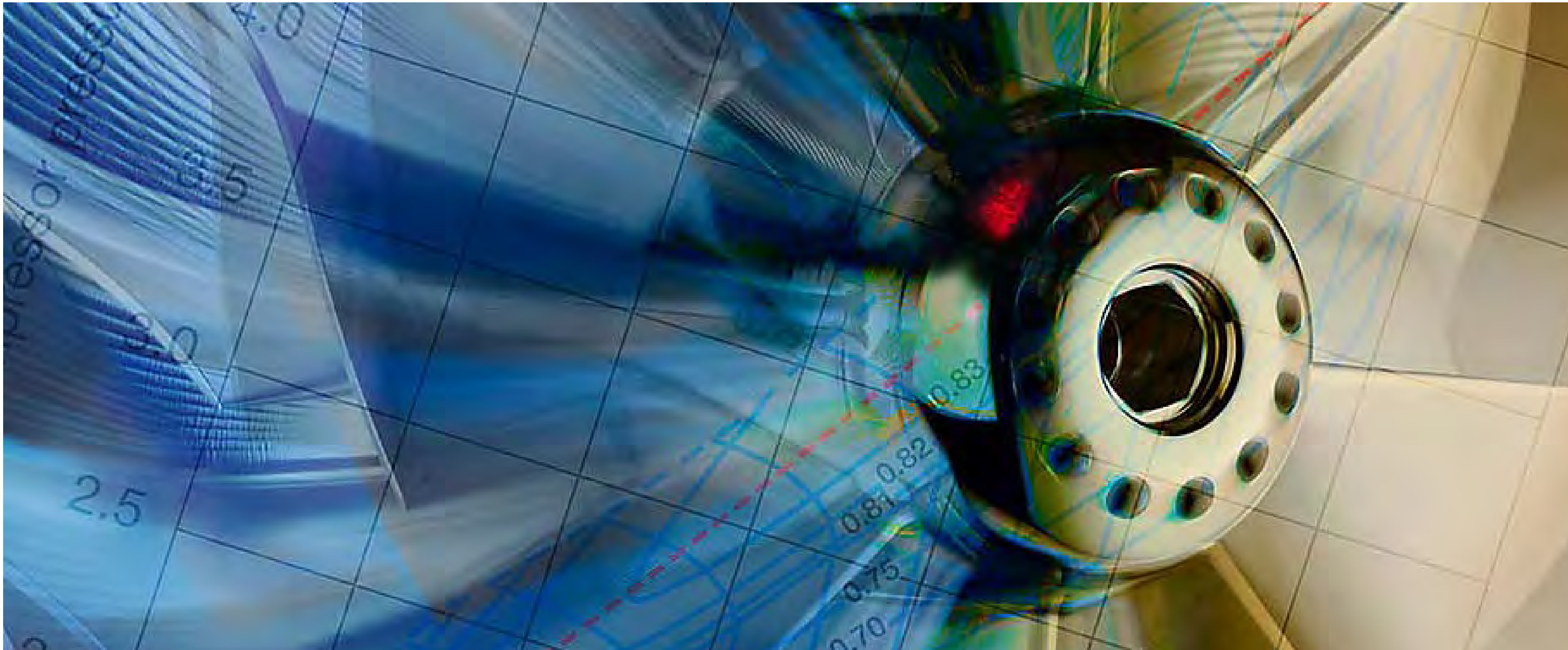

Allan Wang, ABB Jiangjin Turbo Systems Co., Ltd, China

Impact of Turbocharging on Fuel Consumption and Emissions

CIMAC Circle, Marintec 2009, Shanghai

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Impact of Engine Technology Drivers on Turbocharging

Engine Technology Driver

- Emission Legislations
- Fuel Efficiency
- Power Density
- First costs
- Operational costs
- Reliability
- Fuel Flexibility
- Alternative Fuels

