

Safety philosophy and issues of the control system
 for the
 electronically controlled *ME-engine*
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ME Engine Control System

- The ME-engine: Introduction to computer control of the engine combustion process
- The Engine Control System: Principles and safety features
- Integration of the ME-engine to the ship systems
- Life-cycle activities:
 - Maintenance and trouble shooting
 - Update of SW
- The Engine Control System as an off-the-shelf product

The ME-engine essentials - Why?

- Possibility for different operation modes
- Optimal combustion at all operation speeds and loads
- Reduced part load fuel consumption
- Smokeless operation at all operation speeds
- Reduced cylinder lubricating oil consumption
- Easy adaptation to different fuel
- Lower dead slow running and slow steaming, down to 10% rpm L1
- Improved engine acceleration

The ME engine type - the electronically controlled engine

First ME-engine in operation: December 2003

May 2005 12 engines in operation

ME-engine: Electronic Fuel Injection

Timing example of fuel injection

Fuel Oil Injection

Phase 1

1. The pistons move to the bottom position.
2. The fuel inlet is open.

- Hydraulic oil leaves the hydraulic oil chamber via the ELF valve.
- The accumulators are supplied by the Hydraulic Power Supply. The pressurised hydraulic oil is held back by the closed ELF valve.

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Fuel Oil Injection

Phase 2

5. The ELF valve is activated upwards, closing the return flow and opening for the flow of pressurised hydraulic oil. The oil passes through the ELF valve and fills the hydraulic chamber.
6. The high pressure forces the pistons upwards.
7. The fuel inlet is closed.
8. The pressure on the fuel oil rises and exceeds the force of the spring in the cylinder's fuel injection valve.

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S50 ME-C Exhaust Valve System

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Hydraulic System on the ME Engine

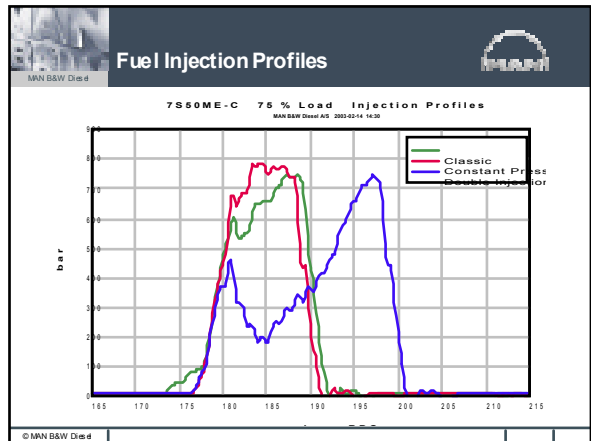
Hydraulic Cylinder Unit (HCU)

