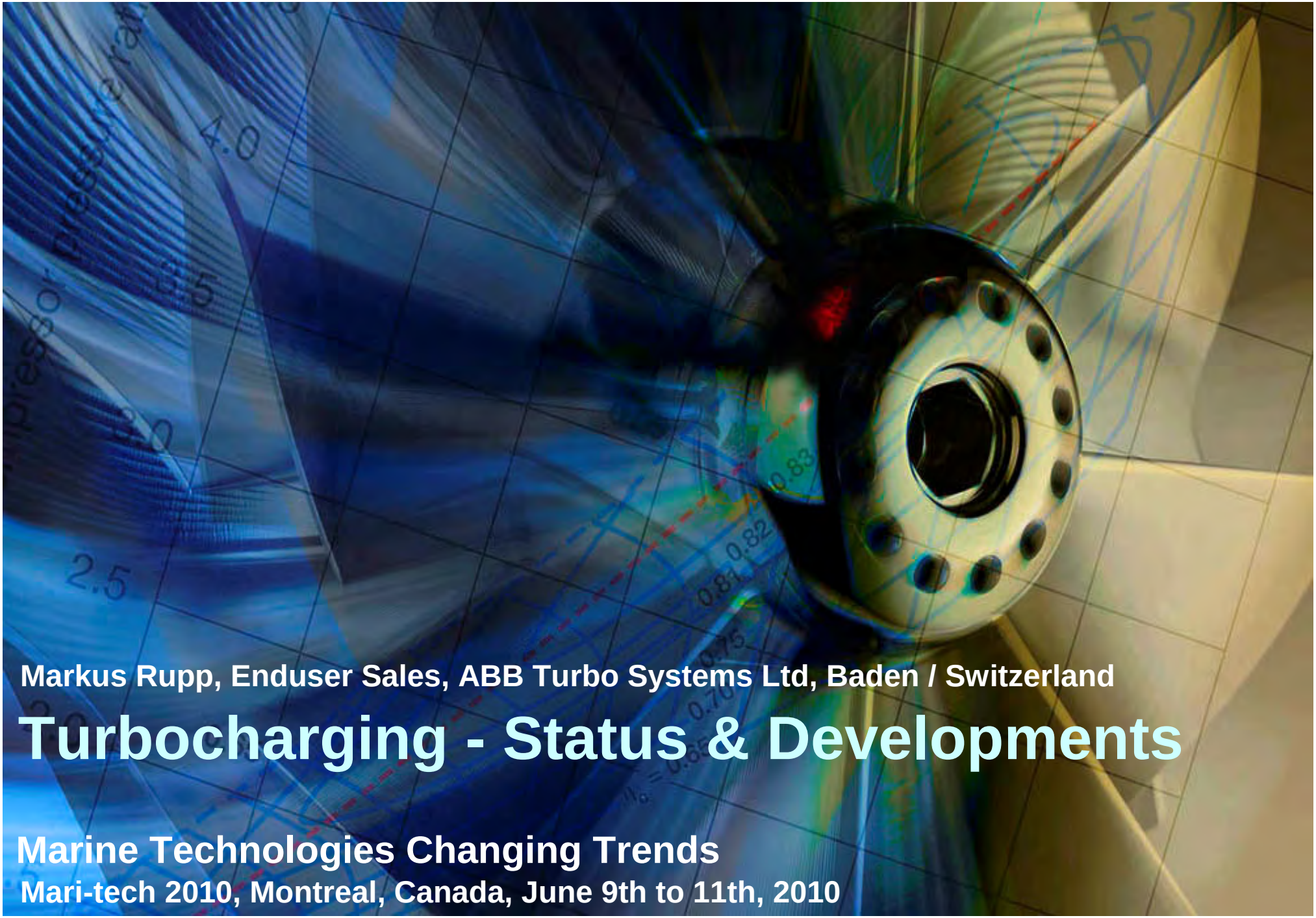


Markus Rupp, Enduser Sales, ABB Turbo Systems Ltd, Baden / Switzerland

Turbocharging - Status & Developments

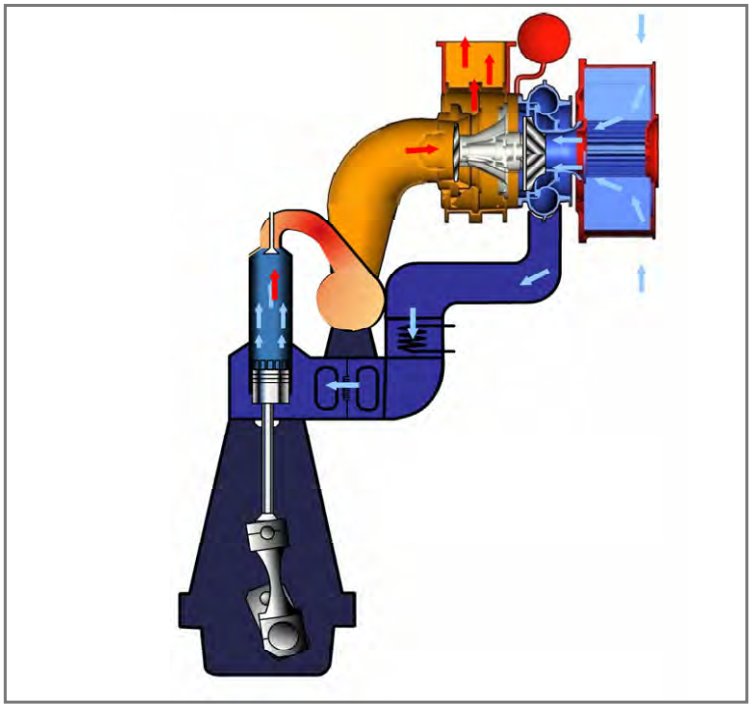
Marine Technologies Changing Trends

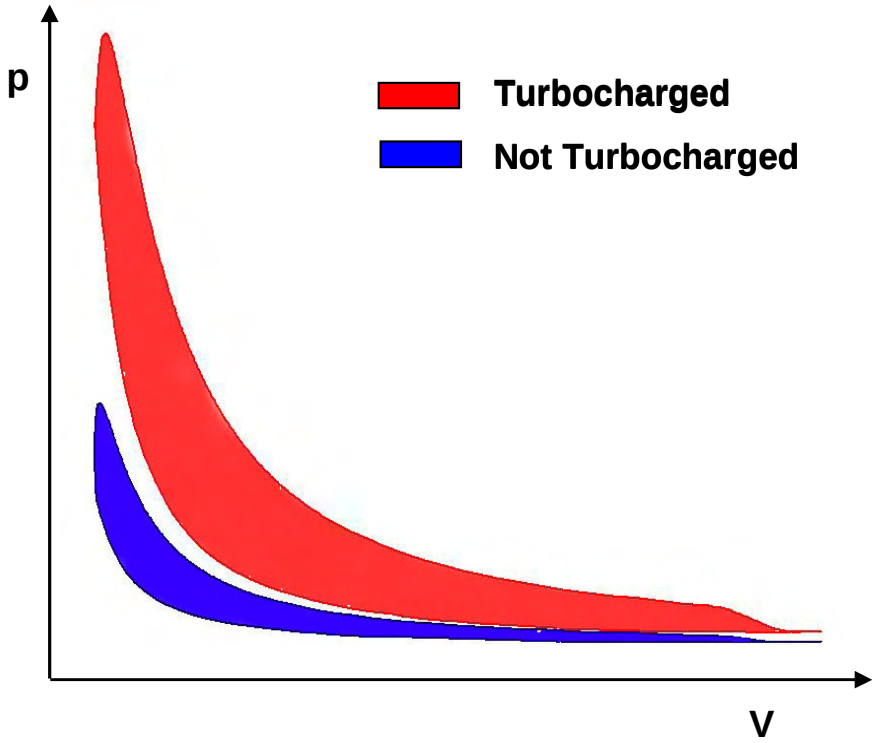
Mari-tech 2010, Montreal, Canada, June 9th to 11th, 2010

Content: Turbocharging – Status & Developments

- Turbocharging – Today & Tomorrow
- New Generation Turbocharger A100
- Variable Turbine Geometry
- Slow Steaming
- Service Aspects

Turbocharging from 500kW to most powerful 80’000kW

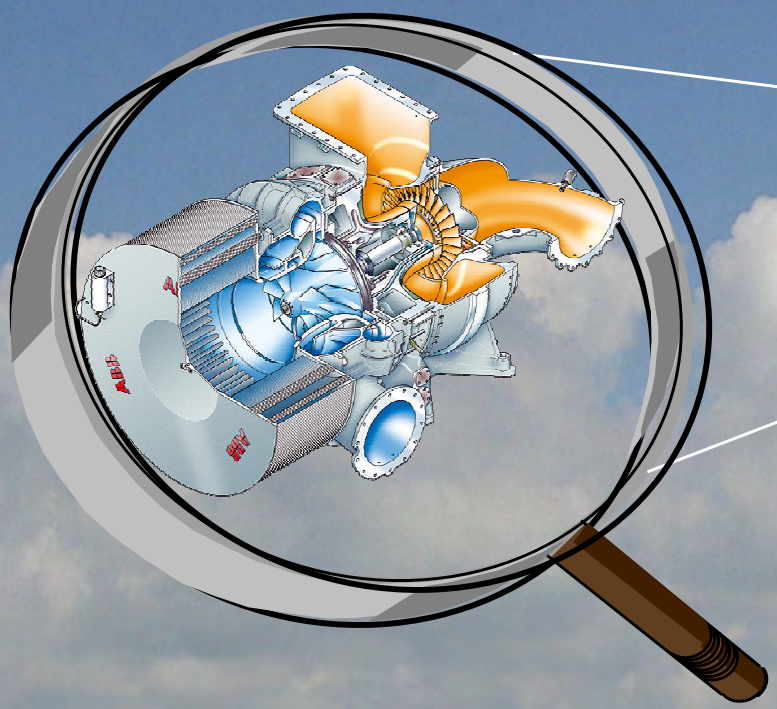




► **TC Function**

$$\underset{\text{Output}}{P_e} = \underset{\text{Swept volume}}{V_H} \cdot \underset{\text{Speed}}{n} \cdot \underset{\text{Mean eff. pressure}}{p_{me}}$$

