Fuel Flexibility in GE LM Engines

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GE Energy
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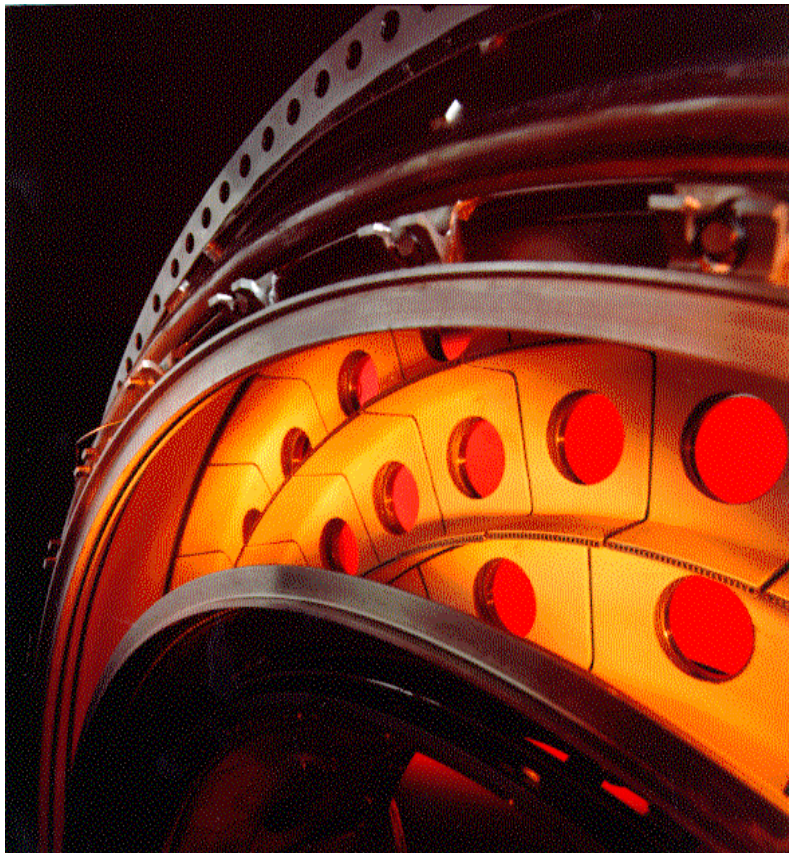


imagination at work

- LM Product Lines
- Combustor Comparison – SAC vs DLE
- Fuel Flexibility
- Summary

LM Product Lines

Marine & Industrial aeroderivative gas turbine power

LMS100

LM500

Danish Navy Stanflex

Foilcat

LM6000

Southern Electric

Asgard FPSO

TransAlta Southdown

Fort Lupton

LM2500+

Queen Mary 2

Aeolos Kenteris

Coral Princess

Sleipner A Platform

LM2500

Aghada Site TM2500s

U.S. Navy DDG 51

Oseberg 2 Platform

U.S. Navy FFG 7

LM1600

Mols Linien

Dusty Lake Station

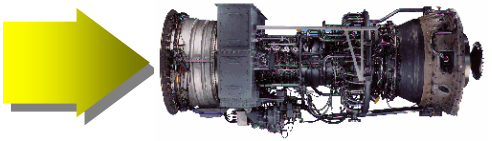
Stena

Foret LaZaida

Where do LMs come from?


