CETC

Inlet Air Supercharging and Low NOx Duct Burners

Rob Brandon, Bryan Halliday

Omar Ramadan

CANMET Energy Technology Center

Natural Resources Canada

ETB

CETC

The Issue

1) Gas turbine power output decreases as ambient air temperature increases and/or ambient pressure decreases, essentially since air density is lower.

   The gas turbine, as a capital asset, is fully exploited only when the air temperature is very low and ambient pressure is high. At all other temperatures/pressures, the opportunity to maximize return on investment is missed.

2) Value of power generally increases as air temperature increases (in the summer), since demand for power generally increases.

   So, at those times when the potential benefit from the investment is the greatest, the capability of the asset is the least.

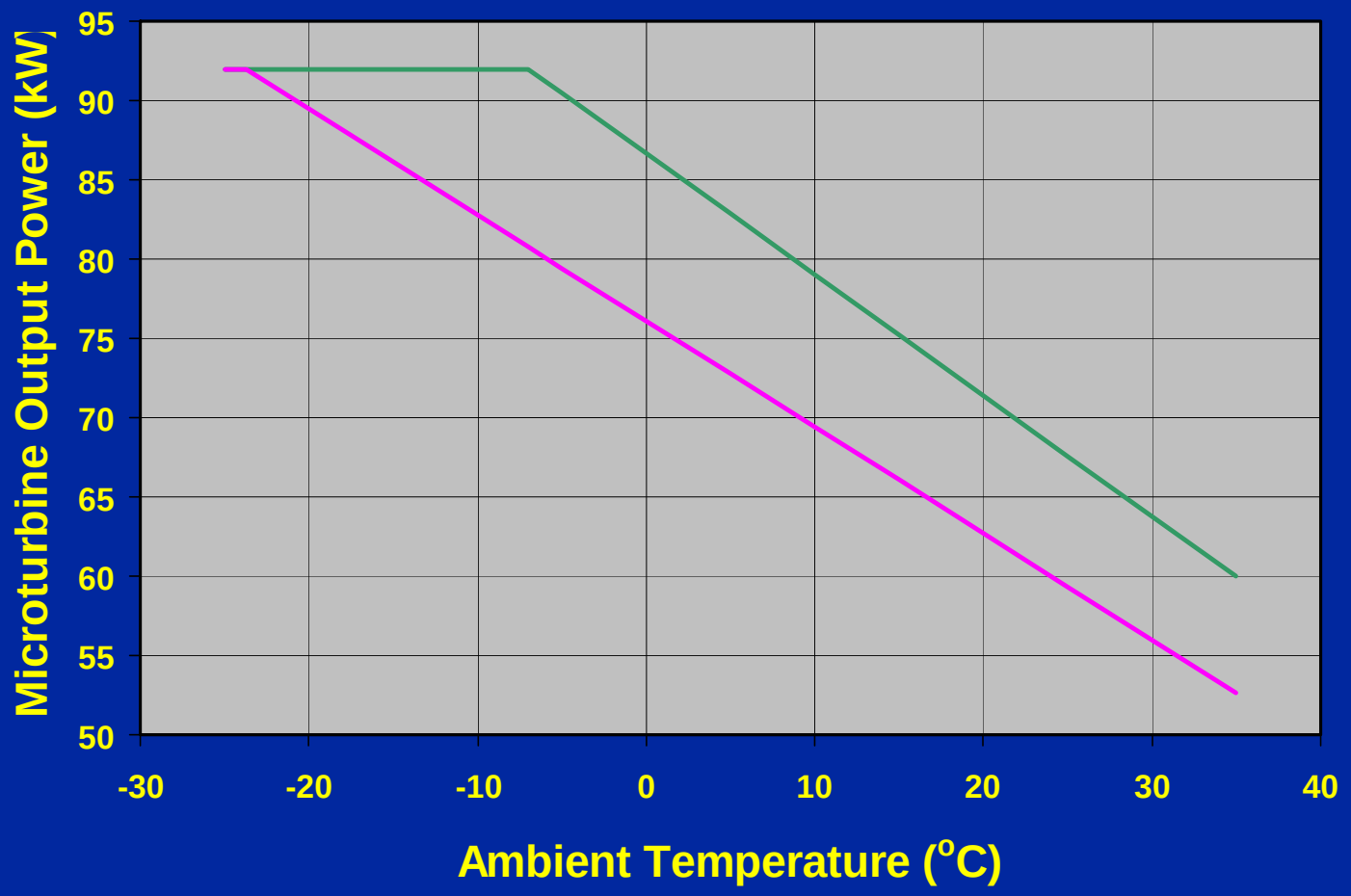
3) Therefore, additional investment may be justified to recover lost capacity, and this additional investment may be less, in terms of $/recovered kW, than the investment in the gas turbine itself.

ETB

CETC

Microturbine Power Production vs Ambient Temperature

Sea Level; Calgary (1084 m above SL)



ETB

CETC

Potential Solutions

1) Inlet air cooling is the most common approach to recovering capacity that would be lost due to high ambient temperature. There are three methods:

   i. Evaporative cooling employing a wetted media;

   ii. Inlet air fogging – injecting fine water droplets into the inlet air stream;

   iii. Mechanical or absorption refrigeration.

2) An approach that was been successfully used on a few industrial gas turbines,such as the Westinghouse B10 rated at 40 MW in the 1960's, is Inlet Air Supercharging.

ETB

CETC

What is Supercharging

1) A gas turbine is supercharged if the inlet pressure exceeds the exhaust pressure. This will tend to increase power output in two ways:

   i. Increased gas turbine compressor inlet air density;

   ii. Increased gas expansion across gas turbine power turbine.

