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The Dual Fuel Hydrogen Engine Pioneer Project

Dr. Eng. Jorge Antunes CEO – TecnoVeritas

SERVICES OF ENGINEERING AND SYSTEMS TECHNOLOGY

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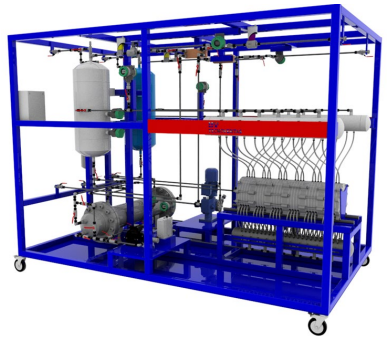
Hydrogen Pioneer Dual Fuel Hydrogen Diesel Engine

- About Hydrogen Pioneer Project (why?)
- The partners;
- The technical challenges;
- Hydrogen on board LOHC;

General View of the Project

Electroliser of high efficiency



Hidrgenation /De-hidrogenation

Diesel Engines Conversion

About the Hydrogen Pioneer Project, why?

- Decarbonization is in the order of the day, being a pre-requisite for a sustainable touristic operation in environmentally sensitive areas;
- The use of Green Hydrogen on Diesel engines, produces a decarbonization equal to the percentage of the substitution ratio in terms of energy;
- A Dual Fuel MGO Hydrogen, is always capable of ensuring propulsion and energy, in case of lack of hydrogen;
- A Diesel Dual Fuel engine is extremely reliable, and cheaper than a corresponding fuel cell;
- The Hydrogen fuel for a Diesel engine, is about 25% cheaper than that required for a Fuel Cell, because of purity;

About the Hydrogen Pioneer Project (why?)

The "**Hydrogen Pioneer Project**" is a collaborative association of **Mitsubishi MTEE**, **TecnoVeritas** and **Progener**.

TecnoVeritas know how (since 1998) on Dual Fuel ICE and Hydrogen is the R&D partner. Developing the hardware and software to convert the Mitsubishi engine **S6R2 T2MPTK5** to Dual Fuel Diesel hydrogen operation, **Progener** will assemble the engine and alternator, delivering the alternator set.

HyChem, the older green hydrogen manufacturer in Portugal, is receiving the engine in one newly built dedicated lab for the R&D activities;

Douro Azul, Douro River cruises operator, will be receiving the converted engine(s) in one of their new buildings and will be cooperating in terms of requirements;

Bureau Veritas, a major Classification Society will be working with all the others to arrange a Type Approval Certification, and develop the required rules for the use of ICE Dual Fuel Operation on board vessels.

Project considerations

The presente project relies on the extensive use of LOHC as a safe carrier of hydrogen:

1º It allows the storing, transportation and bunkering of considerable quantities of hydrogen safelly, namely in what concerns the SOLAS regulations regarding the ignition temperature of fuels;

2º Ship tanking compatibility with LOHC;

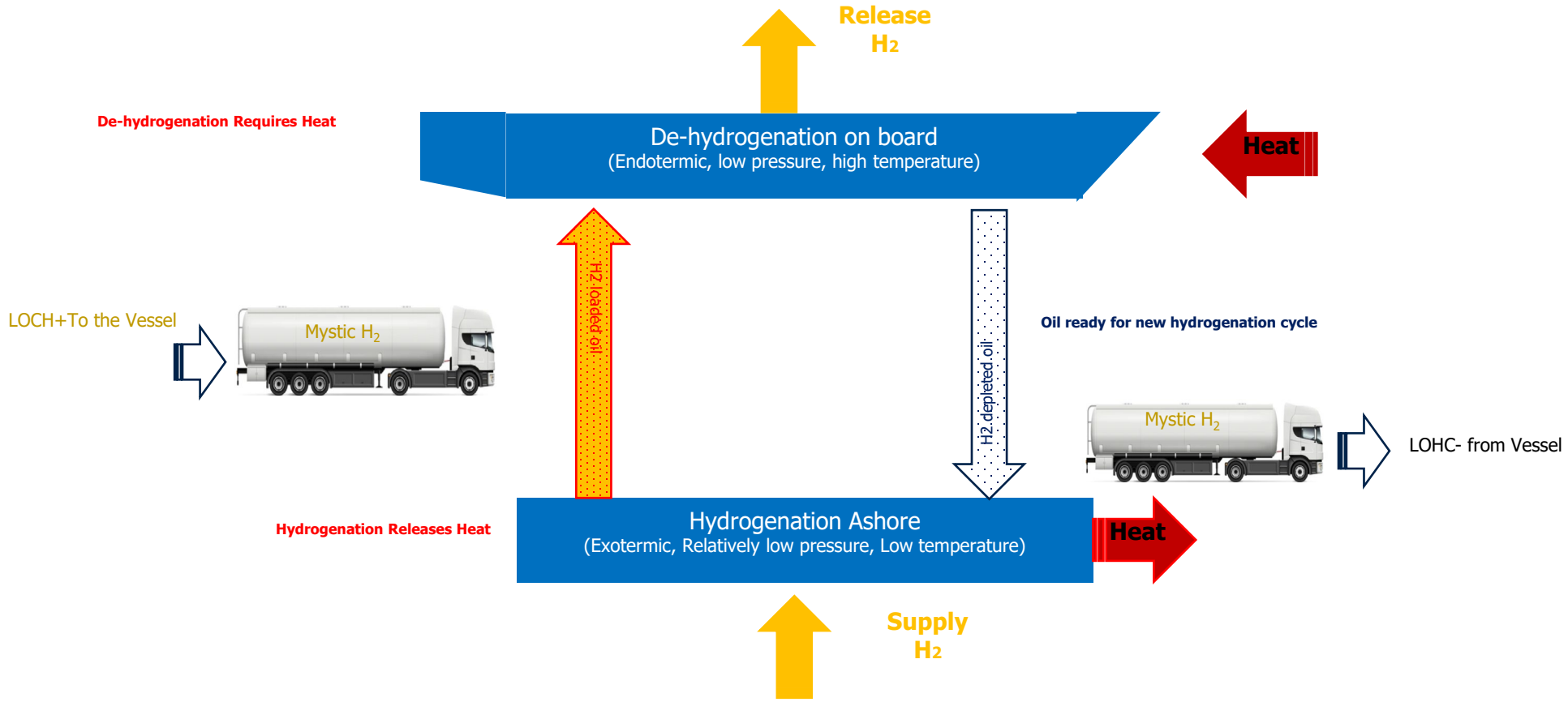
3º Existance of heat sources required for the activation of the de-hydration reactor;

4º Knowledge available at TecnoVeritas in what concerns the use of Hydrogen as fuel for compression ignition engines (various works and papaers about the theme)

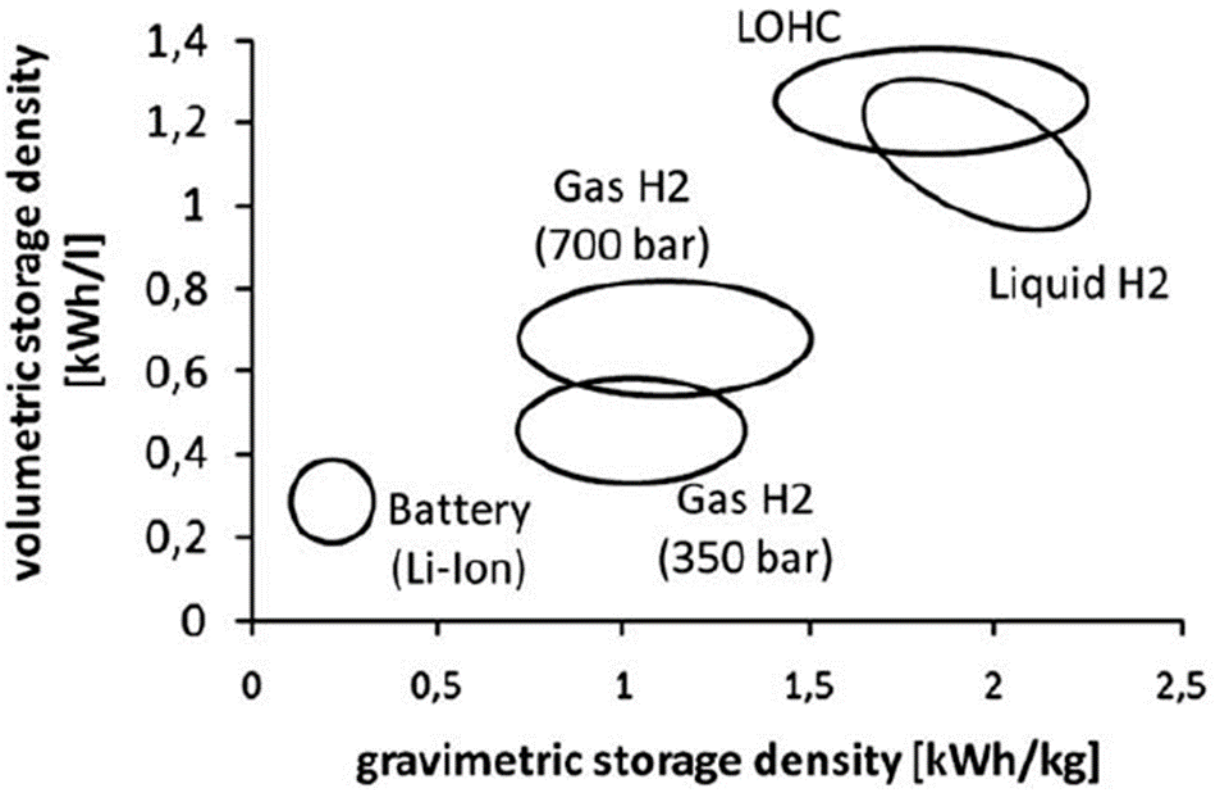
5º Strong support of the National Authorities as well as of the European Union on decarbonisation;

6º Douro Azul, will act as a lead demonstrator of the technology.

Hydrogen onboard using LOHC



Energy density comparision



Wolfgang Arlt,*b Peter Wasserscheidb and Raymond Freymanna

Considerations on the decarbonization project

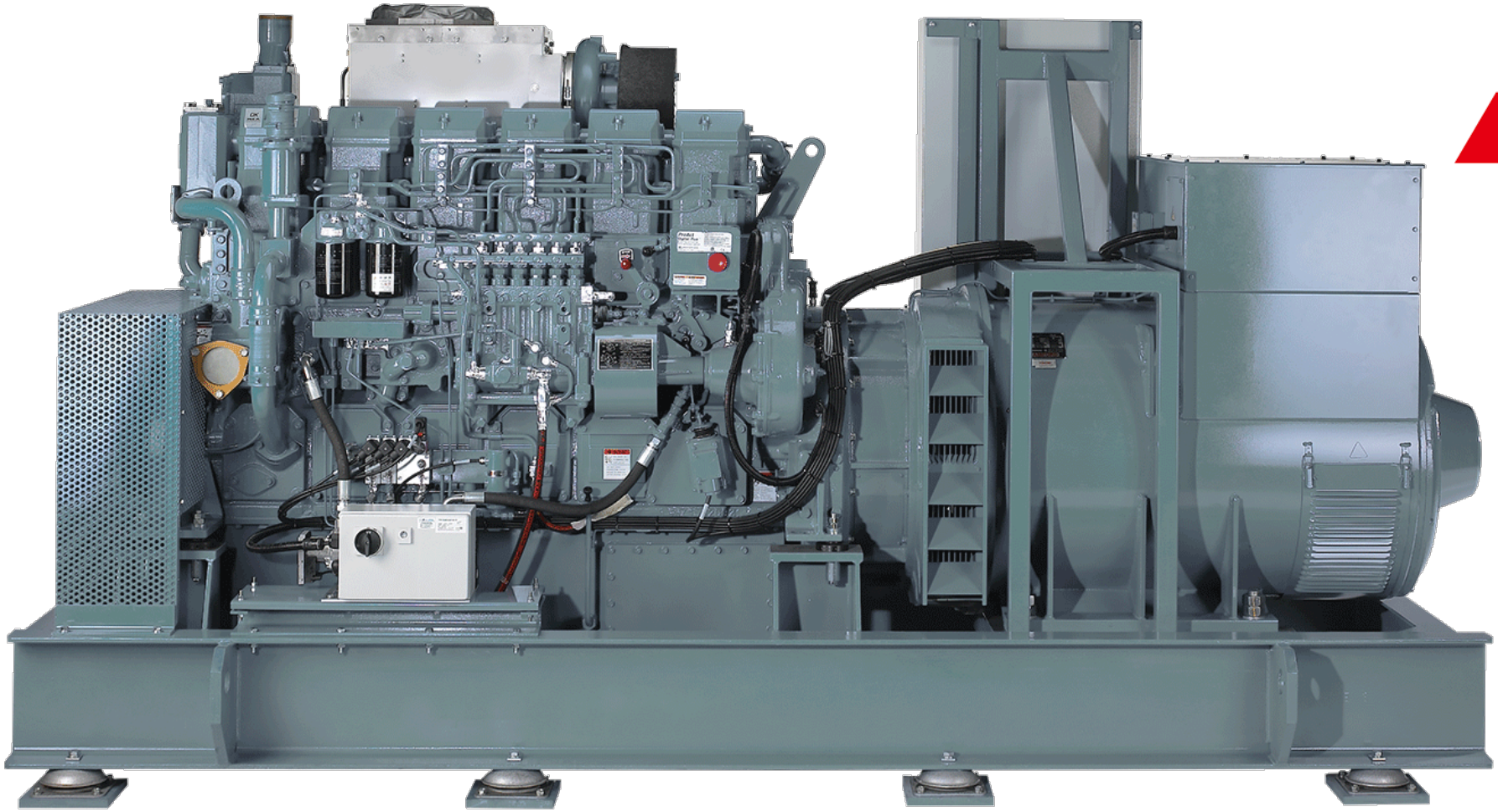
Diesel Hydrogen dual fuel technology is:

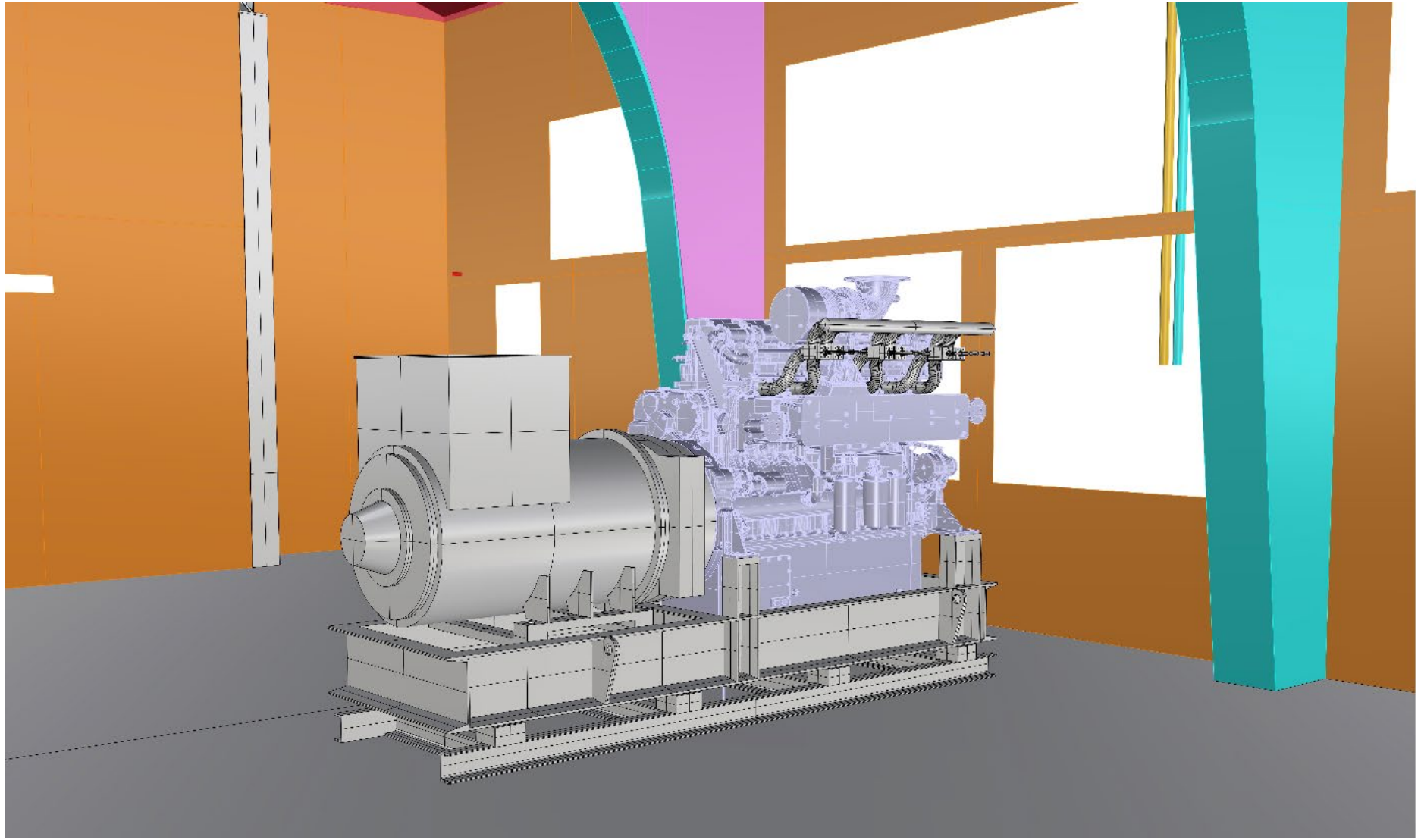
- Sufficiently reliable and flexible;
- Do not require high purity hydrogen, therefore less expensive and fuel redundant;
- Not limited in terms of power (torque and Inertia);
- High ratios of power to weight and power to volume;
- Cheap, and ready available;
- Do not required highly specialised maintenance man power;
- No need for cryogenic tanks (that make these projects economically inviable (cost and time);
- Minimised gaseous hydrogen piping;
- No need for high pressure (350-900bar) tubes;
- No dependence on hydrogen, propulsion at full power is always available with Diesel fuel.

