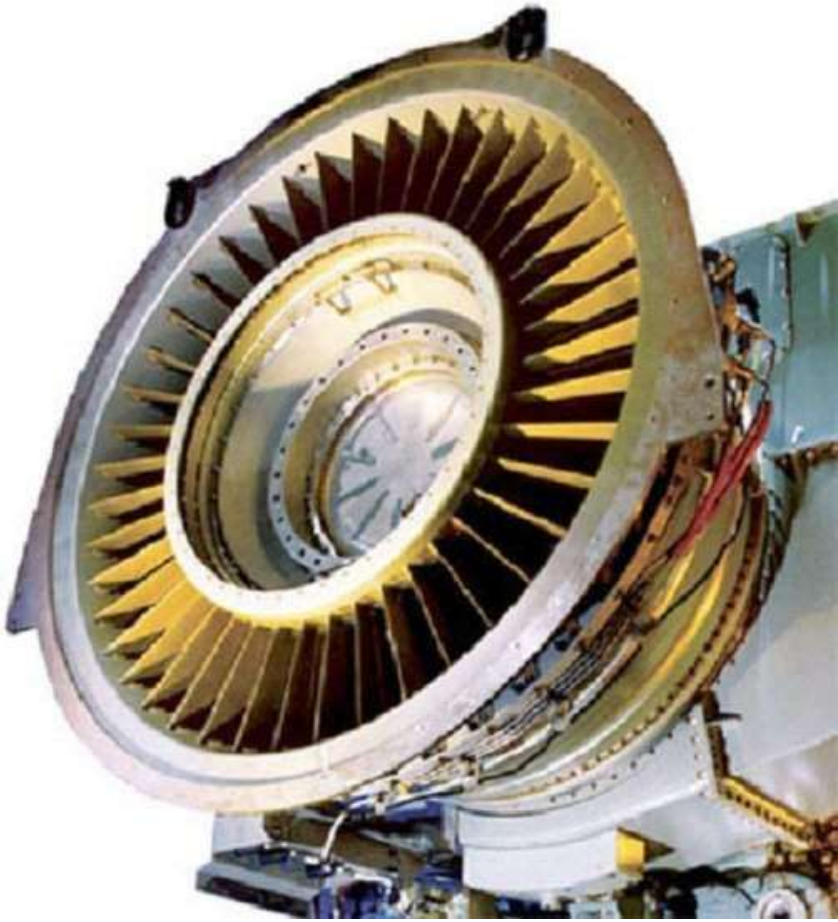
LM6000-PF Gas Turbine Aeroderivative Leader in Dry Low Emissions Technology



imagination at work

LM6000-PF …

… lower emissions …

… while adding flexibility …

… creating more value.

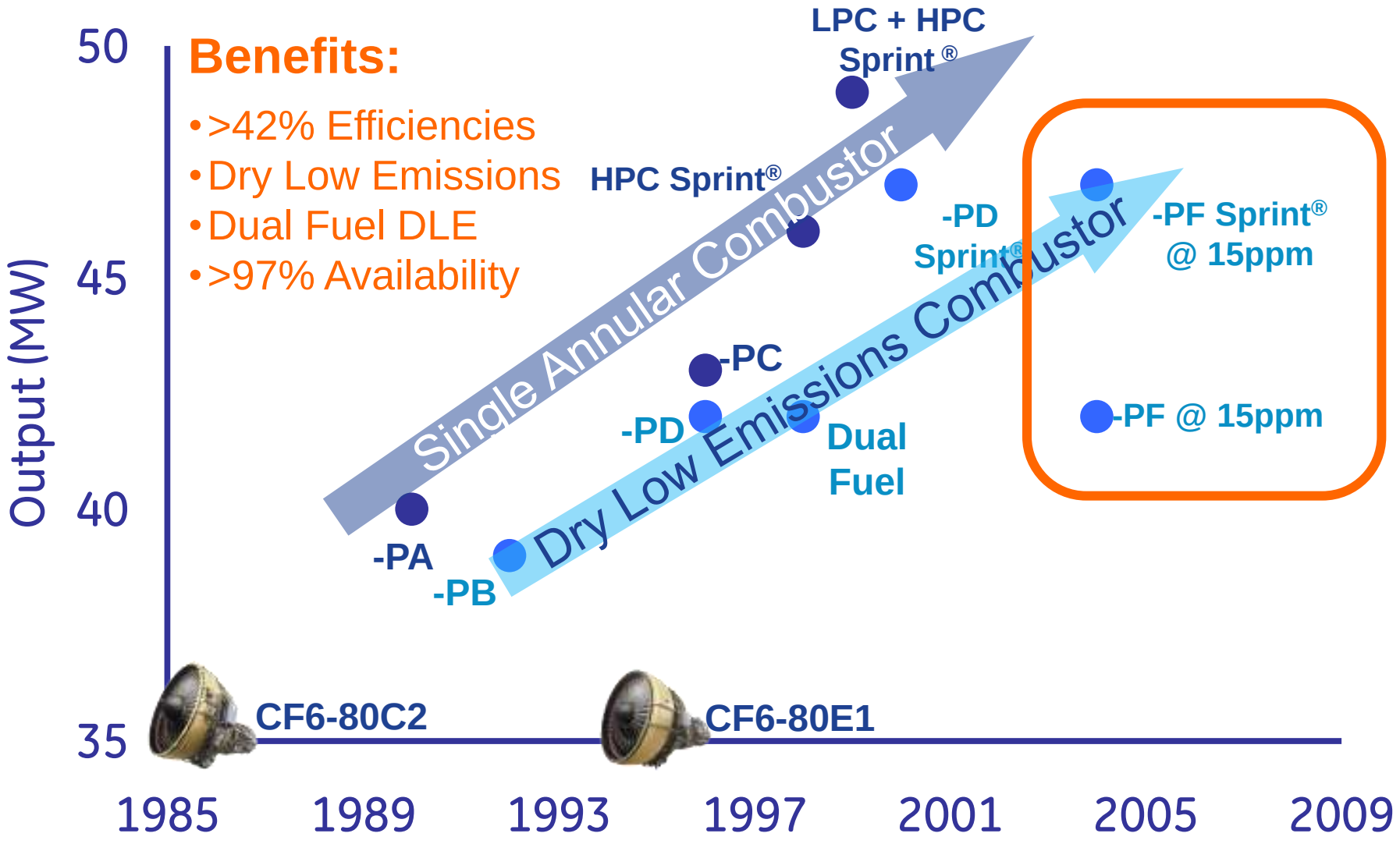
Improved maintainability & greater durability

