Efficient Propulsion for Seagoing Vessels

Wärtsilä Switzerland
Application Development

Heinrich Schmid

Efficient Propulsion for Seagoing Vessels

Introduction

Engine design

- RT-flex electronic engine technology
- WHR for reduced emissions
- Puls lubrication system

Propulsor design

- Tip rake propeller
- Efficiency rudder

Conclusion

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Efficient Propulsion for Seagoing Vessels

- To consume minimum amount of fuel to achieve a defined ship speed
- To generate minimum emissions such as CO2, NOx, SOx and combustion particles for a defined vessel speed

Influences:

⇨ Ship hull geometry	Shipyard
⇨ Engine engine design and technology	Engine designer
⇨ Propulsor design and technology	Propulsor designer

A good economy of the vessel must be respected by applying efficiency improvement concepts

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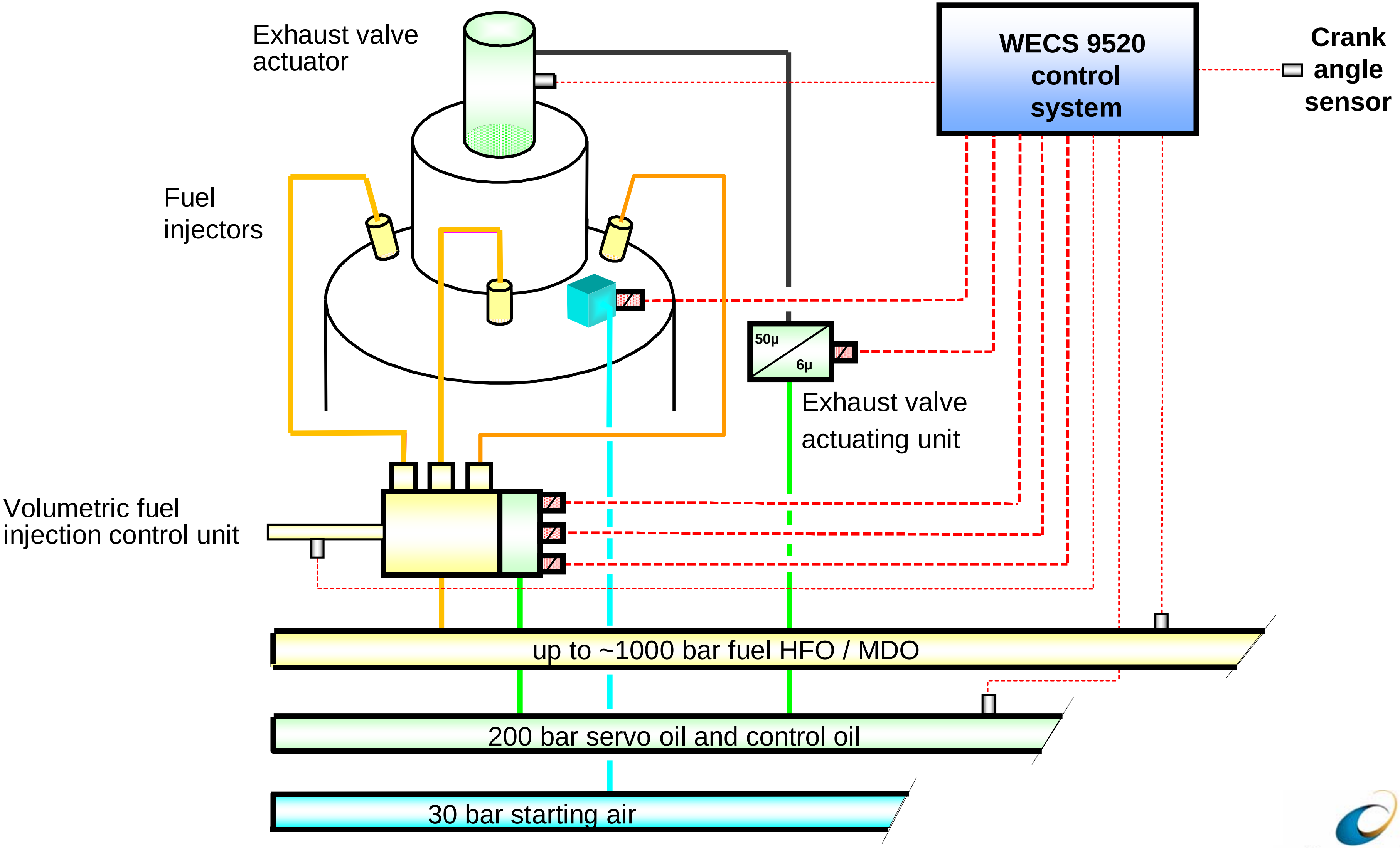
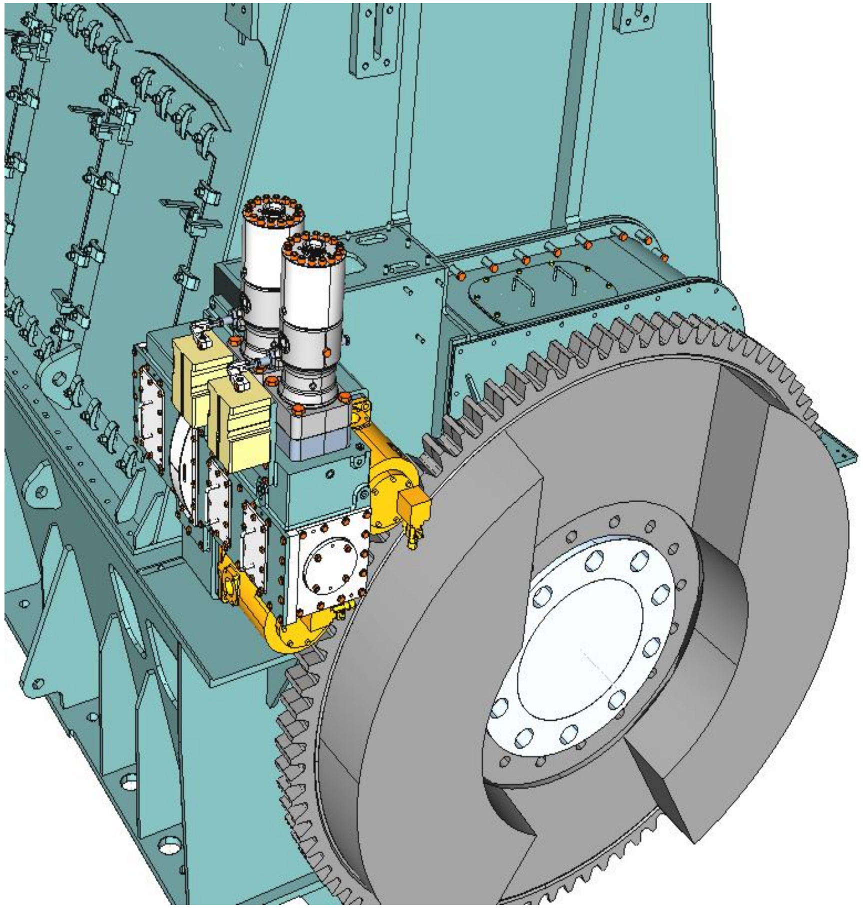
Efficient Propulsion for Seagoing Vessels

Reduced emissions with the RT-flex common rail engine



Efficient Propulsion for Seagoing Vessels

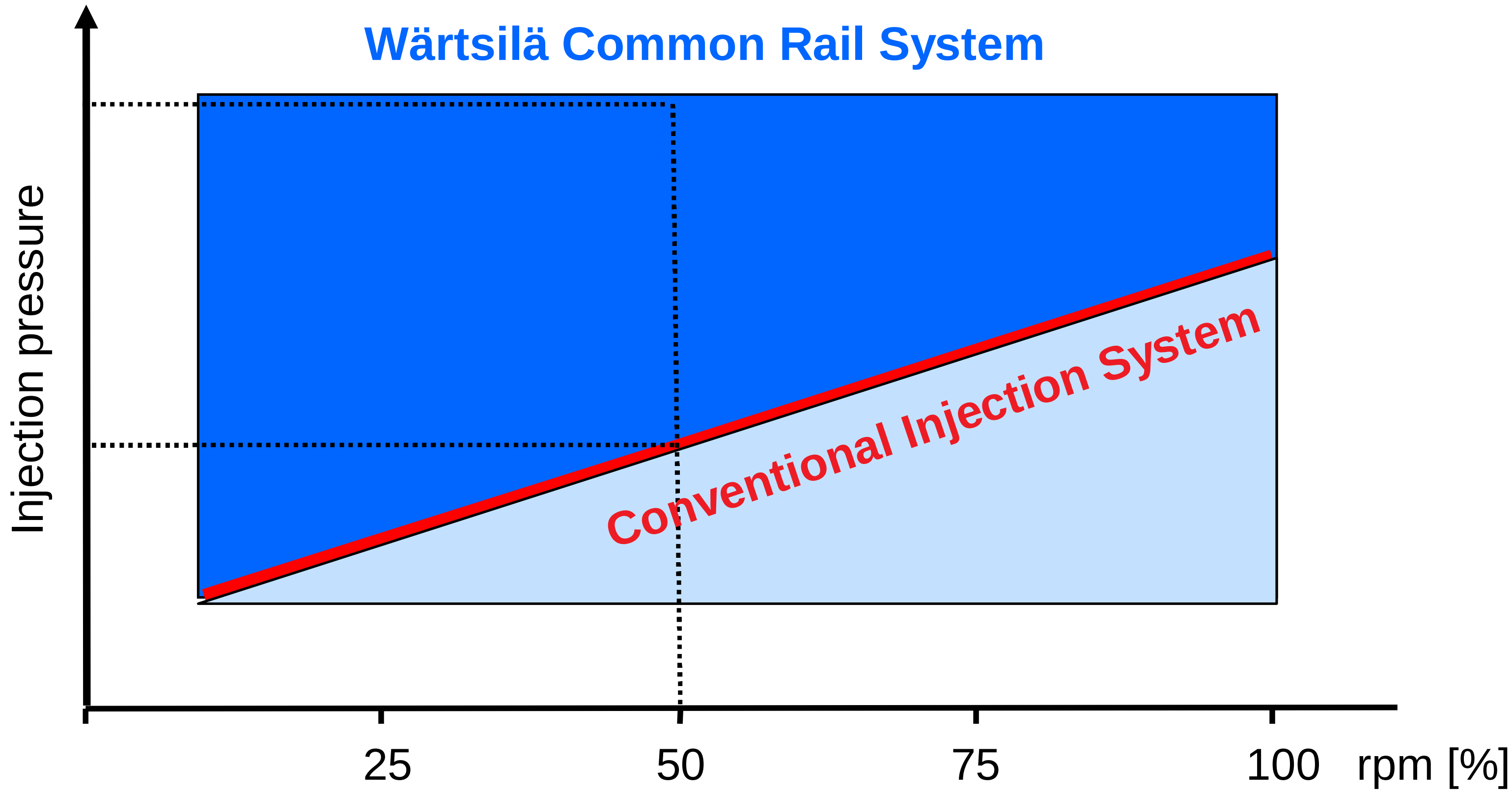
Reduced emissions with the RT-flex common rail engine



- **Direct mechanical gear drive**
- **Generates 1000 bar fuel oil pressure with high efficiency fuel pumps (jerk type)**
- **Generates 200 bar servo oil pressure with reversible oil pumps (axial piston type)**
- **Pumps' capacity ensures redundancy in case of failure**

Efficient Propulsion for Seagoing Vessels

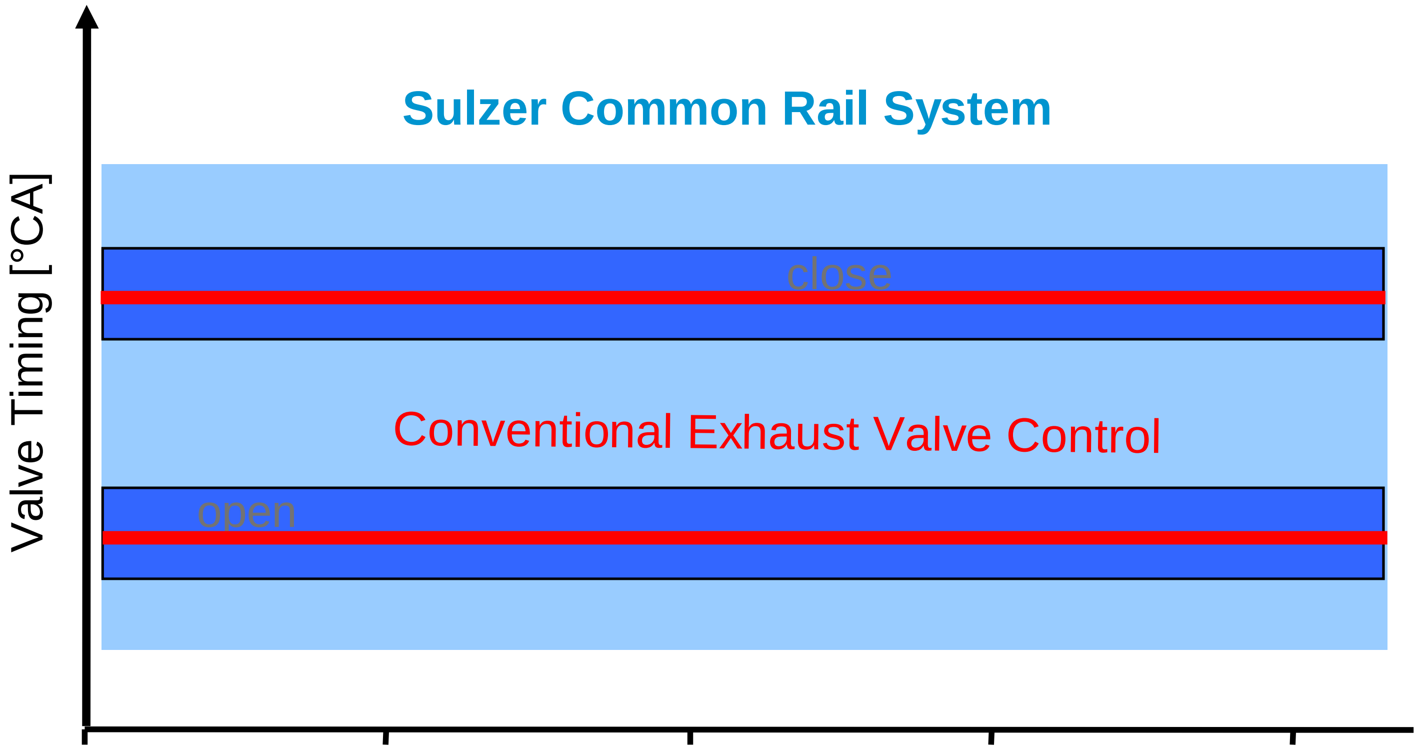
Reduced emissions with the RT-flex common rail engine

