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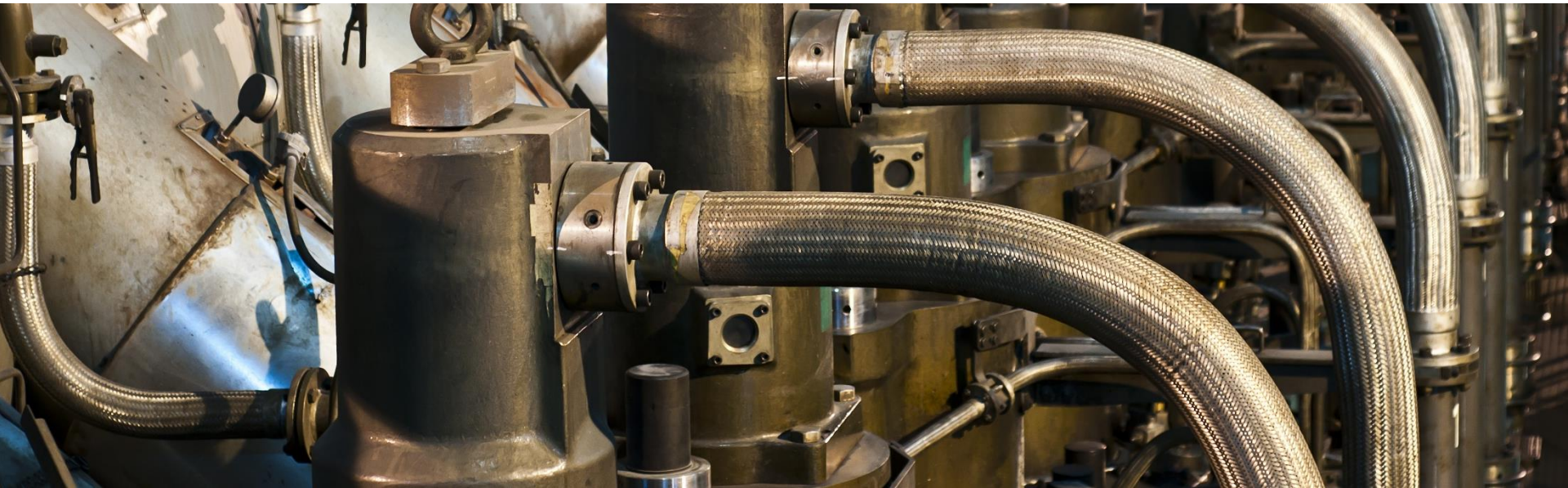
# ICS Class

## 2B: Machinery Systems

In compliance with the IMO resolution MSC.349(92) and MEPC.237(65), RO Code, Appendix 2.



The following Module 2B: Machinery Systems is based on several Example Cases of Machinery Damages. This has the purpose and objective to give a clear example on the survey check points.

# MODULE 2B – Machinery Systems (Content)

1. Introduction
   - Numbers and Damage rates

2. Main diesel engine
   - Crankshaft
   - Degraded heavy fuel
   - Combustion chamber
   - Crosshead pin
   - Damage at shop test
   - Turbocharger

3. Propulsion Shafting
   - Coupling bolts
   - Propeller shaft
   - Propeller Breakage
   - Other notice for shafting

4. Aux. diesel engine
   - Connecting rod

5. Aux. boiler
   - Internal crack
   - Furnace Collapse
   - Exhaust gas economizer

6. Others
   - Fire in engine room
   - Damage due to alumina
   - Fire of feeder panel

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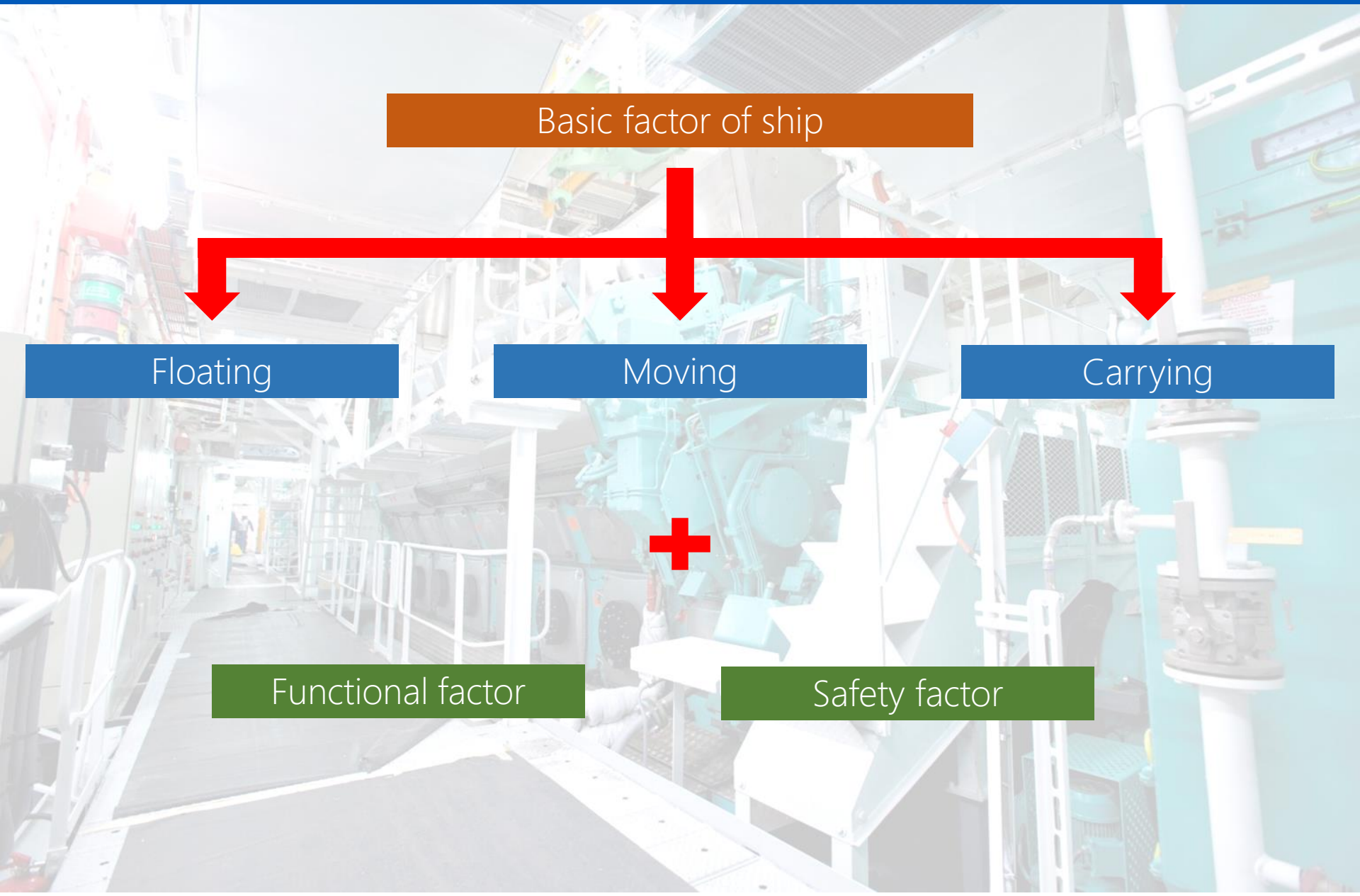
ICS CLASS
INTERMARITIME CERTIFICATION SERVICES

# 1. Introduction: Numbers and Damage Rates

# 1. Introduction: Numbers and Damage Rates



# 1. Introduction: Numbers and Damage Rates

**Functional factor:** corresponding to various condition of transportation

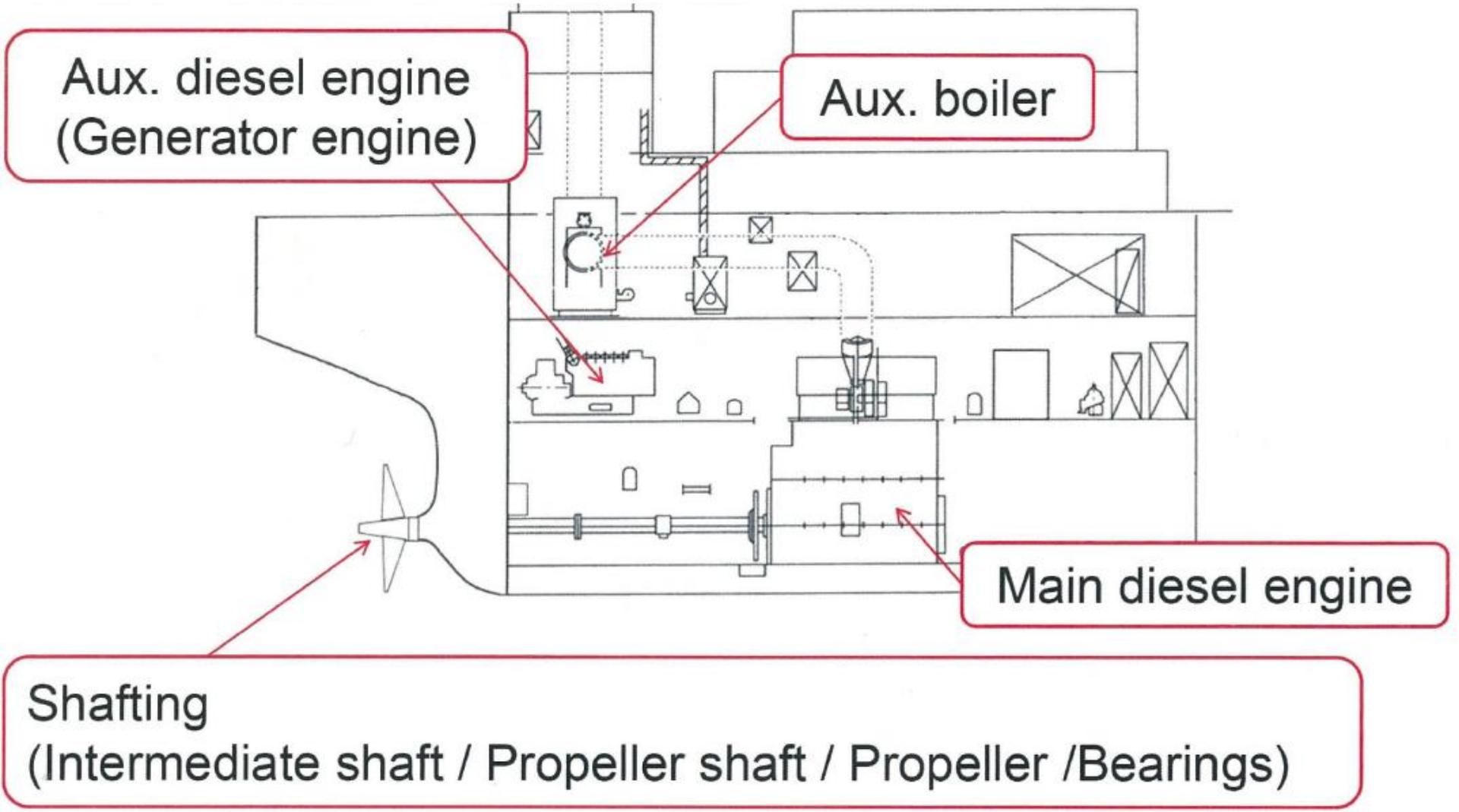
- Transportation of a large quantity: the exclusive, the huge
- A jump in fuel oil prices: the energy-saving design
- A jump in personal expense: the automatic, a small number of crew
- Low quality of fuel oil: various pretreatment equipment
- An increase of demand for conservation of environment

**Safety factor:** Rule of classification, strengthening the requirement of convention, such as SOLAS, etc.

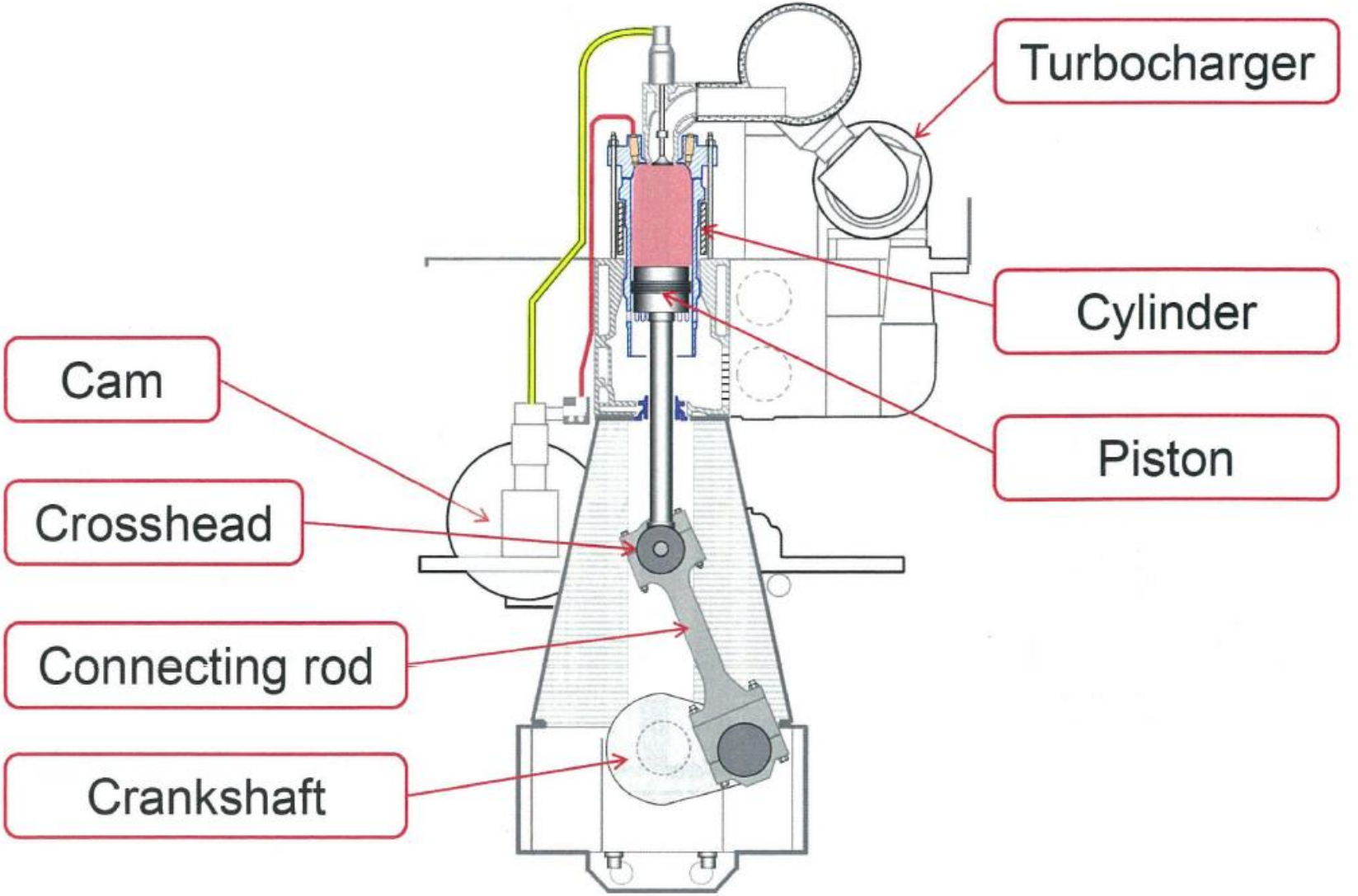
## Cause of Machinery Damage

1. Mishandling (including incomplete repair)
2. Fatigue
3. Thermal stress
4. Corrosion
5. Material and structure
6. Outer factor (ex. Low quality fuel oil)
7. Compound of factor all above factors

## Machinery arrangement

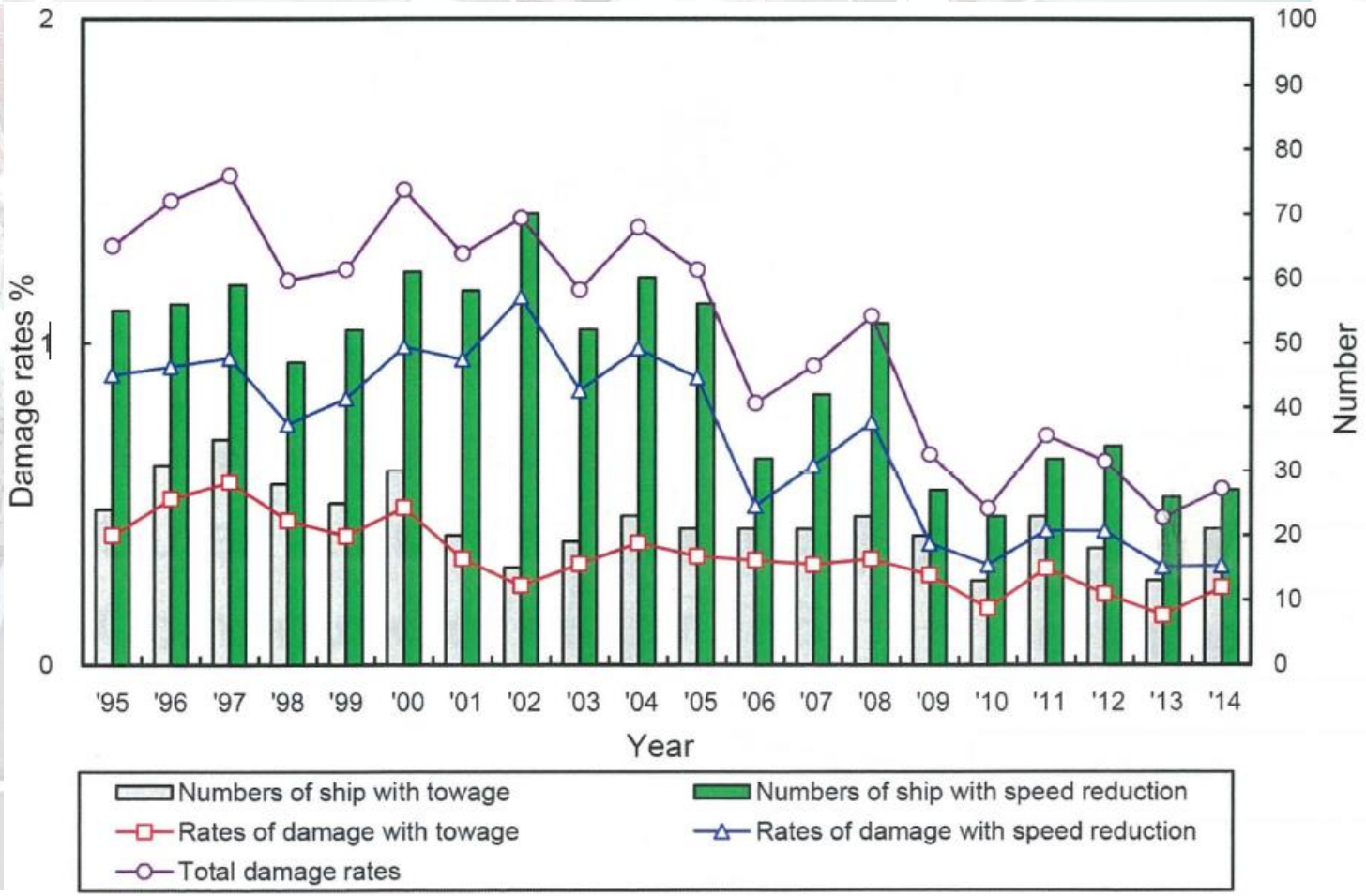


## Structure of 2 stroke cycle engine



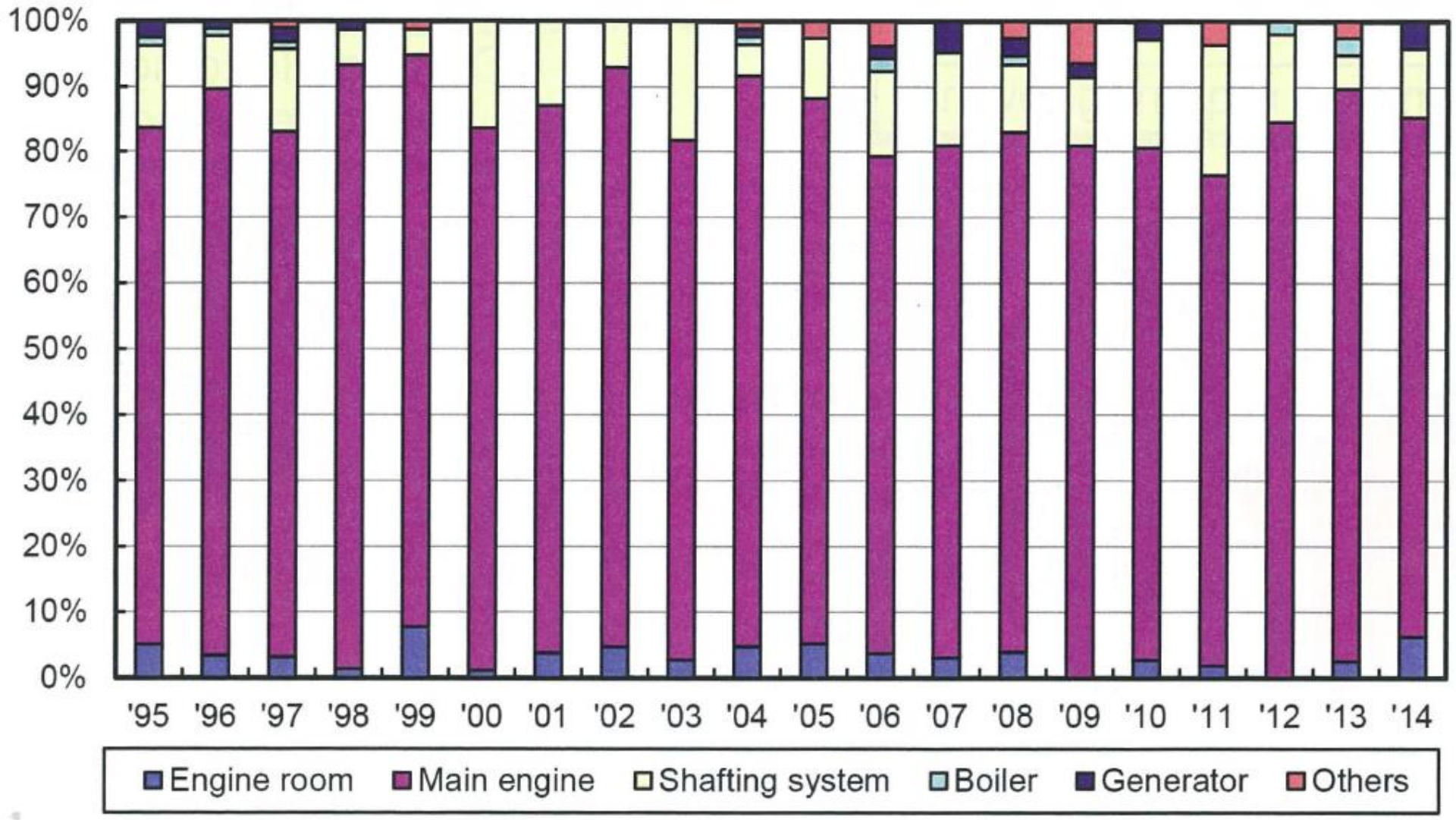
## Major Damage: Numbers and Rates

### Number and damage rates of ships in which damage hindered navigation

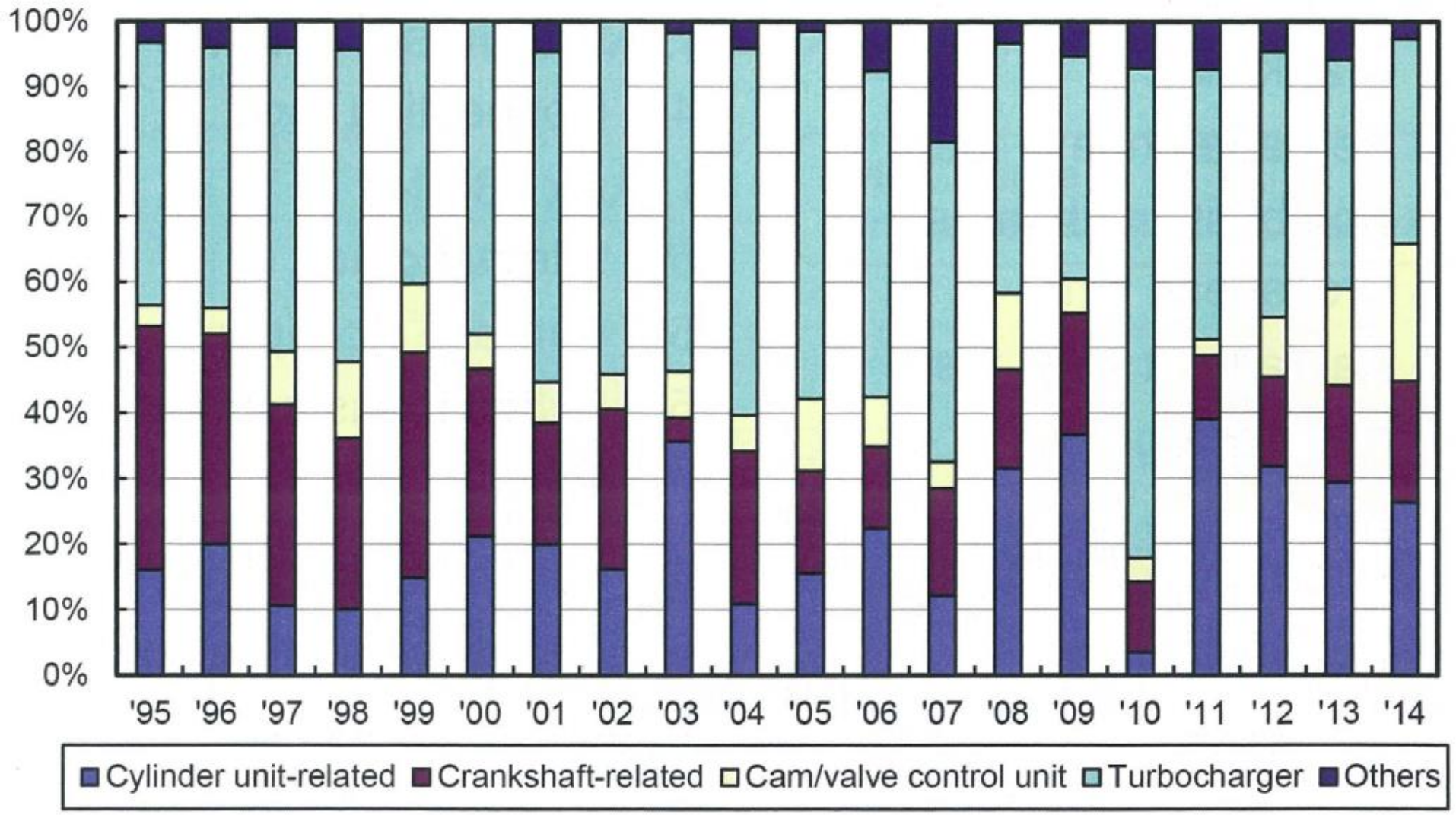


# 1. Introduction: Numbers and Damage Rates (Major Damage Breakdown)

## Percentage by location of damage to machinery/equipment that hindered navigation

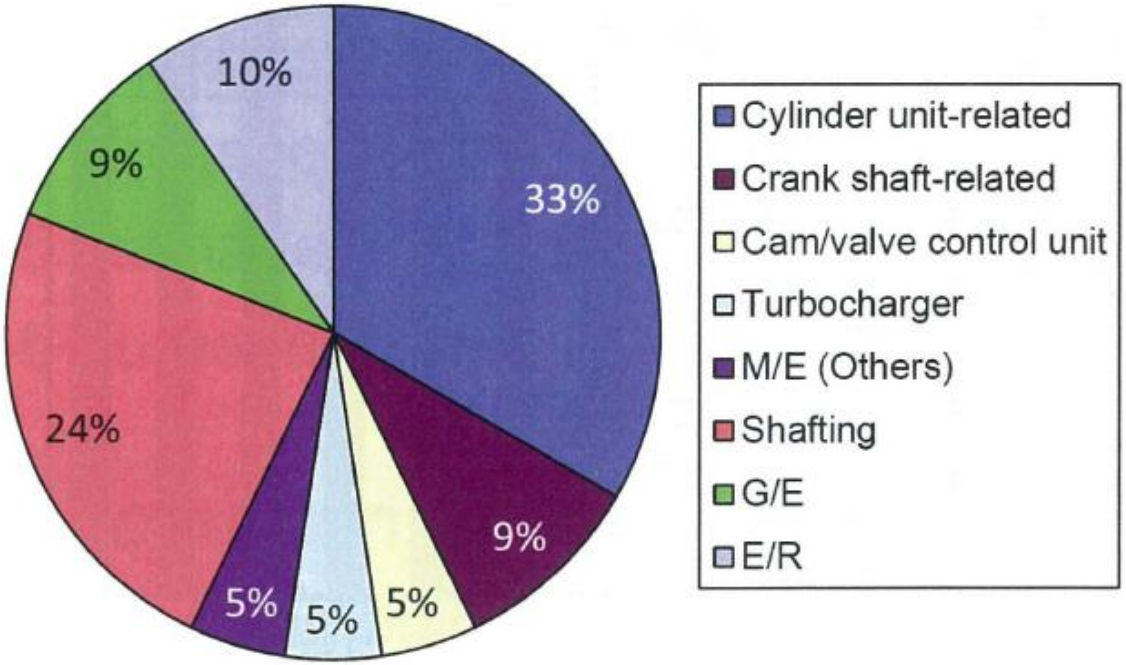


## Percentage by location of damage due to diesel main engines from damage incidents that hindered navigation

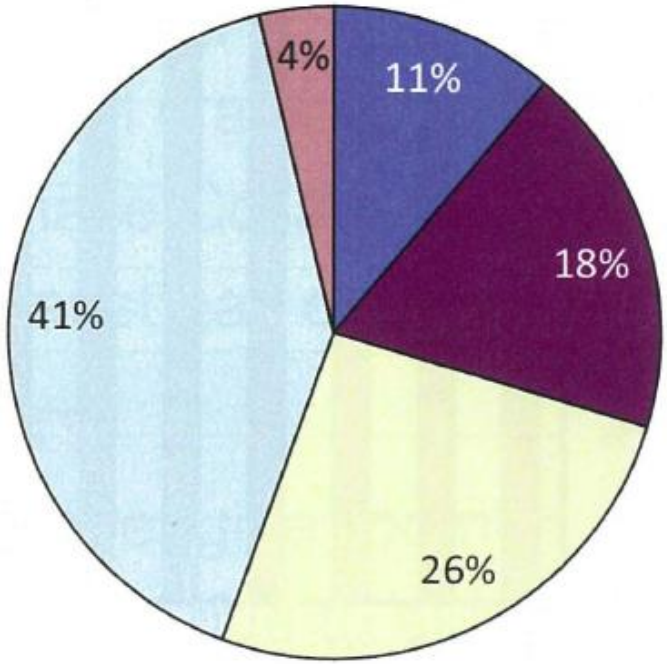


## Percentage by location of damage (divided to towing/speed reduction)

### Damage requiring towing




### Damage leading to speed reduction



# 2. Main diesel engine

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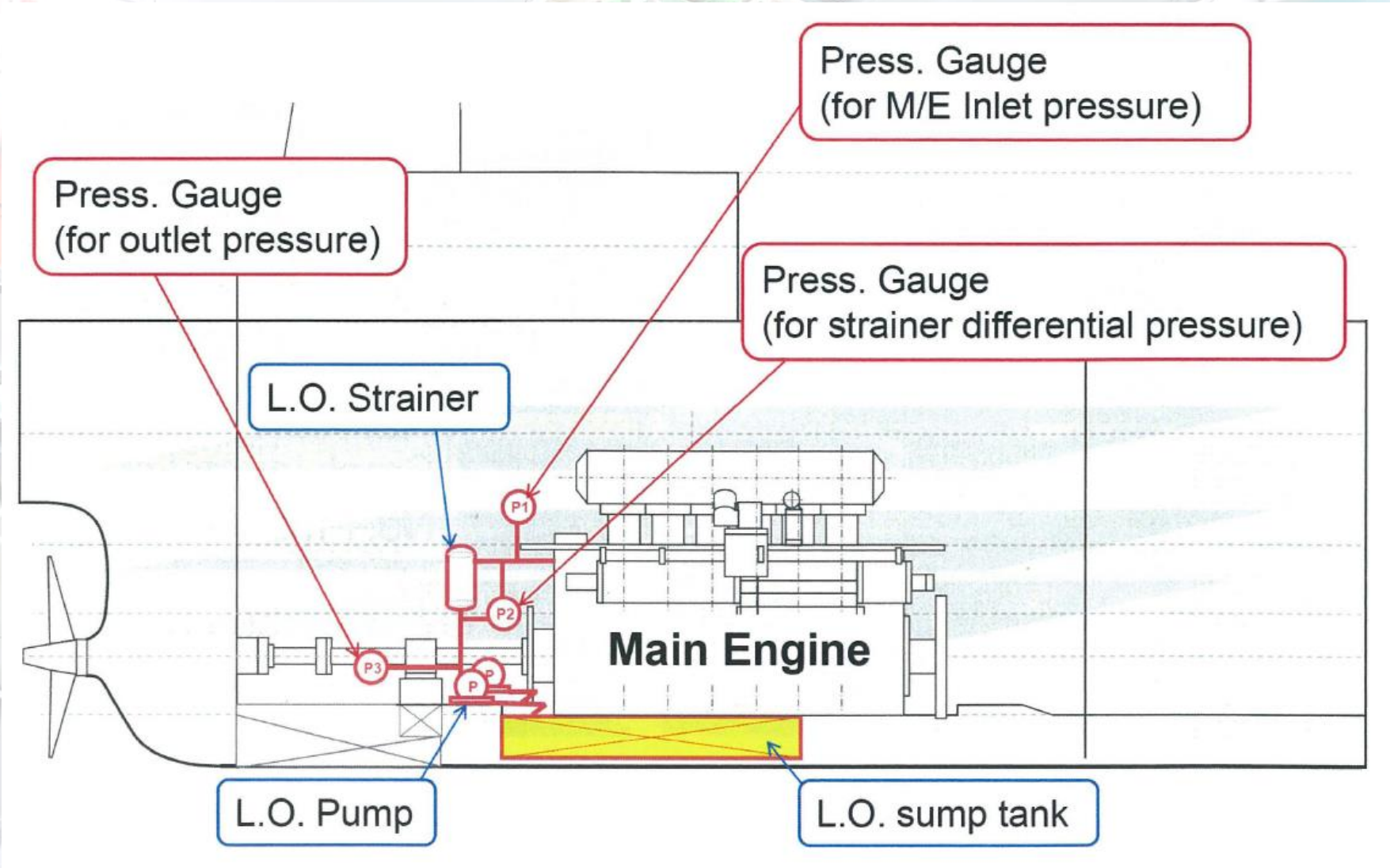
   - Exhaust gas economizer

6. Others
   - Fire in engine room
   - Damage due to alumina
   - Fire of feeder panel

# Main diesel engine: Crankshaft (Example 1)

| Ship Type: | Cement Carrier |
|---|---|
| GT: | 4400 |
| Ship Age: | 15 years |
| ME: | 4 Stroke / 4300 PS |
| Damaged Part: | Crankshaft, Main Bearing Metal, Crank Pin Metal |

## Arrangement of pressure gauge



# Main diesel engine: Crankshaft (Example 1)

## Sequence of events

ALARM - L.O. Inlet Low Pressure
- L.O. Secondary Strainer Differential Pressure

1. Confirmed the discharge pressure of M/E L.O. Pump
2. Pushed the pause button for M/E alarms
3. Continued the running

Increase - Temperature of FWD End Main Bering
- Oil Mist Concentration

Blade Angle 0° by CPP Auto. Blade Reduction Device

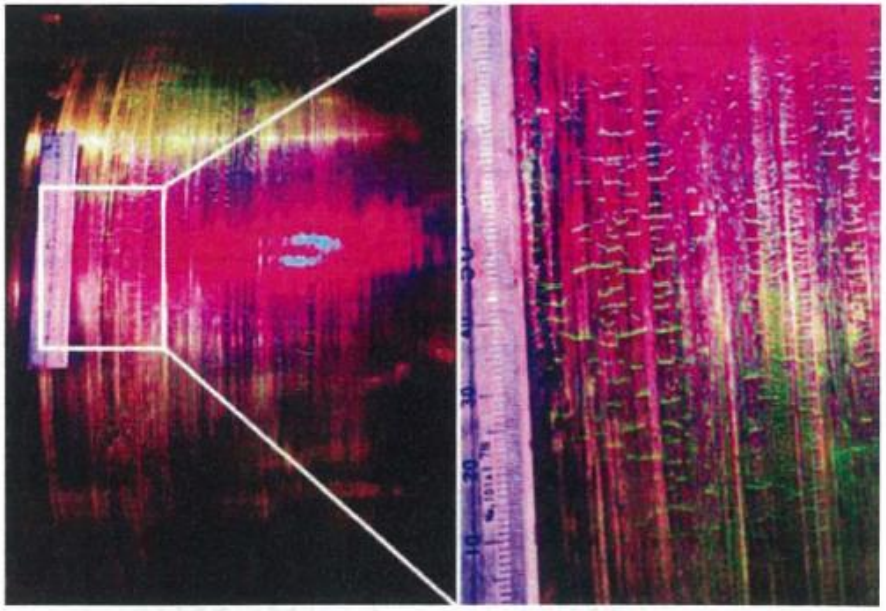
Emergency Anchor and Open-up of Main Engine

Damage - Crankshaft, Main Bearing Metal, Crank Pin Metal

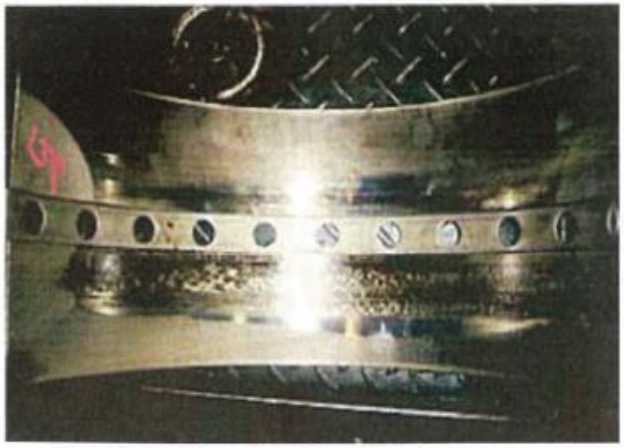
# Main diesel engine: Crankshaft (Example 1)

## Damage condition

No.4 Crankpin metal



Crank journal at
No.1 main bearing



No.5 main bearing metal

No.2 main bearing metal

# Main diesel engine: Crankshaft (Example 1)

## Inspection results

**Instruction of "L.O. Secondary Strainer"**

When L.O. Temp. < 30 ℃ (High Viscosity condition):
Because Auto. back-flushing will not function,
manual back-flushing is required.

**Actual Condition of L.O. line**

1. L.O. Purifier had not been working for 4 days due to repair

2. L.O. Temp. < 30 ℃
Auto. back-flushing were not carried out.
However, Manual back-flushing were not carried out.

Obstruction + Decrease of L.O. Flow

## Inspection results

L.O. Inlet Pressure Low Low Alarm

M/E was not tripped.(Trip sensor problem?)

A waste cloth was stuck in the check valve on the suction of No.2 L.O. Pump.

