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KASDI MERBAH OUARGLA UNIVERSITY
FACULTY OF APPLIED SCIENCES
MECHANICAL ENGINEERING DEPARTMENT

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Presented by: **LEGHIMA FERHAT**

Entitled:

Design of HP hydraulic system for cleaning residues in petroleum units using water heated by thermal energy from exhaust gases

In front of the Jury

Mr. Abdelghani BOUBEKRI	President	Kasdi Merbah Ouargla University
Mr. Zoheir DERGHOUT	Examiner	Kasdi Merbah Ouargla University
Mr. Noureddine CHERRAD	Mentor	Kasdi Merbah Ouargla University

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Summary

Nomenclature

Abbreviations	Definition	Unit
HP	High pressure	/
HRSG	Heat recovery steam generator	/
PM	Particulate matter	/
DOC	Diesel oxidation catalyst	/
DPF	Diesel particulate filter	/
ULSD	Ultra-low-sulfur diesel	/
EGR	Exhaust Gas Recirculation	/
HTC	High-temperature combustion	/
US Tier 3	US Emission standards for light-duty vehicles	/
Euro IV	European emission standards	/
VTG	variable geometry turbocharger	/
HPP	High pressure pump	/
EG	Emission gases	/
Pd	Platinum rate	%
pt	Palladium rate	%
Te1	Inlet exhaust gas temperature	°C
Te2	Outlet exhaust gas temperature	°C
tw1	Inlet water temperature	°C
tw2	Outlet water temperature	°C
IC	Internal combustion	/
Rpm	Rotation per minute	r/min

Figure list

Tables List

General Introduction

Industrial waste heat is the energy that is generated in industrial processes which is not put into any practical use and is wasted or dumped into the environment. Sources of waste heat mostly include heat loss transferred through conduction, convection and radiation from industrial products, equipment, or processes and heat discharged from combustion processes.

Waste heat recovery is a technology in converting waste heat from all kinds of heat sources into useful thermal energy,

However only about 30-40% [28] energy of combustion in the engine chamber was transformed into useful mechanical work.

The exhaust gas source from diesel engines with high temperature was an energy one, in which was utilized to not only to improve the operation efficiency of diesel engines, but also reduce the environmental reduction

40% of the overall loss of energy from the internal combustion (IC) engine dumped as heat through the exhaust gases (Fig 1), the recovery of waste energy in engines not only to reduces the demand of fossil fuels, but also helps for environment saving by decrease gases emission.

The researchers experimented on various technologies to recover the waste heat from the IC engines such as EGR , emission gases heat exchanger , On the other side exhaust heat exchanger may makes effects on the engine performance, its design has very importance to select an appropriate heat exchanger , for each heat exchanger type firstly should be consider:

-The geometry and size

- Exchanger Efficiency

In our study the heat recovered from the exhaust gases of internal combustion engine utilize to heat the water, after that ejected by high pressure (HP) triplex pump to use in equipment's cleaning with safe method avoiding all electric components

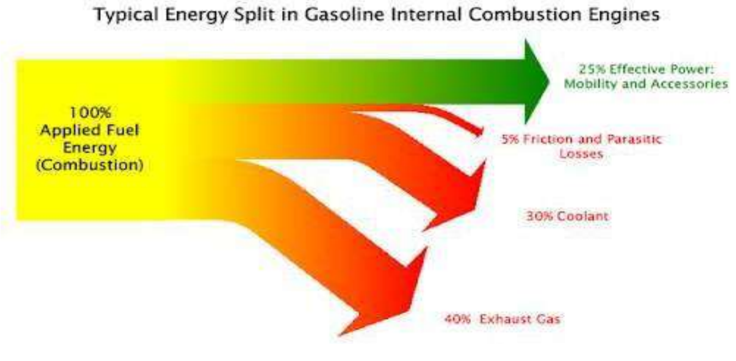


Figure 1 Typical energy

1.1 Introduction:

In order to guarantee continuous work processes and operational safety in oil and gas industry the regular cleaning work and maintenance is essential.[1]

High pressure water is a powerful tool used throughout heavy industry to help maintain the efficiency, production, and capacity of process equipment. Used in various arrangements, high pressure washing equipment and processes replace many of the manual cleaning old methods.[2]

