Power Sources Manufacturers Association

The multinational power electronics association

Key Issues in Vehicle Power Electronics

Interconnect Solutions

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Agenda

- Concerns with Power in Electronic Vehicles
- Busbars
- Pin & Socket Connectors
- Cable Assemblies
- Enhanced Interconnects
- Power Lugs

Concerns with Power in Electronic Vehicles

- **Power**
  - Consumers desire similar power as gas automobiles
- **Efficiency**
  - Manufacturers desire low resistance connections to maintain power levels
- **Battery Life**
  - Consumers desire long battery life and quick recharging capabilities

POWER: Consumers do not like to give up anything. They prefer more for less. In addition, they have grown accustom to the convenience of a gas powered vehicle.

EFFICIENCY: In order to maximize power, prolong battery life and minimize power requirements, low loss connections assists in managing these.

BATTERY LIFE: There are concerns in having a long battery life. Can you perform the daily routine and make it home without locating a recharging station and recharging? How far can you go without recharging? Are there recharging stations available? Multiple locations? How does the car's performance change as the battery is depleted?

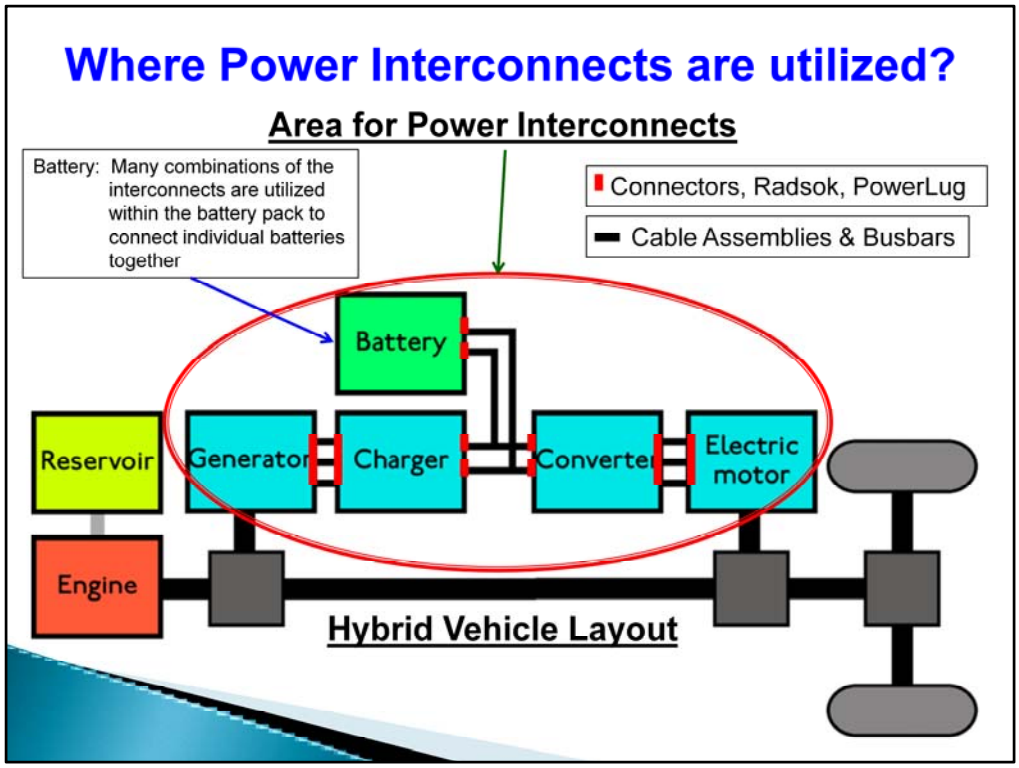
How can Interconnects assist?

- **Efficiency**
  - Low resistance connections minimize power loss
  - Larger AWG wires
- **Modularity**
  - Interconnects facilitate assembly of modular components and future repair/replacement
- **Packaging**
  - Cable assemblies are flexible to route around devices
  - Busbars route in fixed paths
  - High power, small space

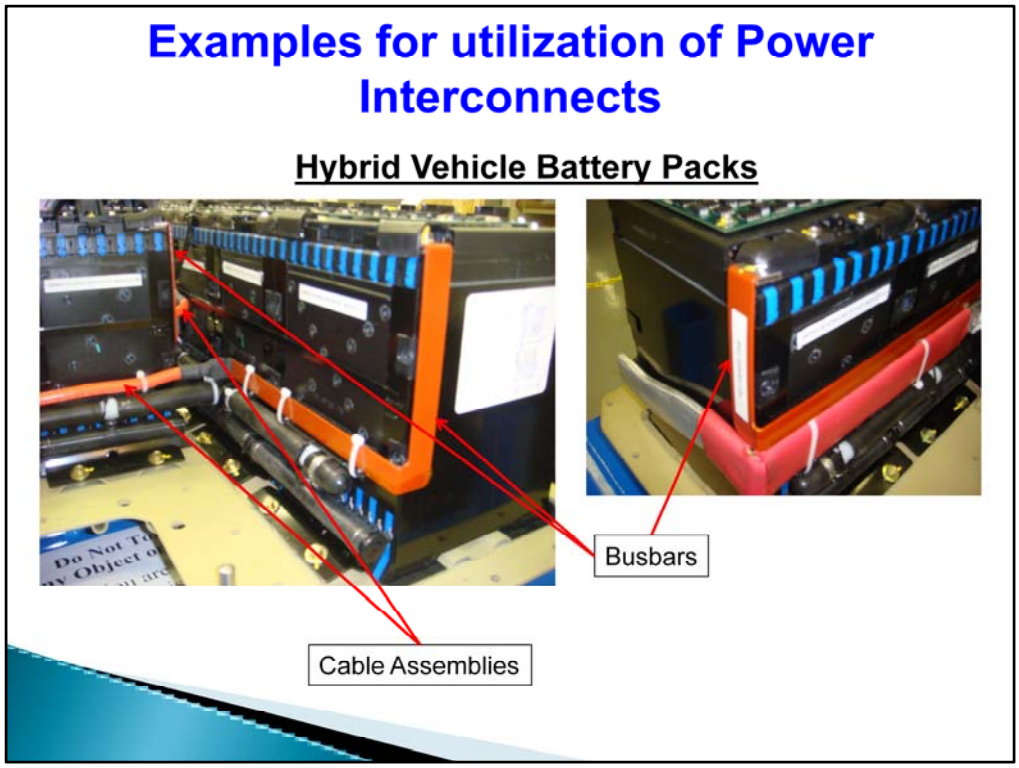
EFFICIENCY: With lower loss connections, the wire AWG may be reduced which in turn reduces the overall weight of the vehicle. Smaller AWG wires are more flexible for ease of routing.

MODULARITY: Interconnects allows for modularity of design. Easier maintenance and upgrades are a possibility.