## Inspection results

### L.O. Related Factors

Inoperative
① L.O. Purifier
② Auto. Back-flushing of L.O. Secondary Strainer

### Operational Factors

① L.O. Inlet Press. Low Low Alarm
② L.O. Strainer Differential Press. Alarm
③ Waste Cloth in L.O. Pump

L.O. Degradation

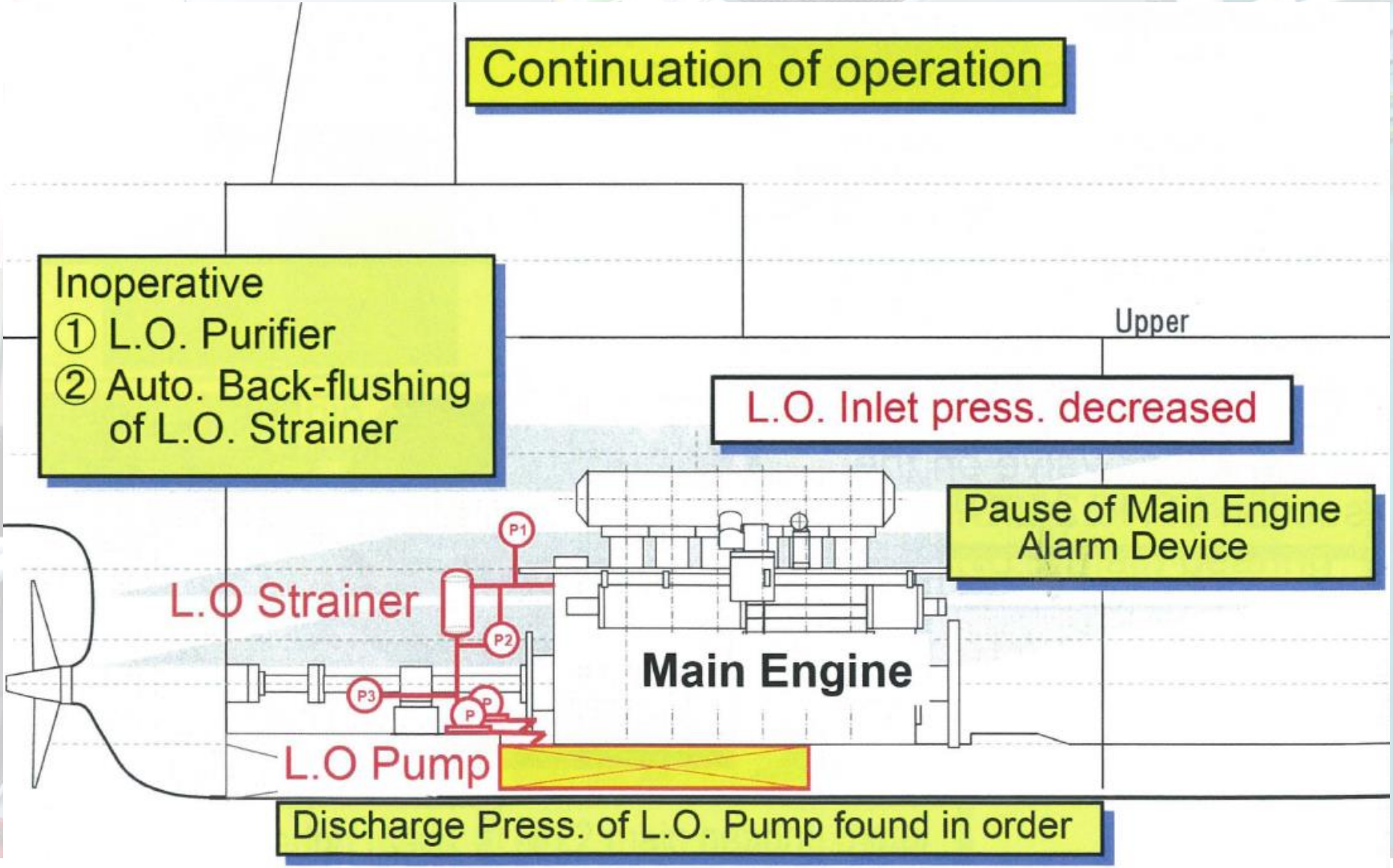
L.O. Inlet Press. decreased
- But -
① Pause of Main Engine Alarm Device
② Monitor and judgment based on only Discharge Press. of L.O. Pump

Continuation of Operations

Burning of Crankshaft, Main Bearing Metal and Crank Pin Metal

# Main diesel engine: Crankshaft (Example 1)

## Causes



# Main diesel engine: Crankshaft (Example 1)

## Repairs

### Crankshaft

MACHINING

| No. | Position | Diameter [mm] | | | |
|---|---|---|---|---|---|
| | | Original | (Reduction) → | After Machining | NK Requirement |
| 1,2,3,5,6 | Journal | 372 | (5) → | 367 | 354.4 |
| 3,4 | Pin | 372 | (3) → | 369 | 365.1 |

### Bearing metal

- No.1,2,3,5,6 Main Bearing Metal: Replacement (Under Size)
- Others : Renewed (Original Size)

- No.3,4 Crank Pin Bearing Metal: Renewed (Under Size)
- Other than the above: Renewed (Original Size)

## Operations and Maintenance Check Points

### L.O. Factors

- Confirmation of infusions, i.e. waste cloth, in the restoration after overhauling
- Periodical and manual back-flushing in case that auto. back-flushing of L.O. strainer can not be used

### Operational Factors

- No judgment based only L.O. Pump Discharge Press. (Judgment adequate L.O. flow by confirming of L.O. Inlet press.)
- Emergency treatment as a new L.O. supply at the trouble of L.O. Purifier

## Repair Check Points

### Temporary Repair-work Flow

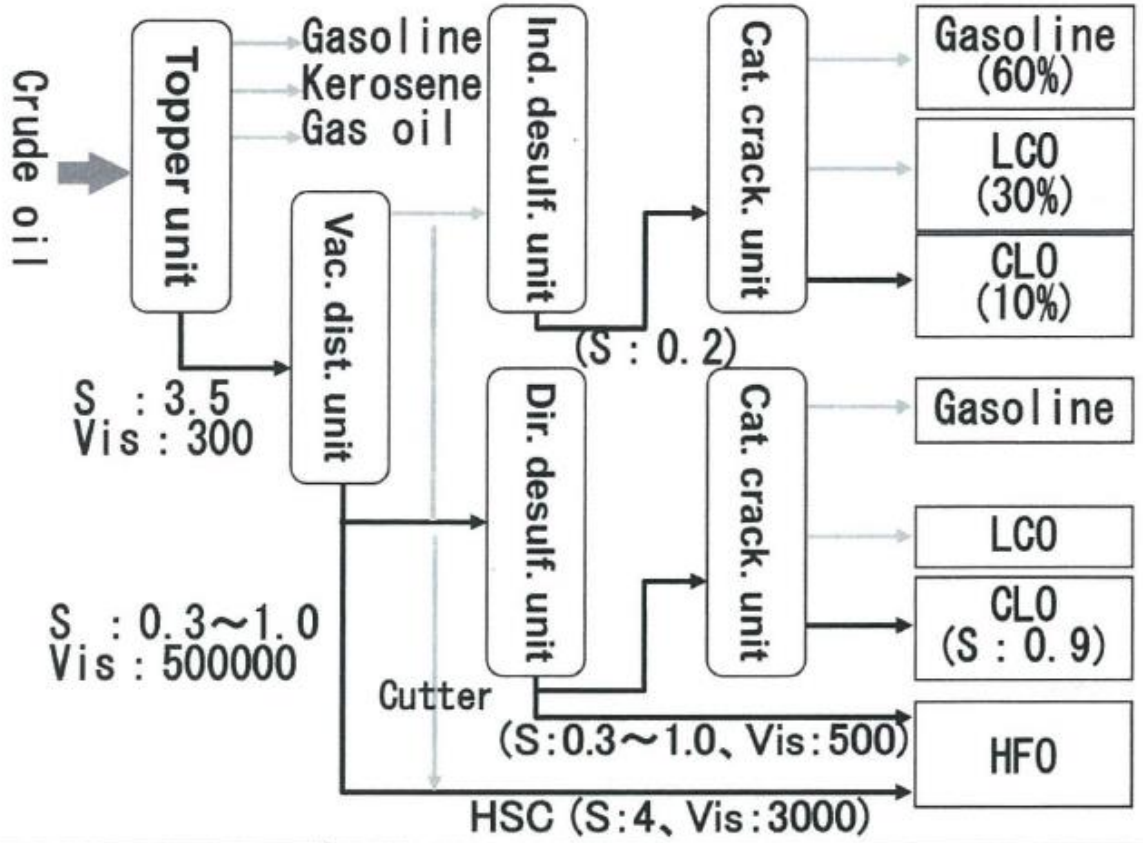
1. Confirmation of required diameter of crankshaft and crank-pin (ClassNK Machinery Department)
2. Arrangement of under sized bearing
3. Decision of diameter for machining
4. main engine manufacturer, repairer with enough repair experience
5. Confirmation of dimension measurement after machining, roundness, shaft center
6. Confirmation of surface hardness
7. Non-Destructive Test (NDT)

# Main diesel engine: Degraded heavy F.O. (Example 2)

| Ship Type: | Car Carrier |
|---|---|
| GT: | 19200 |
| Ship Age: | 7 years |
| ME: | 2 Stroke / 8100 PS |
| Damaged Part: | M/E Combustion Chamber |

# Main diesel engine: Degraded heavy F.O. (Example 2)

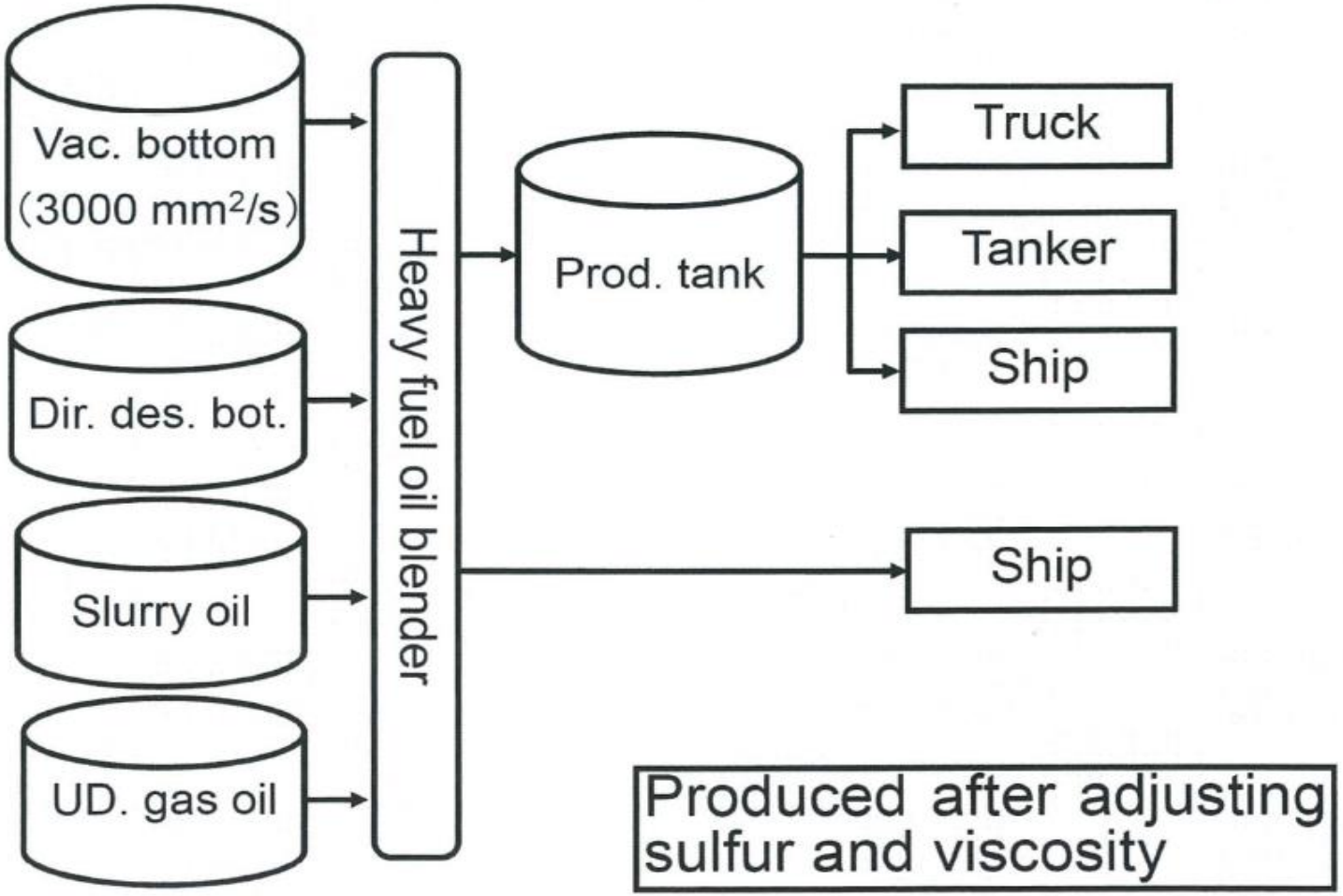
(Guidance for Measures to Cope with Degraded Marine Heavy Fuels)




Note: FCC means Fluid Catalytic Cracking.
In order to promote cracking reaction, they use powdered form catalyst which principal ingredients are alumina, silica.

## Blending of marine fuel oil

(Guidance for Measures to Cope with Degraded Marine Heavy Fuels)




Blending of marine fuel oil

# Main diesel engine: Degraded heavy F.O. (Example 2)

## Damage report

Decrease of revolution speed with increase of exhaust gas temperature in service.

Inspection Result of M/E No.4 Cylinder
Piston Crown: Burnout
Piston Ring: Breakage
Piston Skirt and Cylinder Liner: Burnout and Scratches

Temporary Repair Onboard

# Main diesel engine: Degraded heavy F.O. (Example 2)

## Damage report

Piston ring

Cylinder liner

Piston crown

Piston skirt

## Inspection results

**Piston Ring**

1. Abnormal wear (vertical scratching) on sliding surface
2. Uneven wear at each rings
3. Spherical particles (alumina and silica) in scratches on sliding surface
4. No Abnormalities in material composition and hardness

**F.O.**

**FCC catalytic fines exceeding ISO standard value**

# Main diesel engine: Degraded heavy F.O. (Example 2)

## Causes

Large amount of FCC catalytic fines in M/E

FCC catalytic fines enter in cylinder by fuel atomizing, and invade into clearance between piston ring and cylinder liner

Scores occur to cylinder liner inside wall(Aggressive wear)

Abnormal wear and brakeage of piston ring

Engine damage occurred due to insufficient elimination of alumina and silica at F.O. purifiers.

## Attention

### Pretreatment of F.O.

Marine F.O. is supplied with the assumption that pretreatment will be carried out on board.

Degraded F.O. is highly likely to cause various engine problems.

### $Al_2O_3+SiO_2$ (Alumina and Silica)

Amount of $AL_2O_3+SiO_3$ depends on residue of FCC catalysts during oil refining process.

Damages on sliding surfaces due to high hardness

# Main diesel engine: Degraded heavy F.O. (Example 2)

## Measures

Not bunking low quality fuel oil is most effective measure (necessity of analysis of bunker oil)

Unrealistic since it is difficult to avoid bunkering low quality fuel oil completely

Therefore, steps need to be taken during operation:

- Change engine operation method (Engine side)
- Strengthen purification of fuel oil (Fuel oil side)

# Main diesel engine: Degraded heavy F.O. (Example 2)

## Operation Precaution 1 – Engine Side

- Reduce engine output;
  - Plan a reduction of mechanical loads and thermal loads
- Adjustment of cylinder coolant temperature(decide appropriate amount according to operating manual);
- Increase amount of cylinder lubricant (decide appropriate amount according to operating manual);
  - Strengthens oil film and prevents cylinder deterioration
- Raise scavenger temperature;
  - Improved ignitability of fuel due to increased temperature of compression in cylinder; (however, there will be an accompanying increase in NOx values as a result so be careful of upper limits in technical file.)
- Change fuel injection timing;
  - The earlier the fuel injection, the better the chance of covering problems of slow fuel ignition. (however, there will be an accompanying increase in NOx values as a result so be careful of upper limits in technical file.)

# Main diesel engine: Degraded heavy F.O. (Example 2)

## Operation Precaution 2 – Fuel Oil Side

Addition of combustion promoter
- a pro-oxidant is used to cover problems of slow ignition or incombustibility

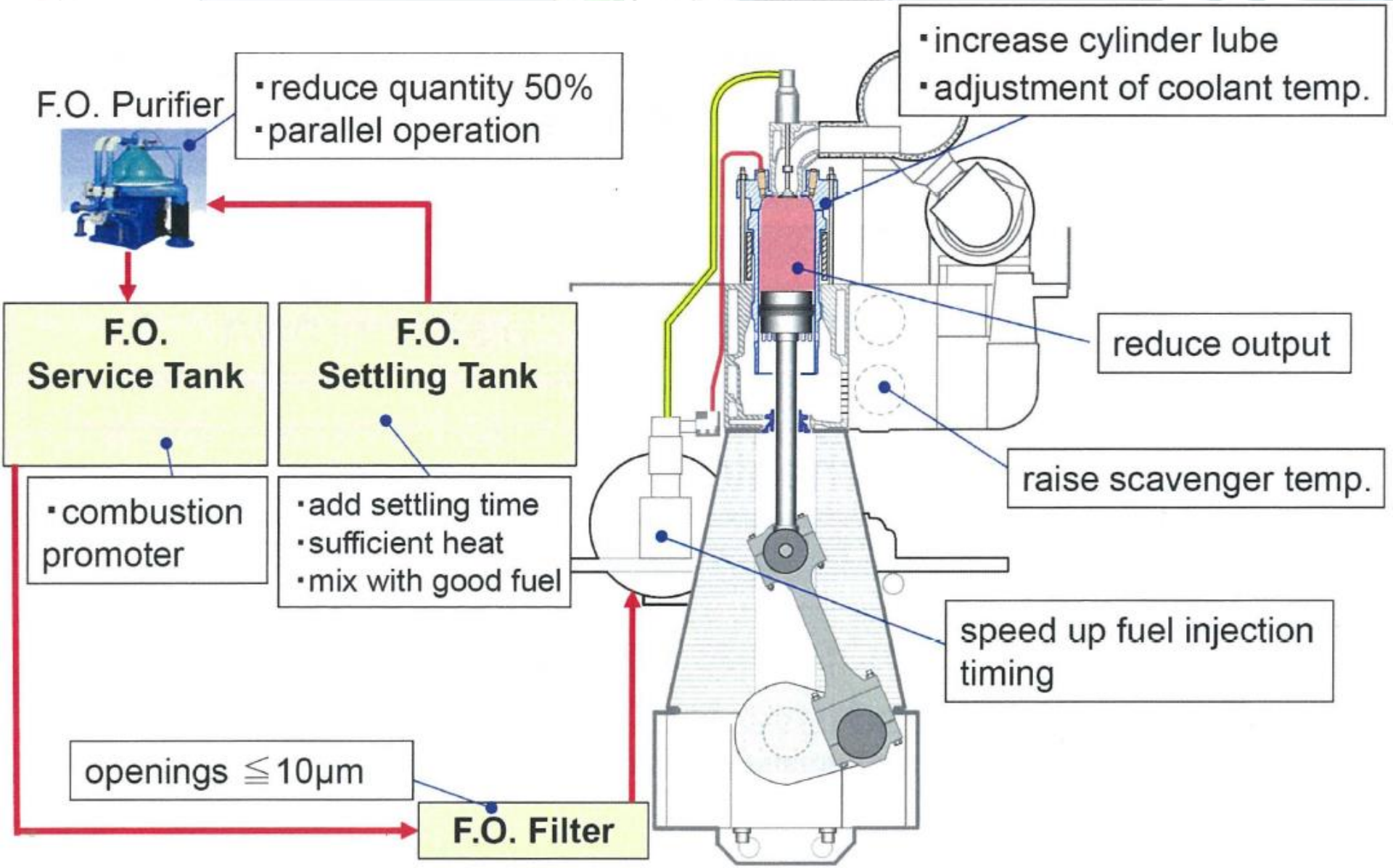
Mixed in with normal fuel (emergency only)
- regular fuel mixed with low quality oil / degraded oil can be used continuously
- Carefully monitor engine operation and cylinder conditions

## Operation Precaution 3 – Response Time

If engine operation becomes abnormal, the faster the response the better.
- responding quickly may result in only piston ring breakage.
- continued operation under abnormal burning conditions could lead to multiple cracks in the cylinder liner

# Main diesel engine: Degraded heavy F.O. (Example 2)

## Operation Precaution – Summary



# Main diesel engine: Combustion Chamber (Example 3 – Case 1)

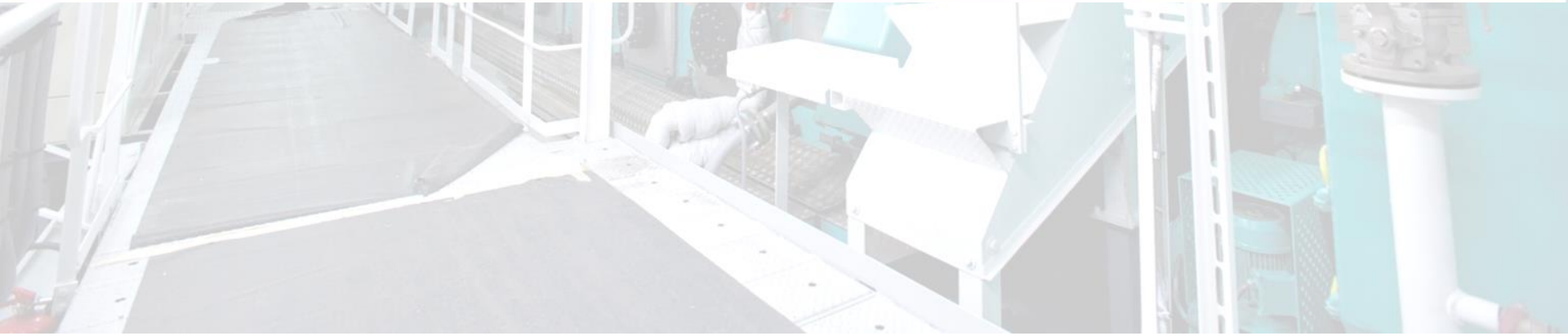
| Ship Type: | Container Carrier |
|---|---|
| GT: | 35200 |
| Ship Age: | 17 years |
| ME: | 2 Stroke / 19500 PS |
| Damaged Part: | Piston Crowns and Rods |

## Overhauling procedures

After overhauling and assembling pistons, air test was carried out.

Air leaking from bolt holes on No.1 piston crown

All cylinders were overhauled for an inspection

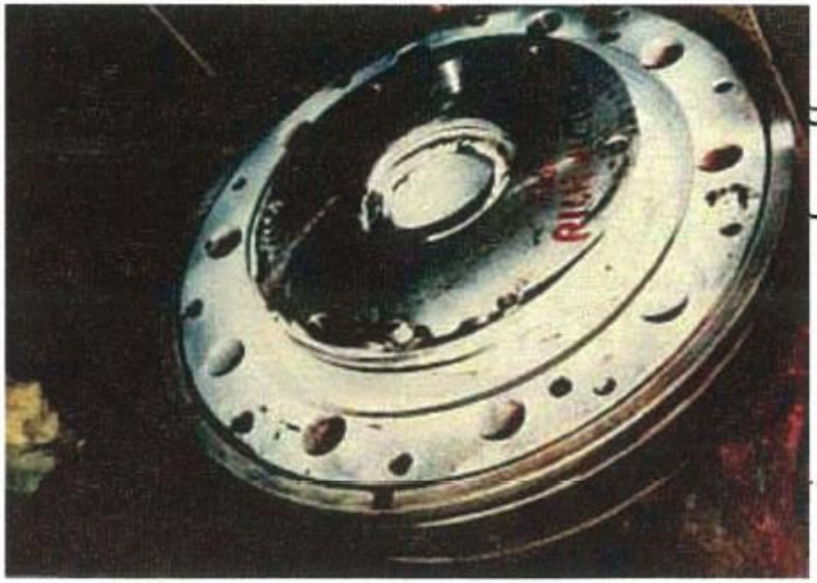


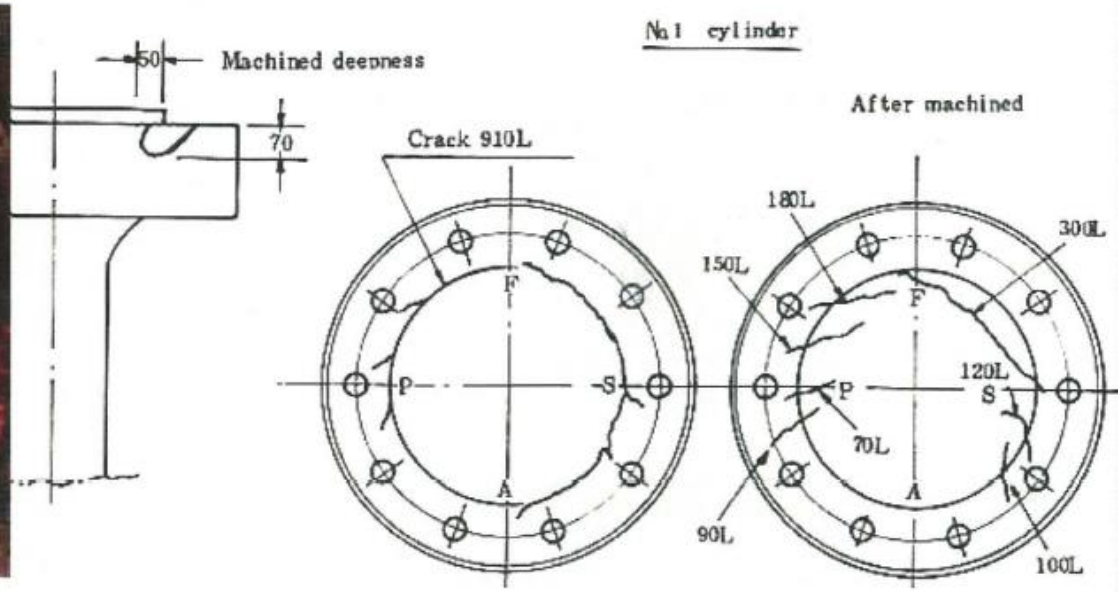
## Condition

The followings were found:

Cracks on No.1,4,6 Piston Rods

Cracks going through bolt holes on No.1 piston rod





## Causes

Fretting occurred on the contact face between No.1,4,6 Piston Rods and piston crowns

Fretting was not found on piston rod with no crack

Cracks occurred due to insufficient tightening of the fitting bolts of the piston crown

Insufficient tightening was suspected when the piston was restored during the last overhaul

# Main diesel engine: Combustion Chamber (Example 3 – Case 2)

| Ship Type: | Car Carrier |
|---|---|
| GT: | 49800 |
| Ship Age: | 20 years |
| ME: | V Type 4 Stroke / 16900 PS |
| Damaged Part: | Piston & Cylinder Liner |

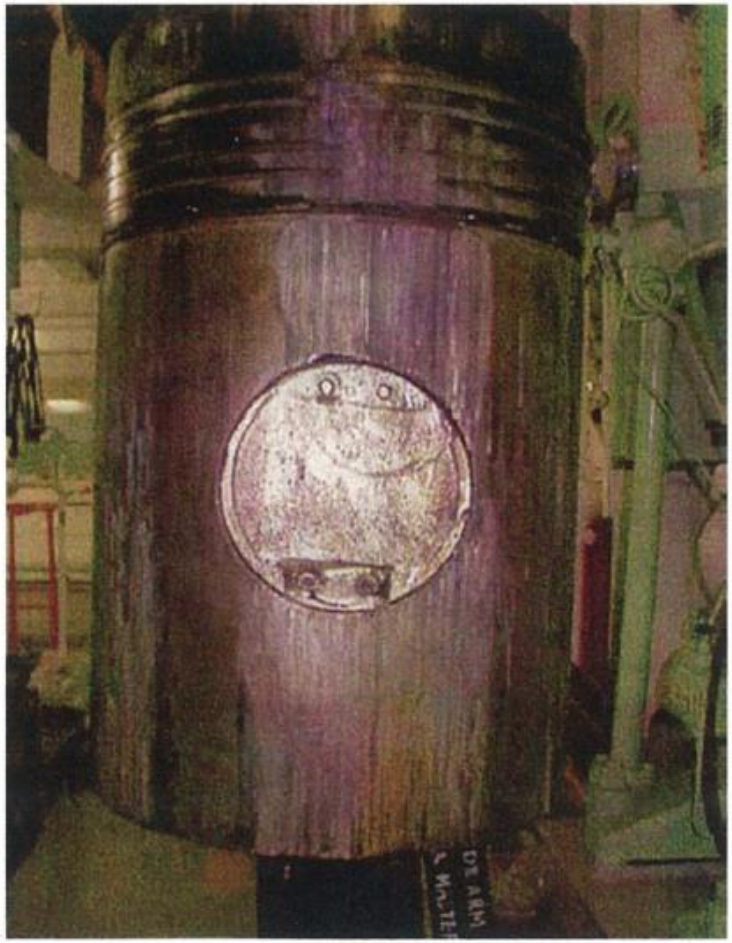
## Report

Crankcase oil mist alarm of main engine was activated

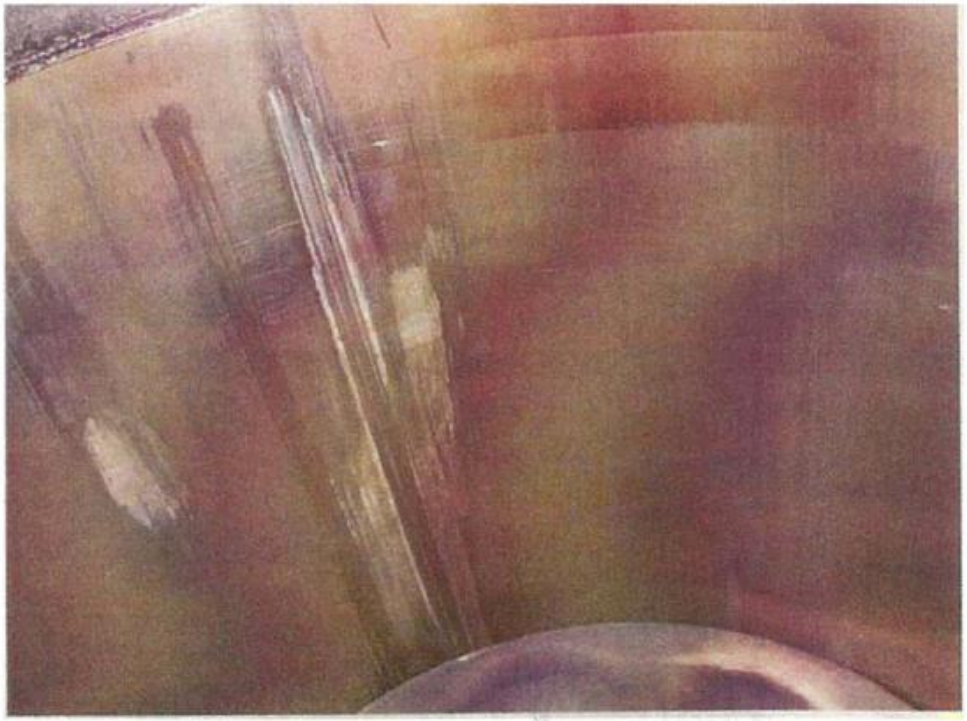
Damage was found upon inspection
No.B-5 Piston: Worn and scratched
Lower part of No.B-5 Cylinder Liner: Worn and scratched

# Main diesel engine: Combustion Chamber (Example 3 – Case 2)

## Condition



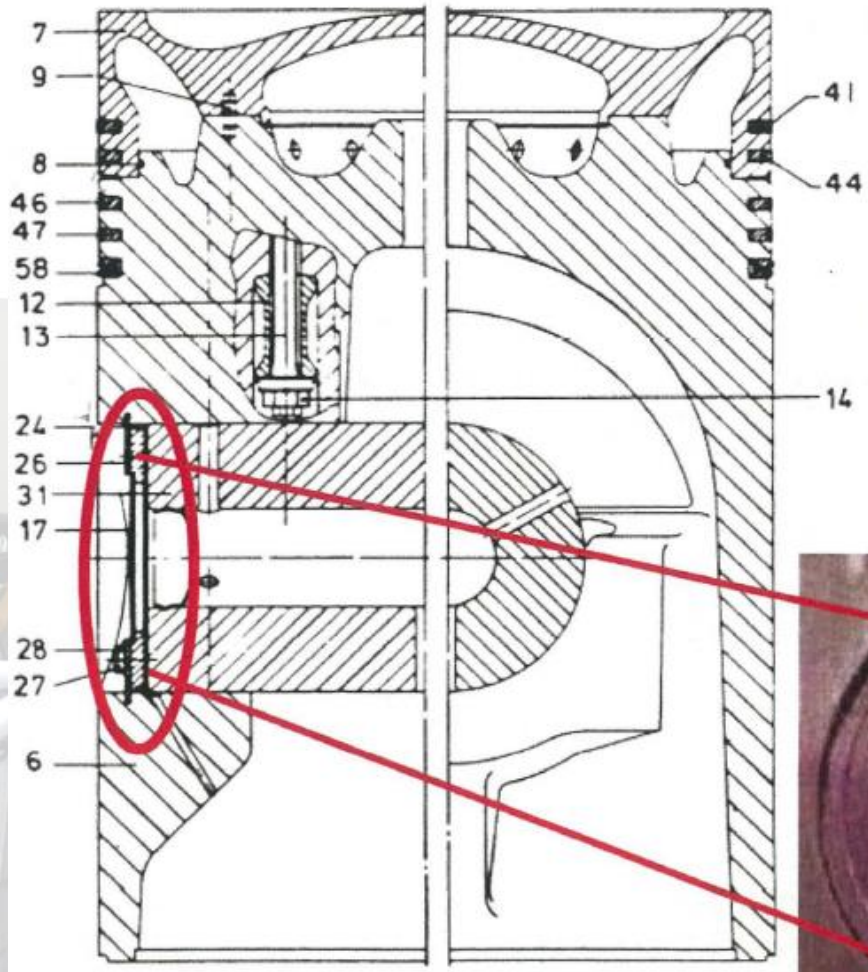
Deep cut of No.B-5 Piston



Deep cut of No.B-5 Cylinder Liner

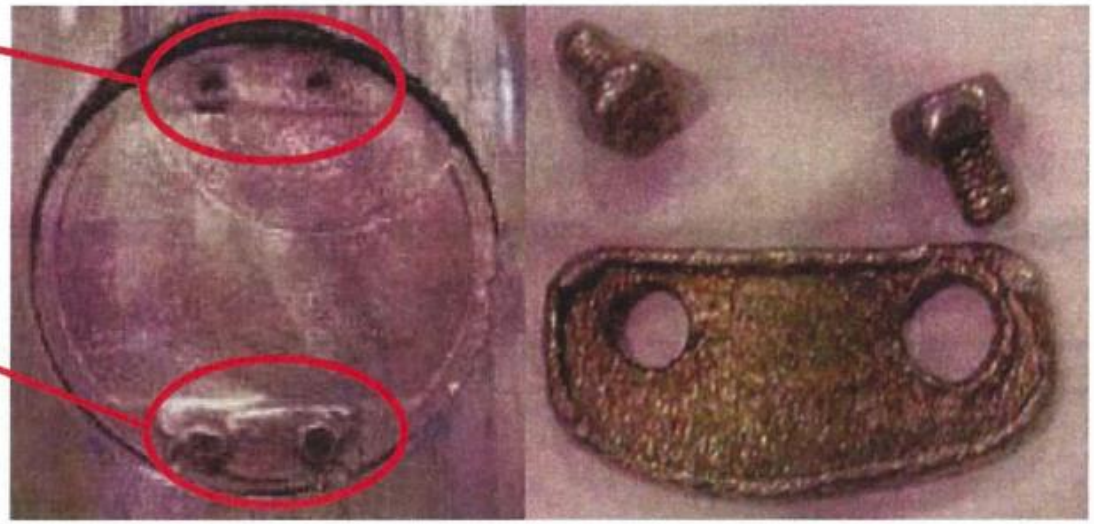
# Main diesel engine: Combustion Chamber (Example 3 – Case 2)

## Condition




Upper holding plate for piston pin had detached

Lower holding plate and bolts were worn



# Main diesel engine: Combustion Chamber (Example 3 – Case 2)

## Causes

Fitting bolts on upper holding plate were loosened

↓

Upper holding plate unfastened

↓

Deep cuts occurred on cylinder liner and piston

↓

Piston cooling oil also leaked

↓

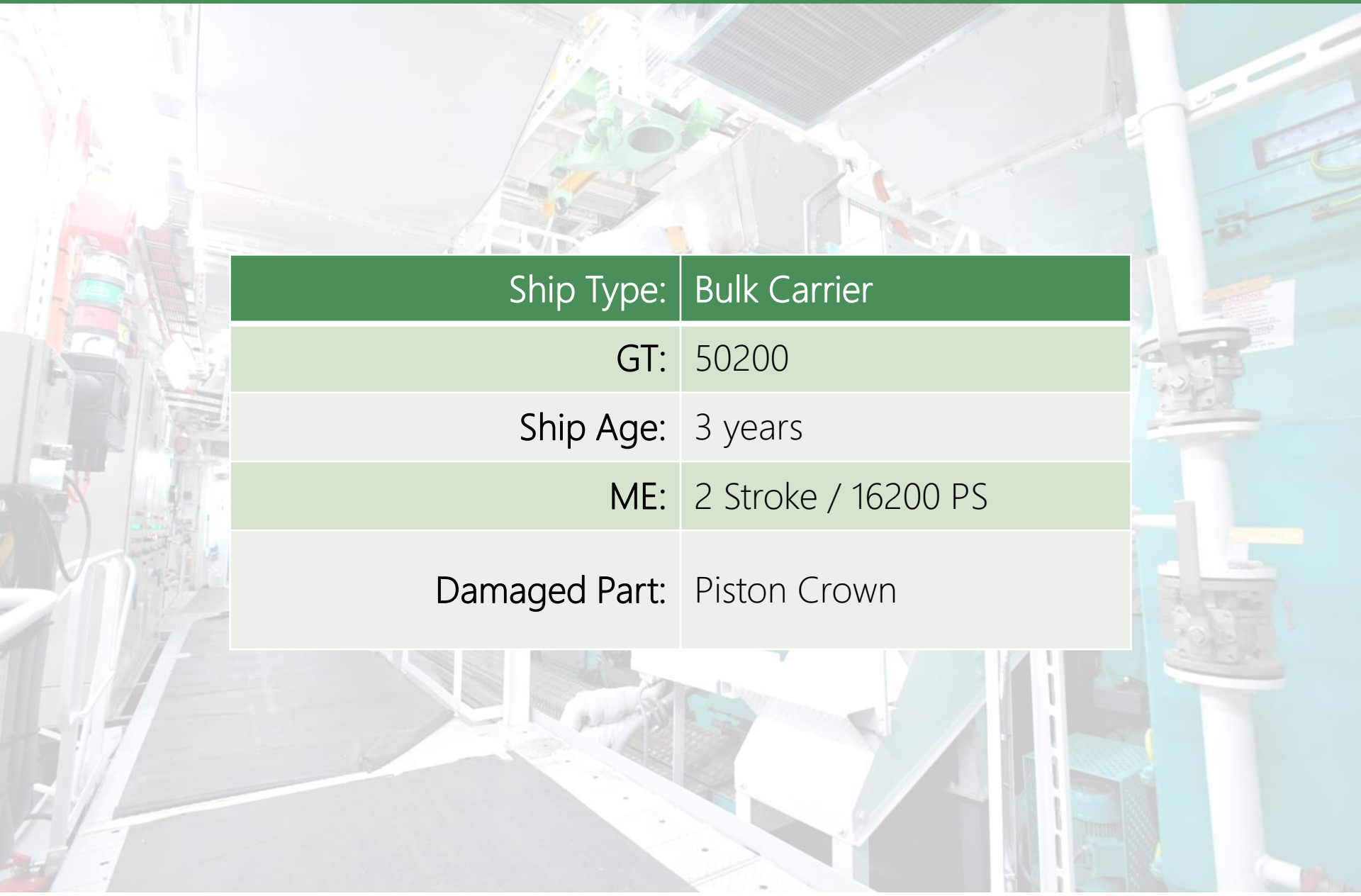
## Causes

Crankcase was filled with mist of leaked cooling oil and oil mist alarm was activated.

Two years before the damage, No.B-5 cylinder was overhauled satisfactorily.
One year before the damage, the engine was overhauled satisfactorily by the manufacturer's agent.

Insufficient tightening of the fitting bolts on the upper holding plate was suspected after the overhauls

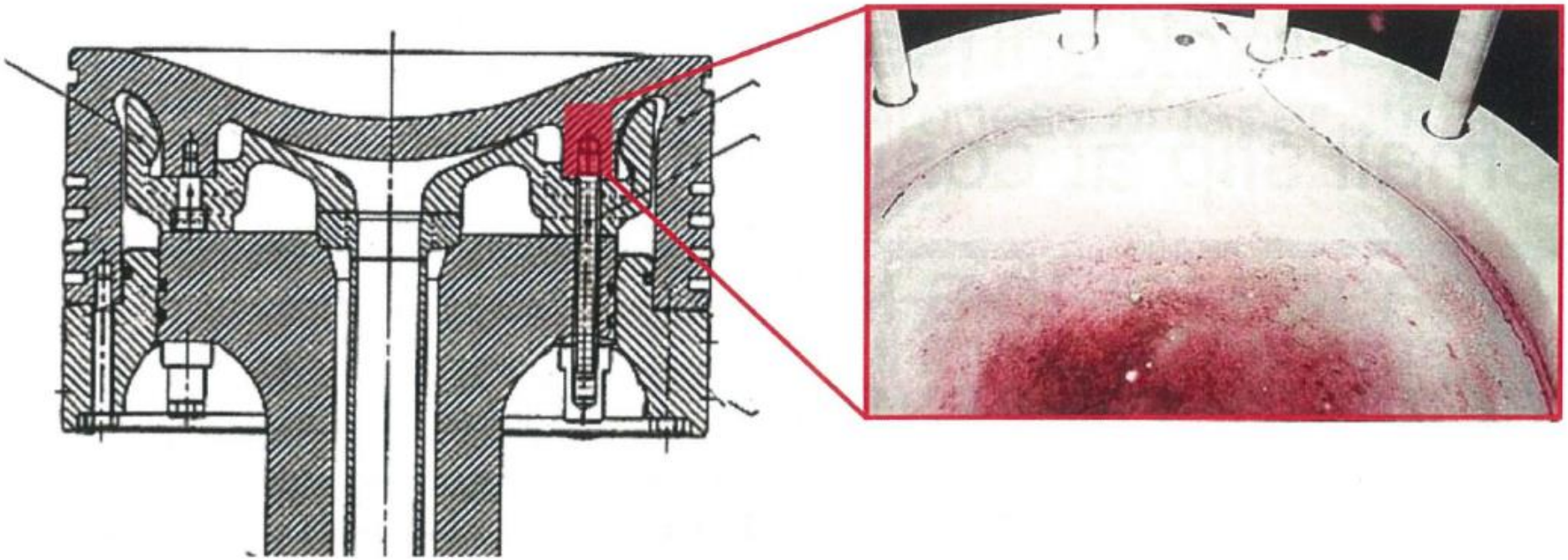
# Main diesel engine: Combustion Chamber (Example 3 – Case 3)



| Ship Type: | Bulk Carrier |
|---|---|
| GT: | 50200 |
| Ship Age: | 3 years |
| ME: | 2 Stroke / 16200 PS |
| Damaged Part: | Piston Crown |

# Main diesel engine: Combustion Chamber (Example 3 – Case 3)

## Report



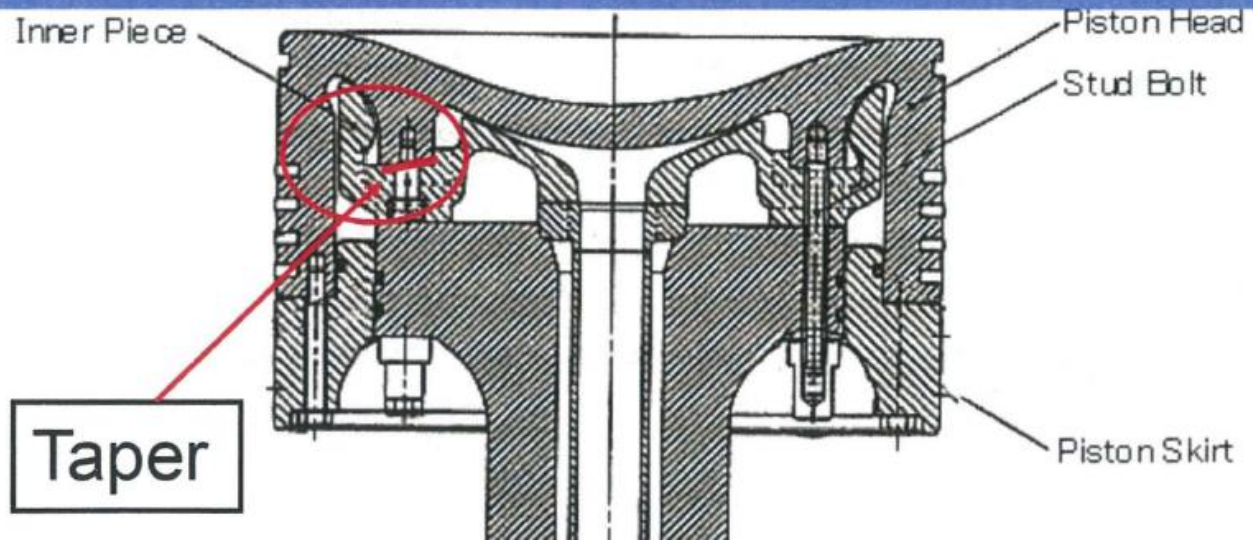
Two Cracks were found at piston head supporting part of M/E during a inspection

## Causes

Taper on contact surface of the inner piece was made for the relaxation of thermal stress

Fretting was occurred on this taper

Fatigue crack initiated at thread roots due to increased fluctuating stress



## Fretting abrasion.

Hair crack caused by repetition of small slip at connecting part

Reason for this incident is not clarified. However it is said that mechanism is caused from adhesion by small slip and peeling off the adhesive part repeatedly.

