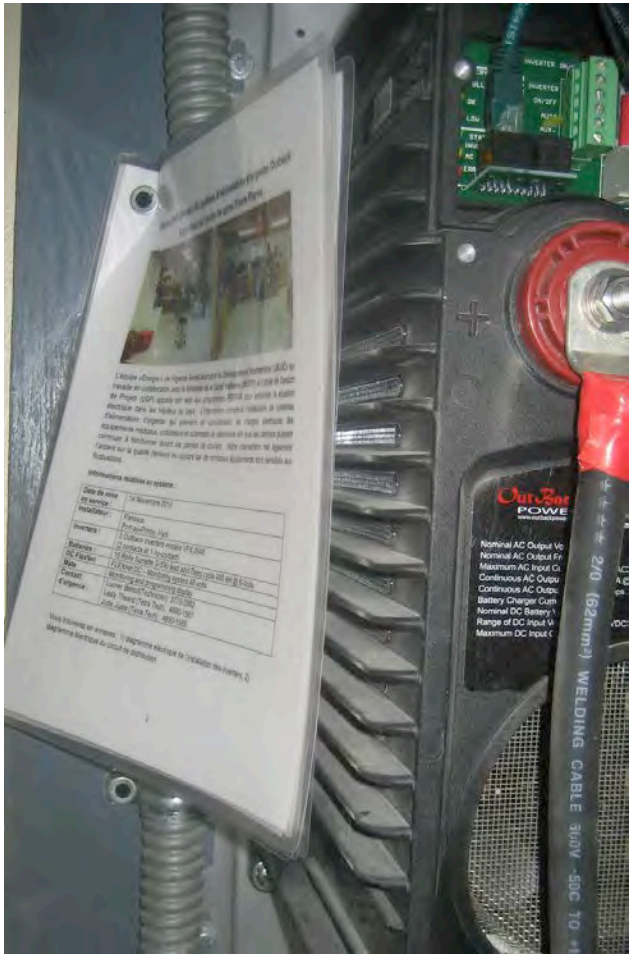
Inverter/Charger Systems

Recommended Mounting Orientation – AC enclosure at top / DC at bottom

Inverter/Charger Systems

Space for Heat Dissipation

Clearance around inverters to allow warm air to flow away from the inverters



Inverter/Charger Systems

Workspace Access

