GE Power & Water
Aeroderivative Gas Turbines

Power of Flexibility

13th Annual Aeroderivative Gas Turbine Conference

Emissions Technology Enhancements

Learning Elective

imagination at work

Different customers … different solutions

- Oil & gas
  - Offshore vs. Onshore
- Industrial plants
- Electricity generation industry
- Marine

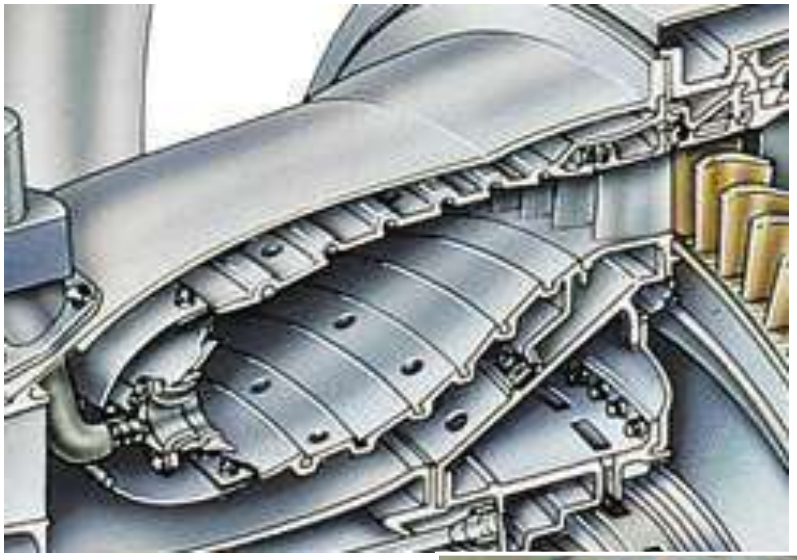
imagination at work

Emissions reduction technologies

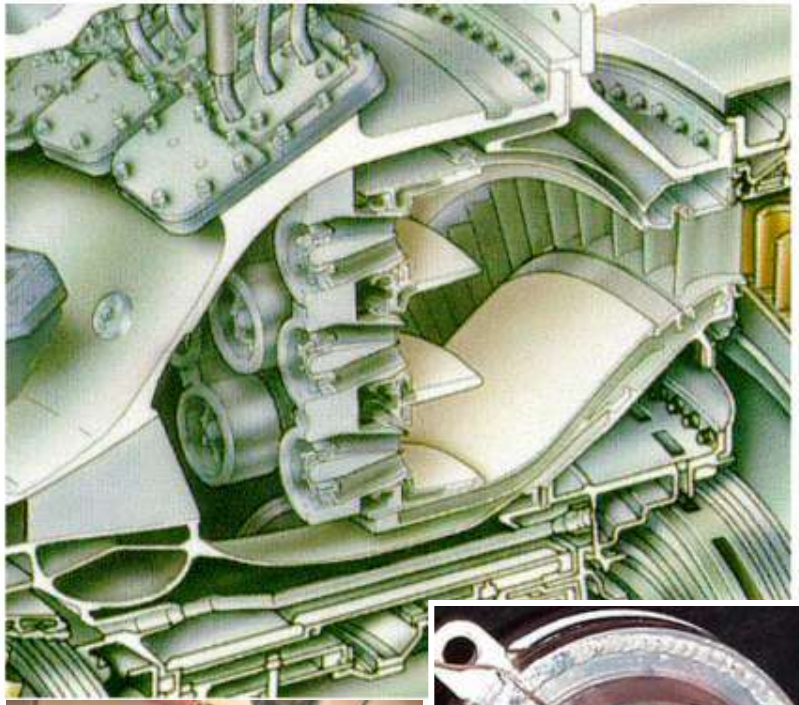
imagination at work

Combustion Systems

Single-Annular Combustor (SAC)

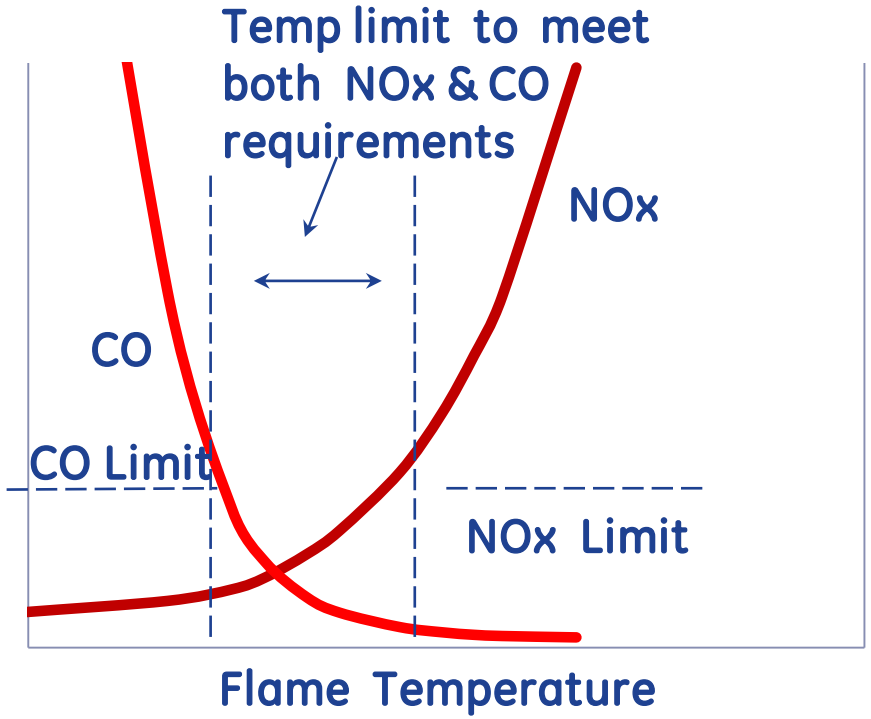


Dry-Low-Emissions (DLE) Combustor

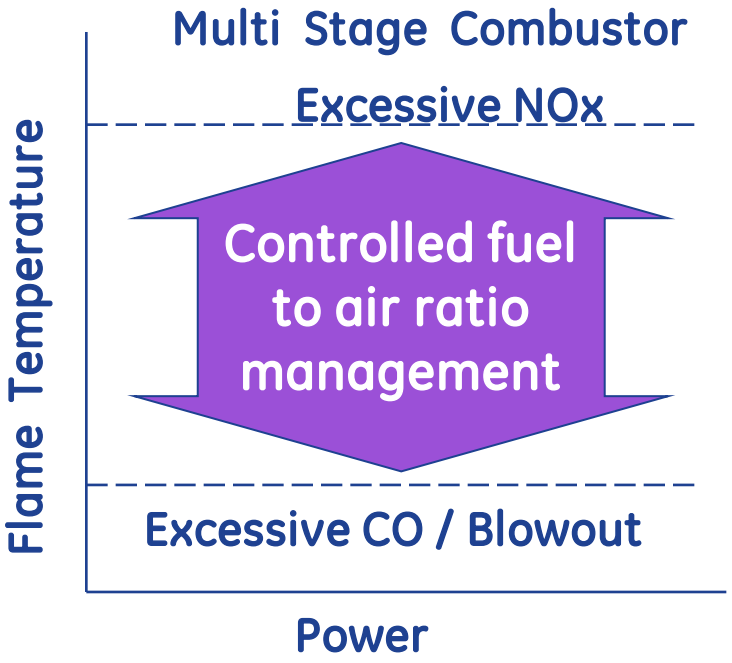


imagination at work

Combustion Principles to Meet Low Emissions



- Low NOx and CO emissions occur in a narrow band of flame temperatures
- With Diffusion Combustors (SAC) emissions can be controlled with water or steam injection