Benefits of turbocharging



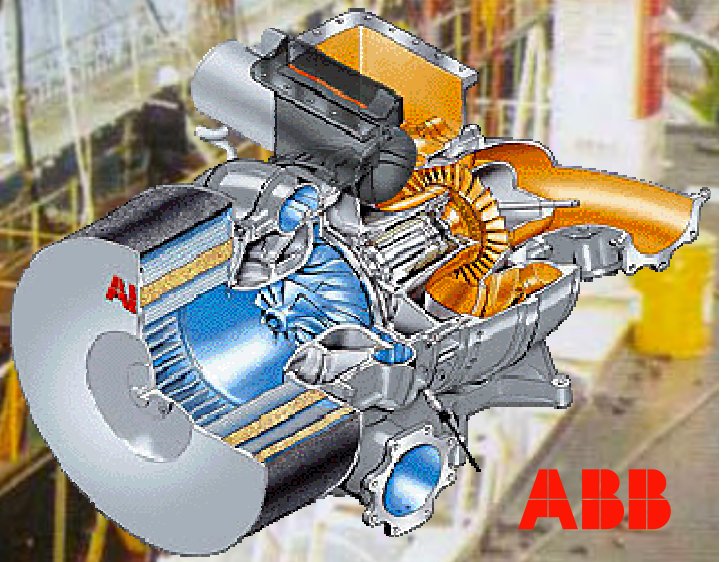
Power: + 300% Output
Price: < 1% Vessel

ABB Turbochargers

Marine applications

Marine applications

Marine applications



HYUNDAI - MAN 10K98MC-C and 6S35MC

Wide range of applications

Power stations

Power stations

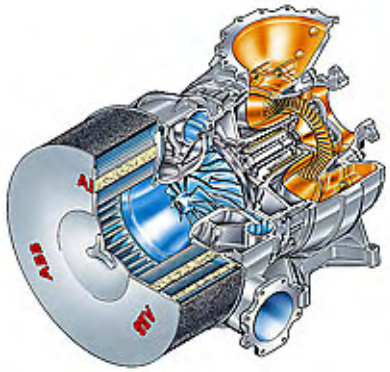
Locomotive applications

Spezial application

TPL & TPS Turbocharger Types

TPL

TPL..-A
TPL..-B
TPL..-C

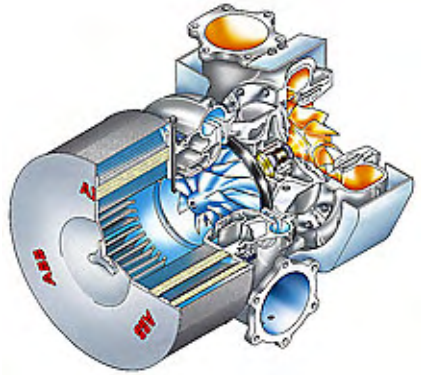


Produced units:
Length: 113 - 380 cm
Weight: 520 - 13 200 kg

Turbocharged power:
2500 - 28 000 kW

TPS

TPS..-D/E
TPS..-F33
TPS..-F32
TPS..-F31



Produced units:
Length: 35 - 65 cm
Weight: 80 - 400 kg

Turbocharged power:
500 - 3300 kW

ABB Turbocharger - Small to Big


TPL91-B


TPS44

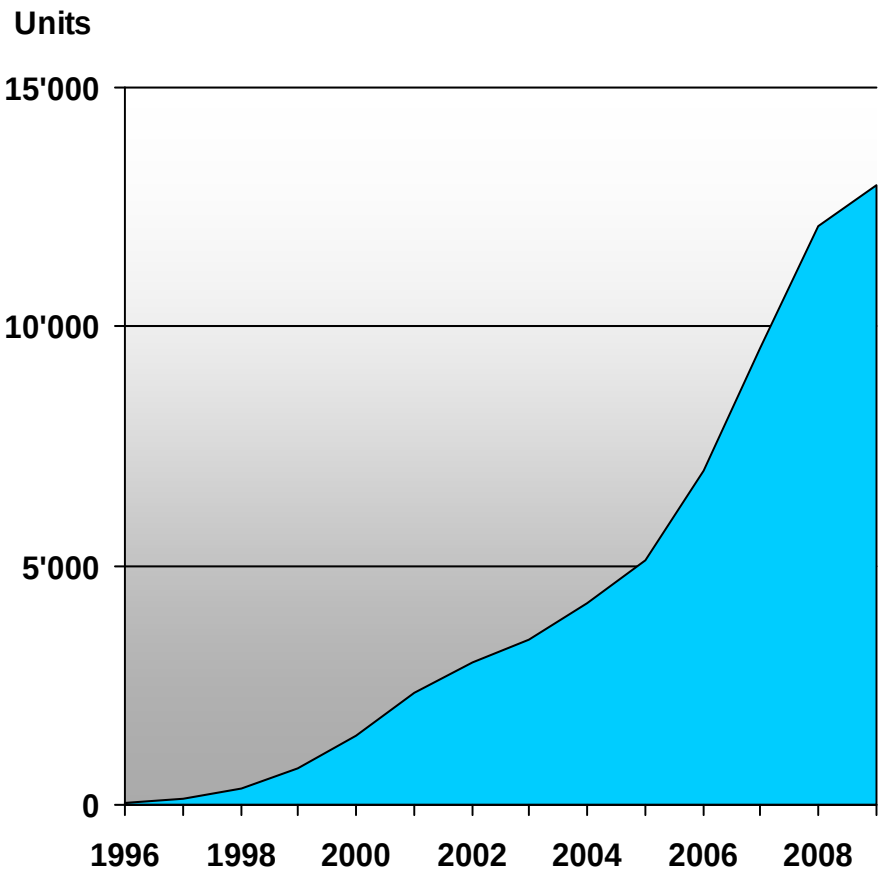
- Engine power (MCR): 74’760 kW
  12K98ME-C & 3xTPL91-B
- Dry mass approx. : 2’300 tons
- Fuel consumption: 270 tons/day
  (at 90% MCR)

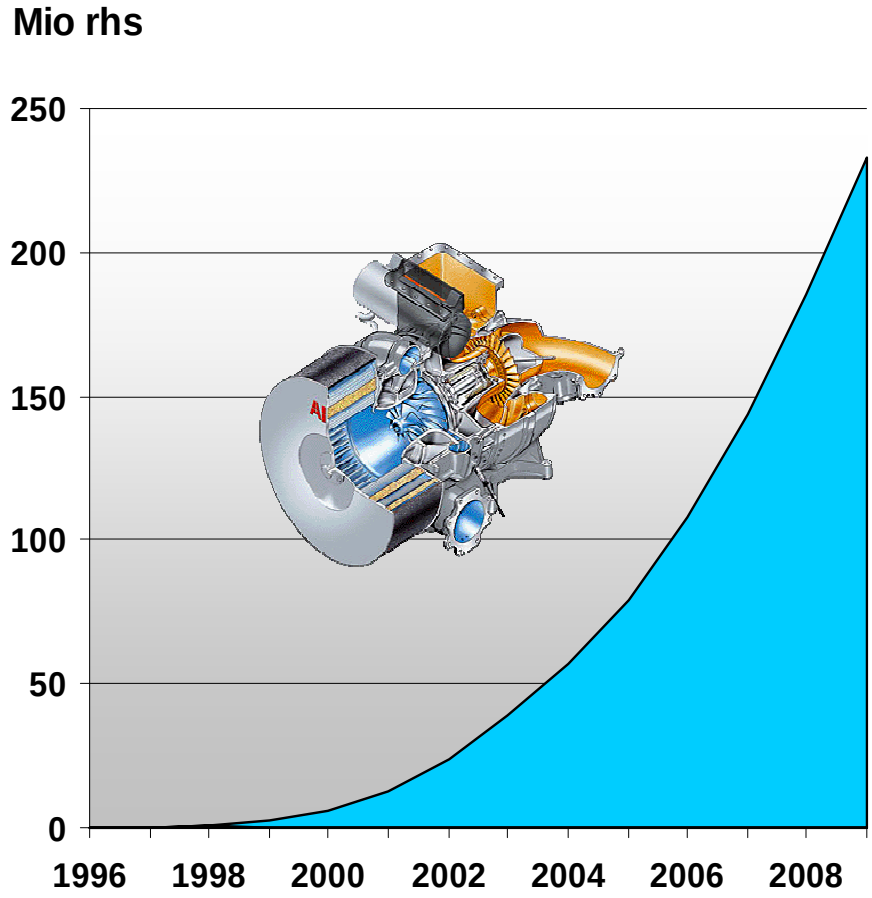
- T/C shaft torque (MCR): 9’800 Nm
- T/C shaft power (MCR): 10’200 kW x 3
  → 30’600 kW
- % of engine power: 41 %