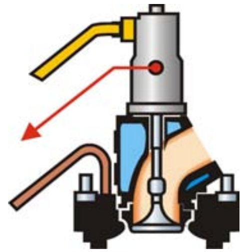


Free selectable injection pressure
for low NOx emissions, high efficiency and no smoke at all loads

Efficient Propulsion for Seagoing Vessels

Reduced emissions with the RT-flex common rail engine

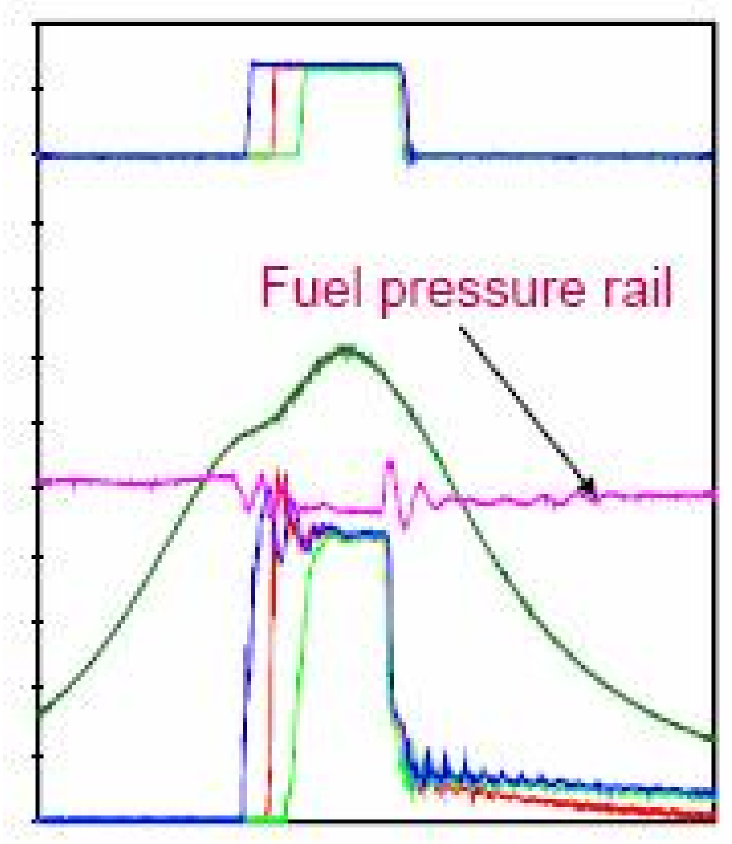




Free selectable exhaust valve timing
for high efficiency, low NOx level, smokeless operation
Special timing for emergency braking and rapid engine loading possible

Efficient Propulsion for Seagoing Vessels

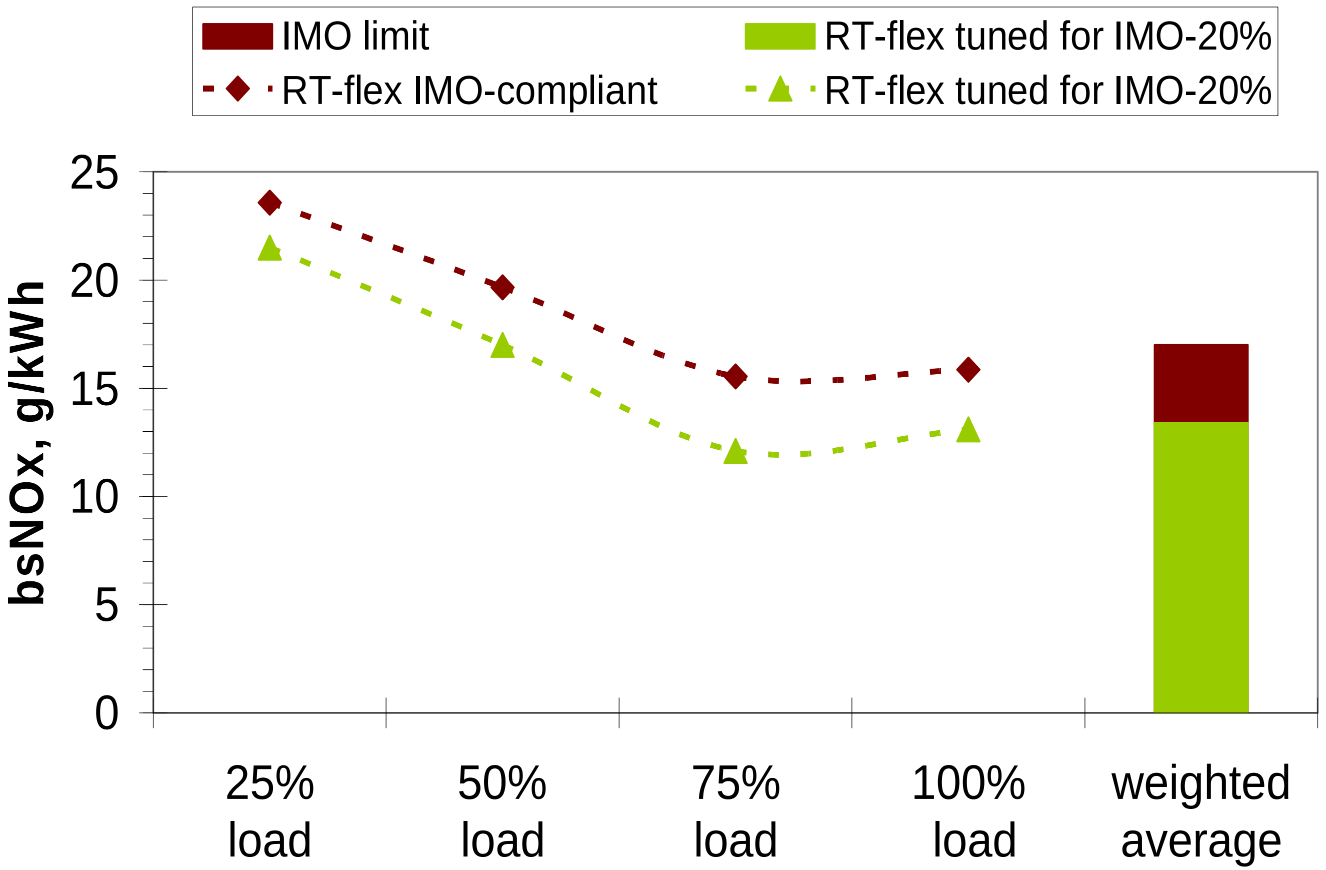
Reduced emissions with the RT-flex common rail engine



Reduced NOx emissions through sequential fuel injection mode

Efficient Propulsion for Seagoing Vessels

Reduced emissions with the RT-flex common rail engine



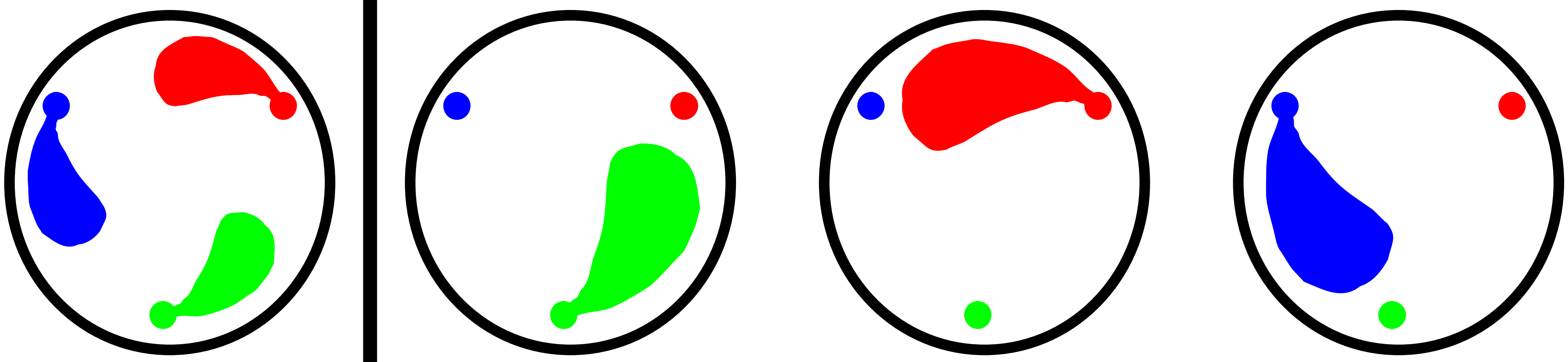
Low-NOx injection:

- Sequential injection
- Adapted injection pressure
- Adapted injection timing

Efficient Propulsion for Seagoing Vessels

Reduced emissions with the RT-flex common rail engine

Sequential operation of single injection nozzles for super dead slow operation



1-nozzle operation for super-dead-slow operation

smokeless down to 10 to 12% rpm R1

(12rpm for 6RT-flex58T-B)

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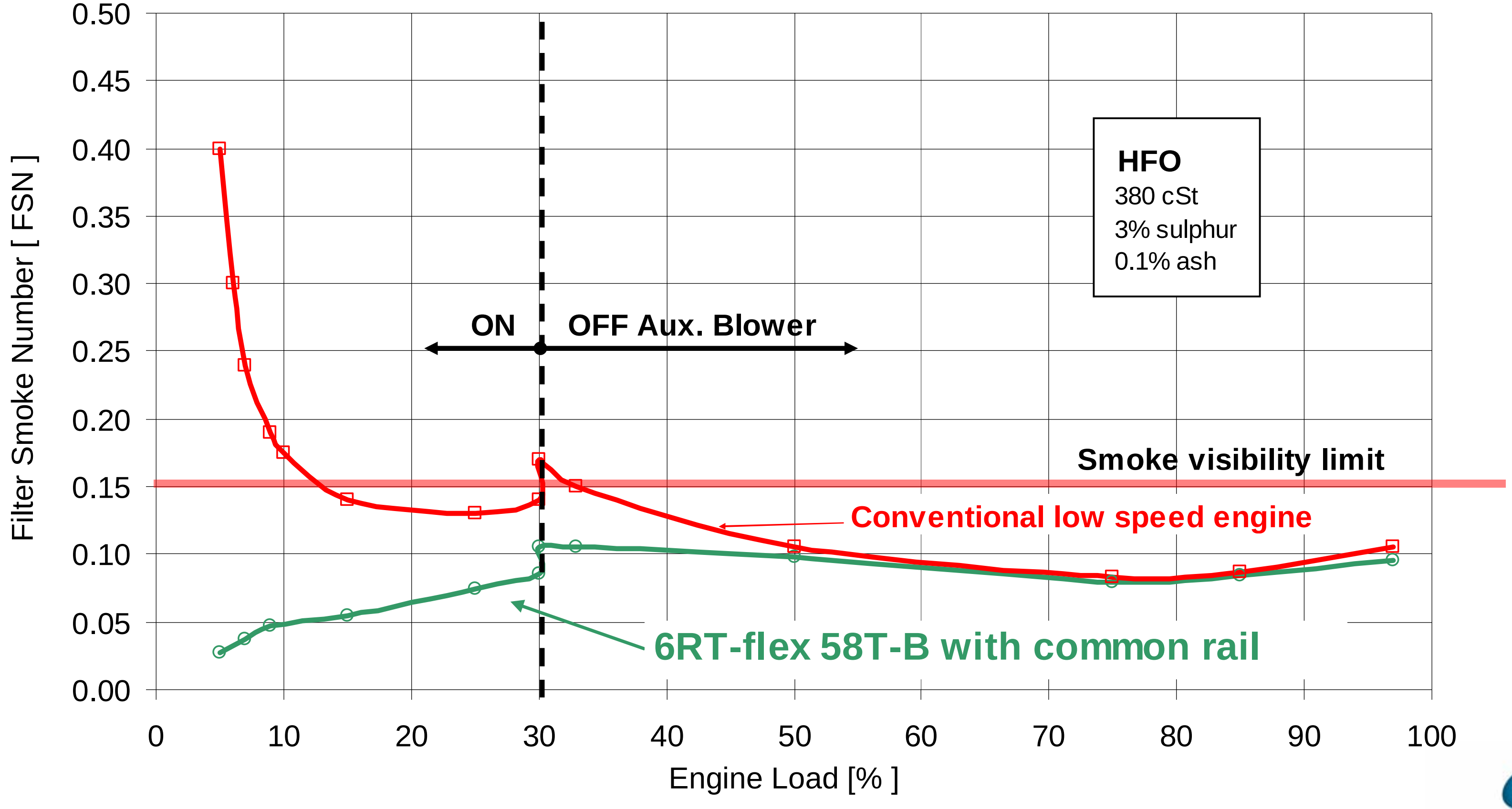
Efficient Propulsion for Seagoing Vessels

