10

AIR AND EXHAUST SYSTEMS AND TURBOCHARGERS

An English language learning unit
based on authentic materials
Turbochargers - videos

- https://www.youtube.com/watch?v=SEnyWGYx8ZE&feature=youtu.be
- https://www.youtube.com/watch?v=69B5K3OX6Pw
- https://www.youtube.com/watch?v=Grzf3JvUne0
- https://www.youtube.com/watch?v=Grzf3JvUne0
- https://www.youtube.com/watch?v=NaN5tH3-EVI
- www.marineinsight.com/marine-ebooks/
Turbocharger and turbocharged engine.
• **Turbocharger** is an integral part of the ship’s marine engine as it *reuses the exhaust gases* in order to increase the *overall efficiency* of the engine.

• It consists of two parts – **blower and turbine sides**, which need equal attention while carrying out routine maintenance procedures.

• As a **marine engineer** working on ships, you would be required to *monitor the performance* of turbochargers during the watch and *carry out maintenance* whenever required.
Modern engines of both the four-stroke and two-stroke type are **turbocharged**, i.e. fitted with a turbine driven air compressor which supplies air under pressure for **scavenging** and **pressure charging**.

All the power required to **operate** the **turbochargers** has been recovered from the waste heat in the **exhaust gases**.
Supply the missing words

- Modern engines of both the four-stroke and two-stroke type .................., i.e. fitted with a turbine driven ................. which supplies air under pressure for ............... and pressure charging.

- All the power required to ............... the turbochargers has been recovered from the ............ in the exhaust gases.
The exhaust gases entering the casing are led up to the **nozzle ring** which is of **annular** form. It contains a number of **stationary blades** which direct the flow of gas on to the **moving blades** on to the **turbine wheel**. The blades of the turbine wheel are individual members **attached to** the disc at their roots by **specially shaped fixing**. Their surfaces are **curved** to extract the maximum amount of energy from the exhaust gases and **transfer** it to the **turbine shaft**.

After passing through the turbine the exhaust gas is at the pressure almost down to the atmosphere. It is **conducted away** from the turbocharger through the **outlet casing** via exhaust pipes to the exhaust **silencer**, then out into the open air through the **stack** or through the exhaust gas boiler.
• The exhaust gases entering the casing ................. to the nozzle ring which is of _________ form. It contains a number of stationary blades which ................. on to the _________ blades on to the turbine wheel. The blades of the _____________ are individual members attached to the disc ................ by specially shaped fixing. Their surfaces are curved to ................. from the exhaust gases and transfer it to the turbine ______________.

• After ......................... the exhaust gas is at the pressure almost down to the atmosphere. It is conducted away from the turbocharger through the outlet casing via ____________ to the __________________, then ......................... through the stack or through the exhaust gas boiler.
The turbine of the turbocharger *drives* a centrifugal *compressor*. The *impeller* of the compressor *is mounted on the same shaft as the* *turbine wheel*. It consists of a disc on the side of which are a number of radial *vanes* which *diminish* in thickness as they approach the periphery. At the centre they *are formed to* gather the air which enters at the *eye of impeller*.

The rotation *imparts* a high velocity flow to the air *so that* it leaves the periphery of the disc at high speed. After leaving the disc it *enters* the *diffuser*. This is a stationary member on which there are number of blades forming *passages* which gradually *increase* in cross section.
Supply the missing verb

- The turbine of the turbocharger is ________ a centrifugal compressor. The impeller of the compressor is ________ on the same shaft as the turbine wheel. It consists of a disc on the side of which are a number of radial vanes which ________ in thickness as they ________ the periphery. At the centre they are ________ to gather the air which enters at the eye of impeller.

- The rotation ________ a high velocity flow to the air so that it ________ the periphery of the disc at high speed. After ________ the disc it ________ the diffuser. This is a stationary member on which there are number of blades ________ passages which gradually ________ in cross section.
• As the air flows through these passages its velocity falls and is converted into pressure. The efficiency of the system is increased by fitting a charge air cooler (or intercooler) after the compressor. This will cool the air at the constant pressure, increasing its density before supplying it for compression in the engine cylinders.