Clearance around inverter system to allow servicing

Inverter/Charger Systems

Workspace Access

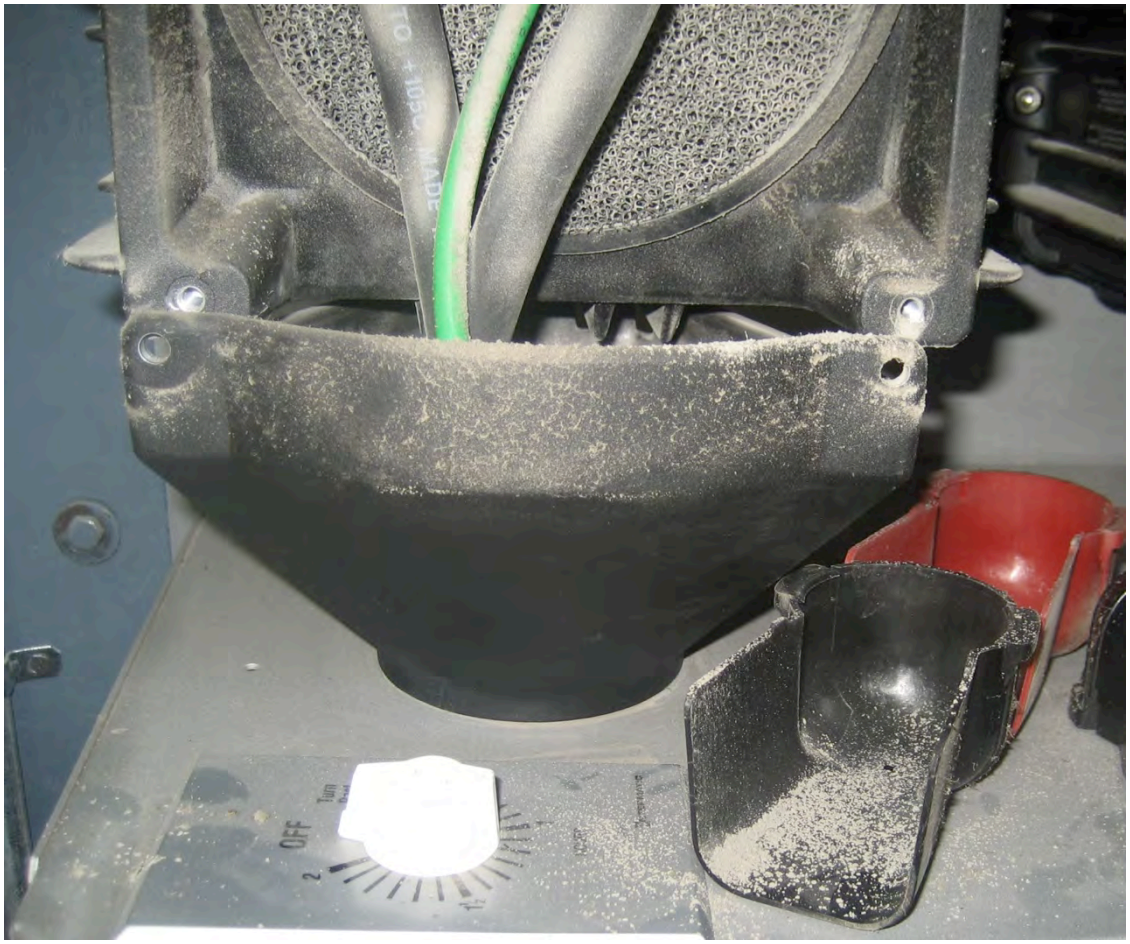
Batteries should not be in front or under the inverters.

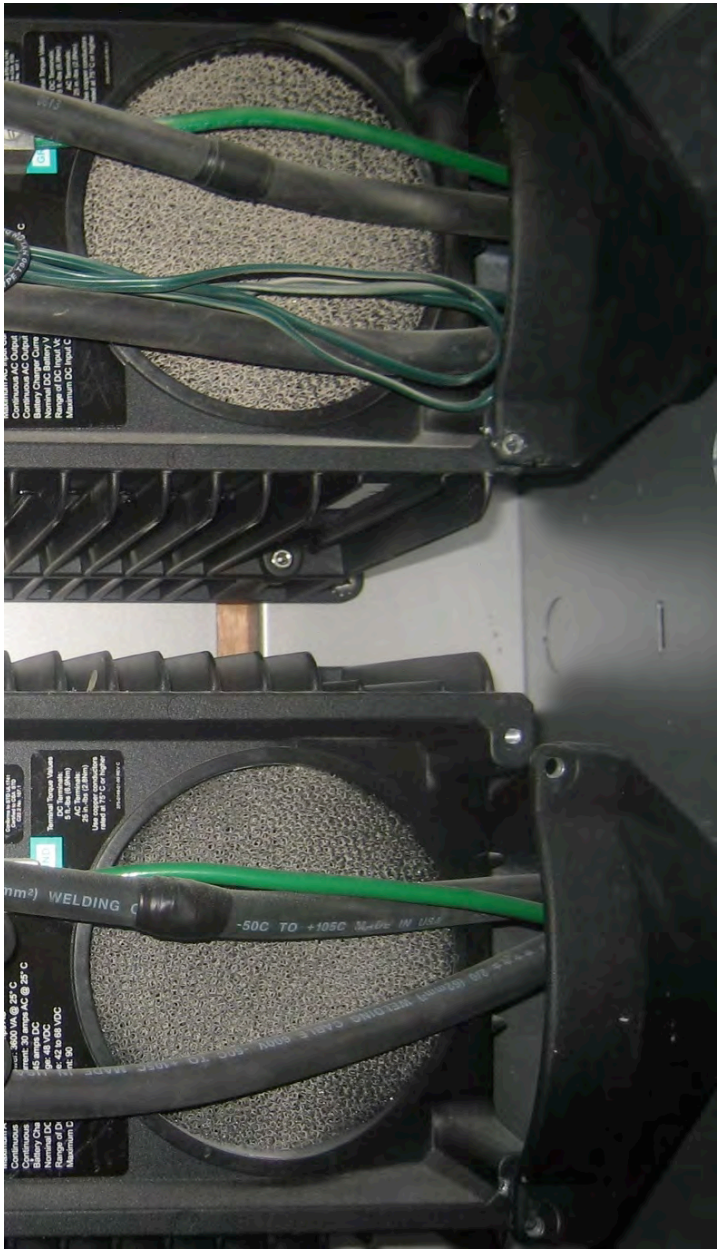
The batteries should be in a protective enclosure to prevent accidental short circuits