High pressure water jetting is a process using a stream of pressurized water to remove material, coatings or contamination and debris from the surface of a work piece or material.[3]

Therefore, typical and frequent tasks include:

- General cleaning work such as the cleaning of machine parts, procedural components, transport containers, valves, etc.
- Cleaning of technical installations and surfaces that influence the production process
- Removal of coating and painting on buildings and technical devices
- De-rusting of steel surfaces
- Removal of burned materials due to high process temperatures or welding work

1.2 Kind of application:

The use of water to clean under high pressure and hot temperature is suitable for a wide variety of surfaces and materials as:

1.2.1 Sieve and filter cleaning:

High pressure water jetting is often used for diverse cleaning work in sieves and filters:

• Removal of incrustation and dirt from sieves and filters

• Cleaning of plastic, long and round sieves

• Cleaning of filter cloth, viscose filters, cartridge filters or wet felts

• Descaling of suction strainers

• Removals of dirt from drainage and filter press

• Removal of residue from steel trays

In almost all sectors of industry, sieves and filters, as well as their baskets, trays and nets come into use. The ability of these important procedural components to function depends substantially on the condition of their surface. Consequently, sieves and filters must be cleaned on a regular basis.[1]

Figure 2 Filer cleaning [1]

1.2.2 Heat exchanger cleaning:

The High pressure water jetting, is usable universally for internal and external cleaning, and through a regular and residue-free cleaning process for the heat exchangers, process efficiency can be improved, and energy can be simultaneously saved.

But some technical requirements and local conditions can be taken into consideration during the planning for the cleaning:

• Large total surface areas that are hard to clean, with partly complicated geometric build, such as U-shaped pipes or narrow pipes with just a 12 mm diameter

• Various deposits with often extremely hard top layers

• In some cases, both internal and external cleaning is necessary

• Often it is not possible to clean the heat exchanger on site, because there is too little space or no access. Then, the heat exchanger must be dismantled and transported to a washing area

• The cleaning tasks must be completed as soon as possible so that production can continue

• Liquid mediums often contain dirt and fixed components, for example, carbonate, minerals, oxide, burned chemicals or deposits from oil and sulphite

Every cleaning method has systemic pros and cons. [1]

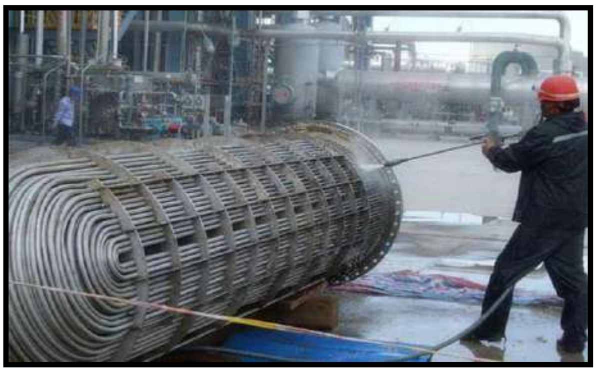


Figure 3 Manuel heat exchanger cleaning [1]

The heat exchanger tube sheet should be cleaned regularly to remove dirt, to ensure efficient heat transfer and normal heat exchanger production.

A horizontal heat exchanger being cleaned with THOMPSON automated equipment.

Figure 4 Automated equipments exchanger cleaning [1]

1.2.3 **Pipe cleaning:**

Pipes are the life line of all facilities in every sector of industry.[1] and the pipeline cleaning process it's very important generally for three main reasons They consist of improving the line flow efficiency, improve or insure good data on inspection tool runs, and to improve the results of chemical programs to increase the lifetime of the pipeline.[4]

High pressure water jetting can be used for the washing and cleaning of pipes, internally and externally, as well as cutting pipes.[1]

Figure 5 Pipe cleaning operation [1]

1.2.4 Industrial oil Tanks Cleaning

Cleaning industrial tanks, vessels and pits containing petroleum residues is an inevitable process in the industry that companies must deal with. The main reason for cleaning is the residues created over time by the settling of the heavier elements contained in petroleum.