- Engine power (TPS44): ~500 kW

TPL Turbochargers delivered & running hours

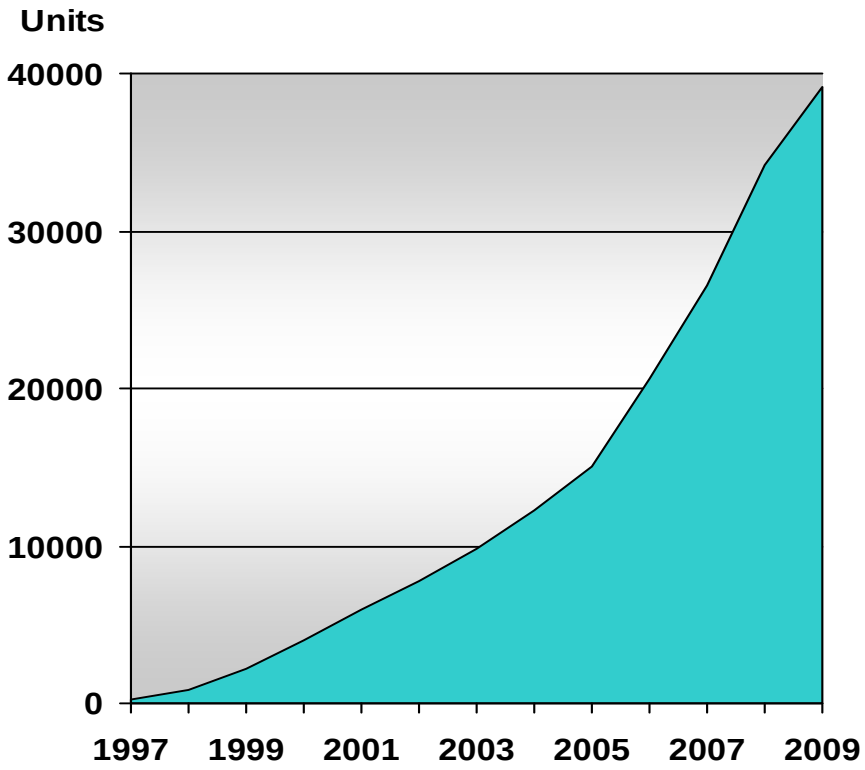
by Dezember 2009

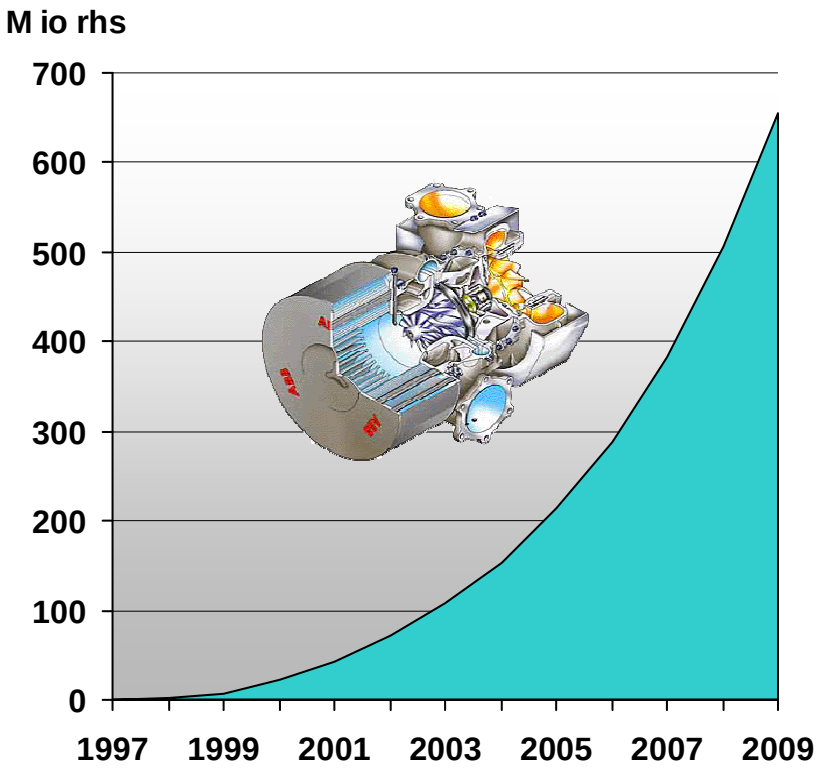




TPS Turbochargers delivered & running hours

by December 2009



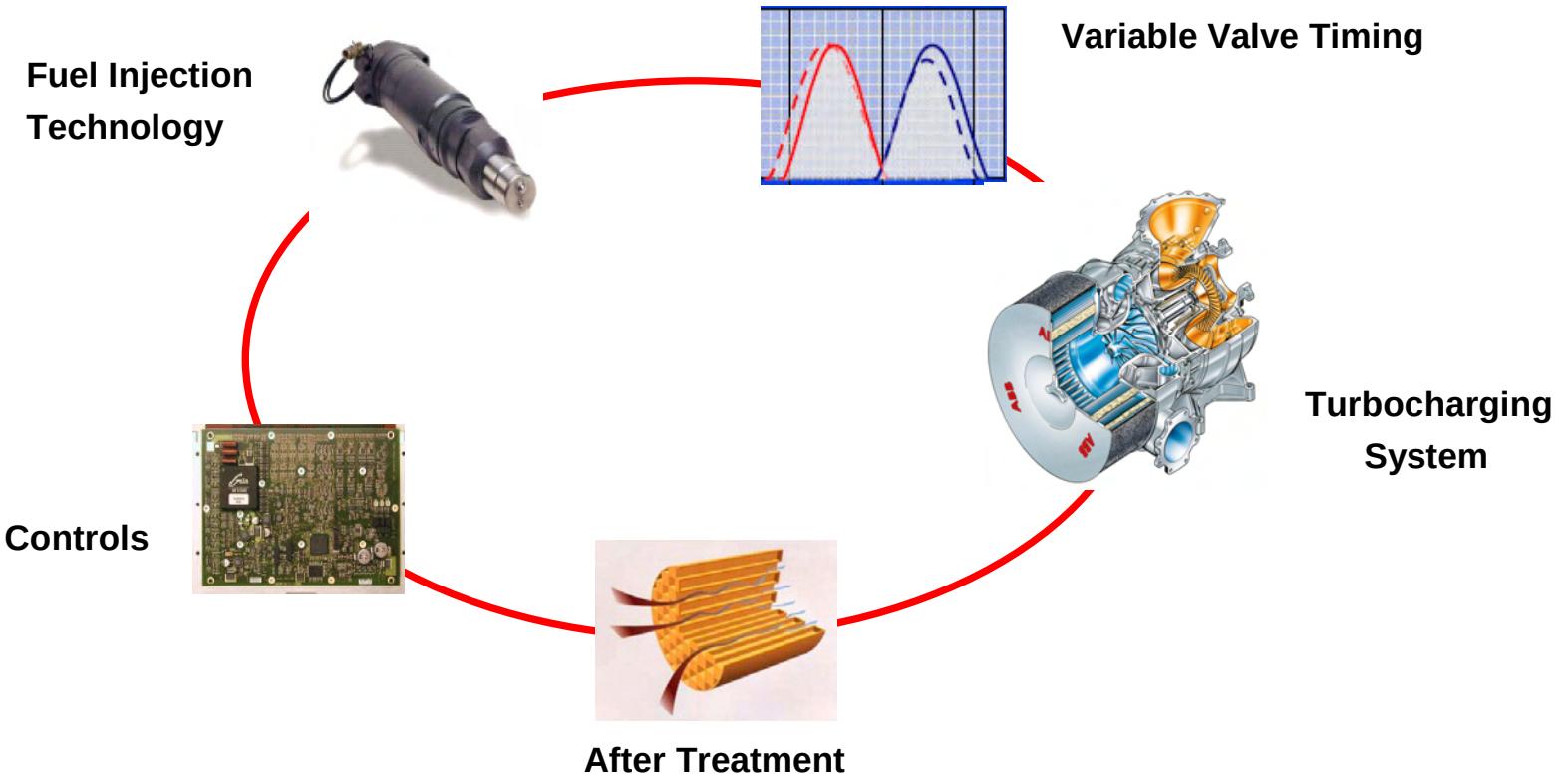


Content

- Turbocharging – Today & Tomorrow
- New Generation Turbocharger A100
- Variable Turbine Geometry
- Slow Steaming
- Service Aspects

Main drivers for engine technology

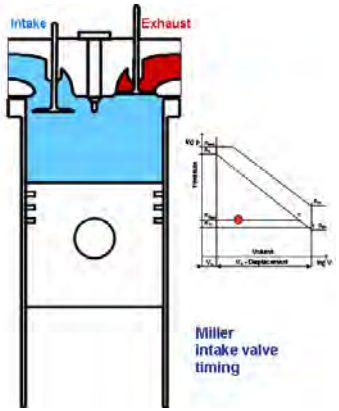
- **Fuel savings**
- **Higher specific output**
- **Emission legislation**
- **CO_2 Emission reductions**