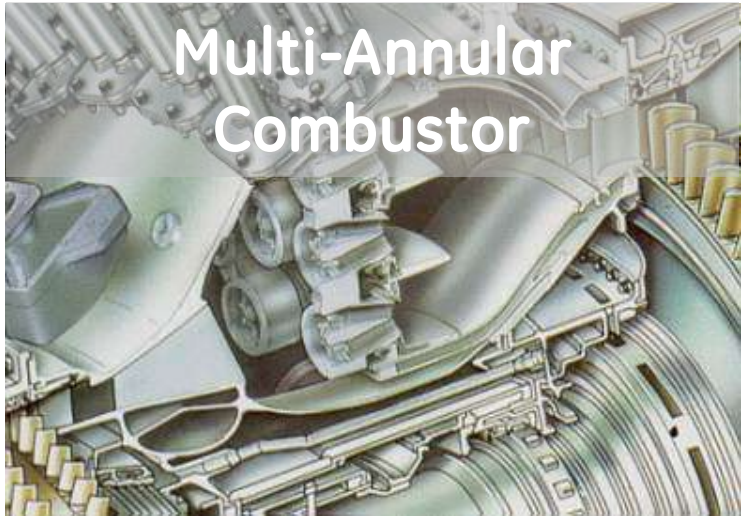


- GE LM Gas Turbines with Dry Low Emissions combustors use Lean Pre-mixed Combustion with Fuel Staging to maintain the narrow flame temperature window

imagination at work

Flexible emissions reduction …

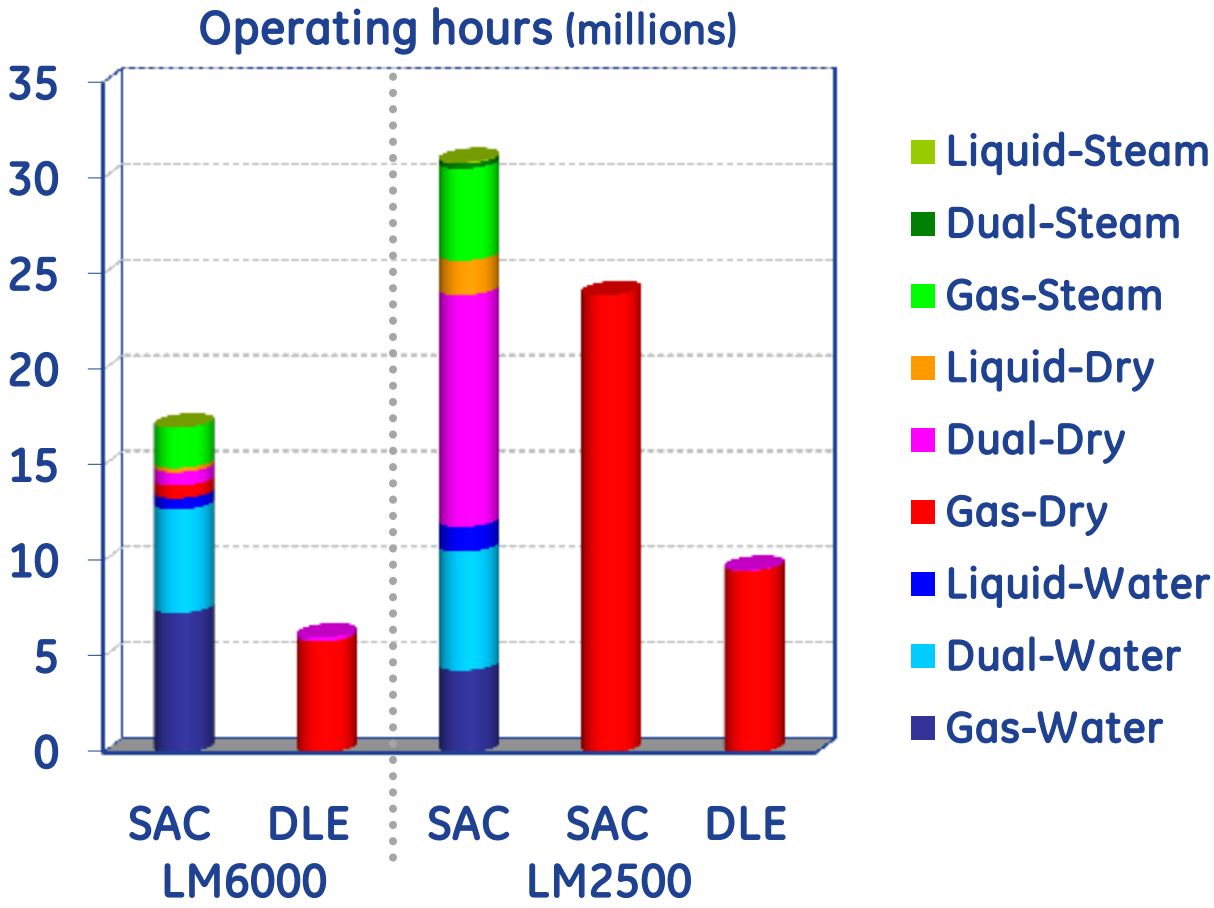
LM2500	LM2500+	LM2500+G4	LM6000	LMS100	Control technology
Water injection					
✓	✓	✓	✓	✓	25ppm NOx (gas fuel)
✓	✓	✓	✓	✓	42ppm NOx (liquid fuel)
Steam Injection					
✓	✓	✓	✓		25ppm NOx (gas fuel)
✓					+15ppm NOx (gas fuel)
Dry Low Emissions					
✓	✓		✓		15ppm NOx (gas fuel)
✓	✓	✓	✓	✓	25ppm NOx (gas fuel)
			✓		65ppm NOx (liquid fuel)
✓	✓	✓			100ppm NOx (liquid fuel)
✓	✓	✓	✓		Dual Fuel DLE



