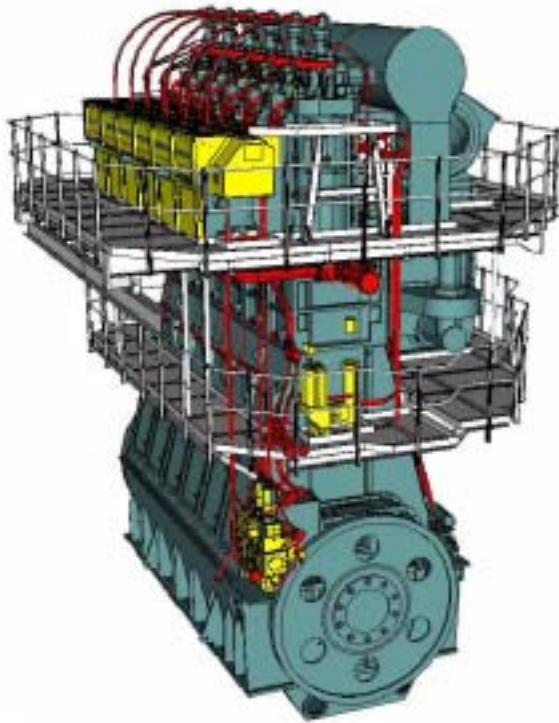


DU-WÄRTSILÄ RT-flex Engine



April 2006

DIESEL UNITED, LTD.

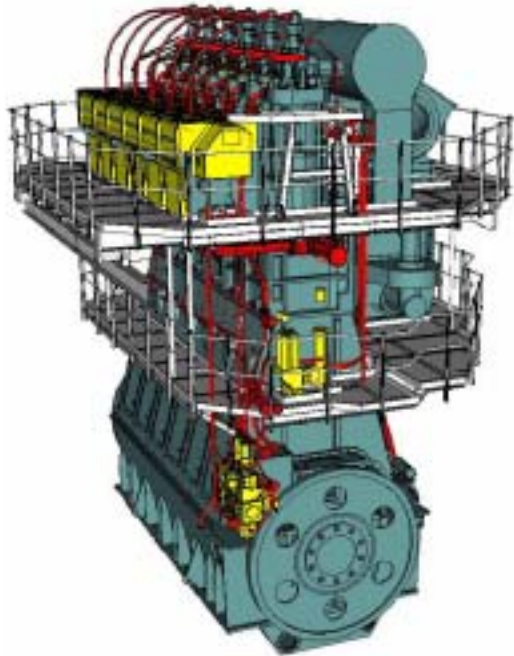
RT-flex

Customer / File.PPT / 1 / Date



RT-flex Engine

Concept of RT-flex Engine



➤ High economy

- Low specific fuel consumption
- Low maintenance cost

➤ High operational flexibility

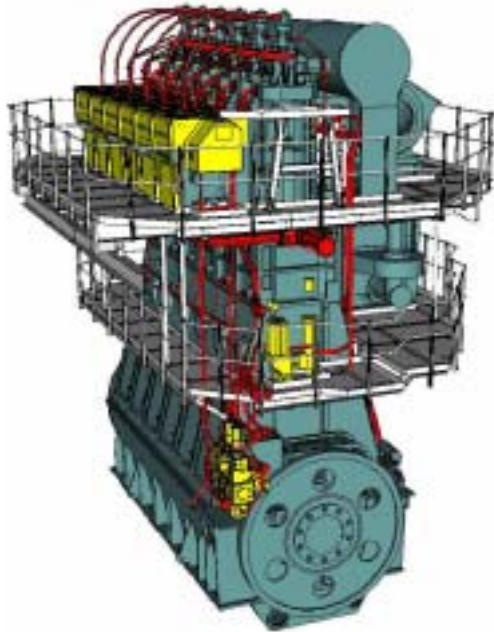
- Lower minimum revolution
- Good slow steaming capability
- Smooth engine starting
- Smooth and immediate reversing action

➤ Operation

- Engine operation is same as conventional engines

RT-flex Engine

Concept of RT-flex Engine

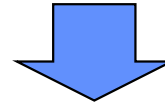


- **High reliability and safety**
 - Redundancy in main components
 - Extended integrated monitoring
- **Gentle to environment**
 - Smokeless operation at all load
- **Maintenance**
 - No adjustment of fuel oil pump

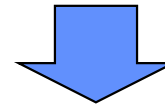
Characteristic of RT-flex Engine



Electronically controlled Fuel Injection
Exhaust Valve Drive
Starting Air
+
Common Rail Technology



