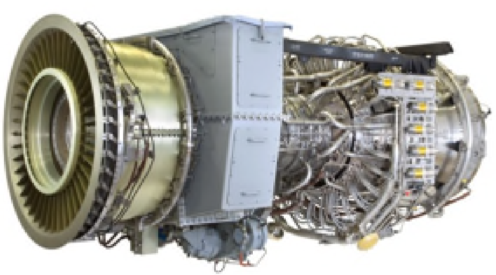
Gas Turbines and Compressors for LNG Liquefaction Plants

Cyrus B. Meher-Homji, PE.

Technology Manager, Turbomachinery

LNG Technology Group

Bechtel Corporation



IAGT LNG TECHNICAL WORKSHOP

Vancouver, May 15-16, 2014

Outline

Introduction to LNG

Gas Turbine Drivers

Compressor Technology

Presentation focuses on Turbomachinery and is Process Neutral.

Key issue is design tradeoffs/compromises

Importance of Interactive System Design for Compressors

Based on Paper presented at
TMS and 2011 METS

Design Compromises

- Gas Turbines are Relatively Standard- core engine design compromises exist but are not influenced by the user
- Key emphasis is on Inlet filtration/ Aux systems, DLN/DLE complexities
- Compressors are custom engineered and

design compromises must be understood

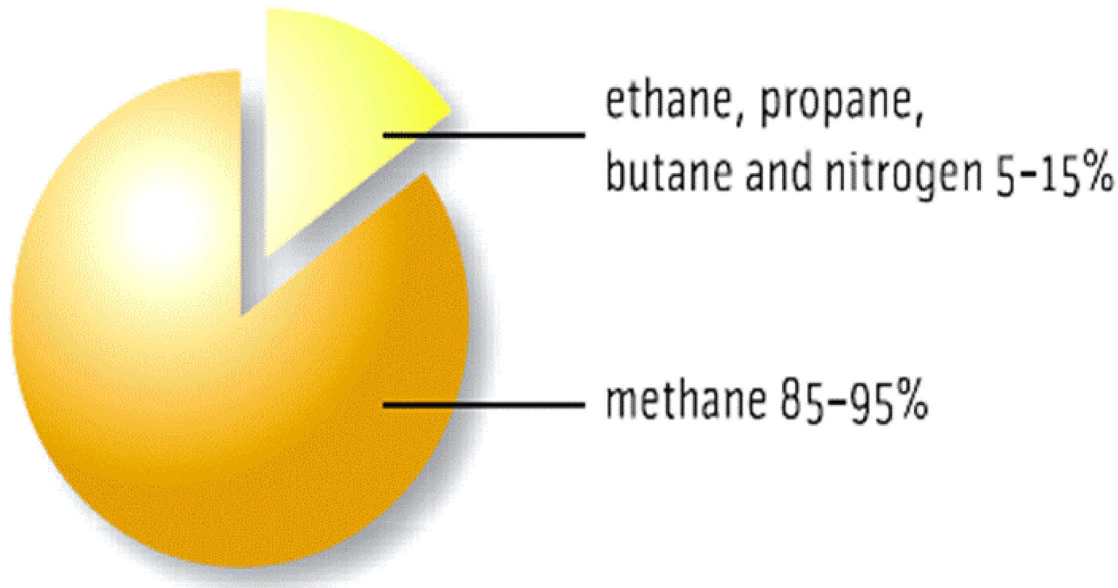
- Need for User- Process Engineer- Machinery

Specialist & OEM to work closely together

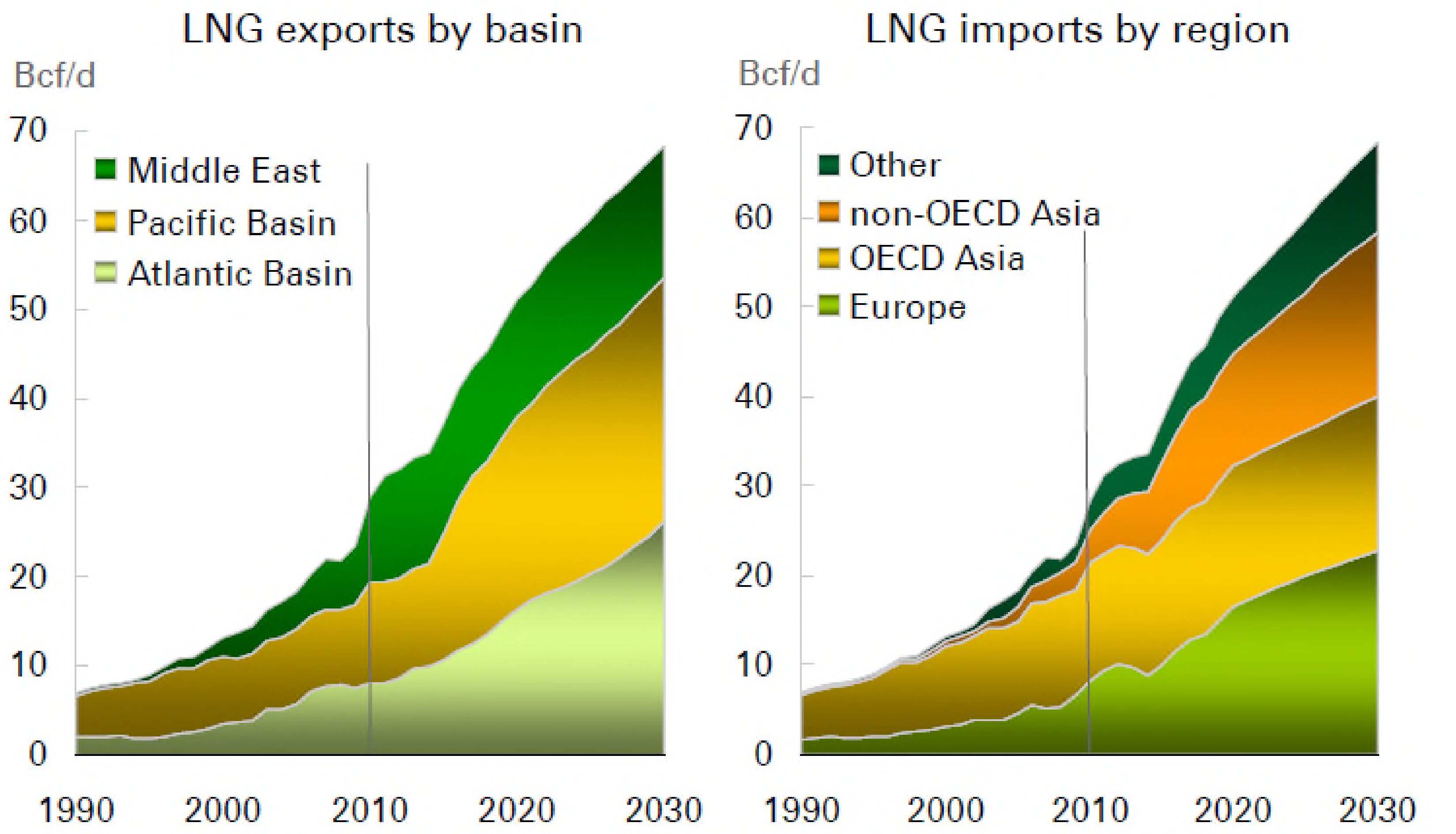
- Understanding of aeromechanical – rotordynamic compromises are most important

LNG

LNG is mostly methane plus a few percent ethane, even less propane and butane, and trace amounts of nitrogen.



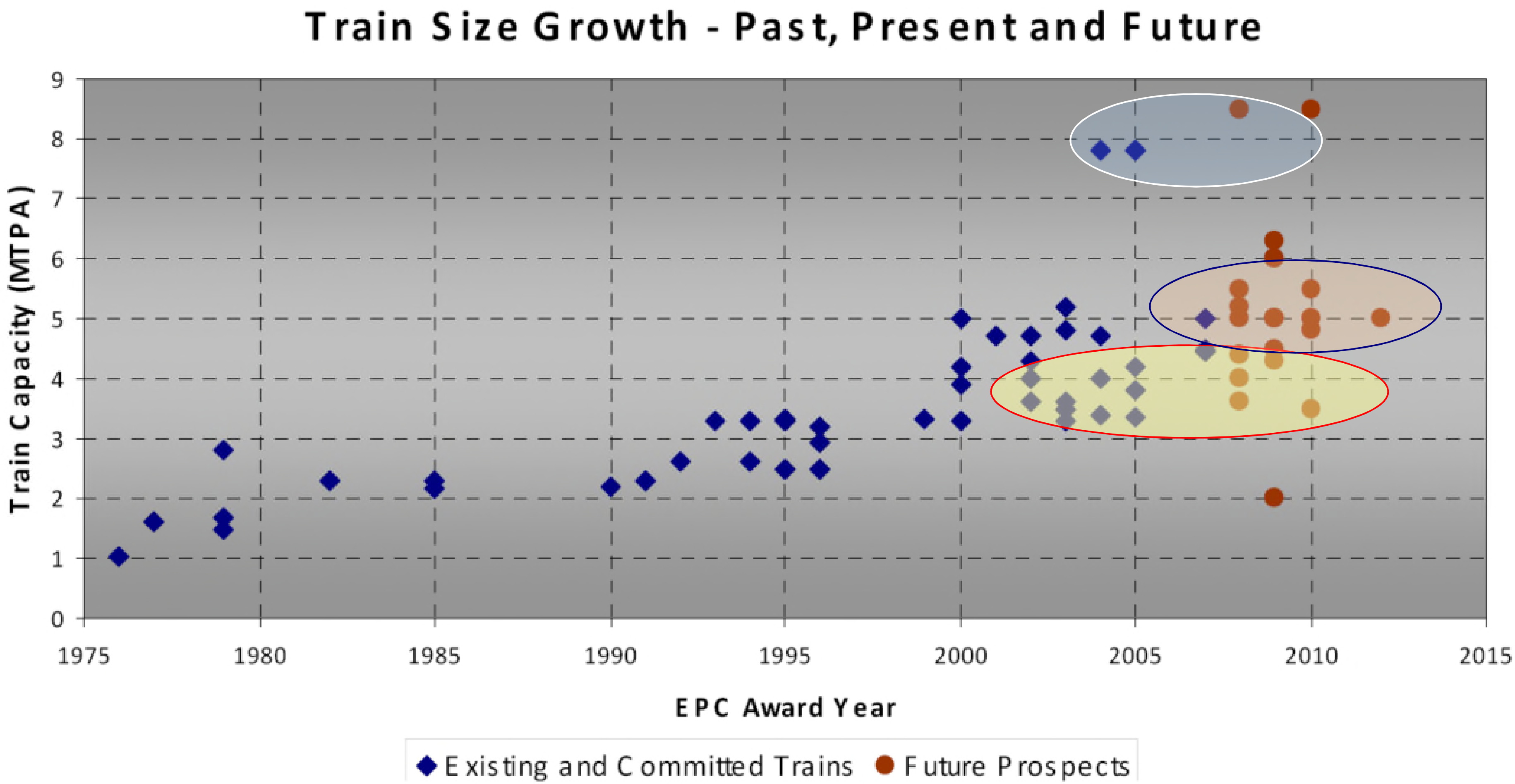
Rapid Growth of LNG Trade



Source: BP Energy Outlook 2031

LNG PLANT SIZES AND TRENDS- now at 8 MTPA

TREND TOWARDS HEAT INTEGRATION- COMBINED CYCLES….



Source: LNG For the Commercially Minded, Durr, C et al

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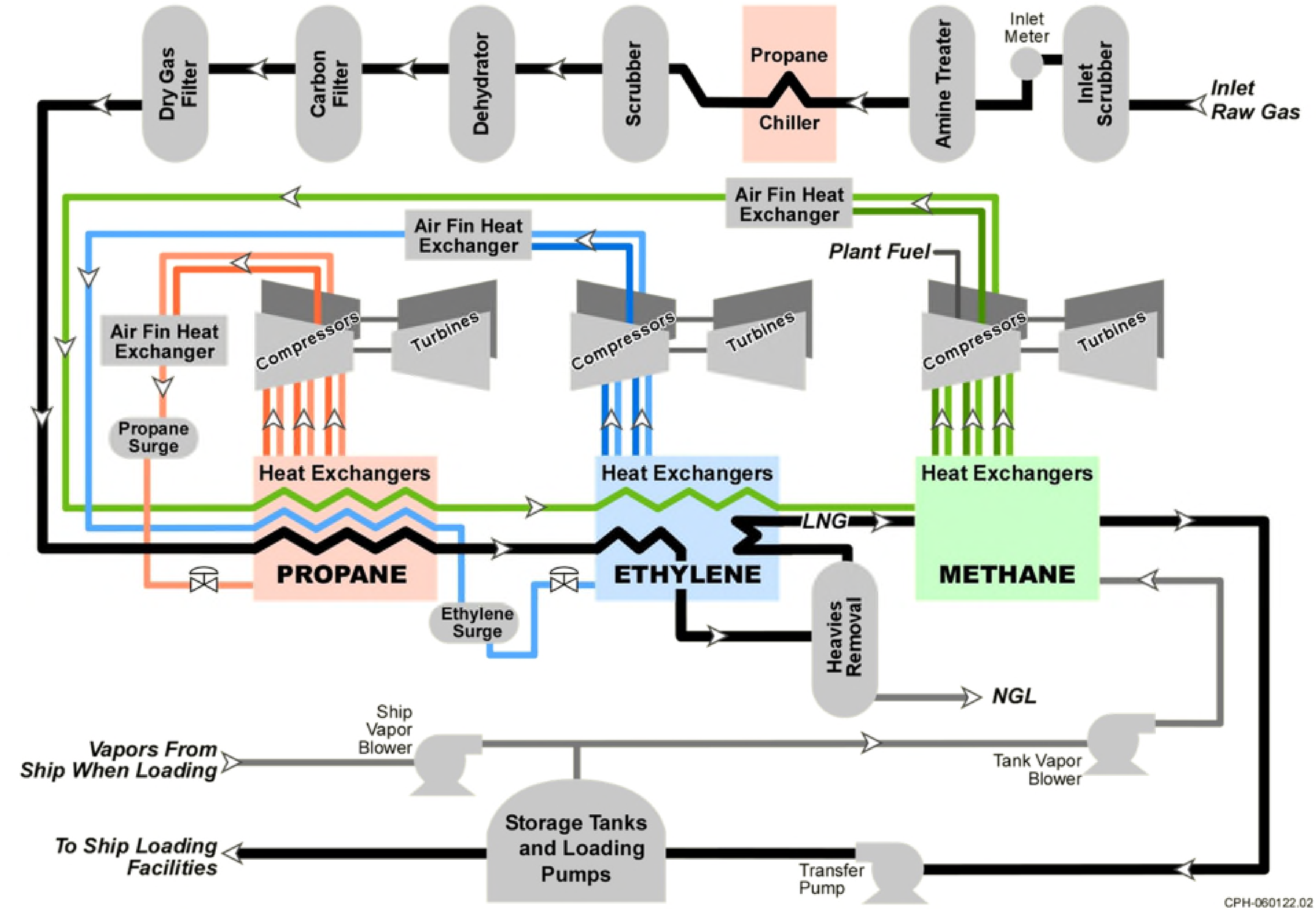
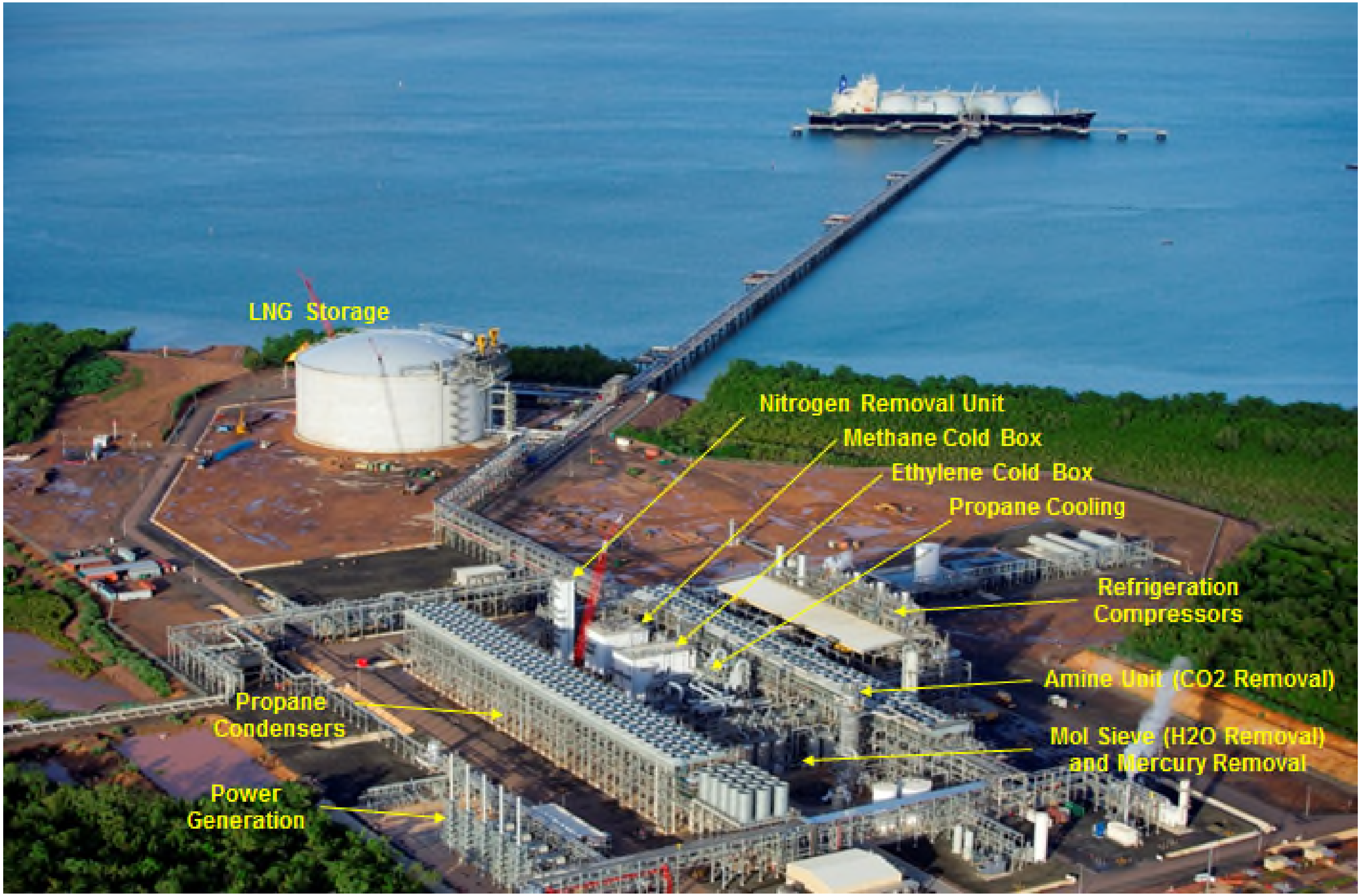
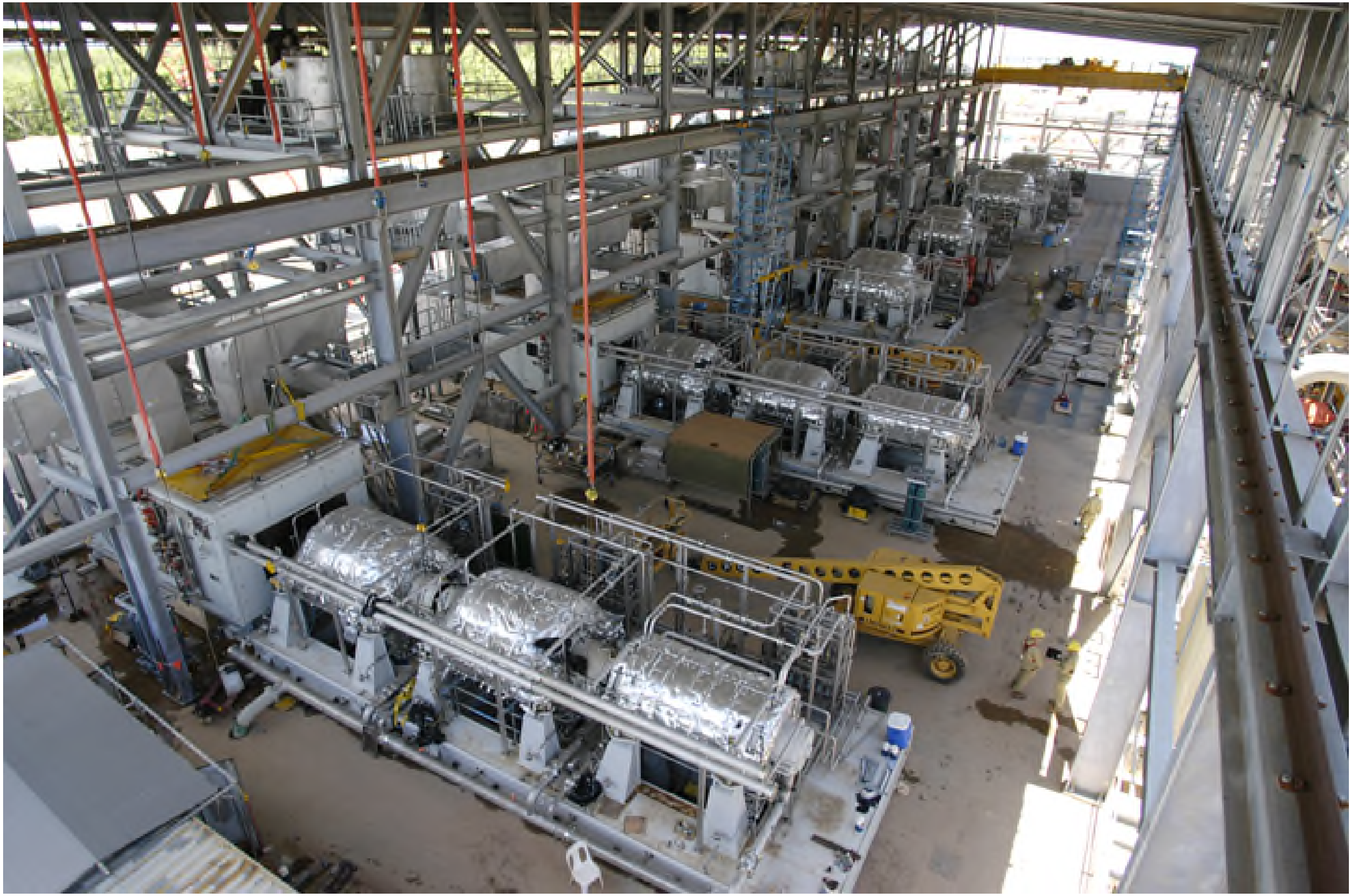
The Optimized Cascade Process



Darwin LNG

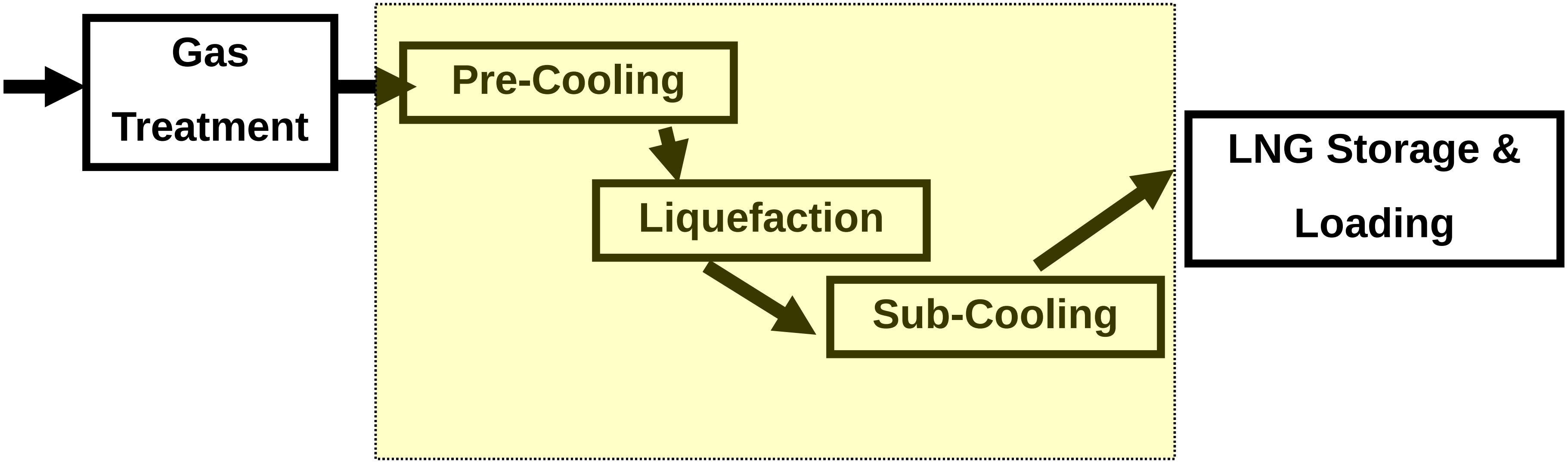

LNG Storage
Nitrogen Removal Unit
Methane Cold Box
Ethylene Cold Box
Propane Cooling
Refrigeration Compressors
Amine Unit (CO2 Removal)
Mol Sieve (H2O Removal) and Mercury Removal
Propane Condensers
Power Generation

Darwin LNG Compressor Deck




Atlantic LNG Facility
Looking northwest
BECHTEL

LNG Liquefaction Plant



Any Liquefaction Technology

Fuel ~ 10%

Refrigerants:

Some combination of Propane, Ethylene, Methane, Mixed Refrigerant, N2

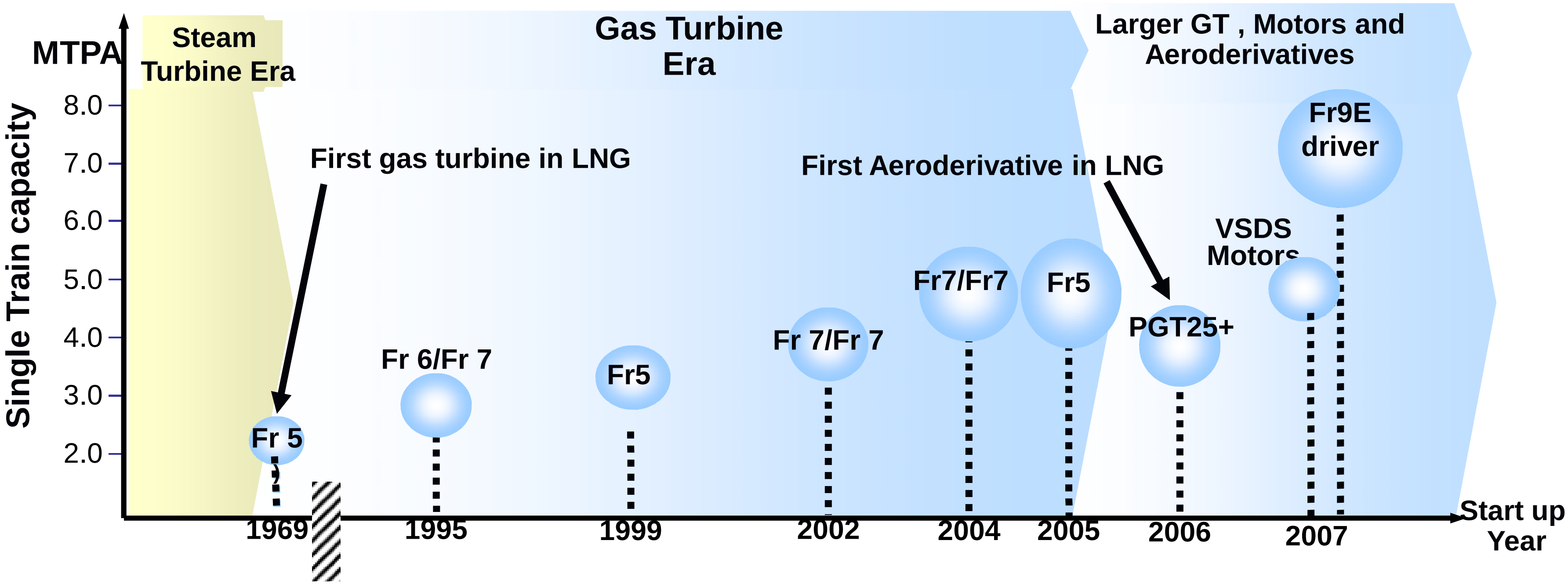
Gas Turbine Drivers

Driver Types

Drivers Available

- **Steam turbines**
- **Gas Turbines**
  - **Heavy Duty**
    - **Single Shaft**
    - **Split Shaft**
  - **Aeroderivative**
- **Electric Motors**
- **Interest in Combined Cycles and Heat Integration**