Inverter/Charger Systems

Keep the Air Filters Clean!

Dirt and dust can block the air flow through the internal fan





Inverter/Charger Systems

OutBack Power Specific Design Issues

- System can be designed to work with 3 phase AC sources – 120/208VAC "Wye" or "Star" four wire / three Hots and one neutral
- Some generators are set-up for 127/230VAC which is similar to 120/208VAC and also supply 3 phase power
- Three phase systems – even systems which are supplied with only two phases of the three phase system – should not be configured with more than one inverter per phase on any of the slave phases

Inverter/Charger Systems

OutBack Power Specific Design Issues:

- **Many sites actually are connected to 2 phases of a 3 phase generator in use**
  - » The phases are 120 degrees out from each other instead of 180 degrees
  - » Inverters may have a problem with connecting to this AC source
  - » Battery charger on the Leg 2 “slave” inverter may battery charge incorrectly if programmed as a split phase system
  - » Cannot use the OutBack X240 autotransformer to “balance” the load on the inverters with 2 legs of 3 phase

Inverter/Charger Systems

Inverter Stacking Limitations

- 120/240VAC “split phase” can have many inverters per phase or leg
  - » *There can be multiple slave inverters on both L1 and L2*
- 120/208 or 127/230 VAC systems (2 or 3 phase) can only have one inverter per phase (except the master phase)
  - » *Makes having four inverter/chargers on a system difficult since we only have two phases of a three phase system – not 120/240 split phase*

Inverter/Charger Systems

Battery Temperature Sensor

- The battery temperature sensor for the battery is important to prevent overcharging and excessive water consumption
- The battery temperature sensor HAS to be plugged into the MASTER inverter or it will not work – Also must use OutBack sensor – not old Trace sensor – it will not work correctly
- The cable for the temperature sensor is vulnerable to damage and chewing on by rats – additional protection is needed and careful installation to prevent damage