Flexible and optimum engine tuning is available



- Improvement of fuel consumption
- Clean environment

Sulzer Common Rail System

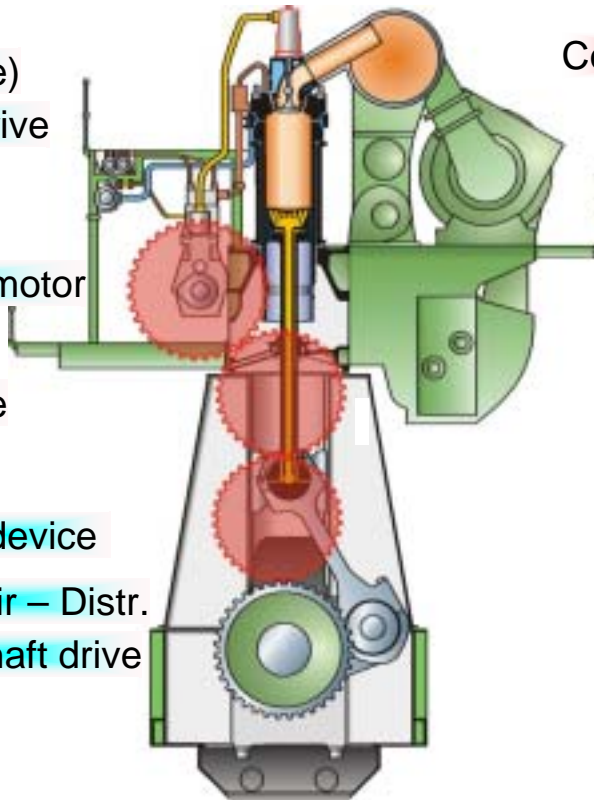
RTA

(VEC device)
Exh. Valve drive
Fuel pumps
Camshaft
Reversing servomotor

Fuel linkage

VIT device

Start - Air - Distr.
Camshaft drive

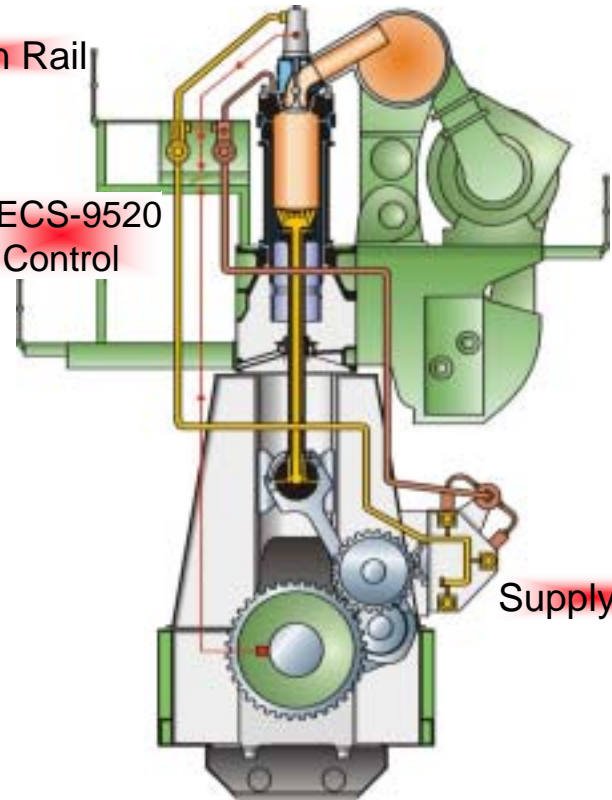


RT-flex

Common Rail

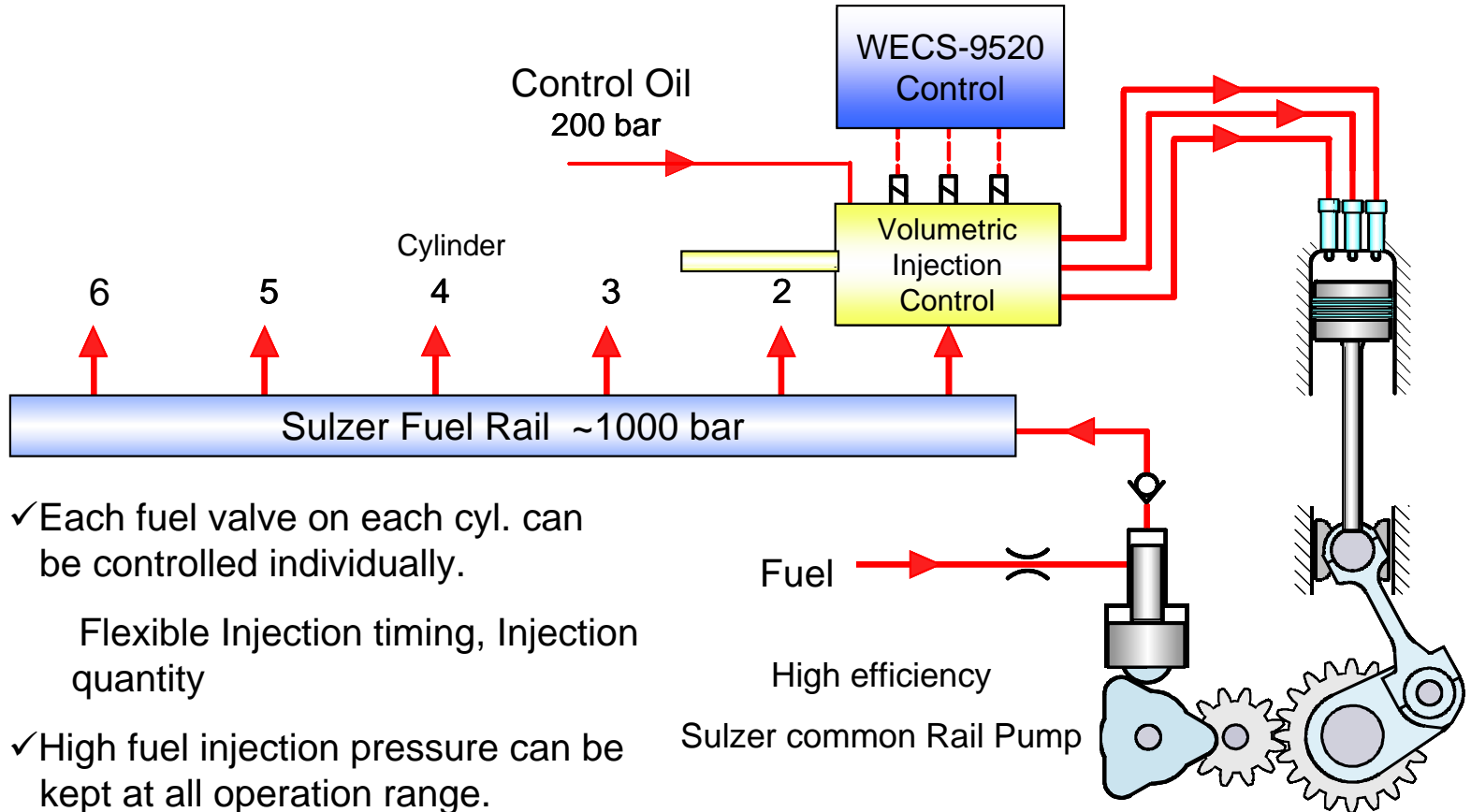
WECS-9520
Control

Supply unit



Common Rail System

Fuel System



✓ Each fuel valve on each cyl. can be controlled individually.

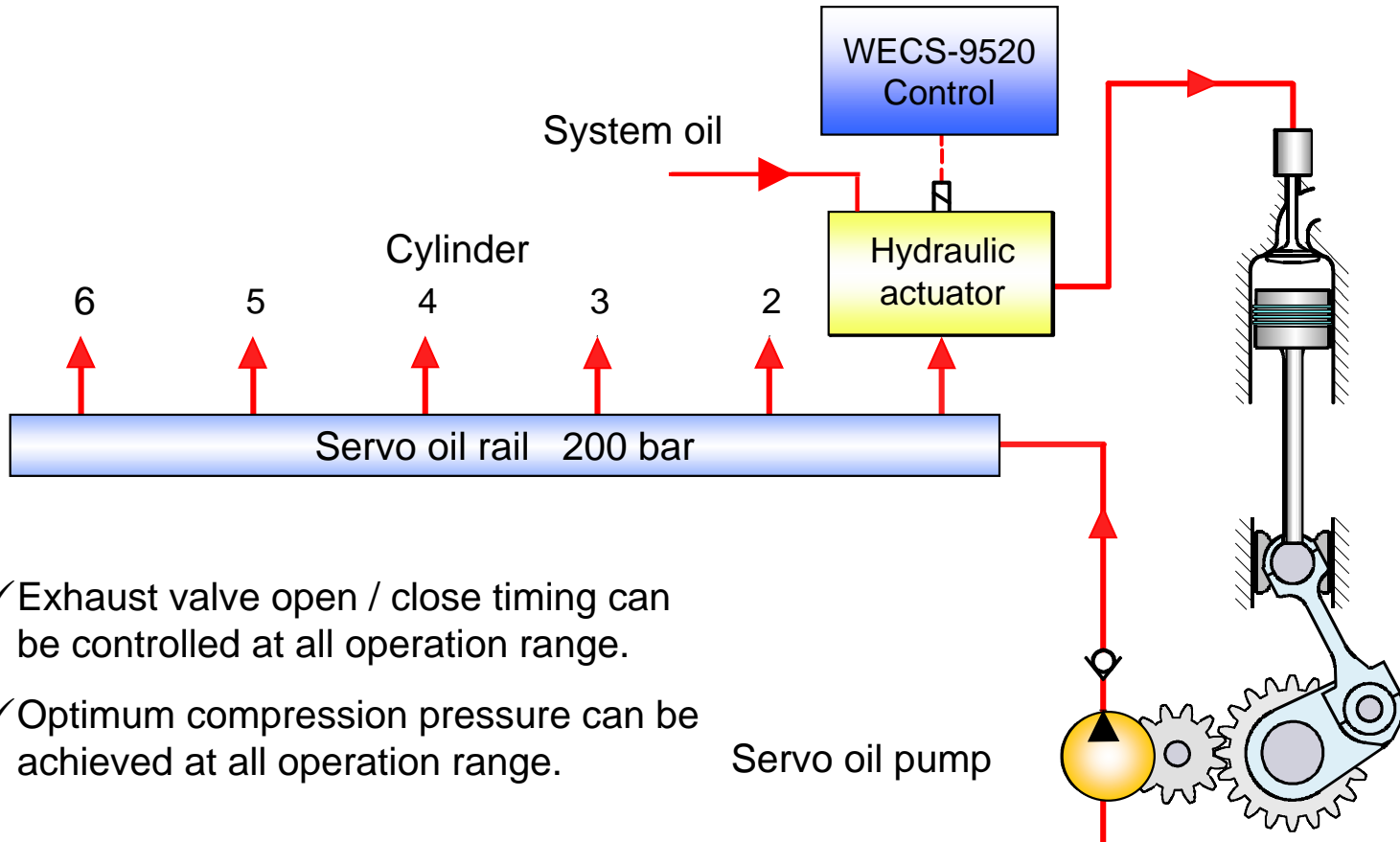
Flexible Injection timing, Injection quantity

