10

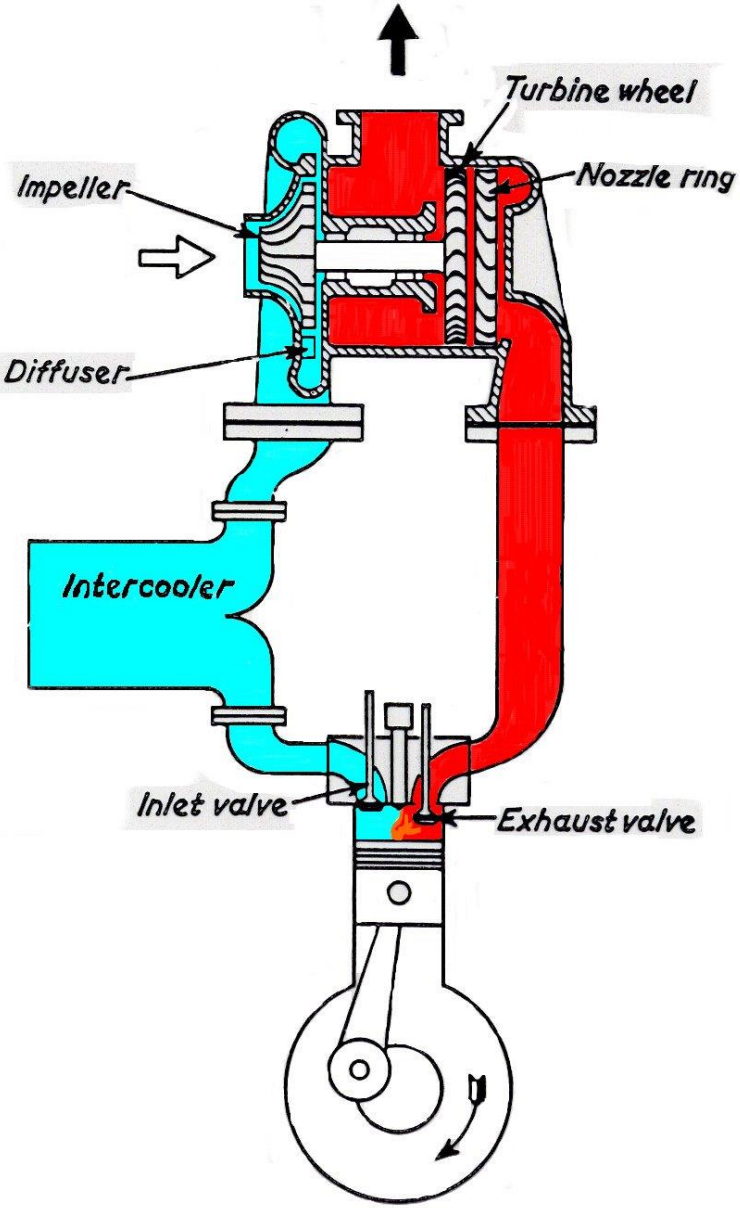
AIR AND EXHAUST SYSTEMS AND TURBOCHARGERS

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.

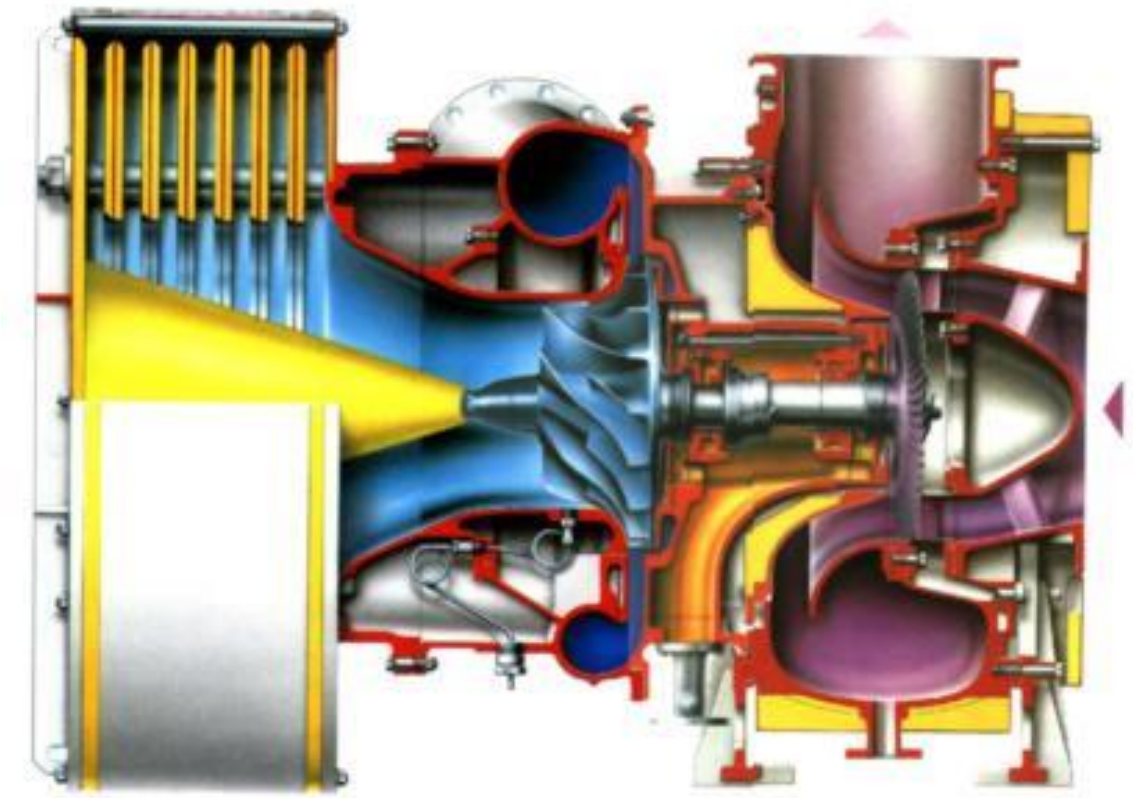
- The turbine of the turbocharger ***drives*** a centrifugal **compressor**. The **impelle**r of the compressor *is mounted on* the same shaft as the **turbine wheel**. It consists of a disc on the side of which are a number of radial **vanes** which ***diminish*** in thickness as they approach the periphery. 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 _____ 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 the 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:

STATIONARY ELEMENTS	ROTATING ELEMENTS

II. Give a description as detailed as possible of each member indicating:

Turbocharger member	what it consist of and its function

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 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.**

Turbochargers
Operational Information
The Two Stroke Crosshead Engine
http://www.marinedieselsinfo/Turbocharging/turbocharger_principles.htm

- 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.

