Investigation of Engine Room Fires – A multi-discipline approach.

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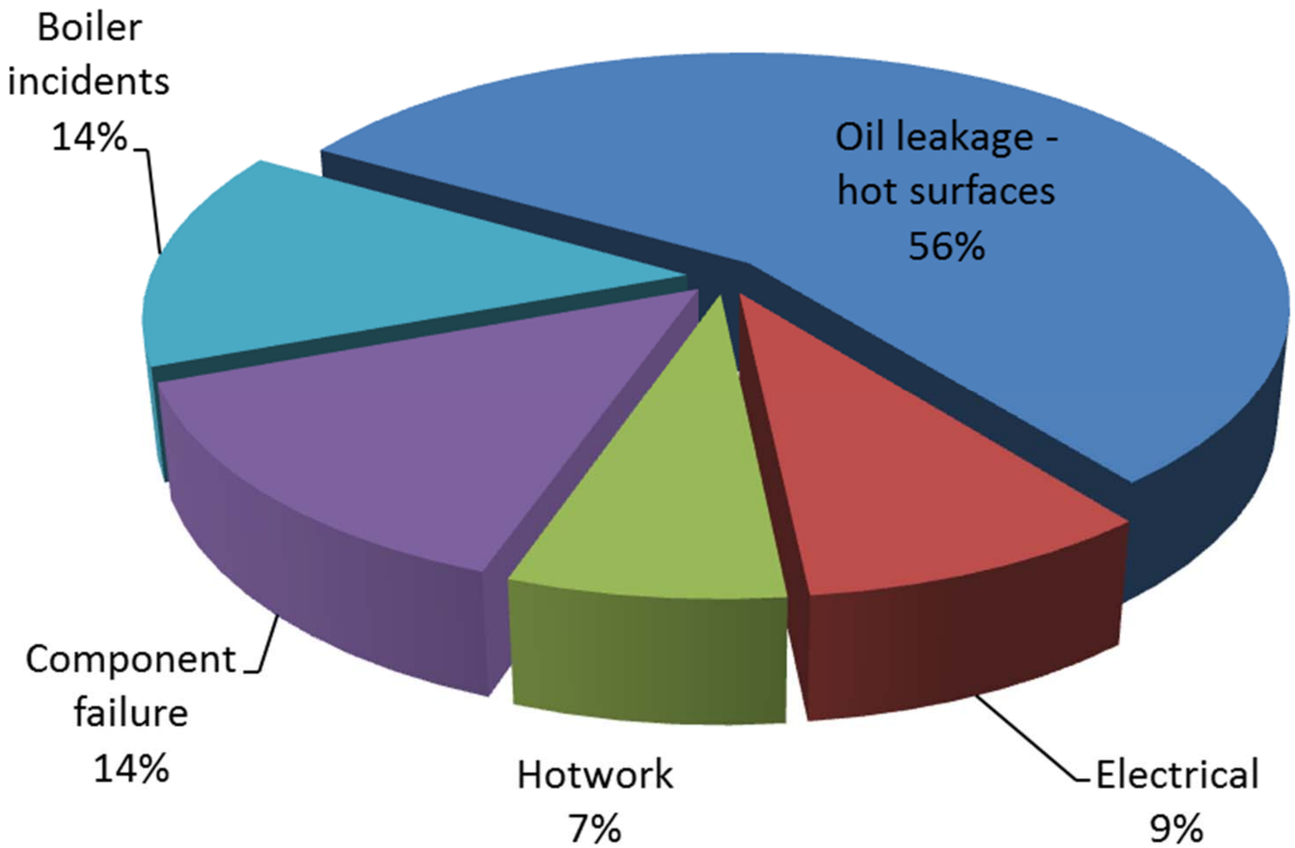
Investigation of Engine Room Fires

In cases of an engine room fire and assessment of cause, there is often a need for a multi-discipline approach. We will discuss how marine engineers, fire investigators metallurgists and naval architects can interact in ship board fire scenarios.

Fire Investigation – A Multi-discipline Approach

Fuel Oil & Lube Oil System Fires
Maintenance & Fire Prevention

Fire Causes in Engine Rooms



Marine Engineer - Content

- Regulations & Legislation
- Fuel & Lube System Design
- Exhaust Systems & Hot Spots
- A Case Study
- Maintenance & Fire Prevention

Regulations & Legislation

Recent Changes to SOLAS 74

Amendments 2000 Chapter II-2

Part B - Prevention of Fire and Explosion

Regulation 4 – Probability of Ignition

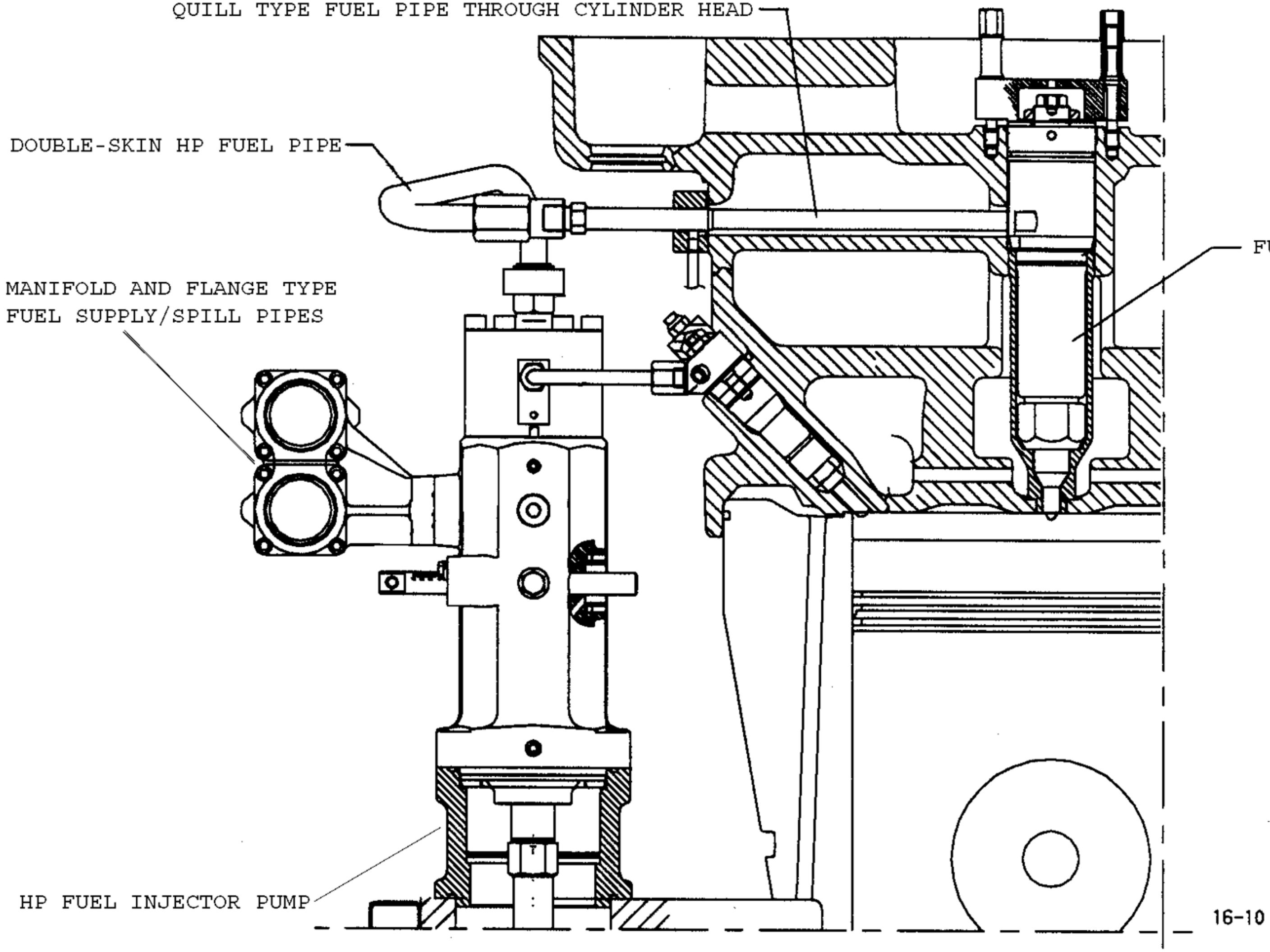
Paragraph 1 - Purpose

Paragraph 2 – Arrangements for Oil Fuel, Lubrication Oil & Other Flammable Oils

Summary of SOLAS Requirements

- Jacketed (double-skin) HP fuel pipes
- Fuel leakage collection and alarms
- Location of pipelines
- Screened pipelines
- Minimum joints
- Design consideration for pulsation pressures, including the LP system.
- Insulation of hot surfaces above 220^{o}C

Fuel Oil System Design


QUILL TYPE FUEL PIPE THROUGH CYLINDER HEAD
DOUBLE-SKIN HP FUEL PIPE
MANIFOLD AND FLANGE TYPE
FUEL SUPPLY/SPILL PIPES
FUEL INJECTOR
HP FUEL INJECTOR PUMP
16-10

