IAGT Fall Course

2012

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Delta Toronto Airport West

# Air Inlet Filtration & Inlet Cooling Enhancements

by

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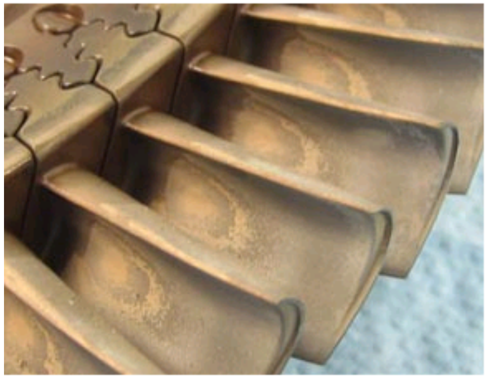
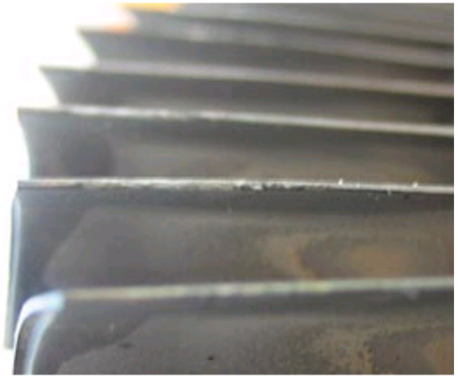
# Agenda

- Inlet Filtration
  - Why filters
  - Environments
  - Filter Testing
- Inlet Cooling
  - Benefits of Cooling
  - Overview of Cooling Technologies

