



GOODRICH

**DEVELOPMENT OF AN ELECTROTHERMAL
ICE PROTECTION SYSTEM
FOR WIND TURBINE APPLICATIONS**

IWAIS Conference

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Goodrich Corporation

right attitude / right approach / right alongside
www.goodrich.com



GOODRICH

- Who is Goodrich?
- Goodrich Aerospace Ice Detection / Protection Capability Overview
- Goodrich Ice Detector Principles & Evolution
- Goodrich COST-727 Involvement
- Goodrich Model 0872N1 Development
- Goodrich Electrothermal Heater Assembly Technology
- Goodrich Heater Assembly Test Set-Up
- Goodrich Heater Assembly Testing Results
- Goodrich Heater Assembly Testing Conclusion
- Goodrich Heater Assembly Next Steps

SIS-Minnesota



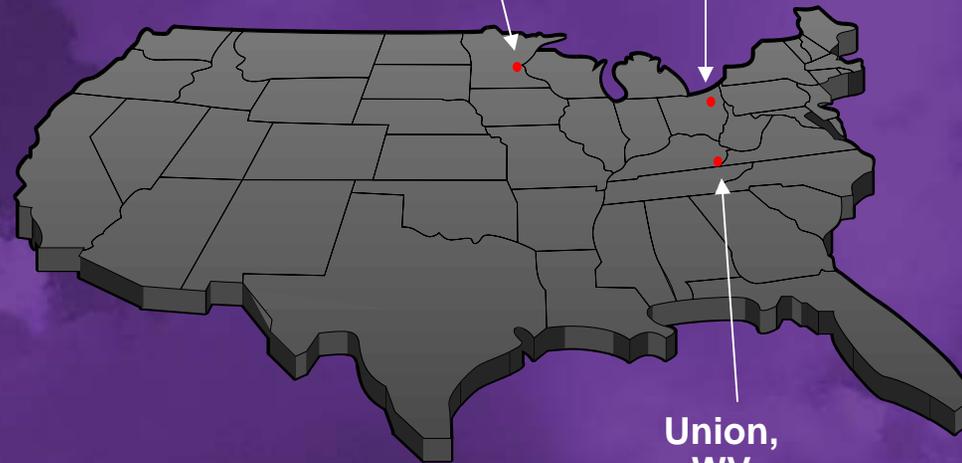
Burnsville, MN
877 employees
243,000 sq. ft.



Eagan, MN
268 employees
64,000 sq. ft.

Burnsville /
Eagan, MN

Uniontown,
OH



Union,
WV

SIS-Ohio



Union, WV
330 employees
140,000 sq. ft.

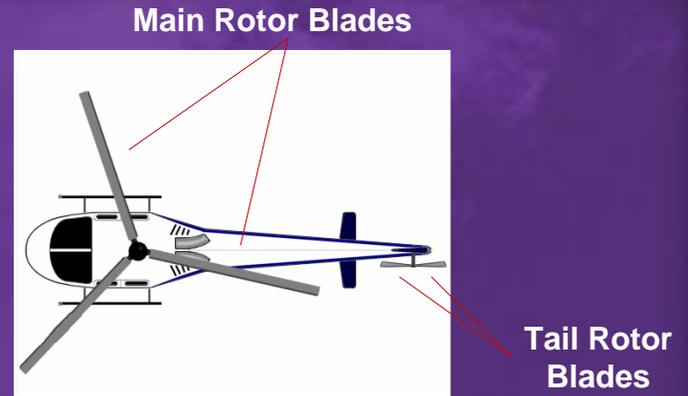
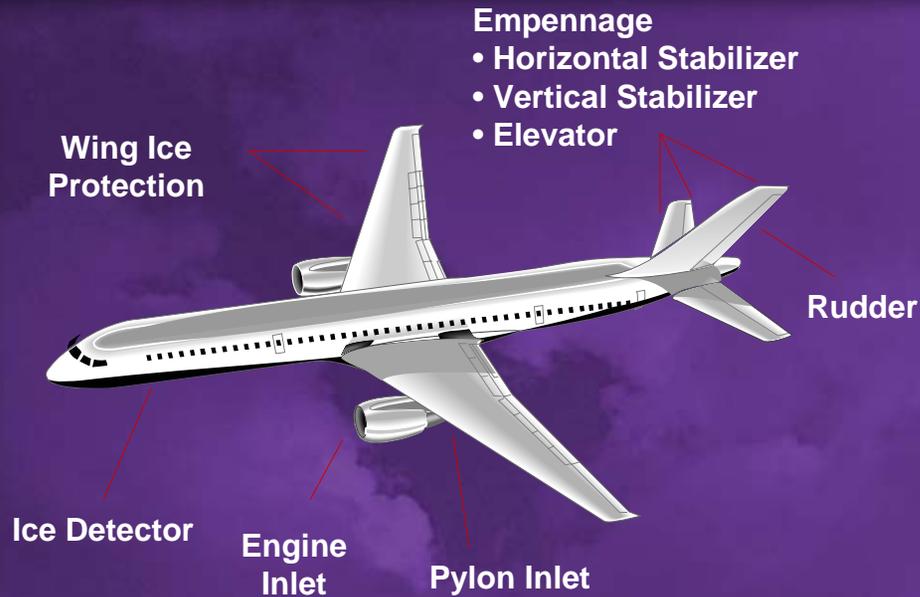