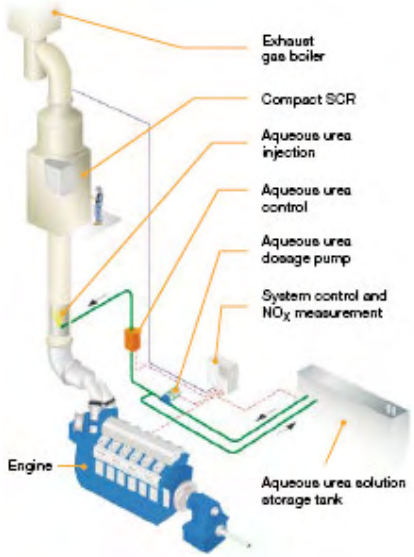
NOx reduction technologies

Possible building blocks for IMO III

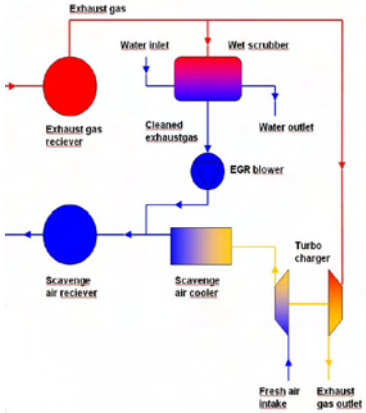
Miller timing



SCR

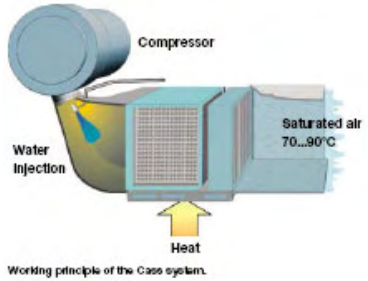


EGR

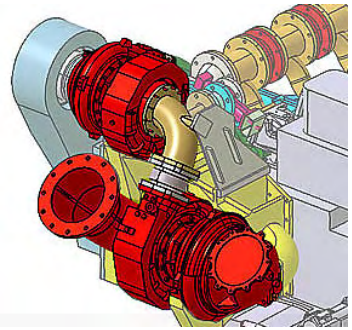


Water injection

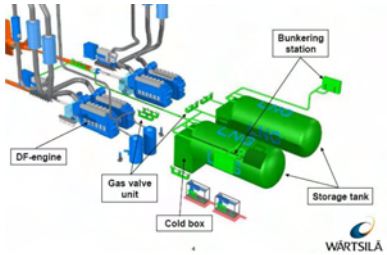
Humid air



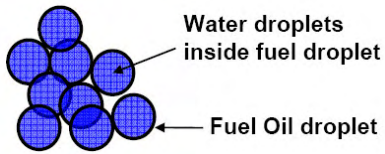
2-stage turbocharging



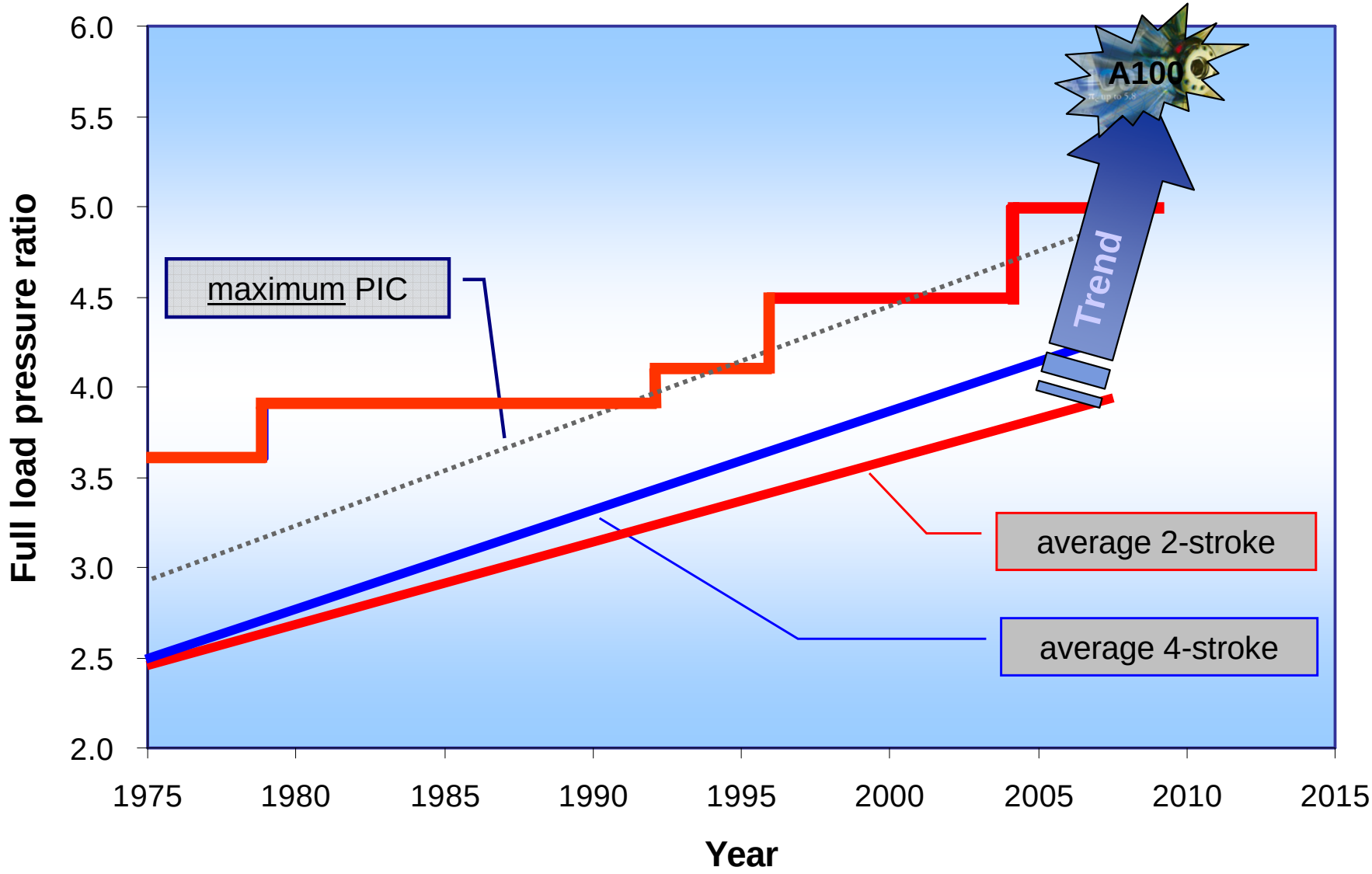
Gas / dual fuel



Emulsion

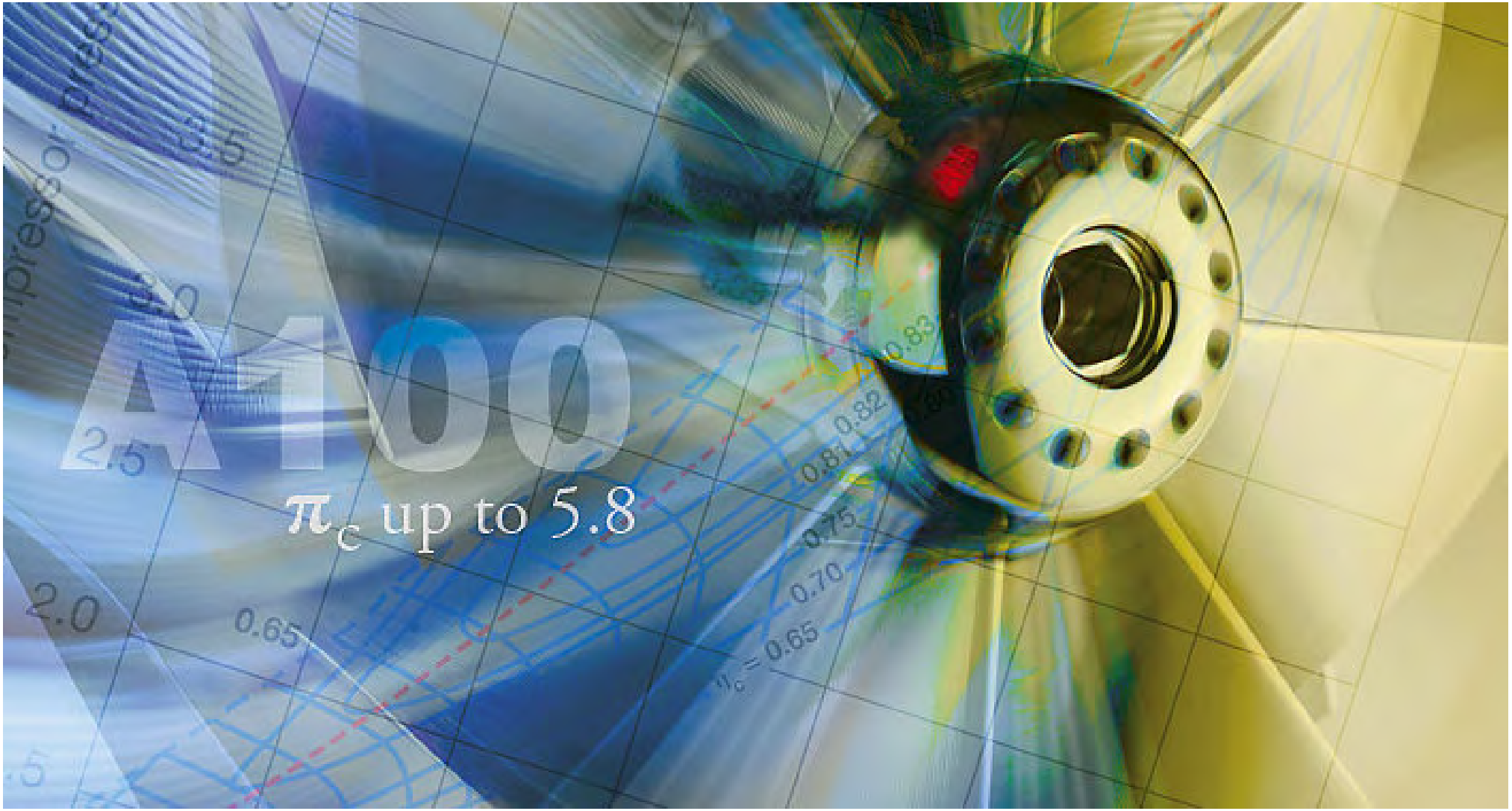


Development of compressor pressure ratio



Full load pressure ratio with aluminum compressor wheel / base load application (50'000 rhrs)