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- 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 ----------. To ensure that the fuel is burnt completely it is supplied with 220% more …… Because it takes about 14kg of air to supply the theoretical oxygen to burn 1kg of fuel, 4.5kg of …… into each cylinder to burn the 0.1kg 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 $3.2m^3$.
- 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.
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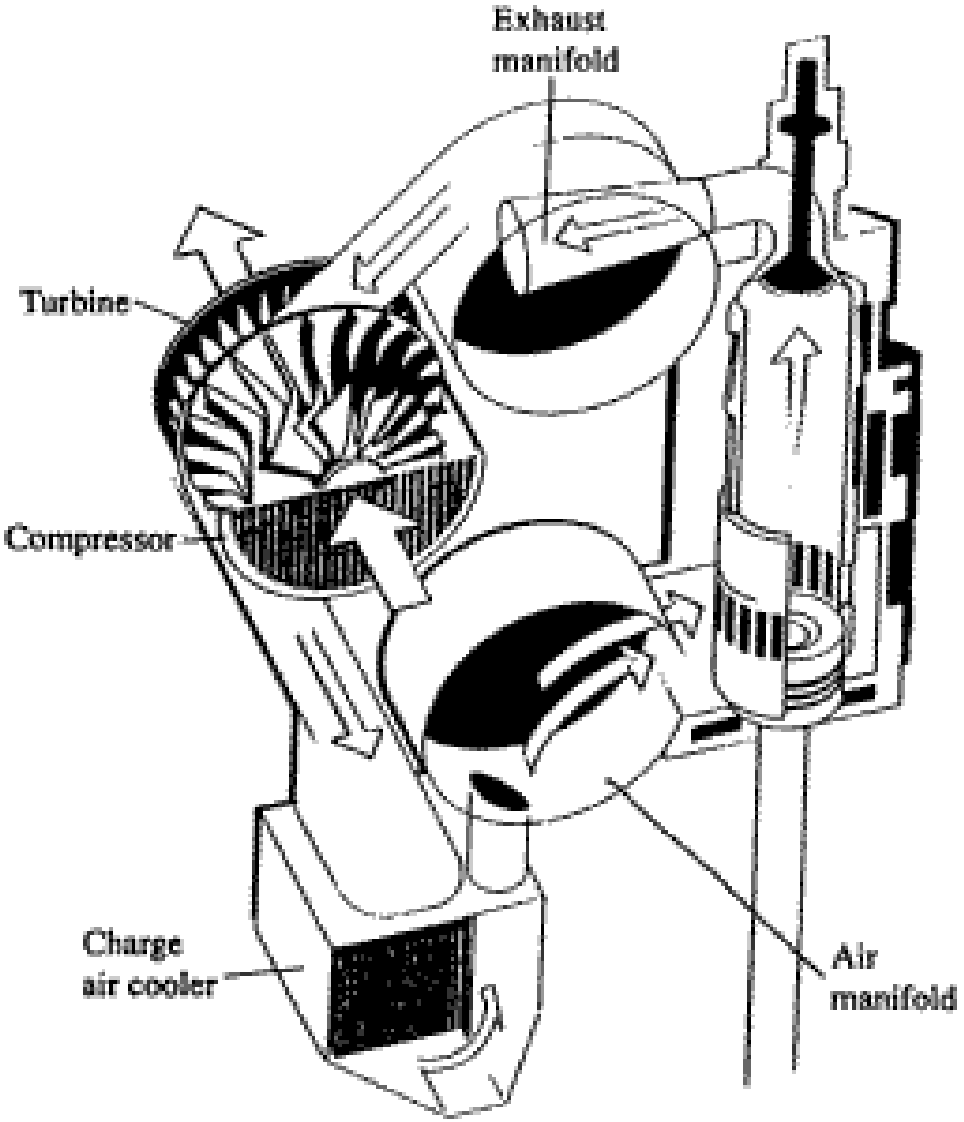
- Quoted figures _____ between 165 and 175g /kWh.
- The actual specific fuel consumption _____ is going to depend on the efficiency of the engine and the _____ of the fuel used

