



De-icing and Specialty Systems Division

COLD CLIMATE - ICE PROTECTION SYSTEM
for
WIND TURBINE APPLICATIONS

WEST VIRGINIA WIND ENERGY SYMPOSIUM
Sept 23 and 24, 2003





History

*Founded in 1870 by
Dr. Benjamin Franklin Goodrich.*

*Today's Goodrich is
a different company
than Dr. Goodrich
could ever have
imagined--different
than most people
today imagine.*





De-icing and Specialty Systems Division

Uniontown, OH



De-Icing & Specialty Systems Division Headquarters

Engineering/Administrative Offices and Laboratories

Product Development Center: Materials, Pneumatics & Electronics

Icing Wind Tunnel





De-icing and Specialty Systems Division

Union, WV - Facilities & Statistics



Facility Statistics:

- ◆ 107,000 ft² Mfg. 15,000 ft² Office
- ◆ Manufacturer - Pneumatic Deicers, Heated Composites, Electronics & Specialty Heated Products
- ◆ Purchasing, QA, Scheduling, Mfg., Eng., Accounting & Information Technology resident
- ◆ ISO 9001 Certified

Demographics

- ◆ Total Number of Employees: 213 Wage, 77 Salary
- ◆ Average Years w/Company: 16
- ◆ Average Years Experience: 23
- ◆ Average Age: 44 years old
- ◆ Average Qualifications: Job Experience, Technical & Vocations Training, Engineering Degree



Total Ice and Freeze Protection Capability



- **Aerospace Leader in Pneumatic De-icing System**
- **Over 70 Years Experience**
- **Thousands of De-icer Designs in Operation Worldwide**
- **Proven Technology and Low Risk Development**
- **Integrated / Embedded or External Installation**



Pneumatic De-icing Components

- ✦ **Pneumatic De-icers**
- ✦ **Microprocessor Controller**
- ✦ **Distributor Valves**
- ✦ **Check Valves**
- ✦ **Shut-Off Valves**
- ✦ **Water Separators**
- ✦ **Regulators**



**Airfoils and
Blades Protection**



PNEUMATIC DE-ICING SYSTEM

Wind Turbine Application

Test Program

- Test Set Up Simulating 750 kW to 1.5 MW Wind Turbines
- Pneumatic Components and Electronic Controller Developed and Tested
- Phase I and Phase II - Performance Feasibility - Concluded
- Phase III - Ice Removal Optimization - Field Installation



Electro-Thermal Ice Protection Systems

- **Aerospace Leader on Electro-Thermal System**
- **Over 40 Years Experience**
- **Proven Technology and Low Risk Development**
- **Integrated / Composite Embedded or External Installation**
- **Innovative Low Power Technology**



ELECTROTHERMAL SYSTEM

- ✦ Slip Ring
- ✦ Brush Assembly
- ✦ Wire Harness
- ✦ Electronic Controls
- ✦ Rotor De-Icers