A100 - The new generation



A100 – The new generation
Single-stage / high-efficiency / high pressure

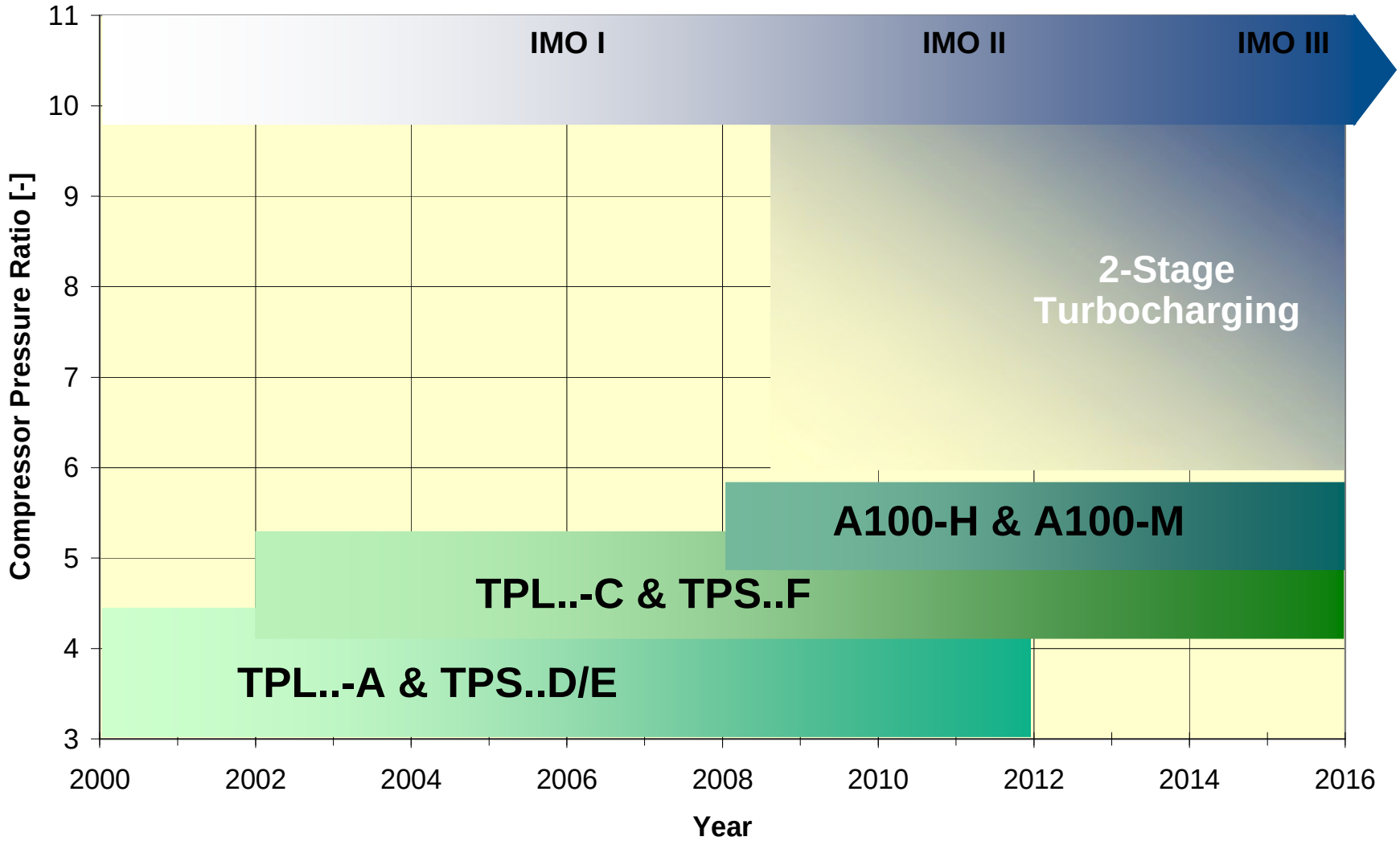
A100-H = for high speed engines

A100-M = for medium speed engines

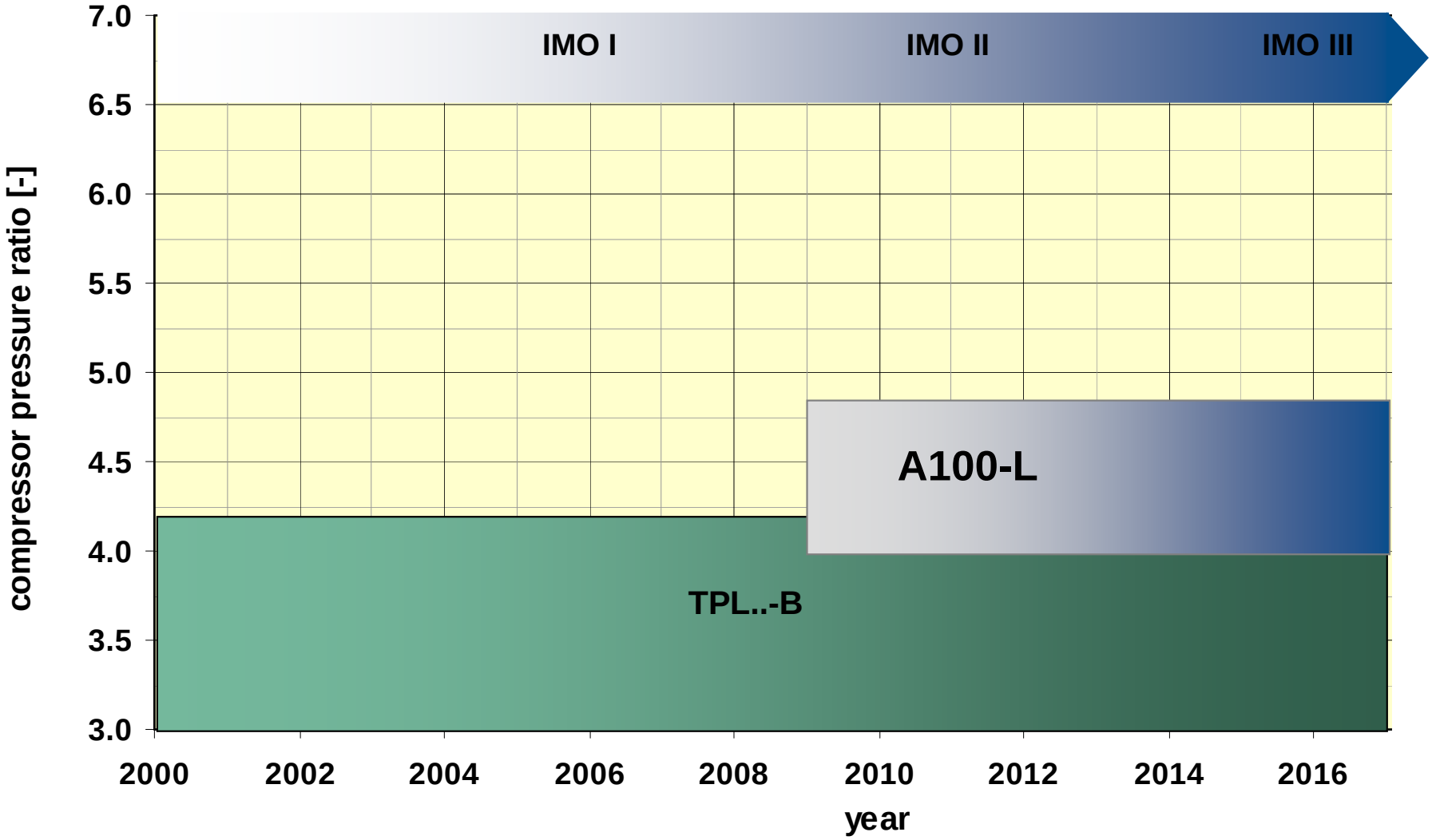
A100-L = for low speed engines

- A100-H & A100-M
  - Highest compressor pressure ratios up to 5.8 for high-speed and medium-speed diesel and gas engines
- A100-L
  - High-efficiency turbocharging for two-stroke diesel engines requiring compressor pressure ratios up to 4.7

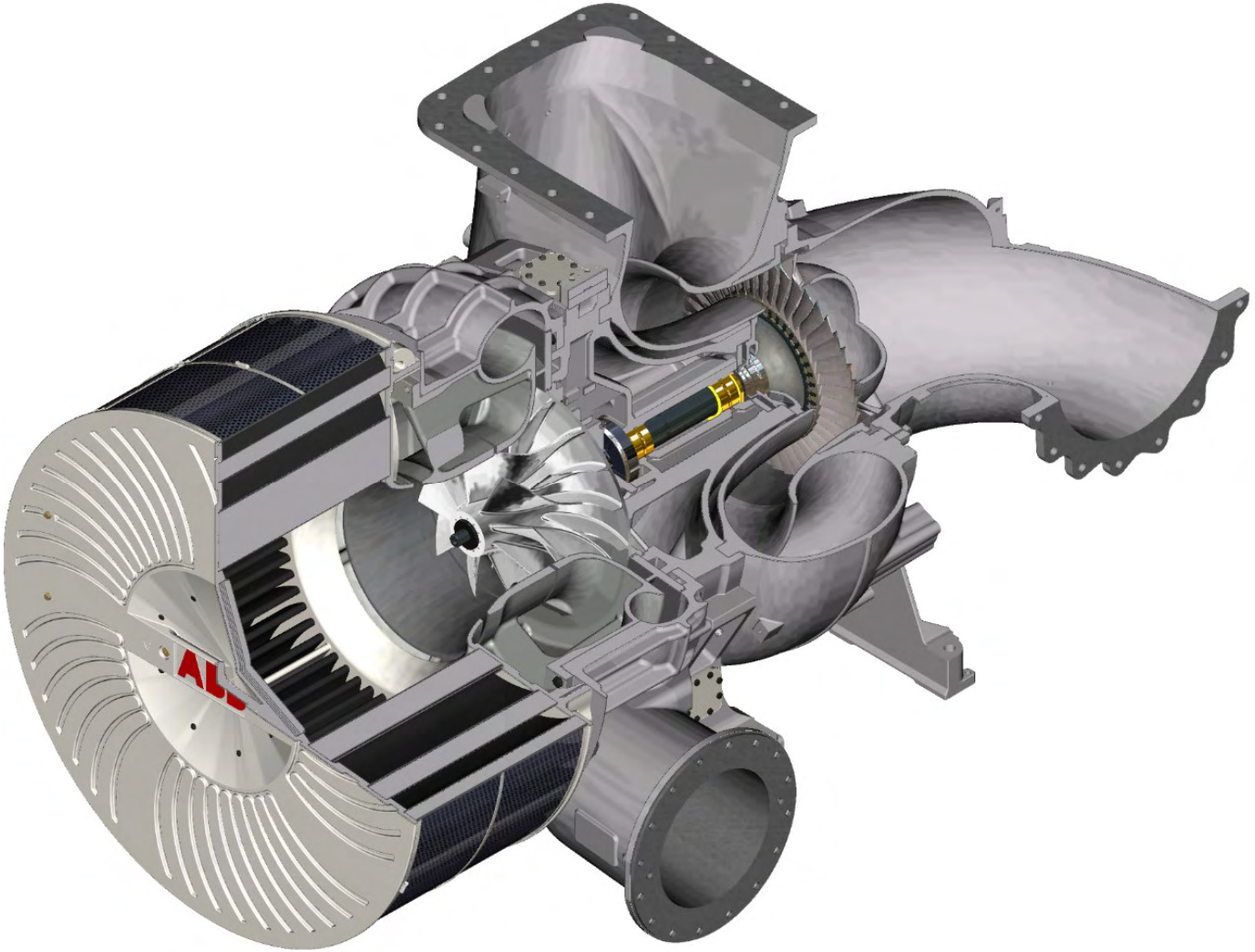
A100 Turbocharging outlook (4-stroke)



A100 Turbocharging outlook (2-stroke)