Resulting TC Requirements

Pressure Ratio
Efficiency

More tailored Products
Shorter Development Cycles

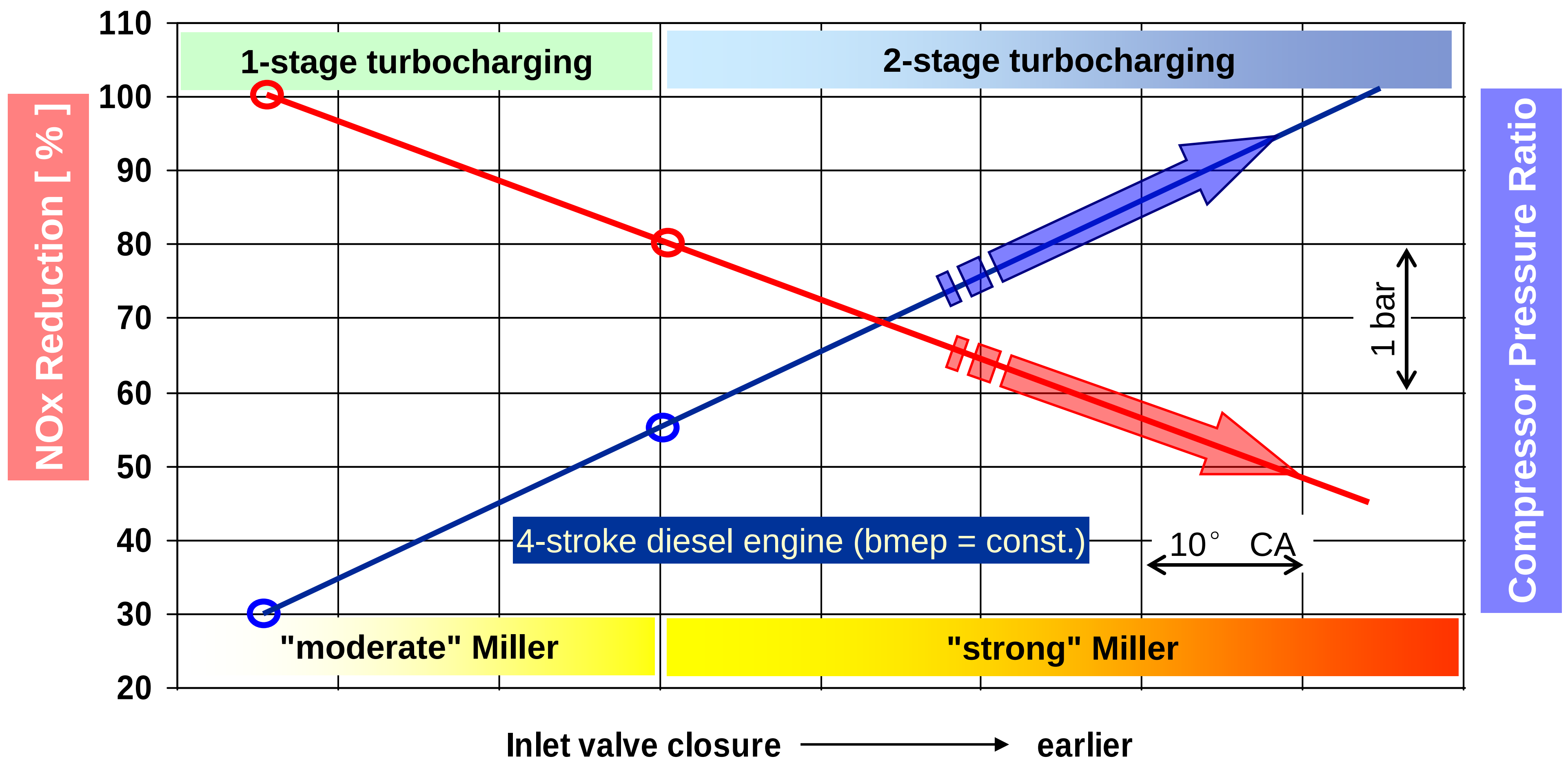
NOx Emission Reduction Technologies

Technology	NOx-reduction potential	Impact on bsfc / CO_2	Additional operating costs	Impact on turbocharging (PIC, ETA)
Engine / air systems optimization (CR, <u>moderate</u> miller, 1-stage TC)	↘	→	→	↗
Engine / air systems optimization (CR, <u>strong</u> miller, VVT, 2-stage TC)	↓	↓	→	↑
Low EGR rate (15%)	↘	→ ↗	↗	↗ *)
High EGR rate (30%)	↓	↗	↗	↗ ↑ *)
Wet measures - Direct water injection - Air humidification - Fuel water emulsion	↓	↗	↑	→ ↗ *)
Exhaust after treatment (SCR)	↓ ↓	→	↑ ↑	→ ↗ *)