## Cause of Fretting

- Insufficient and unbalance tightening of bolt
- Manufacturing accuracy of the contact surface

On the other side, reduction of tightening force is effective for stress reduction at thread root

It comes to conflict and counter measures are difficult

## Cause of Fretting

1. Manufacturer raised the hardness of taper surface by surface treatment

2. Overhaul of piston crown is important because it is difficult to prevent the fretting wear

3. To refer to the manufacturer's service news for the criterion at the examination

## Attention

In order to prevent damage in combustion chambers

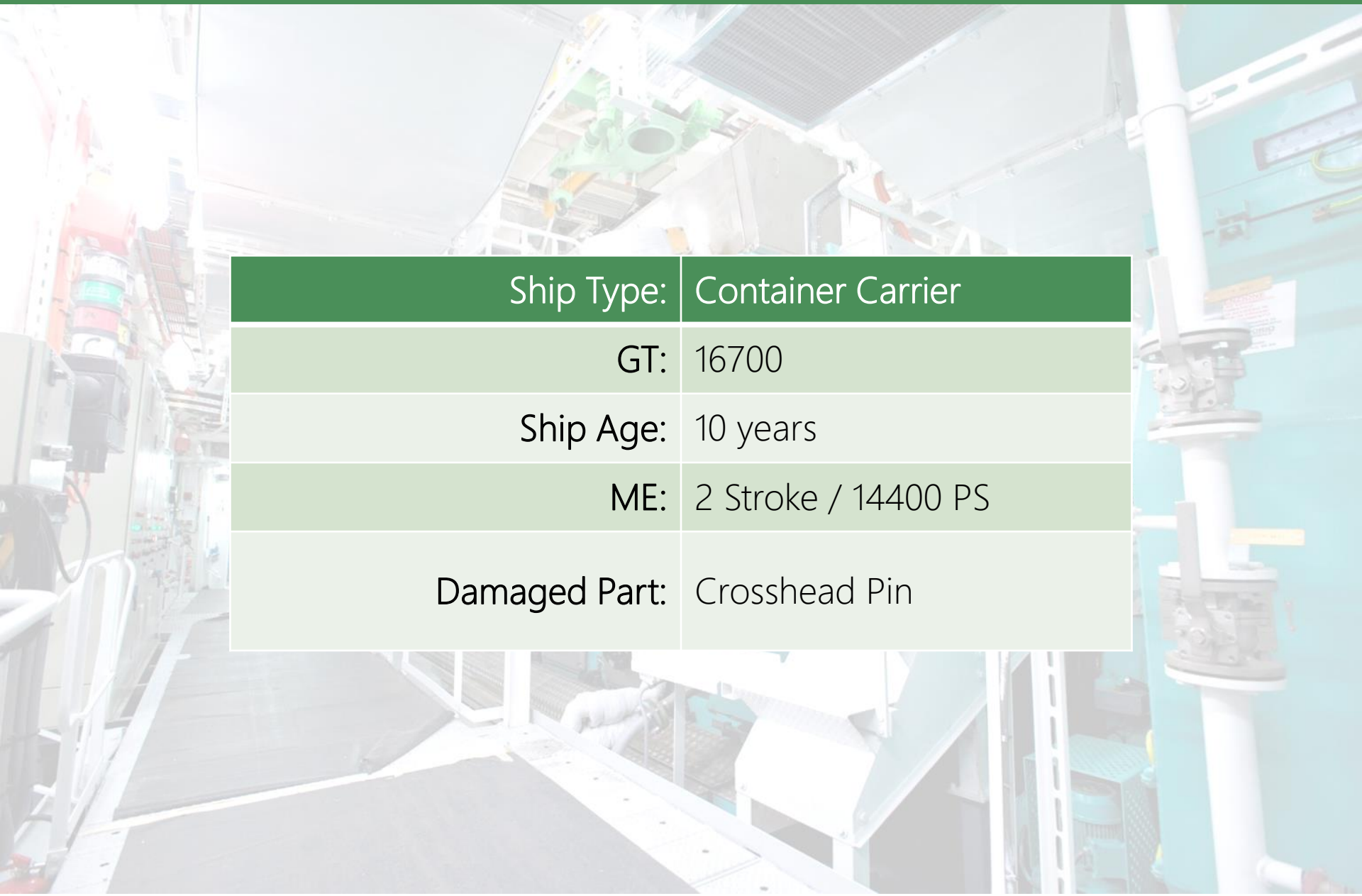
Overhauling periodically combustion chambers

But, many damages were occurred by a mis-assembly at an overhauling inspection

**Note**

1. Bolt tightening is to be carried out in accordance with the maker's manual
2. Any parts are to be assembled with close attention.

# Main diesel engine: Crosshead pin (Example 4 – Case 1)



| Ship Type: | Container Carrier |
|---|---|
| GT: | 16700 |
| Ship Age: | 10 years |
| ME: | 2 Stroke / 14400 PS |
| Damaged Part: | Crosshead Pin |

# Main diesel engine: Crosshead pin (Example 3 – Case 1)

## Narrative

During navigation, the safety valves of crank case for No.4 & 5 Cylinder were blew up

Main engine was stopped and overhauled

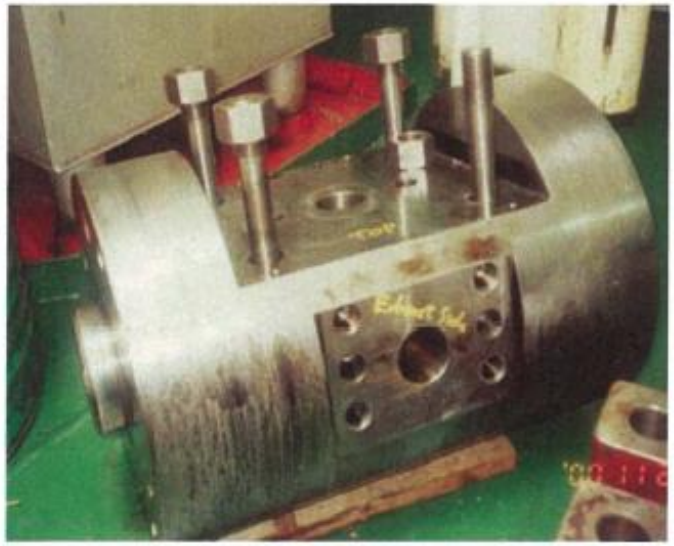
No.4 Cylinder : Damage
No.5 Cylinder : No Damage

No.4 Crosshead Pin & Bearing : Burn out
No.4 Crank Case Safety Valve : Blow up

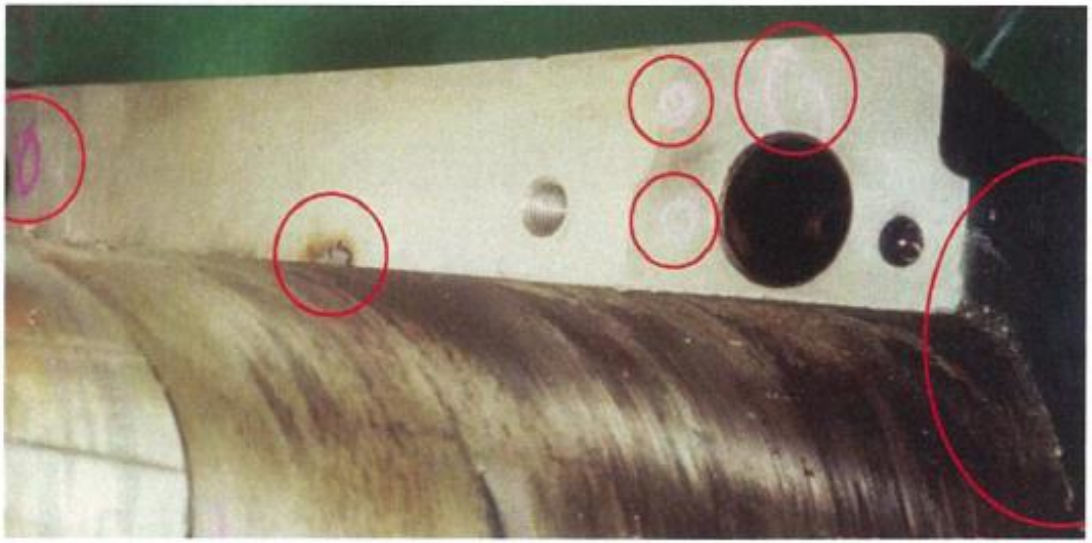
No.4 Cylinder was cut and the ship was operated under a de-rating condition

# Main diesel engine: Crosshead pin (Example 3 – Case 1)

## Condition



No.4 Crosshead Pin



No.4 Crosshead Pin Bearing (Low. Side)

Contacting surface of housing for upper and lower bearing:
1) Damage by fretting (0.2~0.3 mm)
   + Adhesion of the melted white metal
2) Some deeply-pressed marks due to sandwiching something

## Condition

Crosshead pin bearing was tightened with sandwiching something

The fretting was occurred after loosening the tightening bolts for the bearing

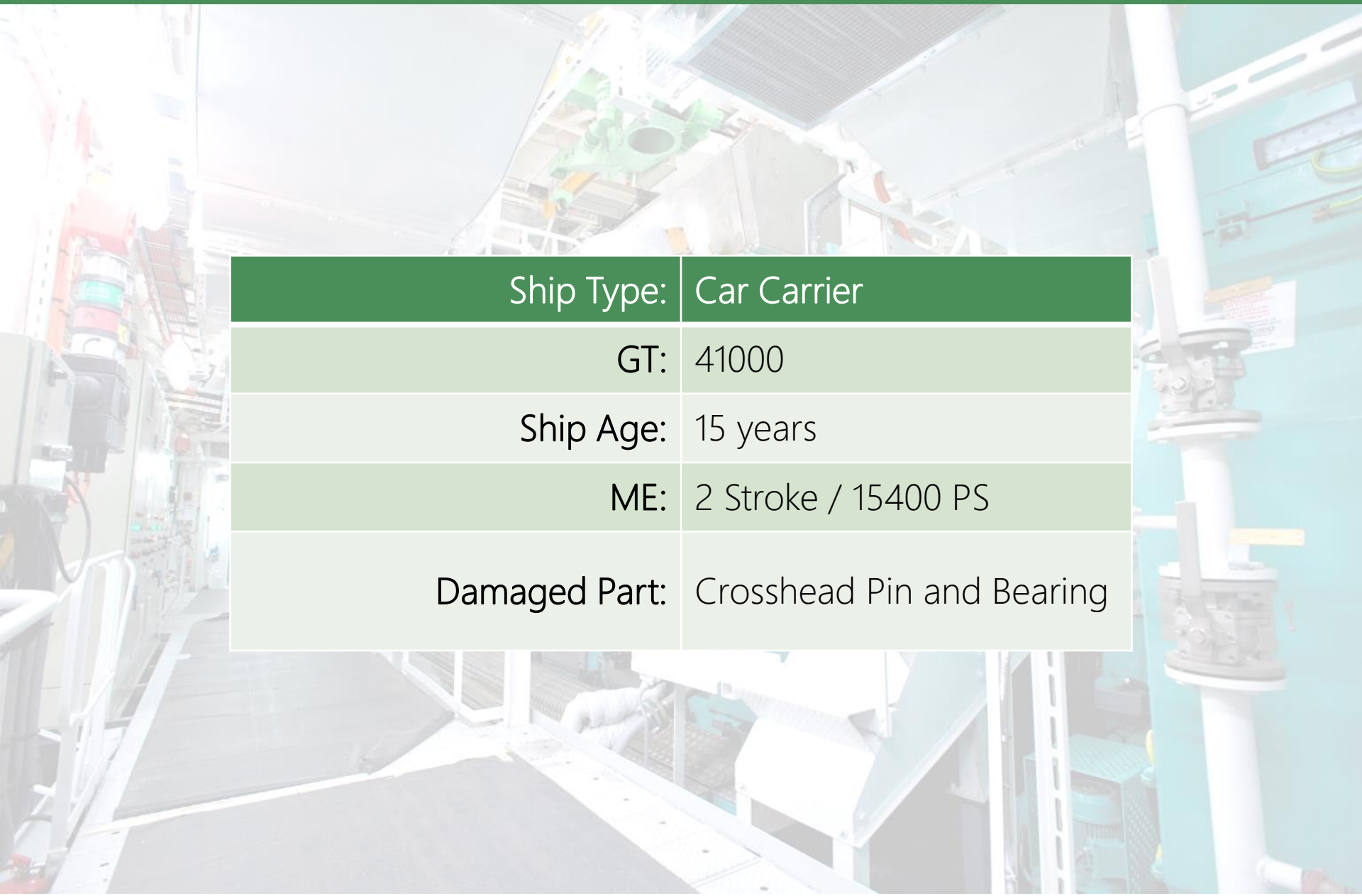
- The contacting surface was worn out
- The clearance of the crosshead pin bearing exceeded the limit

During navigation, the crosshead pin hit and broke the white metal.

The white metal was melted

**Damage**

# Main diesel engine: Crosshead pin (Example 4 – Case 2)



| Ship Type: | Car Carrier |
|---|---|
| GT: | 41000 |
| Ship Age: | 15 years |
| ME: | 2 Stroke / 15400 PS |
| Damaged Part: | Crosshead Pin and Bearing |

# Main diesel engine: Crosshead pin (Example 4 – Case 2)

## Incident

During navigation,
the oil mist detector alarm of No.4 crank case was triggered.

The vessel sailed at reduced speed.

After arriving a port, No.4 cylinder unit was overhauled.

Crosshead Pin : Burnt Out
Crosshead Pin Metal : Burnt Out
Guide Shoe : Burnt Out
Upper Linkage Lever : Bent

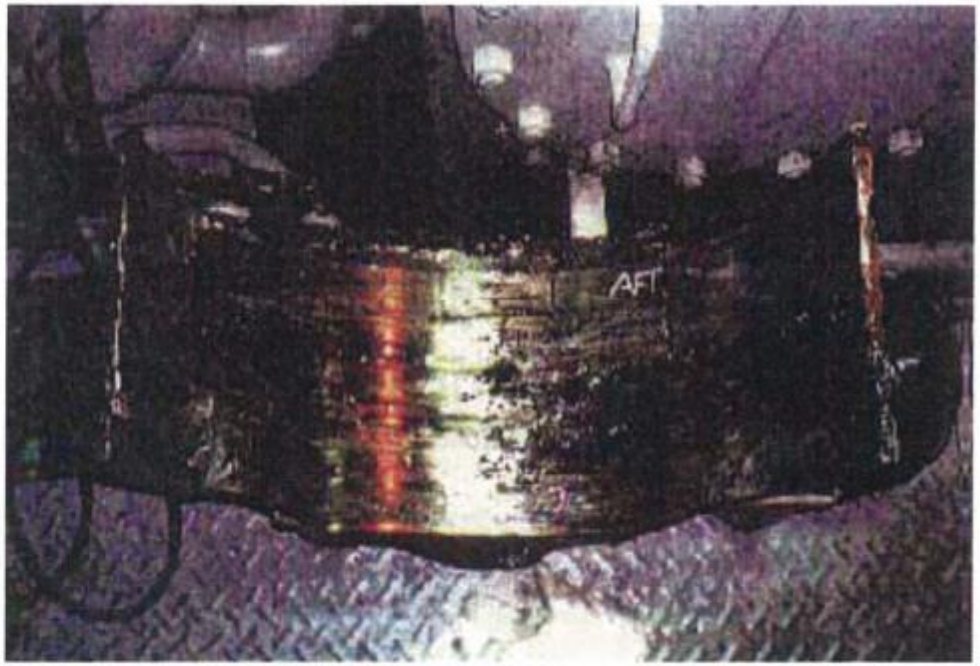
The bolts to the fix pins and the plates to prevent turning were missing at the connection between the upper side and the lower side of shaking levers for supplying oil to the crosshead.

# Main diesel engine: Crosshead pin (Example 4 – Case 2)

## Incident

Crosshead Pin (Lower Side)

Upper Shaking Lever and Pin




Crosshead Pin Bearing (Lower Side)

# Main diesel engine: Crosshead pin (Example 4 – Case 2)

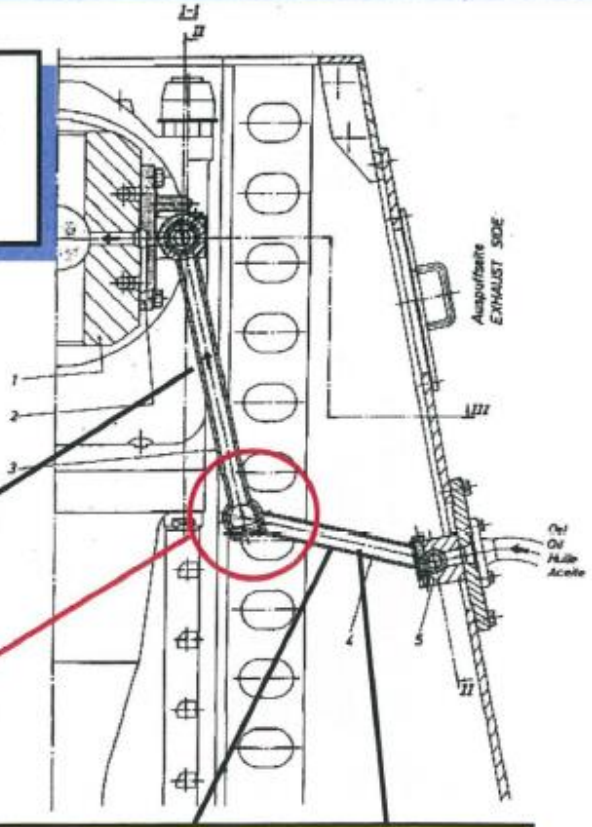
## Causes

Bolts for fixing pin at connecting part of shaking lever were missing.

Part of pin at connecting part of L.O. passage moved

Decreased amount of L.O. for the crosshead

Damage Occurred




Upper Shaking Lever

Connecting Part

Lower Shaking Lever

## Causes

**Why did the pin fixing bolts drop?**

Possibility of forgetting to assemble the bolt fixing plates during the overhaul

**Check During Assembly**

The parts are to be confirmed in accordance with the instruction/manual of the manufacturer strictly

All parts are to be assembled with great care and attention, even if they are only very small parts

# Main diesel engine: Damage during Ship Test (Example 5)

| | |
|---|---|
| Ship Type: | -- |
| GT: | -- |
| Ship Age: | -- |
| ME: | 2 Stroke / 39000 PS |
| Damaged Part: | Piston Cooling Pipe & Tightening Bolt |

# Main diesel engine: Damage during Ship Test (Example 5)

## Report

After 110% load test in shop trial, visual inspection of cylinder liner was carried out from the scavenging port.

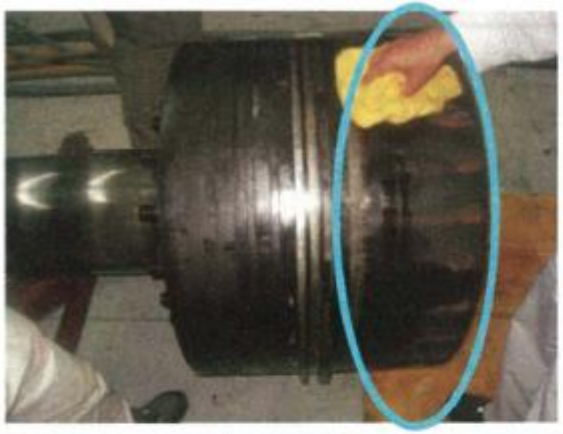
Piston crown of No.7 cylinder was stained black like coal

Damage was confirmed via opening-up inspection

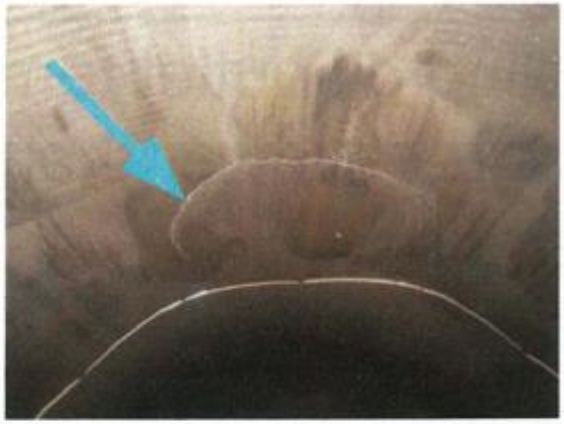
Piston Crown: Abnormal Wear
Cylinder Liner: Crack
Piston Cooling Pipe: Bent
Tightening Bolts for Piston Cooling Pipe: Bent

# Main diesel engine: Damage during Ship Test (Example 5)

## Condition



Abnormally Worn Piston Crown



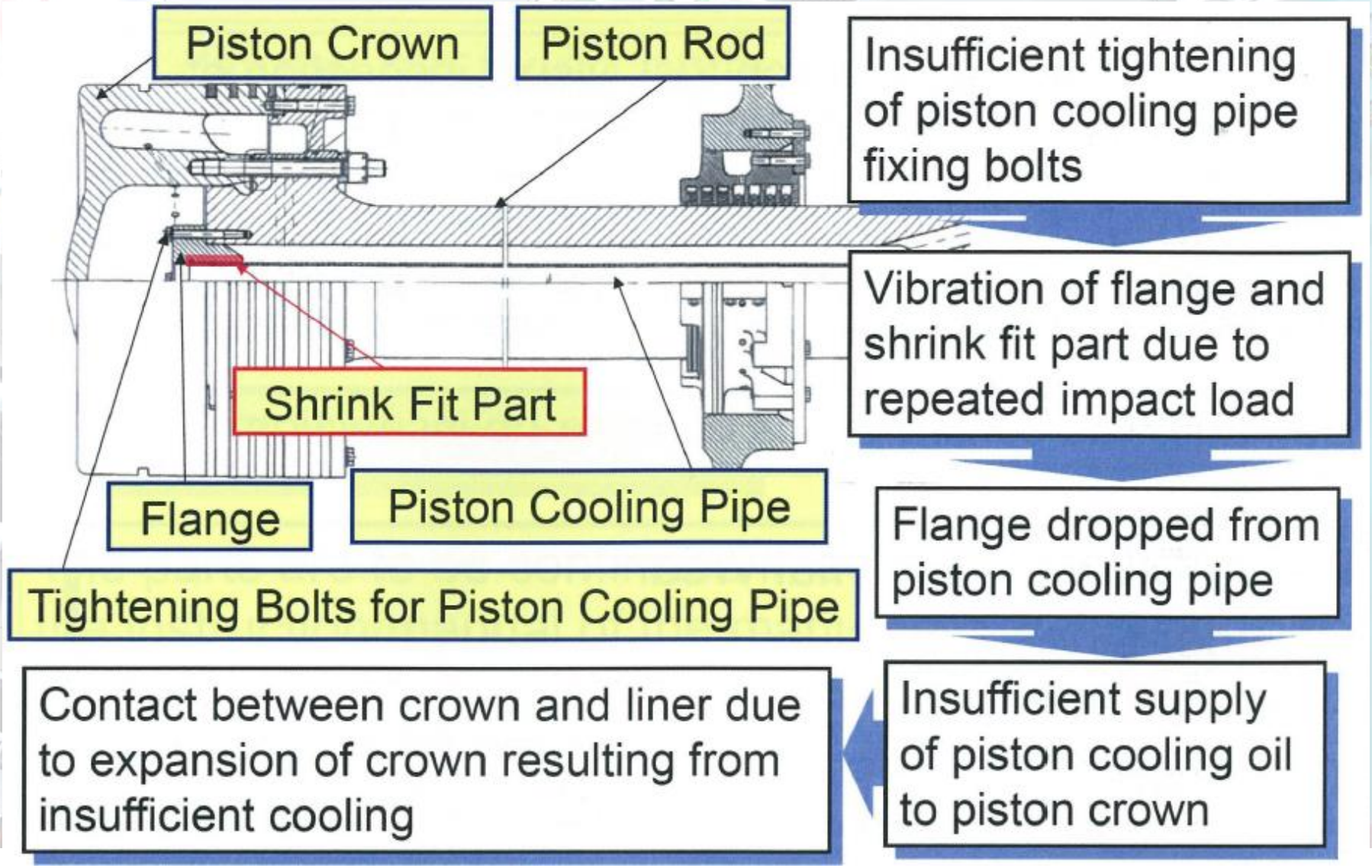
Crack on Cylinder Liner

Bent Piston Cooling Pipe

Bent Tightening Bolts for Piston Cooling Pipe

# Main diesel engine: Damage during Ship Test (Example 5)

## Causes



## Investigation Results

Cooling oil outlet temperature of damaged cylinder : 4 degrees lower than other cylinders at 100% load operation.

Possibility of insufficient cooling

Assembly of Pistons

Tightening record of Tightening Bolts for Piston Cooling Pipe could not be found

# Main diesel engine: Damage during Ship Test (Example 5)

## Check points

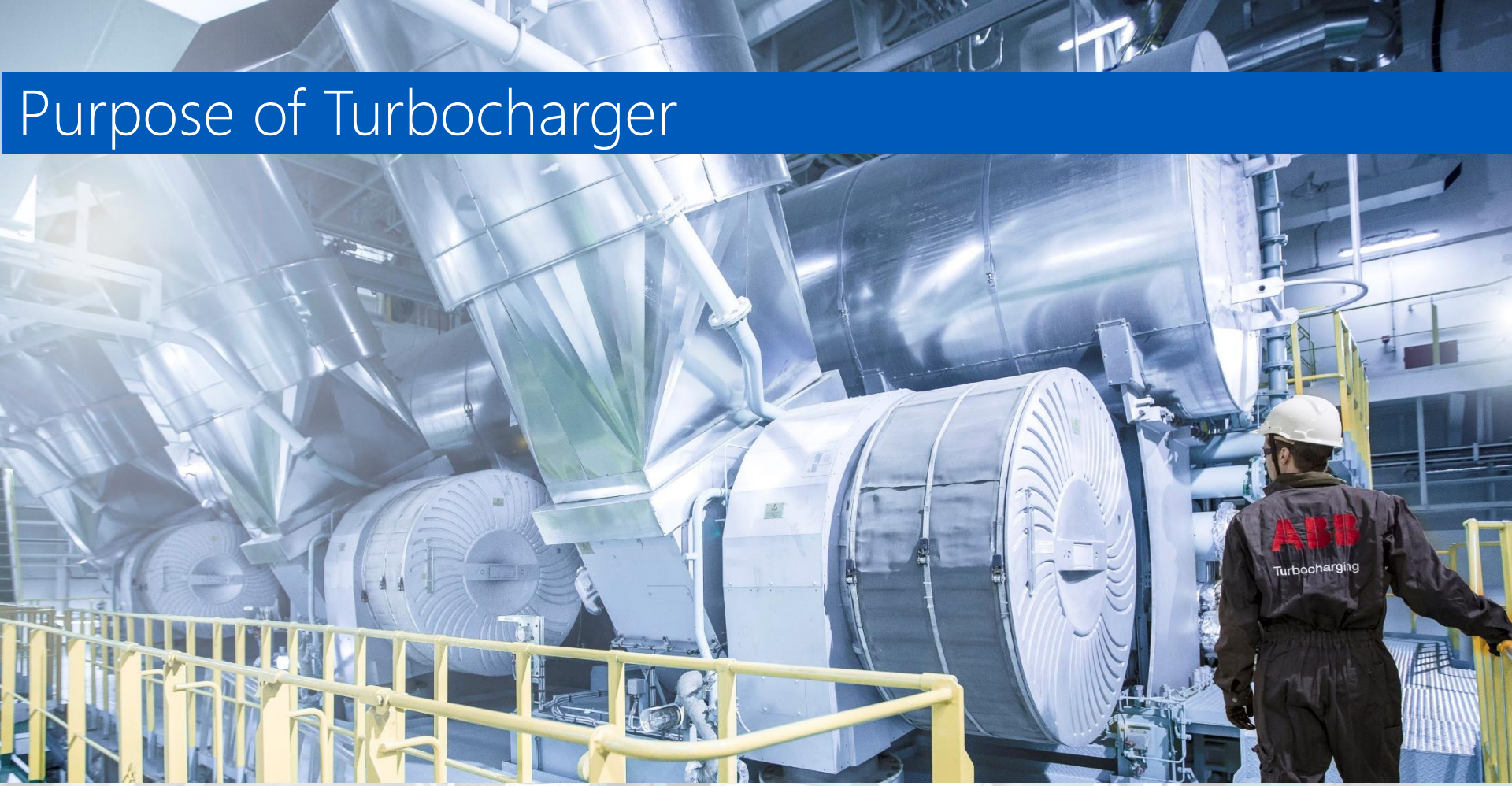
M/E manufacturer established the procedure including improved tightening torque control of tightening bolts for piston cooling pipe.

The same damage has not occurred again.

Pay attention to not only the operating record of M/E but also assembly records of each component during the shop test.

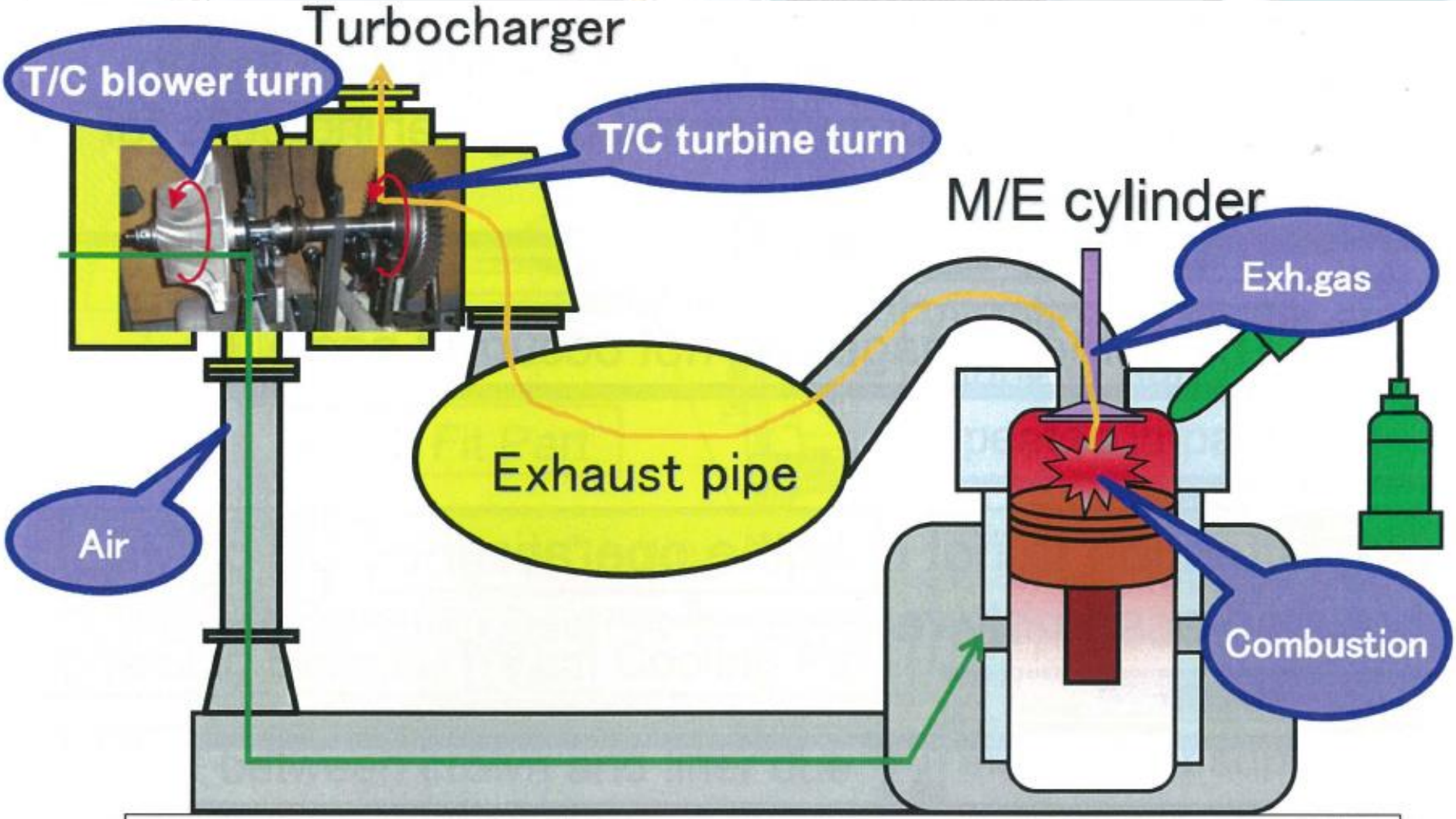
Confirmation of quality controls of M/E manufacturer

# Purpose of Turbocharger




Send large amount of air to combustion chamber in order to increase engine output

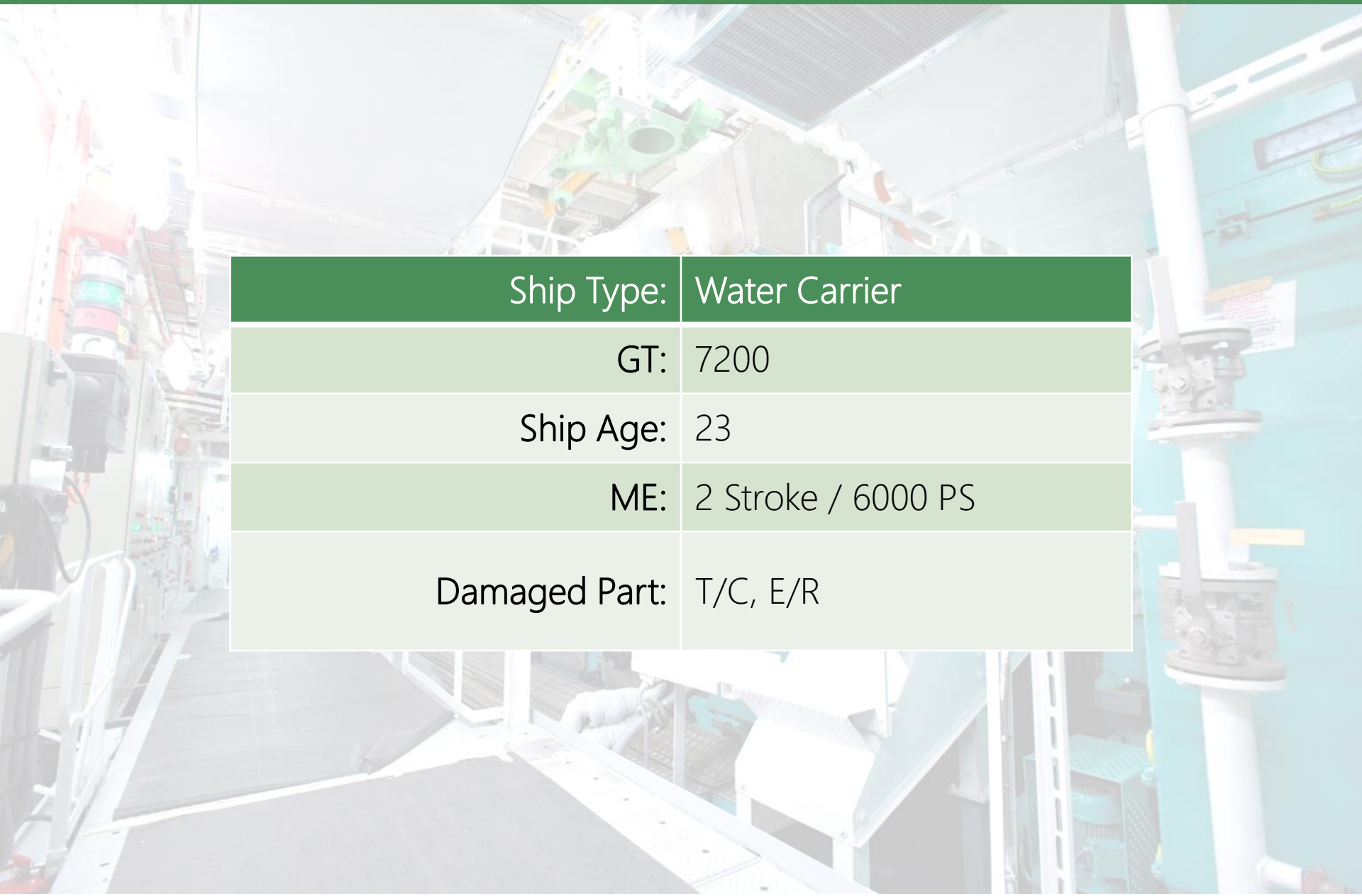
# Main diesel engine: Turbocharger (Example 6)




Purpose of T/C: send large air in order to increase output

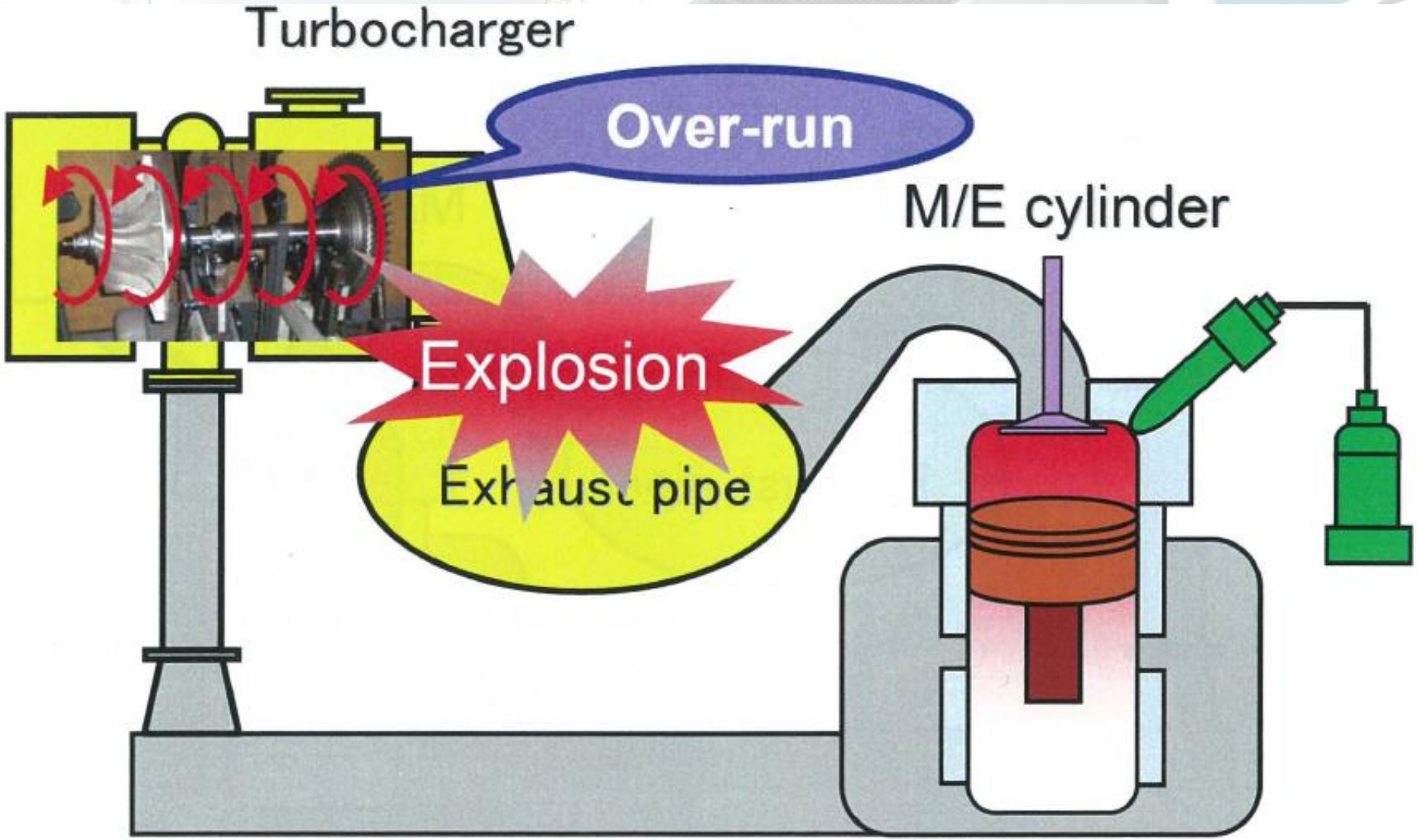
Damage to T/C ⇒ lead to speed reduction

# Main diesel engine: Turbocharger (Example 6 – Case 1)



| Ship Type: | Water Carrier |
|---|---|
| GT: | 7200 |
| Ship Age: | 23 |
| ME: | 2 Stroke / 6000 PS |
| Damaged Part: | T/C, E/R |

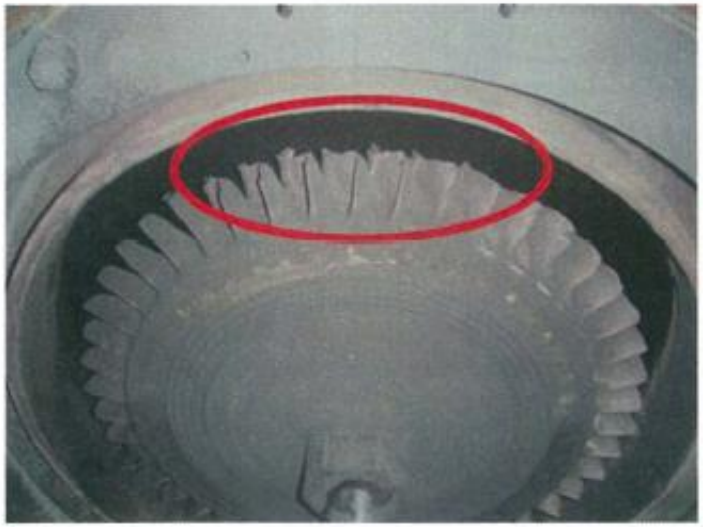
# Main diesel engine: Turbocharger (Example 6 – Case 1)



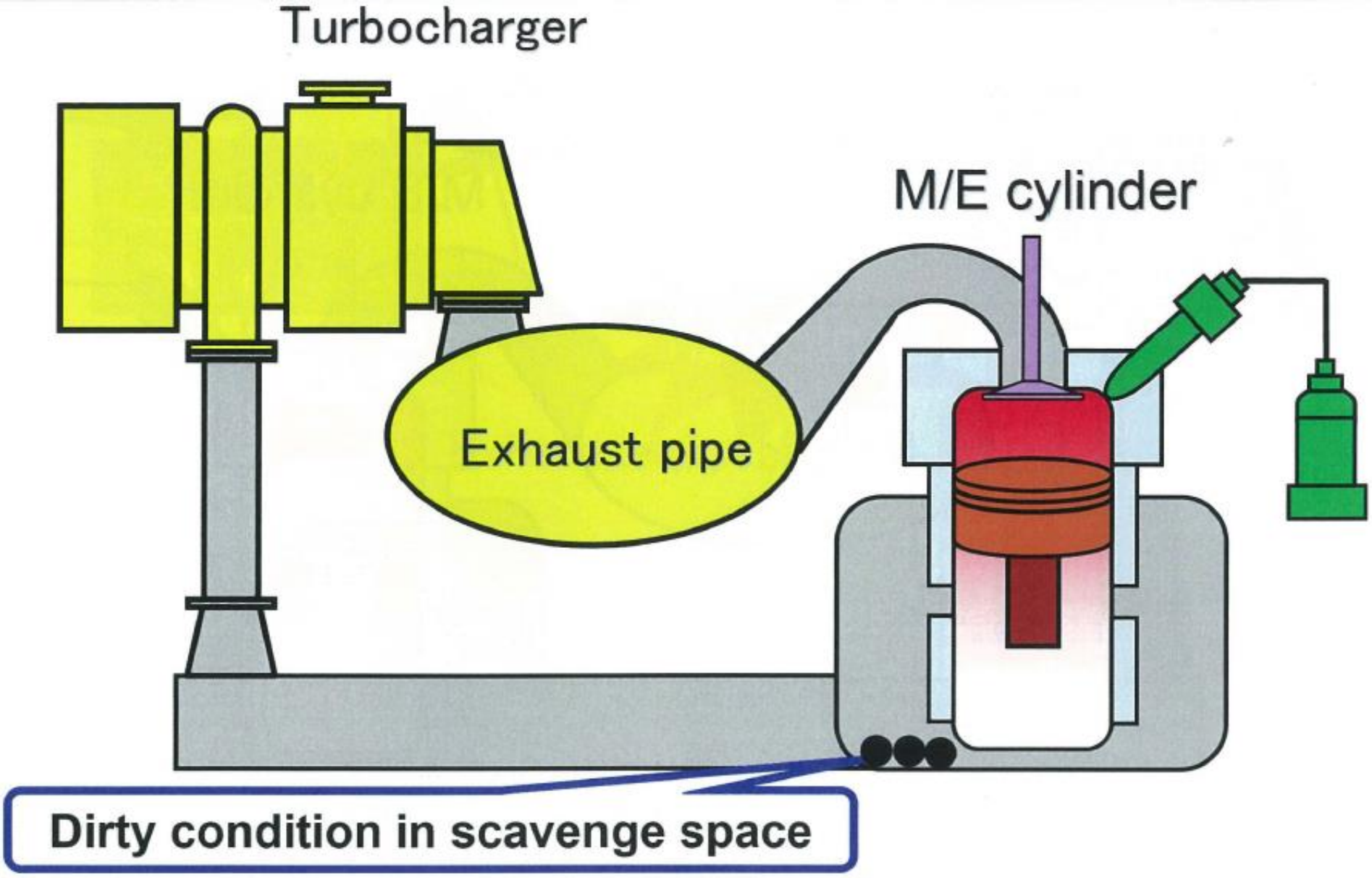
# Main diesel engine: Turbocharger (Example 6 – Case 1)