Reduced emissions with the RT-flex common rail engine

Smoke free operation over the entire load range

Sulzer 6 RT-flex58T-B MV Gypsum Centennial
Smoke measurement on combinator curve during sea trial



Efficient Propulsion for Seagoing Vessels

Reduced emissions with the RT-flex common rail engine

Smoke free operation over the entire load range

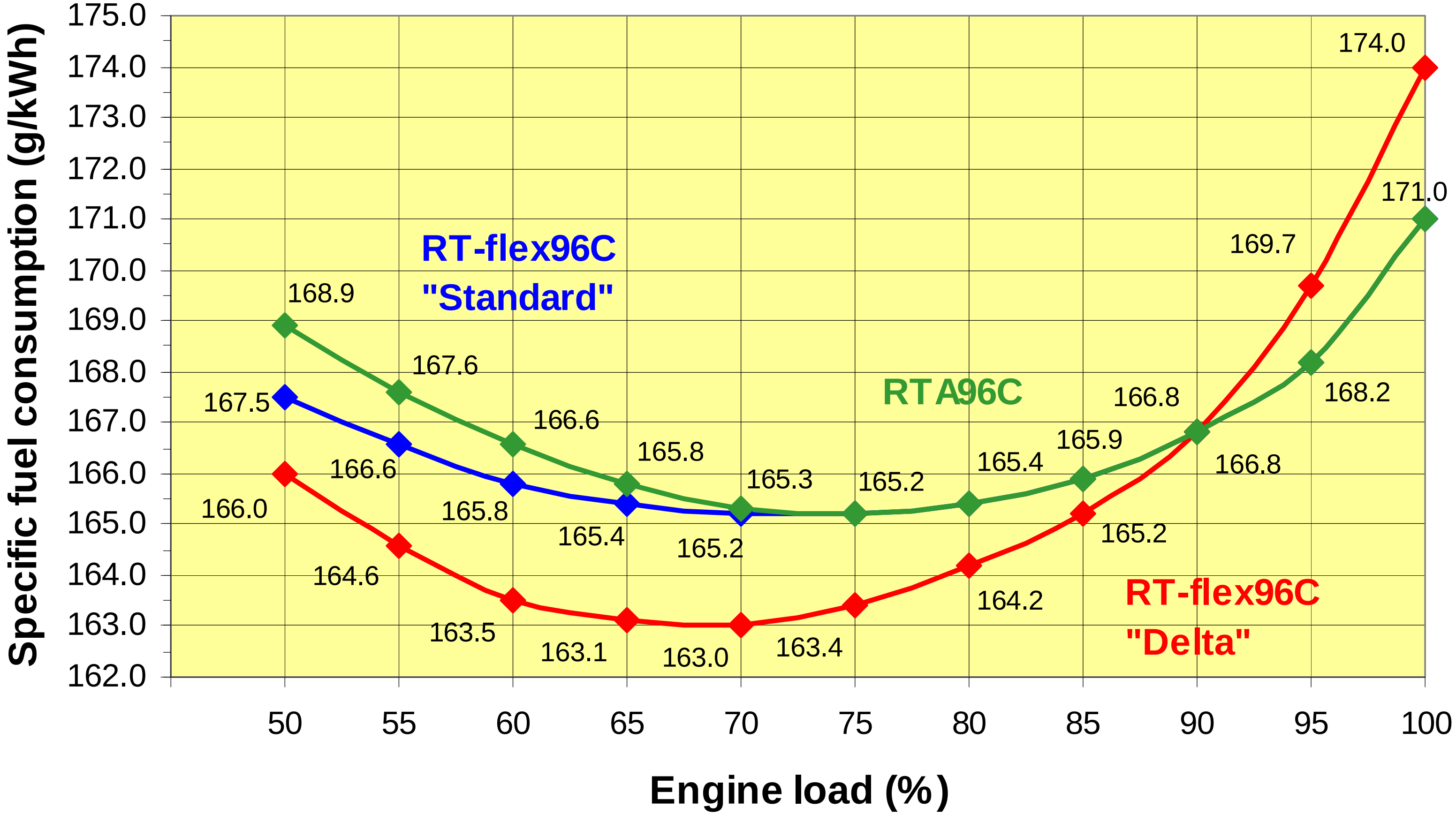
Smokfree operation means less combustion particles in the exhaust

- Cleaner combustion space
- Less deposits in turbochargers
- Less deposits in exhaust gas boiler
  Lower risk for a boiler fire
- Less combustion deposits on deck

Efficient Propulsion for Seagoing Vessels

Reduced emissions with the RT-flex common rail engine

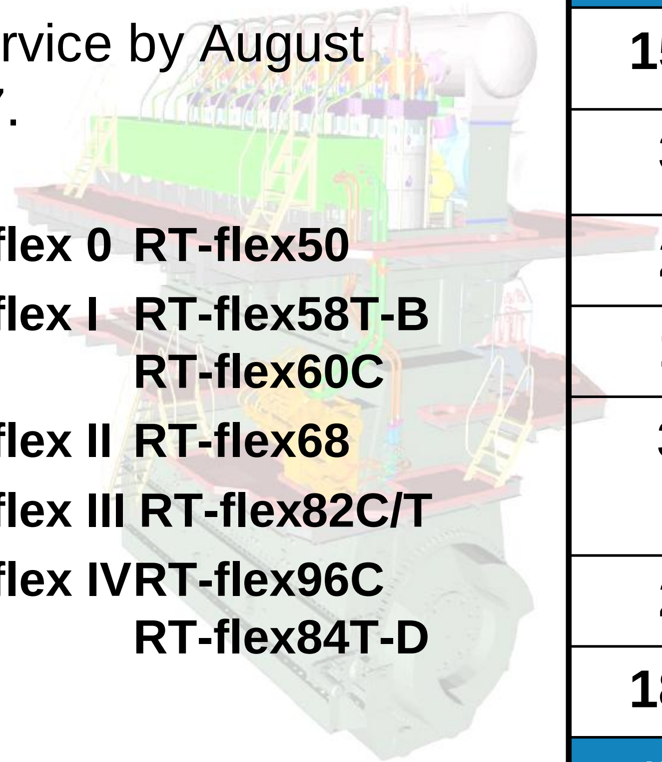
Reduced fuel consumption



Efficient Propulsion for Seagoing Vessels

Reduced emissions with the RT-flex common rail engine

More than 477 RT-flex engines are on order or in service by August 2007.



- flex 0 RT-flex50
- flex I RT-flex58T-B
  RT-flex60C
- flex II RT-flex68
- flex III RT-flex82C/T
- flex IV RT-flex96C
  RT-flex84T-D

N° of	RT-flex engines on order or in service	Total kW
152	**RT-flex50**	**1’557’000**
34	**RT-flex58T-B**	**471’000**
25	**RT-flex60C**	**417’000**
16	**RT-flex68-B**	**357’000**
33	**RT-flex82C**	**1’198’000**
8	**RT-flex82T**	**253’000**
28	**RT-flex84T-D**	**823’000**
181	**RT-flex96C**	**10’985’000**
477	RT-flex engines	16‘061‘000

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Efficient Propulsion for Seagoing Vessels

Reduced emissions with the RT-flex common rail engine

Largest RT-flex engine
14RT-flex96C, 80'080 kW at 102 rpm
Shoptest December 2005

Smallest RT-flex engine
6RT-flex50, 9'720 kW at 124 rpm
Shoptest July 2005

Efficient Propulsion for Seagoing Vessels

Reduced emissions with the RT-flex common rail engine

Totally 110 RT-flex engines in service by August 2007

First engine in service since November 2001

- 12 x RT-flex50
- 10 x RT-flex58T-B
- 13 x RT-flex60C
- 2 x RT-flex68B
- 5 x RT-flex84T-D
- 68 x RT-flex96C

“Gypsum Centenial” with 6RT-flex58T, in service since January 2001

More then 800’000 accumulated running hours

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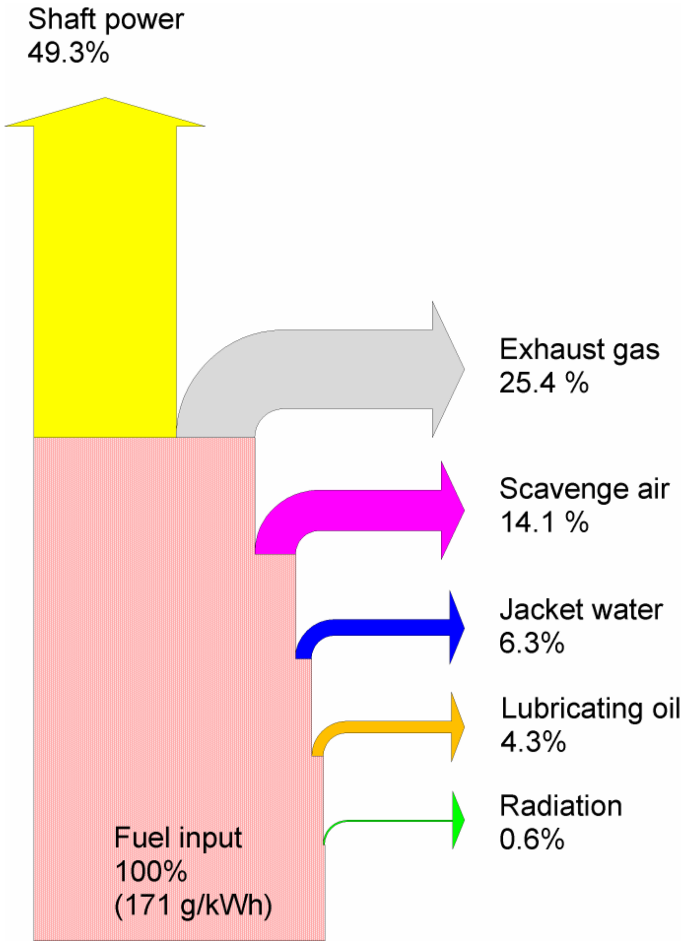
Reduced emissions with Waste Heat Recovery

Why Waste Heat Recovery?



About 50% of the fuel input energy is not being put to productive use.

Recovering part of the wasted energy provides the vessel with:

- lower fuel consumption
- less emissions

Reduced emissions with Waste Heat Recovery

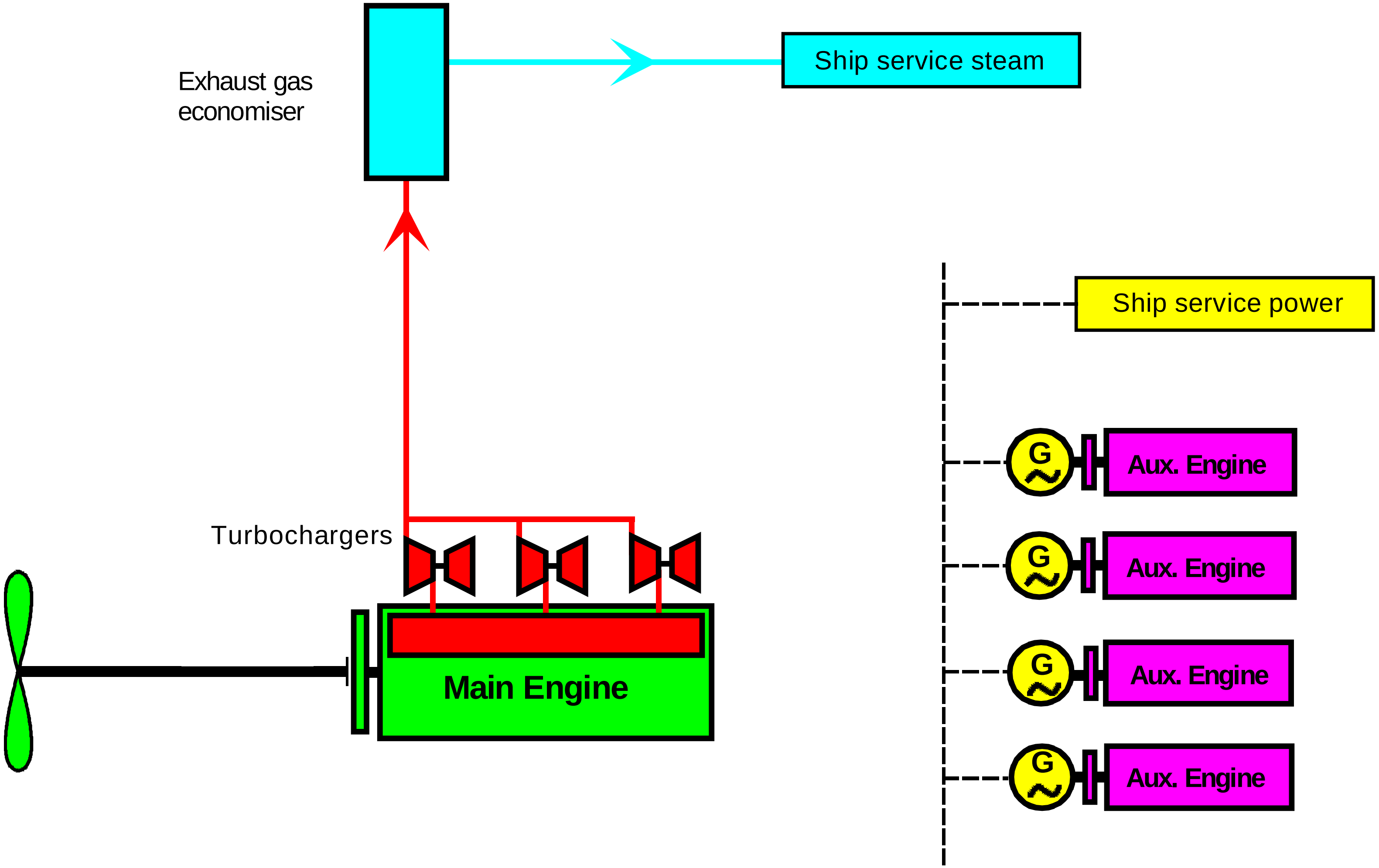
The application of a waste heat recovery system is threefold:

- **The operator profits from a lower annual fuel bill**
- **The operator contributes to lower the emission, such as CO_2, NO_X and SO_X.**
- **The operator benefits from an improved competitivity in the freight market**

Being Green is a Competitive Edge

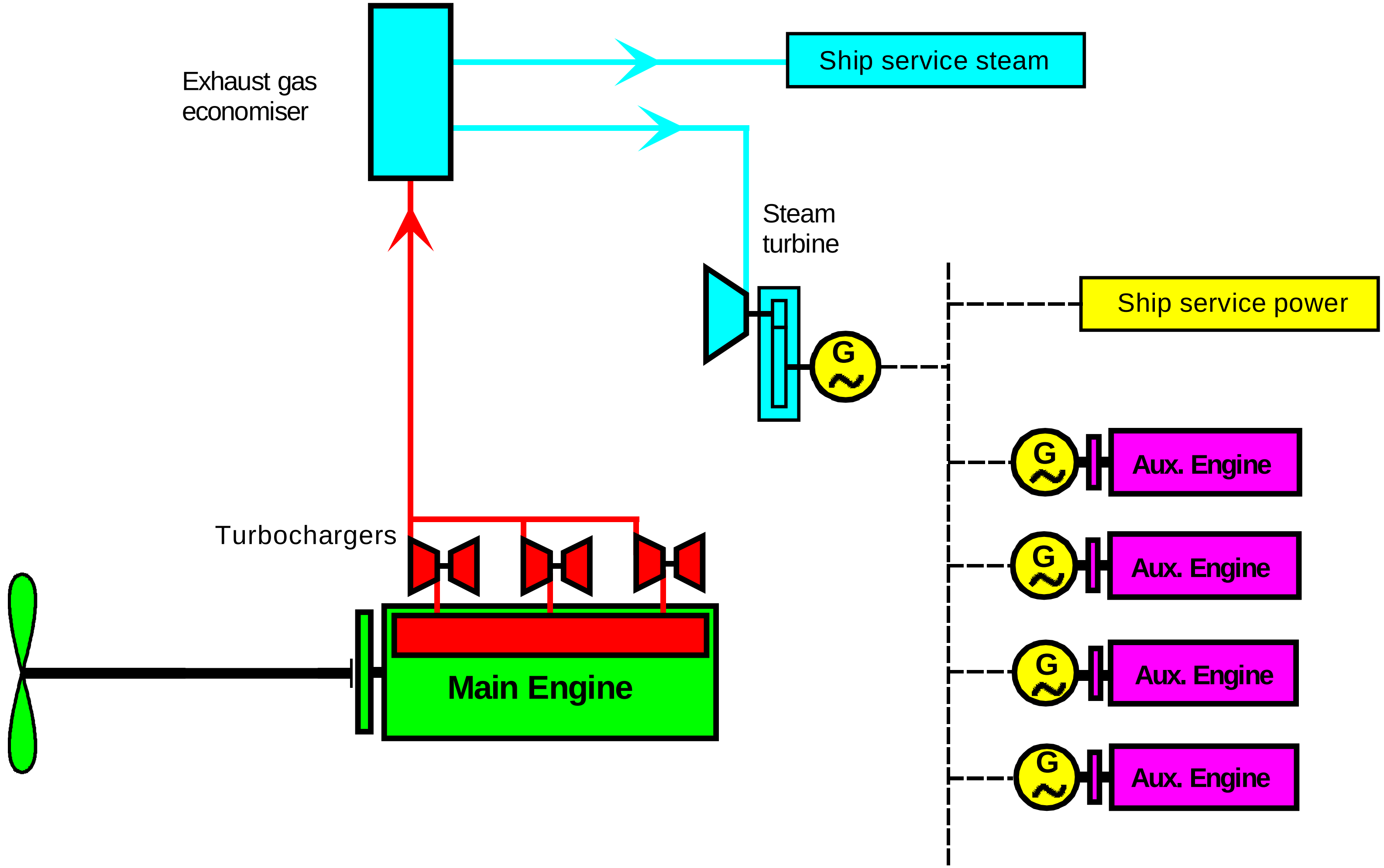
Efficient Propulsion for Seagoing Vessels

Reduced emissions with Waste Heat Recovery



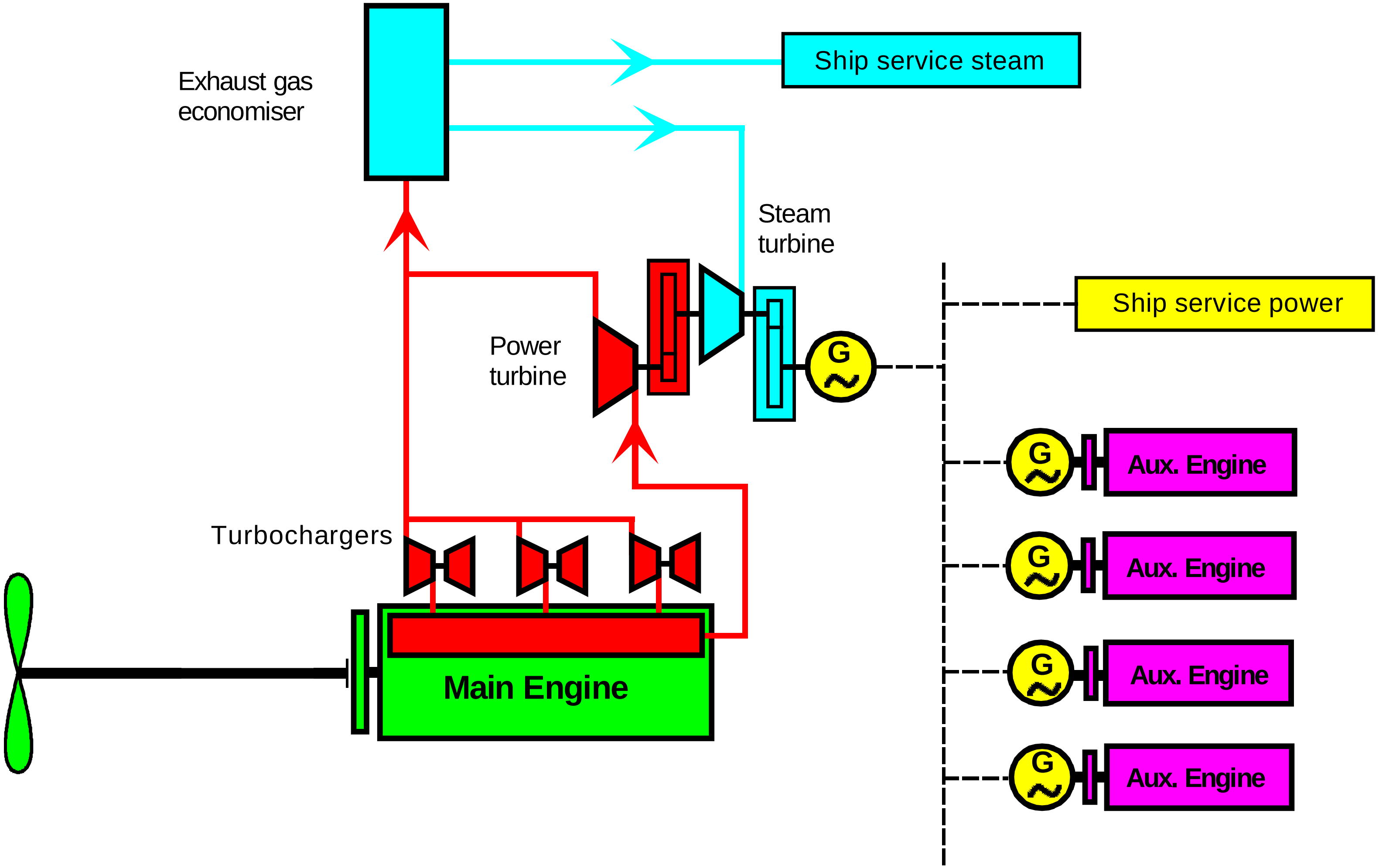
Efficient Propulsion for Seagoing Vessels

Reduced emissions with Waste Heat Recovery



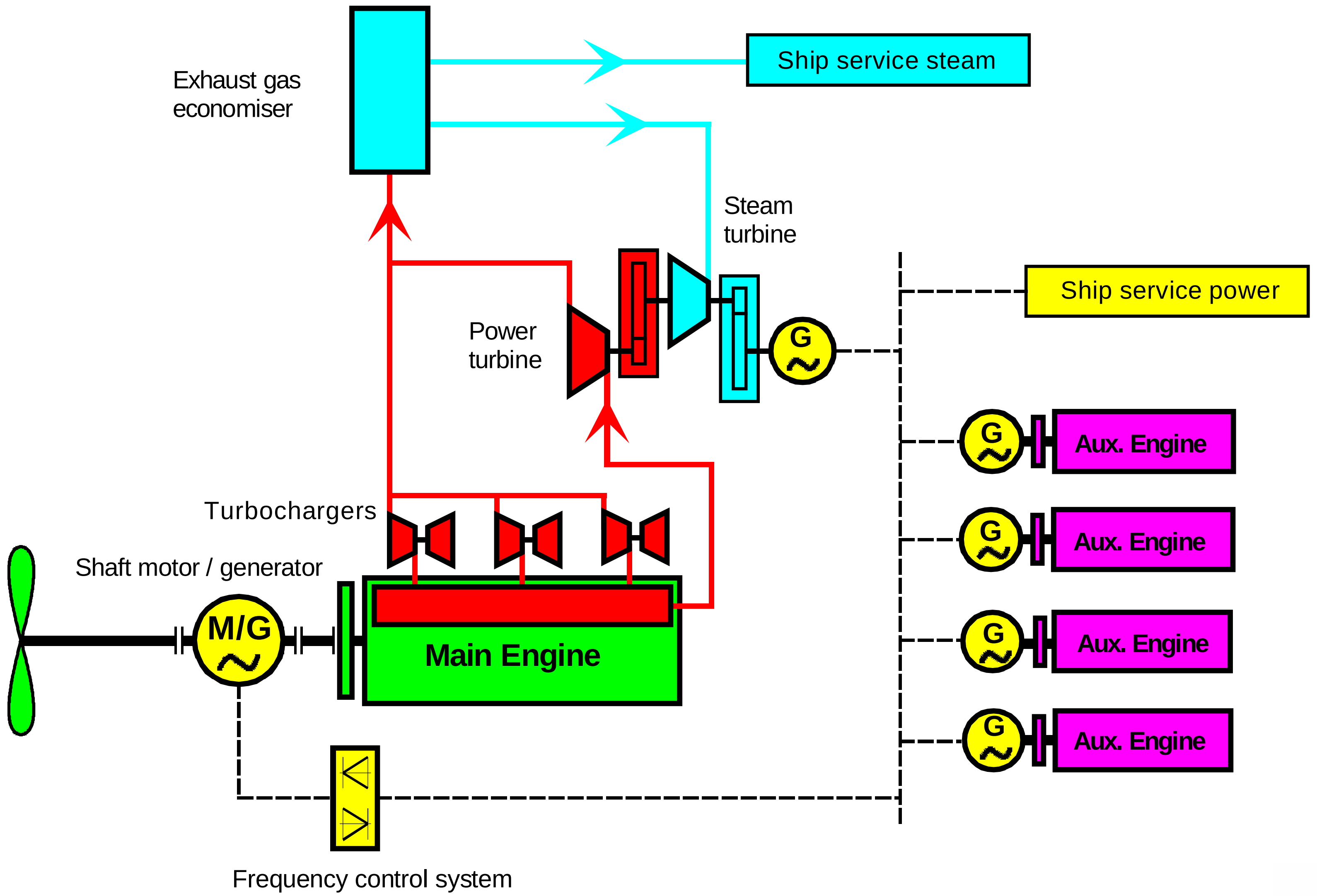
Efficient Propulsion for Seagoing Vessels

