19th SYMPOSIUM ON INDUSTRIAL APPLICATIONS OF GAS TURBINES

IAGT™

Training Session 2 Part II

Gas Turbine Selection Criteria

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Training Session 2 Part II
Gas Turbine Selection Criteria

- Typical historical differences between Aero-Derivative and Heavy frame units
  - ❖ Fuel requirements
  - ❖ Air inlet system requirements
  - ❖ Fuel Efficiency (heat rate) & Power
  - ❖ Site construction time (Modular versus build on site)
  - ❖ Unit Portability (Power to weight ratio)
  - ❖ Maintenance intervals (cycles, hours, load duty)
  - ❖ Control Systems
  - ❖ Starting and loading time
  - ❖ Emissions levels
- Convergence of differences to date

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Fuel requirements

FRAME

- First Generation Frame units capable of burning a wider range of fuels including heavy oils. Ref.1

CONVERGENCE

- Heavy fuel oil operation generally limited to the lower temperature E class Frame units.

AERO-DERIVATIVE

- Higher Natural Gas fuel pressure required for higher pressure ratio Aero Derivative units, compared to Frame units.

CONVERGENCE

- Some Aero Derivative units are now capable of burning a wider range of gaseous fuels Ref. 2

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Comparison of typical Turbine blades used on the first generation gas turbine units 1960-1970 in Canada

FRAME AERO-DERIVATIVE

Comparison of typical Turbine blades used on the first generation gas turbine units 1960-1970 in Canada

- **FRAME**
  - Thick Sections with high mass per blade work & high strains during rapid temperature changes
  - Less sensitive to deposits, minor erosion and impacts
  - High temperature blade path close to disk roots
- **Convergence to present**
  - Thinner sections with advanced cooling
  - Increased sensitivity to deposits, erosion, impacts
  - Roots isolated from hot gas
- **AERO-DERIVATIVE**
  - Thin Sections with low mass per blade work & lower strains during rapid temperature changes
  - More sensitive to deposits, minor erosion and impacts
  - Disk root attachment isolated from hot gas

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Air inlet system requirements comparison