## Over-run

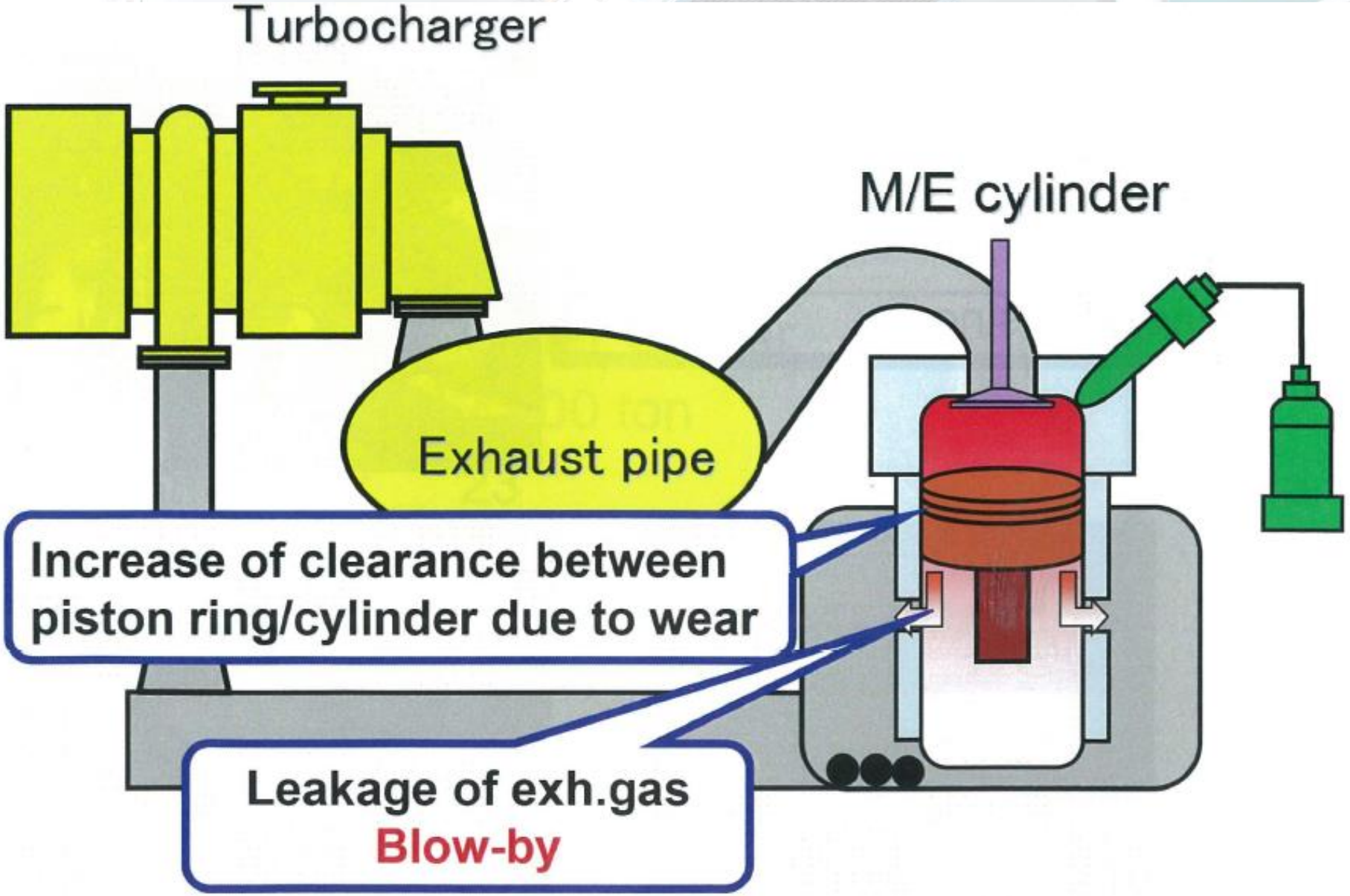
- Breakage of turbine blade/blower
- Heat damage of rotor shaft / bearings
- Fracture of casing

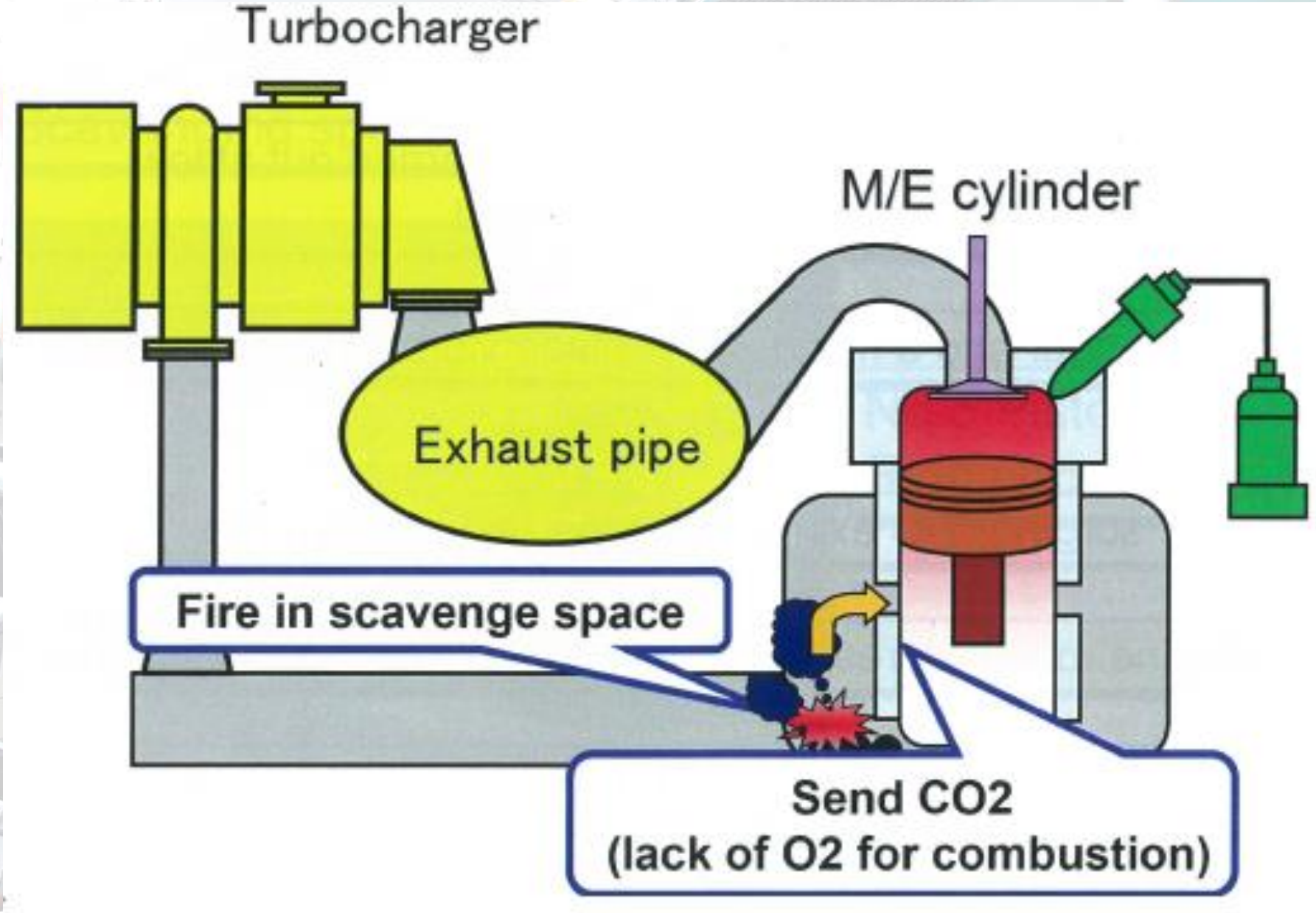
# Main diesel engine: Turbocharger (Example 6 – Case 1)



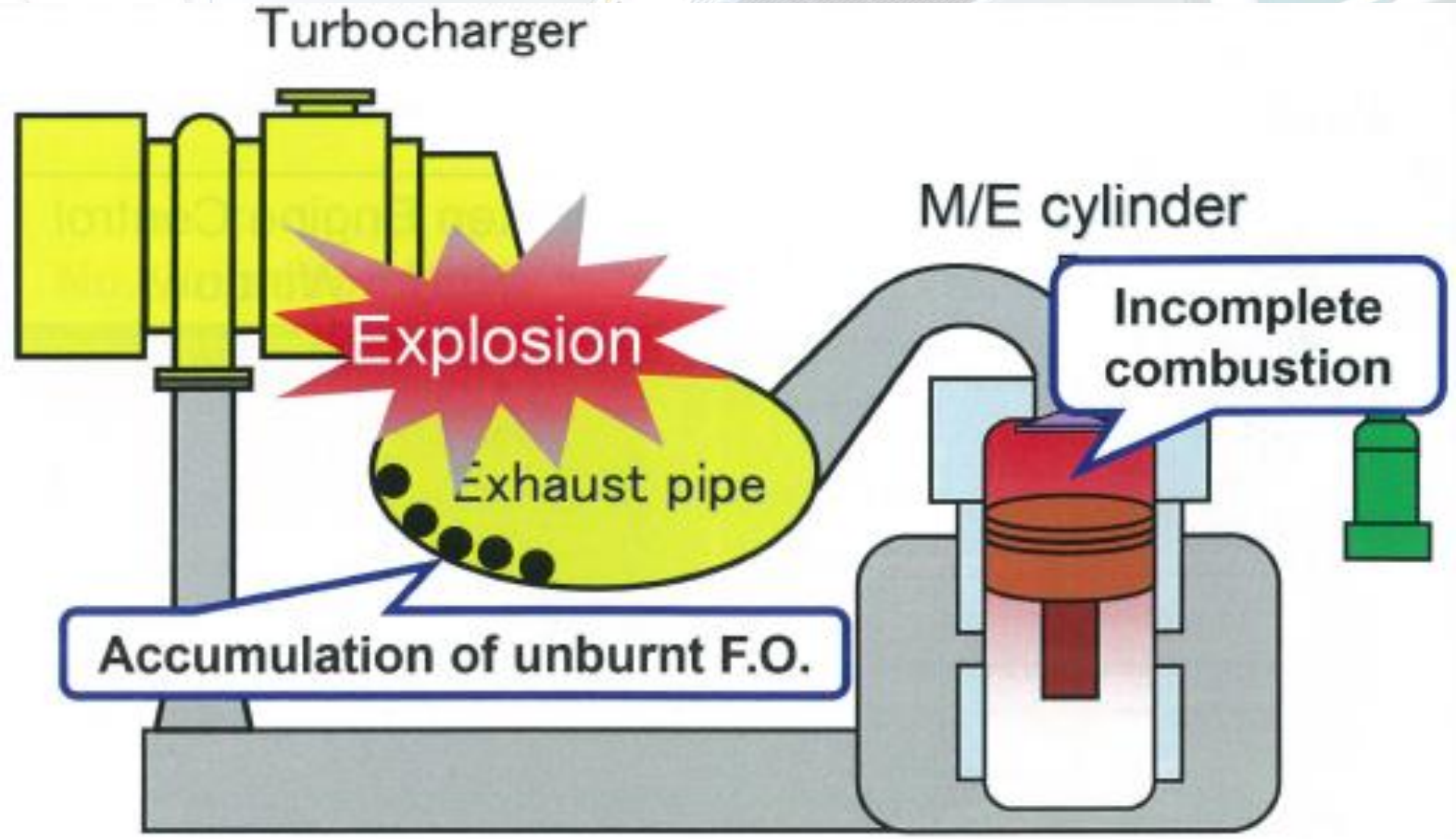
# Main diesel engine: Turbocharger (Example 6 – Case 1)



# Main diesel engine: Turbocharger (Example 6 – Case 1)



# Main diesel engine: Turbocharger (Example 6 – Case 1)



# Main diesel engine: Turbocharger (Example 6 – Case 1)

Reduced speed due to malfunction of T/C for 1 week

After the repair of T/C, a sea trial was carried out at low speed only. Normal navigation resumed.

After 1 hour and a half, turbine blade vibration was confirmed

After surging, T/C exploded as the result of overrun.

Engine room fire resulting from explosion (2 crew injured)

The fire was extinguished completely by fixed type fire extinguishing system half of an hour later

# Main diesel engine: Turbocharger (Example 6 – Case 1)

## Damage Conditions

Turbocharger

Broken Engine Control Room Window

## Investigation results

- Crack at No.5 & 6 Piston Ring Groove
- Scavenging space was dirty with oil

No.5 Piston Ring Groove

## Investigation results

**Unbalanced atomizing of No.2, 5 and 6 FO injection valve**

**No.5 Injection Valve**

**No.6 Injection Valve**

**Atomizing Conditions**

# Main diesel engine: Turbocharger (Example 6 – Case 1)

## Causes

Poor maintenance of M/E and failure to comply with manufacturer's instructions

Poor maintenance of FO injection valves and a long period of running at low speed

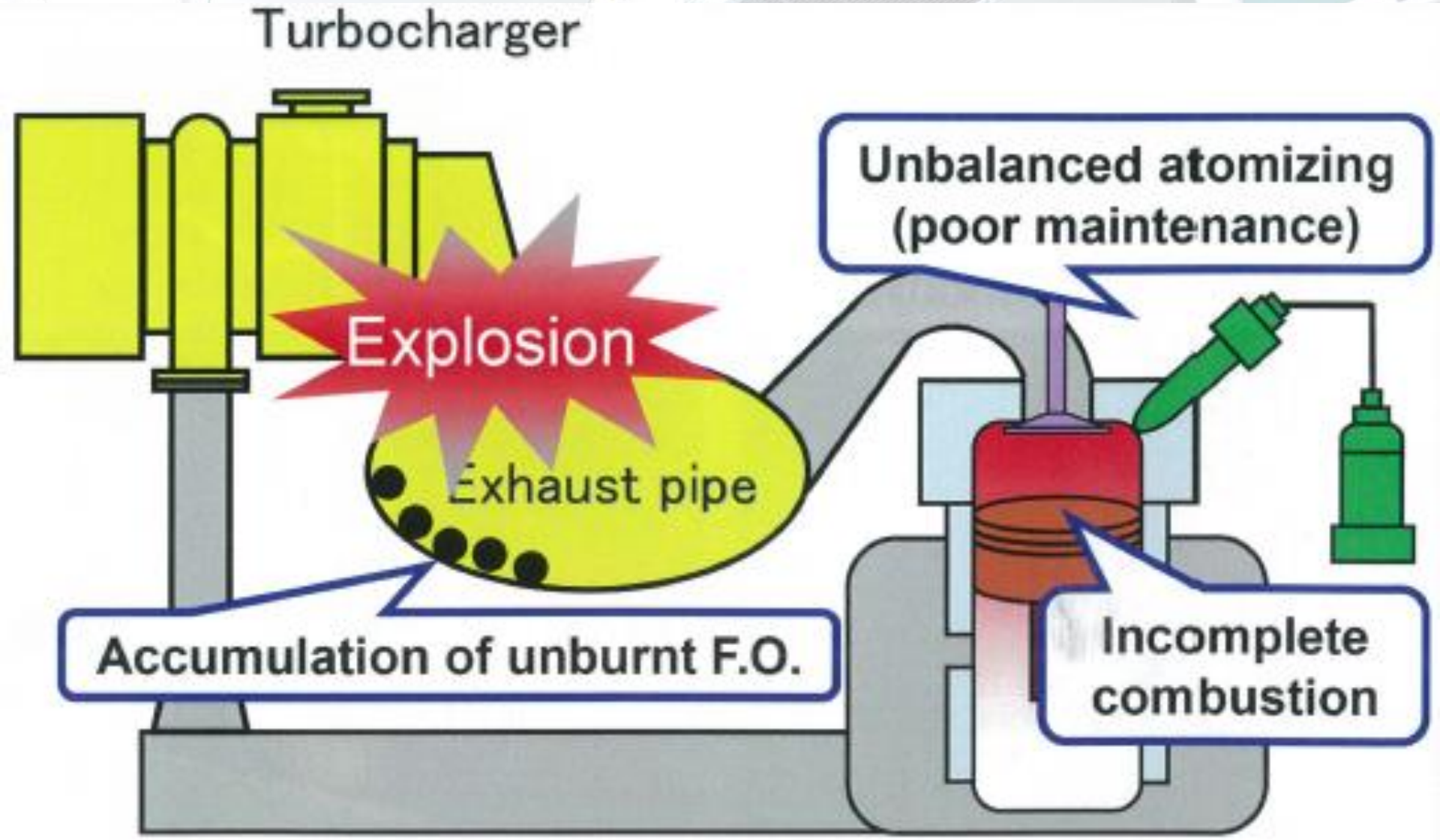
Unburned FO accumulated in the exhaust pipe as the result of unbalanced atomization

Engine speed was increased rapidly

Explosion occurred in the exhaust pipe

T/C over run and explosion → engine room fire

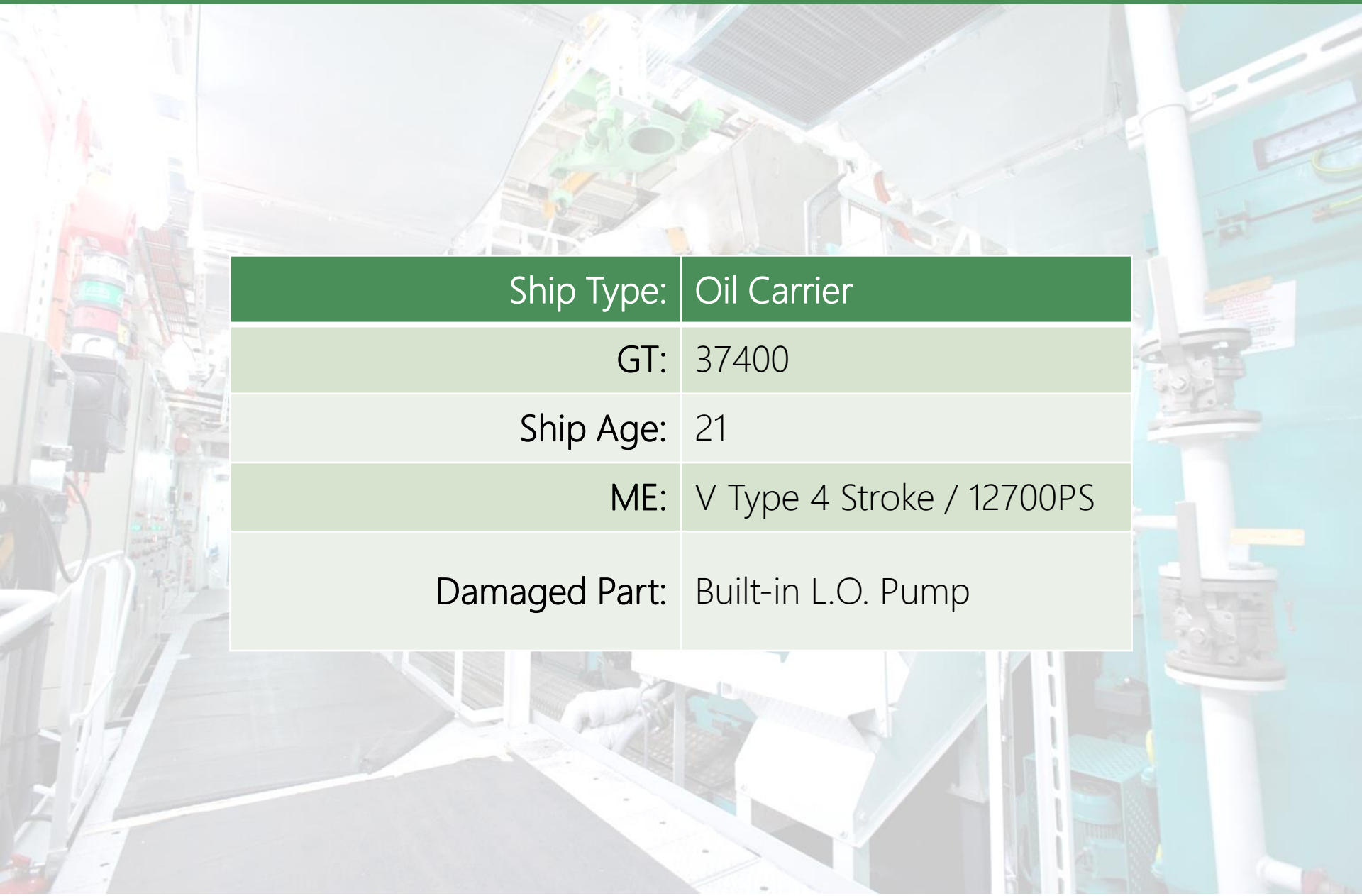
# Main diesel engine: Turbocharger (Example 6 – Case 1)



## Checkpoints for turbochargers

- Periodical inspection and cleaning of T/C, M/E and air cooler
- Appropriate control of system oil
- Appropriate lubrication of cylinder oil
- Appropriate maintenance in compliance with check lists etc.

# Main diesel engine: Turbocharger (Example 6 – Case 2)



| Ship Type: | Oil Carrier |
|---|---|
| GT: | 37400 |
| Ship Age: | 21 |
| ME: | V Type 4 Stroke / 12700PS |
| Damaged Part: | Built-in L.O. Pump |

# Main diesel engine: Turbocharger (Example 6 – Case 2)

## Report

While M/E was running at full speed, a loud noise was heard from starboard T/C of M/E.

Immediately reduced the revolution speed, and after 10 minutes, the engine was stopped

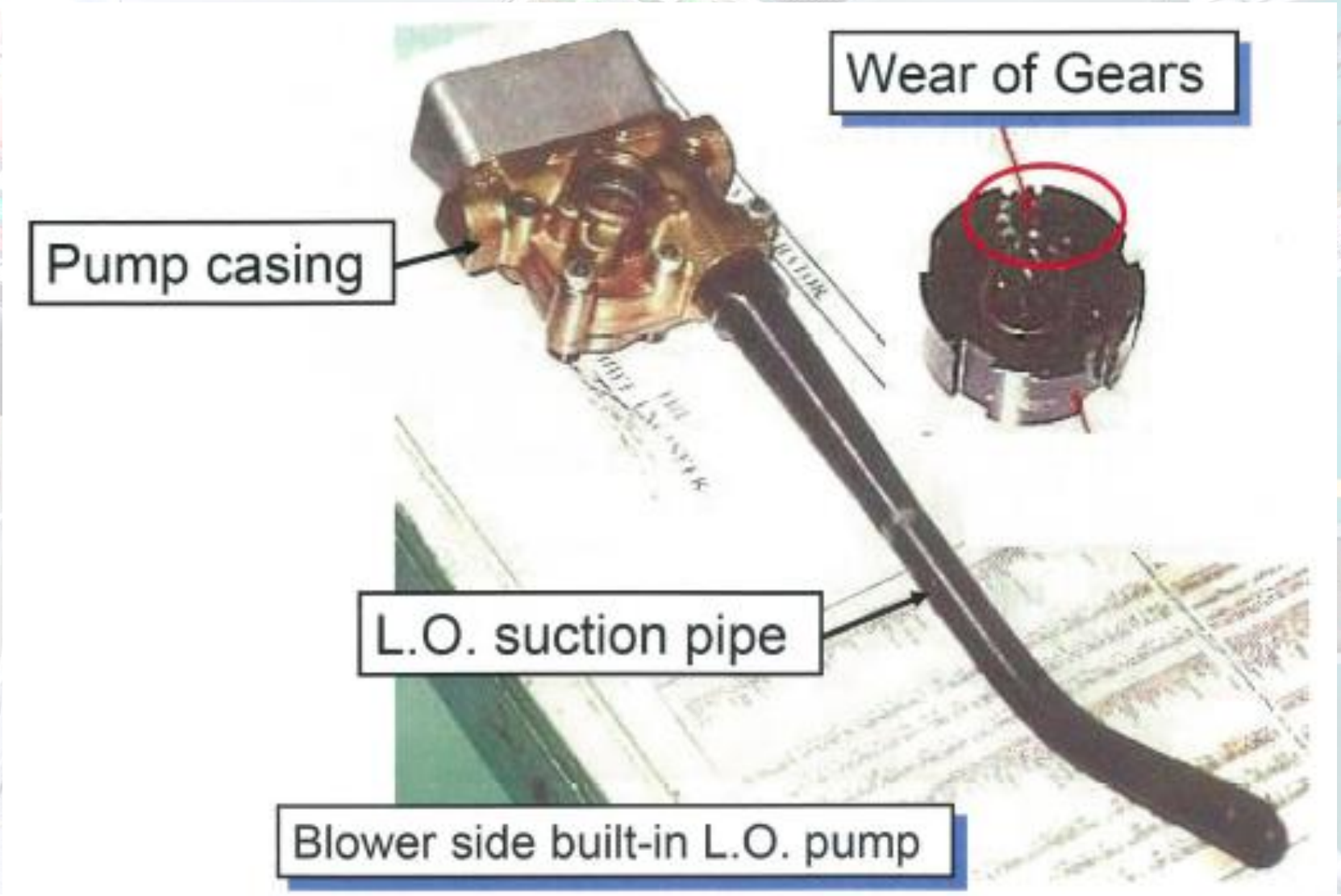
Damages were found at built-in LO pump, rotor shaft etc.

Reduced speed due to cutting off T/C

Reduced speed until completion of repair (1 month)

# Main diesel engine: Turbocharger (Example 6 – Case 2)

## Damaged condition



# Main diesel engine: Turbocharger (Example 6 – Case 2)

## Secondary Damages

Rotor Shaft (Turbine Side)

Blower Impeller (Reduction of 5 mm in thickness)

Blower Casing (Inside) (Reduction of 3 mm in thickness)

## Causes

Condition before damage: No record of any turbocharger malfunctions was found. However, four (4) months before the damage, the T/C was overhauled by the ship's crew

Slight miss alignment of rotor shaft during assembly

Breakage of drive shaft due to drive gear wear

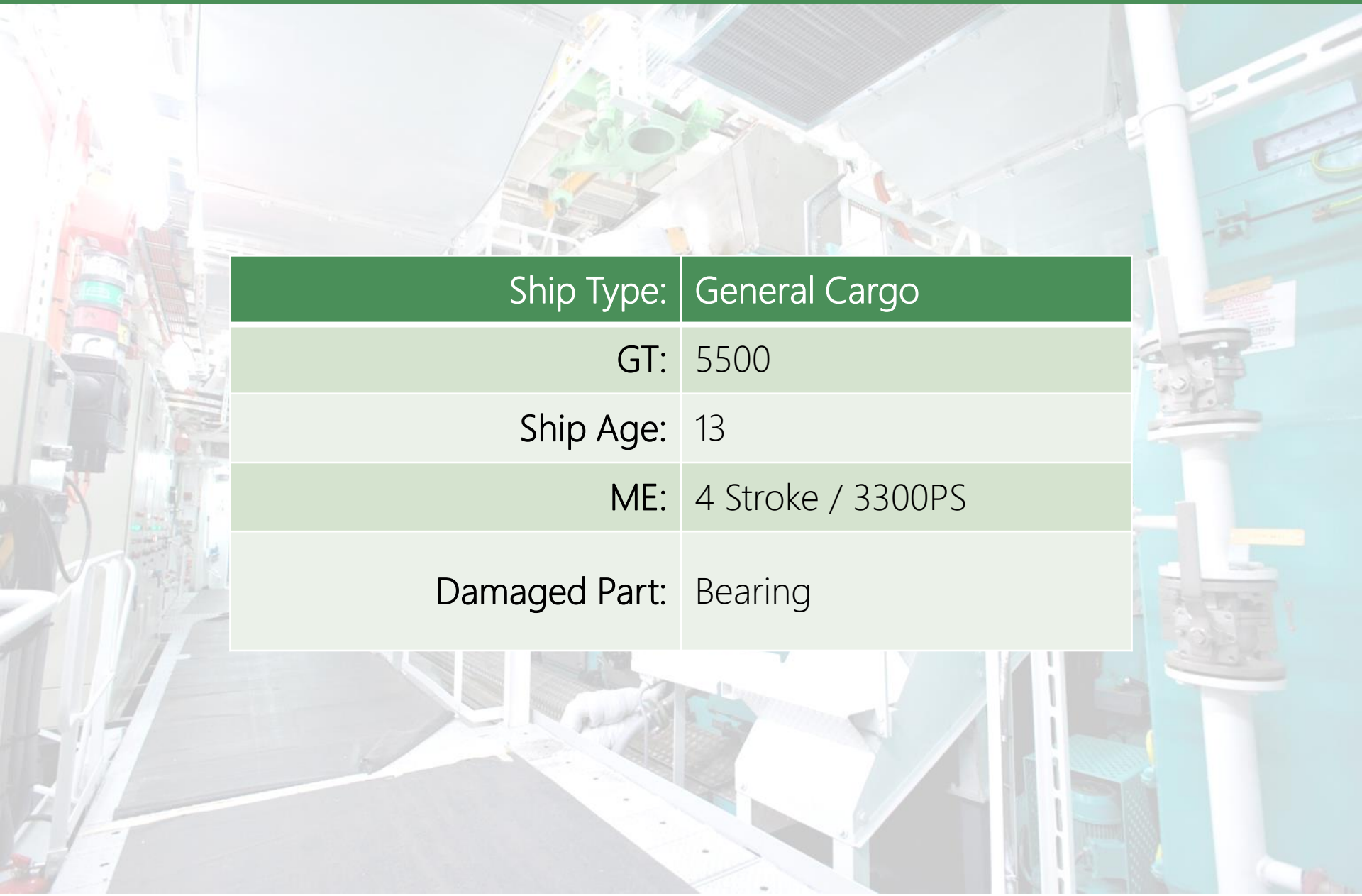
Rack of L.O. supply

Rotor shaft bearing burn out

Vibration of rotor shaft

The damage occurred due to contact of blower impeller to casing.

# Main diesel engine: Turbocharger (Example 6 – Case 3)



| Ship Type: | General Cargo |
|---|---|
| GT: | 5500 |
| Ship Age: | 13 |
| ME: | 4 Stroke / 3300PS |
| Damaged Part: | Bearing |

# Main diesel engine: Turbocharger (Example 6 – Case 3)

## Report

During navigation, noise and vibration occurred from T/C of M/E

After 1 hour, temporary repair was carried out by crews

Cleaning of each parts and replacement of turbine side bearing, labyrinth etc.

Reduced speed (T/C revolution speed: 5000rpm)

Noise and vibration continued
After 5 days, permanent repair was carried out

# Main diesel engine: Turbocharger (Example 6 – Case 3)

## Damaged condition

Rotor Shaft

Turbine Blades

## Causes

Evidence of abnormal running conditions was not present in the log book.

Cooling water line of casing jacket was obstructed by sludge

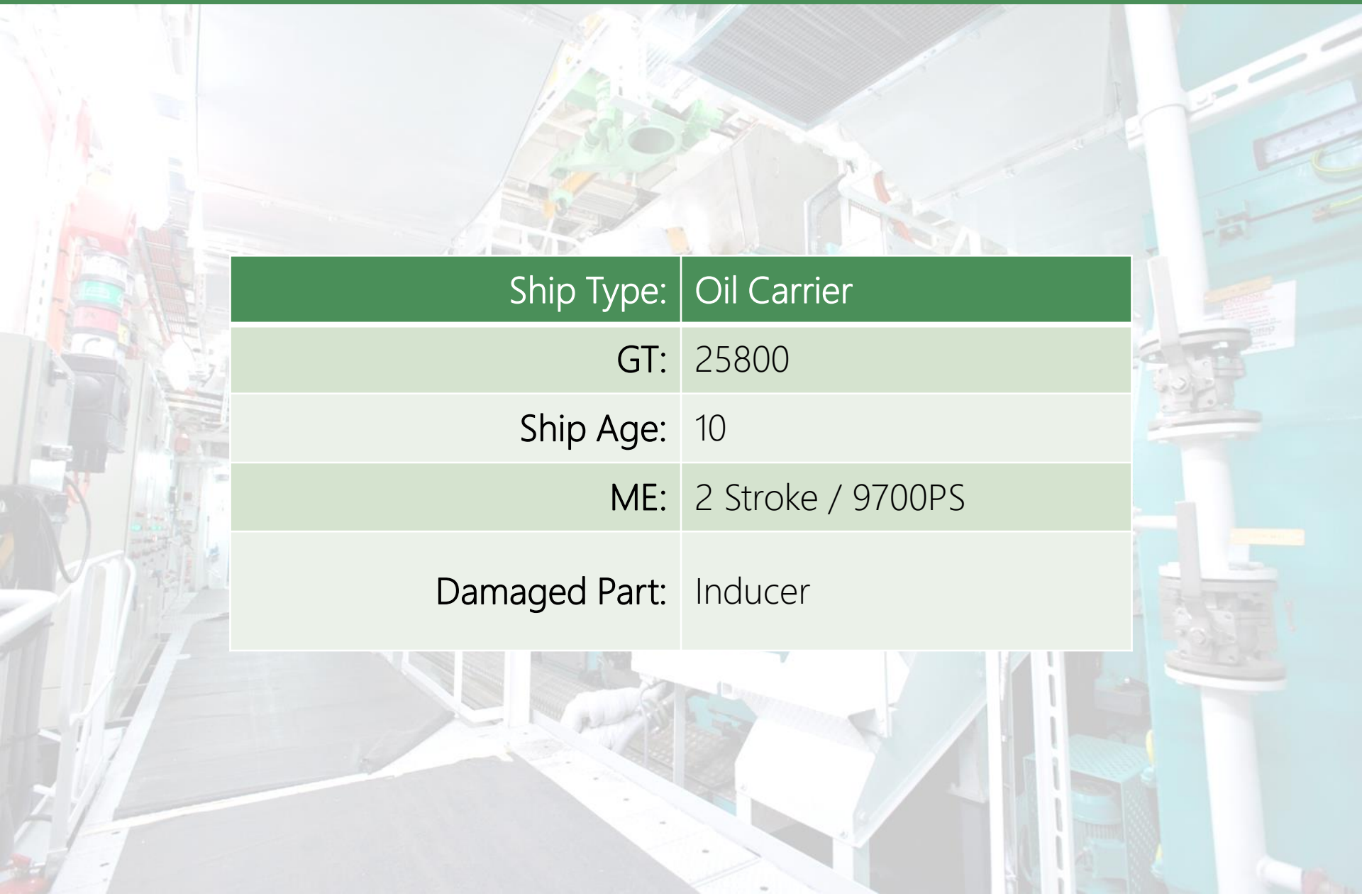
Insufficient cooling due to poor maintenance
→ Harmful effect for L.O.
→ Burn out of bearing

## Checkpoints for turbochargers

- Built-in LO pump is running at high speed
  → even minor failures causes serious damage.
- It is recommended that maintenance of the pump be carried out by the manufacturer.
- Damage was caused due to poor maintenance by the crew

  e.g. It is very hard and requires a large amount of experience to know the needed whirling tolerance (maximum tolerance : 0.02 mm)

# Main diesel engine: Turbocharger (Example 6 – Case 4)



| Ship Type: | Oil Carrier |
|---|---|
| GT: | 25800 |
| Ship Age: | 10 |
| ME: | 2 Stroke / 9700PS |
| Damaged Part: | Inducer |

# Main diesel engine: Turbocharger (Example 6 – Case 4)

## Incident

During navigation, the crew left E/R after confirming that the equipment was free of abnormalities.

M0 operation started (M/E and T/C: Rated operation)

After 2 hours, abnormal noise broke out in E/R and M/E revolution was automatically reduced

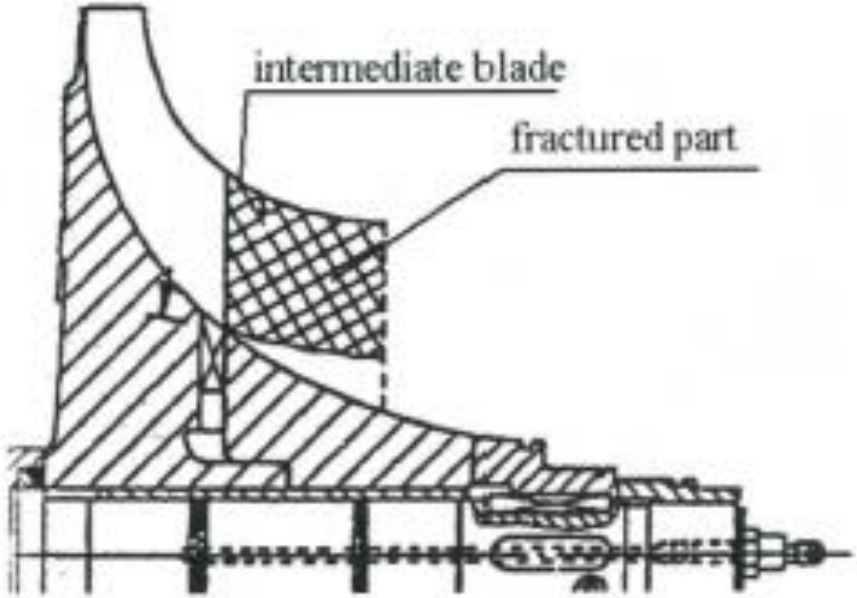
The crew found T/C stopped and Aux. blower was running automatically

The rotor shaft was sticking and the air intake socket of the blower casing was broken

Cut off T/C and reduced ship's speed to keep exhaust gas temperature below 350 degree

## Damaged condition

# Broken Inducer Intermediate blade

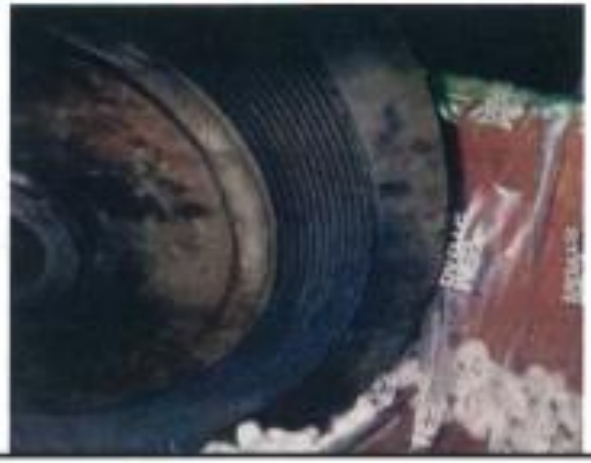



# Main diesel engine: Turbocharger (Example 6 – Case 4)

## Secondary damages

Bent Rotor Shaft

Broken Diffuser Blade

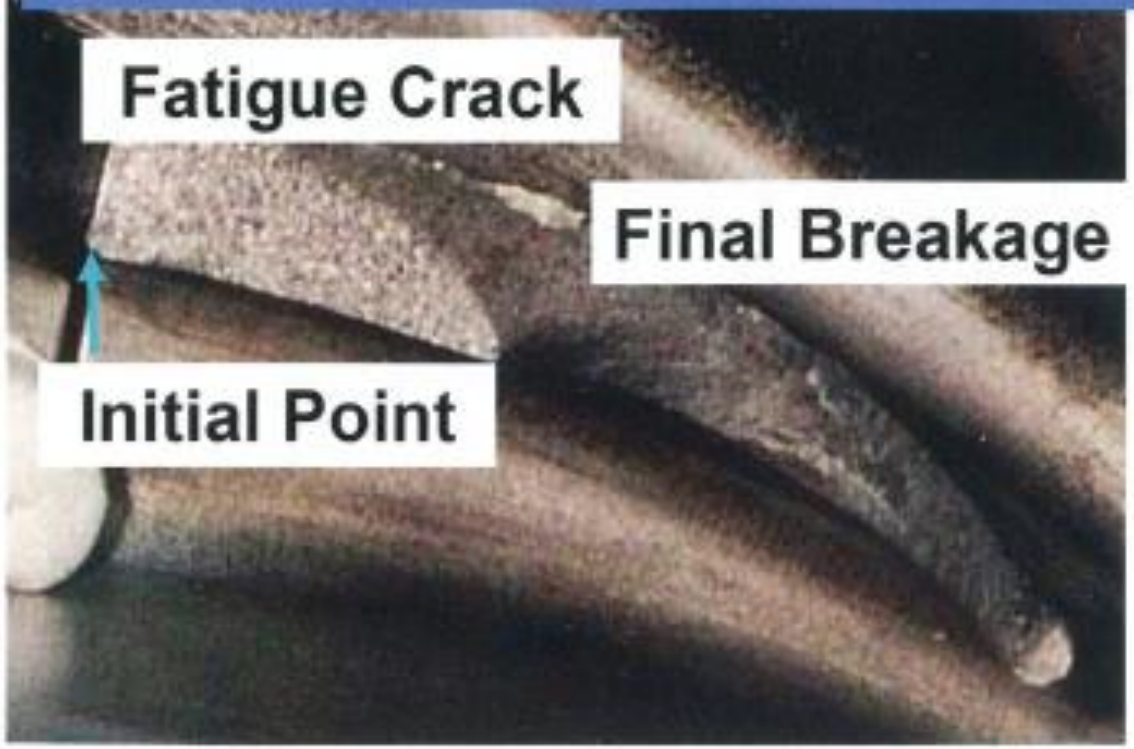


Scratch on Labyrinth Disc

## Causes

Corrosion pits on the intermediate blade
→ a crack developed rapidly from the resonance of the blade, and as a result, a fatigue fracture occurred.

Overhaul had been carried out 3 months prior

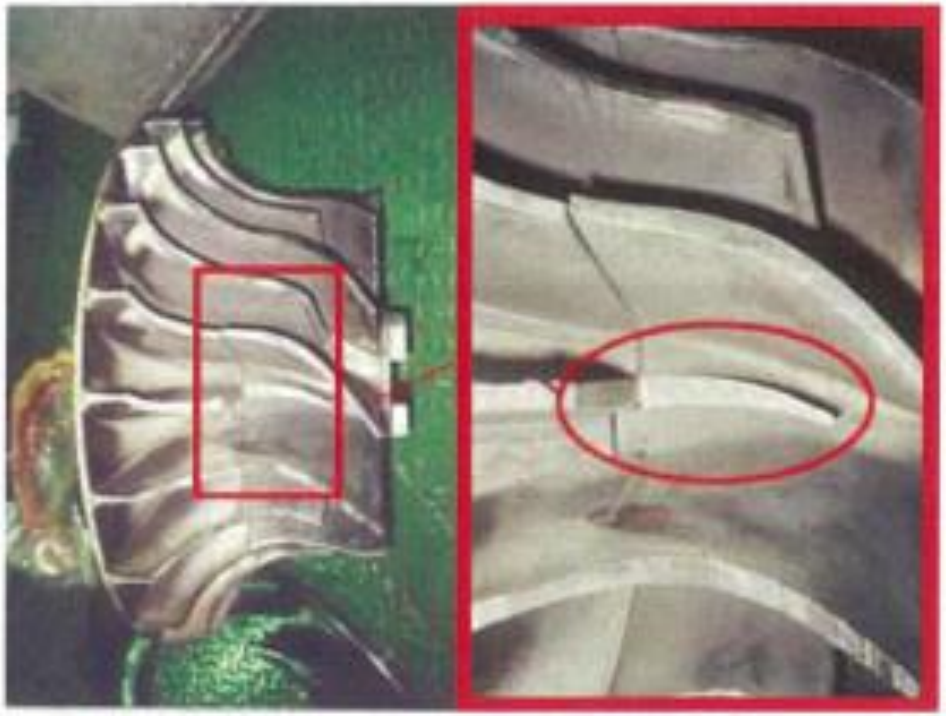


## Second damages

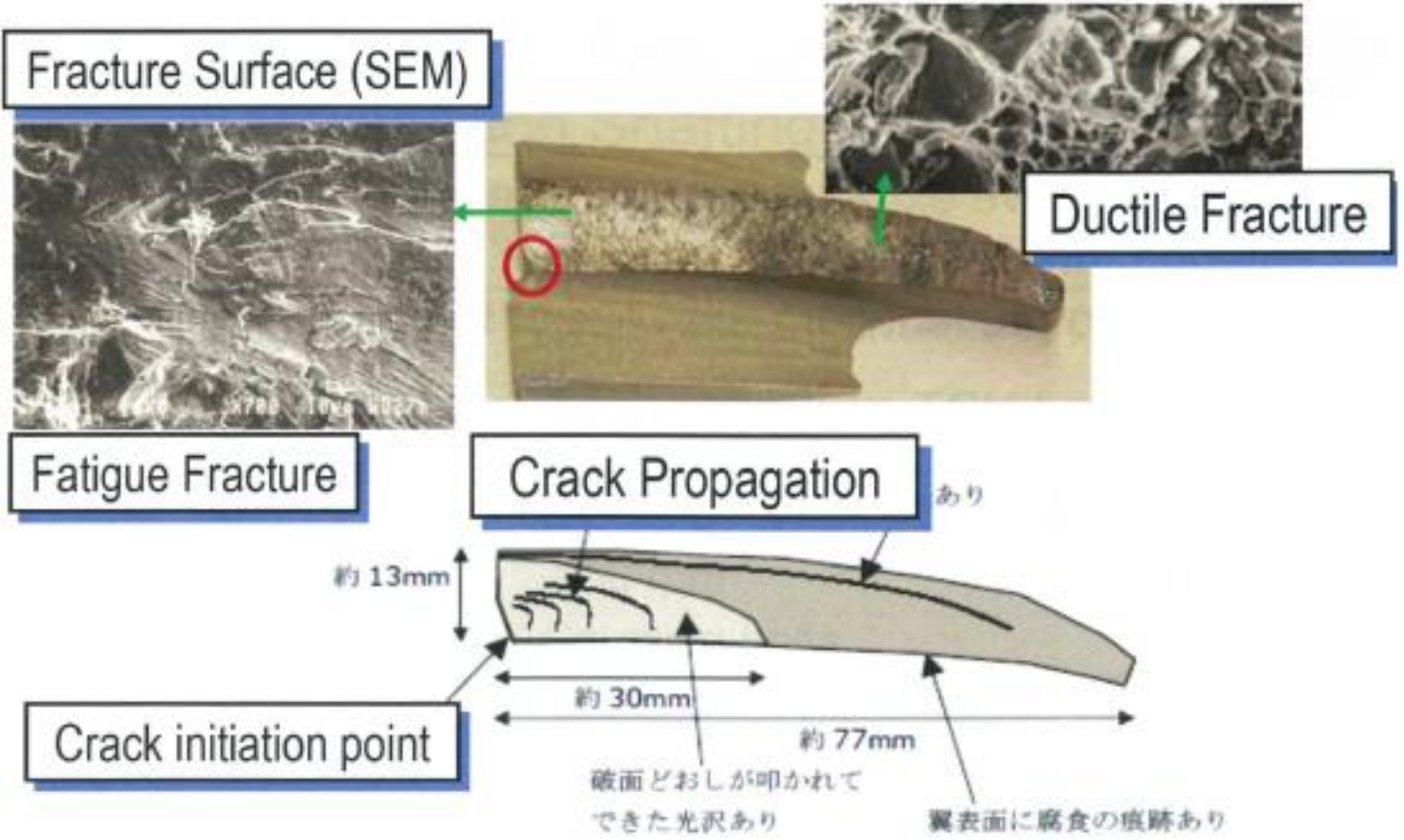
5 months after the first damage incident, a second damage incident occurred

During navigation, T/C exploded suddenly without any indication

Broken Intermediate Blade



## Investigation results



## Causes

Striation → the crack was propagated by fatigue

Breakage occurred in a short period (5 months)
→ Large corrosion pit was generated

High resonance stress on the intermediate blade due to the drift of suction air.
→ The crack propagated from the corrosion pit
→ Fatigue failure occurred.