GT offerings as of 3Q2012

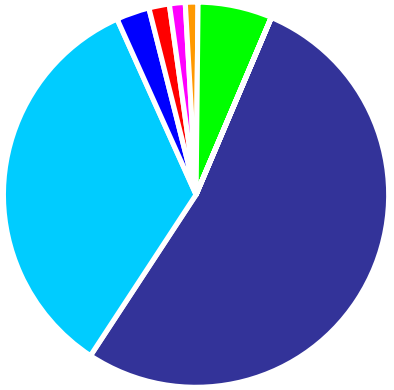
imagination at work

Wide range of combustion systems – serving differing needs



LM2500 SAC - 76% Dry

LM6000 SAC – 96% Wet

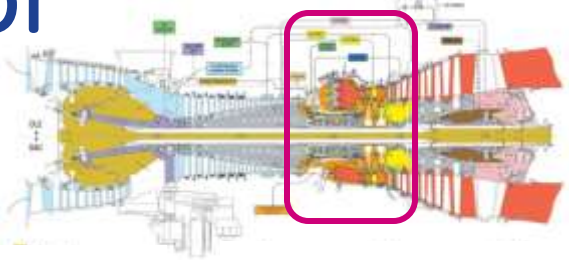


Estimated data as of August, 2011

imagination at work

DLE vs. Standard Combustor

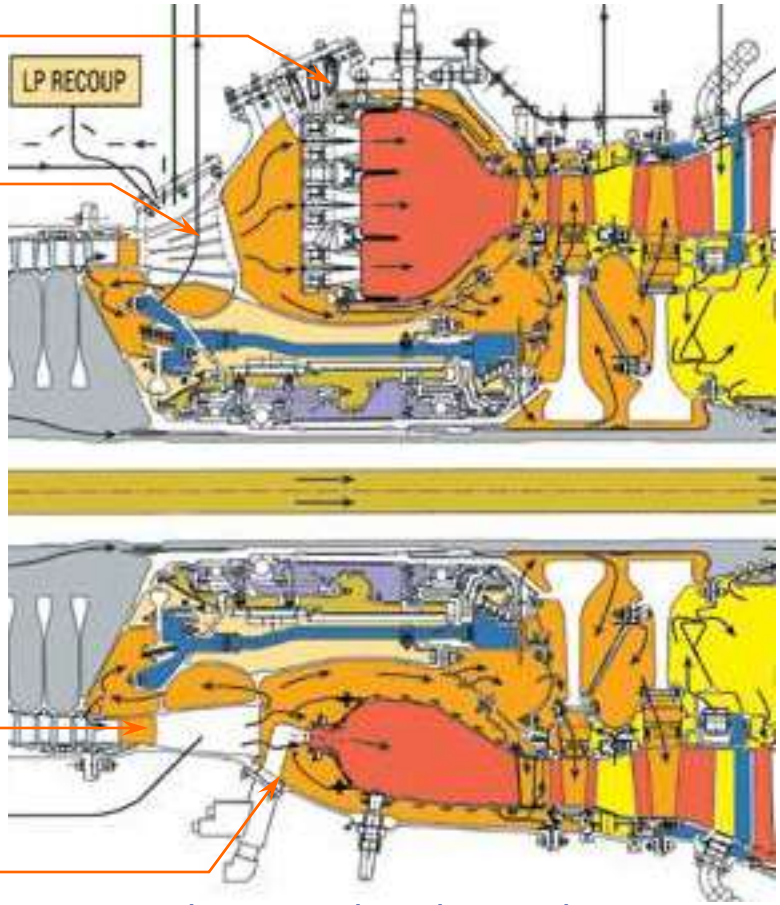
LM6000



With dry low emissions combustor

30 PREMIXERS COMPRISING 75 STAGED INJECTORS

4 PASSAGE COMPRESSOR DIFFUSER



SYSTEM OF CHOICE FOR SITES WHERE EMISSIONS ARE REGULATED AND WATER USE IS RESTRICTED

SINGLE COMPRESSOR DIFFUSER PASSAGE

SINGLE ROW OF 30 FUEL NOZZLES

SYSTEM OF CHOICE FOR SITES WHERE EMISSIONS ARE **NOT** REGULATED OR WATER IS AVAILABLE

With standard combustor

imagination at work

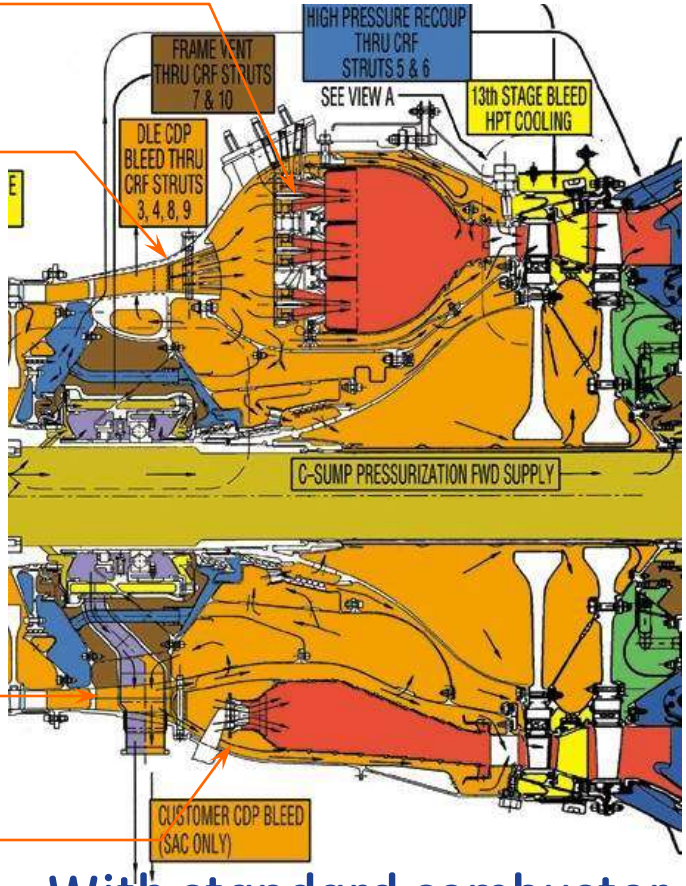
DLE vs. Standard Combustor

LM2500/+

With dry low emissions combustor

30 PREMIXERS COMPRISING 75 STAGED INJECTORS

4 PASSAGE COMPRESSOR DIFFUSER



SYSTEM OF CHOICE FOR SITES WHERE EMISSIONS ARE REGULATED AND WATER USE IS RESTRICTED

SINGLE COMPRESSOR DIFFUSER PASSAGE

SINGLE ROW OF 30 FUEL NOZZLES

SYSTEM OF CHOICE FOR SITES WHERE EMISSIONS ARE **NOT** REGULATED OR WATER IS AVAILABLE

