



engineered to move

### Pamic Representing & DPG OHV Resistors



### **OEM Supplier**



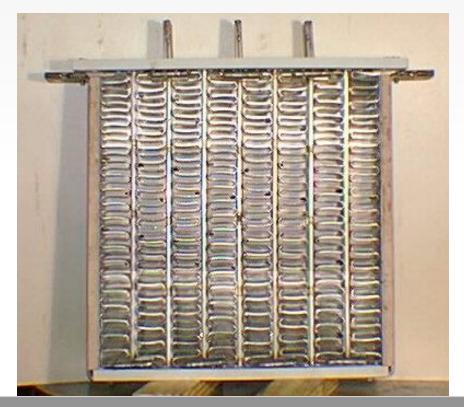
- DPG is the world leader in the design and manufacture of high powered dynamic braking resistors.
- DPG supplies 100% of OEM resistors for:
  - GE
  - CAT
  - EMD
  - Many Others

## GE DC System



 GE DC Traction systems originally used candy ribbon resistors. These are no longer

manufactured.



# GE DC System



 DPG currently produces H and K resistors for GE DC traction systems.





#### **H Series Resistors**



- Characterized by long resistive elements.
- More element material than candy ribbon resulting in lower temperatures.
- In use since 1992.



#### **K Series Resistors**



- Characterized by 2 sections of shorter resistive elements.
- More element material than H series resulting in lower temperatures.
- Designed for heavy duty applications such as in Chile.
- In use since 1998.



### Mixing Resistors



- Candy Ribbon, H Series, and K Series are identical in form and fit.
- Candy Ribbon, H Series and K Series should not be mixed in a stack because they affect airflow differently and hot spots will be created.

### **GE AC Traction System**



- DPG product made with GE owned tooling in a GE system
- GE controls:
  - Approval of design changes to the resistor
  - Aftermarket sales of the resistor

# Current DB System



- The GE DB system has some inherent weaknesses:
  - Horizontal airflow
  - Inadequate footprint
  - Insufficient air flow
  - Difficult to properly distribute air
  - Poor failure recognition/response

#### **DB** Failure Mode



Dominant failure
mode is baking out of
insulator resins
allowing elements to
move and touch.



Resistor pulled from loco in West Colton

### New "J" Resistor Approach



- New DPG "J" Grid design is a form, fit replacement that addresses failure modes of current product.
  - Current carrying portion of element has been moved away from insulators in an order to lower insulation temperatures.
  - Stronger element embossment resists warping even at temperatures well above operating conditions.
  - Elements spaced further apart, creates less backpressure on the fan (resulting in more flow) as well as creating additional insulation volume between elements.

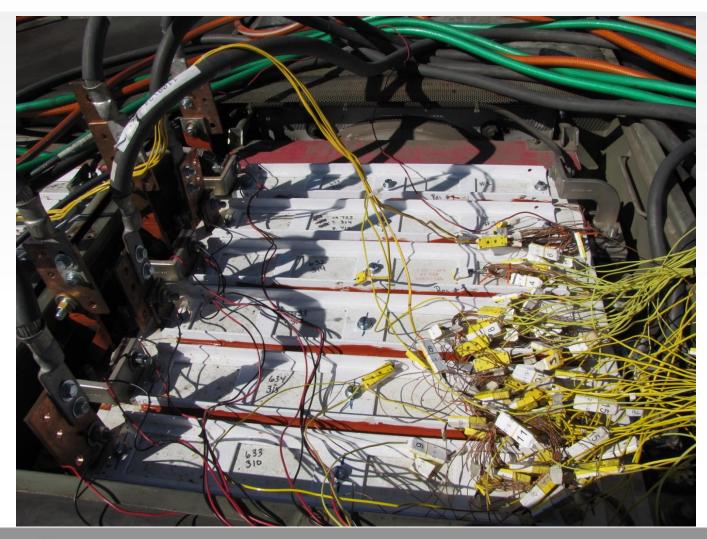
### New DPG Resistor Approach



- DPG owned tooling, allowing direct sales to all customers.
- Design also addresses secondary failure modes, and employs manufacturability and quality improvements.
- Design utilizing the same concepts and approach is also in place for the resistors used on GE DC locomotives.

### **GE** Resistor Test Stack





### Test Results Comparison



Maximum Recorded Insulator Temperature @ 100% Power (°F)											
	Resistor 1	Resistor 2	Resistor 3	Resistor 4	Resistor 5	Resistor 6	Ambient				
Baseline	163	213	292	417	452	485	67				
New Design	154	234	274	358	412	419	92				

- Maximum temperatures of new design approximate maximum temperatures of resistor 4 in baseline design (before adjusting for ambient conditions).
- This projects to a minimum of 100% increase in useful life.

#### Test Results – Mixed Stack



 A stack of resistors was tested which included baseline resistors in positions 1-4 and new resistors in positions 5 & 6 representing service replacement.

Maximum Recorded Insulator Temperature @ 100% Power (°F)											
	Resistor 1	Resistor 2	Resistor 3	Resistor 4	Resistor 5	Resistor 6	Ambient				
Baseline	163	213	292	417	452	485	67				
Mixed Stack	170	220	301	448	445	457	84				

 Mixing the resistor styles within the stack did not create any performance issues, however the improvements gained with a full stack replacement are no longer seen.

#### Conclusions



- New DPG design represents at least a 2x improvement over the current product when used as a full stack. Due to decrease in insulator temperatures alone.
- Current and new resistors can be mixed within a stack but reliability is not necessarily increased.

#### Recommendations



- In order to get full reliability improvement, complete stacks need to be changed to the new resistor design.
- Reliability improvements of new resistors will result in fewer failure opportunities, however shortcomings of system (horizontal airflow with grids near outlet plane, inability to quickly detect failures) are still present.