The challenges of the project

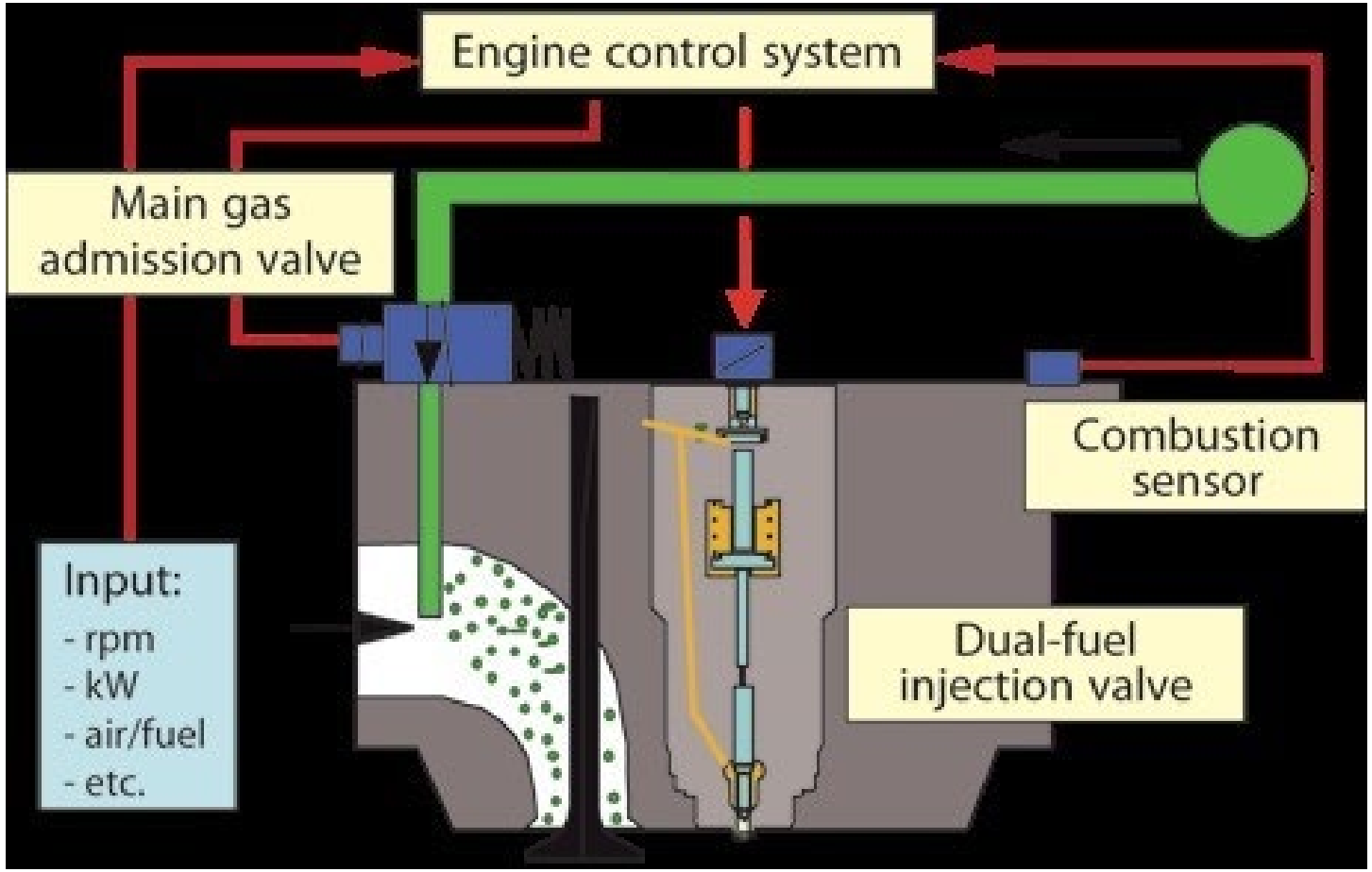
- Lack of regulations for hydrogen as a fuel, namelly from SOLAS (Ignition temperatures 60ºC)/LHOC;
- Possible use of IGC regulations as a first step;
- New to Classification Societies (Regulations needed);
- Easy to implement LOHC capacity (volume) in a new project, may be challanging for an existing ship (permanente ballast, loading conditions/stability);
- Lobby of FC – Hydrogen does not mean Fuell Cell !!!;
- “Warranties”;
- Possible production of Hydrogen on board, by using wast heat (Organic Rankine Cylcle);
- COVID19/Cruise Market impact

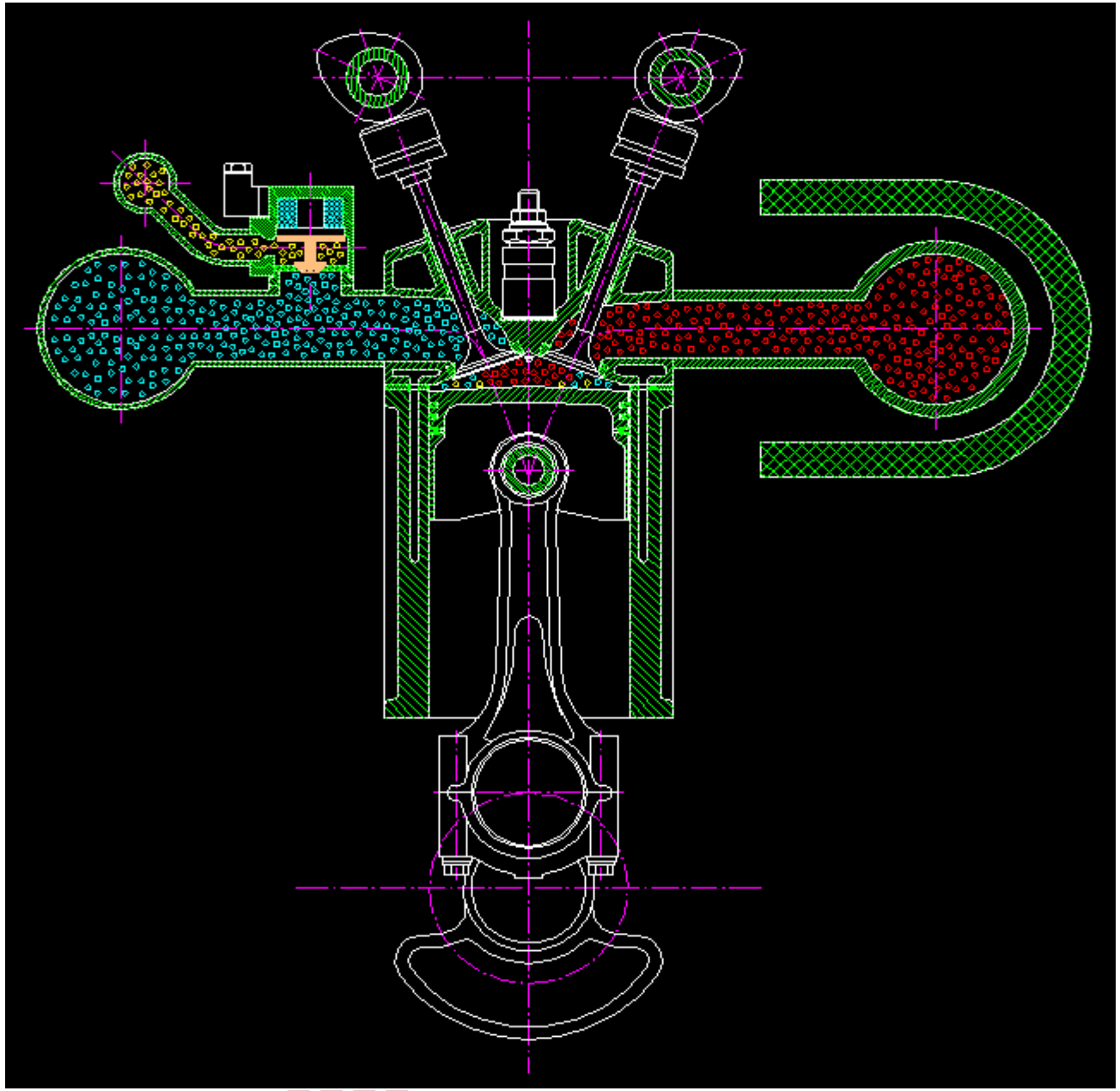
The S6R2-T2MPTK-5 1500rpm pilot engine





The technical challenges;





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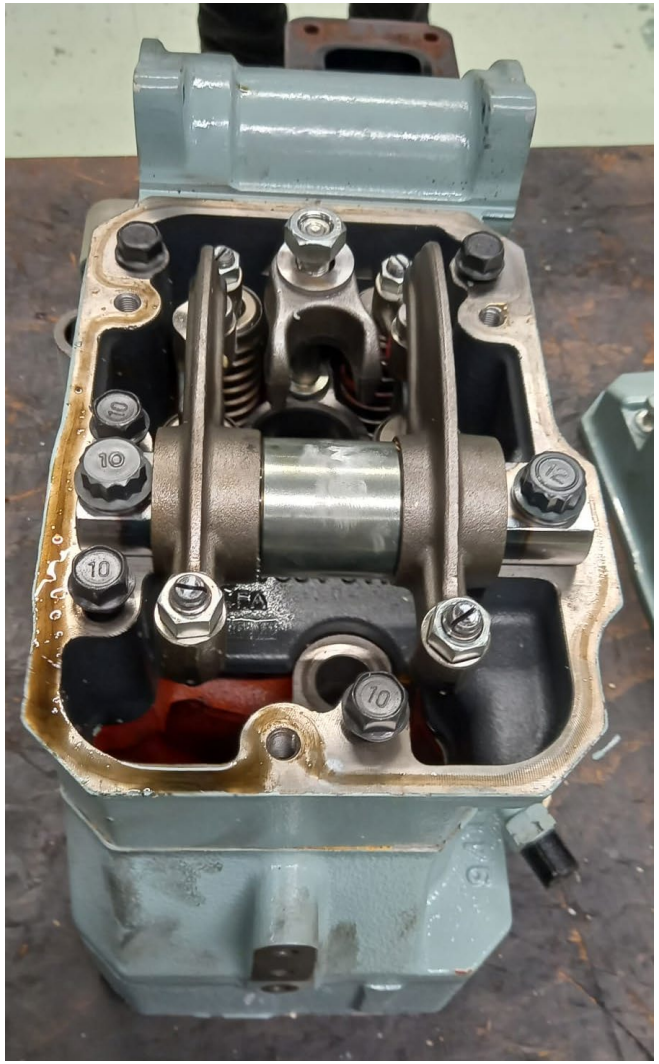
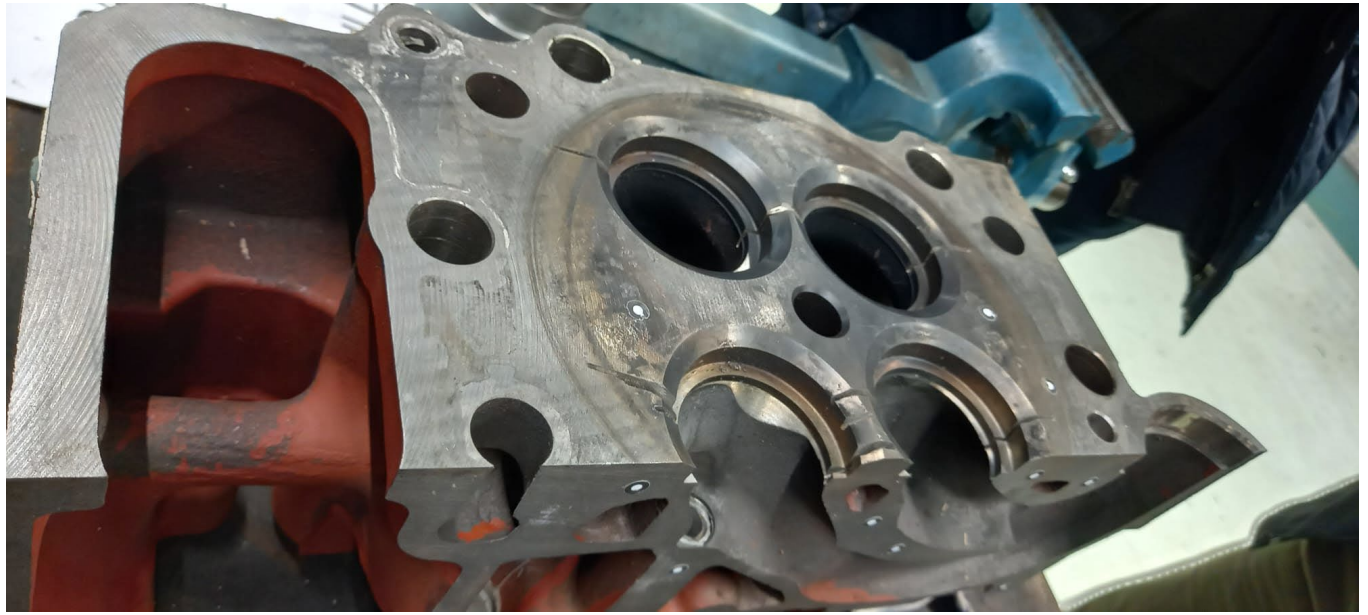
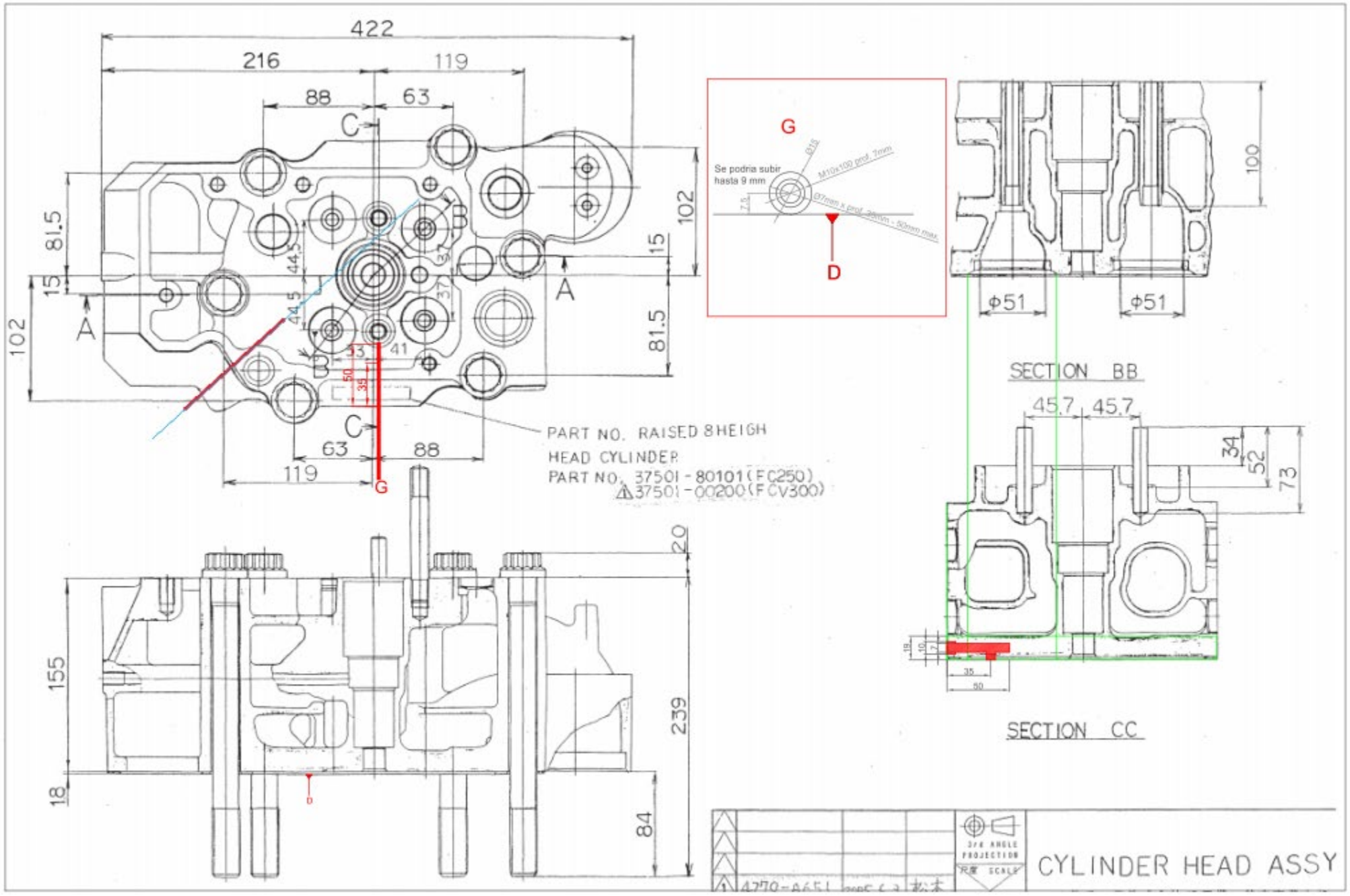
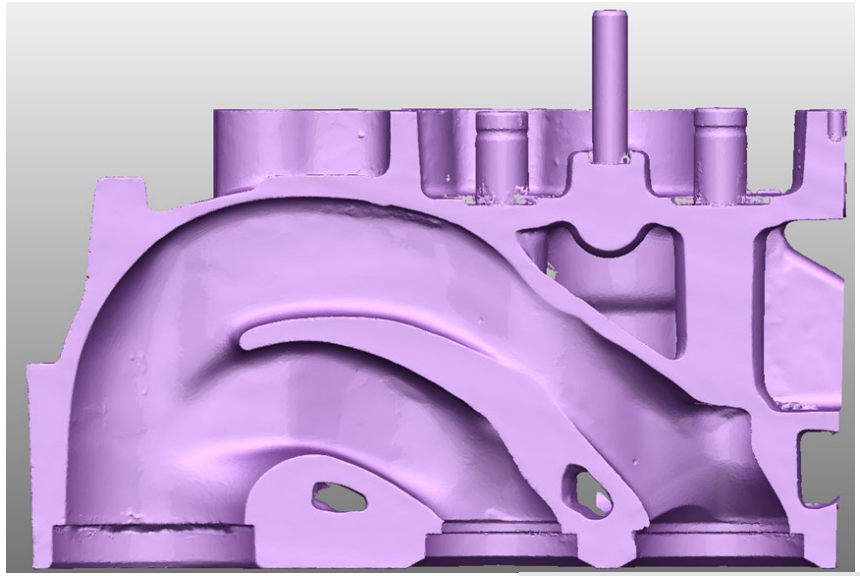
CENTRE FOR MARINE TECHNOLOGY AND OCEAN ENGINEERING

