KMOU Division of Marine System Engineering

Introduction to Internal Combustion Engine

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Lesson content for each week

Ch0_Introduction to the Class

Ch1_Overview of the Internal Combustion Engine

Ch2_Thermodynamics and Compressed Air System

Ch3_Marine Fuels and Internal Fuel Oil System

Ch4_Intake and Exhaust System

Ch5_Turbocharger

Midterm

Ch6_Piston Fittings and Crankshaft

Ch7_Lube Oil System

Ch8_Cooling Water System

Ch9_Introduction to the Main Engine

Ch10_Alternative Fuels and Alternative Fuel Systems

Ch11_Environmental Regulations and Exhaust Gas Aftertreatment Systems

Ch12_Tools, Apprentice Engineer Duties, and Career Direction

Final Exam

Thermodynamics

What is Thermodynamics?

Thermodynamics is a branch of physics which deals with the energy and work of a system.

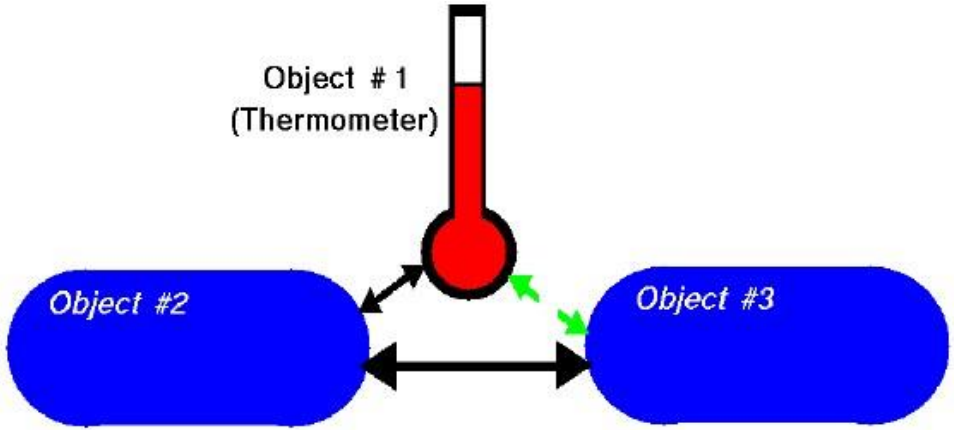
It was born in the 19th century as scientists were first discovering how to build and operate steam engines.

Thermodynamics deals only with the large scale response of a system which we can observe and measure in experiments. Small scale gas interactions are described by the kinetic theory of gases.

Zeroth Law of Thermodynamics

What is the “Zeroth Law of Thermodynamics”?

→ If two systems are each in thermal equilibrium with a third system, then the two systems are in thermal equilibrium with each other.



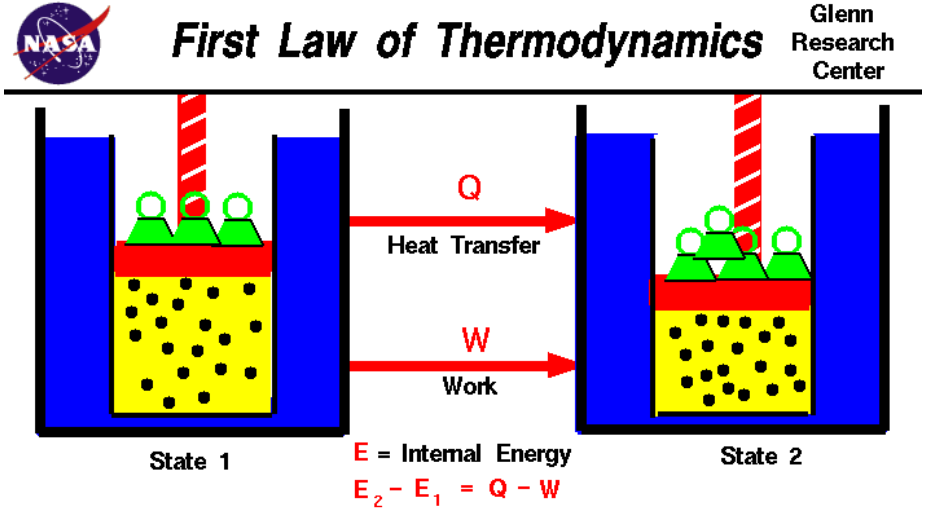
When two objects are separately in thermodynamic equilibrium with a third object, they are in equilibrium with each other.

Objects in thermodynamic equilibrium have the same temperature.

First Law of Thermodynamics

What is the “First Law of Thermodynamics”?

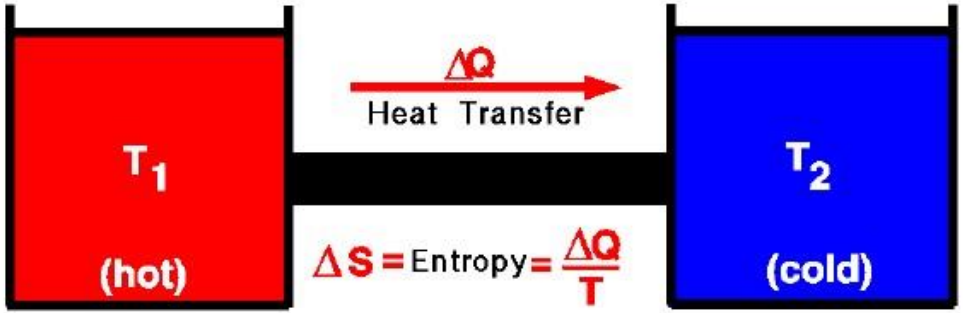
→ Energy is neither created nor destroyed, it only changes form.



Second Law of Thermodynamics

What is the “Second Law of Thermodynamics”?

→ The entropy of an isolated system always increases or remains constant. (Natural processes proceed in the direction of increasing entropy.)



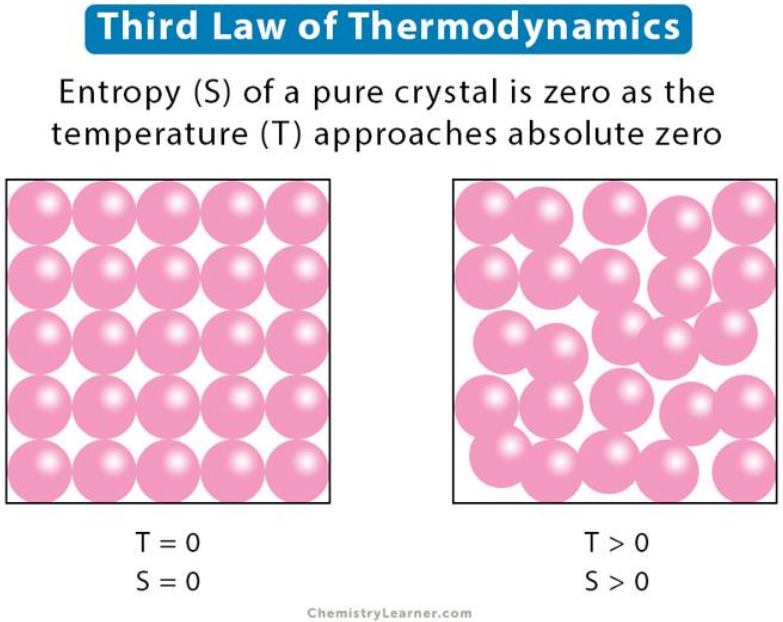
There exists a useful thermodynamic variable called entropy (S). A natural process that starts in one equilibrium state and ends in another will go in the direction that causes the entropy of the system plus the environment to increase for an irreversible process and to remain constant for a reversible process.

$S_f = S_i$ (reversible) $S_f > S_i$ (irreversible)

Third Law of Thermodynamics

What is the “Third Law of Thermodynamics”?

→ The entropy of a closed system at thermodynamic equilibrium approaches a constant value when its temperature approaches absolute zero.



4-stroke ICE (G/E)

4-stroke ICE (G/E)

This class (Internal Combustion Engine) will mainly cover the content for G/E.

Why this class mainly covers for G/E?

1) Most of the students for this class will be onboard soon as an apprentice engineer (A/E).

2) There must be a chance of attending maintenance works for G/E with 2nd engineer.

3) Most of the students for this class will be onboard as a 3rd engineer and then be 2nd engineer before finishing military service.

4) 2nd engineer is in charge of G/E.

5) There will not be the education for G/E after graduation of university. (In my experience, company did not teach for G/E and I had to study by myself when I was 3rd and 2nd engineer.)

6) Therefore, I hope all students get benefit from this class for the knowledge of G/E.

7) At the end of class, I will shortly introduce for M/E too.

4-stroke ICE (G/E)

There are several makers of G/E that you will encounter when boarding a ship.

Some of them are shown in below.

HYUNDAI HiMSEN Hi-touch Marine & Stationary ENgine

HYUNDAI HiMSEN

HD HYUNDAI HEAVY INDUSTRIES (S.Korea)

DAIHATSU

DAIHATSU InfiniEarth (Japan)

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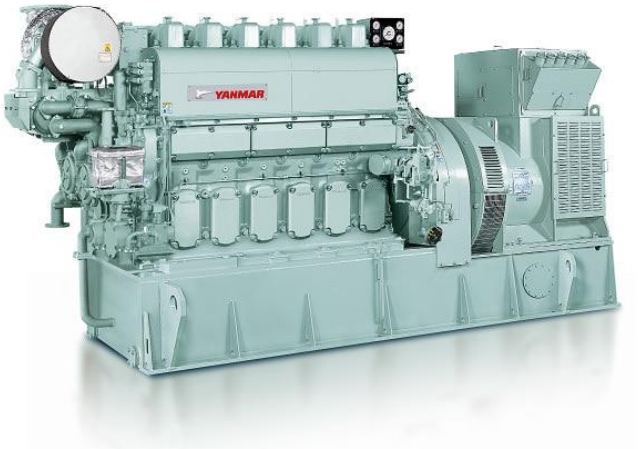
4-stroke ICE (G/E)

There are several makers of G/E that you will encounter when boarding a ship.

Some of them are shown in below.

YANMAR



YANMAR (Japan)

Everllence

MAN B&W

MAN Diesel & Turbo

MAN Energy Solutions

MAN Energy Solutions is now: Everllence

Everllence (Germany)

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4-stroke ICE (G/E)

There are several makers of G/E that you will encounter when boarding a ship.

Some of them are shown in below.

WÄRTSILÄ

WÄRTSILÄ (Finland)

You will encounter the G/E of the five brands described above when you board the ship.

Most ships recently built in Korean shipyards and owned by Korean shipowners are equipped with HiMSEN engines.

As you may have noticed, the G/E of all brands looks similar.

As they look similar, the structure and operating mechanism of all G/Es are almost identical.

Therefore, if you fully understand the G/E of just one brand, you will have no problem understanding the G/E of other brands.