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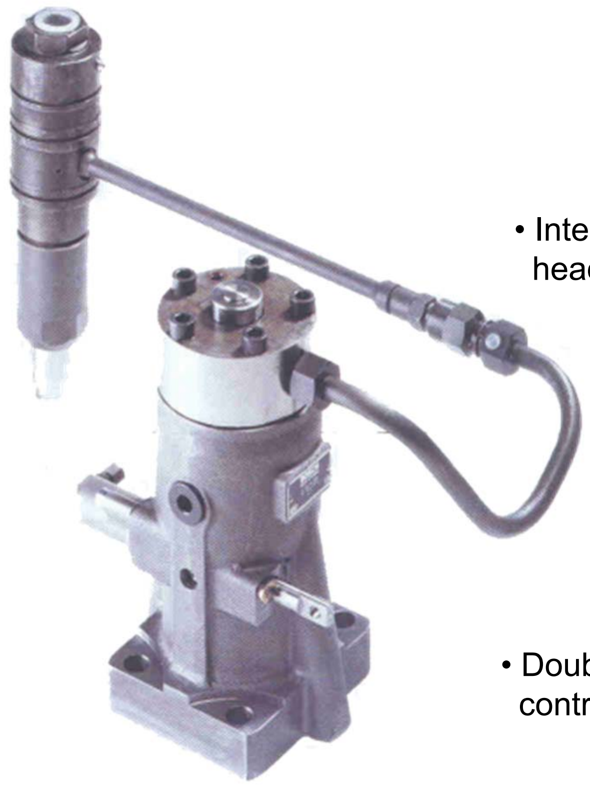
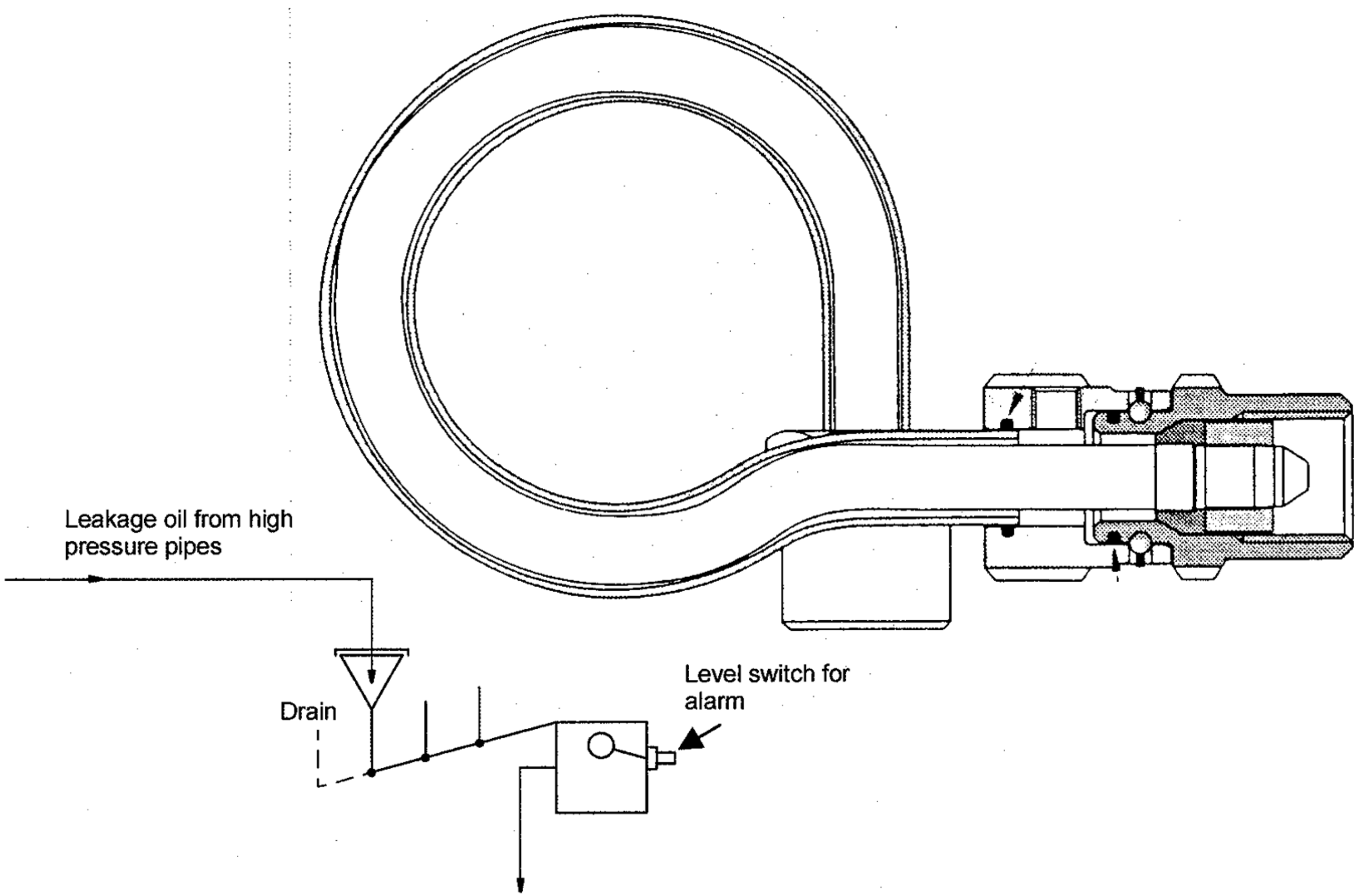
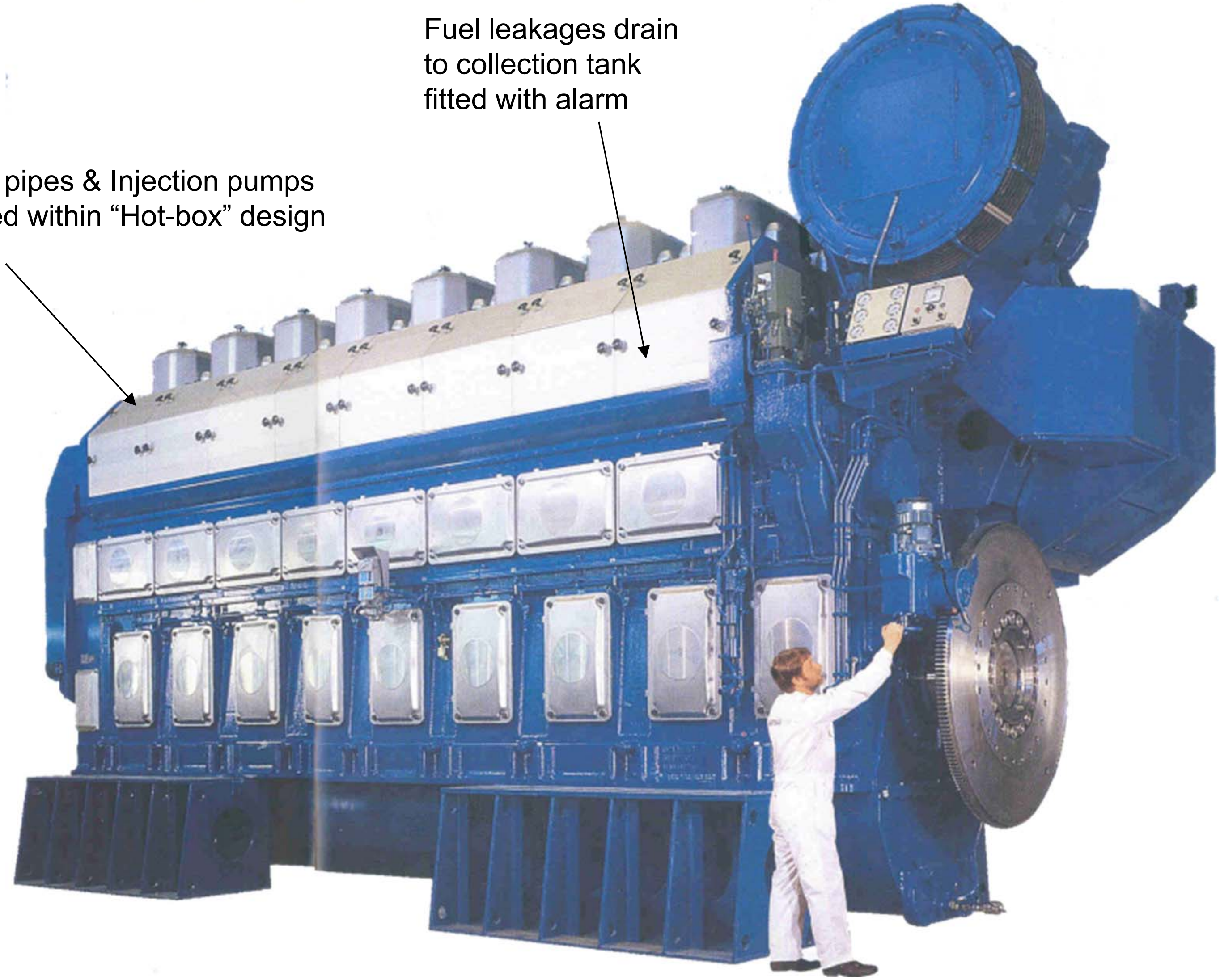
Fuel Injection System

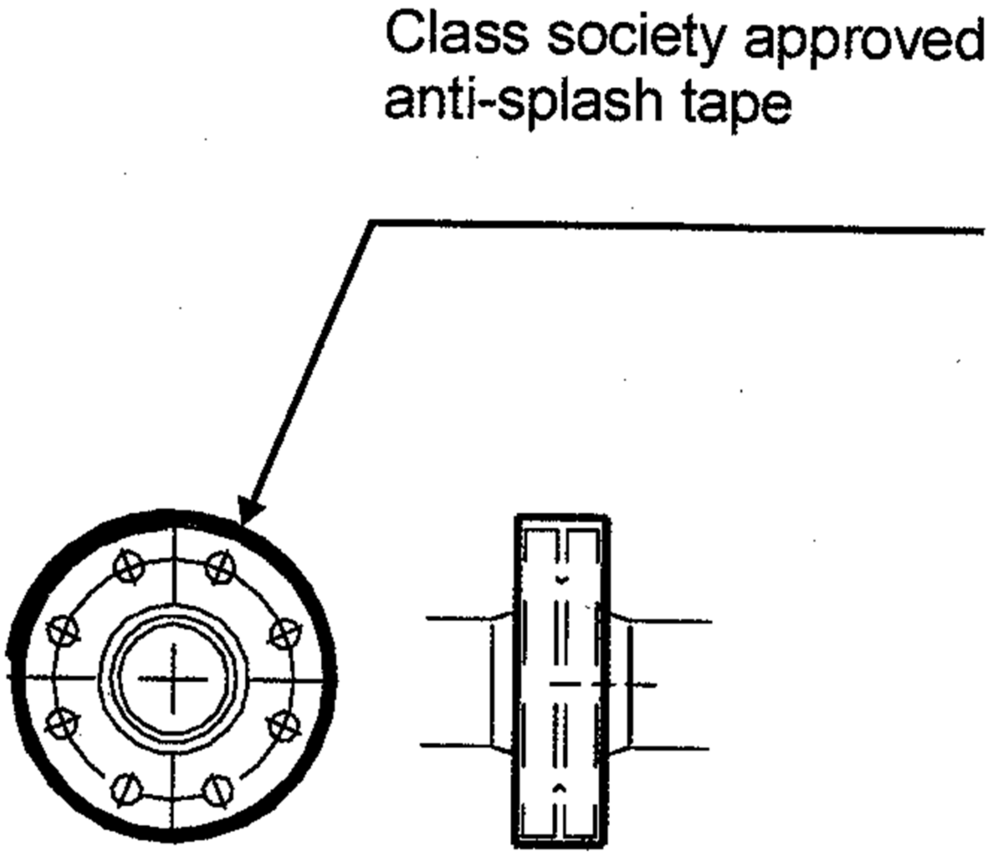


- Internal pipe through side of cylinder head reduces length and bends, etc.
- Fuel feed and return lines integrated in the fuel pump housing results in less pipe joints.
- Double-skin and short length HP pipe contribute to safety