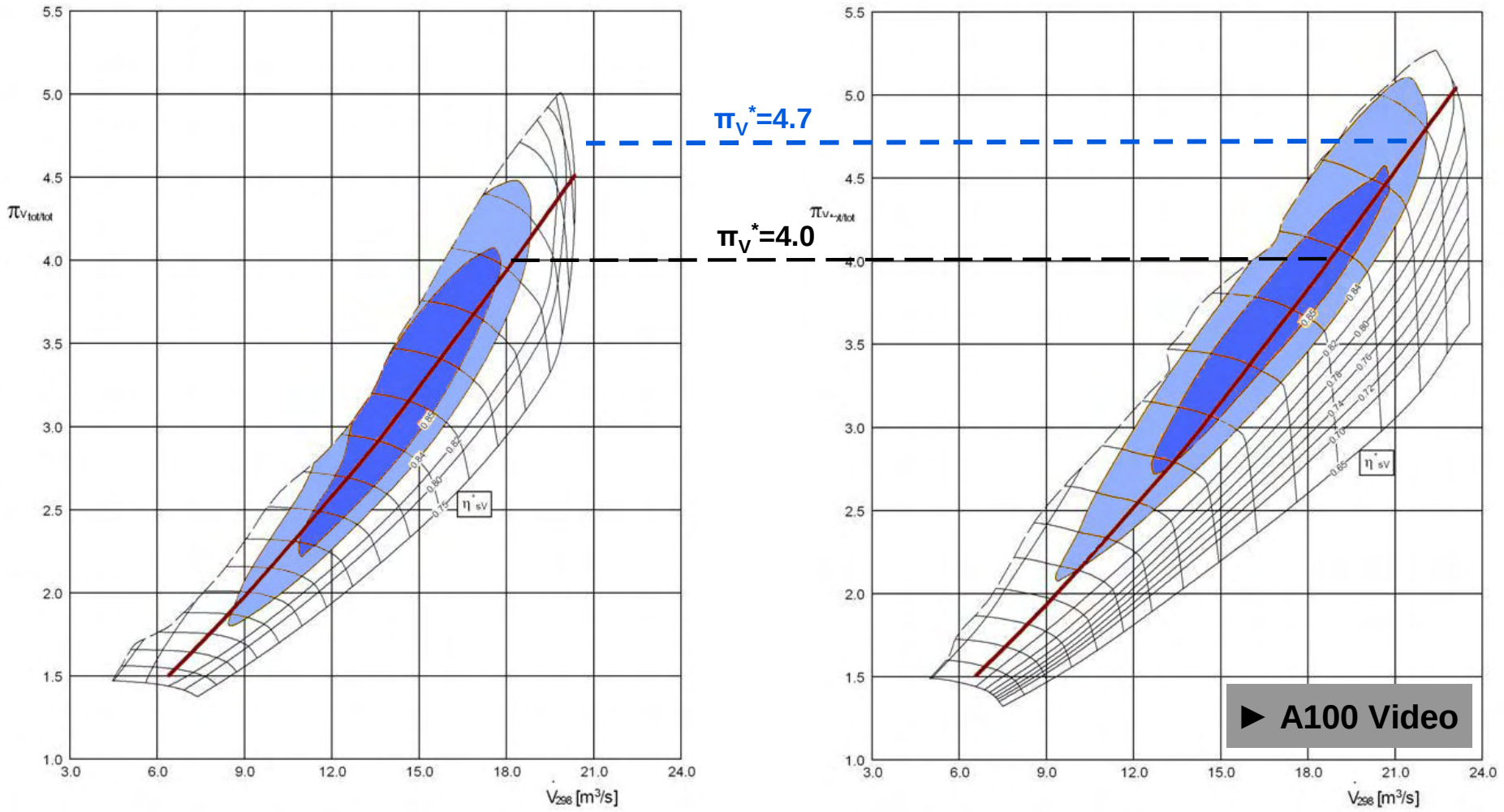
A100L – New for 2 stroke applications



Compressor performance

TPL..-B compressor

Compressor for future requirements



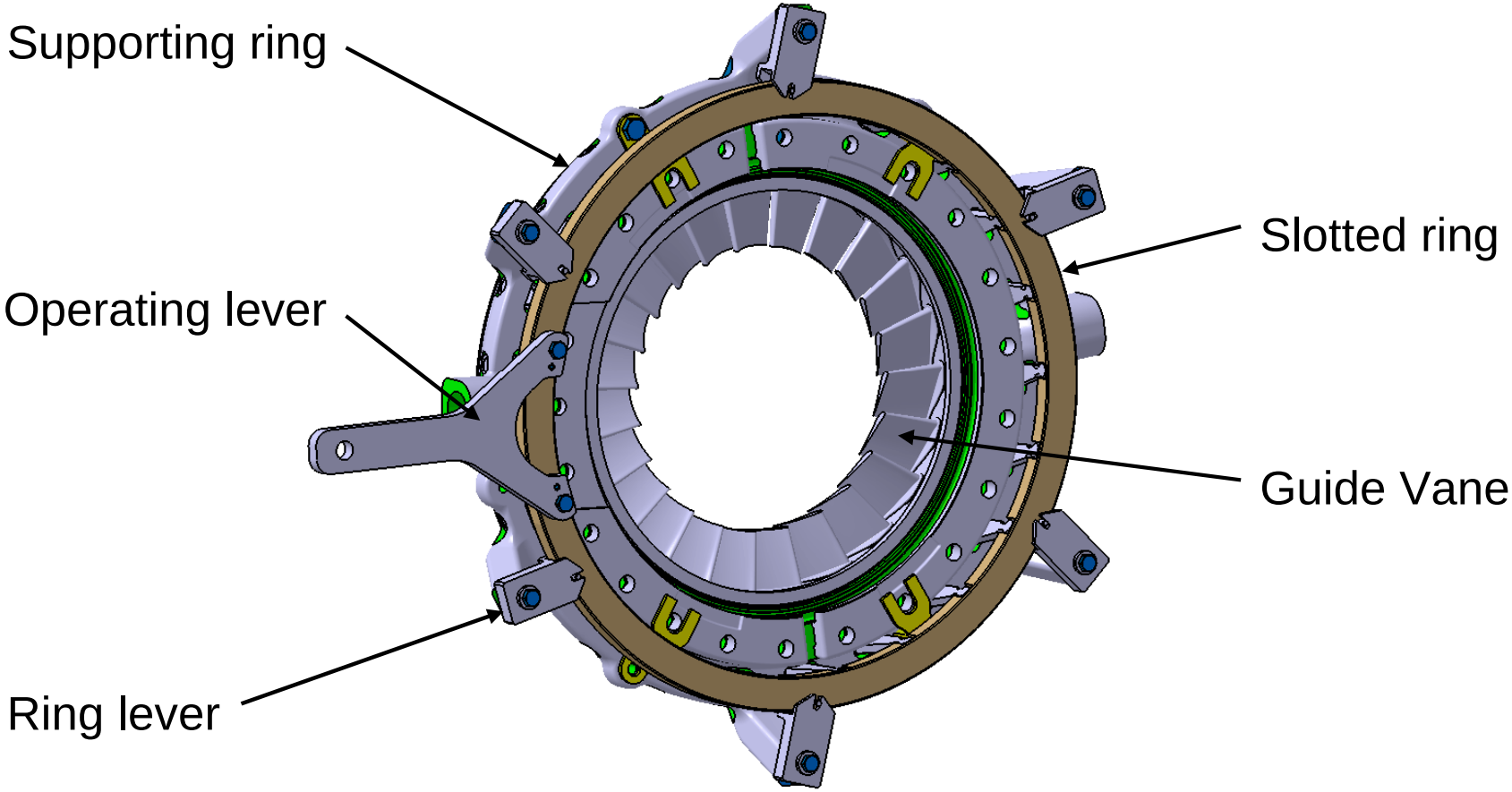
A100-L References
Status April 2010 - 77 x A100-L on 41 vessels

Projects	Engine type	Engine builder	MCR kW x RPM	TC type / engine	TC delivery
Maersk Kalea	1 x 6S46MC-C	HHM	7'860 x 129	1 x A175-L34T	03-2009
MS Monte Carlo	1 x 7RT-flex50	3. Maj	11'060 x 124	1 x A175-L35	03-2009
Alexander Maersk	1 x 7S50MC	HZDE	10'010 x 127	1 x A175-L34T	07-2009
HASU	6 x 8RT-flex96C	Doosan	45'760 x 102	2 x A190-L35	09-2010
Hansa Treuhand	4 x 10RT-flex96C	HHI	57'200 x 102	3 x A185-L35	08-2010
Leonhard& Blumberg	4 x 7K80ME-C	HHI	31'710 x 104	2 x A185-L34	11-2010
Oman	5 x 7RT-flex82T	HHI	31'640 x 78	2 x A180-L35	11-2010
Oman	3 x 7RT-flex82T	HHI	31'640 x 78	2 x A180-L35	01-2011
Saudi Maritime	2 x 7RT-flex82T	HHI	31'640 x 80	2 x A180-L34	02-2011
China Shipping	2 x 5S60ME-C	HHM	8'830 x 101	1 x A175-L32T	12-2010
CSCL	8 x 7RT-flex68D	Doosan	21'910 x 95	2 x A175-L34T	09-2010
Thoresen	4 x 6RT-flex50D	3. Maj	9'960 x 124	1 x A175-L32	05-2010

Content

- Turbocharging – Today & Tomorrow
- New Generation Turbocharger A100
- Variable Turbine Geometry
- Slow Steaming
- Service Aspects

Variable Turbine Geometry (VTG)
Working principle on axial type ABB turbochargers

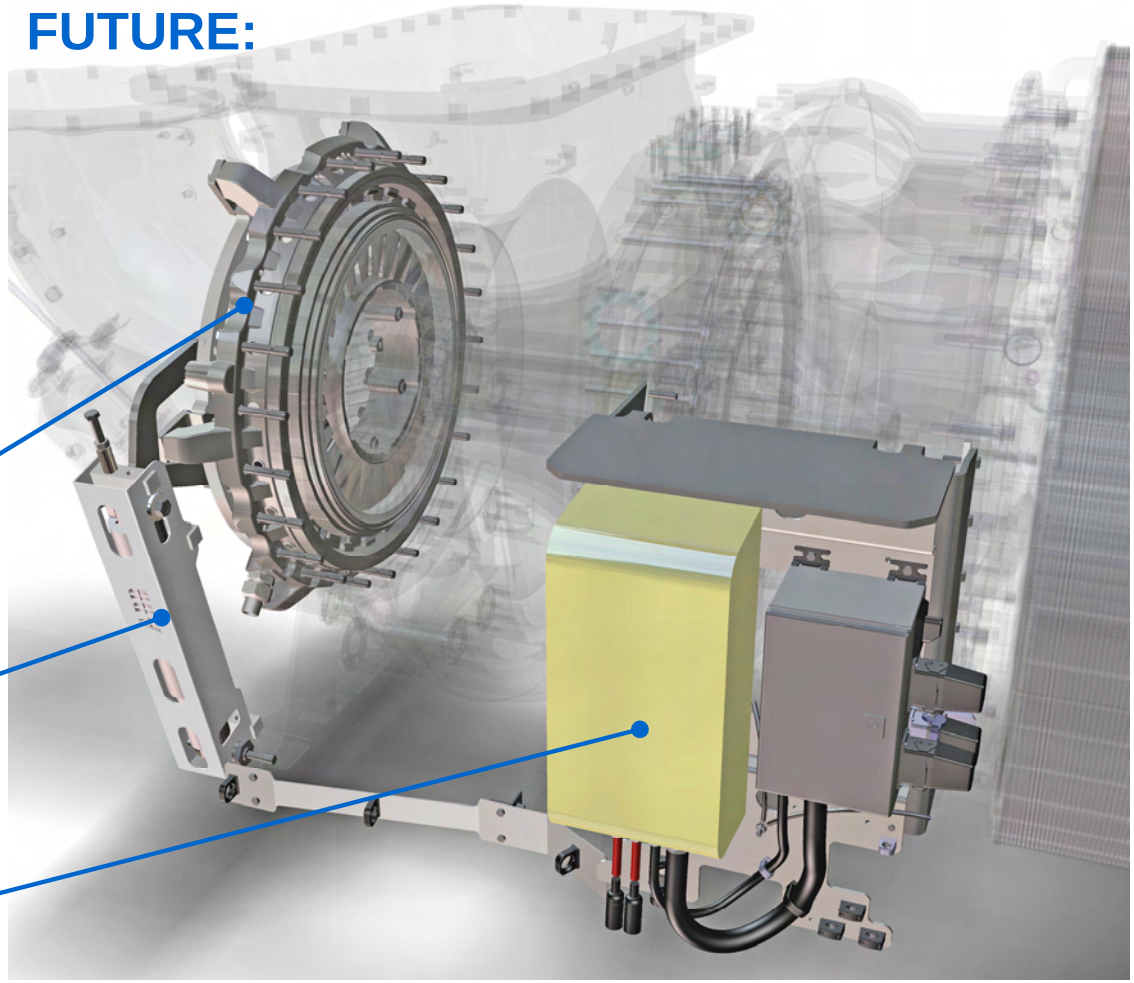


Variable Turbine Geometry (VTG) Status & Future

Status:

Over 800 ABB VTG units in service on TPL&TPS

FUTURE:

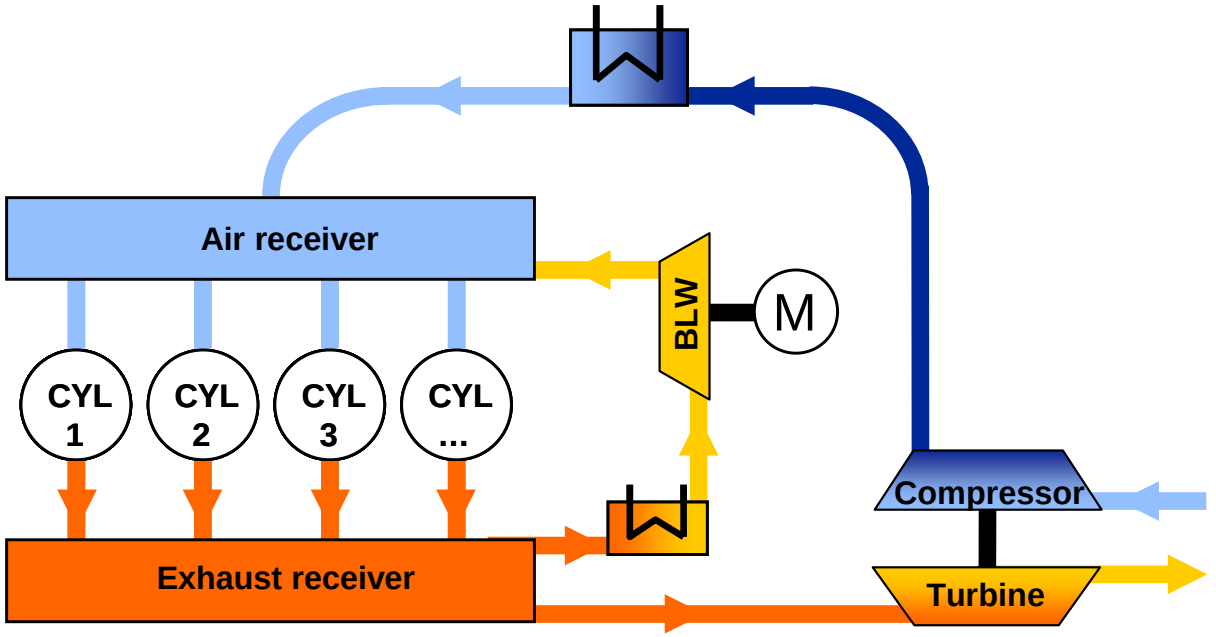


- 18’000 operating hours
- Overhaul of the complete VTG unit on exchange basis (CPEX)