These residues occupy considerable space in the tanks, reducing their capacity and altering the quality of the products. Apart from everything else we mentioned, there is also the need for some scheduled inspections which are required by the operating regulations. These activities cannot be carried out with the presence of residues inside the tank. Companies have focused on finding cleaning methods aimed at staff safety, cleaning efficiency, time/money savings and environmental protection. The methods that could be used to clean a tank could be manual, automatic (mechanical) and robotic processes.[5]

1.3 Gun Nozzeles

Water jetting nozzles are designed to control the direction, velocity, flow rate, pressure, shape and distribution of fluid flow as it exits the nozzle carrier.

Jetting nozzles come in two categories: rear facing nozzles which are used in drain and tube cleaning and forward facing nozzles which are used for general cleaning duties.

Jetting equipment including nozzles should be kept clean and stored safely when not in use.

Nozzles should be inspected before each use for blocked or damaged orifices, damage to threads, cracks or any other structural damage that could adversely affect their safe operation.

Nozzles identified as being defective should be removed from service and repaired or destroyed.

As well as a pre-start measure, inspecting nozzles regularly during jetting operations can identify wear and damage before this causes an injury.

1.3.1 Pin nozzles

Pin nozzles reduce the jet of water to a solid parallel stream of water and are used for cutting or penetrating. They can be either a screw in or step design (Figure 6).

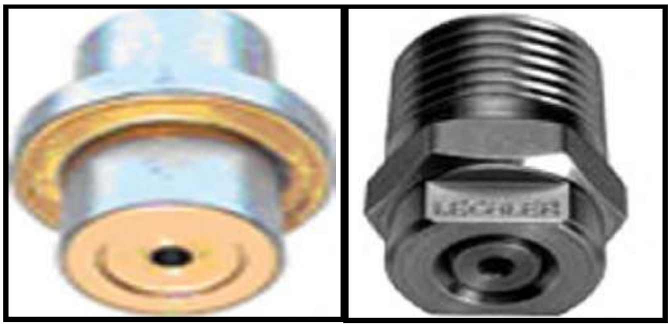


Figure 6 Pin Nozzle [3]

1.3.2 **Fan Nozzles**

Fan nozzles change the jet of water to a designated flat angle and are used as surface cleaners (Figure 7)

Figure 7 Fan Nozzle [3]

1.3.3 **Rotating Nozzles**

Rotating nozzles are driven by the flow of water and are designed to clean surfaces (Figure 8)

Figure 8 Rotating Nozzles [3]

1.3.4 **Fixed nozzles**

Fixed nozzles have a longer dwell time because of the time the jet of water impacts on a point. They are used for harder products (Figure 9)

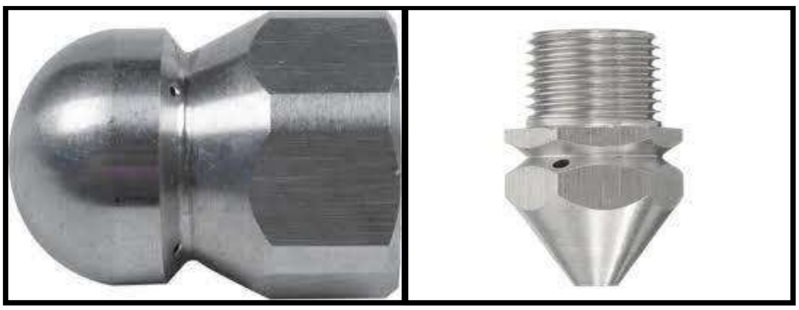


Figure 9 Fixed nozzle [3]

1.3.5 **Spinning nozzles**

Spinning nozzles have a much shorter dwell time and are used for softer products (Figure 10)

Figure 10 Spinning nozzle [3]

1.4 **Guns**

High pressure jetting guns or lances should be fitted with double-action safety trigger mechanisms to prevent inadvertent operation and maintained by a competent person in accordance with the manufacturer's recommendations.

High pressure jetting guns or lances should be fitted with at least one fast acting hold-to-activate device that when deactivated, will stop the flow of high pressure water. This device should be under the direct control of the jetting operator.

There are three types of guns currently being used within the high pressure water jetting industry. They have different operating systems. Each gun type should only be used with the correct operating system.