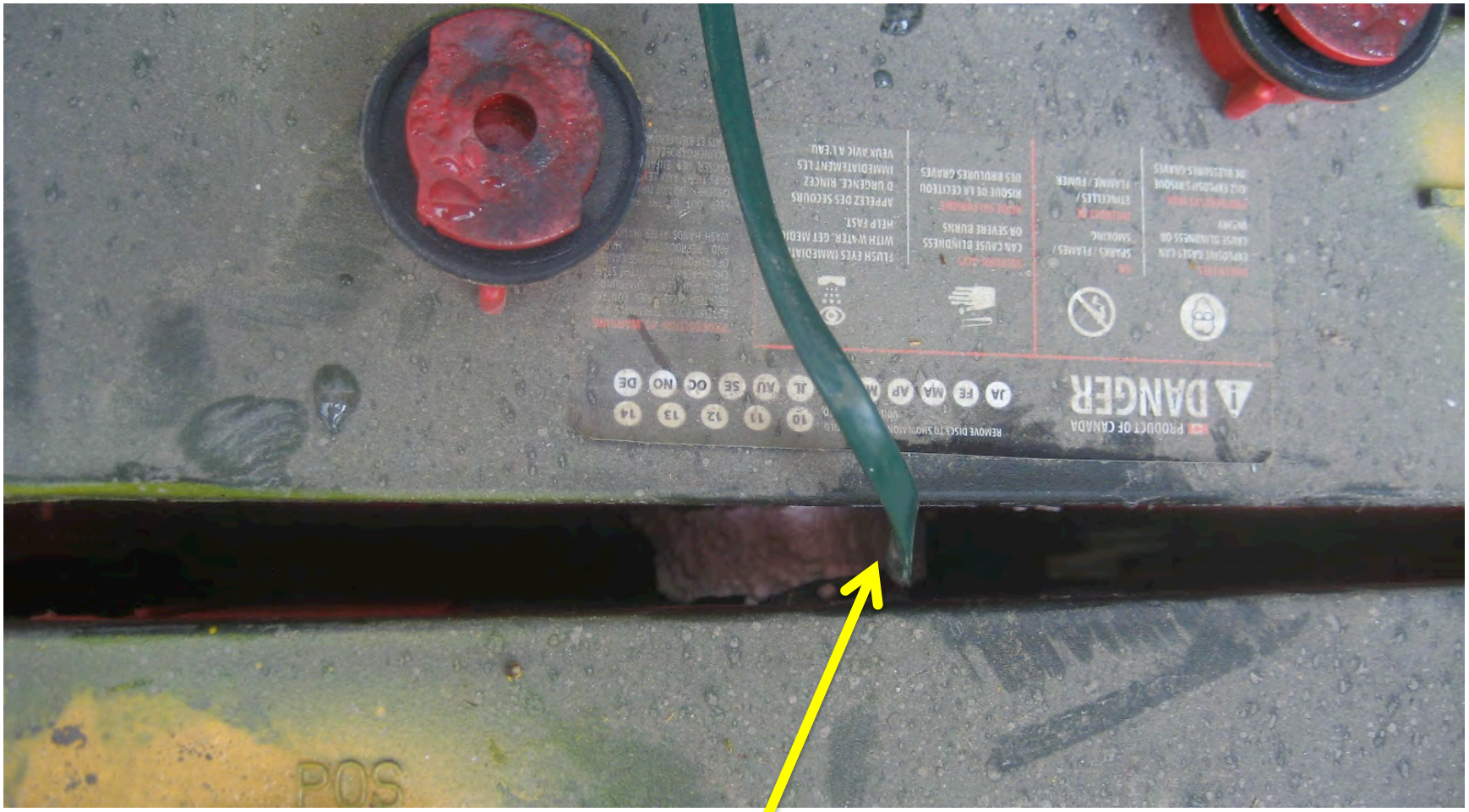
Battery Temperature Sensor Mounting

- The temperature sensor should be mounted on the side of the battery below the level of the electrolyte – ideally between two batteries near the middle of the battery pack – not on the top of the battery!

- The adhesive provided by OutBack Power does not work well on the battery cases – the sensor falls of the battery and then just reads the air temperature instead – which can result in the battery being overcharged and getting very hot

- The sensor should be held in place with some plastic foam material wedged between two batteries – this also will insulate the sensor from the air flow which will make it more sensitive and accurate