✓ High fuel injection pressure can be kept at all operation range.

High thermal efficiency

Common Rail System

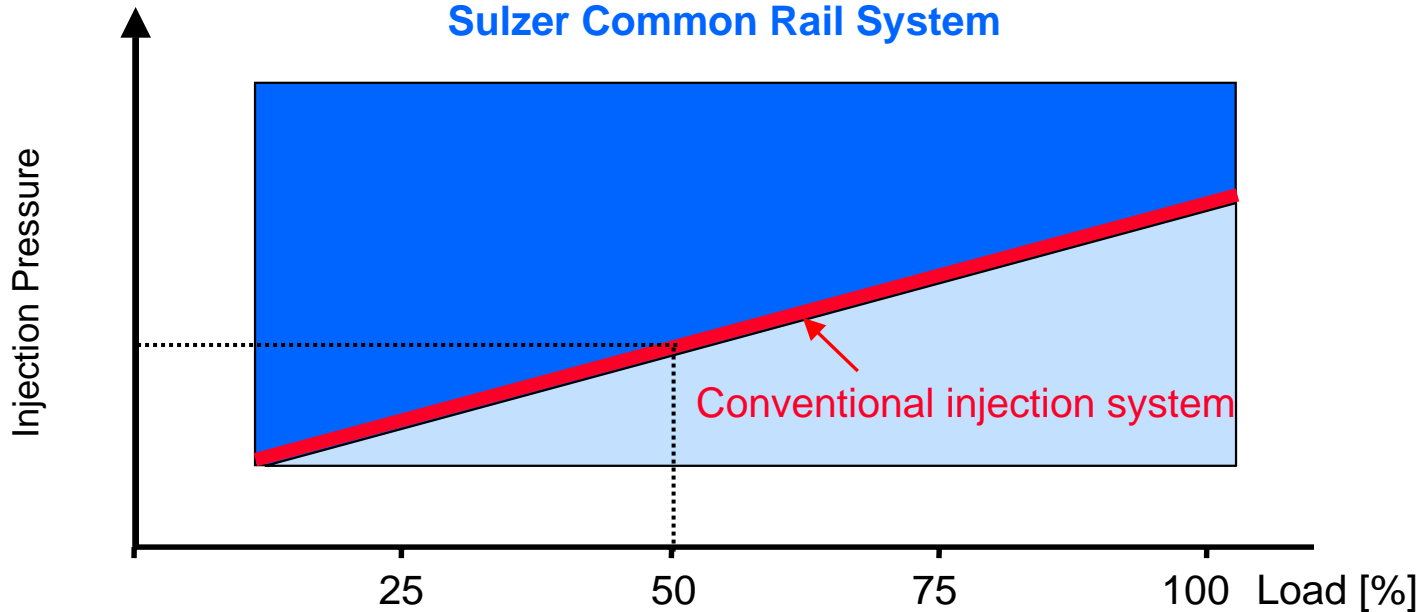
Exhaust Valve Drive



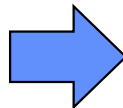
- ✓ Exhaust valve open / close timing can be controlled at all operation range.
- ✓ Optimum compression pressure can be achieved at all operation range.

Fuel Injection Pressure of Common Rail System

Sulzer Common Rail System

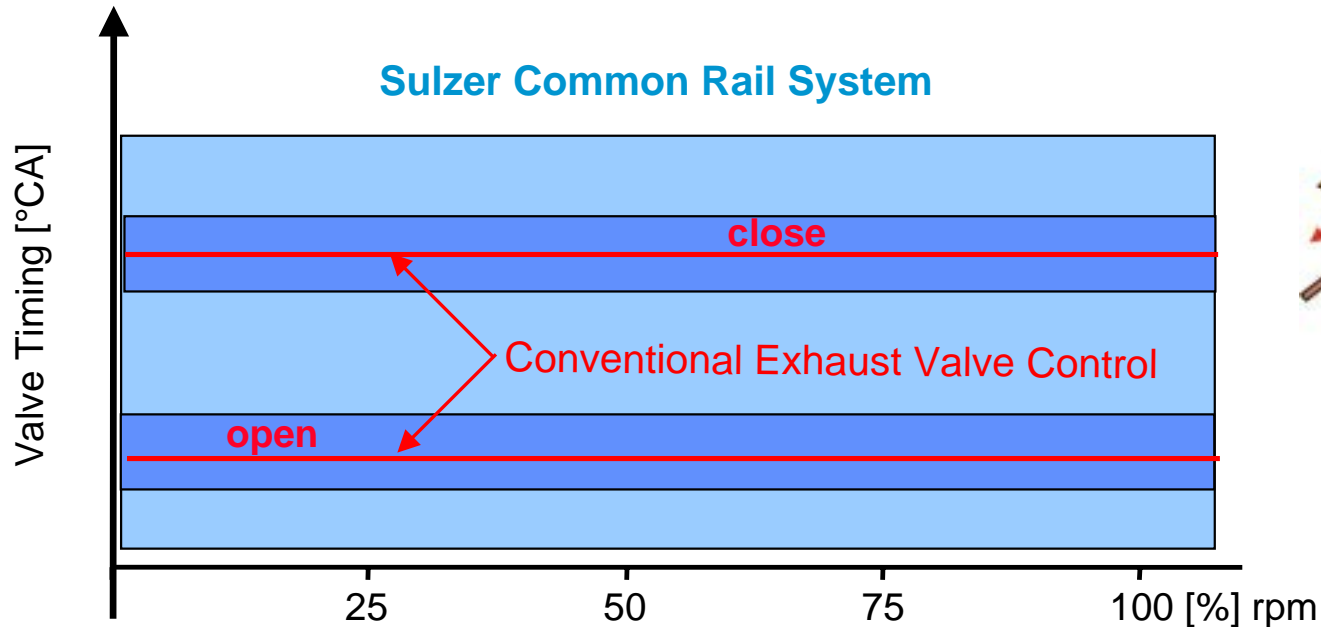


Free selection of injection pressure

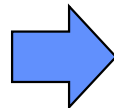


Low fuel consumption
Low Nox
Smokeless operation
Steady running at low load

Exhaust Valve Timing of Sulzer Common Rail System



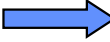
**Free selection of
exhaust valve timing**