Driver Evolution in the LNG Industry



First GT

First Aeroderivative

First Frame 9EA

Driver Selection Criteria

Driver Power Capability

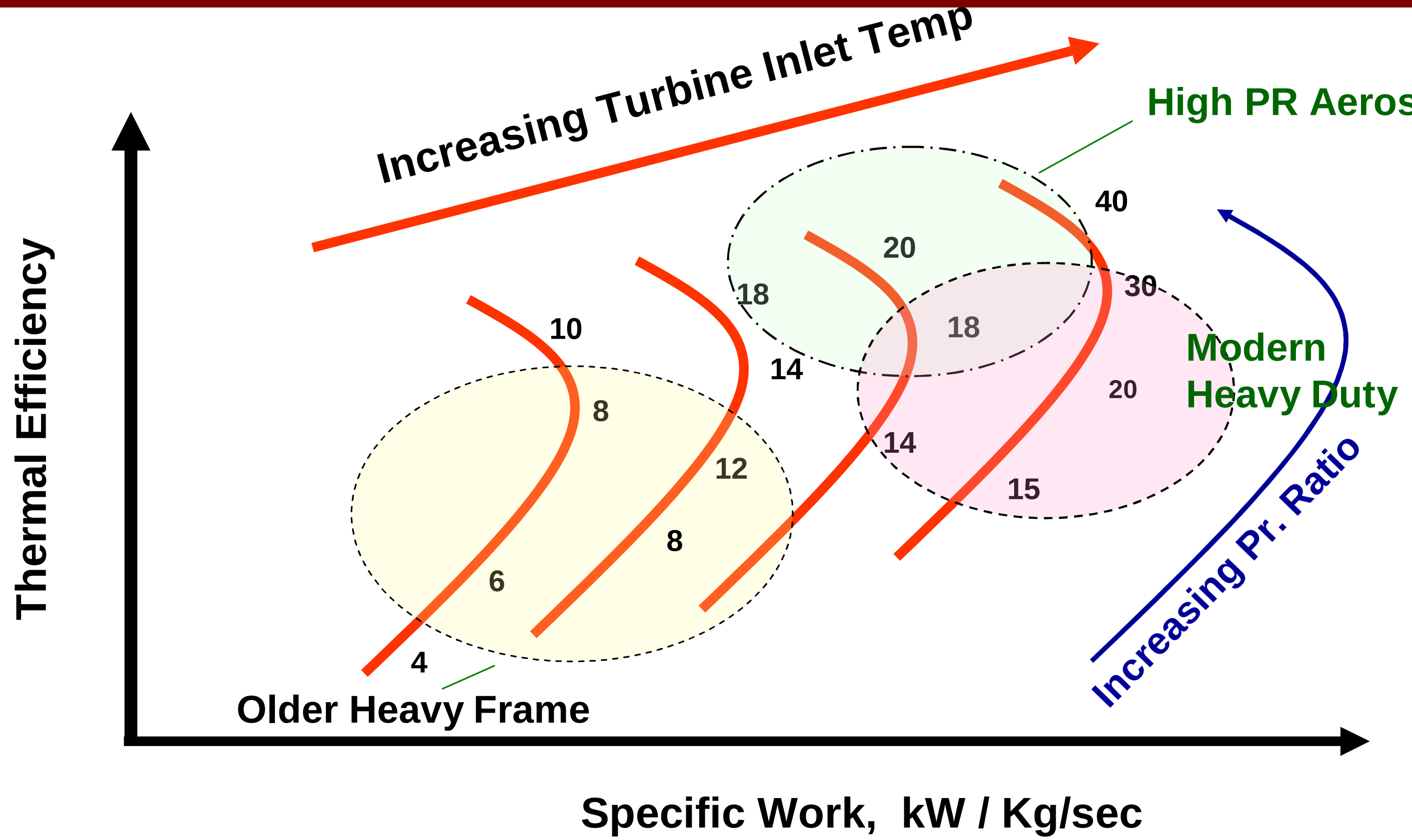
Reliability and Availability Experience

Capital Cost

Efficiency

Technical Issues – these include the operating speed of the driver, driver speed variability, starting torque capability and controllability.

Thermal Efficiency and Specific Work



For a given TIT, gas turbine specific work increases with pressure ratio, reaching a maximum and then decreasing with further pressure ratio increase.

The specific work increases with increasing turbine inlet temperature.

The maximum specific work as the TIT is increased occurs at increasing pressure ratios.

Two "Technology Shift" Changes in the LNG Industry

1969: World's First Application of Gas Turbines in the LNG Industry

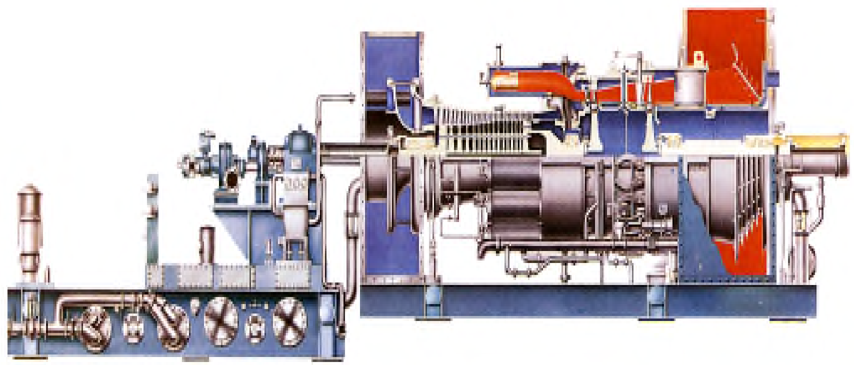
2006: World's First Application of Aeroderivative Gas Turbines in the LNG Industry

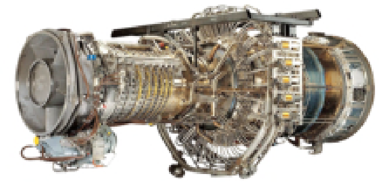
Gas Turbine Mechanical Drivers Utilized to Date in LNG Plants

Gas Turbine	ISO Rated Power, kW	Thermal Eff, %	Pressure Ratio	Air Flow Rate Kg/Sec	Number of Shafts	Output Shaft Speed
PGT25+ PGT25+G4	34,328	41.3	24.4	88.43	2	6100
Frame 5D	32,580	29.4	10.8	141.36	2	4670
Frame 5E **	31,998	36	17	102	2	6100
Frame 6B	42,910	33	12.2	140.9	1	5111
LM6000PF	44,261	42.8	29	128	2	3600
Frame 7EA	86,701	33	12.6	296	1	3600
Frame 9E	129,401	34.4	12.7	412	1	3000
LMS100 **	100,000	44	40	207	3	3000/3600

** Potential drivers

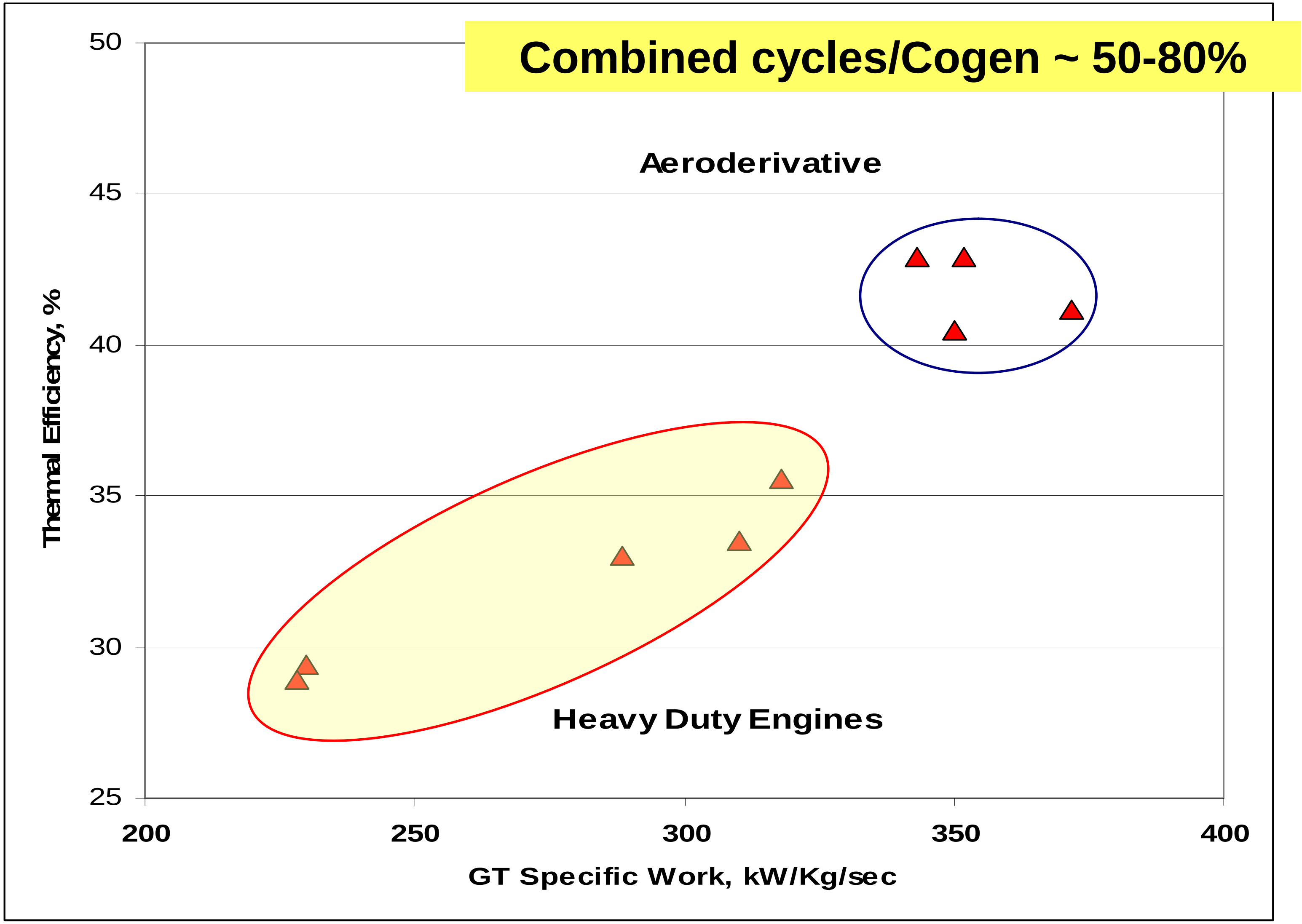
Industrial Vs. Aeroderivative





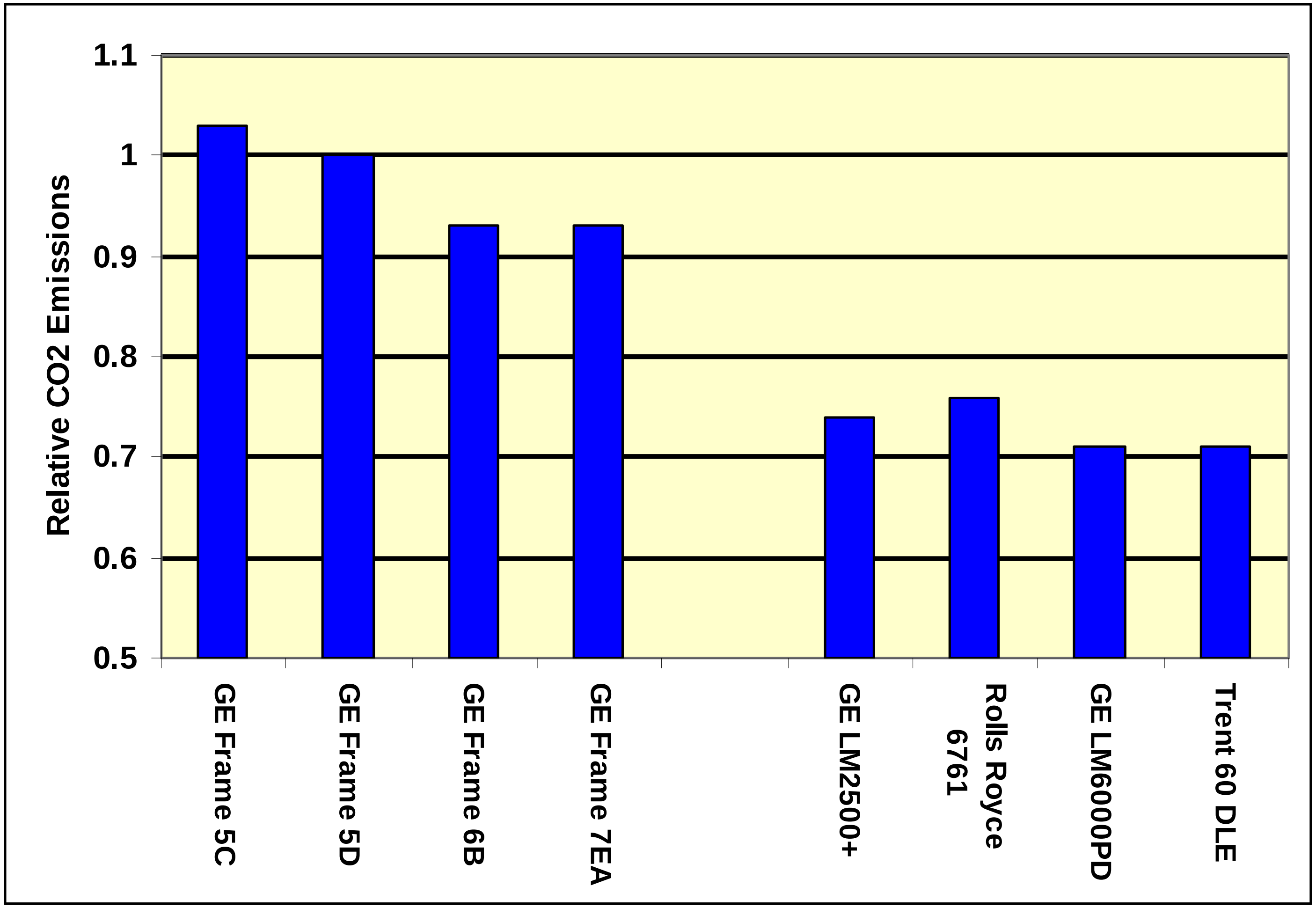
Frame 5D	LM2500+G4
Net Output 32500 kW	Net Output 34000 kW
Efficiency 29.5 %	Efficiency 40 %
PR= 10.7 / TIT ~ 986 °C	PR= 24 / TIT ~ 1260 °C
Mass Flow 141 Kg/sec	Mass Flow 88 Kg/sec
Exhaust Gas Temperature 509 °C	Exhaust Gas Temperature 511 °C
Core Engine Wt = 65 tonne	Core Engine Wt = 7 tonne

Heavy Duty& Aeroderivative Engines

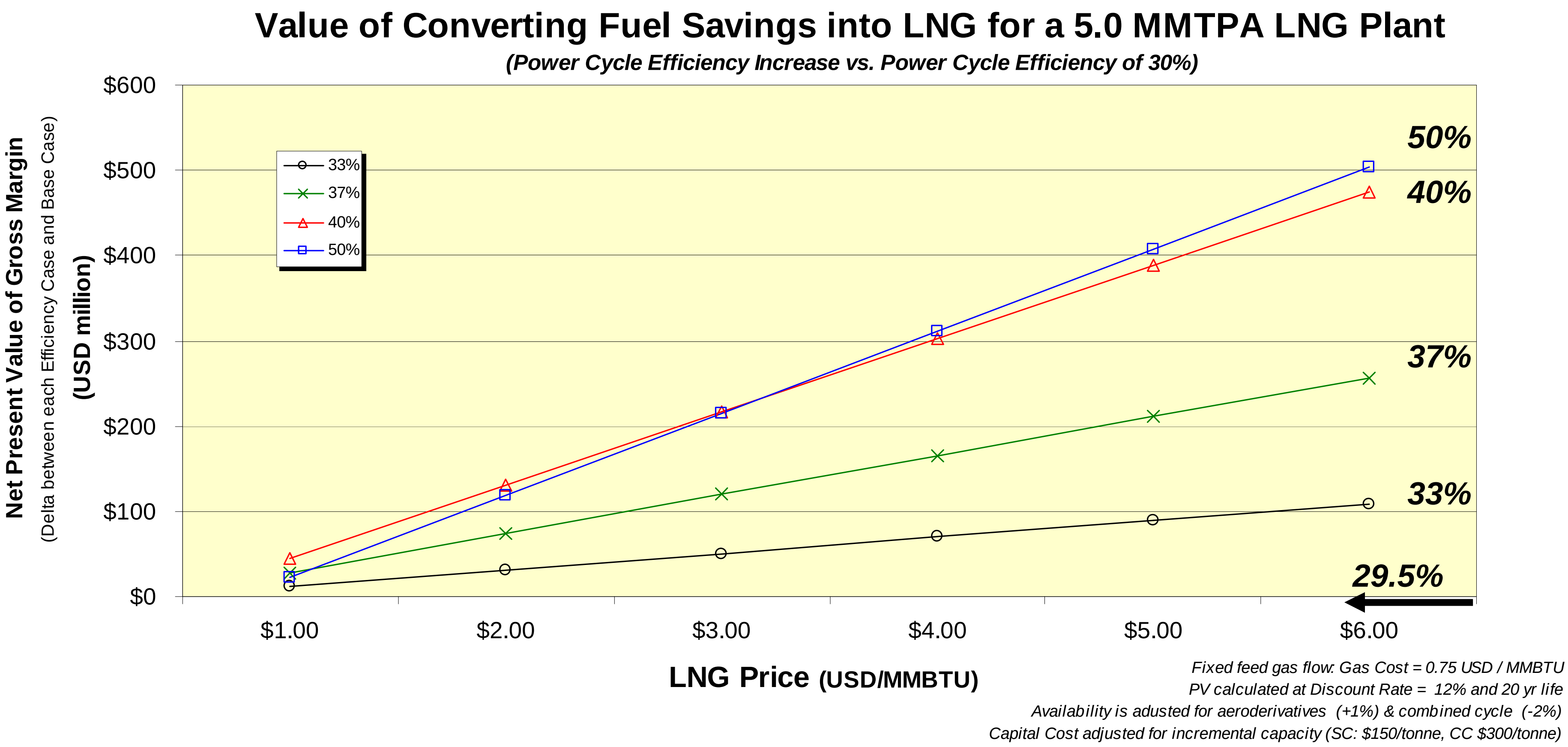


Reduction Of Greenhouse Gasses

- **High efficiency gas turbines**
- **Waste heat recovery on gas turbine exhaust– Trend to CC??**



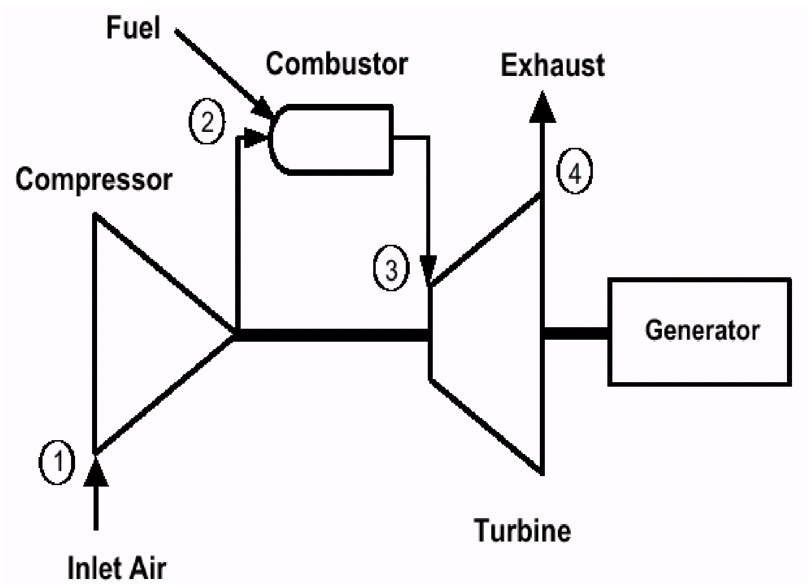
Economic Evaluation- Fuel Savings to LNG

