OPERATING EXPERIENCES AT THE ORNL CHP INTEGRATION TEST FACILITY

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DOE/CETC/CANDRA Workshop on

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OAK RIDGE NATIONAL LABORATORY
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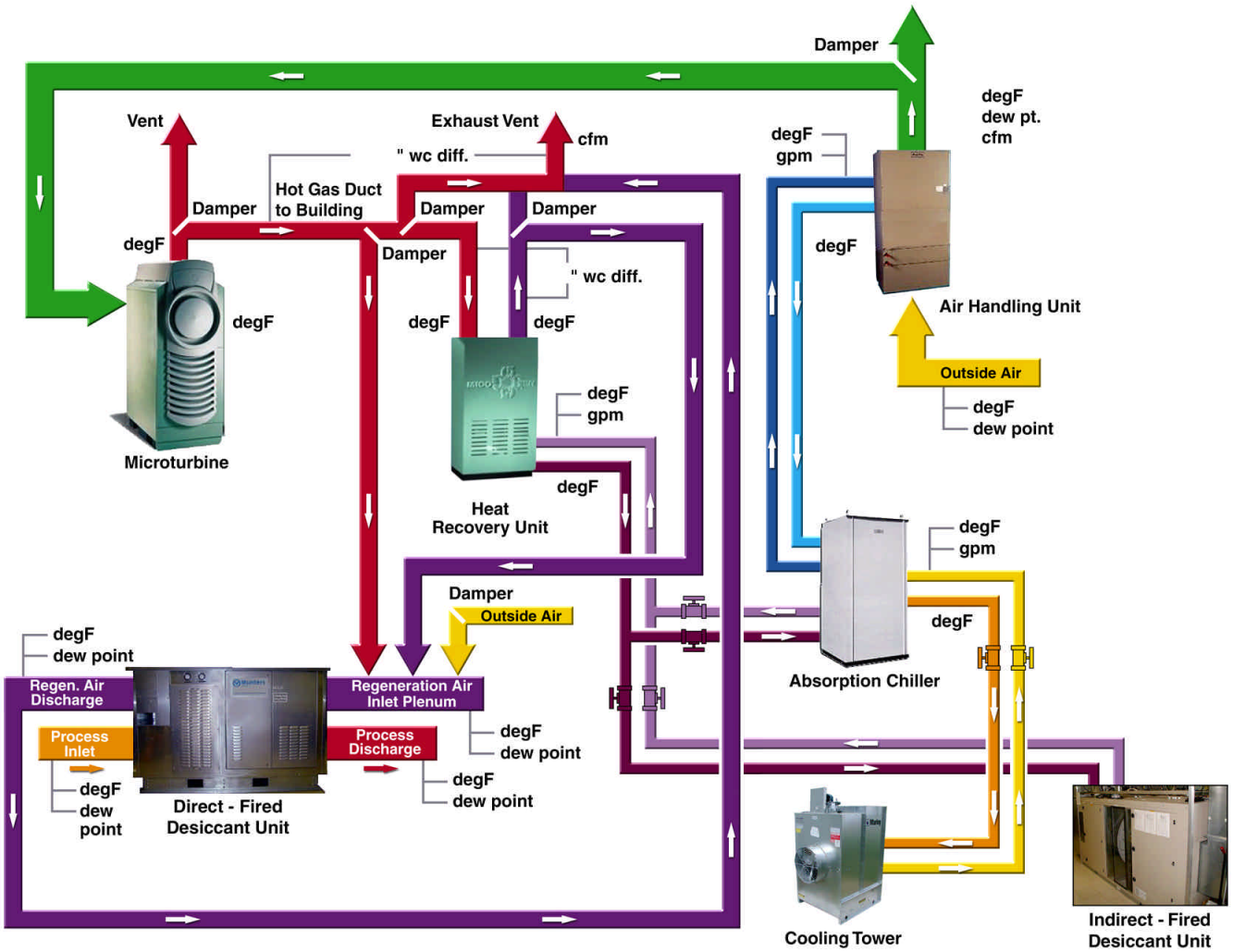
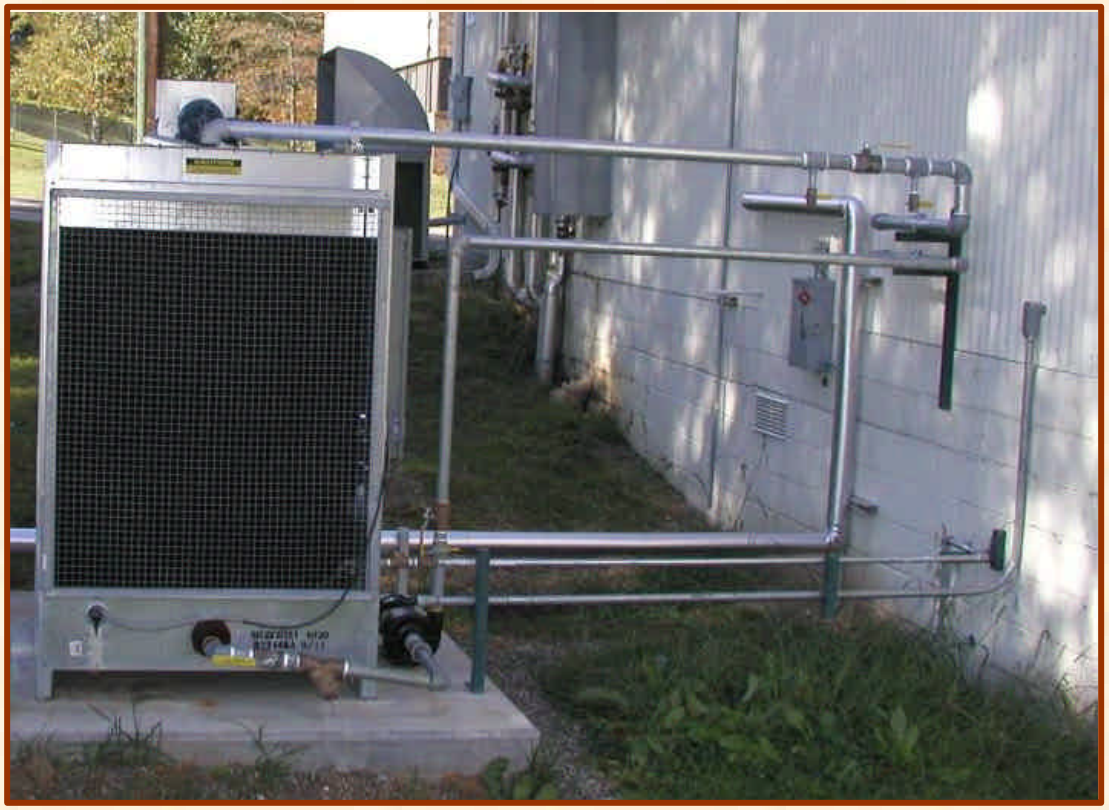
CHP Integration Test Facility