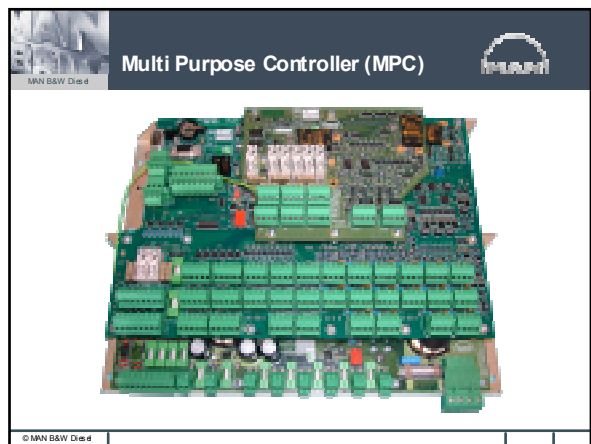
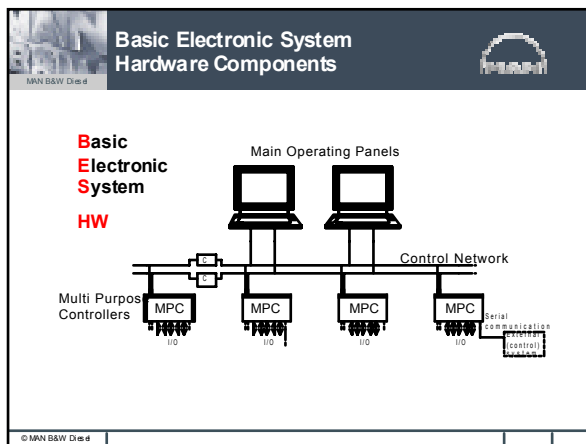
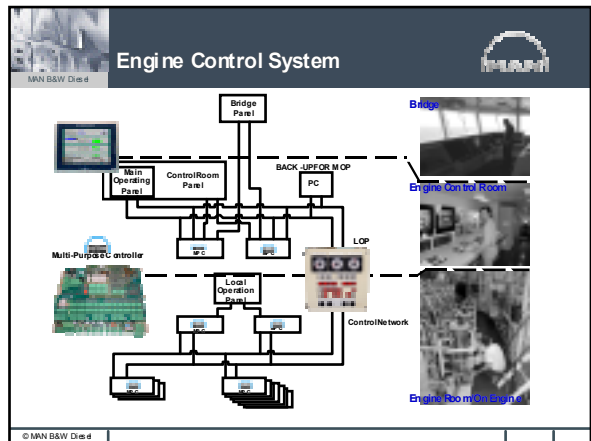
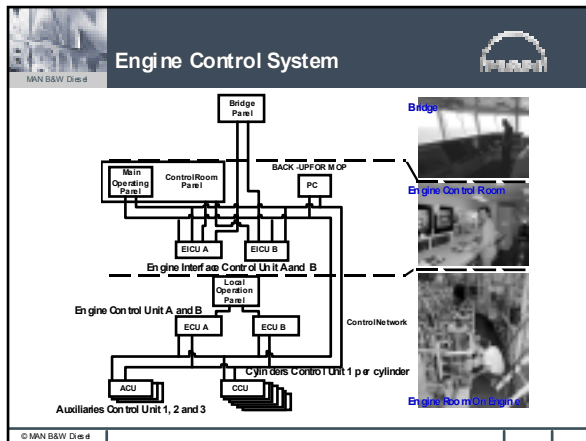
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Hydraulic System on the ME Engine

Hydraulic Cylinder Unit (HCU)

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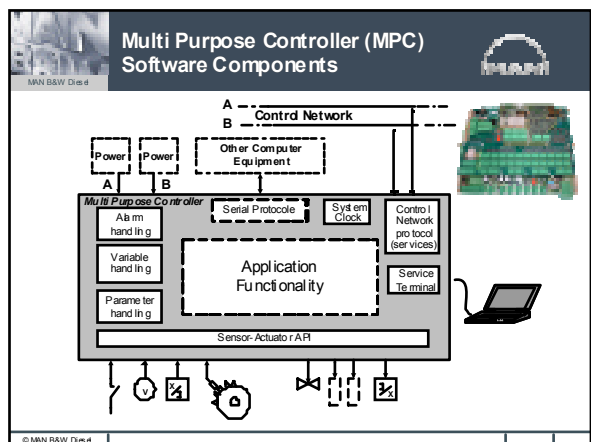


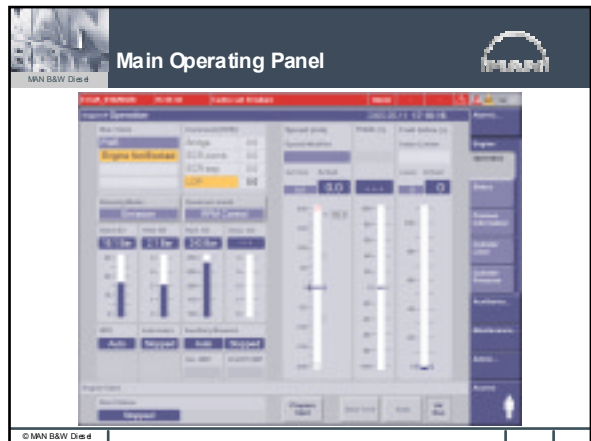


Multi Purpose Controller

- Hardware developed in-house:**
 - Motorola 68332 CPU with Time Processing Unit (Automobile industry CPU with facilities for determination of crankshaft position – programmable in Micro Code)
 - Program stored in Flash-PROMs
- Software:**
 - RTXC pre-emptive real time operating system
 - Basic Electronic System Software platform
 - Implemented in C++
 - Application Software
 - Implemented in C++ and Micro Code
- Control Network:**
 - Media access layers based on ArcNet standard
 - Transport layers of protocol based on EU: ATOMOS project
 - Application layers of protocol are of subsidiary design