B747 A300
B767, MD-11, A310/330

CF6-80C2

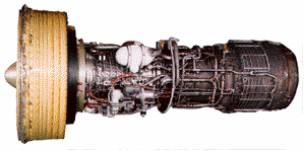


LM6000

Power Output
MW/SHP
Thermal Efficiency

42-50/60,150
43%


C-5 DC-10



TF39/CF6-6

LM2500+

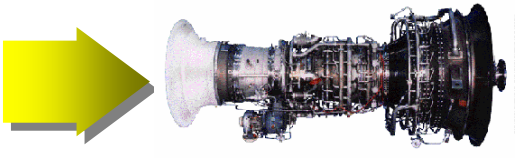
34.0/46,000
39-41%

LM2500

23.3/31,200
38%


F/A-18 F-117

F404



LM1600

14.3/19,200
37%

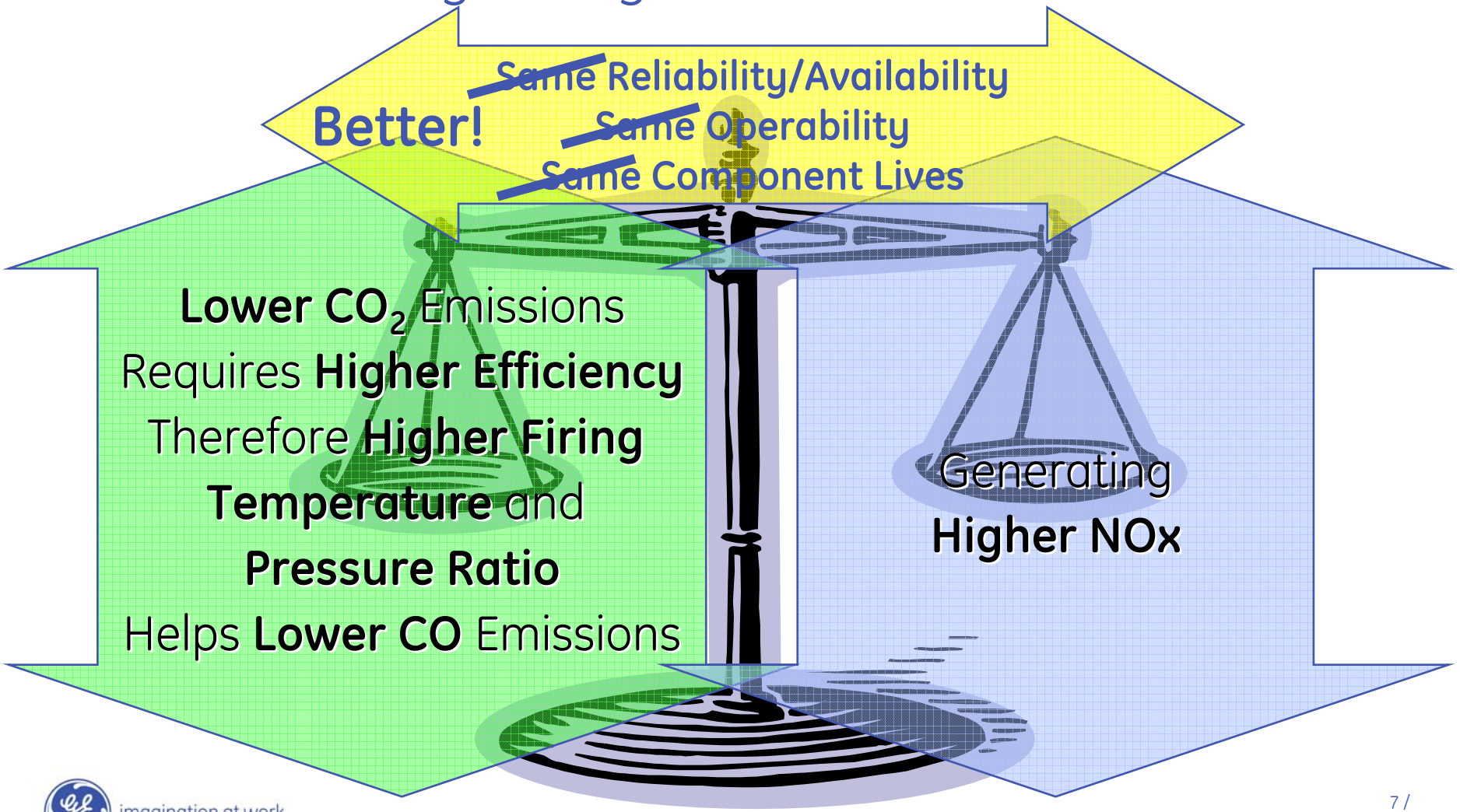
coming soon to a project near you…