Greater operating flexibility

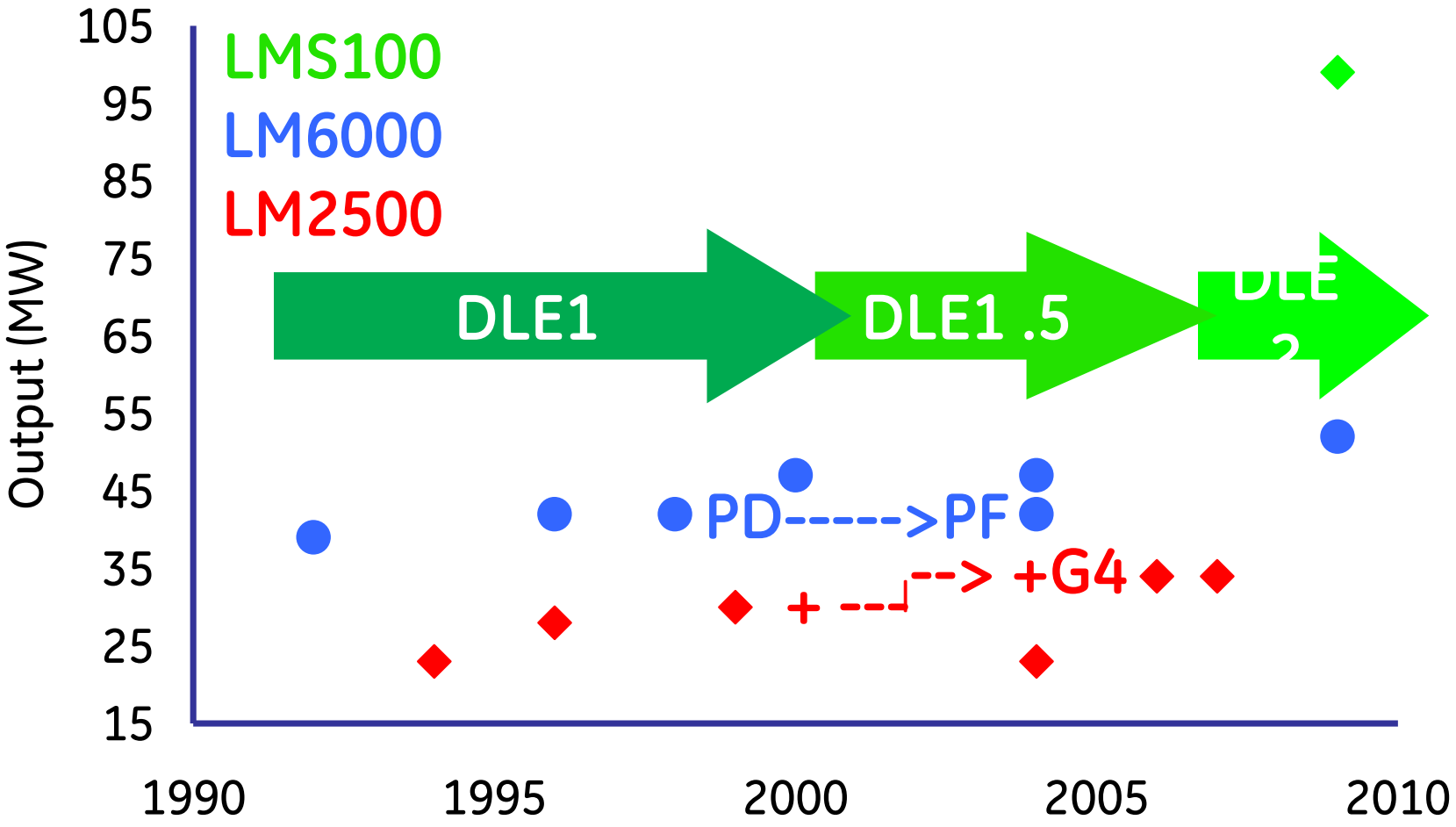
- tolerance to fuel variation
- cold weather operation

The LM6000 Evolution Continues!!

Utilizing proven, advanced technologies to deliver greater value

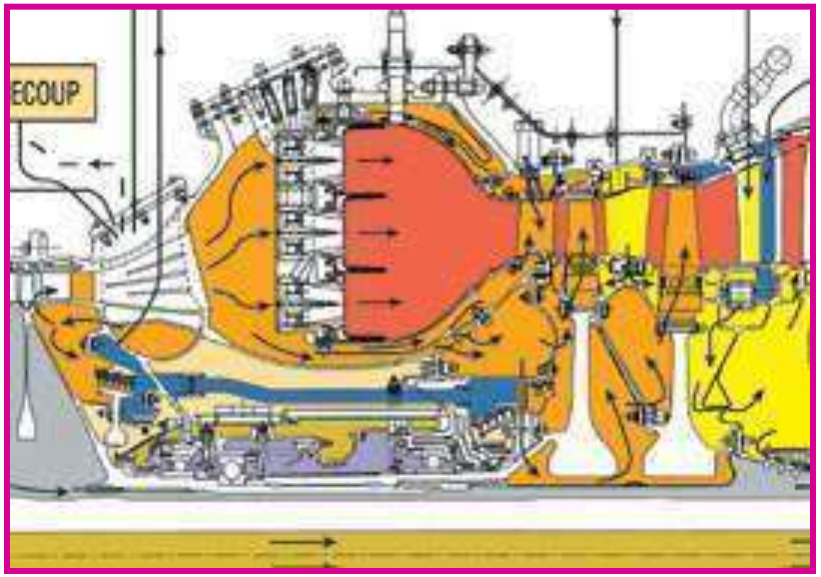


History of DLE technology development



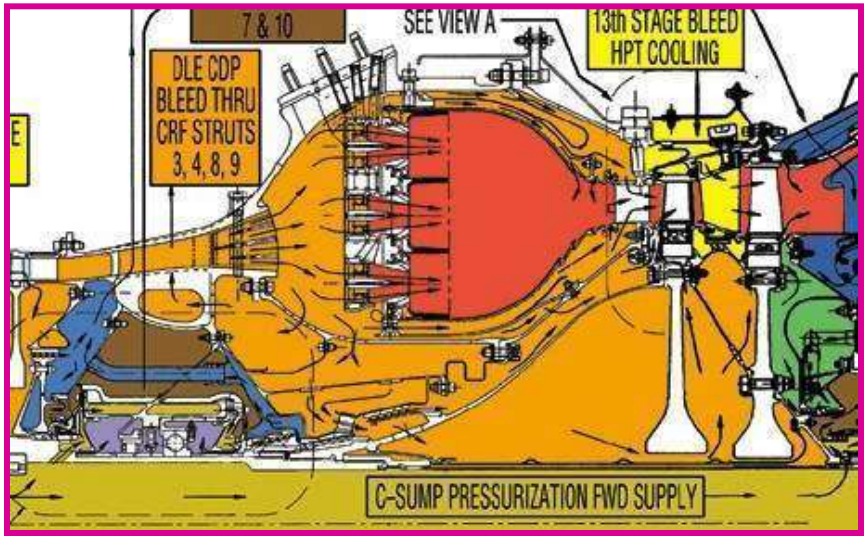
Sharing design approaches across LM DLE products

LM6000



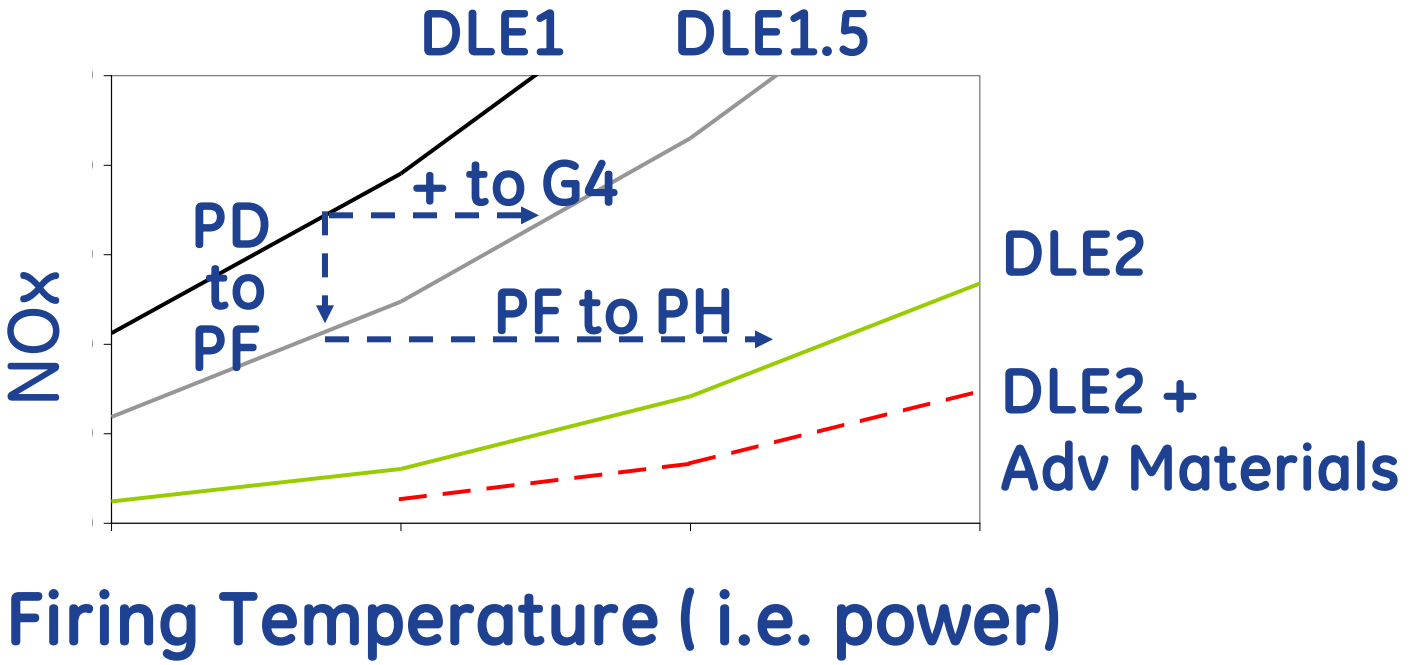
Not to scale
for illustration purposes,
to show similarity