**Low fuel consumption
Low Nox
Smokeless operation
Steady running at low load**

Sequential Operation of Injection Nozzle (Smokeless operation and slow steaming)

Sequential Operation :

Reduce number of injection valve to increase injection quantity of one injection valve at low load.  **Improvement of injection spray**



Standard injection pattern
2 nozzle operation



Low load :
1 nozzle operation

Smokeless operation down to 10-12% rpm R1
(13rpm for 6RT-flex50)

Merit of RT-flex Engine

Reduced Running Costs

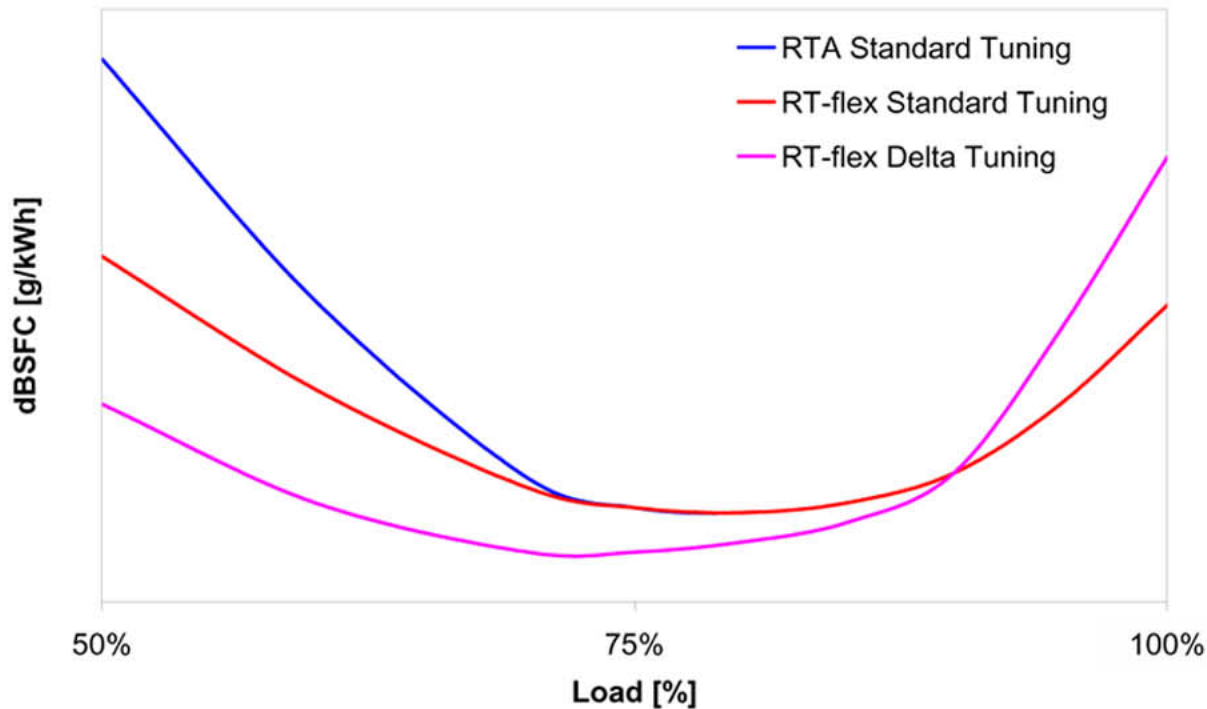
Fuel Oil Consumption

High fuel injection pressure
Optimized exhaust valve timing



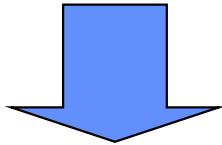
Reduced part-load fuel oil consumption


Difference of fuel consumption



Flexible Operation

- High fuel injection pressure
- Optimized exhaust valve timing
- Sequential injection nozzle operation



- **Lower minimum revolution** : 10-12% rpm R1 (6RT-flex50:13rpm)
- **Good slow steaming capability without any countermeasure**, by improvement of fuel injection.
- **Smooth and immediate reversing action** due to no mechanical reversing device.  Flexible operation can be possible especially in harbor.

Easy Maintenance

- **Simpler engine setting.
(injection / exhaust valve timing)**
- **In case of trouble, control module can
simply be exchanged.**

Easy Operation

RT-flex58TB

**Control console in
control room**



**Same arrangement
as console for
conventional engine**



Easy Operation

Engine side operation stand (RT-flex)



Control panel (without handle)

Engine side operation stand (RTA)



Operation by control handle

- 1. In-house test for flex parts.**
 - **Function test of fuel injection system and exhaust valve drive system.**
 - **Endurance test of Sulzer rail valve by 300,000,000 switching.**
- 2. Built-in redundancy regarding fuel pump and servo oil pump capacities**
Multiple pumps are installed on the engine.

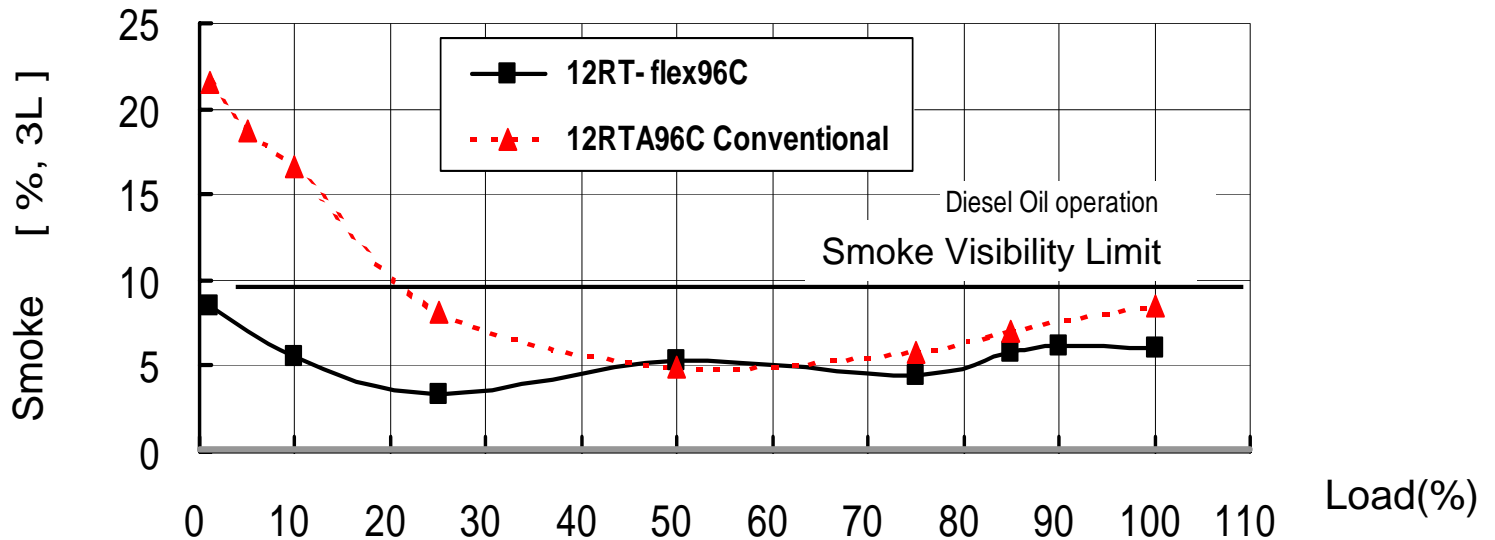
Doubled common functions and sensors to ensure higher reliability