- 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 ……
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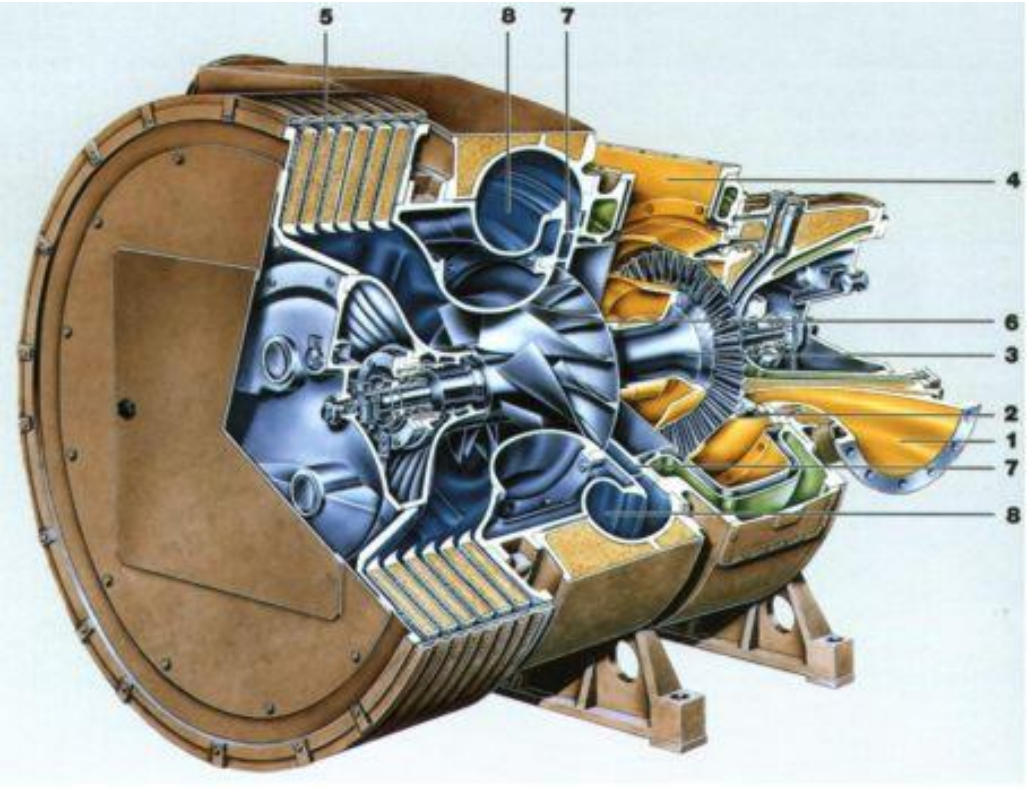
- The turbine is fixed to the same shaft as ……
- Air is drawn in, compressed and, because compression raises the temperature of the air, it is ……
- It is then delivered to the engine cylinders via ……
- The speed of the turbocharger is variable ……
- At …… the turbocharger may be rotating at speeds of 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

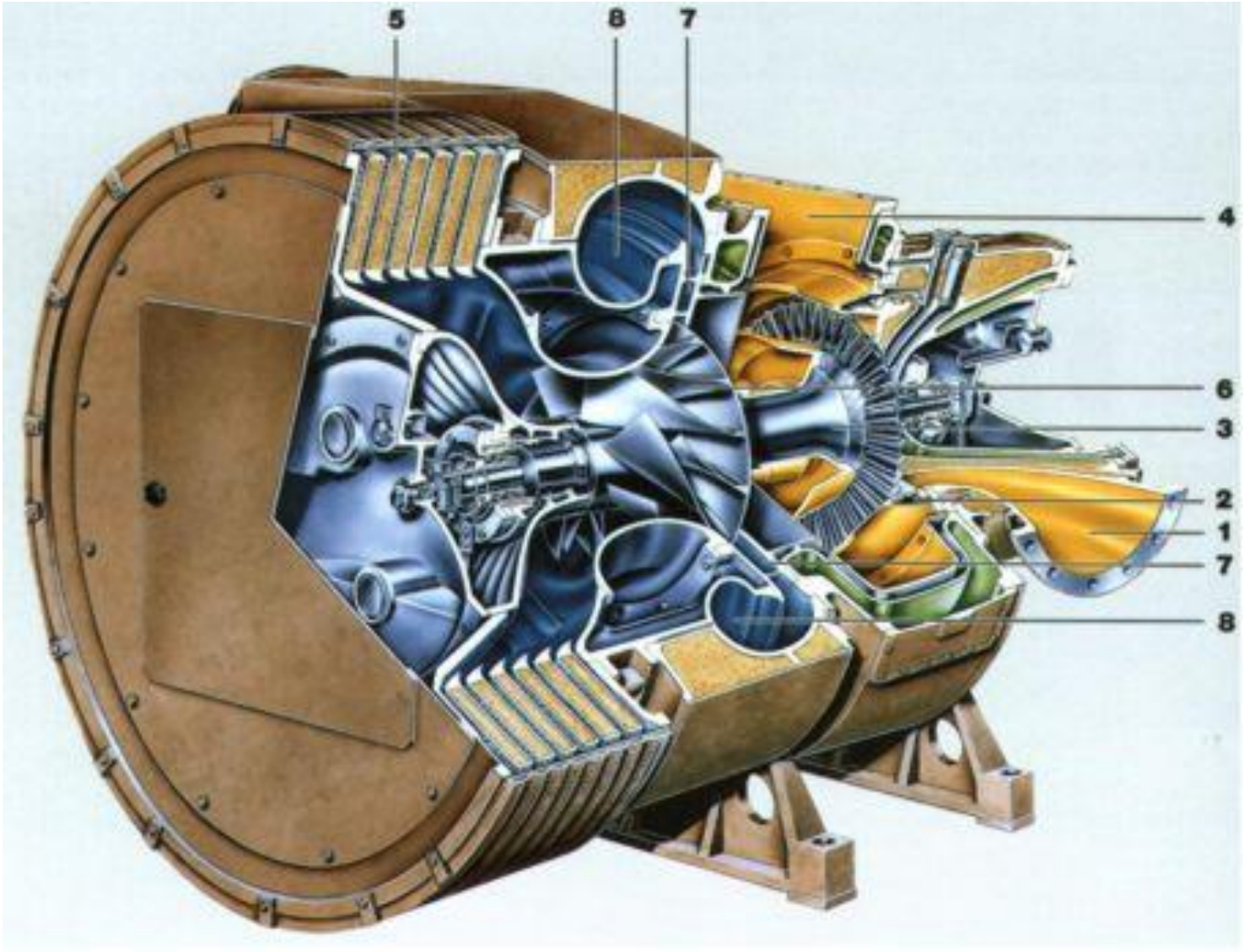
- Because the engine needs to be supplied with air when starting up and running at low speeds, an …….
- This automatically cuts out when the charge air supplied by the turbocharger is sufficient to …….