LM2500



25ppm versions shown

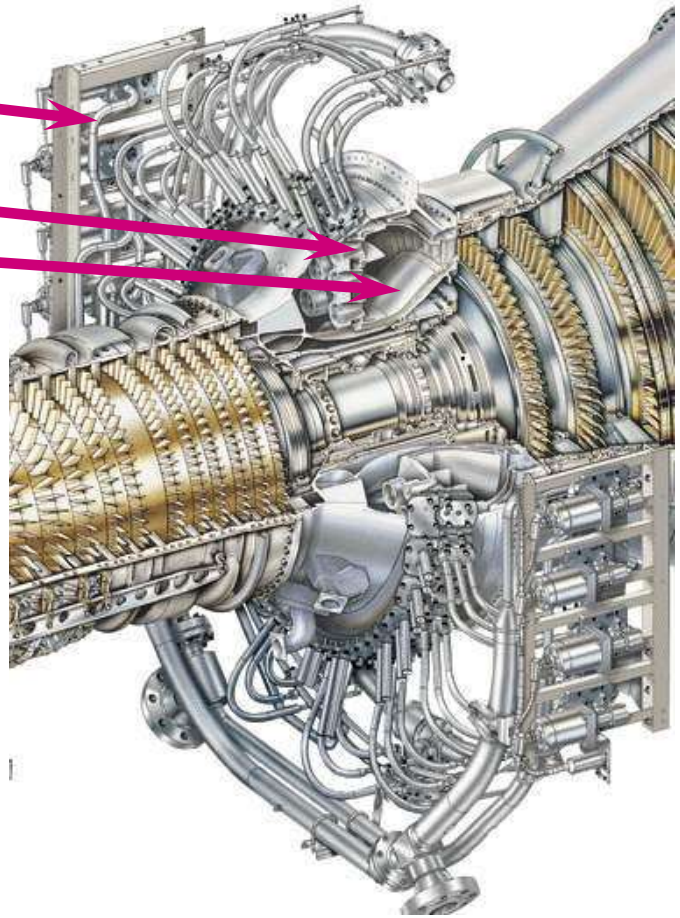
Relation of NOx to firing temperature …
… using technology for lower emissions or …
… for higher power

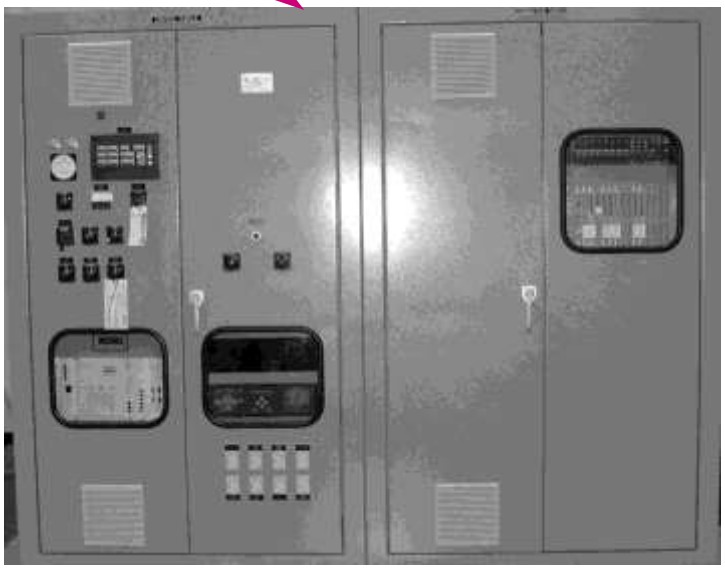


DLE 1.5 Technology for the LM6000-PF

Components redesigned in DLE1.5 technology

Fuel manifold and valving
Premixers
Combustor
Control system

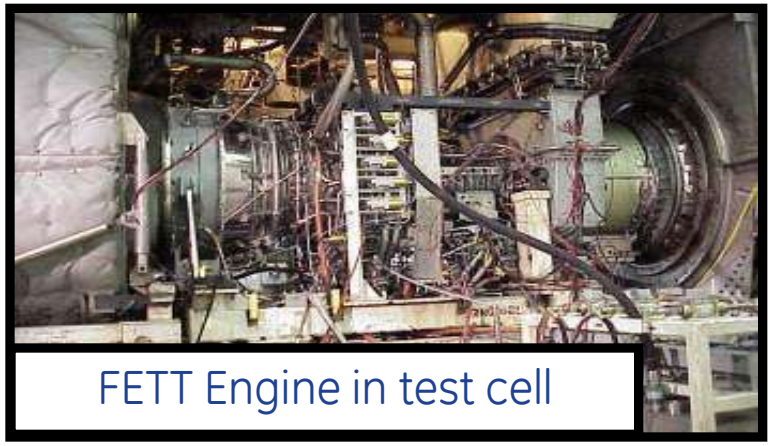




LM6000-PF 15ppm Program

First Engine to Test surpassed all test goals

- 15ppm Nox (gas fuel)
- 65ppm Nox (liquid Fuel)
- Identical Performance to PD
- Improved operability (acoustics) over current 25ppm DLE combustor



FETT Engine in test cell

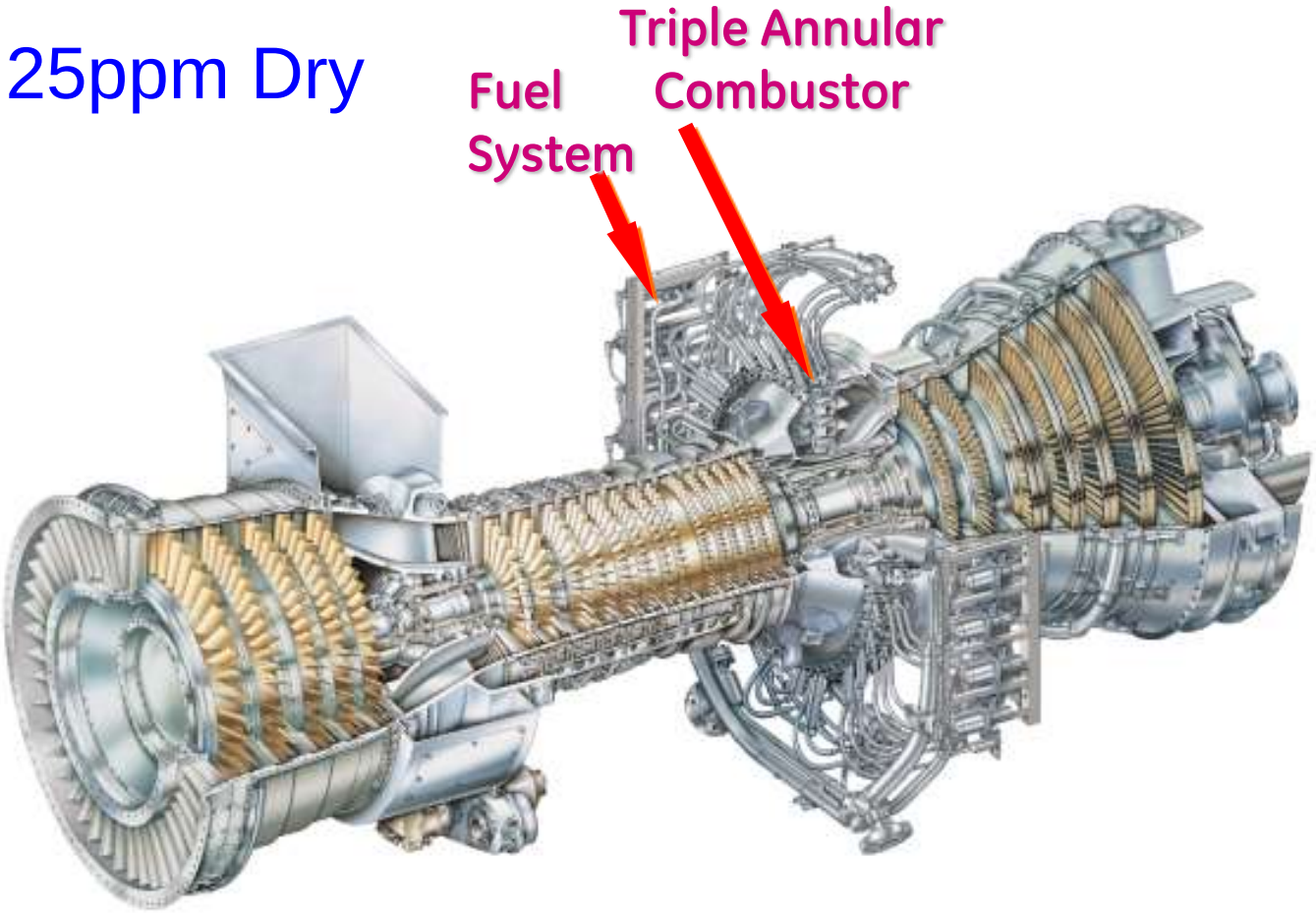
1st unit in commercial operation as of Aug 2005;