1.4.1 **Dry shut-off gun**

Dry shut-off gun incorporates a trigger-operated mechanical valve shutting off the flow of water from the pump. These can only be used on systems with an unloaded valve. The pressure in the hose from the pump to the gun remains constant at all times (Fig 11).

11 Dry shut-off gun [3]

1.4.2 Wet dump gun

Wet dump gun – incorporates a trigger-operated mechanical valve diverting water flow to a large orifice (either a hose or second barrel) outlet thus depressurizing the system (Fig 12).

Figure 12 Wet dump gun [3]

1.4.3 Dry dump gun

Dry dump gun – incorporates a trigger-operated mechanical valve with either an electric or pneumatic control connected to the pump control system. This system diverts the flow of water at the pump and reduces the pump speed to idle (Fig 13).

Figure 13 Dry dump gun [3]

1.4.4 Foot control devices

Foot control devices on guns are designed to shut off or divert the water flow from the pump unit. They should be a ‘hold-to-activate’ type and can be dry shut off, wet dump and dry dump mechanisms.

Foot control devices should be fitted with a guard or cover as well as a double-action trigger mechanism to stop them being operated accidentally.

On mechanical foot control devices the pressure hose should be secured to the device using a braided stocking with an impervious hose shroud covering the pressure hose. This will protect the operator if the hose fails.

Foot control devices should be maintained by a competent person in accordance with the manufacturer’s recommendations.

1.4.5 **Hose connection and layout**

The point where the hose attaches to a hand or foot controlled device should be protected by an over-sheath shroud manufactured from materials capable of withstanding the direct force of the water jet. This also protects the operator if the hose separates or the end fails.

The point where the hose attaches to a hand or foot controlled device should also be protected by a braided stocking that can stop the hose from whipping around and causing injury or damage if the hose separates or the end fails.

Water supply and high pressure jetting hoses should not be laid across thoroughfares, walkways or roads where they are likely to be damaged. Where hoses are to be hung vertically, each hose should be supported by a wire stocking. Where multiple lengths of hose are used in this way they should be supported at points below each coupling so there is no weight on the coupling [3].

2.1 Introduction

Due to limited energy resources and rising production costs, the recovery of waste heat from exhaust gases and the need to use energy more efficiently has become a necessity since the large increase in oil prices. Energy conservation is primarily concerned with the task of extracting maximum production from specific energy consumption. A major result of the energy conservation drive is the development of process recovery aimed at reducing the amount of waste heat discharged to the environment thus increasing the overall efficiency of various processes and systems. Heat recovery conserves energy, reduces the overall operating costs and thereby reduces peak loads.[6]

2.2 Rankine cycle:

Rankine cycle system for waste heat recovery from the exhausts of an internal combustion engine, on the purpose of producing additional mechanical or electrical energy, can be accomplished by means of a suitably designed Rankine cycle.

This section describes the Rankine cycle system that can be used to recover exhaust heat from ICE. Fig. 14 shows the Rankine cycle system.

As shown in this figure, the working fluid passing through high pressure feed pump is sent into preheater and is preheated firstly, then it is carried through a

number of parallel small-diameter tubes and is heated by the hot gas, when the ICE exhaust gas enters in the shell surrounding the tubes. The preheated working fluid is vaporized and superheated in evaporator/super heater, and the produced high pressure steam is sent to a single-stage reciprocating piston expander which is connected to an asynchronous electrical generator to convert mechanical to electrical power.

The exhaust steam flowing out of the expander is condensed and water is pumped back into the heat exchanger by the feed water pump.