Uniontown, OH
99 employees
48,000 sq. ft.

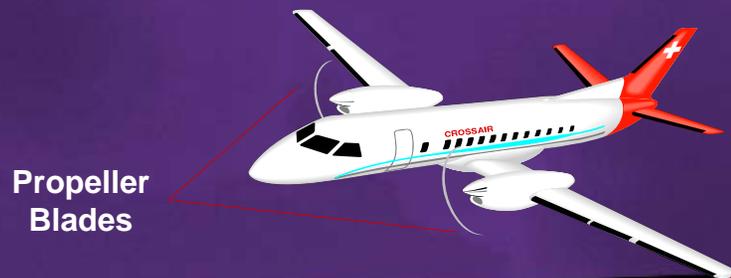
Over 90 locations & 24,000 employees world-wide



- Goodrich (Rosemount) 40+ year history of providing high accuracy ground based sensors
 - Anemometers
 - Ice detectors
 - Freezing rain detectors
- Goodrich (De-Icing & Specialty Systems) 75+ year history of providing ice protection systems
 - Pneumatic Systems
 - Structural Composites
 - Electrothermal Systems
- Long history of working with North America Meteorological Organizations
 - NASA
 - NOAA
 - Environment Canada
 - US Air Force
- Goodrich specializes in specialty heated instruments and integrated system solutions



