

2017 Haulage and Loading

Phoenix, AZ

DC to AC Haul Truck Conversion

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VP of Global Business Development

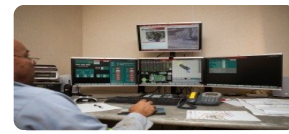


FLANDERS

Listen. Innovate. Serve.

Expanding Capabilities

- Continually building upon yesterday's success to serve customers' needs today and in the future



Advanced Technology
Products



New Motors



Drives and Controls



Service and Repair

1950

1970

1990

2010

2015

Future

FLANDERS

Why Upgrade to AC?

- Increased productivity with a 33% higher top speed
- Elimination of maintenance associated with DC motors
- Improved on-board diagnostics
- Enhanced safety with traction control
- Extend the life of the DC truck with robust mechanical components

DC Truck Baseline

- DC truck available for conversion
- One of the first 830E's ever built
- Review performance data and formulate upgrade specifications
- Truck was moved to KY for closer proximity to Flanders HQ
 - New power unit

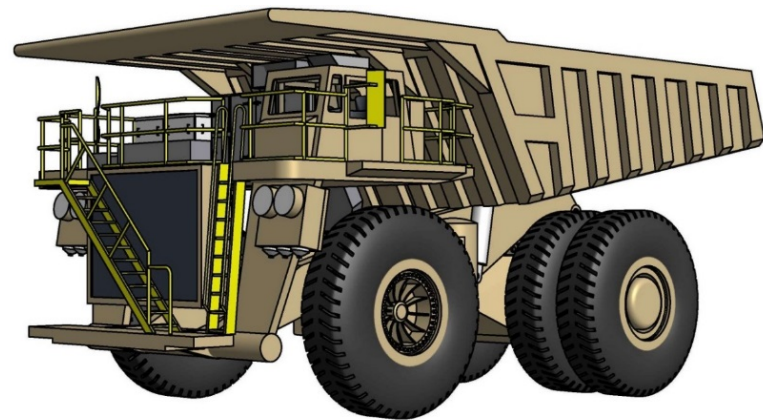


DC Controller is Replaced with AC Controller

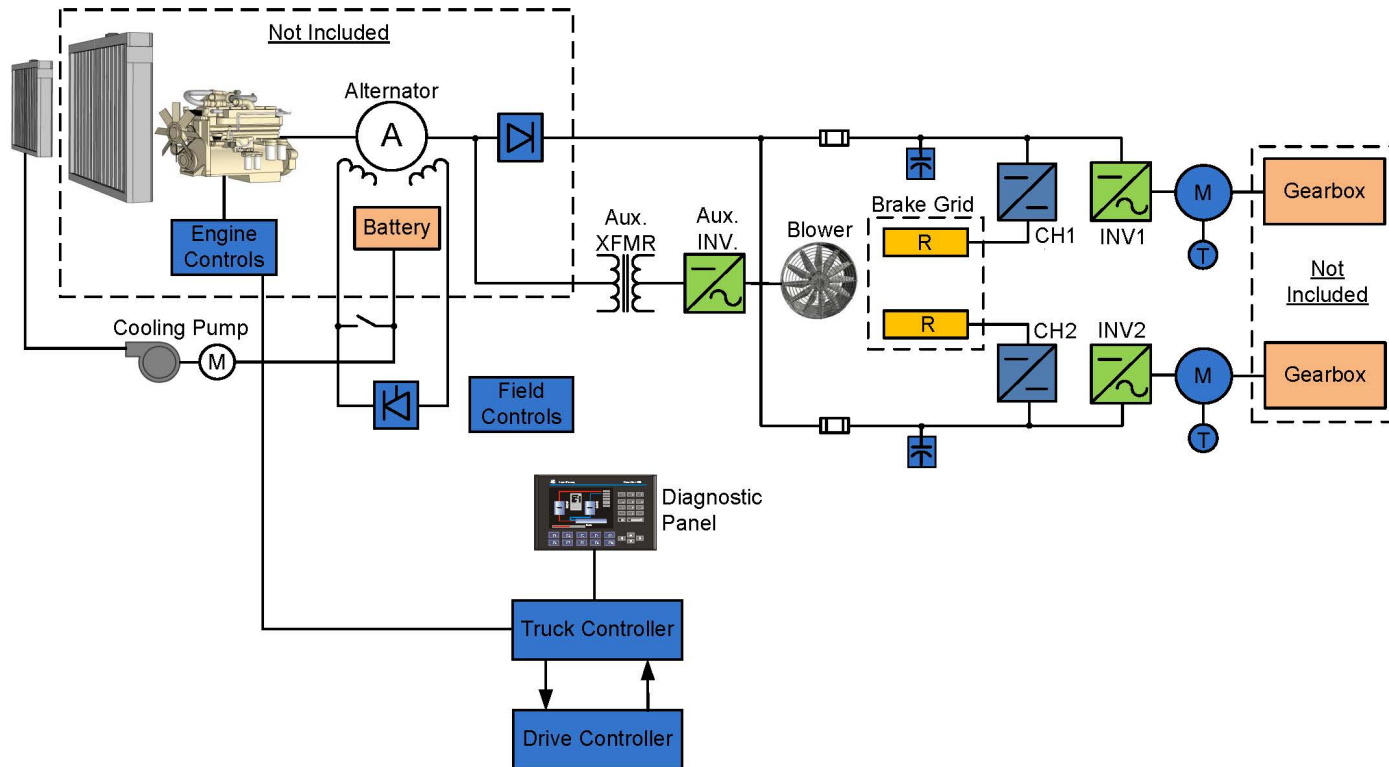
- Open architecture design
- Liquid cooled drive provides for dust free sealed power components
- Separation of power and control reducing arc flash exposure
- Retain the same DC system alternator
 - New alternator voltage regulator
- New enclosures