Double-skin High Pressure Fuel Injection Pipe

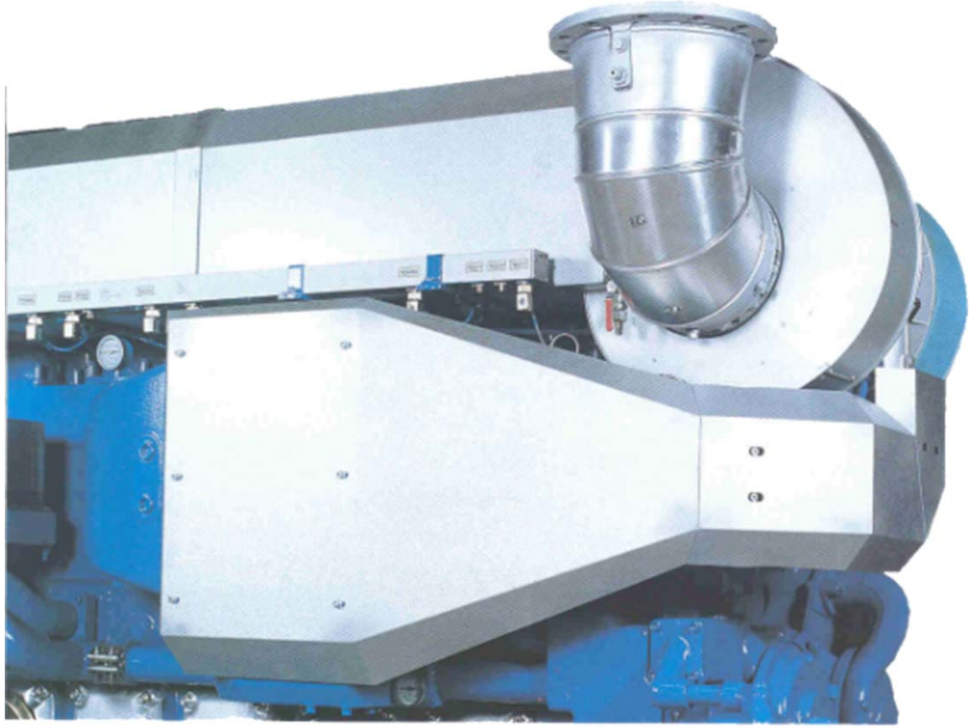


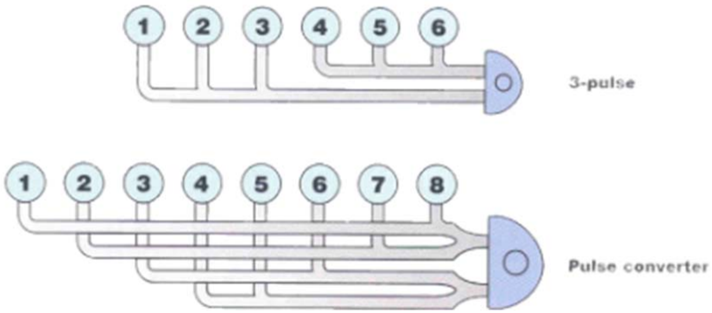

Fuel leakages drain
to collection tank
fitted with alarm
Fuel oil pipes & Injection pumps
enclosed within "Hot-box" design