A100-L with complete integrated VTG option

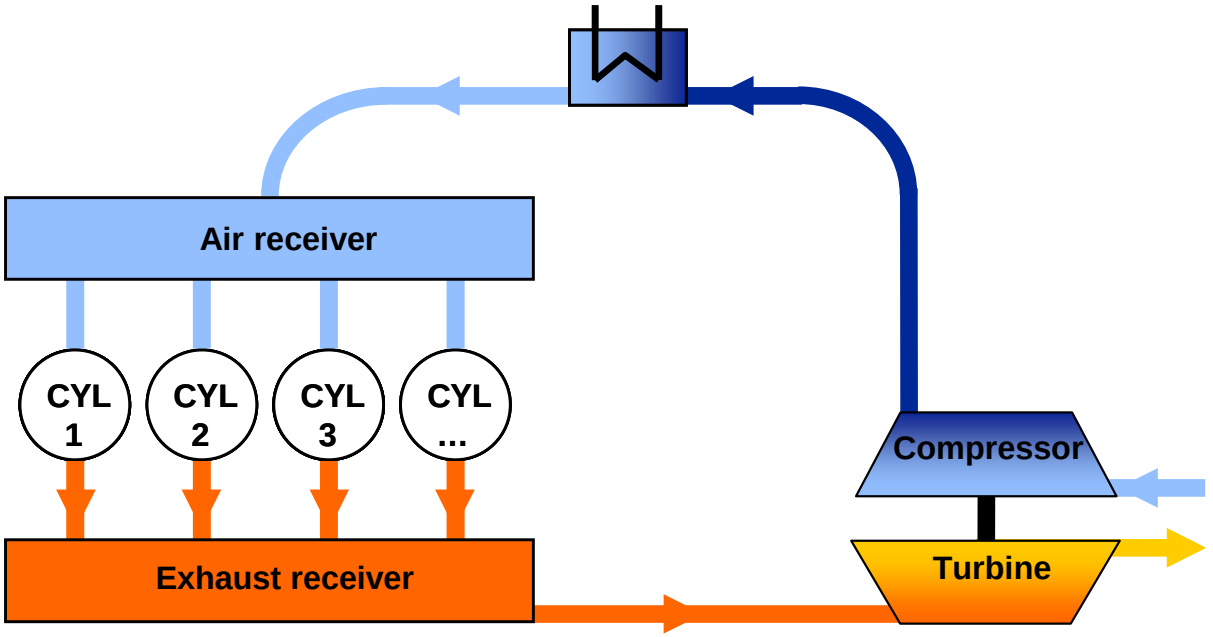
Two first serial units running in the field

Possible application fields under IMO Tier III
VTG with Exhaust Gas Recirculation (EGR)



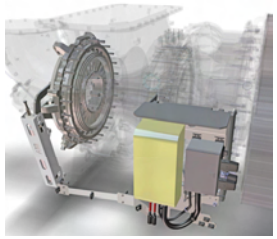
- **ECA mode**: EGR turned ON VTG “closed”

Possible application fields under IMO Tier III
VTG with Exhaust Gas Recirculation (EGR)



- **Open sea mode**: EGR turned OFF VTG “open”

Summary: Variable Turbine Geometry (VTG)



- VTG on ABB turbochargers is a proven technology.
- 10 years of field experience available with radial type TPS.
- 5 years of field experience available with axial type TPL.
- Benefits have been largest on gas engines in the past.

Advantages on diesel engines:

- Reduced thermal load at part load
- Less exhaust smoke
- Lower fuel consumption at part load
- Requirements according to IMO Tier III will open up new application fields for VTG in the area of marine engines.

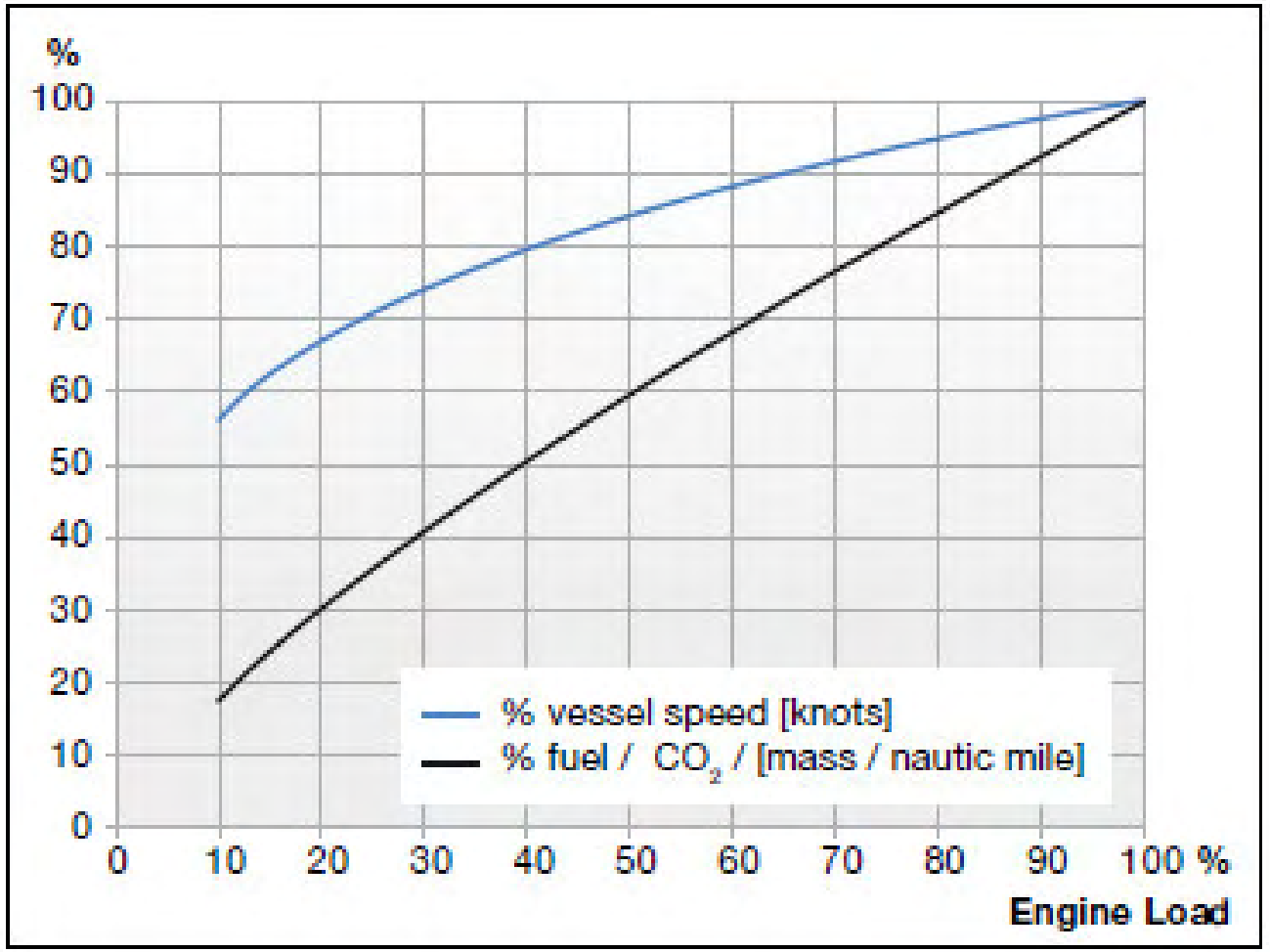
Content

- Turbocharging – Today & Tomorrow
- New Generation Turbocharger A100
- Variable Turbine Geometry
- Slow Steaming
- Service Aspects

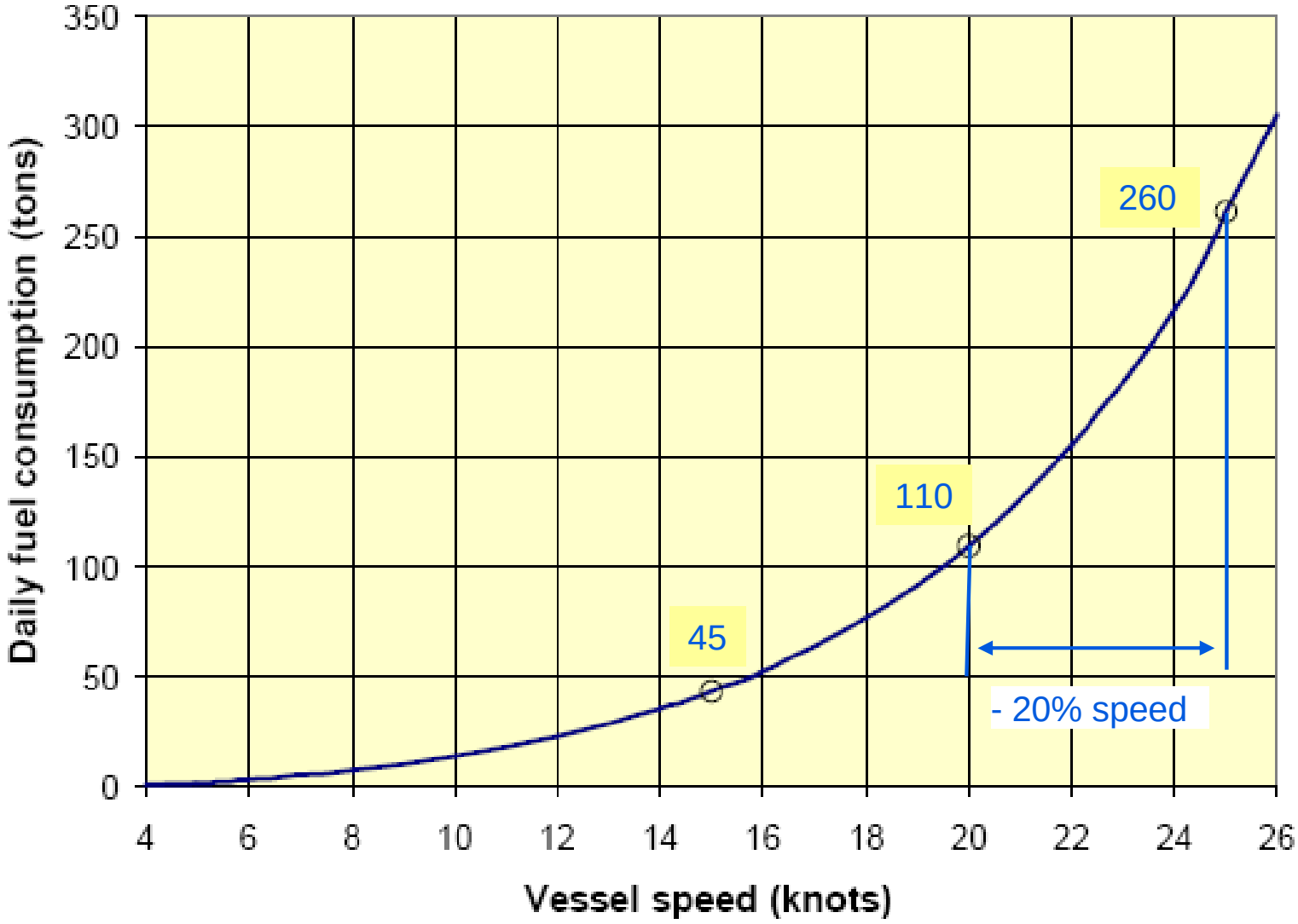
Slow steaming - Status

- The present shipping market seeks for cost reduction methods
- 20% vessel speed reduction results in 50% fuel savings, resulting in a strong demand for slow steaming today
- The turbocharger layout and operation are not affected by slow steaming
- MAN and Wärtsilä allow 10% engine load for continuous operation (see service letters)
- Further minor fuel savings can be achieved by various part load optimisation methods (e.g. TC cut out)
- Any engine or TC modifications may affect the IMO regulations and the NO_x certificate. Clarification with engine designer and classification society is necessary.