• The mass of air per cycle is in this way increased and the quantity of fuel injected can be raised to give a corresponding increase in engine output. It will also increase the thermal efficiency of the engine.
Supply the missing terms

- As the air flows through these _________ its velocity falls and is converted into _________. The efficiency of the system is increased by fitting a charge air cooler (or _________) after the compressor. This will cool the air at the constant pressure, increasing its _________ before supplying it for compression in the engine _________.

- The mass of air per _________ is in this way increased and the quantity of _________ injected can be raised to give a corresponding increase in engine _________. It will also increase the thermal _________ of the engine.
QUESTIONS AND DISCUSSION

1. Why are turbochargers fitted to modern diesel engines?
2. Where is the energy necessary to power the turbochargers derived from?
3. On entering the casing, what component does the exhaust gas go through?
4. Why are the blade surfaces of the turbine wheel curved?
5. What is the pressure of the exhaust gas after it has passed through the turbine?
6. Where do the exhaust gases pass before being let into open air?
1. Is the air compressor of the turbochargers of the reciprocating piston type? For what operation is this type of compressor used?

2. How does a centrifugal blower function?

3. What is air made to pass through before being admitted into the cylinders? Give reasons for it.

4. What is the purpose of supercharging? Mention its main advantages.

5. The method of turbocharging described in Lesson 10 is one of the constant pressure type. Do you know if there is any other system?
I. Fill in the blanks with the main components that form the turbocharger:

<table>
<thead>
<tr>
<th>STATIONARY ELEMENTS</th>
<th>ROTATING ELEMENTS</th>
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II. Give a description as detailed as possible of each member indicating:

<table>
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<tr>
<th>Turbocharger member</th>
<th>what it consist of and its function</th>
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III. Complete the labelling of Fig.10.2. and describe the turbocharging system:
IV. Complete the sentences choosing the right definition. Give also, if possible, the correct term for the remaining statement

Scavenging means:
- to supply a larger mass of air to the cylinder by blowing it under pressure.
- to remove the exhaust gases by blowing in fresh air.

The scavenging process is used:
- in four-cycle engines
- in two-stroke engines
- in both the four-cycle and two-cycle engines

Supercharging means:
- to raise the density and consequently the weight of air supplied to cylinders
- to fill the engine cylinders with a supply of fresh air ready for compression

Supercharging is used:
- in four cycle-engines
- in two-cycle engines
- in both the four-cycle and two-cycle engines
A **centrifugal force:**
- tends to move a rotating body outwards from the centre of rotation
- tends to move a rotating body inward towards the centre of rotation

**Annular means:**
- shaped in sharp corners
- ring-like shape
- coming or happening every year.

- **An impeller is:**
  - a mechanical device having two or more blades which when rotated produces a forward thrust
  - a rotating component which imparts kinetic energy by centrifugal force to fluid

**The intercooler is placed:**
- at the turbine entry casing to reduce the temperature of the exhaust gases in order to avoid heat stresses
- between the supercharger and the engine to reduce the temperature of the air entering the engine

**The term radial means:**
- extending in a direction parallel to the main axis
- extending in a straight line from the centre of the circle to the curve or circumference.
V. Complete the following sentences using the right form of the **VERB – NOUN** collocations listed below:
*convert into pressure/ direct the flow / enter the casing / form a passage / lead the gas / drive the compressor / transfer the energy*

1. After passing through the disc the air _________________ the diffuser casing.
2. In the internal combustion engines the energy _________________ from thermal to mechanical energy.
3. The flow of air through the passages in the diffuser _________________ into pressure.
4. The flow of fuel ___________ by a distributor valve.
5. Through the exhaust manifold the flow of gases _________________ to the turbocharger.
6. The tiny passages _________________ to separate the exhaust streams and lead them to the nozzle ring.
7. After leaving the turbocharger the exhaust gases _________________ to the silencer, then out into the open air.
8. The exhaust gases from the engine cylinders blow on the turbine blades and make it turn at high speed _________________ the air compressor.
VI. Compete the following passage using the appropriate prepositions from the list below:

- at, in, of, from, by, on, to, through

Basically a turbocharger consists _______ two disc connected ___________ a shaft. Both discs carry vanes which make them act like fans. The gases ___________ the engine cylinders blow ___________ one disc and make it turn ___________ high speed driving the other disc. The latter disc which acts as a compressor draws air ___________ the atmosphere, compresses it and then cools it ___________ the charge air cooler before supplying it _______ the engine cylinders ___________ the scavenge ports or inlet valves. The charge air cooler is fitted ___________ the system because compression will raise the temperature of air ___________ a high level thus reducing its density. By cooling the engine is maintained ___________ a safe working temperatures and lower compression temperature reducess stress _______ piston rings, piston and liner.
VII. Go through the text of Lesson 10 and find sentences in the passive voice. Analyze them by:

- determining the tense, number and person
- finding the true subject
- transforming them into active voice where appropriate
VIII. Put the passive sentences from the previous exercise into the interrogative form.

Use the “YES-NO” type questions, i.e. questions beginning with an auxiliary verb.
A two stroke crosshead engine must be supplied with air above atmospheric pressure for it to work. Although the first turbochargers were developed for aero engines in the first world war, it was not until the 1950s that large two stroke engines were turbocharged.
• The pressurised air needed to "scavenge" the cylinders of the exhaust gases and supply the charge of air for the next combustion cycle was first provided by **mechanically driven compressors** (*Roots Blowers*), or by using the space under the piston as a **reciprocating compressor** (*Under Piston Scavenging*).

• This of course meant that the engine was supplying the work to compress the air, which meant that the useful work obtained from the engine was decreased by this amount.
The pressurised air needed to …………………… of the exhaust gases and supply the charge of air for the next combustion cycle was provided

• (a) by ………………………… (Roots Blowers), or
• (b) by using the space under the piston as a __________________________ (Under Piston Scavenging).

• This of course meant that the …………………… the work to compress the air, which meant that the useful work obtained from the engine was __________________ by this amount.
• Engine powers have increased phenomenally in the past 30 years. In 1980 an engine delivering 15000 kW was a powerful engine. Today's largest engines are capable of delivering over 4 times this amount. This is due not only to improved materials and manufacturing techniques, but also to the improvements and developments in the design of the turbochargers fitted to these engines.

• The amount of useful energy that an engine can produce is dependent on two factors;
  • The amount of fuel that can be burnt per cycle and
  • the efficiency of the engine.
• Engine powers have increased phenomenally ..............
• In 1980 an engine ____________ 15000 kW was a ____________ engine.
• Today's largest engines are capable of delivering over ................... .
• This is due not only to improved materials and ________________, but also to the improvements and ___________ in the ______________ of the turbochargers fitted to these engines.
• The amount of useful energy that an engine can produce is ____________ on two factors;
  • The .................... that can be burnt per cycle and the ..................... .
Fuel consists mainly of Carbon and Hydrogen. By burning the fuel in oxygen the energy in the fuel is released and converted into work and heat. The more fuel that can be burnt per cycle, the more energy released.

However, to burn more fuel, the amount of air supplied must also be increased. For example, a 10 cylinder engine with a bore of 850mm and a stroke of 2.35m must burn 1kg of fuel per revolution to deliver 38500kW when running at 105 RPM. (assuming 50% efficiency).
• *This means that* each cylinder burns 0.1 kg fuel per stroke. To ensure that the fuel is burnt completely it is supplied with 220% more air than theoretically required. Because it takes about 14kg of air to supply the theoretical oxygen to burn 1kg of fuel, 4.5kg of air must be supplied into each cylinder to burn the 0.1kg of fuel.
• Fuel consists mainly of ..................., , , , , , , , , , , , , . By burning the fuel in oxygen the energy in the fuel is released and ......................... The more fuel that can be burnt per cycle, ............... energy released.