DC Controller is Replaced with AC Controller

- Front wheel speed sensors
- Limited slip traction control
- Independent torque control of motors
- Shop mode

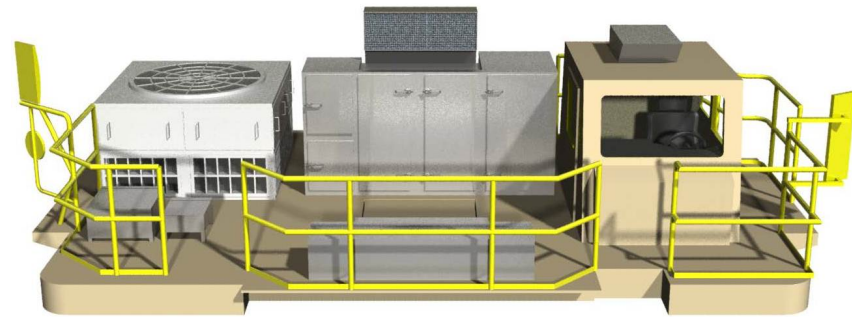


System Component Overview

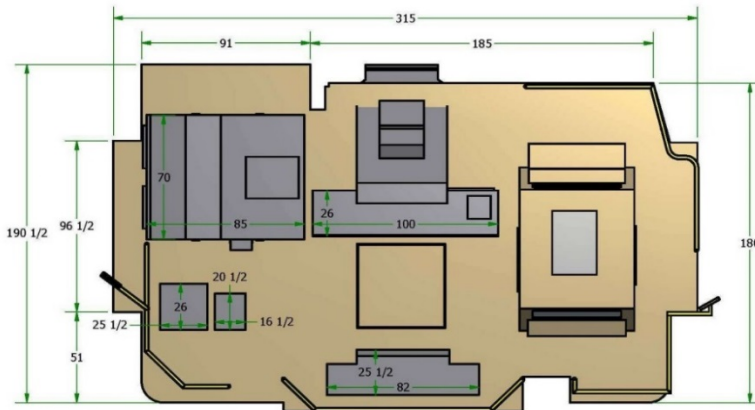


FLANDERS Upgrade Components

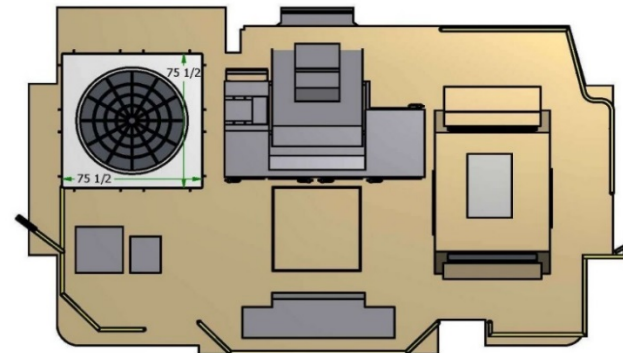
- DC wheel motors are replaced with FLANDERS designed AC wheel motors; the gearboxes are re-used
- DC controller is replaced with AC controller
- Digital displays
- New wiring harness