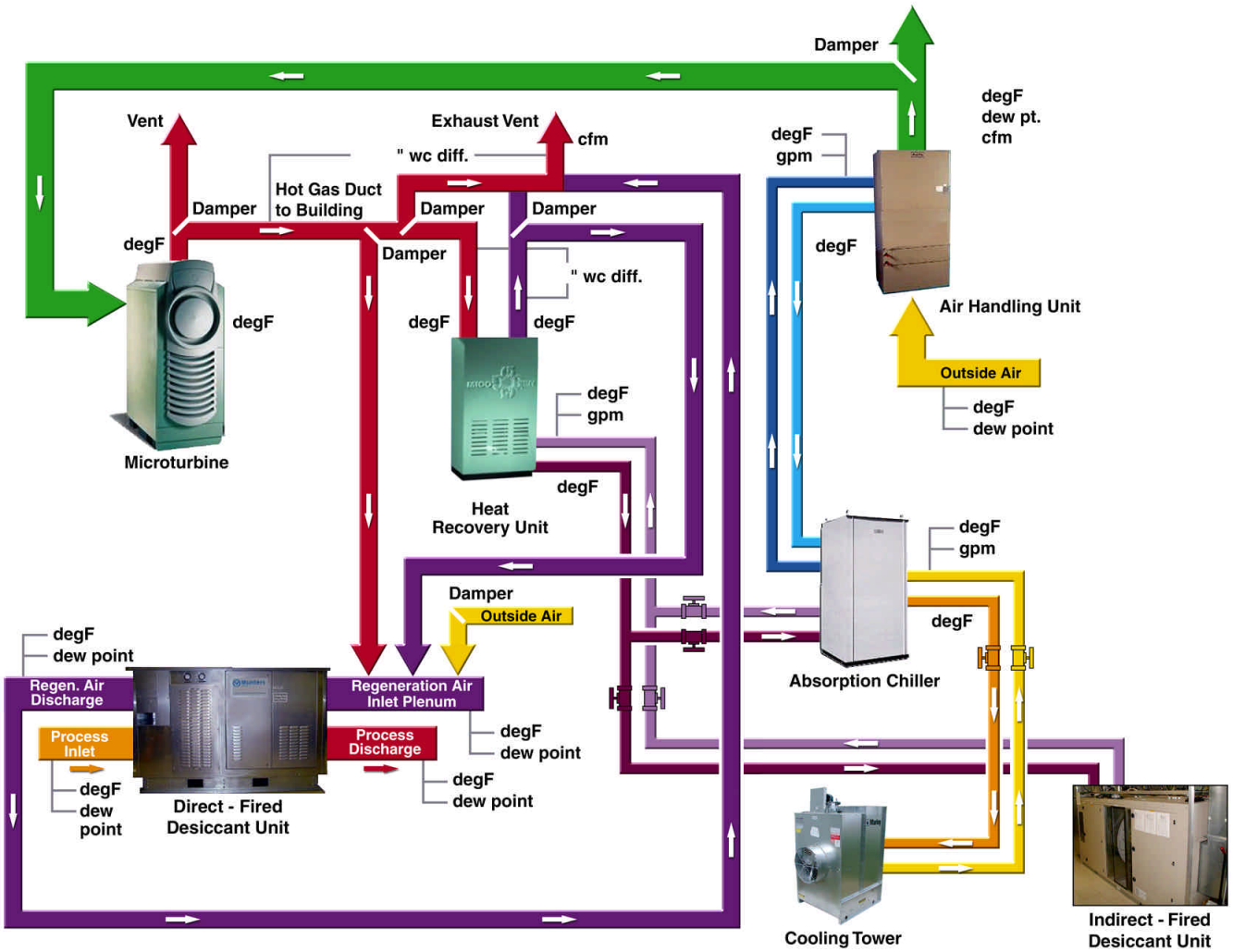
CHP Test Facility Configuration (outdoors)

30-kW Microturbine



Cooling Tower for 10-Ton (35-kW) Single-Effect Absorption Chiller

CHP Integration Test Facility



CHP Test Facility Configuration (indoors)

Exhaust Heat Recovery Test Loops

Overall Objectives Of CHP Integration Test Facility

- **Benchmark Microturbine Equipment Performance and Emissions**
- **Benchmark Microturbine-based CHP System Performance**
- **Provide Data for Computer Algorithm Generation/Verification**
- **Identify Component and System Improvements for "Next Generation" Products and Applications**
- **Provide Diagnostic Support for Field Test Data Analysis**
- **Support Rating/Certification Standards for CHP Products**

Sequence of CHP Performance Testing

- **Task 1 – Microturbine Baseline Performance**
  - **Test microturbine performance without heat recovery**
  - **Apply external backpressure on exhaust to emulate CHP**

- **Task 2 – Heat Exchanger (Air-to-Water) Thermal Loop**
  - **Test microturbine with CHP (combined with heat recovery)**
  - **Recover exhaust heat with air-to-water heat exchanger**
  - **Use recovered heat to produce 190ºF (88ºC) hot water**
  - **Indirect-fired desiccant unit (3,000 cfm or 85 m^3/min) thermal load**
  - **Determine CHP plant Improvements (efficiency)**

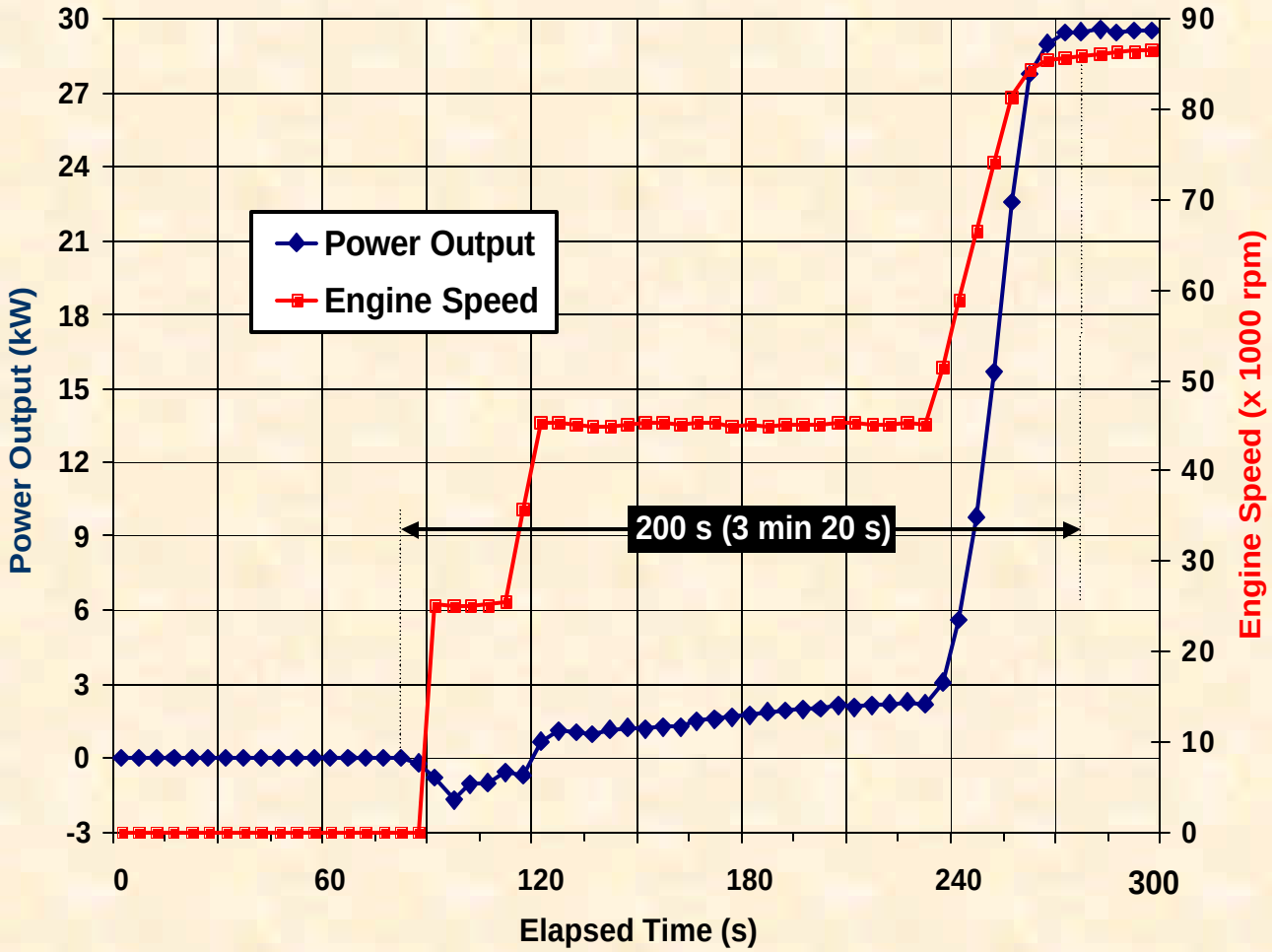
Sequence of CHP Performance Testing (cont.)

- **Task 3 – Desiccant Dehumidification Thermal Loop**
  - **Use Direct-fired desiccant unit (2,500 cfm or 71 m^3/min)**
  - **Feed with 500ºF (260ºC) exhaust (mixed with outside air)**
  - **Or use waste air (260ºF or 127ºC) from heat exchanger**
  - **Use waste heat to regenerate desiccant**

- **Task 4 – Absorption-Chiller Thermal Loop**
  - **Use 10-ton (35-kW) single-effect indirect-fired absorption chiller**
  - **Feed with hot water from heat recovery unit**
  - **Supply 45ºF (7ºC) chilled output water to provide cooling**
  - **Keep inlet air temperature at 59ºF (15ºC) to microturbine**
  - **Maintain turbine's maximum power output & efficiency with inlet air cooling**