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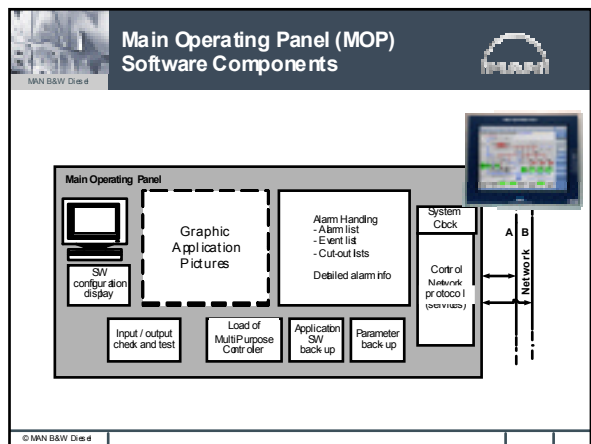


Main Operating Panel

- **Type approved PC**
 - Touch screen operation
- **PCI Control Network board**
 - In-house developed
 - Includes hardware watchdog
- **Software:**
 - Windows 2000
 - Application software implemented in C++ and graphics in Borland C++ Builder



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Basic Electronic System System Supervision and Self-test

The **system supervision** checks that:

- Each unit is responding
- Each unit can be reached on both Control Network lines
- The application is executed in each unit

Supervision in each control unit:

- Test of memory and SW integrity during start-up of unit
- Signal and cable supervision as far as possible
- Supervision of each power section of the unit
- Non-proper SW execution => Shutdown - fail safe state

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Basic Electronic System Computer shutdown - fail-safe state

Shutdown / fail-safe state will be entered caused by:

- Watchdog time-out
 - HW watchdog supervises SW watchdog
 - SW watchdog supervises time schedule of critical tasks
- HW exceptions, e.g. illegal instructions
- SW exceptions, e.g. failure situations, which handling is not implemented in the SW
- Power failure

All outputs enters a state equal to power-off state.

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Life-cycle activities: Trouble-shooting and repair

Consequences of the 'single failure principle':

- In a duplicated system must failures be remedied rather fast
 - in theory within an infinitively short period.
- It must be avoided that trouble-shooting introduces additional failures.

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MOP I/O test

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MOP I/O test

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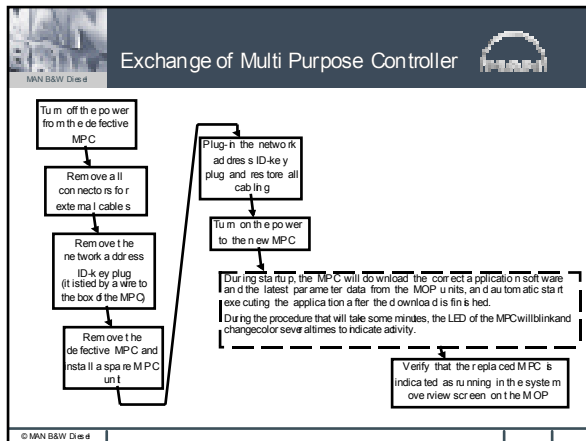
MOP I/O test

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Repair Philosophy - 'Repair by replacement'

- The function and location of Multi Purpose Controllers are identified by an ID-key plug
- Back-up of application SW and adjustment parameters is stored in the Main Operating Panel(s), and is loaded via the ControlNetwork

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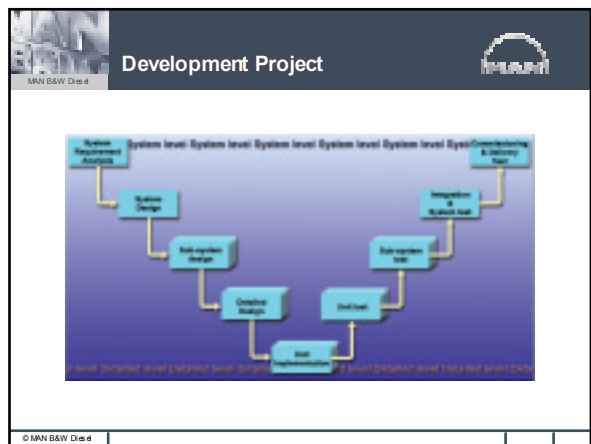
ME Engine Control System