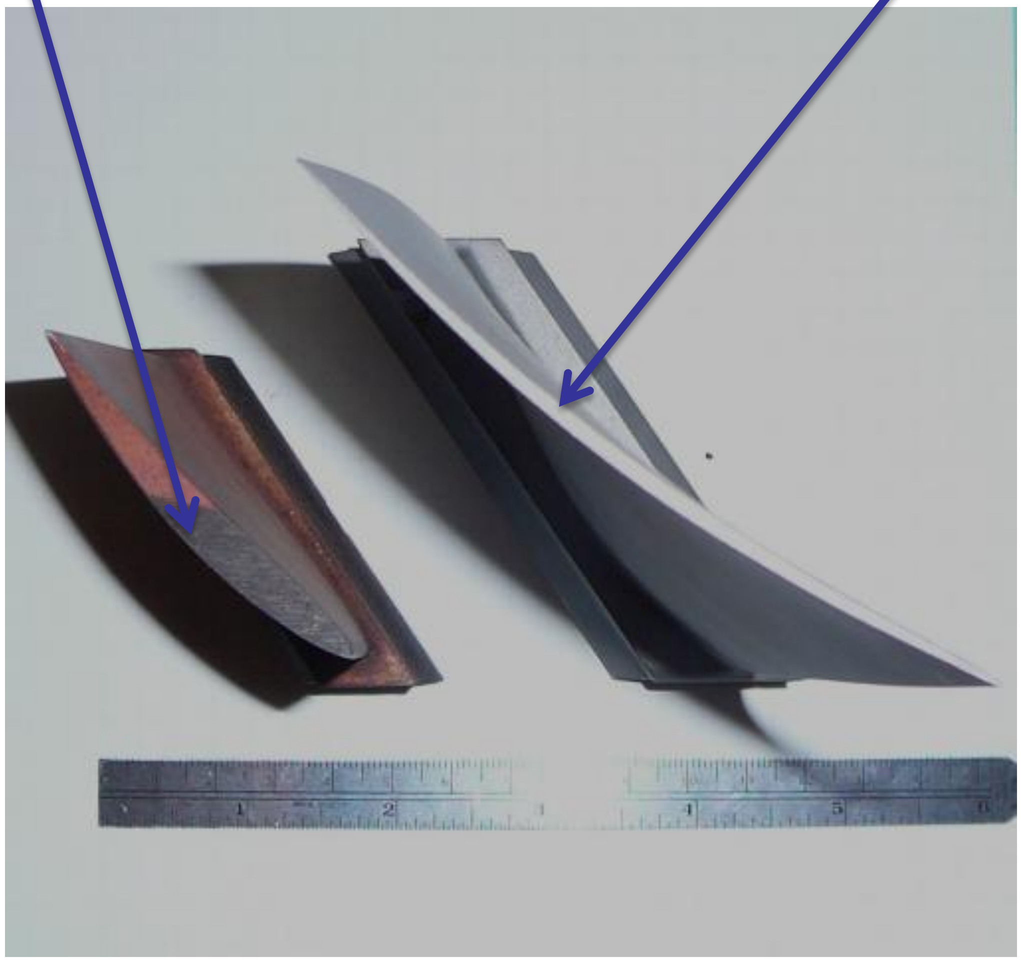
FRAME

- ➢ Low inlet Mach number
- ➢ Asymmetric inlet (sides, top, or bottom)
- ➢ Minimal filtration and less concern regarding icing
- ➢ Provision for compressor cleaning often was solid particles such as pecan shells
- **CONVERGENCE** to date
- ➢ Increased Mach number
- ➢ Filtration and Moisture removal
- ➢ Icing concerns
- ➢ Compressor washing provisions

AERO-DERIVATIVE

- ➢ Higher inlet Mach number
- ➢ Plenum box upstream of compressor in attempt to minimize flow asymmetry into inlet (analogous to gas generator on test bed or under wing on take off)
- ➢ Inlet anti-icing using small amount of compressor bleed
- ➢ Provisions for crank soak compressor washing
- ➢ Filtration to minimize moisture ingress and particulate fouling of the compressor

COMPARISON OF FRAME COMPRESSOR BLADE FROM MATURE **E** CLASS vs. **F** CLASS USING AERO CODES



Comparison of Compressor designs

FRAME

- Low pressure ratio with many stages
- Robust airfoil sections

CONVERGENCE

- Higher pressure ratios with fewer stages
- Increased use of variable stator sections in addition to Variable Inlet Guide vanes
- Thinner airfoil sections suitable for higher Mach number

AERO-DERIVATIVE

- High pressure ratio maximizing work per blade

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SHAFT POWER FUEL EFFICIENCY & SINGLE UNIT POWER CAPABILITY COMPARISONS

FRAME

- Low pressure ratio units with a regenerator (exhaust heats compressor discharge) results in improved full load & part load efficiency
- Largest power capability
- Highest electrical or shaft power efficiency available in combined cycle mode

CONVERGENCE

- Simple cycle efficiencies improved with the use of aero compressor and turbine design tools