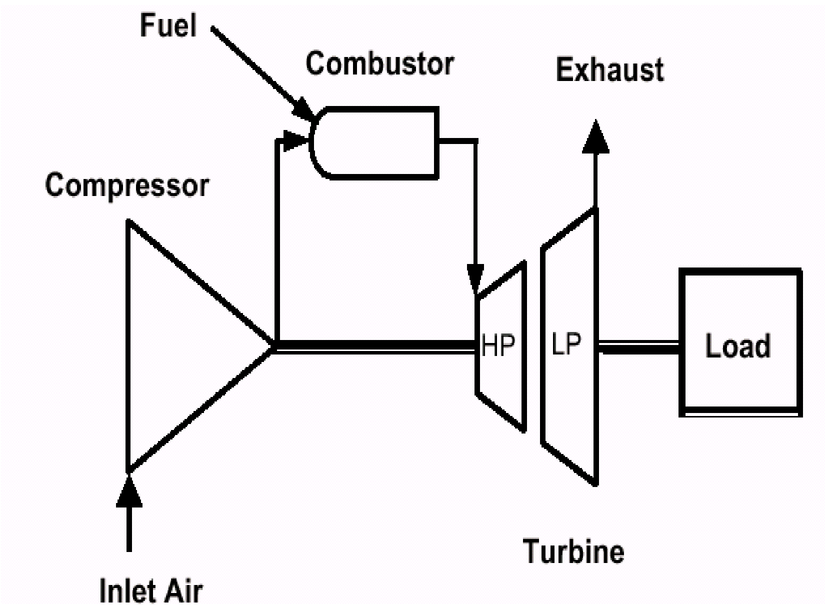


Darwin LNG

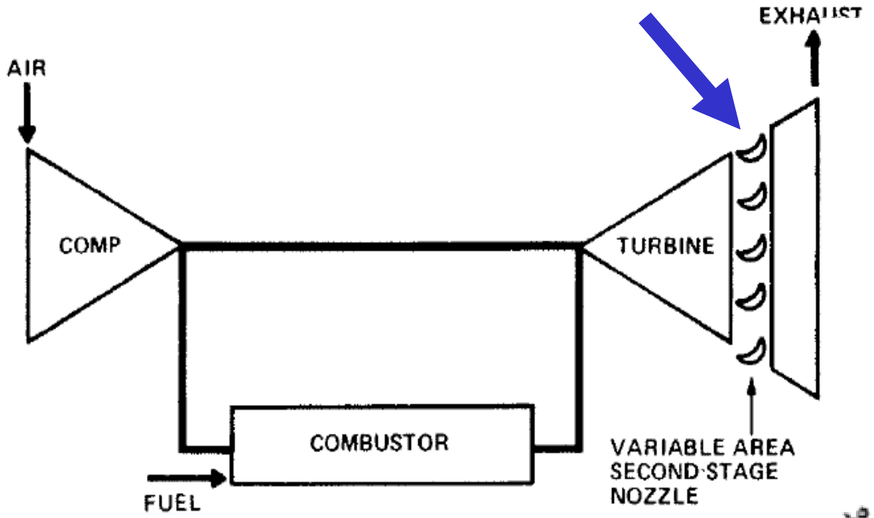
LM2500+ Gas Generator

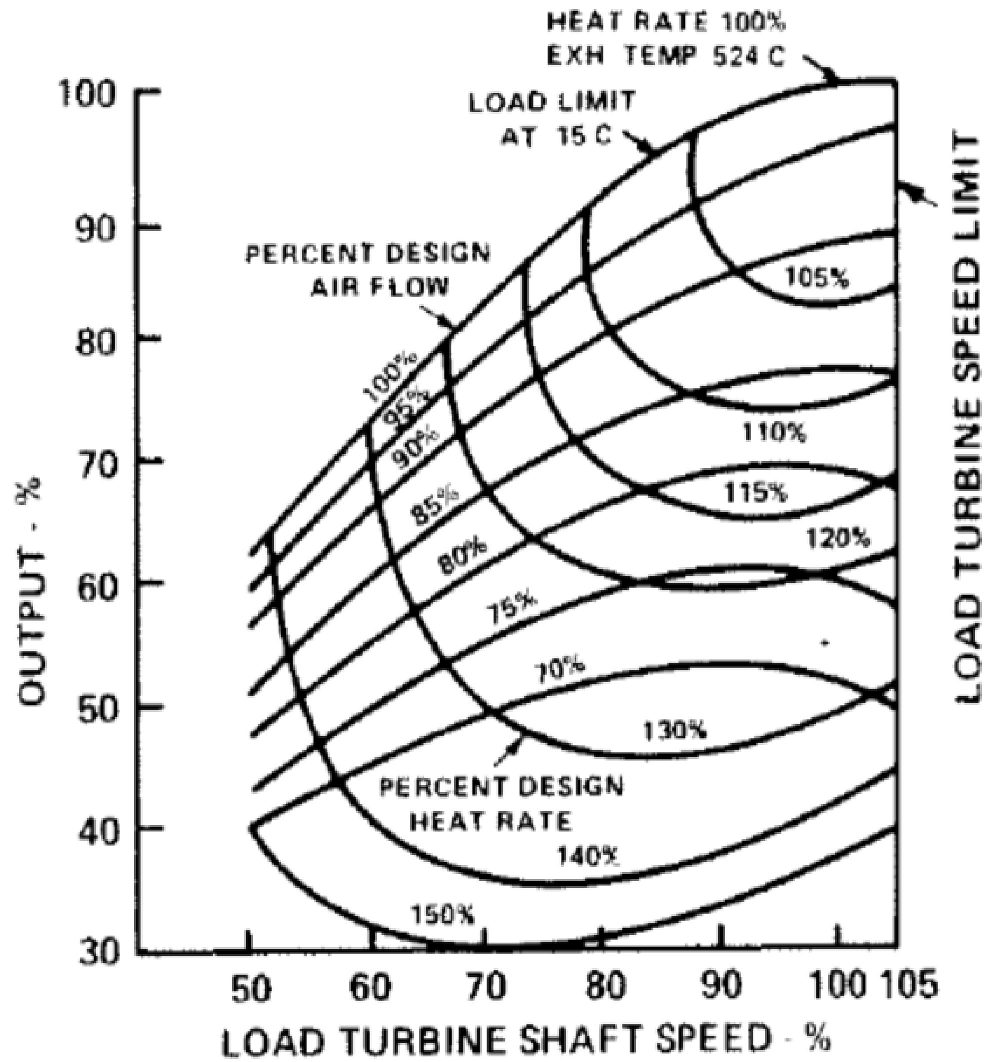
Single and Split Shaft GTs





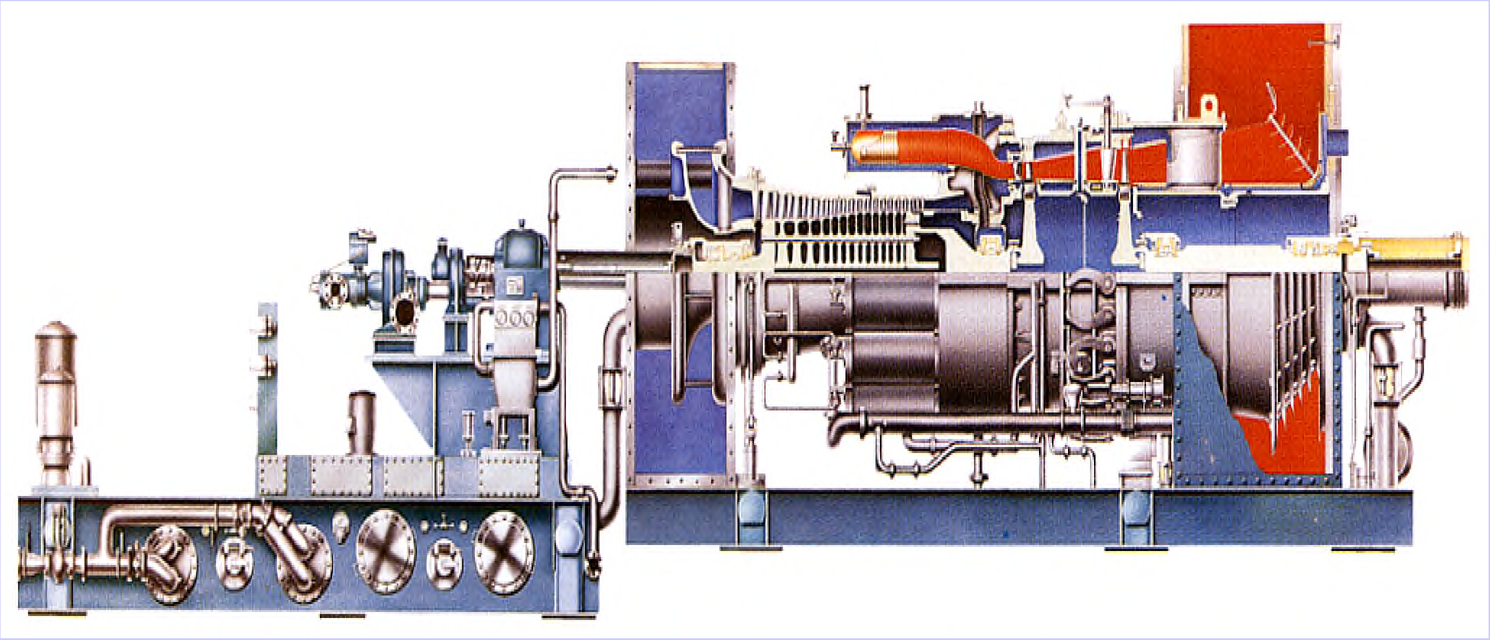
Variable PT Nozzle





Frame 5D- 2 Shaft Gas Turbine

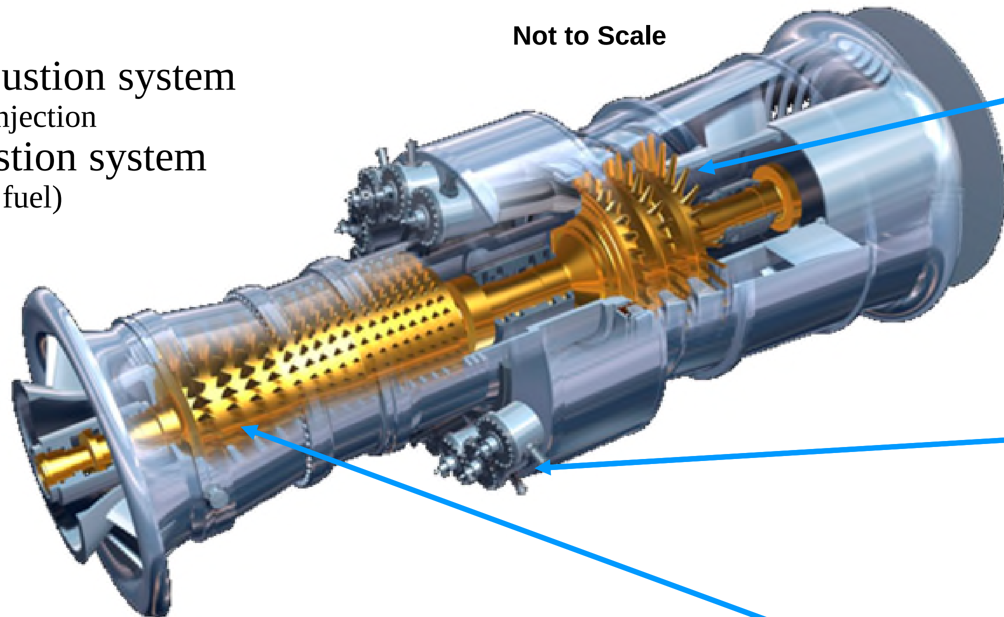
32 MW, Thermal efficiency = 29.5%
17-stage axial compressor; pressure ratio 10.8:1
Air flow rate = 310 lbs/sec; N2 = 4670 RPM
Reverse flow, multi chamber (can-annular) combustion system (12 chambers)
Single stage gas generator turbine
Single stage power turbine (4,670 RPM rated speed) with variable nozzles
Standard configuration: 49 x 10 x 12 ft (15 x 3.2 x 3.8 m); weight 110 tons
Combustors DLN-1 or LHE



High Pressure Gas Generator

MS7001EA *Design Features & Performance*

- Standard combustion system
  - Water or steam Injection
- DLN-1 combustion system
  - 9 ppm NOx (gas fuel)



Turbine
- 3 Stage High Efficiency
- Through Bolted Construction

Combustion System
- 10 Can Annular Chambers
- Standard combustor (water or steam inj.) or DLN-1

Axial Compressor
- 17 Stage Axial Flow
- 12.6:1 Pressure Ratio
- 1 Row IGV

	MS7121EA
Speed – RPM	3600
Speed range %	95-101
Output – MW	86.7
Efficiency %	32.9
Shaft	1
Pressure Ratio	11.9
Exhaust Flow – lb/sec	659
Exhaust Temp °F	998

1

1985	First MS7001EA Shipped
Today	over 500 units in operation
Applications	Mechanical Drive Power Gen for Base or Peak Load

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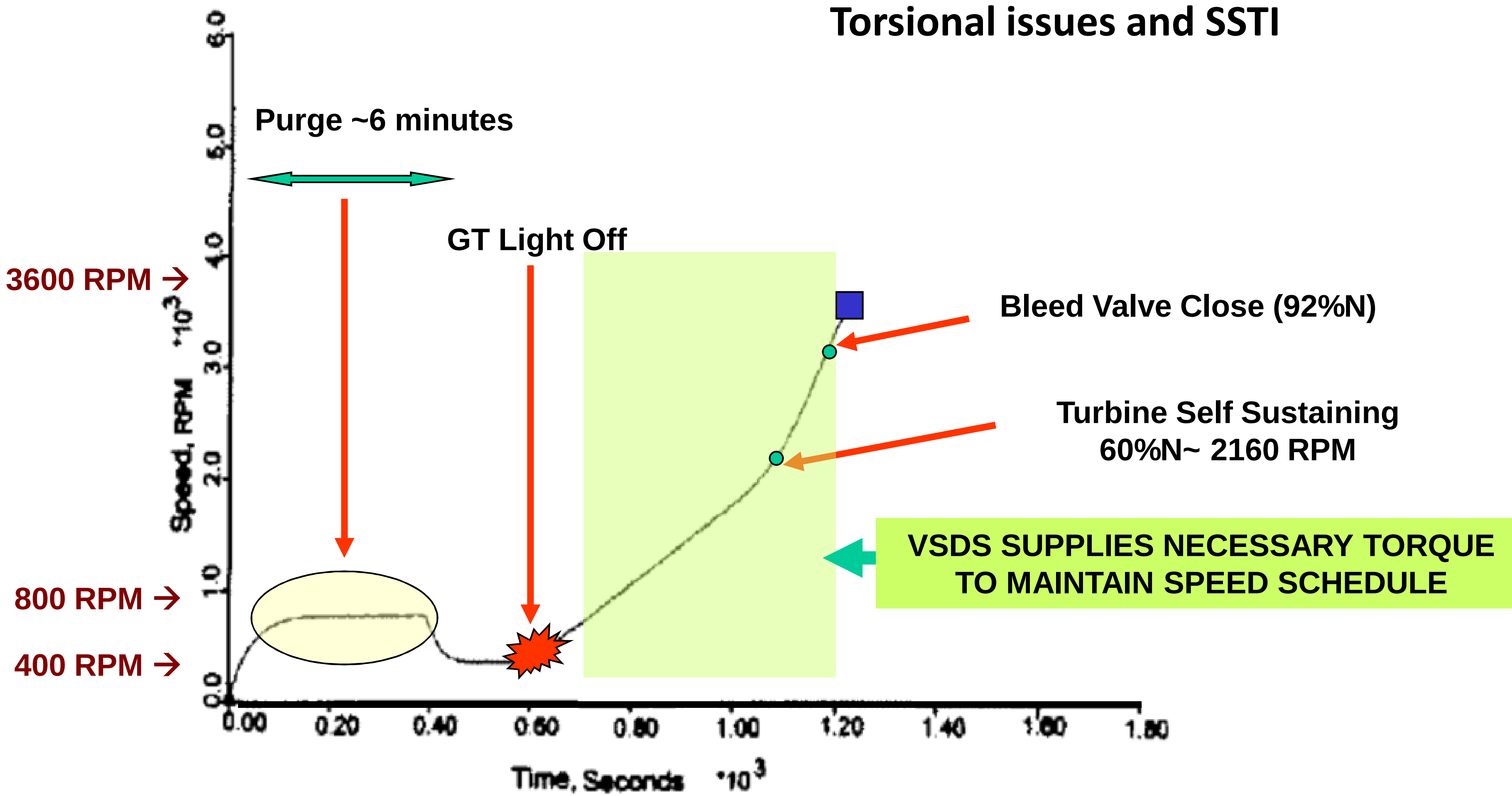
Startup of Single Shaft GT- LNG Strings

Torsional issues and SSTI



Ref: Bruce Heckel & Frank Davis, Proc of the 27th TMS

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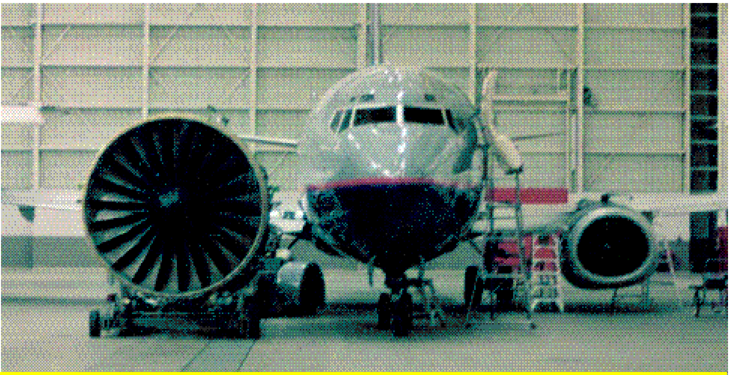
Aircraft Engine Evolution

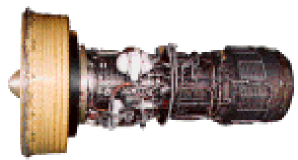


Relative Size of PW - 4090 Engine to Boeing 737 Fuselage

LM2500 Engine Evolution

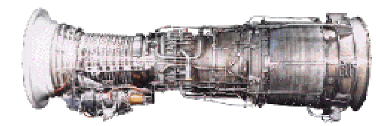
C-5

DC-10



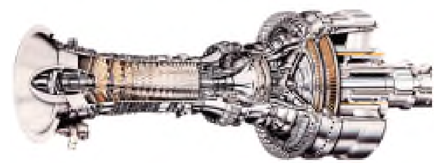
TF39/CF6-6

Power Output
MW/SHP
Thermal Efficiency



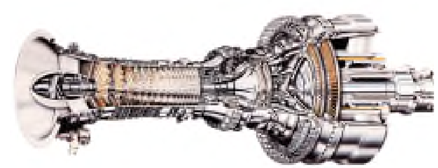
LM2500/PGT25

23/32,000
38%



LM2500+/PGT25+

31.3/42,000
39-41%



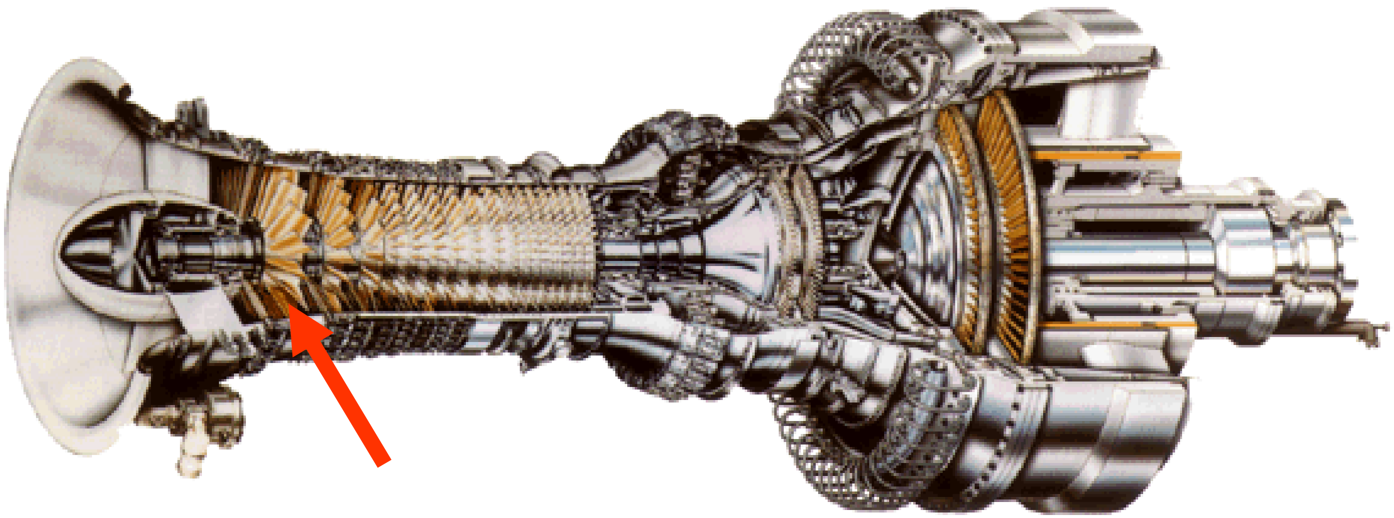
LM2500+G4/PGT25+G4

34.3/46,000
39-41%

PGT25 Aeroderivative GT

Power 31370 kW **Efficiency 41%,** **Pr. Ratio = 23:1**

Air flow 84 Kg/sec **PT Speed 6100 RPM**



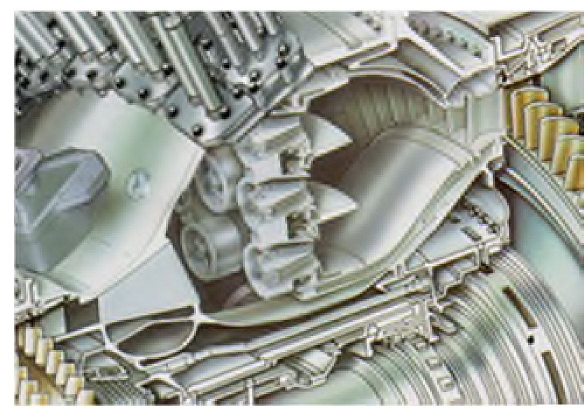
Power +25%

Flow +23% (186 lbs/sec)

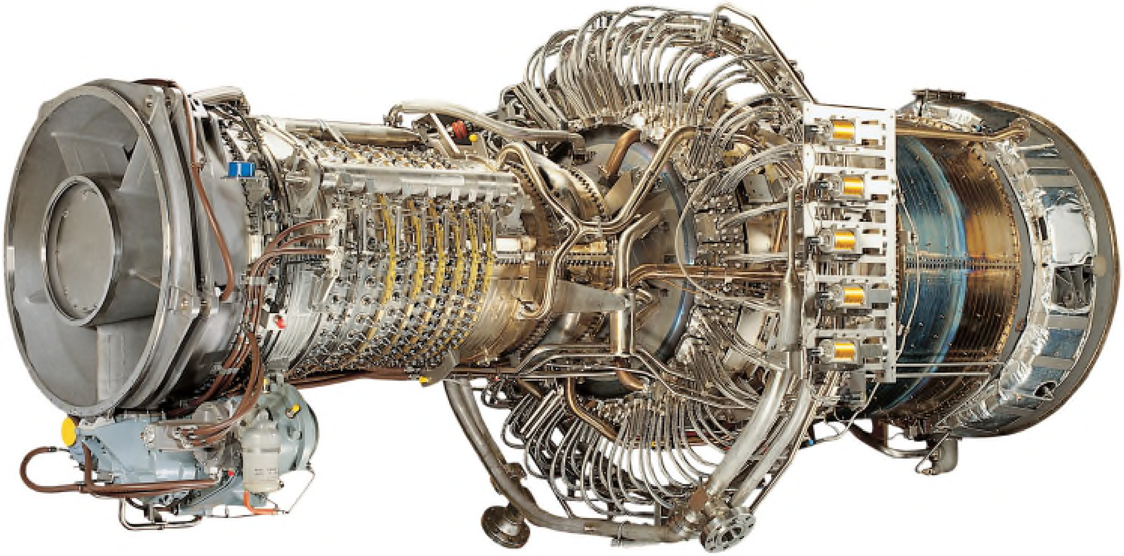
PR = 23:1, +23%

Zero stage blisk-Rel Tip Mach No = 1.19

Blisk Tip Speed = 1363 ft/sec

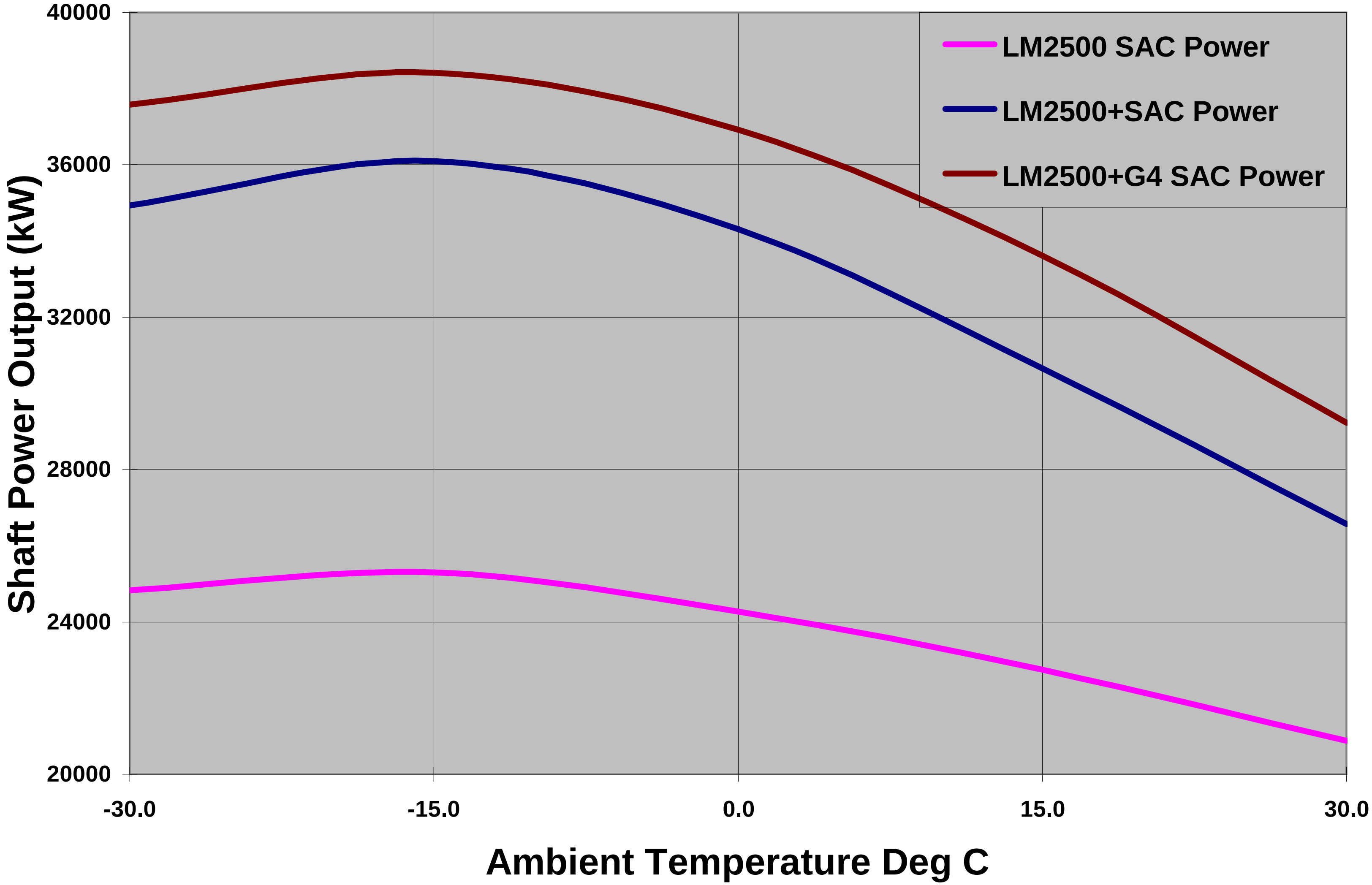


LM2500+G4

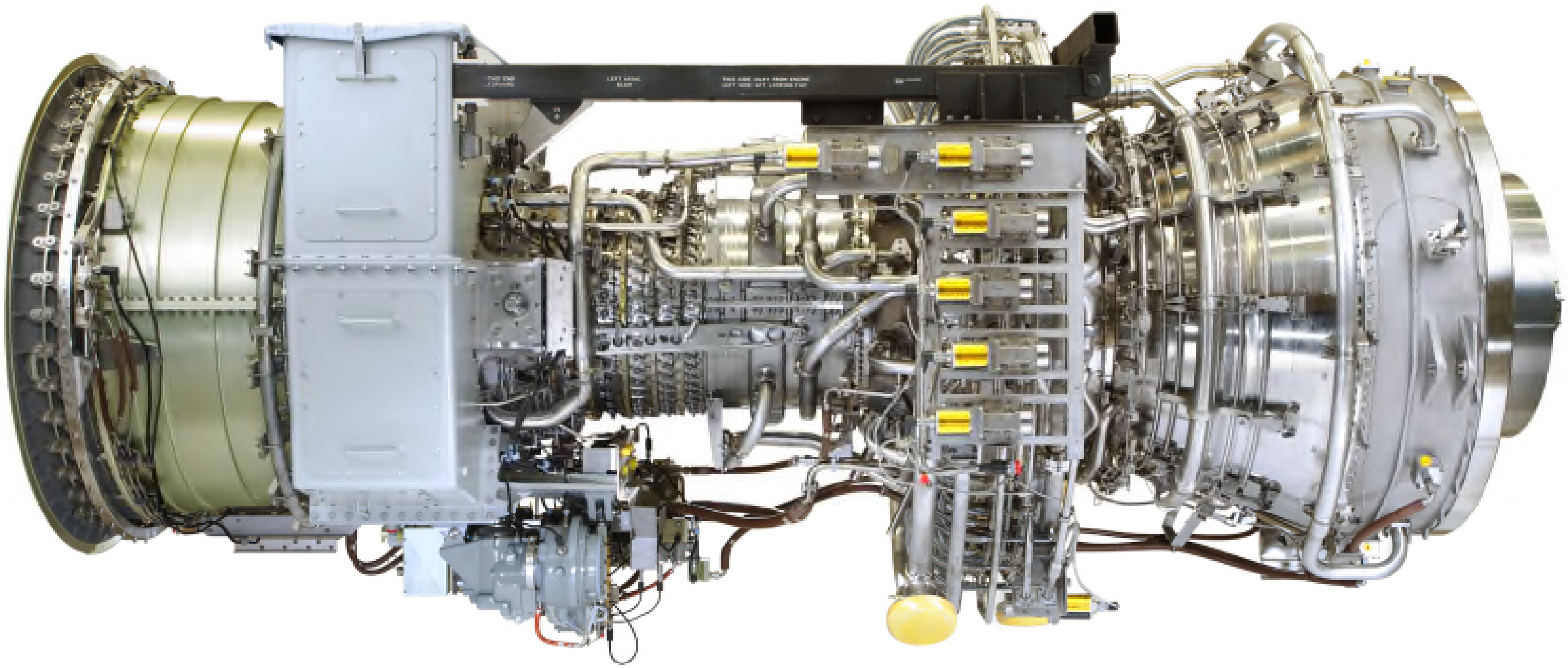


10% increase in Power to 34300 kW, Air flow = 88.4 kg/sec

Growth of the LM2500+G4 Variant



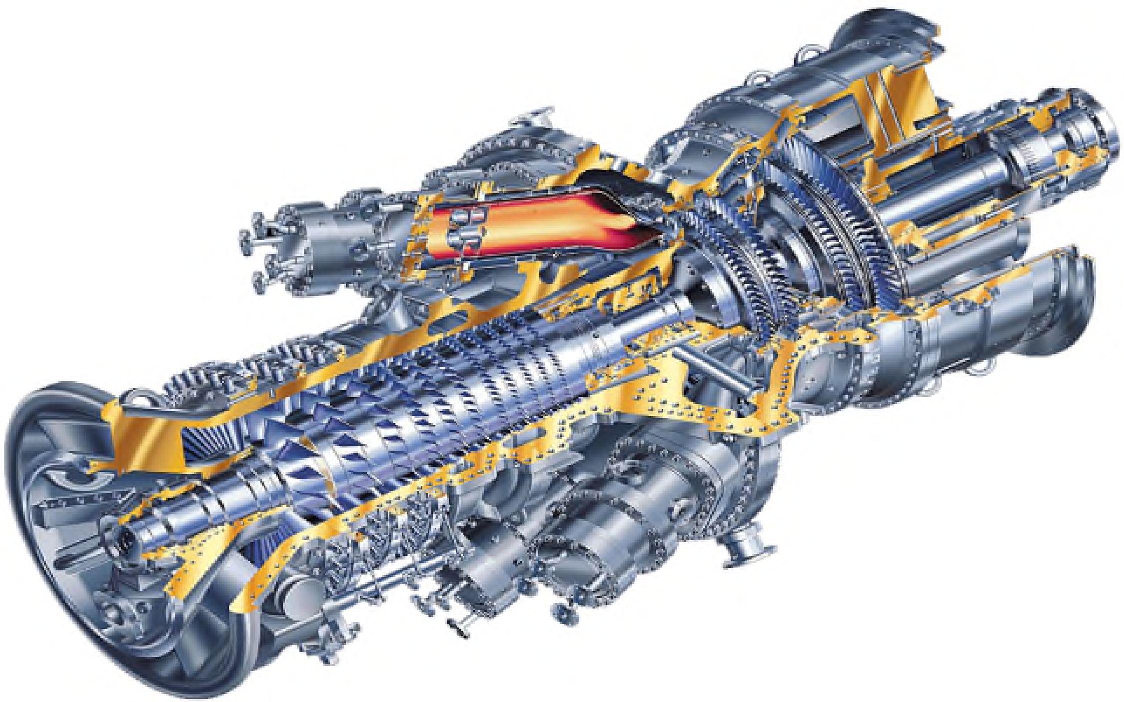
LM6000 PF 44 MW / Thermal Efficiency 42% / 15 ppm NOx



Growth Versions to 50MW (PG PH Variants)

Sta 5/14/2/5

GE FRAME 5E (2005)