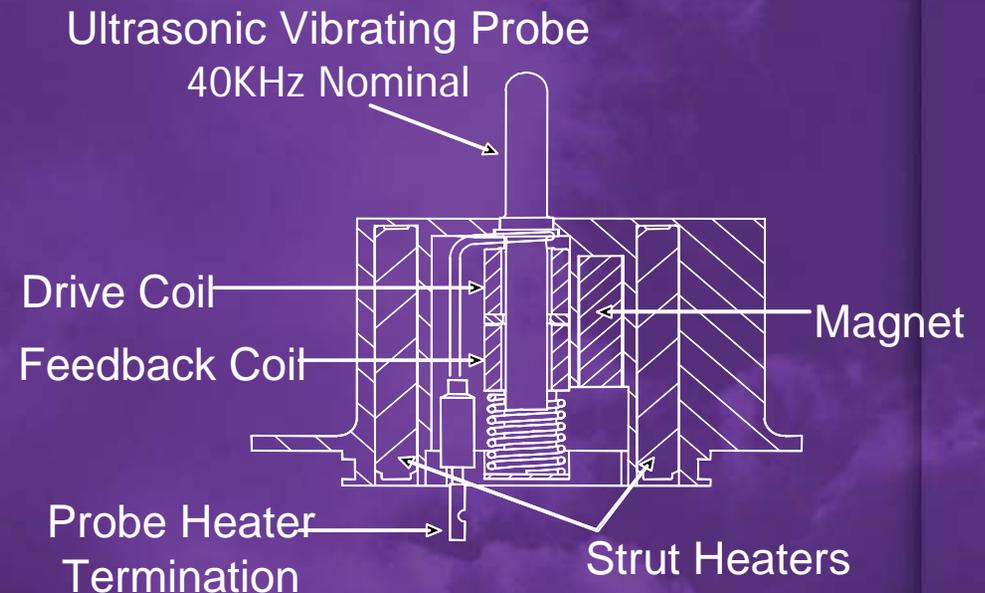
Ice Detector

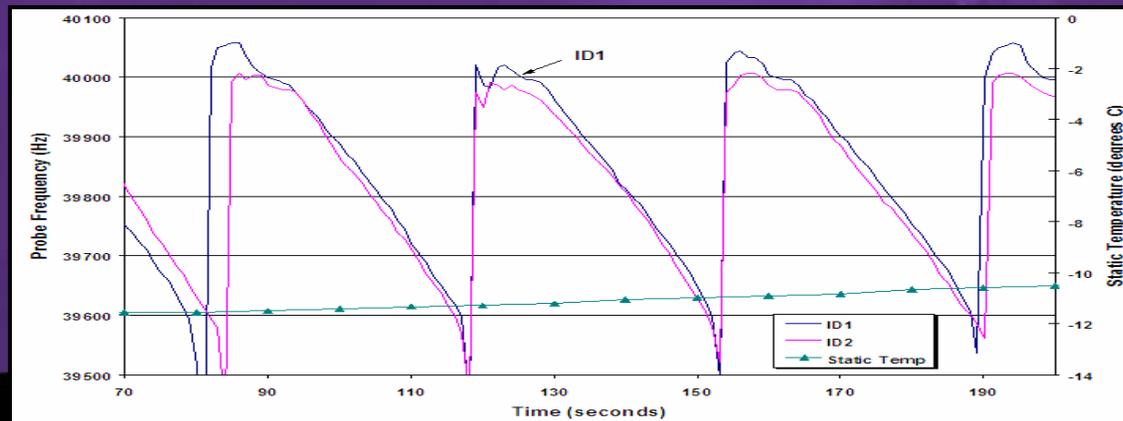
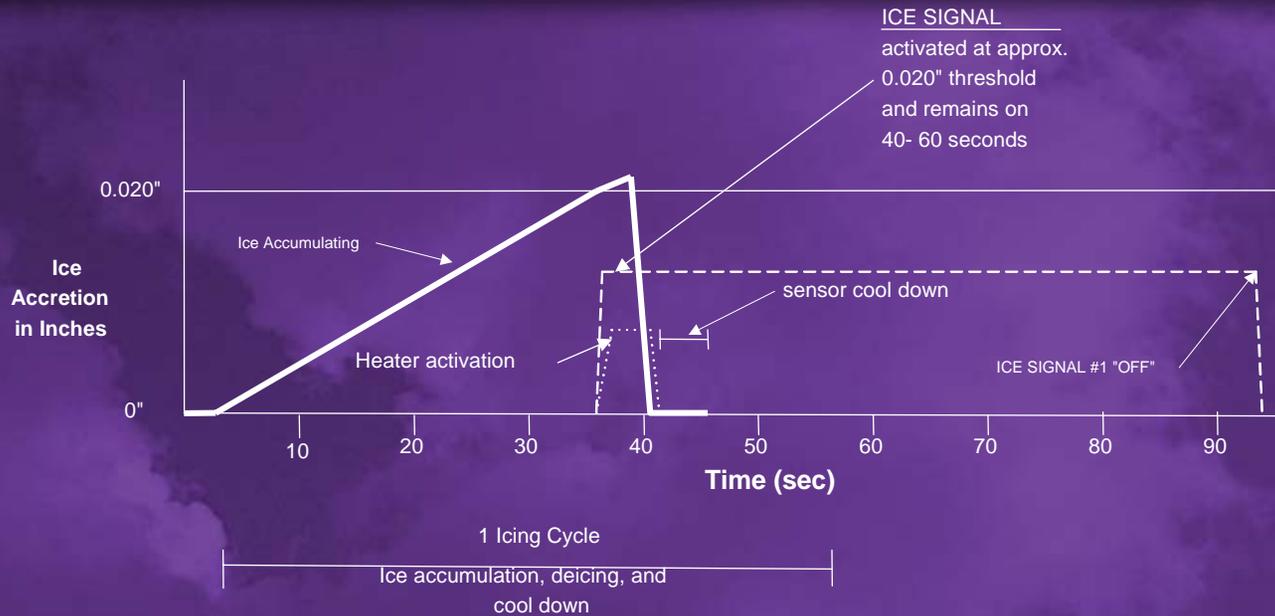