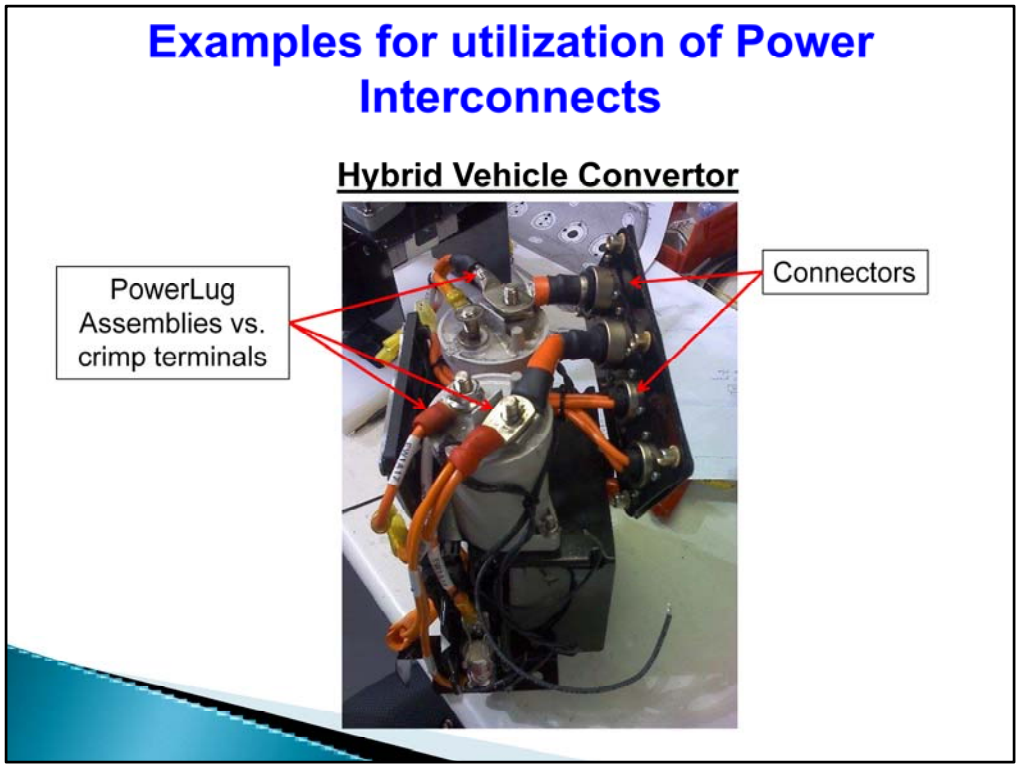
PACKAGING: Cable assemblies and busbars allow the placement of different devices in areas that are convenient to access.



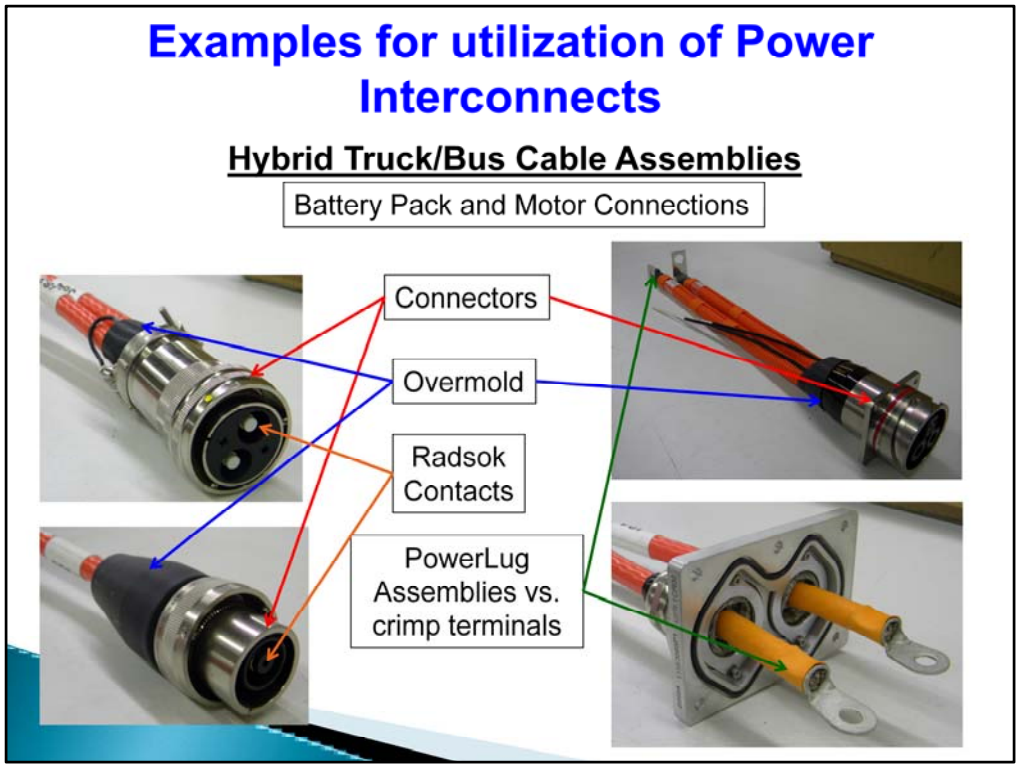
This is a simplified view of a hybrid vehicle. This shows how interconnects, cable assemblies and busbars can be utilized to connect each device. In addition, they can be utilized to connect components within the devices.



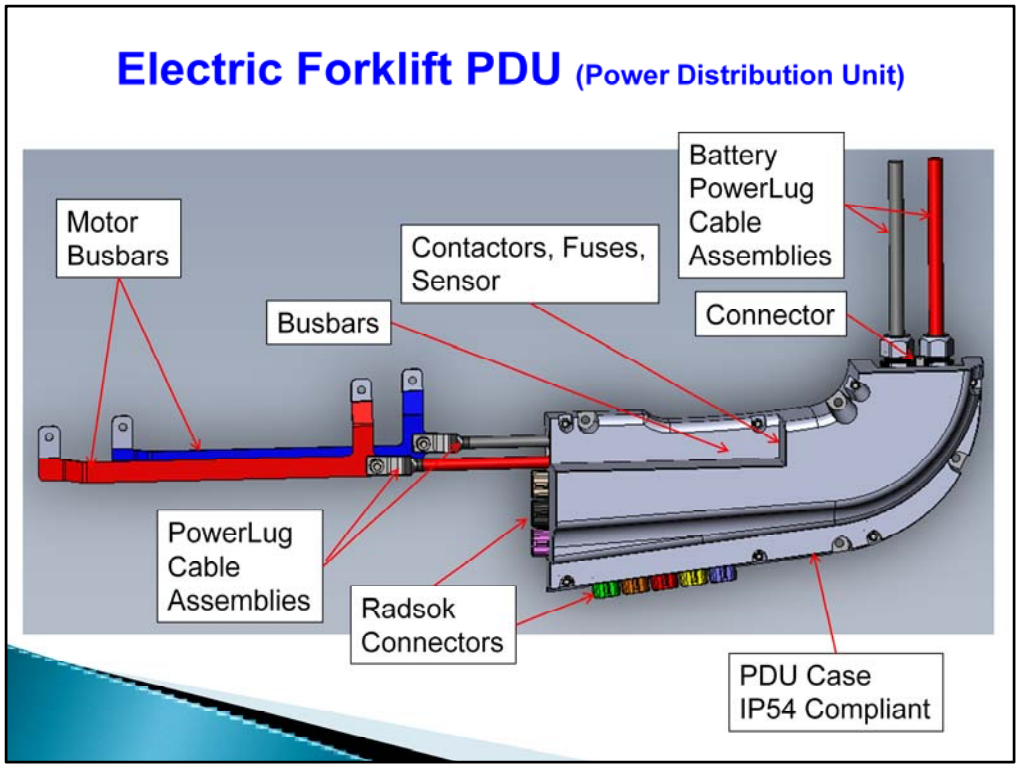
This is an example of how busbars and cable assemblies are utilized in the battery pack of a hybrid vehicle. Assemblies can be routed in tight areas.