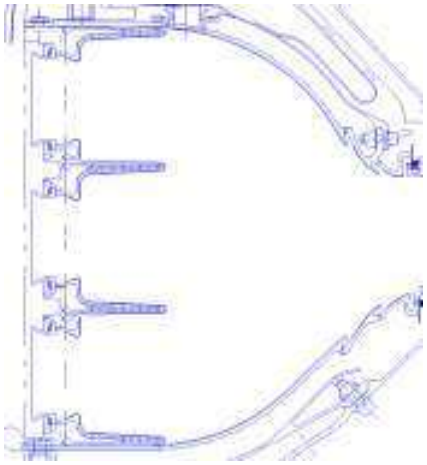
- Reached hot-section in 2008 with 23k hours.
- Hardware in excellent conditions.

First unit – for new GT genset shipped in 1st half of 2006, commissioned in 2007. Now with more than 15k hours

LM6000-PD

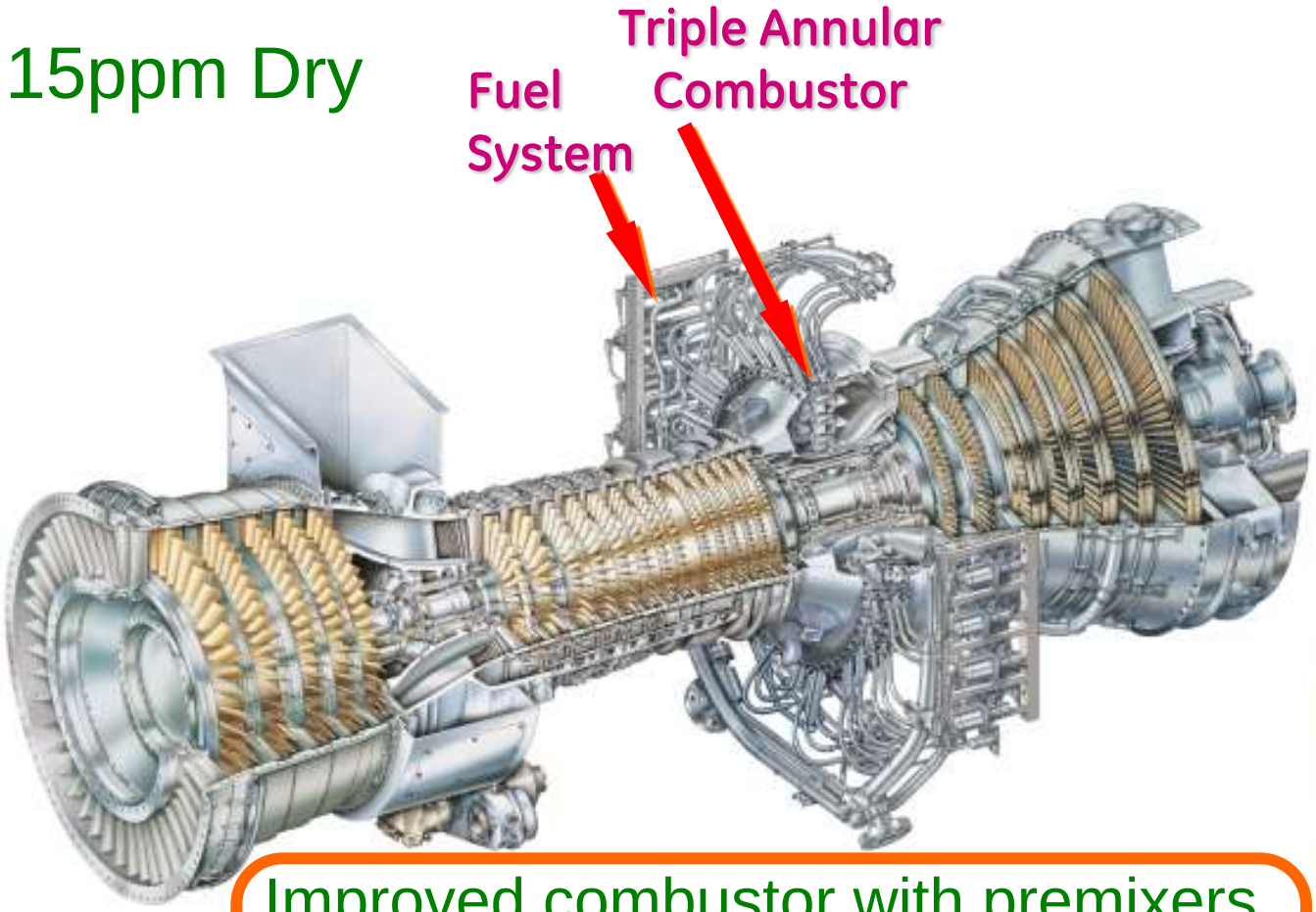
25ppm Dry

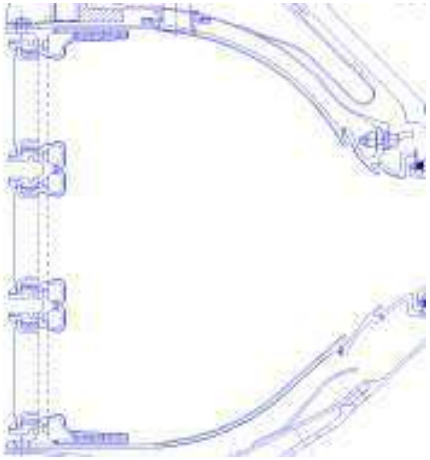




LM6000-PF

15ppm Dry





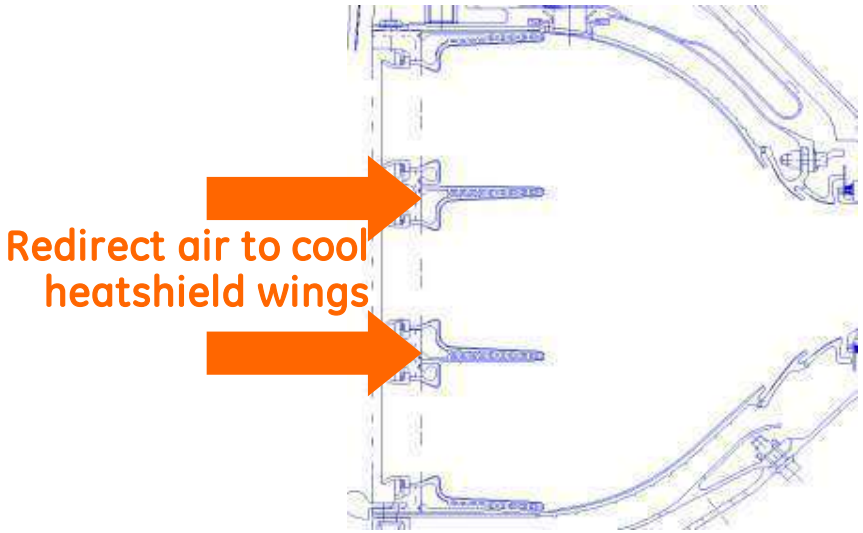
Improved combustor with premixers
Additional manifolds and valves
Software changes
NO other changes to turbomachinery