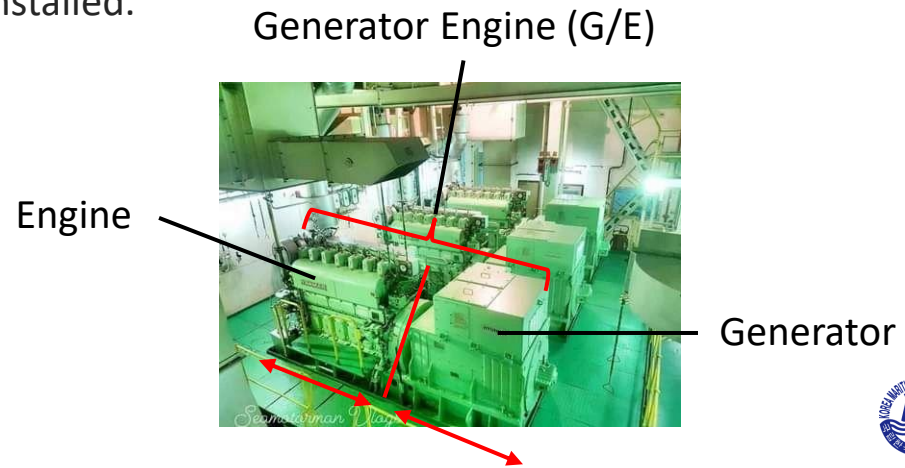
4-stroke ICE (G/E)

As explained in Chapter 1, G/E is divided into the Engine side and the Generator side.

The Engine side generates rotational force to the crankshaft through the reciprocating motion of the piston.

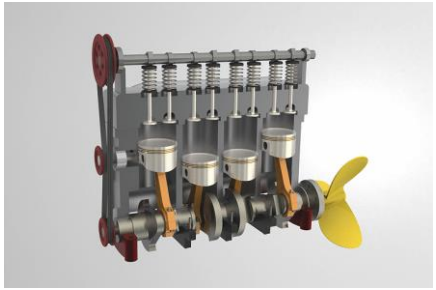
The Generator side uses the rotational power of the crankshaft to produce electricity from the generator.

A ship usually has 3 to 4 G/Es installed.



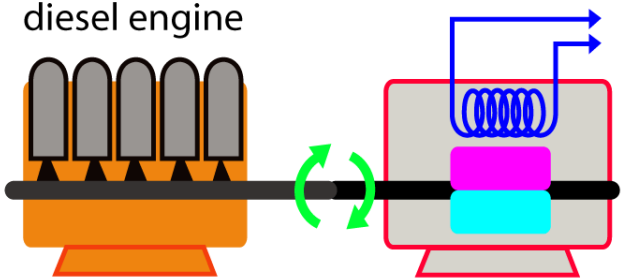
4-stroke ICE (G/E)

Engine side



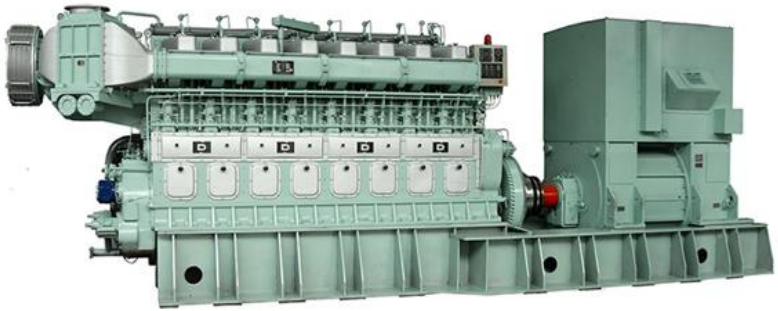
Engine side

Generator side

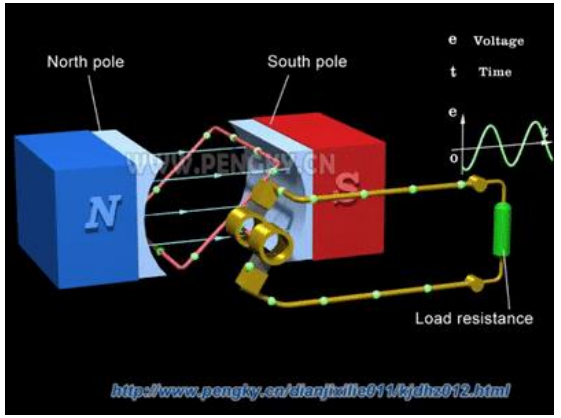


how equipment works .com

Imagine
a generator
connected to a
shaft instead of a
propeller.



Generator side



4-stroke ICE (G/E)

Since the generator side is probably covered in the class of "Marine Electrical and Electronic Engineering," this class (Internal Combustion Engine) only focuses on the engine side.

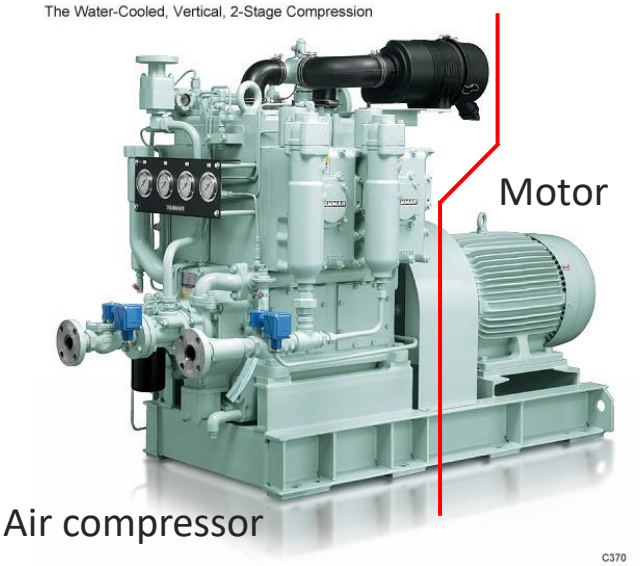
Compressed Air System for G/E

Marine air compressor

How does G/E start?

To answer this, you need to understand the Compressed Air System.

There are 2 to 3 air compressors installed on the ship, and they look like below.

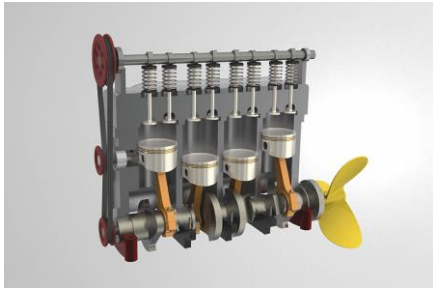


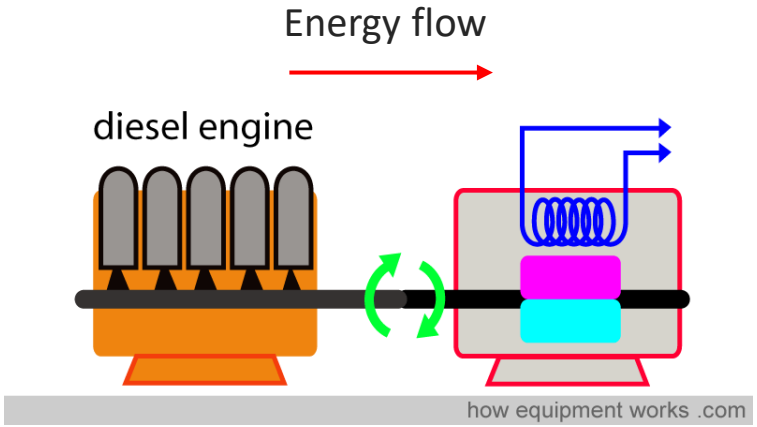
4-stroke ICE (G/E)

The engine side of the G/E and air compressor have a similar structure.

The differences between the driving mechanisms of G/E and air compressor are as follows.

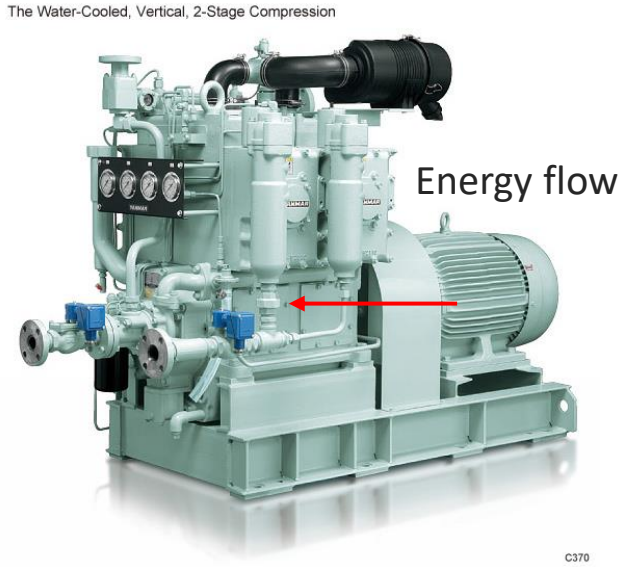
G/E creates a reciprocating motion of the piston by the explosive force from the combustion of air and fuel, which rotates the crankshaft, and a generator is connected to the crankshaft to produce electricity.

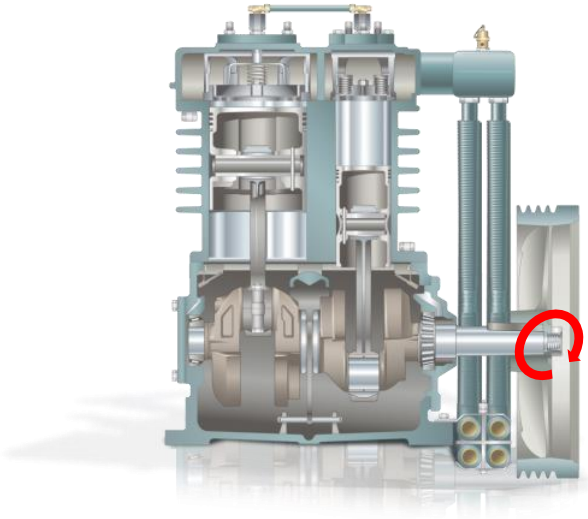




Marine air compressor

An air compressor has a crankshaft connected to the shaft of a motor, and the rotational force of the motor creates a reciprocating motion of a piston, which compresses the air and produces compressed air.





Motor rotational power

Marine air compressor

Compressed air produced by the air compressor is stored in air reservoir tanks for starting the M/E and G/E.

No. 1 air reservoir tank

No. 2 air reservoir tank

3 air compressors

Air reservoir tank

The air reservoir tank is filled with compressed air, and there is condensed water at the very bottom of the tank, so the apprentice engineer usually opens the drain valve to drain it in the morning and at afternoon.