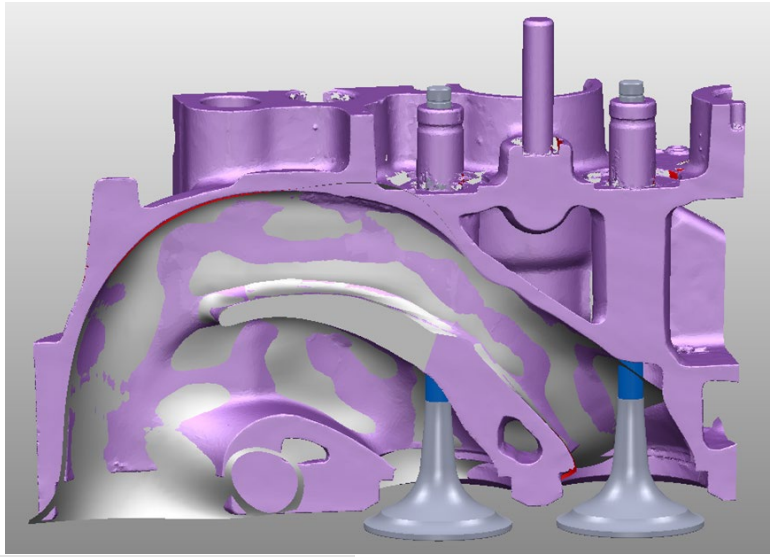


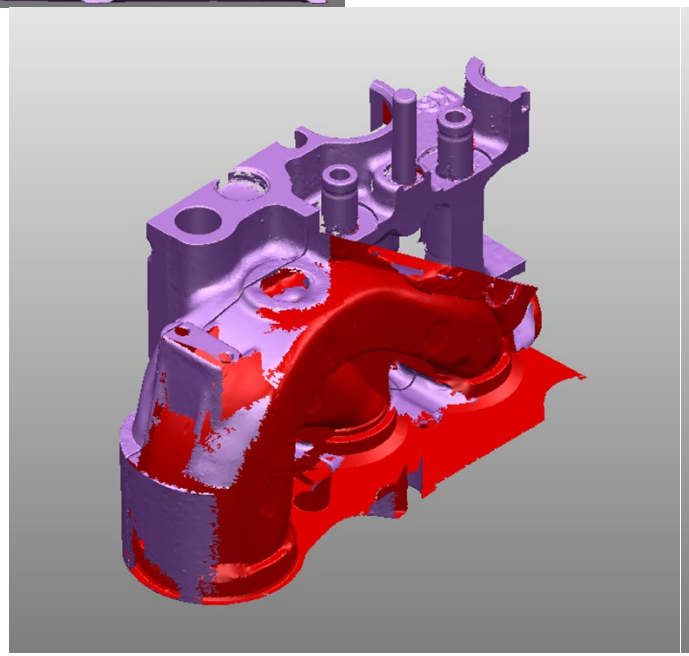


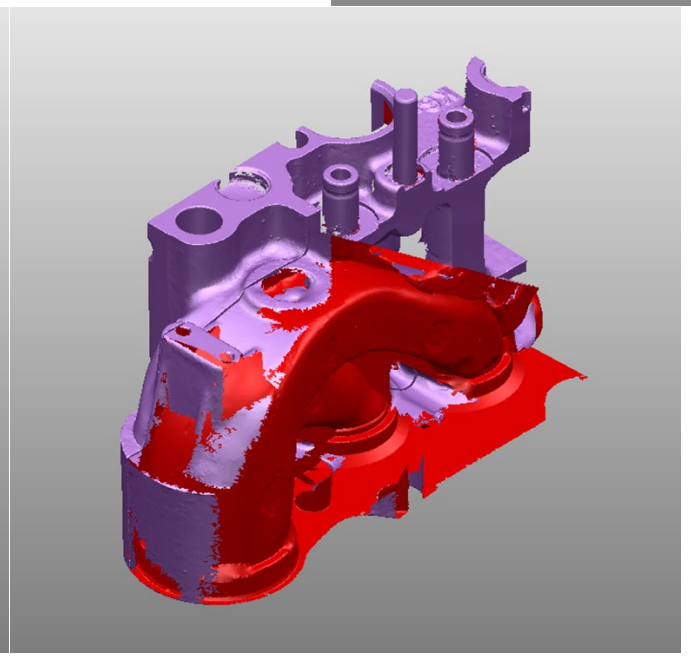

422
216
119
88
63
C
81.5
15
102
A
44.5
37
33
41
50
35
B
G
PART NO. RAISED 8HEIGH
HEAD CYLINDER
PART NO. 37501-80101(FC250)
37501-00200(FCV300)
G
Se podria subir
hasta 9 mm
D
100
φ51
φ51
SECTION BB
45.7
45.7
34
52
73
SECTION CC
155
18
239
84
20
CYLINDER HEAD ASSY

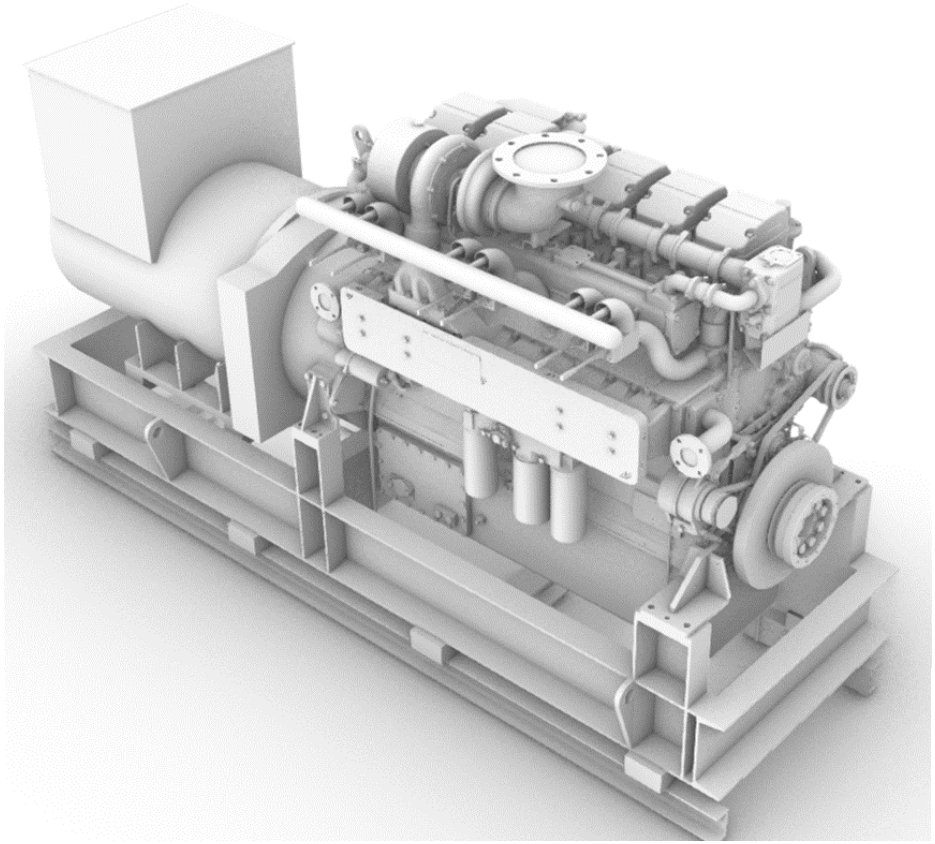
Cylinder head modelling

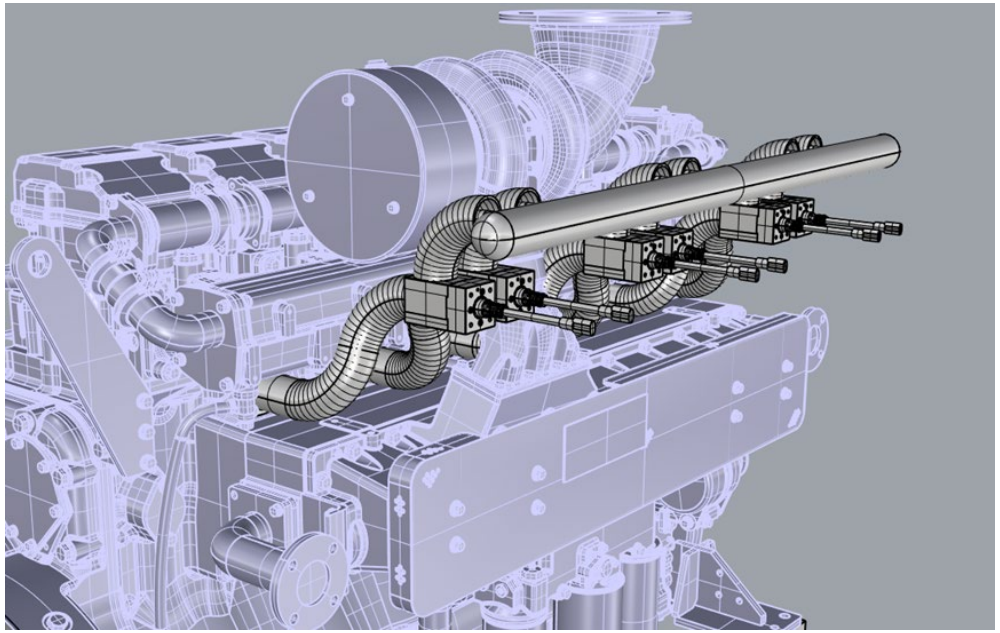


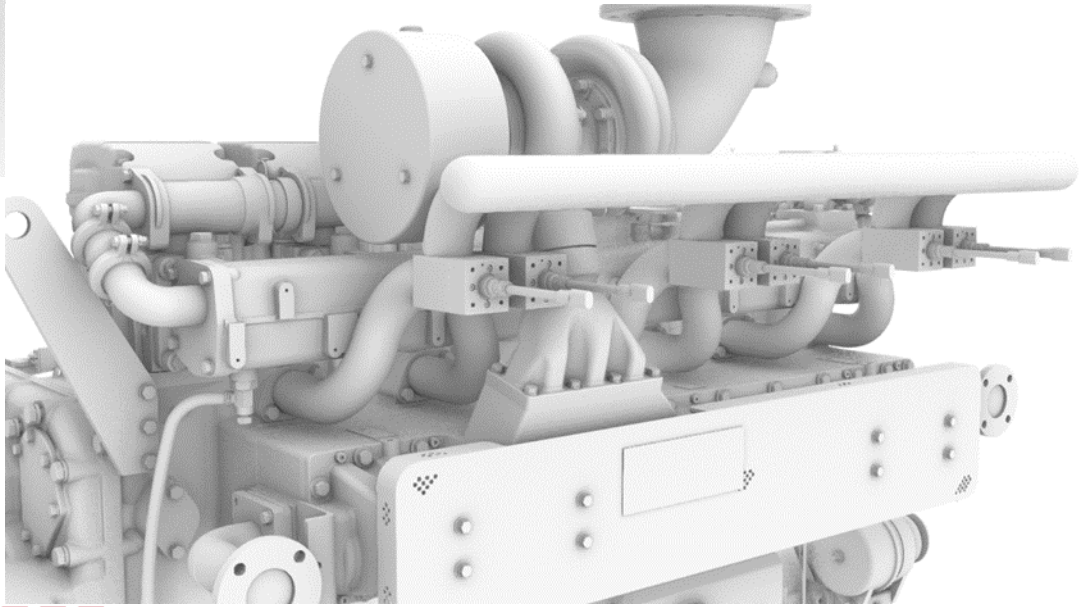












Modelling of positioning of hydrogen valves

Type of vessels to receive the project

N/M AMADOURO”

Possible engine room arrangement impacts

	Advantage	Disadvantage
ESD Room	• No ATEX material required for external parts • Easy maintenance due to direct access to the gas train components • Relatively "cheap" solution with simple geometry	• At least 2 independent engine rooms mandatory • Ventilation rate ≥ 30 room content • Less redundancy • Not allowed above 10 bar (g)
Gas Safe Area	• Each gas engine can be placed in the same GSA – no separate machine rooms needed • Ventilation of outer section of piping and enclosure only	• Always Zone 1 requirement • The enclosure is expensive • Maintenance is time consuming and difficult to handle

Gas safe machinery spaces are safe under all conditions. A single failure cannot lead to release of fuel gas into the machinery space. All fuel piping within machinery space boundaries shall be double walled.

ESD-protected machinery spaces are non-hazardous under normal conditions, but may become hazardous.

Machinery space of gas engine

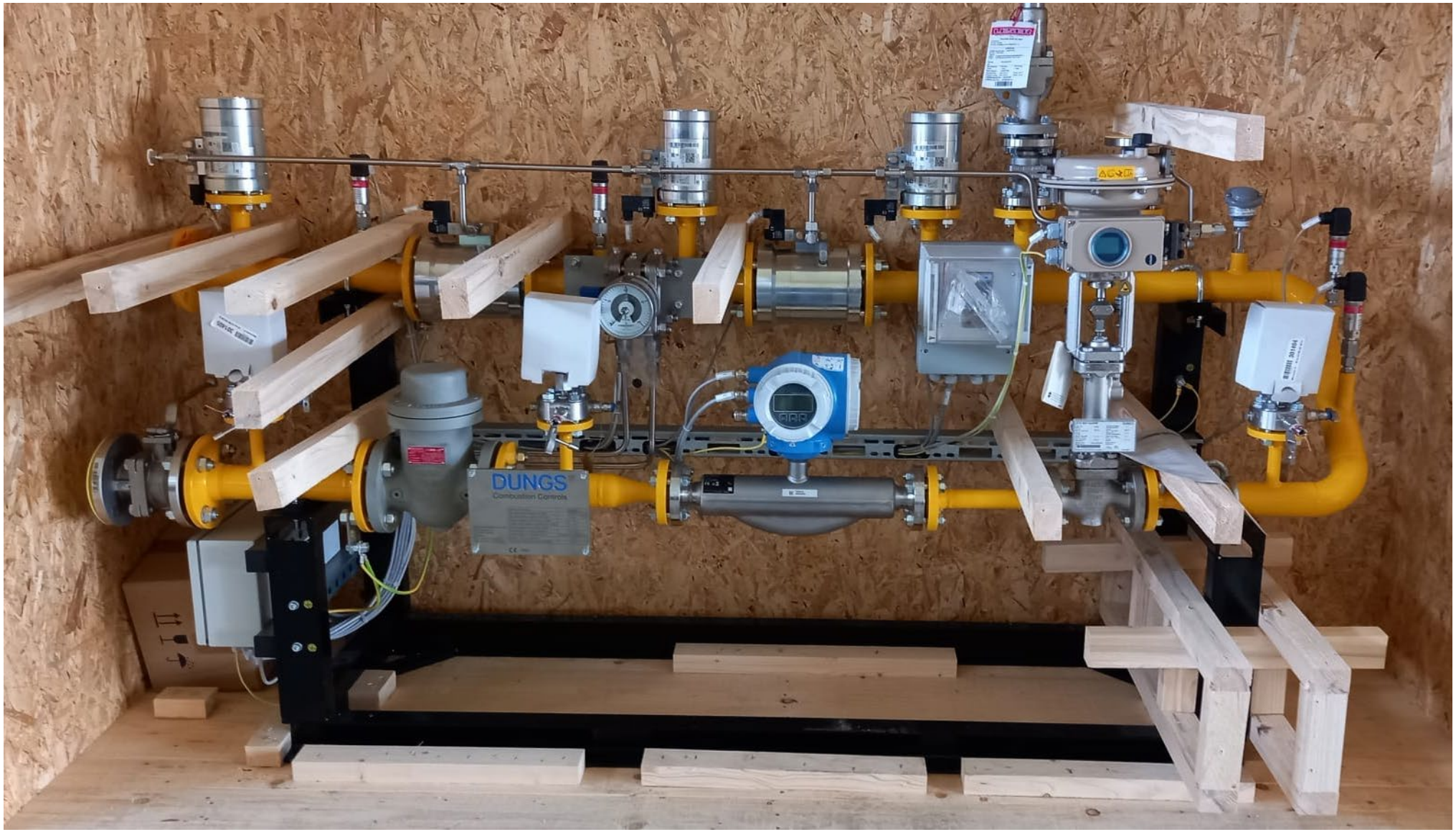
Select of machinery space ・・・ ESD protected machinery space
or
Gas safe machinery space