# Why Filter

- FOD
- Erosion
- Corrosion
- Cooling Passage Plugging
- Fouling

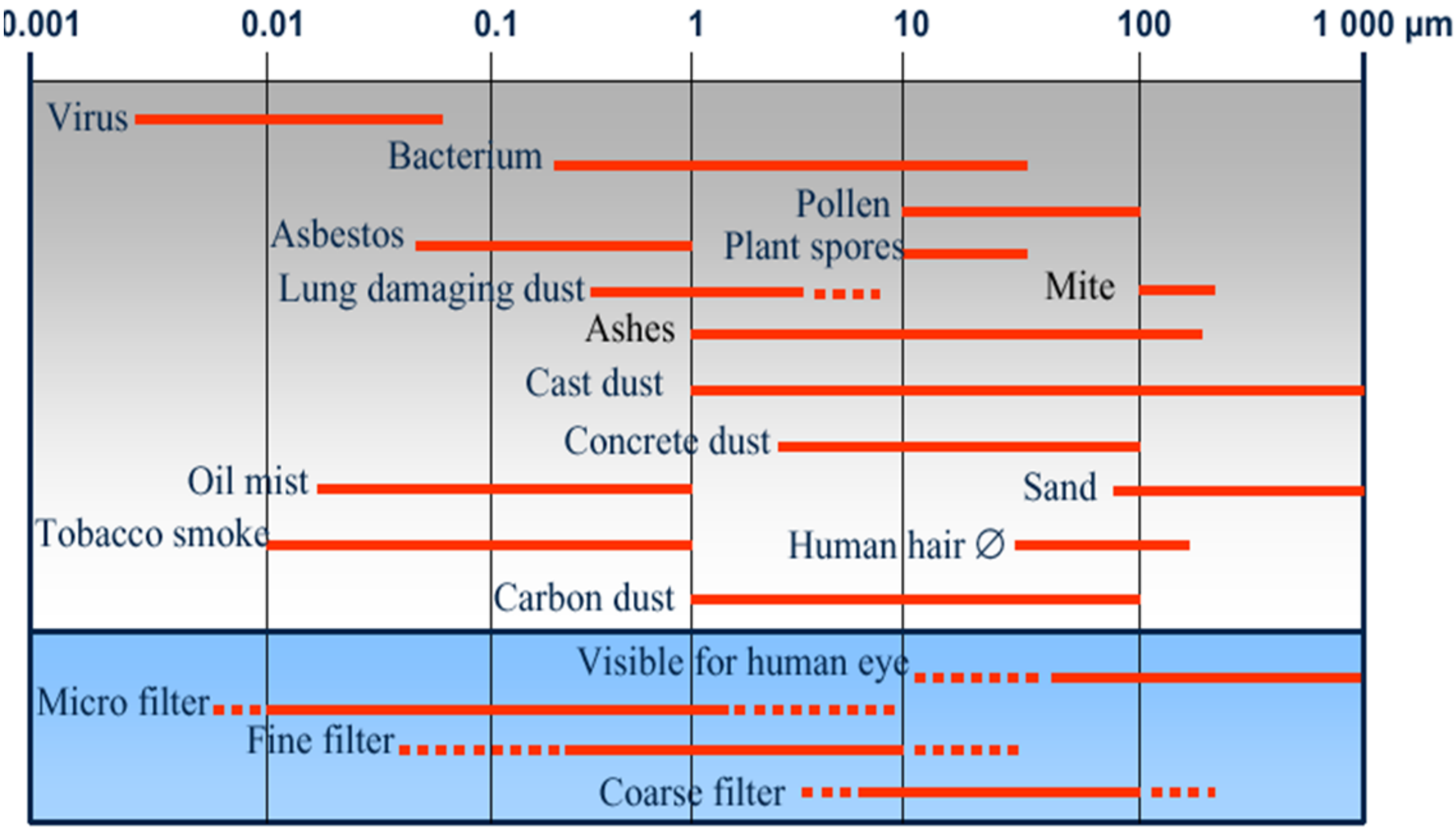




# Environments

- **Marine**
- **Offshore**
- **Coastal**
- **Desert**
- **Arctic**
- **Tropical**
- **Industrial**
- **Rural**
- **Urban**

# Aerosols




*Source: ASHRAE Handbook*

# Filter Parameters

- Pressure Drop
  - ***Compressor Work***
    - Initial
    - Avg. over life
- Efficiency
  - ***Compressor Fouling***
- Service Life
  - Pressure Drop
  - Age
  - Scheduled Maintenance

# Filter Parameters
# Test Standards

- Common Standards
  - ASHRAE 52.2
  - EN 779
  - EN 1822 ( high efficiency)
- Particle count by size
  - Rated per Std.
    - ASHRAE 52.2
      - "MERV 14"
        - Minimum efficiency reporting value
    - EN 779 2012
      - Avg + min efficiency
        - "F9"
- General ventilation filter standards
    - A specific ISO air filter for Turbomachinery
    - is in a working group phase but likely some time away

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# Test Standards common methods

- Tested at rated airflow
- Efficiency by particle size
- Efficiency measured at several dust loading press. Drops
  - Initial
  - Final pressure drop
  - Intermediate points as % of loading to final.

# Filter Parameters
# Efficiency EN 779 2012

| Classification of air filters[1] | | | | | |
|---|---|---|---|---|---|
| Group | Class | Final pressure drop (test) Pa | Average arrestance (Am) of synthetic dust % | Average efficiency (Em) for 0.4 µm particles % | Minimum efficiency[2] for 0.4 µm particles % |
| Coarse | G1 | 250 | 50≤Am<65 | - | - |
| | G2 | 250 | 65≤Am<80 | - | - |
| | G3 | 250 | 80≤Am<90 | - | - |
| | G4 | 250 | 90≤Am | - | - |
| Medium | M5 | 450 | - | 40≤Em<60 | - |
| | M6 | 450 | - | 60≤Em<80 | - |
| Fine | F7 | 450 | - | 80≤Em<90 | 35 |
| | F8 | 450 | - | 90≤Em<95 | 55 |
| | F9 | 450 | - | 95≤Em | 70 |

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# Filter Testing “HEPA”

- HEPA efficiency – original definition:
  - 99.97% on 0.3 um particle

- Requirements and test instruments evolved
- Today defined as several grades  when tested to EN 1822