NOx reduction: up to 30% (↘), 30-60% (↓), above 60% (↓ ↓)
bsfc / CO_2 impact: neutral (→), up to +2..3% (↗); up to -5% (↓)
Additional operating costs: none (→), 1% (↗), 2..3%(↑), >3% (↑ ↑) of fuel price

*) Miller timing advantageous to reduce cylinder out emission ⇨ lower additional operating costs and bsfc

Impact of Miller Timing on NO_x and PIC

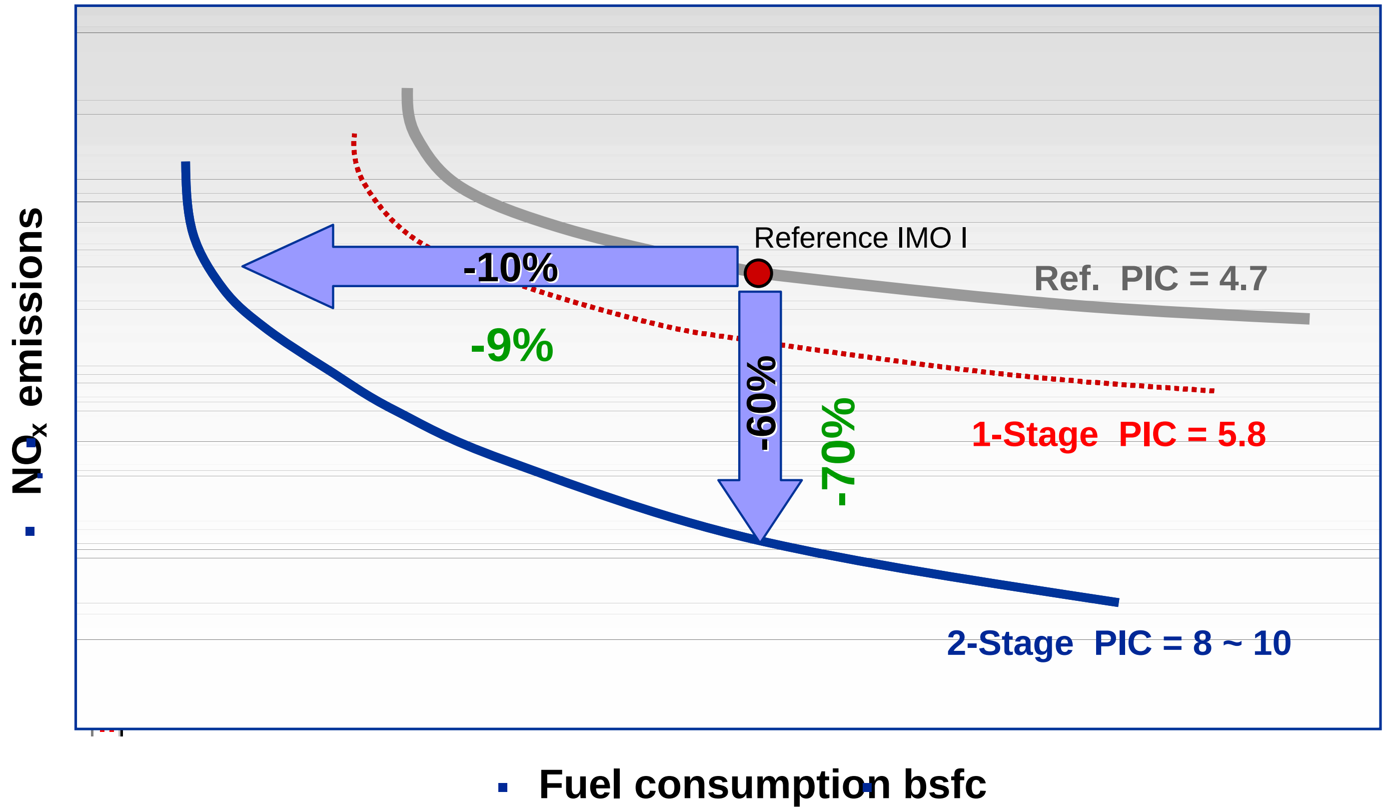


Source: CIMAC Congress 2007, Paper No. 101

Favorable NO_x - bsfc Trade-off with Miller Cycle
Potential 4-stroke Diesel Engines