- Goodrich is a World Market Leader in Ice Detection Systems
 - Over 5,000 ice detectors produced on an annual basis
- Over 40 years In-Service Experience on over 100 aircraft and numerous wind turbines, radio towers, AWOS/ASOS stations, etc...
- Ice Detectors certified by FAA/EASA, Military and UL/CSA/CE
- Goodrich Ice Detection Technology Advantages:
 - Accurate Detection and low false alarms
 - Solid De-icing Capabilities
 - Robustness (Vibration, Temperature, EMI, etc...)
 - High Reliability
- Various Ice Detection Technologies Available
 - Magnetostrictive (most common)
 - Thermal Icing Conditions Detector
 - Optical Ice Detection
- Capabilities Include:
 - Ice / No Ice
 - Icing Rate and LWC Measurements
 - Liquid Water / Ice Crystal Differentiation



- The Goodrich Ice Detector probe and electronics are tuned to resonate at approximately 40 KHz.
- The probe is made of a magnetic material and is forced to resonate at its natural frequency by magnetostriction.
- Magnetostriction is the ability of certain materials to expand or contract in the presence of a magnetic field.
- As ice accretes on the probe, the resonant frequency reduces due to the added ice *mass*.
- Reduction of the probe frequency below a predetermined threshold causes the ICE signal to be activated and the strut and probe to be deiced.







0872DE Family

Ground Turbine Engines

Rugged Environment
Analog I/O Interface

0872CE
0872DE



0872C3 Family

ASOS/AWOS
Met Stations

Improved Detection Near 0°C
RS-232 Digital Comm

0872C3
0872E3
0872F1



8204A Family

Power Lines
Roads/Bridges

IR Optical Technology
Differentiates Water / Ice

8204A



0871LH Family

Wind Turbines

Low Power Deicing
Discrete I/O, RS-422

0871LH1
0871LP1



0872N1 Family

Radio Towers
Met Stations
Wind Turbines

Severe Environment
Improved Deicing
Discrete I/O, RS-422

0871CB1
0872B12
0872J1
0872N1



- Goodrich has donated Model 0871LH1 ice detectors to COST-727
- Model 0871LH1 was developed and designed for low power applications and light duty icing (i.e. wind turbines)
- Preliminary COST-727 test results indicate:
 - LH1 model detected ice well under most environments
 - Some deicing problems experienced with no strut heater
 - Validated the market need for a more robust ground based ice detector
- **Proposed Improvement / Solution**
 - Implement Model 0872N1 for severe environments
- Goodrich intends to actively review/monitor Model 0872N1 performance and incorporate improvements as necessary during the next COST Action



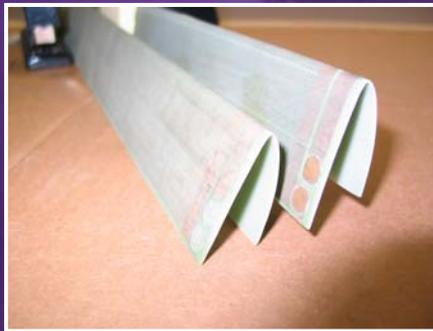
- Replaces Goodrich Model 0871CB1, 0872B12, and 0872J1
- Potential Applications
 - Meteorological Stations
 - Wind Turbines
 - Radio/TV Towers
- Features:
 - **2 Ice and 1 Fail Outputs**
 - Capable of Driving Relays
 - **Robust BIT Testing**
 - Power-Up, Initiated, and Continuous
 - **Full De-icing capability (both strut and sensing probe)**
 - Approx. 300W power, 115 or 230 VAC versions
 - **RS-422 Serial Output**
 - Probe frequency, Heater and Ice/Fail activation, Failure history
- Two units provided to Meteotest for 2009-2010 winter testing
- Safety, Performance and EMI Certification testing (UL/CSA/CE) to be completed by end of 2009