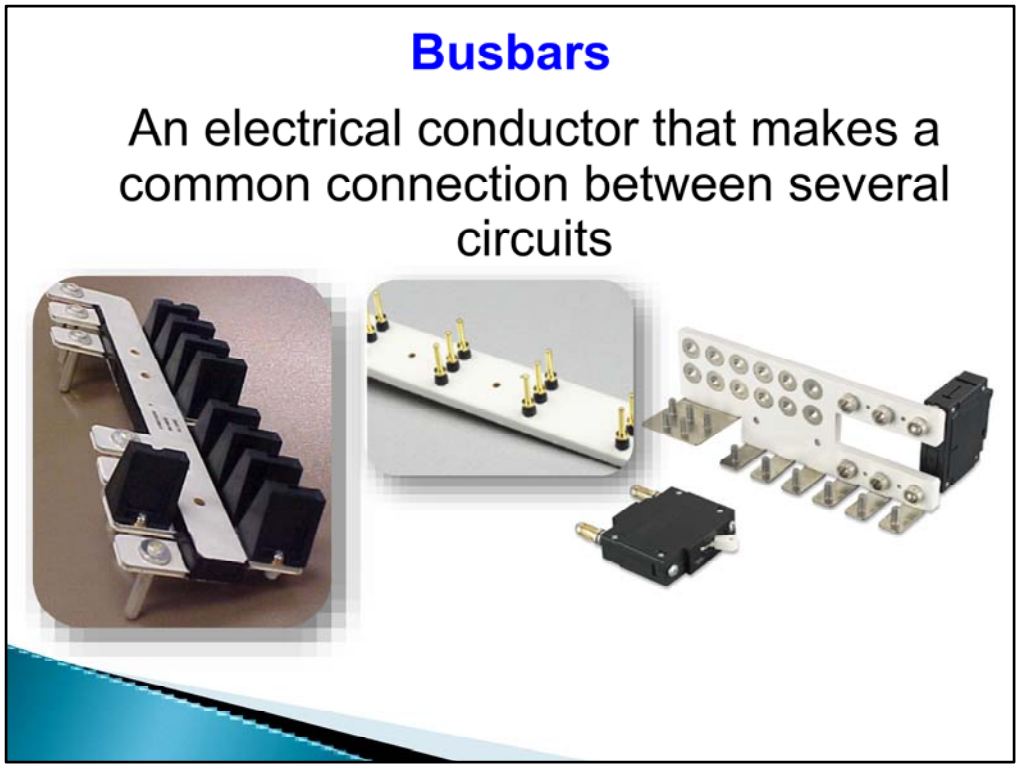
This is an example of how interconnects are utilized in a convertor. This shows the use of PowerLugs, crimp terminals and connectors. The picture shows that flexible cable is used; however, a busbar could also be incorporated in some designs.



For heavier applications, larger interconnects are required. Also environmental concerns (salt, dirt and water) need to be considered. It is important to maintain low resistance connections. Safety is also a major consideration. Need to maintain a safe environment for assembly and maintenance personnel.



Products are not limited to just simple assemblies and busbars. Power distribution units are required for other electric vehicles such as forklifts. These units manage the power and distribution to the destinations. Contactors, fuses, sensors, connectors, busbars, cable assemblies and PowerLugs can be utilized in multiple combinations. Due to environmental concerns, the PDU may need to be resistant to dust, dirt, oils and moisture. In addition, depending on the actual use of the vehicle such as in the food industry, resistance to cleaning agents have to be considered.

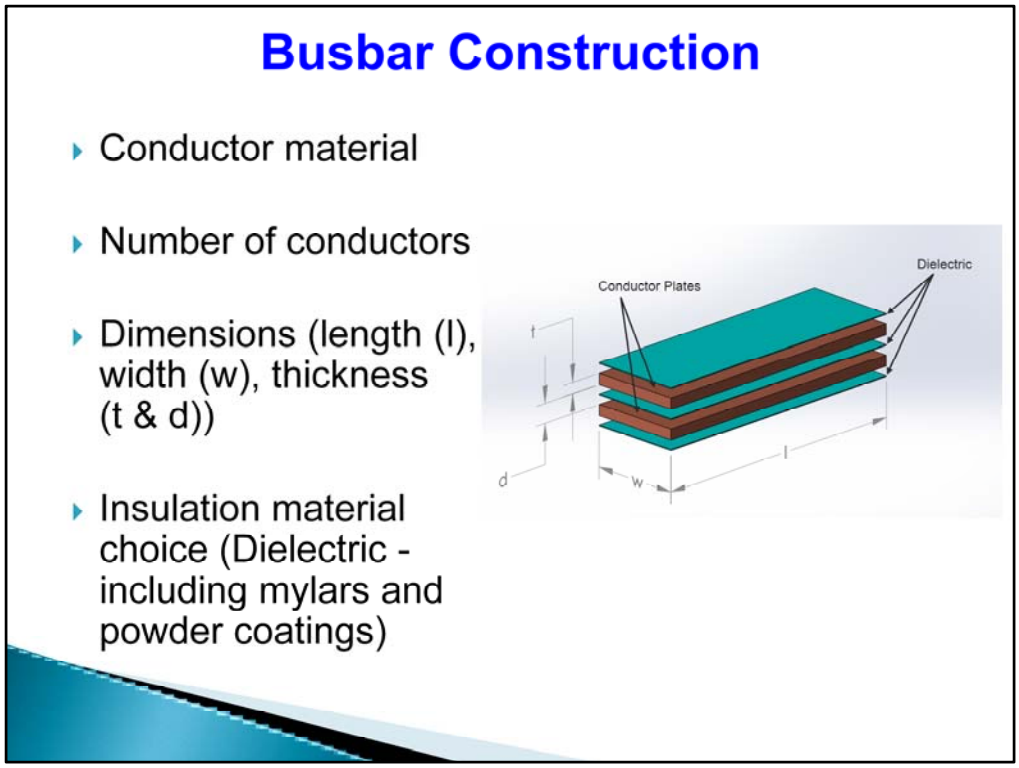


Busbars are a common method to connect and distribute power within a vehicle and within devices. They are ridged and are designed to route around components.

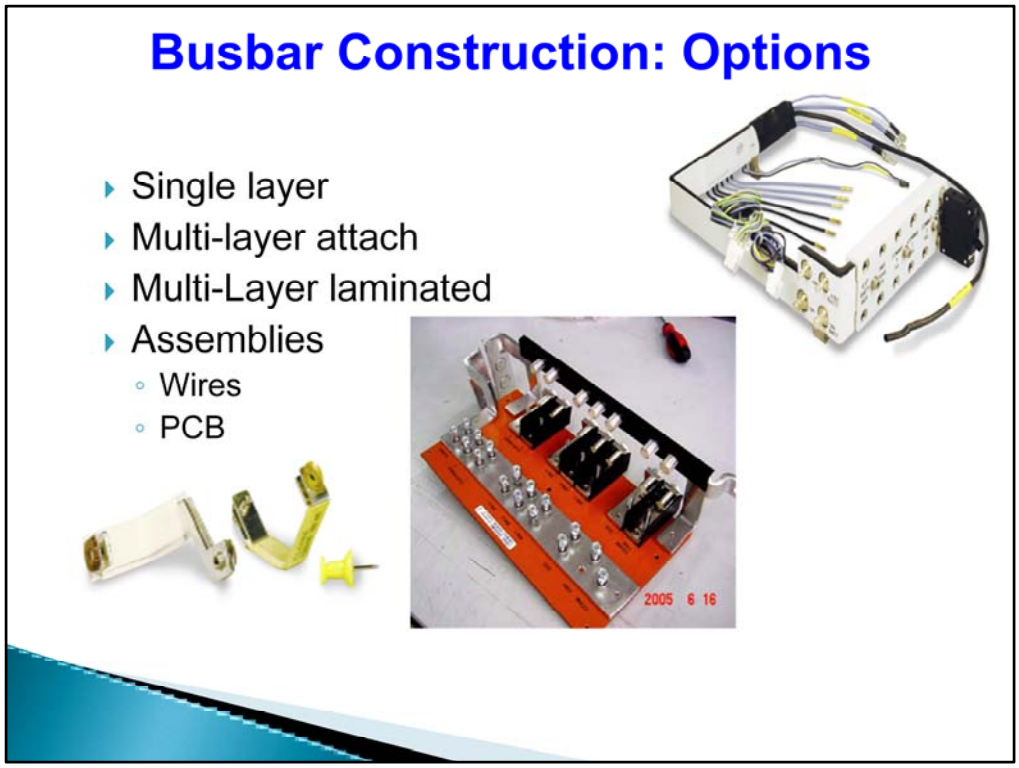
Busbar Design Considerations

- Electrical Parameters
  - Power (Amperage)
  - Voltage
  - Temperature range (T-rise over ambient)
- Termination points and methods
- Structural envelope
- Agency requirements (UL, CSA, DOT)