Maker recommended to replace air intake socket to new type (for decrease of resonance stress) by maker service news

But after the first damage, air intake socket was replaced with an older type of air socket

## Checkpoints

### Checkpoints for turbochargers

1) Keep corrosive exhaust gas and sea water away from entering through the ventilation duct
(in order to prevent corrosion pits at turbine blades)

2) Carrying out NDT on the blower side of blade

3) Check latest maker's service news

# 3. Propulsion Shafting

# MODULE 2B – Machinery Systems (Content)

1. Introduction
   - Numbers and Damage rates

2. Main diesel engine
   - Crankshaft
   - Degraded heavy fuel
   - Combustion chamber
   - Crosshead pin
   - Damage at shop test
   - Turbocharger

3. Propulsion Shafting
   - Coupling bolts
   - Propeller shaft
   - Propeller Breakage
   - Other notice for shafting

4. Aux. diesel engine
   - Connecting rod

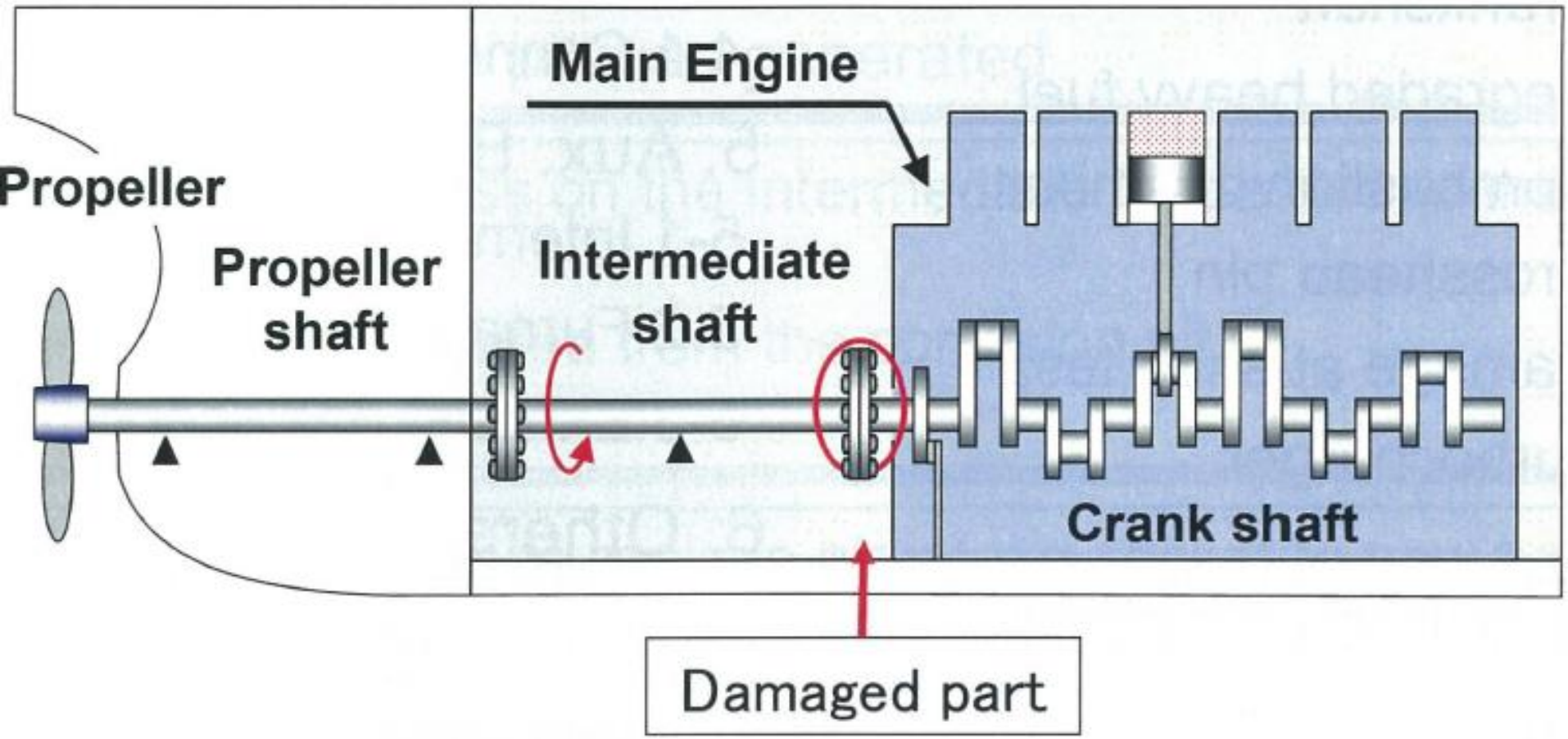
5. Aux. boiler
   - Internal crack
   - Furnace Collapse
   - Exhaust gas economizer

6. Others
   - Fire in engine room
   - Damage due to alumina
   - Fire of feeder panel

# Propulsion Shafting: Coupling bolts (Example 1 – Case 1)

| Ship Type: | Chemical Tanker |
|---|---|
| GT: | 4200 |
| Ship Age: | 14 |
| ME: | 2 Stroke / 3300PS |
| Shaft r.p.m: | 250 rpm |
| Damaged Part: | Coupling bolts |

# Propulsion Shafting: Coupling bolts (Example 1 – Case 1)



# Propulsion Shafting: Coupling bolts (Example 1 – Case 1)

## Role of coupling bolts:

- Transmission normal torque at flange connection part;
- Responding to bending moment by their own strength;
- To avoid adhesion and looseness at flange connection part, it is necessary to tighten the bolts sufficiently.

# Propulsion Shafting: Coupling bolts (Example 1 – Case 1)

## Damage

A test of changing to ahead from astern was carried out upon entering the port.

M/E revolution hunting was found.

All coupling bolts between the crank and intermediate shafts were broken.

Fore flange of intermediate shaft

Section of bolt breakage (Crack is occurred at circumferential direction)

# Propulsion Shafting: Coupling bolts (Example 1 – Case 1)

## Damage

Material and work of coupling bolts : Good

Condition of coupling bolts on latest propeller shaft survey

Damage was not found on external examination of the bolts

After open up inspection of propeller shaft, coupling bolts were recovered by cold fitting method

There was no record of additional tightening of the bolts after the temp. of the bolts returns to the ambient temp. Therefore there is a possibility of looseness of the bolts

Torque fluctuation of torsional vibration would be principal reason of this damage

## Investigation

Torque fluctuation of torsional vibration
: Relatively large

Resonance point of torsional vibration
:154rpm（Maximum revolution: 250rpm）

Barred range
:142-167rpm

The number of start and stop
:Relatively many
(The number of passing through the barred range is also relatively many)

# Propulsion Shafting: Coupling bolts (Example 1 – Case 2)

| Ship Type: | General Cargo |
|---|---|
| GT: | 6400 |
| Ship Age: | 10 |
| ME: | 2 Stroke / 4200PS |
| Shaft r.p.m: | 210 rpm |
| Damaged Part: | Coupling bolts |

# Propulsion Shafting: Coupling bolts (Example 1 – Case 2)

## Report

Fretting corrosion at prop. shaft and interm. shaft flanges

Magnetic particle inspection for shaft coupling bolts

Confirmation of cracks at Bolt neck end of thread

Replacement of all coupling bolts

Accident was prevented before major damage.

## Investigation Results

### Condition of Flange and Bolts


Fretting on connection part of flange

Crack

## Caution

Occurs on roughly one (1) vessel / year.
However, if it happens, it will cause serious damage.

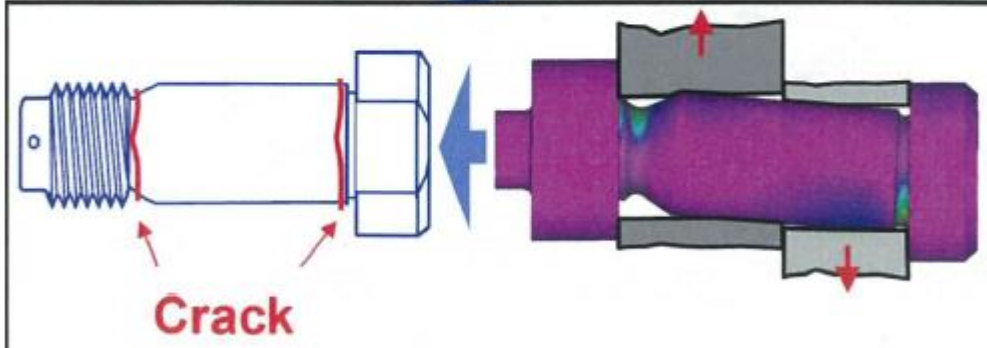
Confirming condition and tightness of bolt at drawing out propeller shaft at dock

Smooth avoidance of barred speed range on navigation

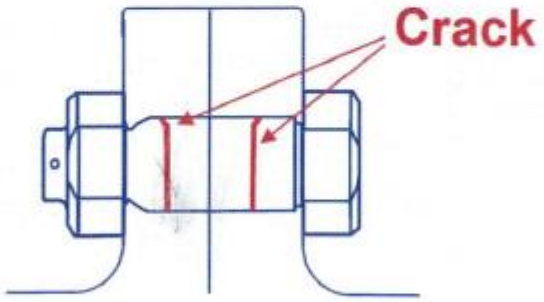
## Caution

If cracks occur,
1. the bolts must be replaced and
2. service schedule needs to be changed.

### Check points for existing vessels




1. Shortage of interference fit clearance
2. Misalignment of shafting

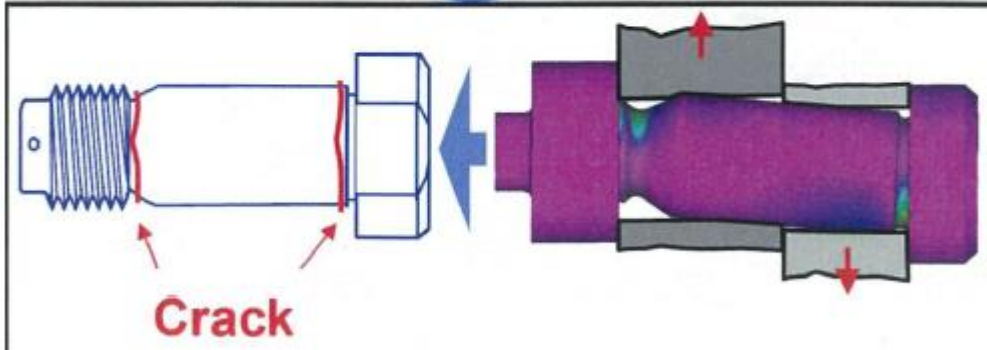



1. Large torque fluctuation
2. Insufficient tightening

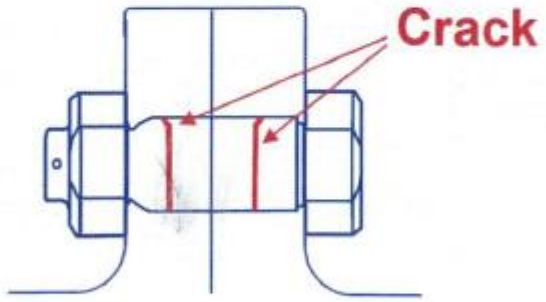
## Repair/Check points

If cracks occur,
1. the bolts must be replaced and
2. service schedule needs to be changed.

### Check points for existing vessels




1. Shortage of interference fit clearance
2. Misalignment of shafting




1. Large torque fluctuation
2. Insufficient tightening

# Propulsion Shafting: Crack on large end of propeller shaft cone (Example 2 – Case 1)

| Ship Type: | Refer Cargo Carrier |
|---|---|
| GT: | 2700 |
| Ship Age: | 5 |
| ME: | 2 Stroke / 3300PS |
| Shaft r.p.m: | 250 rpm |
| Propeller Shaft: | **KSF60, diameter: 260mm** |
| Propeller: | Keyless 4 blades F.P.P. |
| Damaged Part: | Large end of cone for fitting propeller of propeller shaft |

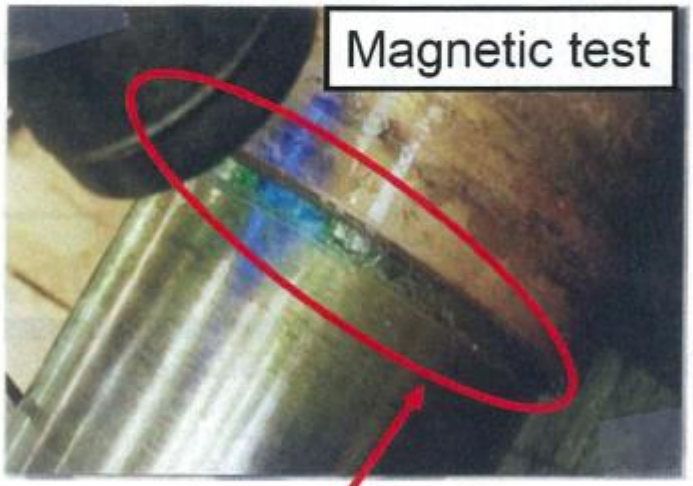
# Propulsion Shafting: Crack on large end of propeller shaft cone (Example 2 – Case 1)

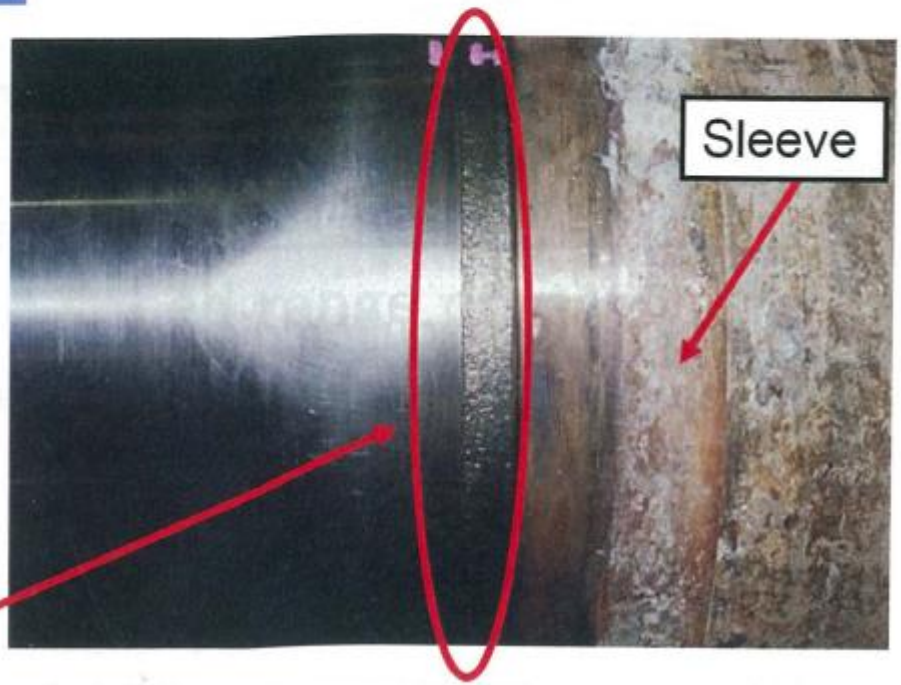
## Condition of damage

Drawing out propeller shaft at propeller shaft survey

Magnetic test at large end of cone of propeller

Finding crack with corrosion



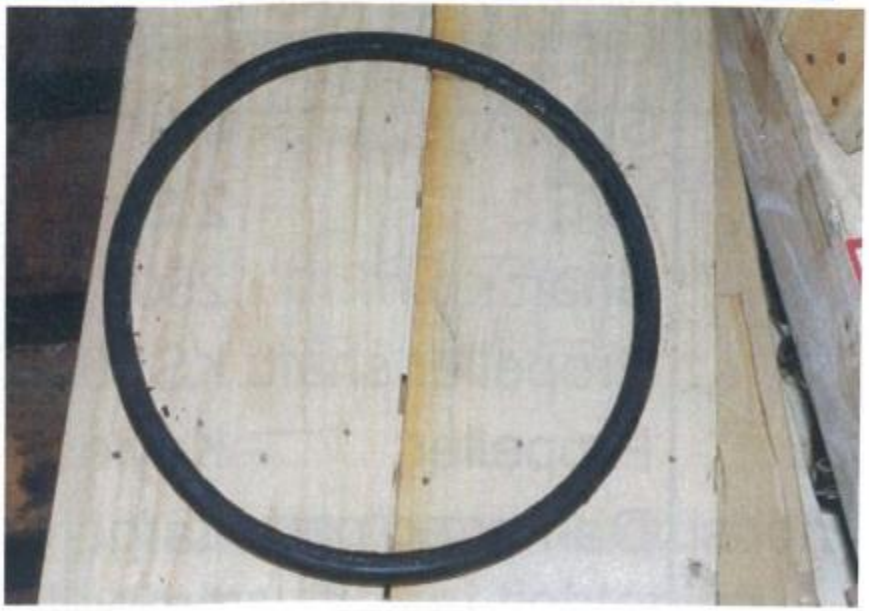
# Propulsion Shafting: Crack on large end of propeller shaft cone (Example 2 – Case 1)

## Condition of damage

Boss of propeller : Black on contact surface of O ring due to entering of sea water

O ring : Wholly weak contact and unequal contact (especially inside)

Propeller boss

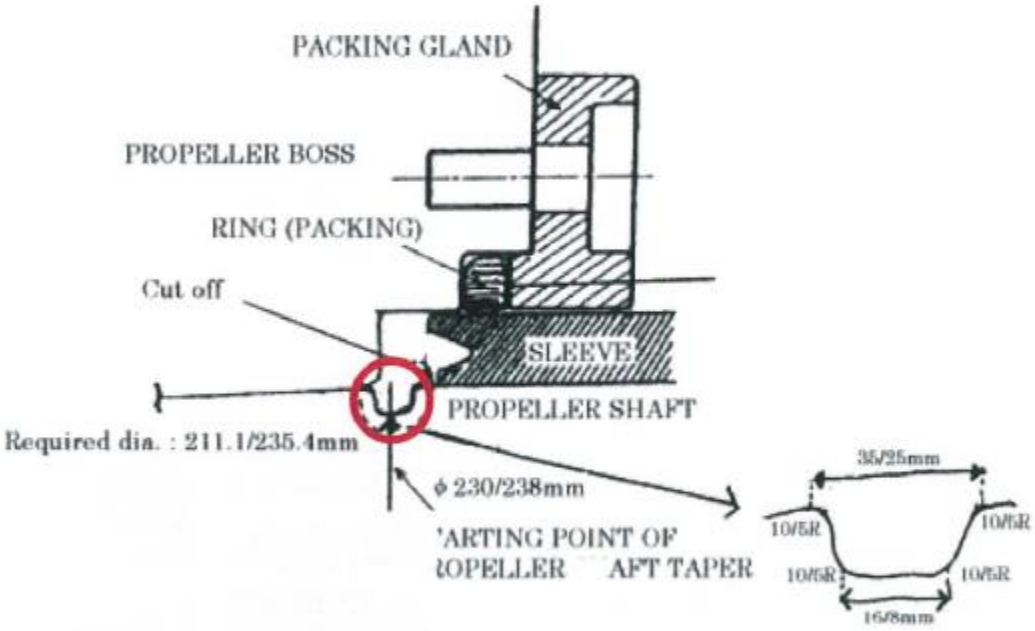


O-ring

# Propulsion Shafting: Crack on large end of propeller shaft cone (Example 2 – Case 1)

## Repair

### Removing crack



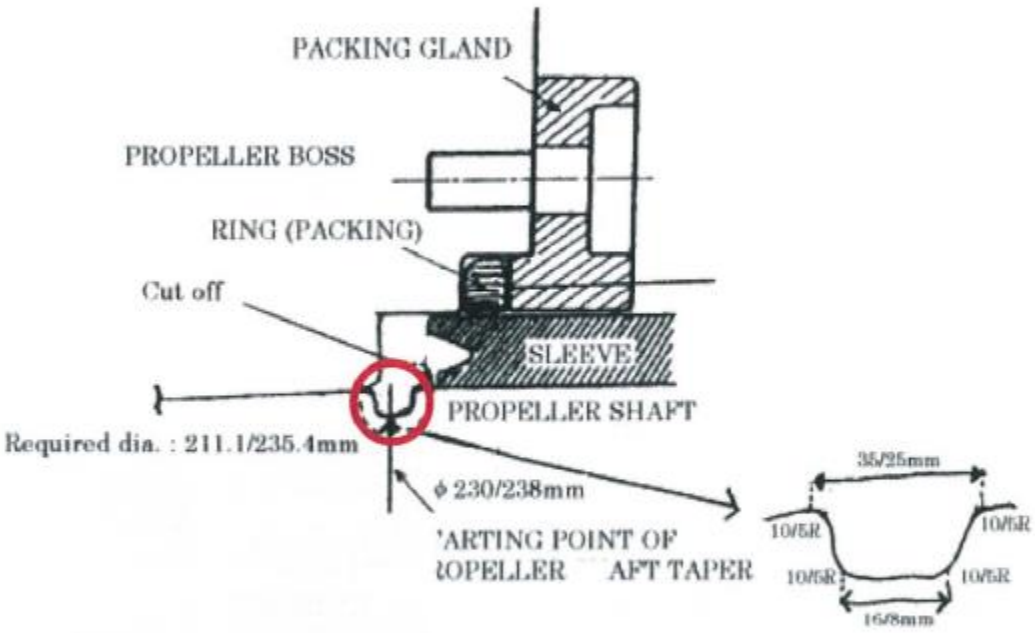

Original diameter: 260 mm → 230 mm

Required diameter: 211 mm

# Propulsion Shafting: Crack on large end of propeller shaft cone (Example 2 – Case 1)

## Repair

### Removing crack




Original diameter: 260 mm → 230 mm

Required diameter: 211 mm

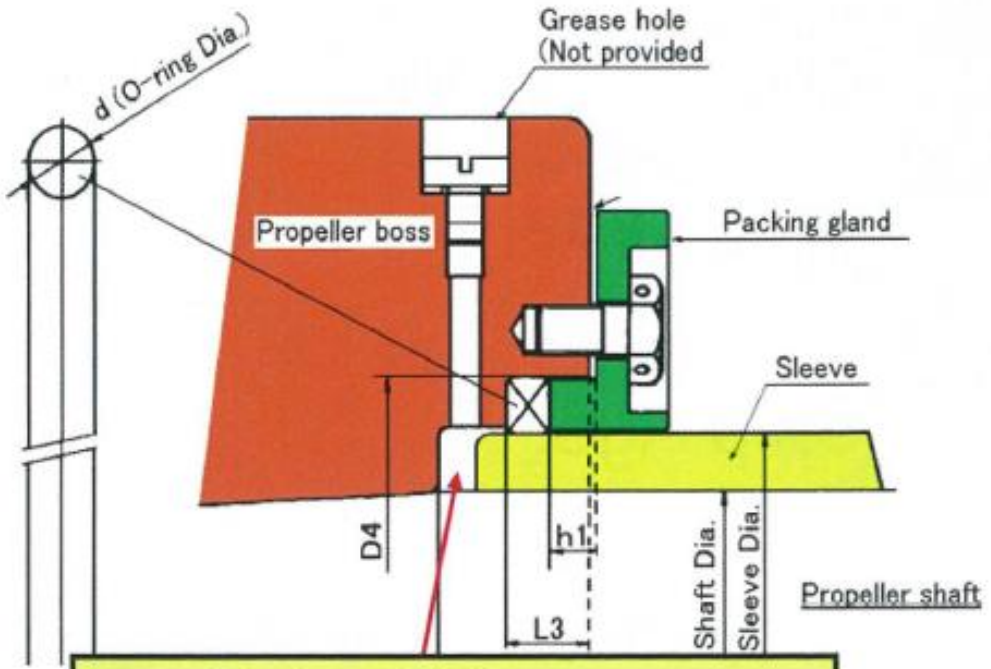
# Propulsion Shafting: Crack on large end of propeller shaft cone (Example 2 – Case 1)

## Cause

**Dimension of O ring**

Drawing of manufacture :

No indication of allowance for dimension of O ring




**Filling grease**

**Position of filling grease**

No filling of grease (No grease hole for this ship)

# Propulsion Shafting: Crack on large end of propeller shaft cone (Example 2 – Case 1)

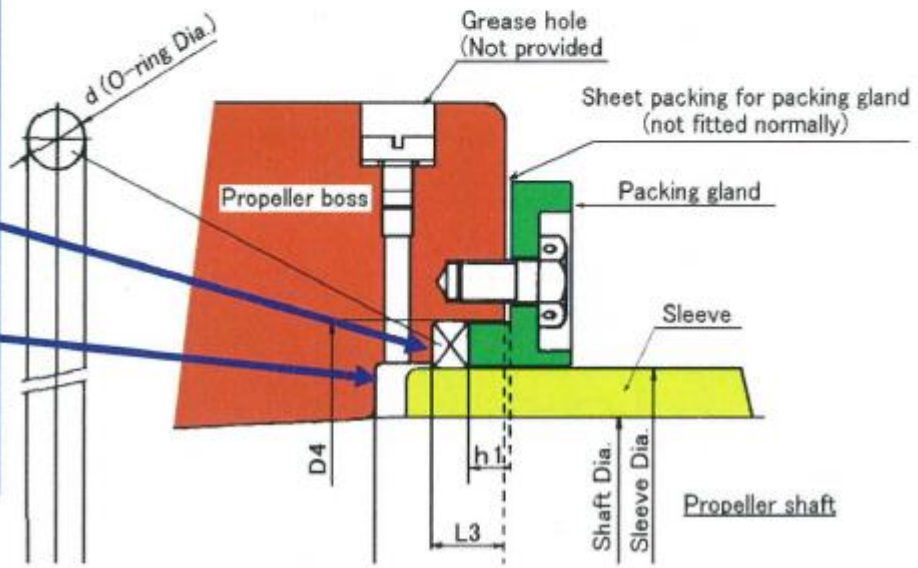
## Noted point

Filling grease surely

In case of no grease hole, application of grease at following parts surely

- Space of O-ring
- Between propeller boss and propeller shaft sleeve

Adequate provision of O- ring



# Propulsion Shafting: Propeller breakage (Example 3 – Case 1)

| Ship Type: | Oil Carrier |
|---|---|
| GT: | 142800 |
| Ship Age: | 19 |
| ME: | 2 Stroke / 30600PS |
| Propeller: | 5 Blades Fixed-pitch Keyless Propeller |
| Damaged Part: | Propeller |

# Propulsion Shafting: Propeller breakage (Example 3 – Case 1)

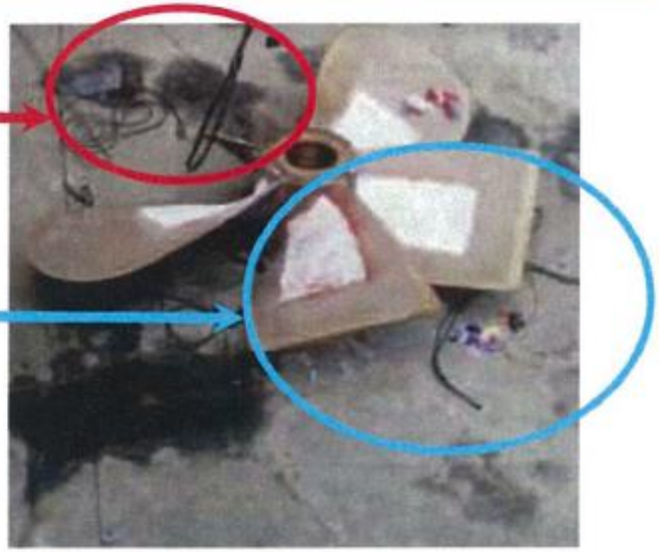
## Report

Horizontal vibration occurred during full speed ahead running

Breakage of Propeller Blade “A”

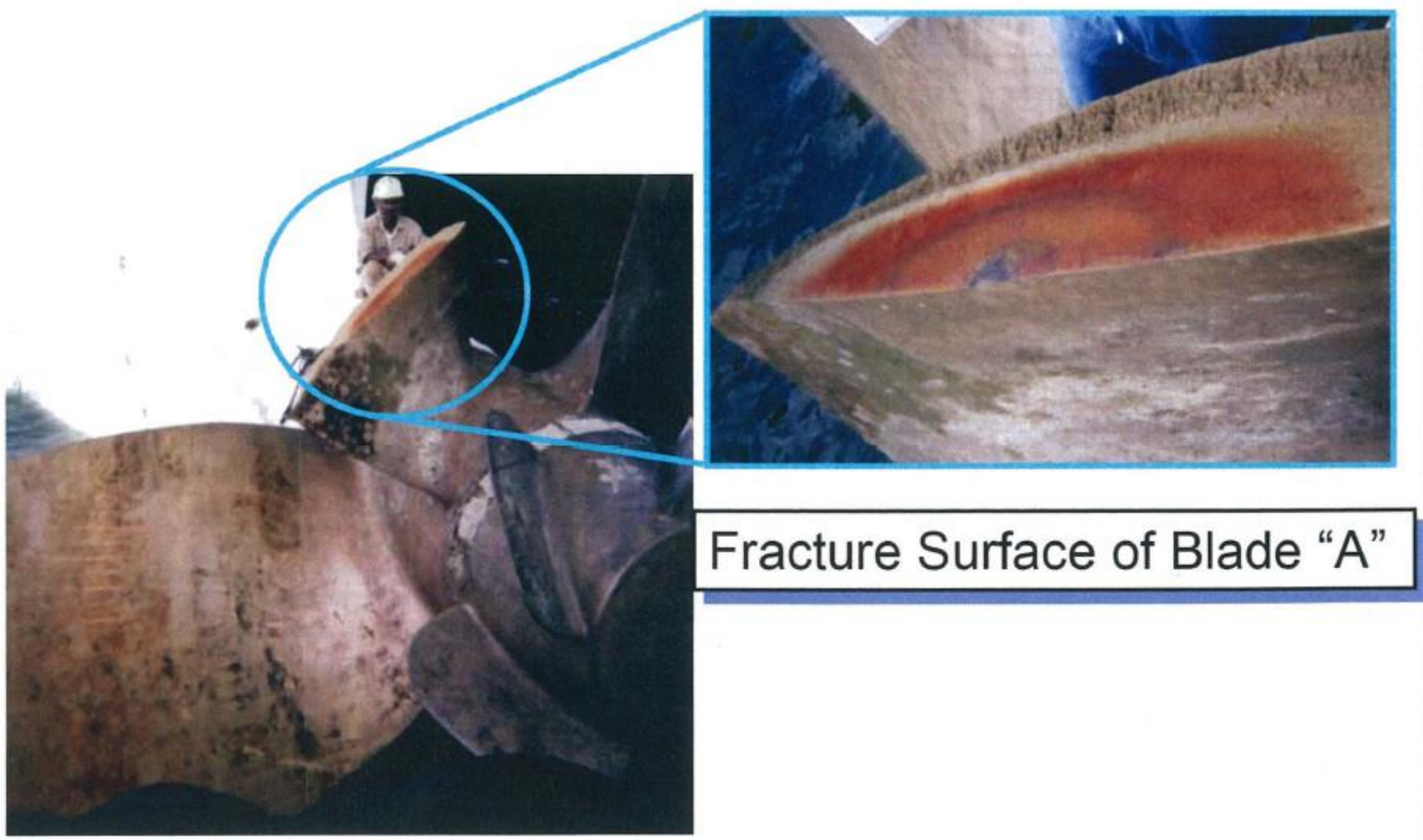
Cut blade “C” and “D” to prevent vibration

Reduced speed operation



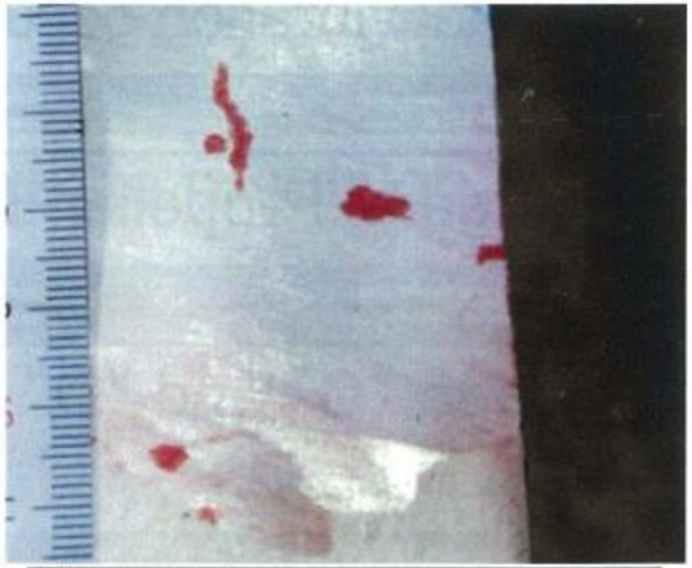
# Propulsion Shafting: Propeller breakage (Example 3 – Case 1)

## Damaged Condition



## Damaged Condition

Condition of Blade "A"



Crack Starting Point = 0.35R

Crack on Surface

"Beach Mark" = Fatigue Fracture

# Propulsion Shafting: Propeller breakage (Example 3 – Case 1)

## Causes

Cast defect around crack starting point (0.35R)

Sea water entered inside through blowholes open to the surface allowing corrosion and grinding

Minute initial cracks were caused by stress-corrosion fatigue, and the cracks were in a state of stasis for a long period.

# Propulsion Shafting: Propeller breakage (Example 3 – Case 1)

## Causes

"A" Blade hit something floating 8 month before the damage

↓

The crack progressed onto the surface due to the impact

↓

Breakage due to variable stress caused by the thrust force

# Propulsion Shafting: Propeller breakage (Example 3 – Case 1)

## Attention

If linearly adjacent blowholes are confirmed

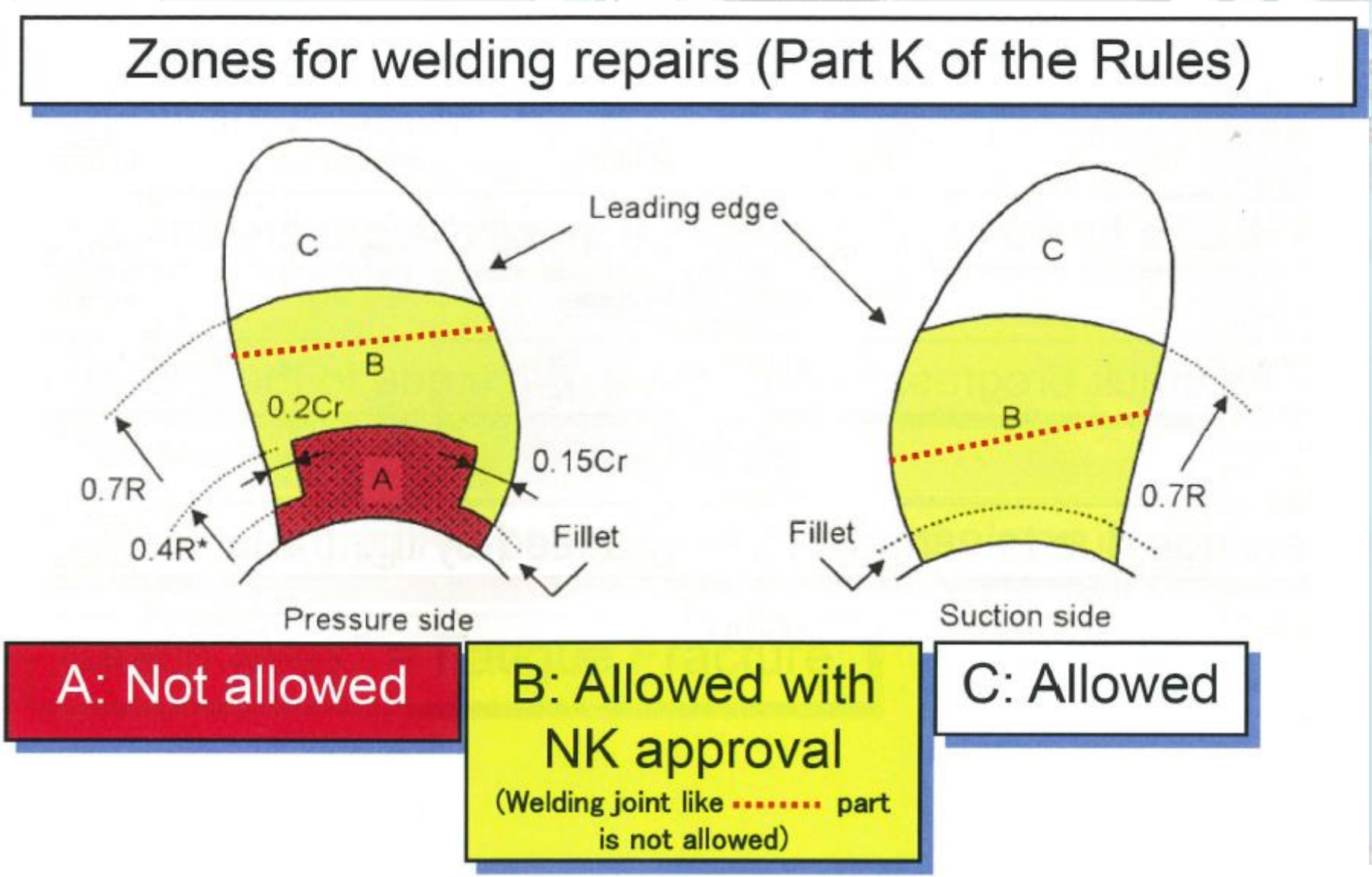
Carry out PT after grinding off

If cracks are found

Possibility of cracks at the same position of other blades

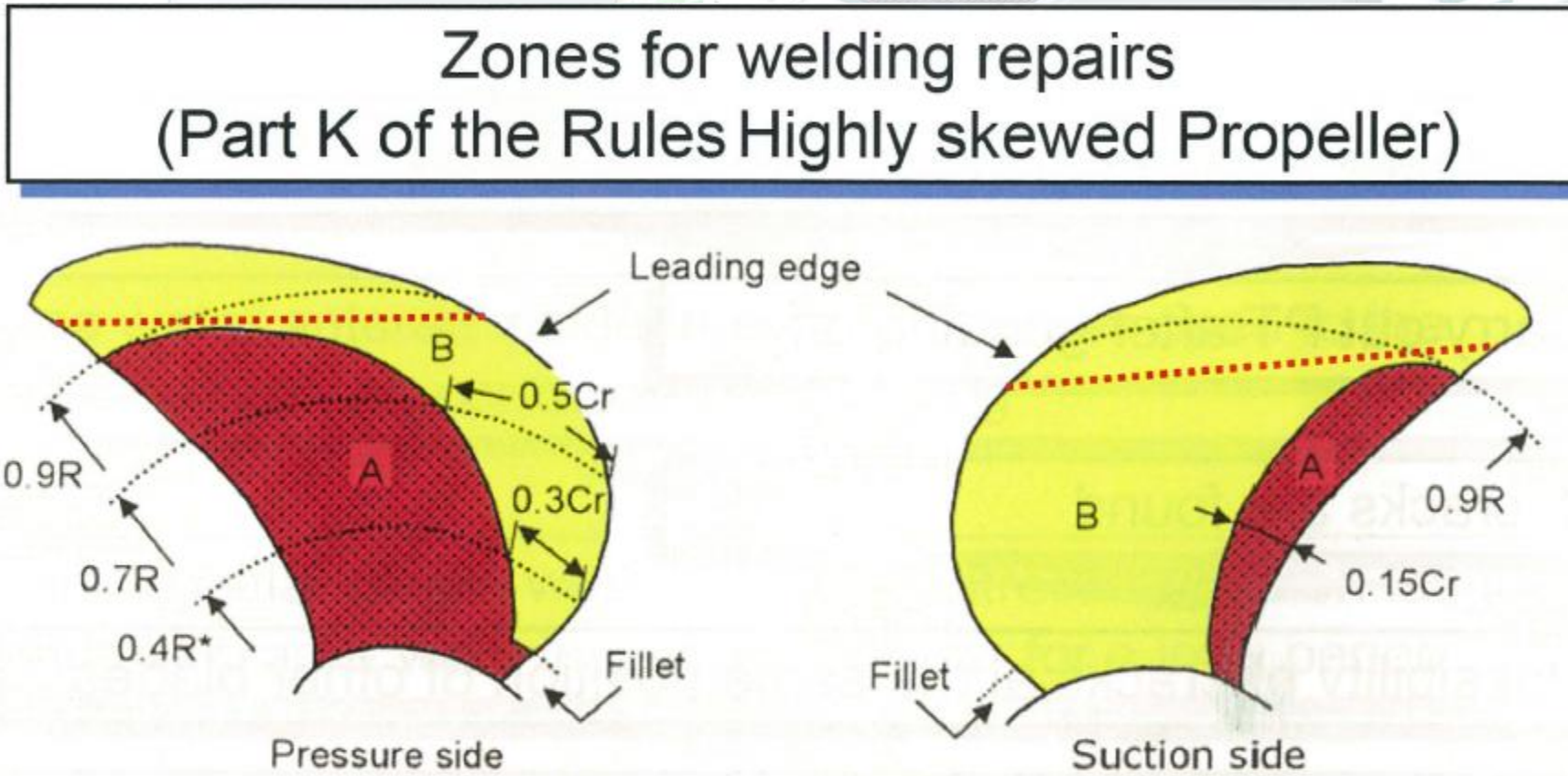
Dye Penetrate Test (PT) for propeller surface