2) Though Inlet Air Supercharging is a proven technique, the early attempts to apply it to stationary engines were uneconomical due primarily to the prevailing “spark spread”. Also controlling the inlet fan proved difficult

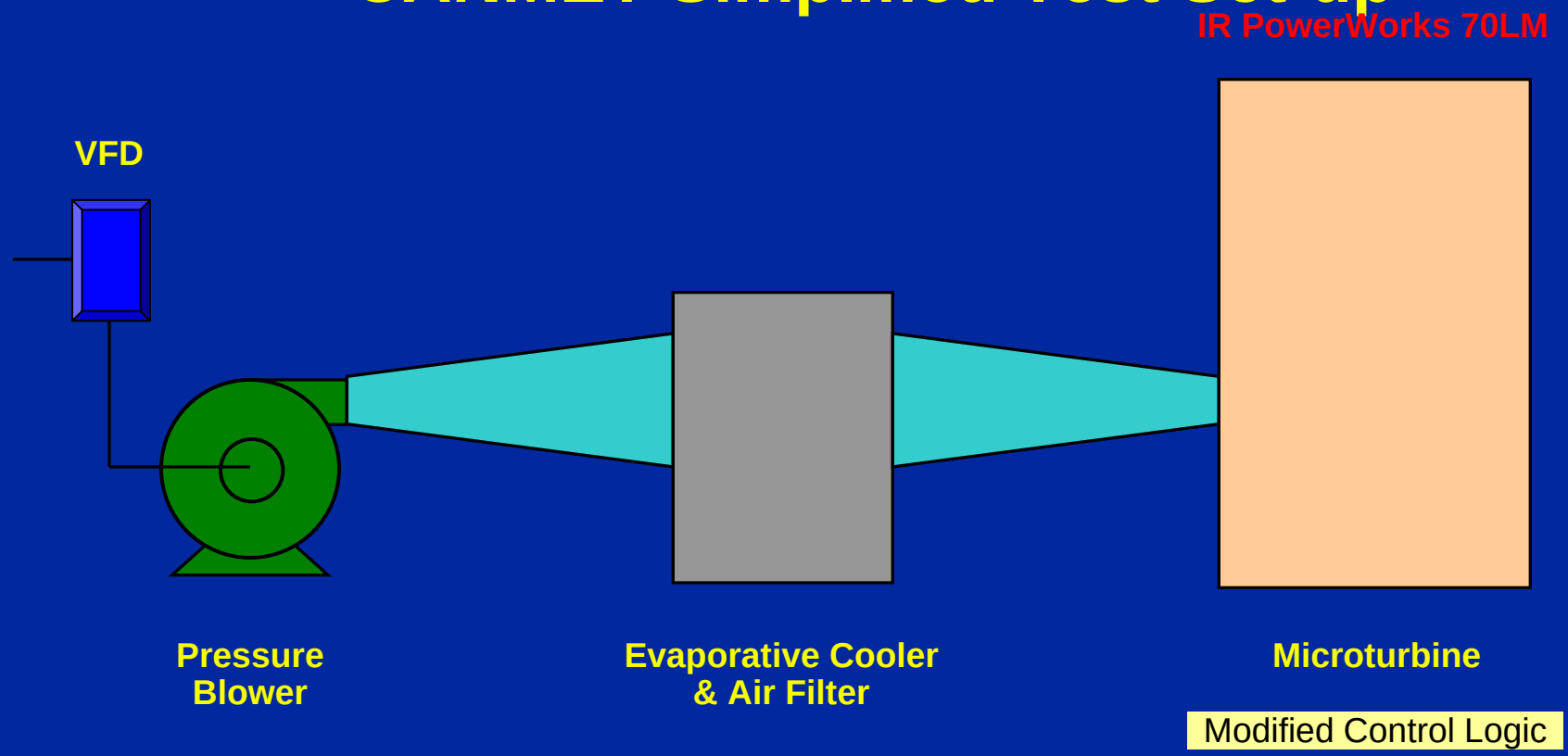
3) The company ***Enhanced Turbine Output LLC (ETO)*** has recently patented an improved technique for supercharging of stationary gas turbines which they call ***PowerCool***.

4) CANMET is investigating this gas turbine supercharging concept under agreement with ***ETO***.