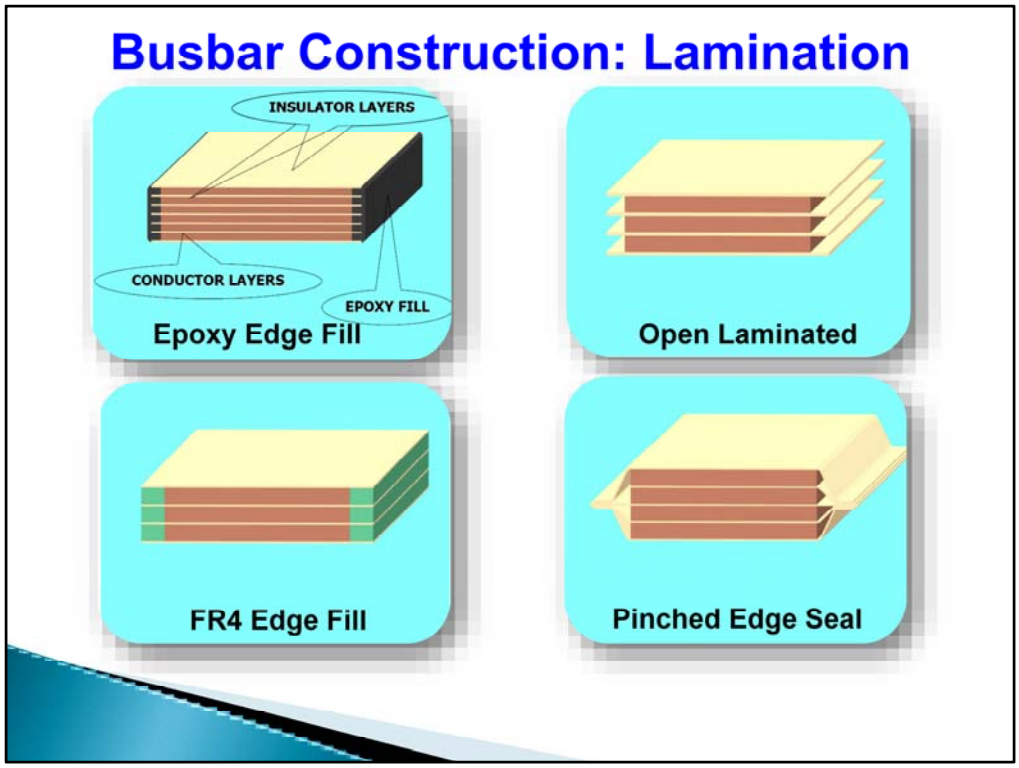
In designing a busbar, it is critical to understand the requirements (expectations) that are critical to the Customer. This includes the electrical, environmental, mechanical and agency requirements. Having this information early in the design cycle ensures proper design and minimizes over design (costs).



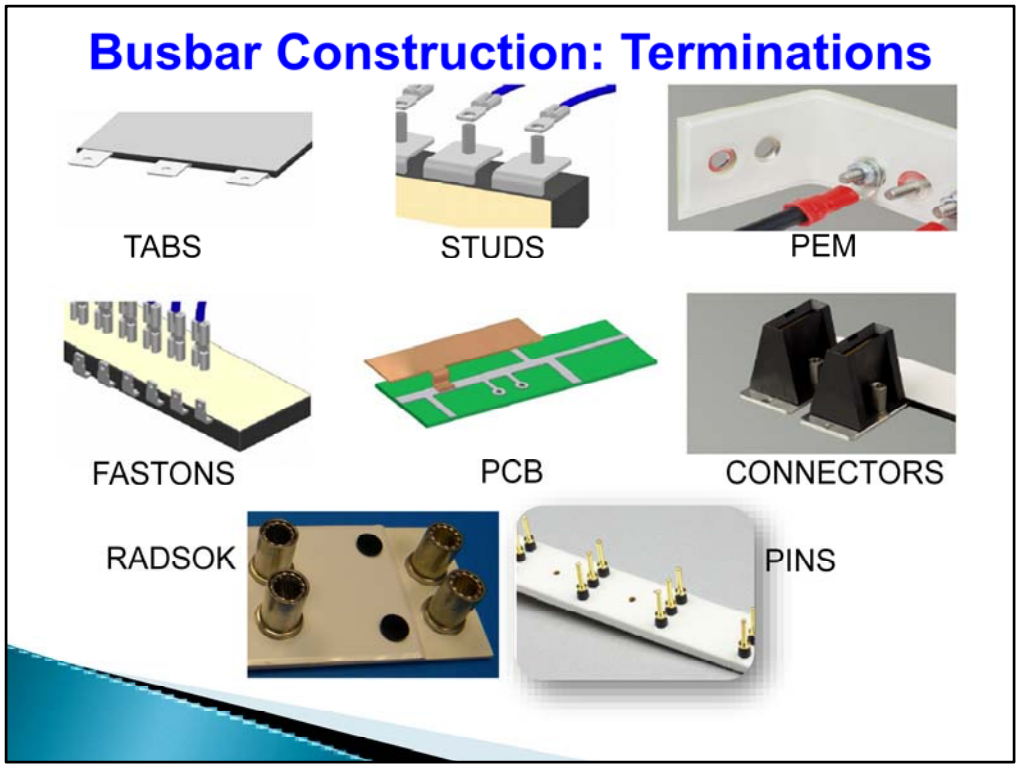
Defining the busbar material (copper or aluminum) and the number of potentials starts the process. Voltage, amperage, size constraints, environment, T-Rise, connections and routing are all considerations to determine the size, shape and laminate (insulation) materials.



Busbars are in many different shapes and sizes. Each busbar is a custom solution for each application and customer. Busbars can include many types of components (connectors, tabs, contacts, PEM nuts, cable assemblies, contactor, fuses, switches, etc.).



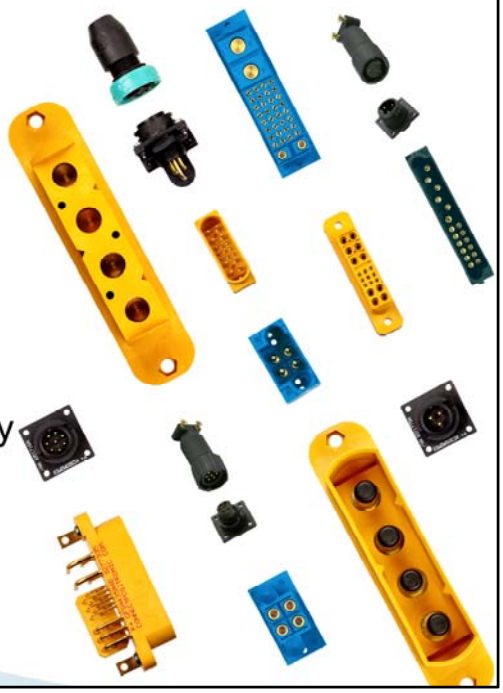
There are different ways to work with the edges of the busbars when laminates are utilized. Most common are the Epoxy Edge Filled and Pinched Edge Sealed. These as well as the FR4 Edge Filled insulated the edges for creepage concerns. These also serve as a moisture barrier. Choosing the proper method greatly depends on the busbar shape and bends. FR4 is the most expensive and limiting on bends. When using the Open Laminated option, there must be sufficient excess laminate to mitigate any creepage effects due to the environment.