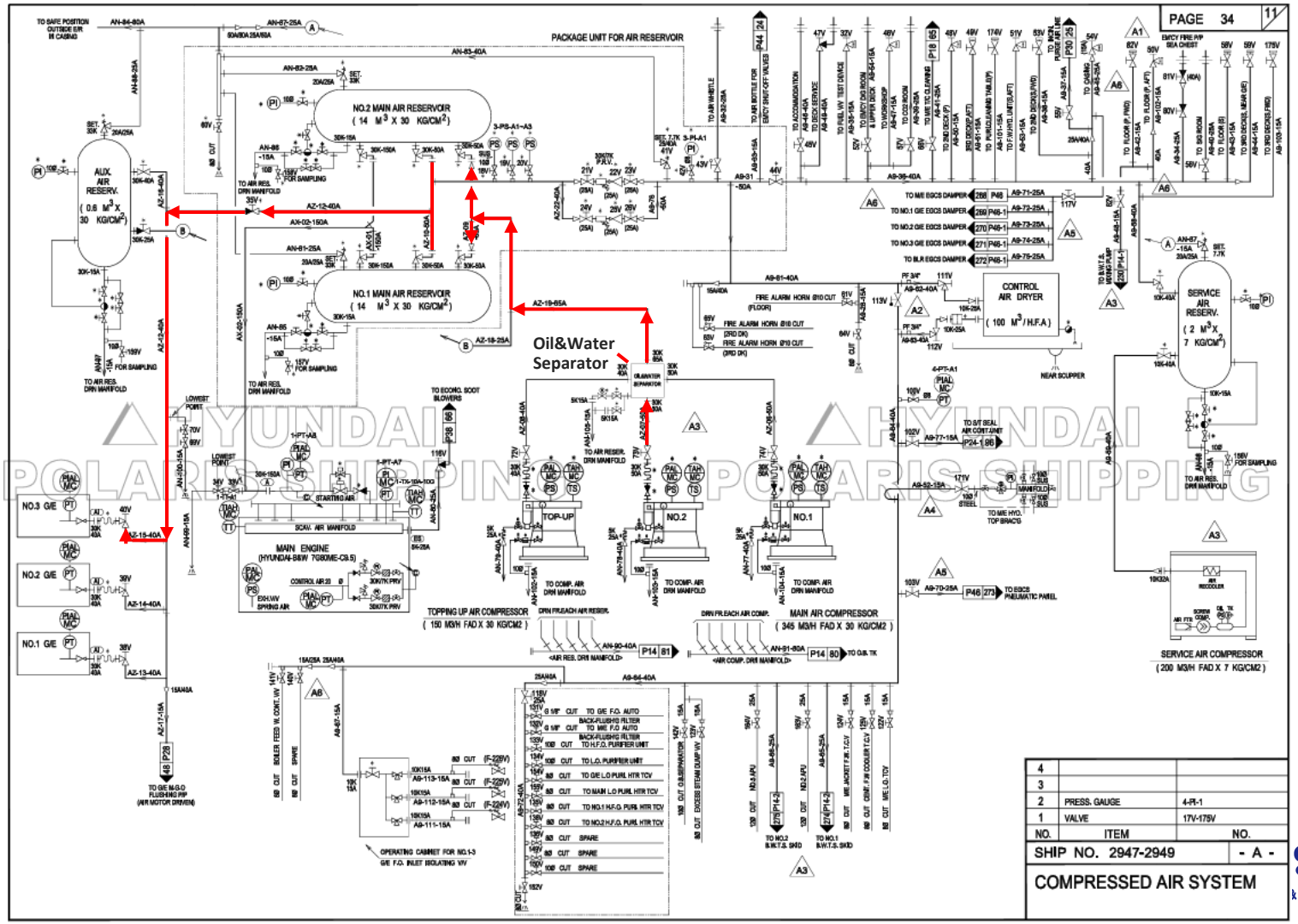
The reason for draining is that if moisture is mixed in the compressed air and flows into the M/E or G/E when they are started, there is a possibility that it will cause a damage and malfunction.

Water drain valves

The actual air reservoir tank on a ship is not as small as the picture on the left, but is very large as shown in the picture on the previous slide.
The left one might be the auxiliary air reservoir tank .

Clockwise: Valve close
Counterclockwise: Valve open

Valve



Compressed Air System of G/E

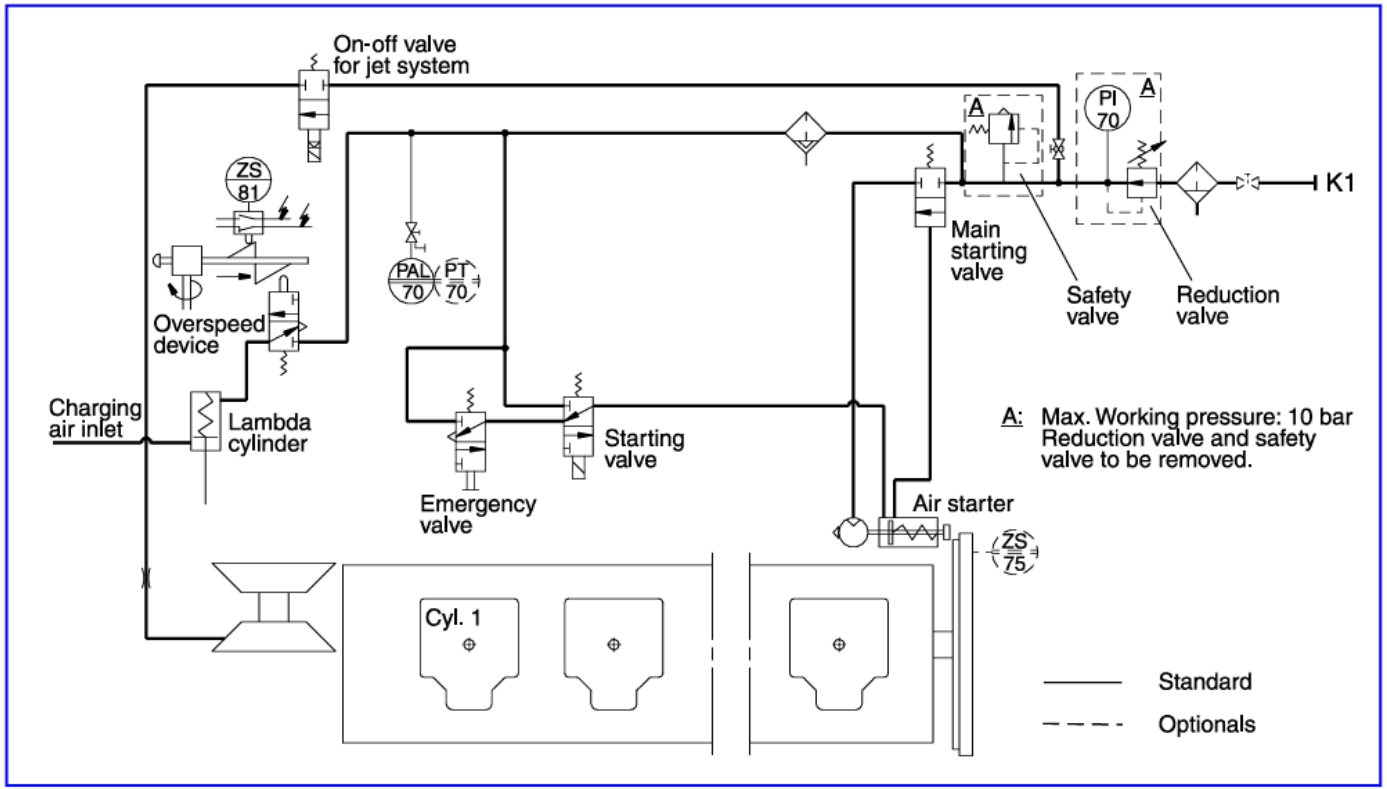


Fig 1 Diagram for compressed air system.