In the combined cycle, Rankine cycle system is actually used to recover exhaust heat from IC engine, which implies that the Rankine bottoming cycle is added to enhance the performances of a diesel engine. The graph plotted in Fig. 15 shows the thermodynamic cycle on the TS diagram for the combined cycle. [7]

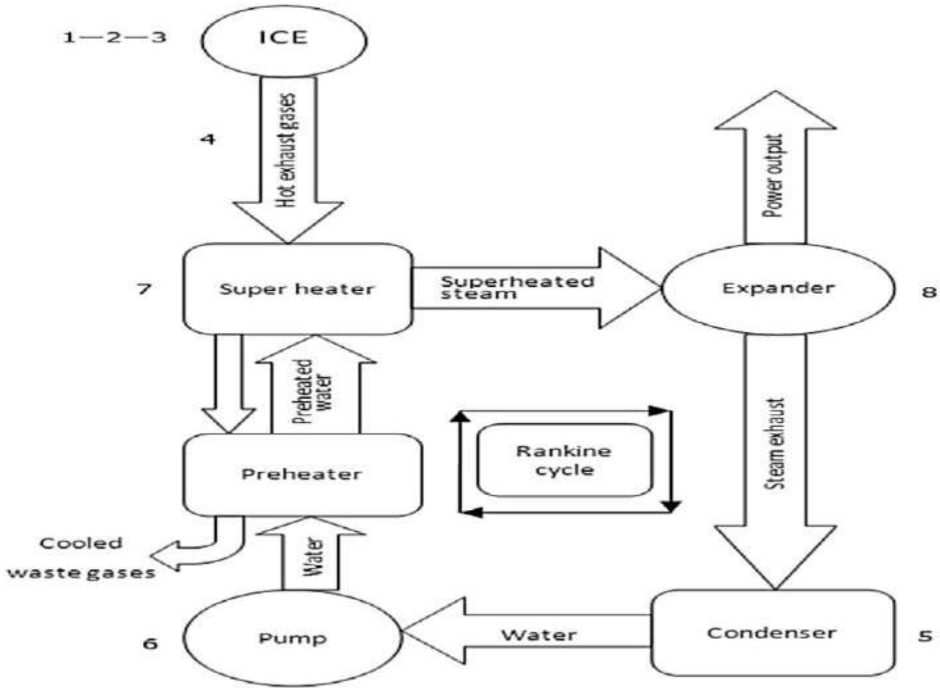


Figure 14 Rankine cycle system [7]

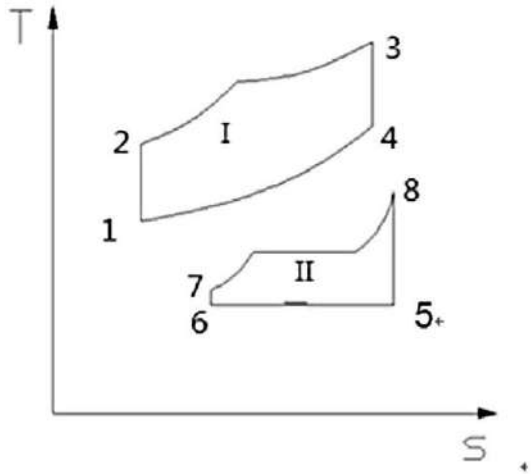


Figure 15 TS diagram of combined cycle. [7]

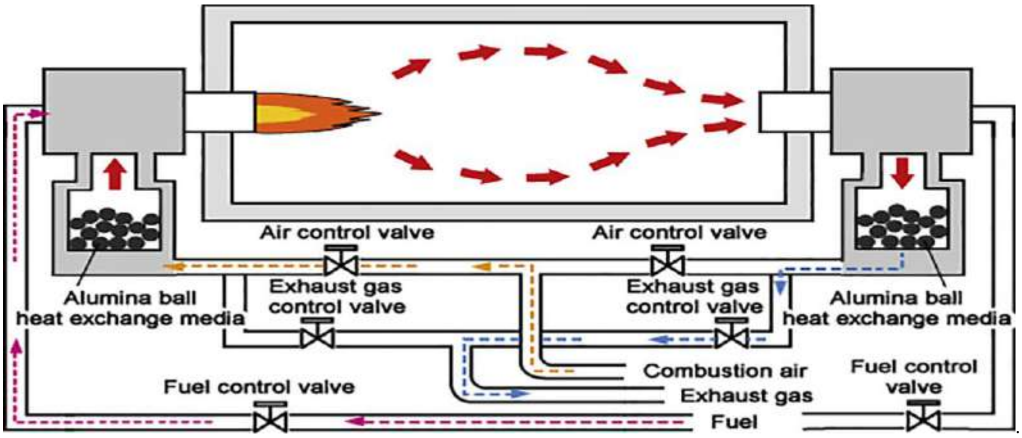
2.3 Regenerative and recuperative burners

Regenerative and recuperative burners optimize the thermal energy efficiency by insertion of heat exchanger surfaces to capture and use the waste heat from the exhaust gas of combustion process.