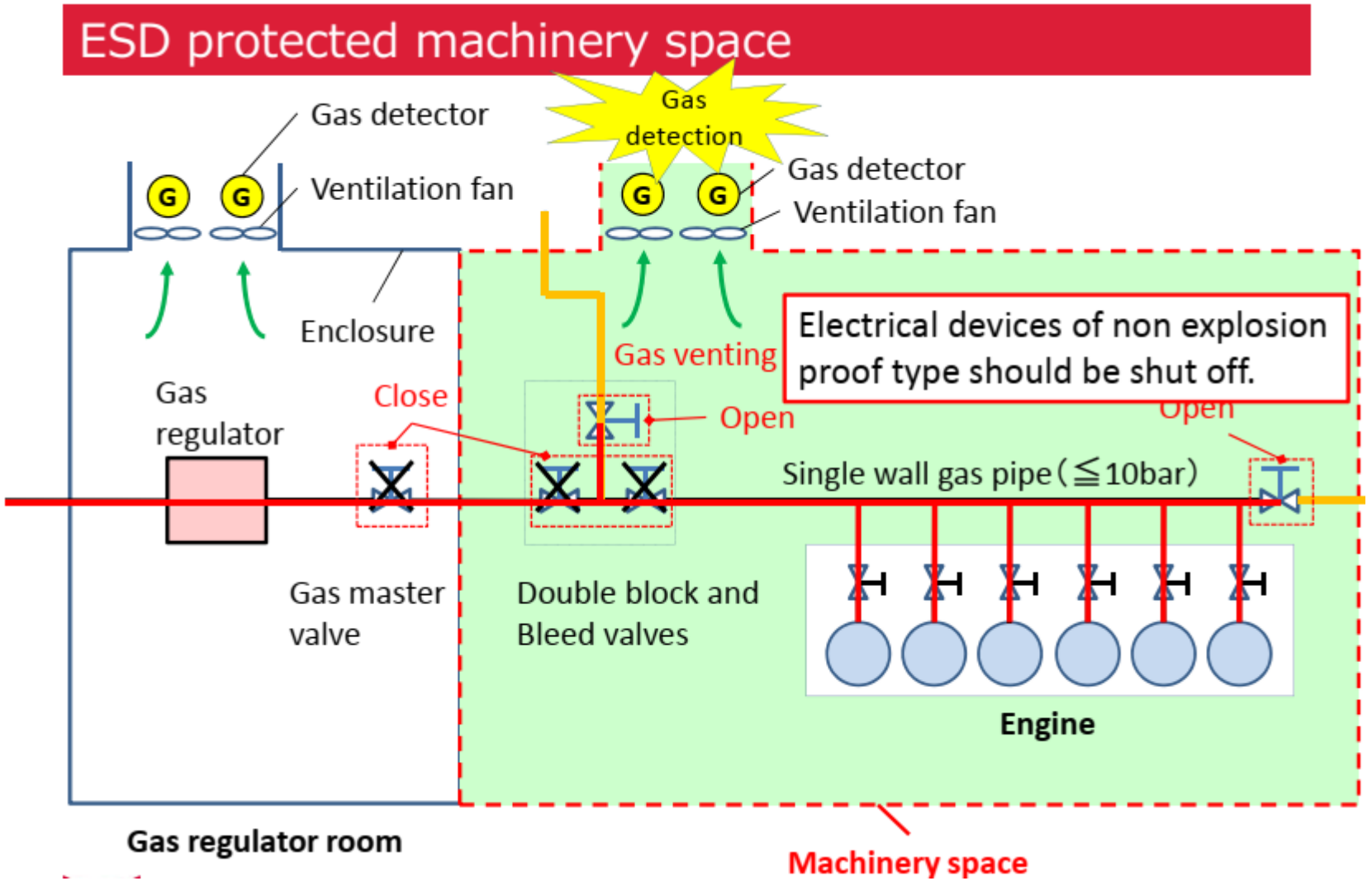
ESD protected machinery space

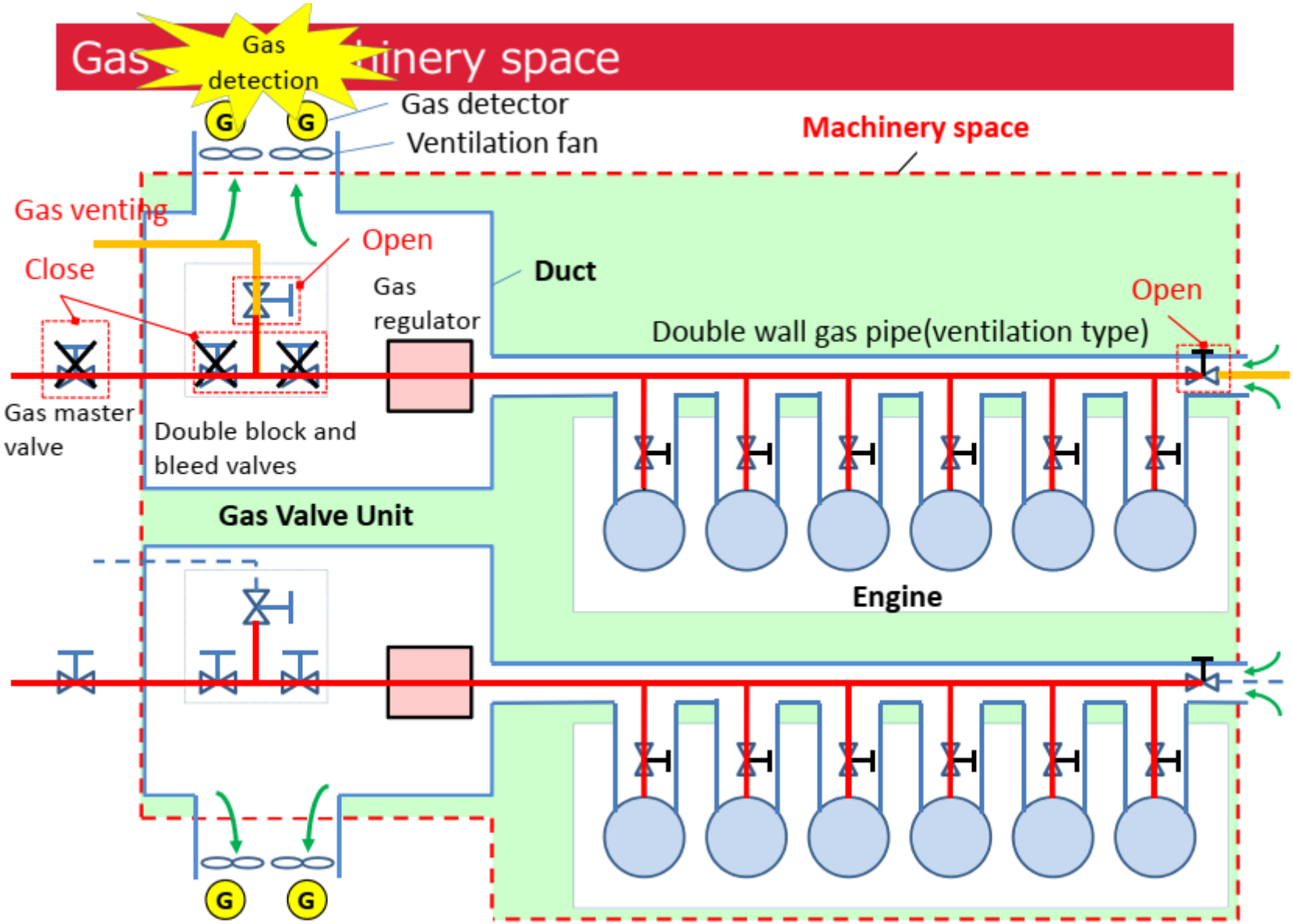
- Each machinery space is separated by a single bulkhead which can withstand the local explosion.
- One engine is installed in each machinery space.
- Fuel gas pipe is single wall (gas pressure ≦10bar)
- If gas leak in this space, the engine and gas supply are stopped and the electrical devices of non-explosion-proof type are shut off.
- A gas supply system is needed in each machinery space.
- 2 gas detectors are needed in each machinery space. etc…

Common requirement

- Double block valves(gas supply shut off) and bleed valve(gas vent) are needed in each gas supply system

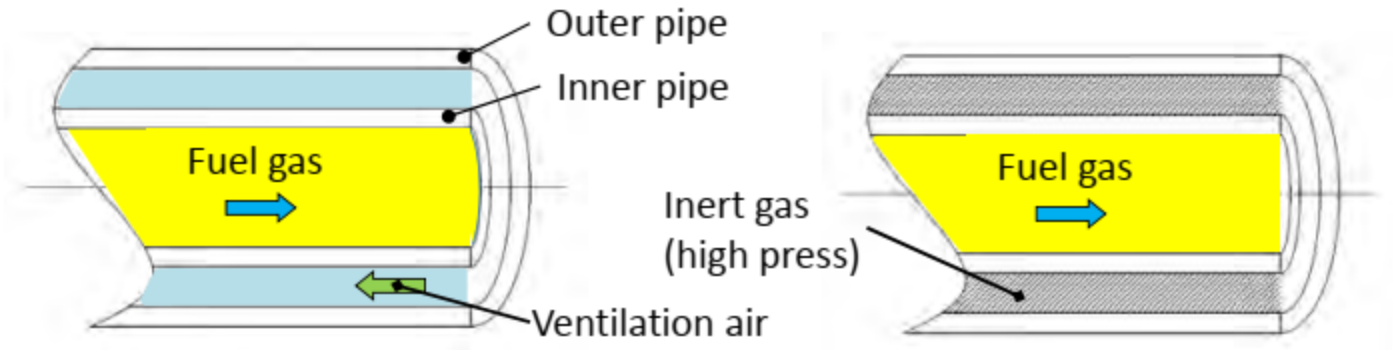

DUNGS
Combustion Controls


ESD protected machinery space
Gas detector
Gas detection
Gas detector
Ventilation fan
Ventilation fan
G
G
G
G
Enclosure
Gas venting
Electrical devices of non explosion proof type should be shut off.
Gas regulator
Close
Open
Open
Single wall gas pipe (≦10bar)
Gas master valve
Double block and Bleed valves
Engine
Gas regulator room
Machinery space


Gas detection
Gas detector
Ventilation fan
Machinery space
Gas venting
Open
Close
Duct
Gas regulator
Open
Double wall gas pipe(ventilation type)
Gas master valve
Double block and bleed valves
Gas Valve Unit
Engine
G
G
G
G

Double wall pipe

- Structure of double wall pipe



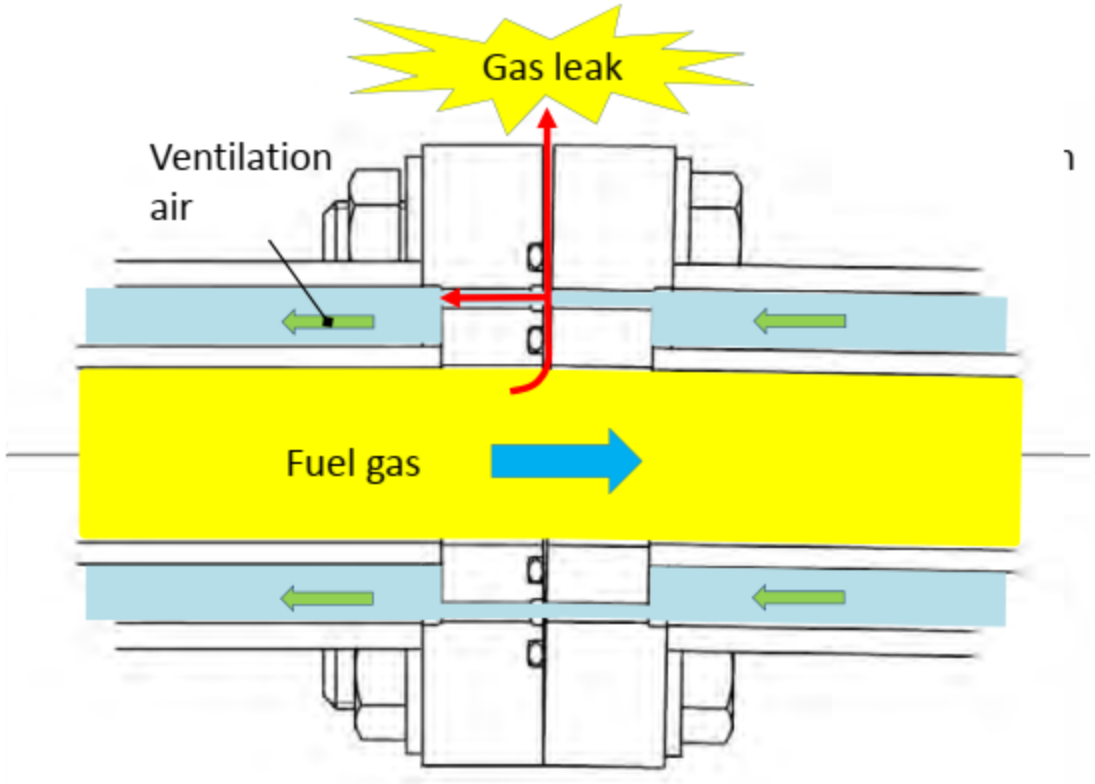
1.Air venting with mechanical device

2.Inert gas filling
(≧ fuel gas pressure)

- Material of pipe : carbon steel, iron casting etc…

Flange of double wall pipe

- Cross section of double wall pipe flange planned at first



In the case of this flange, measures no gas leak into the machinery space are needed when bolt is broken

Classification of hazardous area

Hazardous area

ZONE0

Area in which flammable gas is present continuously or long time.

→ **In fuel gas piping**

ZONE1

Area in which flammable gas is likely to occur in normal operation.

→ **・ESD protected machinery space when gas leaks**
・Ventilation space of double wall pipe(inside of outer pipe)

ZONE2

Area in which flammable gas is not likely to occur in normal operation and , if it does occur, will exist for a short period only.

Non-hazardous area

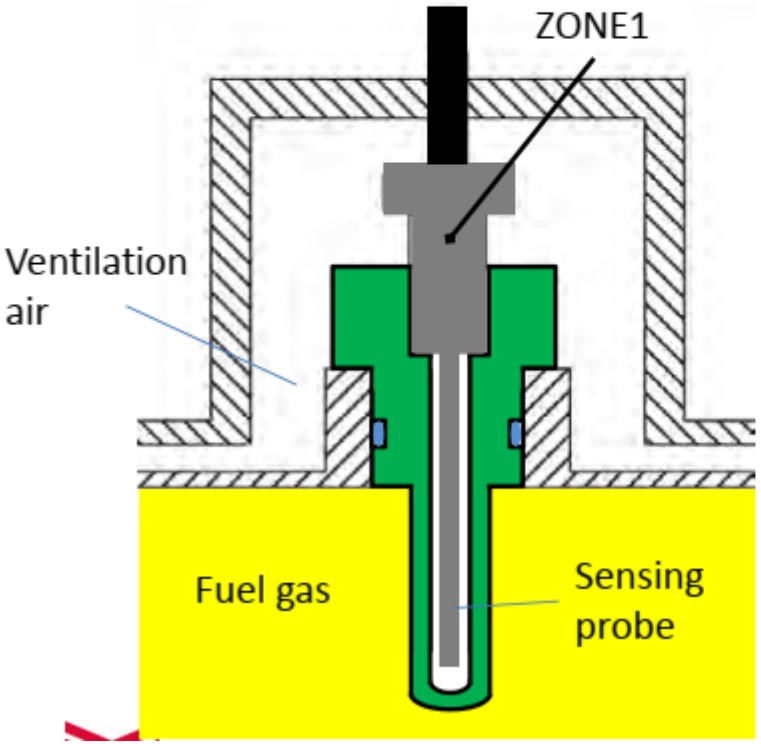
An area not considered to be hazardous , i.e. gas safe.

→**Gas safe machinery space**

Explosion proof of sensor and electrical device in double wall pipe

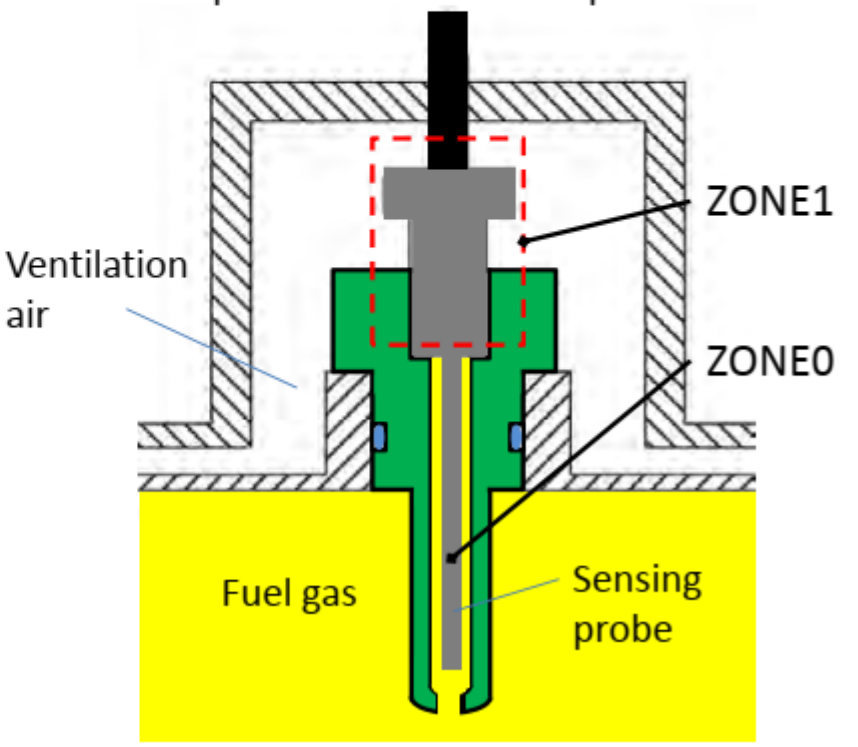
a) Sensor don't touch fuel gas directly

→Sensor should be correspond to ZONE1.



b) Sensor touch fuel gas directly

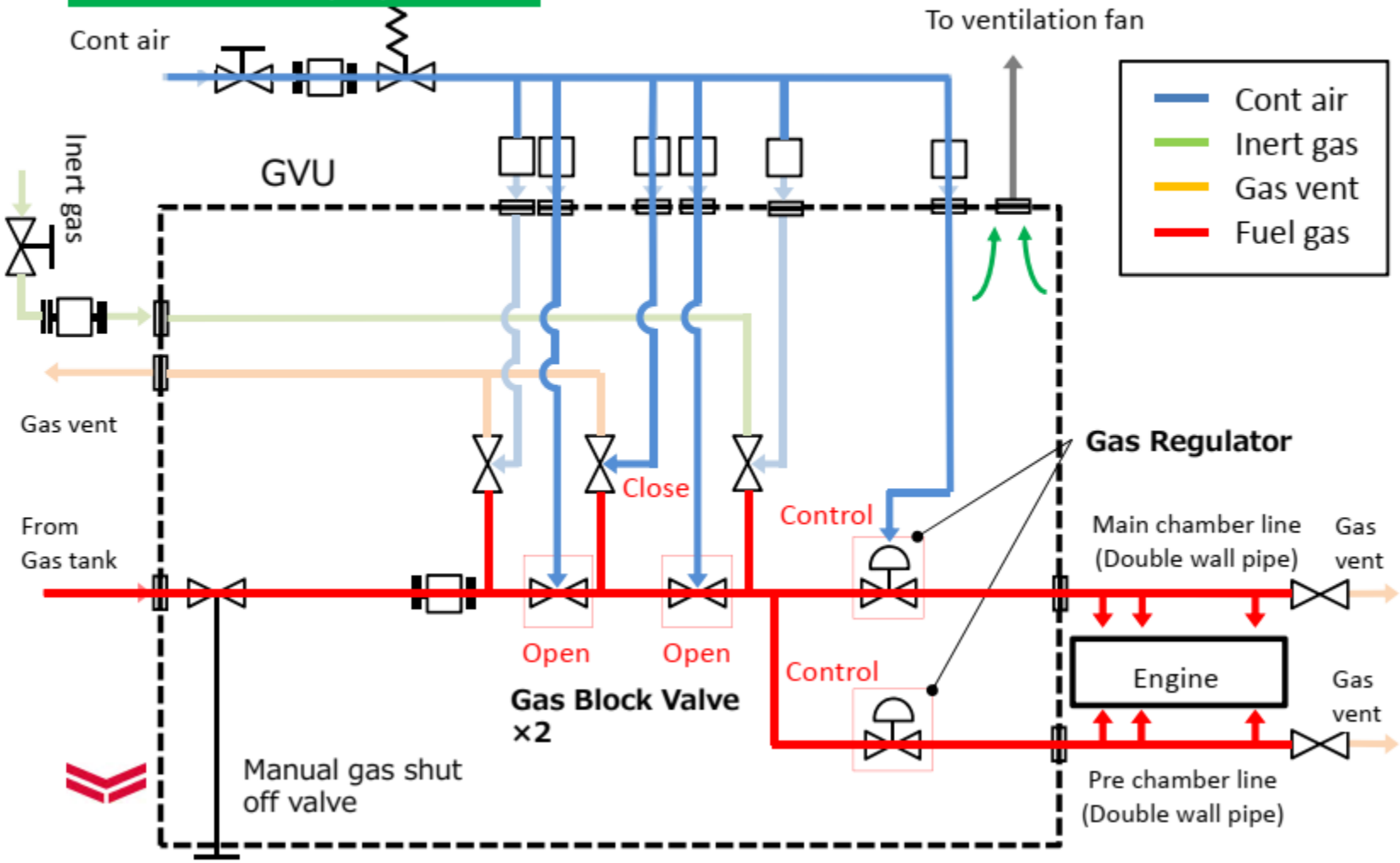
→Sensing probe should correspond to ZONE0.
The other parts should be correspond to ZONE1.