imagination at work

Combustor Comparison

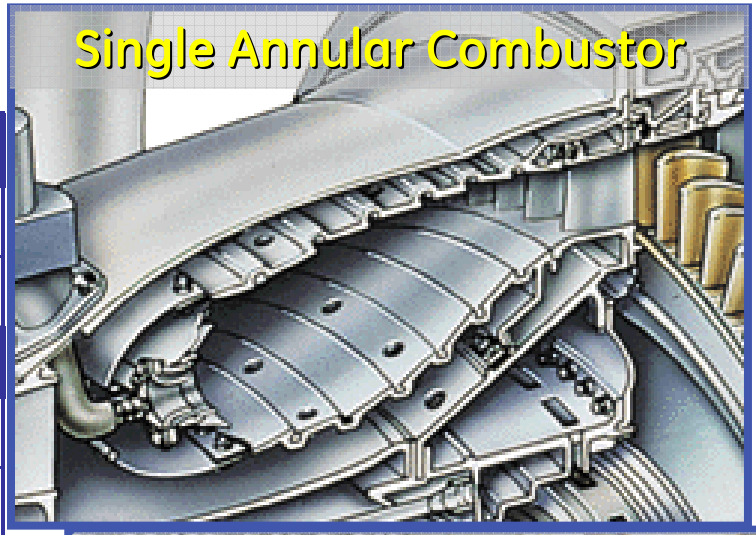
Challenging Requirements

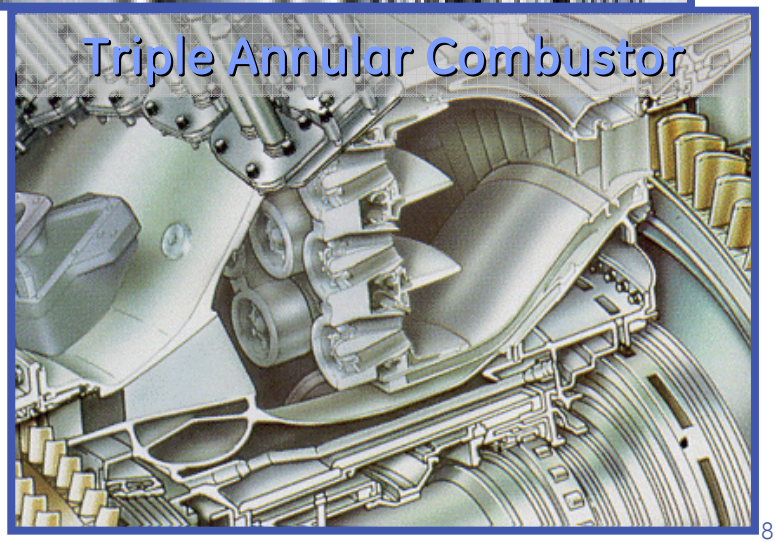
Trying to Balance the Forces of Nature with Business and Regulatory Realities



Flexible emissions reduction

LM1600	LM2500	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)
	✓	✓		Liquid fuel
	✓	✓		Dual Fuel DLE