## Attention



# Propulsion Shafting: Propeller breakage (Example 3 – Case 1)

## Attention



## Attention to welding

Procedure of welding repair for propeller

Repair plan is to be submitted and approved by NK

Repair plan:
Welding method (MIG or TIG)
Welding material (Aluminum bronze/ metal of similar composition )
Edge preparation for welding after removing defects
Heat treatment

Welding by qualified welders

PT should be carried out after completing the repair

# Propulsion Shafting: Other notice for shafting

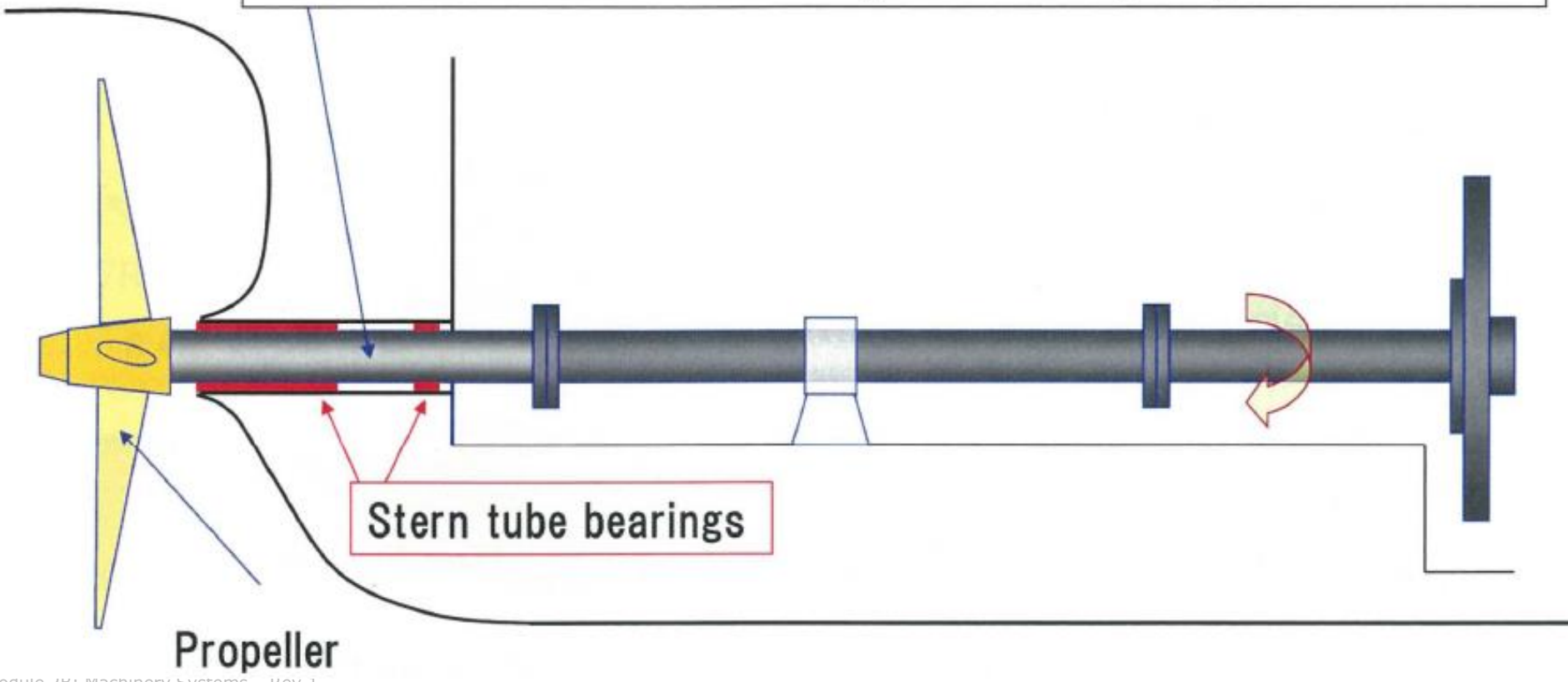
1. Attention for water-lubricated propeller shaft

2. Attention for fitting of Keyless propeller

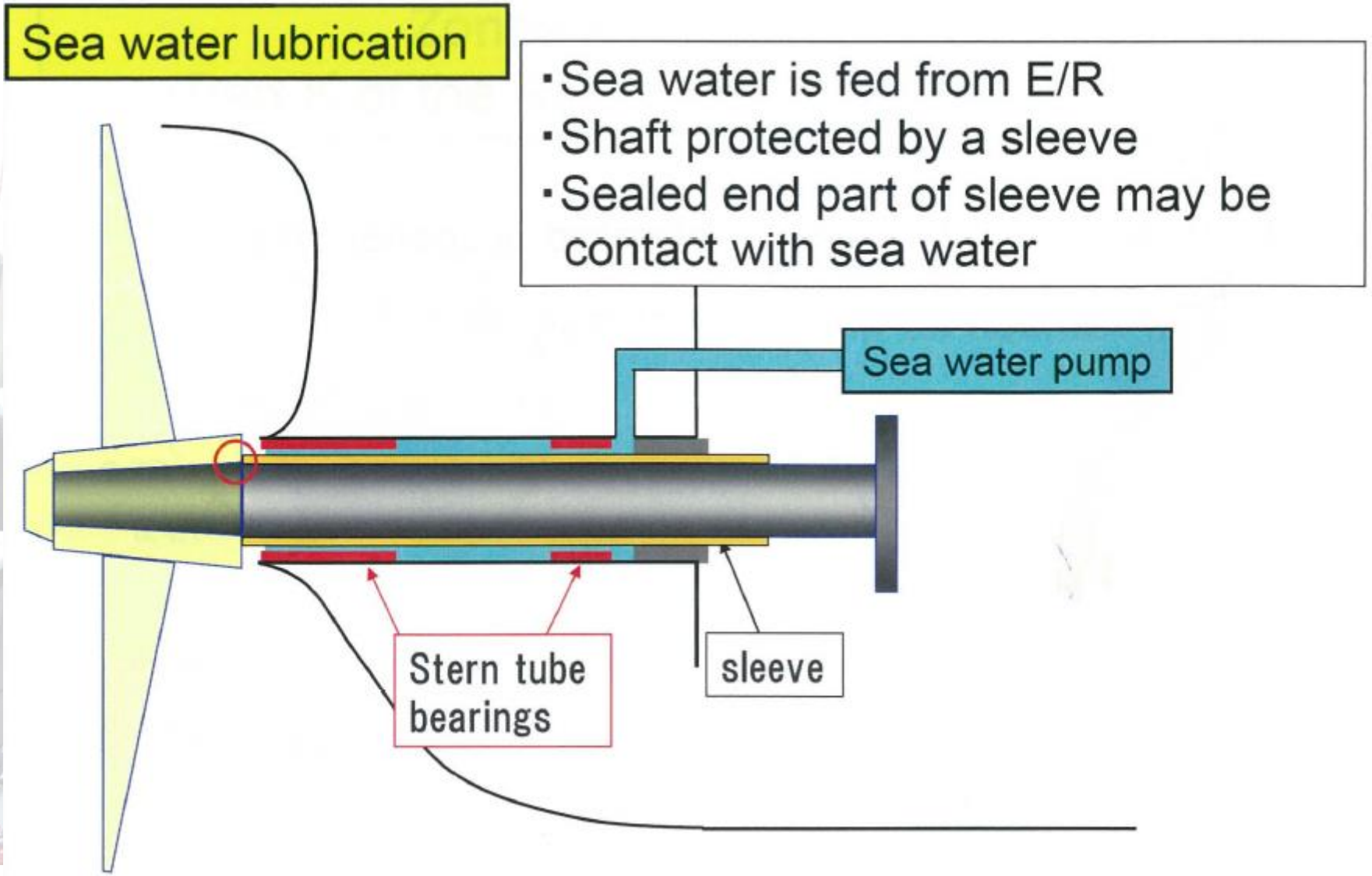
## 1. Attention for water-lubricated propeller shaft

# Propeller shaft

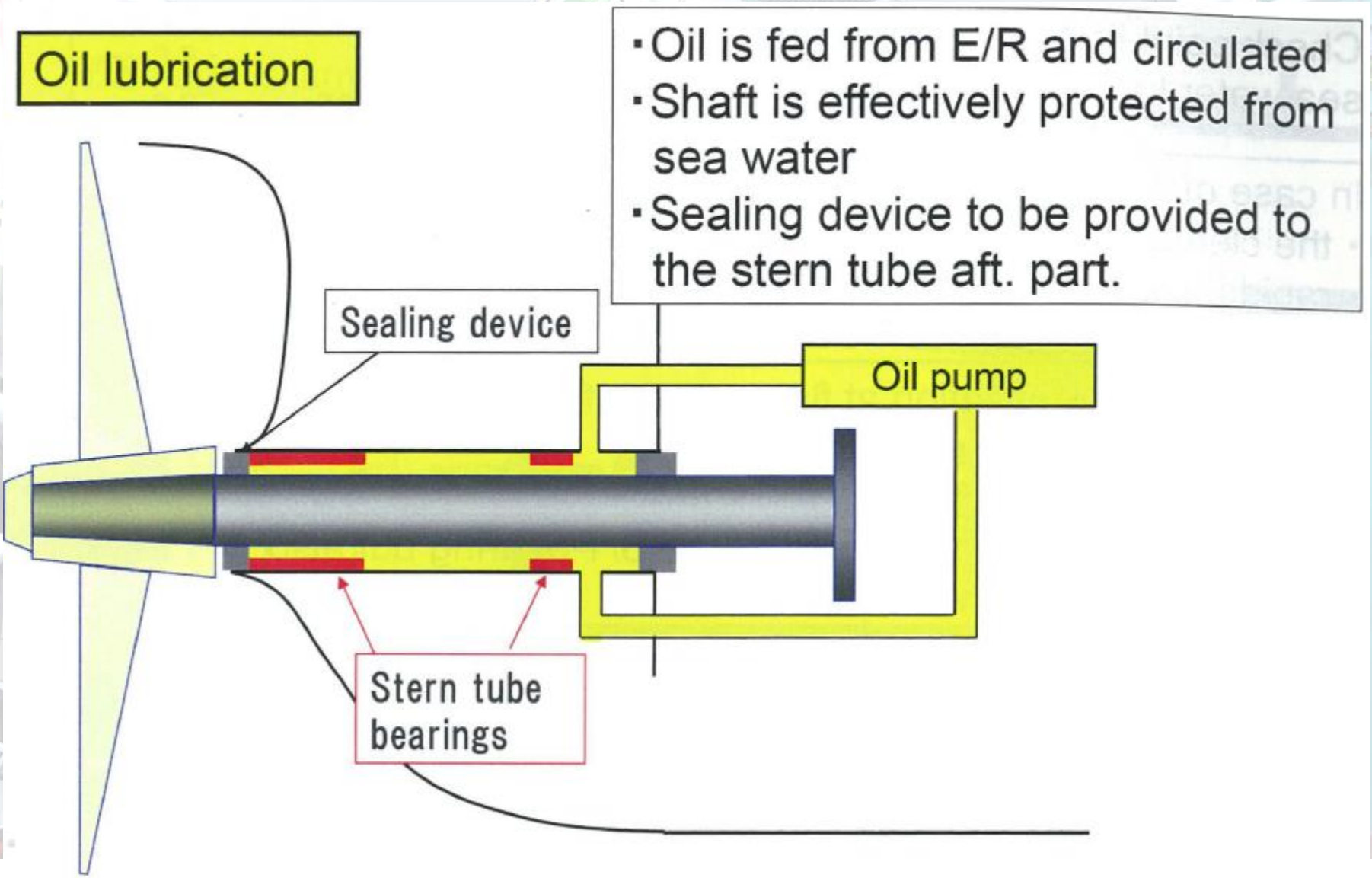
- To be effectively protected from sea water
- Two lubrication method (Sea water, Oil)



## 1. Attention for water-lubricated propeller shaft



## 1. Attention for water-lubricated propeller shaft



## 1. Attention for water-lubricated propeller shaft

### Kind of propeller shaft

Propeller shaft Kind 1
A propeller shaft which is effectively protected against corrosion by sea water with an approved means

Propeller shaft kind 1A : having a water lubricated stern tube bearing
Propeller shaft kind 1B : having an oil lubricated stern tube bearing
Propeller shaft kind 1C : having an oil lubricated stern tube bearing and monitoring, control and alarm systems for maintaining propeller shaft bearings

Propeller shaft Kind2
A propeller shaft other than those specified in the above

## 1. Attention for water-lubricated propeller shaft

Check point for inspection of sea water lubricated bearing

In case of
- the clearance exceeds the standard value
- rapid increases of clearance at short interval

| Propeller shaft dia.,d | : Clearance |
|---|---|
| d≤ 230mm | : 6.0mm |
| 230mm <d≤ 305mm | : 8.0mm |
| 305mm <d | : 9.5mm |

Check the crack initiation at flange part of the shaft.
(increase of bending moment )

Carry out not only replacement of the S/T bearing but also measurement of the worn sleeve.

In case of rubber bearing or resin bearing

Supply sufficient cooling sea water
(A shortage of cooling water occurs a carbonization of S/T bearing)

## 1. Attention for water-lubricated propeller shaft

Metal-Resin is accepted for use only for contact gland packing.

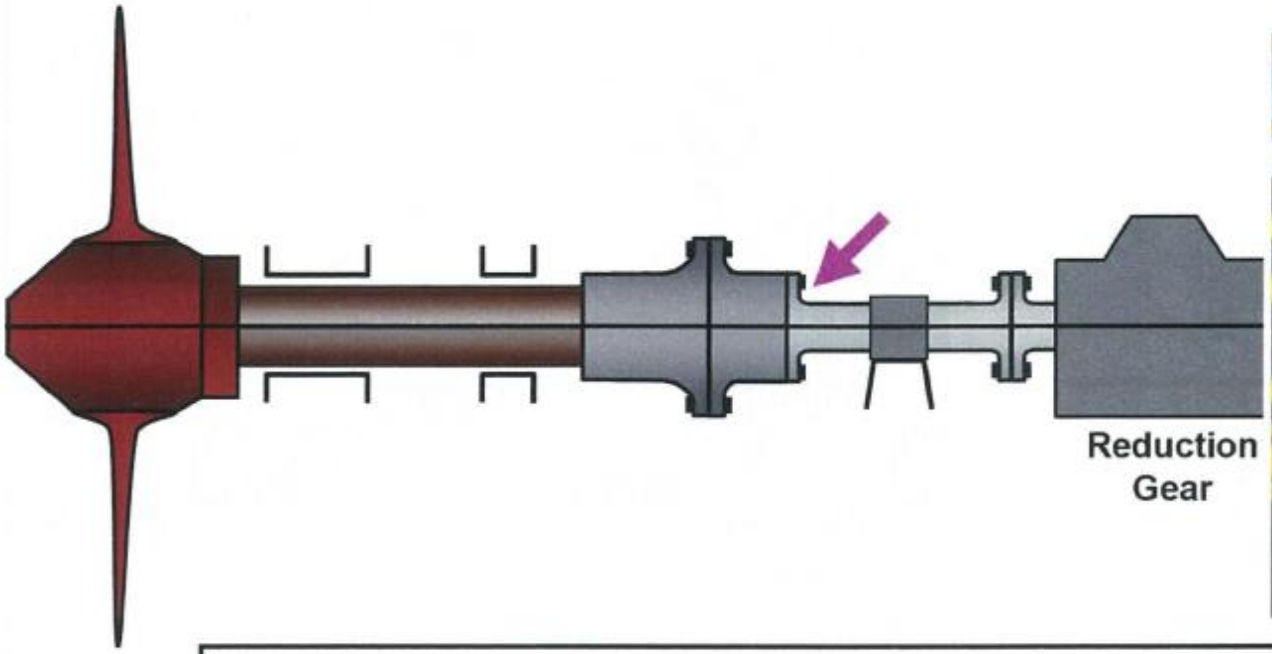
Reason: Metal-Resin must not be used for the part of bearings, because Resin can not endure the actual load.

Temporally repair method for propeller shaft sleeve other than a part of gland packing

1. Grinding the sleeve down to the required thickness.
2. Replace the bearing to undersize one as necessary
3. Replace the sleeve, in the case that the sleeve is ground over the required thickness

## 1. Attention for water-lubricated propeller shaft

Damage example due to insufficient use of metal resin




Intermediate shaft (oil transfer shaft for CPP) fractured at aft side flange

# Propulsion Shafting: Other notice for shafting

## 1. Attention for water-lubricated propeller shaft

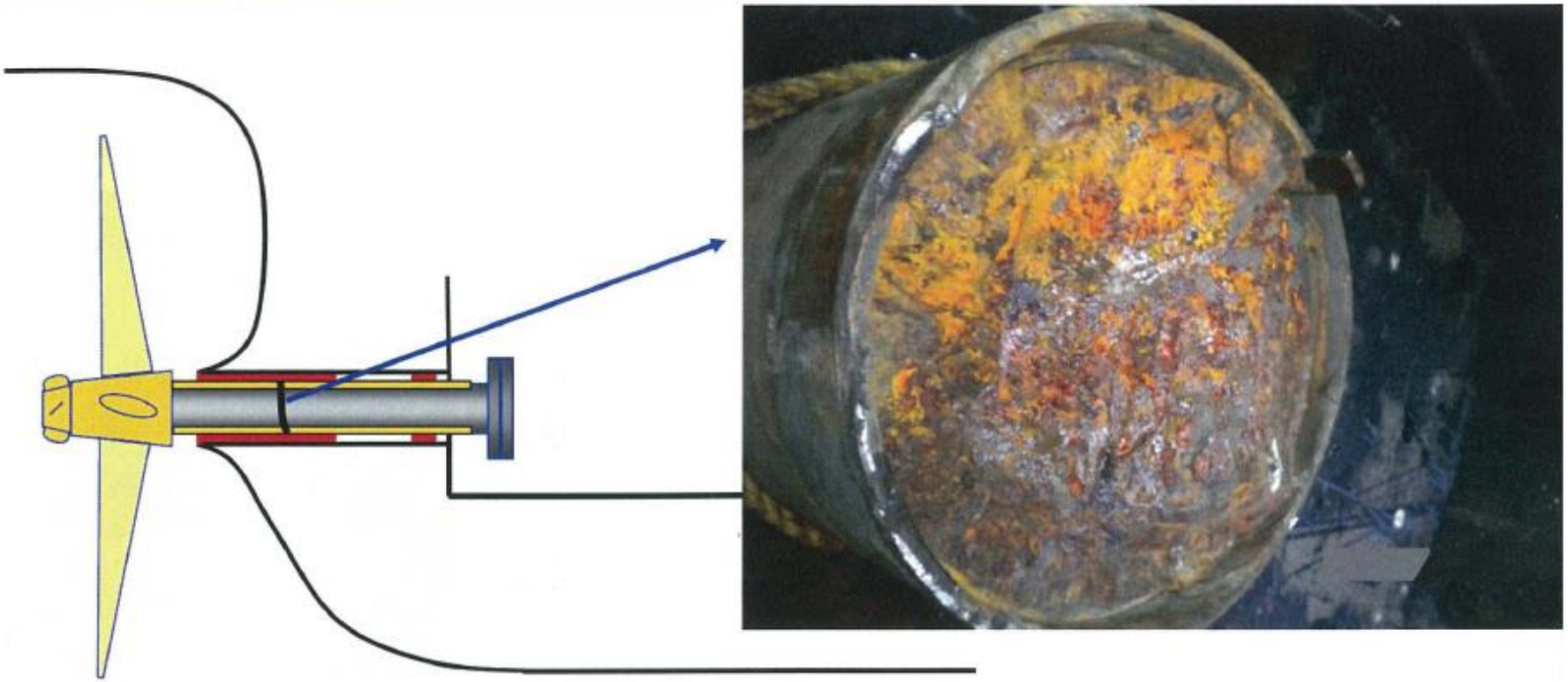
**In case of sleeve replacement**

- To be replaced with the original continuous sleeve
- To be replaced with the approved separate sleeve
  (Rubber or other synthetic resin materials with approval)

Inappropriate replacement to non-approved separate sleeves can cause a breakage of propeller shaft

## 1. Attention for water-lubricated propeller shaft

Damage example due to insufficient use of separate type sleeves



The propeller shaft was broken during voyage.
Sleeves were connected each other on the stern tube bearing

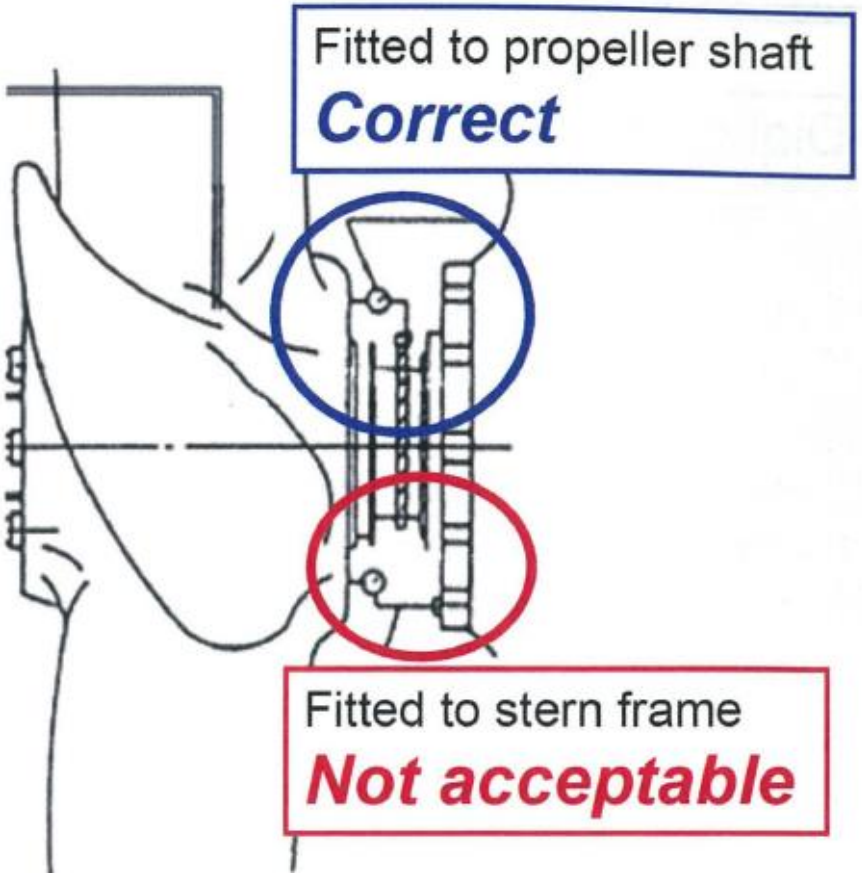
## 2. Attention for fitting of Keyless propeller

**Position of Dial Gauge**

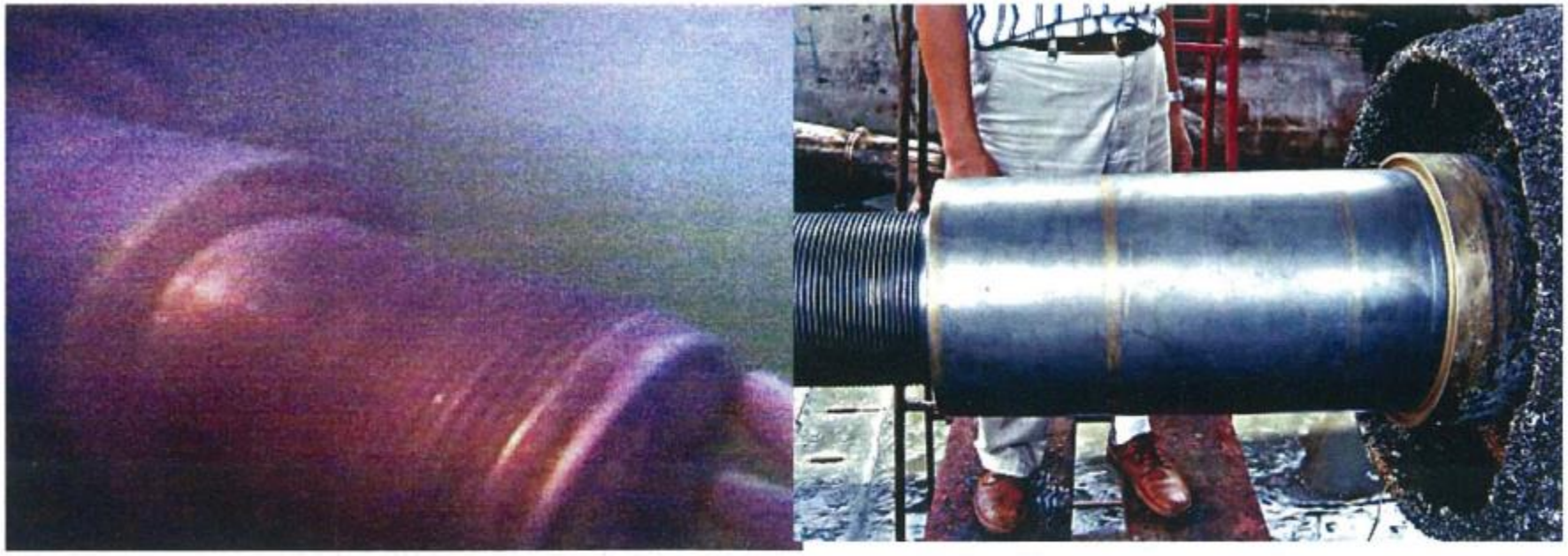
Correct:
Dial gauge to be fitted to propeller shaft

Incorrect:
Dial gauge to be fitted to stern frame (Hull)

insufficient distance



## 2. Attention for fitting of Keyless propeller



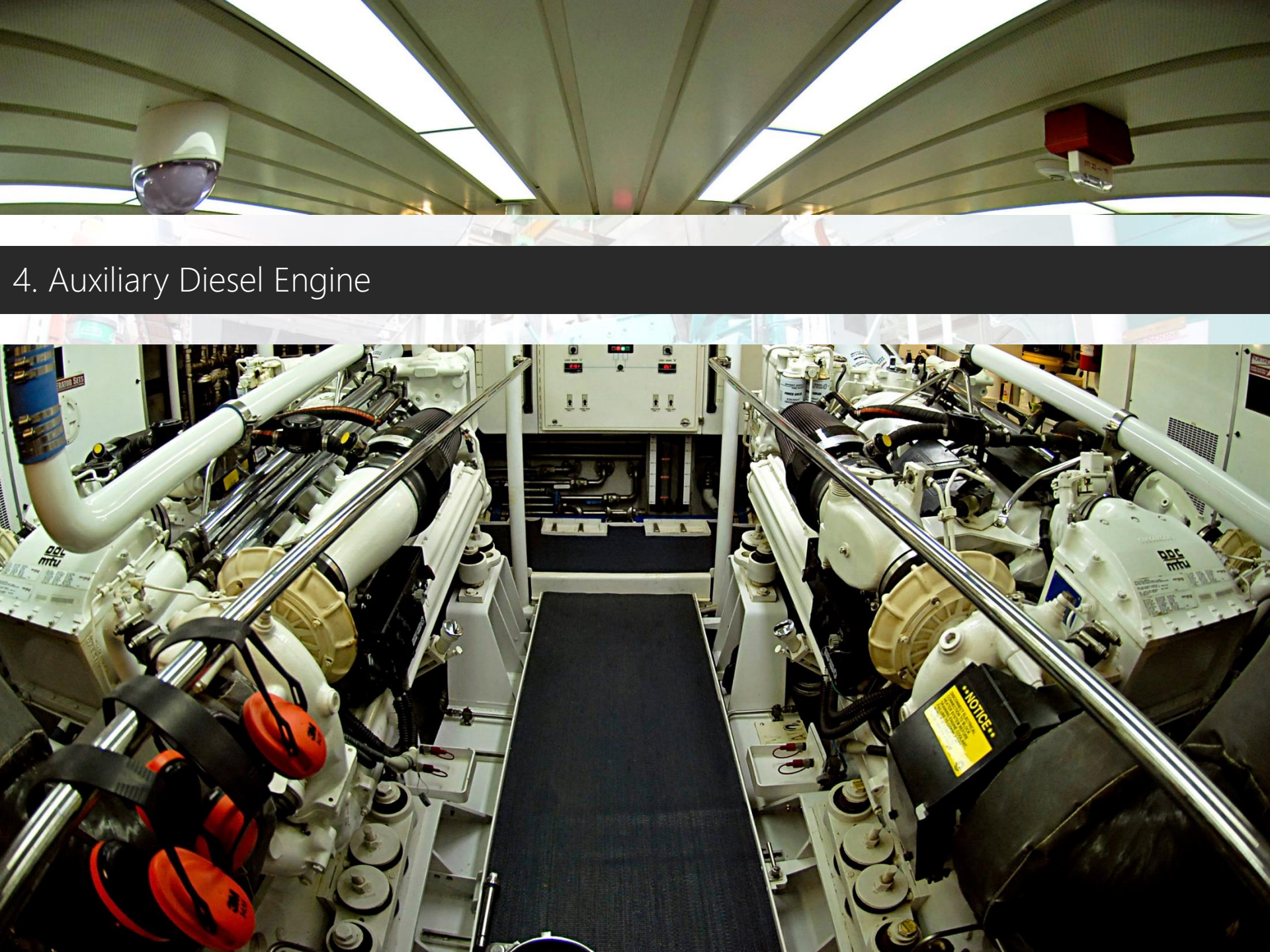
Condition of Corn Part after the propeller loss

## 2. Attention for fitting of Keyless propeller

**Attention of propeller fitting**

- Confirmation of matching mark (marking-off line)
- Dial gauge should be fitted to propeller shaft.
- You are recommended to use two dial gauges.
- Fitting record should be made during the fitting work, and actual traveling distance should be confirmed immediately.
- After fitting, propeller nut is tightened certainly.

# 4. Auxiliary Diesel Engine



# MODULE 2B – Machinery Systems (Content)

1. Introduction
   - Numbers and Damage rates

2. Main diesel engine
   - Crankshaft
   - Degraded heavy fuel
   - Combustion chamber
   - Crosshead pin
   - Damage at shop test
   - Turbocharger

3. Propulsion Shafting
   - Coupling bolts
   - Propeller shaft
   - Propeller Breakage
   - Other notice for shafting

4. Aux. diesel engine
   - Connecting rod

5. Aux. boiler
   - Internal crack
   - Furnace Collapse
   - Exhaust gas economizer

6. Others
   - Fire in engine room
   - Damage due to alumina
   - Fire of feeder panel

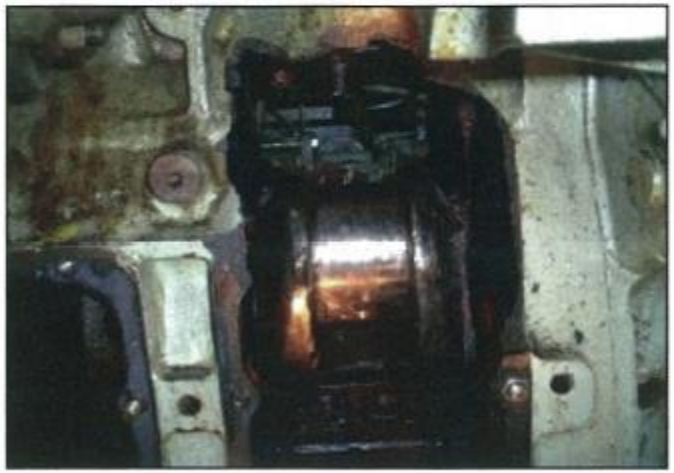
# Aux. Diesel Engine: Connecting Rod

| Ship Type: | Container Carrier |
|---|---|
| GT: | 5200 |
| Ship Age: | 11 |
| No.2 G/E: | 480 PS x 1200 rpm |
| Damaged Part: | Connecting Rod |
| Operating Hours of No.2 G/E Crank Pin Bolts: | 10600 |

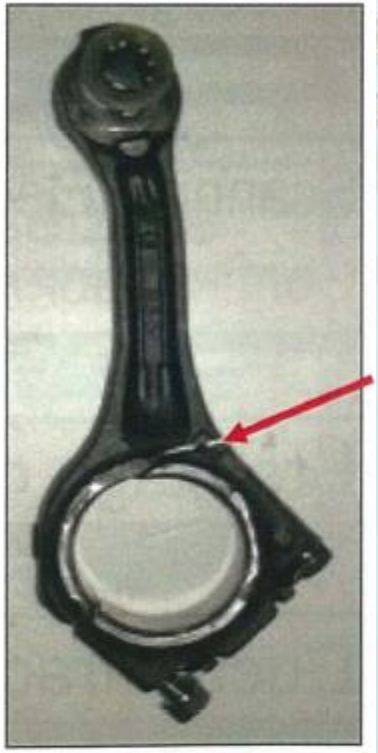
## Report

Change over to No.2 G/E single operation at harbor or anchorage.

Breakage of No.6 Piston Rod of No.2 G/E Occurred



Fracture of Crankcase



Breakage of Piston Rod

# Aux. Diesel Engine: Connecting Rod

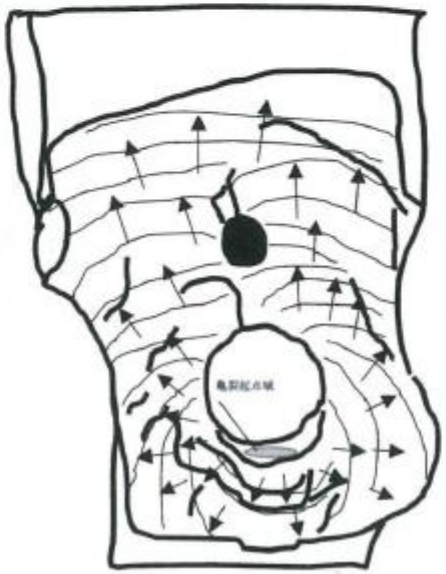
## Report

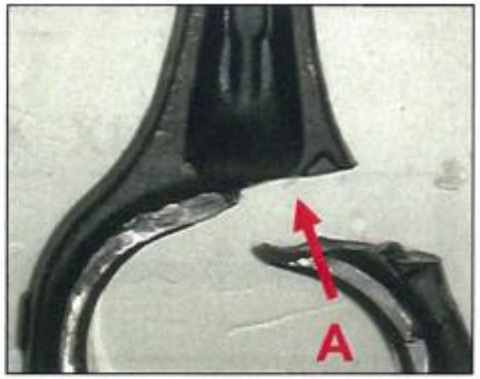
Investigation of Connecting Rod Breakage

Confirmation of Beach-Mark

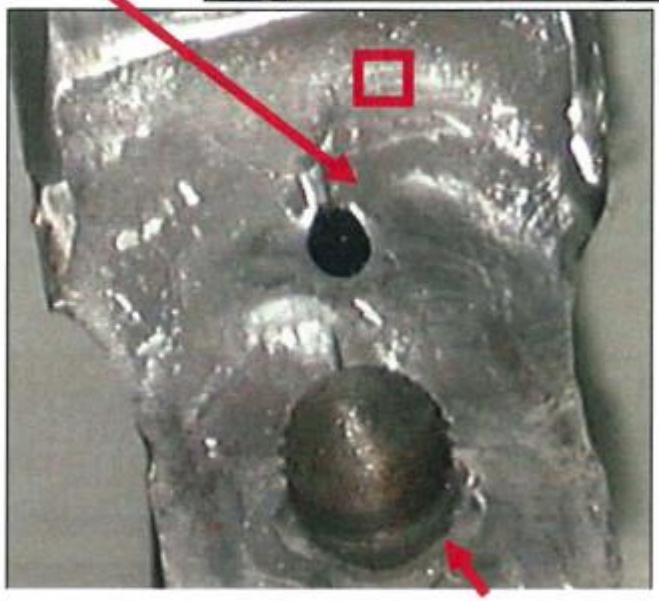
Scanning Electron Microscope (SEM)
Confirmation of Striation

Fatigue Fracture






Beach Mark



Initiation Point of Crack

View from A

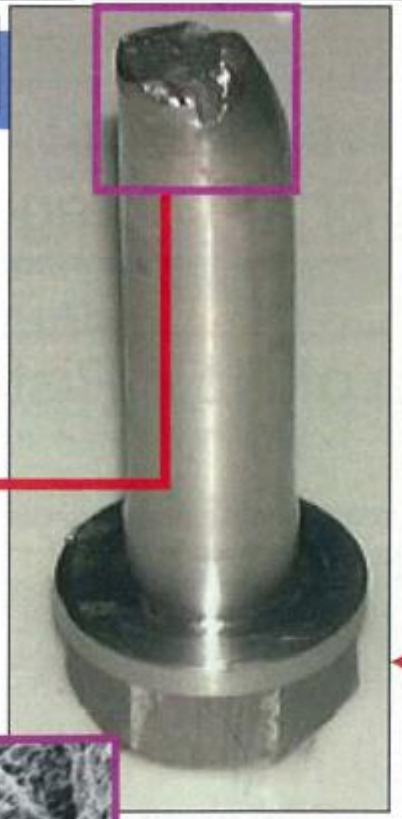
## Investigation results

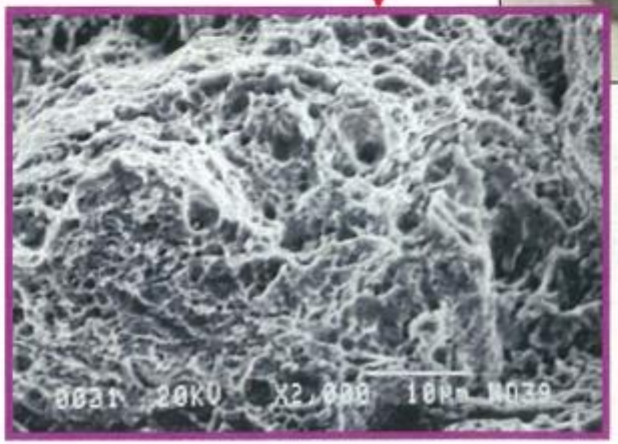
Investigation of crank pin bolt breakage

Scanning Electron Microscope (SEM)
Confirmation of dimple

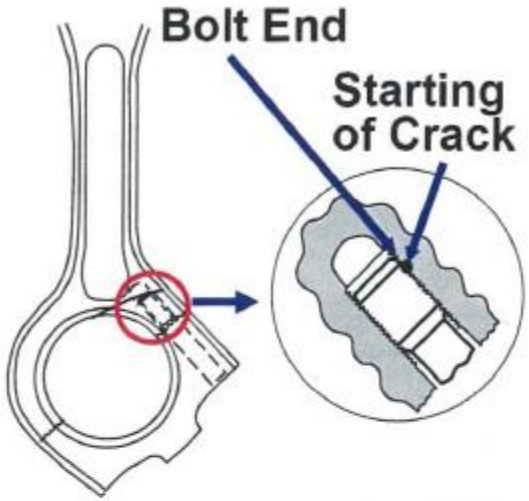
Breakage due to tensile load

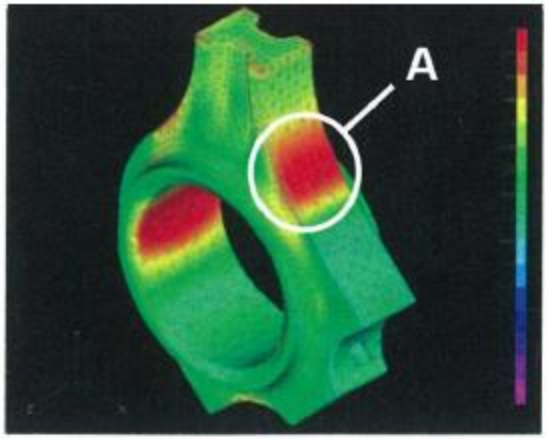
Ductile fracture

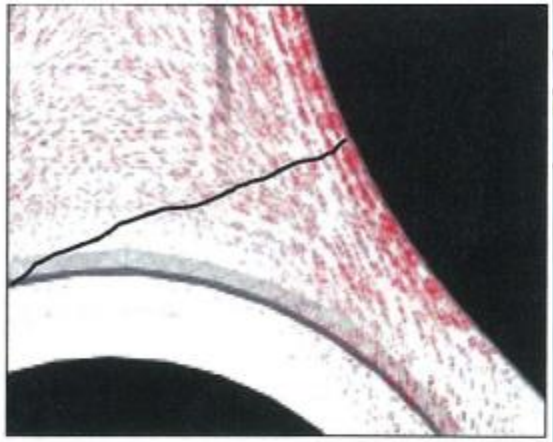




## Causes



Direction of Maximum Principal Stress at A

Fatigue failure may occur due to small initial defect because stress around crack starting point is comparatively high.

Max principal stress in vertical direction to fracture surface

The initial crack progressed by repetitive stress fluctuation, and breakage of the rod and the bolts occurred.

## Causes/Countermeasure

Seizure between the bolt and the screw hole

Insufficient tightening condition due to the seizure

Seizure is thought to have been caused by foreign particles in the screw hole

**Countermeasures**

- Careful cleaning of the bolts and the screw holes
- Pre-tightening test by hand in order confirm that the bolt turns smoothly.