DLE 1.5 Combustor

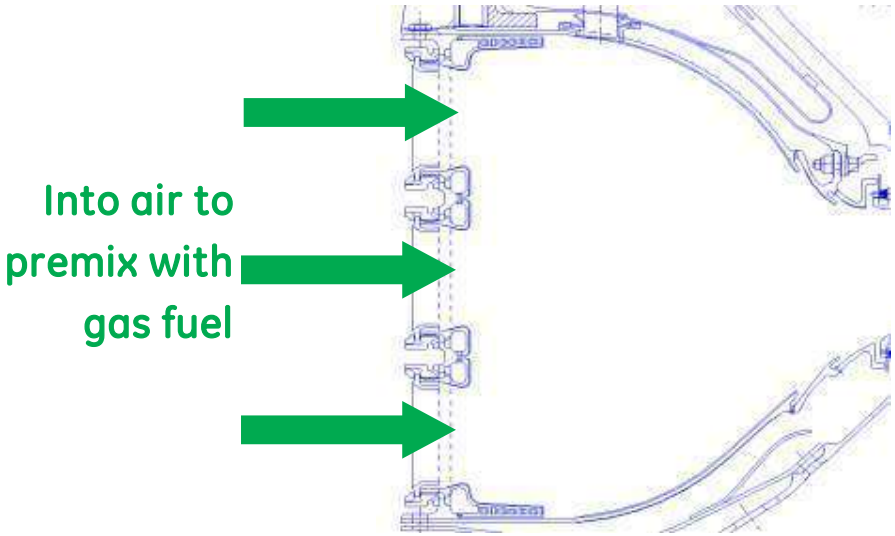
Benefit 1 = Lower NOx !!

Changes in the combustor design provide increased airflow for fuel premixing to operate with lower flame temperature and generate lower emissions

DLE1 →LM2500/+ & LM6000-PD



DLE1.5 → LM2500+G4 & LM6000-PF

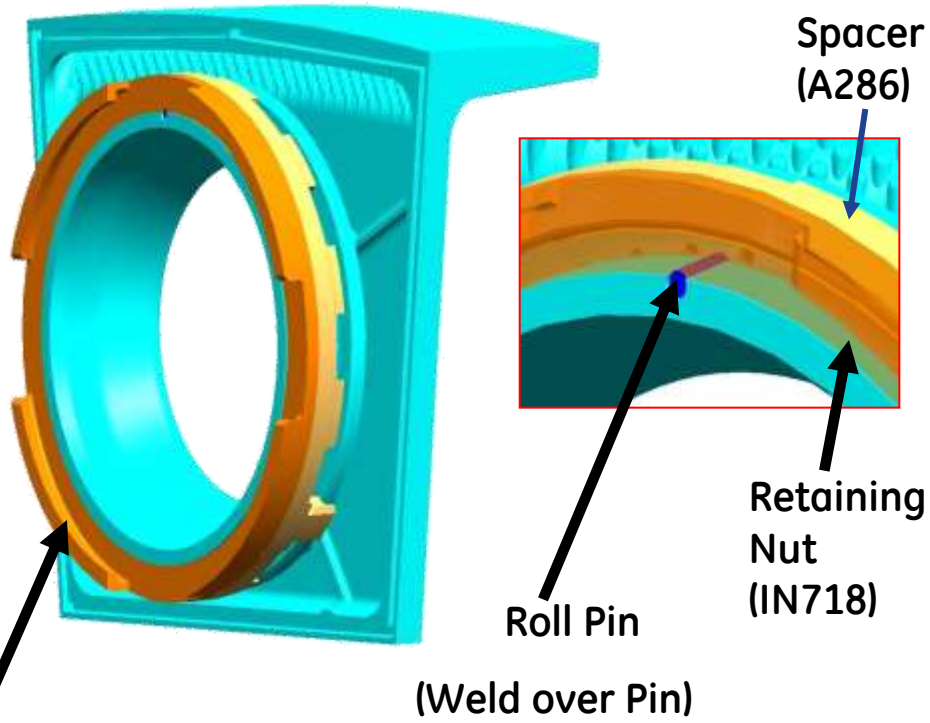


- Wingless center heatshields
- Short wing inner and outer heatshields
- Modified pre-mixers to optimize fuel to air ratio in the combustor

Benefit 2 = Replaceable Heat Shields !!