Reduced emissions with Waste Heat Recovery



Efficient Propulsion for Seagoing Vessels

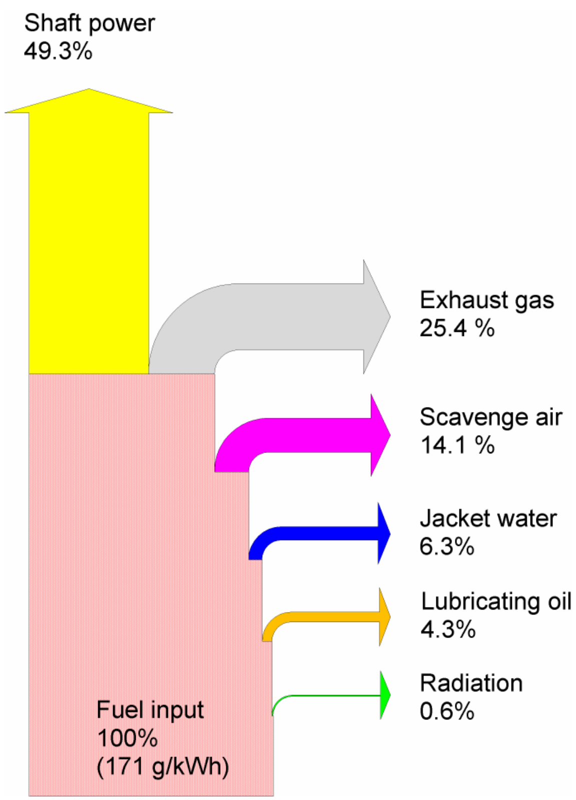
Reduced emissions with Waste Heat Recovery



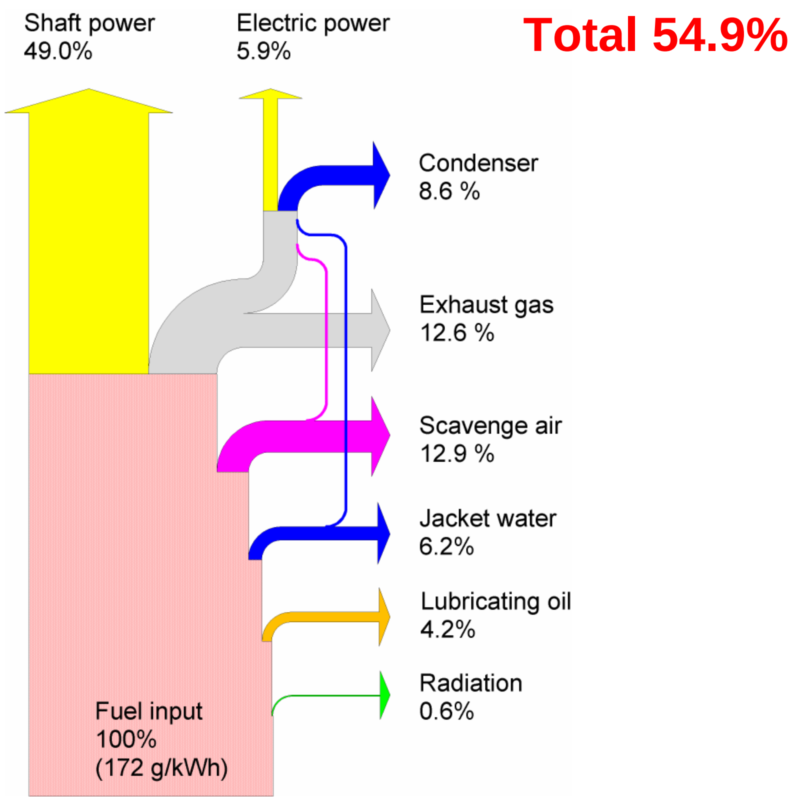
Efficient Propulsion for Seagoing Vessels

Reduced emissions with Waste Heat Recovery

Heat Balance Standard Engine



Heat Balance with Heat Recovery



Engine efficiency improvement with heat recovery = 54.9 / 49.3 = **11.4%**

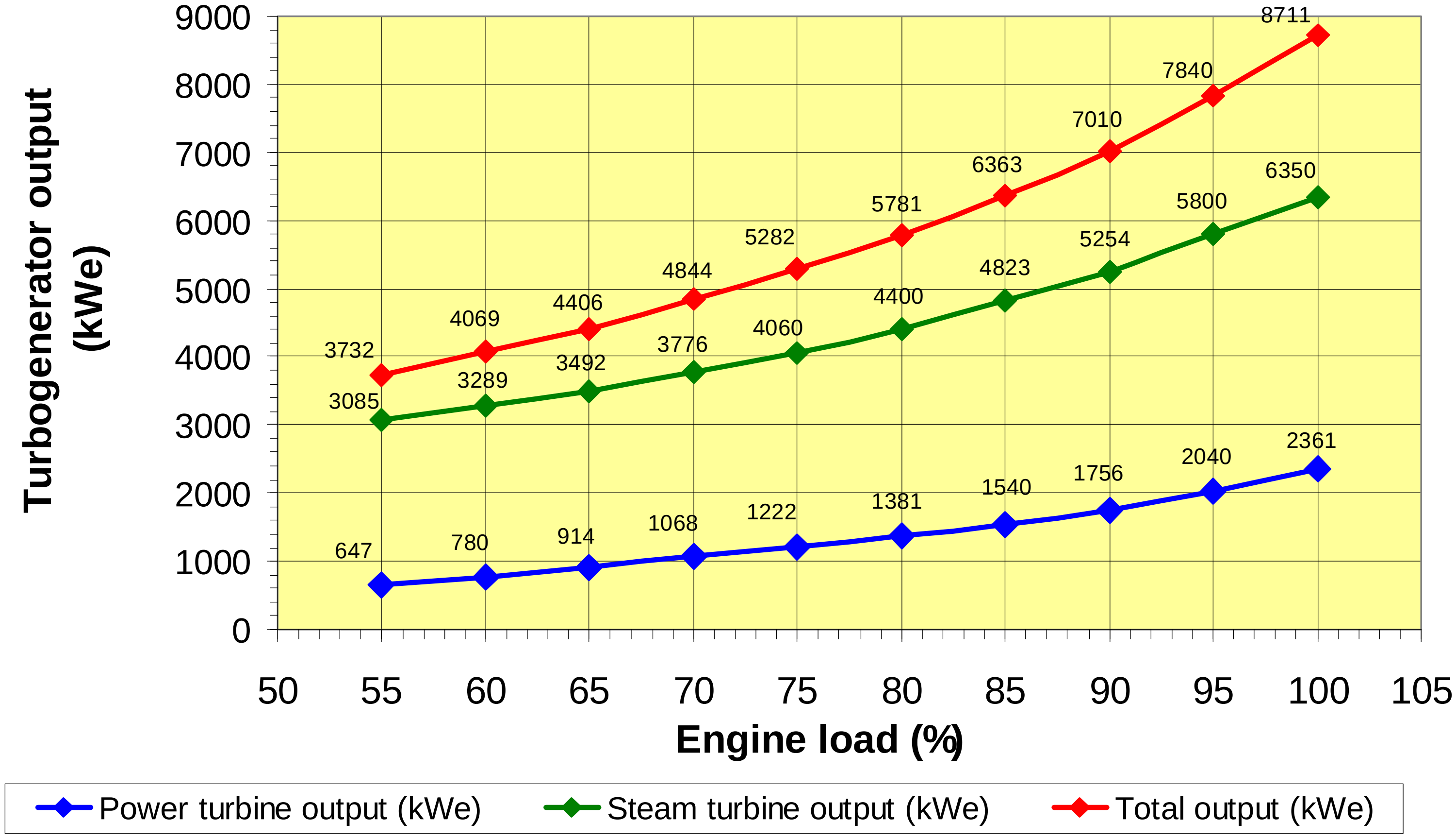
Efficient Propulsion for Seagoing Vessels

Reduced emissions with Waste Heat Recovery

12RT-flex96C, Delta tuning, Turbogenerator output

Dual pressure steam system, 10% P/T gas flow

ambient suction tuning, ISO, average aged engine

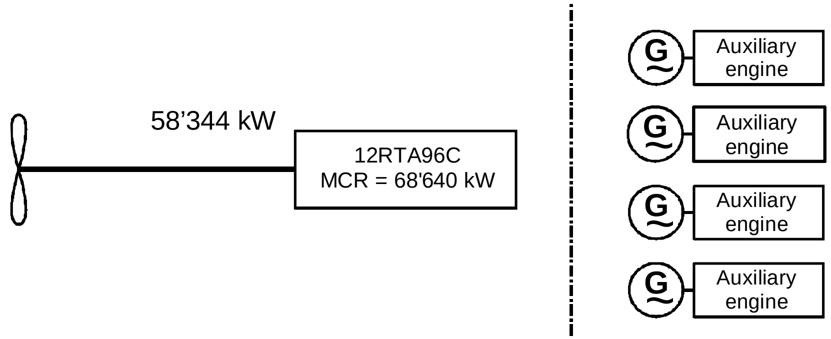


Efficient Propulsion for Seagoing Vessels

Reduced emissions with Waste Heat Recovery

12RT-flex96C - Case Study

Delta tuning, average aged, ISO conditions



Four auxiliary engines, each 3'000 kW

Annual operating costs

	Main engine	Auxiliary engines
Fuel costs		
Engine power	58'344 kW	5'350 kW
BSFC	166.2 g/kWh	200 g/kWhe
Daily F.C. MDO	232.7 tons	25.7 tons
Daily F.C. HFO	245.4 tons	27.1 tons
Total D.F.C	272.5 tons	
Total annual F.C.	**18'449'000 $**	
Maintenance costs		
Specific costs	0.7 $/MWh	5.0 $/MWh
Annual costs	312'000 $	174'000 $
Total	**486'000 $**	
Lube oil costs		
Specific consumption	1.0 g/kWh	0.6 g/kWh
Annual L.O. cons.	279.2 tons	22.0 tons
Annual L.O. costs	569'000 $	33'000 $
Total	**602'000 $**	
Total annual operating costs		
	19'537'000 $	

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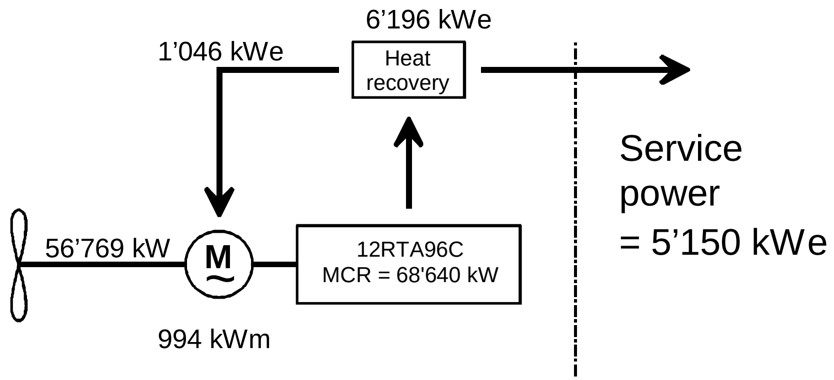
Efficient Propulsion for Seagoing Vessels

Reduced emissions with Waste Heat Recovery

12RT-flex96C - Case Study

Delta tuning, average aged, ISO conditions



CSR power= 57’350 kW = 83.6% load

Service power saving with ambient air supply = 200 kWe

⇨ New service power = 5’150 kWe

Annual operating costs

	Main engine	Heat recovery
Fuel costs		
Engine power	57’350 kW	0
BSFC	166.9 g/kWh	0
Daily F.C. MDO	229.7 tons	0
Daily F.C. HFO	242.2 tons	0
Annual fuel costs	**16’395’000 $**	0
Maintenance costs		
Specific costs	0.7 $/MWh	0.5 $/MWh
Annual costs	312’000 $	20’000 $
Total	**333’000 $**	
Lube oil costs		
Specific consumption	1.0 g/kWh	0
Annual L.O. cons.	373.0 tons	0
Annual L.O. costs	**559’000 $**	0

Total annual operating costs

17’287’000 $

Efficient Propulsion for Seagoing Vessels

Reduced emissions with Waste Heat Recovery

12RT-flex96C - Case Study

Delta tuning, average aged, ISO conditions

Operating cost savings *HFO price = 250 $/t, L.O. price = 1’500 $/t, 6’500 hours p.a.*

	Classic propulsion system	**Propulsion system with heat recovery**
Total fuel costs	18’449’000 $	16’395’000 $ 88.9%
Total maintenance costs	486’000 $	333’000 $ 68.5%
Total lube oil costs	602’000 $	559’000 $ 92.9 %
Total operating costs	**19’537’000 $**	**17’287’000 $** **88.5 %**
Annual savings		**2’250’000 $**

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Efficient Propulsion for Seagoing Vessels

Reduced emissions with Waste Heat Recovery

12RT-flex96C - Case Study

Delta tuning, average aged, ISO conditions

Operating cost savings

	Heavy fuel price (380 cSt)			
	250 $ / tonne	300 $ / tonne	350 $ / tonne	400 $/t
Annual savings	**2’250’000 $**	**2’661’000 $**	**3’072’000 $**	**3’482’000 $**

14RT-flex96C

Annual savings	**2’625’000 $**	**3’105’000 $**	**3’584’000 $**	**4’062’000 $**

Reduced emissions with Waste Heat Recovery

12RT-flex96C - Case Study

Delta tuning, average aged, ISO conditions

Expected investment costs for:

- **Turbogenerating set,** consisting of:
  Multistage dual pressure condensing steam turbine, power turbine, gear between power turbine and steam turbine, gear between steam turbine and generator, 6.6 kV generator, base frame, valves and controls.
- **Exhaust gas economiser,** consisting of:
  High pressure evaporator and superheater, low pressure evaporator and superheater, LP and HP steam drums, cleaning system.
- **Shaft motor / generator plant,** consisting of:
  Shaft motor / generator, propulsion converter, propulsion control system, transformers, synchronous condenser.