## Checkpoints

Almost all breakages of connecting rods occur due to insufficient tightening of bolts

The damage may occur up to several months after delivery

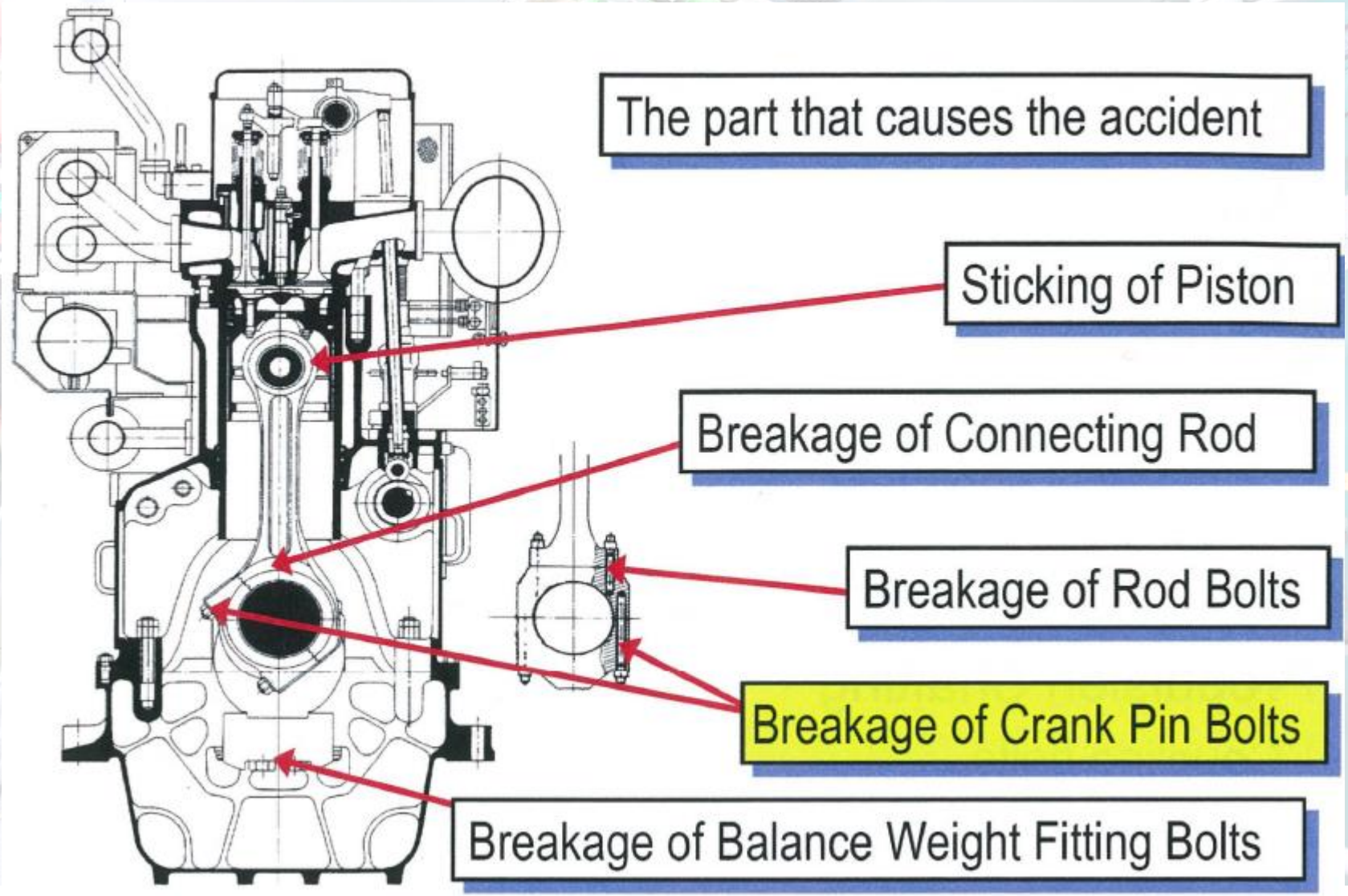
There may be no indications of the damage (e.g. LO alarm)
Difficult to forecast the damage

## Checkpoints

- Promoting awareness at repair shipyards
- Bolt tightening should be recorded as a part of the quality control.
- Designation of appropriate workers and confirmation of the worker's experience
- Stamping of matching mark and confirmation of tightening torque
- Confirmation of screw condition (seizure etc.)
- Confirmation of the appropriate tightening method from service information of engine manufacturers

# Aux. Diesel Engine: Connecting Rod

## Checkpoints

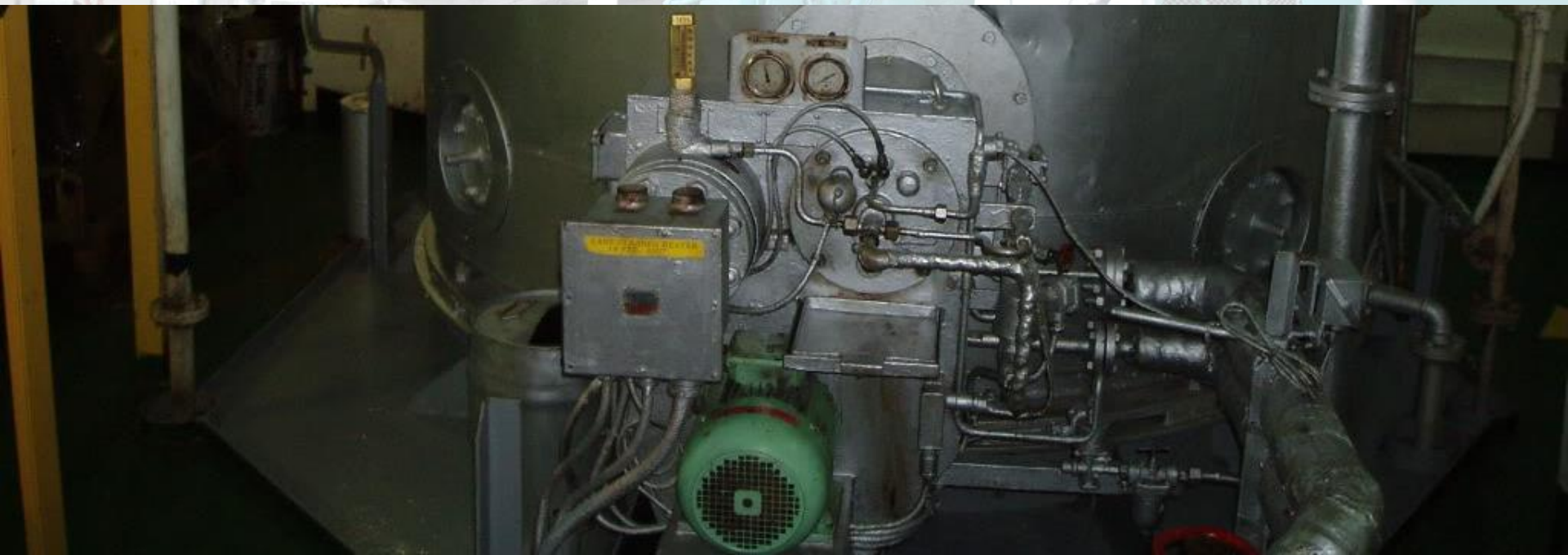


## Countermeasures

**Countermeasures**
**in case the G/E is taken out of commission**

1. Confirmation of required electrical power
2. At least 2 generators are required in accordance with Reg.41, Chapter II-1 of SOLAS
3. Confirmation of operating condition of other generators
4. Installation of portable generators, if necessary


# 5. Auxiliary Boiler



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   - Exhaust gas economizer

6. Others
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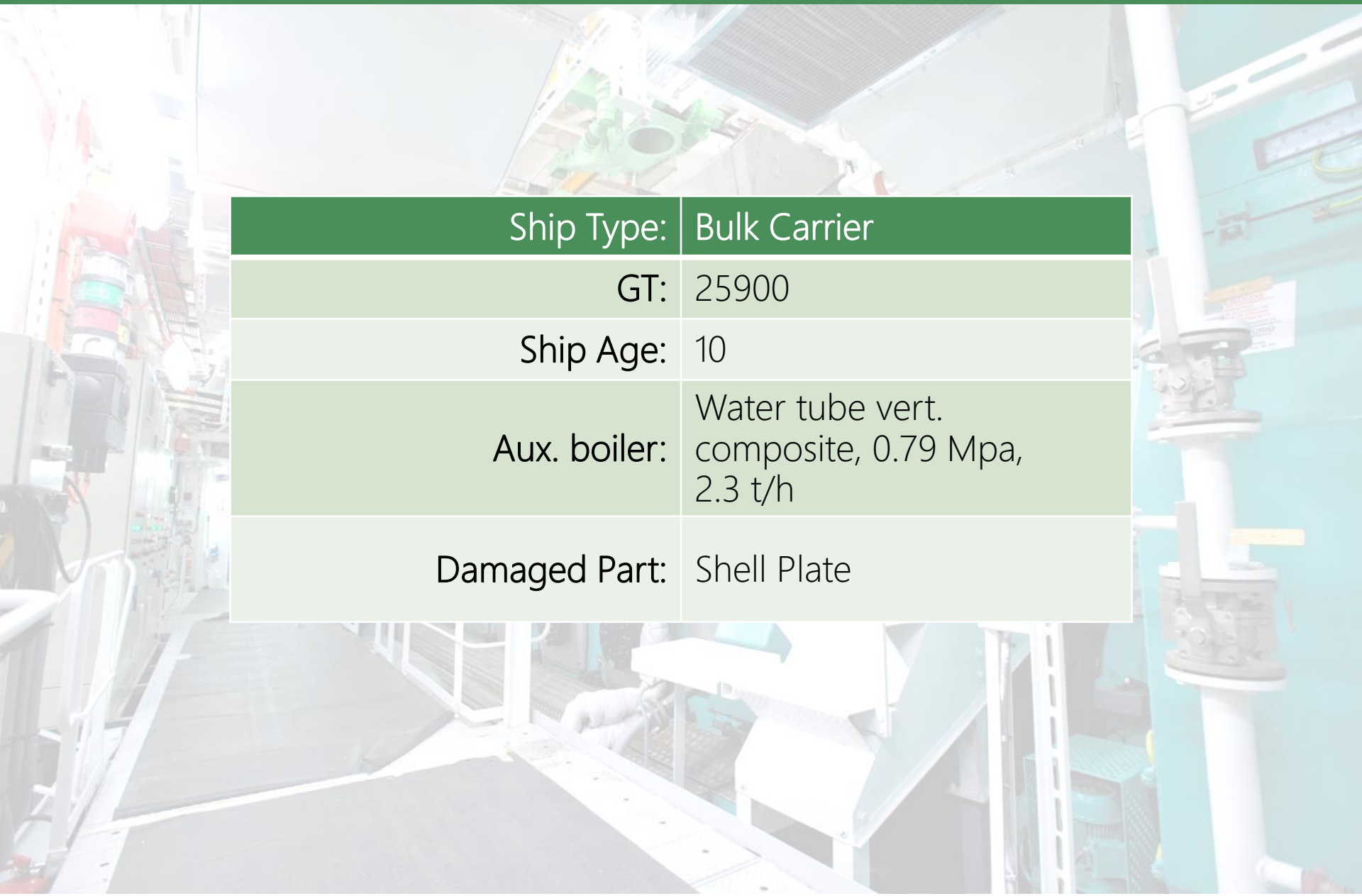
   - Damage due to alumina
   - Fire of feeder panel

# Aux. Boiler: Internal Crack



| Ship Type: | Bulk Carrier |
|---|---|
| GT: | 25900 |
| Ship Age: | 10 |
| Aux. boiler: | Water tube vert. composite, 0.79 Mpa, 2.3 t/h |
| Damaged Part: | Shell Plate |

# Aux. Boiler: Internal Crack

## Report

Steam leaked on the aft side of the lower parts of the boiler during M/E at MCR running.

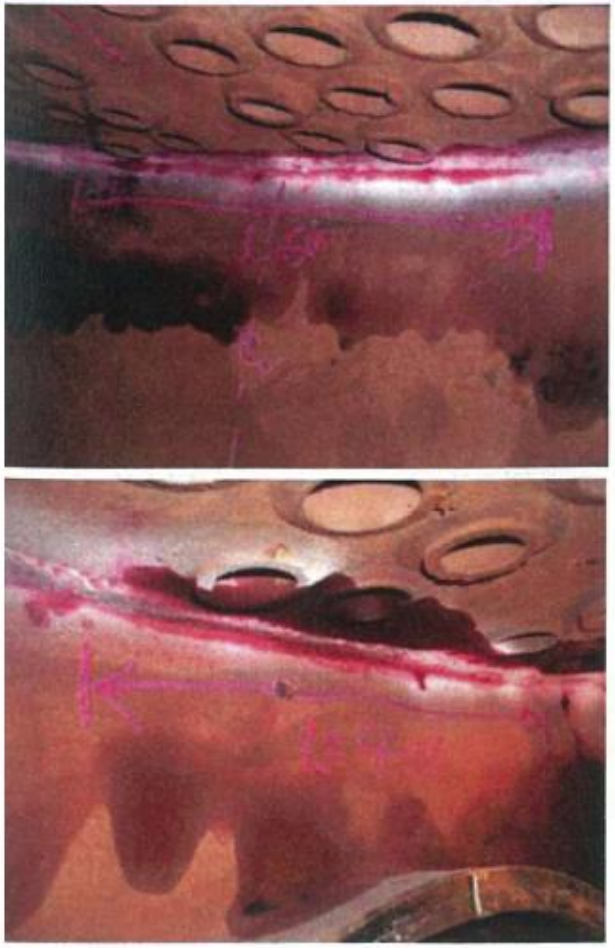
The inside of the water drum was inspected after M/E stopped.

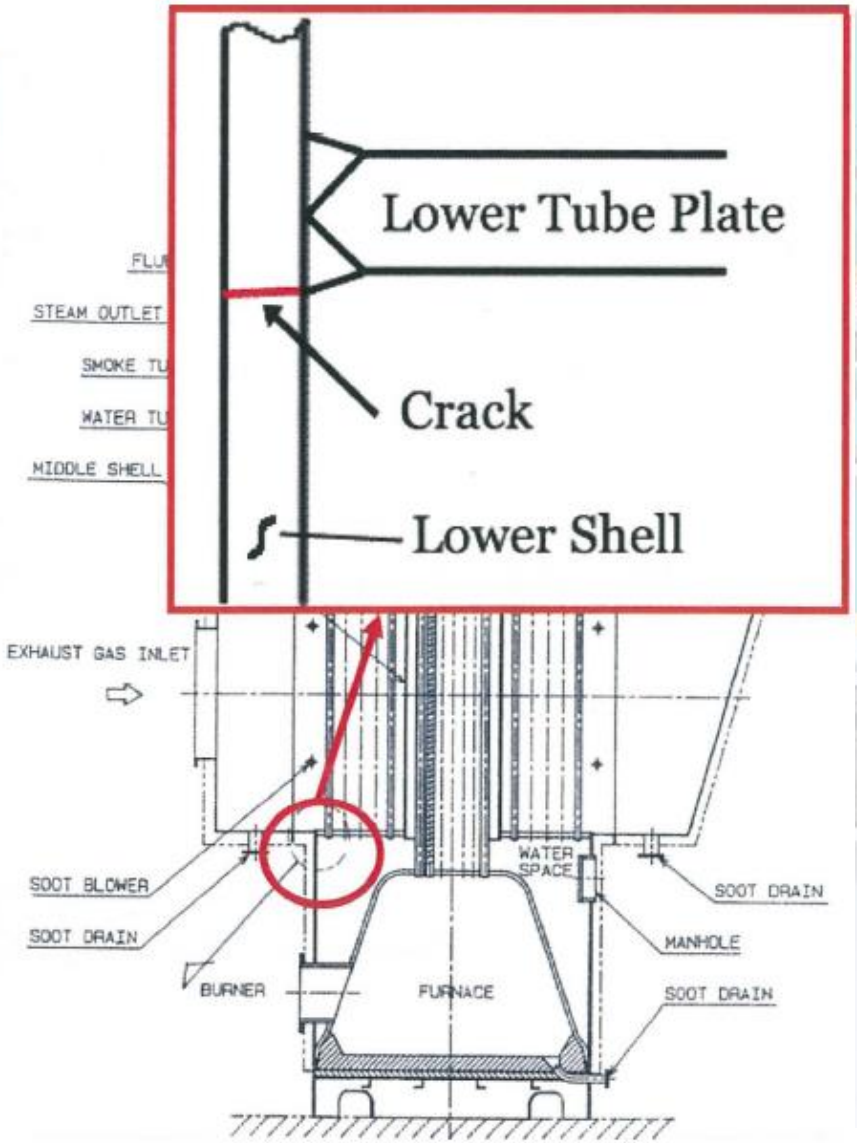
Cracks on the shell plate were found.

# Aux. Boiler: Internal Crack

## Investigation results

**Condition of Damage**



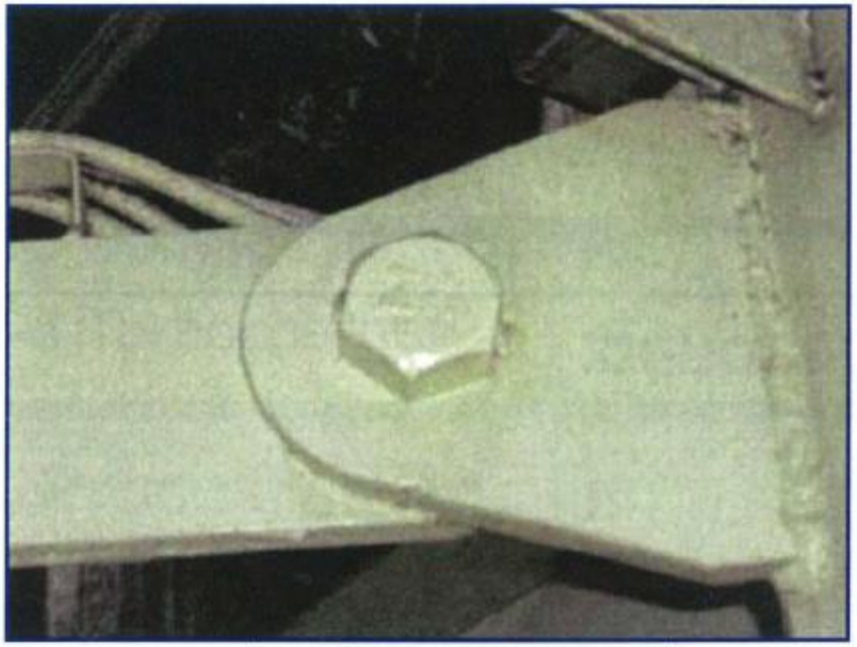


# Aux. Boiler: Internal Crack

## Investigation results

Welding of the bolts for prevention of loosening by the ship's crew

Welded Stay



Hull Side

Boiler Side

## Causes

- Damaged part, where the tube plate is welded with the shell plate at inside of water drum, is highly stressed area.
- It is possible that cracks are initiated due to welding defects.

+

Thermal expansion is not absorbed efficiently by the boiler stays due to the welding of the bolts to prevent loosening.

↓

**Cracks occurred**

## Repairs

### Repair procedure for cracks on boiler shell

1. PT or MT to be carried out for surface crack detection.
2. Stop holes to be drilled at the both ends of crack.
3. Edge preparation
4. Welding by qualified welder
5. PWHT (Post Weld Heat Treatment) to be carried out, if necessary.
6. PT or MT to be carried out for surface crack detection.
7. RT or UT to be carried out for detection of inner defects.
8. Hydrostatic test to be carried out.

*1 PT: Penetration Testing
*2 MT: Magnetic Particle Testing
*3 RT: Radiography Testing
*4 UT: Ultrasonic Testing

# Aux. Boiler: Internal Crack

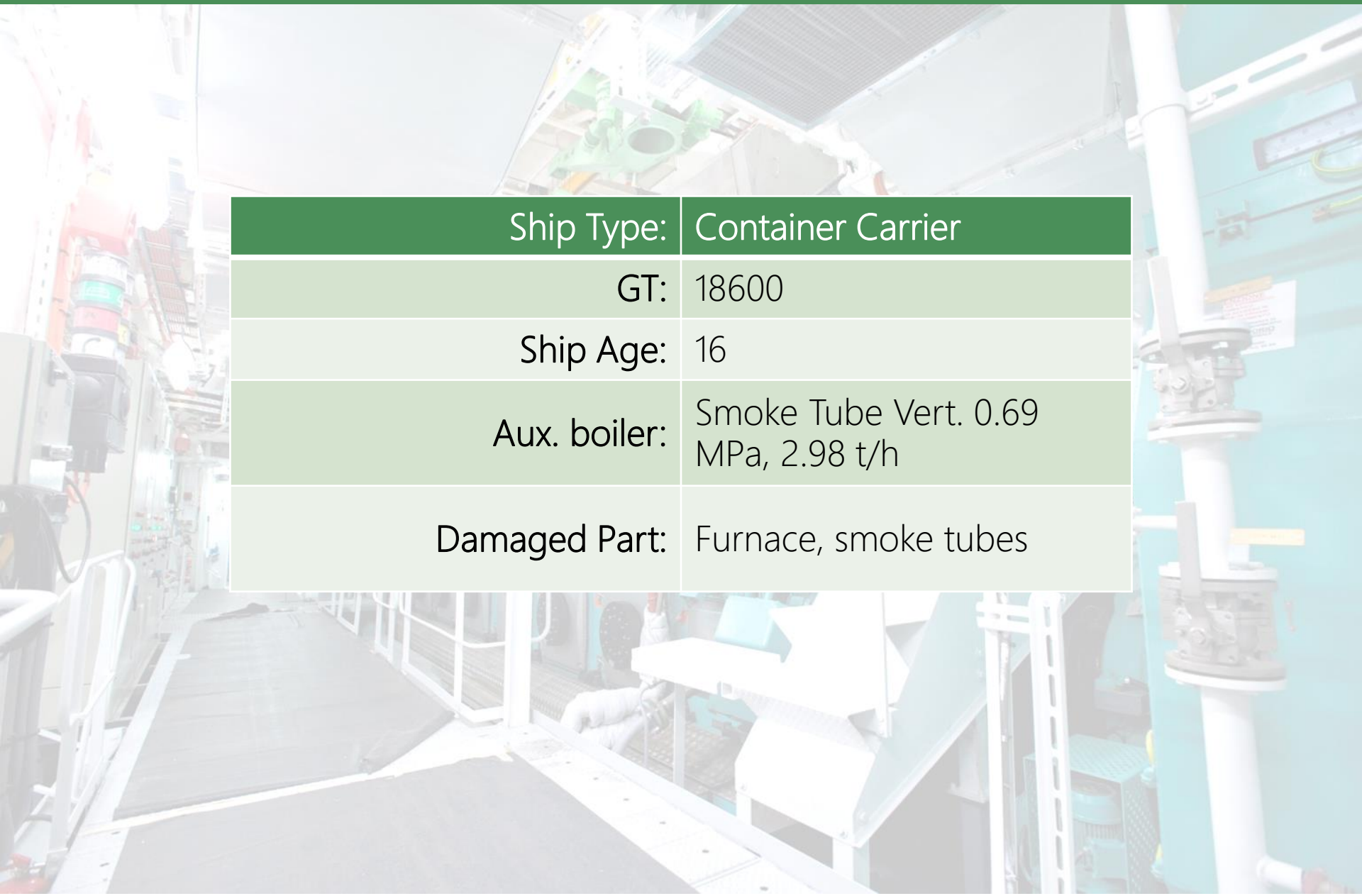
## Attention for maintenance

Inspection of Water Tube Vertical Composite Boiler:
Special attention to be paid to the high stressed area where the tube plate is welded with the shell plate at inside of the water drum.

Purpose of Boiler Stay:
Absorption of thermal expansion and vibration

Inadequate welding causes damage to boiler

# Aux. Boiler: Furnace Collapse



| Ship Type: | Container Carrier |
|---|---|
| GT: | 18600 |
| Ship Age: | 16 |
| Aux. boiler: | Smoke Tube Vert. 0.69 MPa, 2.98 t/h |
| Damaged Part: | Furnace, smoke tubes |

# Aux. Boiler: Furnace Collapse

**Furnace collapse due to water shortage :**

is caused by combustion continuation under the water low low level condition.

The main cause of occurrence of shortage of water is un-cutting of burner operation under water low low level condition due to malfunction of safety devices.

Deformation of the furnace

Deformation of the tube plates

# Aux. Boiler: Furnace Collapse

After departure, crew found water leakage in furnace of boiler.

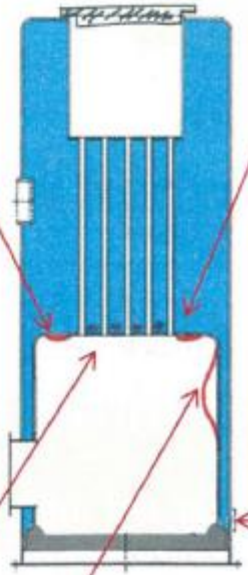
At repair port, followings are found;

(1)Leakage of water from smoke tube lower part
(2)Deformation of lower tube plate
(3)Deformation of furnace
(4)Accumulation of scale in water side
(5)Malfunction of feed water control system
(6)Malfunction of low low water level burner cut system
(7)Blockage of feed water nozzle

# Aux. Boiler: Furnace Collapse

**condition**

Deformation of lower tube plate



Accumulation of scale

Leakage through smoke tube

Deformation of furnace

Accumulation of scale(mud hole)

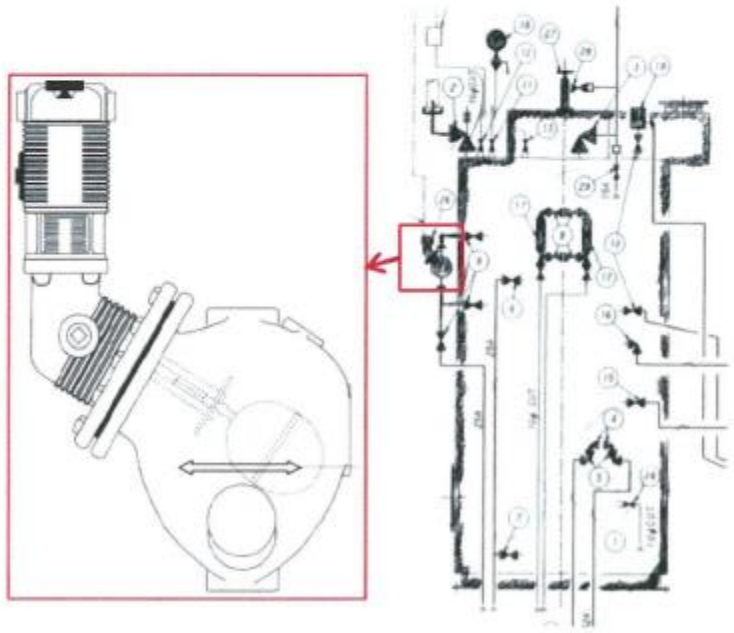
**condition**

## Feed water control system:

control by signal from differential pressure transmitter through controller.
Transmitter had malfunction that continues outputting max.value of signal always.

## Low low water level burner cut system by float switch

internal piece of float switch was broken/stuck.
(due to bad boiler water condition?)



# Aux. Boiler: Furnace Collapse

## Possible cause of damage

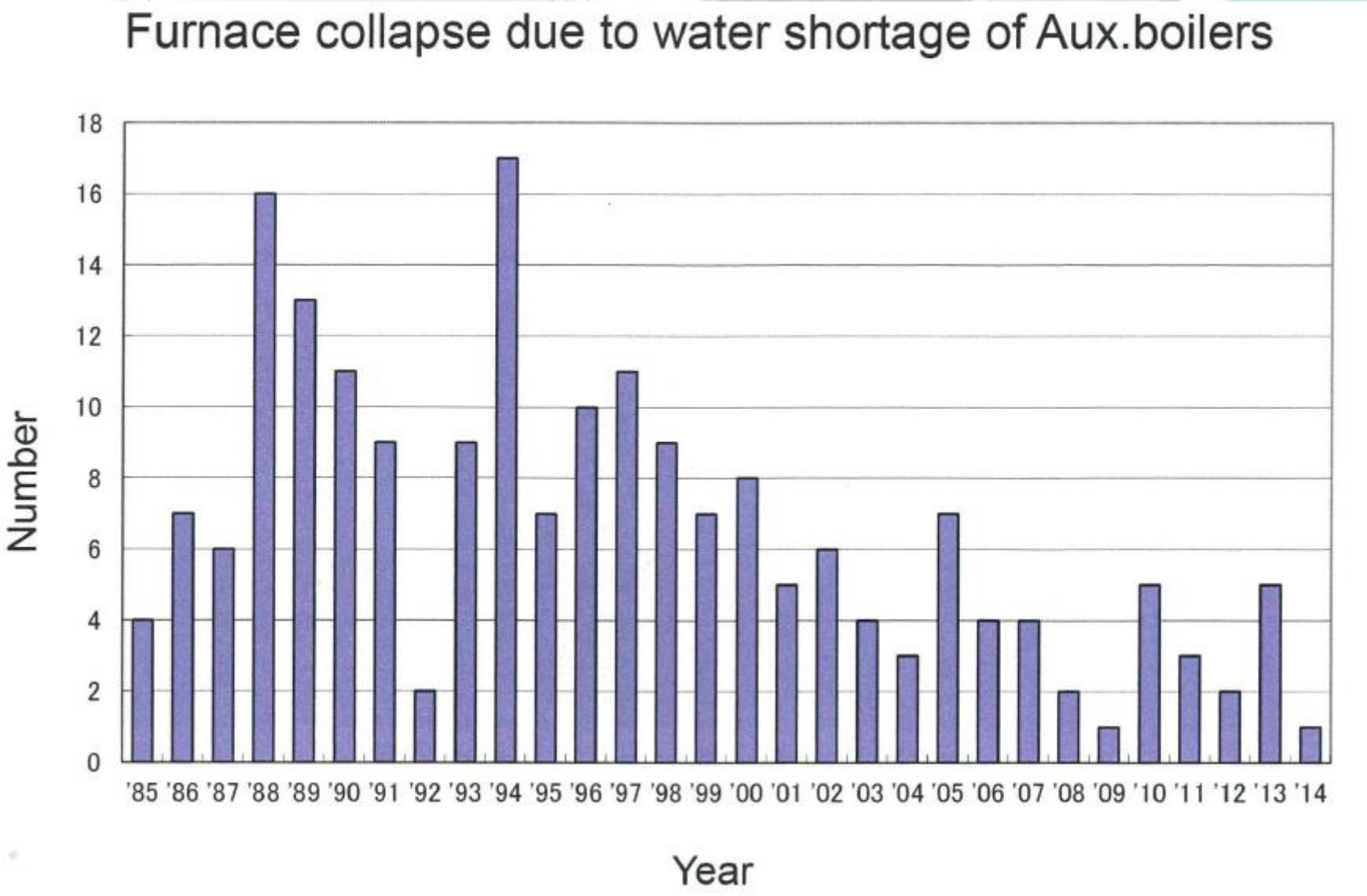
**Malfunction of feed water system:**
**boiler water is not supplied when water level is low**
**Malfunction of float switch:**
**burner is not cut when water level is low low**
**So, combustion is continued without boiler water**

**Deformation/heat damage of furnace/tube/tube plate etc.**

**On the other hand, Accumulation of scale**
**Blockage of feed water nozzle**
**Malfunction of feed water check valve**

**Ship maintenance/cleaning might not function well.**

# Aux. Boiler: Furnace Collapse



# Aux. Boiler: Furnace Collapse

## Checkpoints

Furnace collapse accident

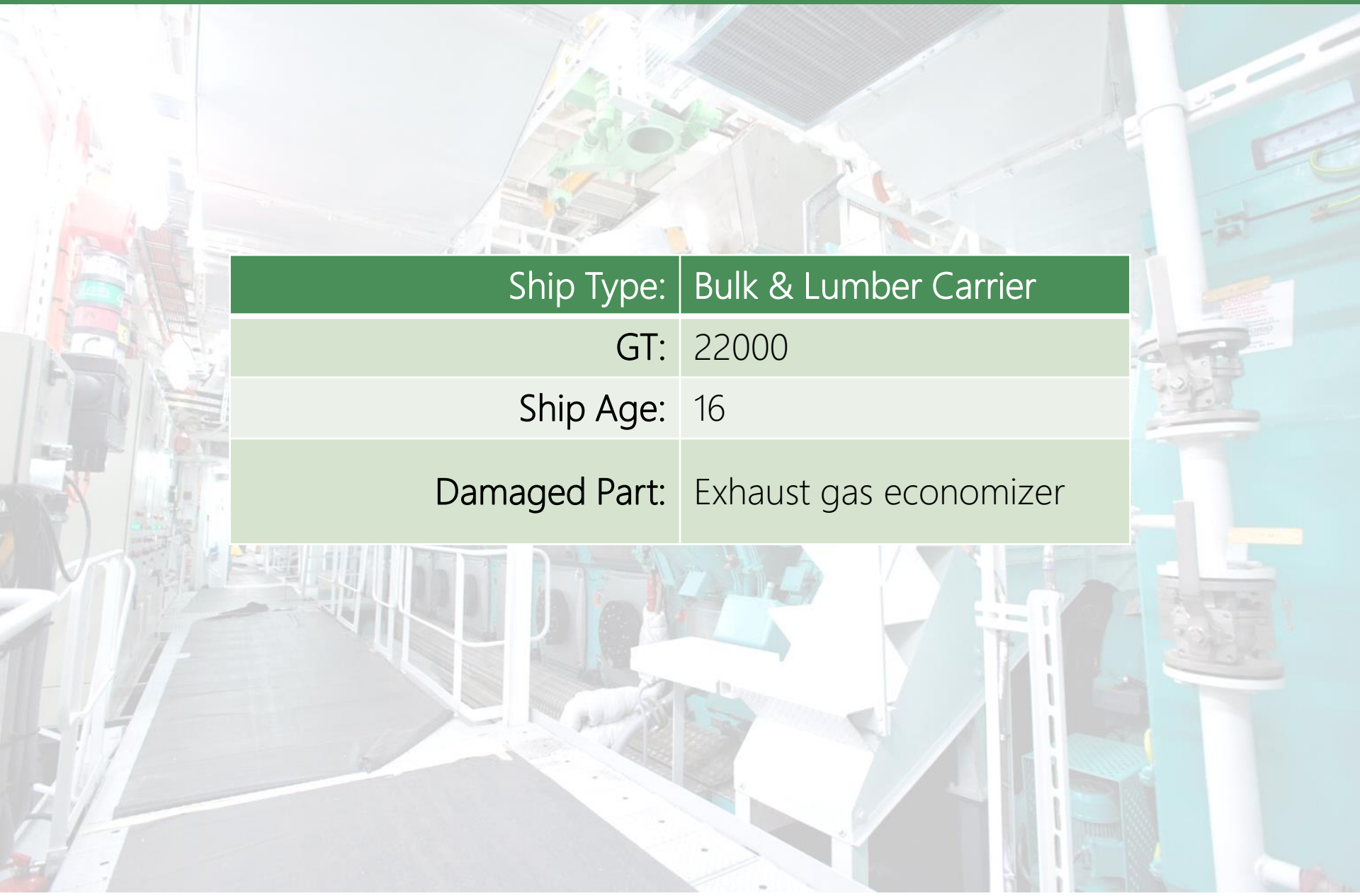
Extensive repairs are required.

Serious consequence for ship's schedule

1) Water level indicators
(including remote water level indicator)

2) Feed water control system
3) Low water level alarm device
4) F.O. shut-off device

# Aux. Boiler: Exhaust gas economizer



| Ship Type: | Bulk & Lumber Carrier |
|---|---|
| GT: | 22000 |
| Ship Age: | 16 |
| Damaged Part: | Exhaust gas economizer |

# Aux. Boiler: Exhaust gas economizer

## Report

During navigation at NSR, a soot fire took place in the exhaust gas economizer and water leakage was found

Overheat and deformation were found in 80% of generating tubes

Damaged generating tubes

## Repair

**Temporary repairs:**

All overheated generating tubes were removed and repair via by-pass was carried out.

By-pass of generating tubes

## Causes

**Main cause : Accumulated soot**

- Adequate soot blowing
- Water washing

Recently, damages due to soot fire of exhaust gas economizer have decreased

Maintenance is to be carried out in compliance with manufacturers instructions

## Checkpoints

### Prevention measures for soot fires

1. Prevention by shape and structure
   (Considering the location of pipe elbow and fittings on economizer during design stage)

2. Prevention by mechanical procedure
   (Using by-pass of exhaust gas economizer)

3. Prevention by chemical procedure
   (Combustion additives)

## Checkpoints

### Prevention measures for soot fires

4. Prevention by maintenance
   (Replacement of FO nozzle tips at prolonged low load operation)

5. Prevention by operation
   (Boiler water holding time)
   (Increasing soot blows)
   (Exchange to high quality FO at low load operation)

6. Cleaning up of soot after soot blow
   (Consideration of cleaning instrument and additional soot blow line)

# 6. Others

# MODULE 2B – Machinery Systems (Content)

1. Introduction
   - Numbers and Damage rates

2. Main diesel engine
   - Crankshaft
   - Degraded heavy fuel
   - Combustion chamber
   - Crosshead pin
   - Damage at shop test
   - Turbocharger

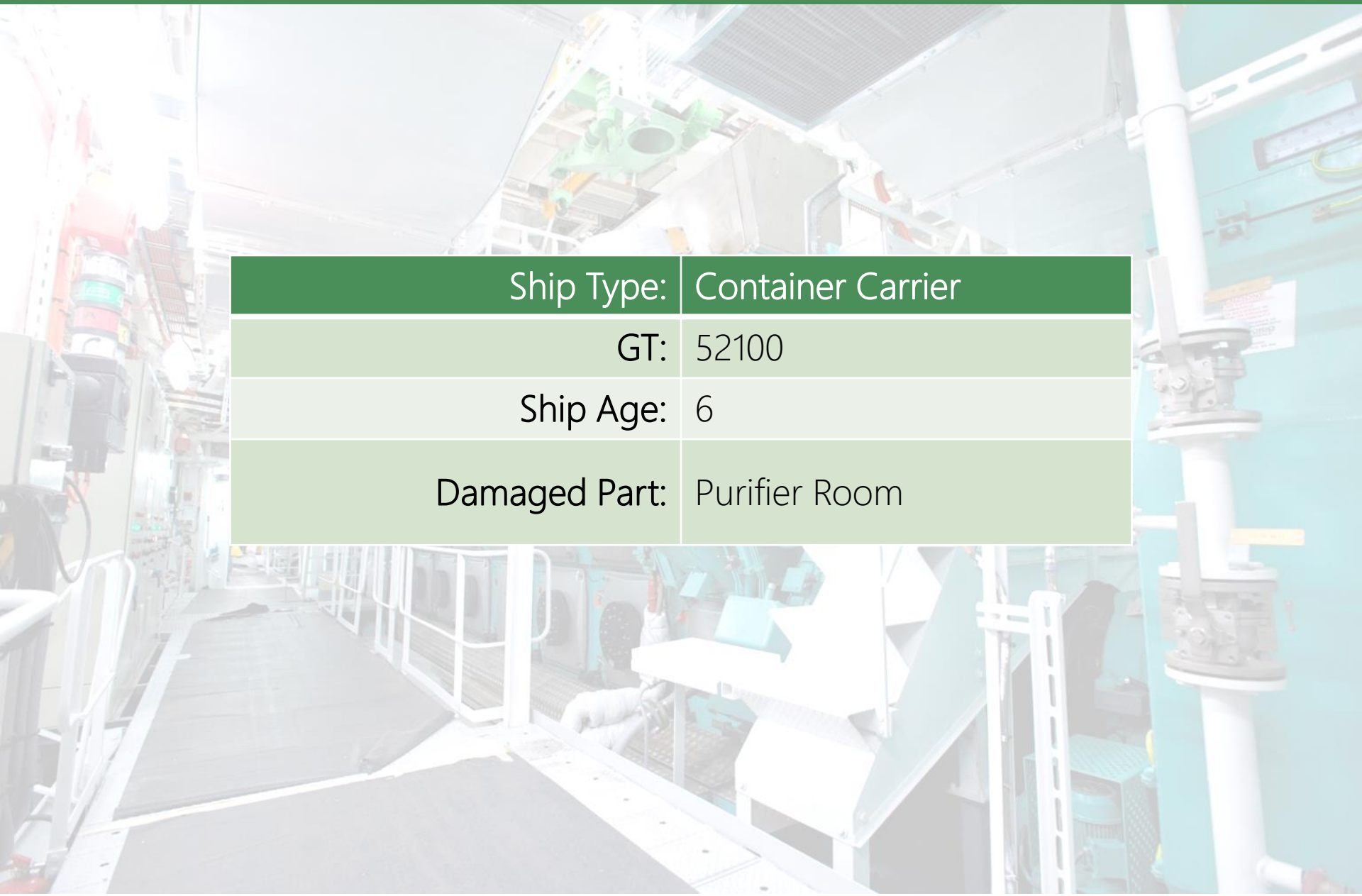
3. Propulsion Shafting
   - Coupling bolts
   - Propeller shaft
   - Propeller Breakage
   - Other notice for shafting

4. Aux. diesel engine
   - Connecting rod

5. Aux. boiler
   - Internal crack
   - Furnace Collapse
   - Exhaust gas economizer

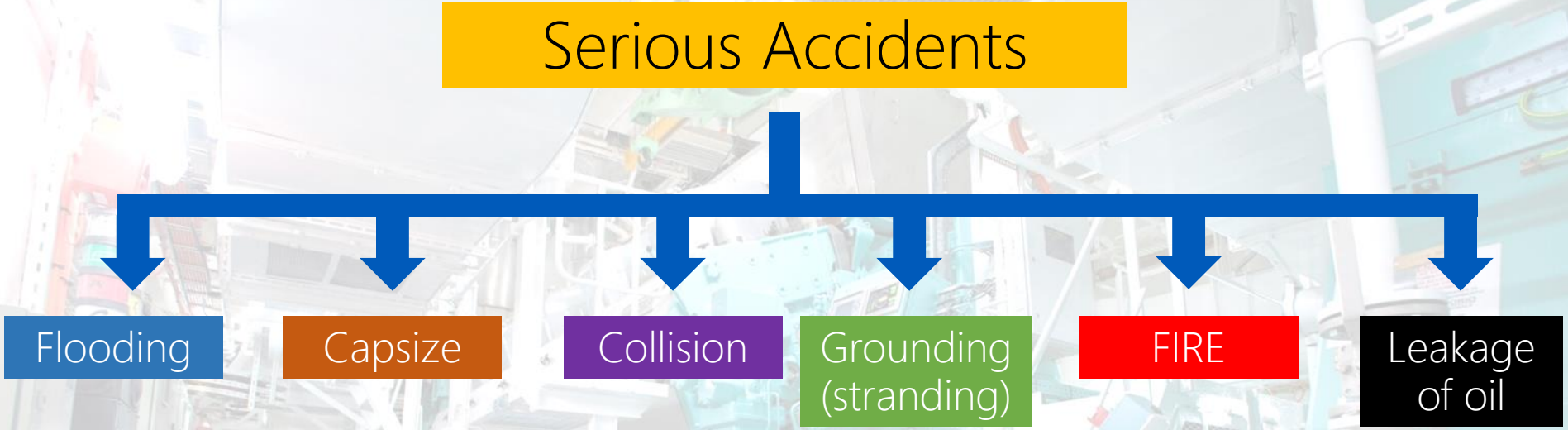
6. Others
   - Fire in engine room
   - Damage due to alumina
   - Fire of feeder panel

# Others: Fire in engine room (Case 1)



| Ship Type: | Container Carrier |
|---|---|
| GT: | 52100 |
| Ship Age: | 6 |
| Damaged Part: | Purifier Room |

# Others: Fire in engine room (Case 1)




- The requirements by International Conventions( SOLAS, ILL, MARPOL, etc.) for prevention of serious accidents.
- FIRE is a serious accident having influence over the human life and the property (ship).
- In Engine Room exists high possibility of FIRE due the amount of oil and ignition sources.