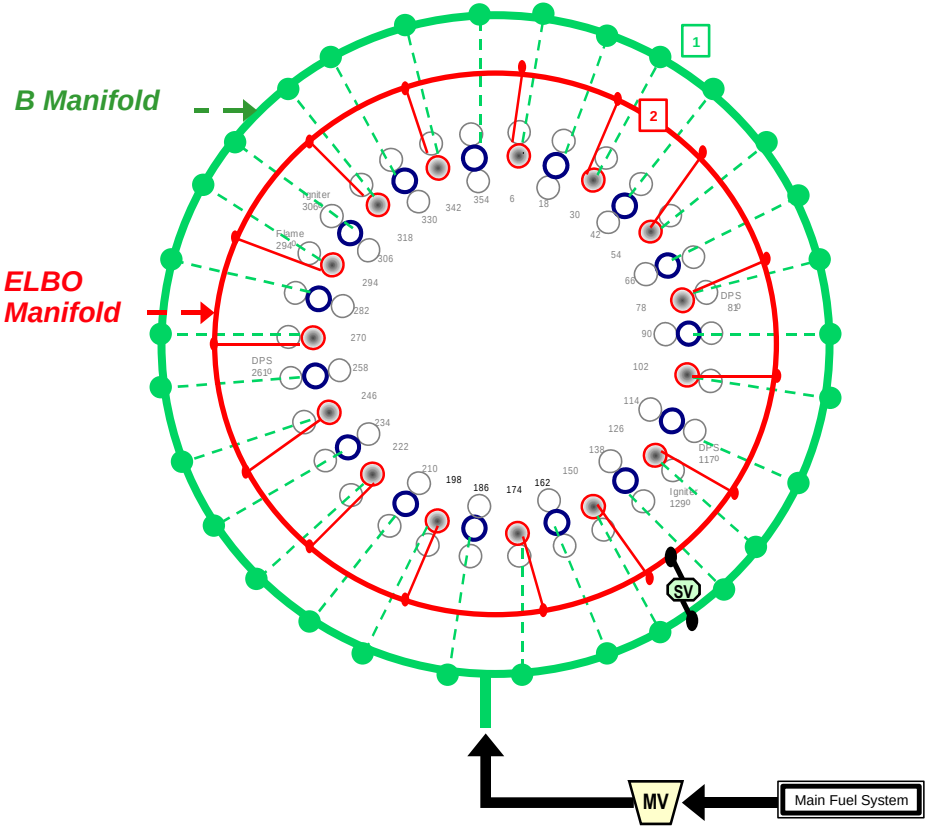
Dome assembly

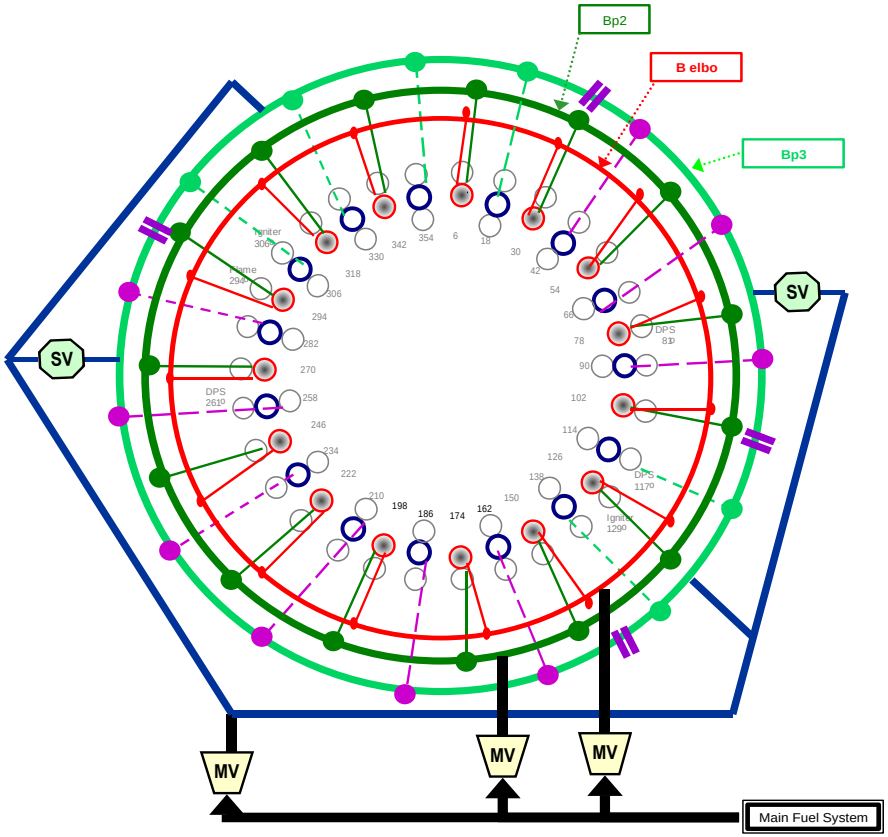
Details of Secondary retention



DLE 1.5 Fuel System

Optimize the gas fuel system to provide ability to better distribute the fuel





DLE1system

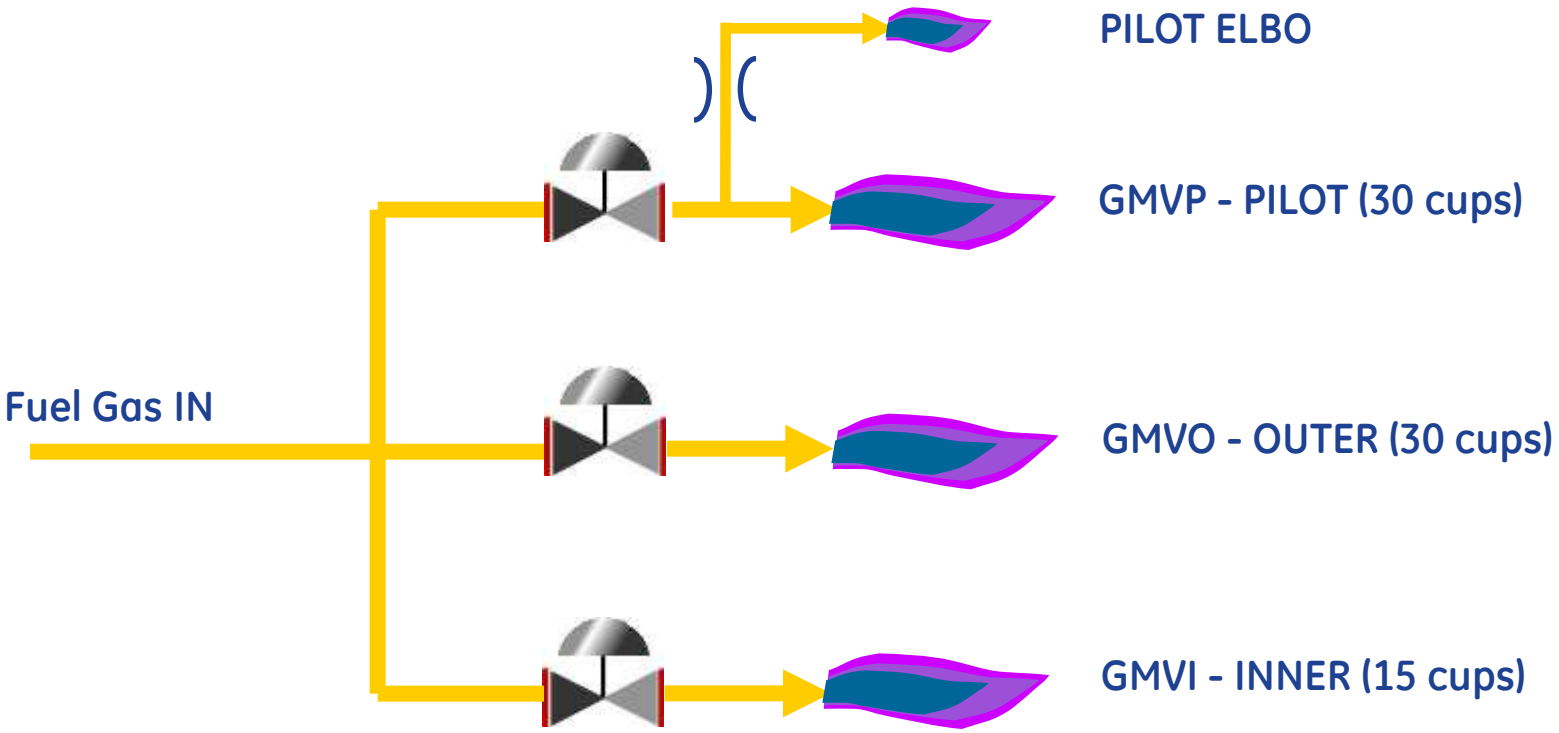
- Two-flow ELBO
- Single B manifold
- 3 metering valves

DLE1.5 system

- Variable ELBO
- Segmented B manifolds
- 5 metering valves

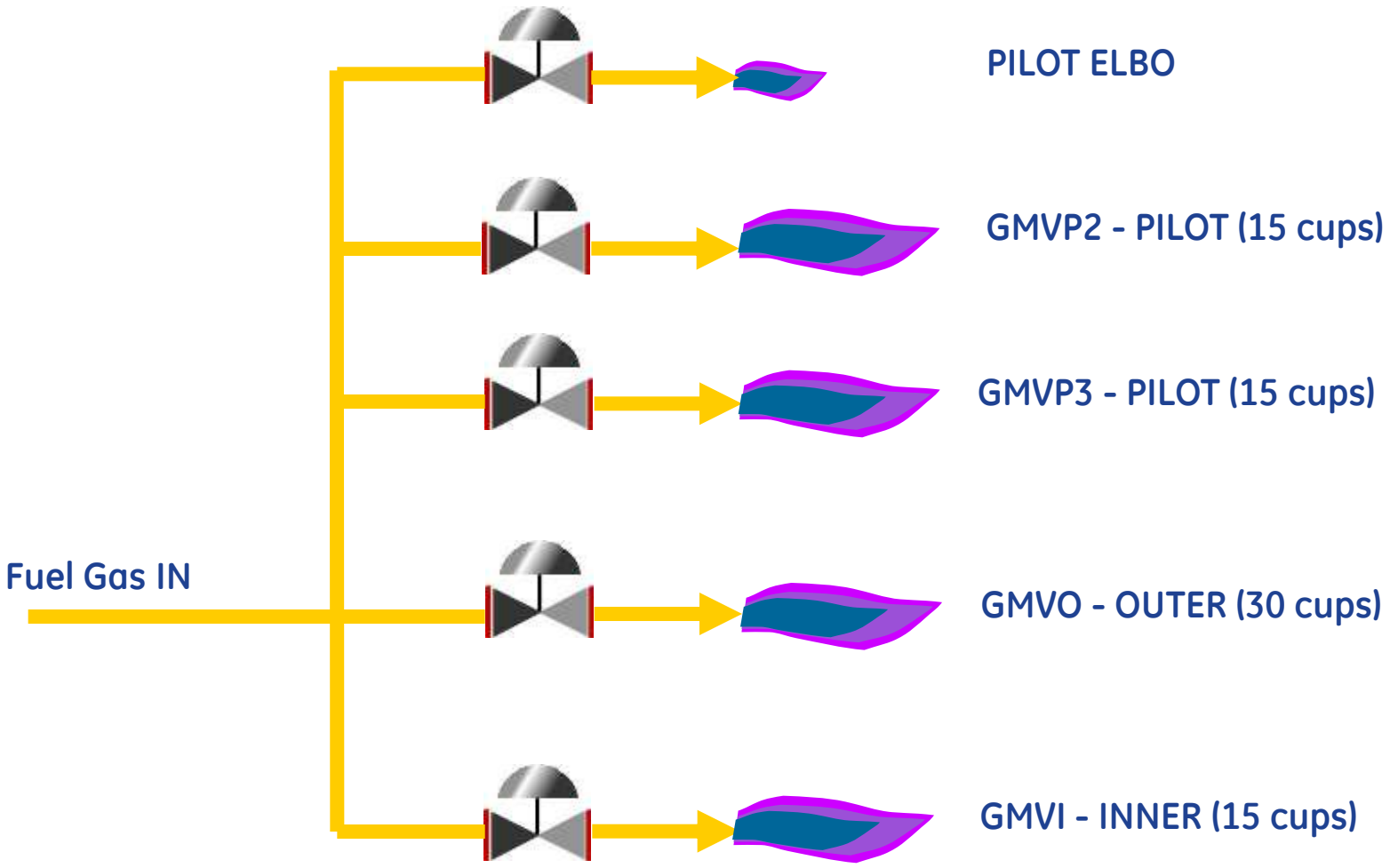
Benefit 3 = Better DLE Operability !!