- Operational Information
- Turbocharging
- Principles and Construction

INTRODUCTION

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
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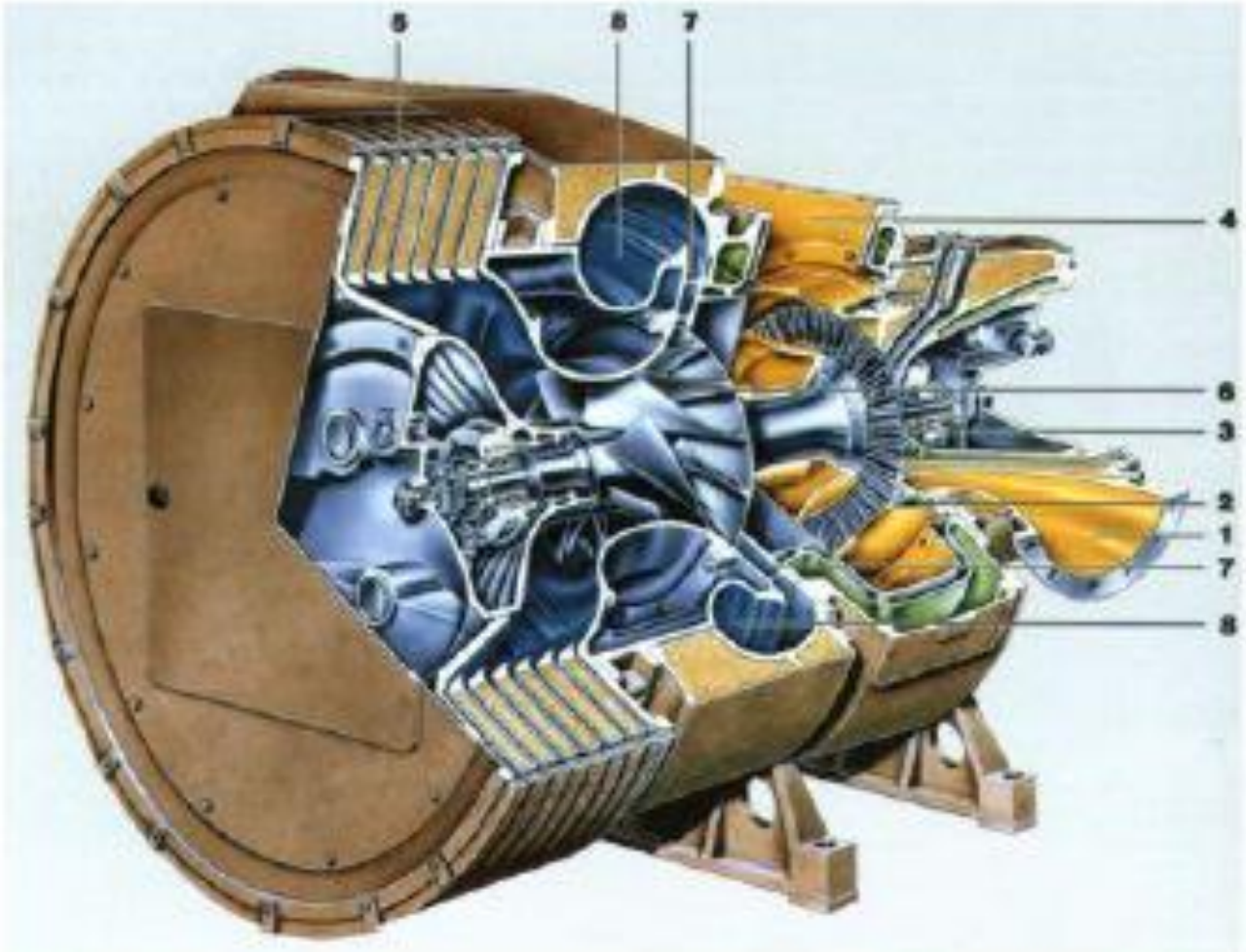
Supply your language equivalents for the labels below



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 _____.

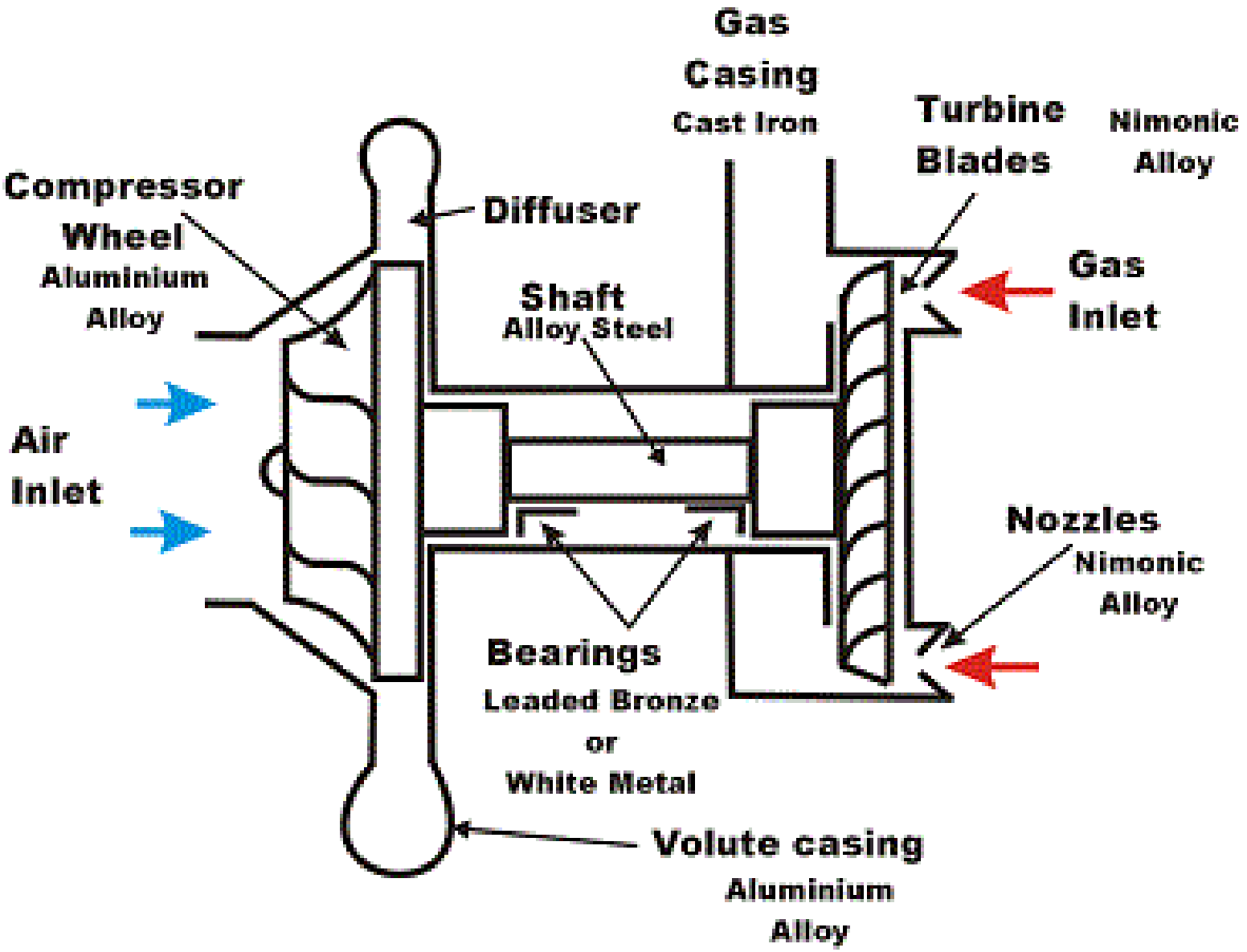
- On the air side air is drawn in through filters, and enters the compressor wheel axially where it is accelerated to high velocity. The air exits the impeller radially and passes through a diffuser, where some of the kinetic energy gets converted to pressure energy. The air passes to the volute casing 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:



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.

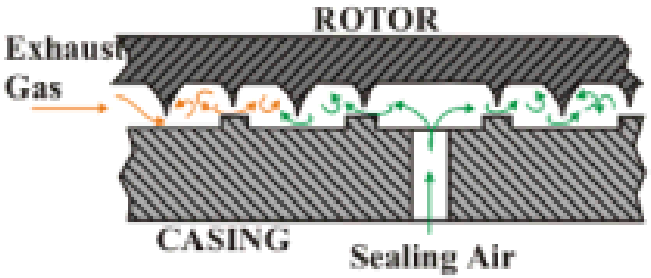
- One way of achieving this is to …… where the ambient air temperature is below that of the engine room.
- Efficient filtration and separation to …… is essential and the impeller will have to be coated to prevent …… by the ……

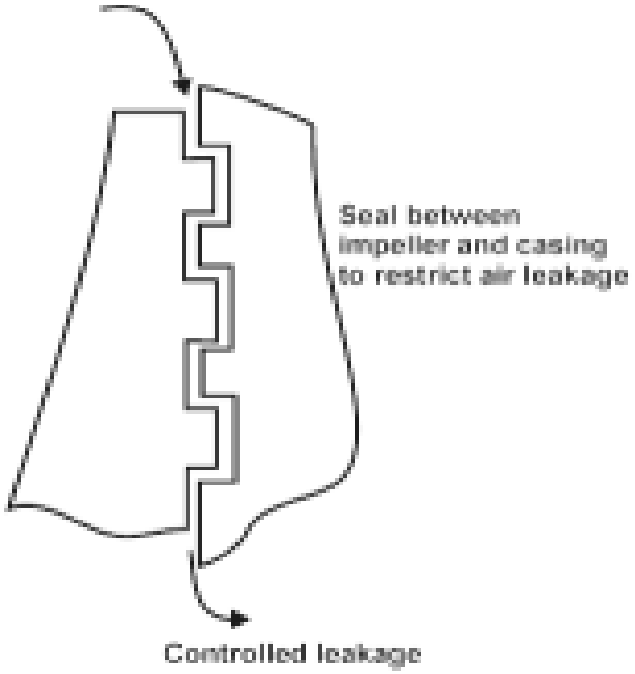
- Bearings are either of the ball or roller type or plain white metal journals. The ball and roller bearings are mounted in resilient mountings incorporating spring damping to prevent damage due to vibration. These bearings have their own integral oil pumps and oil supply, and have a limited life (8000 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

A, B, C …	1,2, 3 …	
A. Bearings are either of the ball or roller type or	**1. to supply oil to the bearings whilst the turbocharger comes to rest should the oil supply fail.**	A6
B. The ball and roller bearings are mounted in resilient mountings incorporating spring	**2. to cool as well as lubricate.**	
C. These bearings have their own integral oil pumps and oil supply,	**3. and have a limited life (8000 hrs).**	
D. Plain journal bearings are lubricated from the main engine oil supply or	**4. from a separate system incorporating drain tank, cooler and pumps.**	
E. Oil is supplied in sufficient quantity	**5. hold the rotor axially in the casing.**	
F. The system may incorporate a header tank arrangement	**6. plain white metal journals**	
G. A thrust arrangement is required to locate and	**7. damping to prevent damage due to vibration.**	