Inverter/Charger Systems



Battery temp sensor compressed with styrofoam

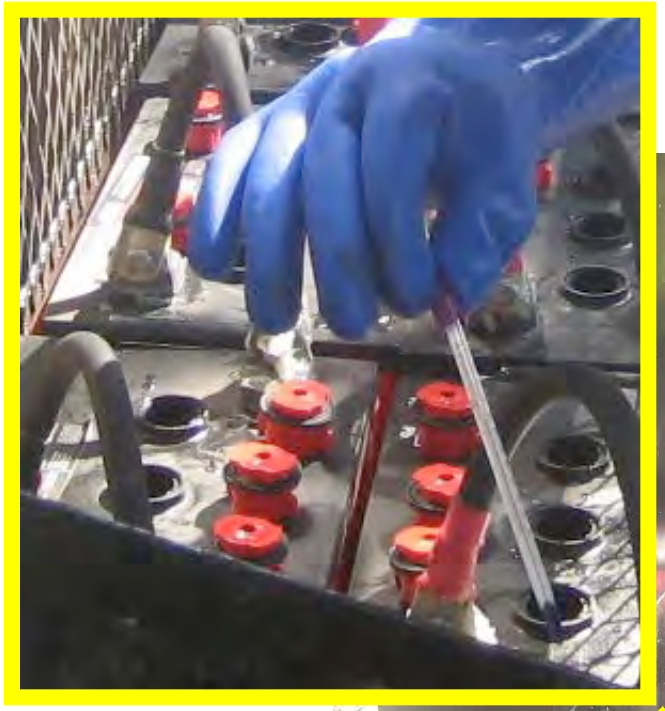
Inverter/Charger Systems

Battery Charging Procedure

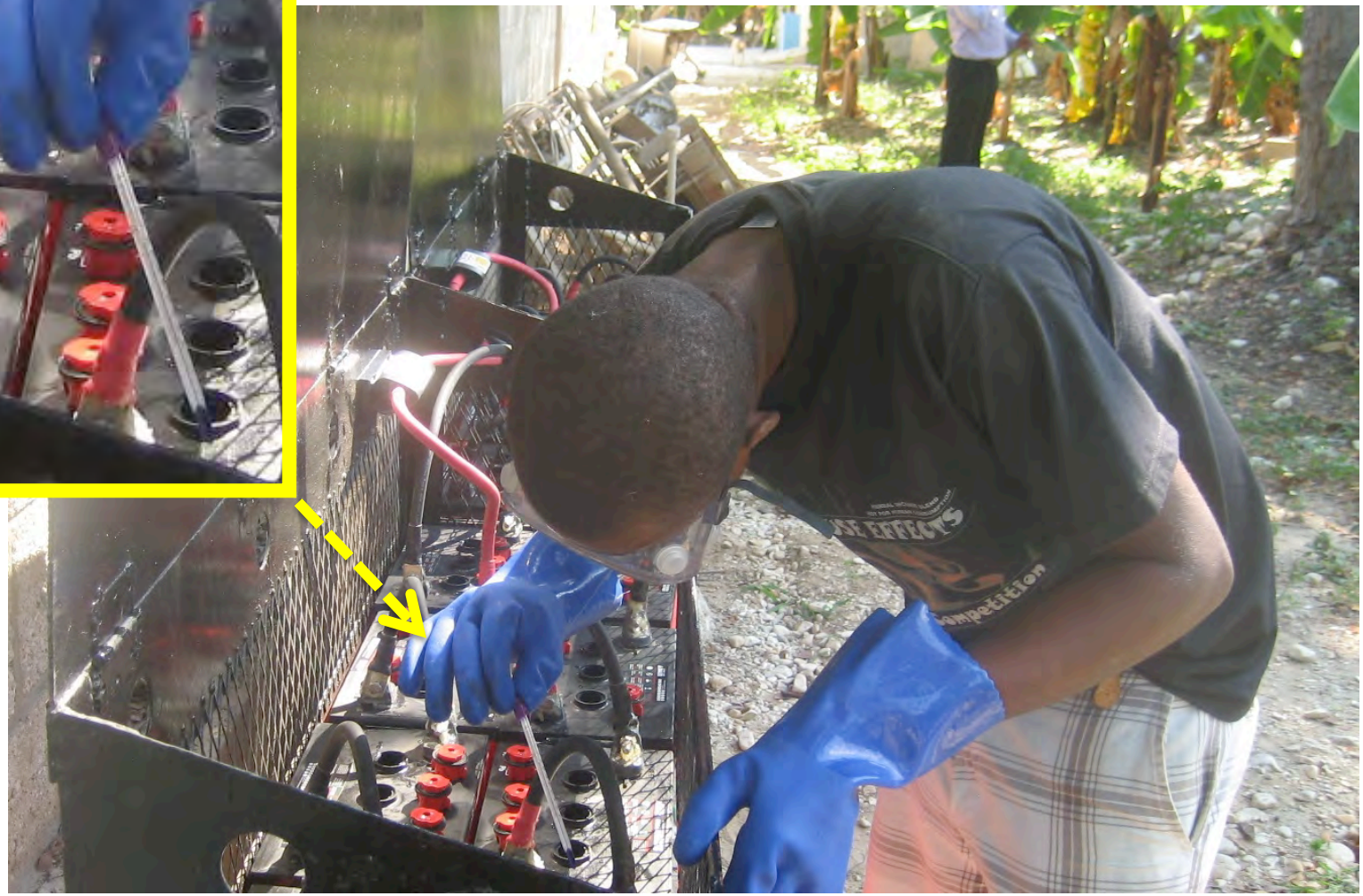
- Analysis of failed batteries indicates that charging has been effective in preventing sulfation of the batteries – but - we might be charging and equalizing too much or too long and damaging the batteries by getting them too hot