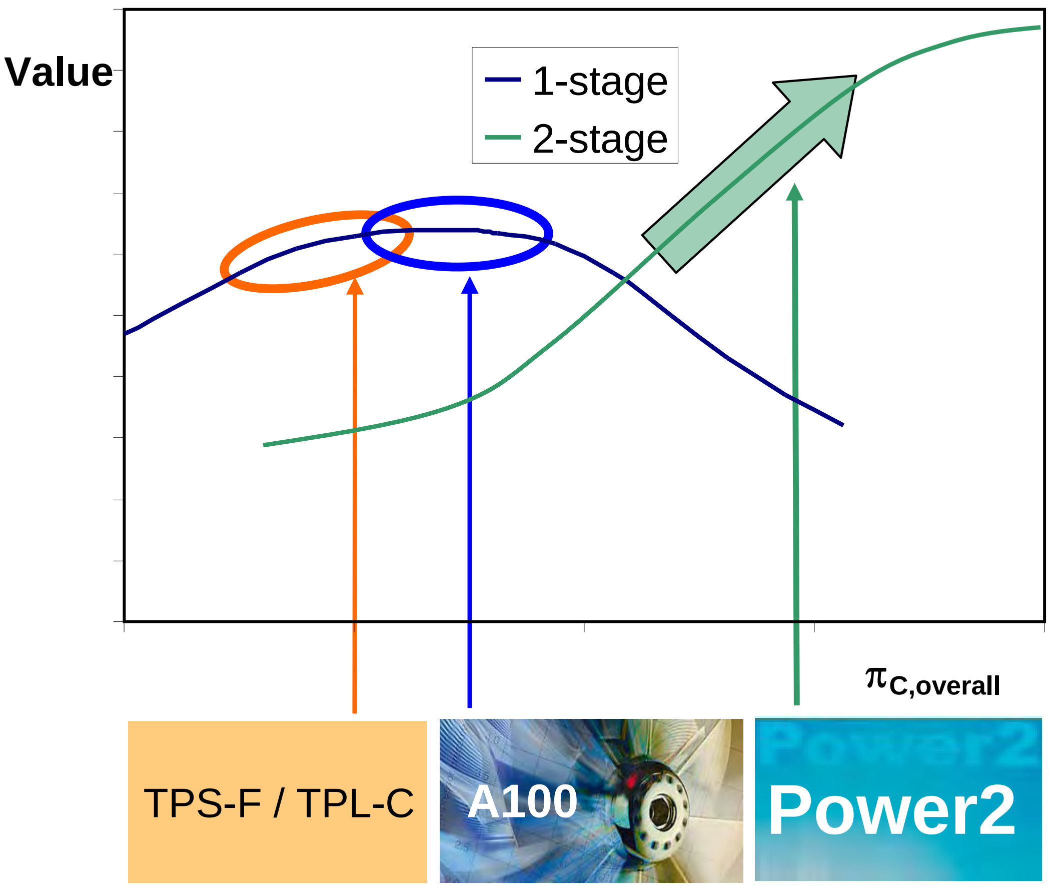
Source: CIMAC Congress 2007 Paper No. 245

Source: ATK Dresden 2009



	Status 2007	Update 2009
NO_x emission potential:	-60% at constant bsfc	-70% at constant bsfc
bsfc potential:	-10% at constant NO_x	-9% at constant NO_x

Value Fuction 1- and 2-stage Turbocharging



1-stage $\pi_{sV} > 5.8$

- increased TC-size
- limited η_{TC}
- limited matching flexibility
- higher stress level

2-stage $\pi_{sV} > 6.5$

- smaller TC sizes
- increased η_{TC}
- matching flexibility high
- lower stress level
- improved load response