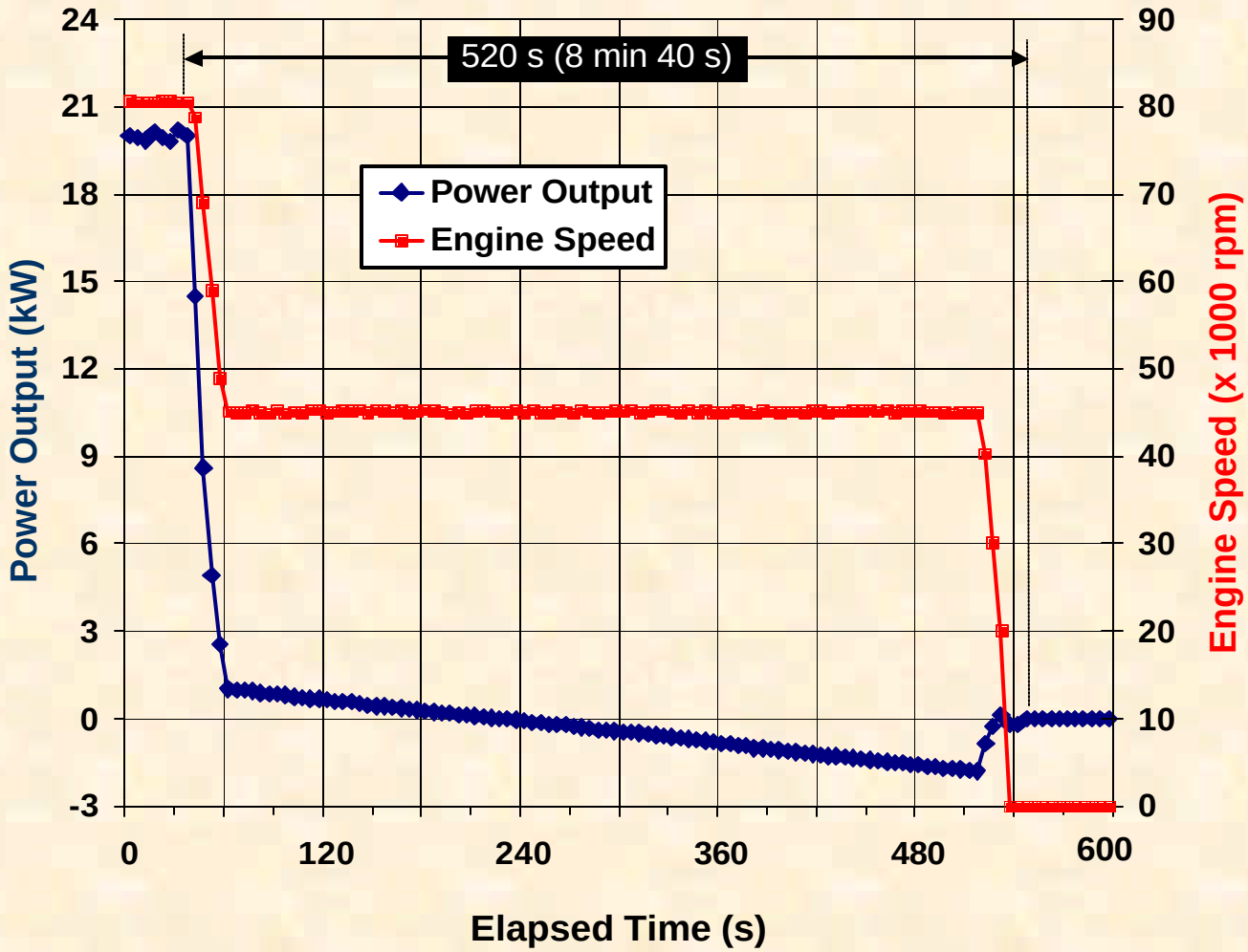
Microturbine Startup Dynamics

Output & Speed, 0 to 30 kW, no external backpressure



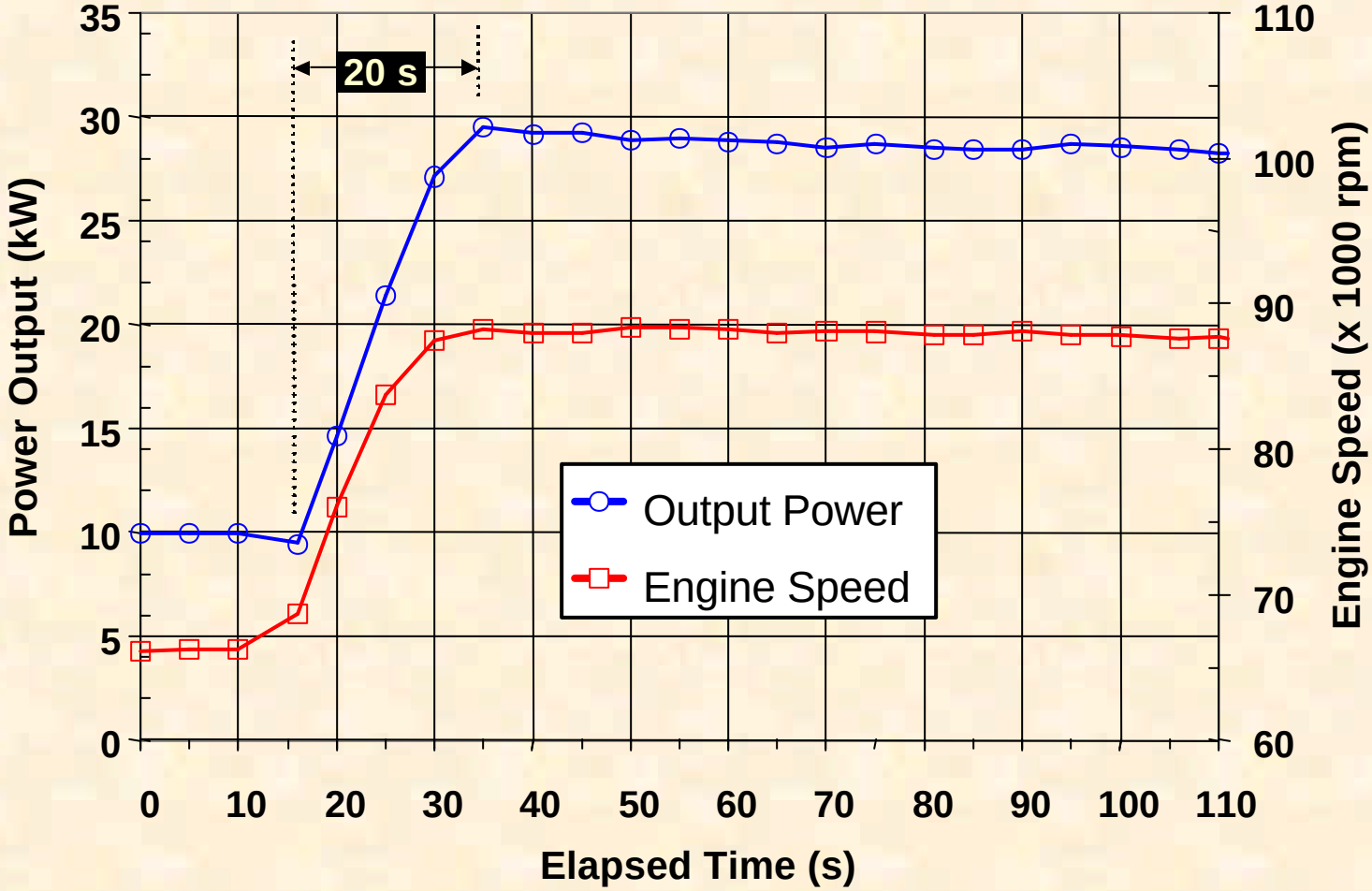
Microturbine Shutdown Dynamics

Output & Speed, 20 to 0 kW, no external backpressure