- 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


ROTOR
Exhaust
Gas
CASING
Sealing Air

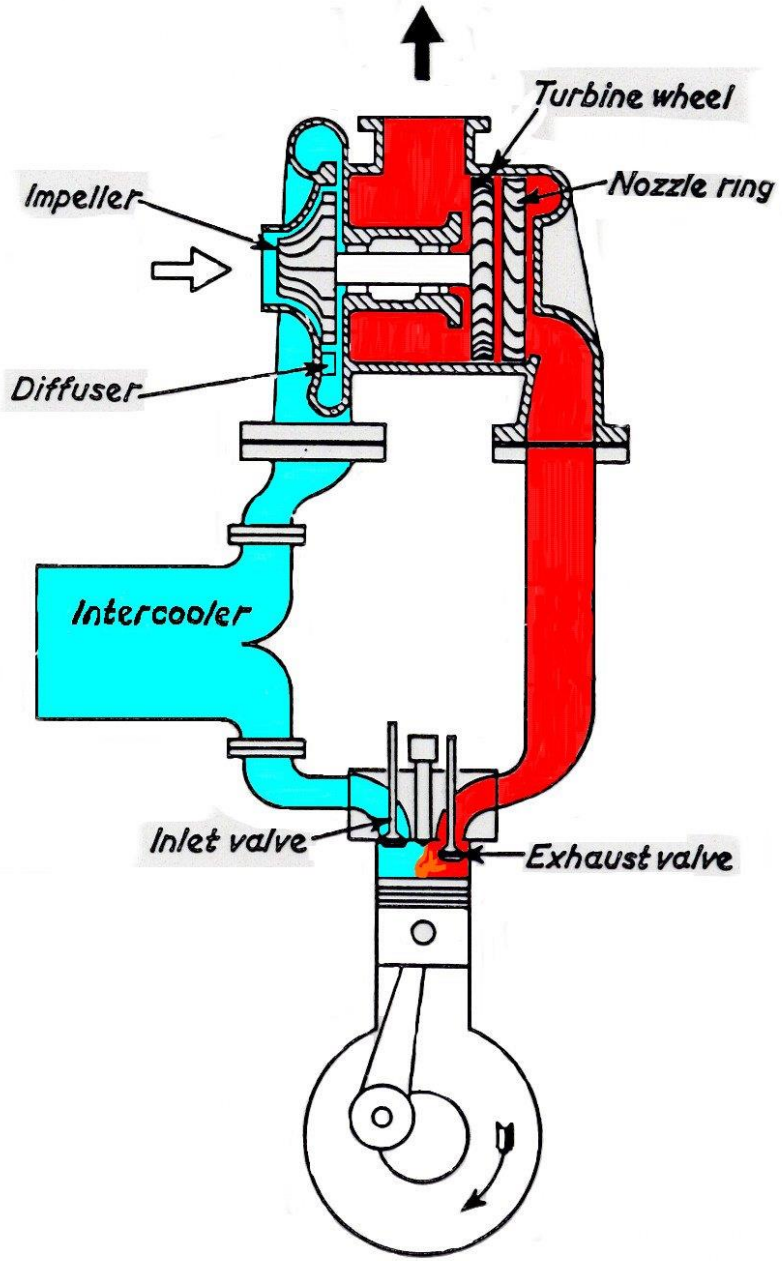

Seal between
impeller and casing
to restrict air leakage
Controlled leakage

Complete the text of the sentences below

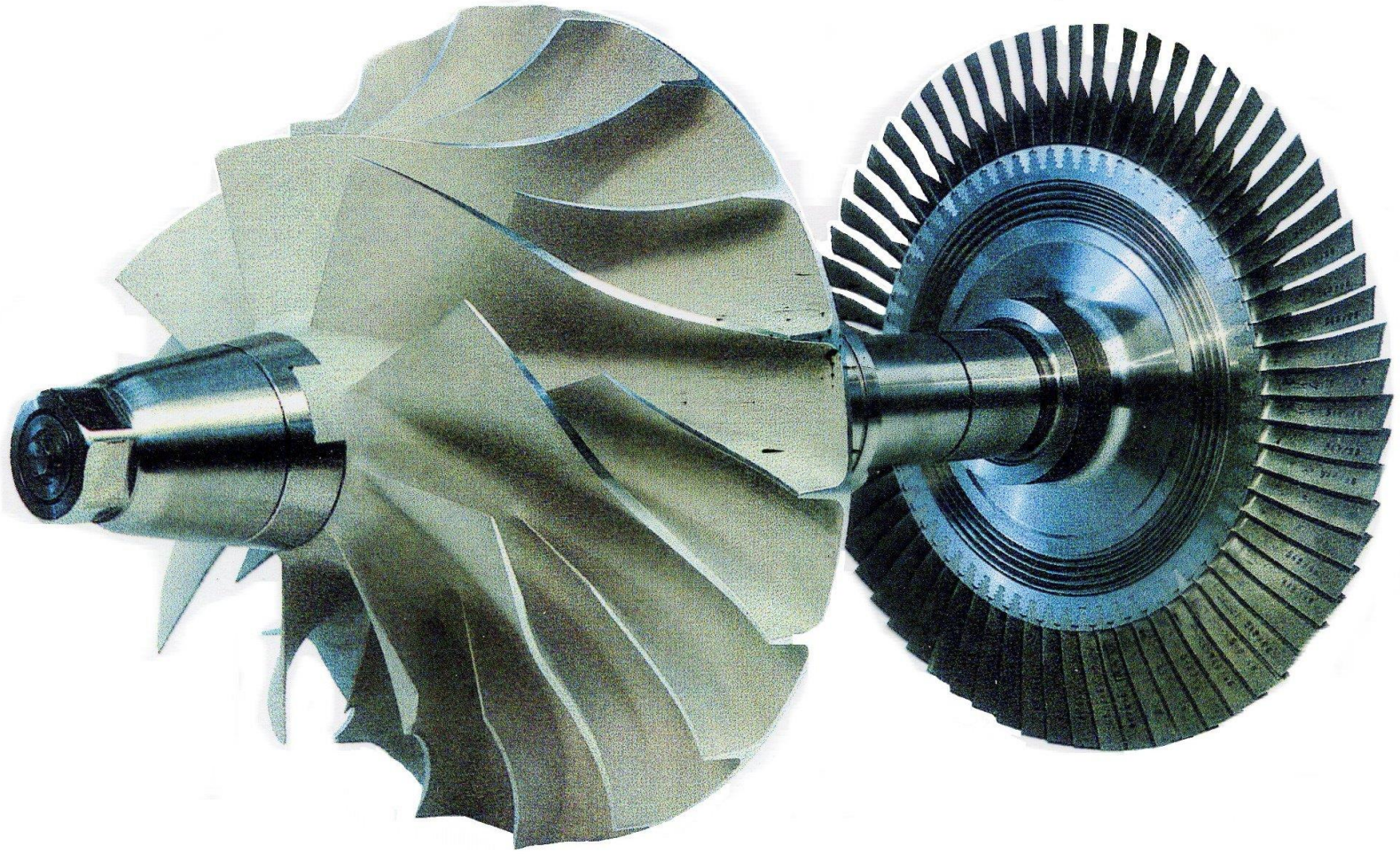
- Labyrinth seals or glands are fitted to the shaft and casing to prevent …… , or to prevent oil being drawn into the compressor.
- To assist in the sealing effect, air from the compressor volute casing is led ……
- A vent to atmosphere at the end of the labyrinth gives a guide ……
- Discoloring of the 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 ……