- **Fuel oil and servo oil piping**
- **Crank angle sensor, exhaust valve stroke sensor, pressure transmitter**
- **Communication cable**
- **Main power supply unit**

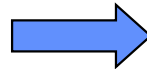
Monitoring of engine condition by sensors

- **Sulzer rail valve operation**
- **Injection timing and quantity from injection control unit**
- **Exhaust valve open / close timing**
- **Crank angle sensor monitoring**
- **Fuel oil and servo oil pressure monitoring**

Smoke Measurement Result 12RT-flex96C

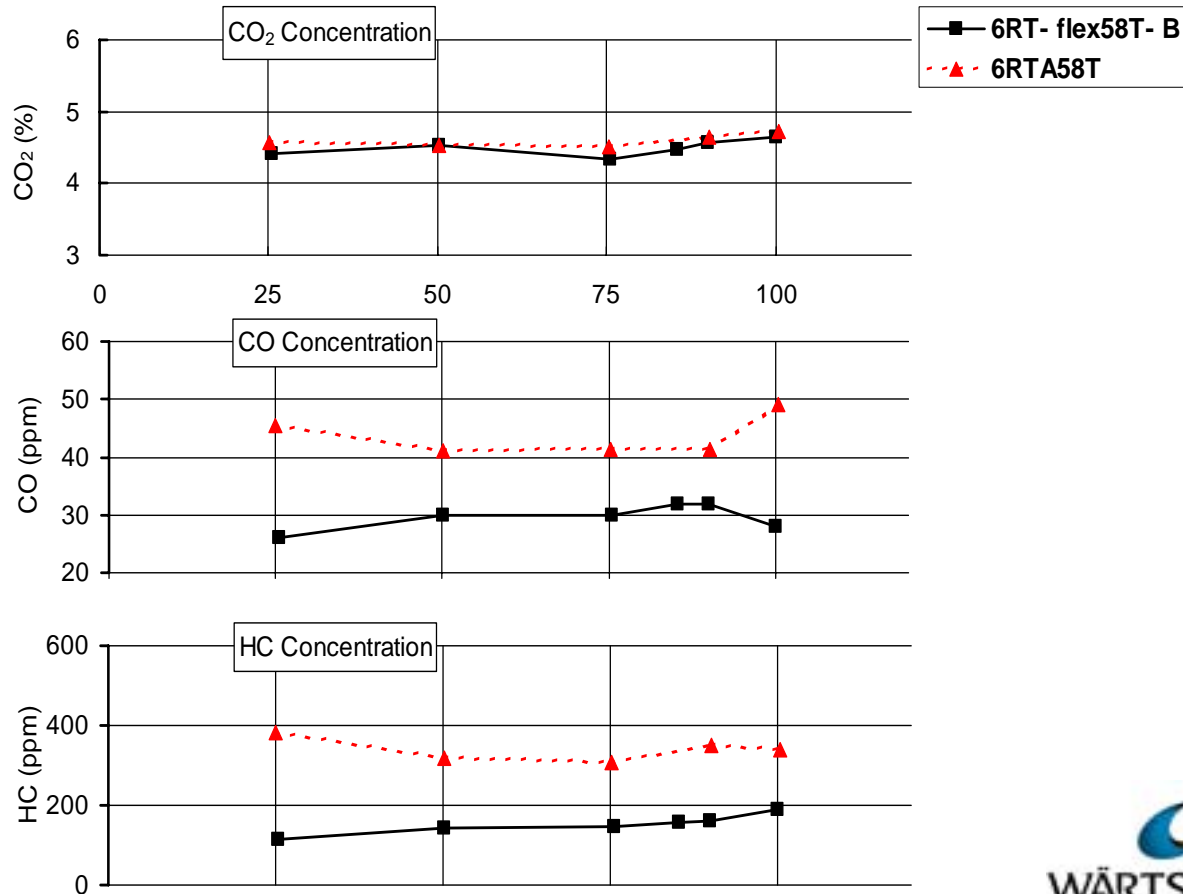


High injection pressure
Optimized exhaust valve timing
Sequential injection nozzle operation

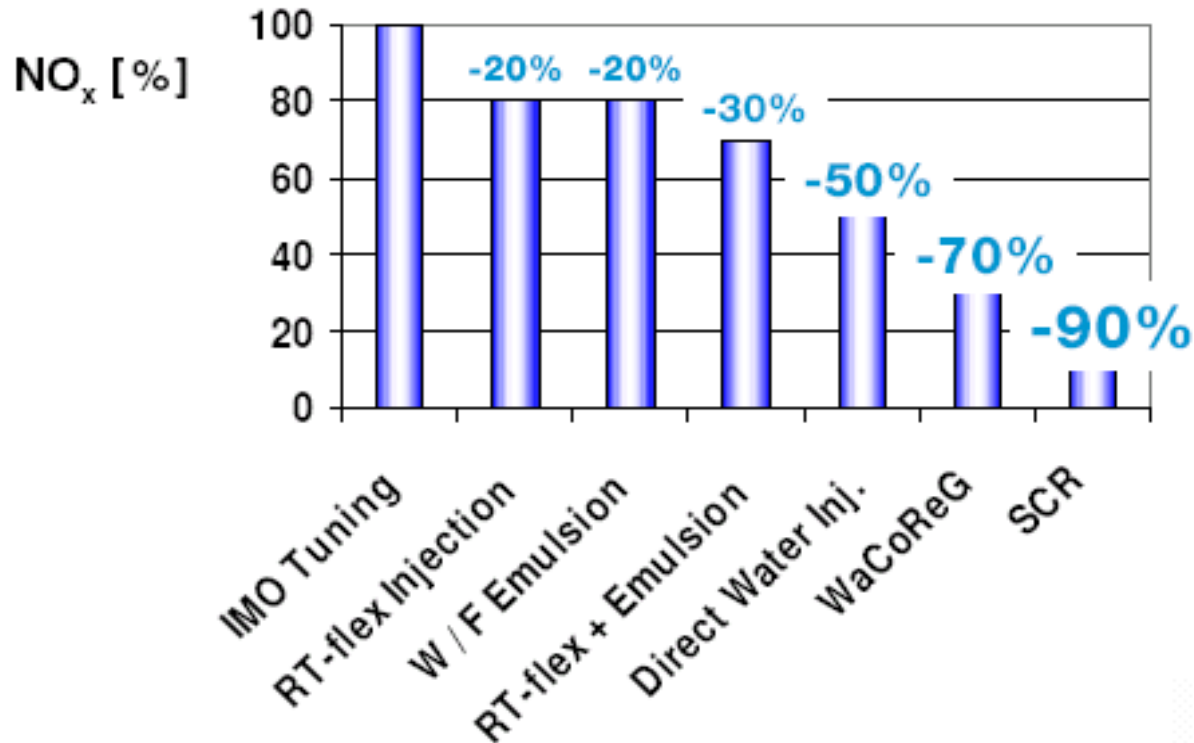


Improvement of fuel injection
Smokeless operation at all operation range

Exhaust Gas Emission Measurement Result 6RT- flex58T- B



Different steps of NO_x reduction technologies



First flex Engine in the world

6RT-flex58T-B

Since September 2001

General Statements:

- **More than 8000 running hours**
- **Running behaviour exceeds all our expectations for a revolutionary engine**
- **No real down-time besides 2hrs**
- **Operators quickly got acquainted to the system**
- **Several non-concept troubles solved**



- Lubrication of rail pumps failed

- ☞ Rail pumps replaced with correctly machined ones plus design changed

> **solved**

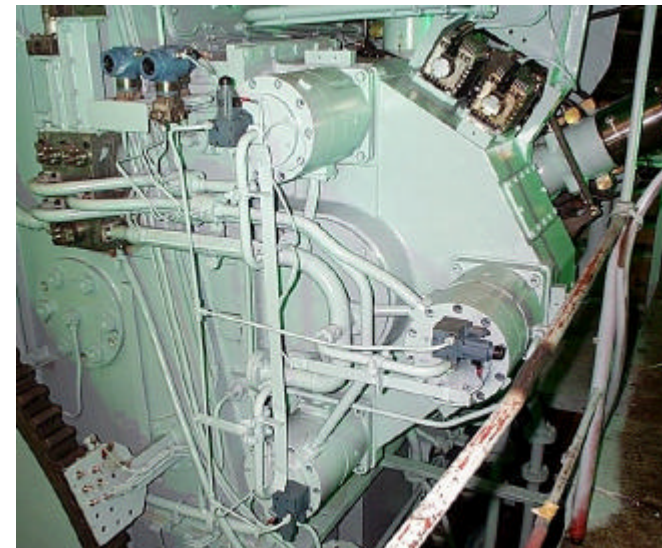
燃料ポンプ潤滑ラインが正規に明けられていなかったためのポンプ損傷。 => 正規のものと交換



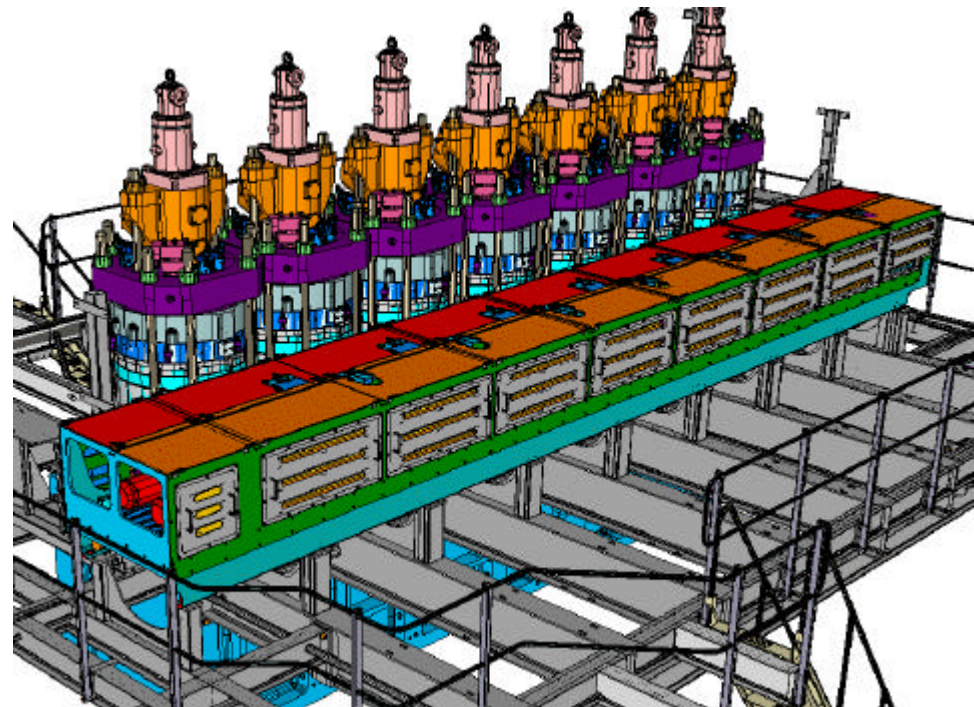
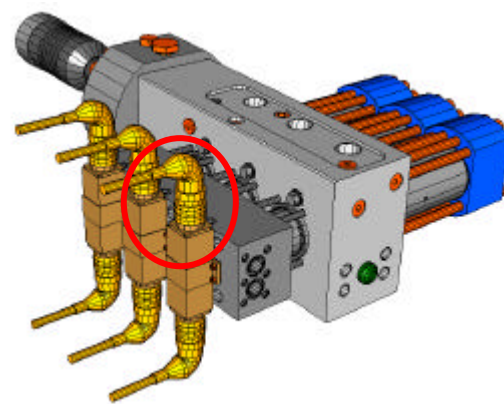
- Servo oil connecting pipes to collector block cracked

- ☞ Connecting pipes replaced by flexible hoses > **solved**

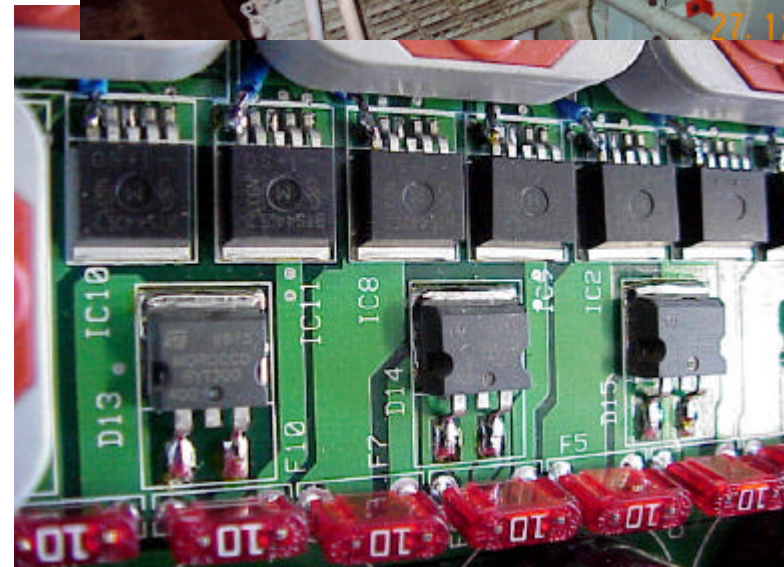
サーボオイル接続配管が振動で損傷 => 可撓継手に交換して解決



- Vibrations on upper platform
 - ☞ Modified design for new engines
 - > **solved**
 - 上部格子の振動が発生 => 補強により対策。新機関はこれをフィードバックして設計変更
- Rail valve connections broken
 - ☞ Better quality assurance and slight modification on connectors
 - > **solved**
 - レールバルブの電線接続が断線 => 電線接続部を固定
- Insufficient accessibility of rail unit casing internals
 - ☞ Accessibility vastly improved by new design
 - > **solved**
 - レールユニットの内部へのアクセスに手間がかかる => 新設計の導入で解決