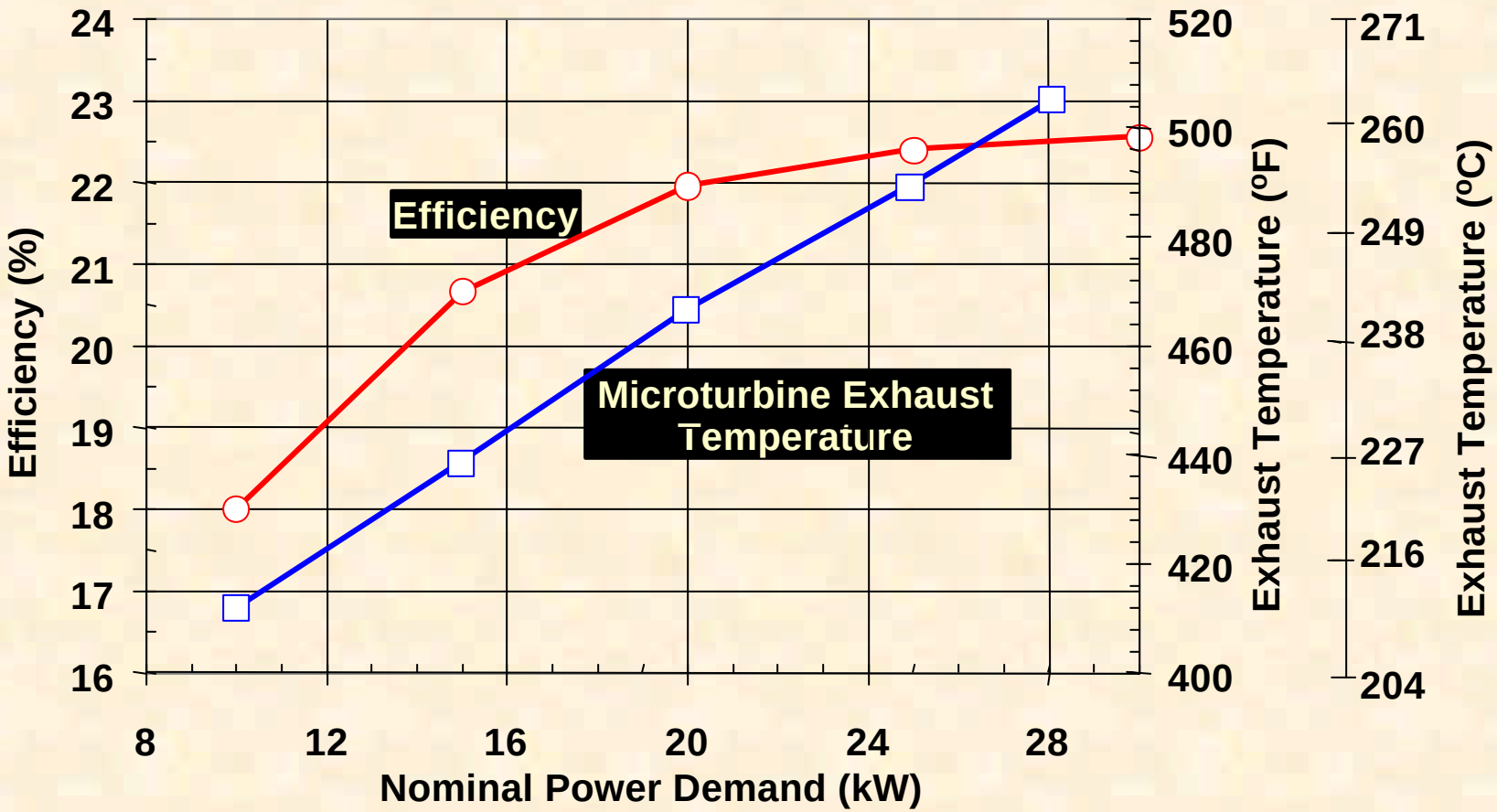


Microturbine Ramping Dynamics

10 to 30 kW, no external backpressure

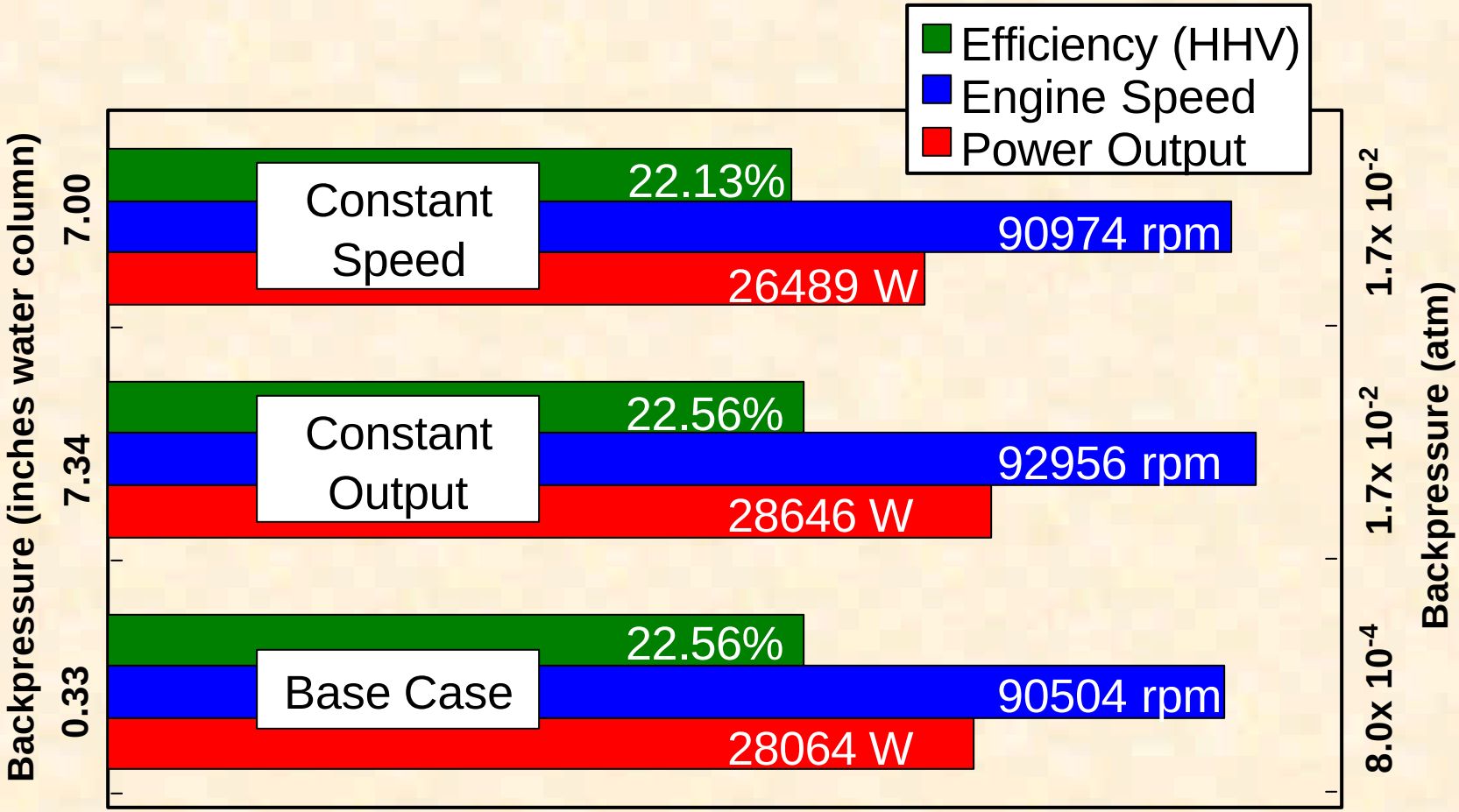


Microturbine Benchmark (Efficiency vs. Power Output)*

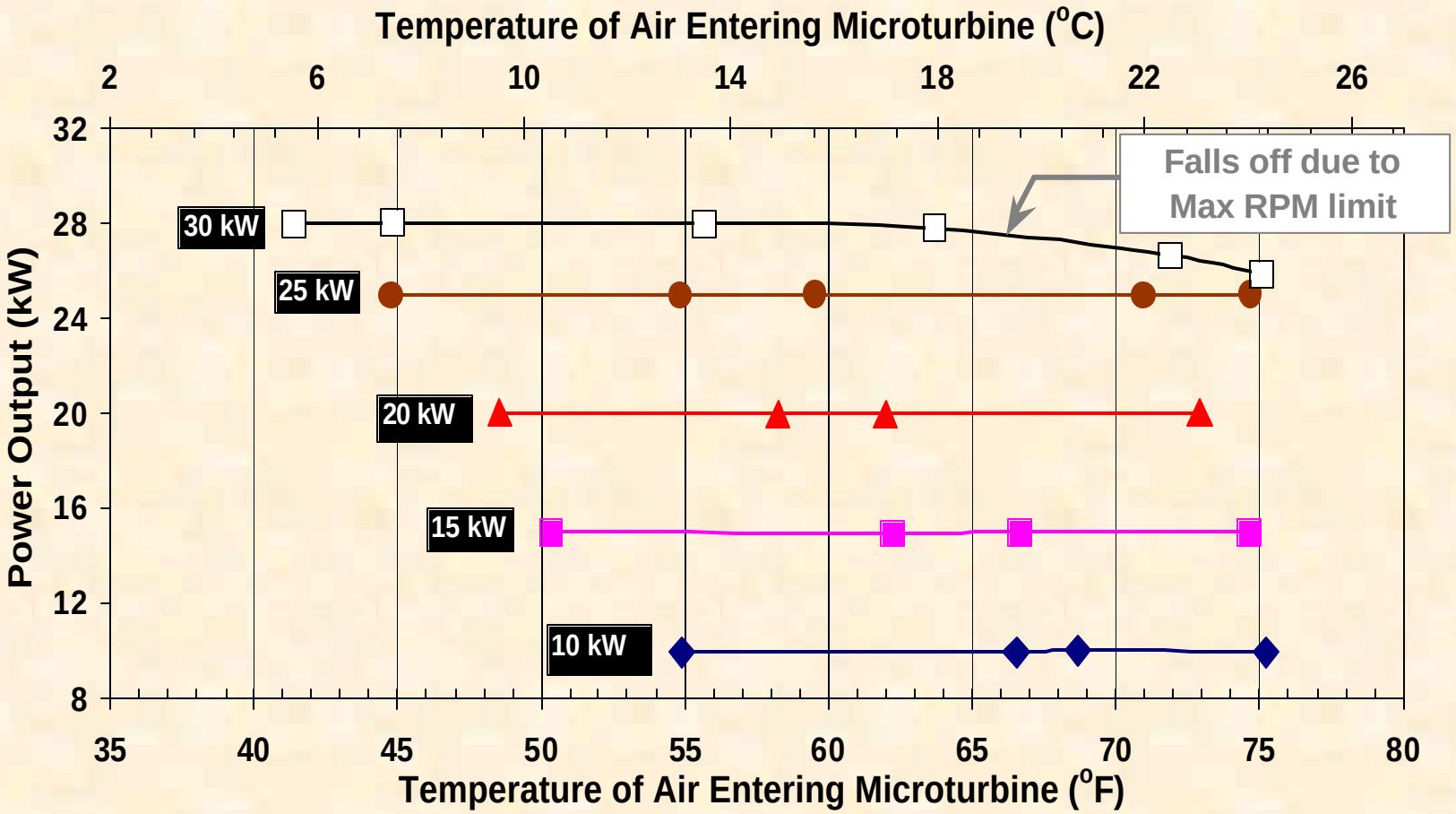