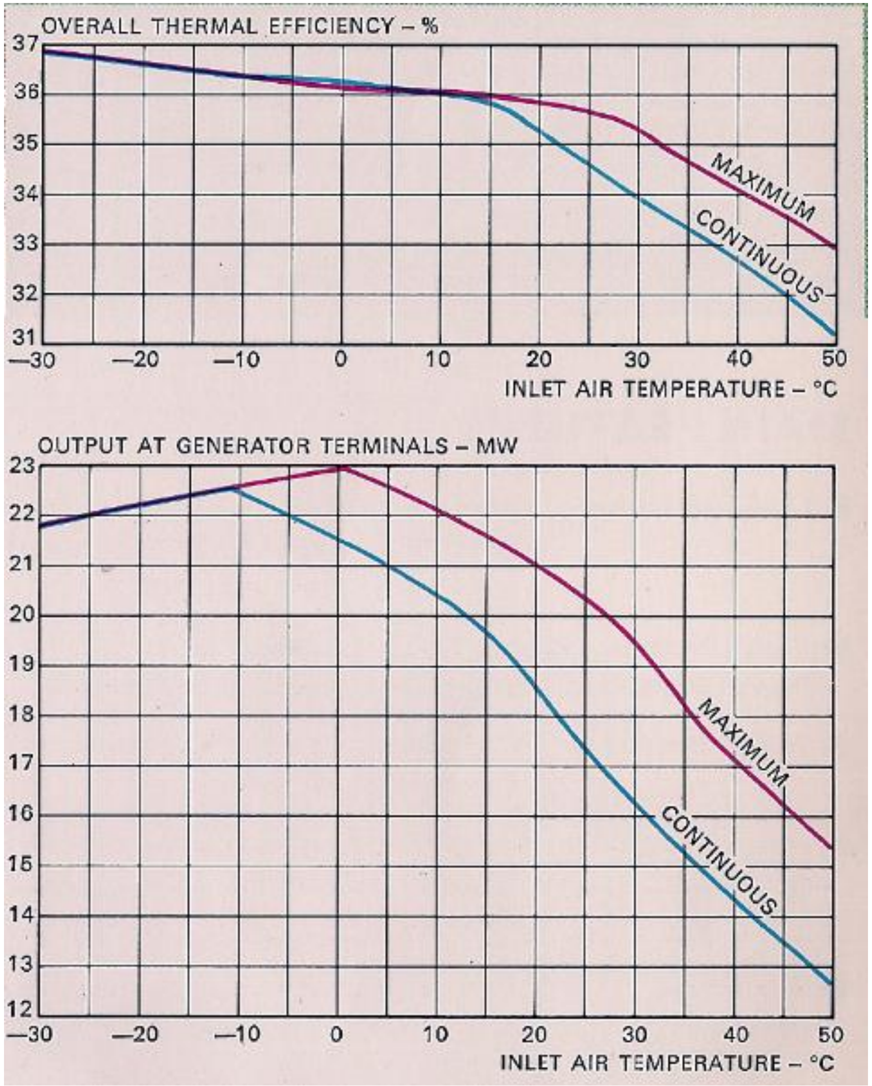
AERO-DERIVATIVE

- Highest simple cycle efficiency

CONVERGENCE

- Waste heat recovery on pipeline units to generate additional shaft power

1980 AERO-DERIVATIVE PERFORMANCE Simple Cycle Ref 3



SITE CONSTRUCTION TIME

FRAME

- Gas Turbine typically similar mass to driven generator so larger foundation required
- For Larger units only core engine is suitable for transport

CONVERGENCE

- Modular construction of auxiliary packages to minimize site work

AERO-DERIVATIVE

- Low mass gas generators and power turbines suitable for pre-packaging in acoustic enclosure.

CONVERGENCE

- Acoustic enclosures and/or single lift packages sometimes placed inside a larger power house to control climate and facilitate maintenance

UNIT PORTABILITY

FRAME

- Generally not considered practical for land transport when compared to Diesel Railcar capability.

CONVERGENCE

- Frame units can be barge mounted for transport to any coastal location in the world.

  This is particularly helpful if site conditions are not conducive to foundation construction and/or the movement of heavy machinery.

AERO-DERIVATIVE

- Several road trailers can provide either electric or mechanical drive power.
- Compact units can be part of single lift off-shore modules or barge mounted for sea or river transport around the world.