ETB

CETC

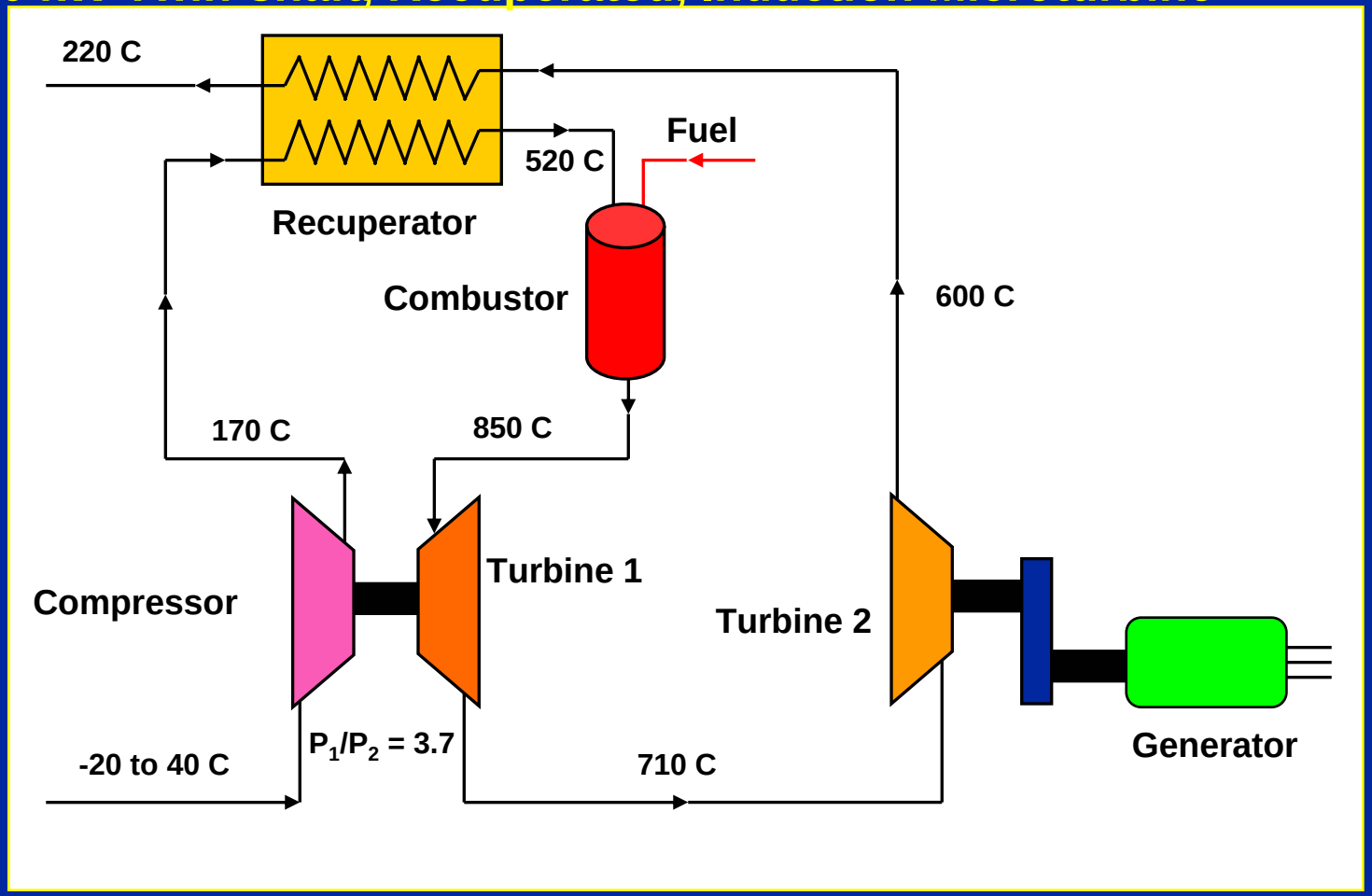
CANMET Simplified Test Set-up



ETB

CETC

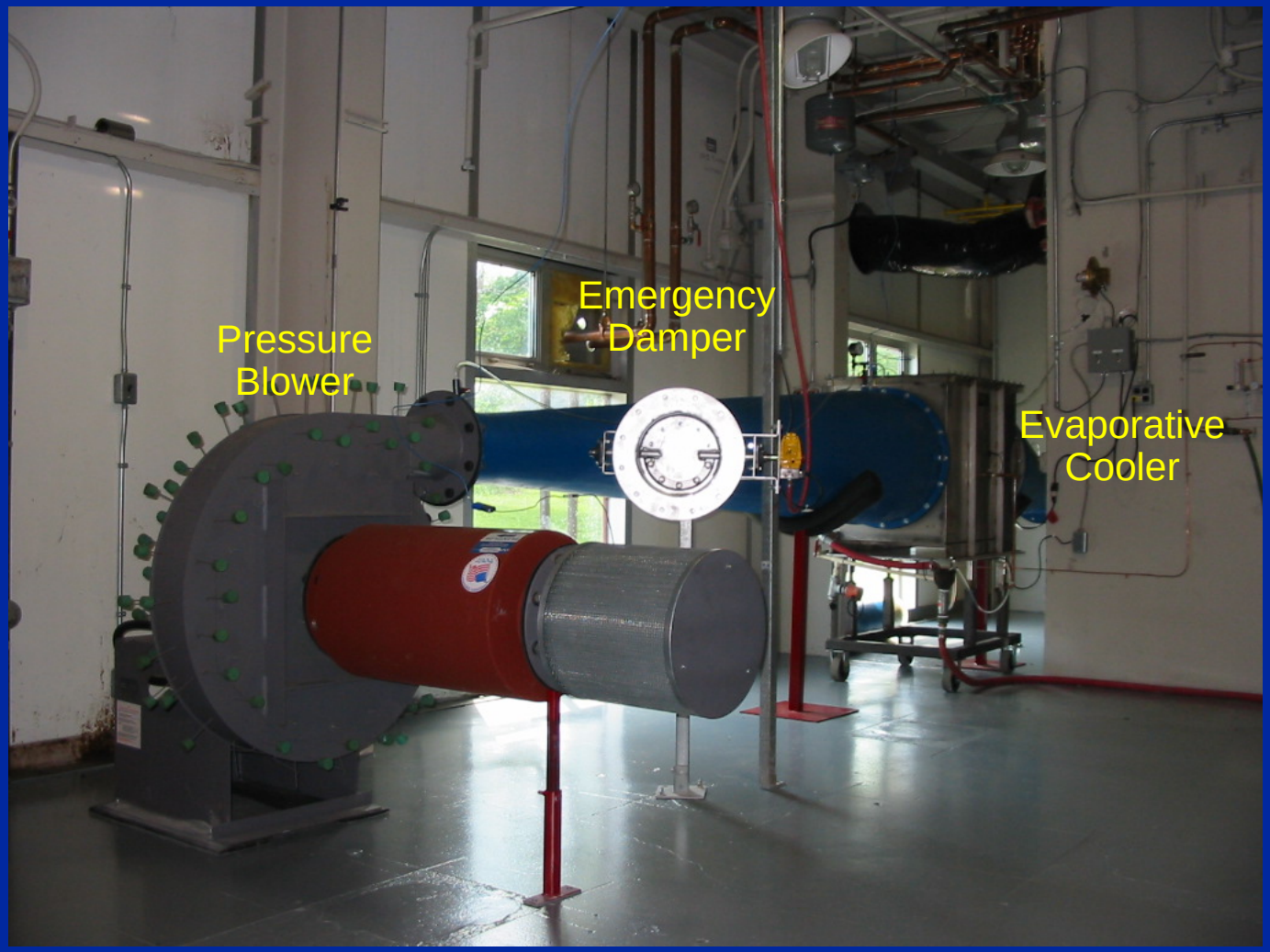
70 kW Twin-shaft, Recuperated, Induction Microturbine