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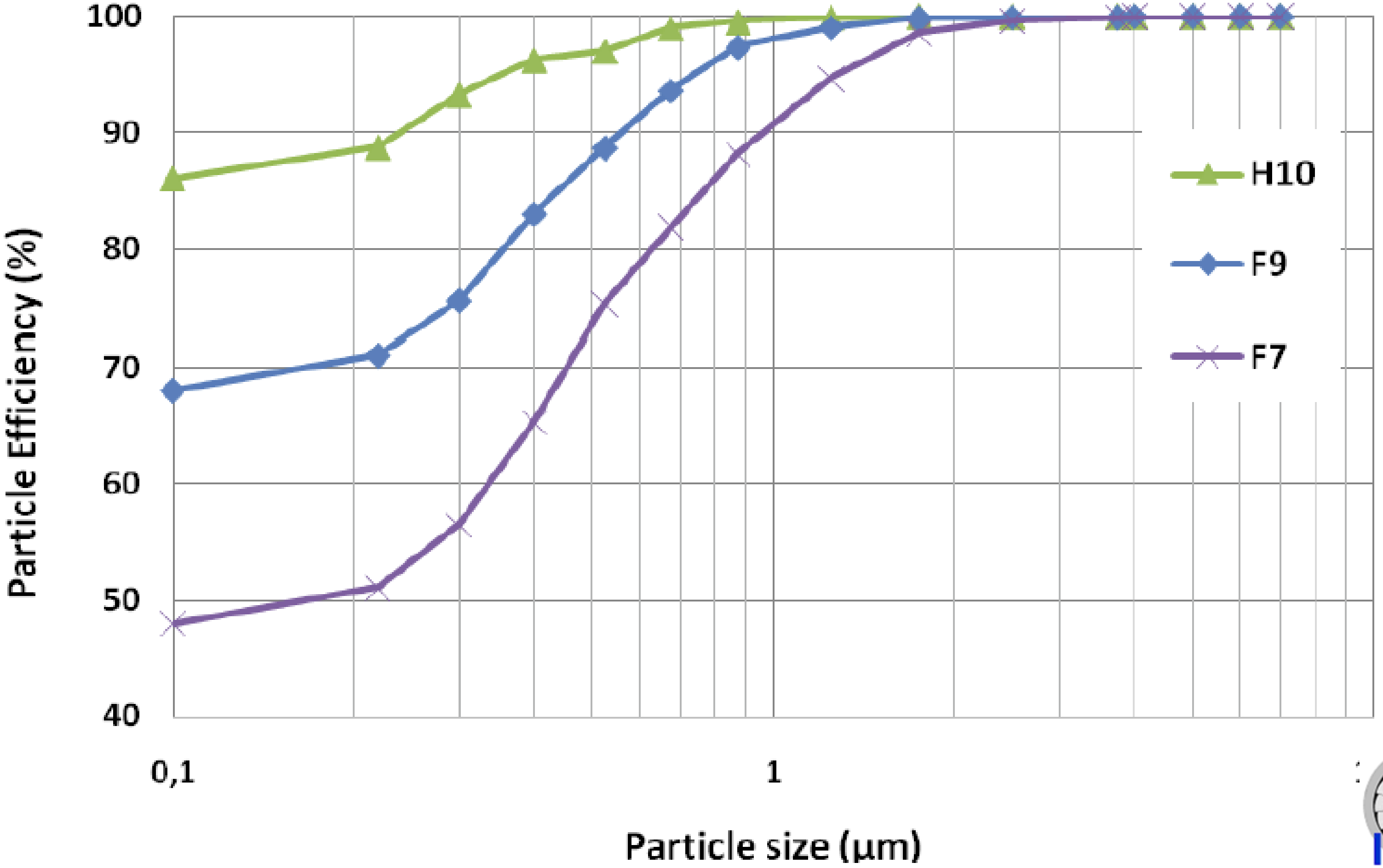
# Filter Parameters Efficiency  EN 1822

| Classification of EPA, HEPA (part of EN 1822 table) @ MPPS – most penetrating particle size | | |
|---|---|---|
| Filter Group Filter Class | Integral value | |
| | Efficiency (%) | Penetration (%) |
| E10 | ≥ 85 | ≤ 15 |
| E11 | ≥95 | ≤ 5 |
| E12 | 99,5 | ≤ 0,5 |
| H13 | ≥ 99,95 | ≤ 0,05 |
| H14 | ≥ 99,995 | ≤ 0,005 |

# Typical particle removal efficiency for clean filter based on EN779:2002



# Filter Comparison
# EN 779 F7 vs. F9 @ 0.4 um

F7

Efficiency 90 %

Or

Inefficiency 10%

10 out of 100 particles pass thru

F9

Efficiency 95 % (min)