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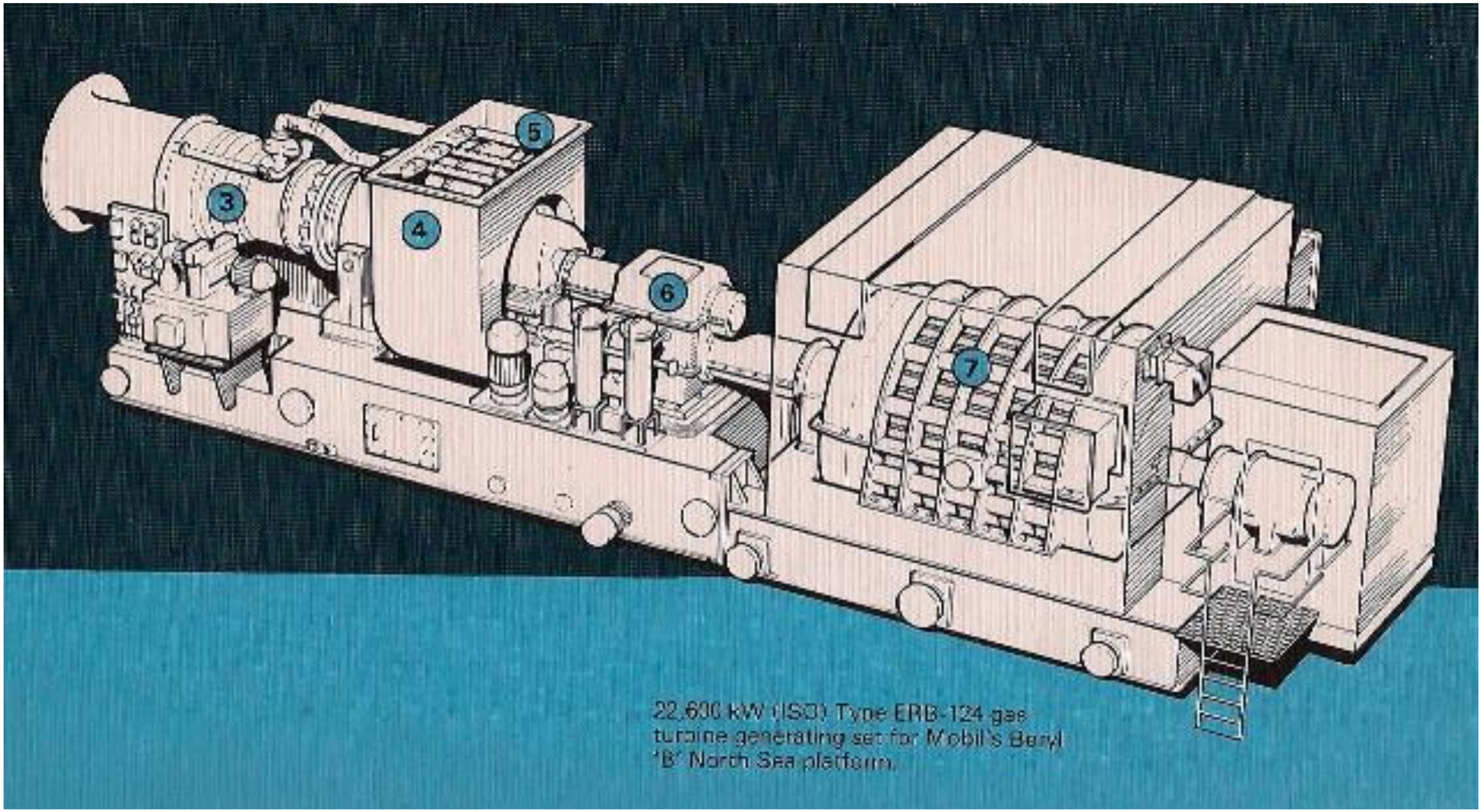