- Need to check the temperature of the batteries while equalizing and stop if they get too hot – the electrolyte is hotter than terminals or the case of battery by a significant amount

Inverter/Charger Systems



Battery technician taking temperature reading



Inverter/Charger Systems

Battery Charging Procedure

- Analysis of failed batteries indicates that charging has been effective in preventing sulfation of the batteries – but - we might be charging and equalizing too much or too long and damaging the batteries by getting them too hot

- Need to check the temperature of the batteries while equalizing and stop if they get too hot – the electrolyte is hotter than terminals or the case of battery by a significant amount

- May also need to reduce the charge rates to allow the batteries to charge slower and not get so hot – maximum rate recommended is C/6 or ~15%

Capacity / 6 = 400AH / 6 = 66 amps

Capacity x 0.15 = 400AH x 0.15 = 60 amps

Inverter/Charger Systems

System Programming and Setpoints

- Review setpoint guide
- Discuss alternative settings

Inverter/Charger Systems

Solar Power System Specific Details

- Grounding
  - *Frames of solar modules must be well grounded*
- Ground Fault Protection
  - *Additional device is required to provide additional protection*
- PV array sizing with controllers
  - *Do not put too many solar modules on a controller – waste of money*
- Surge protection
  - *Needed for solar arrays as they are susceptible to surges*

Inverter/Charger Systems

Other Possible Design Improvement Ideas

- AC Coupled Solar Electric Systems
- Automatic Generator Start Systems
- Remote Monitoring and Data Collection Systems
- Improved Low Battery Alarm Systems
- Fire Extinguishers