Compressed Air System of G/E

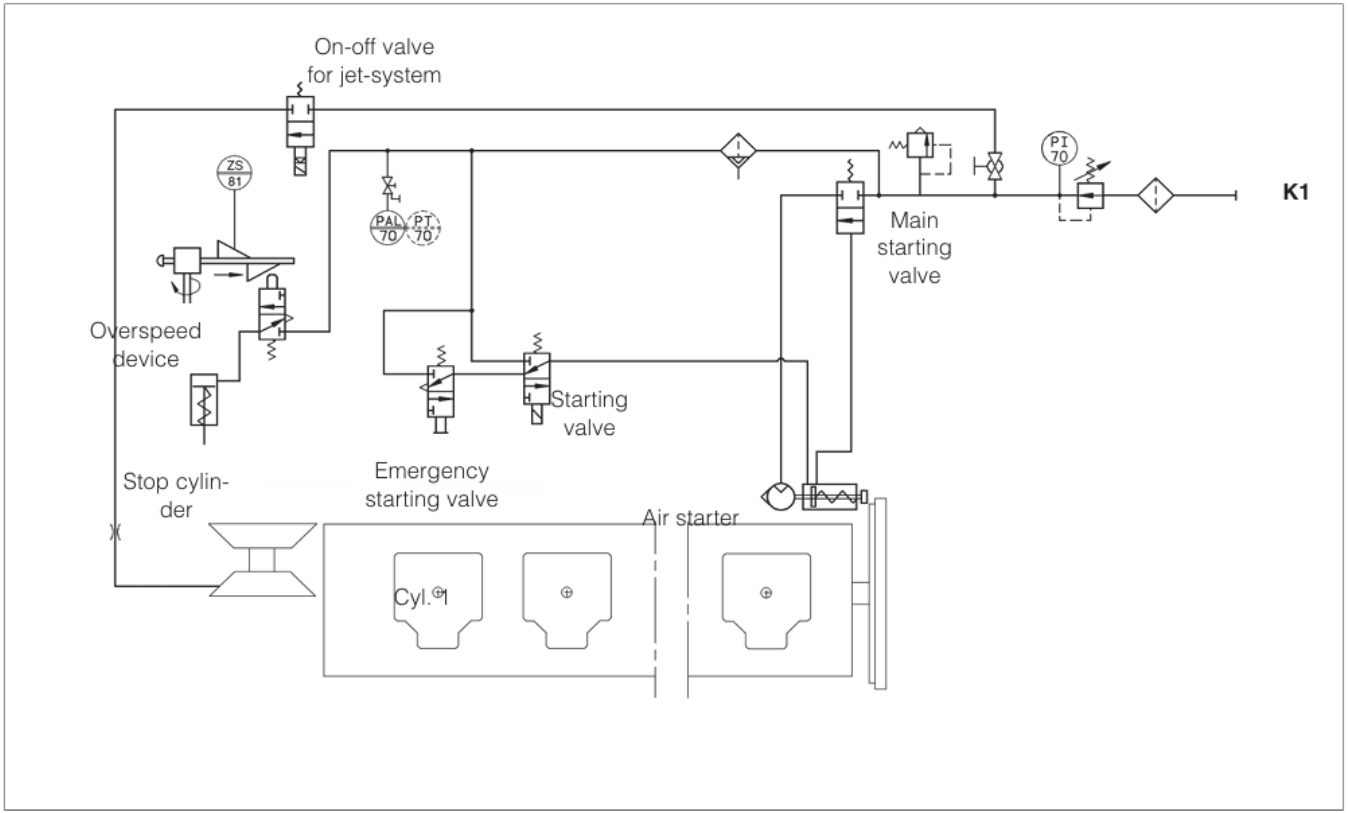


Fig. 1. Diagram for Compressed Air System

Compressed Air System of G/E

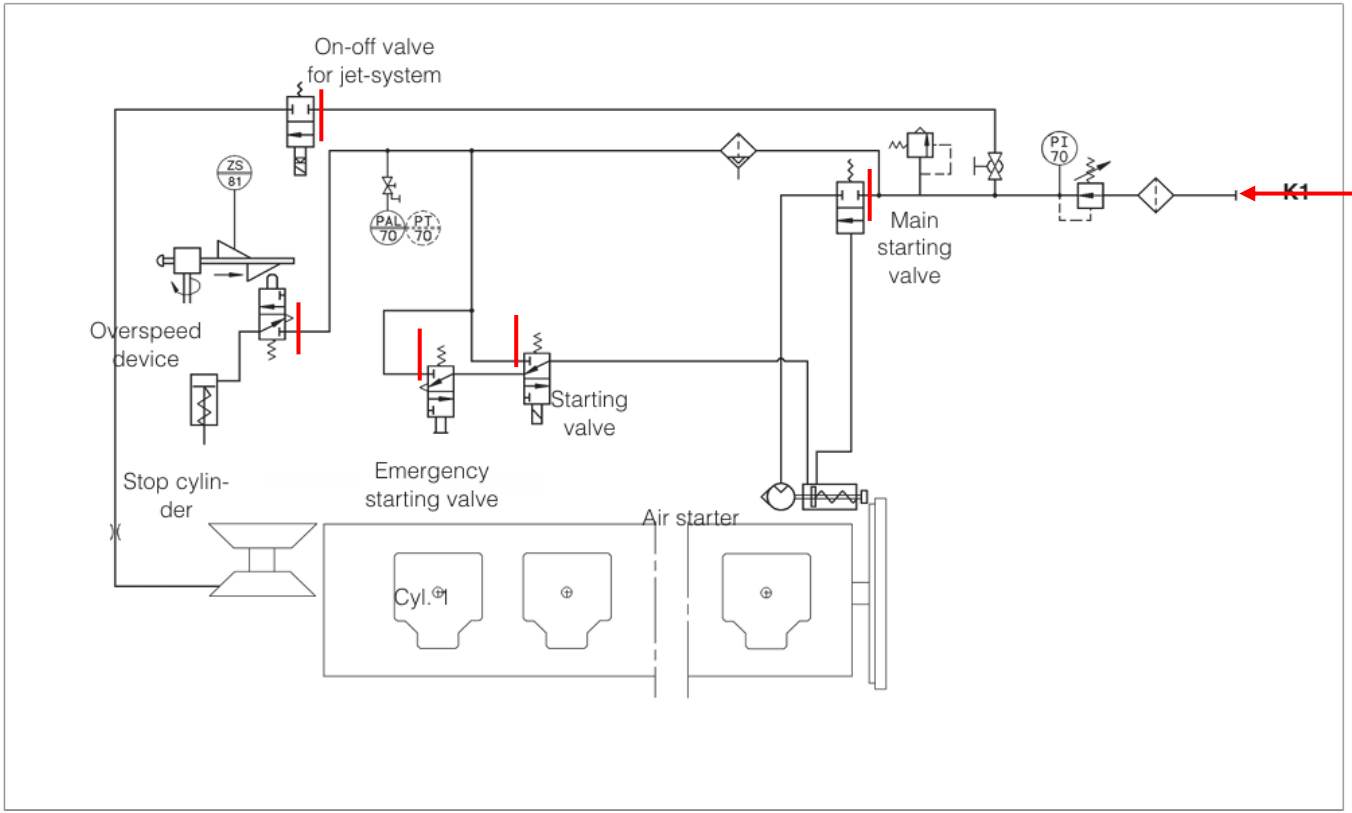


Fig. 1. Diagram for Compressed Air System

The compressed air is continuously supplied from the starting air receivers (30 bar) through a reduction station to the Compressed Air System of G/E.

1 atm = 1.01325 bar

atm = atmospheres

Compressed Air System of G/E

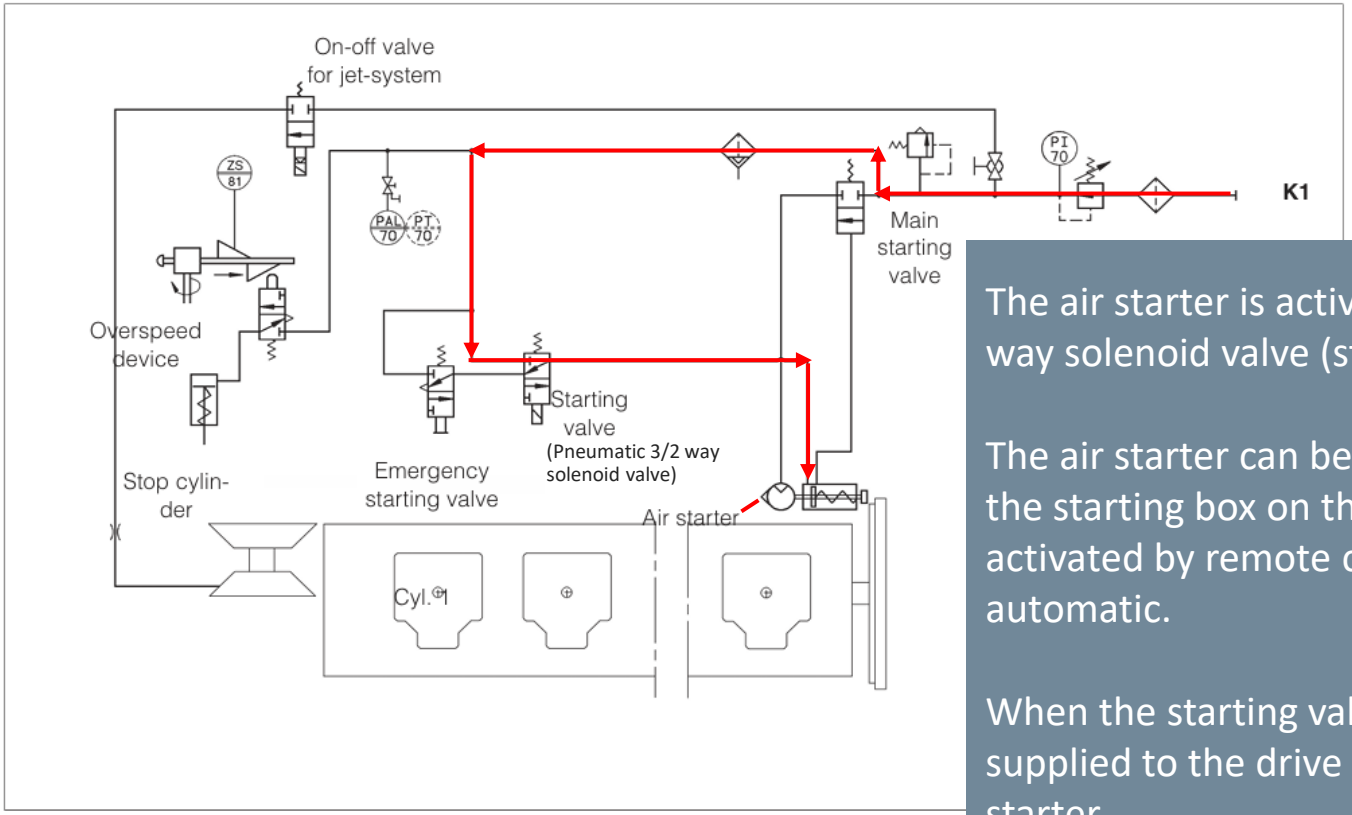


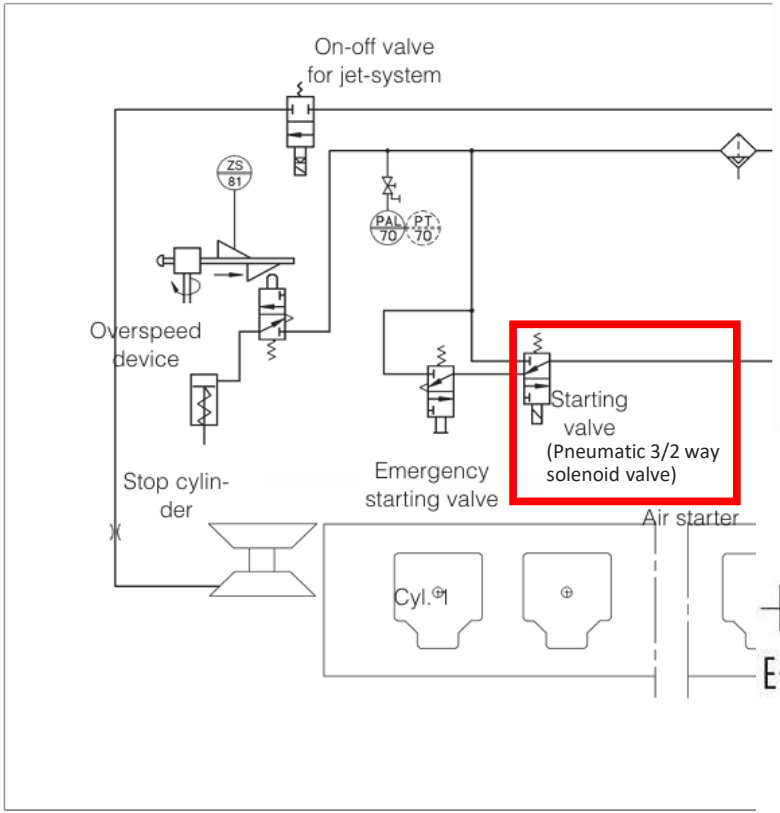
Fig. 1. Diagram for Compressed Air System

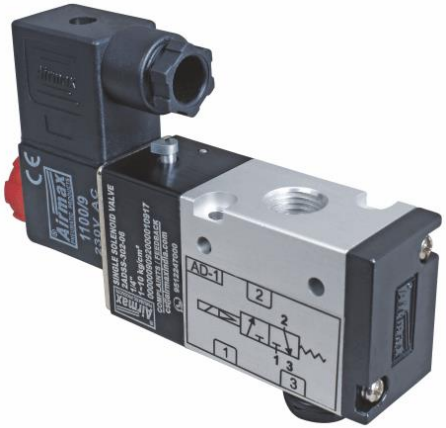
The air starter is activated with a pneumatic 3/2 way solenoid valve (starting valve).

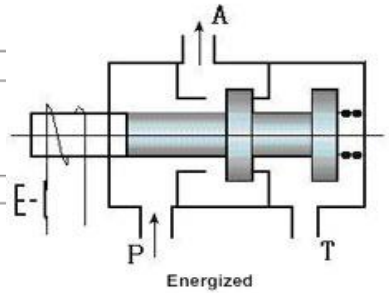
The air starter can be activated manually from the starting box on the engine, and it can be activated by remote control, manual or automatic.

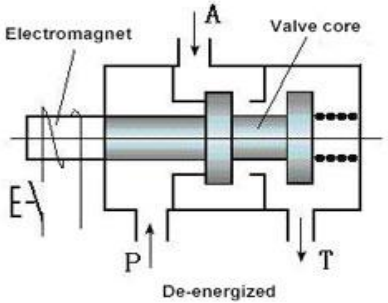
When the starting valve is opened, air will be supplied to the drive shaft housing of the air starter.