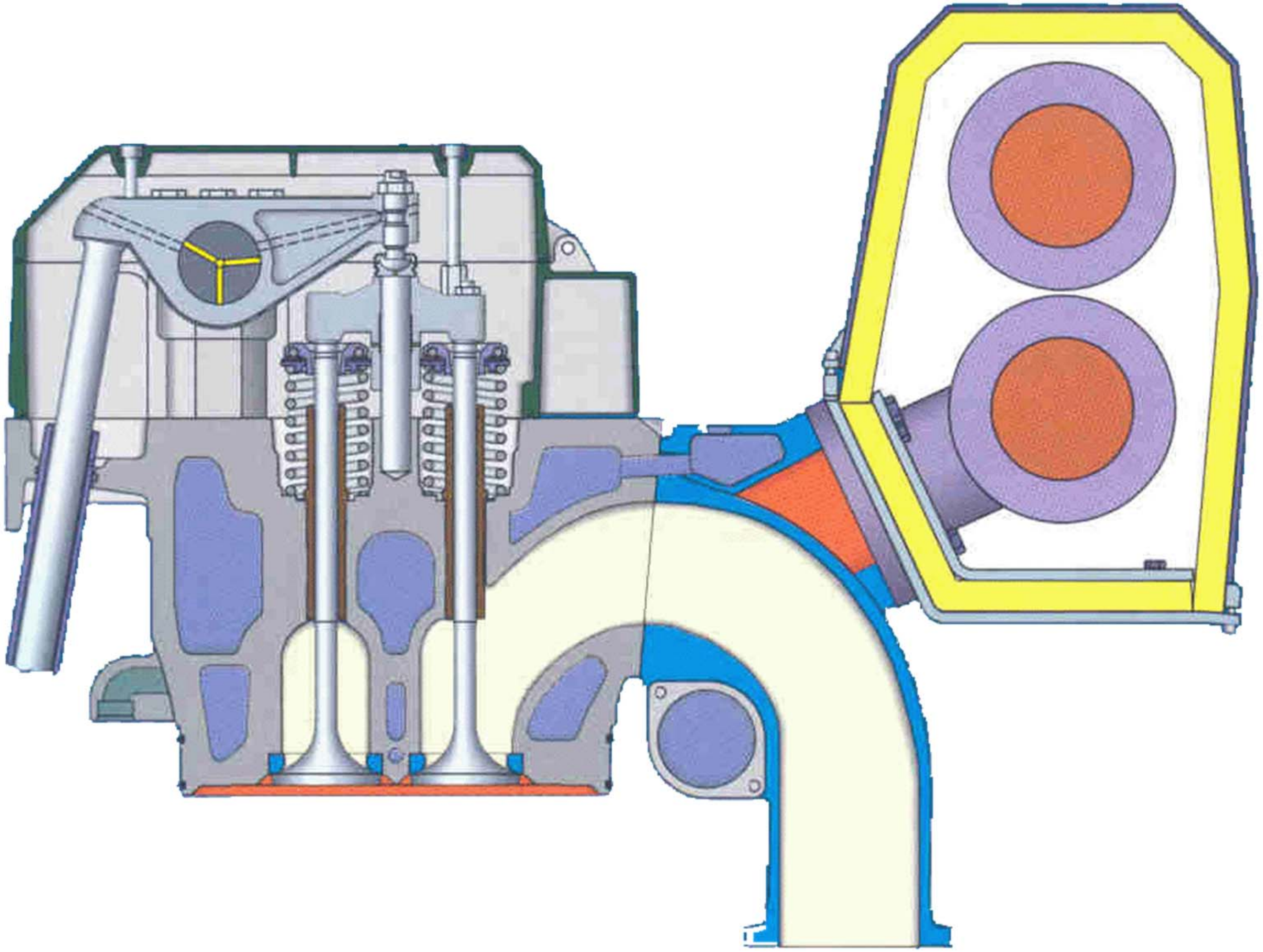

Class society approved
anti-splash tape

Exhaust Systems
&
Hot Spots

Exhaust Shielding & Insulation

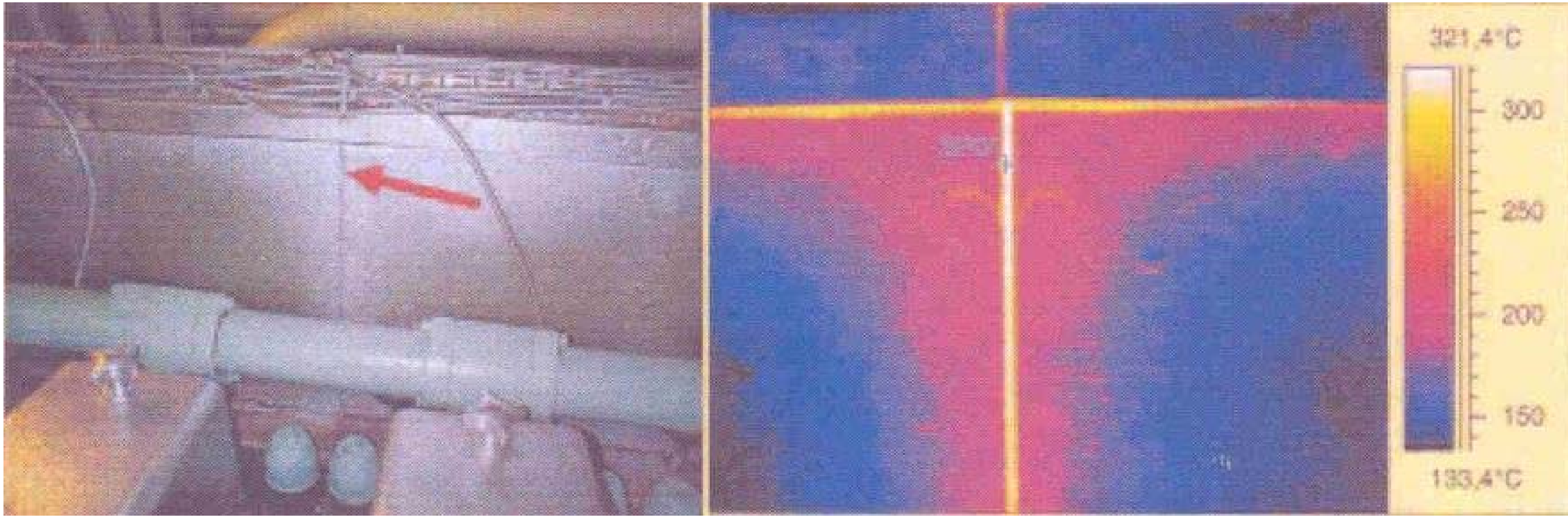






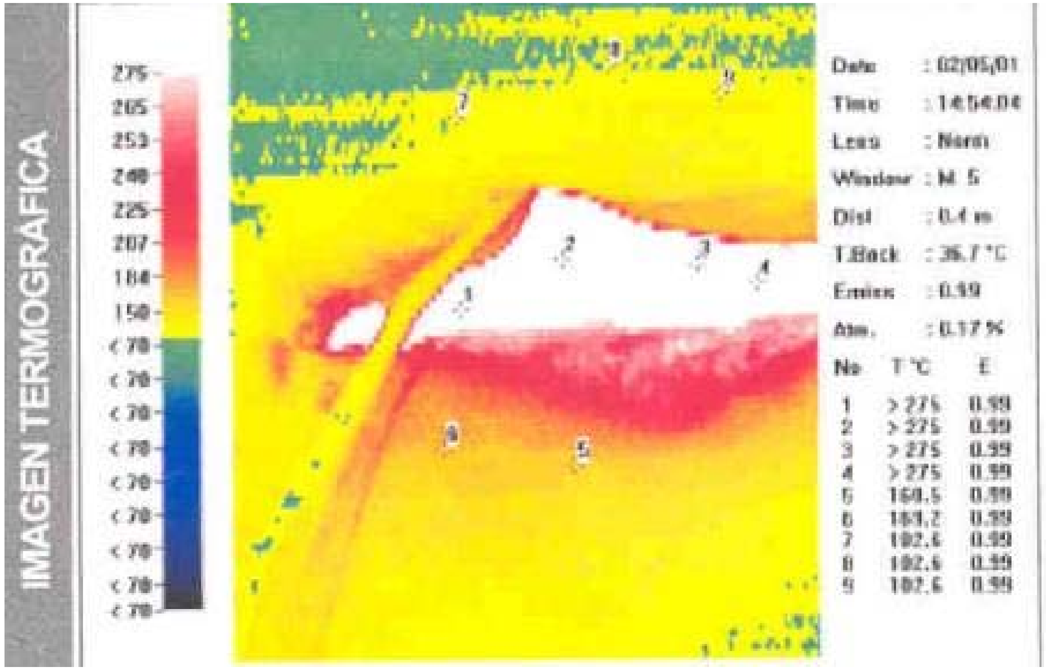
Tracing Hot Spots (>220^{o}C)

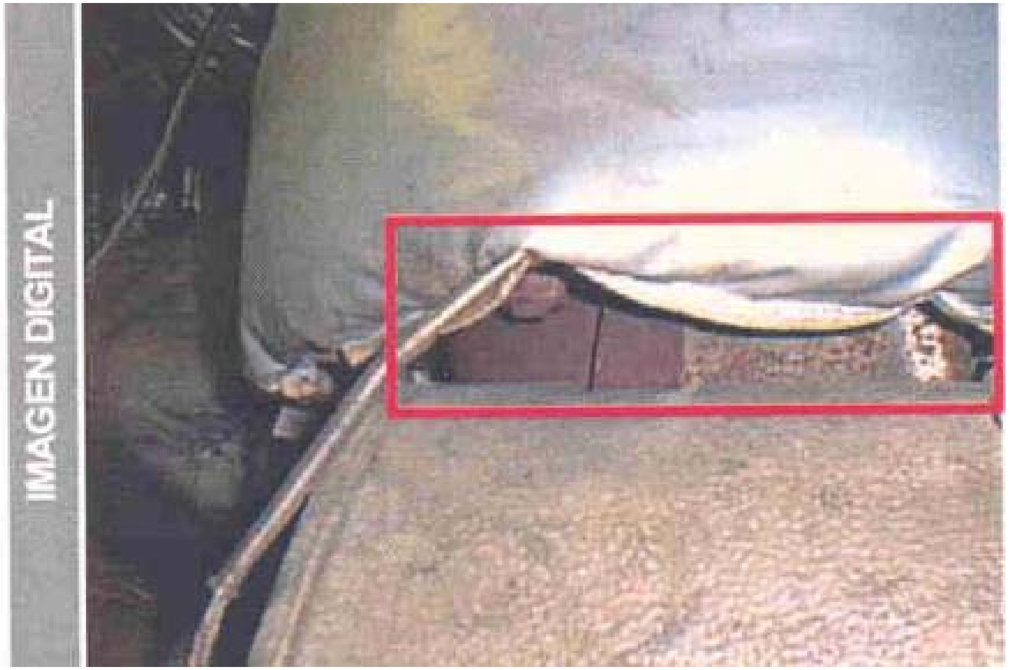
- Infrared Thermographic Surveys
- Infrared Laser Thermometers



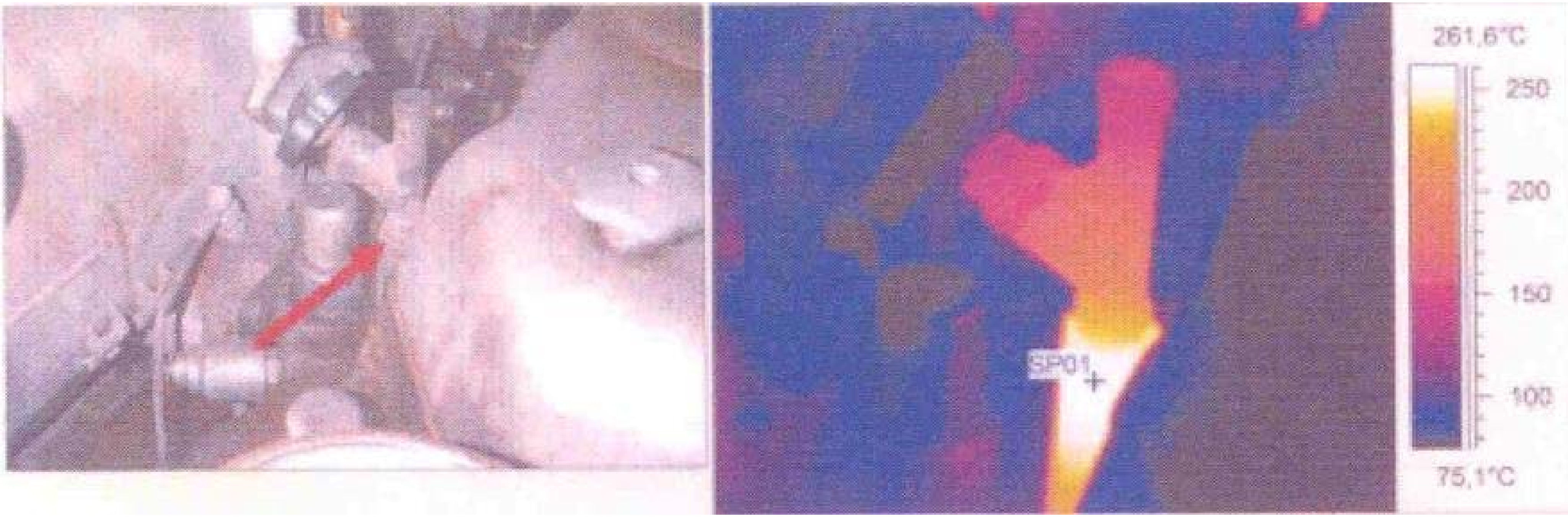
Hot spot indicated by arrow is 320°C

Hot spot indicated by arrow is 230°C

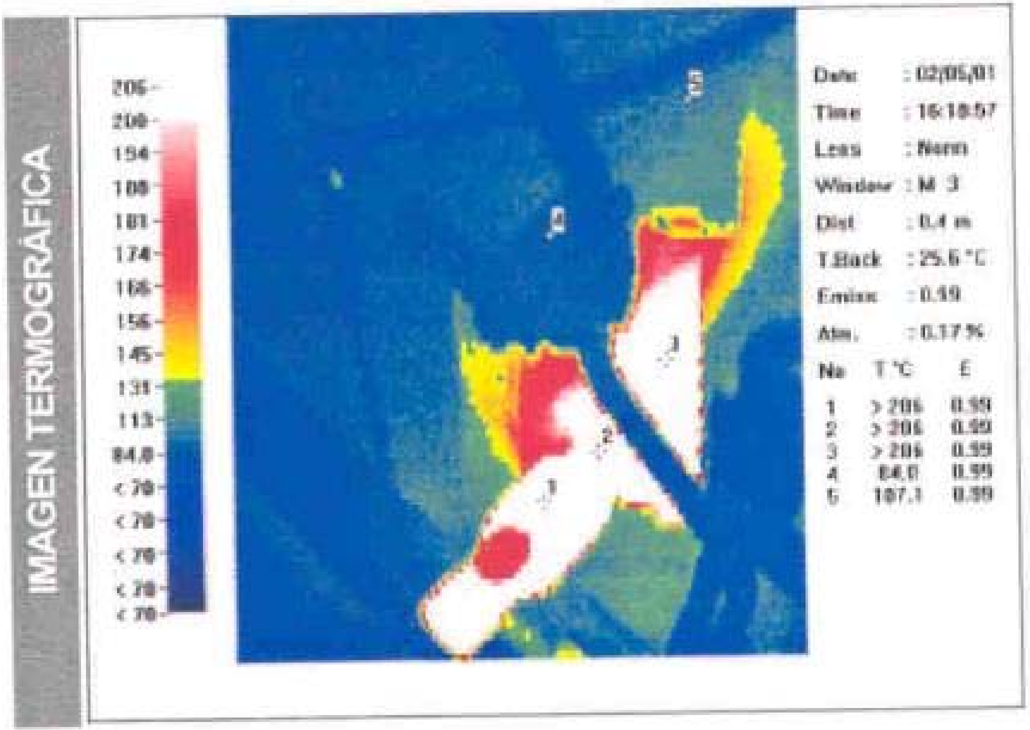


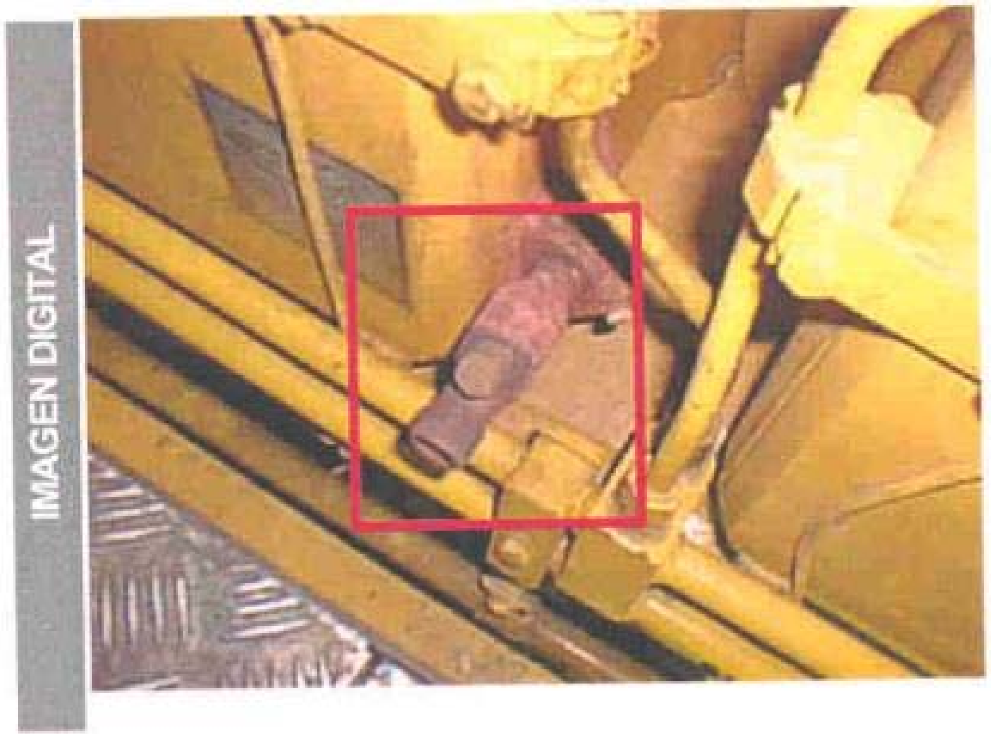


Hot spot maximum temperature = 347°C



Hot spot indicated by arrow is 260°C





Heating over 220°C in way of indicator cock.
Maximum temperature 286 °C

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Cause of Fuel and Lube Oil Leakages
&
Case Histories