With standard combustor

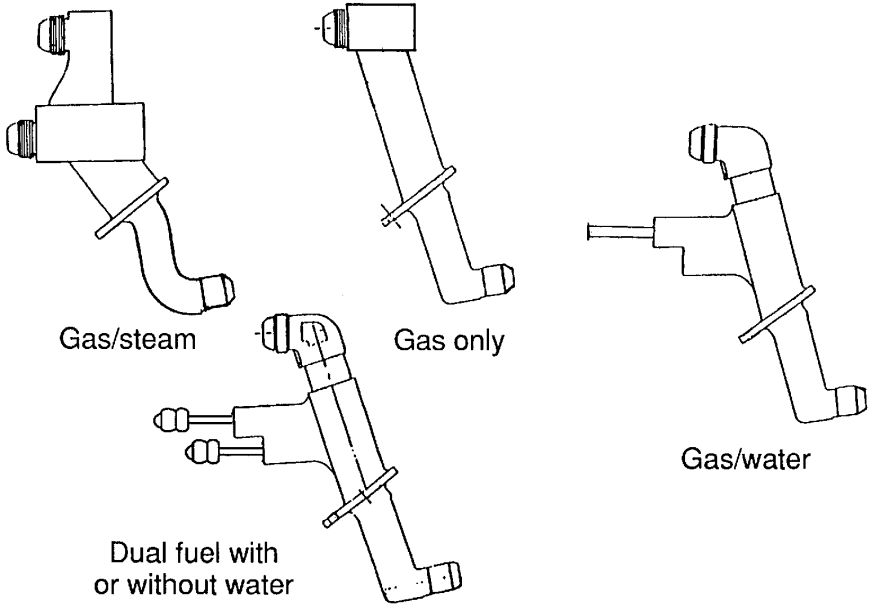
imagination at work

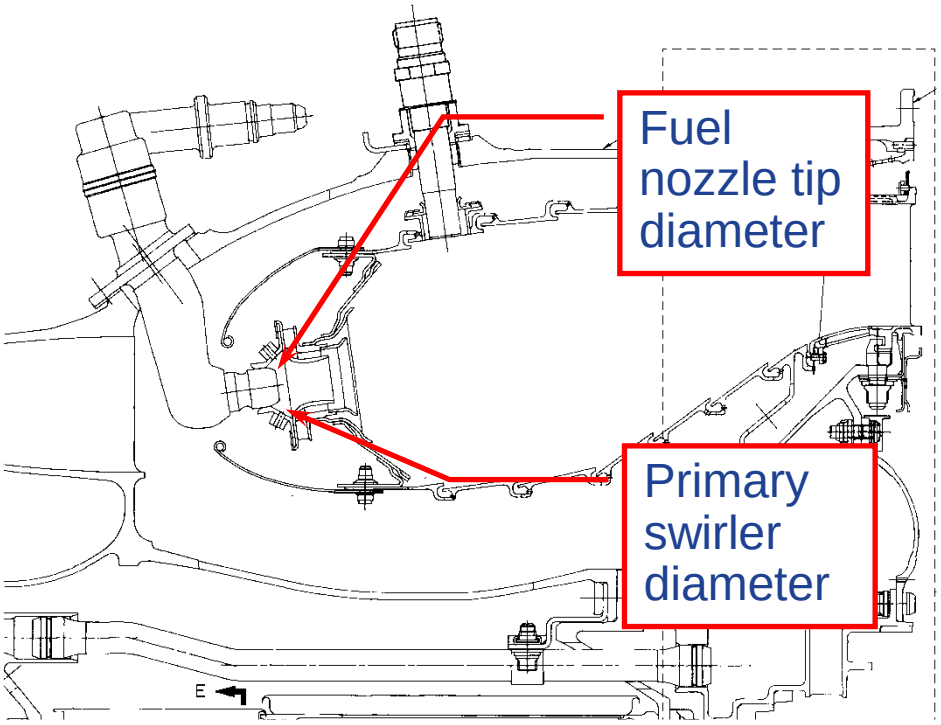
SAC

Single Annular Combustor

imagination at work

Fuel nozzle to SAC Combustor interface must be considered when selecting the emissions control method





imagination at work

LM2500 product line has 2 swirler diameters, therefore another degree of flexibility

Original LM2500 **High flow LM2500** **LM6000**

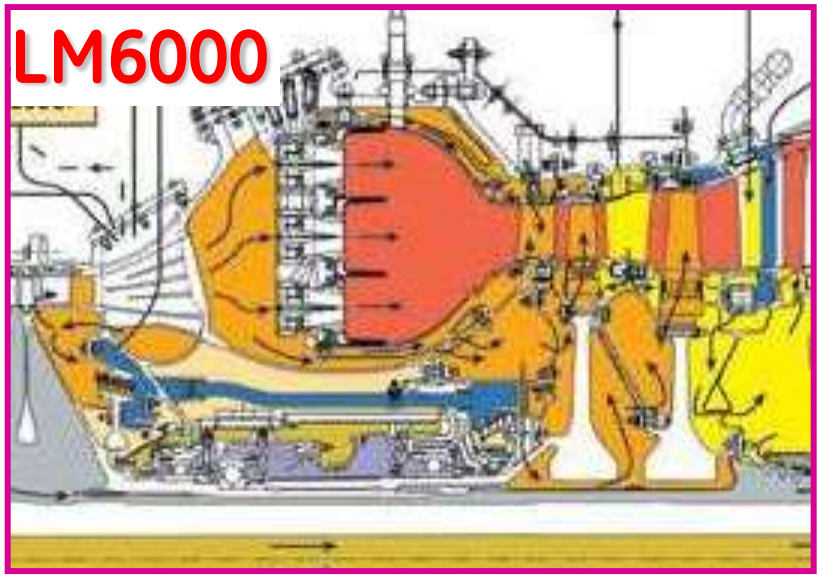
imagination at work

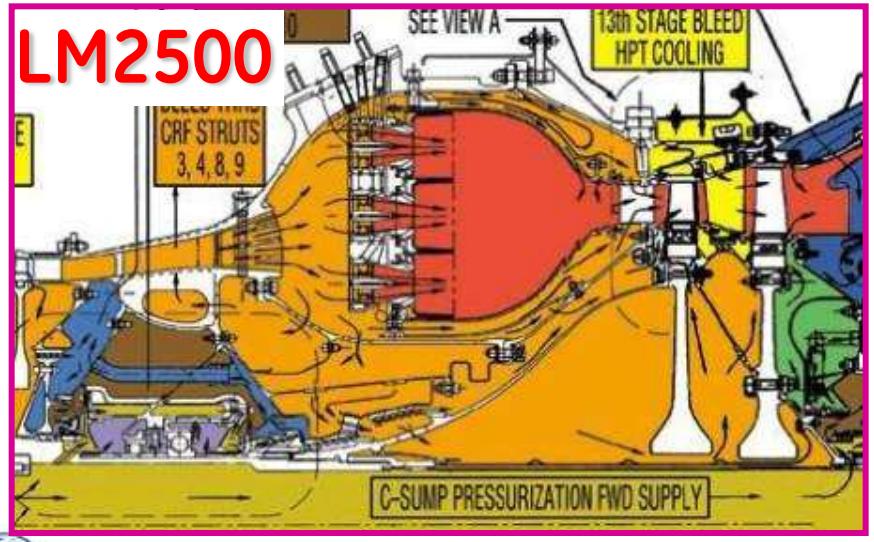
DLE

World-leading technology for aeroderivatives

imagination at work

Common Design Approach





- ✓ Common triple-annular architecture
- ✓ Common premixer technology
- ✓ Similar combustor flow splits and emissions characteristics
- ✓ Similar staging and controls
- ✓ Similar acoustic behavior and abatements
- ✓ Same/similar materials for heat shields and liners

imagination at work

Leaders in DLE combustion for aeroderivative gas turbines …

… more than 700 units and 17 million hours!!

LM2500

Gas	456	10,354,060
Dual	15	54,598

LM6000

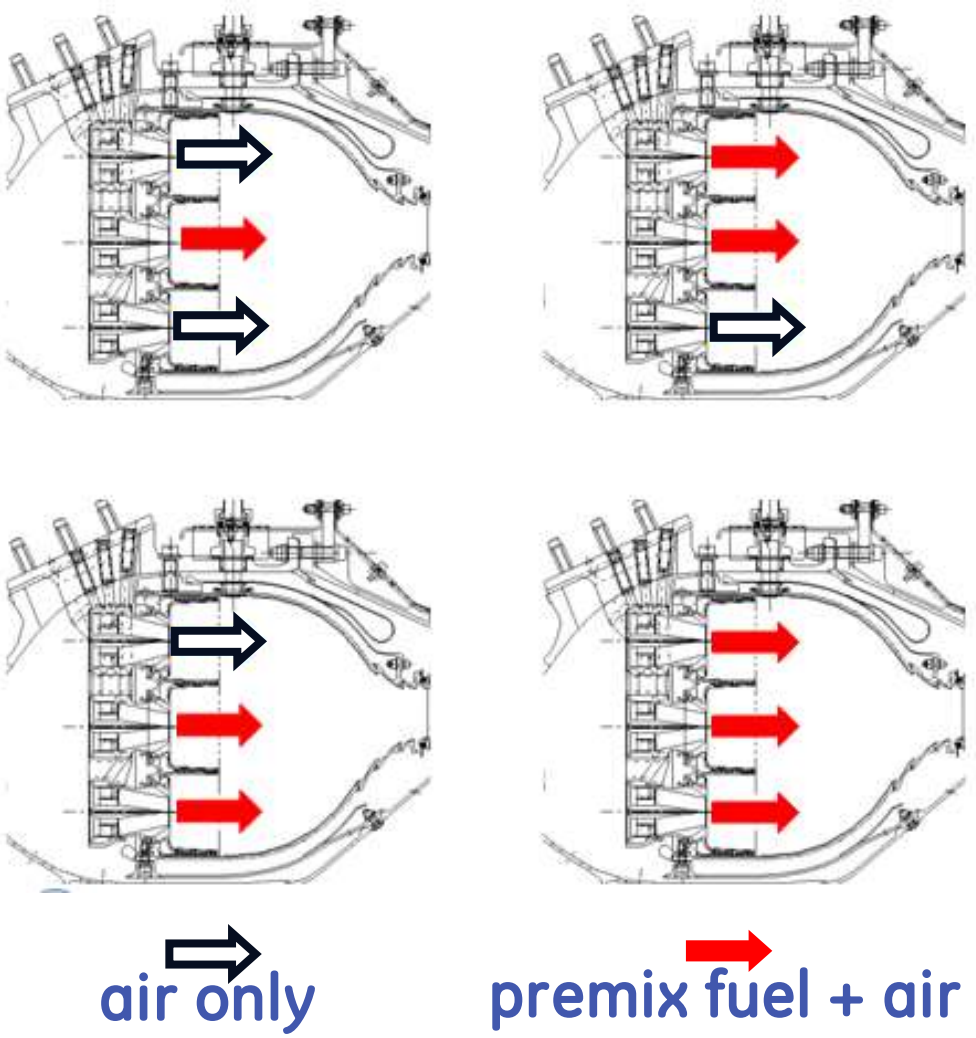
Gas -25ppm	228	6,465,578
Gas -15ppm	29	161,579
Dual-25ppm	4	126,313
Dual-15ppm	2	106,045