Or

Inefficiency 5%

5 out of 100 particles pass thru

*F9 is 2x more efficient than an F7*

## Standards Comparison

| ASHRAE Standard 52.2-1999 | | | | ASHRAE 52.1 | | EN 779 Efficiency | EN 1822 Efficiency |
|---|---|---|---|---|---|---|---|
| Minimum Eff Reporting Value | Composite Average Particle Size Efficiency, % in Size Range, µm | | | Average Arrestance | Average Dust Spot Efficiency | Average Eff at 0.4µm | Average Eff at MPPS |
| | Range 1 | Range 2 | Range 3 | | | | |
| (MERV) | 0.30 - 1.0 | 1.0 - 3.0 | 3.0 - 10.0 | % | % | % | % |
| 1 | n/a | n/a | $E_3 < 20$ | $A_{avg} < 65$ | < 20 | G1 | |
| 2 | n/a | n/a | $E_3 < 20$ | $A_{avg} \geq 65$ | < 20 | G2 | |
| 3 | n/a | n/a | $E_3 < 20$ | $A_{avg} \geq 70$ | < 20 | | |
| 4 | n/a | n/a | $E_3 < 20$ | $A_{avg} \geq 75$ | < 20 | | |
| 5 | n/a | n/a | $E_3 \geq 20$ | 80 | 20 | G3 | |
| 6 | n/a | n/a | $E_3 \geq 35$ | 85 | 20-25 | | |
| 7 | n/a | n/a | $E_3 \geq 50$ | 90 | 25-30 | G4 | |
| 8 | n/a | n/a | $E_3 \geq 70$ | 92 | 30-35 | | |
| 9 | n/a | n/a | $E_3 \geq 85$ | 95 | 40-45 | F5 | |
| 10 | n/a | $E_2 \geq 50$ | $E_3 \geq 85$ | 96 | 50-55 | | |
| 11 | n/a | $E_2 \geq 65$ | $E_3 \geq 85$ | 97 | 60-65 | F6 | |
| 12 | n/a | $E_2 \geq 80$ | $E_3 \geq 90$ | 98 | 70-75 | | |
| 13 | n/a | $E_2 \geq 90$ | $E_3 \geq 90$ | 98 | 80-85 | F7 | |
| 14 | $E_1 \geq 75$ | $E_2 \geq 90$ | $E_3 \geq 90$ | 99 | 90-95 | F8 | |
| 15 | $E_1 \geq 85$ | $E_2 \geq 90$ | $E_3 \geq 90$ | 99 | 95 | F9 | |
| 16 | $E_1 \geq 95$ | $E_2 \geq 95$ | $E_3 \geq 95$ | 100 | 99 | H10 | > 85 |
| N/A | N/A | N/A | N/A | N/A | N/A | H11 | > 95 |
| | | | | | | H12 | > 99.5 |
| | | | | | | H13 | > 99.95 |
| | | | | | | H14 | > 99.995 |
| | | | | | | U15 | > 99.9995 |
| | | | | | | U16 | > 99.99995 |
| | | | | | | U17 | > 99.999995 |

Note: The final MERV value is the highest MERV where the filter data meets all requirements of that MERV.

# Summary

- Inlet Filtration Protects GT
- Filtration Performance
  - Environment
  - Aerosol Contaminant
  - Filter Selection
- Inlet Filtration affects GT Performance and Economics

# Turbine Inlet Cooling

- What is it?
  - A system that cools the ambient temperature of the turbine's inlet air
- Why Cool?
  - Increase power output and efficiency
- How?
  - Cooling the inlet air increase the density of the air, thus increases the mass airflow thru the unit thus more power, efficiency