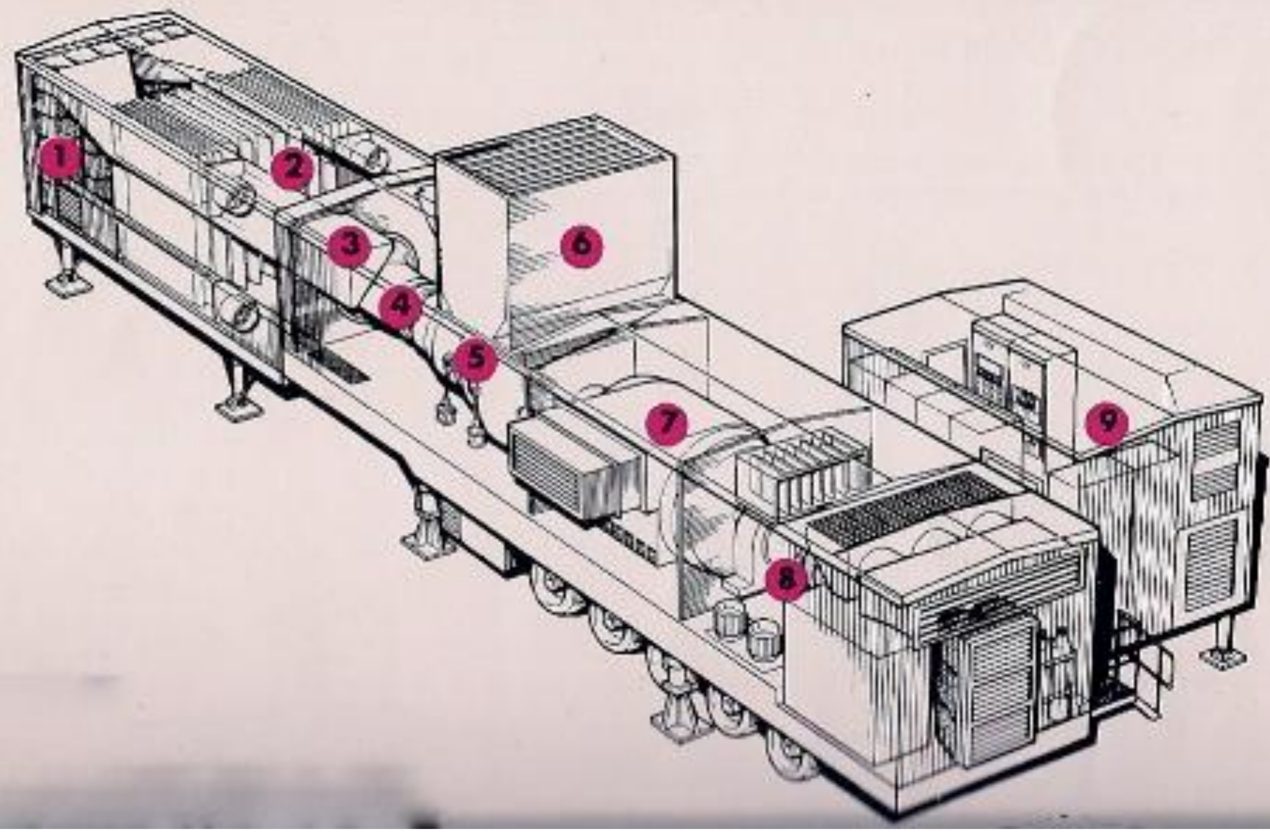
AERO-DERIVATIVE OFFSHORE ARRANGEMENT 1982 Ref 4