- Malfunction of some sensors
 - ☞ Sensors were defective or showed bad wiring
 - > solved
- Valve drive module failures
 - ☞ センサーが誤動作 = > 配線が悪く、センサーが故障
 - ☞ new print set-up for lower thermal stress of components
 - > solved
 - ☞ VDMが誤動作 = > 各製品の熱応力を下げるPCBの採用
- Regulating behaviour unsuitable for large swell and light ship
 - ☞ Software control loops modified for compatibility
 - > solved
 - ☞ 載荷条件により機関制御に不安定性が出た = > ソフトウェアの変更



Conventional Parts



Very good results on liner wear
ライナ摩耗は良好



Very good result on piston ring wear
ピストンリング摩耗も良好



Very good load pattern on crankshaft gear wheel
クランク軸付歯車の歯当たり良好



Clean valve seat
排気弁座はきれいな状態を示す



Good injection nozzle shape
燃料弁ノズルチップも腐食や他の問題なく良好



RT-flex Specific Parts



Very good load pattern on gear wheels of supply unit

サプライユニットの歯車の当りは良好



No wear on fuel cams

燃料カムに摩耗なし



No wear on hydraulic actuator for ExVa

排気弁駆動部品にも摩耗なし



No wear on crank angle sensor assembly

クランク角度検知センサー組立にも摩耗なし



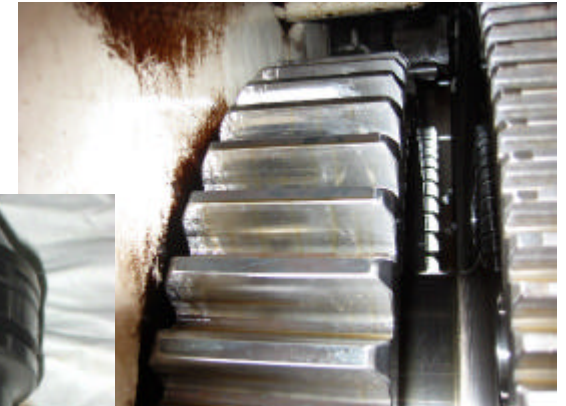
Electrically driven hydraulic pumps have been modified (couplings, vibs)

電動モーター駆動の油圧ポンプの接手に振動を原因とする問題があり、型式変更した。



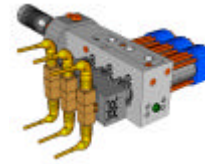
Emergency pressure regulating valve has been modified (tightness)

圧力調整弁のシール性の問題が発生していたので、形式変更した。



燃料噴射制御ユニット部品の開放結果は新品テスト中とまったく同じ噴射パターンであった。

RT-flex Injection Control Unit



Shows absolutely same injection pattern as when tested new

No wear on sealing surface of injection

control valve

燃料噴射制御弁のシール座に摩耗なし



No wear on control oil piston

制御ピストンは摩耗なし



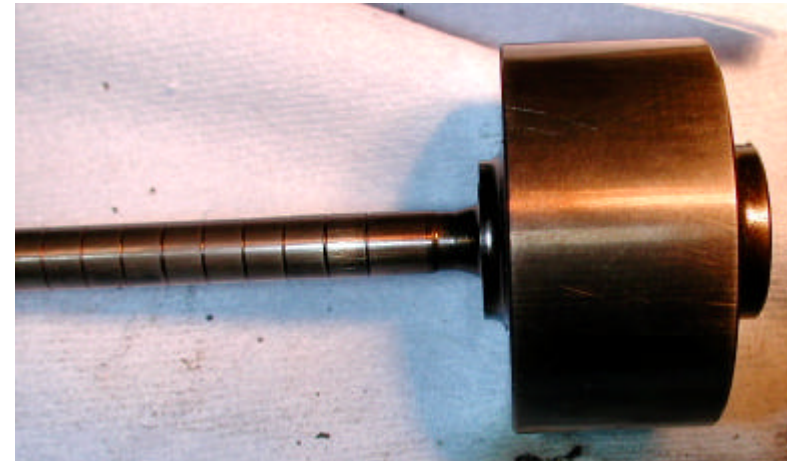
No wear on injection control valve slide