Deck Layout



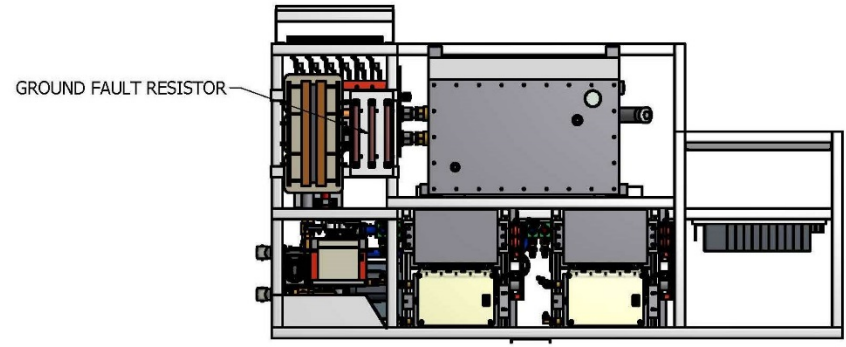
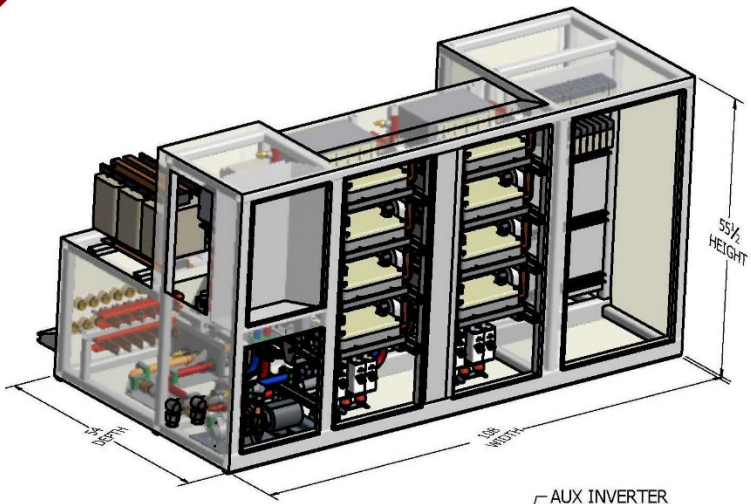
DC DECK PLAN VIEW