** Based on Natural Gas Higher Heating Value (HHV), outside ambient temperature between 30 to 40ºF (-1 to 4 ºC)*

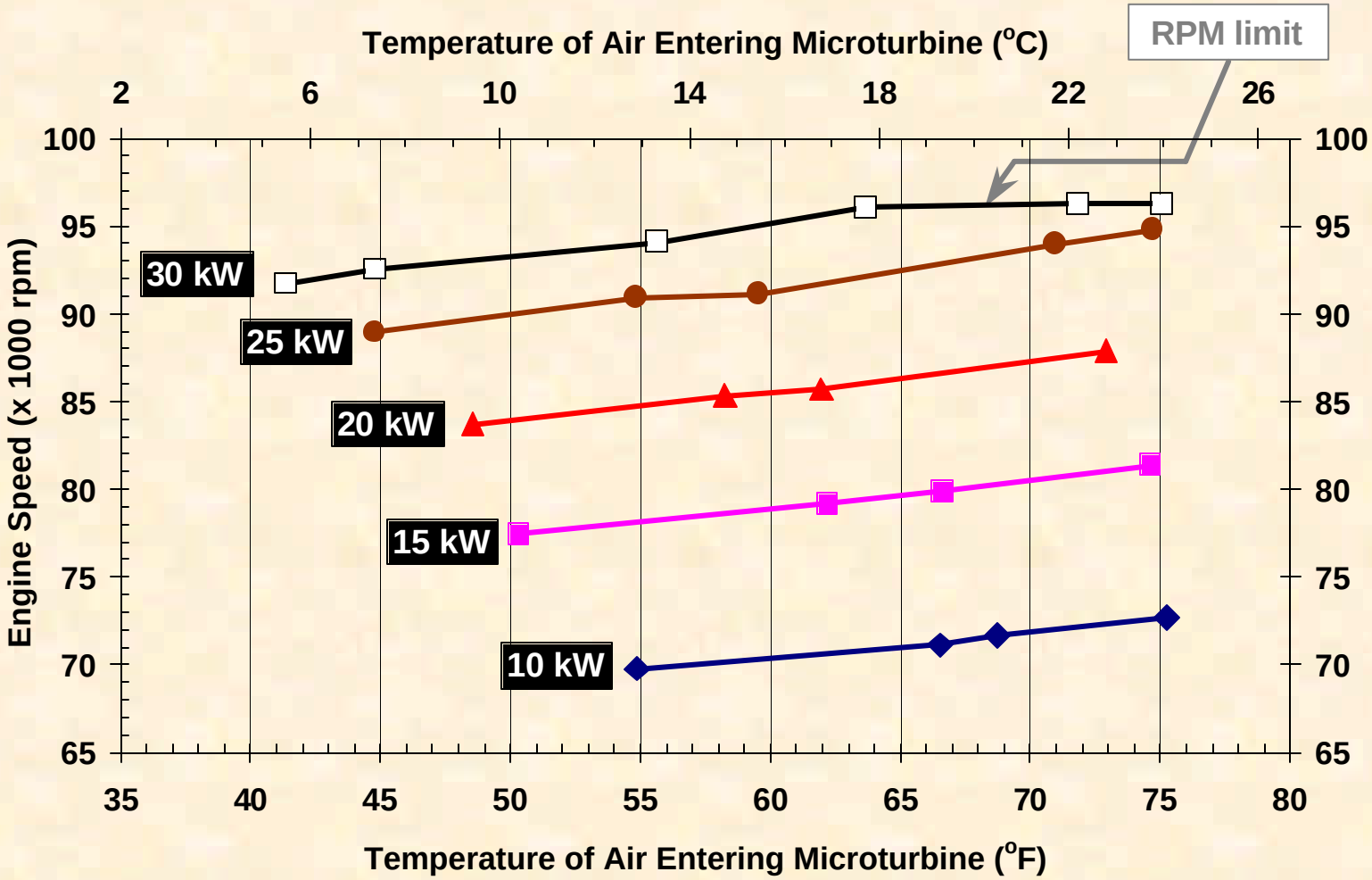
Microturbine CHP Backpressure Tests



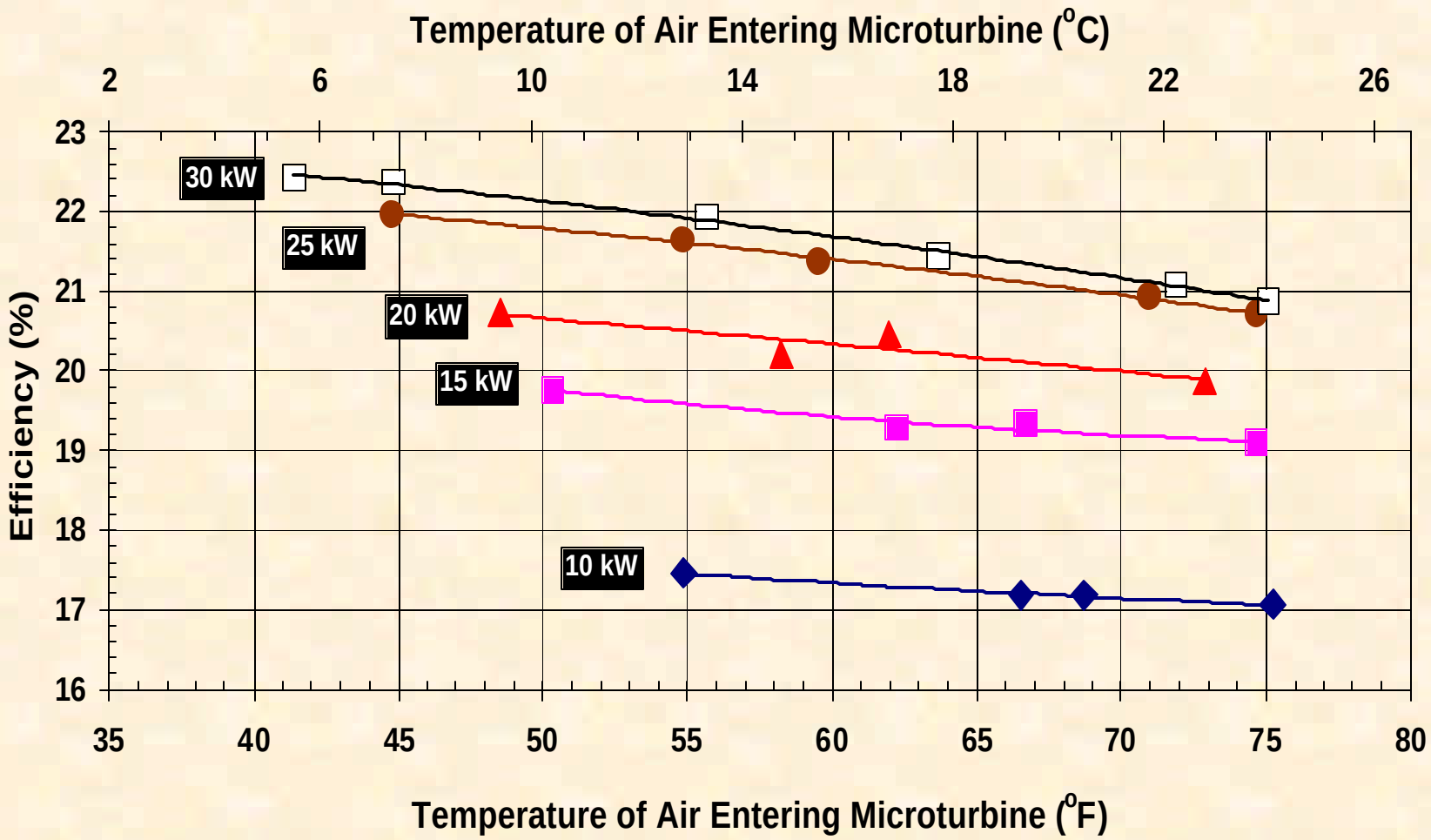
Microturbine Benchmark (Power Output vs. Ambient Temperature)