Diesel Engine Fuel Oil Fires

Low pressures system – 50%

Pipe failures	50%
Pipe fitting failures	50%

High pressure system – 10%

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Pipe & Fitting Failures

- Fatigue – but what are the underlying causes?
- Vibration & Pulsations
- Chafing
- Lack of security
- Damage during frequent dismantling/assembly
- Improper repairs
- Incorrect tightening procedures
- Poor quality materials

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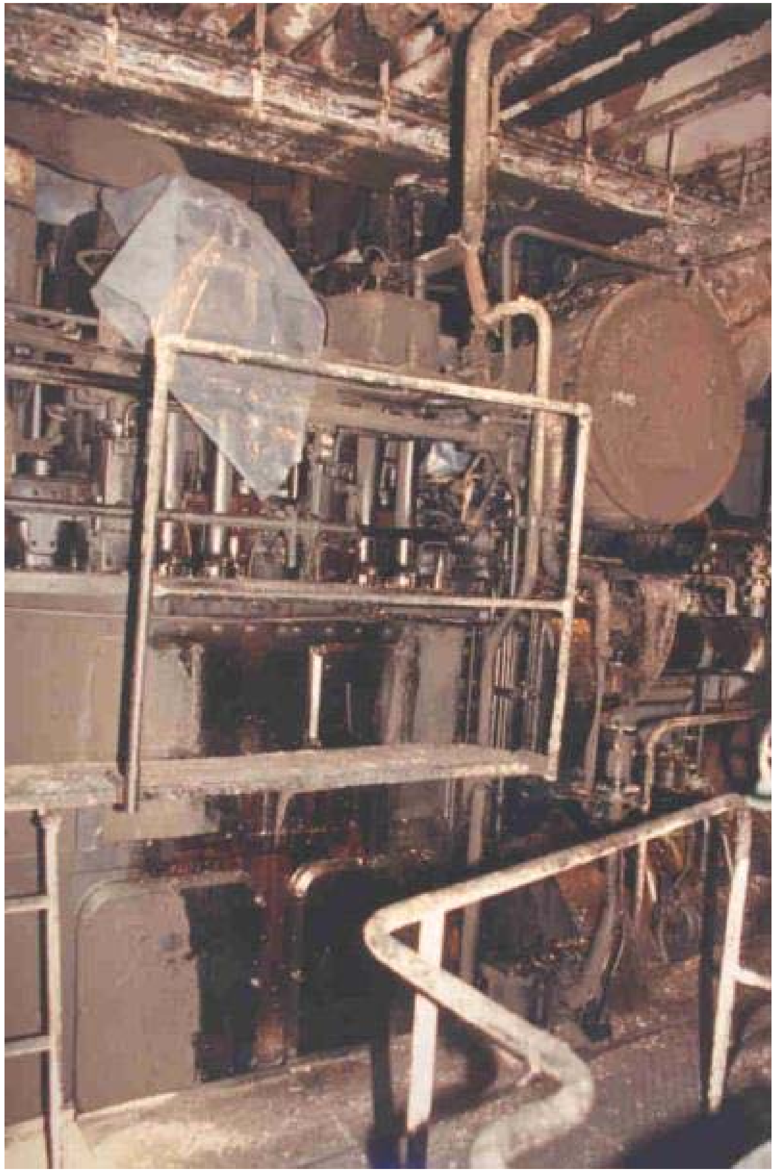
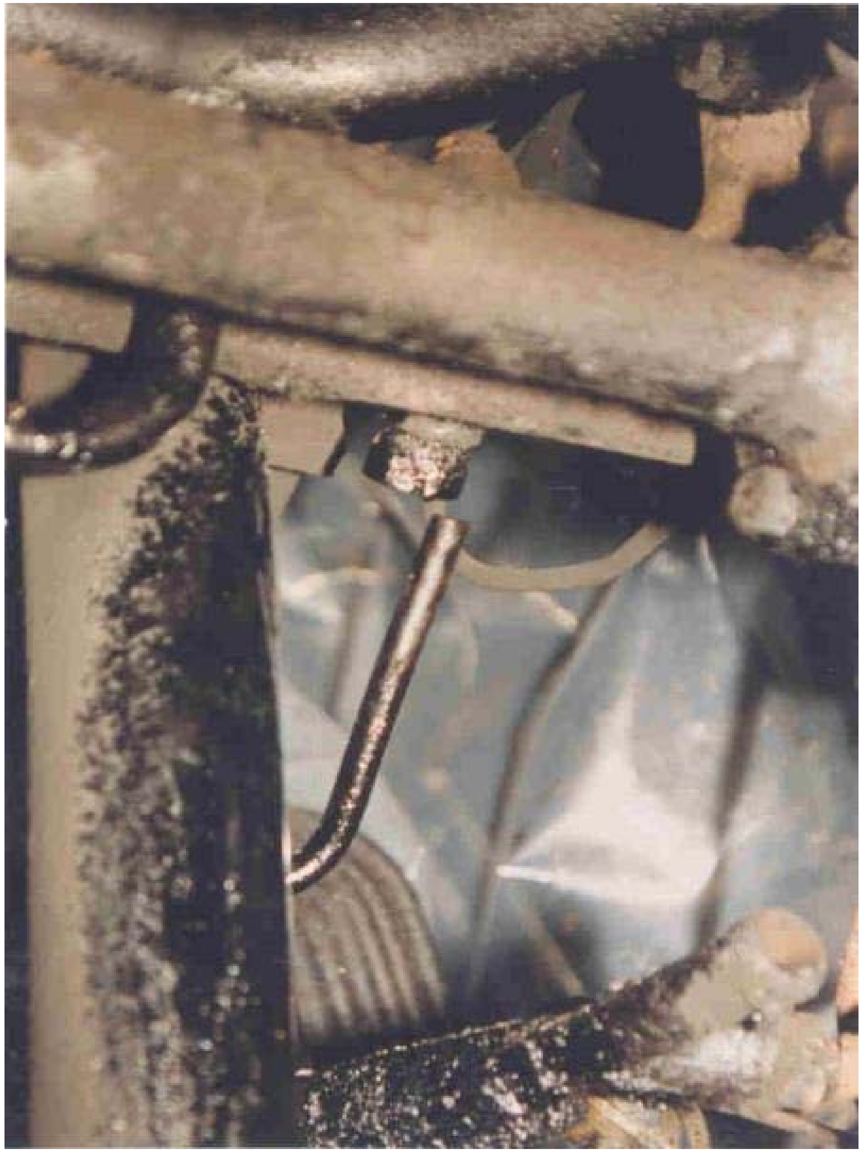




Maintenance & Fire Prevention

- General maintenance & repairs of fuel and lube oil systems
- Routine inspections/tests
- Superintendent visits
- Demonstration of compliance with SOLAS
- ISM/SMS and crew training
- Class surveys

Routine Inspections & Tests

- Regular tightness checks (but not over-tightening) of:-
  - Fuel injection pump holding down bolts
  - Plugs on injection pumps and LP pipe systems
  - Ensure locking devices such as wires, tab washers, etc., are intact
  - Pipe bolted flange & compression fittings
  - Bolted connections for pipe brackets.
- Regular removal of covers for fuel injection pump galleries (hot box covers) to check for leakages, chafing pipes, etc. Proper replacement of covers afterwards.
- Keep fuel pump galleries as clean as possible to prevent blockages in drains etc., which could cause accumulation of leakage and prevent activation of leakage tank level alarms.
- Regular testing of leakage alarms.
- Proper fitting of insulation on hot surfaces.
- Hot surface inspections using thermographic or laser instruments during full load operation.