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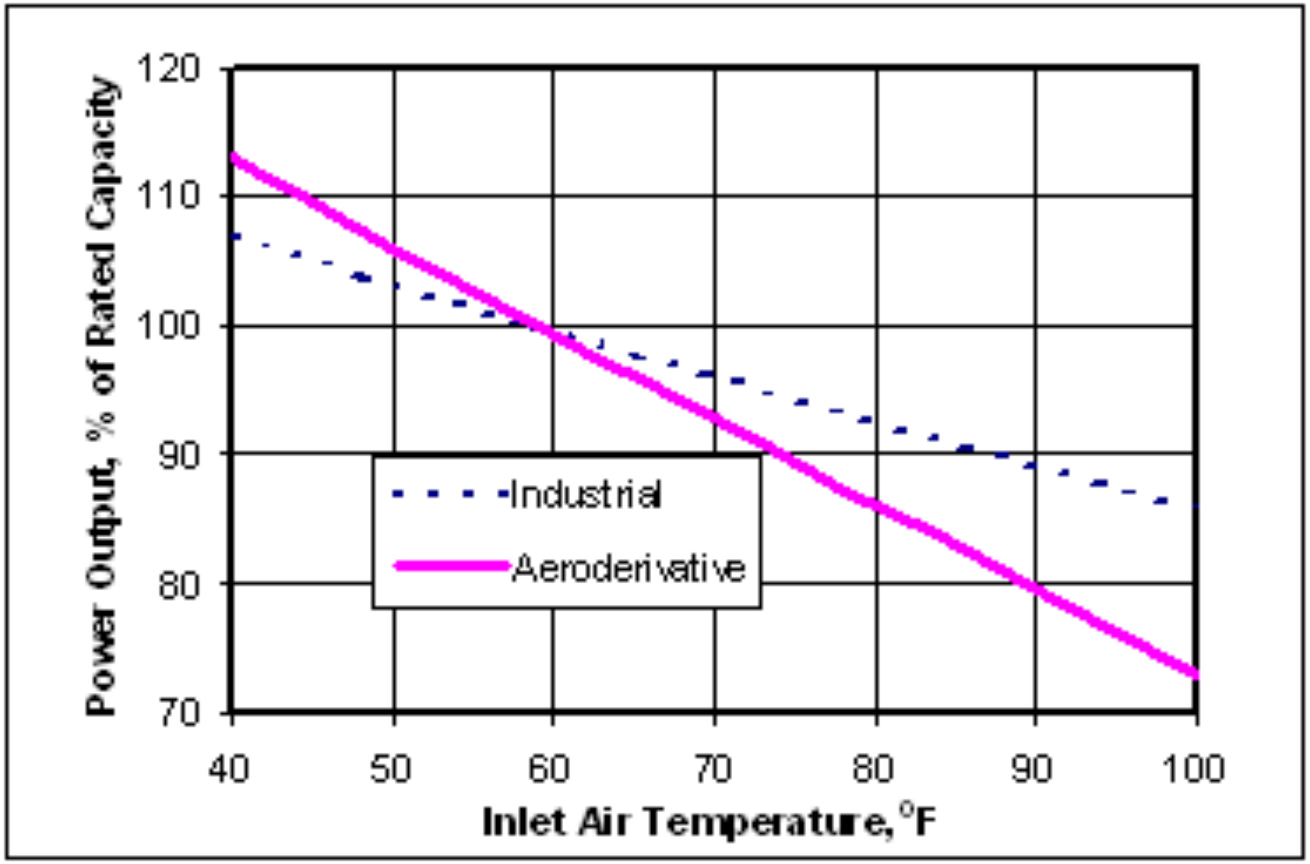
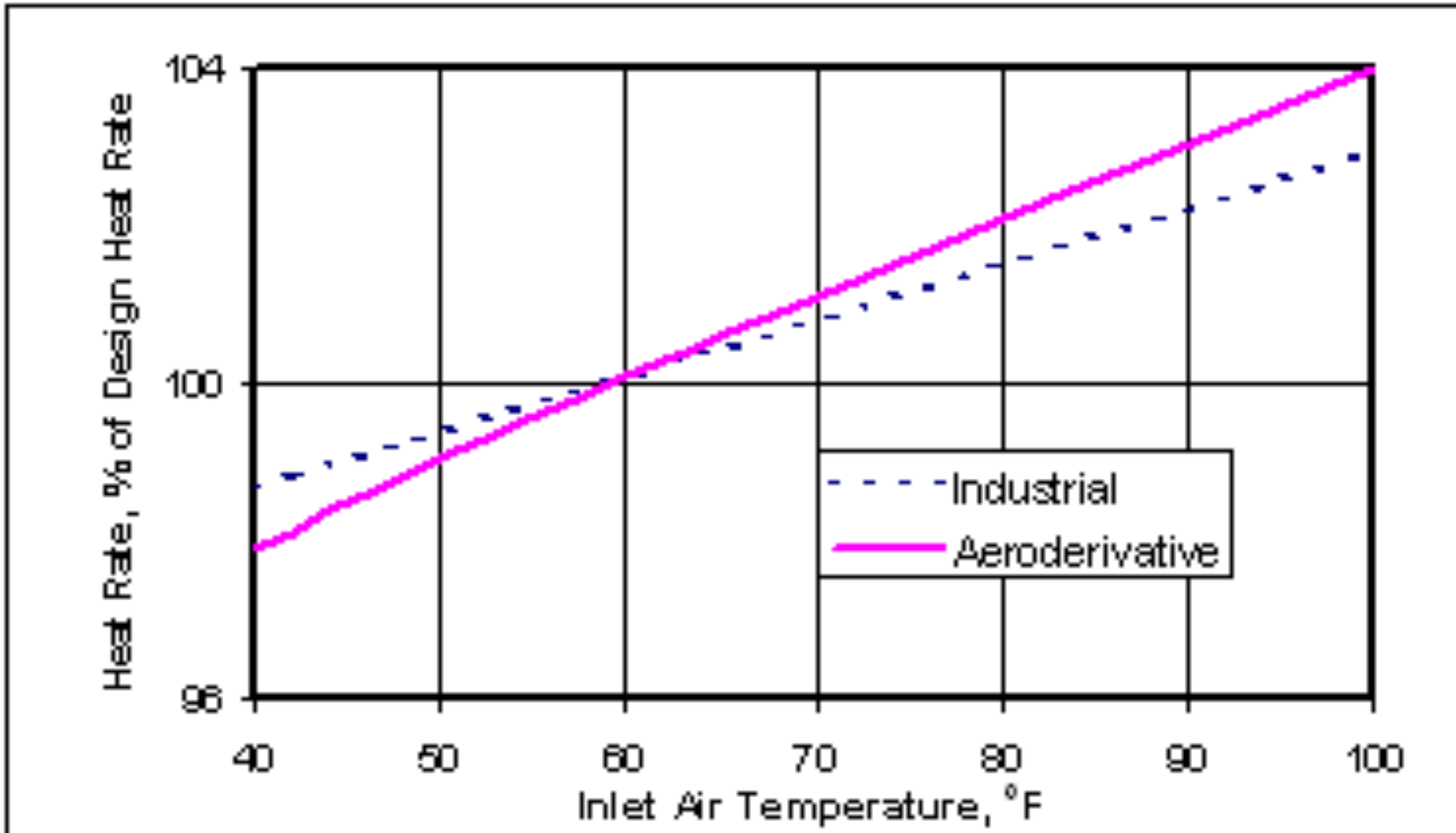
# Temperature effect vs. Power