ETB

CETC

CANMET Laboratory Installation



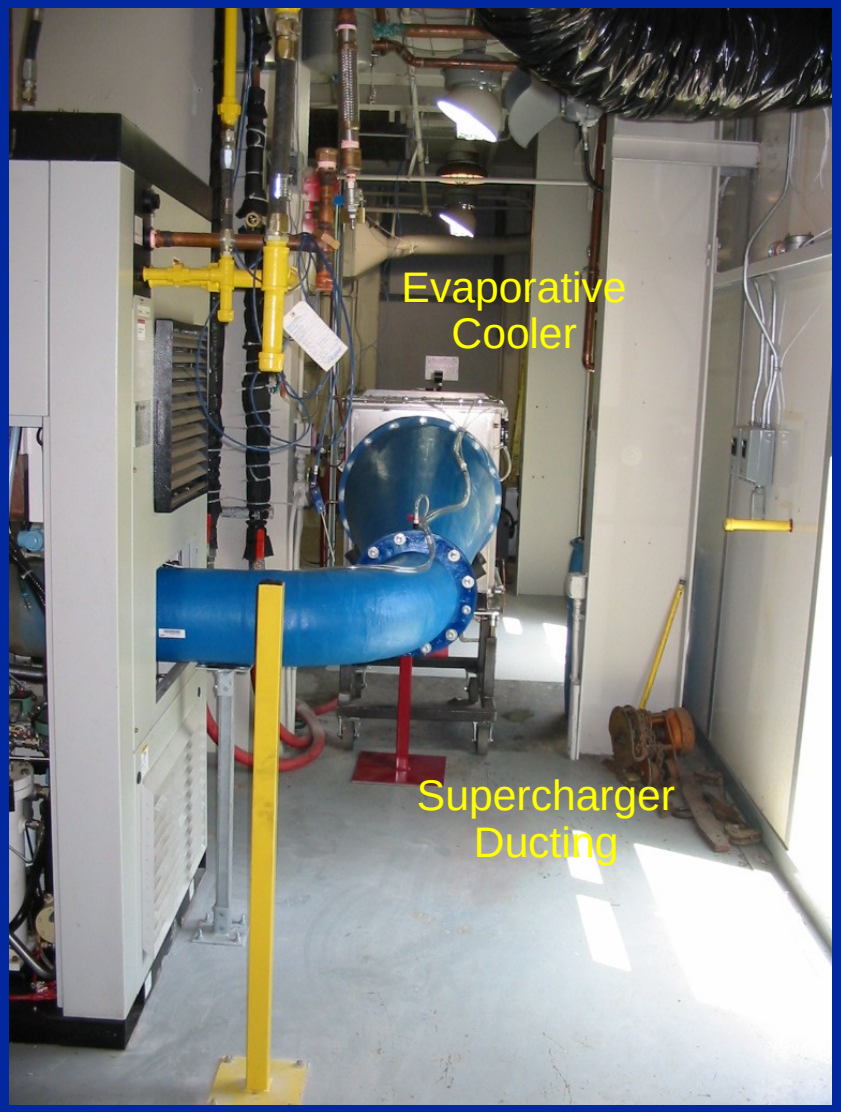
ETB

CETC

CANMET Laboratory Installation

Microturbine

IR PowerWorks 70LM

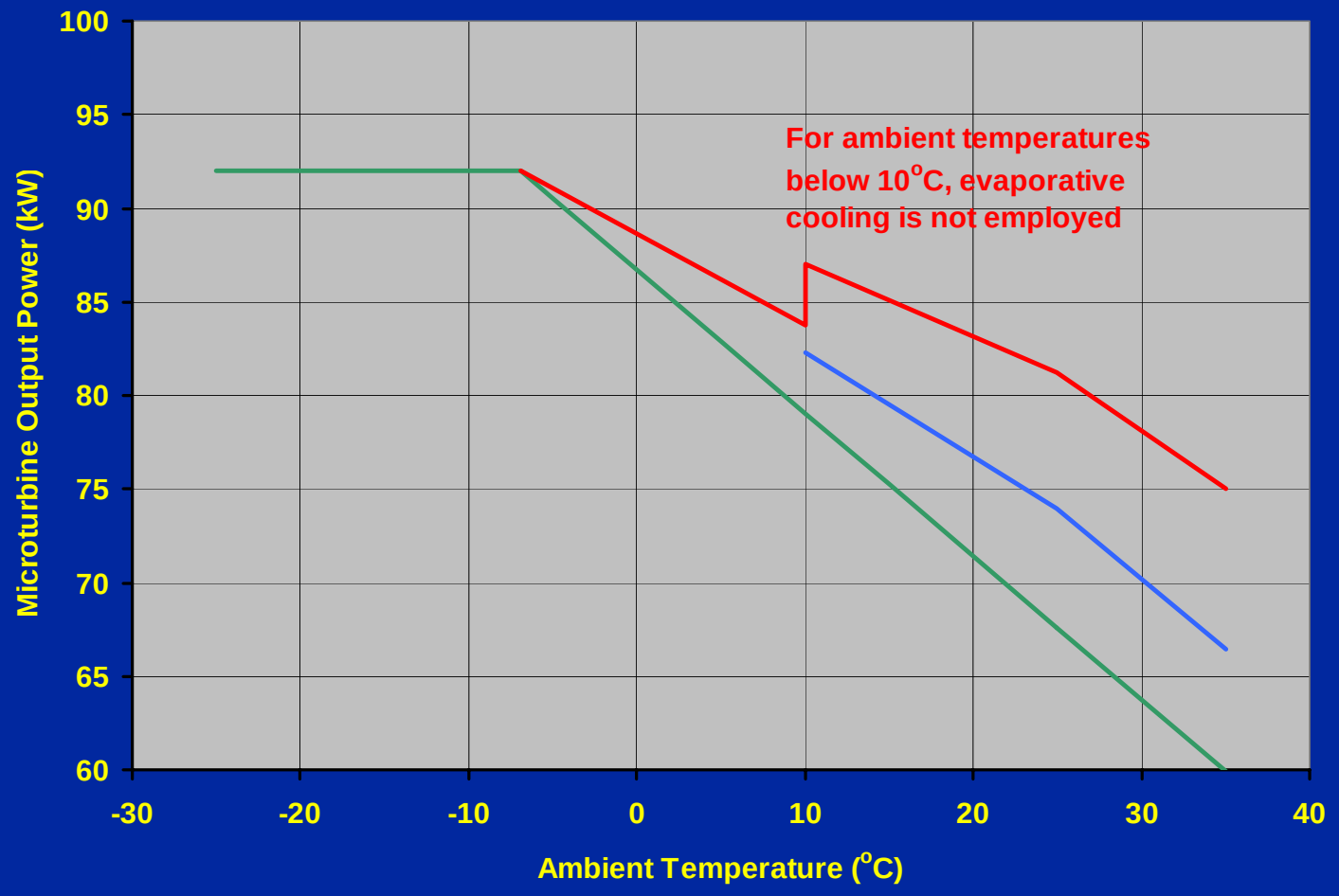


ETB

CETC

Microturbine Output Power vs Ambient Temperature

Inlet Air: Normally Aspirated; Cooled only; Supercharged and Cooled

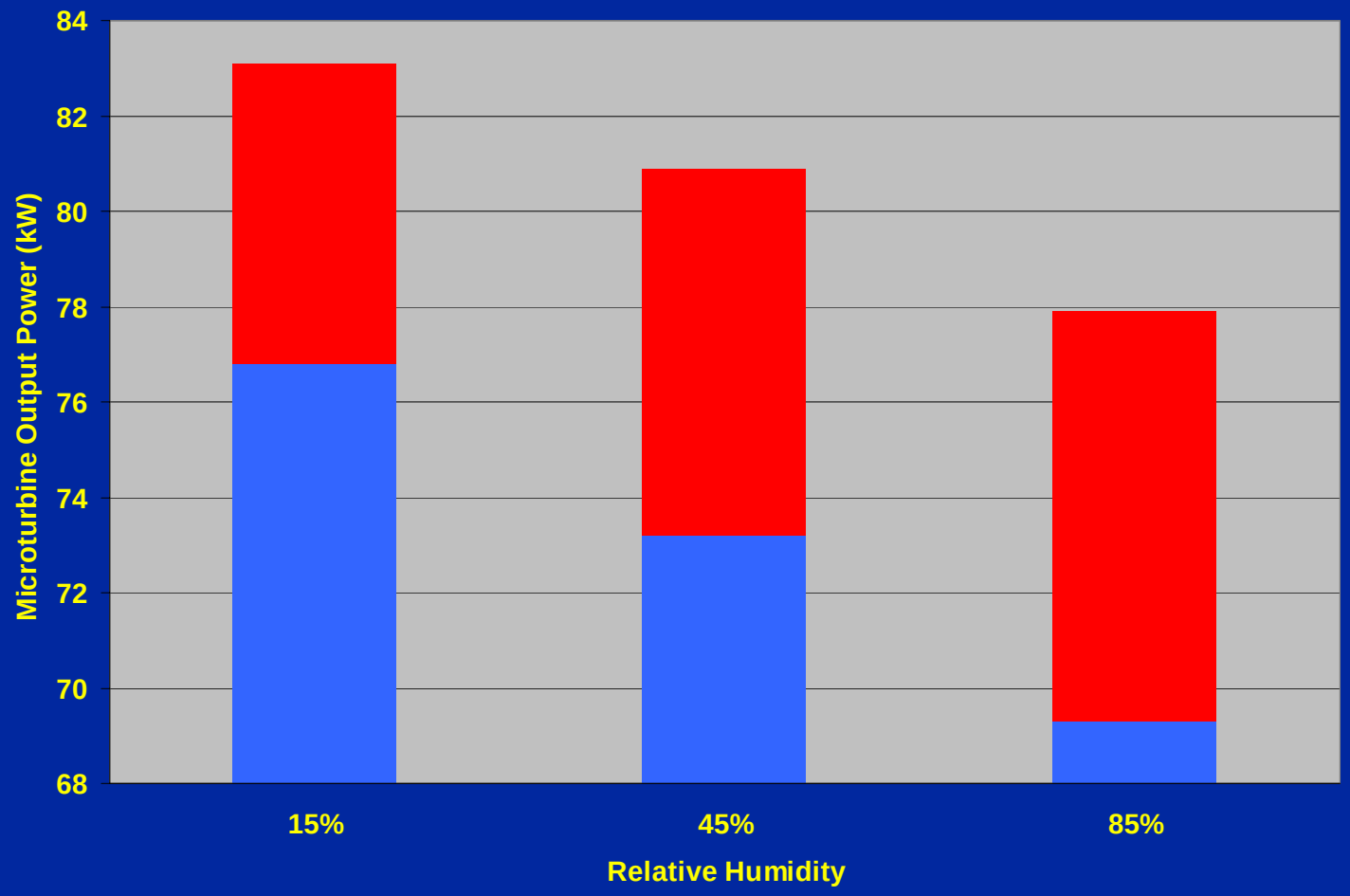


ETB

CETC

Power Augmentation vs Ambient Relative Humidity

Evaporative Cooling; Supercharged with Evaporative Cooling



ETB

CETC

Economic Analysis

- Using hour by hour power data an economic analysis was carried out using 2005 Toronto weather and power price data
- Complete results will be published at ASME TurboExpo 2006 in Barcelona in May 2006
- Results indicate that although supercharging a single 70 kW might not be cost effective, economies of scale result in the concept being economic in Ontario with multiples of 4 x 70 kW turbines or a 250 kW turbine

ETB

CETC

Investigation Plan Going Forward

Stage 1 – Laboratory Testing

- Completed

Stage 2 – Field Trial

- Relocate and reinstall the supercharging system to a field installed PowerWorks 70LM. Monitor system operation over long-term.
- CANMET is interested in working with partners (including those in the US) to field trial the concept

Stage 3 – Large Machine

- Investigate technical feasibility and economic potential to provide a supercharging/inter-cooled system for a larger (MW) gas turbine.