Airfoils and
Blades



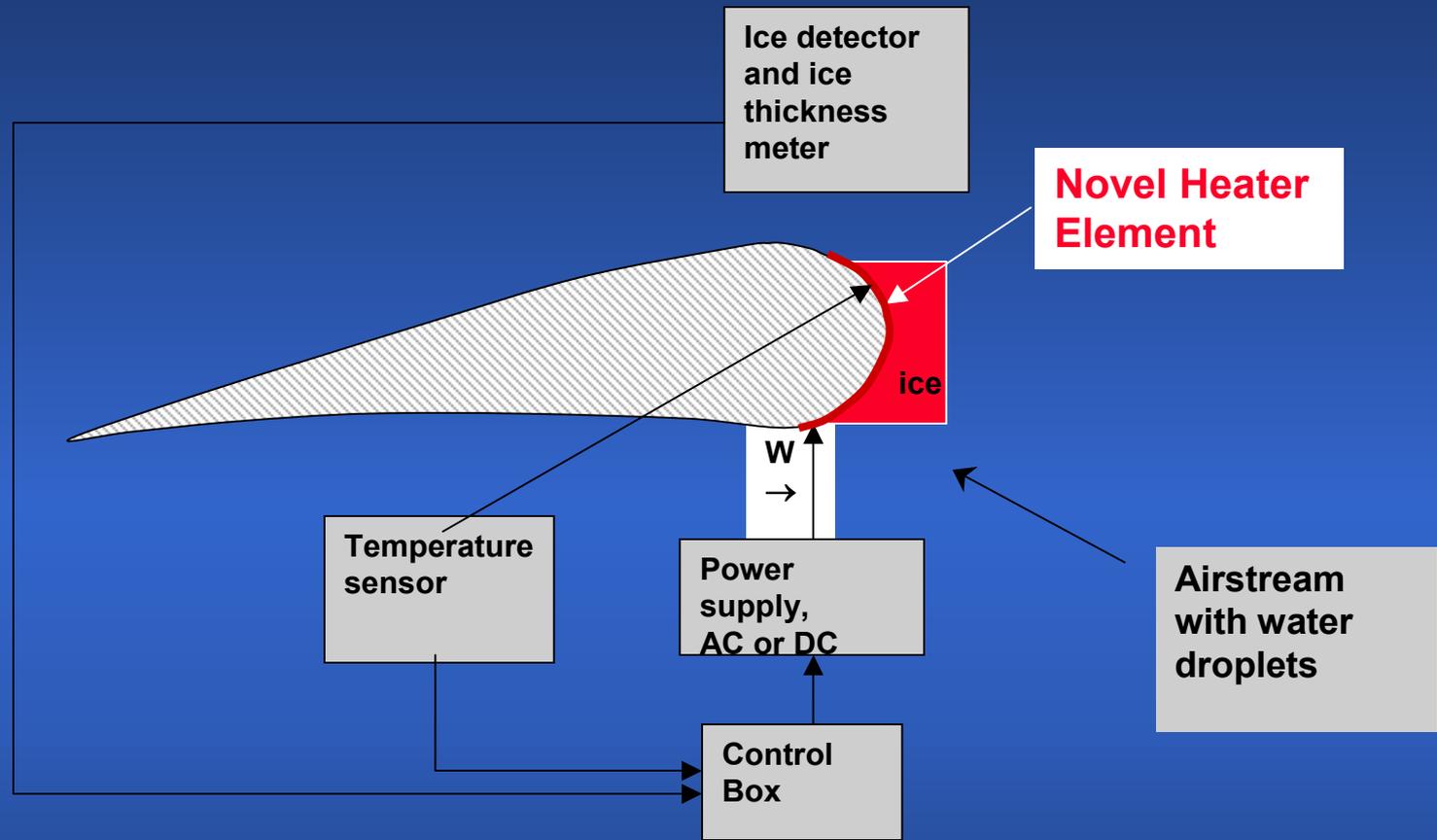


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New Development

Novel Electro-Thermal System





- **Low Power - Breakthrough Concept**
- **75 - 90 % of Power Saving Compared to Conventional System**





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Novel Electro-Thermal System Video *Wind Turbine Application*

DSS Icing Wind Tunnel Evaluation

- Leading Edge with 0.05" - 0.020" Gelcoat
- Tested at - 20°C
- Ability to Shed Very Thin Ice





Freeze Protection Technology



Heated Composites

Products

- Leading Edges
- Engine Inlets and Guide Vanes
- Fairings
- Wall and Floor Panels
- Drain Masts
- Rotor and Propeller Blades



Characteristics

- Etched-foil or wire-resistance elements for dependable heater performance
- Integrated temperature control, including electronic and mechanical thermostats and thermal fuses
- Leading edge erosion protection



AREA SPECIALTY HEATERS



- Provide supplemental heat to interior "cold spots" and prevent freezing in unheated interior areas.

Applications

- Water System Heaters
- Ram Air Turbine Generator Heater
- Floor Panel Heaters
- Smoke Detection System Heaters
- Hydraulic Fluid Component Heaters

Features

- Operation from -67°F (-55°C) to 232°F
- Power Density to 30 w/in²
- Wire or Foil Resistance Element
- Silicon or Kapton Insulation



AIR HEATERS



Provide supplemental heating of cabin air in "cold spots" in and around exit doors, galleys, lower lobe crew rest areas and cargo holds

Applications

- Flight Deck
- Galley
- Crew Rest Module
- Lower Lobe Attendant Rest Module
- Cargo Hold
- Flight Deck
- Turbine Heater
- Cabin Heating System

Typical Features

- Power: 500 to 6000 Watts
- Air Flow: Up to 260 SCFM
- Element: Cal Rod, Insulated Wire or Foil Element
- Control: Thermostatically controlled and electronically regulated

Advanced Features

- Heater and Blower Assemblies
- Closed Loop, Microprocessor Controlled Heating Systems





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WIND TURBINE Freezing Protection Technology

WHY?