Shown are the types of terminations utilized in busbar designs. The most common are Connectors, Radsok, Pins, PEM's and Studs.

Pin & Socket Connector Considerations

- Pin count
- Sealing
- Voltages
- Reliability (stamped vs. machined)
- Polarization
- Keying
- Blind installation
- Current carrying capability (series vs. parallel)
- Current density
- Locking



Cable Assemblies come in many shapes and sizes based on the requirements that they must perform. Wire AWG are determined based on the power and the flexibility requirements. Connectors are designed to meet the requirements for power (amerage, voltage, safety), strain relief and the environment in which they must work.

Power Cable ASM Design Considerations

- Electrical Parameters
  - Power (Amperage)
  - Voltage
  - Temperature range (T-rise over ambient)
- Termination points, methods and connectors
- Cable Flexibility
- SAE Type Wires
- Environment
- Agency requirements (UL, CSA, DOT)

As with busbars, early understanding of the requirements (electrical, mechanical, environment, agency approvals, flexibility, routing and space limitations) are needed to develop a cost effective and safe assembly. Selection of the appropriate wires is critical.

Power Cable Assemblies

- Utilizes various components in the assembly:
  - Customized and Standard Components
    - Contacts and Connectors
    - Splicing
    - Terminals and Lugs
    - Wire and Cable
- Cable Flexibility
  - Harness Assembly
  - Routing
  - Length(s)
- Environment
  - Indoor/Outdoor
  - Temperature Extremes

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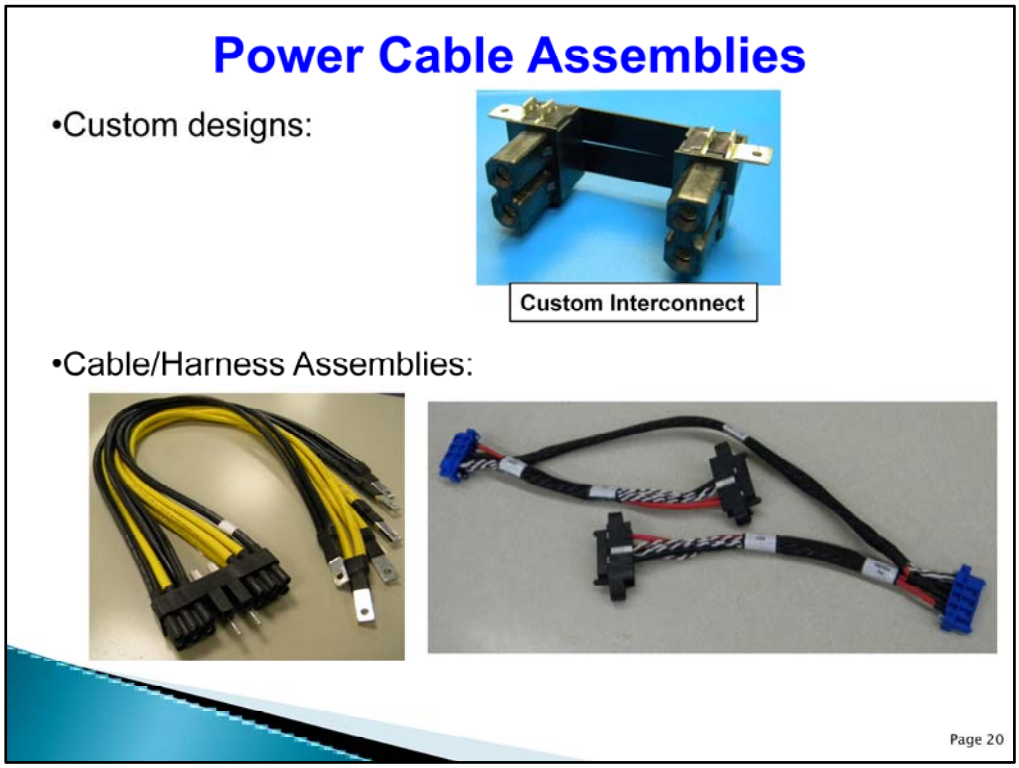
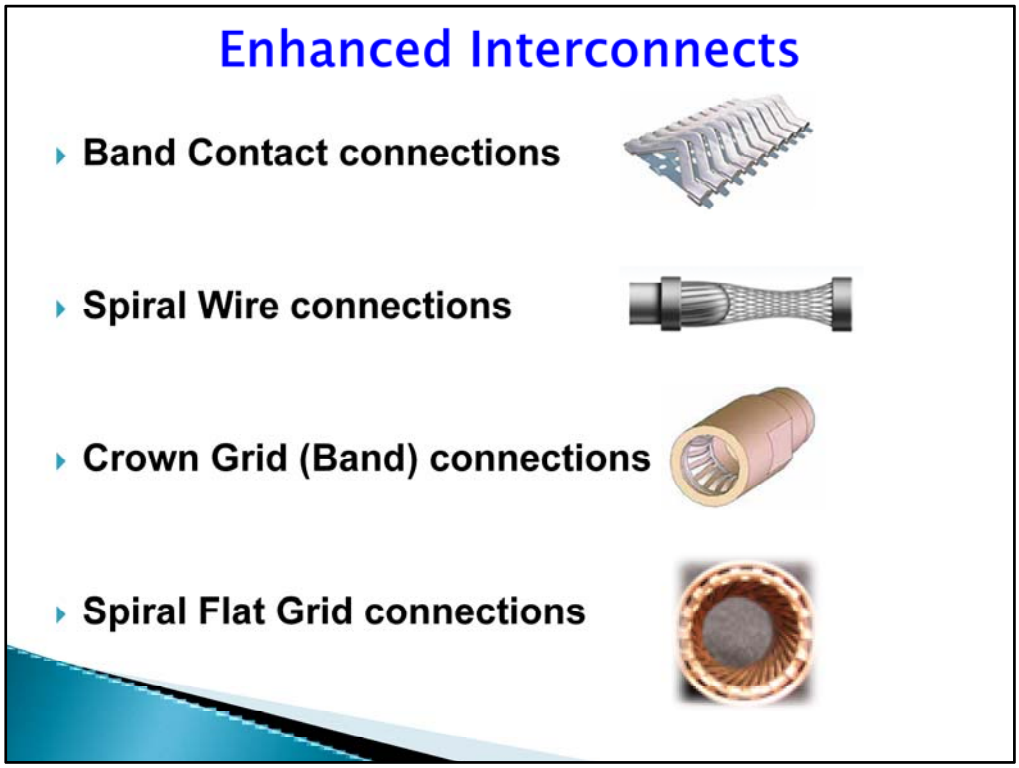
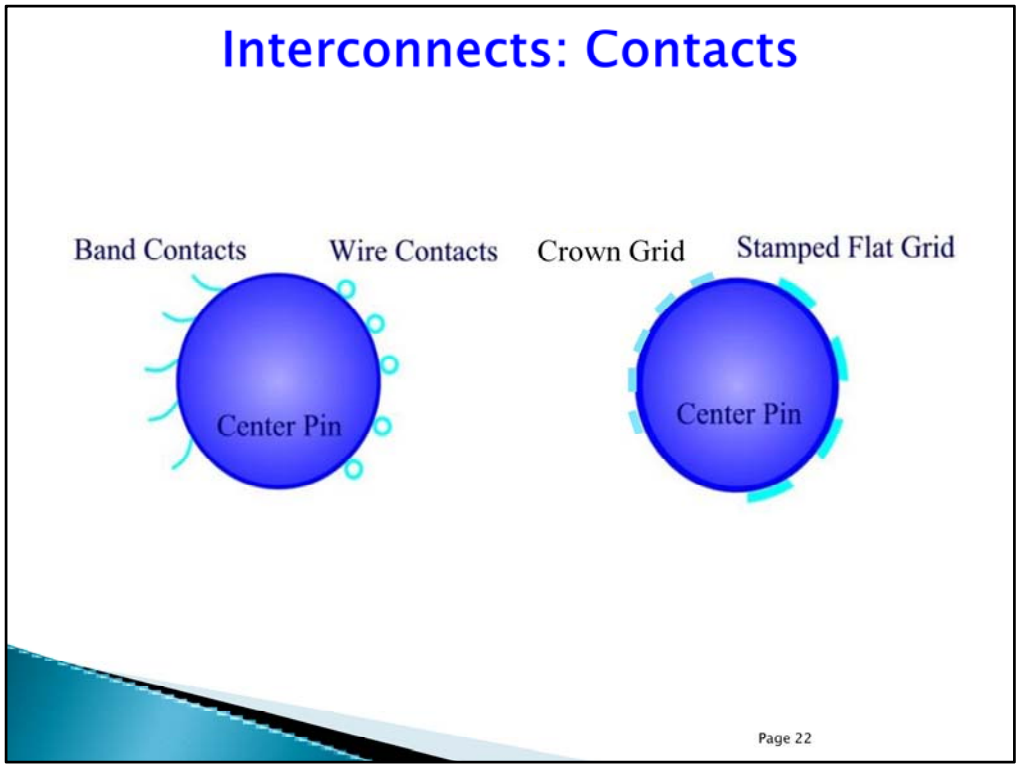
Selection of components are critical for the performance of the assembly. Minimizing the number of connections and utilizing efficient connections are common goals. Also understanding any EMI considerations is important. Does the assembly require EMI shielding and if so, how is it grounded is important in component selection and design.