22,600 kW (ISO) Type ERB-124 gas turbine generating set for Mobil's Beryl 'B' North Sea platform.

AERO-DERIVATIVE MOBILE UNIT 1980 Ref 3



ELM-125 22,000 kW mobile generating set in operating mode. For transportation all equipment is contained within two tractor-drawn trailers.

MAINTENANCE INTERVALS

FRAME

- Fired hours maintenance intervals (normally on site)
- Start (cycles) based intervals (normally on site)
- Prescriptive intervals modified by fuel, load, duty cycle, water/steam injection

Ref 5, 6

AERO-DERIVATIVE

- In some cases Inspection and Maintenance intervals similar to Frame units Ref 2, 7
- Base and Peak ratings may result in differing operating windows for hours and starts per year, dependent on model Ref 8
- Condition assessment in conjunction with routine visual to determine need for overhaul Ref 9
- Major overhaul normally involves gas generator removal to a repair depot

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MAINTENANCE INTERVALS

FRAME

CONVERGENCE

- Maintenance intervals and programs must include driven equipment and auxiliaries
- Component and system design improvements can result in interval extensions
- Condition assessment in conjunction with routine visual to determine need for overhaul
- Long Term Maintenance agreements may dictate intervals
- Life Time extensions to frame specific design lives (hours and starts) Ref 10

AERO-DERIVATIVE

CONVERGENCE

- Maintenance intervals and programs must include driven equipment and auxiliaries
- Component and system design improvements can result in interval extensions
- Long Term Maintenance agreements may dictate intervals
- Life Time extensions to frame specific design lives (hours and starts)

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CONTROL SYSTEMS

FRAME

- Pneumatic and Hydraulic controls and actuators
- Analog controls

CONVERGENCE

- Digital control in conjunction with either electric or hydraulic actuated valves for precise start ramps, fuel scheduling, and speed control.
- Rapid data acquisition in conjunction with a historian allows detailed analysis and trouble shooting of upset events, and normal operation

AERO-DERIVATIVE

- Lower shaft moments of inertia requires faster response than Frame units

CONVERGENCE

- Similar to Frame units

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STARTING AND LOADING TIME

FRAME

- Typical: synchronous speed in 10-15 minutes, possible warm up, loading 6-10% per minute
- Larger starter power requirement compared to aero-derivative

CONVERGENCE

- Some large frames now designed and configured to provide full load in 12-13 minutes from start.
  Ref 11

AERO-DERIVATIVE

- Typical: full load in 10 minutes

EMISSIONS LEVELS

FRAME

- Single burner large combustor units tend to have highest uncontrolled NOx levels
- E class Frame units either steam injected, or with DLN combustion could meet the 1992 CCME Emission NOx guidelines of 140 g/GJ shaft output (approx. 25 ppm with 30% efficient cycle)
- Many E class and higher firing F class units now have DLN capabilities well below the 1992 guideline Ref 11

AERO-DERIVATIVE

- Uncontrolled NOx levels tend to be less than similar rated uncontrolled Frame units
- Space limitations make DLN designs more difficult compared to Frame units