OUTPUT = 32 MW

Ma = 96 kg/sec; EGT =523 C

GE10 SCALE UP COMPR PR=17:1

11 STAGE COMPRESSOR

2 STAGE GG TURBINE

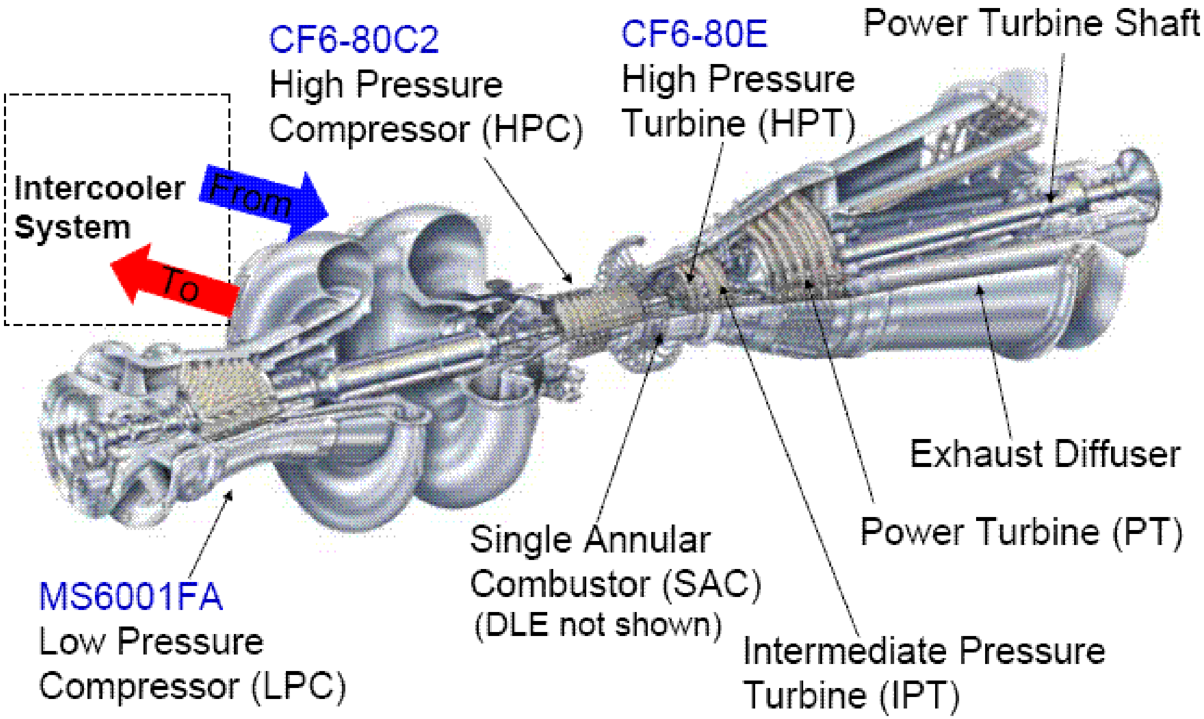
NGG =7455 RPM

NPT = 6100 RPM (NP- 2 STA HSPT)

EFFICIENCY = 36.4 %

HIGH N2 CAPABILITY

LMS 100



N= 3000/3600

DLE eff = 45%

M= 470 lb/sec

PR = 40:1

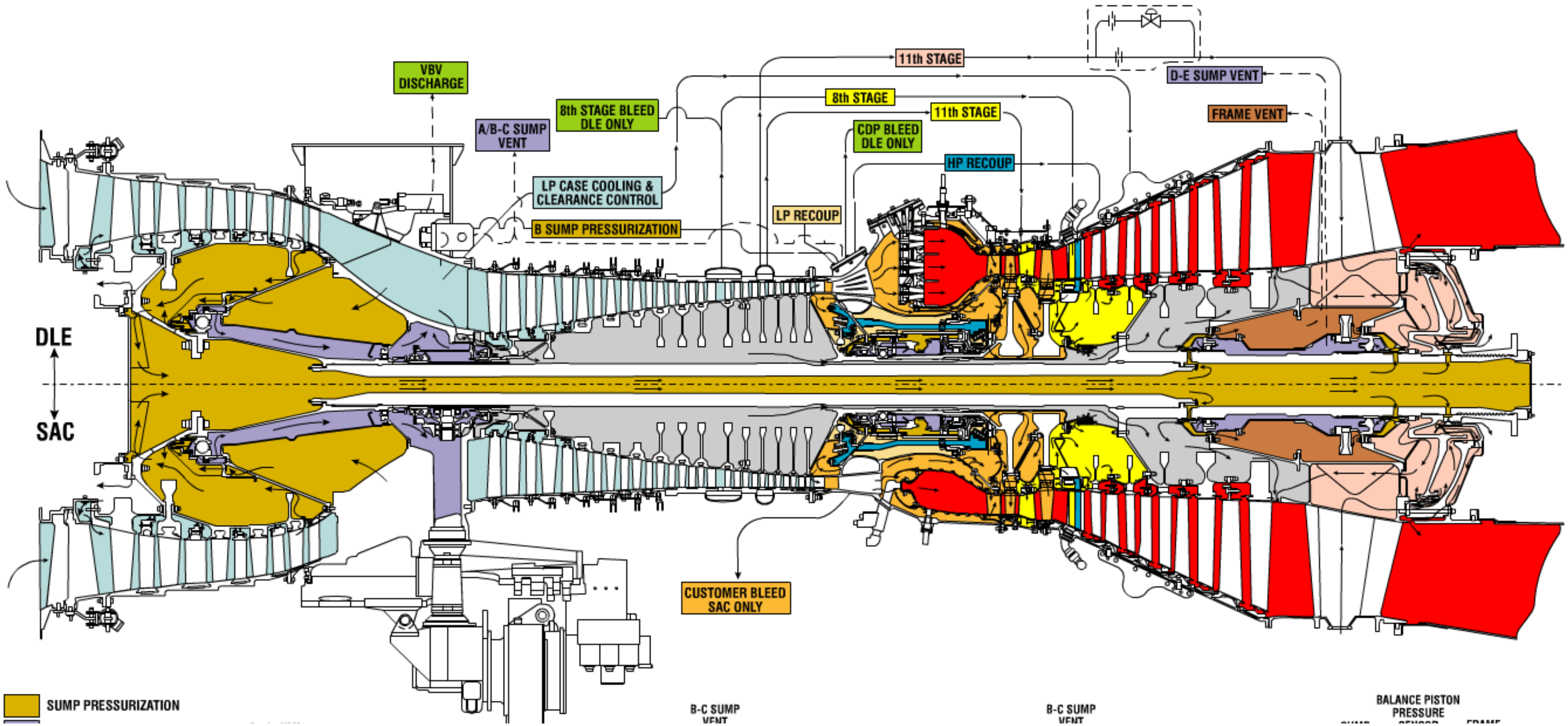
Ht Rejection 110 MMBTU/hr

Ramp Rate 50 MW/min

99 MW ISO DLE, 103 MW SAC

LM6000-PF Gas Turbine

LM6000PF Engine Cross Section



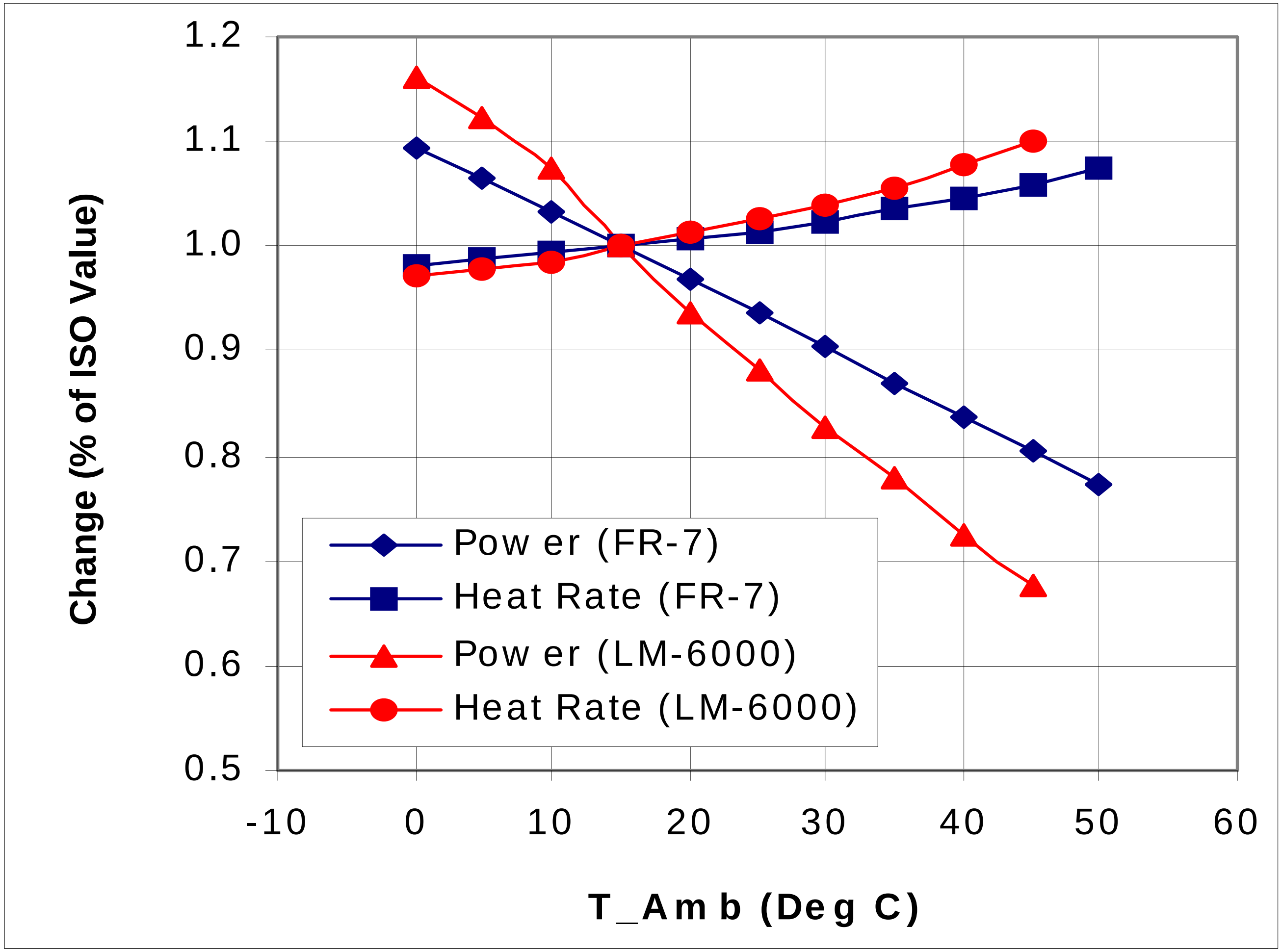
Site Conditions that Effect Gas Turbine Performance

- Ambient Temperature
- Altitude
- Inlet Pressure Losses
- Exhaust Pressure Losses
- Ambient Humidity
- Changes of Fuel LHV
- Operating Speed (opt NPT)

$$\text{Modified Wobbe Index} = \frac{LHV}{\sqrt{SGgas \ x \ Tgas}}$$

ALLOWABLE MWI RANGE ENSURES FNPRs ARE MAINTAINED DURING ALL MODES OF OPERATION.

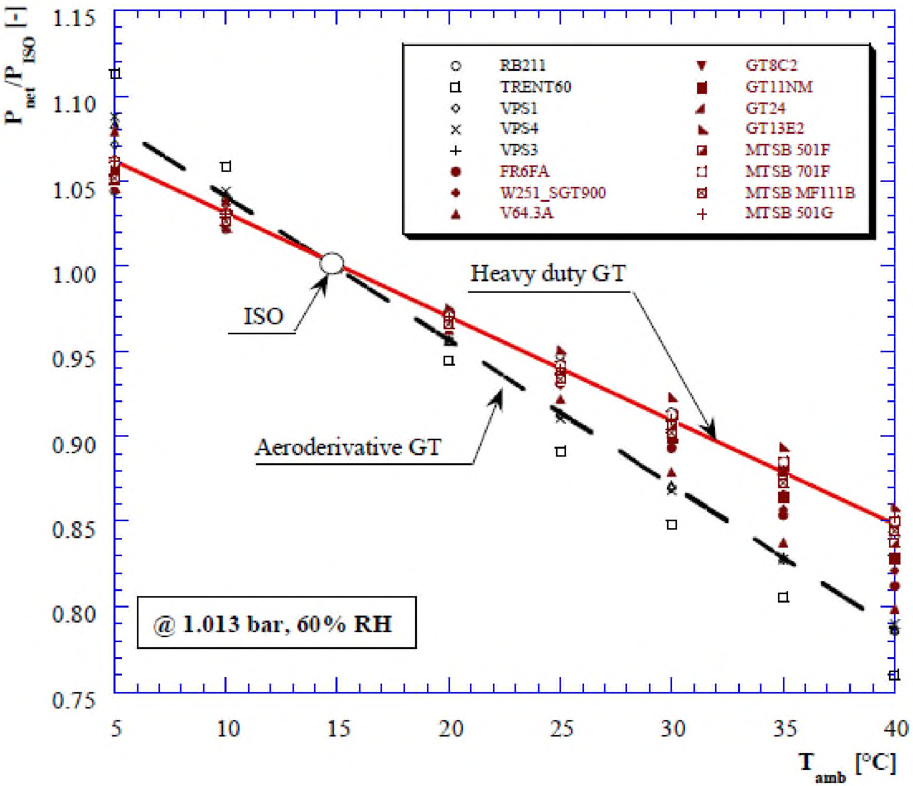
Gas Turbine Output and Heat Rate versus Inlet Air Temperature

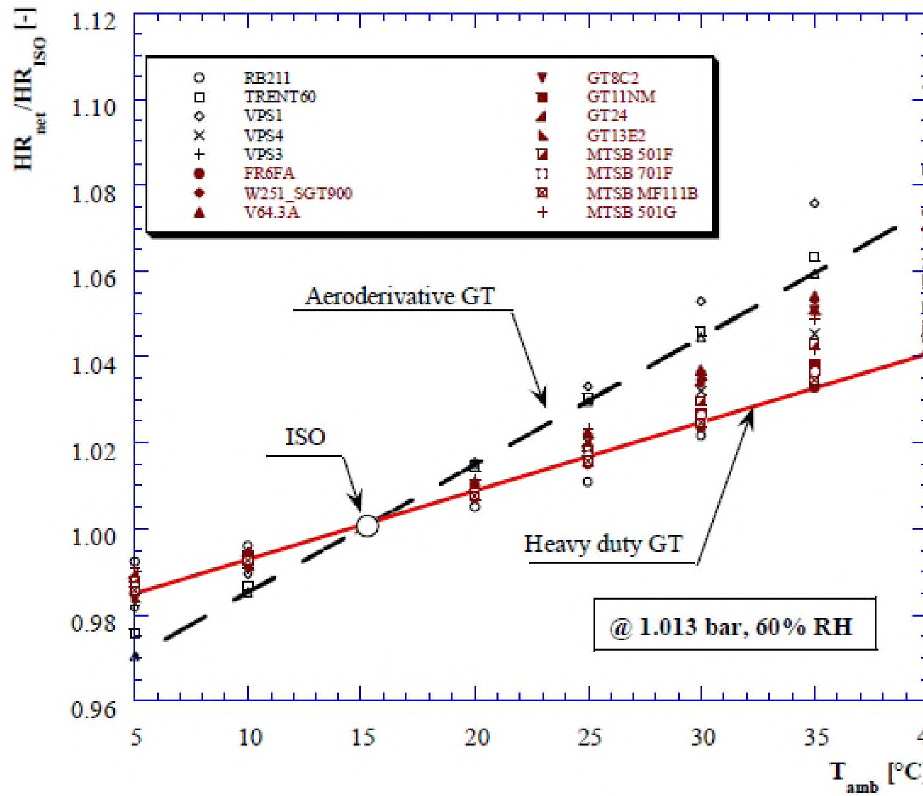


Frame 5D: 215 kW/°C

LM 6000: 514 kW/°C

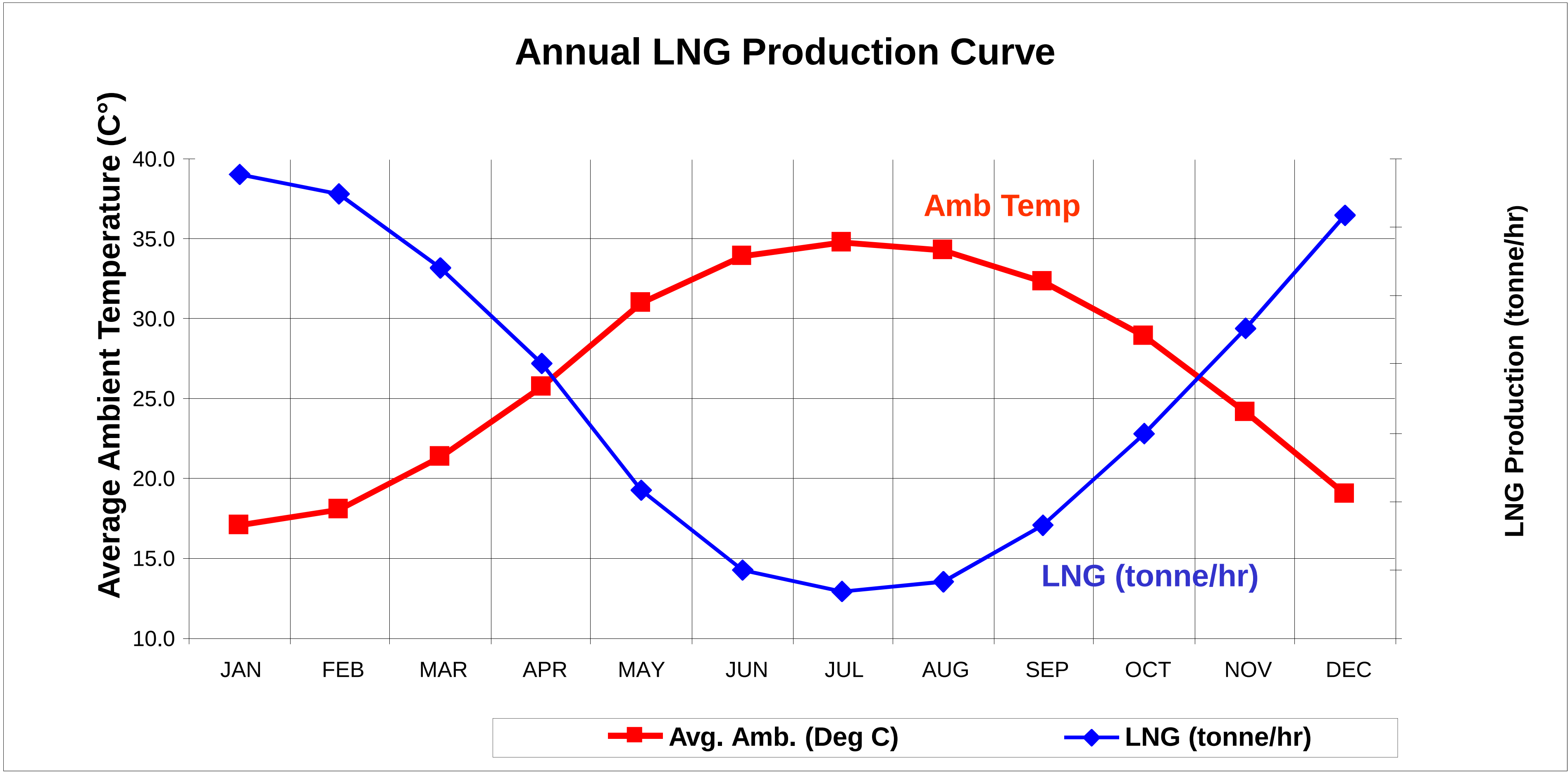
Gas Turbine Output and Heat Rate versus Inlet Air Temperature



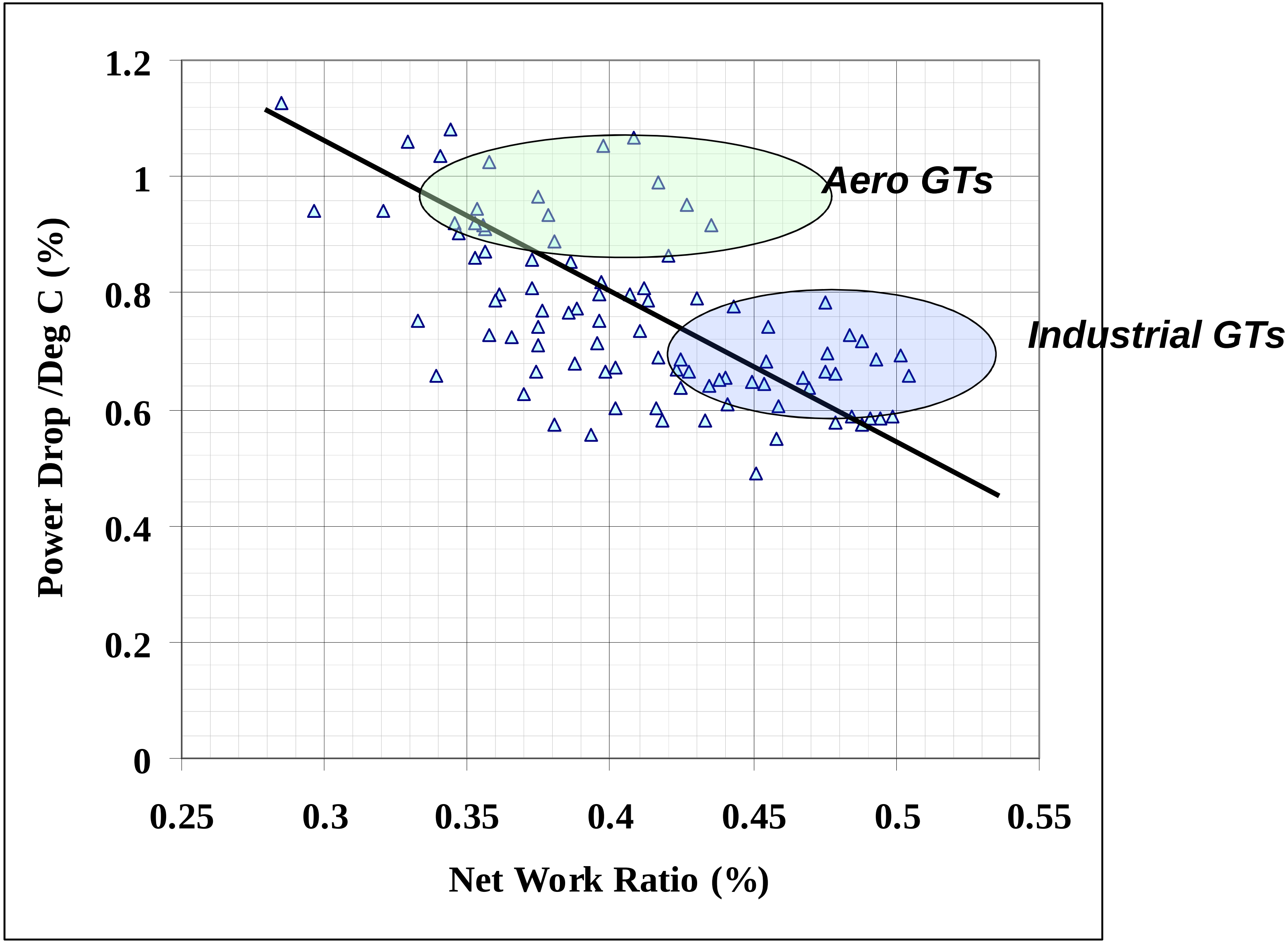


Source: Bruno Belvedere et al "**Comparison of available and future gas turbine power Augmentation technologies for various climatic scenarios**"
ASME-ATI-UIT 2010 Conference on Thermal and Environmental Issues in Energy Systems May2010 Sorrento Italy

LNG Production versus Inlet Air Temperature



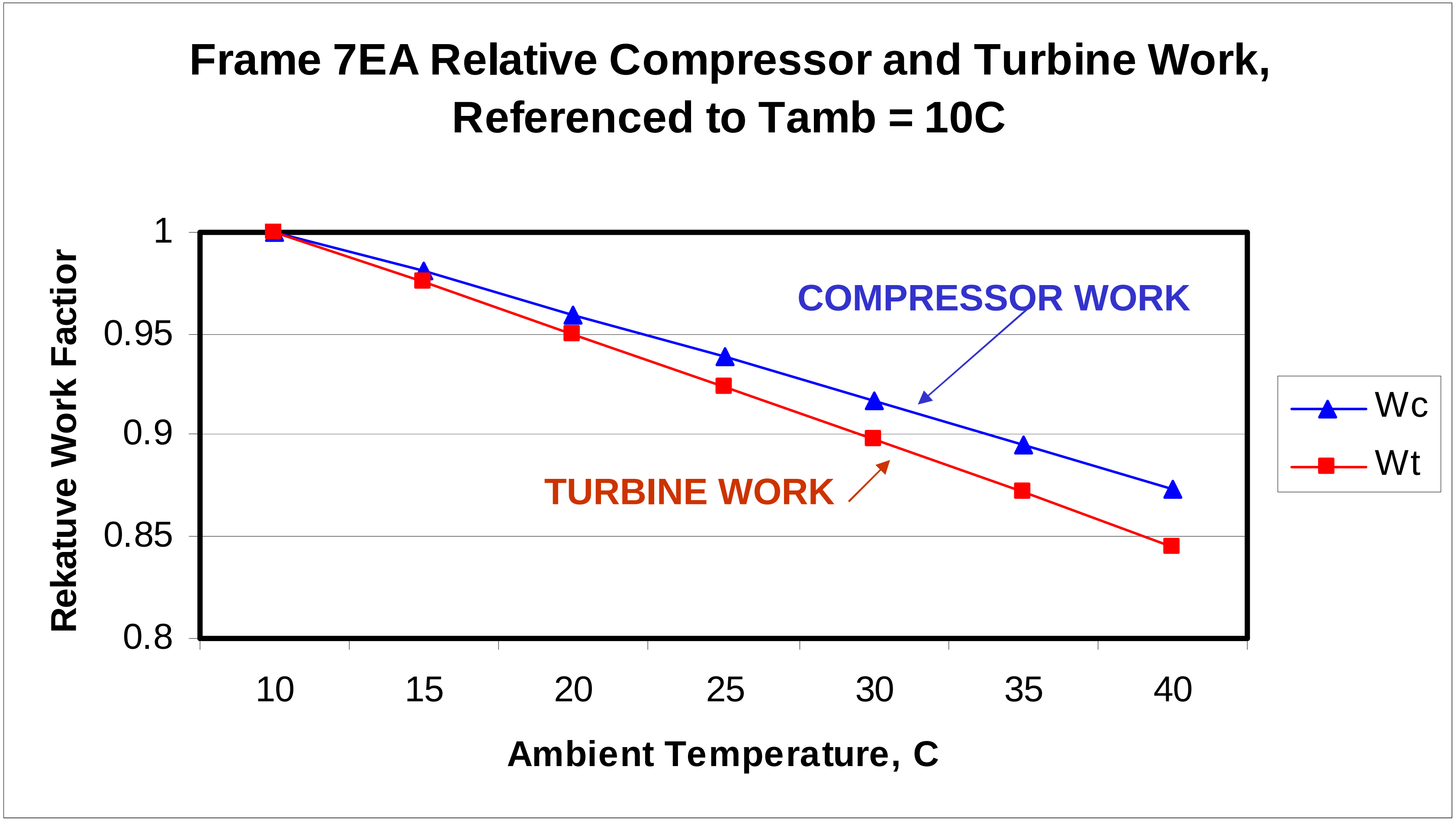
GT Power Drop/Deg C Vs. Net Work Ratio



Effect of Ambient Temp on Frame 7EA

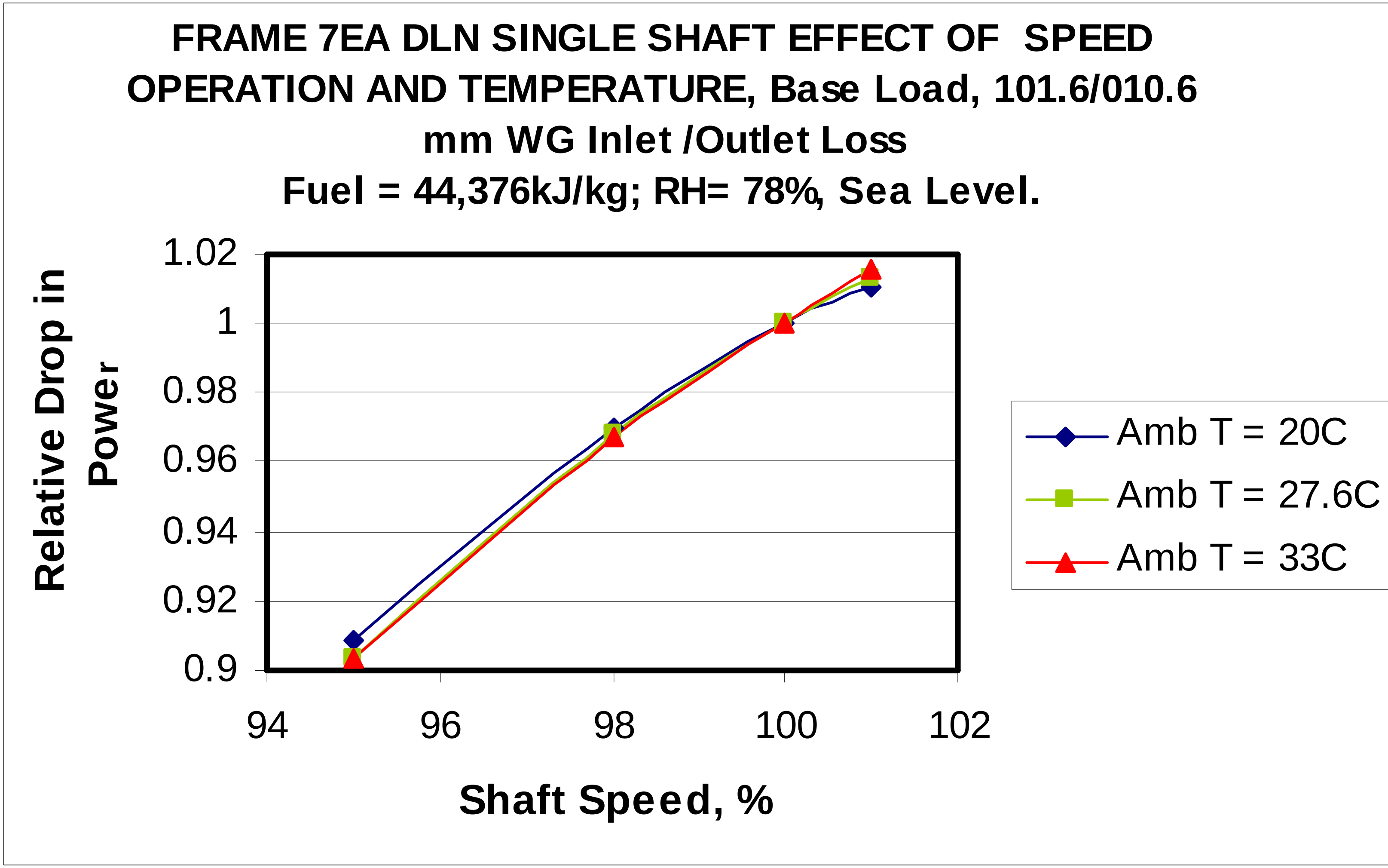
T_{amb} °C	Output kW	Ma, kg/sec	CDP Bar	PR	Heat Rate, KJ/kWhr	Wc, kW	Sp. Comp Wk	Wt kW	Sp. Turb Wk
10	88,041	298	12.9	12.9	10,790	107,344	360.	197,426	651
15	85,215	292	12.64	12.64	10,867	105,264	360	192,481	647
20	82,431	286	12.38	12.38	10,945	102,989	360	187,385	644
25	79,730	280	12.11	12.11	11,029	100,717	360	182,377	641
30	76,954	273	11.84	11.84	11,130	98,428	360	177,277	638
35	74,136	267	11.56	11.56	11,245	96,106	361	172,104	635
40	71,311	260	11.29	11.29	11,374	93,757	361	166,896	631

Frame 7EA Relative Compressor and Turbine Work with Tamb



Turbine HP drops at a faster rate than the compressor HP, as the ambient temperature gets hotter.