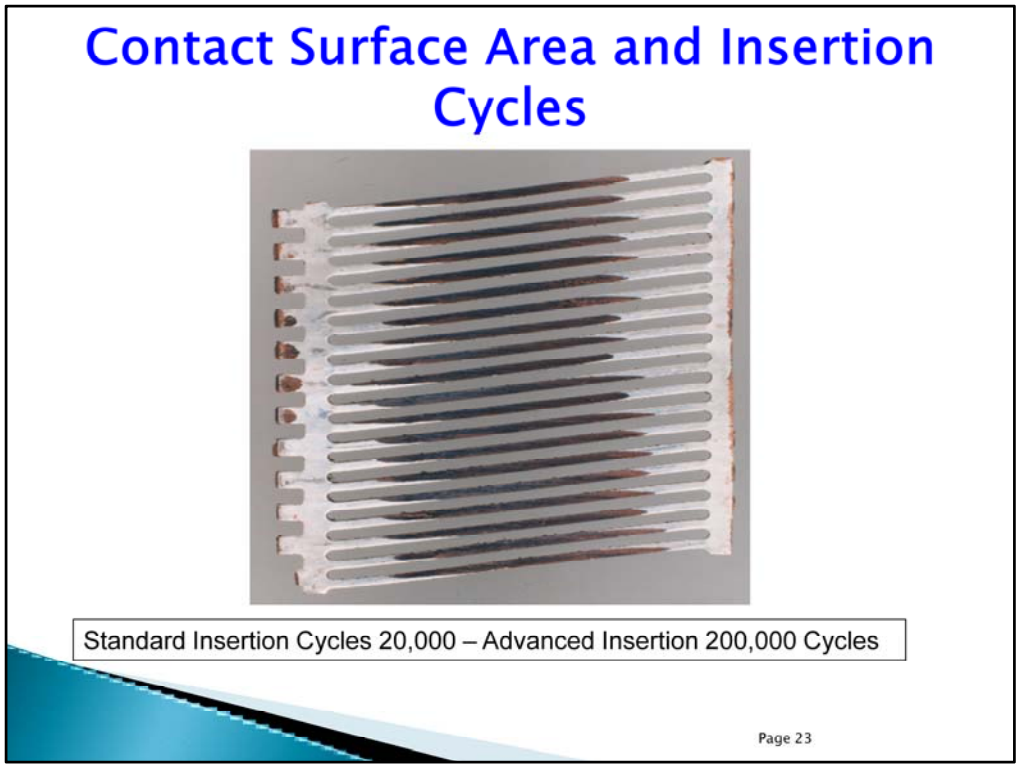
These are examples of various designs and shapes of assemblies. Depending on the use of the assemblies, they can be small to the use of large (4/0+ AWG) gage wires. In addition, the connectors will be in many different shapes and sizes. Power assemblies can utilize standard components as well as custom design solutions or a combination of these two.



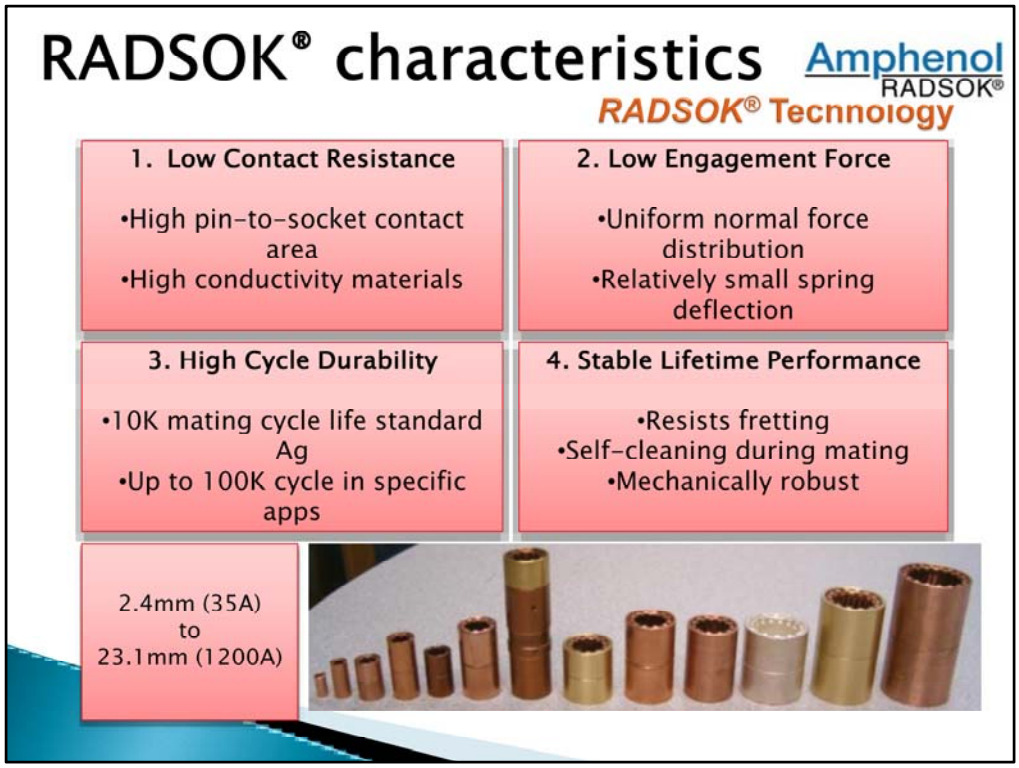
There are many different ways to improve the efficiency of the connections (lower the connection resistance). Each design has various cost impacts, levels of efficiency and mating dynamics. Lowering the resistance of each connection provides added efficiencies to the total system in which they are used. The two most common are the Crown Grid (Band) and the Spiral Flat Grid connections.