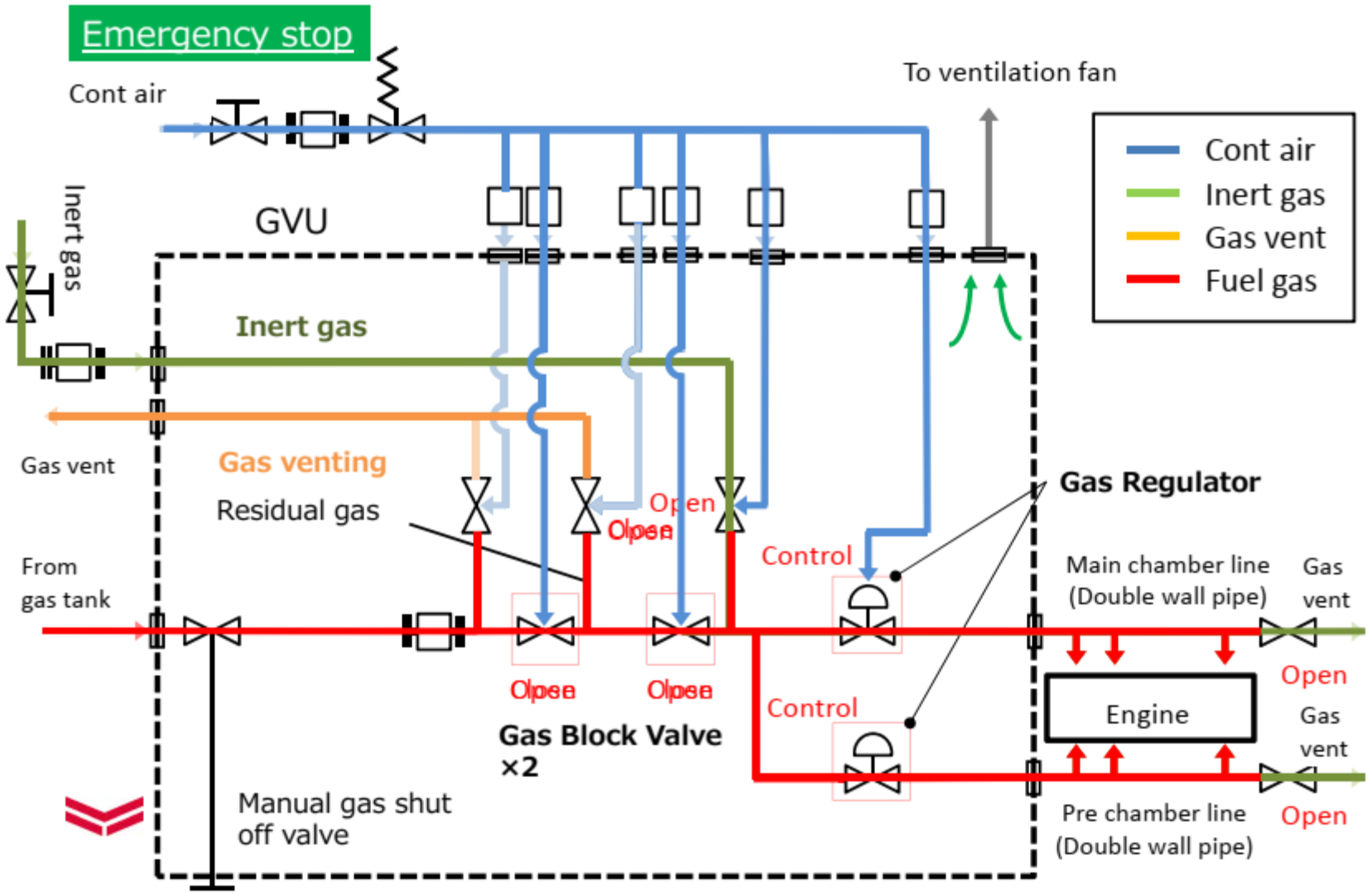
- Requirement level of explosion proof of sensors and electrical devices used in double wall pipe should be correspond ZONE 0 if it touch gas directly and ZONE 1 if it is separated from the gas

Gas flow line of GVU(Gas Valve Unit)

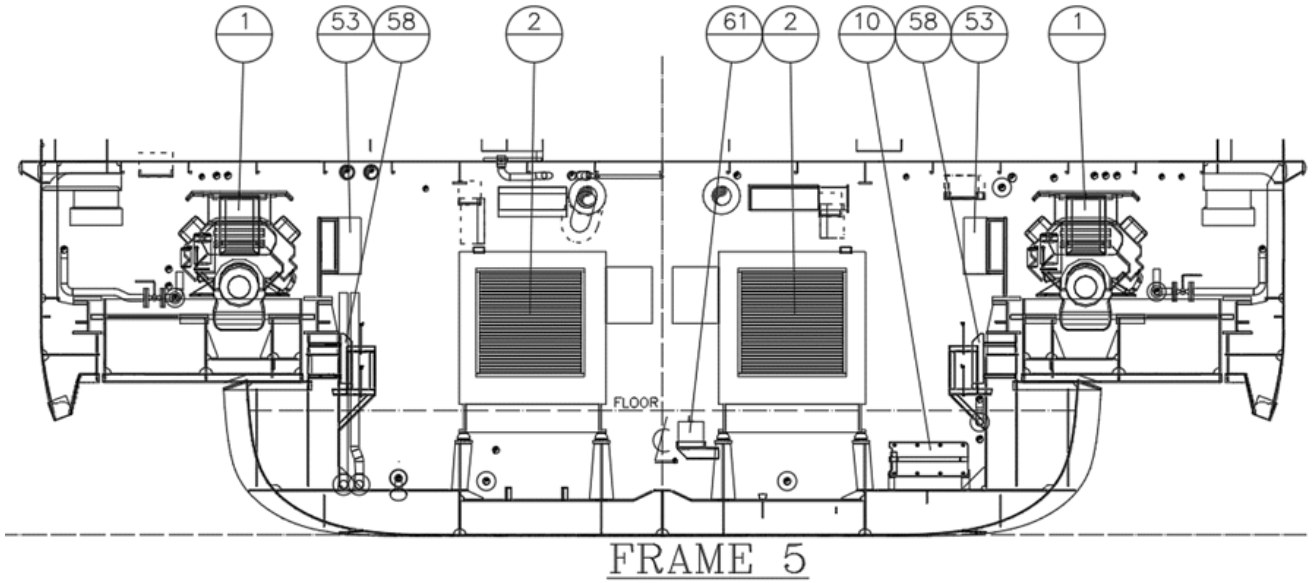
Start → Steady operation



Gas flow line of GVU(Gas Valve Unit)