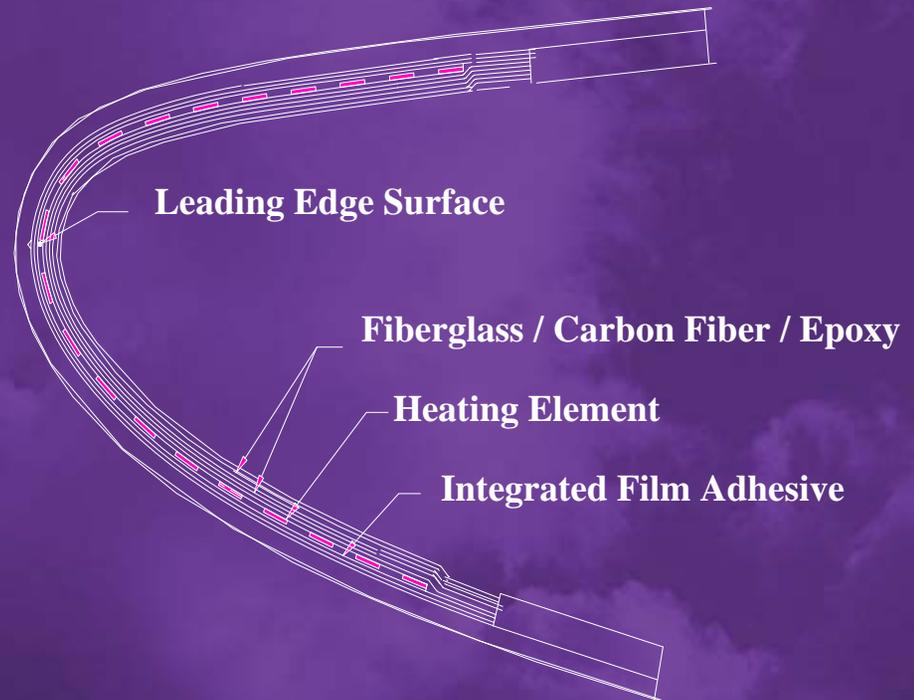
Goodrich has over 40 years experience integrating electrothermal IPS technologies with various structures



- **The technology behind the Goodrich Electrothermal Heater Assemblies consists of:**
 - **Elastomeric**
 - Flexible heater assemblies with elastomeric insulation
 - **Metal Clad**
 - Heater assemblies insulated with plies of fiberglass/epoxy and protected with a metallic outer cladding
 - **Anti-Icers**
 - Heater Assemblies that prevent the formation of ice on a protected surface
 - **De-Icers**
 - Heater Assemblies that cyclically removes ice from a protected surface
 - **The Wind Turbine Blade Electrothermal Heater Assemblies may utilize both Ant-Icer and De-Icer technologies**
 - **Heaters can be integrated into composite structures**