Single Shaft – Effect of Speed



UNDER SPEED AND HIGH TEMPERATURE- CORRECTED SPEED LOW, FRONT END STALL

EFFECT OF INLET PRESSURE LOSS

Causes reduced inlet density and mass flow

Causes reduced Cycle Pressure Ratio

Effect of 4” WG , 10mb Inlet Pressure Loss

- **Power drop of 1.4%**
- **Efficiency drop of 0.4 %**
- **Exhaust mass flow drop of 1%**
- **EGT Increase of 1.8 F (1C)**

EFFECT OF EXHAUST PRESSURE LOSS

Increased Back Pressure

Reduced Turbine Pressure Ratio

Effect of 4’ WG , 10mb Inlet Pressure Loss

- **Power drop of 0.4%**
- **Efficiency drop of 0.4 %**
- **Exhaust mass flow drop – no effect**
- **EGT Increase of 1.8 F (1C)**

EFFECT OF ALTITUDE

Reduced Inlet density and mass flow

Corrected flows and PR – no effect

Effect of 1000 ft , 300 m altitude ASL

- **Power drop of 3.4 %**
- **Efficiency drop of 0 %**
- **Exhaust mass flow drop 3.4 %**
- **EGT – no effect**

EFFECT OF RELATIVE HUMIDITY

Relatively minor effect on GT

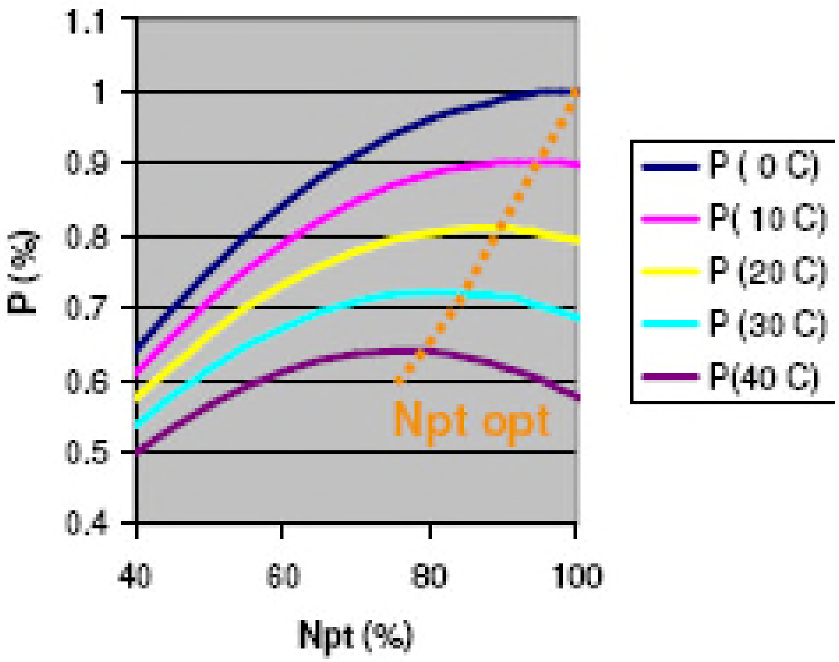
- Depends on Control Curve

- Effect is typically well within 1% Power Change but Function of Tamb

- Major impact for design of power augmentation- chilling or evaporative cooling

Optimal PT Speed

RELATIVE POWER



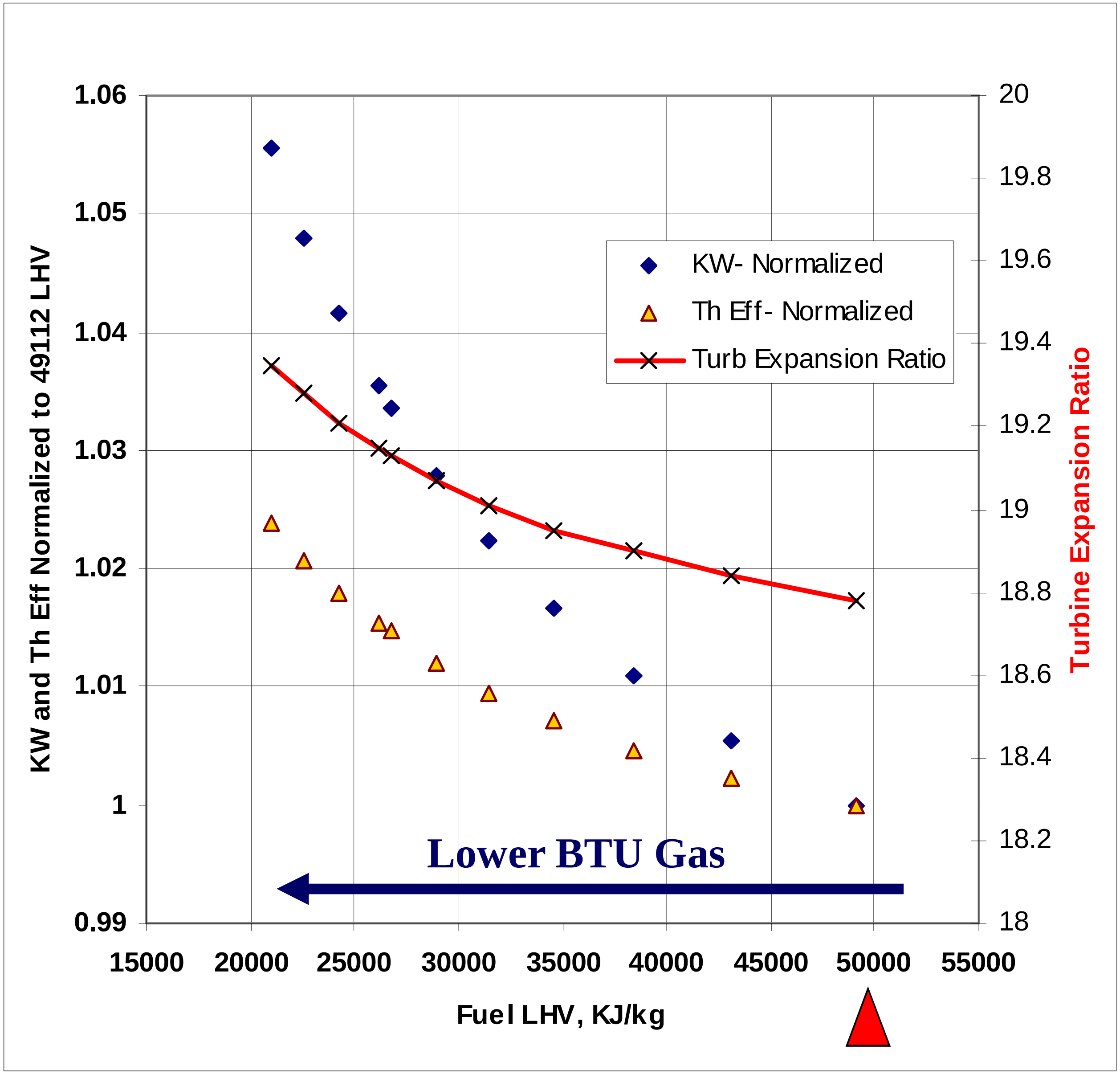
AMBIENT HOTTER

$$\frac{P}{P_{opt}} = \frac{h}{h_{opt}} = \left| 2\frac{N}{N_{opt}} - \left(\frac{N}{N_{opt}}\right)^2 \right|$$

NPT opt drops at Tamb gets hotter

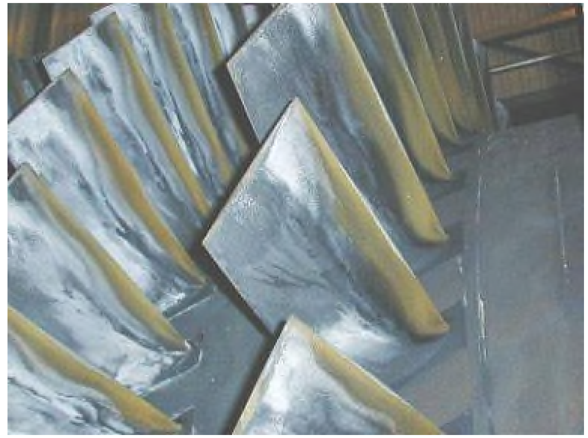
REF: R.Kurz, Solar Turbines

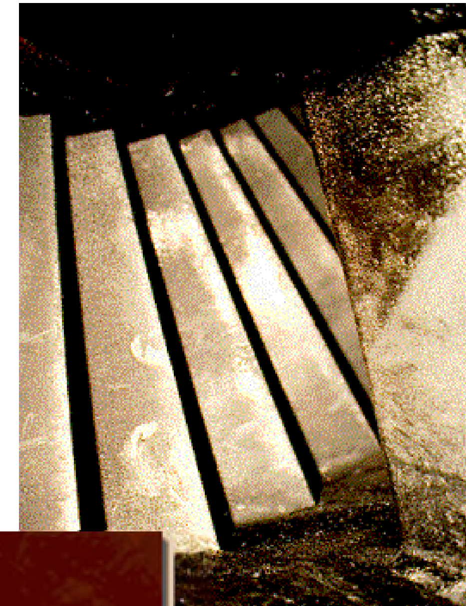
Effect of Fuel LHV on GT Performance

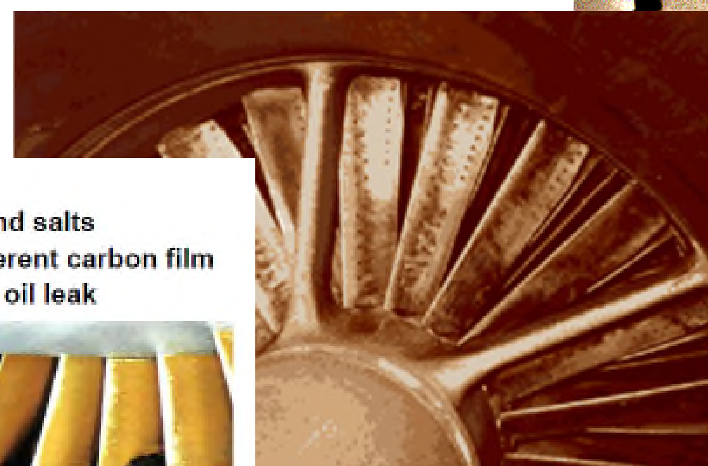


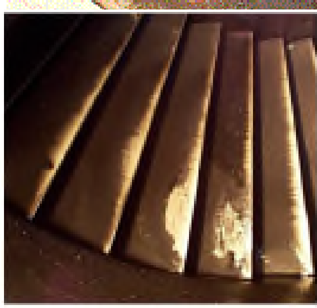
Normalized to 49112 LHV

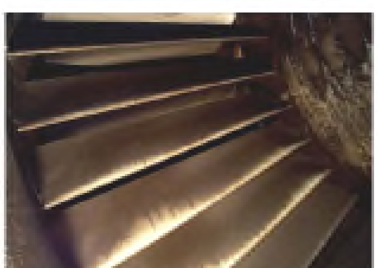
AXIAL COMPRESSOR FOULING







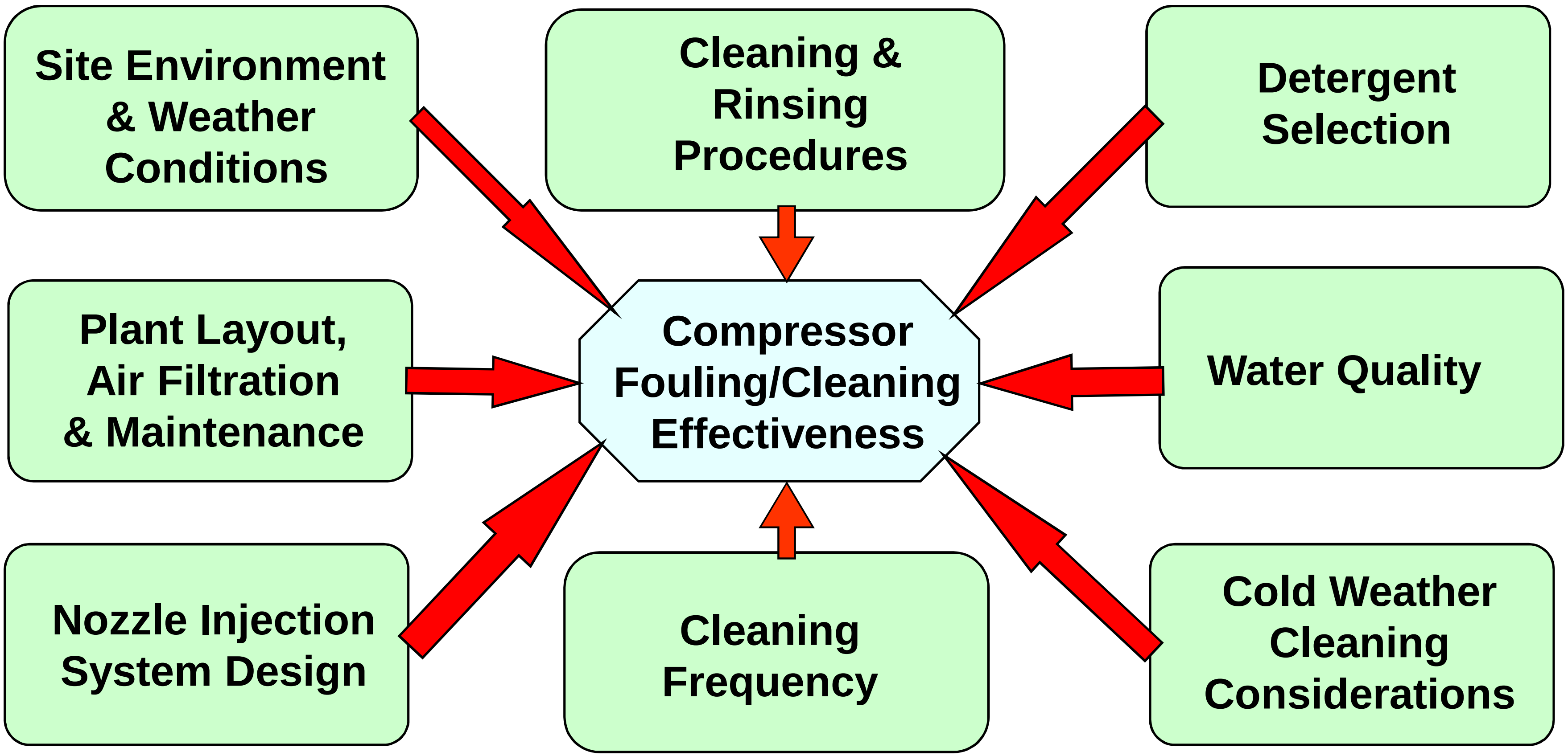




Left: Mixture of oil and salts
Lower left: Thin adherent carbon film
Lower right: Internal oil leak

Oil and grease act as "glue" to trap and hold other fouling materials

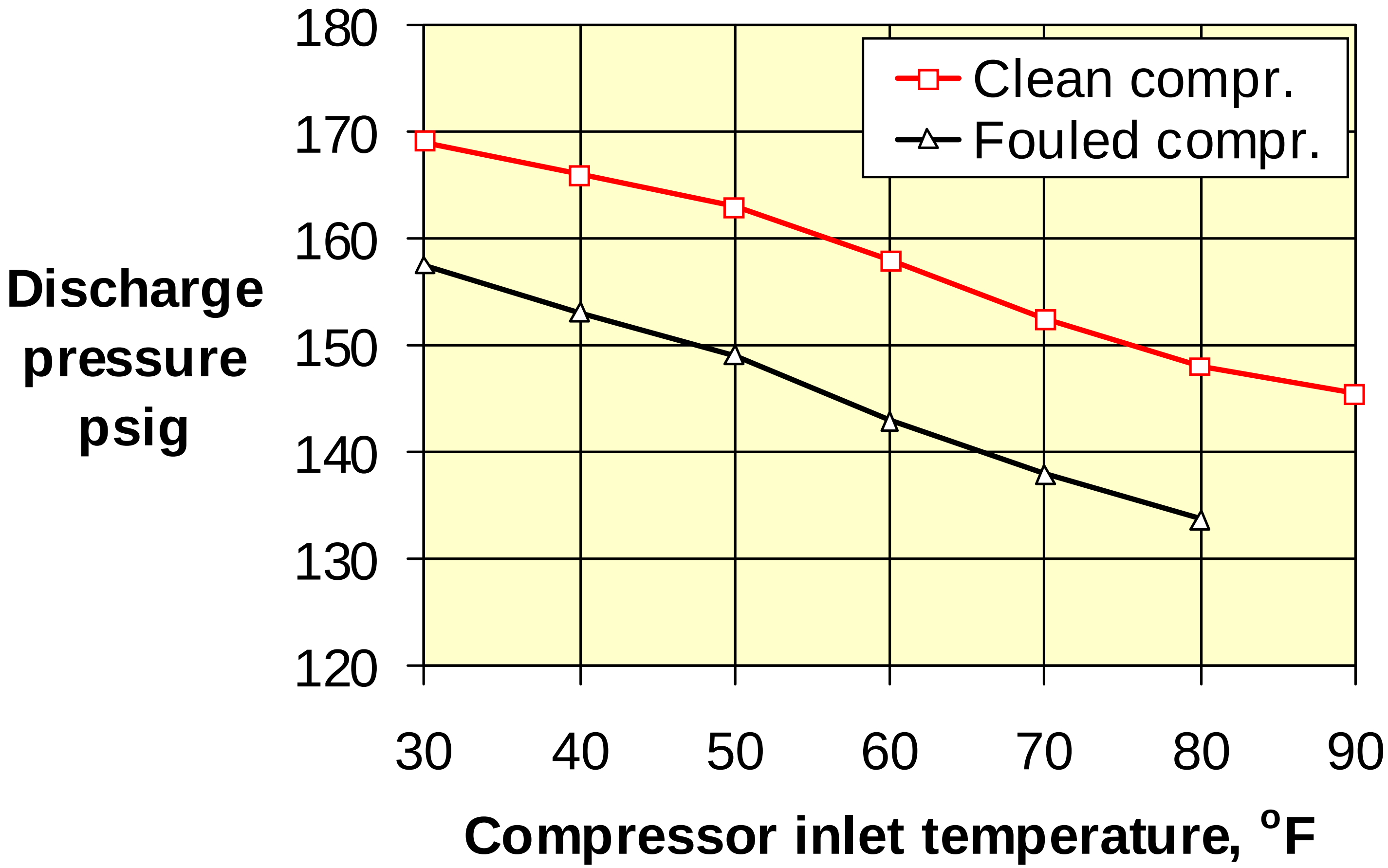
FACTORS AFFECTING COMPRESSOR FOULING AND CLEANING



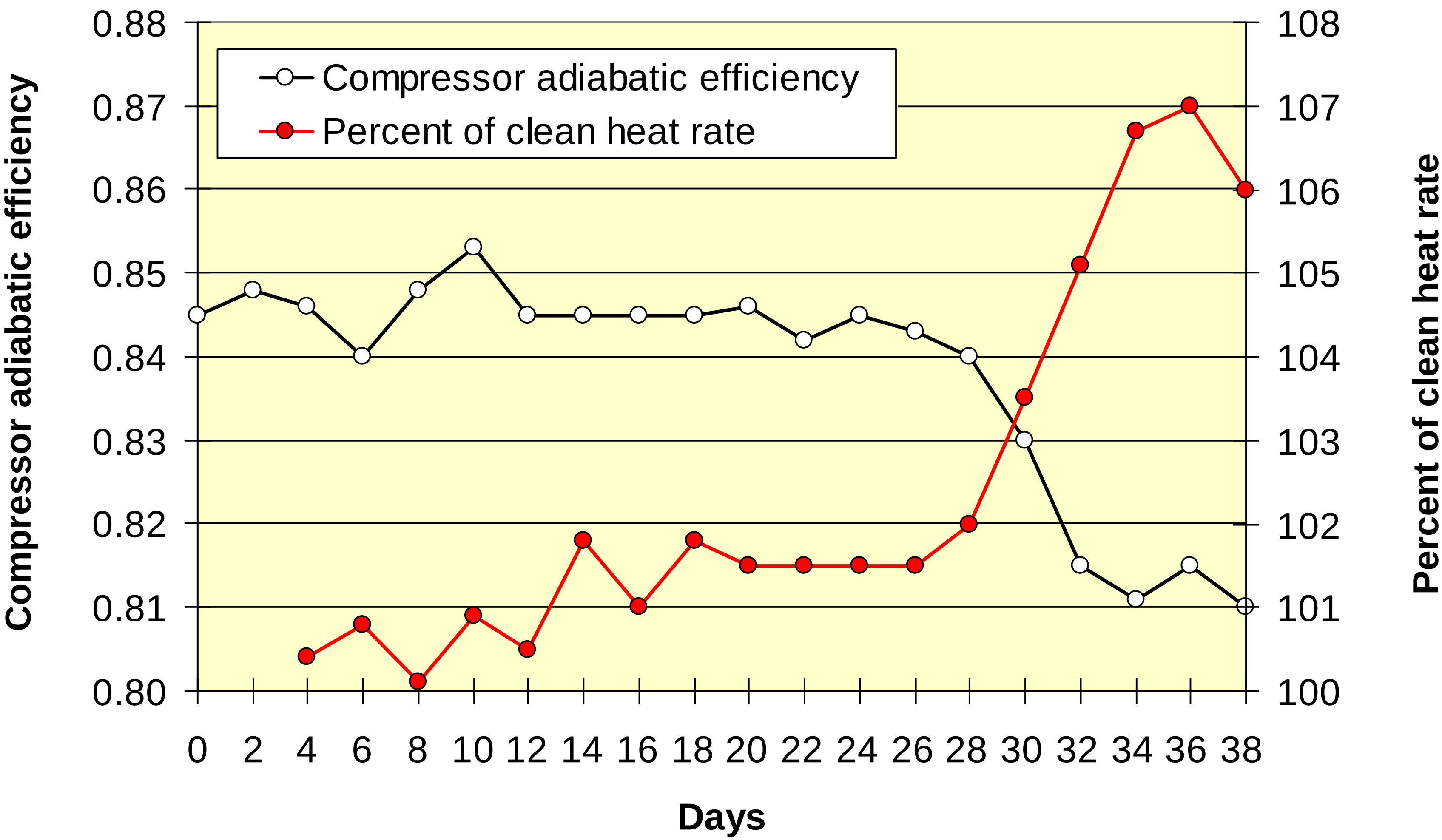
FOLLING SOURCES

- Industrial & Urban Pollution – hydrocarbons, fly ash, smog, traffic exhaust
- Airborne salt
- Ingestion of gas turbine exhaust or lube oil tank vapors
- Mineral deposits such as limestone, coal dust and cement dust
- Other airborne materials - soil, dust, sand, chemical fertilizers, insecticides and plant matter
- Insects – this can be a serious problem in tropical environments
- Internal gas turbine oil leaks – leakage from the front bearing of the axial compressor is a common cause. Oil leaks combined with dirt ingestion cause heavy fouling problems
- Impure water from evaporative coolers (carryover)
- Spray paint
- Vapor plumes from adjacent cooling towers