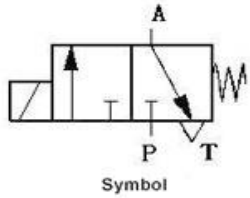
Compressed Air System of G/E







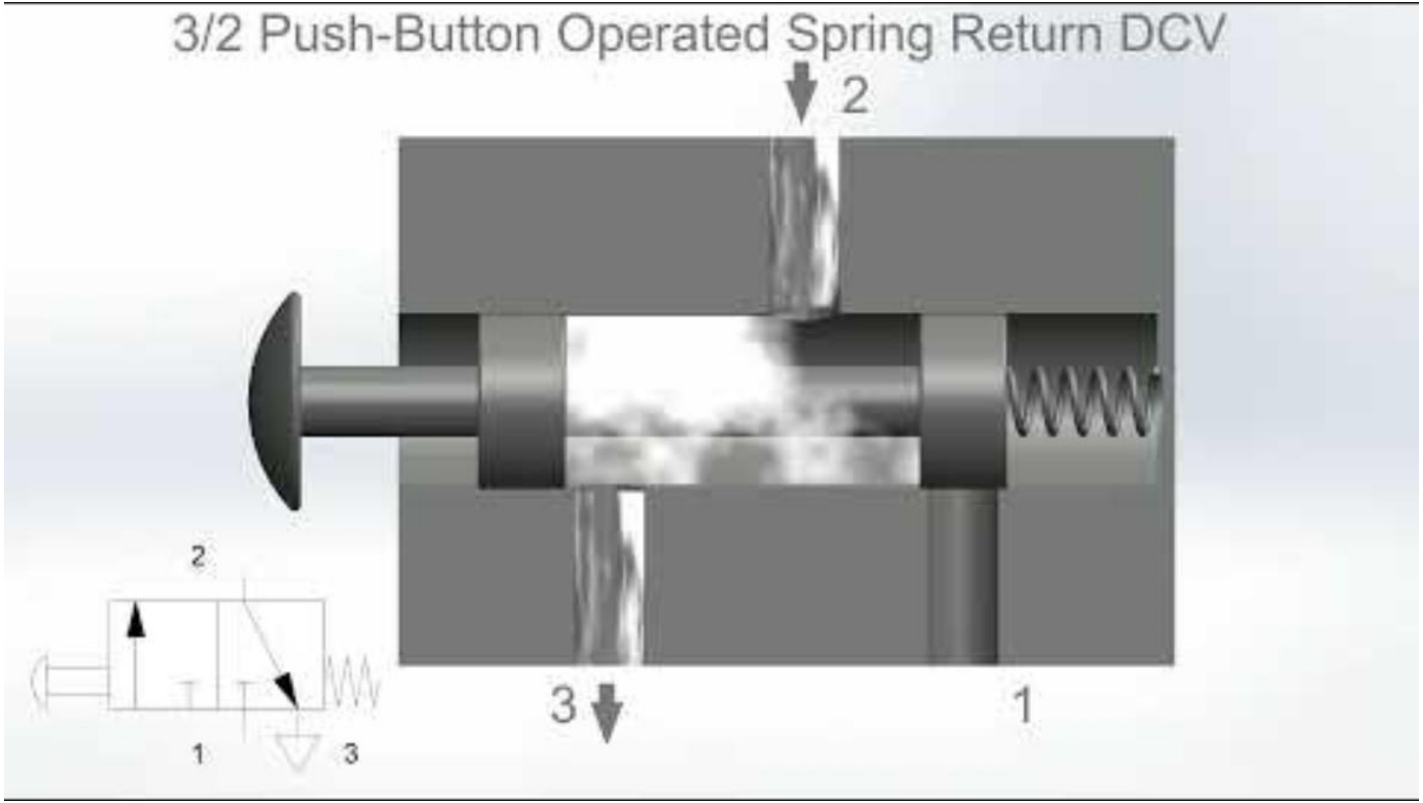




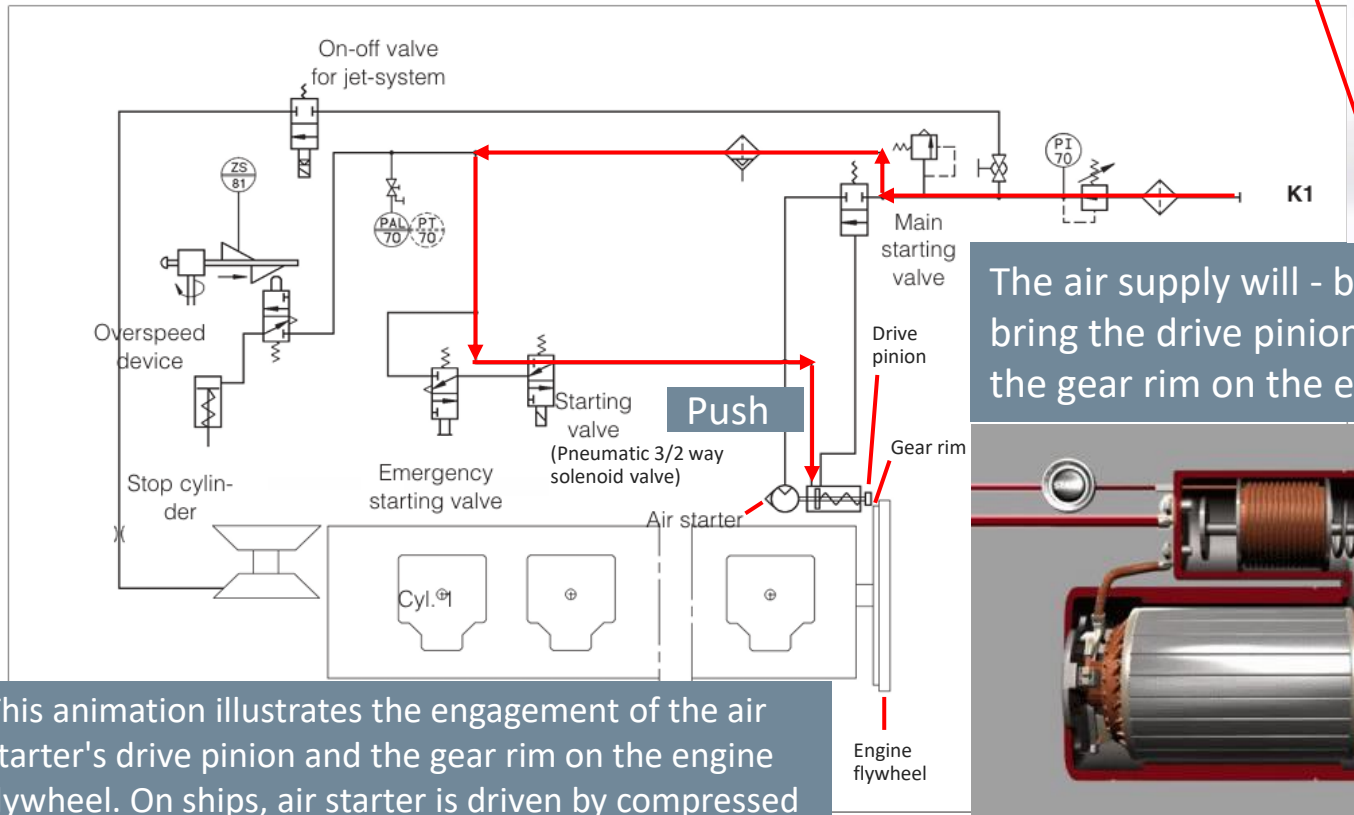
3/2-way Normally Closed Solenoid Valve

Fig. 1. Diagram for Compressed Air System

Compressed Air System of G/E



Compressed Air System of G/E



The air supply will - by activating a piston - bring the drive pinion into engagement with the gear rim on the engine flywheel.

This animation illustrates the engagement of the air starter's drive pinion and the gear rim on the engine flywheel. On ships, air starter is driven by compressed air, not electricity.

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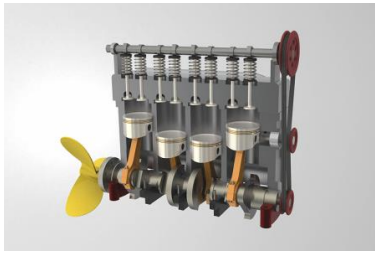
Compressed Air System of G/E



Air starter

Drive pinion

Engine flywheel

Gear rim of flywheel

Example of an air starter installed in a G/E

Compressed Air System of G/E

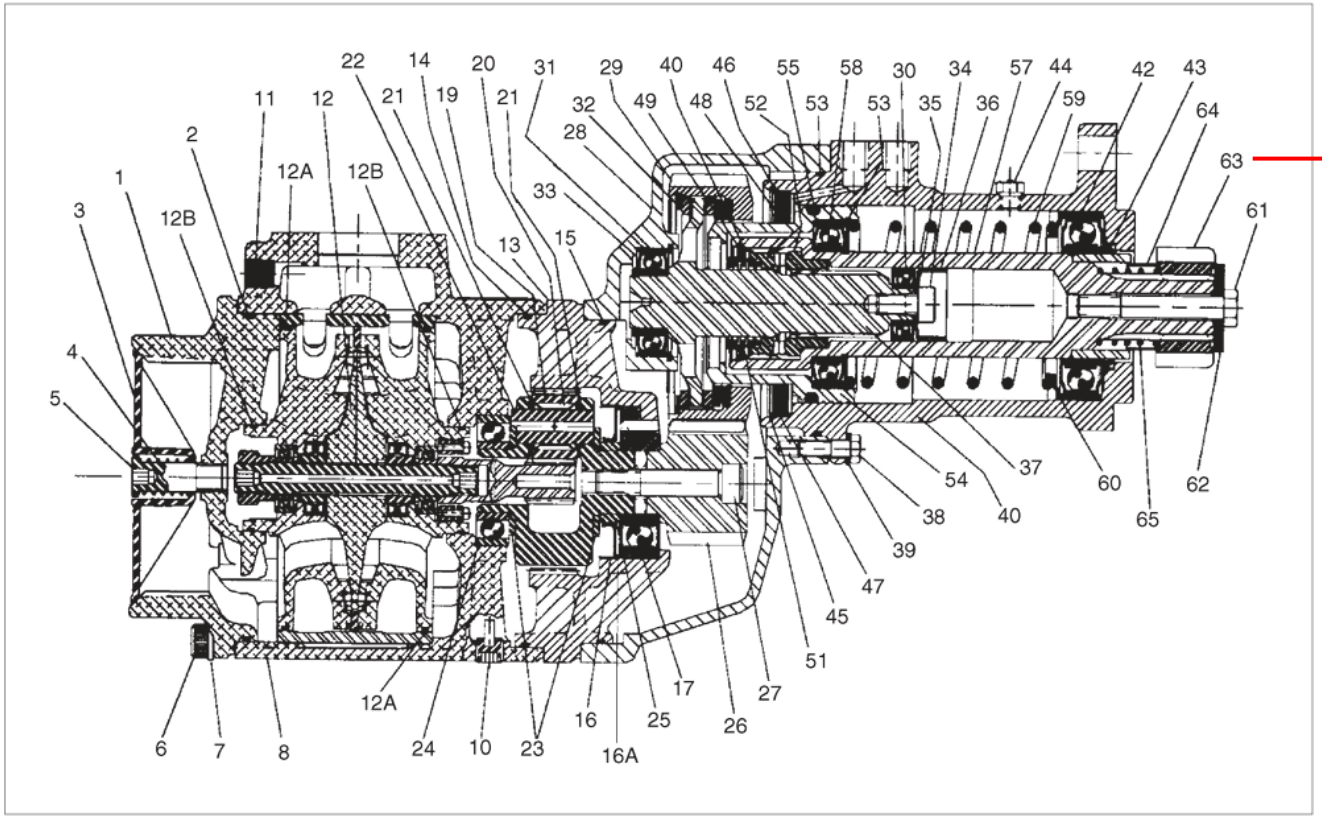
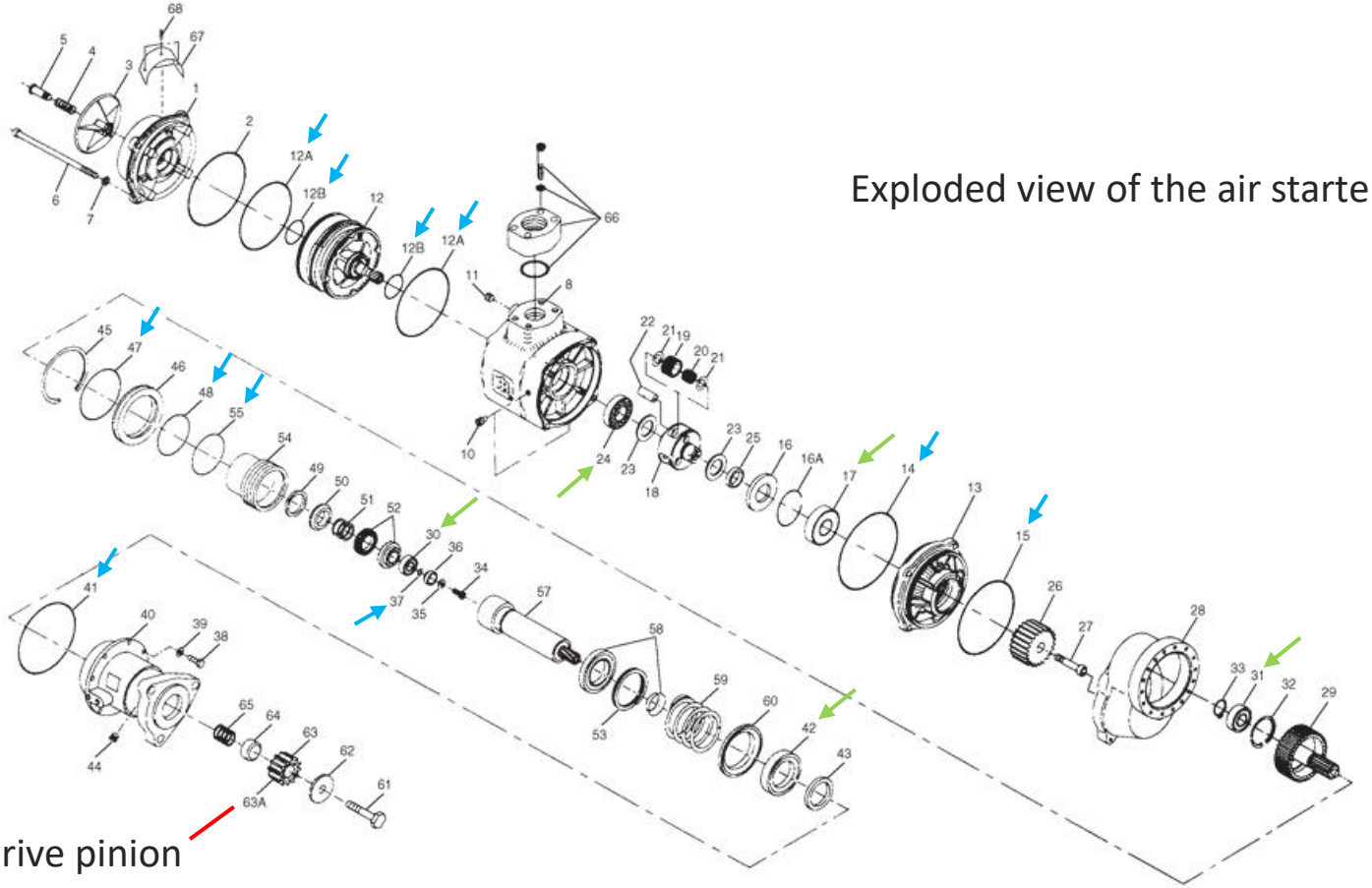