# Temperature effect  on Heat Rate



# Turbine Inlet Cooling Technologies

- Evaporative
  - Wetted Media
  - Fogging
  - Wet Compression
- Chillers
  - Mechanical
  - Absorption
  - Thermal energy storage optional
  - LNG Vaporization
- Hybrid System
  - Combination of above technologies

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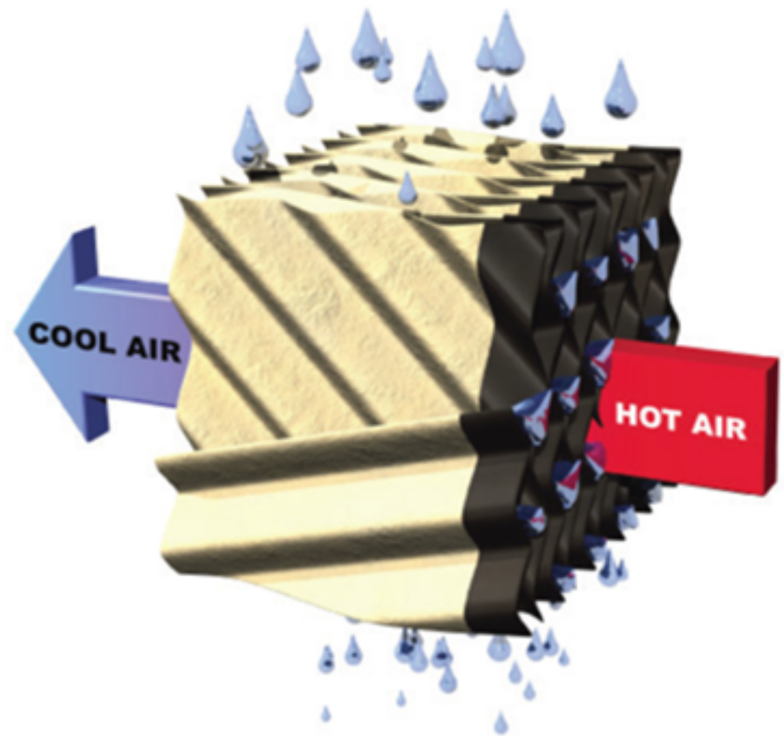
# Evaporative Technologies