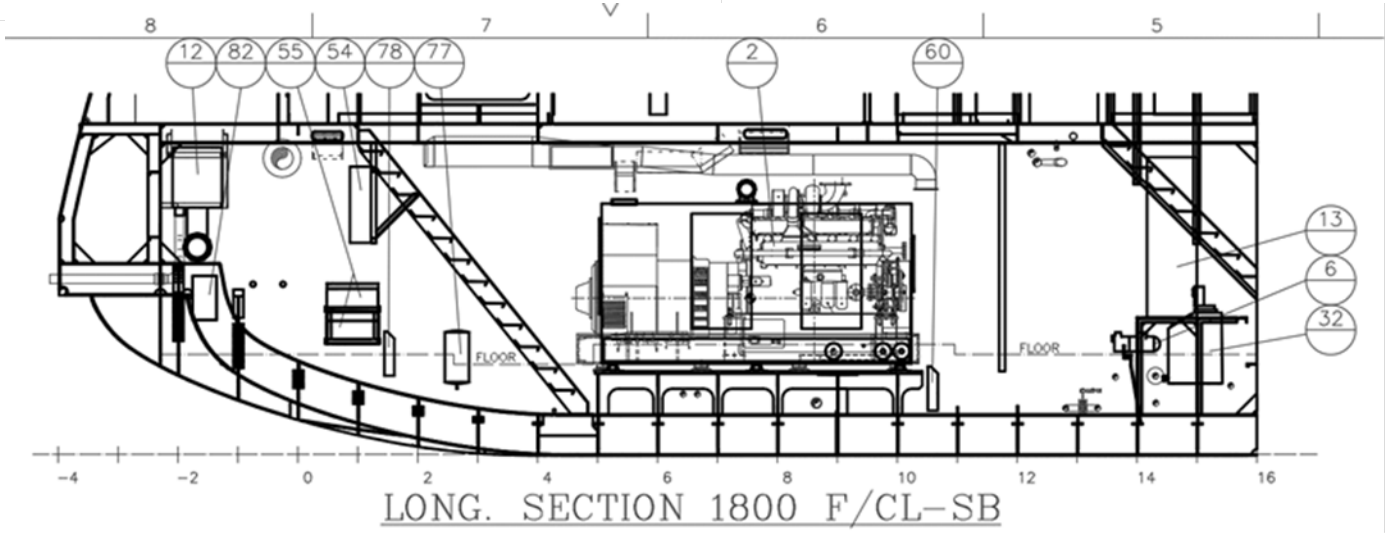


Possible engine room arrangement



Hydrogen engines are to be incapsulated

Hydrogen is to be bunkered on double bottom tanks on LOHC



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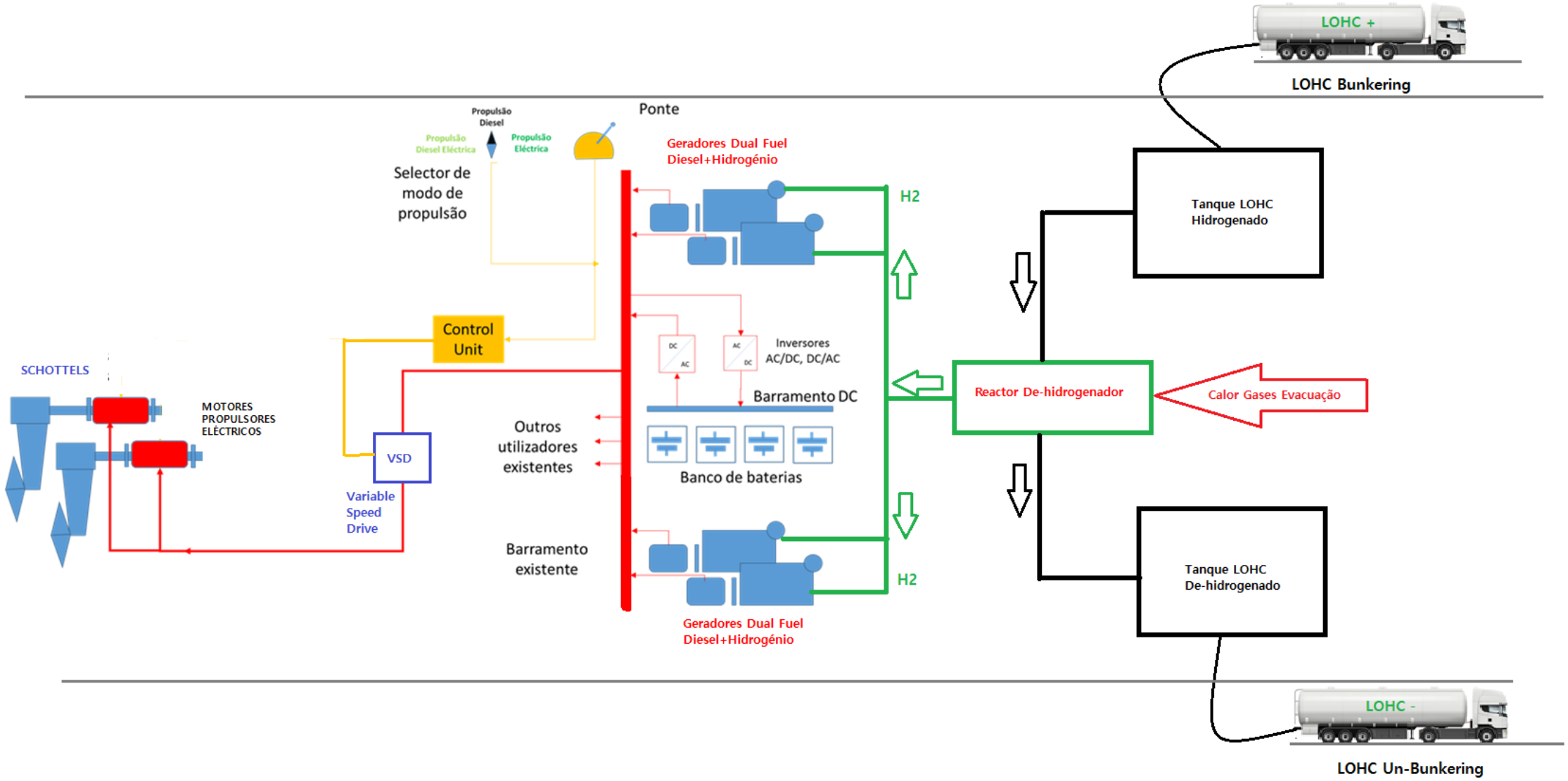
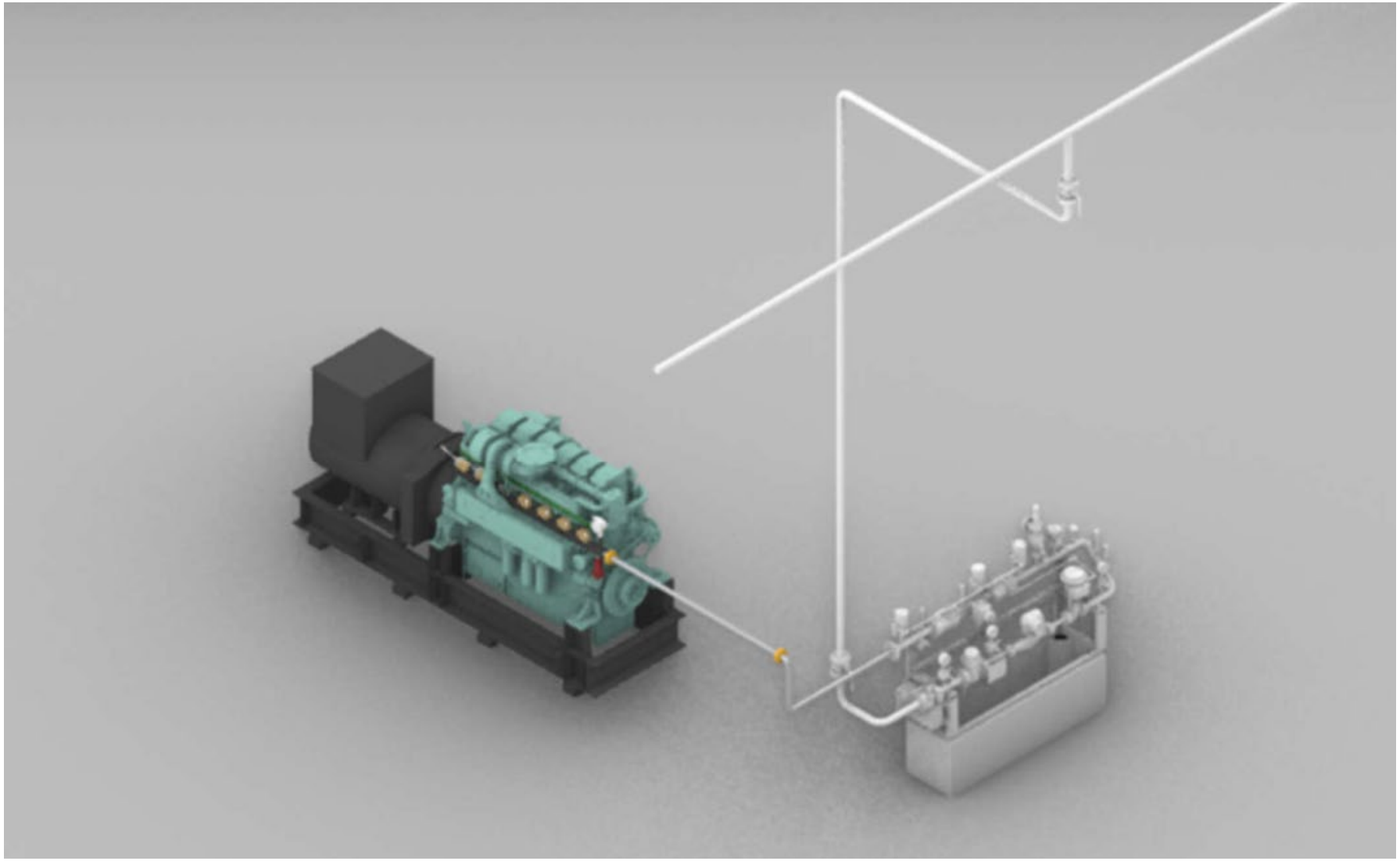
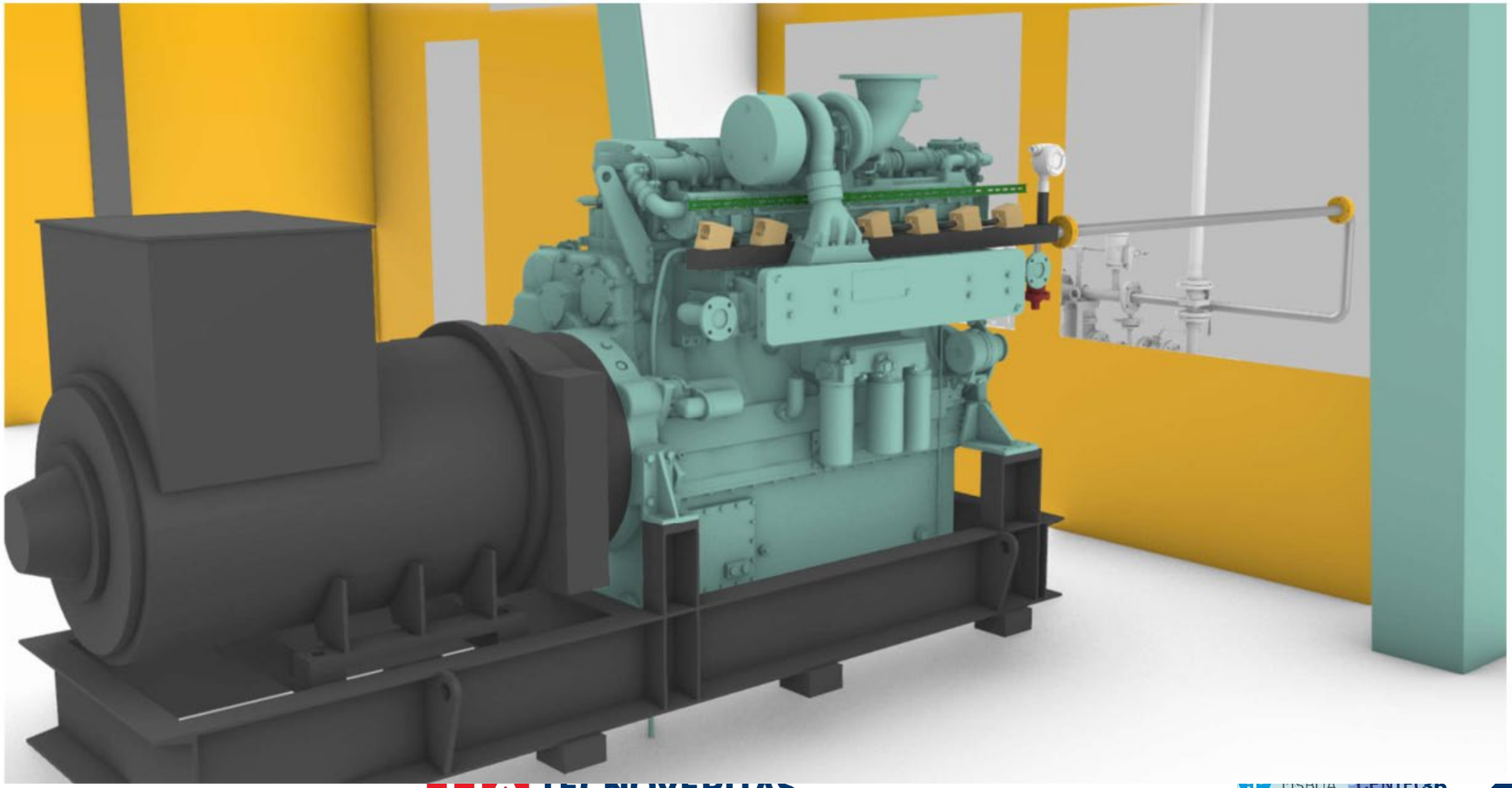
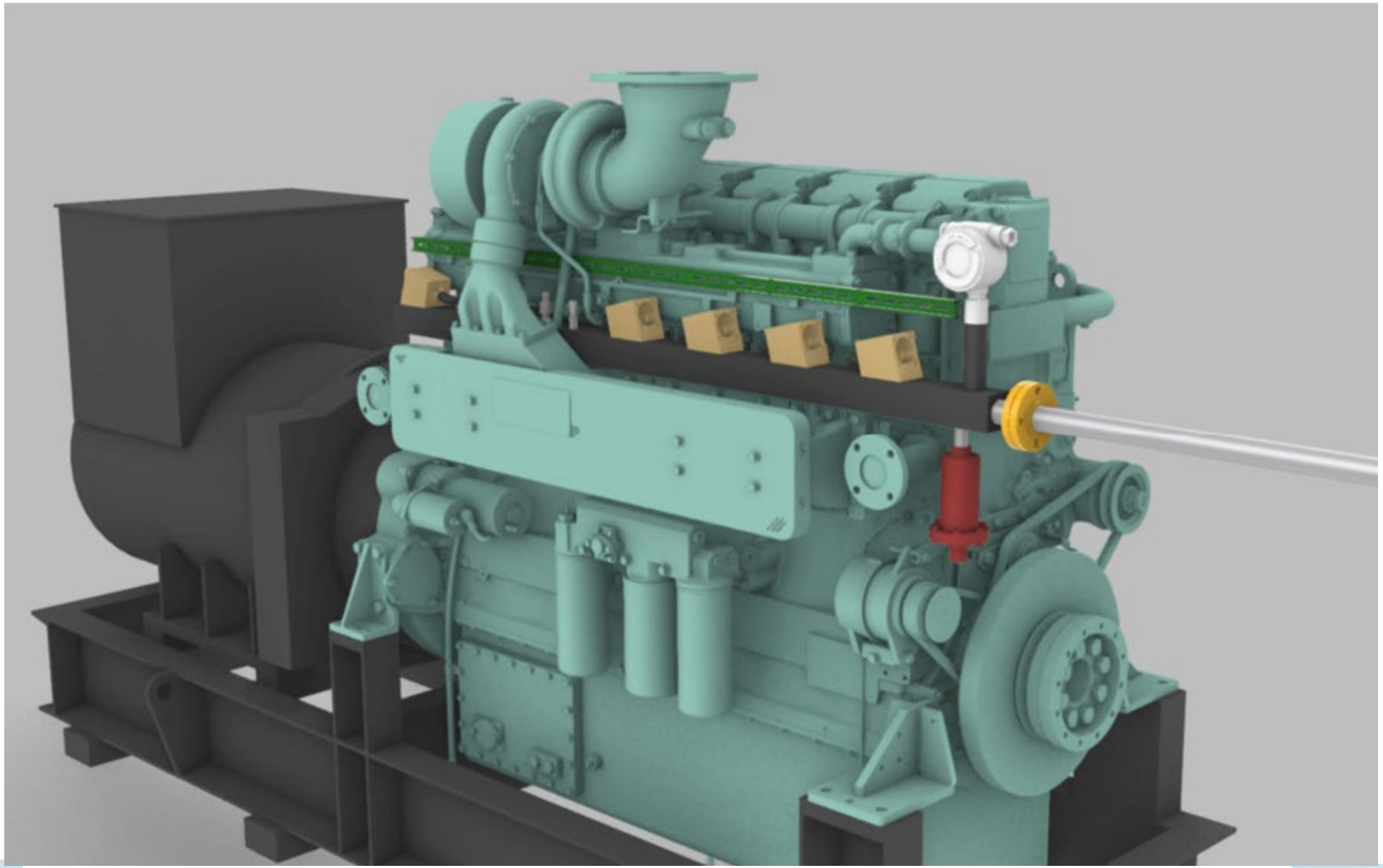
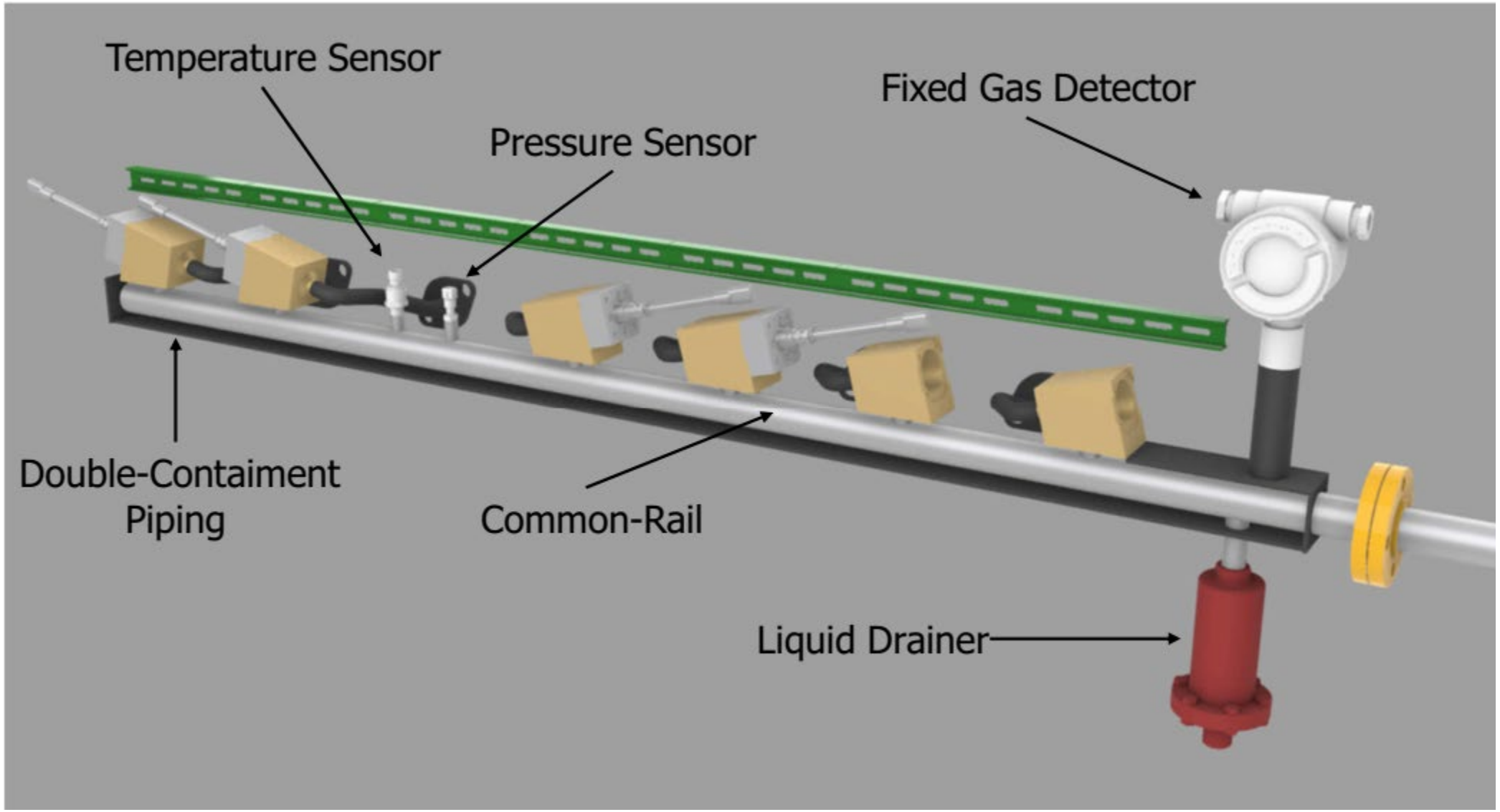
Vessel Propulsion and Power on Hydrogen (95-98%)