## Numbers of Fire in Engine Room

| Year | Total number | Serious damage | Main location of cause for serious damage |
|---|---|---|---|
| 2002 | 5 | 5 | Return pipe of FO pump, T/C, Air pipe of FO tank |
| 2003 | 2 | 0 | — |
| 2004 | 2 | 2 | Pretreatment equipment of FO |
| 2005 | 7 | 6 | T/C, FO piping and tank for boiler, generator |
| 2006 | 7 | 6 | Exhaust manifold of M/E, Joint of FO supply piping, T/C |
| 2007 | 2 | 1 | Scavenging space of M/E |
| 2008 | 7 | 3 | T/C, Generator |
| 2009 | 0 | 0 | — |
| 2010 | 3 | 2 | Generator, Main Switch board |
| 2011 | 5 | 3 | Aux. Boiler |
| 2012 | 2 | 2 | Return pipe of FO pump, T/C |
| 2013 | 6 | 1 | LPG re-heater |
| 2014 | 4 | 3 | Generator engine (black-out), T/C, D.O. strainer (crew's mis-handling) |

# Others: Fire in engine room (Case 1)

## Report

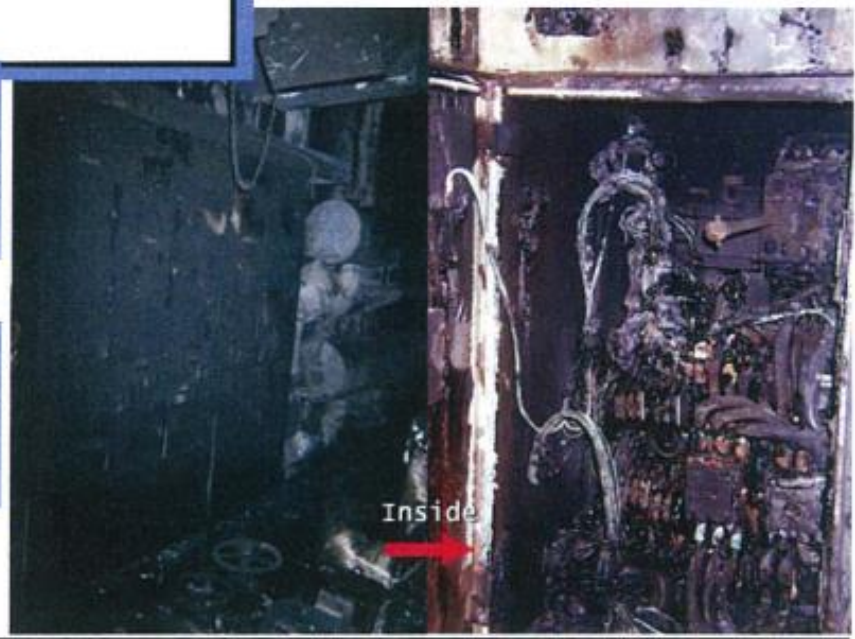
Fire alarm triggered after the ship berthed

E/R was filled with black smoke that blocked a firefighting team

$CO_2$ gas was released to the purifier room and to whole the E/R

Purifier room burnt for 4 hours

Towed for repair work




Burned Group Starter Panel in the Purifier Room

# Others: Fire in engine room (Case 1)

## Causes

L.O. leaked from the homogenizer

Driving shaft ball bearings were damaged due to L.O. shortage and shaft vibration occurred

F.O. leaked due to the vibration

F.O. sprayed and touched the high temperature bearings and ignited

(note) the homogenizer was installed as owner's option

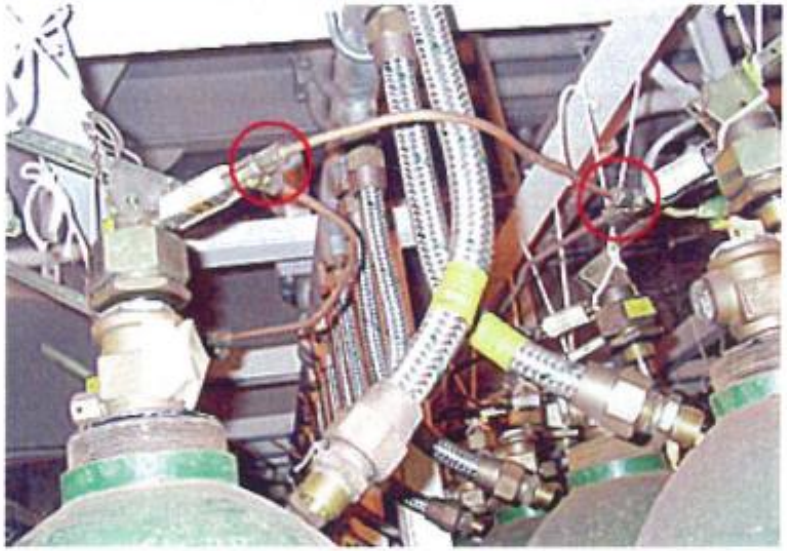
Damaged Shaft of the Homogenizer

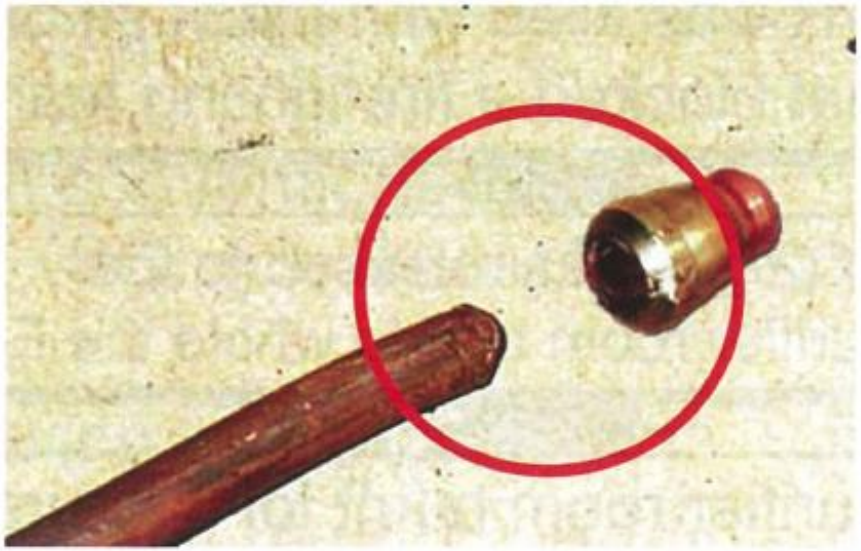
# Others: Fire in engine room (Case 1)

## Causes

Some $CO_2$ gas was not released (80 bottles /Total 192)

pilot lines (6mm, copper) were disconnected at 16 places

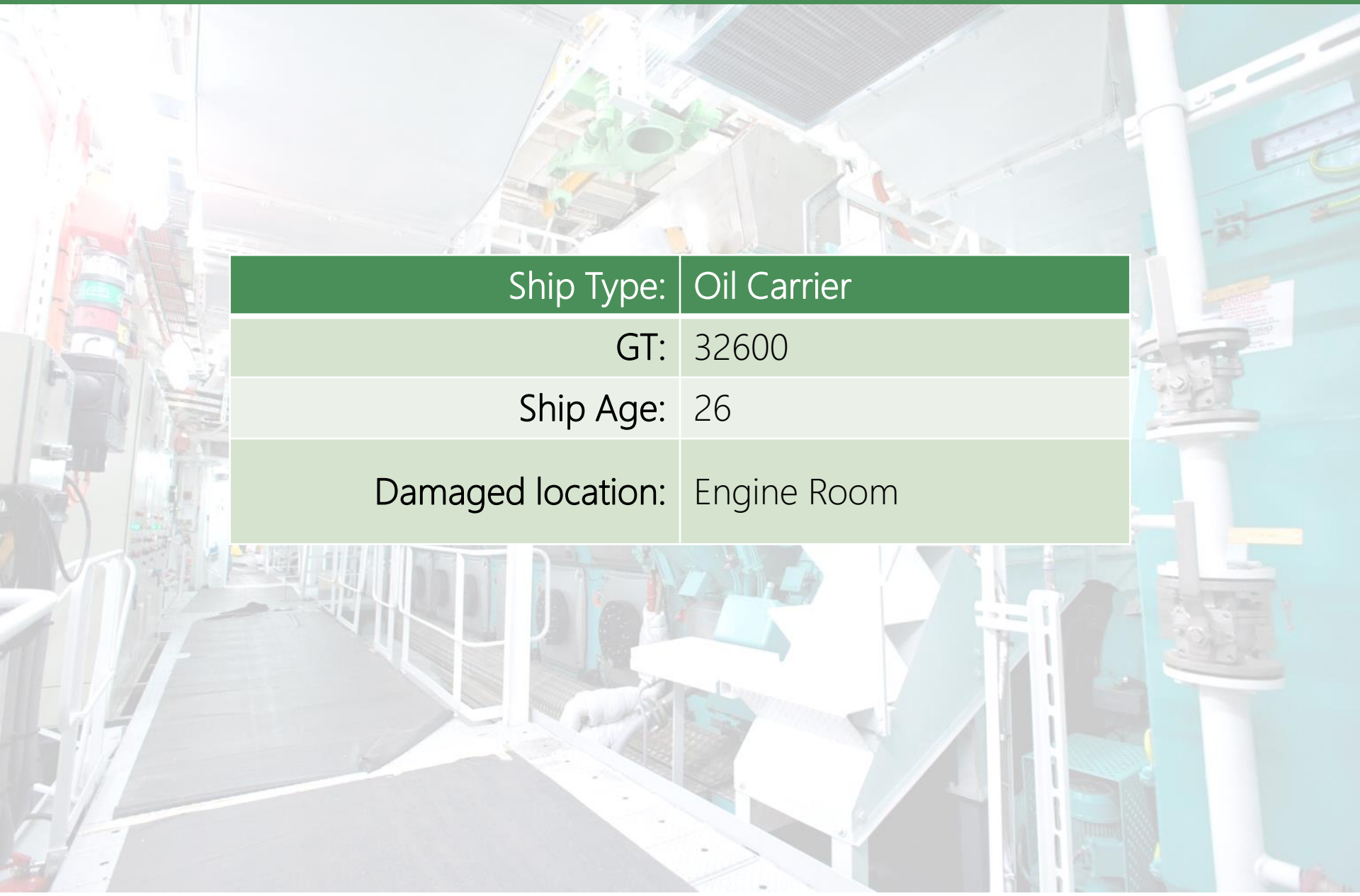




Over-tightening at installing

Disconnection due to hull vibration during voyages

# Others: Fire in engine room (Case 2)



| Ship Type: | Oil Carrier |
|---|---|
| GT: | 32600 |
| Ship Age: | 26 |
| Damaged location: | Engine Room |

# Others: Fire in engine room (Case 2)

E/R fire alarm sounded during voyage

↓

Main Engine was stopped

↓

Emergency fire pump was started

↓

Black smoke and intense heat prevented access to E/R + the emergency fire pump was stopped

↓

E/R burnt down and fire was extinguished 10 hours later. Three crew members died.

# Others: Fire in engine room (Case 2)

## Damaged condition

Inside of Engine Control Room

Outside of Engine Control Room

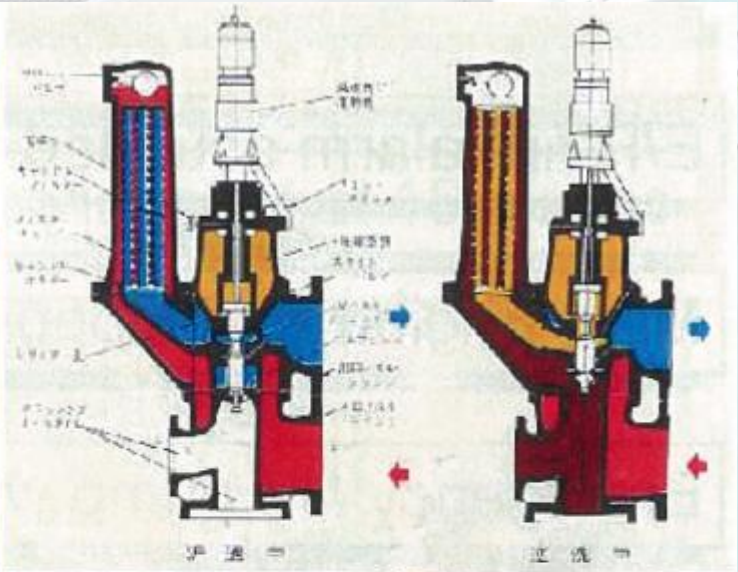
## Damaged condition

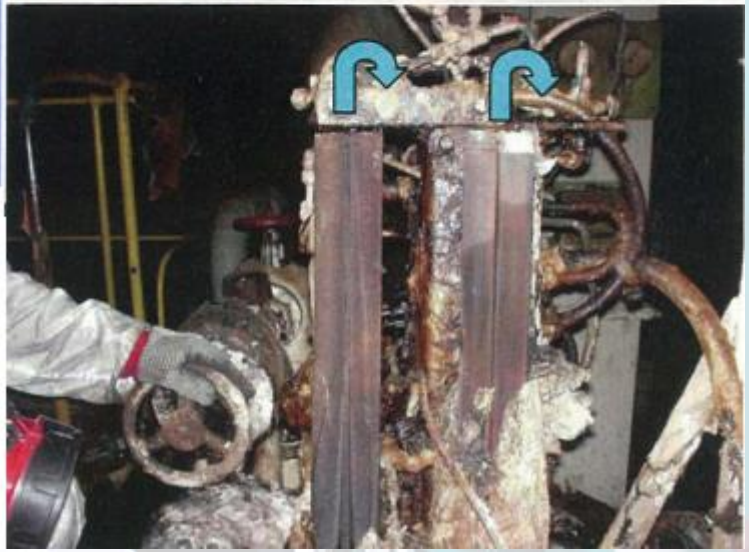
**Condition of the 2nd FO Filter**

Most severely burnt and its cover was completely burnt down

- Replaced with the automatic back flushing filter with aluminum cast cover after the ship was built

The Classification Society did not mention the use of aluminum cast in E/R when the ship was built





## Investigation results

**Condition of Exhaust Gas Expansion Joints of the M/E**

No suitable enclosures or lagging

2003/07 Oil Fuel Arr. (SOLAS amendment) in force

2003/08 Class Confirmed

Lagging may have been removed after the compliance survey

# Others: Fire in engine room (Case 2)

## Causes

Due to unknown reasons,
F.O. sprayed from 2nd F.O. filter of the M/E

The F.O. touched exhaust gas expansion joints

A fire broke out

**Reasons for the expansion of the fire**

Enclosures/lagging were removed from expansion joints

Cover of the 2nd F.O. filter of the M/E was made of aluminum cast which melted by flames

Leakage of large amount of F.O.

## Checkpoints

Special attention must be paid to all machinery and equipment in FO pipe lines during routine inspection

Prevent FO leakage i.e. the source of ignition

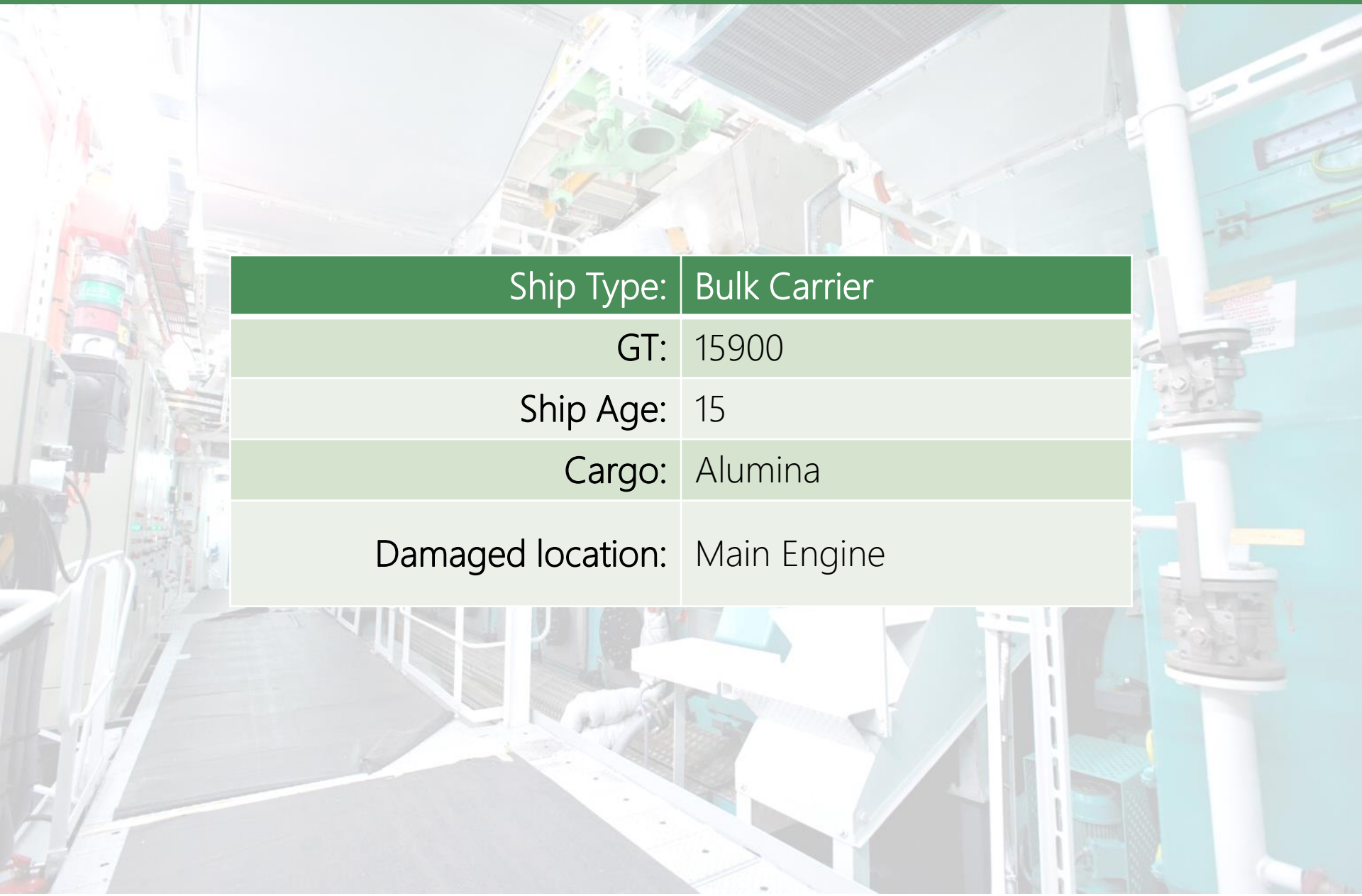
Routine inspection of laggings on high temperature parts

Reduce the risk of ignition even if FO leaks

Visual inspection of fixed $CO_2$ gas pilot lines (copper)

Prevent slack and/or disconnection due to hull vibration

# Others: Damage due to alumina (Case 3)



| Ship Type: | Bulk Carrier |
|---|---|
| GT: | 15900 |
| Ship Age: | 15 |
| Cargo: | Alumina |
| Damaged location: | Main Engine |

# Others: Damage due to alumina (Case 3)

## Report

M/E rpm was reduced during voyage

Found that no FO was supplied to the combustion chamber of M/E

Piston rings, FO valves, cylinder liners etc. were scored.

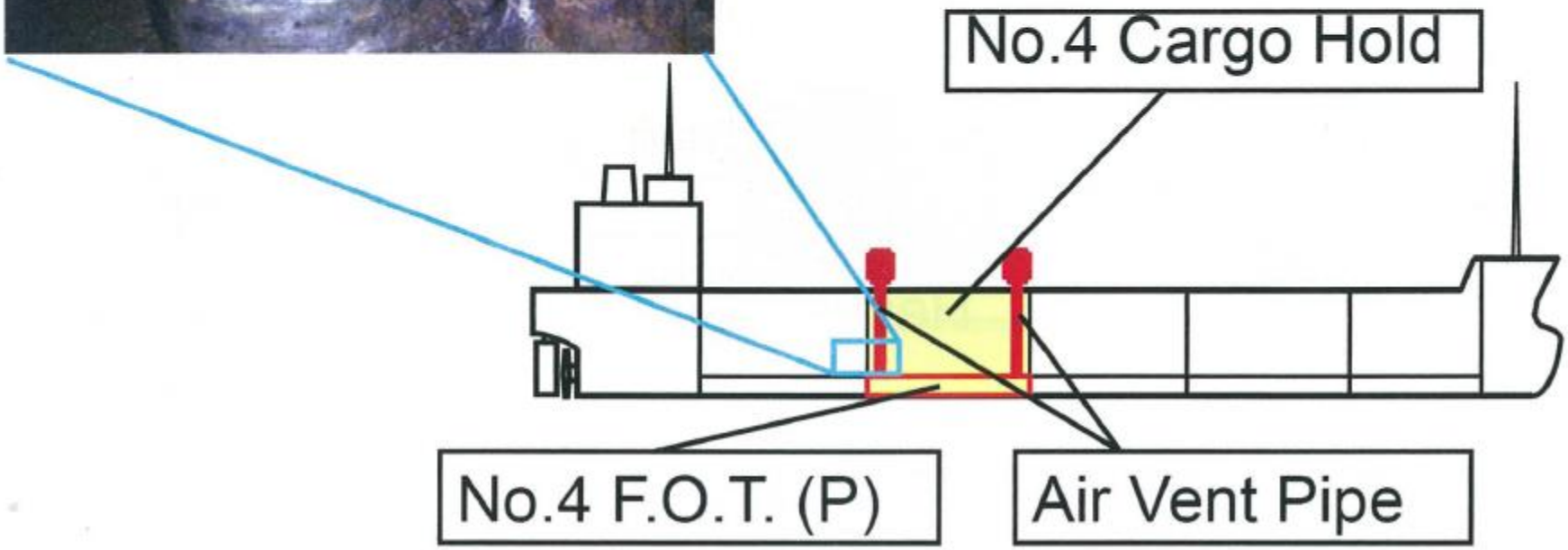
Running M/E was suspended and the ship had to be towed

# Others: Damage due to alumina (Case 3)

## Investigation result

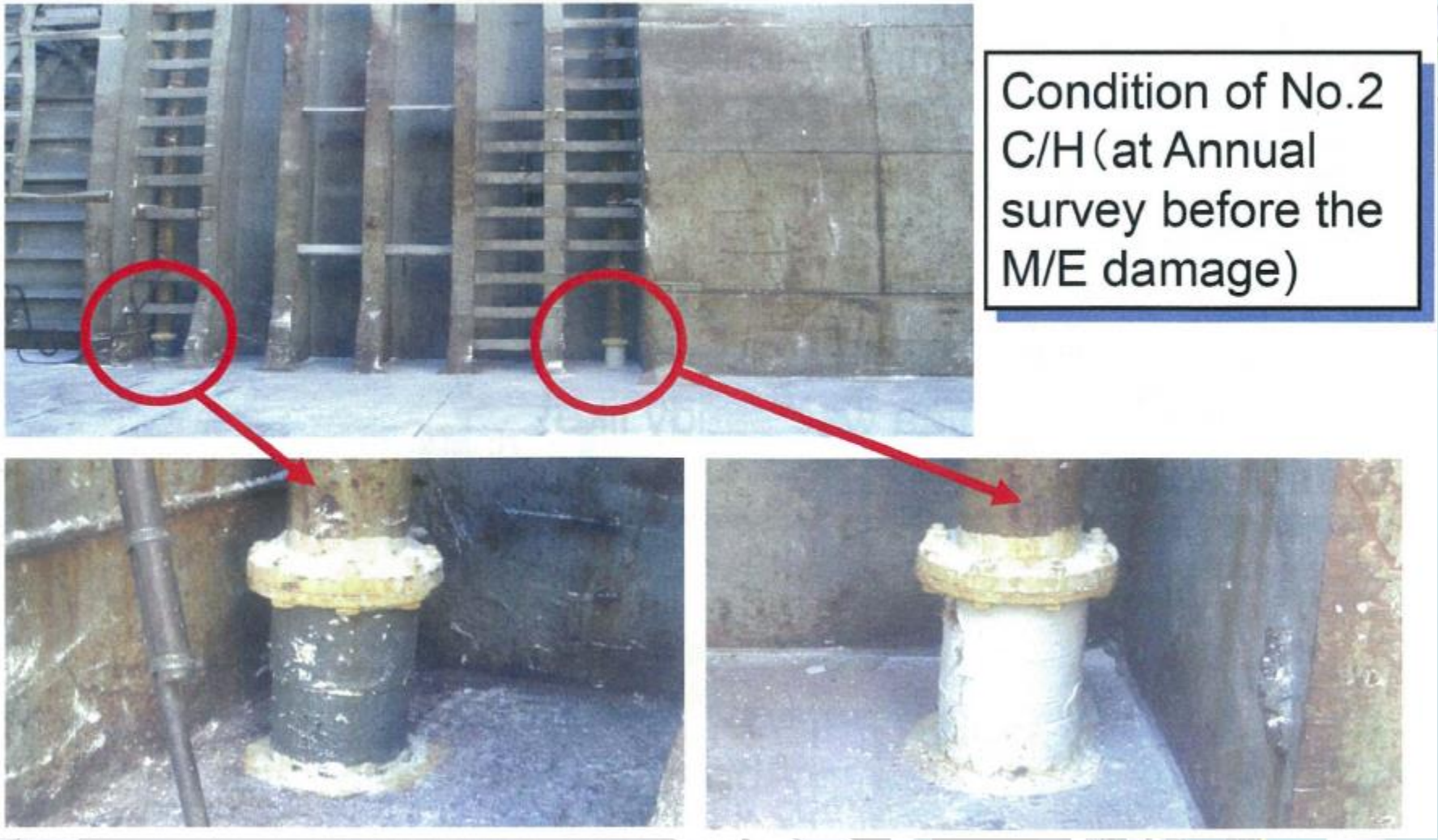
Small holes at temporarily repaired part of air vent pipe for FOT

Split pipes were taped as a temporary repair.



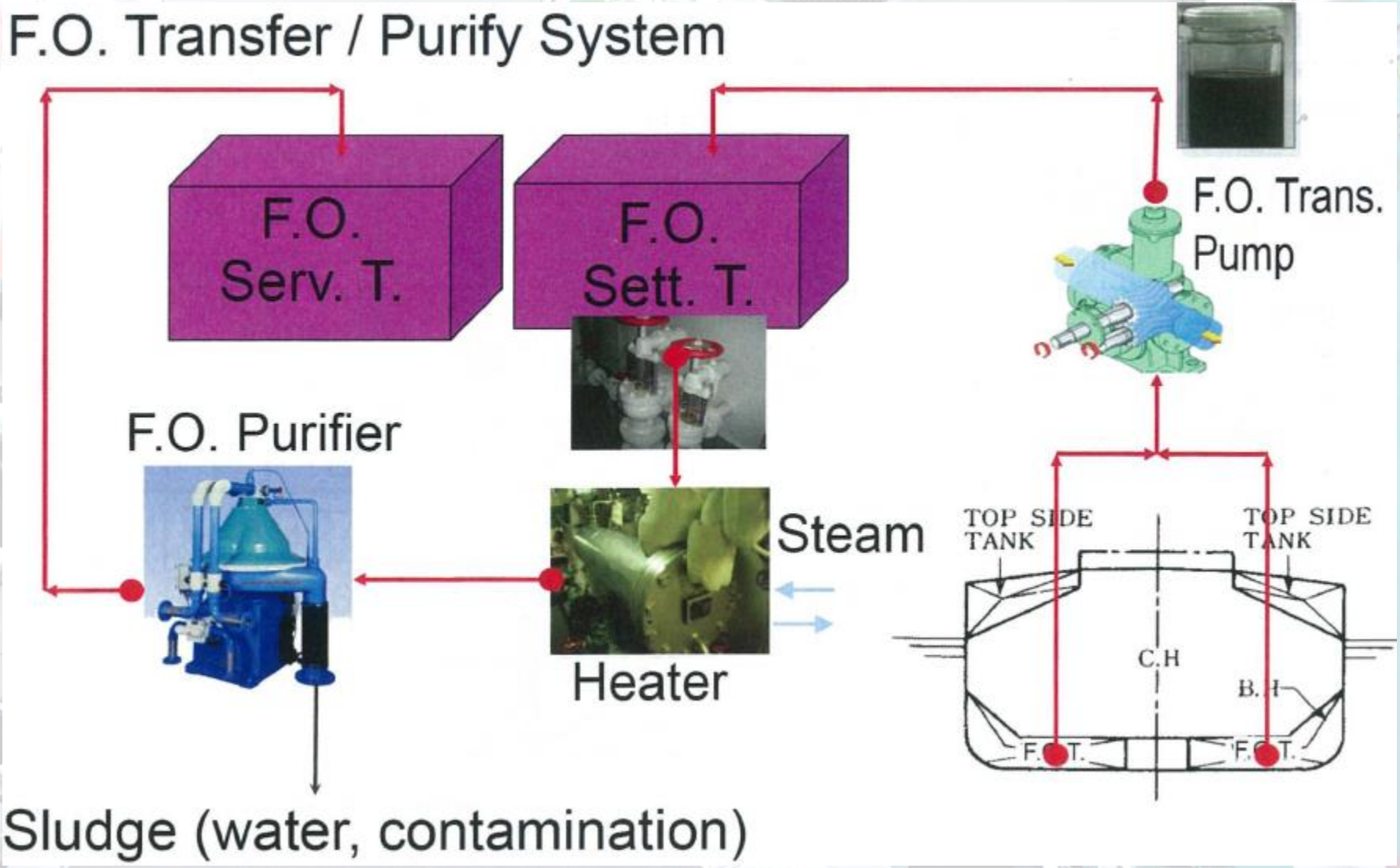
# Others: Damage due to alumina (Case 3)

## Investigation result



# Others: Damage due to alumina (Case 3)

## Investigation result



# Others: Damage due to alumina (Case 3)

## Investigation result

Analysis of FO:
- Large quantity of aluminum in No.4 FOT(P) & FO Sett./Serv.T.

Properties of alumina (general):
- Particle sizes: 5-50μ
- Particles adverse to combustion: 10-20μ
- Density : 3.97g/㎤
- The remaining alumina was sandy like sands in an hourglass.

Left: Remaining alumina
Above: FO tank with alumina
(photograph of another ship)

# Others: Damage due to alumina (Case 3)

## Investigation result

**Conditions after alumina mixed with FO**

The finest FO filter of M/E ＝50μ

Harmful alumina particles passed through and M/E was damaged.

The finest FO filter of G/E ＝10μ

No G/E was damaged as harmful alumina particles were captured.

# Others: Damage due to alumina (Case 3)

## Checkpoints

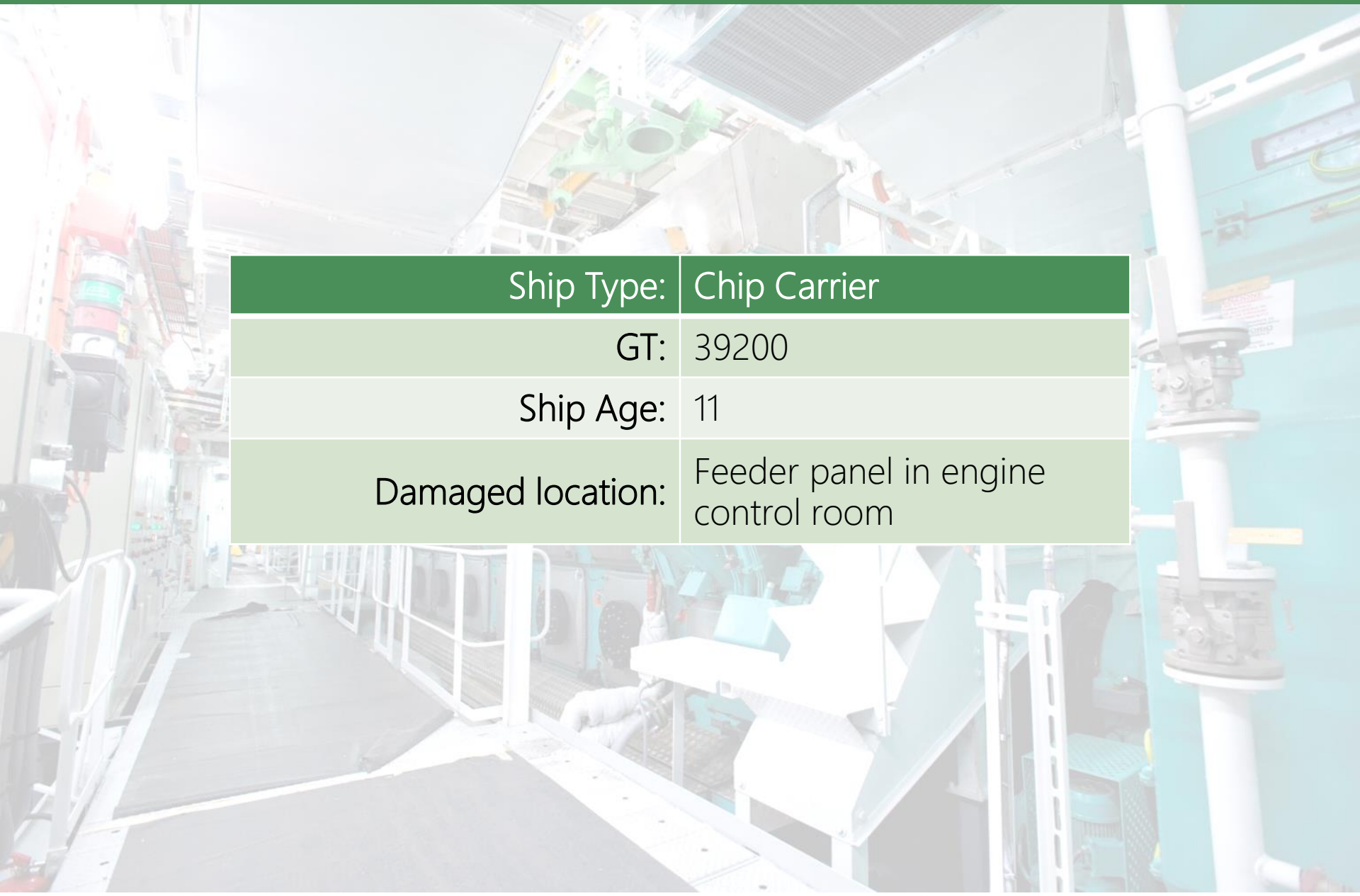
**4) When risk of contamination of FOT by alumina etc. exists**

- FO analysis
- Use FO from other tanks
- Parallel use of FO purifiers

**5) Examples of countermeasures by shipping companies**

- Modification of Air Vent Pipes from SGP to STPG（Sch-80） (new ship)
- Addition of flanges to Air Vent Pipes directly above FOT (existing ship)
  → filling Air Vent pipes with water is effective to find if a hole exists

# Others: Fire of feeder panel (Case 4)



| Ship Type: | Chip Carrier |
|---|---|
| GT: | 39200 |
| Ship Age: | 11 |
| Damaged location: | Feeder panel in engine control room |

# Others: Fire of feeder panel (Case 4)

## Report

Situation: Ballasting into No.4 cargo hold was completed

Low insulation alarm was triggered

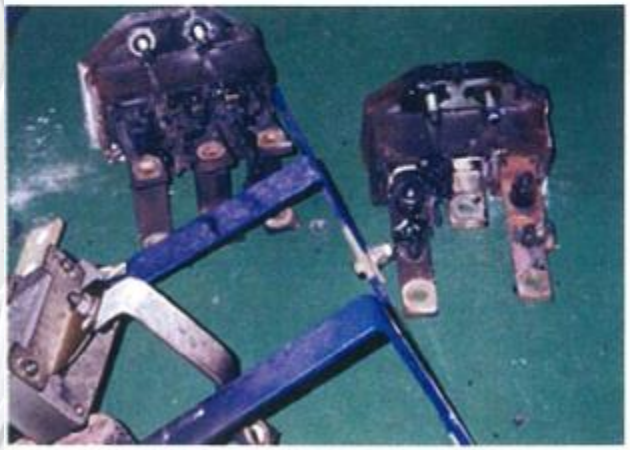
Engineer confirmed this at the engine control room

- Fire in the back of 440V feeder panel (smoke and sparks)
- Sound of water flowing & falling

Fire was extinguished with portable fire extinguisher

# Others: Fire of feeder panel (Case 4)

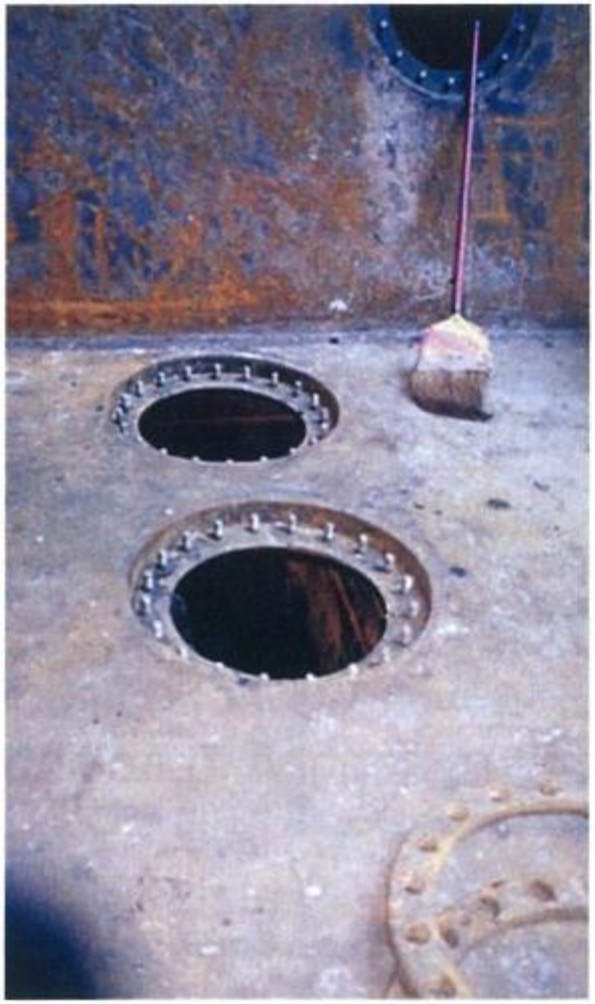
## Damage condition



Most of electrical parts in 440V feeder panel became non-usable

# Others: Fire of feeder panel (Case 4)

## Causes



The manhole cover of bilge well that located between No.4 cargo hold and void space had not been tightened enough.

When ballasting into No.4 cargo hold, ballast water invaded the void space

## Causes

**Ballast water invaded the void space**

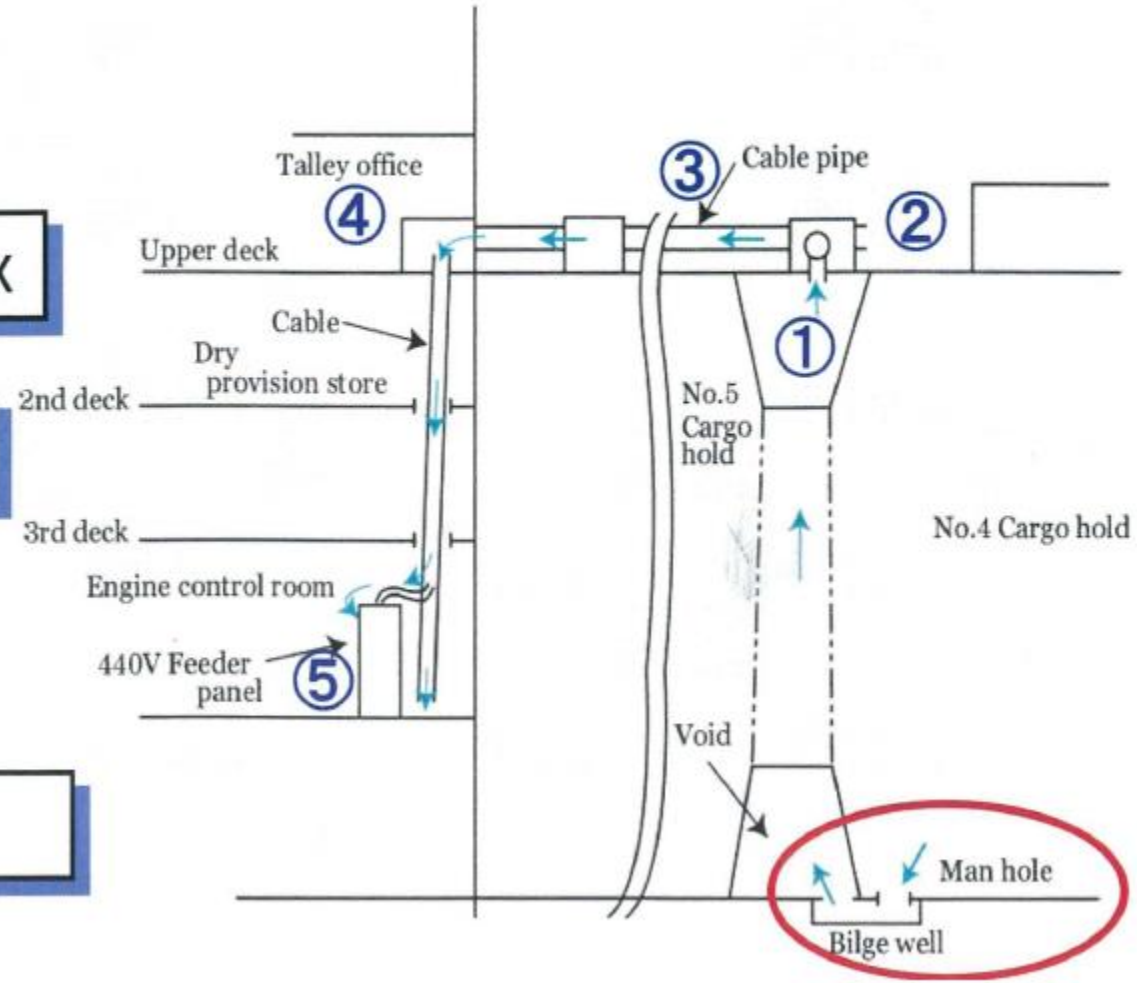
1) Cable pipe

2) Cable expansion box

3) Cable pipe on deck

4) Talley office

5) Engine control room



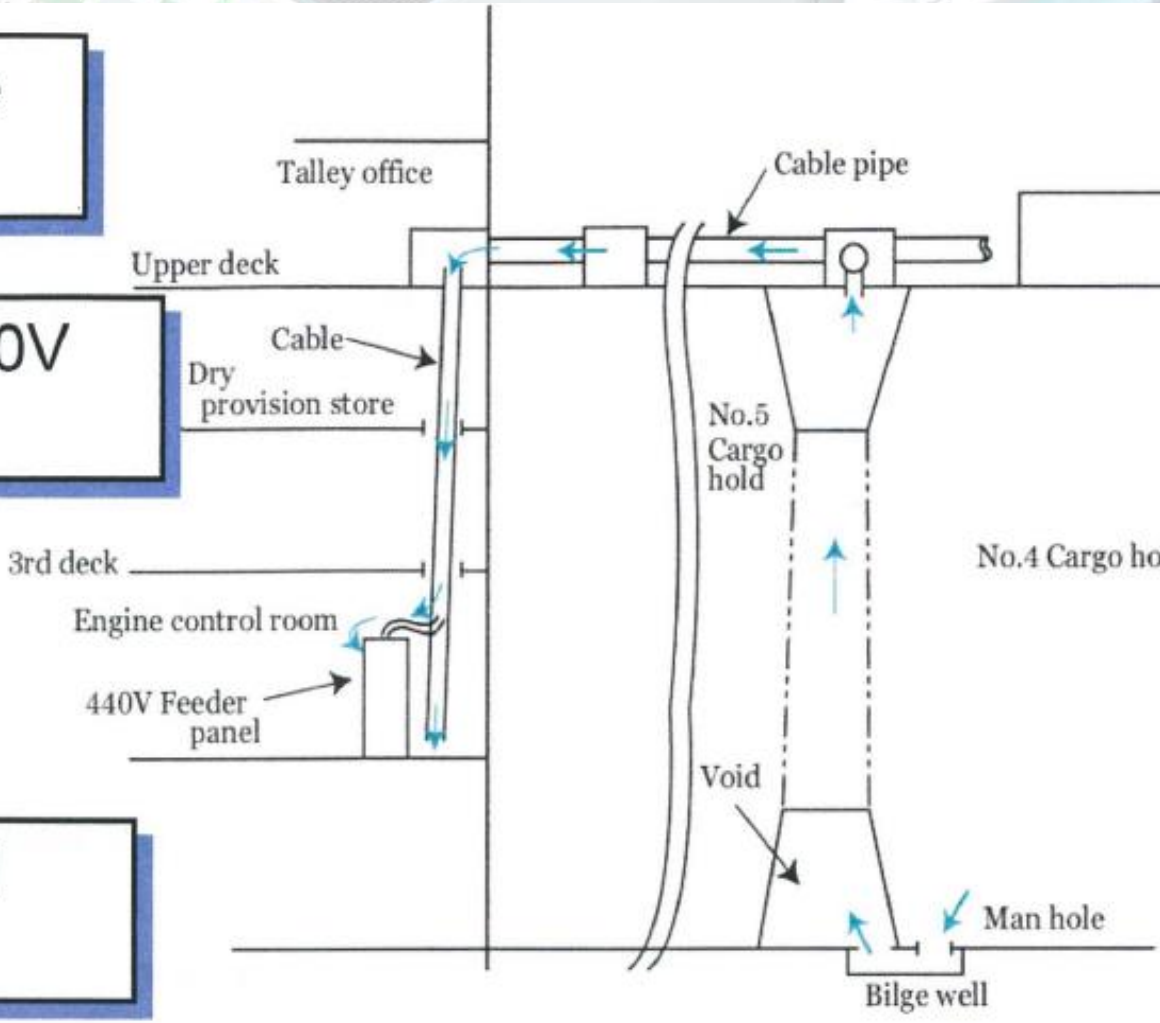
## Causes

Ballast water invaded the Engine control room

Invaded upper part of 440V feeder panel

Water reached the inside of the panel

Panel short-circuited and overheated.



## Checkpoints

Main cause:
Insufficient tightening of the manhole cover of bilge well

Firm confirmation before ballasting

Sounding the void space

If the sounding was done, the invading of ballast water into void space would have been confirmed.

# CONCLUSIONS

1. In these introduced cases as serious damages, there are many accidents as cracks, fractures, breakages, fire/explosions, etc. due to compound of initial cause and others causes.

2. Almost half of initial cause (22 cases in 28 cases) is the mishandling (poor maintenance, mis-operation/mis-monitor, insufficient repair).

3. Rate of damage around combustion chamber of main engine, turbocharger is big. But the few causes are due to some problem of equipment and a lot of causes are due to low quality of fuel oil.

4. For minimizing the mishandling
   - Effective usage of safety management system (machinery maintenance plan)
   - Sufficient education/training to person in charge of operation and person in charge of repair
   - Close maintenance of fuel oil, lubricate oil

# END

## 2B: Machinery Systems

In compliance with the IMO resolution MSC.349(92) and MEPC.237(65), RO Code, Appendix 2.