Slow steaming - Benefits



Slow steaming for large container vessel
MAN 12K98 & Wärtsilä 12RT96

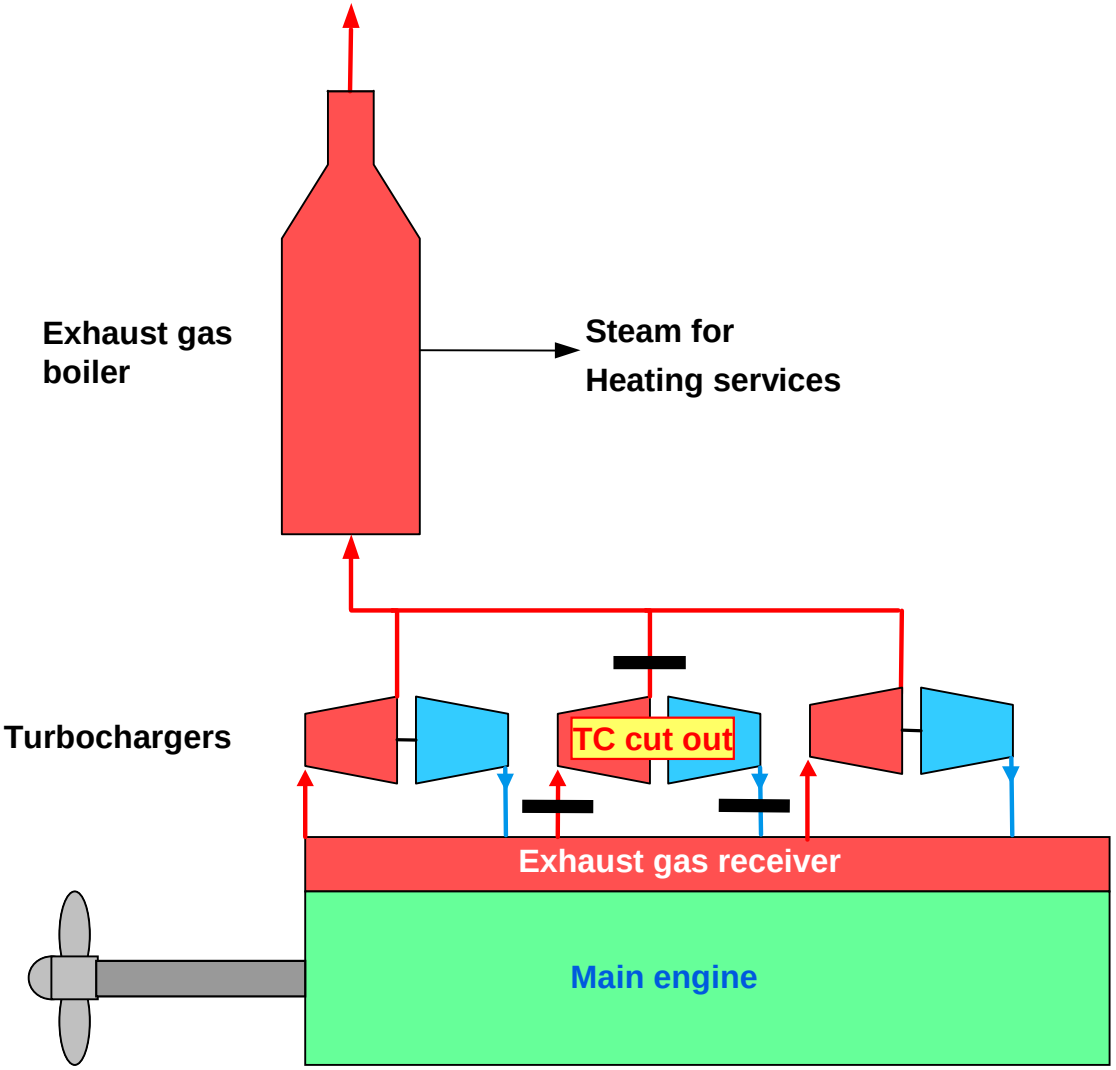


- 20% speed → fuel saving: 110t/day x 1.2 (time) / 260t/day = 50%

Slow steaming - turbocharger

System	Remarks
TC cut out ▪ fix ▪ variable	Possible for existing vessels and newbuildings
Exhaust gas bypass & tc spec change (part load optimisation)	Preferably for newbuildings
VTG (Variable Turbine Geometry)	Preferably for newbuildings for A100-L

Turbocharger cut out



Turbocharger cut out

Turbocharger cut out:

Engine make (OEM) to be involved

1 of 1 TC, 15% power, only for emergency running

1 of 2 TC's, 50% power, to be investigated by OEM

1 of 3 TC's, 66% power

1 of 4 TC's, 75% power

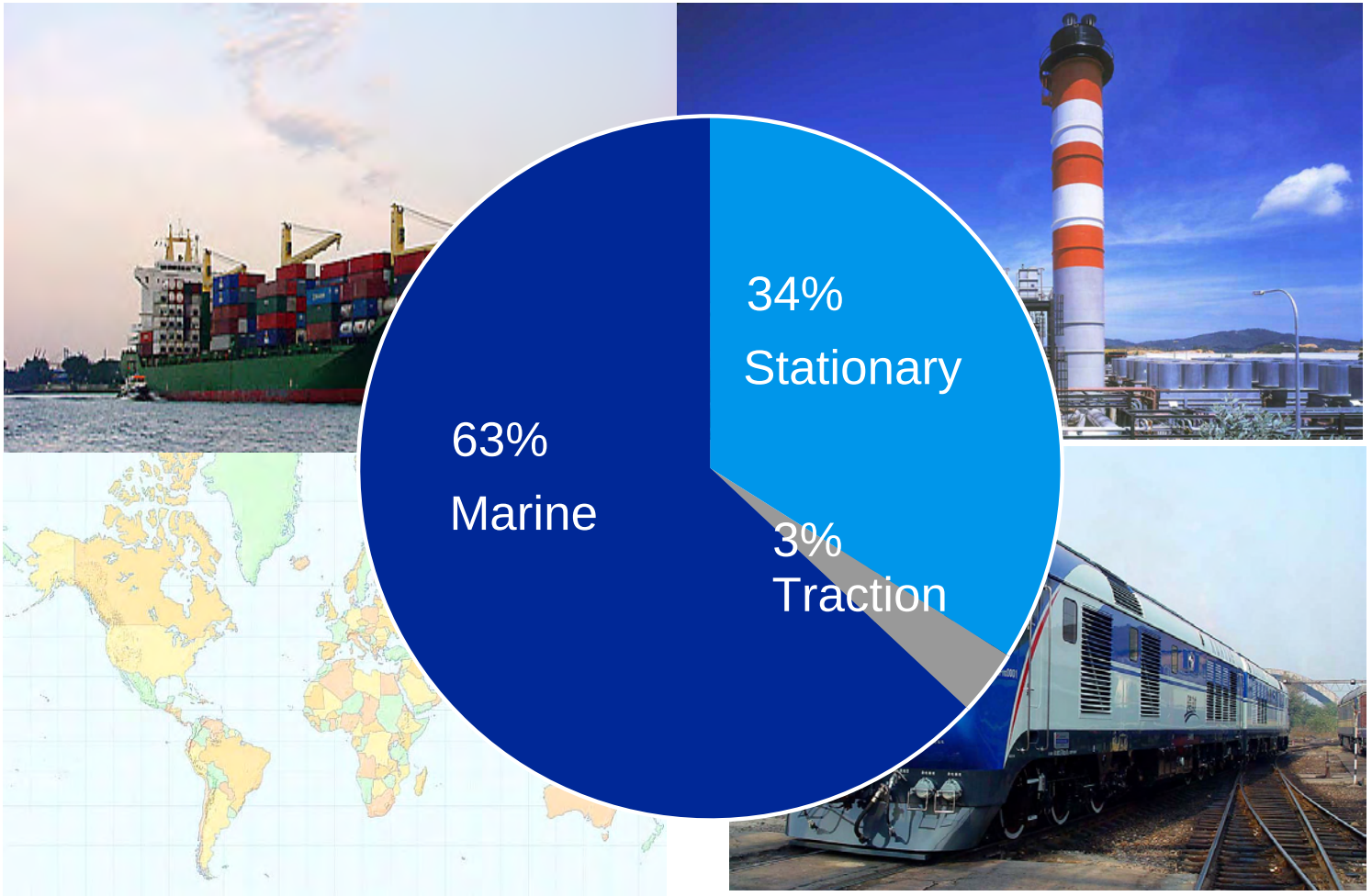
Considerations:

- Limited service experience with flexible TC cut out
- IMO NOx certification and MCR?
- Engine performance
- Torsional vibrations
- Bearing load

Content

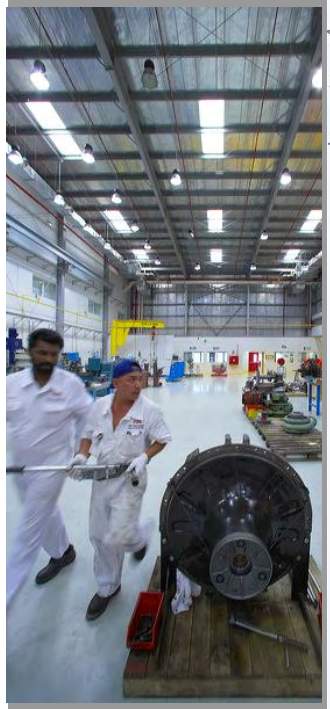
- Turbocharging – Today & Tomorrow
- New Generation Turbocharger A100
- Variable Turbine Geometry
- Slow Steaming
- Service Aspects

About 190‘000 ABB Turbochargers in operation



The unique worldwide service

> 100 sales & service stations in 55 countries



status 2010

Spare Part Center Baden/Switzerland

- 24 hours / day
- 365 days a year
- Inventory positions: 11‘000
- 18,000 orders per year
- Availability: >98%

Turbocharger transportation

Database - ATURB@Web

Power and productivity
for a better world™