Typically, regenerative devices consist of two burners with separate control valves, which are connected to the furnace and alternately heat the combustion air entering the furnace. The system works by guiding the exhaust gases from the furnace into a case which contains refractory material such as aluminum oxide.

The exhaust gas heats up the aluminum oxide media and the heat energy from the exhaust is recovered and stored. When the media is fully heated, the direction of the flue gas is reversed, with the stored heat being transferred to the inlet air entering the burner and the burner with hot media starts firing.

Combustion air from the hot media then heats up the cooler media and the process starts again. Through this technique, the regenerative burner can save the fuel needed to heat the air and this improves the efficiency of combustion (fig 16). [8]



16 Regenerative burner mechanism [8]

2.4 **Economisers**

Economisers or finned tube heat exchangers that recover low –medium waste heat are mainly used for heating liquids.

The system consists of tubes that is covered by metallic fins to maximise the surface area of heat absorption and the heat transfer rate .

Case of Steam boiler use economizers to greatly improve efficiency as the system heats water for steam.

The first economizer, patented in 1845, was used to improve the efficiency of boilers used in steam engines for mills and factories. By the 20th century, almost all steam engine boilers included economizers as a standard feature.

The modern economizers reduce energy consumption and improve boiler energy efficiency.

The concept behind an economizer is simple; Boilers produce heat that is transferred to water, creating steam. During that process, some heat energy is inevitably lost.

Economizers capture heat from the exhaust flue and return it to the boiler by heating the incoming feed water. By heating the feed water, the boiler does not have to expend as much fuel to turn the water into steam.

Over the long term, fuel costs are the top expense involved in running a boiler. By greatly improving efficiency, economizers significantly decrease the cost of running a boiler over its lifetime.[9]

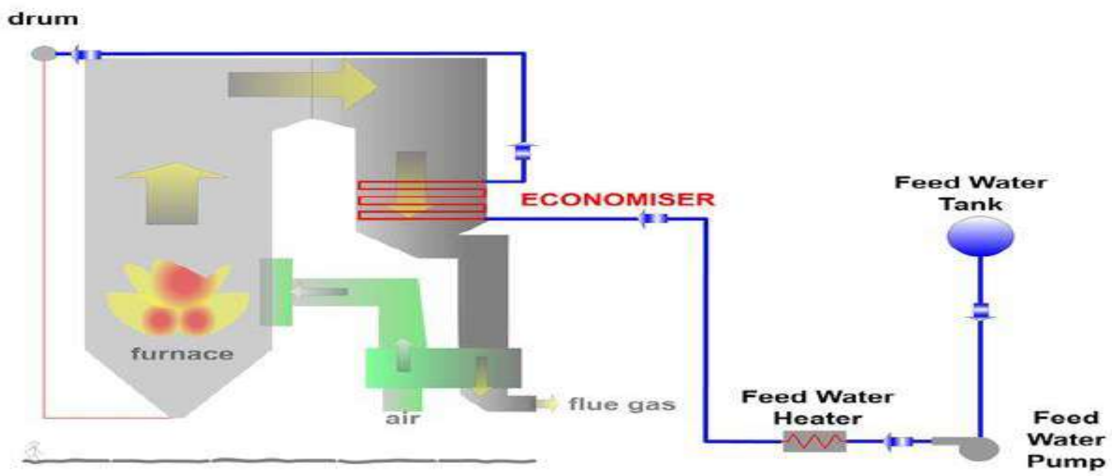


Figure 17 Economiser system [9]

2.5 Air pre-heaters

Air pre-heaters are mainly used for exhaust-to-air heat recovery and for low to medium temperature applications. This system is particularly useful where cross contamination in the process must be prevented.

Such applications can include gas turbine exhausts and heat recovery from furnaces, ovens, and steam boilers.

Air preheating can be based on two different designs, the plate type and the heat pipe type.