Total price € 6’000’000.00

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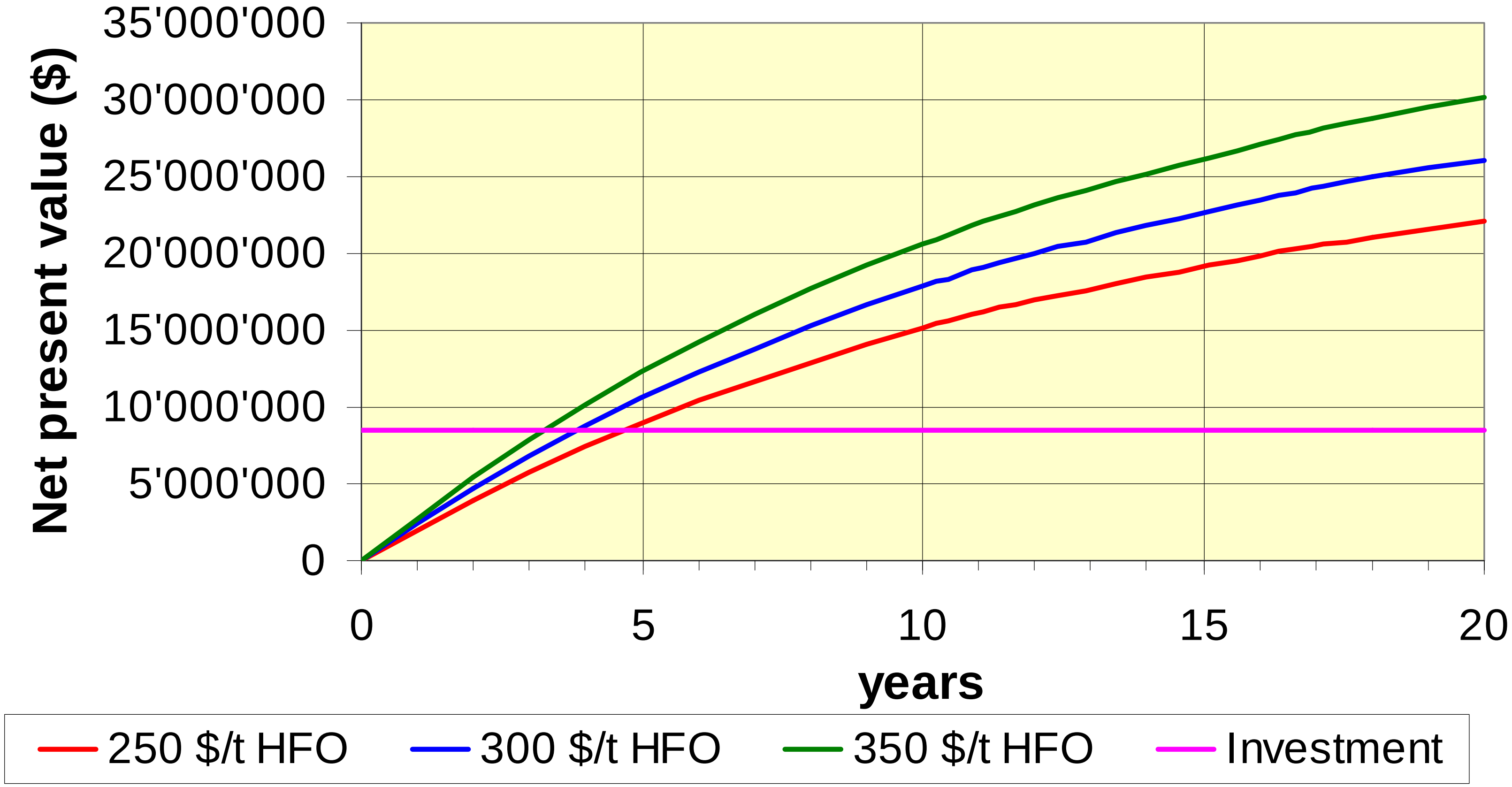
Efficient Propulsion for Seagoing Vessels

Reduced emissions with Waste Heat Recovery

12RT-flex96C - Case Study

Delta tuning, average aged, ISO conditions

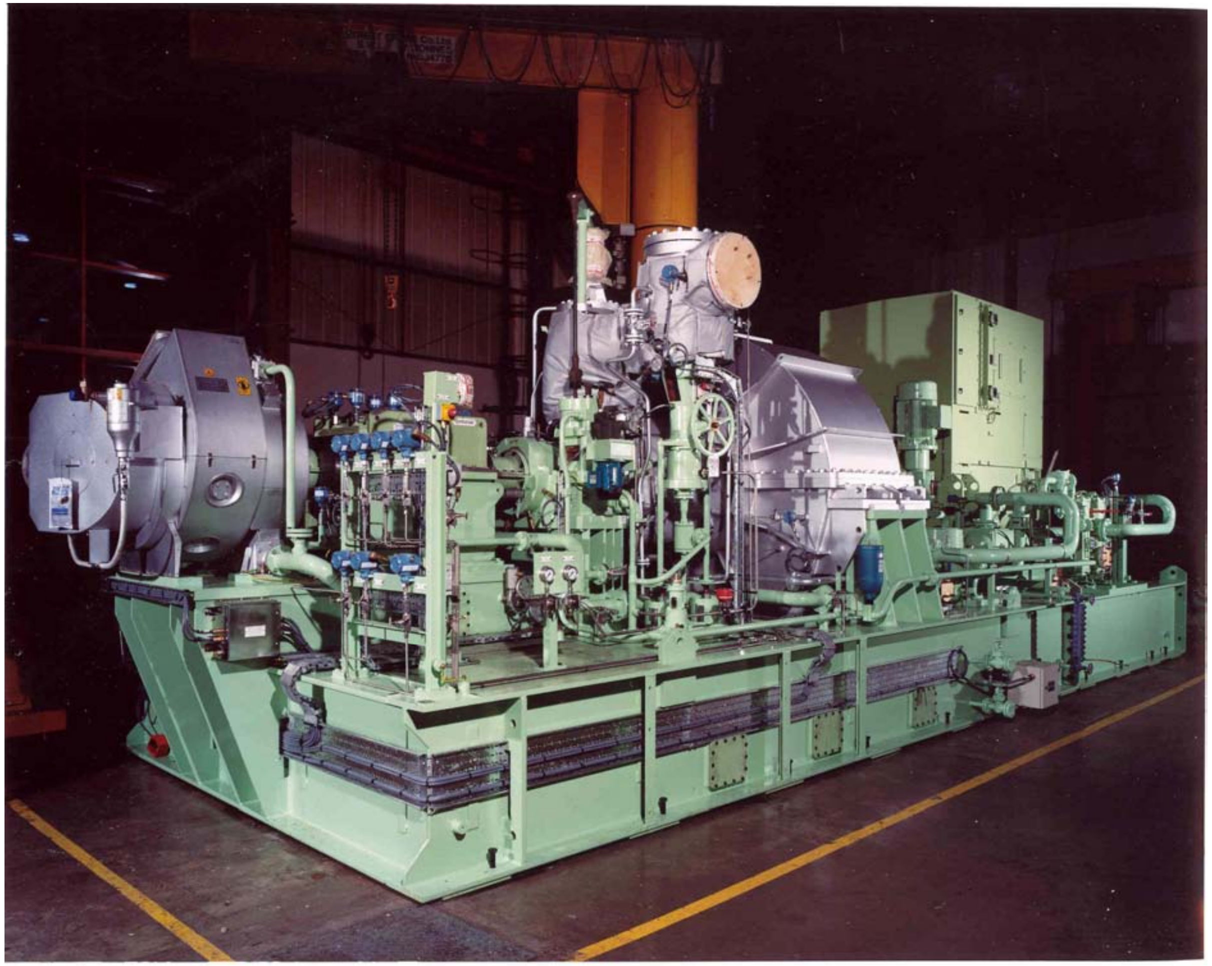
Expected pay-back time



Efficient Propulsion for Seagoing Vessels

Reduced emissions with Waste Heat Recovery

Turbogenerator with power turbine as manufactured by Peter Brotherhood Ltd.



Efficient Propulsion for Seagoing Vessels

Reduced emissions with Waste Heat Recovery

Typical shaft motor / generator

Efficient Propulsion for Seagoing Vessels

Reduced emissions with Waste Heat Recovery

“Gudrun Maersk”

First vessel with a high efficiency Waste Heat Recovery plant

In service since June 2005, totally 6 vessels of this series

Length:	367.28 m
Beam:	42.8 m
Deadweight:	115’000 tons
Main engine:	12RT-flex96C 68’640 kW
Aux. engines:	3 x 8L32 3’600 kW each

Efficient Propulsion for Seagoing Vessels

Reduced emissions with Waste Heat Recovery

“Emma Maersk”

Equipped with a high efficiency Waste Heat Recovery plant

In service since September 2006, totally 8 vessels of this series

Length:	397.0 m
Beam:	56.0 m
Main engine:	14RT-flex96C 80’080 kW
Aux. engines:	5 x 4’140 kW
Reefer containers:	1000 units

Efficient Propulsion for Seagoing Vessels

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Engine design

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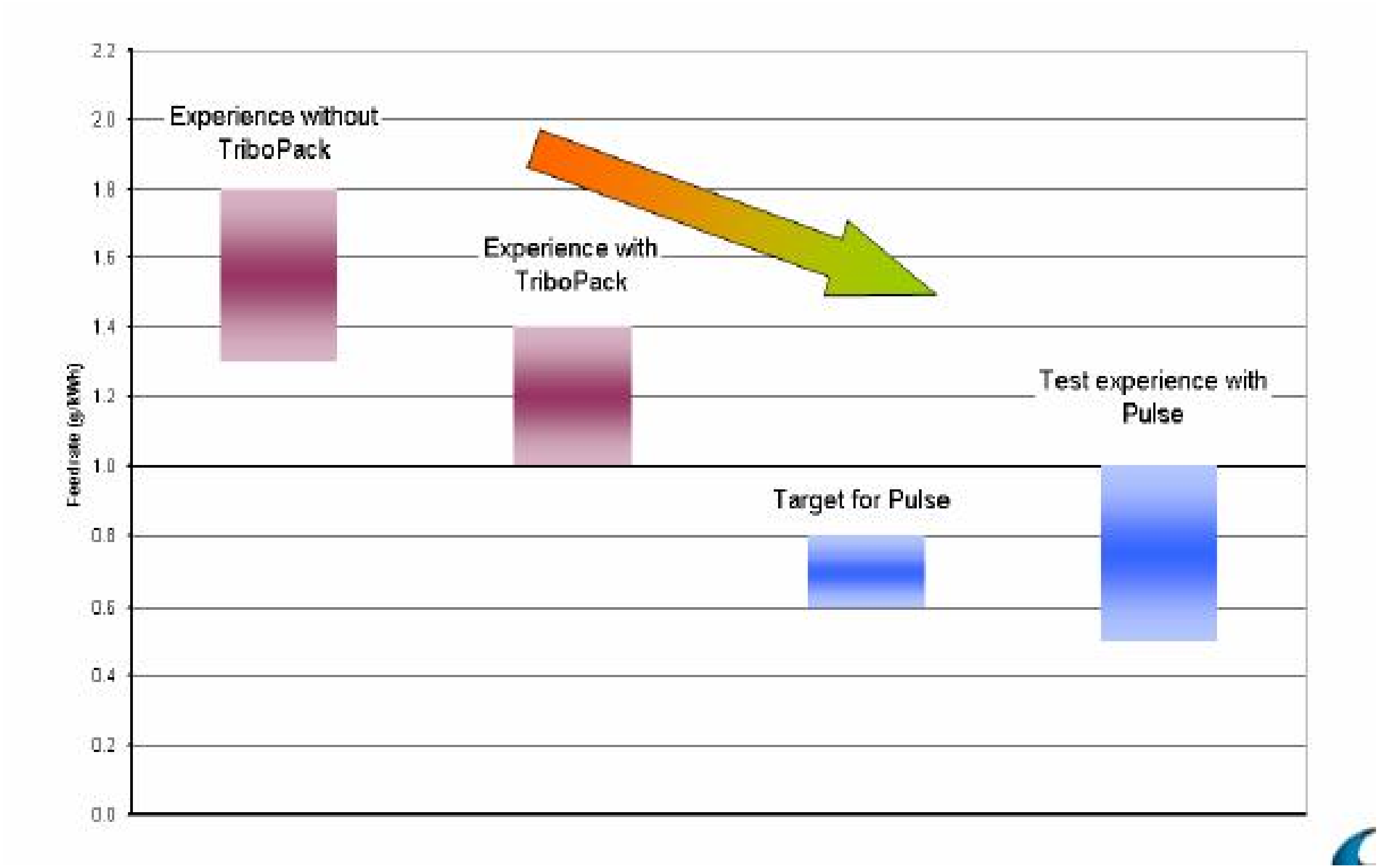
Efficient Propulsion for Seagoing Vessels

Electronically controlled Puls cylinder lubricating system

Lower cylinder oil consumption with the new Puls System



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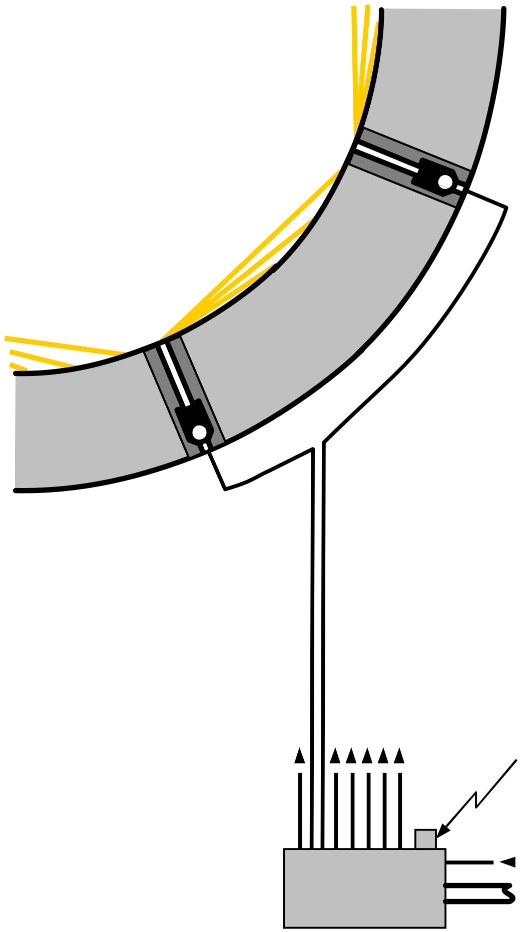
Electronically controlled Puls cylinder lubricating system