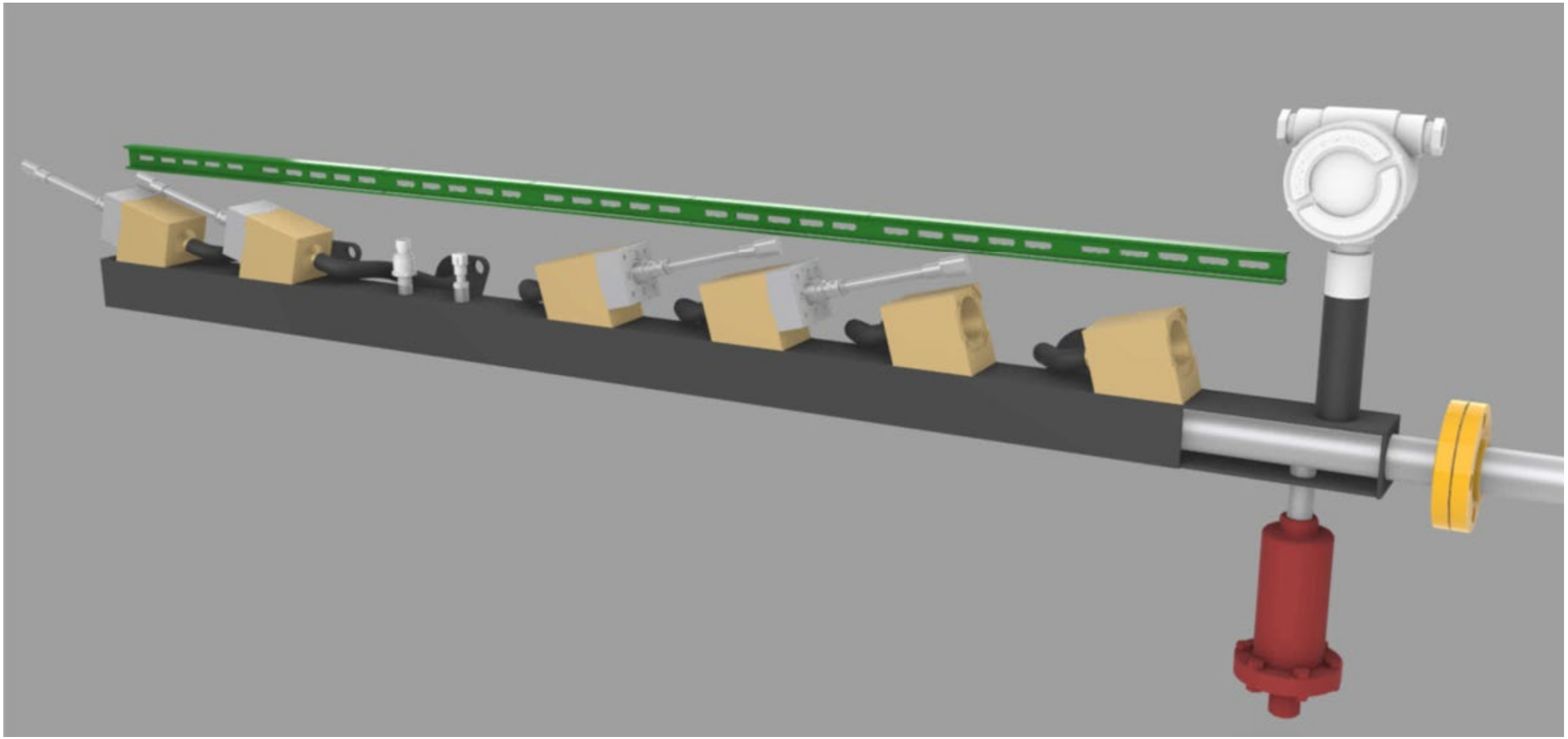


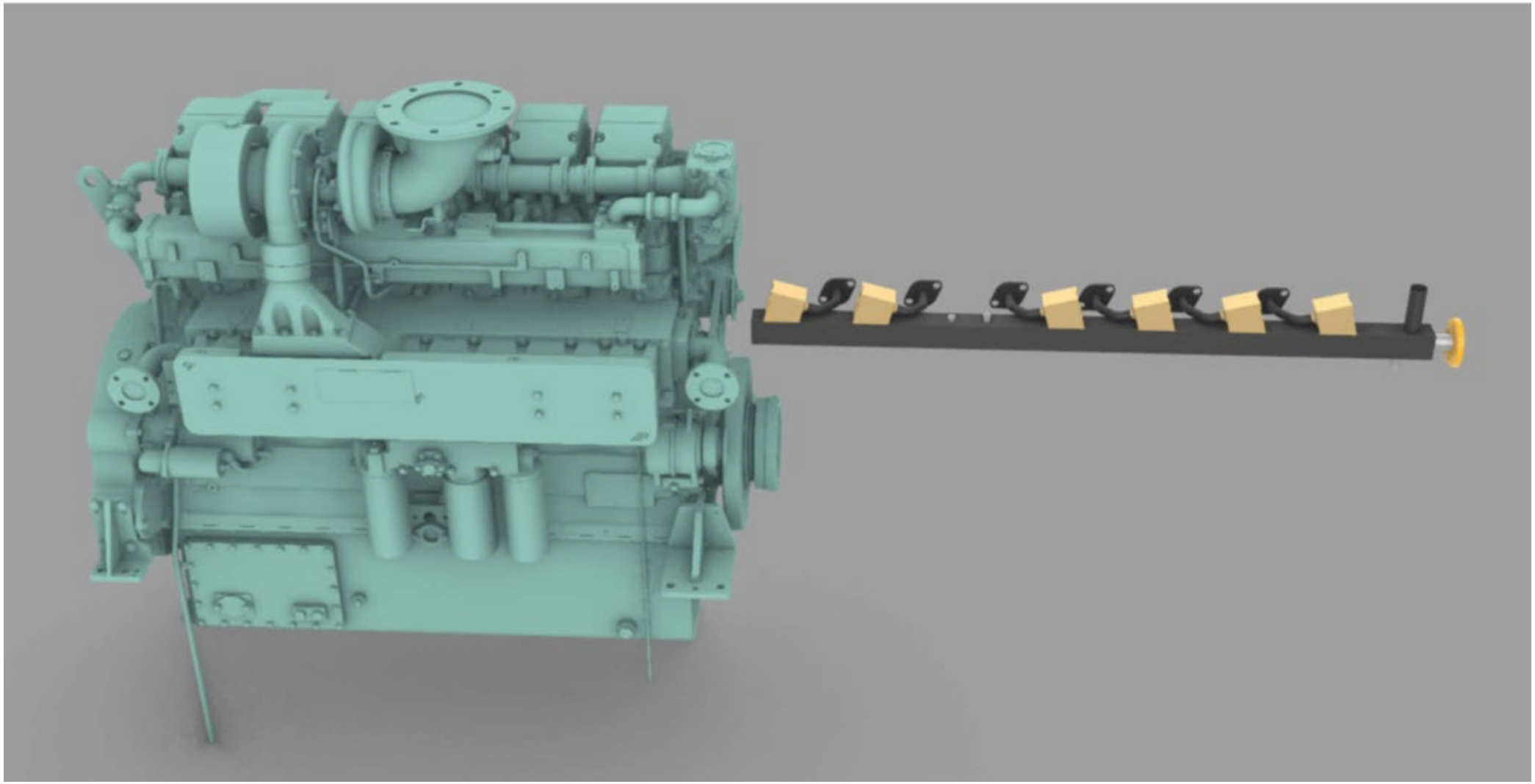


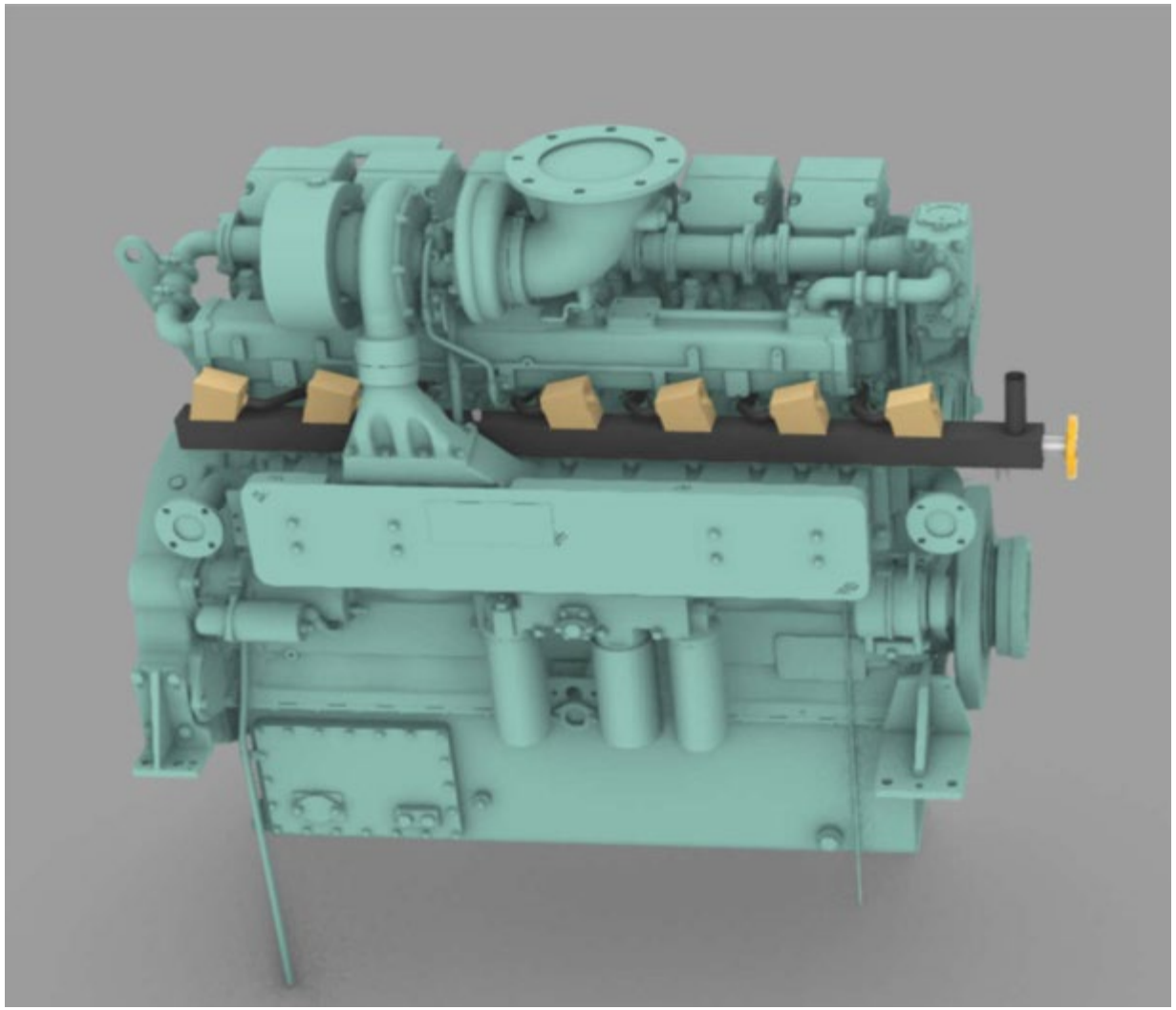


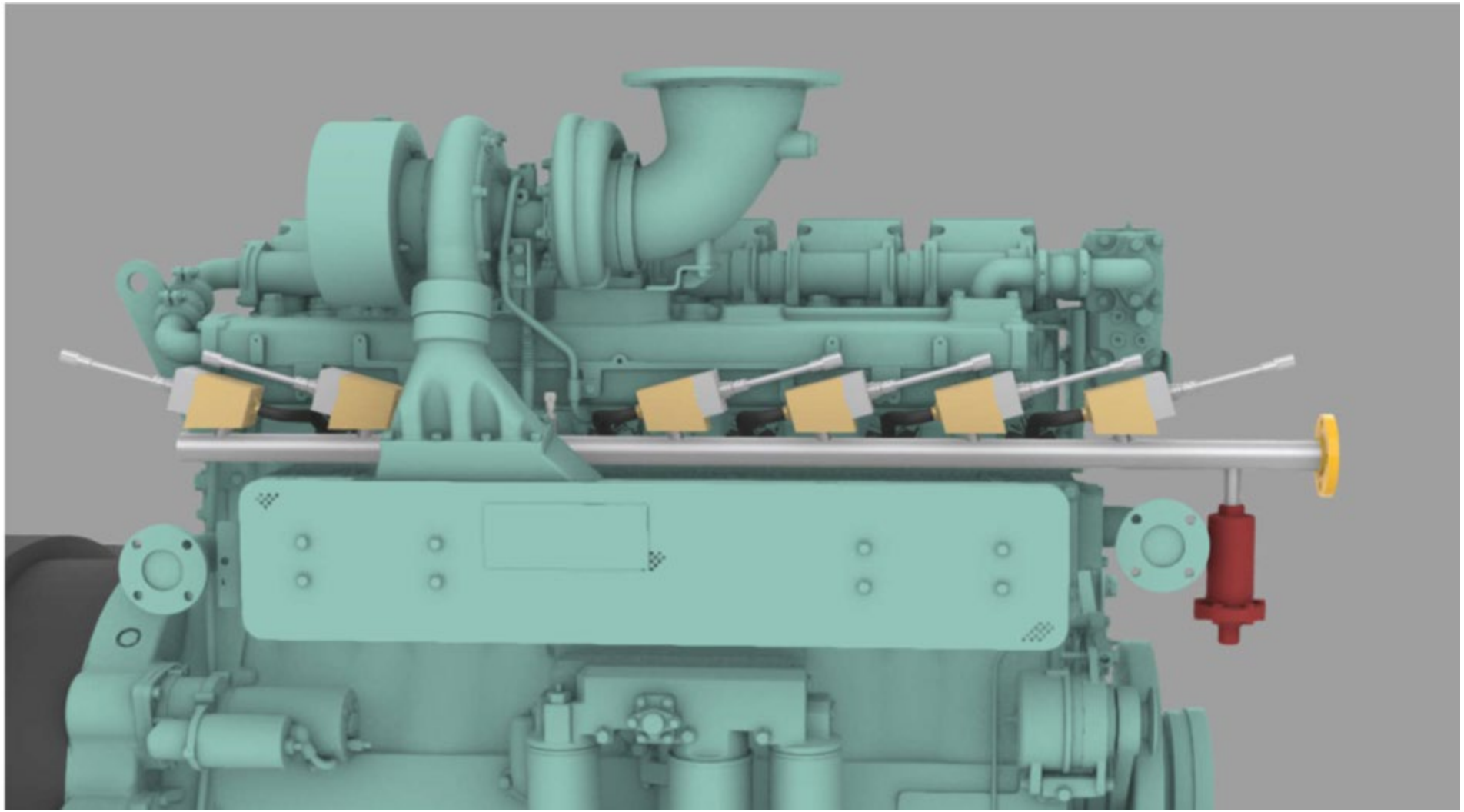


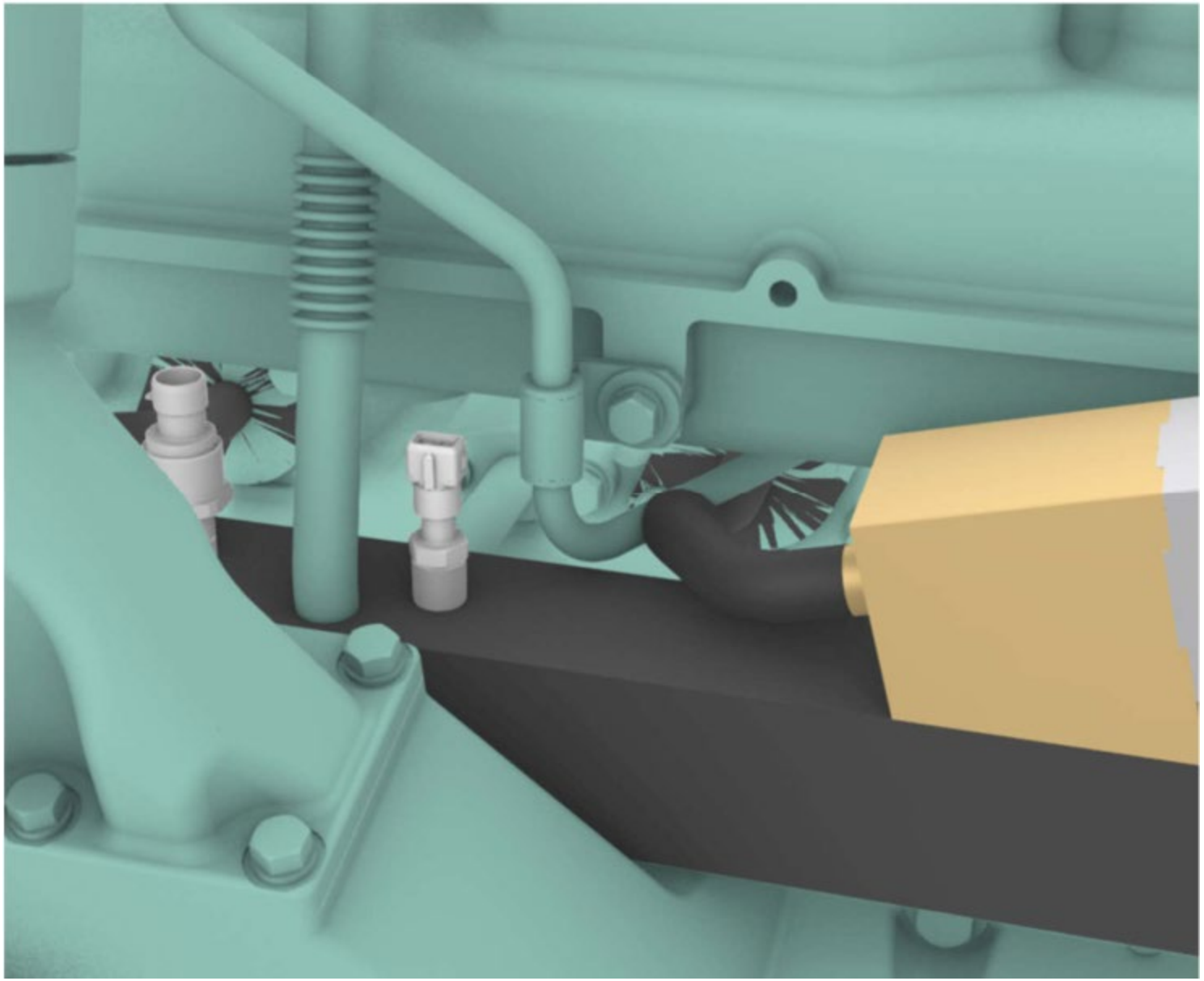

Temperature Sensor
Pressure Sensor
Fixed Gas Detector
Double-Containment Piping
Common-Rail
Liquid Drainer

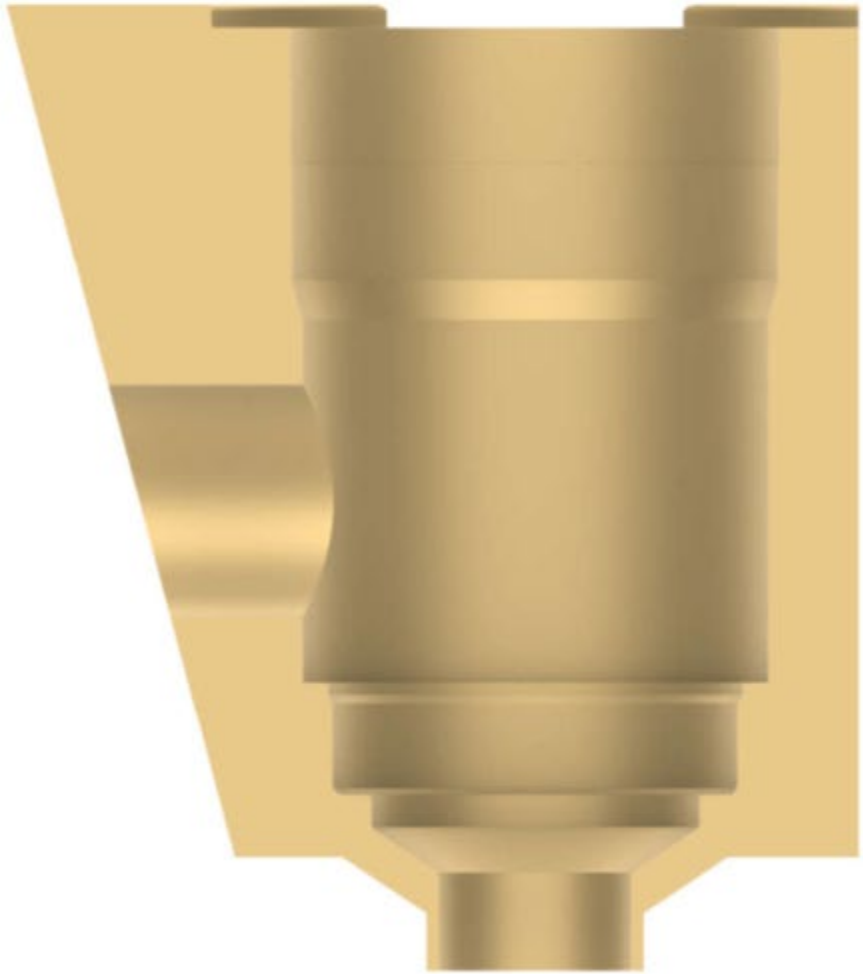


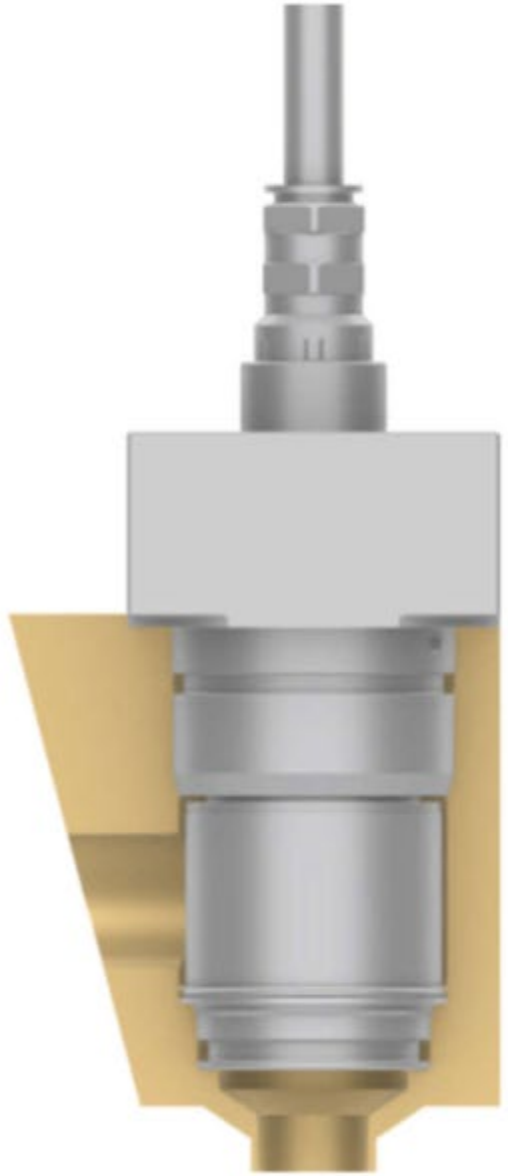




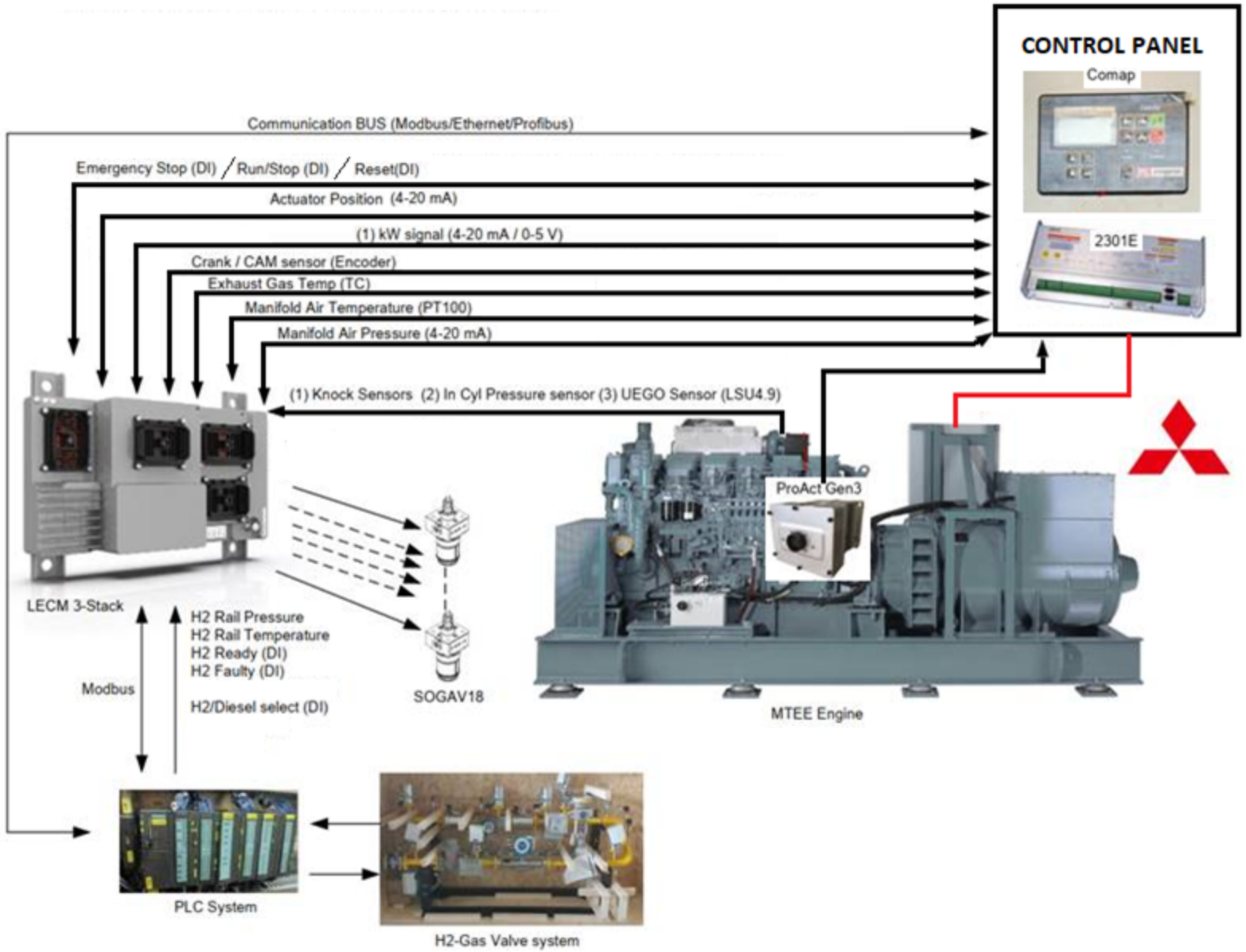








HYDROGEN-FUELLED SHIPS NR678-NOVEMBER 2023



CONTROL SYSTEM FUNCTIONS (DIESEL OPERATION) (SSCC REQUERIMENTS)