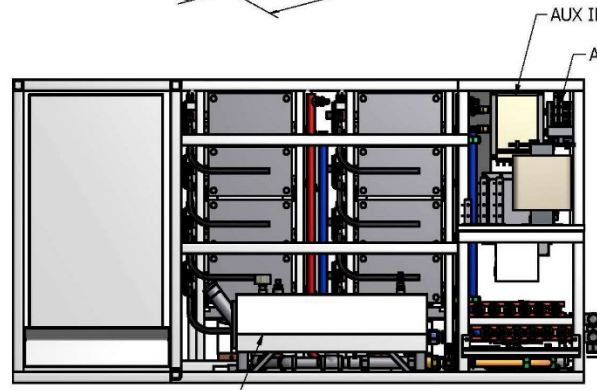
AC DECK PLAN VIEW



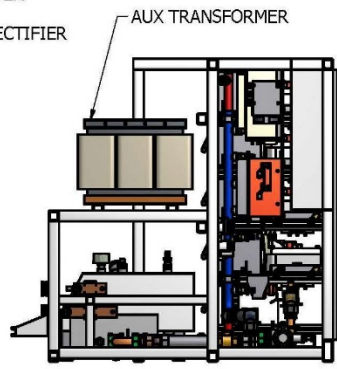
Control Enclosure



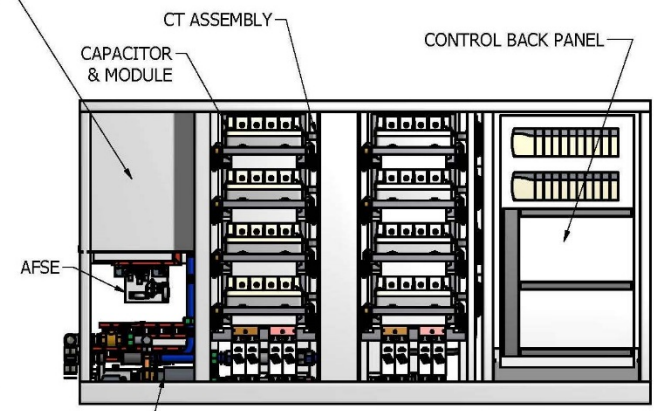
TOP VIEW



RESERVOIR BACK VIEW



LEFT SIDE VIEW

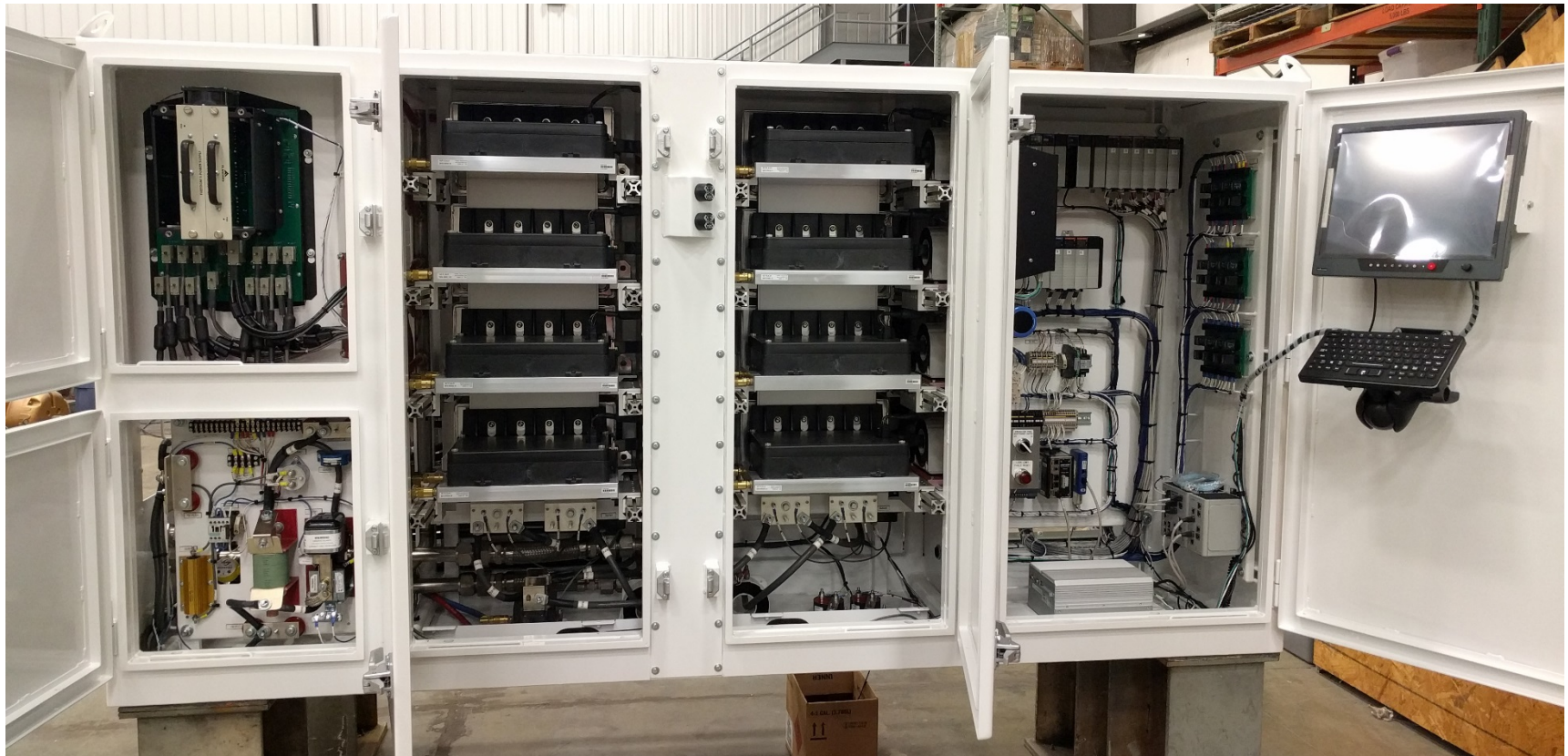


FRONT VIEW

Interior View of Control Enclosure

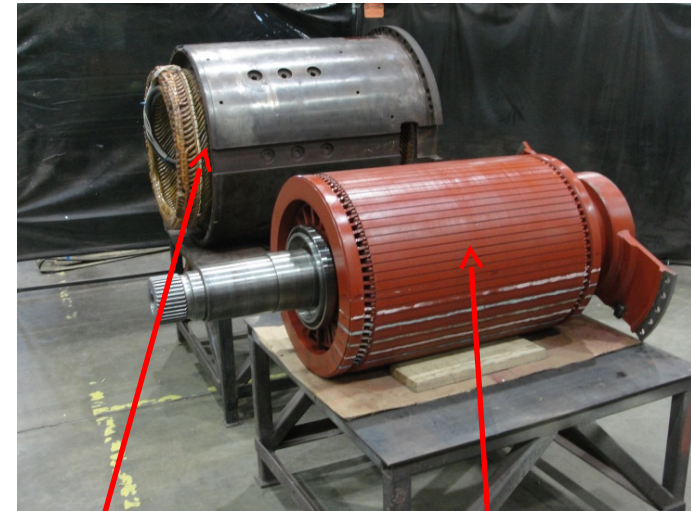
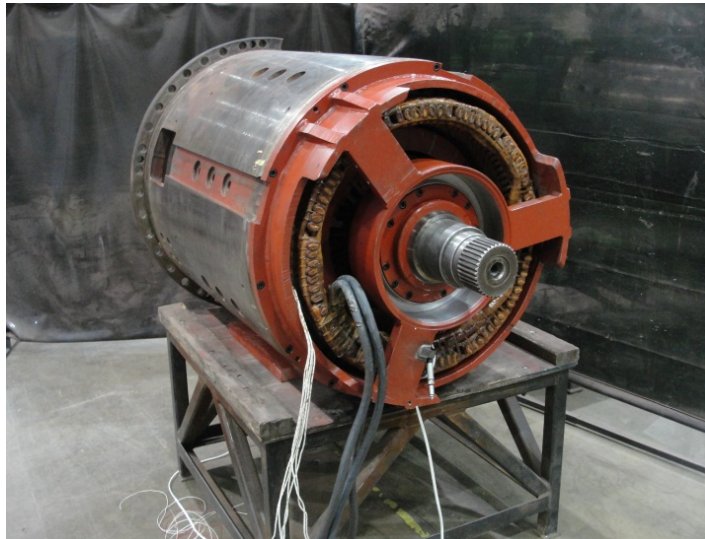