• However, to ........................., the amount of air supplied must also be _______________. For example, a 10 cylinder engine with a _________ of 850mm and a _________ of 2.35m must burn 1kg of fuel per _________________ to deliver 38500 kW when ___________ at 105 RPM. (assuming 50% efficiency).
This means that each cylinder burns 0.1 \text{ kg}. To ensure that the fuel is burnt completely it is supplied with 220\% more \text{ kg}. Because it takes about 14\text{ kg} of air to supply the theoretical oxygen to burn 1\text{ kg} of fuel, 4.5\text{ kg} of \text{ kg} into each cylinder to burn the 0.1\text{ kg} of fuel.
• Some of this air is used up scavenging (clearing out) exhaust gas from the cylinder. The air also helps cool down the liner and exhaust valve.

• As the piston moves up the cylinder on the compression stroke and the exhaust valve closes, the cylinder must contain more than the theoretical mass of air (about 3.7 kg) to supply the oxygen to burn the fuel completely.
• Some of this air is used up __________ (clearing out) exhaust gas from the cylinder. The air also helps __________ the liner and exhaust valve. As the piston _______ up the cylinder on the compression stroke and the exhaust valve ________, the cylinder must contain more than the _________________ of air (about 3.7 kg) to supply the ____________ to burn the fuel completely.
• 3.7kg of air at atmospheric pressure and 30°C occupies a volume of 3.2m$^3$. The volume of the cylinder of the engine in our example is about 1.2m$^3$ after the exhaust valve closes and compression begins.

• Because the temperature of the air delivered into the engine is raised to about 70°C as it enters the engine, it can be calculated that to supply the oxygen required for combustion, the air must be supplied at 3 × atmospheric pressure or 2 bar gauge pressure.
• 3.7kg of air at _______________ and 30°C occupies a ___________ of 3.2m³.

• The volume of the cylinder of the engine in our example is about _______________ after the exhaust valve closes and ___________ begins.

• Because the temperature of the air delivered into the engine is _______ to about 70°C as it ___________ the engine, it can be calculated that to ___________ the oxygen required for combustion, the air must be supplied at 3 × atmospheric pressure or 2 bar _______________.
• NOTE: These figures are approximate and for illustration only. Manufacturers quote the specific fuel oil consumption of their engines in g/kWh. These figures are obtained from testbed readings under near perfect conditions. Quoted figures range between 165 and 175g /kWh. The actual specific fuel consumption obtained is going to depend on the efficiency of the engine and the calorific value of the fuel used.
• NOTE: These figures are ____________ and for illustration only.
• ____________ quote the specific fuel oil consumption of their engines in ____________.
• These figures are obtained from ____________ readings under near perfect conditions.
• Quoted figures ____________ between 165 and 175g /kWh.
• The actual specific fuel consumption ____________ is going to depend on the efficiency of the engine and the ____________ of the fuel used
• About 35% of the total heat energy in the fuel is wasted to the exhaust gases. The Turbocharger uses some of this energy (about 7% of the total energy or 20% of the waste heat) to drive a single wheel turbine. The turbine is fixed to the same shaft as a rotary compressor wheel. Air is drawn in, compressed and, because compression raises the temperature of the air, it is cooled down to reduce its volume. It is then delivered to the engine cylinders via the air manifold or scavenge air receiver.

• The speed of the turbocharger is variable depending on the engine load. At full power the turbocharger may be rotating at speeds of 10000RPM.
Writing skills: Describe the operation of the turbocharger
• About 35% of the total heat energy in the fuel is ..................
• The Turbocharger uses some of this energy (about ..................) to drive a single wheel turbine.
• The turbine is fixed to the same shaft as ..........................................
• Air is drawn in, compressed and, because compression raises the temperature of the air, it is ..........................................
• It is then delivered to the engine cylinders via ..........................................
• The speed of the turbocharger is variable .................................
• At ...................... the turbocharger may be rotating at speeds of 10000RPM.
MATERIALS

- Gas Casing: Cast Iron (may be water cooled)

- Nozzle ring and blades: Chromium nickel alloy or a nimonic alloy.