燃料噴射制御スライドにも摩耗なし

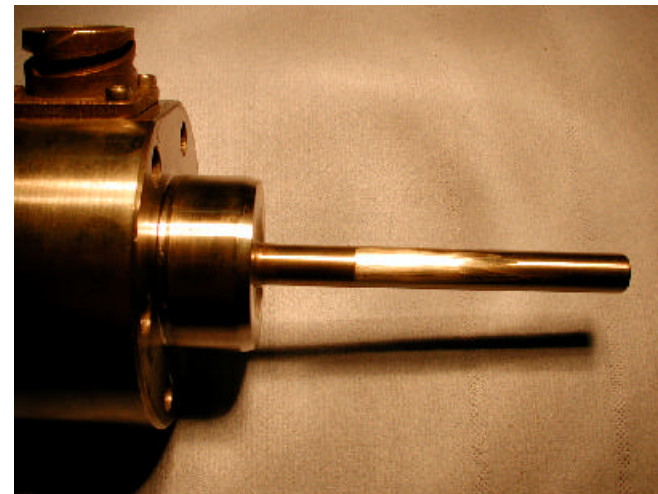


RT-flex Injection Control Unit

No wear on fuel quantity piston
燃料噴射量制御ピストンに摩耗なし

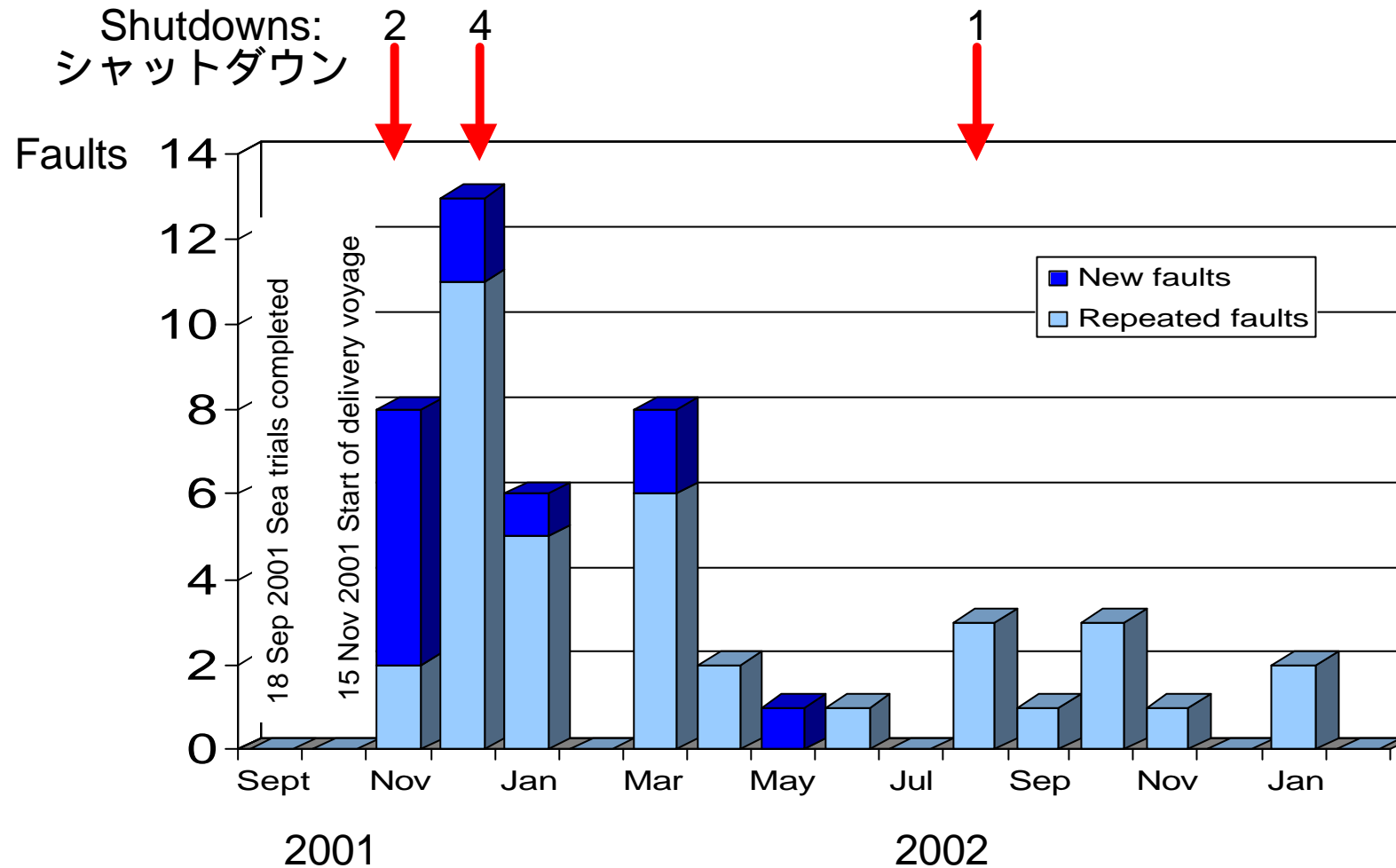


No change of wear on fuel quantity
sensor since beginning of operation
燃料噴射量検知センサーも連続使用中



Experience

Fault History



Note that faults are only recorded from start of delivery voyage

Repeated faults are owing to time taken to develop final solutions

Conclusions

- RT-flex system concept works fine
flexに当初意図した種々の性能が、予定通り実現していることを確認した。
- Some “teething” problems solved
幾らかの初期問題を経験した。
- Our feed-back concept for continuous product improvement paid off
連続生産にあたり、必要なフィードバックを行った。
- Crew is operating the engine without assistance since May 2002
乗組員は2002年5月以降Wartsilaエンジニアの助けなく問題ない運行を続けている。
- Complete inspection after 5300Rhrs showed very low wear figures on engine parts incl. RT-flex system
5300hrs後の開放検査によって、RT-flexだけでなく各部の摩耗も良好であることを確認した。
- Some components later adapted according to inspection
いくつかの部品は同開放検査の結果に鑑み、改善を図った。

Service Experience 2

M/T SEA LADY 6RT-flex58T-B

First RT-flex Engine at DIESEL UNITED

Eng. Type : 6RT-flex 58T-B

MCR : 12,000kW x 103min⁻¹

Vessel name : SEA LADY
(Afra max tanker)

In Service : August 28 2003

Total running hour : 9,700 hrs
(September 2005)

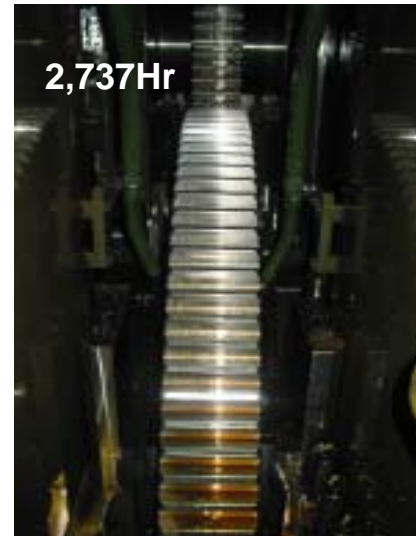
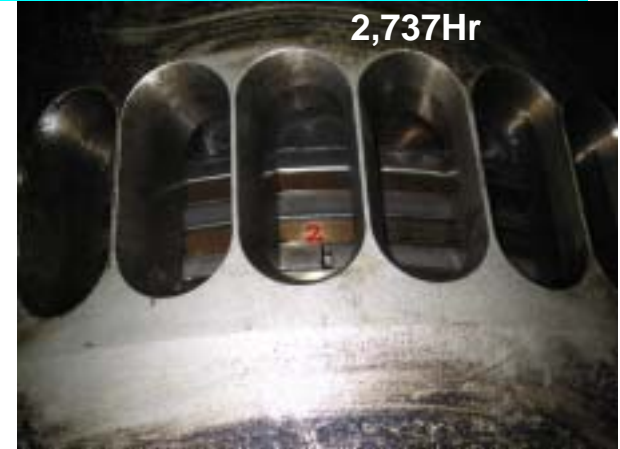




- **Total run hour : 9,700 Hr
(September 2005)**
- **Cyl. Oil feed rate : 1.36 g/kW · hr
(85%Load)**
- **Some initial problems were solved.**
- **Operators quickly got acquainted to the flex system. Now the engine runs without problem.**

Conventional Parts

- Piston ring / Cylinder liner : Very good condition
- Crank shaft gear : Very good condition
- Sludge accumulation in piston under side on flex engine compared with conventional engines :
“Clear”, “Excellent” (Ship crew’s evaluation)
Extension of maintenance interval



Conclusion

- RT-flex system concept works fine.
- Some “teething” problems were experienced and solved. Necessary feed-back for improvement were carried out.
- Operators quickly got acquainted to the flex system and operate the engine without problem.
- Overhaul inspection result of flex parts shows very good condition.
- Sludge accumulation in piston under side is “clean & excellent”.

Voice of chief engineer

At Halifax June 3 2005

- **We are satisfied with the flex engine. Basically better than conventional engines.**
- **Smokeless operation at starting and shifting slow half speed.**
- **Easy handling. Electric module exchange work requires only 15 minutes.**
- **Simple setting of fuel injection timing.**
- **Smooth and immediate reversing operation.**

Improvement of Main Parts Reliability

- Main Bearing
 - Optimized design by Elasto Hydro Dynamic.
 - Application of back relief and lemon shape.
- Guide Shoe
 - Optimized design consideration of deformation by FEM.
 - Increased contact area between guide rail and guide shoe at BDC.
- Piston Ring / Cyl. Liner
 - Application of Tribo-pack.
- Stuffing Box
 - Application of BICO-type Stuffing box.

RT-flex Conclusion

● High Reliability and Reduced Running Costs

● Image1 : Is running cost of RT-flex higher?

➤ Saving fuel oil consumption.

Running cost of RT-flex decreases.

➤ Reducing maintenance hours.

➤ Extension TBO and simple structure.

● Image2 : Is operation of RT-flex difficult?

Easy operation of RT-flex.

➤ Operations can quickly get acquainted to flex system and operate the engine.

➤ Easy trouble shooting of WECS system.

● Image3 : Is reliability of RT-flex lower?

➤ Higher reliability of flex system was proved by good service experience more than 70,000 hours.

Higher reliability of RT-flex compared with conventional mechanical engines.