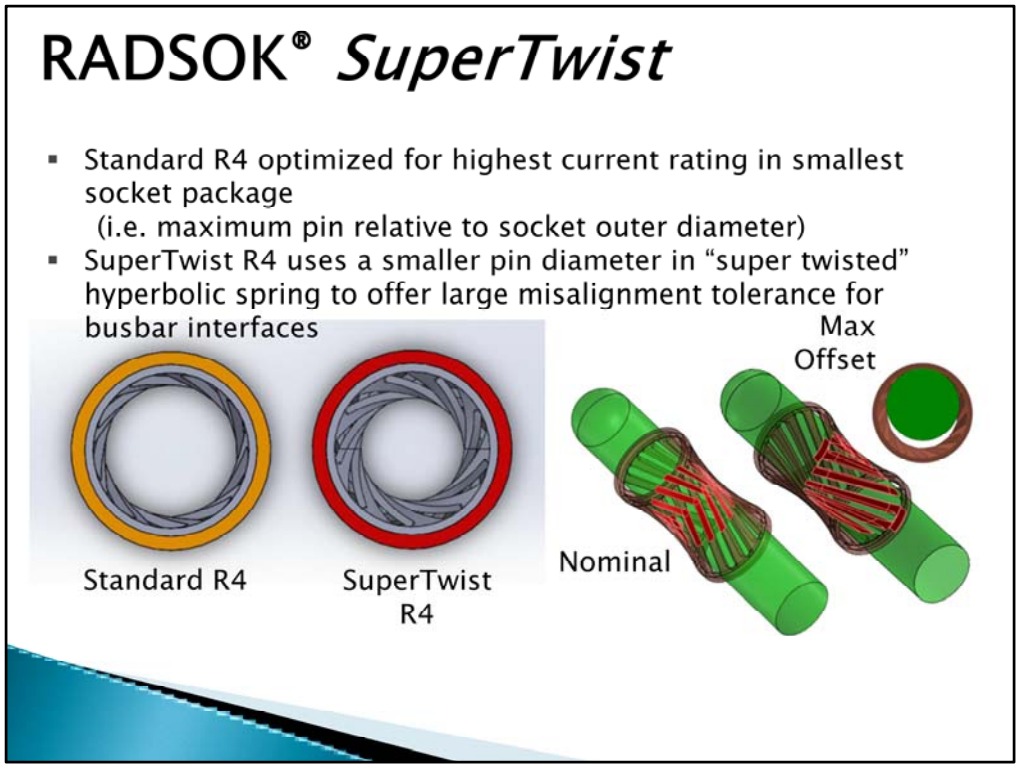
This shows how each enhanced interconnect reacts to a pin in a mated condition. The critical factor is the amount of surface area that is utilized. There is a relationship: more surface area in contact with the pin, the lower the resistance. All of the enhanced interconnects have advantages over a standard pin socket connection.



This is an example of the surface area of contact with the Spiral Flat Grid (Amphenol Radsok) connection. Approximately 80%+ utilization of the grid array.



Advantages of the Radsok technology. Main benefits are the low contact resistance, durability and size availability.

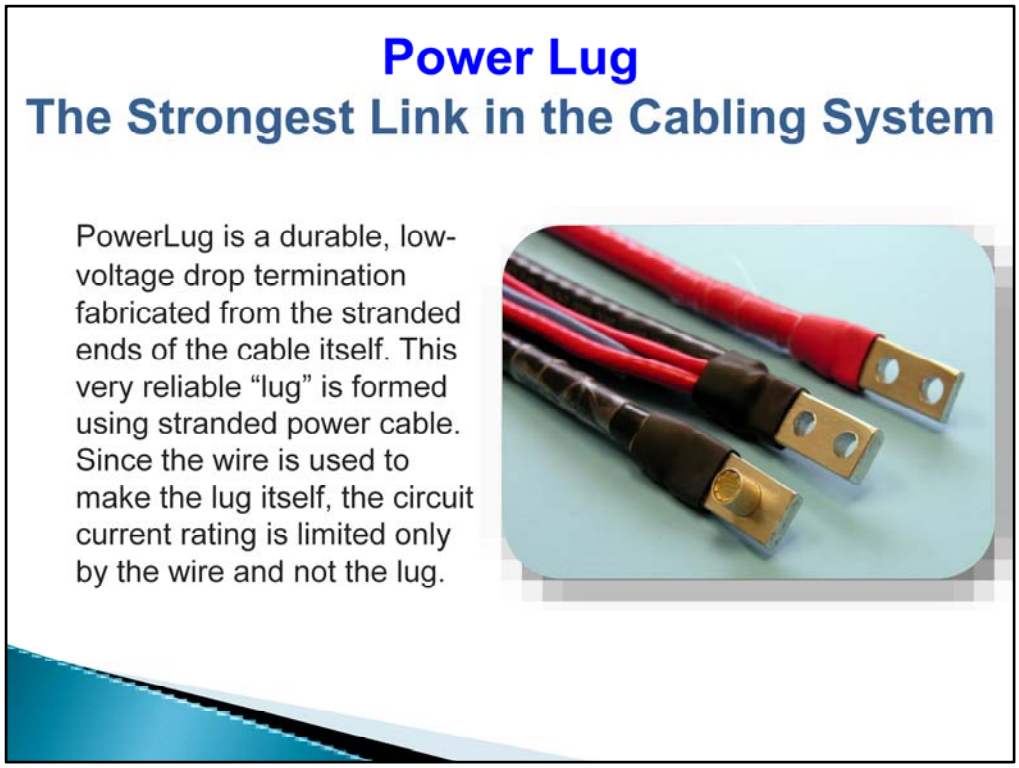


New enhancements to the Radsok family include the R4 type (reduced size while maintaining the same mating pin size) and the Super Twist (greater radial tolerance) for location.

The R4 is a welded grid that eliminates the need of the outer barrel and reduces the overall size of the socket. This does not change the mating pin size.

The Supertwist is a tighter wound grid that allows for greater radial tolerance. An example is the 3.6mm version with a standard radial tolerance of ± 0.005" increasing to ±0.025" with Supertwist version. This is a big benefit when utilized with busbars. This allows greater locating of the mated pin with a fixed socket location of the Radsok for blind mating.

Radsok is a technology that can be utilized in many different forms: connectors, busbars, PowerLugs and wire terminations. It is flexible in many different applications and consistently achieve reduced resistance. With the reduction of the resistance, smaller wires and busbars may be utilized.

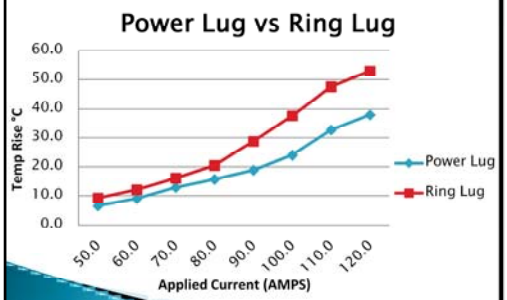


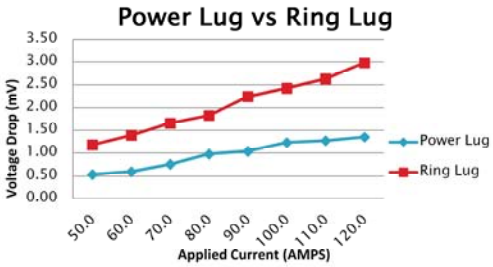
The PowerLug Technology offers lower resistance terminations when compared to a crimp terminal. In addition, if offers flexibility in its use and abilities to splice many wires. This technology utilizes the wire as a major component of the lug. The lug is formed around the wire conductors; therefore, the wire ends become the lug. When under a pull force test, the wire will break before the terminal fails.