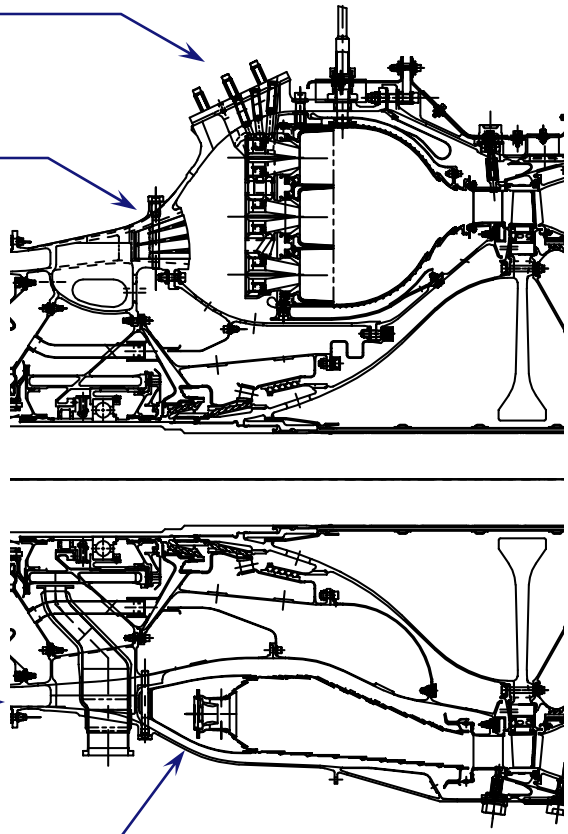


DLE vs. Standard Combustor

With dry low emissions combustor

30 PREMIXERS
COMPRISING 75
STAGED INJECTORS

4 PASSAGE
COMPRESSOR
DIFFUSER



SINGLE COMPRESSOR
DIFFUSER PASSAGE

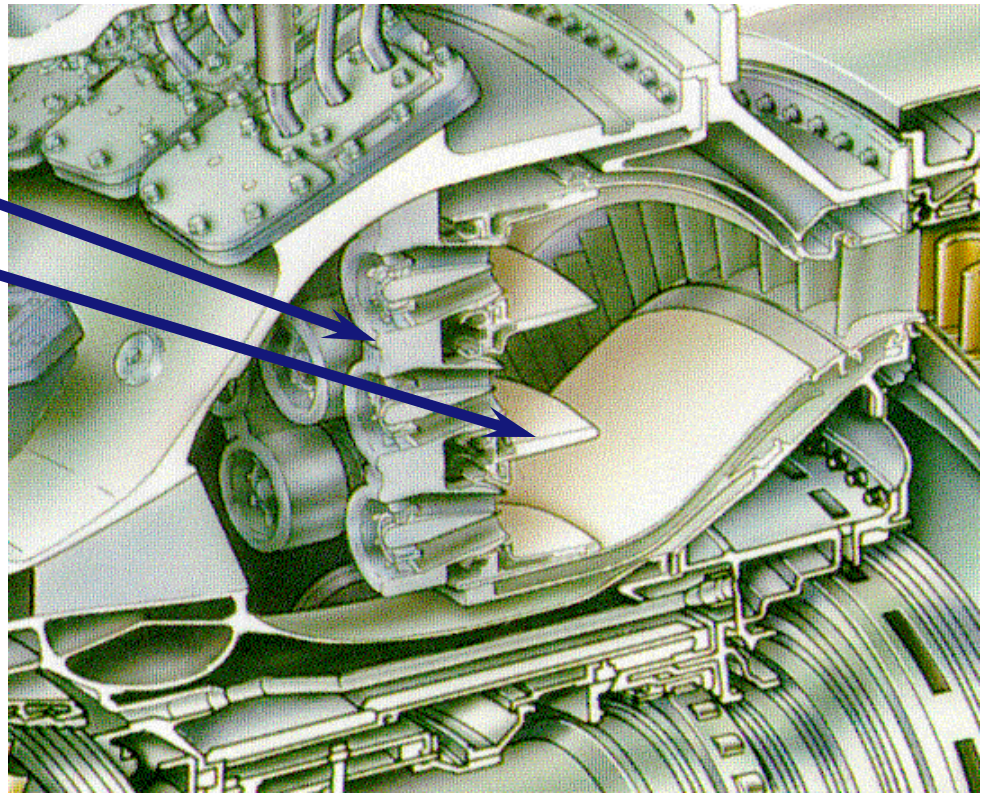
SINGLE ROW OF 30
FUEL NOZZLES

With standard combustor

DLE Combustor Design