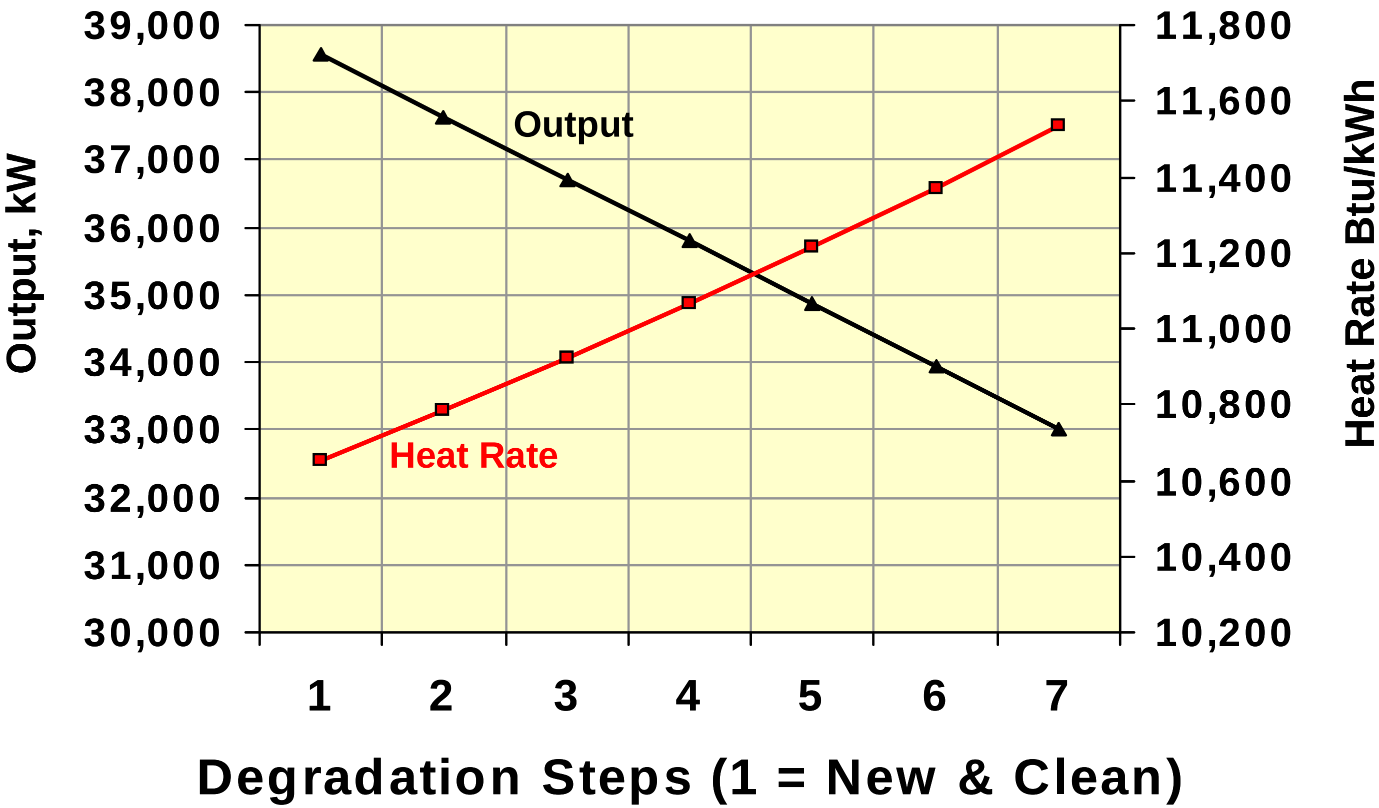
COMPRESSOR FOULING- Frame 6B



COMPRESSOR FOULING



GT Deterioration- Simulation



TMS33.Sept 2004

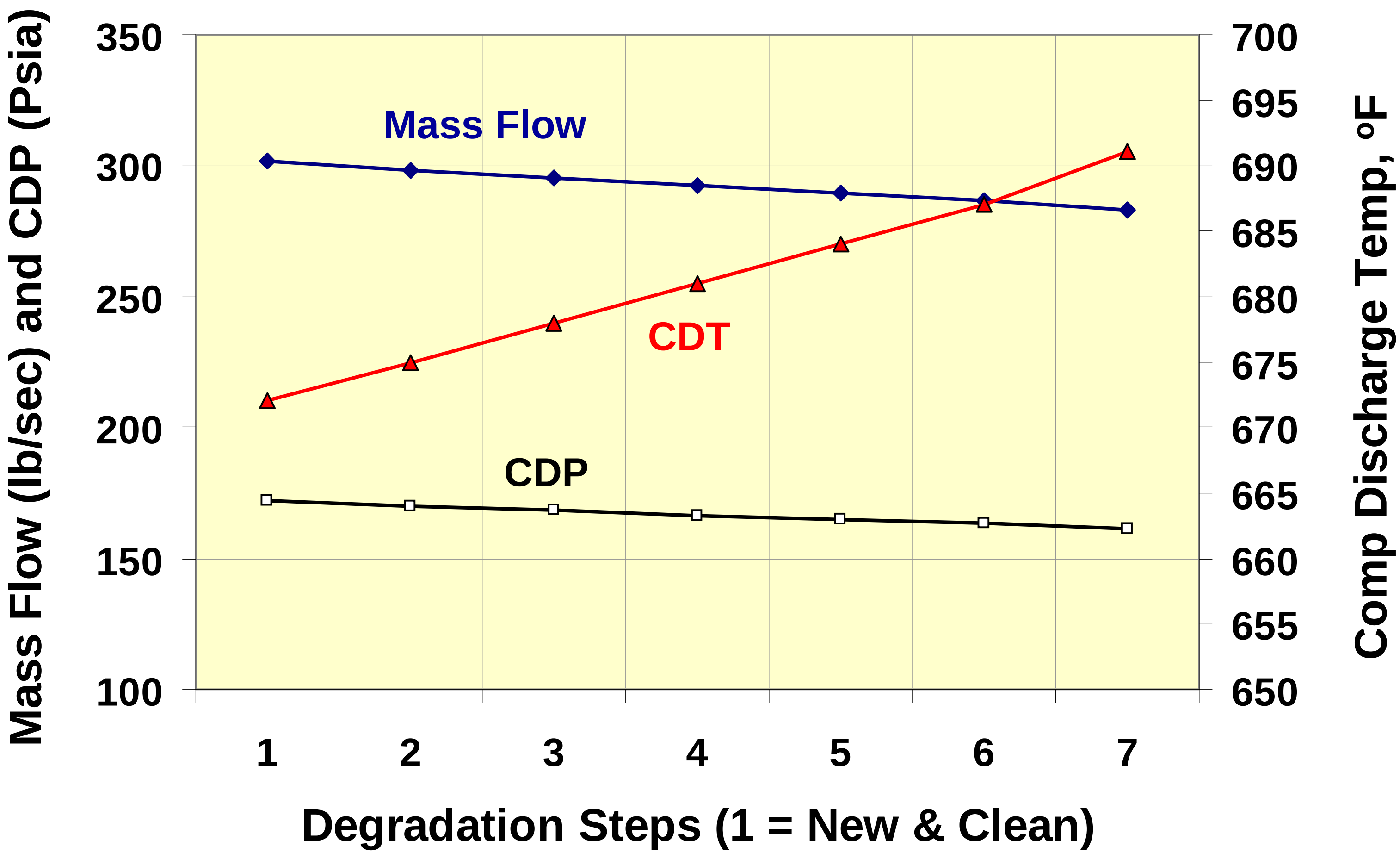
7 degradation steps 1 thru' 7:

Drop in mass flow: 0% (step 1) to 6% (step 7)

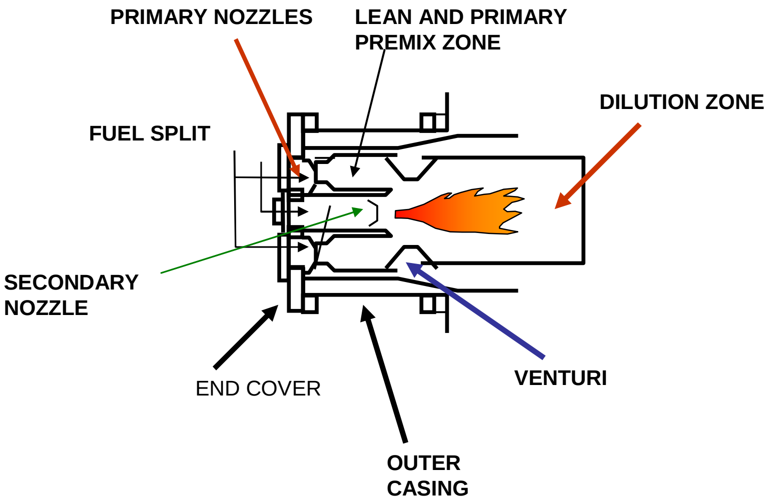
Drop in compr eff: 0% (step 1) to 5% (step 7)

Step 1 represents "new and clean" condition

GT Deterioration- Simulation



GT DLN DLE Combustion and Fuel Considerations



Why is Wobbe number important

Why is rate of change important

Why are there limits to Wobbe number

Why do we have chromatographs

Why is the Operability so sensitive

Why is fuel quality/ dryness important

Why do we have to tune DLN/DLE combustors

COMPLEXITIES OF DLE/ DLN COMBUSTORS

- **NO_X minimized at flame temp of ~ 1500 C (1800K)**
- **Run lean and run with uniform fuel/air ratio**
- **Oscillations in pressure, heat release and flow rate**
- **Result in structural vibration, fretting, wear, flame flashback**
- **Heat release fluctuations couple with acoustic modes of the combustion chamber (self excited growth)**
- **Primixer is key component- elimination of FAR fluctuations**

RELATIONSHIPS BETWEEN DIFFUSION FLAME COMBUSTOR OPERATION CONDITIONS AND THERMAL NOX

- **NOx increases exponentially with increasing flame temperature.**
- **HIGHER FUEL/AIR RATIO- HIGHER TEMP**
- **NOx increases approximately as the square root of the combustor inlet pressure.**
- **NOx increases with increasing residence time in the flame zone.**

Dry Low Emission - Combustion Concepts

- **If the "flame speed" does not match the flow speed of the reactants, the flame front will move**
- **If flame speed is too high → flashback (flame moving upstream into fuel nozzle)**
- **If flame speed is too low, → blow-off (flame pushed downstream)**

Autoignition

BRANDT ET AL, ASME 2003-GT-38224, VIENNA

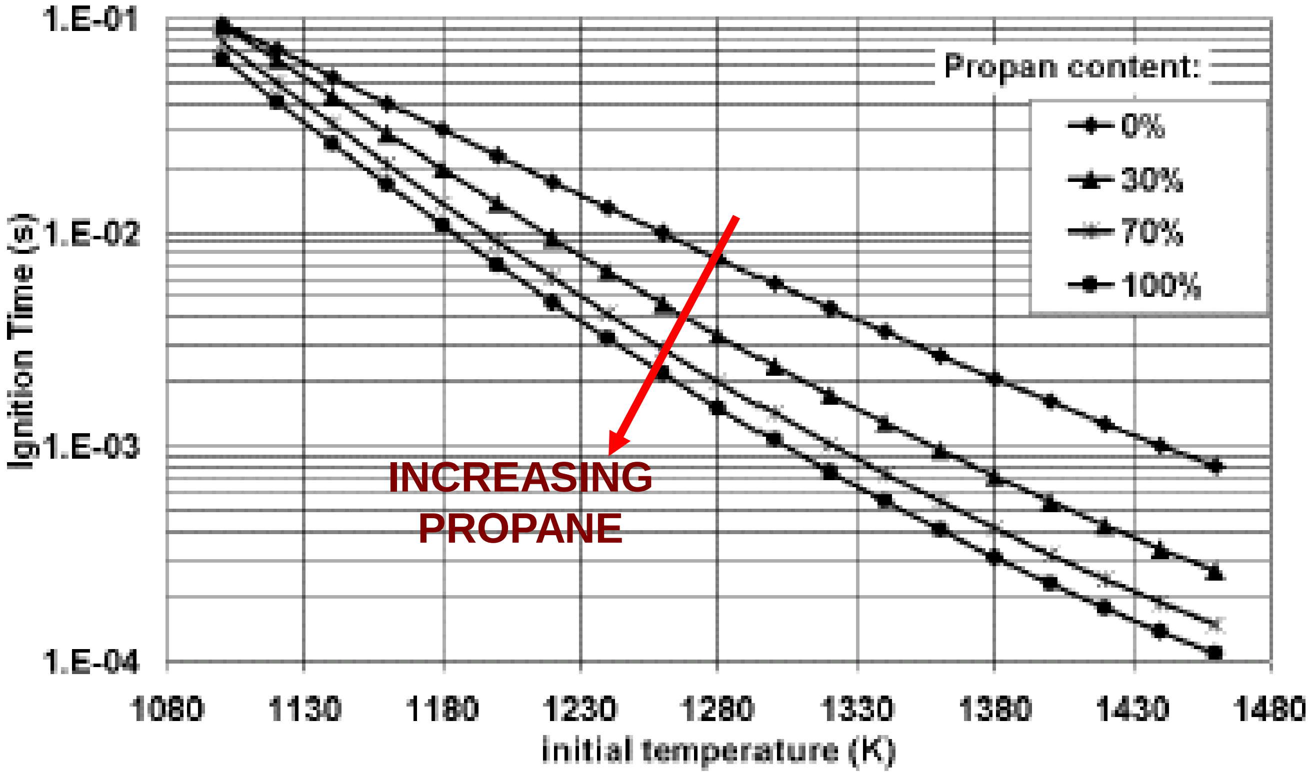


Figure 8. IGNITION DELAY TIMES FOR NATURAL GAS ("SWISS GAS") WITH VARIOUS PROPANE ADDITIVES AS A FUNCTION OF THE INITIAL TEMPERATURE

DLE Manifold and Resonator Pipes

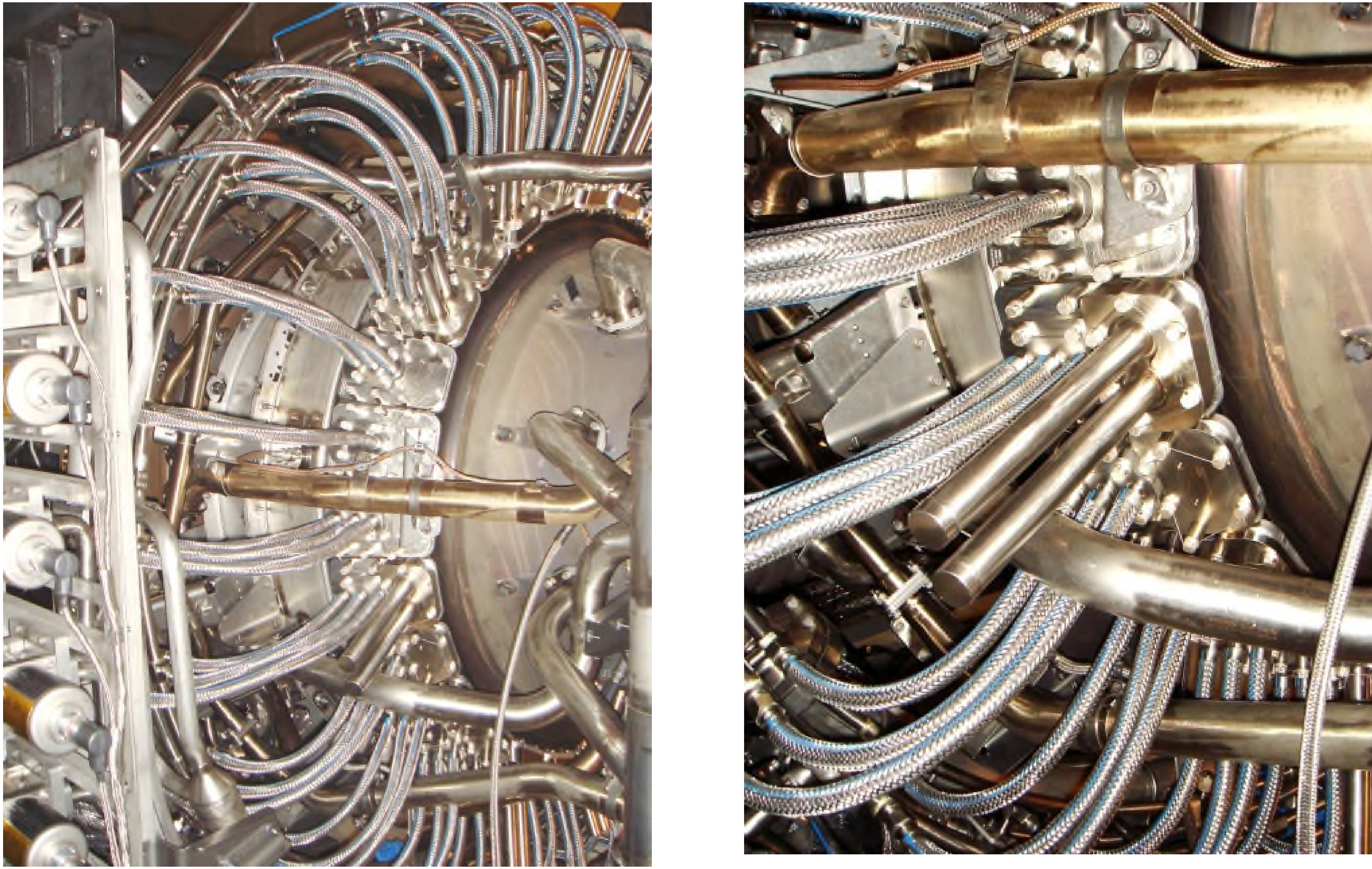
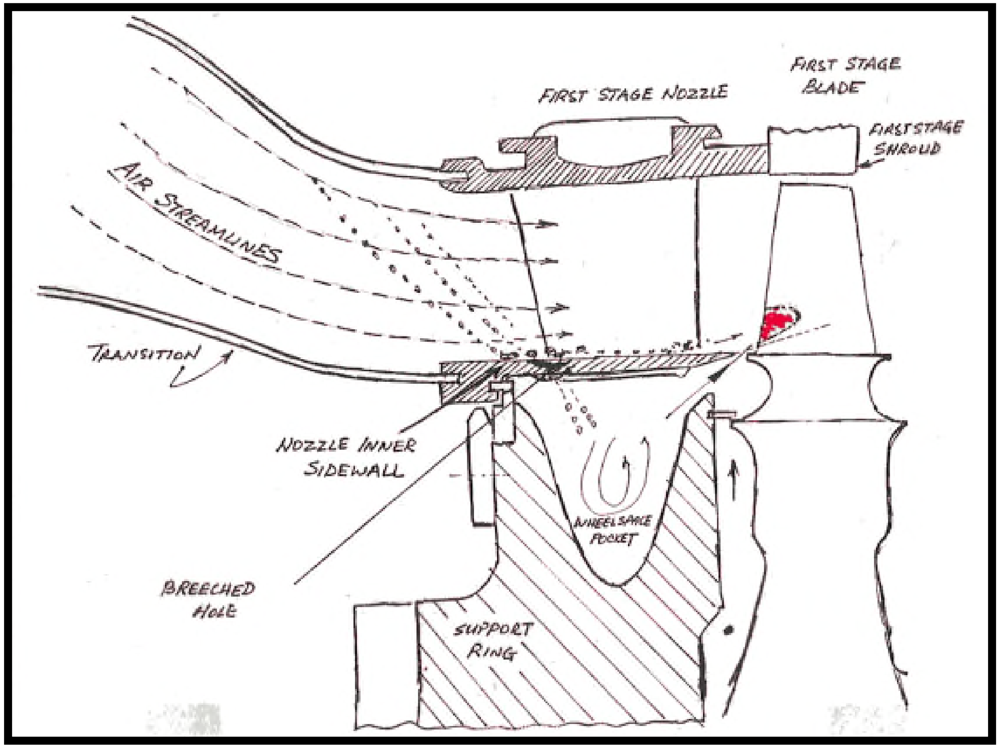


Figure 19: Resonance Tubes in an Aeroderivative Engine (pulsation control)