- Evaporation of water added to the inlet air stream cools the air
- Performance limited  to the wet-bulb temperature

# Evaporative Technologies
# Wetted Media

- inlet air is exposed to a film of water in one of the many types of wetted media.
- A honey-comb-like medium is most commonly employed media
- Cools to 85 -95 % of the dry –wet blub difference




Munters inc.

# Evaporative Technologies
# Fogging

- Water Droplets sprayed into the inlet air
- Demineralized water
- Pressurize system
- Cools to 85 -95 % of the dry –wet blub difference

Mee Industries inc.

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# Evaporative Technologies
# Wet Compression

- Similar to Fogging
- But Droplets injected near the Bellmouth
  - Greater mass flow
  - May be used with other cooling technology

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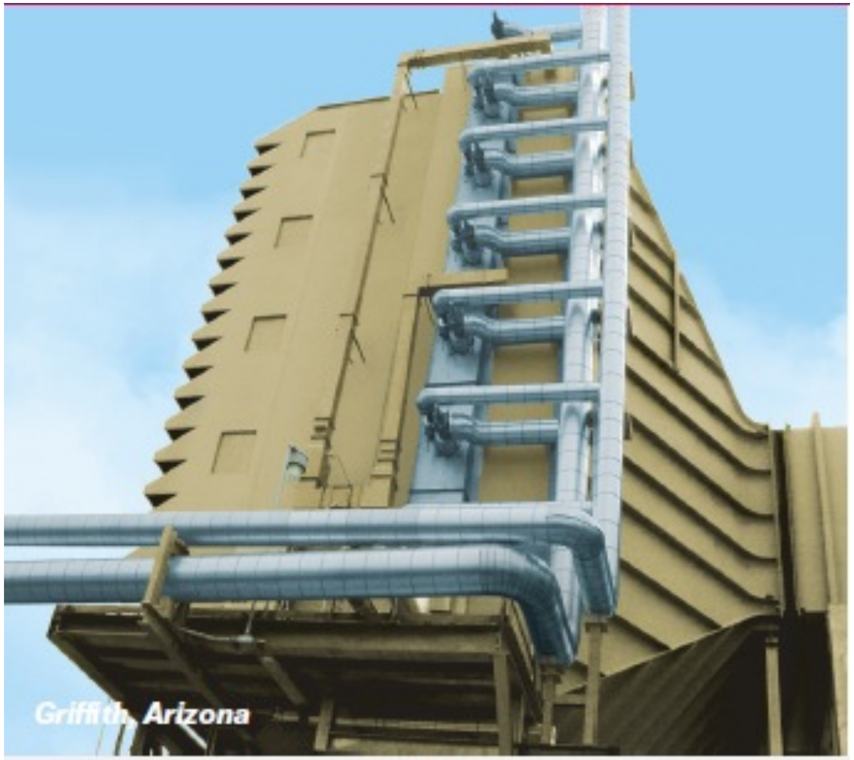
# Chillers

- Heat Exchanger – Coils installed in the duct
- Chilled fluid or refrigerant is circulated through the coils
- Can cool below wet-blub
- Higher Capital & operating cost
- Higher Temperature performance




Options:
Internally Mounted Coils • Bulk Air Cooler

StellarEnergy

# Chillers

- Require Refrigeration System
  - Mechanical
    - Motors/Compressor
  - Absorption
    - Steam or heat for chiller system
    - excess thermal energy is available
  - Thermal energy storage
    - Storage of ice or chiller water
      - Use in peak duty cycles
  - LNG Vaporization

# Turbine Inlet Cooling

- Considerations for Selection
  - Climate conditions
    - Ambient dry blub and wet blub temperatures
  - Operating economics
    - Cost of fuel
    - Price of output
      - Peaking price “bonus”
    - Reference  Turbine Inlet Cooling Association
      - www.turbineinletcooling.org

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# Thank You

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