Fig 6. Turbine Starter. Example of an air starter (turbine starter) installed in a G/E

Compressed Air System of G/E



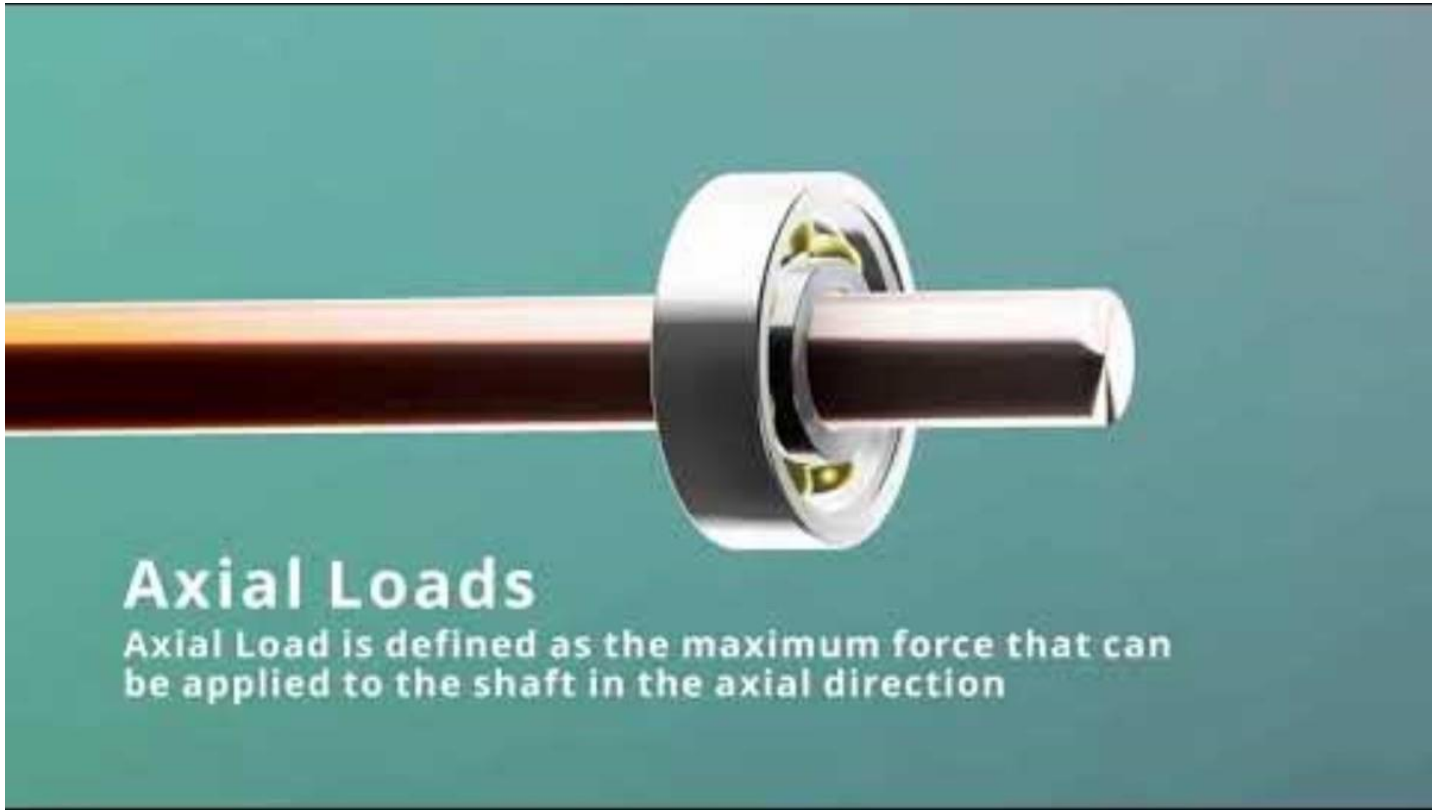
Exploded view of the air starter

: Bearing

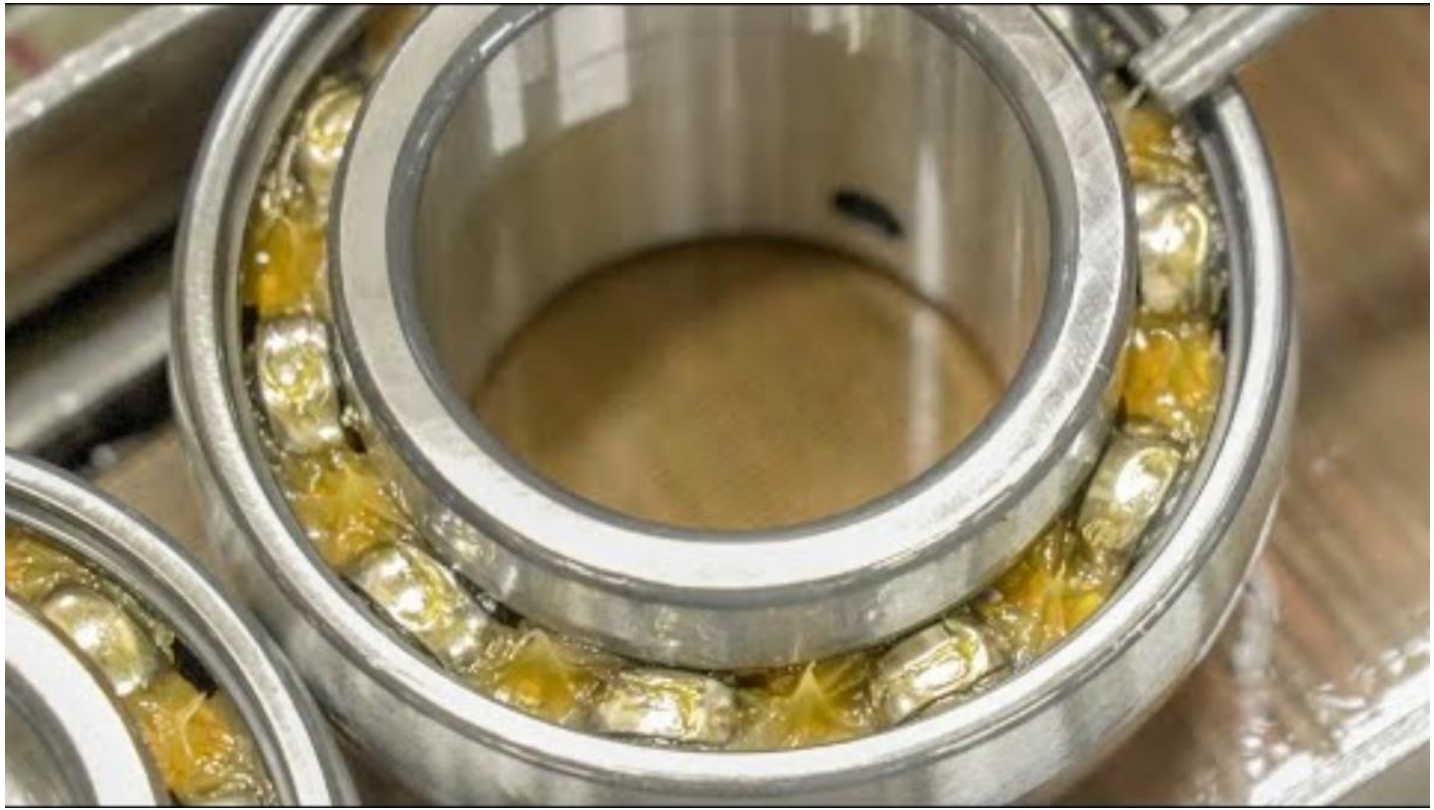
: O-ring

Ball bearing

Ball bearing



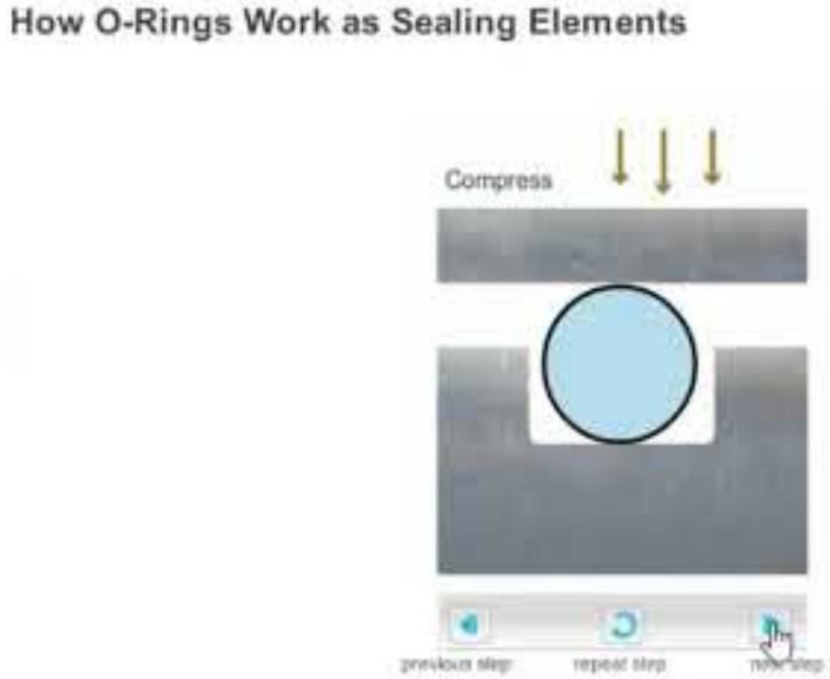
Ball bearing



Ball bearing

O-ring

O-ring


How O-Rings Work as Sealing Elements
Compress
previous step
repeat step
next step