FLANDERS AC Control Enclosure



DC Wheel Motor Replaced with FLANDERS Designed AC Wheel Motor

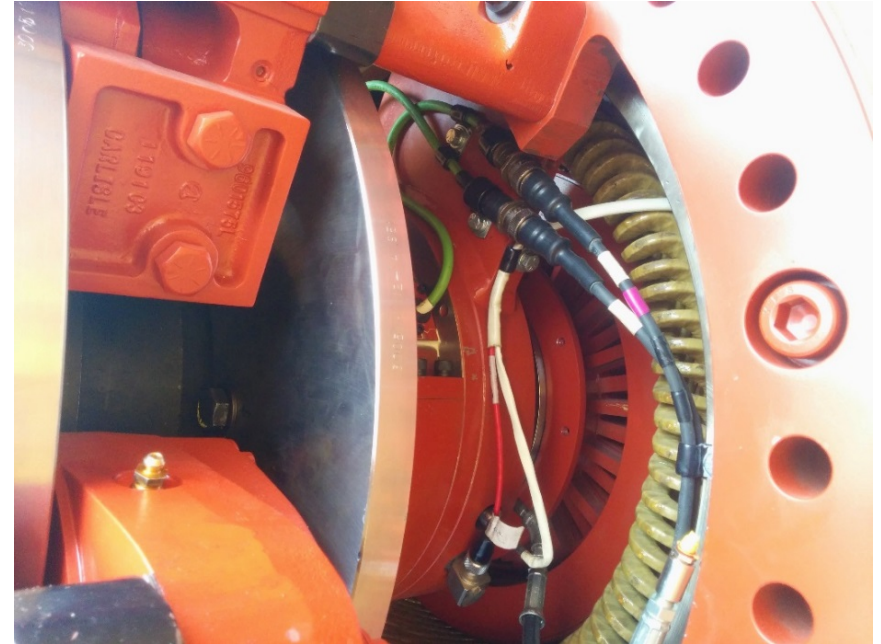
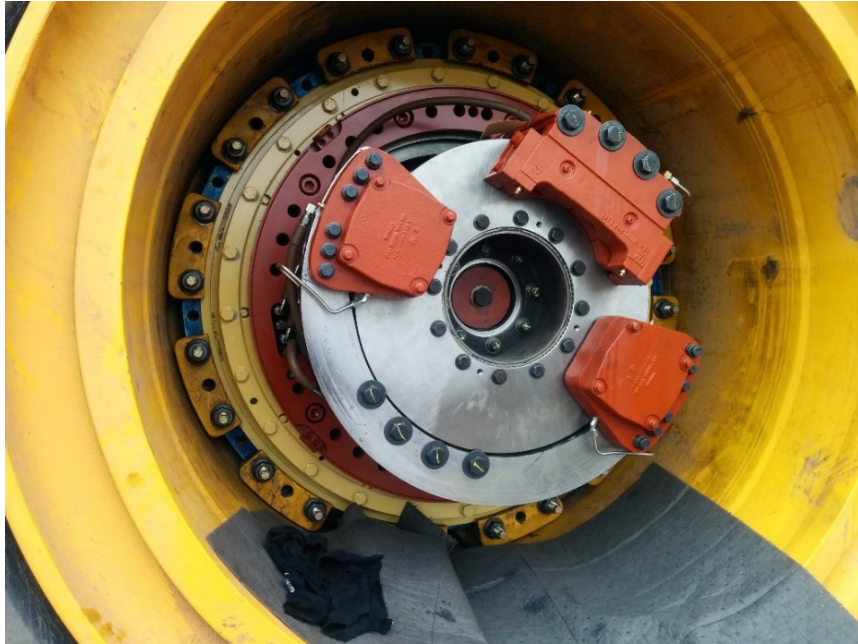
- Reduced maintenance
- Commutation issues eliminated
- 30% higher speeds
- High efficiency motors
- Equipped with RTDs on windings and bearings
- Equipped with vibration sensors on bearings