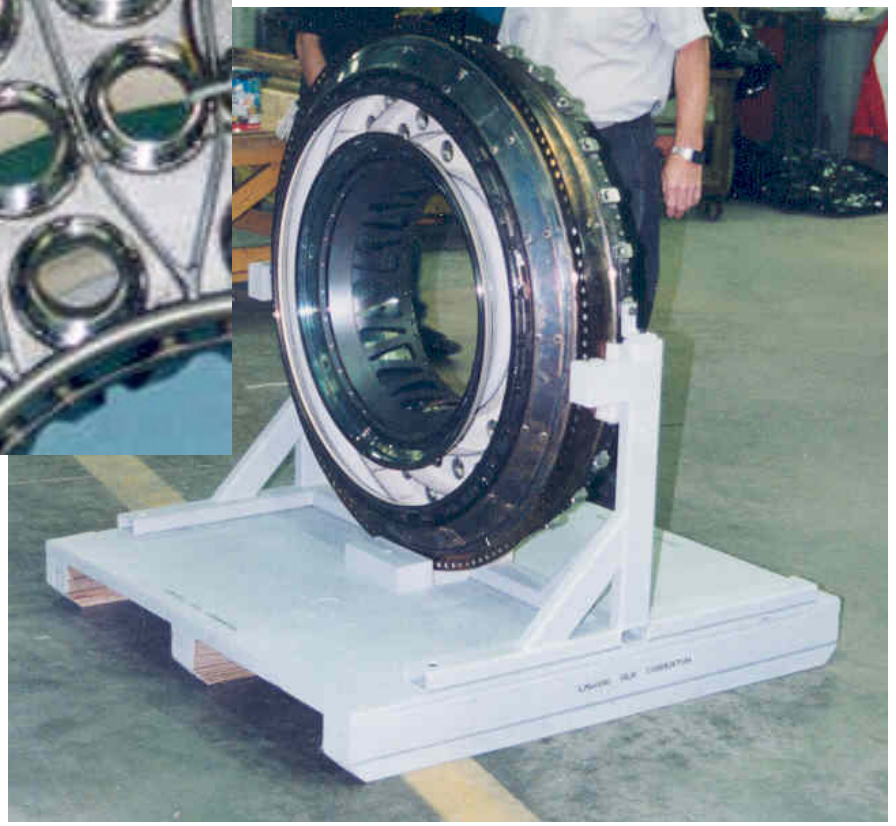
Premixers

Heat Shields

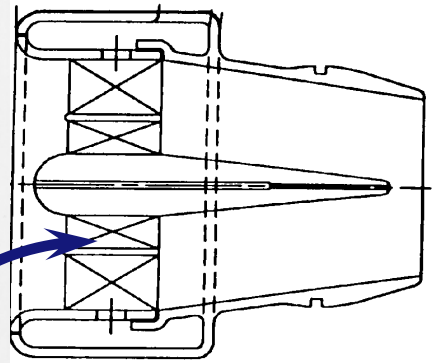


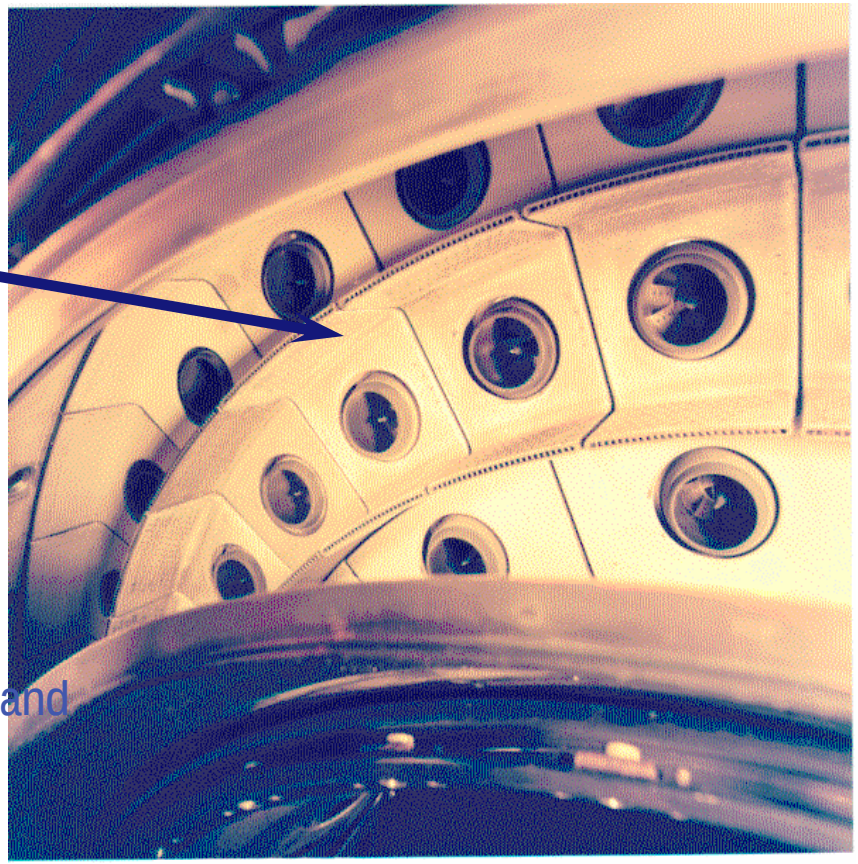
Combustor details

Alternating 2 cup and 3 cup premixers



Premixer design



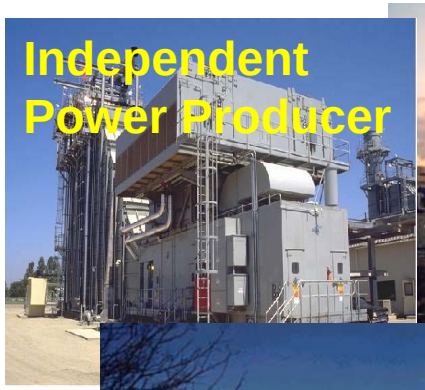


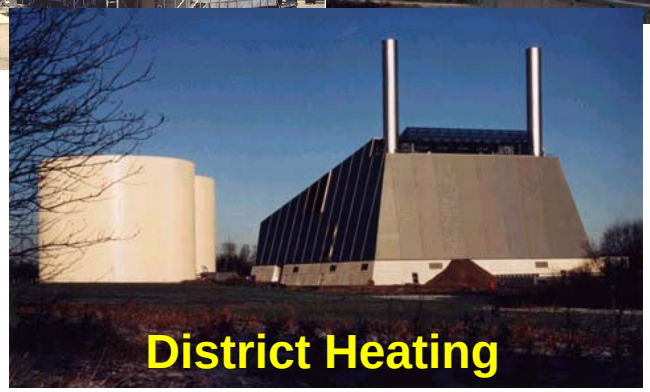
- Axial counter rotating swirlers for efficiency mixing and low NOx
- High axial velocities -Flashback resistance
  -Prevents Auto-ignition

LM DLE Experience – 330 Engines

Model	Type	Cumulative Hours
LM6000PD	Gas Fuel	~2,400,000
LM2500+	Gas Fuel	~2,000,000
LM2500	Gas Fuel	~2,500,000
LM1600	Gas Fuel	~170,000
Total		>7,000,000

LM DLE Applications:





- Experience in extreme temperature environments
  - ✓North Slopes Alaska…-50 F
  - ✓Sahara Desert… > 100 F

Fuel Flexibility

Fuel Properties – SAC Combustors

- Can accommodate wide band of Wobbe numbers
- No special instrumentation required
- Extreme Wobbe number ranges will need to be evaluated for proper fuel system sizing
- Current capability exceeds proposed interim guidelines

Fuel Properties – DLE Combustors

- Multiple LM DLE applications have gas properties vary:
  - O&G upstream applications…changing gas wells
  - O&G midstream applications…blending gas supplies
  - Power Generations applications…gas supply varies due to market pricing

Fuel Properties – DLE Combustors

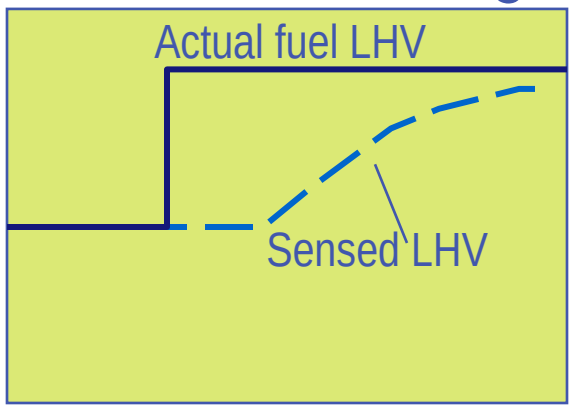
- Typical Wobbe Number range is 40 to 60
- On-site gas analysis equipment is supplied for most installations where gas properties are expected to vary
- Gas calorimeter or chromatographs are typically used
- Calorimeters – faster, not as accurate, and sensitive to disturbances.
- Gas chromatographs – Slower, more accurate, updates are in the range of once every 90 to 180 seconds –
  - New technology is being developed to greatly reduce the response speed

Fuel Property Accommodation

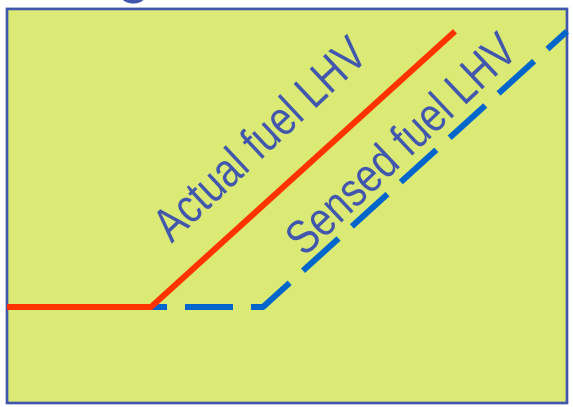
- Annular combustion System…one set of instrumentation

- Adaptive flame temperature control designed to accommodate transient shifts in operation