O-ring

https://www.youtube.com/shorts/o-Qs2qcS4dU

Compressed Air System of G/E

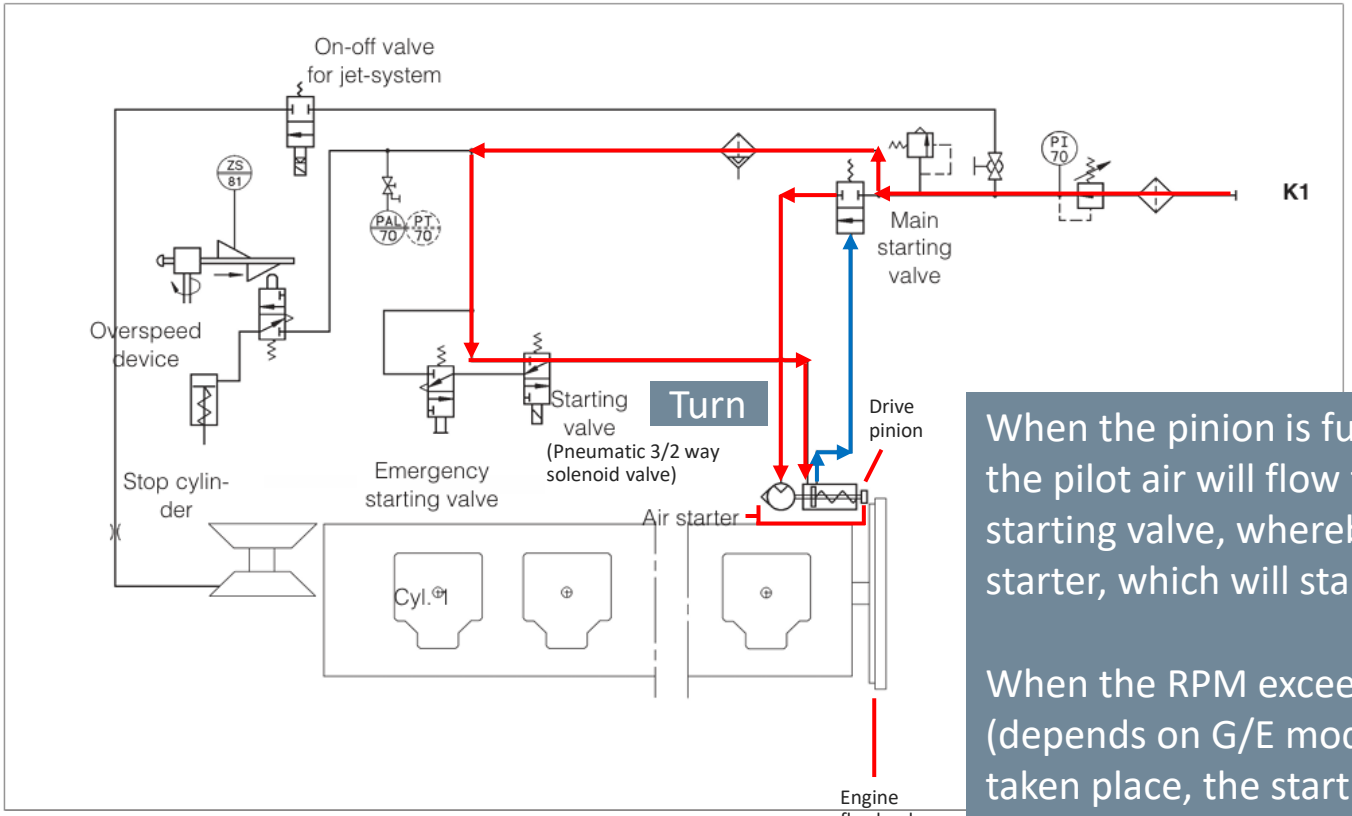


Fig. 1. Diagram for Compressed Air System

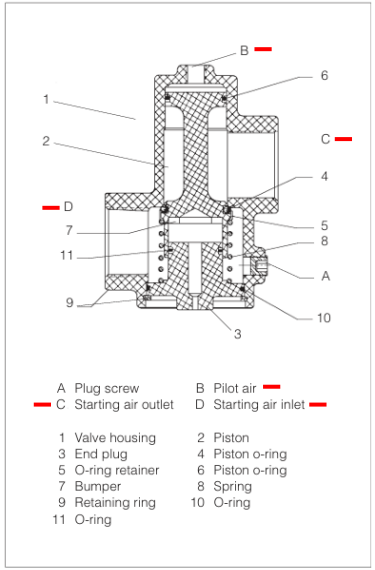
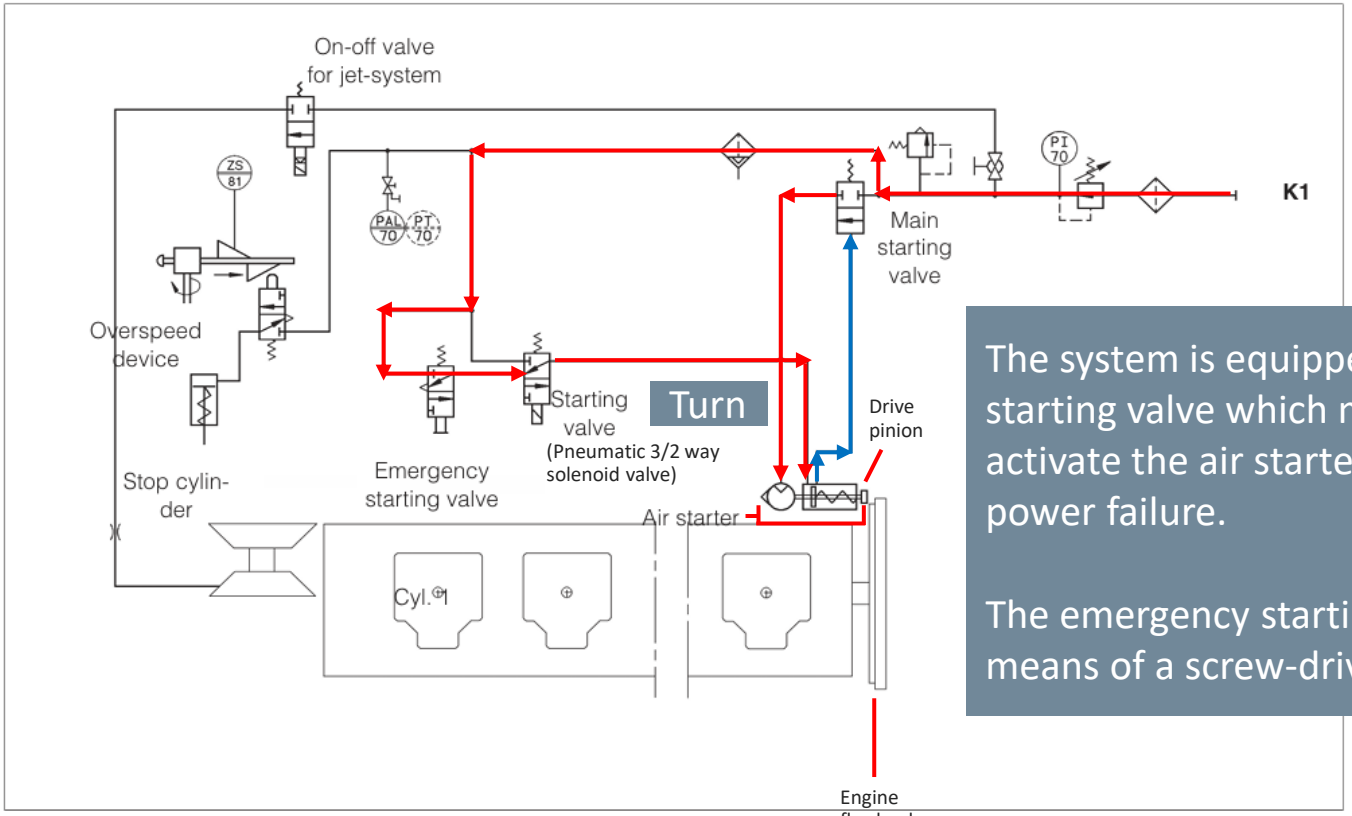


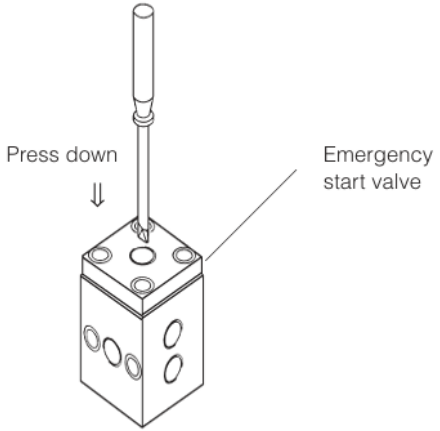
Fig. 1. Main starting valve.

When the pinion is fully engaged, the pilot air will flow to, and open the main starting valve, whereby air will be led to the air starter, which will start to turn the engine.

When the RPM exceeds approximately 110 (depends on G/E model), at which firing has taken place, the starting valve is closed whereby the air starter is disengaged.

Compressed Air System of G/E



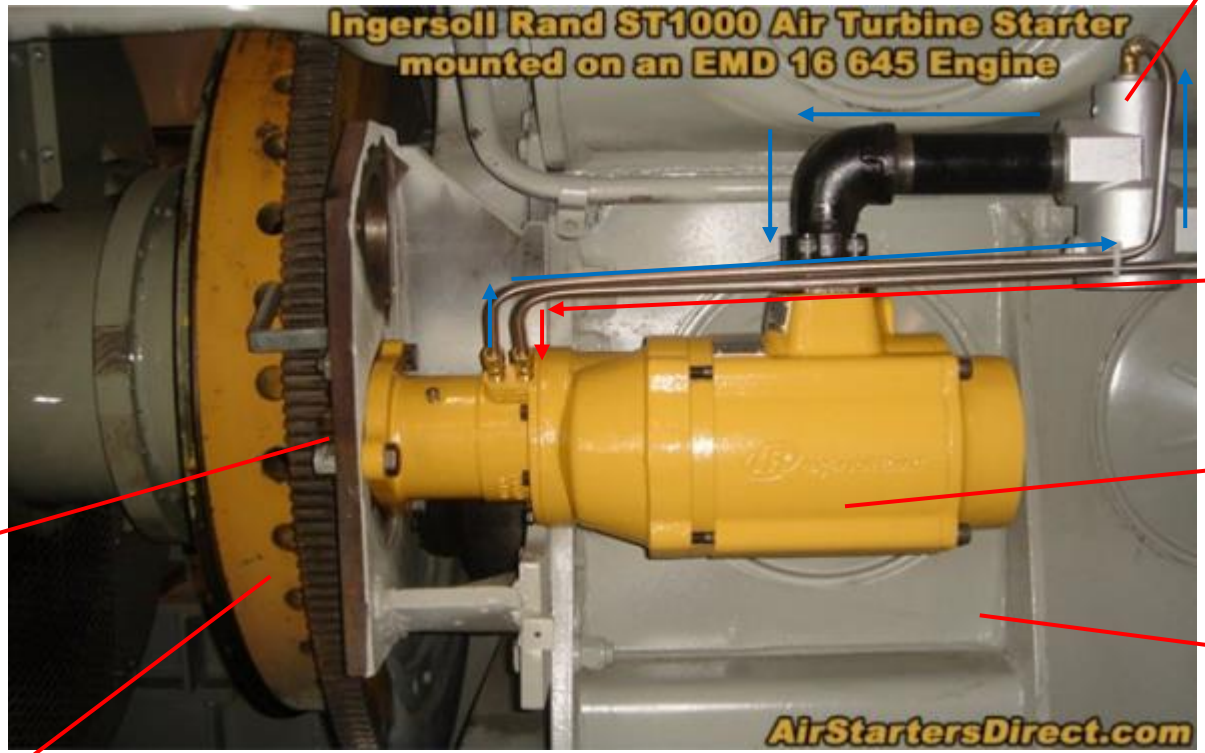


The system is equipped with an emergency starting valve which makes it possible to activate the air starter manually in case of a power failure.