**Field frame
with stator core
assembly**

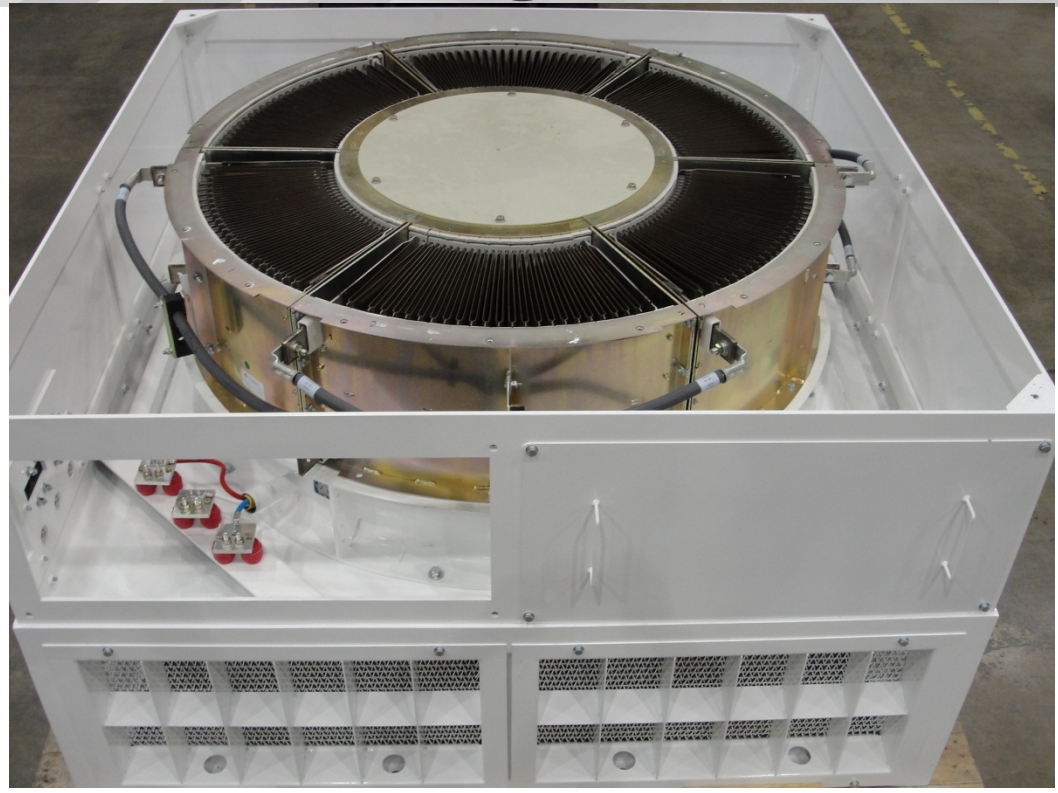
**Rotor core
assembly and
shaft**

FLANDERS AC Wheel Motor



Improved Dynamic Braking

- Grid resistor bank and blower replacement
- AC blower motor with independent inverter control
- Dynamic braking to zero speed
- Independent grid matched to each motor