- Compressor casing: Aluminium alloy

- Compressor Wheel: Aluminium alloy, titanium or stainless steel
1. Gas Inlet Casing
2. Turbine Nozzles
3. Turbine Wheel
4. Gas Outlet Casing
5. Silencer Filter
6. Compressor
7. Diffuser
8. Volute Casing
MATERIALS

- Gas Casing: 

- Nozzle ring and blades: 

- Compressor casing: 

- Compressor Wheel: 
STARTING THE ENGINE

• Because the engine needs to be supplied with air when starting up and running at low speeds, an auxiliary blower powered by an electric motor is provided.

• This automatically cuts out when the charge air supplied by the turbocharger is sufficient to supply the engine on its own.
STARTING THE ENGINE

• Because the engine needs to be supplied with air when starting up and running at low speeds, an ...........................................

• This automatically cuts out when the charge air supplied by the turbocharger is sufficient to ............................................

.........................................................
• Operational Information
• Turbocharging
• Principles and Construction
By turbocharging an engine, the following advantages are obtained:

- Increased power for an engine of the same size OR reduction in size for an engine with the same power output.
- Reduced specific fuel oil consumption - mechanical, thermal and scavenge efficiencies are improved due to less cylinders, greater air supply and use of exhaust gasses.
- Thermal loading is reduced due to shorter more efficient burning period for the fuel leading to less exacting cylinder conditions.
1. Gas Inlet Casing  
2. Turbine Nozzles  
3. Turbine Wheel  
4. Gas Outlet Casing  
5. Silencer Filter  
6. Compressor  
7. Diffuser  
8. Volute Casing
Supply your language equivalents for the labels below
INTRODUCTION – supply the missing words

By turbocharging an engine, the following ______________ are obtained:

• ____________ power for an engine of the same size OR reduction in size for an engine with the same power output.
• Reduced specific fuel oil ______________ - mechanical, thermal and scavenge efficiencies are improved due to less cylinders, greater air supply and use of ______________ gasses.
• Thermal loading is ______________ due to shorter more efficient burning period for the fuel leading to less exacting cylinder conditions.
The turbocharger consists of a single stage impulse turbine connected to a centrifugal impeller via a shaft.

The turbine is driven by the engine exhaust gas, which enters via the gas inlet casing. The gas expands through a nozzle ring where the pressure energy of the gas is converted to kinetic energy. This high velocity gas is directed onto the turbine blades where it drives the turbine wheel, and thus the compressor at high speeds (10 - 15000 rpm). The exhaust gas then passes through the outlet casing to the exhaust uptakes.
The turbocharger consists of a single stage connected to a centrifugal via a shaft.
The turbine is by the engine exhaust gas, which enters via the gas inlet. The gas expands through a nozzle ring where the pressure energy of the gas is to kinetic energy. This high velocity gas is directed onto the turbine where it drives the turbine, and thus the compressor at high speeds (10-15000 rpm). The exhaust gas then passes through the outlet casing to the exhaust.
• On the air side air is drawn in through filters, and enters the compressor wheel axially where it is accelerated to high velocity. The air exits the impeller radially and passes through a diffuser, where some of the kinetic energy gets converted to pressure energy. The air passes to the volute casing where a further energy conversion takes place. The air is cooled before passing to the engine inlet manifold or scavenge air receiver.
• On the air side air is drawn in through filters, and enters the compressor wheel axially where ..................................
• The air exits the impeller radially and passes through a diffuser, where some of ..........................................................
• The air passes to the volute casing where a further energy ........................................
• ............................................... before passing to the engine inlet manifold or scavenge air receiver.
The nozzle ring is where the energy in the exhaust gas is converted into kinetic energy. It is fabricated from a creep resistant chromium nickel alloy, heat resisting moly-chrome nickel steel or a nimonic alloy which will withstand the high temperatures and be resistant to corrosion.
The nozzle ring is where the energy in the exhaust gas is ________ into kinetic energy. It is ________ from a creep resistant chromium nickel alloy, heat resisting moly-chrome nickel steel or a nimonic alloy which will ________ the high temperatures and be ________ to corrosion.
Pair work – speaking skills:

Describe the operation of the turbocharger.
Turbine blades are usually a nickel chrome alloy or a nimonic material (a nickel alloy containing chrome, titanium, aluminium, molybdenum and tungsten) which has good resistance to creep, fatigue and corrosion. Blade roots are of fir tree shape which give positive fixing and minimum stress concentration at the conjunction of root and blade. The root is usually a slack fit to allow for differential expansion of the rotor and blade and to assist damping vibration. On small turbochargers and the latest designs of modern turbochargers the blades are a tight fit in the wheel.
Turbine blades are usually a _____________ alloy or a nimonic material (a ______________ containing chrome, titanium, aluminium, molybdenum and tungsten) which has good resistance to creep, ______________ and corrosion.

Blade ______________ are of fir tree shape which give positive fixing and minimum stress concentration at the ______________ of root and blade. The root is usually a ______________ to allow for differential expansion of the rotor and blade and to assist ______________ vibration. On small turbochargers and the latest designs of modern turbochargers the blades are a ______________ in the wheel.
Lacing wire is used to dampen vibration, which can be a problem. The wire passes through holes in the blades and damps the vibration due to friction between the wire and blade. It is not fixed to each individual blade. The wire can pass through all the blades, crimped between individual blades to keep it located, or it can be fitted in shorter sections, fixed at one end, joining groups of about six blades. A problem with lacing wire is that it can be damaged by foreign matter, it can be subject to corrosion, and can accelerate fouling by products of combustion when burning residual fuels. Failure of blading due to cracks emanating from lacing wire holes can also be a problem. All the above can cause imbalance of the rotor.
• Lacing wire is used to __________ vibration, which can be a problem. The wire __________ through holes in the blades and __________ the vibration due to friction between the wire and blade. It is not __________ to each individual blade.

• The wire can pass through all the blades, crimped between individual blades to __________ it located, or it can be fitted in shorter sections, fixed at one end, __________ groups of about six blades.

• A problem with lacing wire is that it can be __________ by foreign matter, it can be __________ to corrosion, and can accelerate __________ by products of combustion when burning __________ fuels. Failure of blading due to __________ emanating from lacing wire holes can also be a problem. All the above can cause __________ of the rotor.
The turbine casing is of cast iron. Some casings are water cooled which complicates the casting. Water cooled casings are necessary for turbochargers with ball and roller bearings with their own integral LO supply (to keep the LO cool). Modern turbochargers with externally lubricated journal bearings have uncooled casings. This leads to greater overall efficiency as less heat energy is rejected to cooling water and is available for the exhaust gas boiler.
The turbine casing is of .................

Some casings are water cooled which complicates the casting.

Water cooled casings are necessary for turbochargers with ................. bearings with their own ................. (to keep the LO cool).

Modern turbochargers with externally lubricated journal bearings have .................

This leads to ................. as less heat energy is rejected to cooling water and is available for .................
The compressor impeller is of aluminium alloy or the more expensive titanium. Manufactured from a single casting it is located on the rotor shaft by splines. Aluminium impellers have a limited life, due to creep, which is dictated by the final air temperature. Often the temperature of air leaving the impeller can be as high as 200°C. The life of the impeller under these circumstances may be limited to about 70000 hours. To extend the life, air temperatures must be reduced. One way of achieving this is to draw the air from outside where the ambient air temperature is below that of the engine room. Efficient filtration and separation to remove water droplets is essential and the impeller will have to be coated to prevent corrosion accelerated by the possible presence of salt water.
The air casing is also of aluminium alloy and is in two parts
• The compressor impeller is of ____________ alloy or the more expensive ____________. Manufactured from a single ____________ it is located on the rotor shaft by ____________. Aluminium impellers have a limited ____________, due to creep, which is dictated by the final air temperature.

• Often the temperature of air leaving the impeller can be ...................... 200°C.

• The life of the impeller under ......................... may be limited to about 70000 hours.