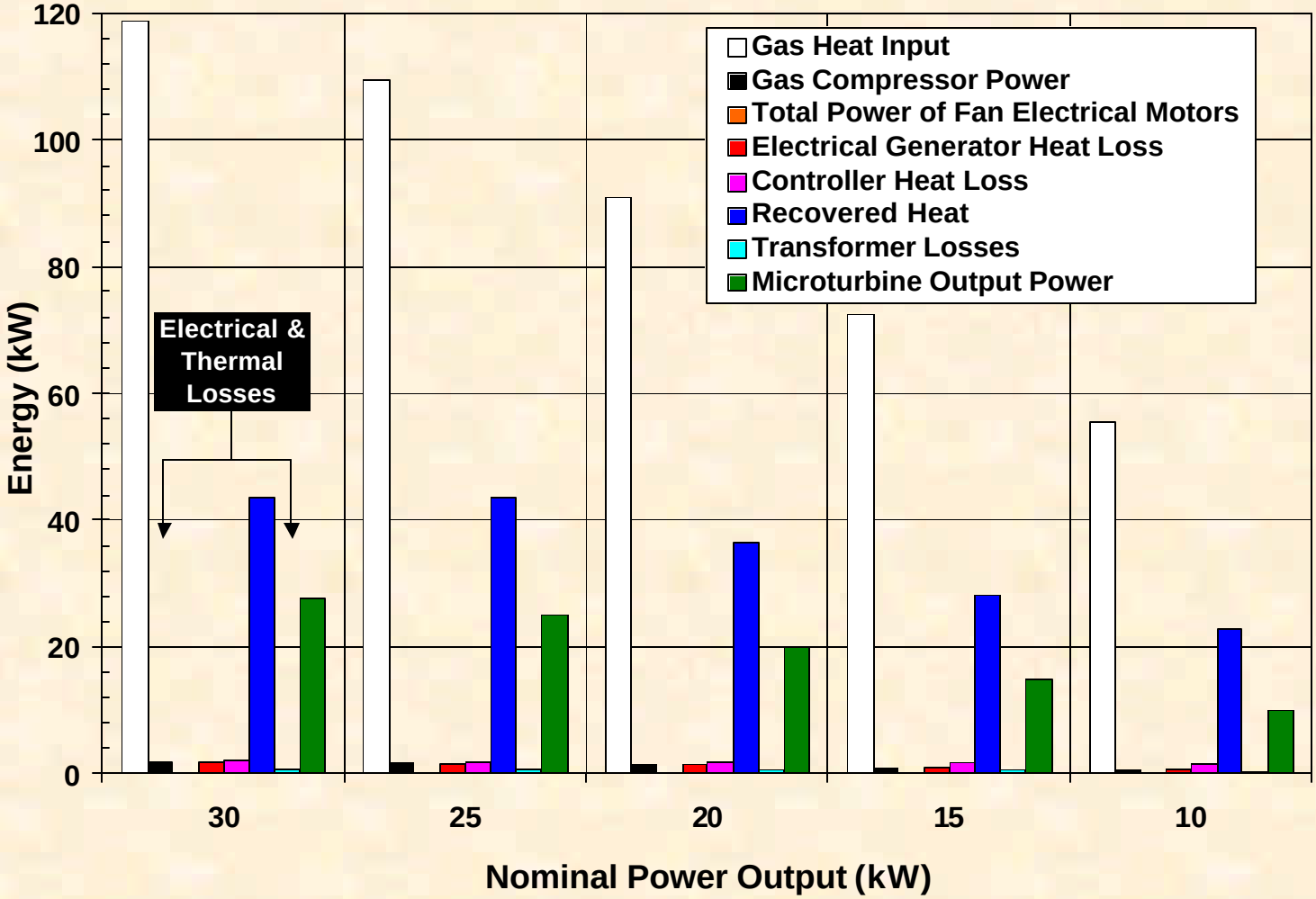
Microturbine Benchmark (Engine Speed vs. Ambient Temp.)



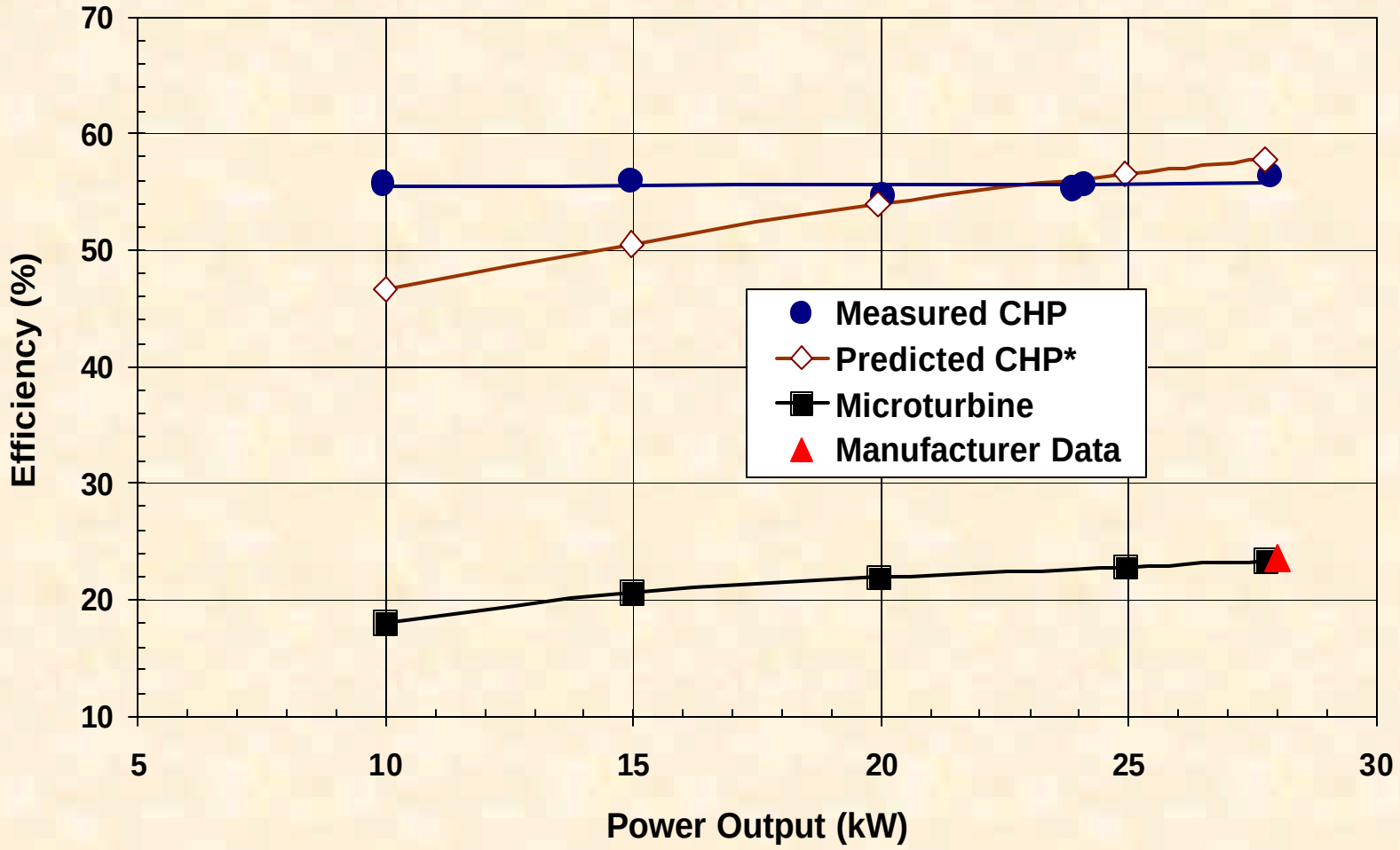
Microturbine Benchmark (Efficiency vs. Ambient Temperature)