PowerLug T-rise and Voltage Drop

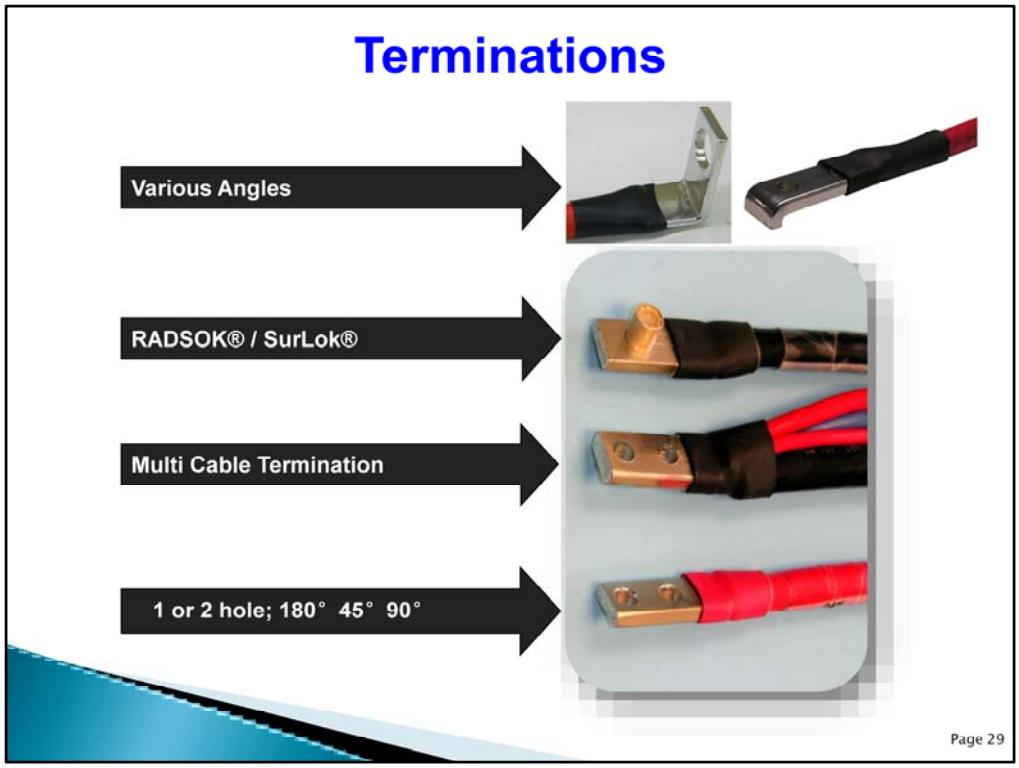
		POWER LUG		
Applied Current (A)	Ambient Temp °C	Measured Temp °C	Temp Rise °C	Voltage Drop (mV)
50.0	21.7	28.3	6.6	0.54
60.0	21.9	31.0	9.1	0.60
70.0	21.5	34.5	13.0	0.76
80.0	21.5	37.3	15.8	0.98
90.0	21.7	40.5	18.9	1.04
100.0	22.0	46.0	24.0	1.23
110.0	22.0	54.7	32.7	1.27
120.0	22.1	60.1	38.0	1.35

		RING LUG		
Applied Current (A)	Ambient Temp °C	Measured Temp °C	Temp Rise °C	Voltage Drop (mV)
50.0	21.9	31.2	9.3	1.18
60.0	22.0	34.2	12.2	1.39
70.0	21.7	37.9	16.2	1.66
80.0	21.6	42.4	20.5	1.83
90.0	21.9	50.6	28.7	2.25
100.0	22.1	59.8	37.7	2.43
110.0	22.4	70.0	47.6	2.63
120.0	22.4	75.3	52.9	2.98

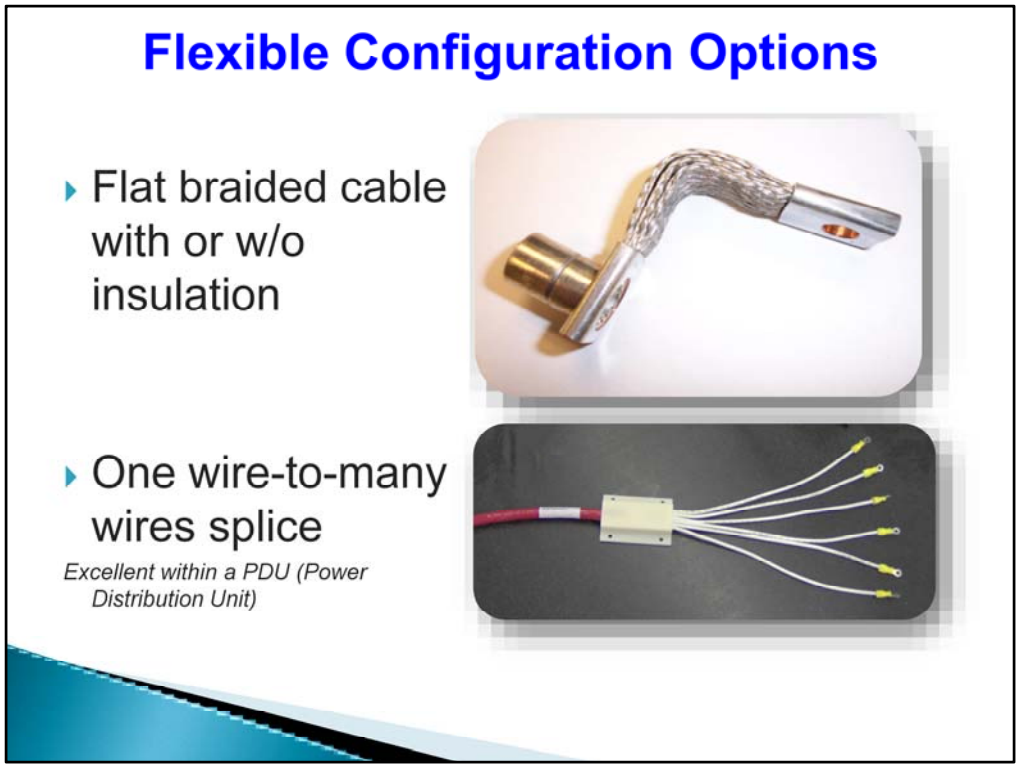




A study was performed utilizing the same wire AWG and comparable crimp terminal (two hole) and PowerLug (two hole). In general, there is approximately 25% improved resistance performance and this in turn, has lower T-Rise results. The use of the PowerLug allows considerations of smaller AWG cable for the application; therefore, increasing flexibility and reducing assembly size (easier routing).



The use of the PowerLug Technology is very flexible in its application. The lug can be bent into various angles. It can be modified as a two hole or one hole terminal. It can also be adapted for use with a Radsok socket or pin. But one of the key benefits is the Multiple Wire terminations either as a terminal or a splice. Unlike crimp terminals, multiple wire AWG's can be utilized. In addition, there is no limitation to the number of wires that can be terminated. The only limitation is the size, which can be very large.



Adding to the PowerLug's flexibility, it is not limited to the use of only round wires. Multiple flat flex braids can be utilized. This type of assembly is used in areas that need to minimize the transfer of vibration effects by isolating the end that is under vibration from the end that can not see any vibration. This allows the integrity of the connection to be maintained over time.

The benefit of terminating various AWG wires and quantities of wires is important. This allows for more flexibility of the design of the devise(s) and lower resistance of the connection.

Benefits

- Any Power Cable
  - The larger the wire gauge the better
- Robust / Reliable
  - Contiguous piece of copper
- Efficient
  - 25% less resistance than traditional lug
  - Lower Temperature Rise
- Shock and Vibration
- Space Saver
  - Multiple terminations within a single crimp
- Cost Effective


Busbars
Power Assemblies
THANK YOU!
Busbar Connectors
PowerLugs
Pin/Socket Connectors
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