Data as of July, 2012

imagination at work

DLE1/1.5 Combustor Staging

- ✓ Lean premixed operation throughout operating range
- ✓ Radial staging by fueling banks of premixing cups
- ✓ Some circumferential staging modes to provide extend overlap



imagination at work

DLE Combustor Design Evolution

DLE1

LM2500 Base & +
LM6000PB & PD

30 premixers
75 cups

DLE1.5

LM2500 +G4
LM6000PF

Now also for the
LM2500 at 15ppm!!

DLE2

LM6000PH
LMS100PB

15 premixers
30 cups

imagination at work

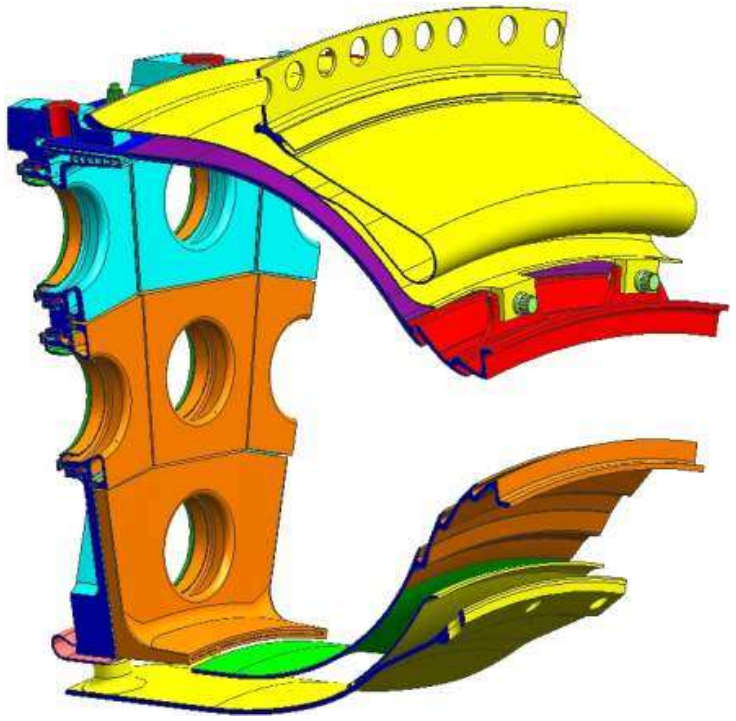
DLE 1/1.5 Advancements

imagination at work

LM2500 Base 15-ppm Combustor

15-ppm combustor design characteristics:

- ✓ Same combustor as LM2500+G4
- ✓ Re-sized premixers for Base cycle
- ✓ Shortened A-cup and C-cup heat shield wings
- ✓ Optimized cooling
- ✓ Spline seals for reduce leakage
- ✓ Variable B2-cup ELBO* for improved CO emissions and operability



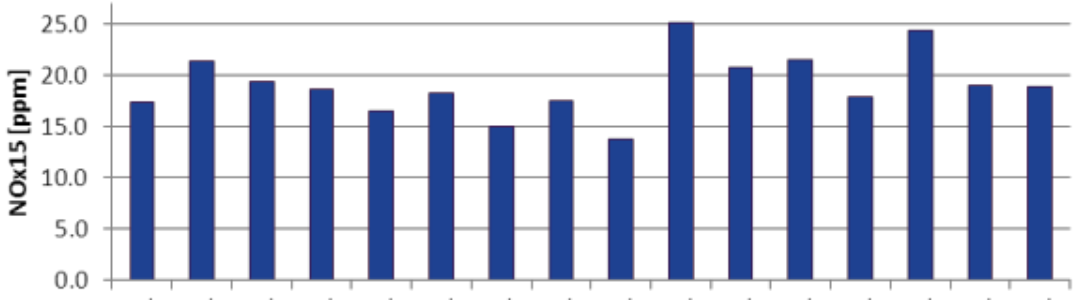
* ELBO = non-premixed fuel for flame stabilization and turn-down

imagination at work

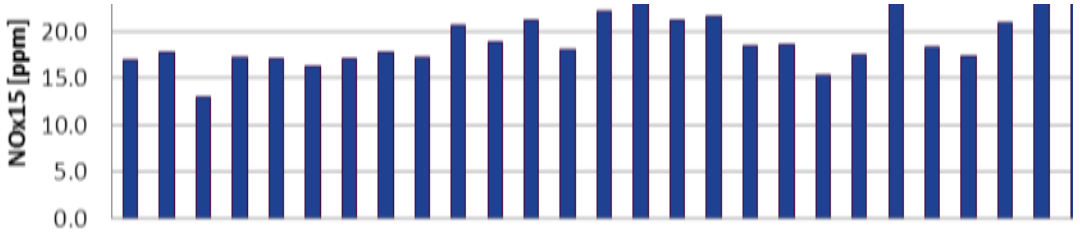
LM2500+/+G4 Emissions @ 50% Power

- ✓ Production test data now obtained at 50% power
- ✓ No hardware or control system changes
- ✓ Average NOx emissions <20 ppm
- ✓ Average CO emissions ~10 ppm

LM2500+ NOx Emissions



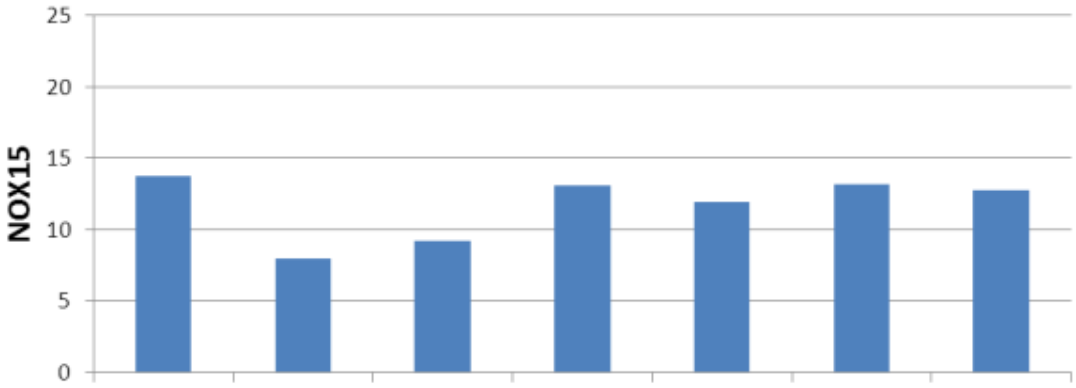
LM2500+G4 NOx Emissions



imagination at work

LM6000PF Emissions @ 50% Power

- ✓ Production test data now obtained at 50% power
- ✓ No hardware or control system changes
- ✓ Average NOx emissions <12 ppm
- ✓ 15 ppm NOx guarantee extended to 50% power
- ✓ Average CO emissions <25 ppm



imagination at work

DLE2

Taking combustion technology to the next level

imagination at work

Strategy

Leverage proven multi-annular technology for higher flow, higher firing temperature cycles