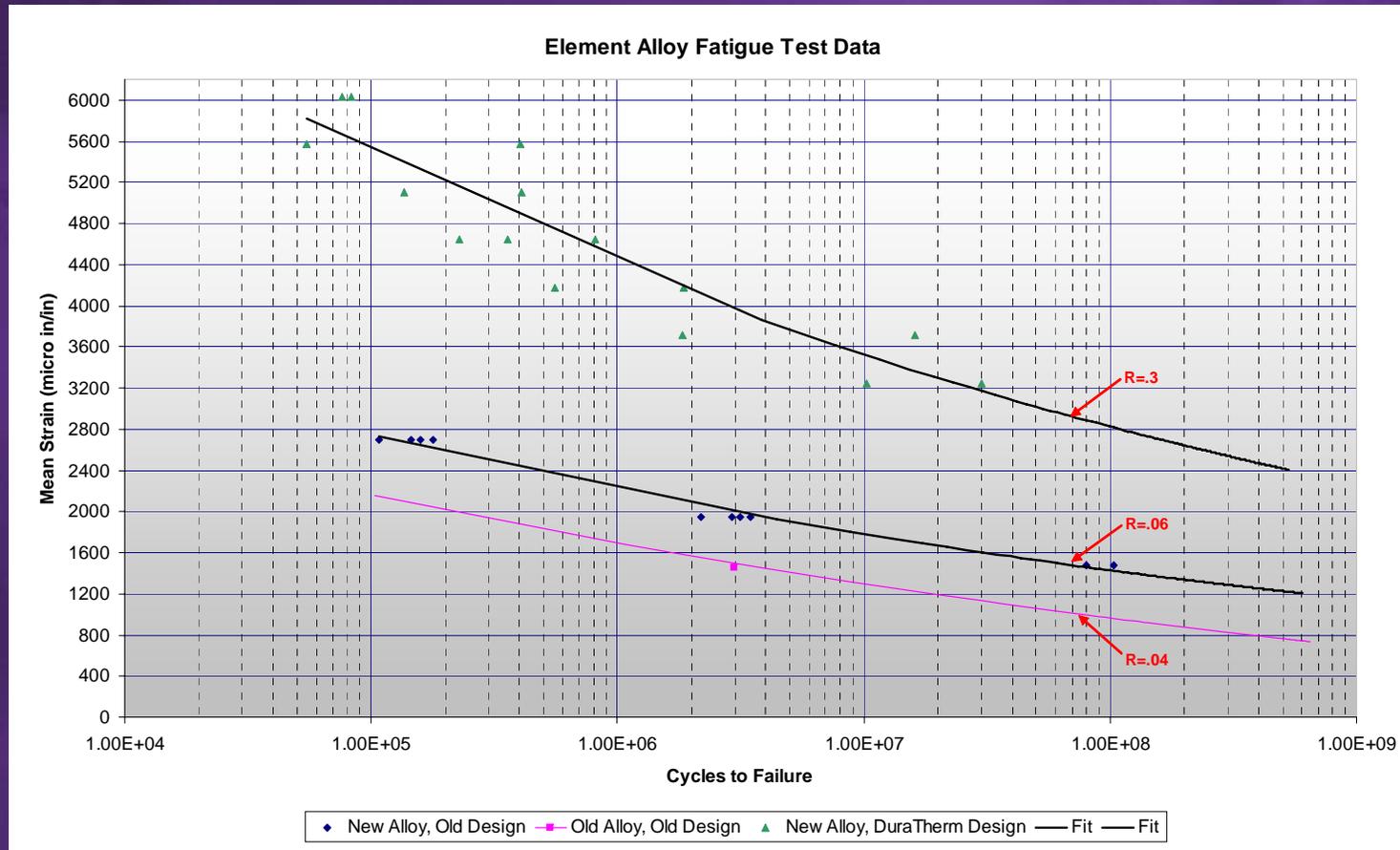


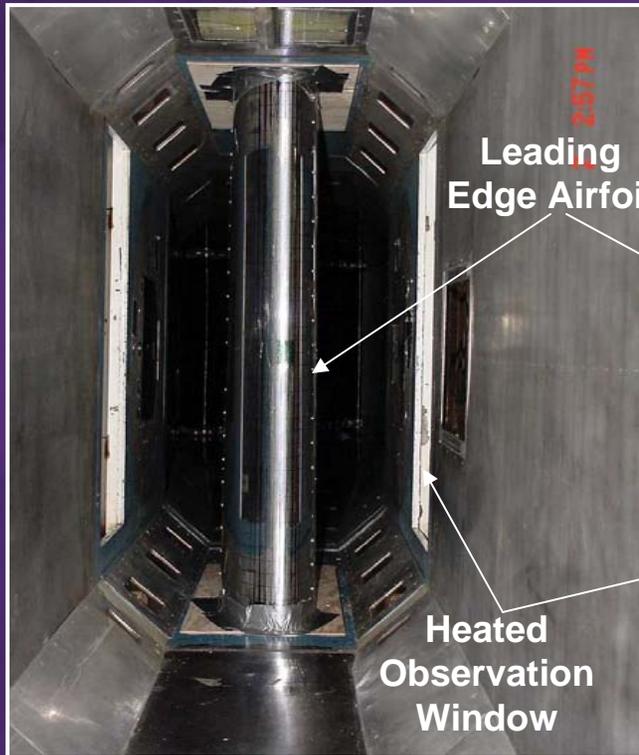
Electrothermal Heater Assembly Samples



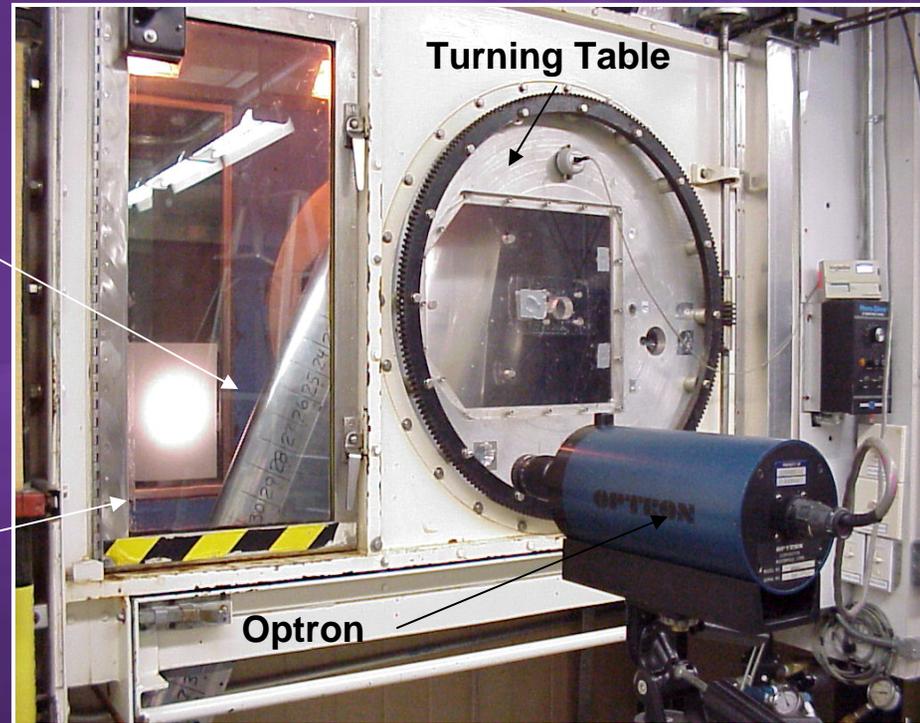
Electrothermal Heater Assembly Cross-Section

Standard Heater Element: New vs. Old Alloy Fatigue Strength





Icing Wind Tunnel
– Forward Looking (Spray System) View



Icing Wind Tunnel
– Side View

Simulated Wind Turbine Blade Test

- Hybrid Electrothermal System
 - De-icing and Anti-icing
 - Composite leading edge structure
- Leading Edge with 0.050" - 0.020" (1.27mm – 0.508mm) Gelcoat
- Tested at -4°F (-20°C)



[IWT Heater Assembly Video](#)

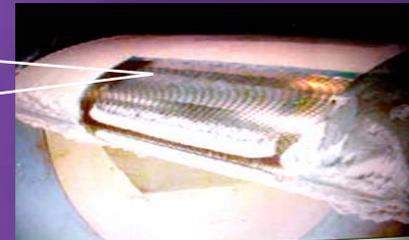


ET+LVB_-22F_.53LWC_150MPH_5min

Note Parting-Strip area... here on stagnation zone



1 Second after "cycle" activation



2 Seconds...
- Ice shedding in small pieces



3 Seconds...
- All ice removed



- The electrothermal system produced successful icing wind tunnel test results
- Ability to Shed Ice Very Thin
- Graphite heater assembly tested for 1,000,000 temperature endurance cycles
- Electrical connections tested for extreme temperature from -200°F (-129°C) to $+300^{\circ}\text{F}$ (149°C) without degradation
- Heater Assembly reliability in order of 1 failure per 500,000 flight hours

- **Goodrich electrothermal heater assembly technology has been installed on various rotorcraft and engine propellers with proven performance and reliability**
- **Goodrich aerospace Ice Protection Systems can be converted to wind turbine applications**
- **Goodrich extensive experience in ice protection development provides unique capabilities to minimize project risk**
 - **Internal test facilities:**
 - Icing Wind Tunnel
 - Rain Erosion Facility
 - Advanced Ice Testing methods
- **Goodrich provides complete integrated solutions for ground based applications**
 - **Ice Detection, Ice Protection and Heath Monitoring Systems**

- Development of Model 0872N1 harsh weather ice detector
- Development of cost effective Ice Protection System (Heater assemblies, controllers and wiring integration)
- Looking for the right Ice Protection System collaboration for near-term and future ground based test platforms and applications

- For more Information
- Visit the Goodrich Website: www.goodrich.com
 - Business Segments
 - Capabilities
 - Literature
 - Product Overviews
 - Pedigree

QUESTIONS ???