Microturbine Energy Losses

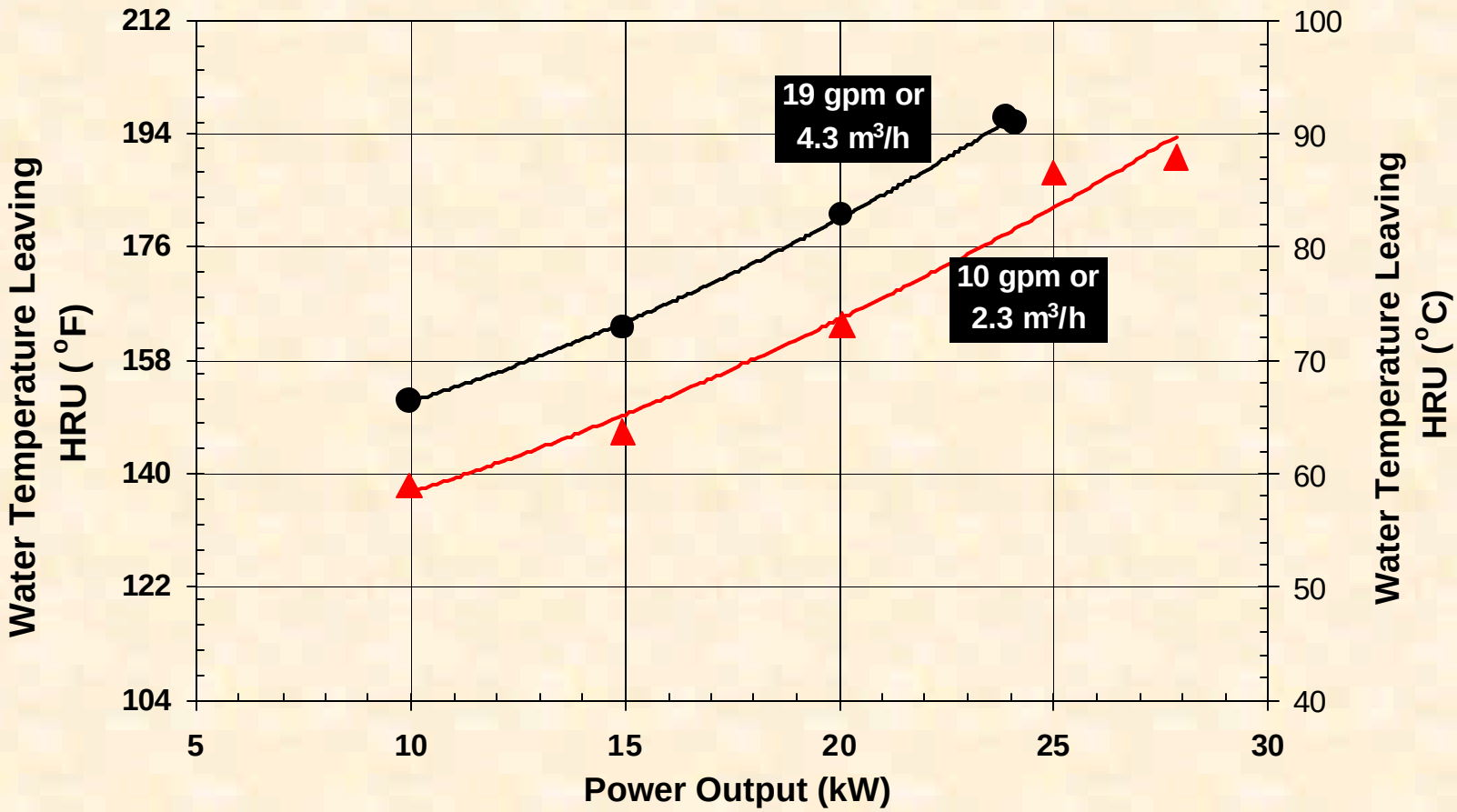


Microturbine and CHP Efficiencies



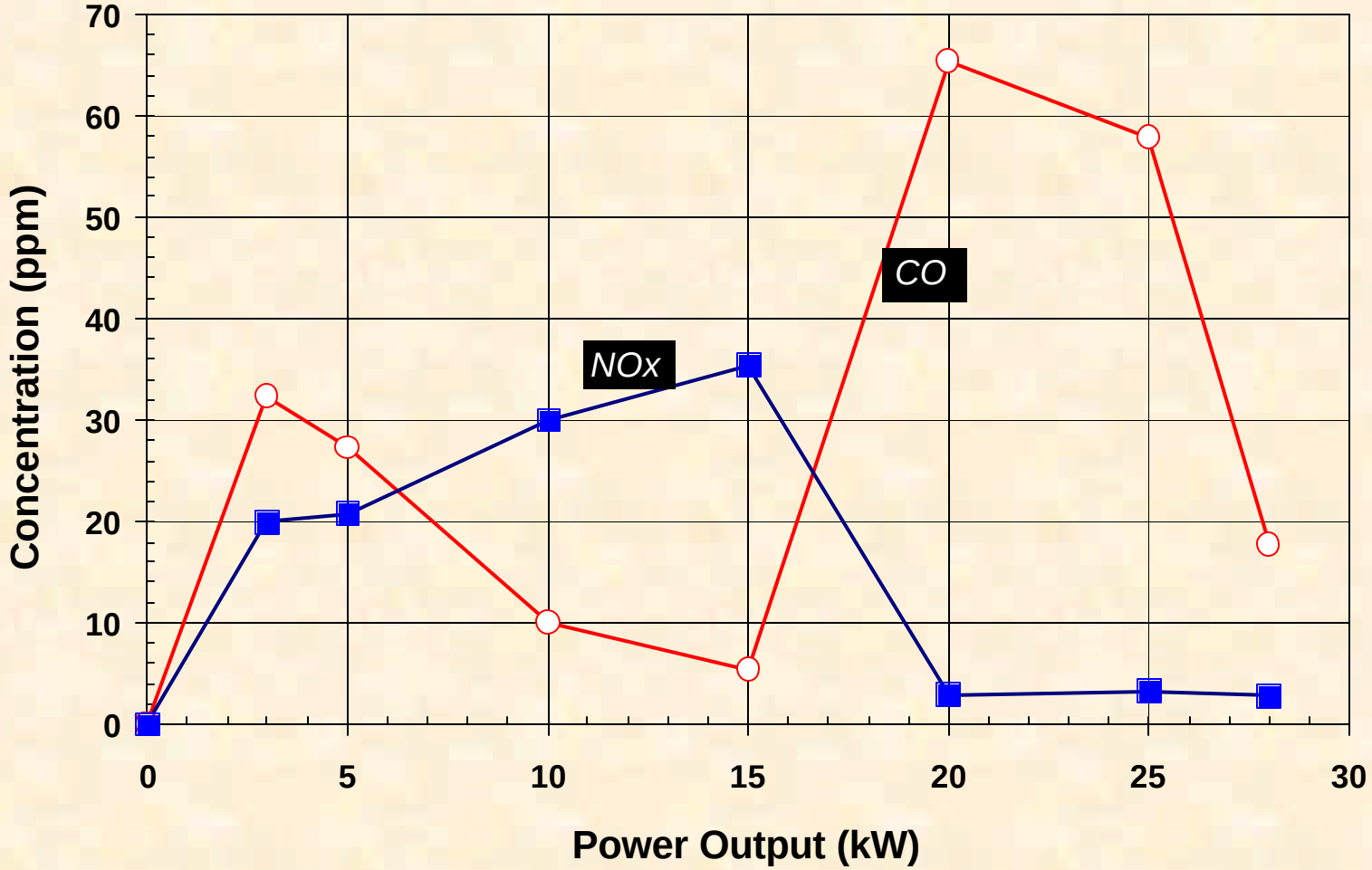
**Based on 127°C or 260°F flue gas rejected to the atmosphere*