ABB A100 Turbocharger Generation
Single-stage / High Efficiency / High Pressure

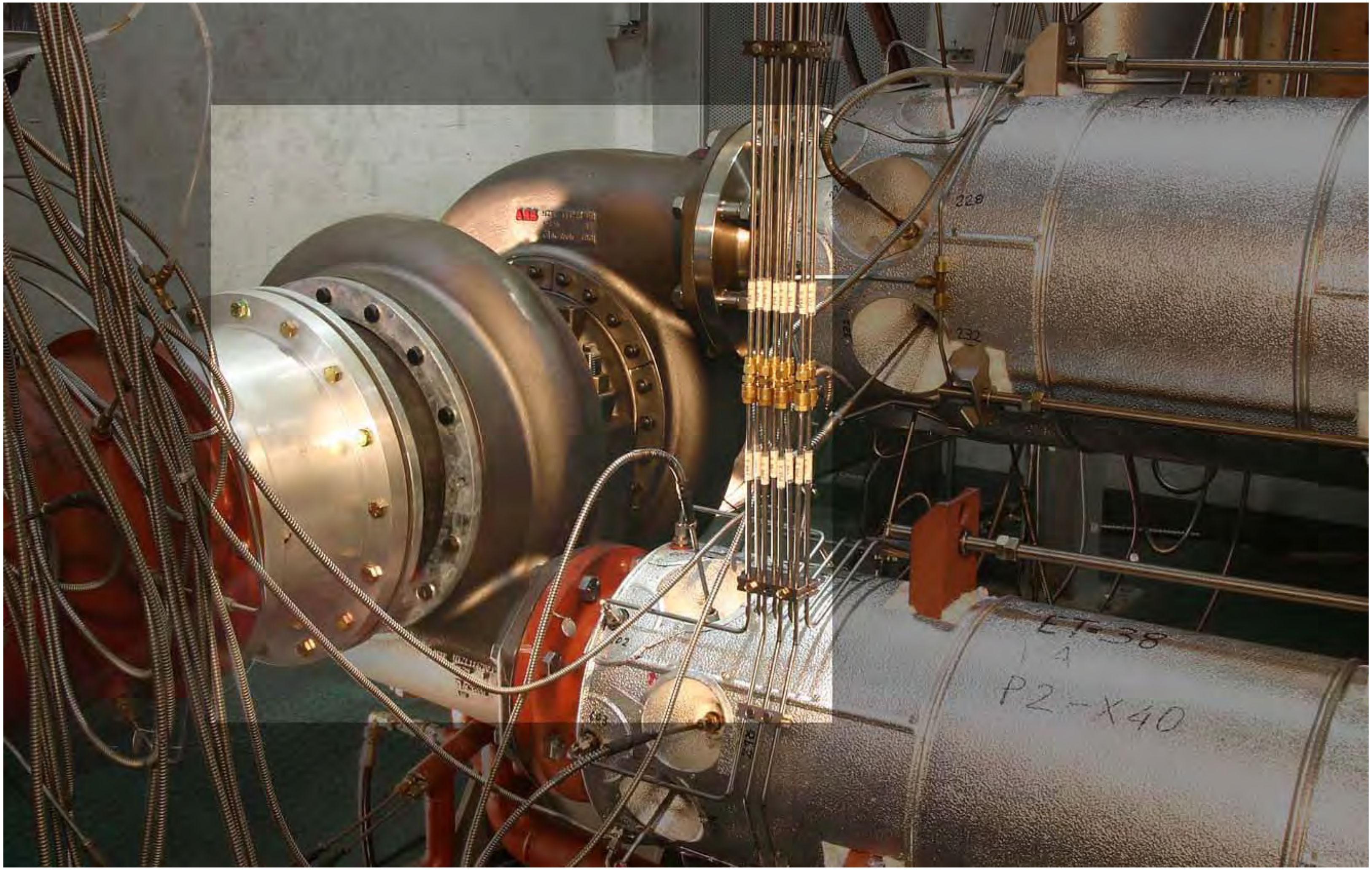
A100-H = for high speed engines

A100-M = for medium speed engines

A100-L = for low speed engines

- A100-H
  - Pressure ratio up to 5.8
  - Turbocharger efficiency close to 68%
- A100-M
  - Pressure ratio up to 5.8
  - Turbocharger efficiency up to 68%
- A100-L
  - Pressure ratio up to 4.7
  - Turbocharger efficiency up to 75%
- ABB A100 turbocharger generation is an enabler for meeting the IMO II regulations, while eliminating or limiting bsfc penalties.

ABB Prototype 2-stage Turbocharging



High pressure TC on test rig / Switzerland / September 2008

Conclusions

- High performance turbocharging supports low emissions and high fuel efficiency engine concepts.
  - ABB A100 turbocharger generation is the today's enabler for meeting IMO II regulations, while eliminating or limiting bsfc penalties.
  - ABB 2-stage turbocharging is currently tested on engines, and will be one of key technologies for meeting IMO III regulations in the near future.
- High performance turbocharging is a benefit for everybody.
  - For the enduser: lower fuel consumption
  - For the engine builder: higher power density
  - For the environment: less NO_x and CO_x

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