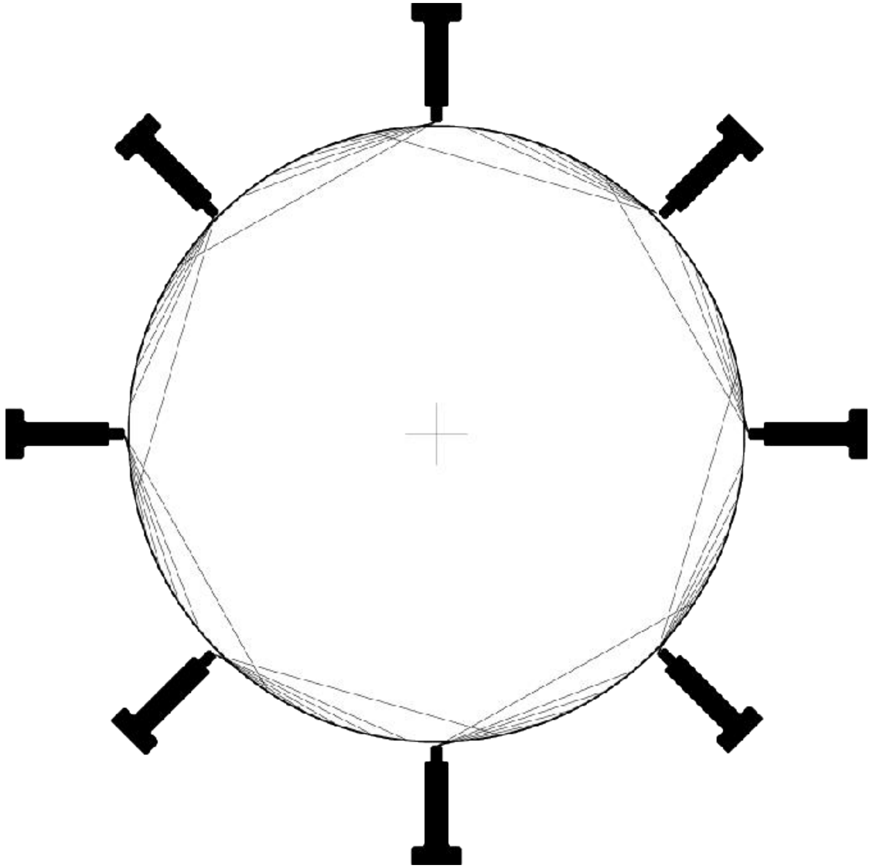


Working Principle

- New lubricator pump
- Electronically controlled timing with full flexibility of timing point
- Electronically controlled feed rate
- Oil distribution by a series of compact jets, no atomization, no loss of oil in scavenge air
  no influence of oil temperature
- Precise dosage even for low feed rates
- Reliable oil quills (simple non return valves)
- Control of lubricating system fully integrated in RT-flex control system WECS 9520

Efficient Propulsion for Seagoing Vessels

Electronically controlled Puls cylinder lubricating system



Configuration for:

RT-flex96C

RT-flex82C/T

- 8 quills
- 5 oil jets per quill
- Total of 40 lubricating points on the liner surface

Efficient Propulsion for Seagoing Vessels

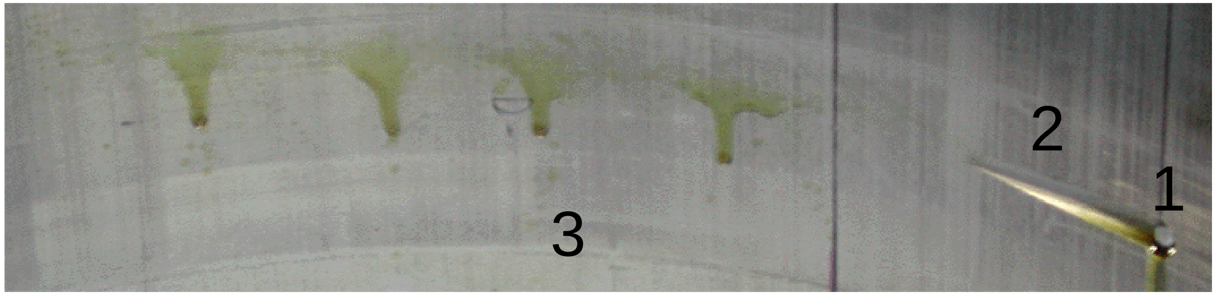
Electronically controlled Puls cylinder lubricating system

Pulse Lubrication ensures regular distribution of oil film on liner surface:

1 Oil quill

2 Groove for jet propagation

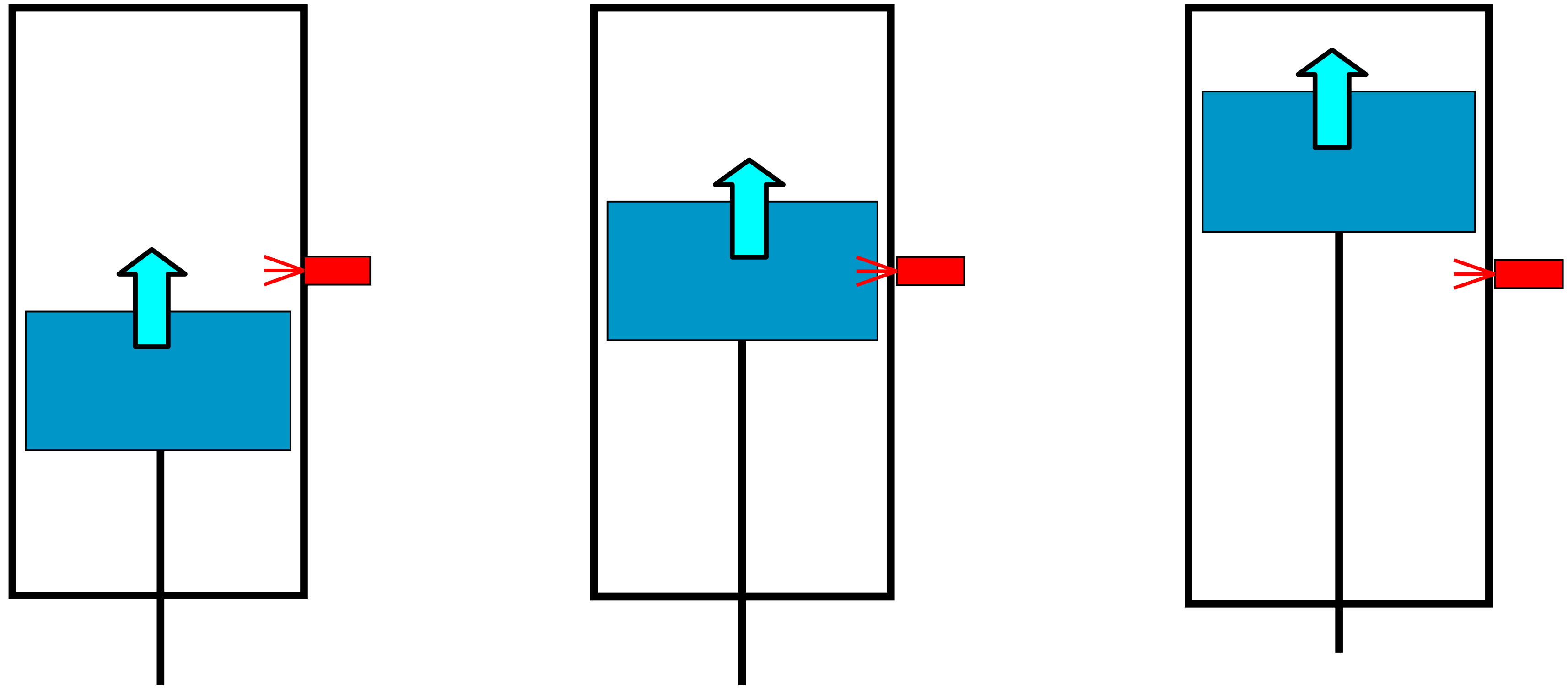
3 Distributed lube oil



Efficient Propulsion for Seagoing Vessels

Electronically controlled Puls cylinder lubricating system

Electronically Controlled Flexible Timing of Lube Oil Injection



Lube oil distribution above piston to lubricate upper part of liner

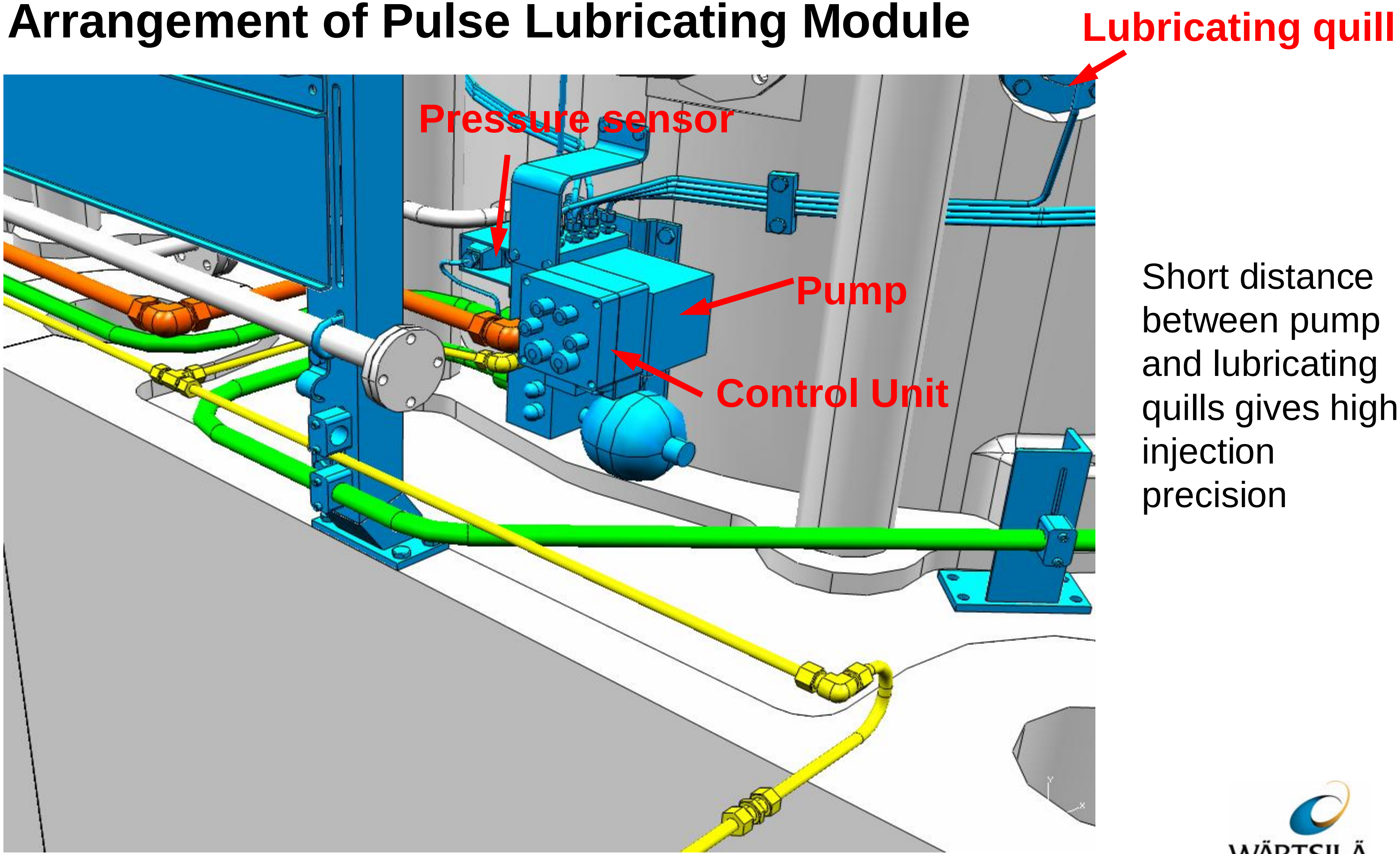
Lube oil distribution into piston ring pack to lubricate piston rings

Lube oil distribution below piston to lubricate lower part of liner

Efficient Propulsion for Seagoing Vessels

Electronically controlled Puls cylinder lubricating system

Arrangement of Pulse Lubricating Module



Short distance between pump and lubricating quills gives high injection precision