Dynamic Braking Grid



- Operator feedback indicated that grid is quieter than OEM design

Operator Interface Before



Glass Dash



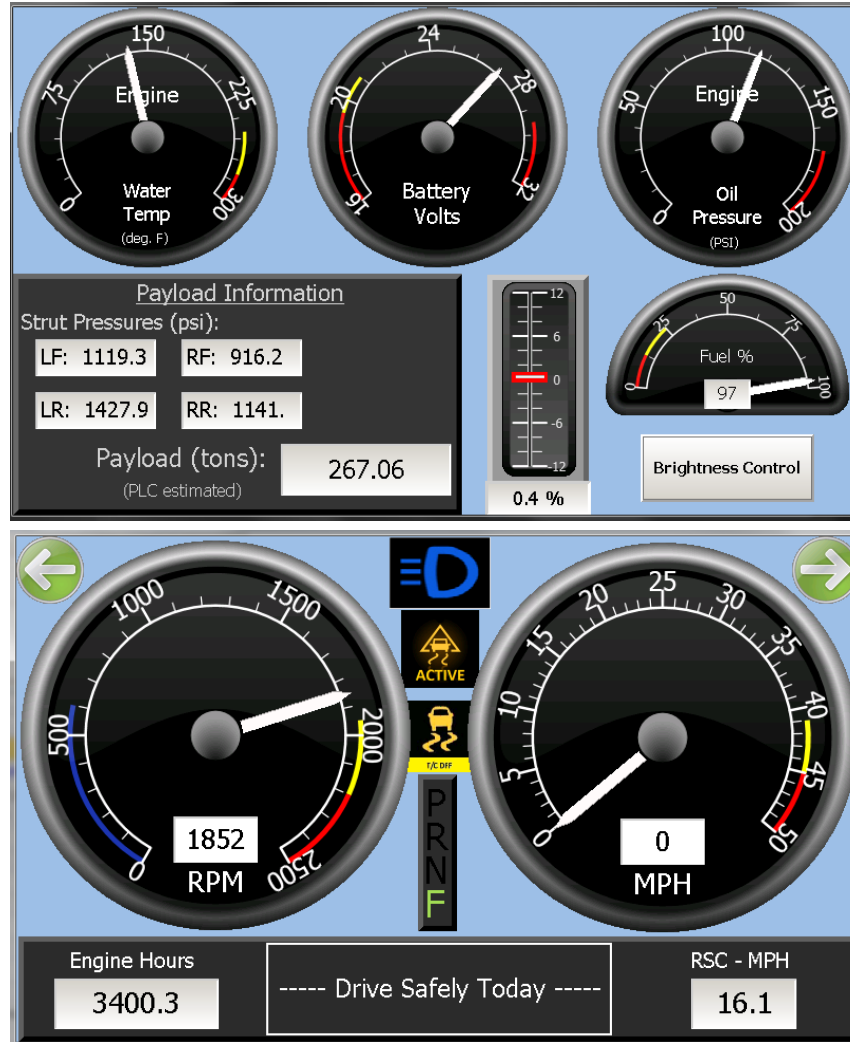
Glass Dash



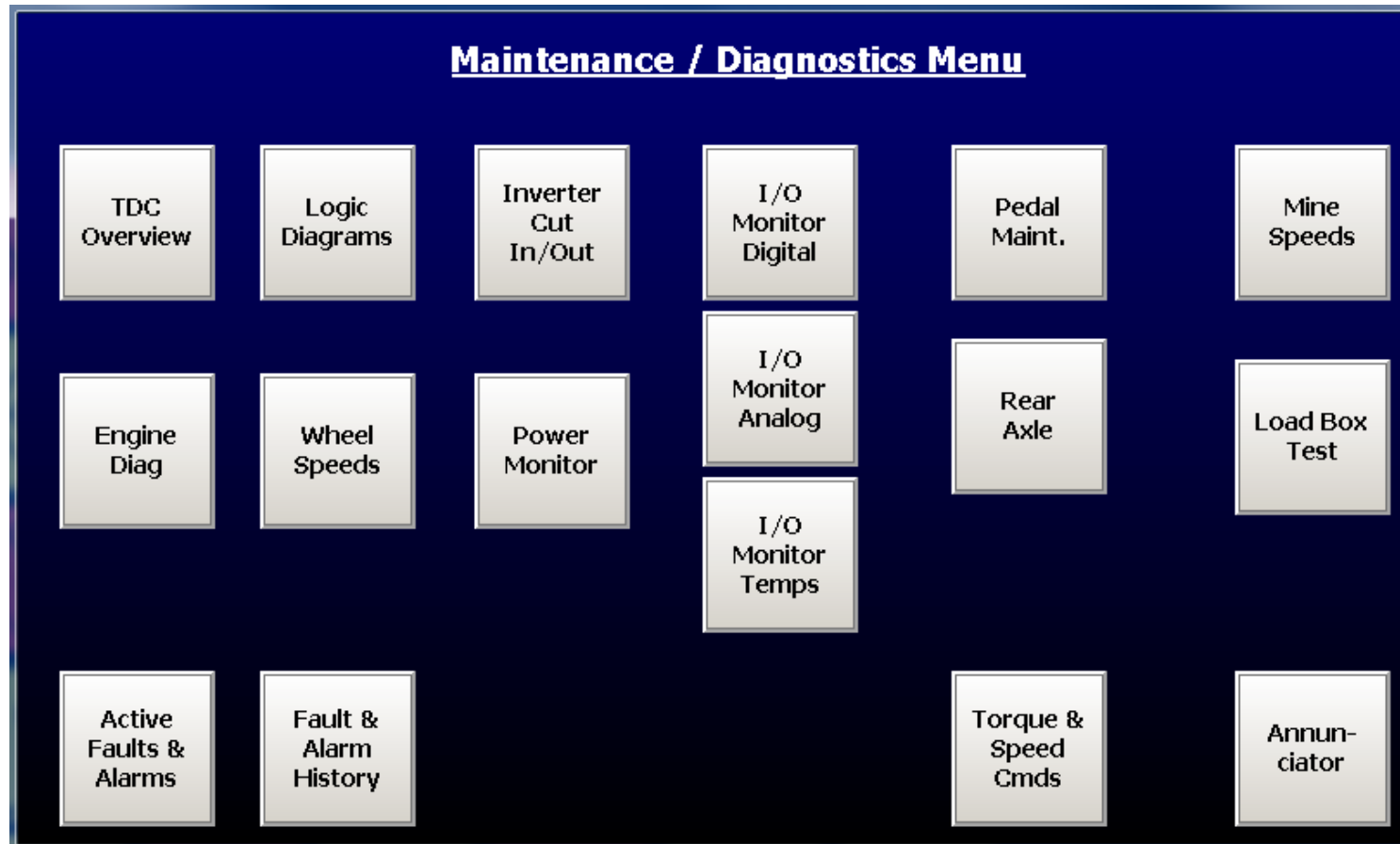
Glass Dash



Operator Interface Digital Displays



In Cab Diagnostics



On Board Diagnostics



On Board Diagnostics

Command Help

Truck 251

System Overview

Alarms: 12
Faults: 11

FLANDERS

Overview

Sys Test Menu

Engine Info

Maintenance Menu

Logic Diagrams

TDC Status

Trend Menu

Event Viewer [F8]

Alarm Viewer [F7]

Back
[ctrl-bkspc]

1:40:12 PM

user

Torque CMD

60 %

Truck Speed

0.4 mph

Truck Modes

READY

Accel OK

Retard OK

Using RSC

Hill Hold

LOAD BOX

BRAKE TE...

Brake Status

Brake System: OK

Park Brake Applied

Brake Lock SSW

Brake Lock Applied

Service Brake Appl...

Retard Pedal Press...

Battery Volts

-0.94

Wheel Motors

Speed (rpm)	0
Amps	0
Torque (%)	0

Engine Status

Command: 0 rpm

Speed: 0 rpm

0 HP

Engine 3.3

Cooldown sec. remaining

Boost Pressure	0
Intake Temp	93.6
Exhaust Temp	223.8
Coolant Temp	205
Oil Pressure	127
Oil Temp	147.3

Engine Hours: 117.5

Caution
Warning

Traction Drive Controller

TDC1		TDC2	
DC Bus Volts	0	0	0
DC Bus Current	0	0	0
IGBT Temp (C)	0	0	0

TDC Speed Ref. 0 mph

rpm 0