DLE1.0 3 x Gas Metering Valve Configuration:



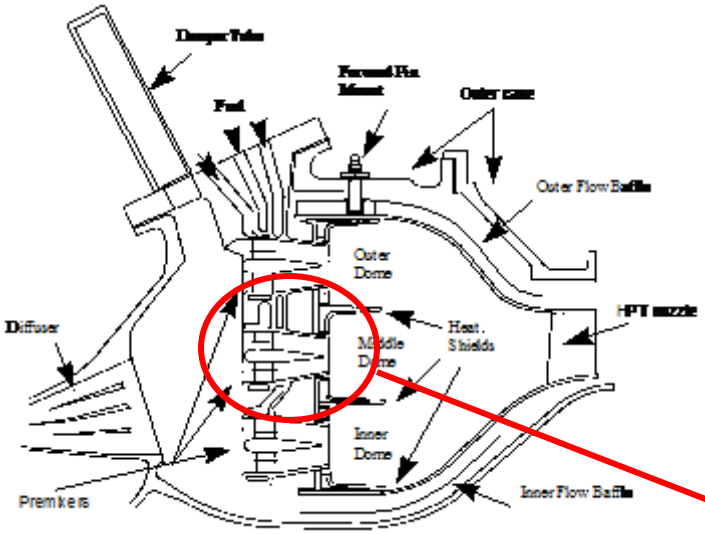
Benefit 3 = Better DLE Operability !!

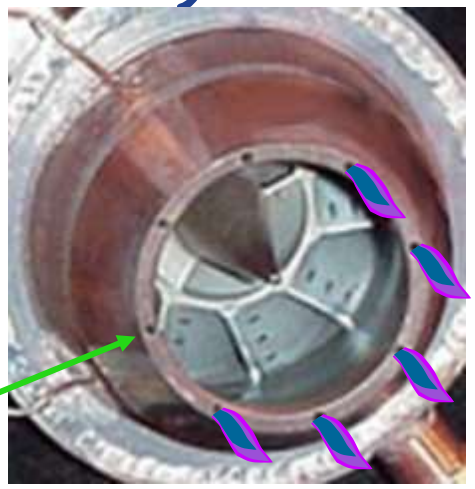
DLE1.5 5 x Gas Metering Valve Configuration:



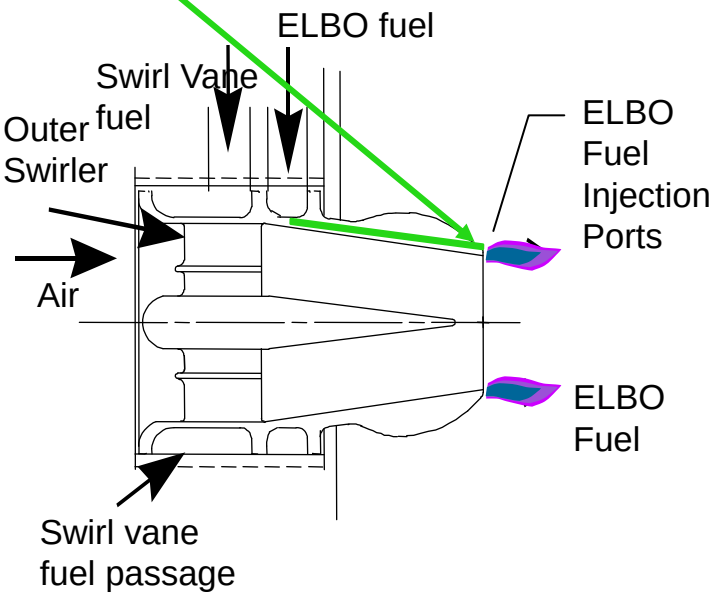
DLE 1.5 Premixer

ELBO fuel injection for flame stability





ELBO Fuel injection



ELBO = "Enhanced Lean Blow Out"

~10% fuel injected through shroud trailing edge provides relatively fuel-rich region to aid flame stabilization under very fuel-lean conditions

Axial dispersal of fuel injection aids in combustion acoustic control

Optimize premixers for the specific operating characteristics of the engine model