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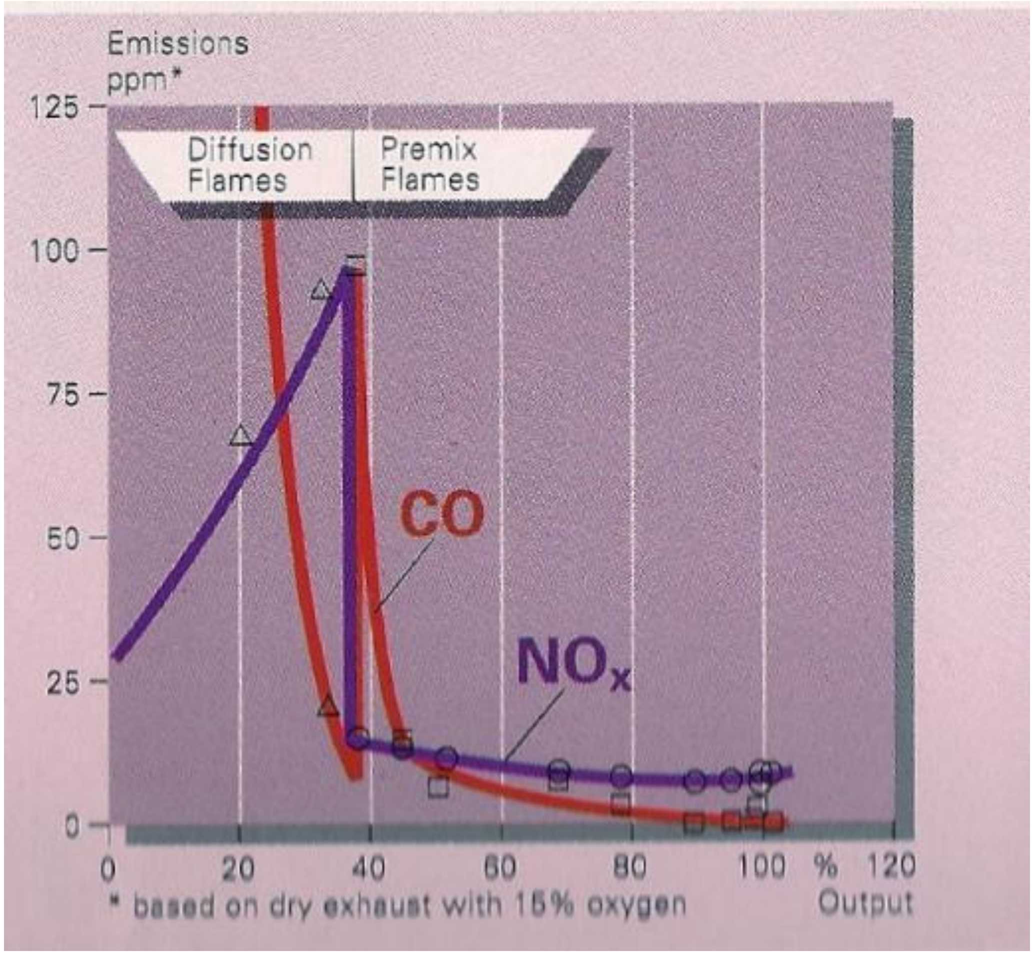
EMISSIONS LEVELS
Frame DLN capability advertisement
Gas Turbine World September-October 1993



EMISSIONS LEVELS

FRAME

CONVERGENCE

- Low NOx at Part load with reasonable CO levels is the DLN challenge
- Water Injection is a potential option for peaking units to allow wider operating range with less stringent NOx requirements

AERO-DERIVATIVE

CONVERGENCE

- Low NOx at Part **load** with reasonable CO levels is the DLN challenge
- Water Injection is a potential option for peaking units to allow wider operating range with less stringent NOx requirements
- Some DLN units now below 25 ppm NOx Ref 2

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REFERENCES

Ref 1: 2010 IAGT Course 2 Gas Turbine Designs & Systems Applications (A Canadian Perspective)

Ref 2: GER-3695E GE Aeroderivative Gas Turbines – Design and Operating Features

Ref 3: GEC Gas Turbines Limited 1980 ELM-125 22 MW Gas Turbines brochure

Ref 4: GEC Gas Turbines Limited 1982 ERB-124 18-22 MW Gas Turbines brochure

Ref 5: Offshore Gas Turbine (and major driven equipment) integrity & inspection guidance notes for Health Safety Executive 2006 HSE.gov.uk

Ref 6: GER-3620J GE Heavy-Duty Gas Turbine Operating & Maintenance Considerations

Ref 7: 07-IAGT-2.3 Life Cycle Impact of Steam Injection on the LM6000PC Turbine Blades

Ref 8: RR IGT5325A/1 Performance Data Rolls-Royce Industrial Avon January 1984

Ref 9: RR IGT5325A Avon Industrial Gas Turbine 1984

Ref 10: Lifetime Extension For Siemens Gas turbines. Diesel & Gas Turbine Worldwide Sept 2011

Ref 11: Advanced SGT6-5000F Development. Power-Gen International 2008 Orlando Florida

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