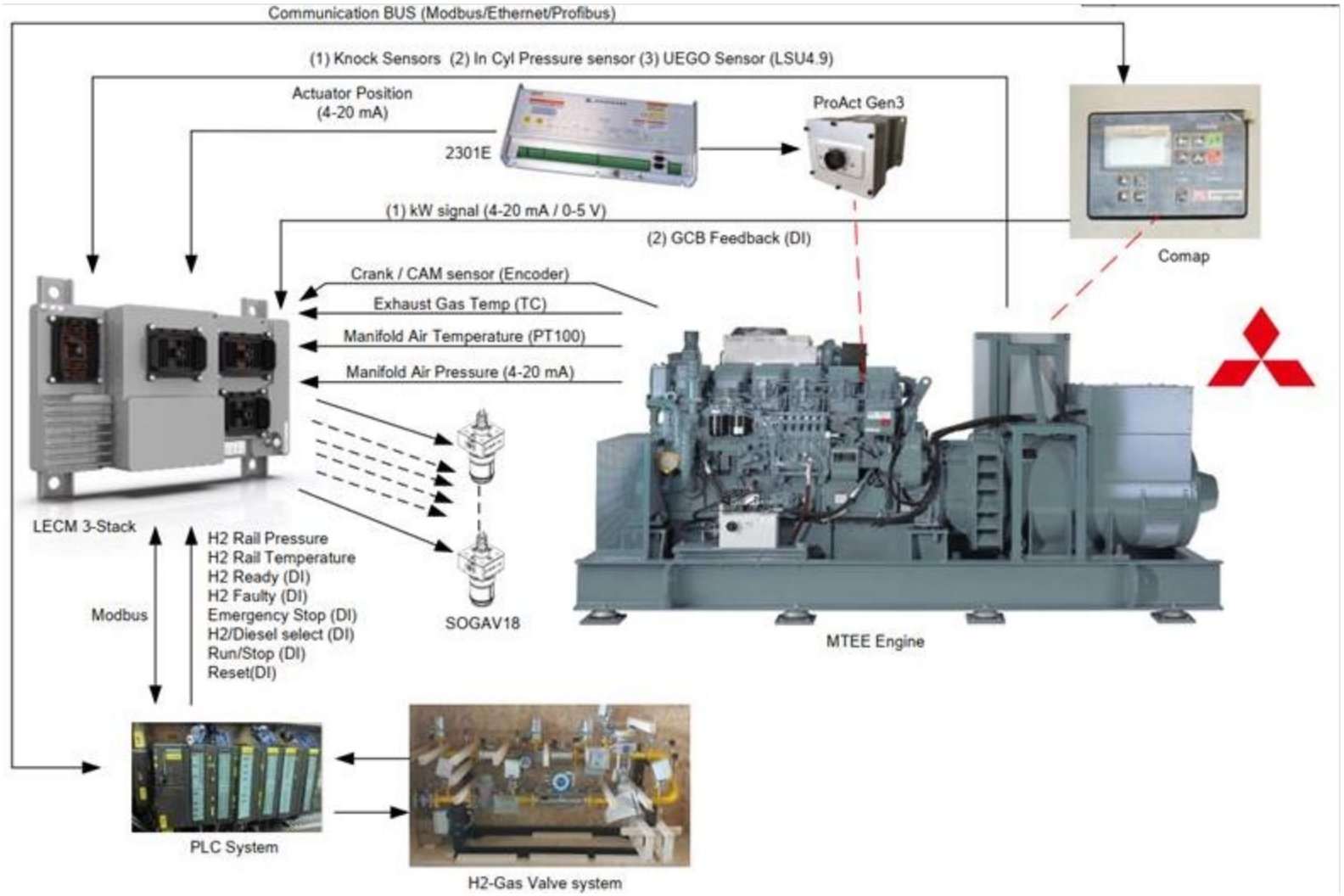
- Start
- Stop
- Idle speed
- Start inhibition in case of failure

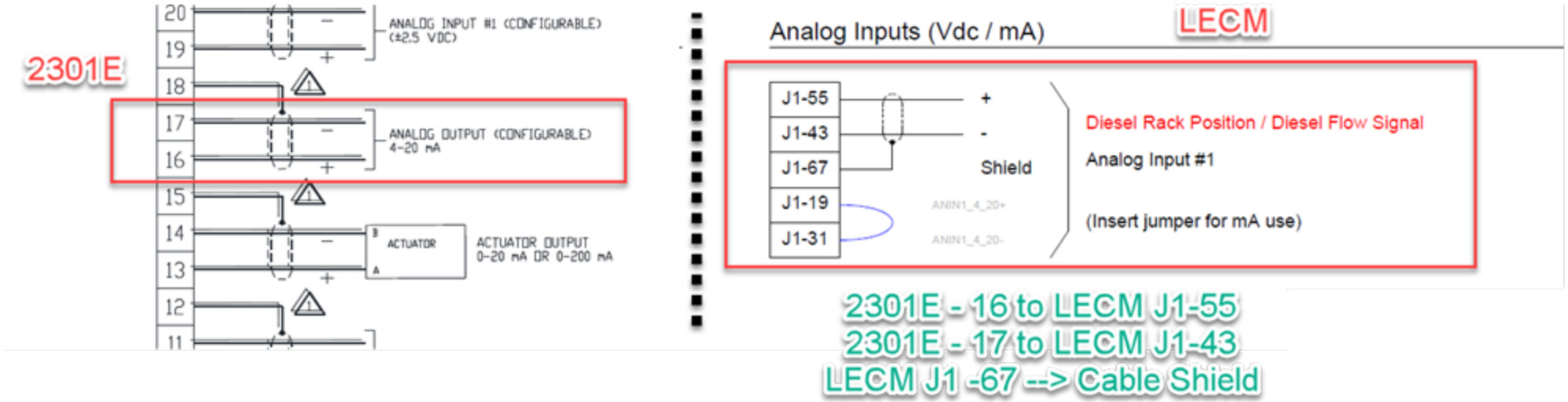
Control Systems Alarms

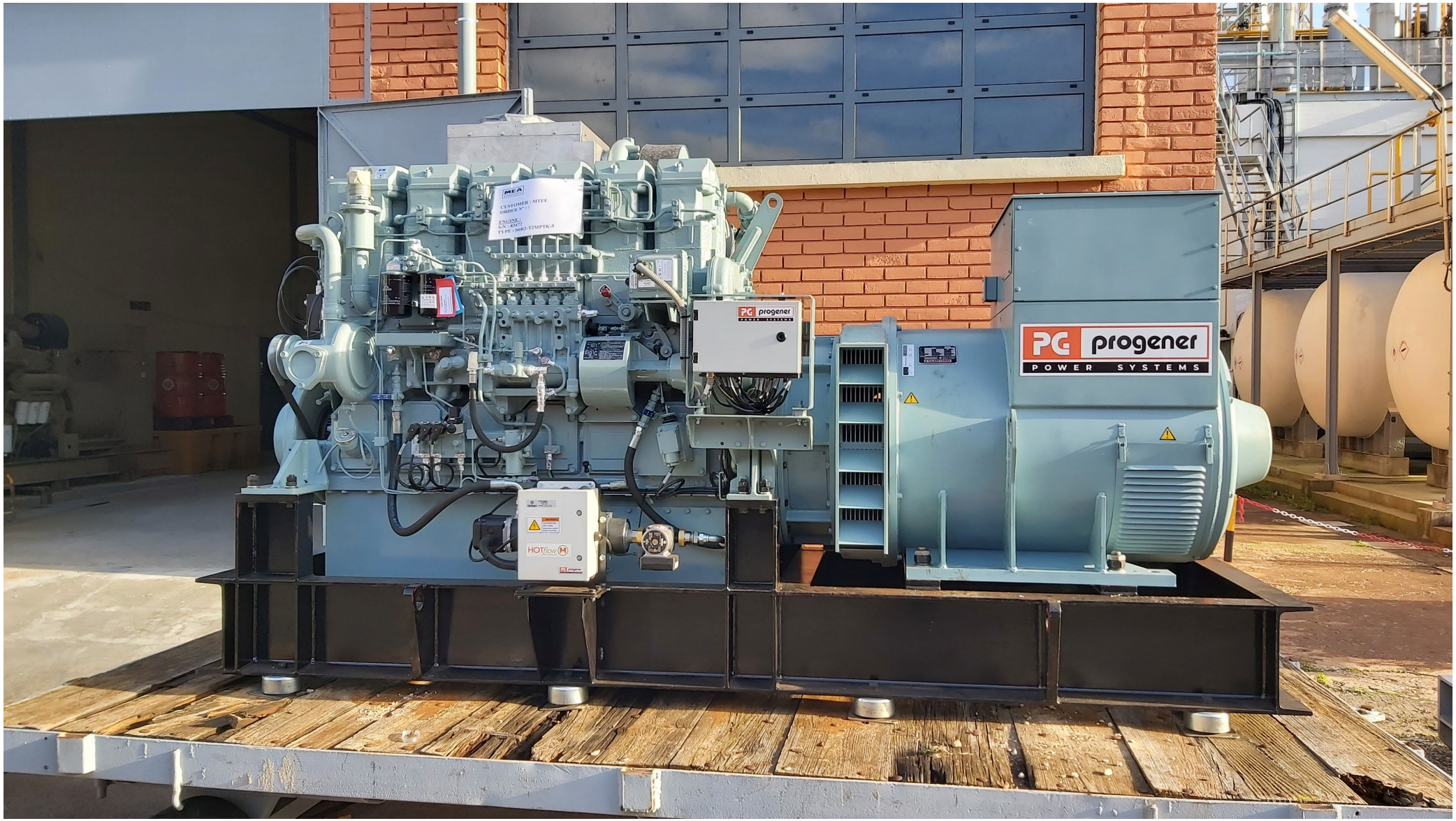
- Fuel Pressure ***(SSCC Mandatory)***
- Oil Pressure ***(SSCC Mandatory)***
- HT Cooling Water Pressure ***(SSCC Mandatory)***
- LT Cooling Water Pressure
- Turbo Pressure
- Charging Air Temperature
- HT Cooling Water Temperature ***(SSCC Mandatory)***
- LT Cooling Water Temperature
- Oil Temperature
- Exhaust Gas Temperature
- Oil filter Differencial Pressure
- Fuel Oil Leakage ***(SSCC Mandatory)***
- HT Cooling Water Level
- LT Cooling Water Level

Security System

- Engine Overspeed ***(SSCC Mandatory)***
- HT Cooling Water Temp
- Oil Pressure Engine ***(SSCC Mandatory)***
- Governor System Fault ***(SSCC Mandatory)***


Communication BUS (Modbus/Ethernet/Profibus)
(1) Knock Sensors (2) In Cyl Pressure sensor (3) UEGO Sensor (LSU4.9)
Actuator Position (4-20 mA)
2301E
ProAct Gen3
Comap
(1) kW signal (4-20 mA / 0-5 V)
(2) GCB Feedback (DI)
Crank / CAM sensor (Encoder)
Exhaust Gas Temp (TC)
Manifold Air Temperature (PT100)
Manifold Air Pressure (4-20 mA)
LECM 3-Stack
H2 Rail Pressure
H2 Rail Temperature
H2 Ready (DI)
H2 Faulty (DI)
Emergency Stop (DI)
H2/Diesel select (DI)
Run/Stop (DI)
Reset(DI)
Modbus
SOGAV18
MTEE Engine
PLC System
H2-Gas Valve system


2301E
20
19
18
17
16
15
14
13
12
11
ANALOG INPUT #1 (CONFIGURABLE)
(±2.5 VDC)
ANALOG OUTPUT (CONFIGURABLE)
4-20 mA
ACTUATOR
ACTUATOR OUTPUT
0-20 mA OR 0-200 mA
Analog Inputs (Vdc / mA)
LECM
J1-55
J1-43
J1-67
J1-19
J1-31
+
-
Shield
ANIN1_4_20+
ANIN1_4_20-
Diesel Rack Position / Diesel Flow Signal
Analog Input #1
(Insert jumper for mA use)
2301E - 16 to LECM J1-55
2301E - 17 to LECM J1-43
LECM J1 -67 --> Cable Shield


progener
POWER SYSTEMS

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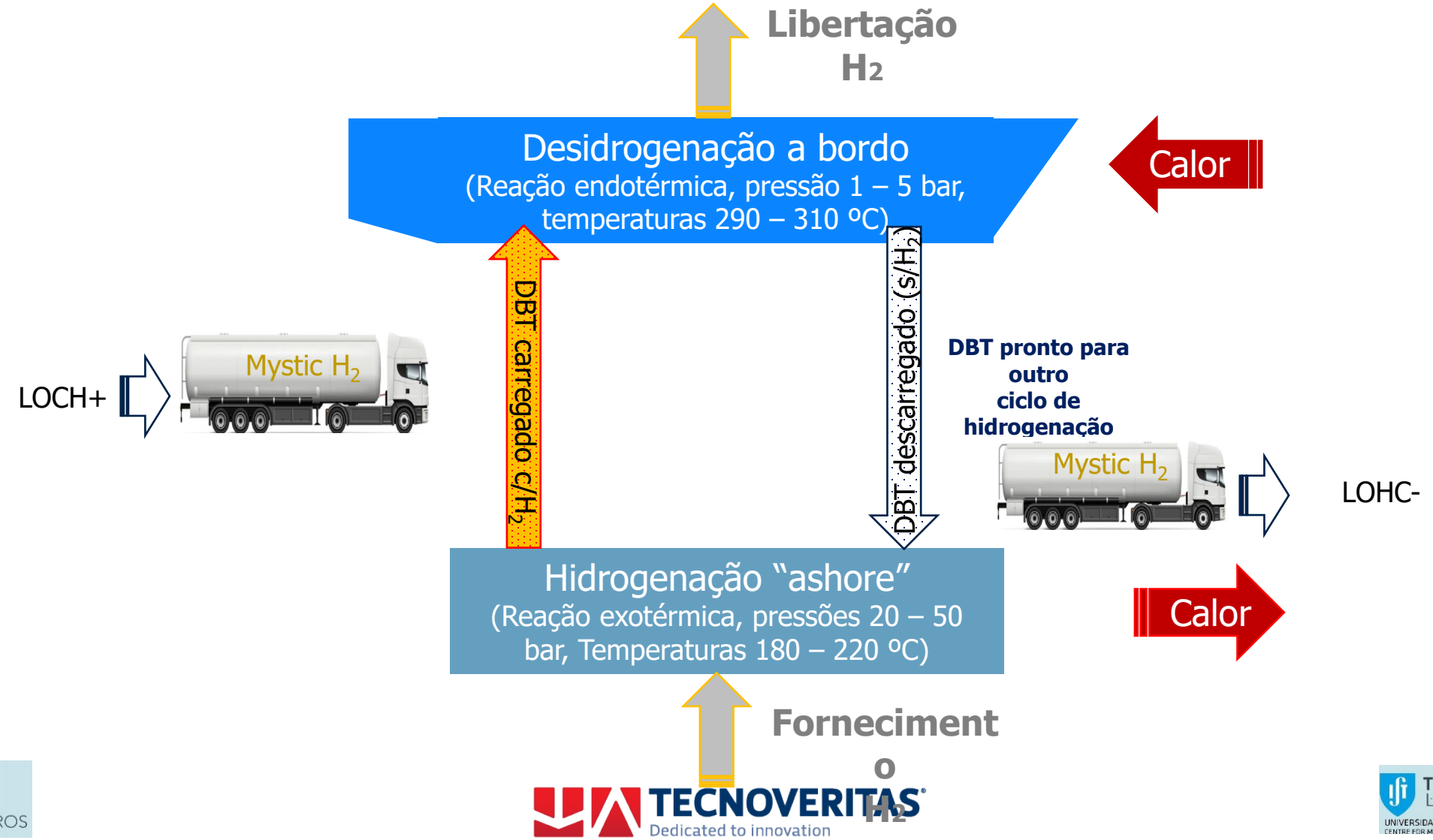
Na prática


Libertação
H_2
Desidrogenação a bordo
(Reação endotérmica, pressão 1 – 5 bar, temperaturas 290 – 310 ºC)
Calor
DBT carregado c/H_2
DBT descarregado (s/H_2)
LOCH+
Mystic H_2
DBT pronto para outro ciclo de hidrogenação
Mystic H_2
LOHC-
Hidrogenação "ashore"
(Reação exotérmica, pressões 20 – 50 bar, Temperaturas 180 – 220 ºC)
Calor
Fornecimento
H_2