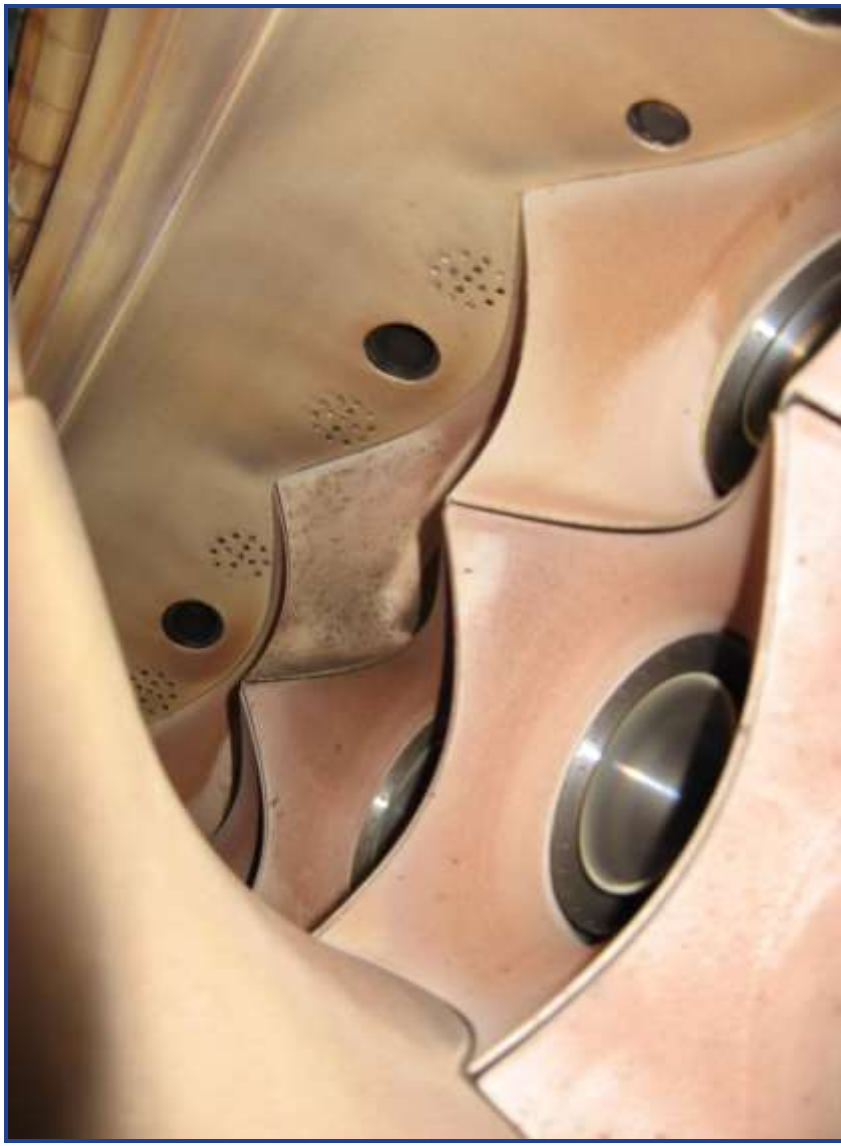
Design validation with advanced computational tools and component tests

Utilize rigorous development testing to provide robust designs for the first production engine

imagination at work

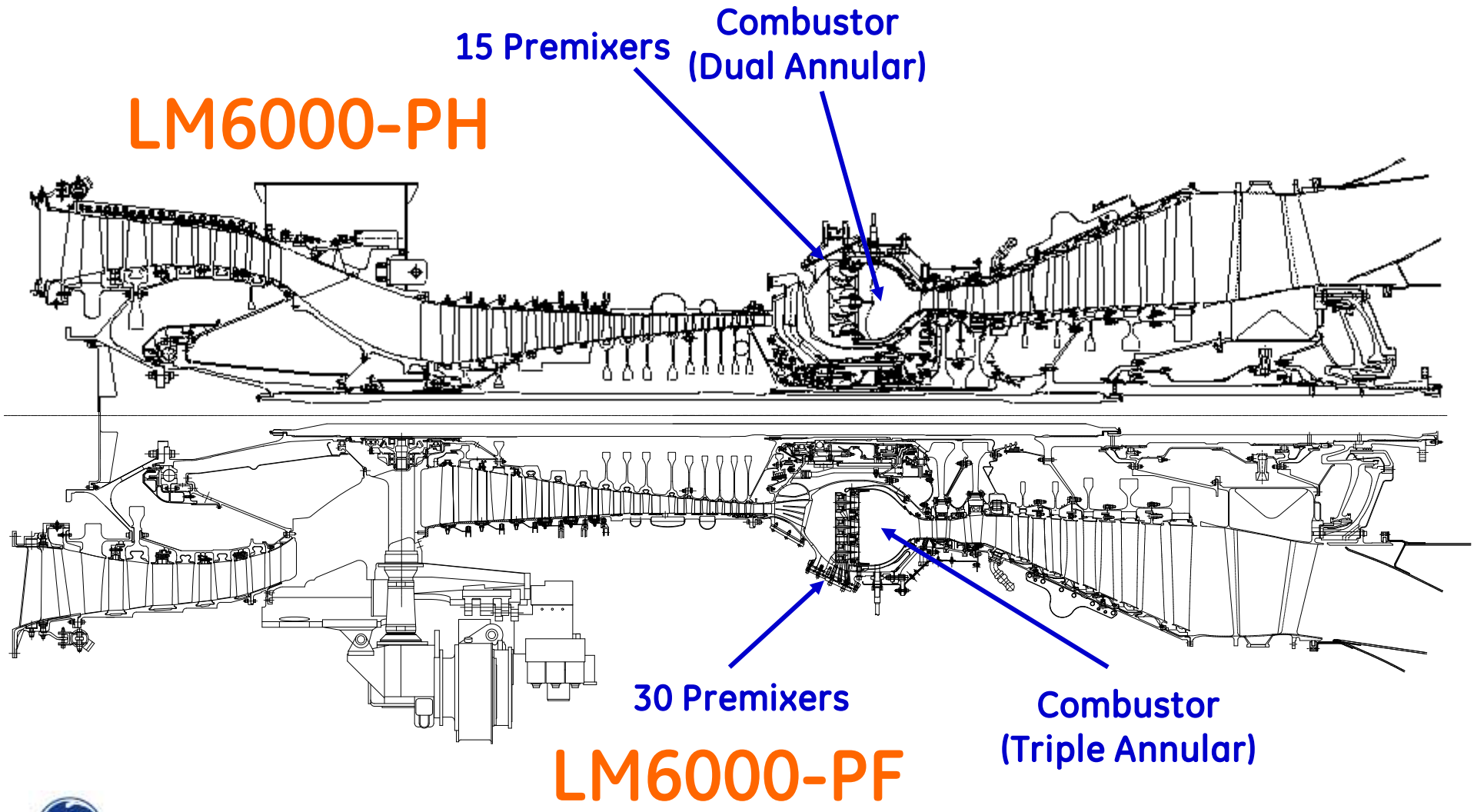
Features of DLE2 technology

- Lean Premixed Combustion
- Tight Flame temperature boundaries
- Enhanced Controls
- Same combustor envelope and Compressor Rear Frame interfaces as LM6000
- New domeplate designs
- Acoustics abatements