Dependence of HRU Water Temperature on Microturbine Power Output

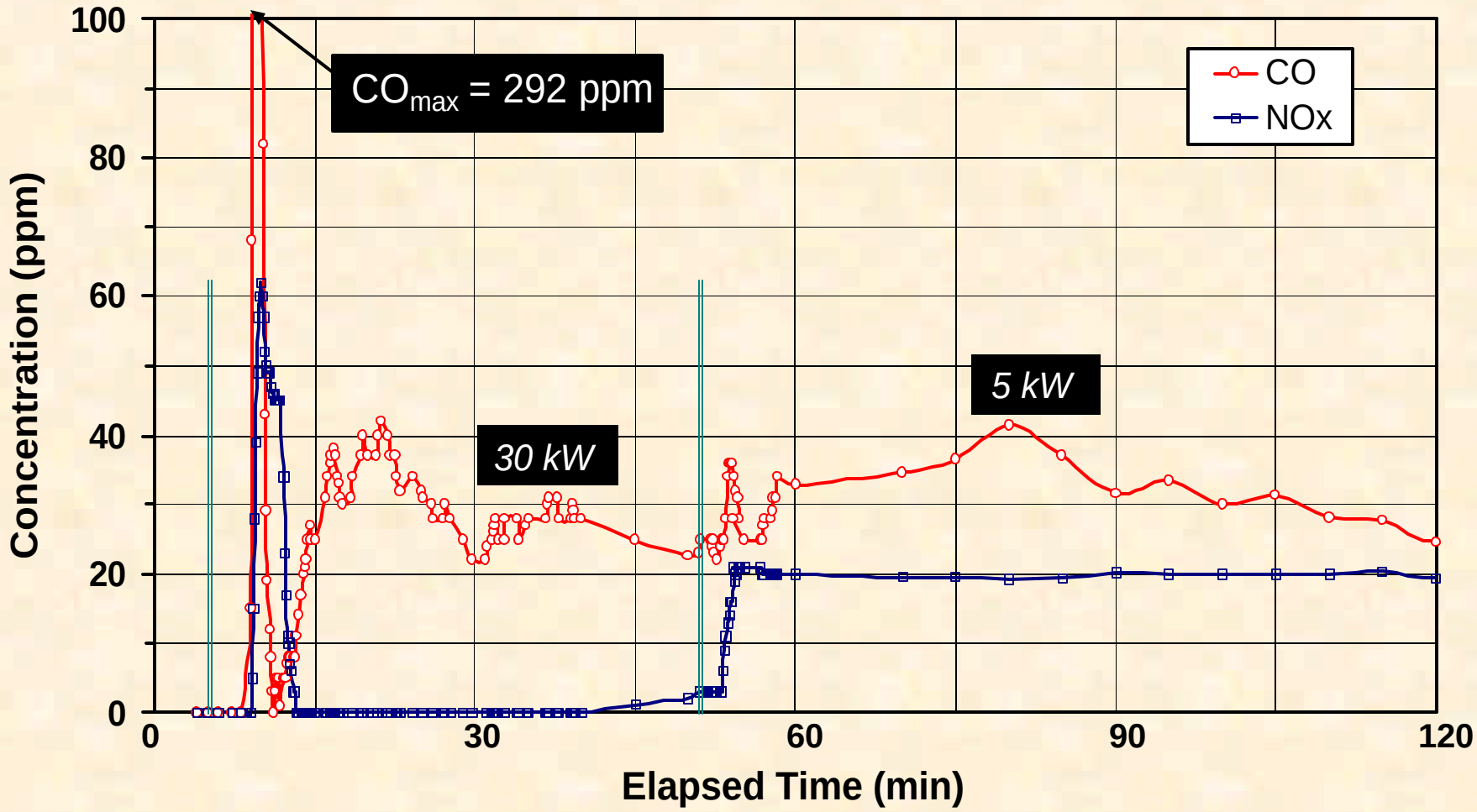


Heat Recovery in the HRU with Water Flow Rate of 19 gpm or 4.3 m^3/h

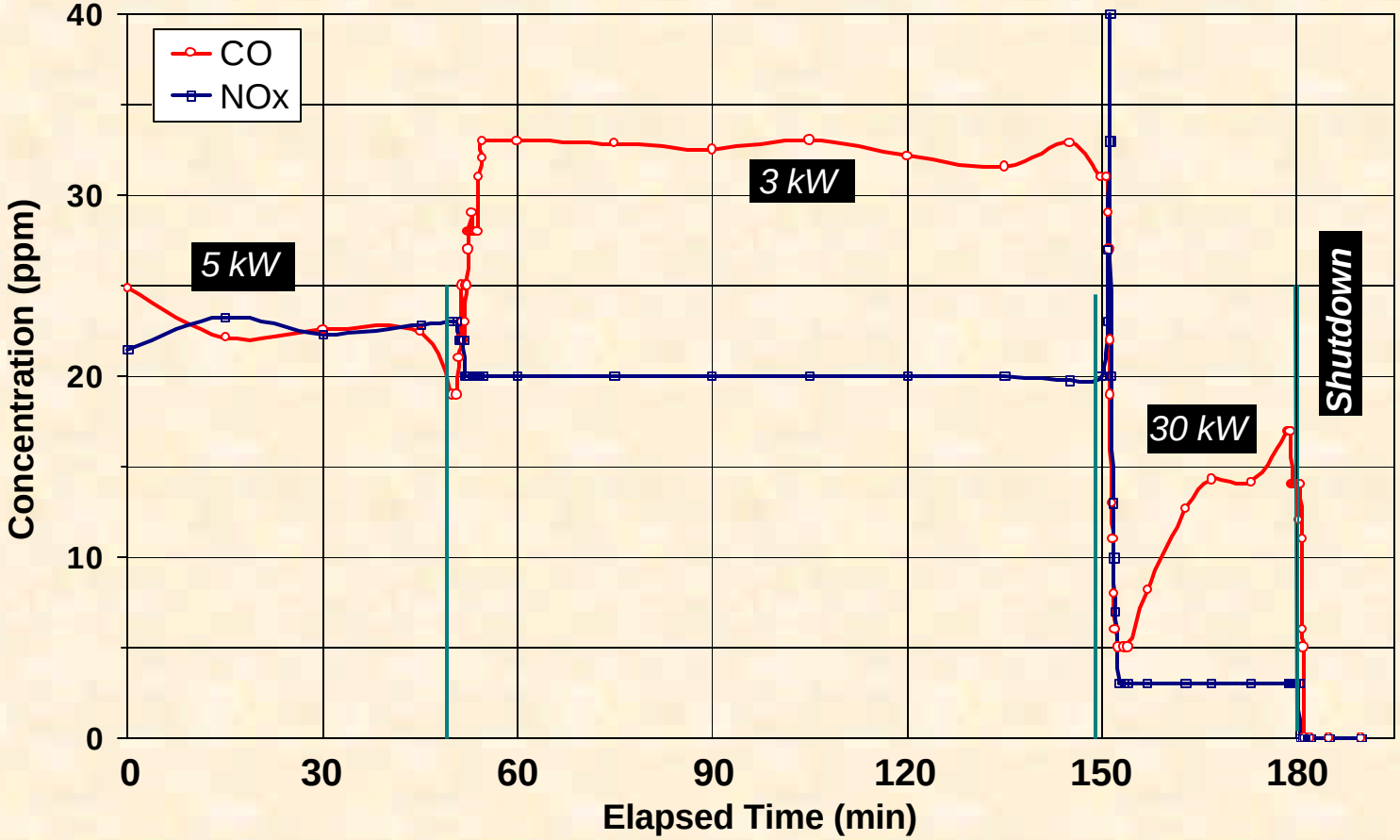
Flue Gas Emissions at Various Power Outputs (Steady-State)



Flue Gas Emissions STARTUP (Transient)



Flue Gas Emissions SHUTDOWN (Transient)



SUMMARY

Microturbine Performance

- **Efficiency of Unit Drops Off Significantly with Power Output**
  - **23% at full power — 18% at 1/3 power**
  - **Efficiency drops off significantly below 1/3 power**
- **Above 65°F or 18°C, Turbine RPM Limit Causes Drop Off in Power Output**
  - **Quite apparent when unit is operating at full power**
- **Only Major Problem Encountered is the Natural Gas Compressor**
  - **Ball-bearing rotary flow compressors (RFC) failed at ~90 and ~300 h**
  - **Replaced with new foil-bearing RFC and re-benchmarking**

SUMMARY

Microturbine Performance (Cont.)

- **Slow Startup and Shutdown (minutes)**
- **Relatively Fast Dispatch (~20 s)**
- **Low Emissions At Full Power**
  - **~3 ppm NO_X (measured at 18.5% Oxygen)**
  - **~8 ppm NO_X (corrected to 15% Oxygen)**
- **Current Source (Follows Grid Voltage/Frequency)**
- **Relatively Constant Power Factor (~Unity)**

SUMMARY

Microturbine Combined with Heat Recovery Unit (HRU)

- **Externally Applied Maximum Exhaust Backpressure (<1.7x10^{-2} atm) has minimal effect on power output and efficiency**
  - **4% Drop in Microturbine Power Output**
  - **2% Drop in Microturbine Efficiency**
- **Efficiency (~55%) with HRU was Relatively Constant Over the Microturbine's Power Output Range**
- **CHP Tests Proceeding**
  - **With Indirect/Direct-Fired Desiccant Dehumidifiers**
  - **With Indirect-Fired Single Effect Absorption Chiller**

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