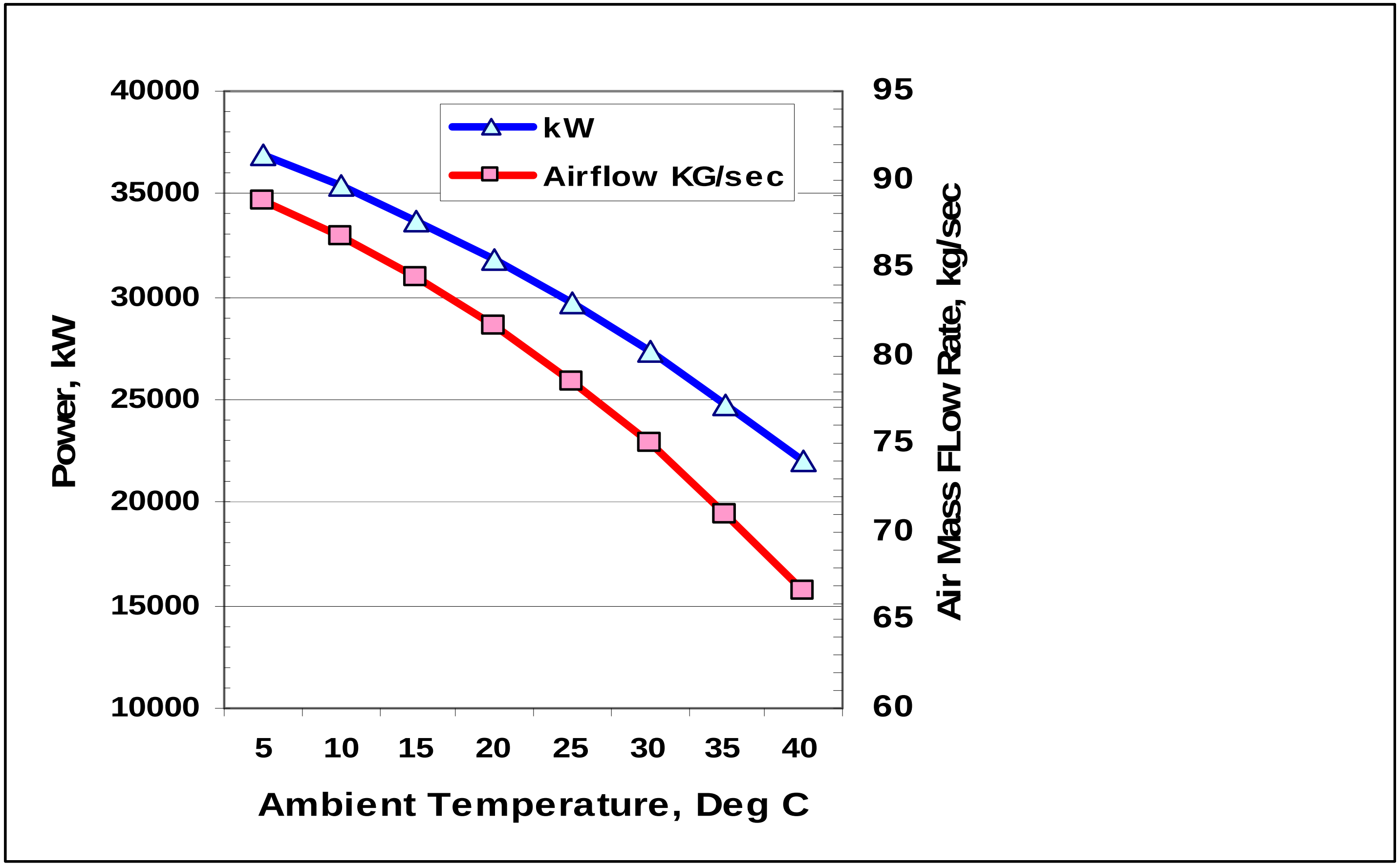
FUEL SYSTEMS- HC LIQUIDs IN FUEL



Importance of Superheat

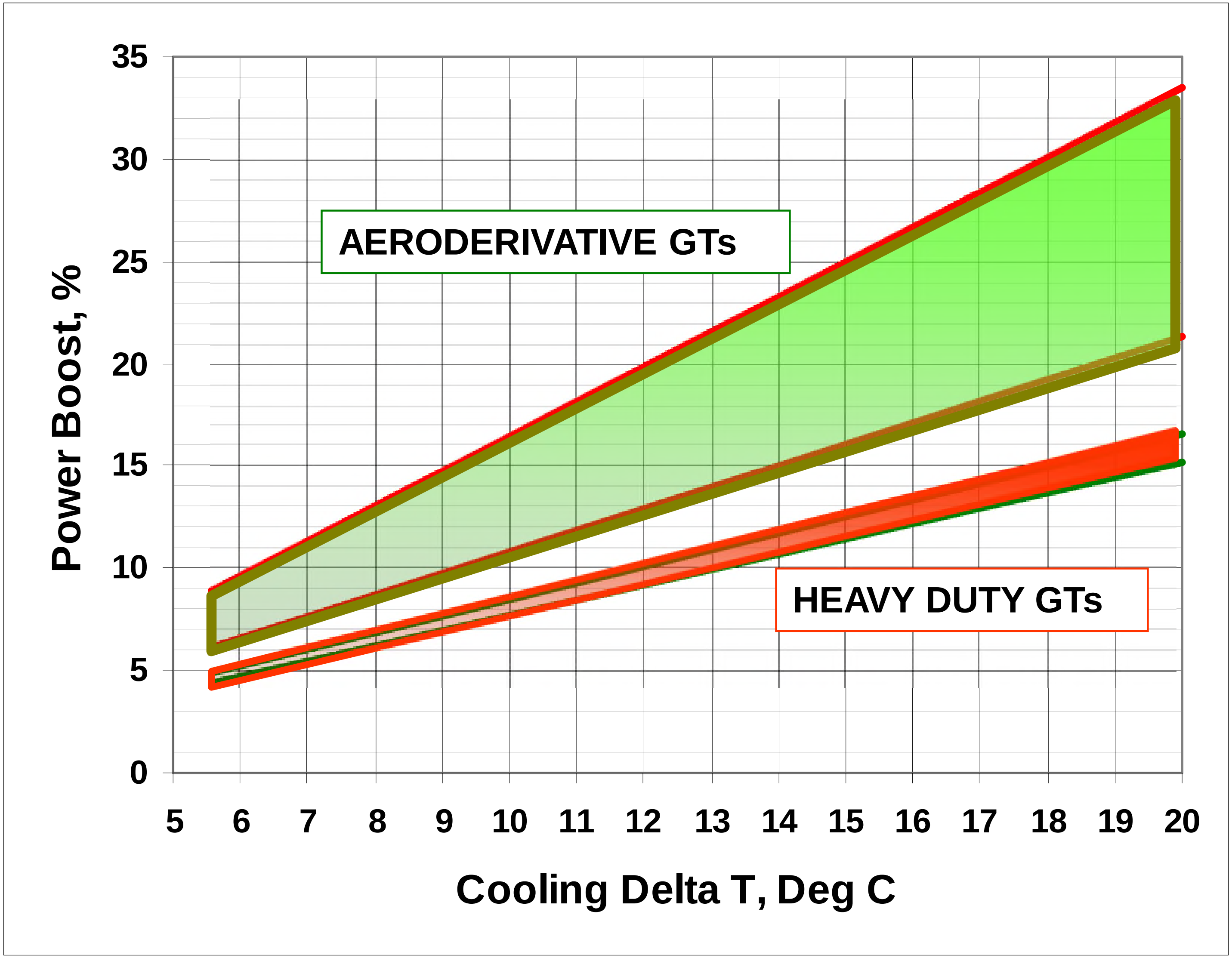
Dangers of C4+

Power Augmentation Approaches

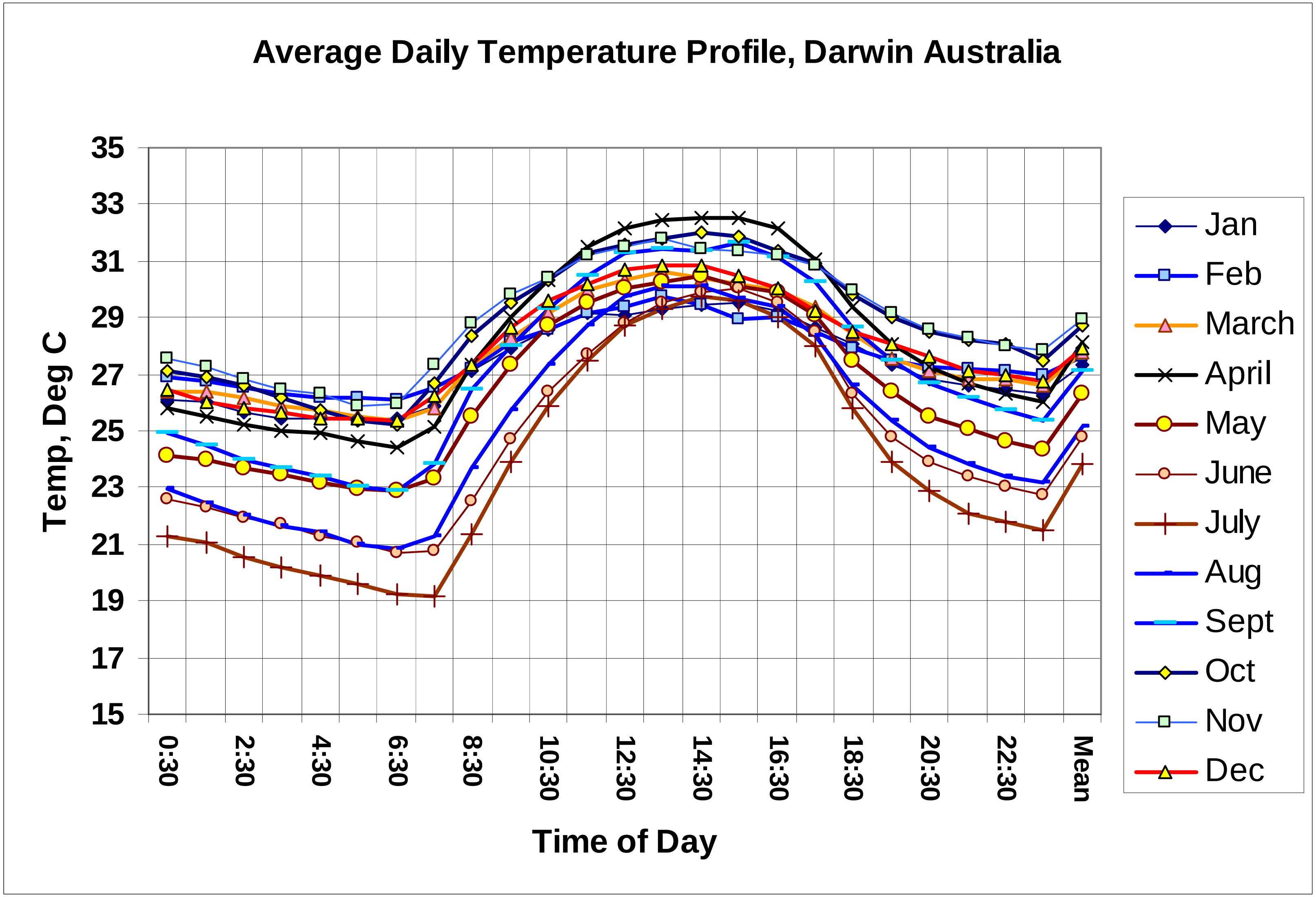


- **Evaporative Approach**
- **Inlet Chilling**

Sensitivity Of Gas Turbine Types To Inlet Air Cooling



Power Augmentation Approaches



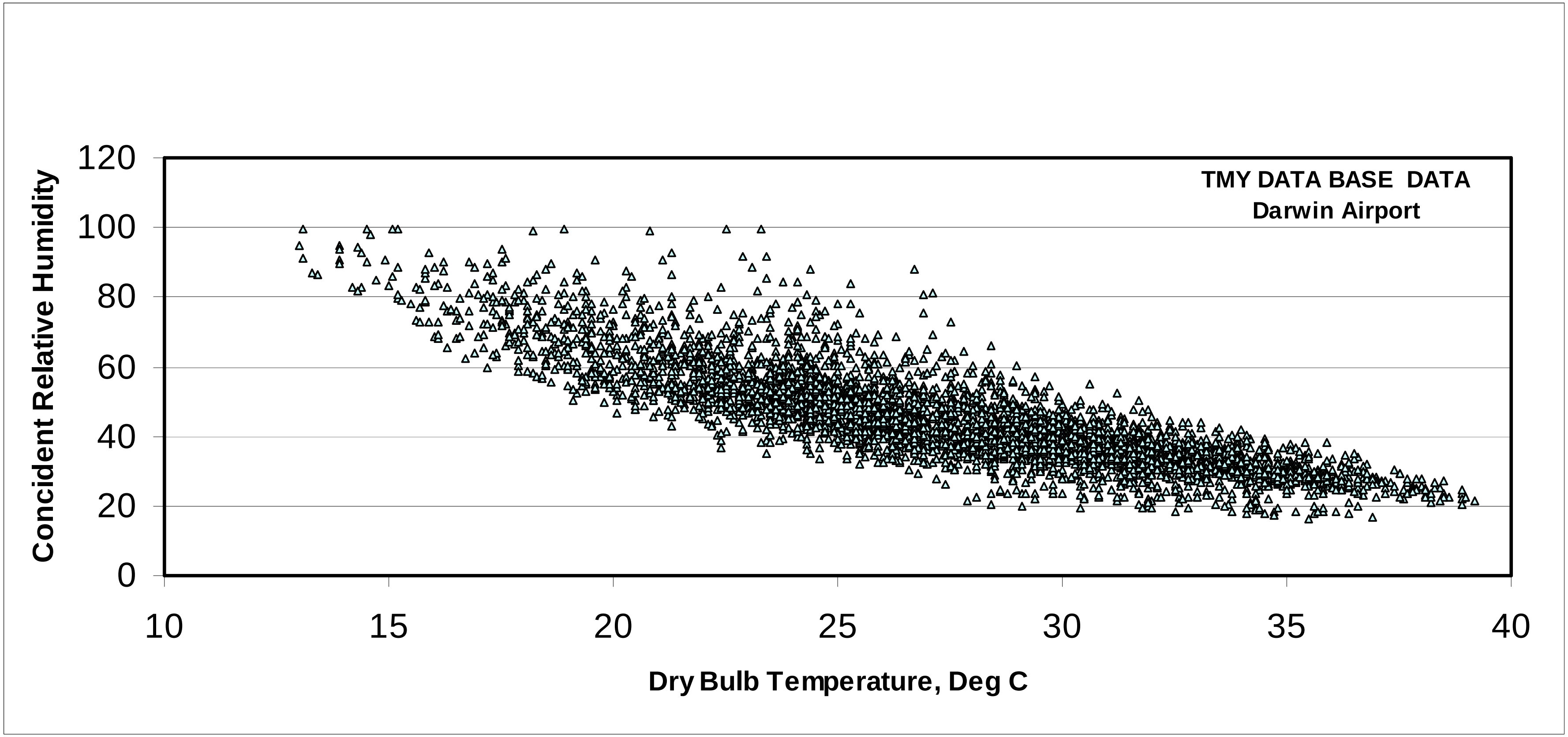
Power Augmentation Approaches

- **MEDIA EVAP COOLING**
  - **Humidity dependant, inlet Pr. drop, simple**

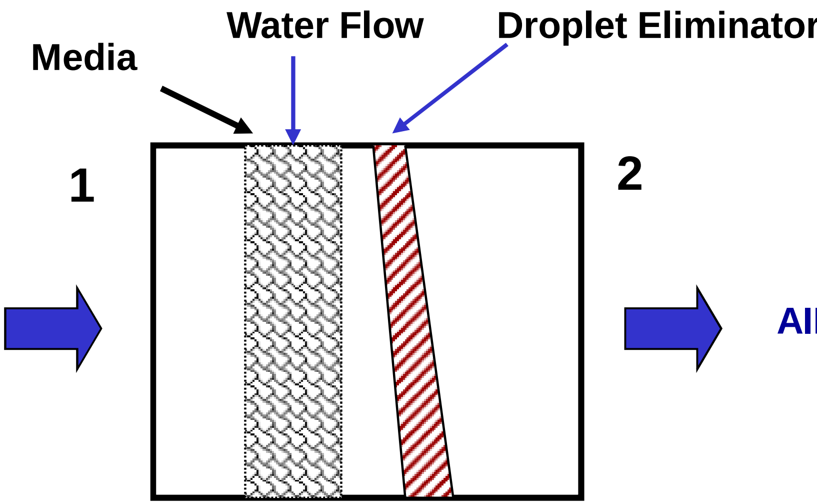
  INLET FOGGING
- **INLET CHILLING**
  - **Constant CIT possible, proven technology**
  - **Mechanical (Ammonia, Other, Propane) or Absorption**

- **WET COMPRESSION**
  - **High power boost, less humidity dependant,**
  - **SPRINT on LM6000 Engine**

Power Augmentation Approaches



Evaporative Cooling



$$Cooler\,Effectiveness = \frac{T1_{DB} - T2}{T1_{DB} - T2_{WB}}$$

AIR FLOW TO GAS TURBINE

DB = dry-bulb temperature

WB = wet bulb temperature.

If effectiveness = 90%

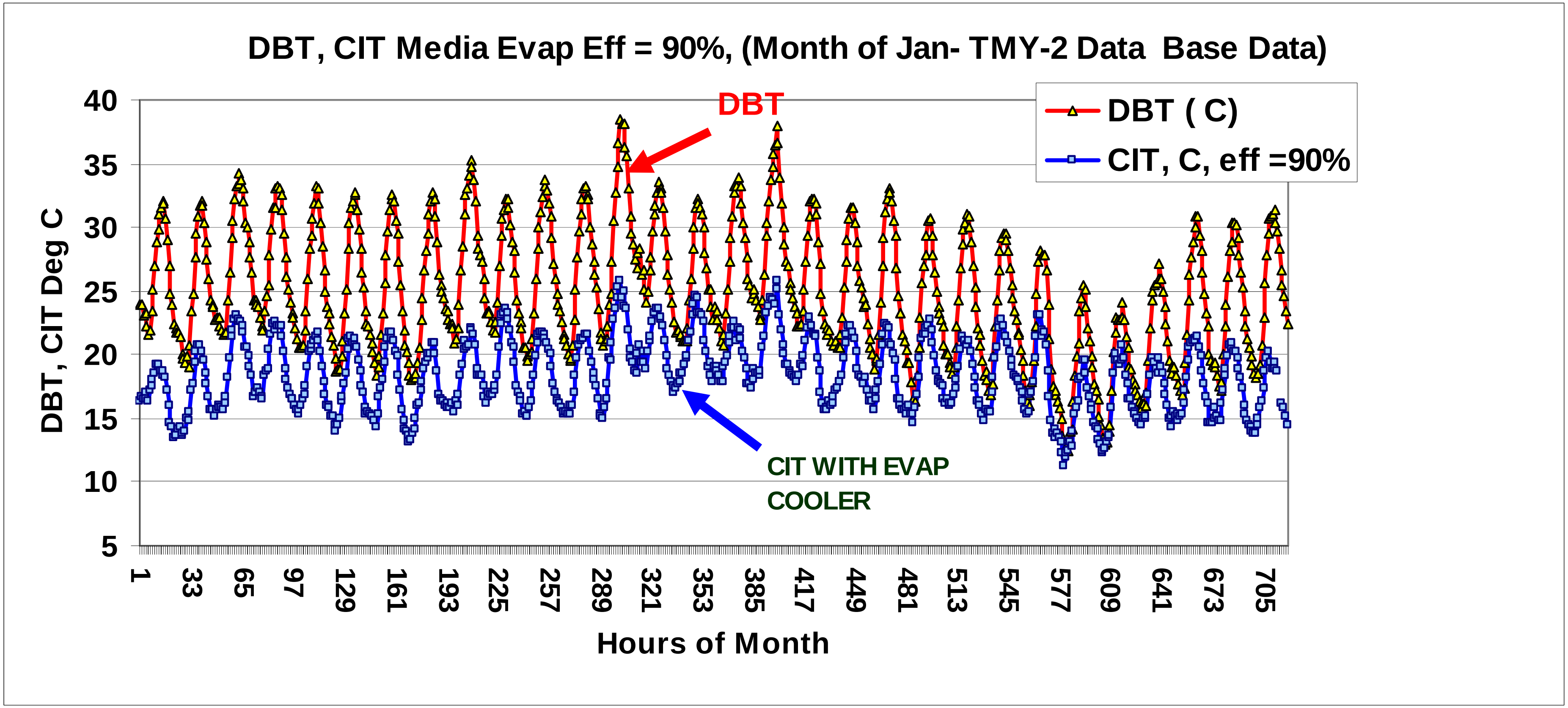
Temperature Drop = 0.9 ($T1_{DB}$ – $T2_{WB}$)

34C, 35% RH, 90% Eff

Temp Drop = 10.8 C

Power Boost = 10 %

Evaporative Cooler Performance



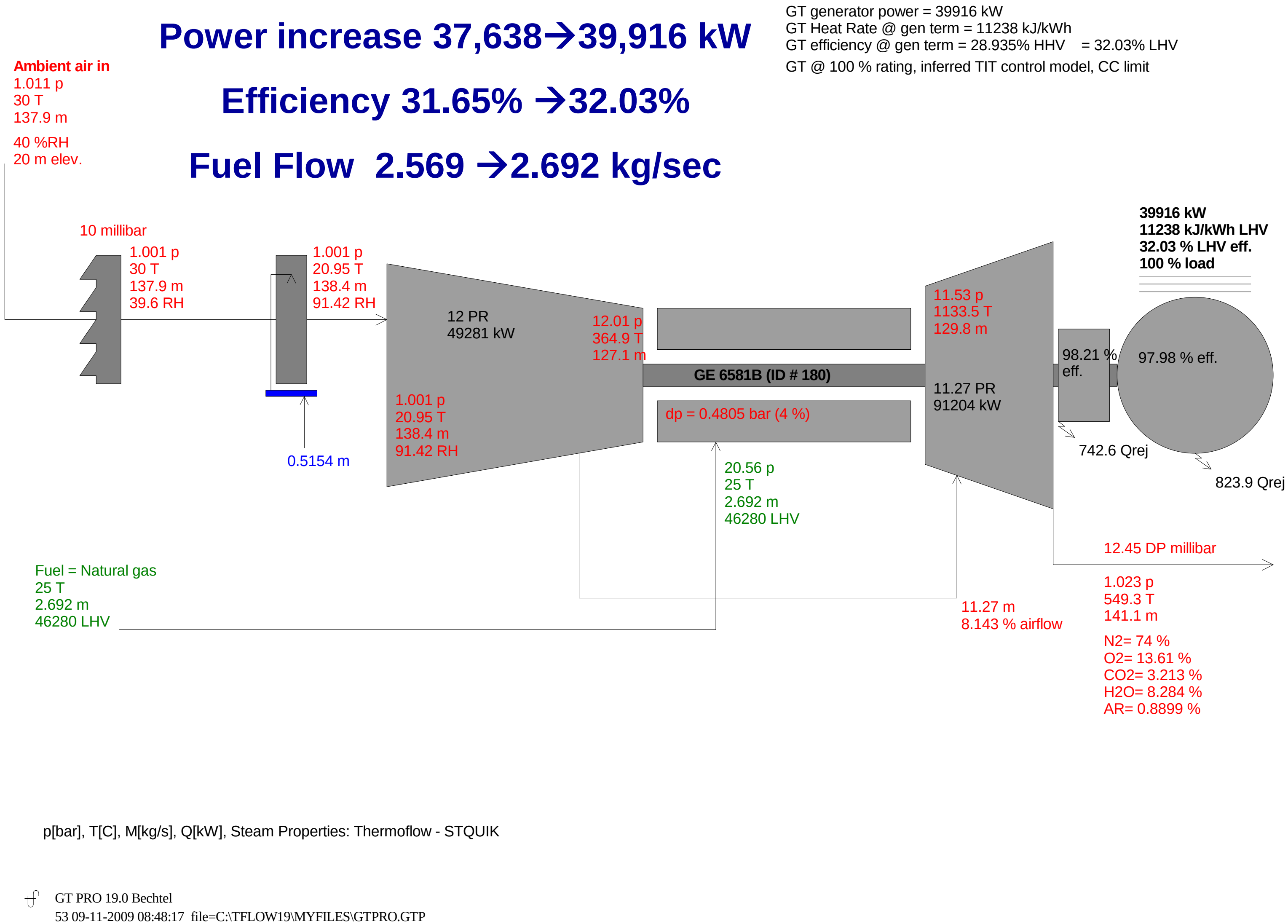
With Inlet chilling CIT can be "flatlined" = 10C, 15C

Frame 6B- 30C/40% RH, with Media Evap Cooler

Power increase 37,638→39,916 kW

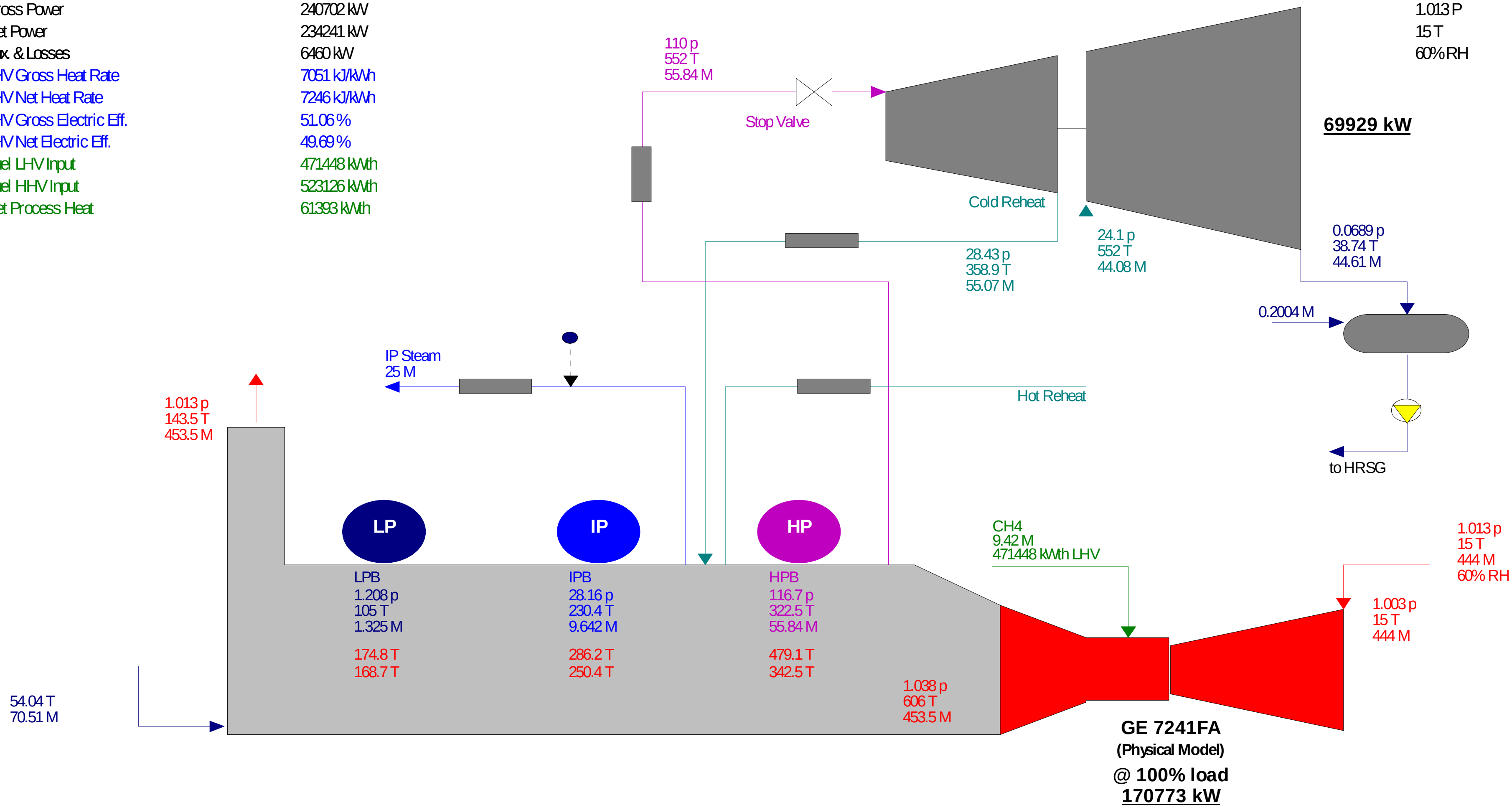
Efficiency 31.65% →32.03%

Fuel Flow 2.569 →2.692 kg/sec



Cogeneration: Frame 7FA

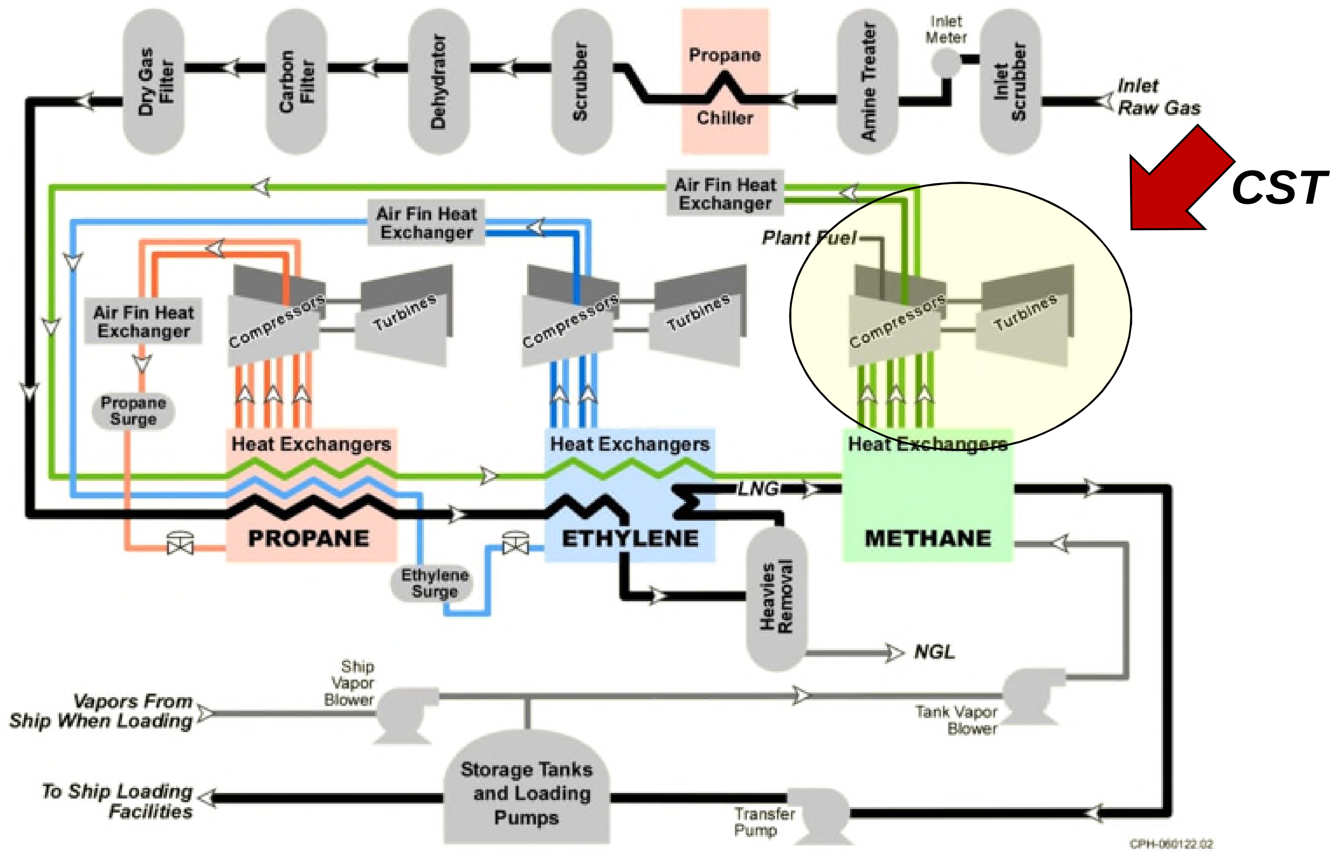
GT PRO 21.0 Microsoft	
Gross Power	240702 kW
Net Power	234241 kW
Aux & Losses	6460 kW
LHV Gross Heat Rate	7051 kJ/kWh
LHV Net Heat Rate	7246 kJ/kWh
LHV Gross Electric Eff.	51.06 %
LHV Net Electric Eff.	49.69 %
Fuel LHV Input	471448 kWth
Fuel HHV Input	523126 kWth
Net Process Heat	61393 kWth

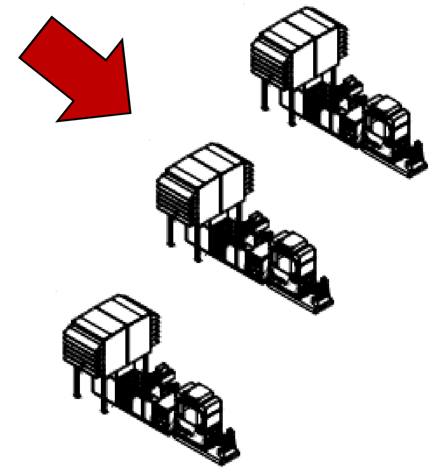


p [bar] T [C] M [kg/s], Steam Properties: Thermoflow - STQUIK
53 06-07-2011 23:29:42 file=C:\TFLOW21\MYFILES\GTPRO.GTP

GT PRO 21.0 Microsoft

The Optimized Cascade Process- Combined Cycle Possibilities





POWER BLOCK

-Design solutions for efficiency vs. Cost- simplicity--Choice of GT for H/P ratio desired
-HRSGs- number of pressure level, Horizontal or Vertical, supp firing
-Choice of Steam Turbine- BP / Condensing
-Possible to consider Absorption Chilling Approaches

FOUR LIQUEFACTION COMBINED CYCLE CONFIGRATIONS EXAMINED

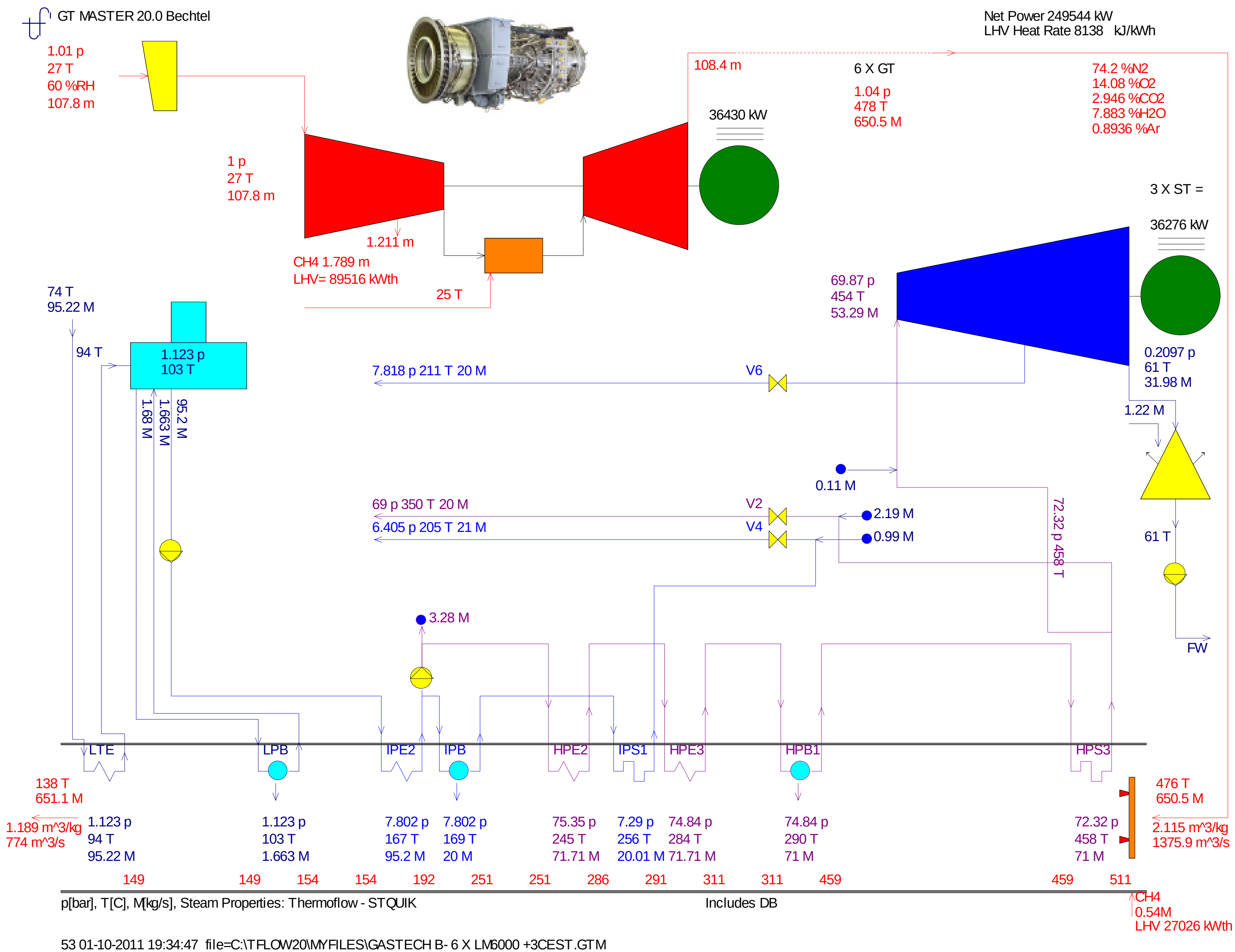
Goal was Technology Evaluation- Constrained Cogen Cycle Design

CONFIGURATION	Gas Turbines for Liquefaction	Power Plant Configuration (Operating load)	Thermal Load
CONFIGURATION A 2P+2E+2M Approximate MTPA≈ 5.x	4 LM6000PF + 2 Condensing Steam Turbines Propane – 2 x LM6000PF Ethylene- 2X LM6000PF Methane – 2 Condensing Steam Turbines	4 X Solar Titan130 and HRSGs	Steam from HRSGs from Power block
CONFIGURATION B 6 LM6000PF engines in 2+2+2 Configuration Approximate MTPA≈ 5.x	6 x LM6000PF Propane – 2 x LM6000PF Ethylene- 2X LM6000PF Methane- 2X LM6000PF	All Power derived from Condensing Steam Turbines using heat recovered from Refrigeration Drivers.	Steam from HRSGs and extraction from steam turbines
CONFIGURATION C 3 X LMS100 1+1+1 Configuration Approximate MTPA≈ 7.x	3 X LMS100 Propane – 1 x LMS100+ Ethylene- 1X LMS100 Methane- 1X LMS100	All Power derived from Condensing Steam Turbines using Refrigeration Drivers.	Derived from HRSGs directly and extraction from the CSTs
CONFIGURATION D 2X Frame 7EA +2 X Frame 6B Gas Turbines Approximate MTPA≈ 7.x	Propane and Ethylene- Frame 7EA+BPST (Helper starter)- two string Methane- Frame 6B +BPST – two strings.	Power derived from HRSGs of the Frame 6 Strings utilizing condensing steam turbines.	Derived from BPSTs .