imagination at work

Similarity between DLE1.5 and DLE2
Minimizing changes to the turbomachinery

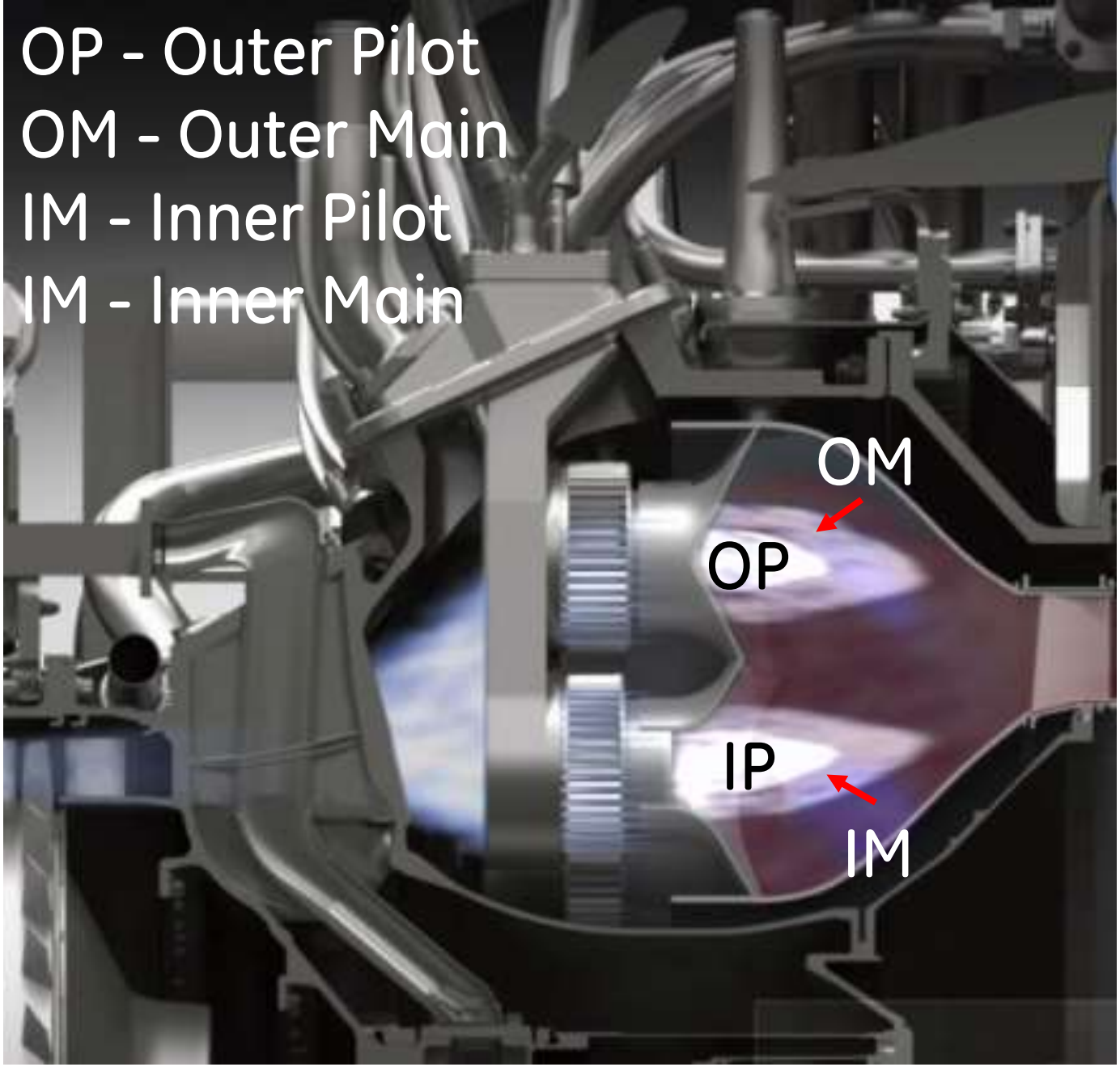


imagination at work

With a simplified premixing technology

Radial air inflow
for twin-annular
premixed swirling
Provides larger
operating windows
Reduces mapping needs
Has greater turndown