ETB

CETC

Experimental Investigation and Evaluation of Low NOx Natural Gas-Fired Mesh Duct Burner

The Issue

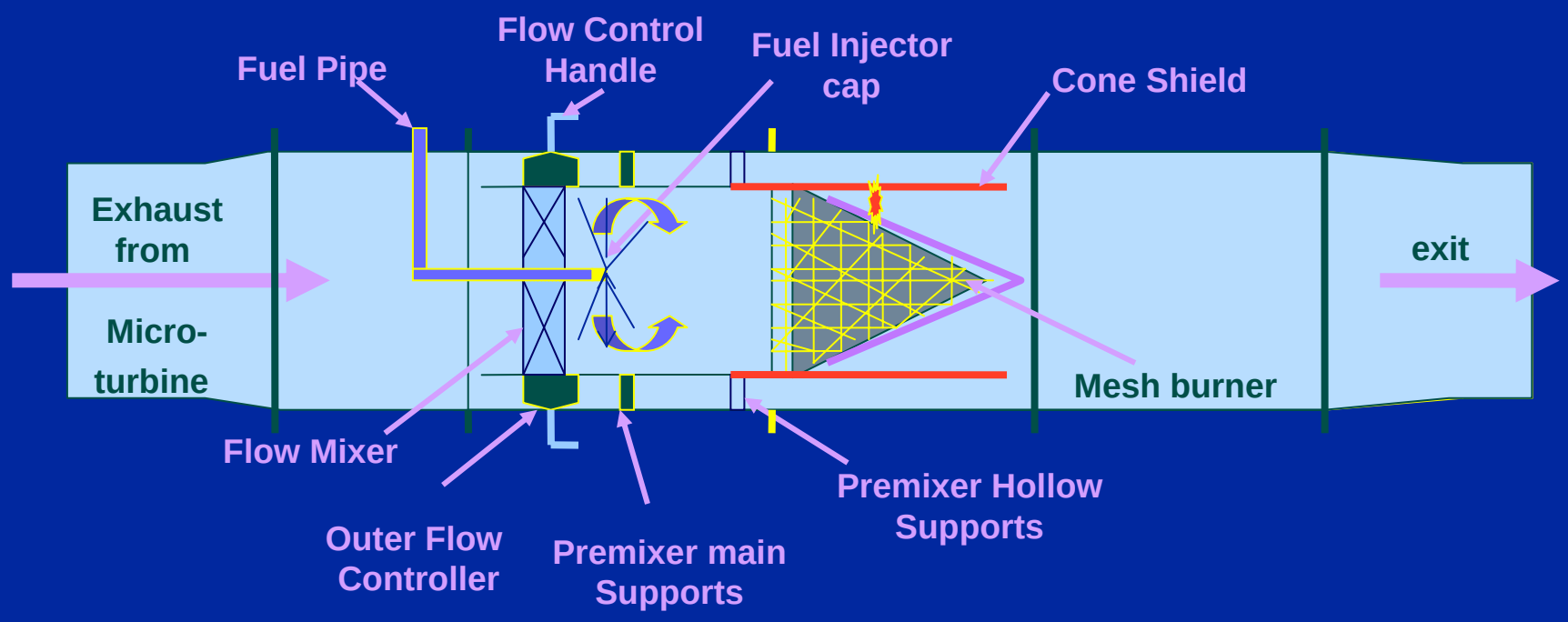
- In order to increase the thermal output from microturbines it will be required to burn additional gas on occasions in the turbine exhaust
- A critical attribute of microturbines is their ability to produce power at very low NOx emissions. Therefore the duct burner should result in similar NOx emissions so this environmental value is not degraded significantly

ETB

CETC

Duct burner design (test rig)