Good Winds are often in Tough Places

Cold Climate and Mountains



Challenges

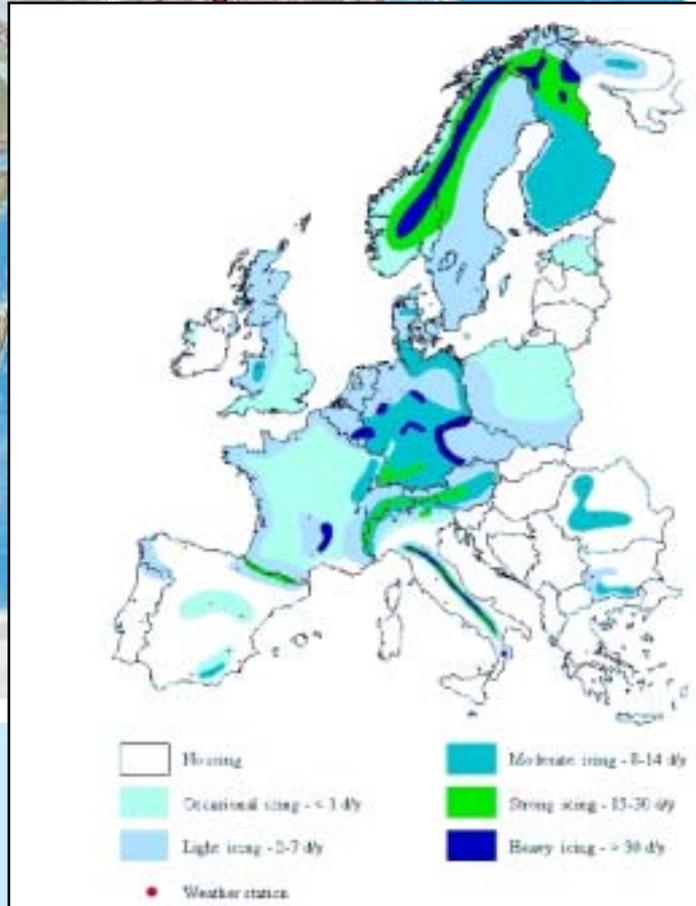
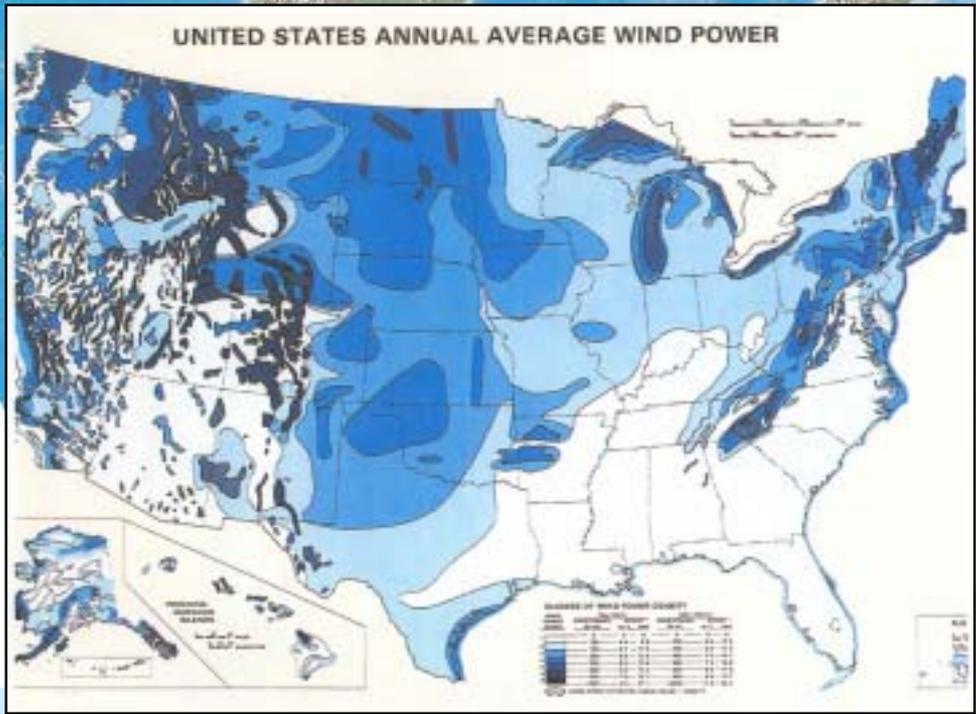
- Harsh Environment
- Remote Access
- Low Temperatures
- Icing Conditions

Icing Effects

- Loss of Performance
- Excessive Vibration
- Personal/Property Safety
- Turbine Shutdown



Ice Protection Concern North of "Ice Line"



Where there is ice, there is good wind



- **Decades of Ice Protection Systems Design, Development, and Testing**
- **Simulation and Manufacturing Capability**
- **Laboratories and Ice Tunnel Facility for Reduced Development Time and Risk**
- **Proven Technology Applicable to Wind Turbines**
- **Uniquely Qualified to Address All Ice and Freeze Protection Concerns**





GOODRICH

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QUESTIONS and ANSWERS