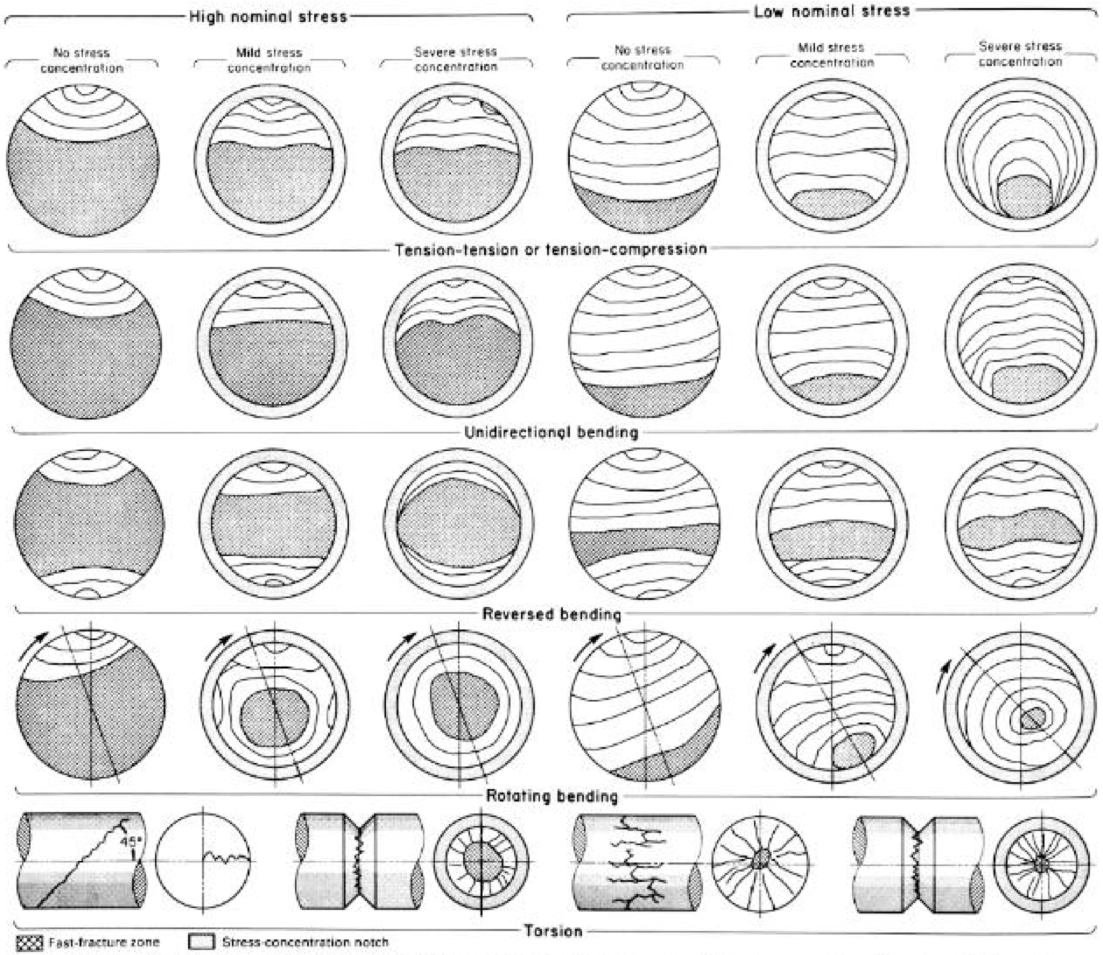
Fire Investigator - Content

- Metallurgical failures
- Hot Surface Ignition
- CFD Modelling

Metallurgy

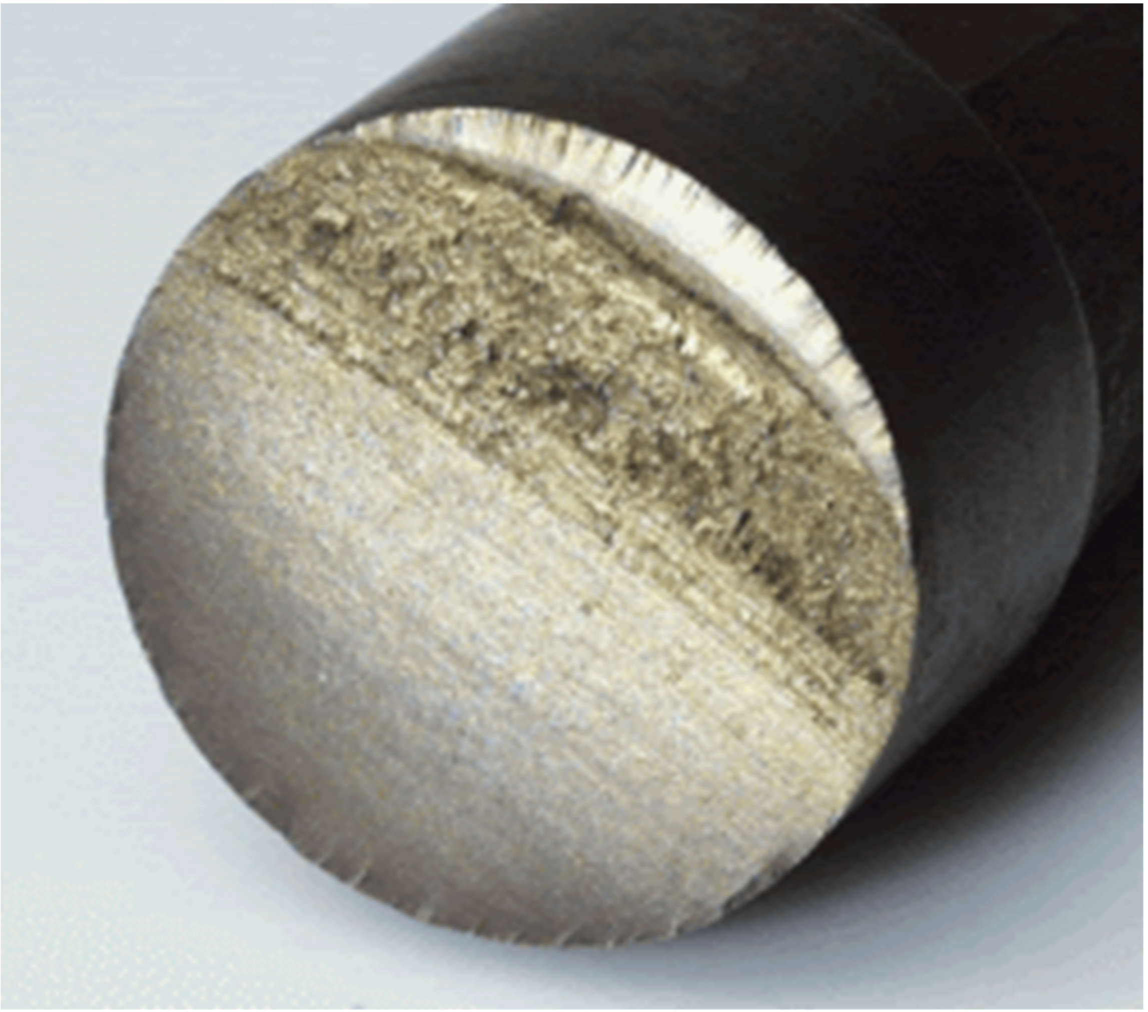
Schematic microscopic fatigue fracture surfaces for axial and bending loads

- *Load type*
- *Load magnitude*
- *Geometry*



Schematic representation of fatigue fracture surface marks produced on smooth and notched components with circular cross sections under various loading conditions

Reverse Bending Fatigue



- In an engine room fire, when fuel such as heavy fuel oil (HFO) or marine gas oil (MGO) has leaked and ignited, it is often reported that the ignition source was a hot surface, such as the exhaust system from the main engine or a generator.

Definitions:

- Auto Ignition Temperature (AIT)
  - The lowest temperature at which a substance when heated will produce sufficient vapours which will ignite without the application of an external piloted ignition source.
- Piloted Ignition Source
  - Arc, Spark or flame.

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- Can a hot surface ignite a flammable liquid?

- It is often stated that the auto ignition temperature of the fuel was X, and the temperature of the hot surface was greater than X, therefore it could ignite the fuel.