Inverter/Charger Systems

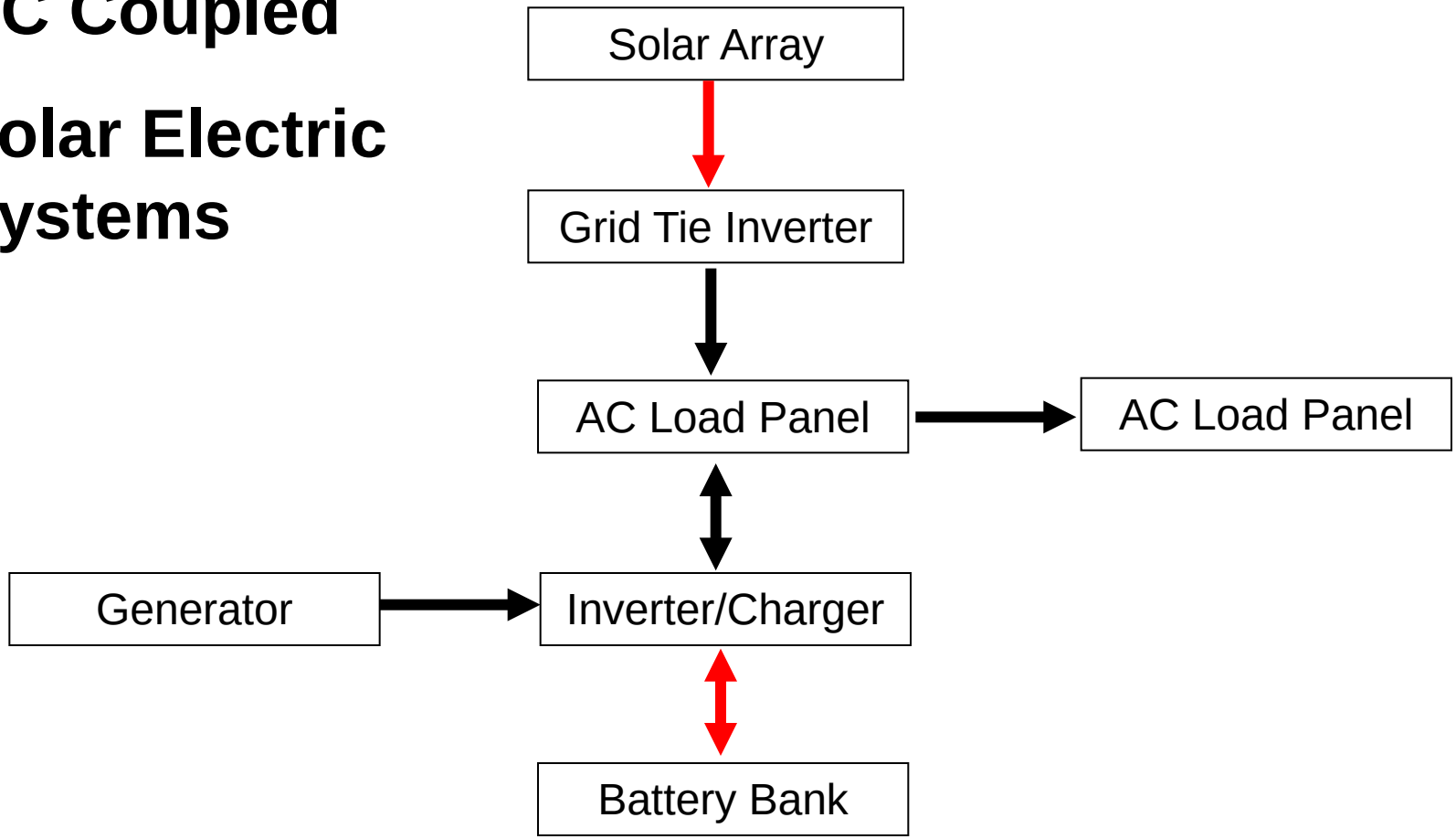
AC Coupled Solar Electric Systems Benefits and Issues

- The solar charge controllers are replaced with grid-tie inverters which use a high voltage PV array configuration
- The grid-tie inverters are connected to the AC output of the inverter/charger system
- The solar power is supplied directly to the AC loads during the daytime
- The inverter/chargers take excess power and charge the battery with it when there is excess power produced

Inverter/Charger Systems

AC Coupled

Solar Electric Systems



Inverter/Charger Systems

AC Coupled Systems Benefits and Issues

- Smaller wires and less specialized disconnects and breakers
- Higher efficiency when powering loads during the day
- Slightly lower efficiency when recharging the batteries
- Tends to be more expensive – requires more inverters
- But the installation can be cheaper – smaller wires/conduits
- Can be more difficult to troubleshoot

Inverter/Charger Systems

Automatic Gen Start System Benefits / Issues

- Can make system easier to operate – “automatic”
- Often causes the generator to run more hours or at times when not required as the generator doesn’t know what is happening with the loads and system users
- Can reduce contribution from the solar array as it does not know what the weather will be like and battery may be charged at start of a sunny day
- Can make system more difficult to troubleshoot

Automatic Gen Start System Benefits / Issues

- May require that the generator has more features
  - » *Two wire starting circuit*
  - » *Low oil pressure protection*
  - » *Fuel solenoids (shut-off)*
  - » *AC Output / Load control contactor*

Inverter/Charger Systems

Remote Monitoring and Data Collection

- MATE3 vs. MATE2 system display and controller

- Have in past been using mostly using MATE2's for installations
  - » Data is stored internally inside the MATE2 itself
  - » Limited to 125 days of data

- Will be switching to MATE3's to get additional data logging
  - » Data is stored on the SD card so more can be saved
  - » Years of data possible

Inverter/Charger Systems

Remote monitoring and data collection

- Have been developing a remote monitoring systems
  - » Several test systems installed
  - » Uses low cost Iridium satellite transmission
  - » Currently works only with the MATE2's
  - » Working on getting it to work with MATE3's
  - » Concerns about costs of system