• ...............the life, air temperatures must be reduced.
• One way of achieving this is to ......................... where the ambient air temperature is below that of the engine room.

• Efficient filtration and separation to ......................... is essential and the impeller will have to be coated to prevent ..................... by the .........................
Bearings are either of the ball or roller type or plain white metal journals. The ball and roller bearings are mounted in resilient mountings incorporating spring damping to prevent damage due to vibration. These bearings have their own integral oil pumps and oil supply, and have a limited life (8000 hrs). Plain journal bearings are lubricated from the main engine oil supply or from a separate system incorporating drain tank, cooler and pumps. Oil is supplied in sufficient quantity to cool as well as lubricate. The system may incorporate a header tank arrangement to supply oil to the bearings whilst the turbocharger comes to rest should the oil supply fail. A thrust arrangement is required to locate and hold the rotor axially in the casing. In normal operation the thrust is towards the compressor end.
Match the right rows in the columns

<table>
<thead>
<tr>
<th>A, B, C …</th>
<th>1,2, 3 …</th>
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<tbody>
<tr>
<td>A. Bearings are either of the ball or roller type or</td>
<td>1. to supply oil to the bearings whilst the turbocharger comes to rest should the oil supply fail.</td>
<td>A6</td>
</tr>
<tr>
<td>B. The ball and roller bearings are mounted in resilient mountings incorporating spring</td>
<td>2. to cool as well as lubricate.</td>
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<tr>
<td>C. These bearings have their own integral oil pumps and oil supply,</td>
<td>3. and have a limited life (8000 hrs).</td>
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<tr>
<td>D. Plain journal bearings are lubricated from the main engine oil supply or</td>
<td>4. from a separate system incorporating drain tank, cooler and pumps.</td>
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<tr>
<td>E. Oil is supplied in sufficient quantity</td>
<td>5. hold the rotor axially in the casing.</td>
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<tr>
<td>F. The system may incorporate a header tank arrangement</td>
<td>6. plain white metal journals</td>
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<tr>
<td>G. A thrust arrangement is required to locate and</td>
<td>7. damping to prevent damage due to vibration.</td>
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</tbody>
</table>
• Labyrinth seals or glands are fitted to the shaft and casing to prevent the leakage of exhaust gas into the turbine end bearing, or to prevent oil being drawn into the compressor. To assist in the sealing effect, air from the compressor volute casing is led into a space within the gland. A vent to atmosphere at the end of the labyrinth gives a guide to the efficiency of the turbine end gland. Discoloring of the oil on a rotor fitted with a roller bearing will also indicate a failure in the turbine end gland.

• A labyrinth arrangement is also fitted to the back of the compressor impeller to restrict the leakage of air to the gas side
Seal between impeller and casing to restrict air leakage

Controlled leakage
Labyrinth seals or glands are fitted to the shaft and casing to prevent
 oil being drawn into the compressor.

To assist in the sealing effect, air from the compressor volute
casing is led

A vent to atmosphere at the end of the labyrinth gives a guide

Discoloring of the oil on a rotor fitted with a roller bearing will also indicate

A labyrinth arrangement is also fitted to the back of the compressor impeller to
IX. Translate into English:

- Kod ovog motora ispušne cijevi spojene su na svaki cilindar posebno.
- Ove cijevi vode izravno do sapnice.
- Na dnu cijevi nalaze se prirubnice.
- Putem cjevovoda za dovod goriva dovodi se gorivo do svakog cilindra.
- U sredini diska prolazi (vanes) su širi nego na krajevima.
- Na osovini montiran je rotor turbopuhala.
- Zrak izlazi iz kućišta turbine velikom brzinom.
- S lijeva nadesno poprečni presjek cijevi se smanjuje.
Turbocharger and turbocharged engine.
1. Compressor Housing
2. Bearing housing cover
3. Thrust bearing disk
4. Piston ring
5. Turbine/ Rotor
6. Turbine housing
7. Bearing housing
8. Strap
9. Bearing bush
10. Impeller wheel
11. Shaft nut