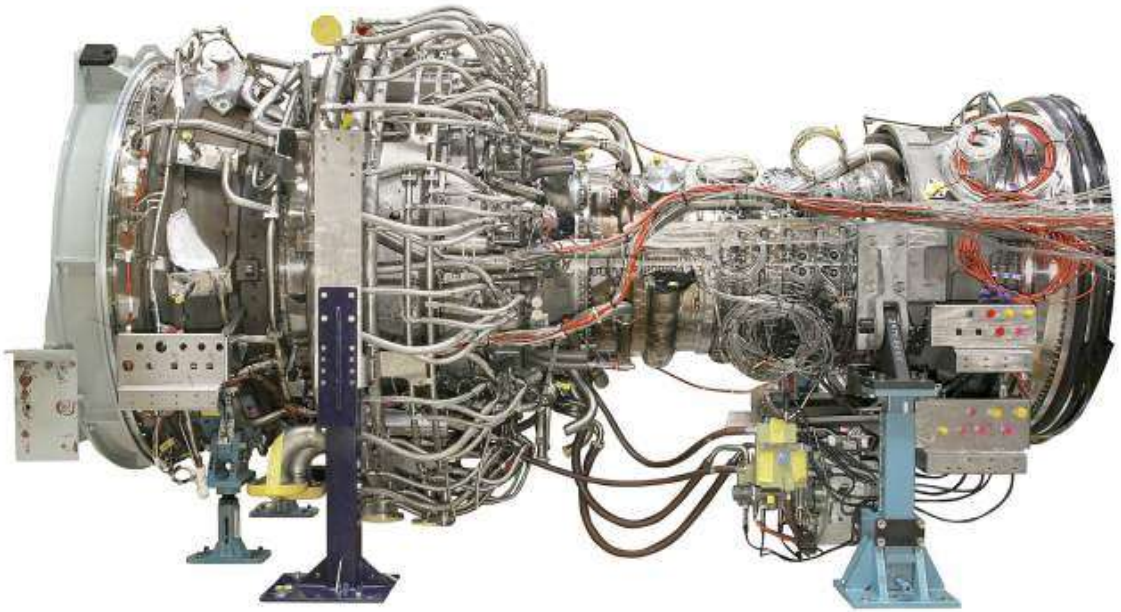
imagination at work



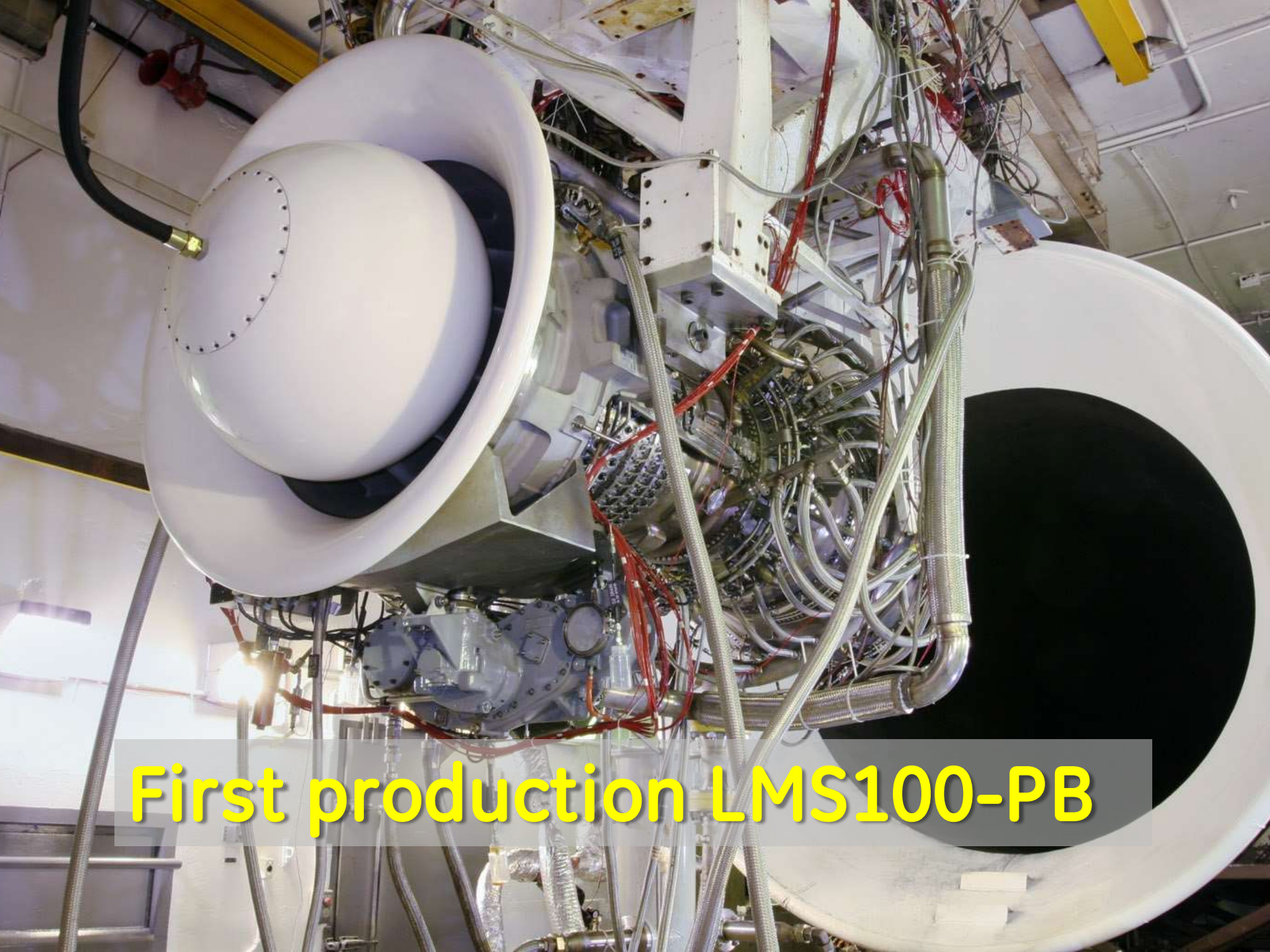
imagination at work

LMS100-PB and LM6000-PH Testing

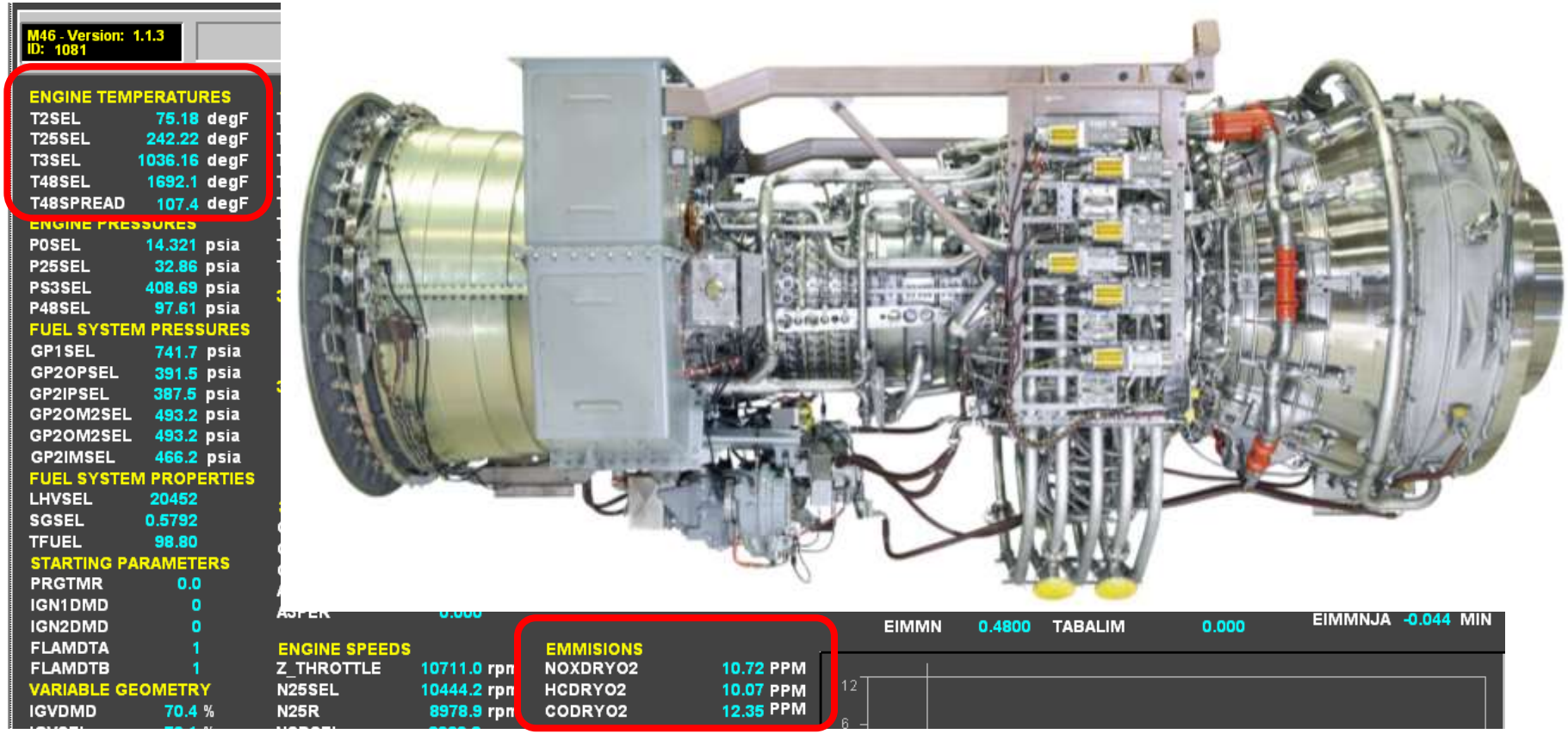
- ✓Technology validated
- ✓Power and Heat Rate met predictions
- ✓NOX levels at 15ppm for LM6000-PH
  25ppm for LMS100-PB
- ✓Confirmed full system operation
- ✓10 minute start
- ✓Load drop-accept
- ✓First production units completed



imagination at work


First production LMS100-PB

Demonstrating NOx and CO at high power
During 336-101 Production Test



Production DLE 2 combustor

Thank you!!

imagination at work