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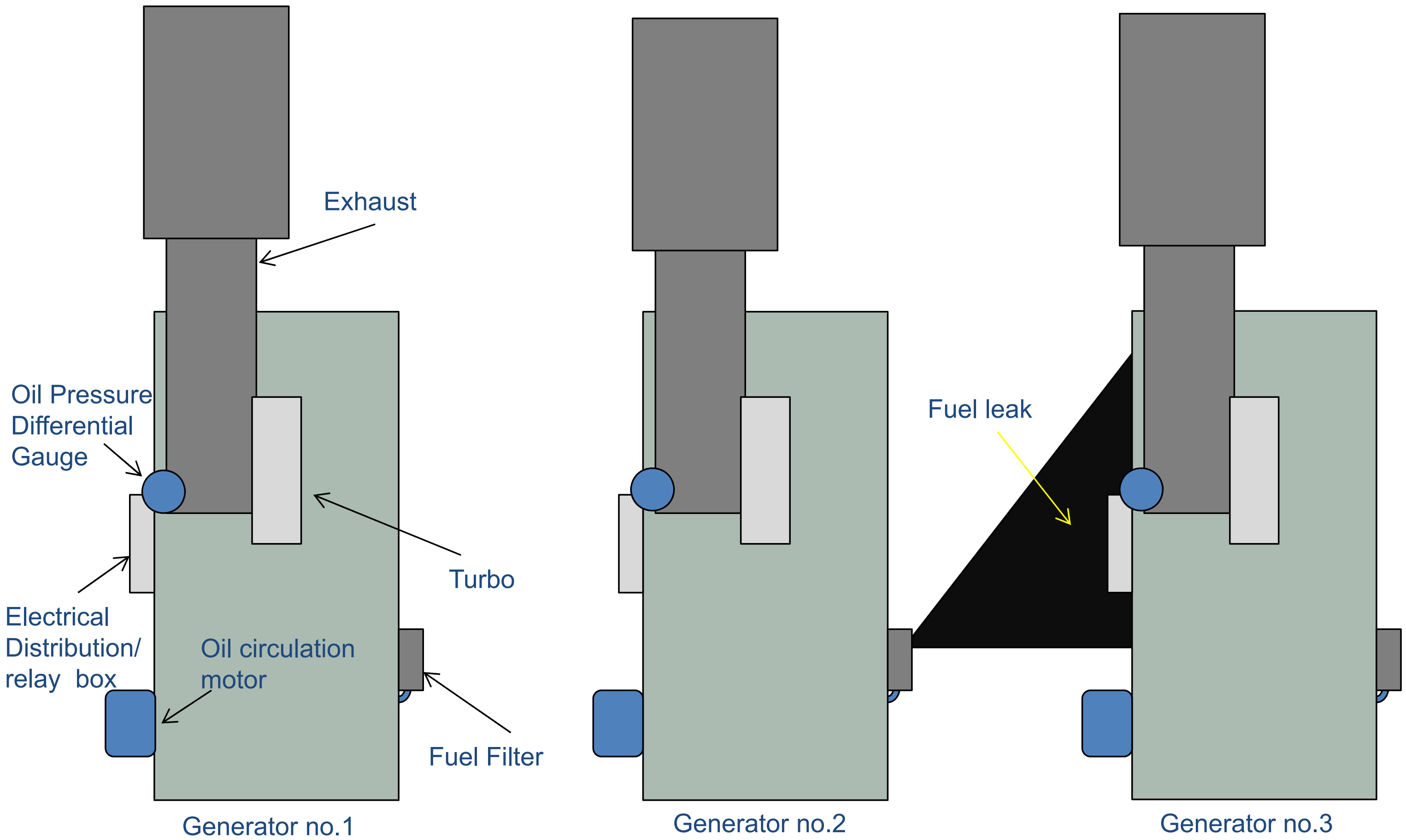
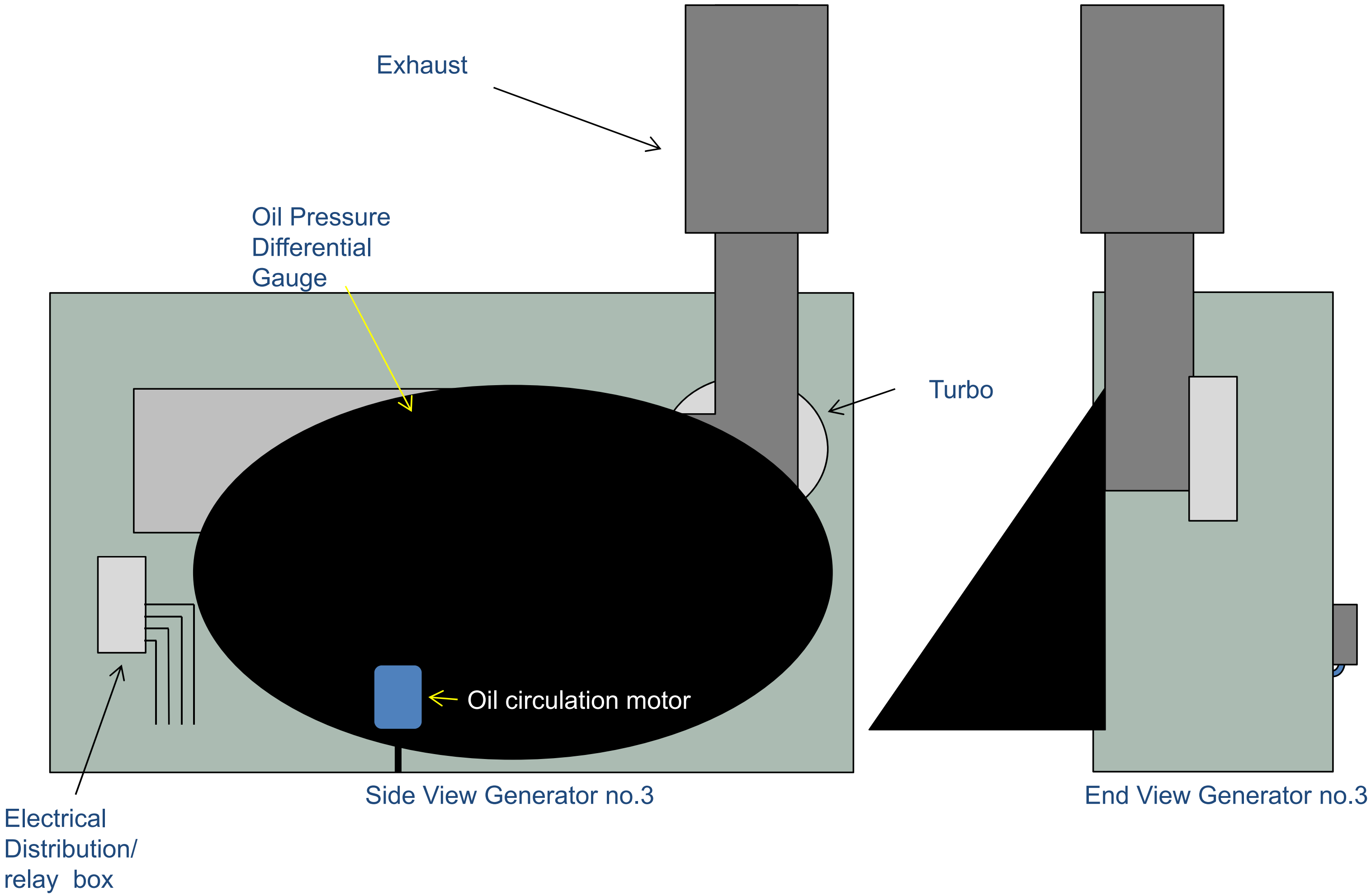
- Do flammable liquids burn?

- A, no
- B, yes

- Do flammable liquids burn?

- No, but flammable gases do burn.


Exhaust
Oil Pressure Differential Gauge
Turbo
Electrical Distribution/ relay box
Oil circulation motor
Fuel Filter
Generator no.1
Generator no.2
Fuel leak
Generator no.3


Exhaust
Oil Pressure Differential Gauge
Turbo
Oil circulation motor
Electrical Distribution/ relay box
Side View Generator no.3
End View Generator no.3


1
2
3

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- For a flammable liquid fuel to undergo combustion it needs to be converted into a vapour (gas).

- The vapour needs to be within its flammable (or explosive) limits.

- The vapour needs to be heated for sufficient time to raise its temperature to a level where it will ignite (AIT?).

- How is the auto ignition temperature (AIT) quantified?
- This is measured in a closed cup where the air temperature is equal to or slightly lower than the hot surfaces of the cup.
- However…

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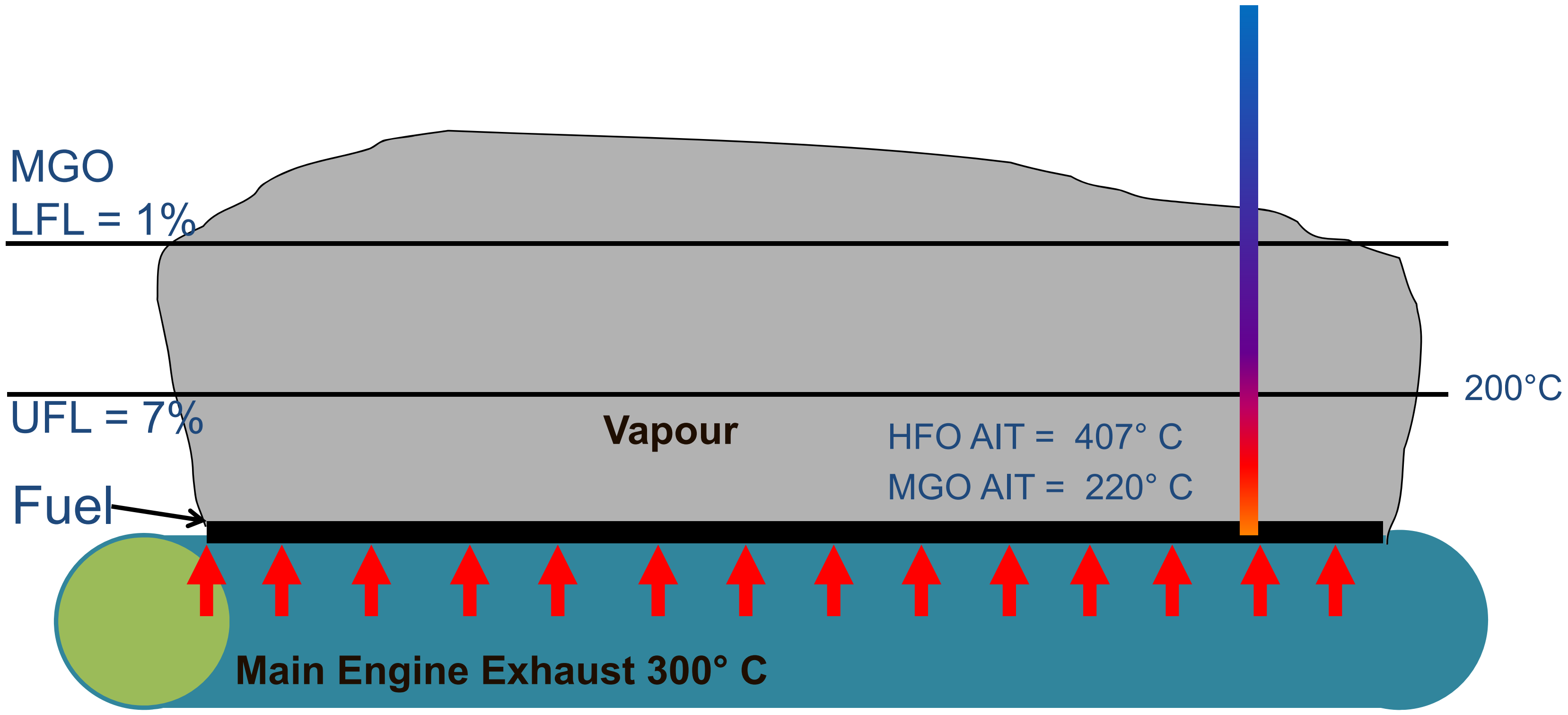
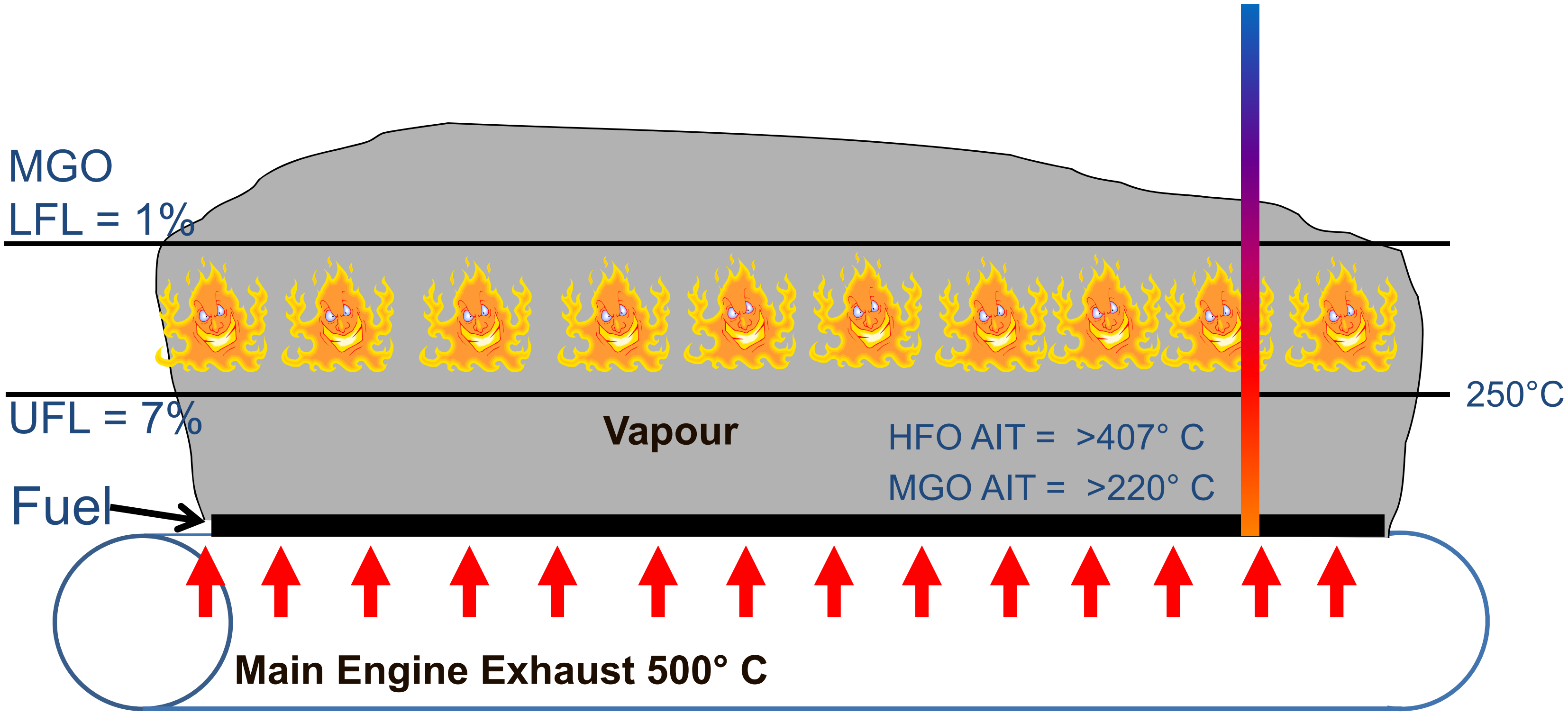
- In an engine room the air surrounding the hot exhaust pipe is not in an enclosed cup.
- As such, the temperature of the air drops rapidly in proportion to the distance from the exhaust.