Software update

The Engine Control System is built as an **off-the-shelf** product

The software and – not least – the test is under on-going evolutionary development

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Unit Test

Software module test

Scope: Software modules executed in test stubs and simulation environment on PC

Specification: Test stubs defined by the developer. Test stubs and results are configuration controlled, maintained and used for regression test

Who: Software developer

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Tests

Test automation:

Compiler
The compilation of source code must not cause warnings. In case it is unavoidable in a specific module, the specific warning is explicitly suppressed in this module

Scripts: Runs the test stubs and compares the results with previous stored results

PLint: Static source code analysis: Strict type checking, syntax checking etc.

Codeguard: Boundary checks, memory leaks

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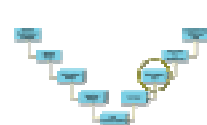
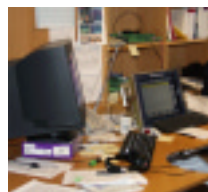
Sub-system Test

Network node software test

Scope: Assembled software for the network node executed in simulation environment on PC

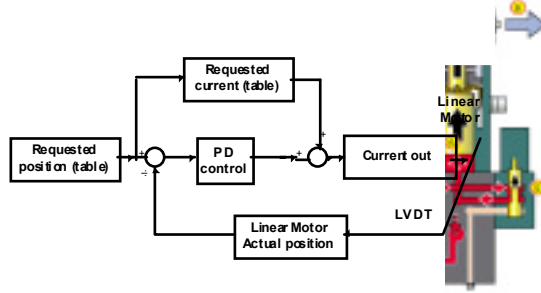
Specification: Simulated environment defined by the developer. Simulated environment and previous results are configuration controlled, maintained and used for regression test

Who: Software developer

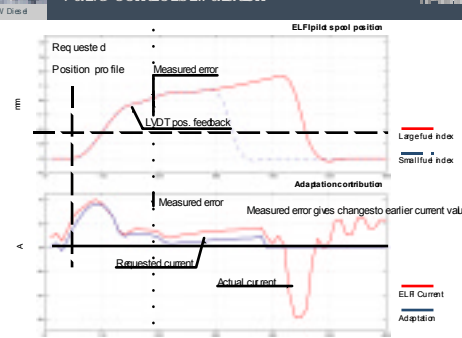
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Position control model



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Valve control simulation



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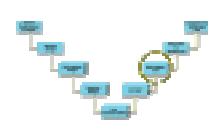

Sub-system Test

Network node test

Scope: Software in Control unit with IO and network in laboratory

Specification: Network node: Test environment defined by the developer. Test stubs and results are configuration controlled, maintained and used for regression test

Who: Software developer

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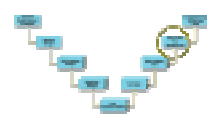

Integration & System Test

Integration & System test (step A)

Scope: All control units with network and I/O's connected to simulator

Specification: System test specification

Who: Software developer(s) and person responsible for test

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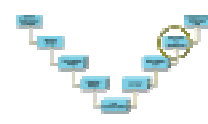

System Test

System test (step B)

Scope: Control system etc. on the research engine

Specification: System test specification & test programs for 'Type approval test' and 'Engine delivery test'

Who: Software developer(s) and person responsible for test


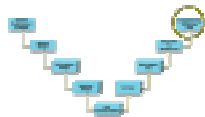
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Commissioning & Delivery Test

Delivery of Engine

Scope: Engine
Specification: Engine Delivery Test specification
Who: Engine builder, Owner and Classification Society


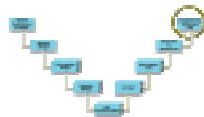
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Commissioning & Delivery Test

Delivery of Engine

Scope: Actual engine in the ship propulsion plant
Specification: Sea trial test specification
Who: Engine builder, Owner and Classification Society

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Thank you for your attention!




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