Inverter/Charger Systems

Low Battery Alarm Systems

- Some of the alarms are installed in areas where people do not work or have access to silence the alarm / klaxon

  » *This makes it less useful and less effective*

Inverter/Charger Systems

Low Battery Alarm Systems

Inverter/Charger Systems

Low Battery Alarm Systems

- Most have used an AC powered light and AC powered Klaxon which will not work if the inverters shut off
  - » *Better to use a 12V DC LED light – and, if possible, a 12VDC klaxon too*

Inverter/Charger Systems

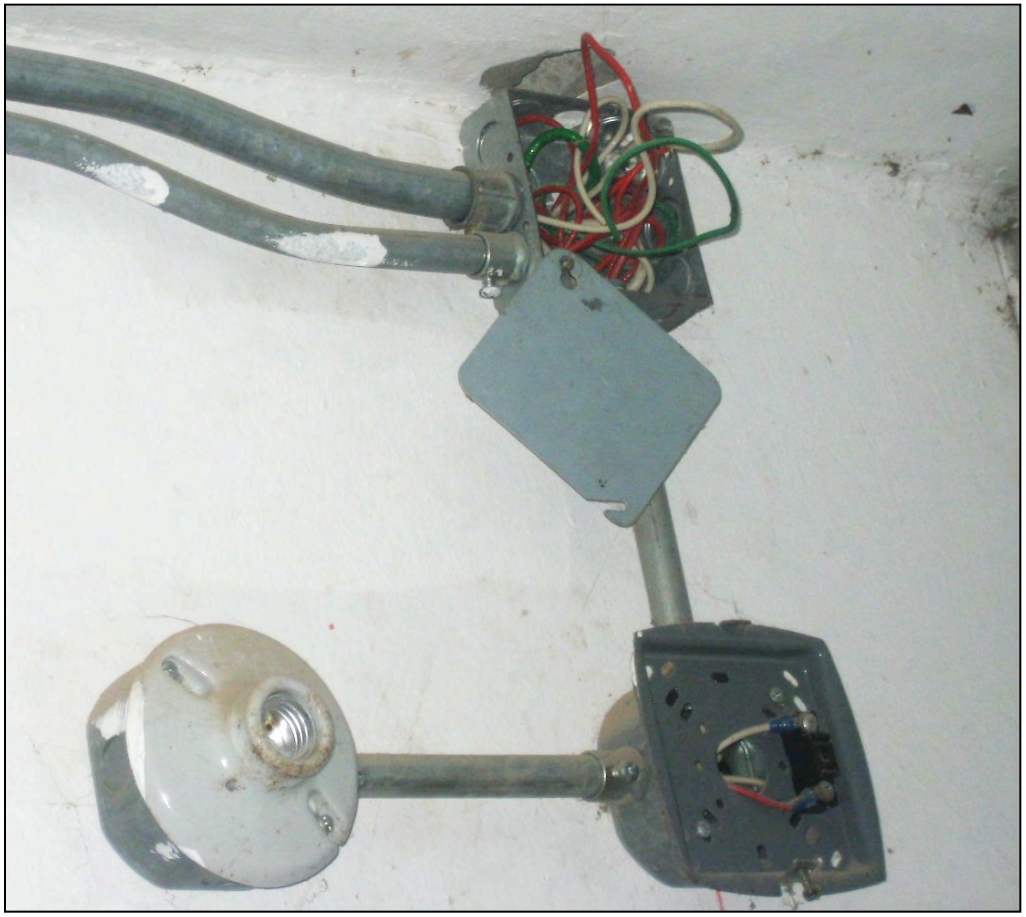
Low Battery Alarm Systems

Inverter/Charger Systems

Low Battery Alarm Systems

Many have been disable with the red lamps removed

Use of more appropriate horns and DC LED warning lamps which are "screwed down" and not easily removed is recommended



Inverter/Charger Systems

Fire Extinguishers

Need to consider safety more in both the design and in the Installation of these inverter / battery systems