Hot Surface Ignition



Hot Surface Ignition

Summary

- We can't assume that because a hot surface temperature is greater than the auto ignition temperature of a fuel, the fuel will ignite.

- There are a lot of other factors that need to be taken into account such as size, shape, surface texture, orientation, fuel velocity and air velocity.

- A general rule of thumb is that a hot surface temperature needs to be about 100 - 200°C higher than the auto ignition temperature to ignite vapor of a flammable liquid.

CFD Modelling

CFD Modelling

- There are two main types of model used to represent the growth and development of fire within a compartment.

  - Zone Models.
  - Field Models, also known as computational fluid dynamic (CFD) models,.

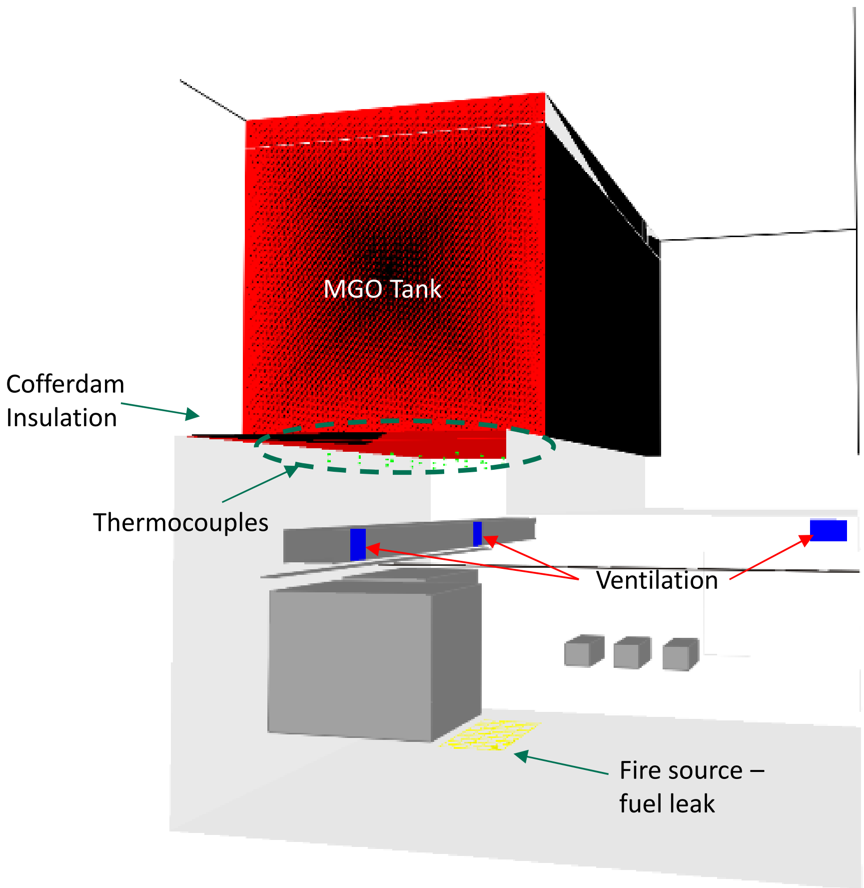
- A range of spreadsheet calculation suites are also available.

Analysis – FDS

Engine Room Fire

Analysis Setup - Cofferdam

- Fuel leak and ignition.
- MGO fuel tank directly above engine room.
- Cofferdam separating engine room and MGO tank.
- Design case assessing the effectiveness of the cofferdam in insulating the MGO tank from effects of potential fire.
- Internal surface temperatures of MGO tank are monitored with 'thermocouples'.
  - Smoke removed.
  - Animation speed increased.



Analysis – FDS

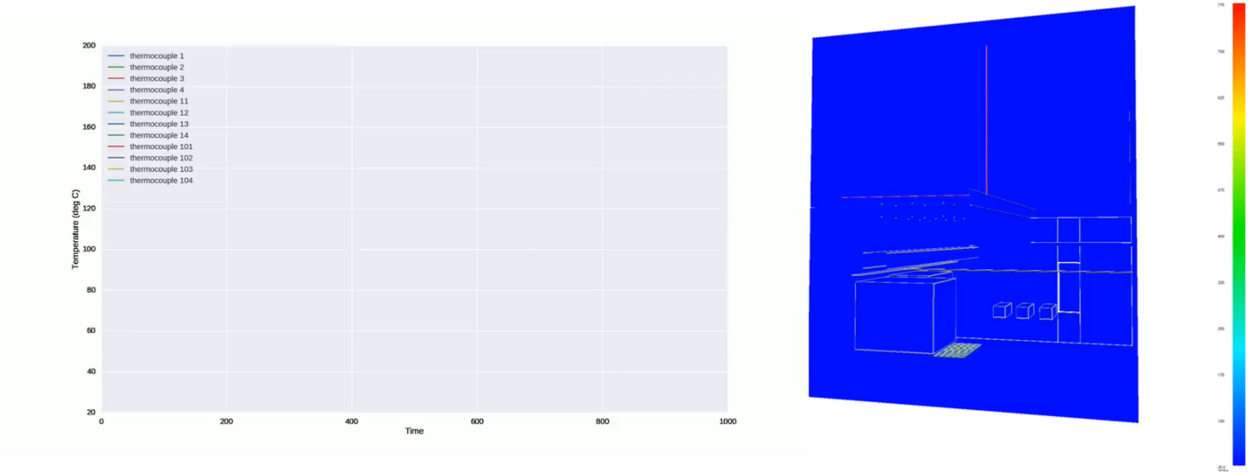
Engine Room Fire

Analysis Results - Cofferdam v A60 Insulation

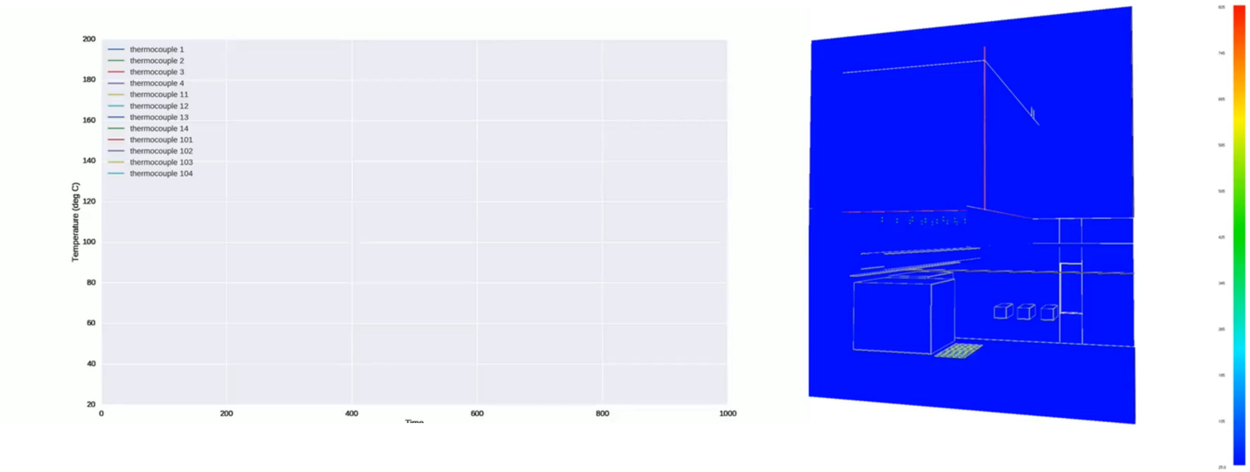
- Qualitative and quantitative comparison of surface temperatures
  - Cofferdam vs. A60 insulation.

- A60 insulation superior to cofferdam for surface temperatures.

Cofferdam



A60 Insulation



Questions?

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- Situation – engine room fire following the fracture of a MGO fuel pipe:

- Q 1. From a H&M perspective, is this a recoverable loss?
  - A, yes
  - B, no
  - C, depends on the policy.

- Situation – engine room fire following the fracture of a MGO fuel pipe:

- Q 2. What conditions under the policy would you consider in evaluating the loss?
  - A, proper maintenance and exercising due diligence
  - B, crew negligence
  - C, obligation of full disclosure
  - D, all of the above

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- Situation – engine room fire following the fracture of a MGO fuel pipe:

- Q 3. In what situations would you consider recovery from other parties?
  - A, a new build defect
  - B, a sale and purchase transaction – sold with defect
  - C, all of the above

- Situation – engine room fire following the fracture of a MGO fuel pipe:

- Q 4. What would you consider may be required in terms of technical evidence to pursue a recovery?

Questions?

Excellence • Integrity • Proficiency

There are things we know we know.

There are things we know we don’t know.

There are things we don’t know we know.

There are also things we don't know we don't know.

Donald Rumsfeld

for your attention