Salient Features of the Four Configurations

CONFIGURATION	A	B	C	D
	5.x MTPA	5.x MTPA	7.x MTPA	7.x MTPA
Total Number of Gas Turbines for Refrigeration block	4	6	3	4
Number of Gas Turbines for Power Block	4	0	0	0
Total Number of HRSGs Suplemental Firing	8 yes	6 yes	3 yes	4 yes
Power Generation Scheme	4 X Solar Titan130 [6] with HRSGs	3 condensing steam turbines	3 condensing steam turbines	2 or 3 condensing steam turbines
Total Fuel In, kW	652694 [7]	564121	878884	757271
Power Out (Electrical + Mechanical) [8]	256676	254845	343903	283231
Thermal Energy out, kWt	154026	156742	217984	212874
CHP Efficiency, %	63	72.96	64.9	70.97
Power efficiency, %	39	45	40	42.86
HRSG Efficiency, %	85.32 (Mech drive GT) and 89.19 (Power)	77.04	86.73	79.07 (Fr 7EA) 84.62% Frame 6
CO_2 kg/TPA	0.19	0.175	0.20	0.183

Configuration B: Cycle Flow Schematic



Summary- Cogen Approaches for LNG Liquefaction

Combined cycles are attractive for LNG Liquefaction plants – Can be applied to either Aeroderivative or Industrial GT Solutions.

The appropriate configuration depends on quality and demand variability of heat and the power (both for refrigeration liquefaction drive and electrical loads).

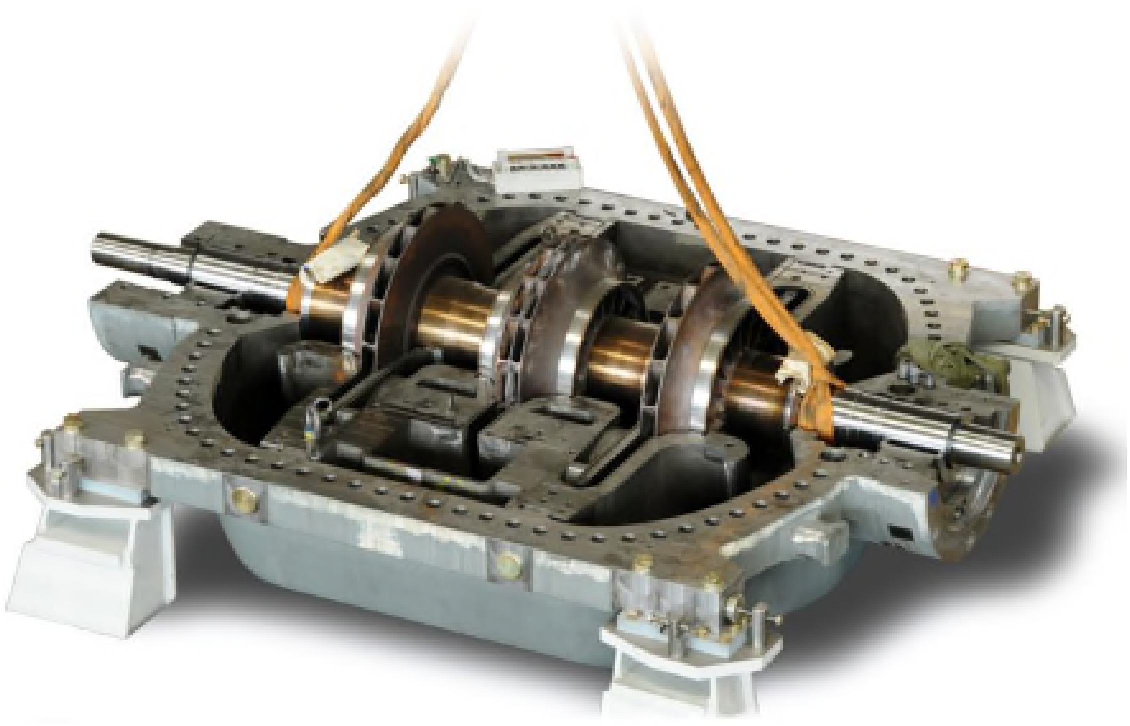
Based on unfired designs, the heat to power ratio is lower (0.8 to 1.0) with aeroderivative engines and higher (approximately 1.5) with industrial engines.

This ratio is mainly dependent on the gas turbine thermal efficiency, it will also depend on the mode of heat recovery, and number of pressure levels

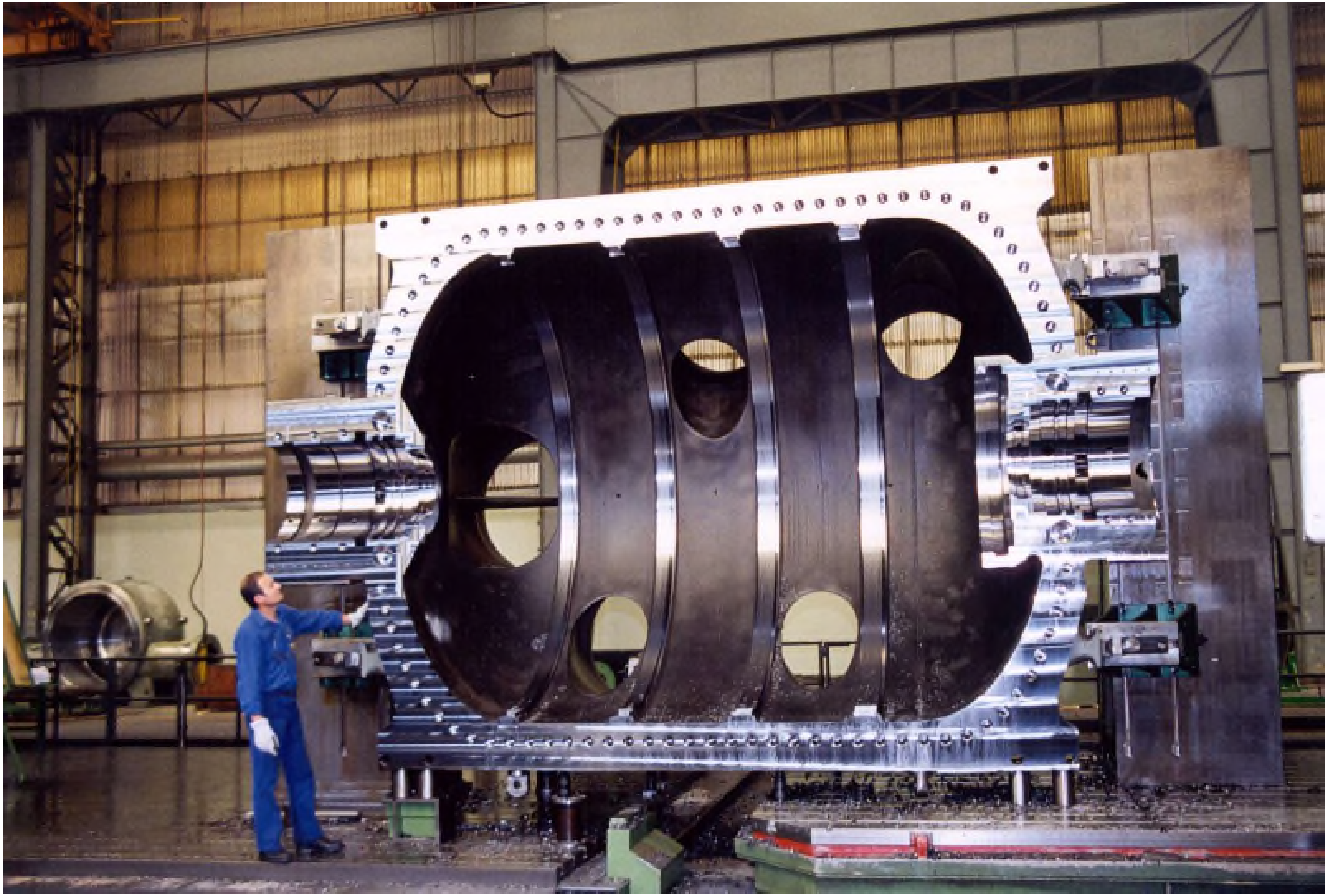
The use of supplemental firing makes aeroderivatives and industrial engines relatively close in terms of the overall heat to power ratio and CHP efficiency.

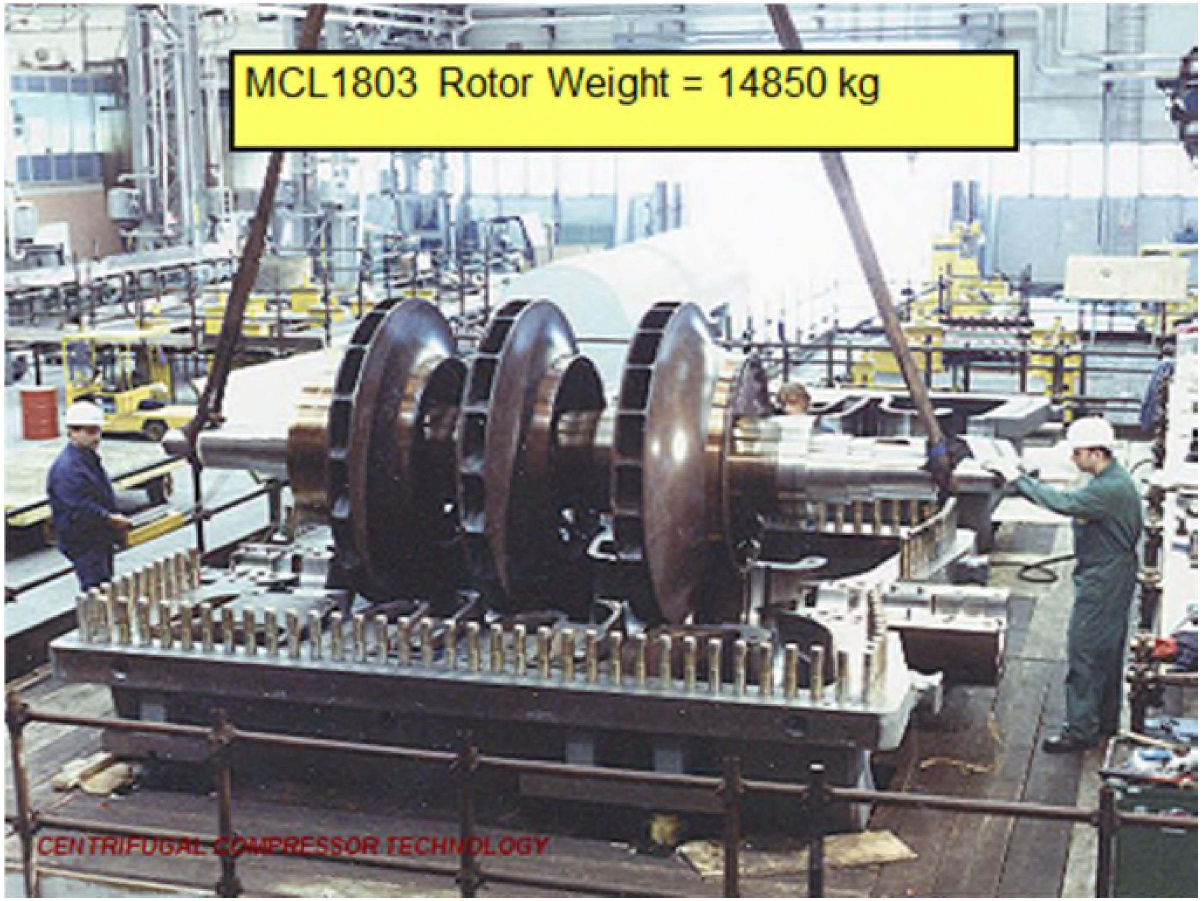
Regardless of the cogeneration scheme dictated by thermodynamic efficiency considerations, practical considerations relating to the plot plan, operational complexity, startup considerations and transient behavior must be evaluated

LNG Centrifugal Compressor Technology



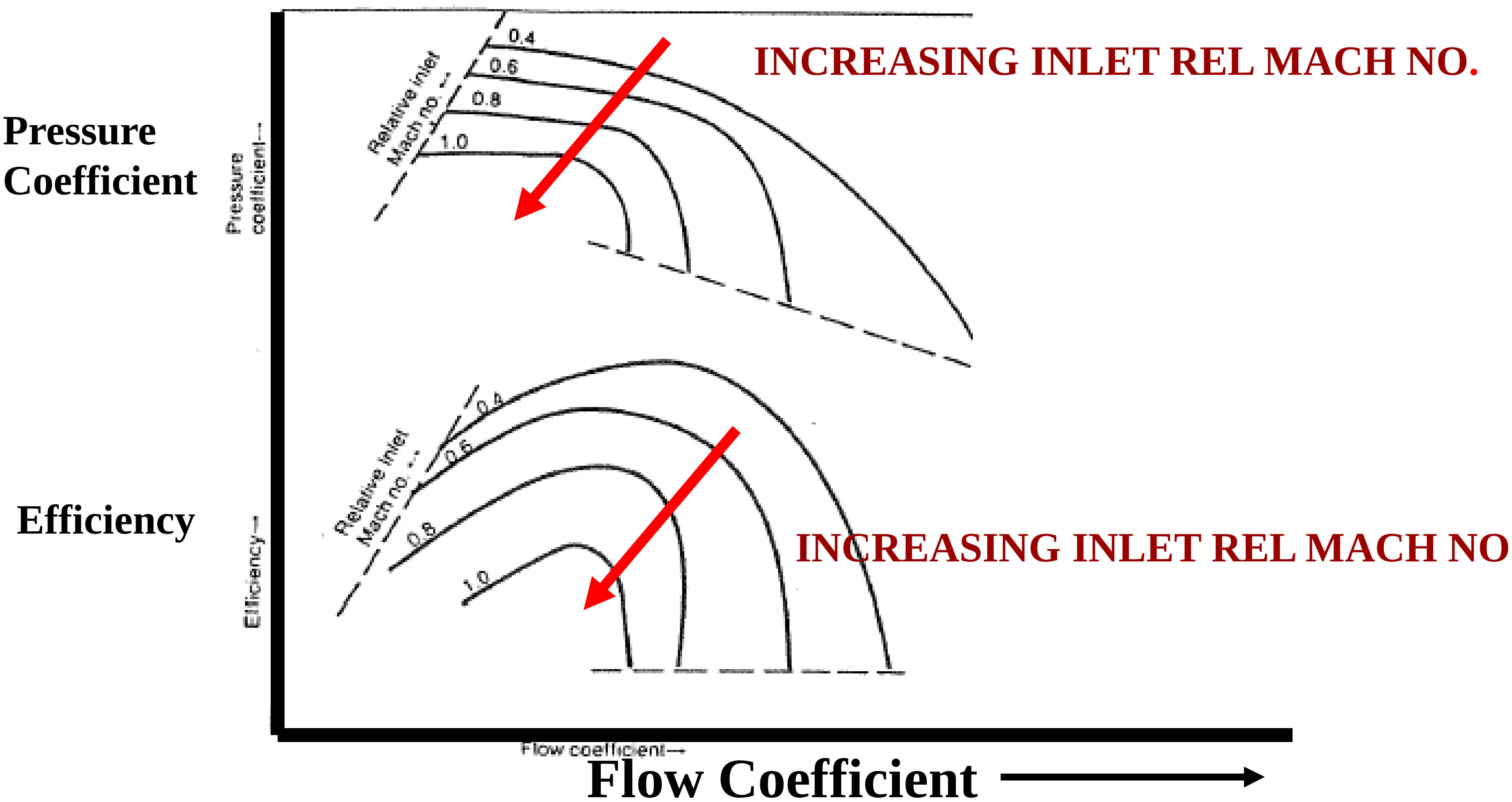
LARGE COMPRESSORS



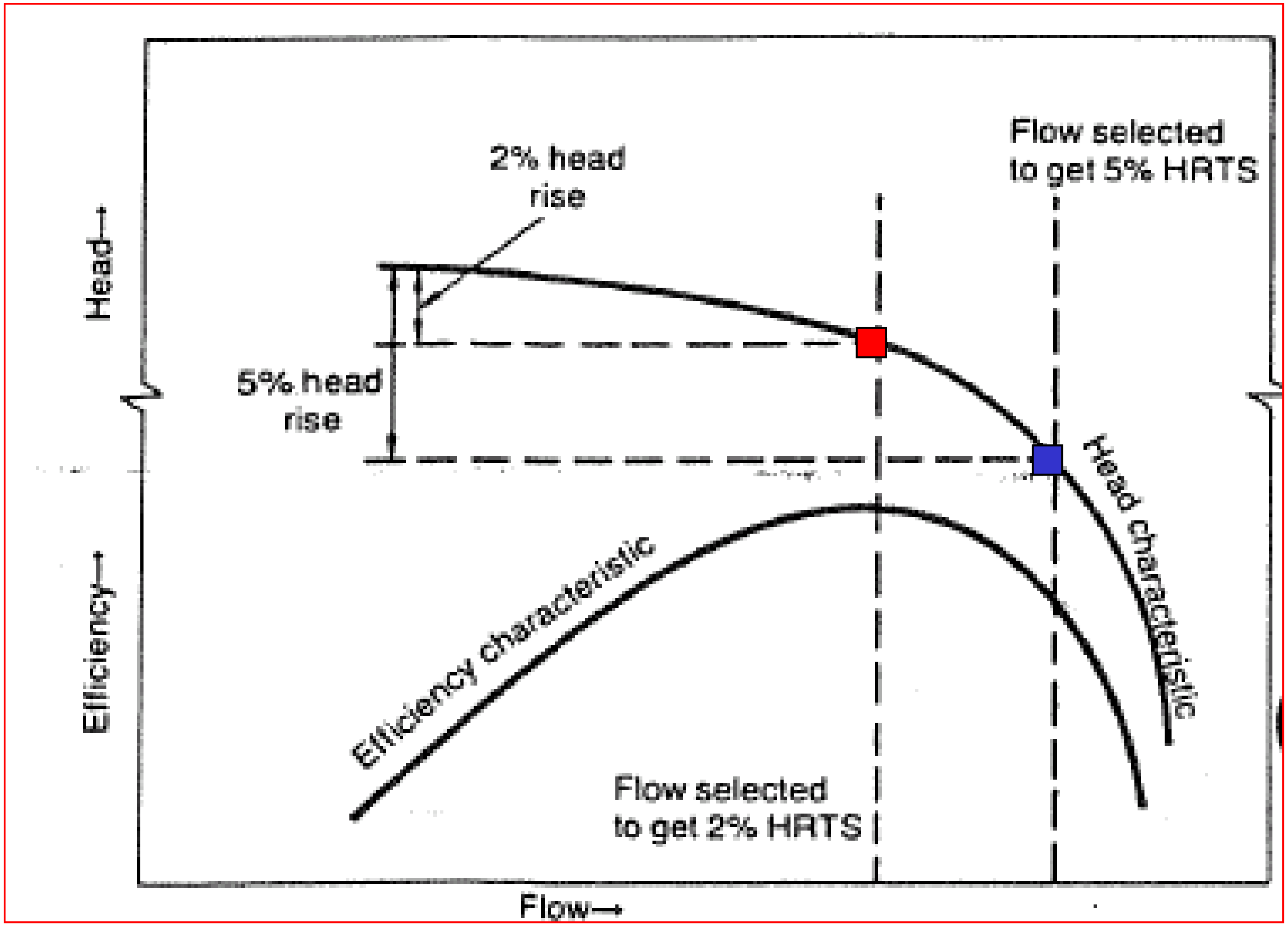

MCL1803 Rotor Weight = 14850 kg
CENTRIFUGAL COMPRESSOR TECHNOLOGY

Large LNG Impellers -- 1800 Series

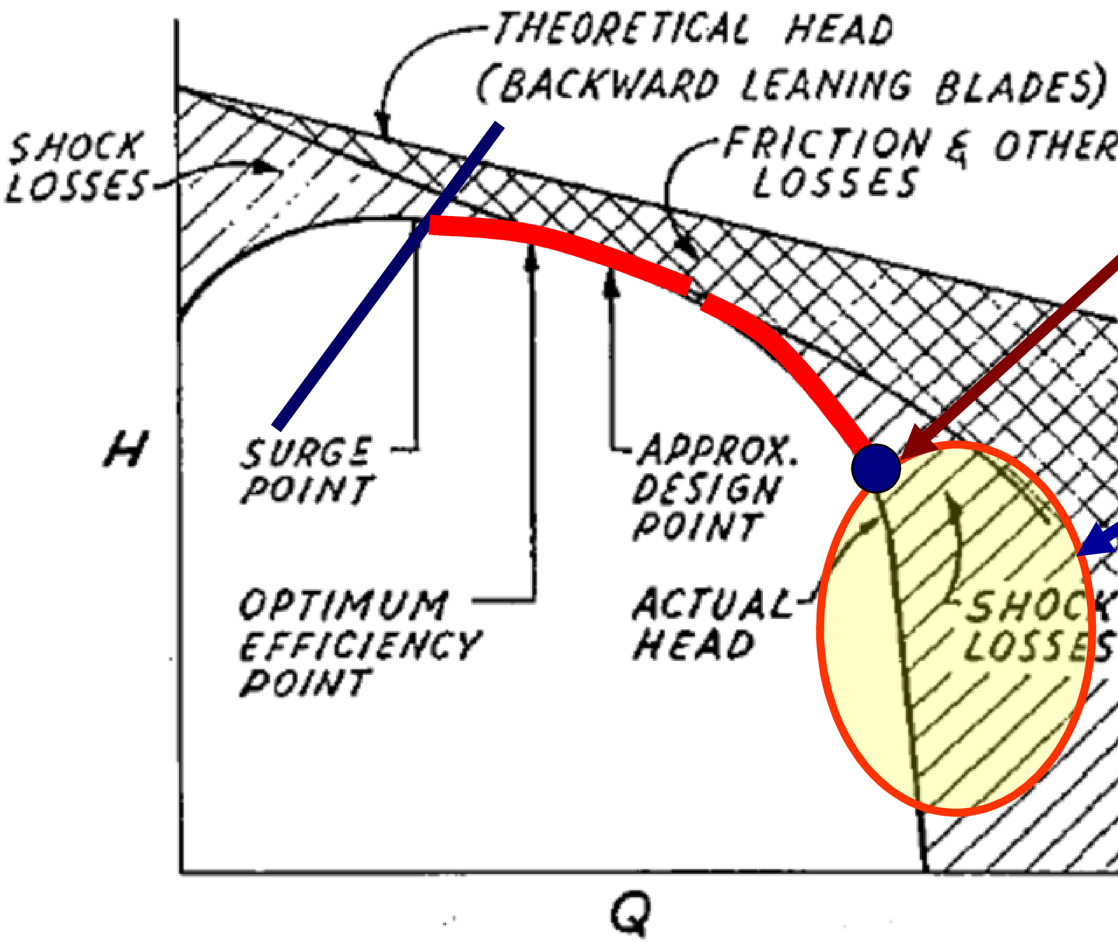
Effect of Inlet Relative Mach Number on Operating Range



HRTS –CAREFUL SELECTION REQUIRED



Centrifugal Compressor Map- Operation in Choke



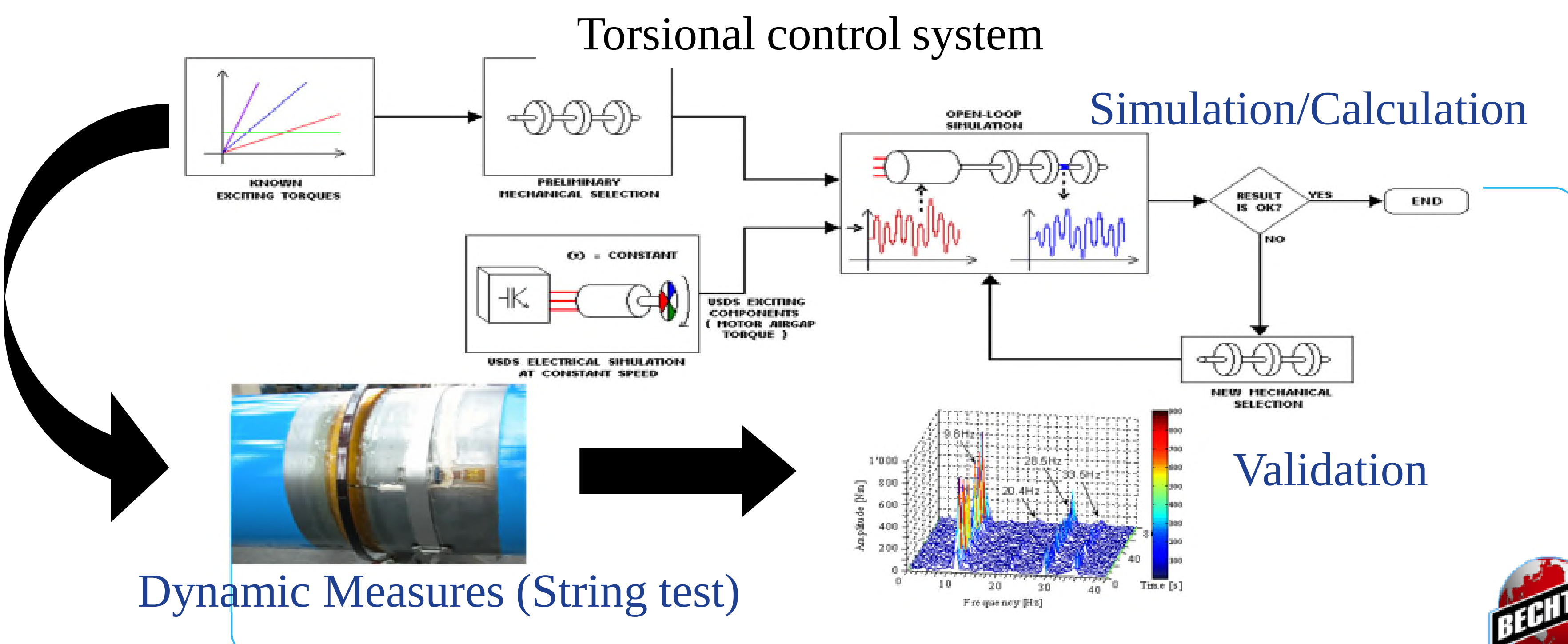
End of Curve on Compressor Vendors Map

Region of Overload Operation (Choke)

When Flow reaches sonic velocity at some cross-section of the stage the flow chokes. - typical location is in the impeller inducer or entry to diffuser

String Testing- Longest Train Tested

- LNG Train (5 MTPY) with FR7
- 1 FR7 + 3Large CC + 1EM (18MW)
- Advanced testing campaign for torsional interaction



DARWIN LNG – WORLD'S FIRST AERODERIVATIVE LNG PLANT