Rest Mode OFF

Cooling System

Level Low Temperature 328 °F Flow ●

Low Flt

Wheel Motor Temperatures

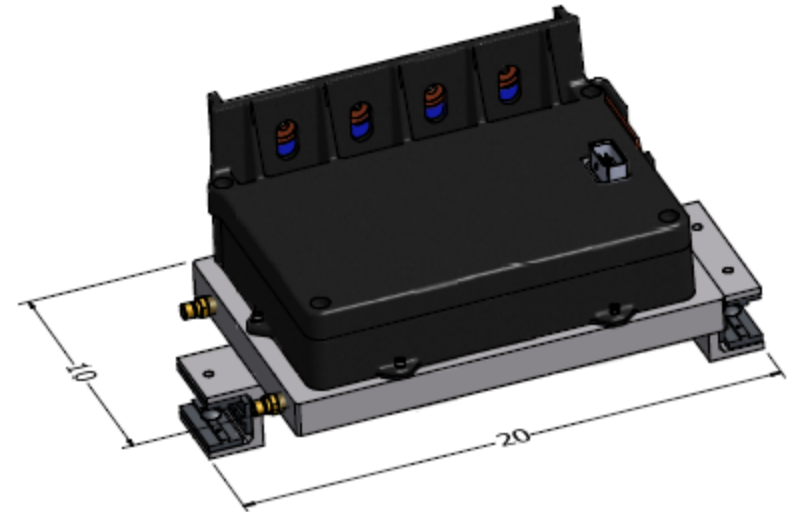
Bearing DE	84.2 °F
Bearing ODE	81.6 °F
Winding	84.5 °F

AC System Validation

- ISO 3450 service brake test
 - 10% grade, fully loaded
- Motor heat run
 - 220°C motor insulation rating
 - Shop test and empirical truck testing
- Thermal verification of drive system
 - Testing in the shop
 - Testing on the truck in hot and cold environments

AC System Validation

- Temperature sensors on each power module heat sink
 - Thermal model within the drive to protect from high power transient overloads



APPROX. WEIGHT = 42 lbf

AC System Validation

- Tested against an OEM AC Truck
 - FLANDERS met or exceeded the current AC truck performance
- List of tests completed:
 - Acceleration up 8% grade
 - Deceleration down 8% grade
 - 0-40-0mph loaded and unloaded runs
 - Max retard speed control capability
 - Gearbox vibration

Conclusion

- FLANDERS system upgrade met all performance requirements
- System is now available for delivery, including a FLANDERS flexible commercial innovation package
- ROI is optimal for mines running a mixed fleet of AC and DC trucks
- Minimal downtime for conversion dependent on truck condition



Questions?