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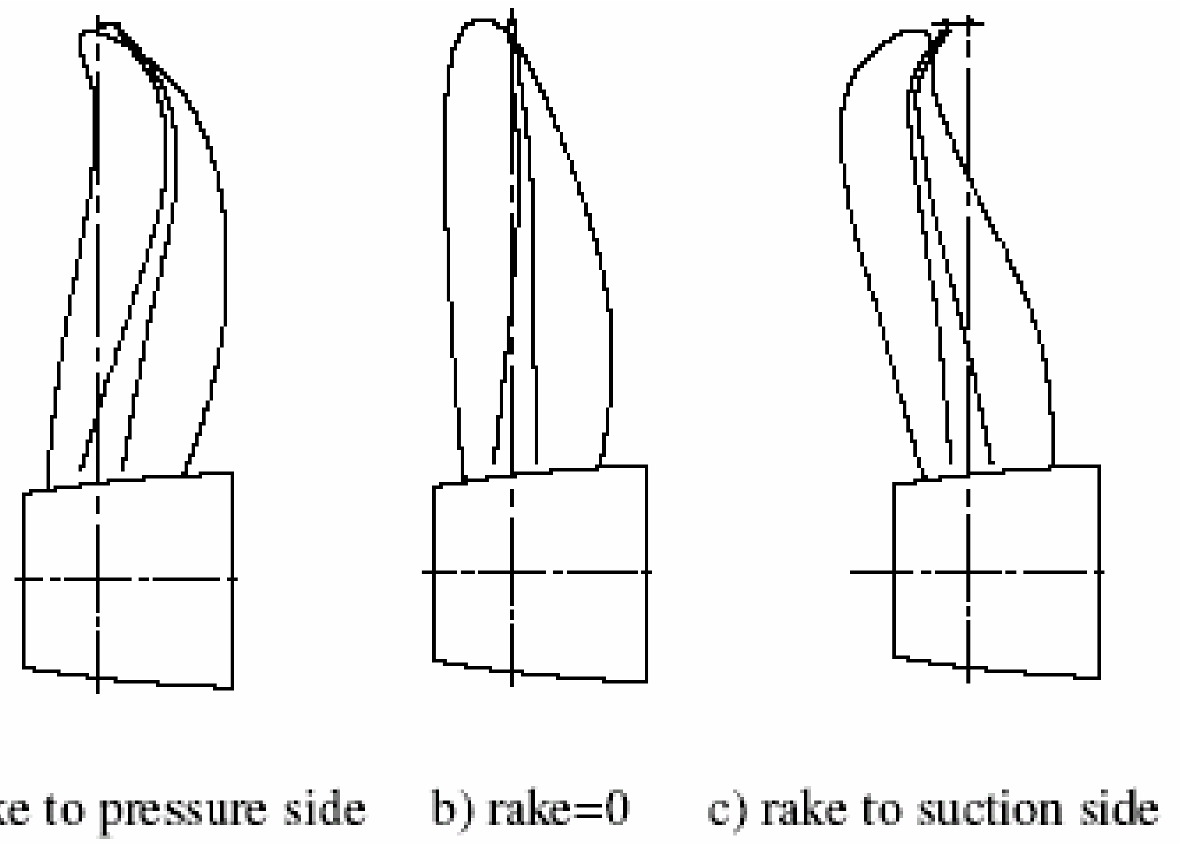
Propeller efficiency improvement by tip rake

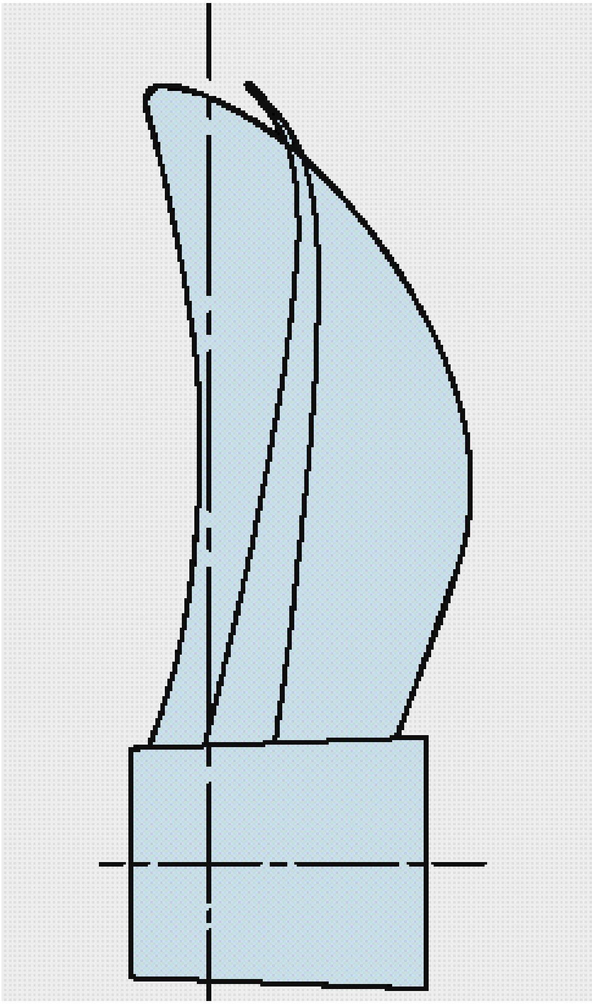


Efficient Propulsion for Seagoing Vessels

Propeller efficiency improvement by tip rake

Pressure side tip rake

- efficiency gain 2-3 %
- pressure pulses reduction ~10%



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Propeller efficiency improvement by tip rake

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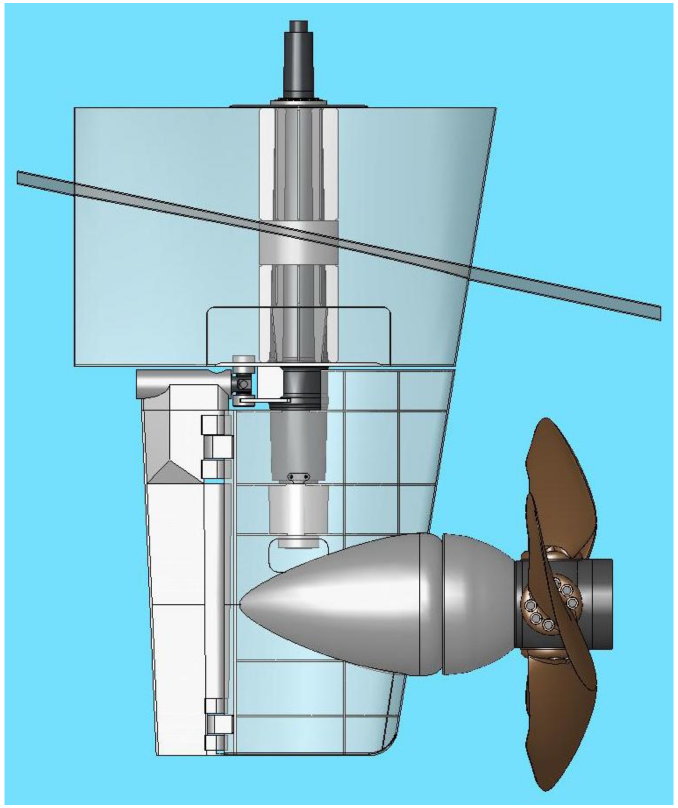
Efficiency improvement by Wärtsilä Efficiency Rudder

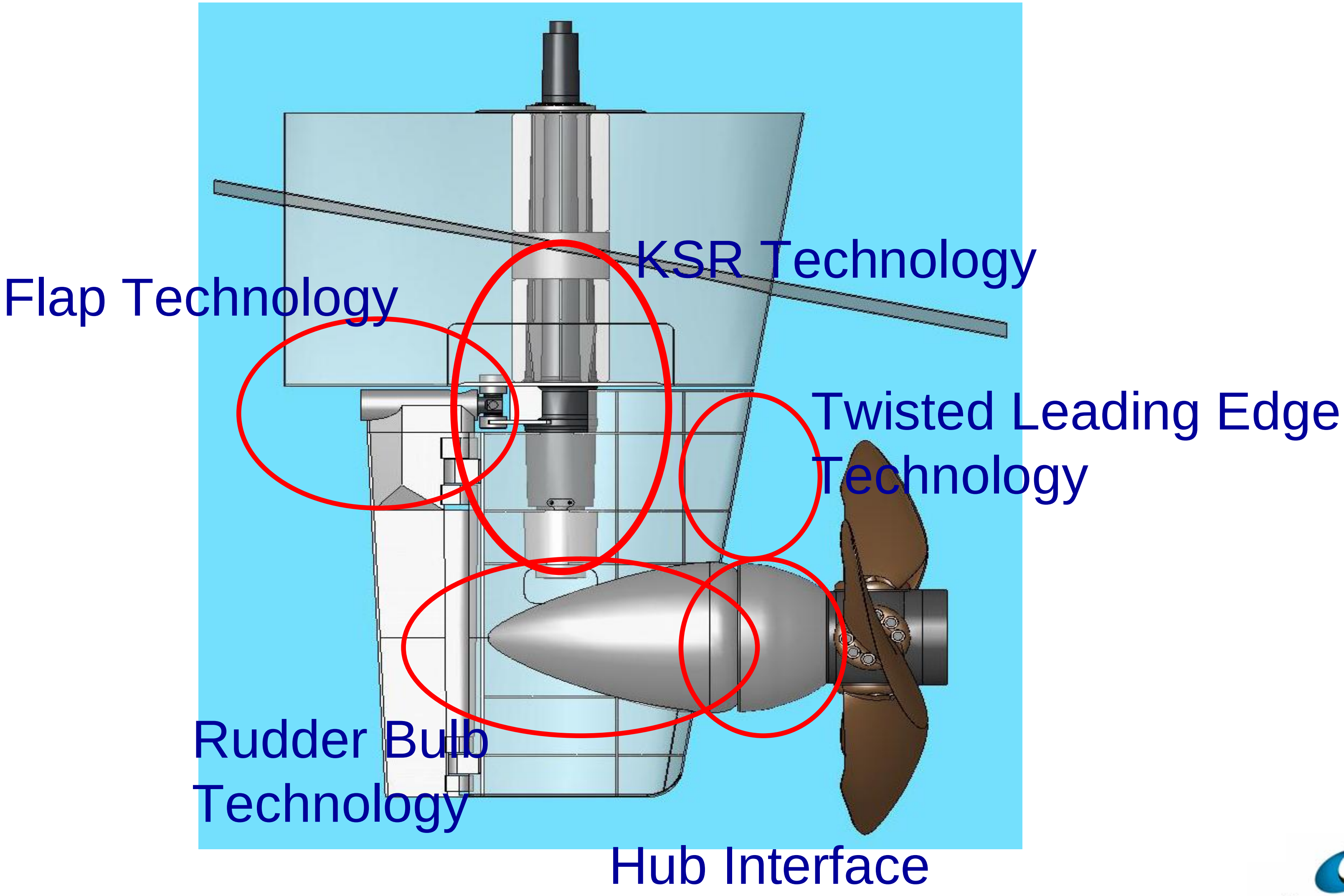
Introduction of co-operation with Becker Marine Systems

- Becker Marine Systems and Wärtsilä co-operate on rudders (contract signed Dec 2006)



Efficient Propulsion for Seagoing Vessels

Efficiency improvement by Wärtsilä Efficiency Rudder



Efficient Propulsion for Seagoing Vessels

Efficiency improvement by Wärtsilä Efficiency Rudder

- **Technical benefits Wärtsilä Efficiency Rudder**
  - Optimised combination of rudder and propeller
  - Reduced drag and better efficiency due to rudder bulb
  - Improved hull efficiency
  - Reduced rudder drag due to asymmetric profile
  - Less rudder cavitation due to better alignment of the flow behind the propeller
  - Application of flap reduces steering angles and improves service performance

- **Expected eficiency improvement**
  - 6% (TLE 1.5%, rudder bulb 4%, propeller 1%)

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Propulsion efficiency improvements through:

- RT-flex common rail technology
- Waste heat recovery
- Wärtsilä efficiency rudder

⇨ Lower fuel cost, lower vessel operating costs

⇨ Less emissions

Efficient Propulsion for Seagoing Vessels

Less fuel consumption through propulsion efficiency improver

12RTA96C, 75% load
versus
12RT-flex96C with WHR and ER

- RT-flex common rail technology
  2 g/kWh lower fuel consumption
  1.2 % efficiency gain
- Waste heat recovery system
  10% efficiency gain
  16 g/kWh lower fuel consumption
- Wärtsilä efficiency rudder
  6% efficiency gain
  10 g/kWh lower fuel consumption

Cumulative:
17.2% efficiency gain
28 g/kWh lower fuel consumption

Efficient Propulsion for Seagoing Vessels

Less fuel costs through propulsion efficiency improvements

12R-flex96C, 75% load, 51’480 kW
6’000 operating hours per year
Heavy fuel price = 350 $ per tone

28 g/kWh HFO saving

⇨ 3’000’000 $ per year fuel cost saving

WÄRTSILÄ

Efficient Propulsion for Seagoing Vessels

Less CO_2 emissions through propulsion efficiency improveme

12RTA96C, 75% load versus 12RT-flex96C	29’000 kg/h CO_2 emission
▪ RT-flex common rail technology 2 g/kWh lower fuel consumption 1.2 % efficiency gain	360 kg/h CO_2 reduction
▪ Waste heat recovery system 10% efficiency gain 16 g/kWh lower fuel consumption	2’900 kg/h CO_2 reduction
▪ Wärtsilä efficiency rudder 6% efficiency gain 10 g/kWh lower fuel consumption	1’740 kg/h CO_2 reduction
Cumulative: 17.2% efficiency gain	5’000 kg/h CO_2 reduction

WÄRTSILÄ

Efficient Propulsion for Seagoing Vessels

Cost savings through less CO2 emissions with CO2 emission certificates

12R-flex96C, 75% load, 51’480 kW
6’000 operating hours per year
Value for 1 tone CO_2 = 20 $

5’000 kg/h CO_2 reduction

⇨ **600’000 $ per year CO_2 certificates trading**