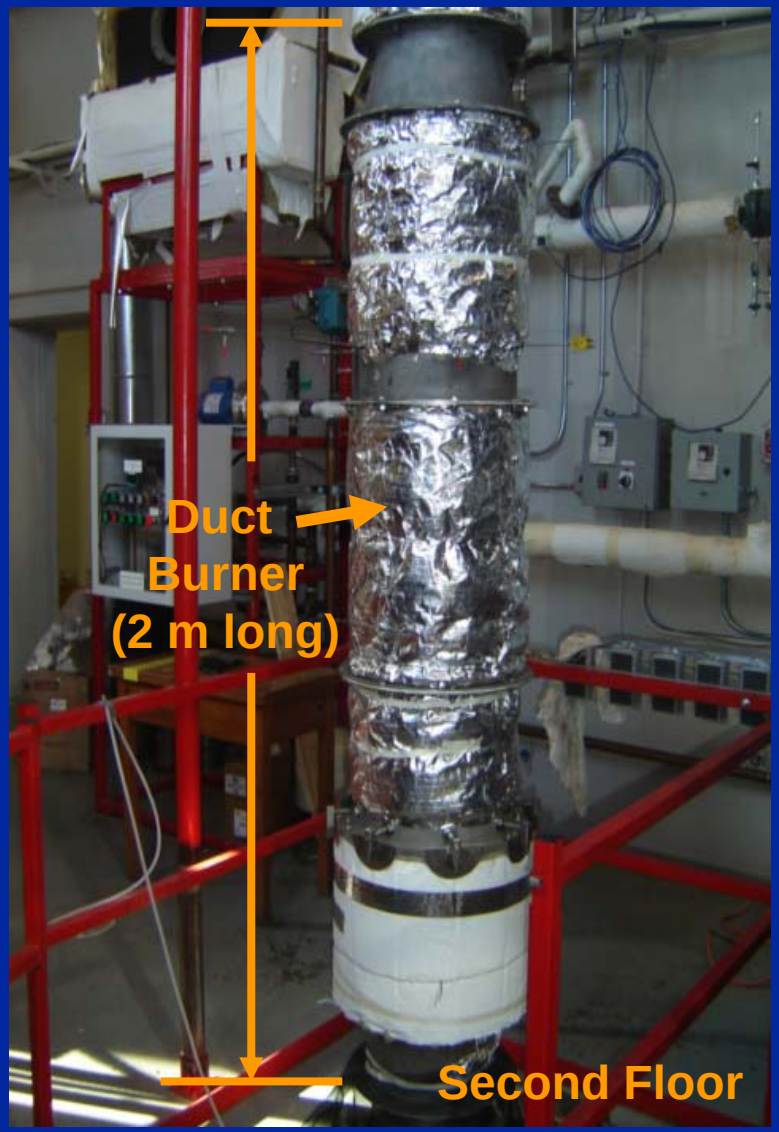
Schematic of the proposed duct burner :