The emergency starting valve is activated by means of a screw-driver or similar.

Fig. 1. Diagram for Compressed Air System

Compressed Air System of G/E



Main starting valve

Compressed air from starting valve

Air starter

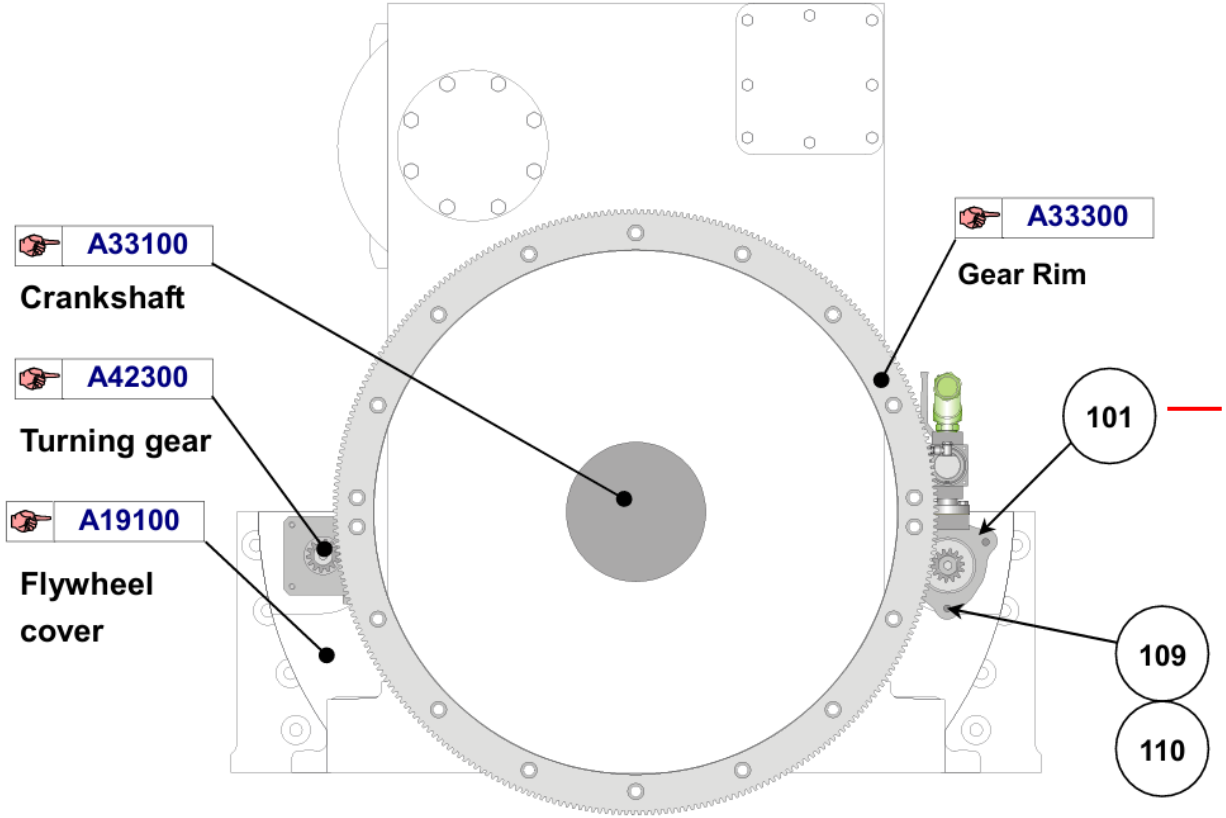
G/E

Drive pinion

Engine flywheel

Example of an air starter installed in a G/E

Compressed Air System of G/E



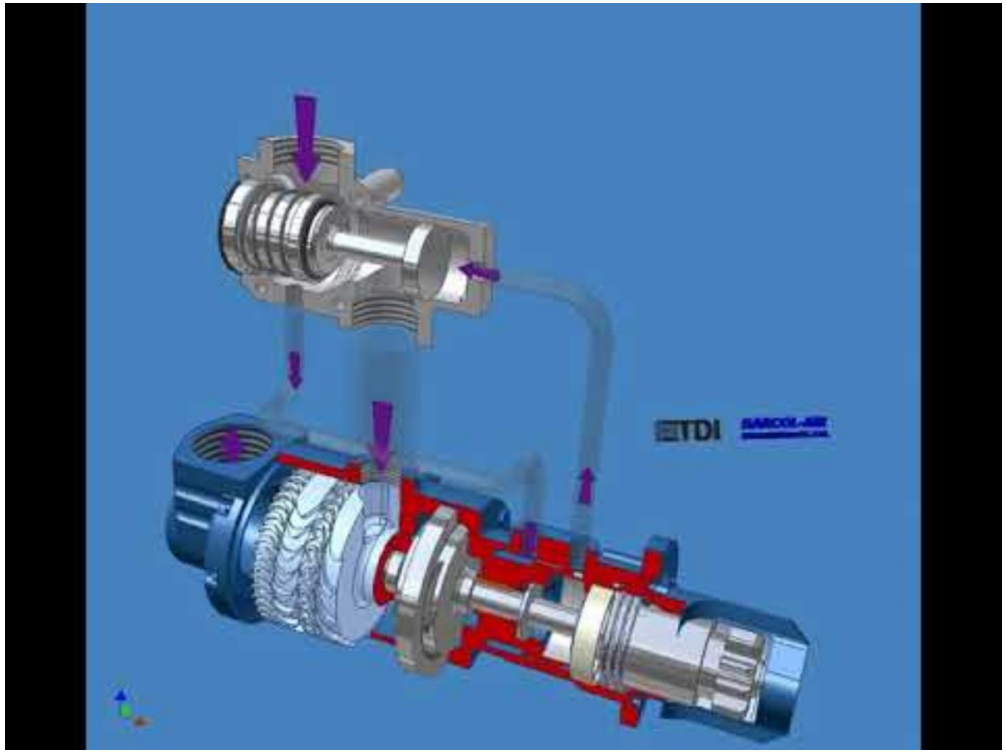
Starting air motor (=Air starter)

Compressed Air System of G/E

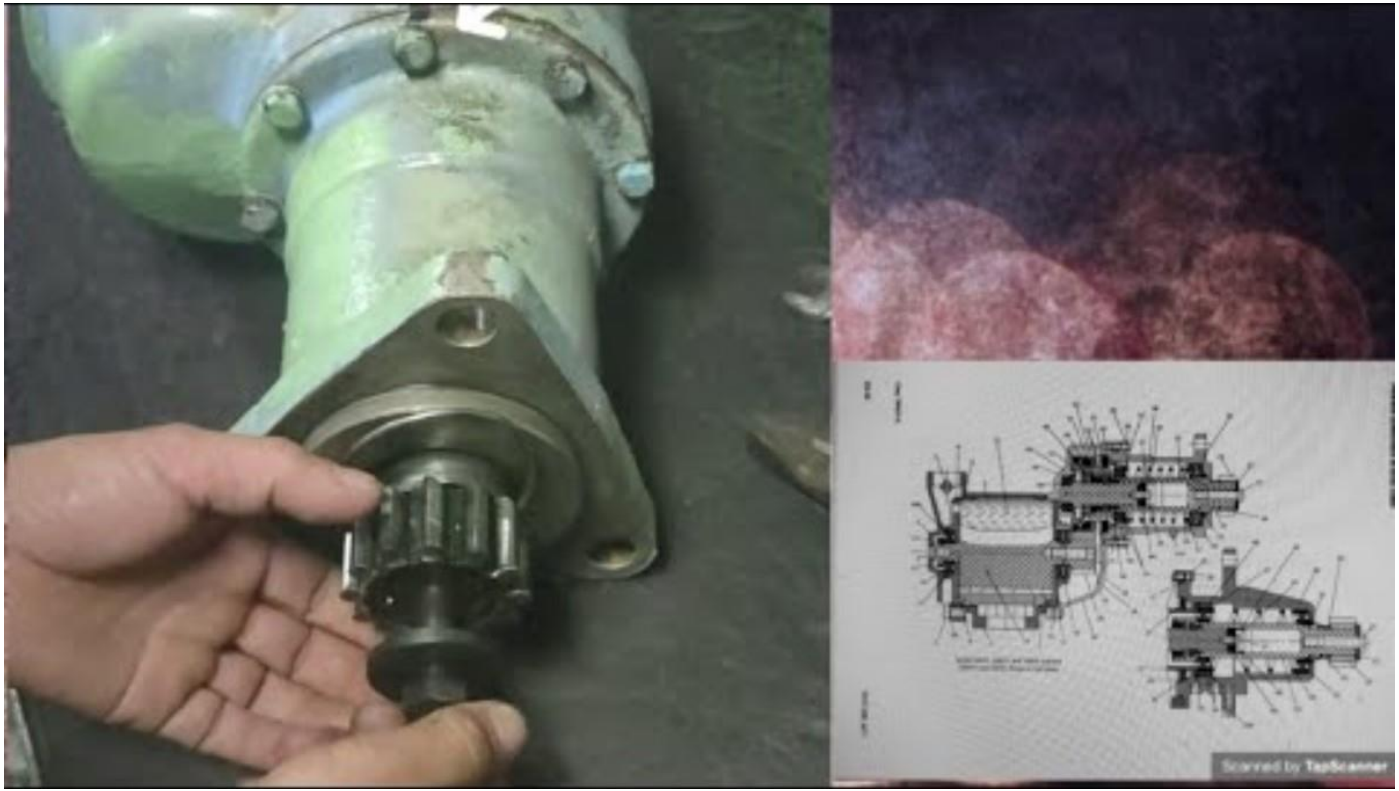
Compressed Air System of G/E

Compressed Air System of G/E

Compressed Air System of G/E



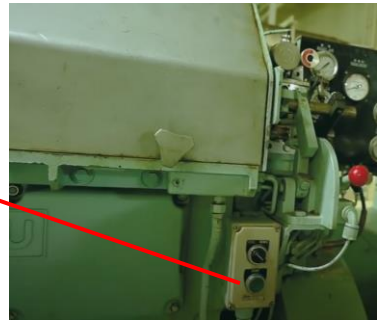
Compressed Air System of G/E



Compressed Air System of G/E

Start & stop panel for G/E (HiMSEN)

It is located next to G/E.



It is located on the main switchboard in the engine control room.

'START' button on the control panel activates starting solenoid valve opened to supply compressed air into the starting air motor. Then, the pinion of the air starting motor is engaged with the gear rim of the engine flywheel and turns crankshaft of the engine.

Hence, when the engine rotating speed reaches predetermined speed, fuel oil is injected into the combustion chamber for self-rotating. Then, starting is completed and the pinion of the air starting motor is disengaged from the gear rim at predetermined speed.

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