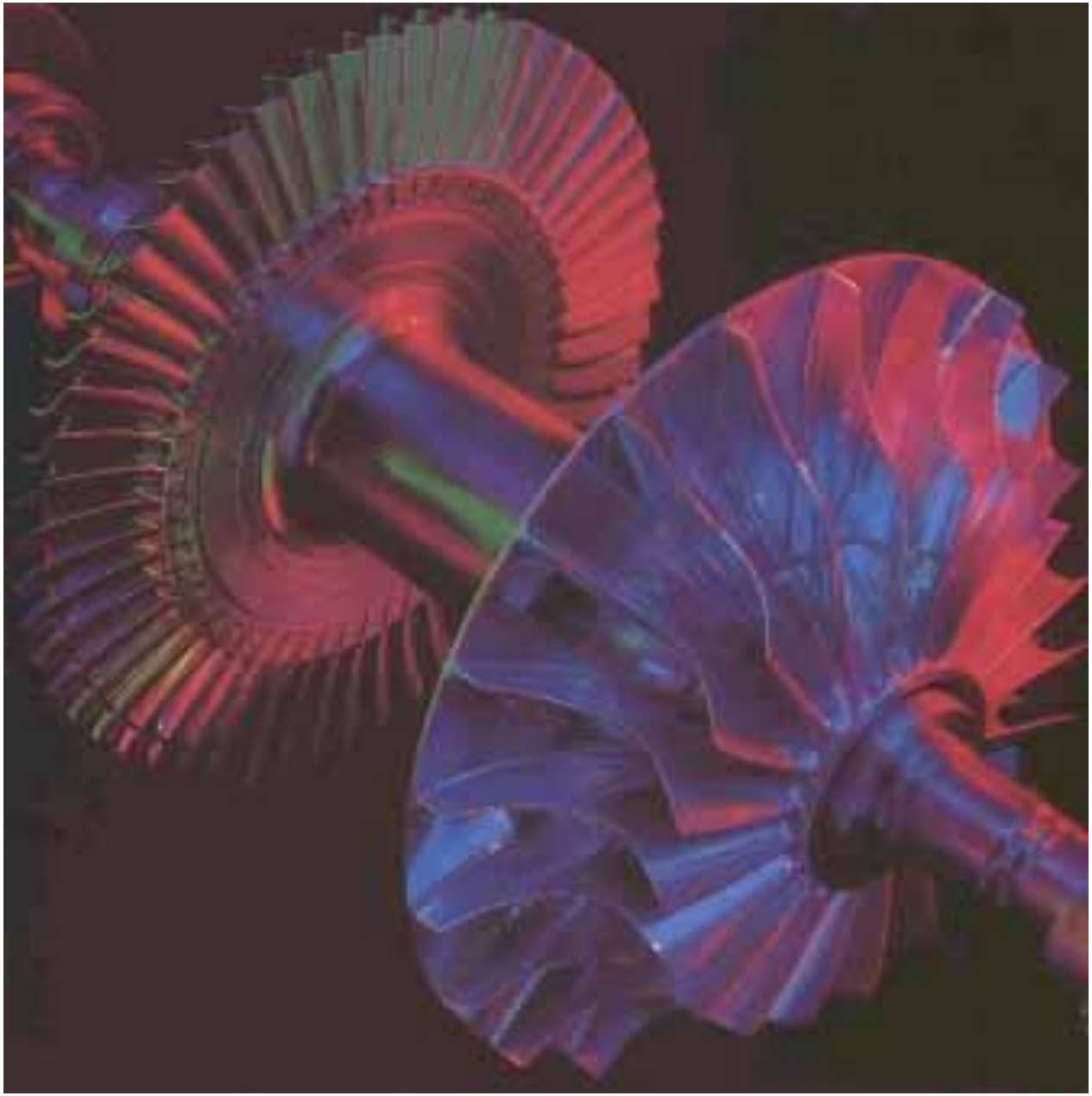
IX. Translate into English:

- 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.