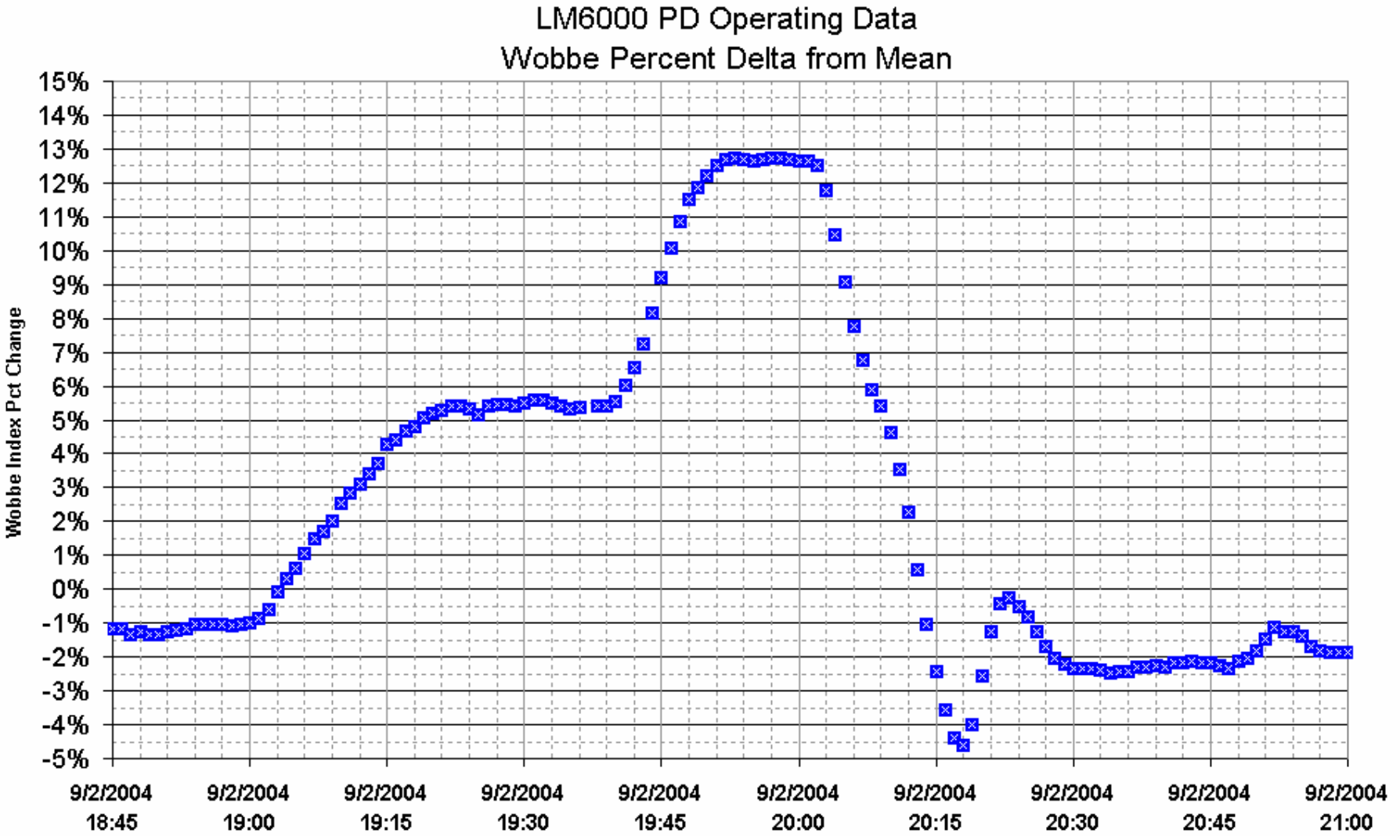
Example: Rapid change in actual fuel properties where the sensed lower heating value (LHV) lags the true LHV



Step change in LHV



Ramp change in LHV


LM6000 PD Operating Data
Wobbe Percent Delta from Mean
Wobbe Index Pct Change
15%
14%
13%
12%
11%
10%
9%
8%
7%
6%
5%
4%
3%
2%
1%
0%
-1%
-2%
-3%
-4%
-5%
9/2/2004 18:45
9/2/2004 19:00
9/2/2004 19:15
9/2/2004 19:30
9/2/2004 19:45
9/2/2004 20:00
9/2/2004 20:15
9/2/2004 20:30
9/2/2004 20:45
9/2/2004 21:00

Summary

Summary of LM Fuel Flexibility

Annular combustor allows for single integrated instrumentation and control system

LM DLE system has demonstrated the ability to handle significant variation in fuel properties

- Over 12% Wobbe number change
- Using gas analysis as control inputs
- Maintains low emissions with fuel property changes
- Adaptive logic increases capability for fuel variations

LM products currently operate with proposed interim guidelines:

- 4% Wobbe variation
- 1.5% max Butane +, 4% max inerts