- Flow, pressure, temperature

Fuel injection holes for thorough premixing with air

ELBO holes

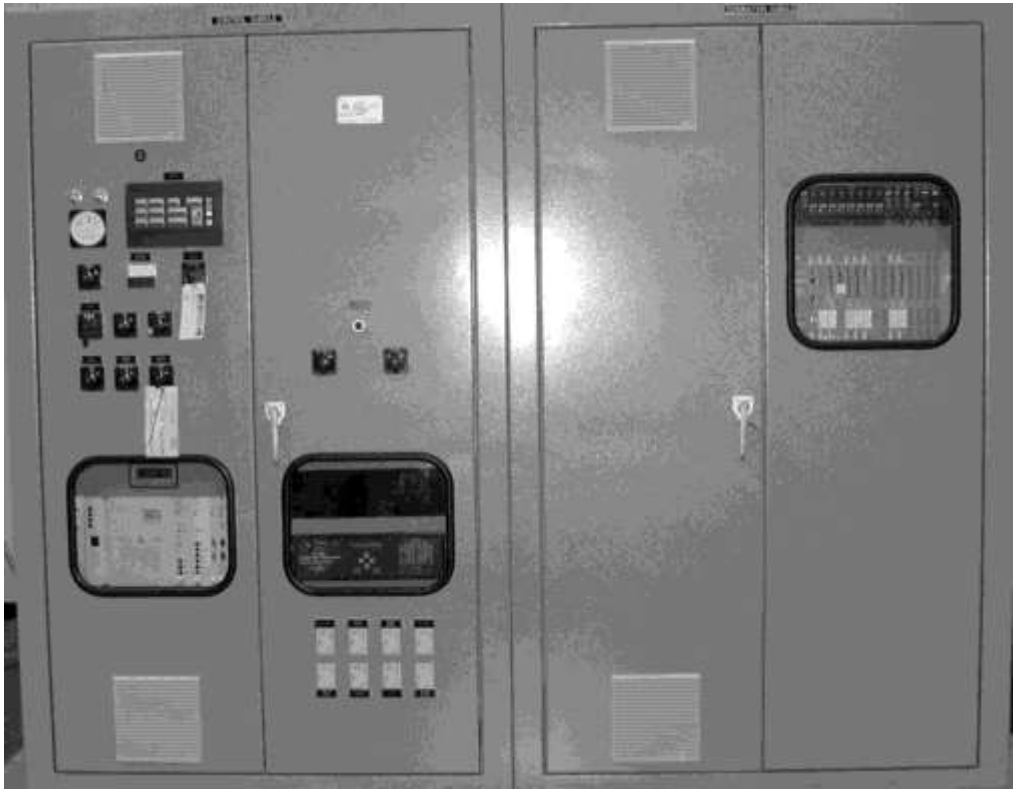
DLE 1.5 Control

Introduce the necessary logic to the control system

Optimize fuel to air regulation

New staging logic

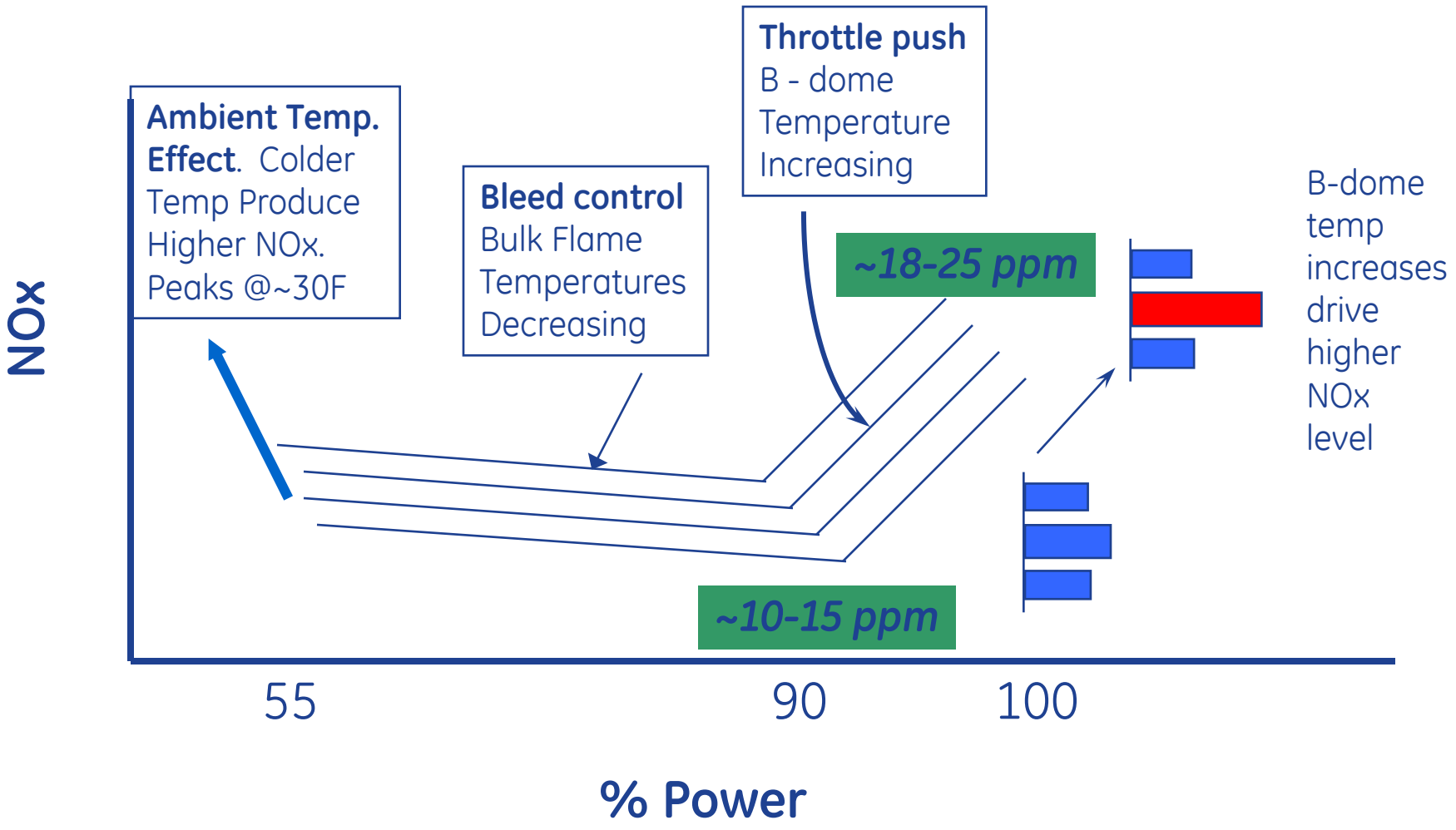
Computing capacity



Summary of features and advantages of DLE1.5 vs. 1.0

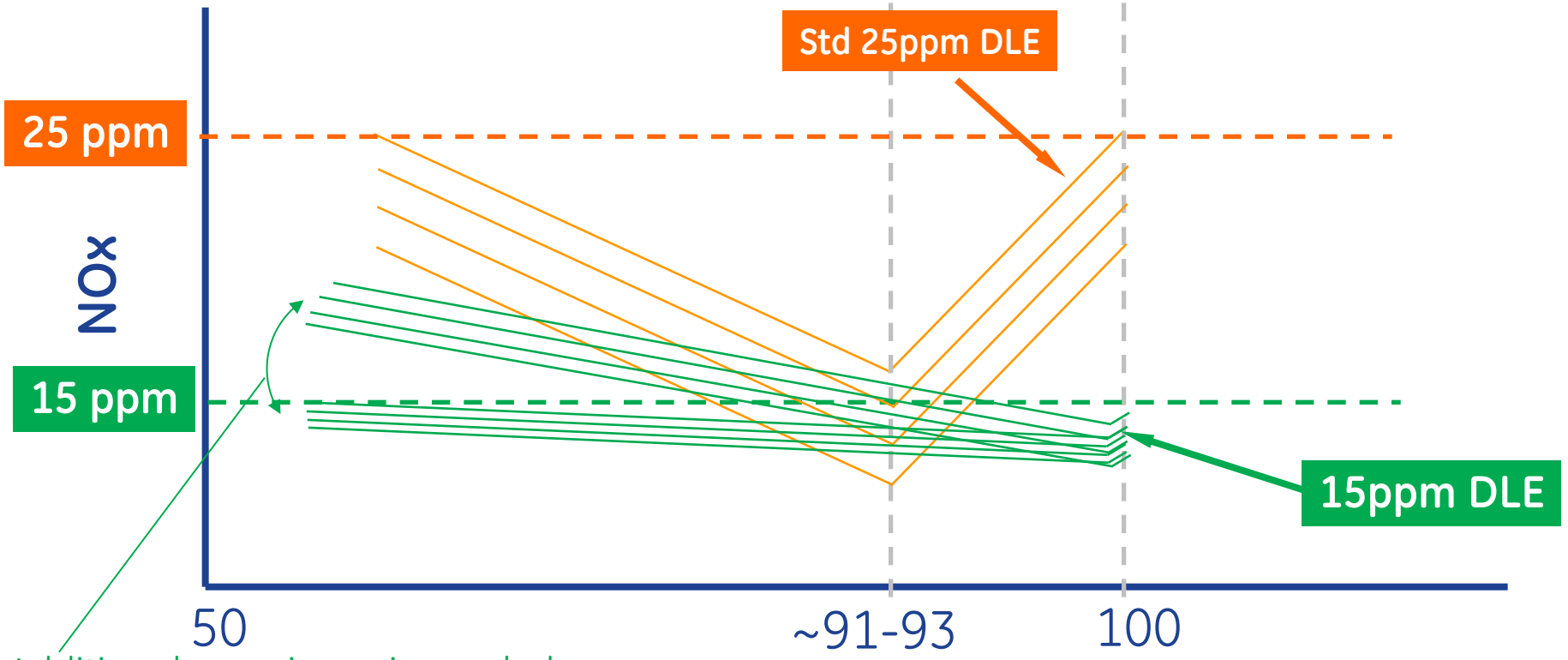
- DLE1.0 has only one B ring metering valve.
- DLE1.5 B ring has two metering valves, B2 cup & B3 cup for greater flexibility in fuel injection.
- DLE1.0 B2 cup ELBO is set either to high or low flow
- DLE1.5 adds B3 cup ELBO which is fixed & B2 cup ELBO is continuously variable as a function of burner mode and is tunable. This is used to provide lower acoustics which deliver additional margin in operability.
- DLE1.5 B2 cup ELBO is off at max power hence NOx levels are lower (2-5 ppm lower).

DLE Combustor NOx Characteristics - Gas Fuel



From 90 to 100% power, most of the NOx is generated in the B dome

With the new premixers and control valves the DLE 1.5 system is capable of maintaining a much flatter emissions characteristic



Additional experience is needed to identify emissions signature for wider range of inlet temperatures and power levels

For illustration purposes only – not to scale

DLE1.5
Technology Experience

PGT25+G4 Fleet Leader Experience

At 12079 hrs borescope inspection:

- Great hardware conditions

PGT25+G4 Fleet Leader Experience - 12079 hrs

LM6000-PF Hot Section @ 23.5k hours