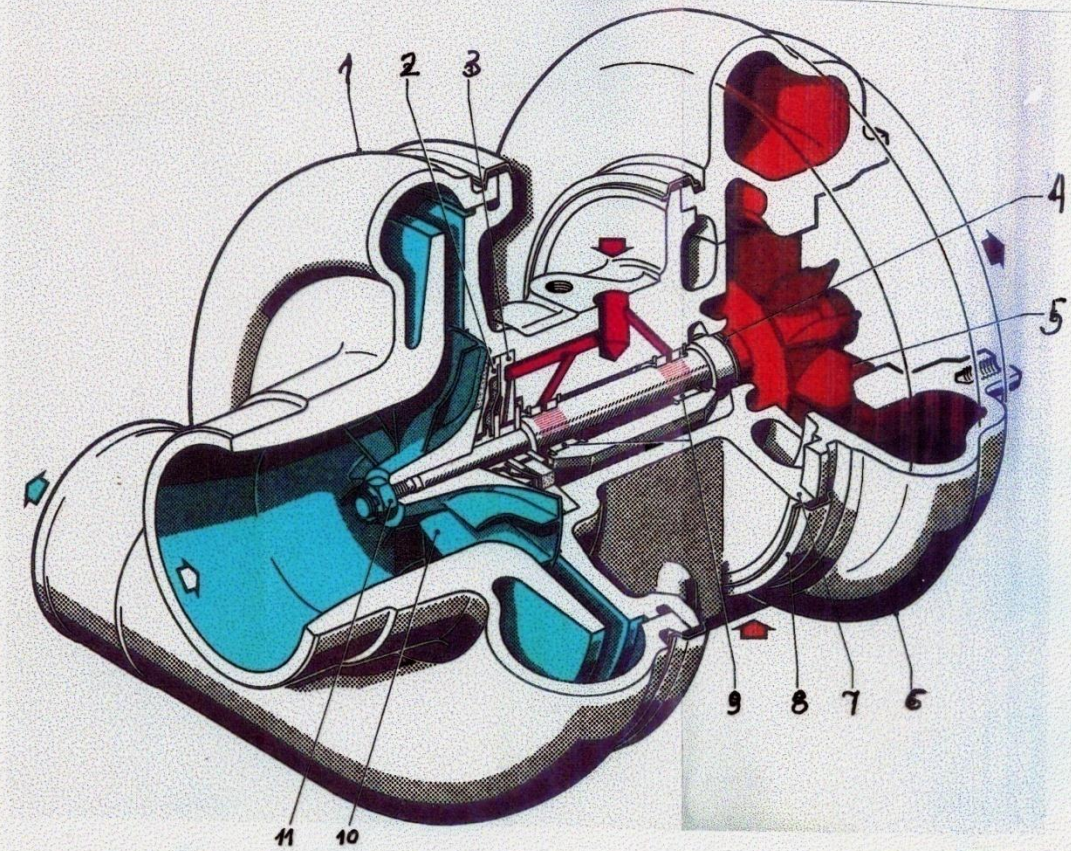


Turbocharger and turbocharged engine.

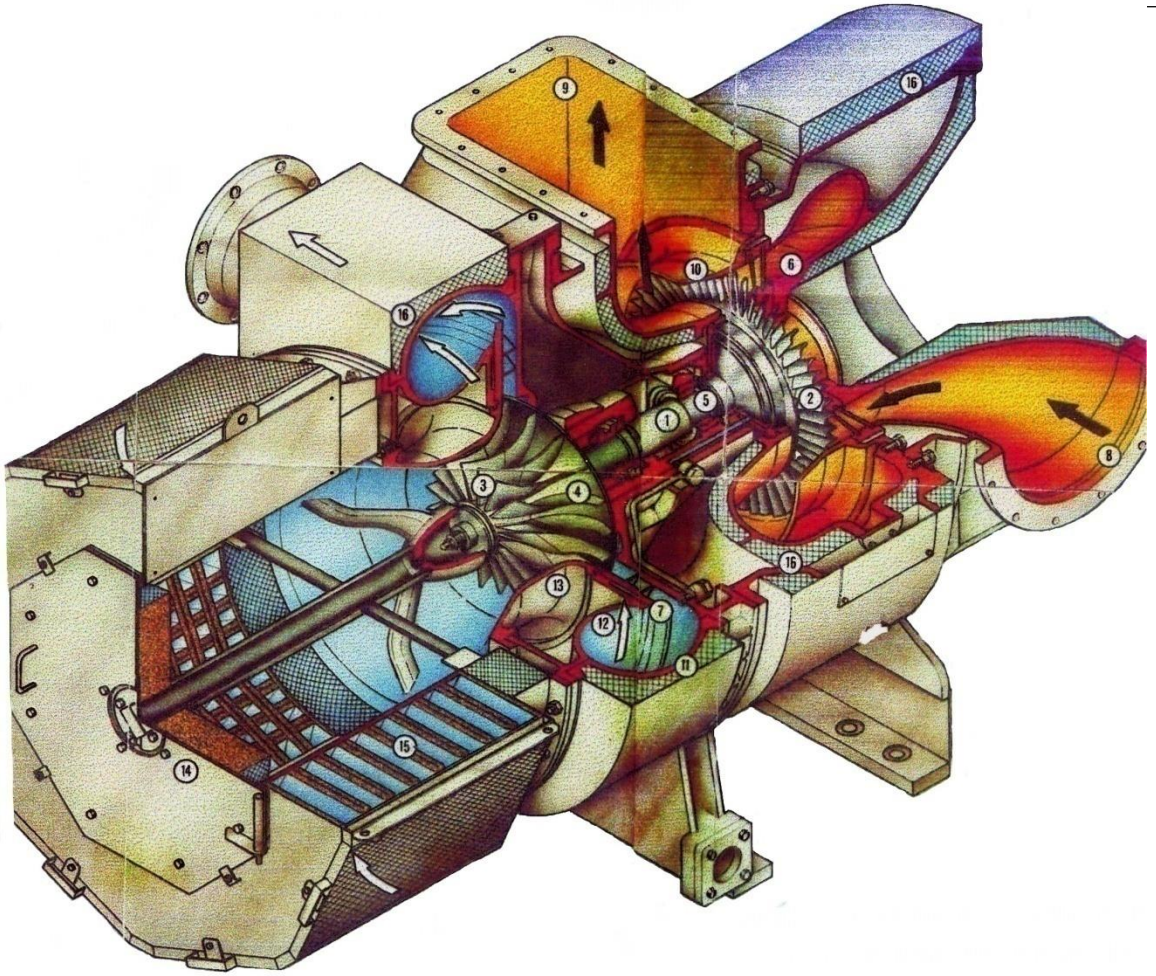




EXHAUST GAS TURBOCHARGER



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. Beraring bush
10. Impeller wheel
11. Shaft nut



KEY

1 Rotor shaft
2 Turbine blades
3 Induction wheel
4 Impeller wheel
5 Journal bearing
6 Turbine nozzle
7 Diffuser
8 Gas inlet casing
9 Gas outlet casing
10 Gas outlet guide
11 Outer scroll
12 Inner scroll
13 Air inlet guide
14 Air suction casing
15 Silencer
16 Insulation

Air

Exhaust Gas