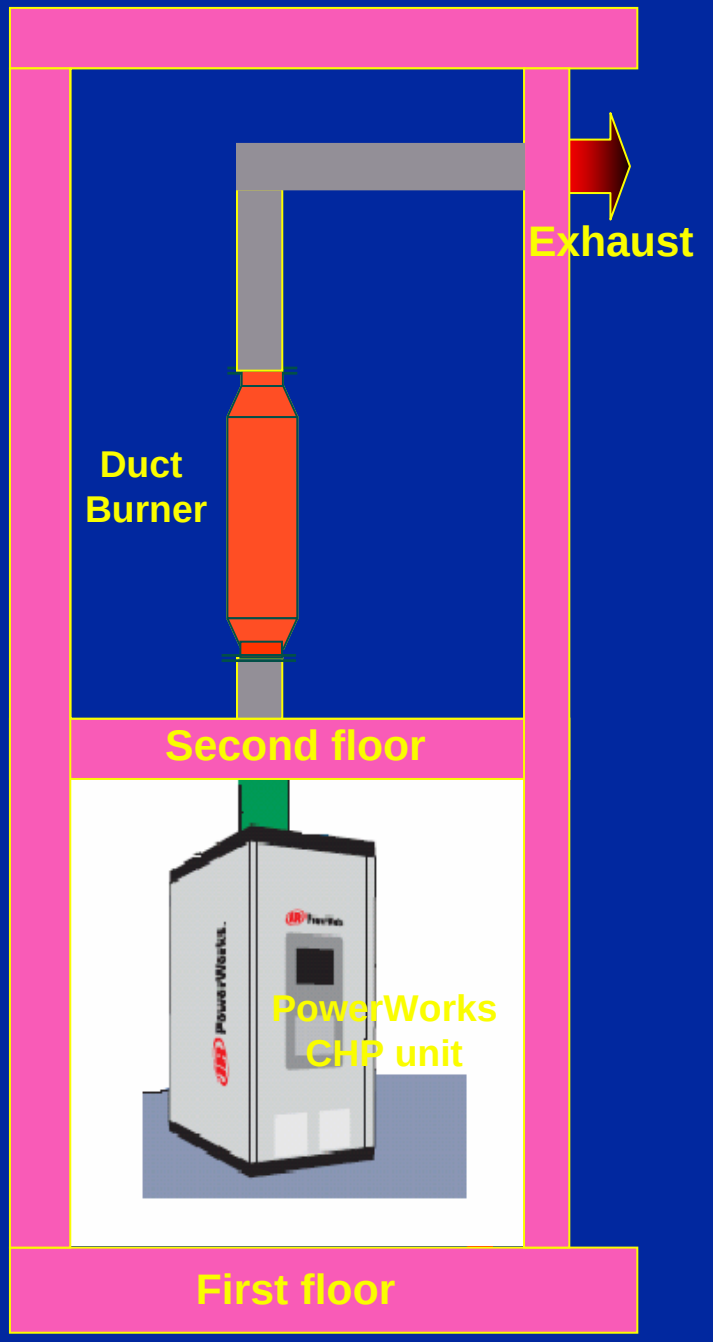


ETB

CETC

CANMET test facilities Ottawa



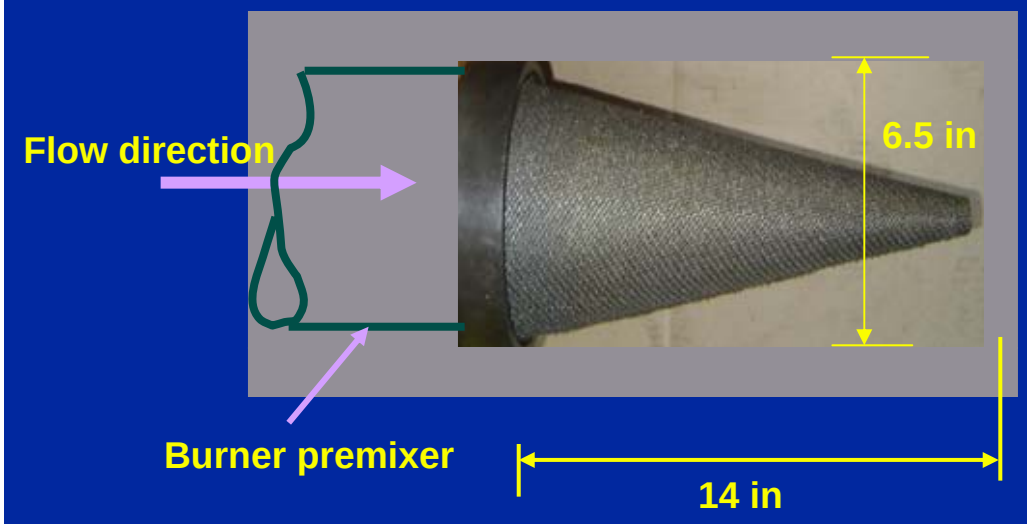


CETC

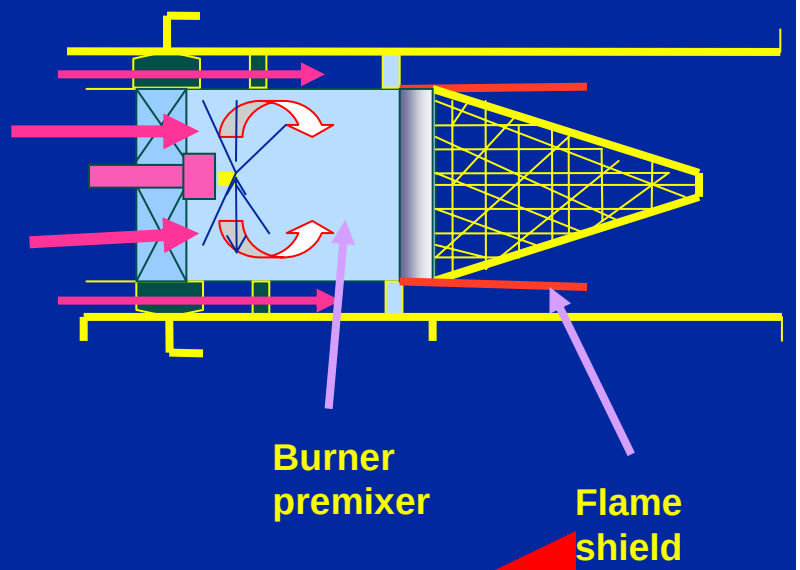
Conical Mesh Burner

ACOTECH * (Advanced Combustion Technology) fabricated three test burners of different pressure drop for this investigation

The design was based on heat release per unit area of 2500 kW/m^2 and 236 kW of heat release with 100% excess air.



Schematic showing the location of the conical mesh in the duct burner



* N. A. Acotech S.A. of Belgium (Bekaert Group + Royal Dutch/Shell Group)

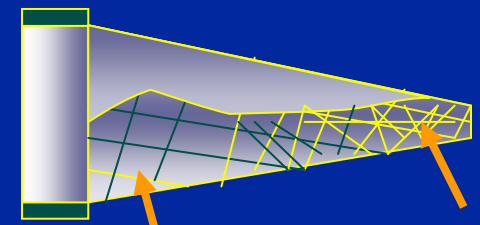
ETB

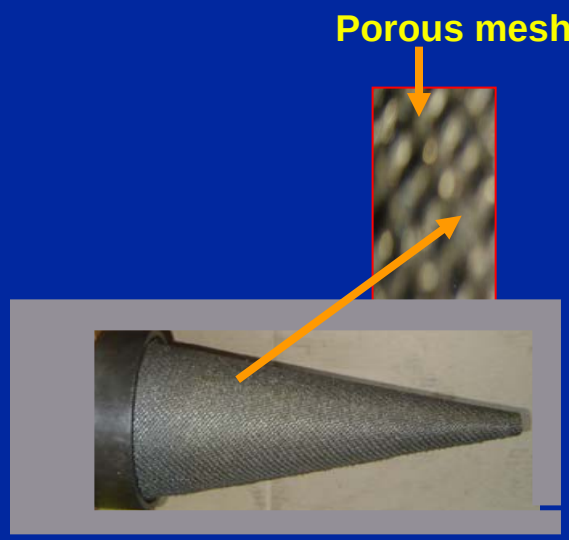
CETC

Conical Mesh Burner (cont.)

Material:

- **LD04 grid (with diamant shapes of 4 mm long and 2 mm wide 1.4 kg/m^2 made of wire of 0.65 mm wide and 0.4 mm thick) , with 97% open area**
- **NIT 100: is Fecralloy alloy, made mostly out of Iron, Chrome & Aluminum of 1/16" thick wire with 95% open area**





FeCralloy Composition:

* 20% Chromium (Cr)
* Yttrium(Y) > 0.1%
* 0.08% Manganese (Mn)
* 0.03%Carbon &
* 5% Aluminum (Al)
* 0.3% Silicon (Si)
* 0.03% Copper (Cu)
* Iron (Fe) balance

ETB

CETC

Modes of operation of surface combustion burner

Depending on the local momentum of the gaseous mixture introduced through the porous mesh, the flame stabilizes within the porous mesh(Radiant mode) or outside the burner mesh (Blue flame mode).

Characteristics of the blue flame mode:

- Flame stabilized outside the mesh
- High specific power input
- High excess air
- Less radiation and most of the heat released remains in the combustion products
- Low metal temperature

The micro-turbine duct burner operated in a blue flame mode

ETB

CETC

Experimental Testing

First preliminary results show the emissions results of the Low Nox Duct burner integrated with the micro-turbine unit at one of the test conditions

Burner Firing Rate		NOx	CO	CO2	O2
kW		ppm	ppm	%	%
Micro-Turbine Only	Turbine	**1.67**	**4.8**	**1.5**	**18.5**
215	Burner+ Turbine	**12.6**	**5.9**	**4.86**	**12.69**
191	Burner+ Turbine	**6.32**	**5.2**	**4.52**	**13.32**
187	Burner+ Turbine	**5.66**	**5**	**4.48**	**13.39**
184	Burner+ Turbine	**5.2**	**5.3**	**4.46**	**13.42**

ETB