The plate type consists of parallel plates that are placed perpendicular towards the incoming cold air inlet. Hot exhaust air is fed into the channels between the plates, transferring heat to the plates and creating hot channels, through which the cold air is passed.

The heat pipe type on the other hand consists of a bundle of several sealed pipes placed in parallel to each other in a container. The container is split into two sections accommodating cold and hot air, inlet and outlet. The pipes inside the container accommodate a working fluid which when faced with the hot waste gas at one end of the pipes, evaporates and moves towards the other end of the pipe where cold air is passing. This result in heat being absorbed at the hot section of the pipe, which is transferred to the cold section, heating the cold moving air over the pipes. The working fluid then condenses and moves towards the hot section of the pipe, repeating the cycle.[8]

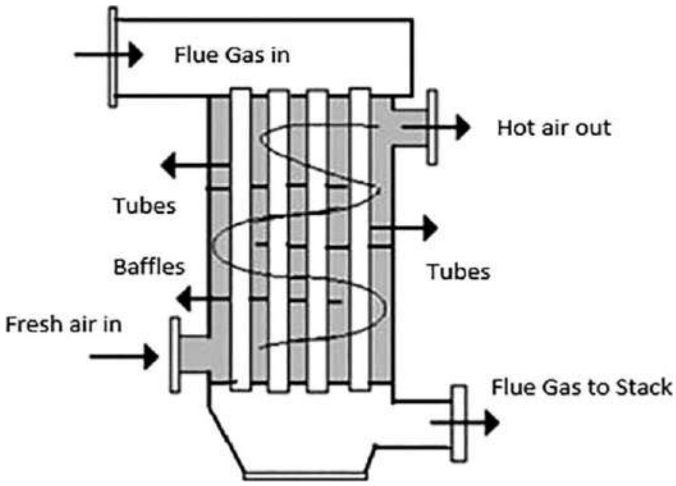


Figure 18 Air preheater layout showing air movement. [8]

2.5.1 **Recuperators**

Since the thermal efficiency of a furnace is determined primarily by the final temperature of the exit gases, recuperators can be employed so that combustion products do not leave the system at excessively high temperatures.

Recuperators recover heat in the flue gas to preheat the combustion air. Recuperators are similar to air heaters but are used for higher stack temperatures (above 900'F). The performance of these heat exchangers is limited by the temperature of the materials which separate the air from the hot flue gas. Due to these temperature limitations, the majority of present metallic recuperators are restricted to air preheat temperatures less than 1000'F 537.7°C.

Metallic recuperators are divided into two main groups according to which heat transfer mechanism dominates: radiation or convection.

A metallic radiation recuperator usually consists of two concentric lengths of metal tubing.

The inner tube contains the flue gas, while the combustion air flows parallel to the flue gas in the annulus. The parallel-flow configuration enables lower recuperator wall temperatures than counter flow designs, thereby extending the lifetime of the wall. The inner tube is usually made of high-nickel-content stainless steel, methods of supporting the recuperator must allow for significant axial expansion.

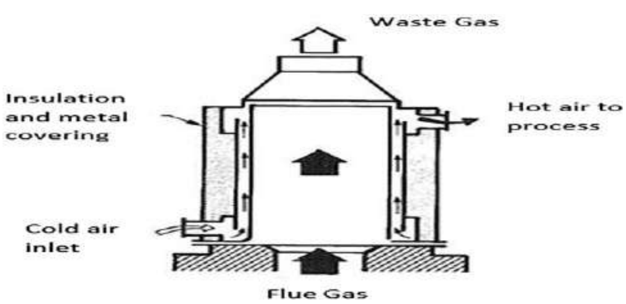


Figure 19 Diagram of metallic recuperator [10]

The convective recuperator consists of a shell and tube design. The stack gas flows through tubes in parallel, while the combustion air passes over the tubes one or more times. Convective recuperators are generally more compact than radiation recuperators because of the larger heat transfer area due to multiple tubes and passes.

Recuperator installations may require the purchase of high-temperature burners if preheat temperature is above 500'F 260°C, increased air ducts for higher volume flow, cold-air line for burner cooling, modified controls to ensure constant air/fuel ratio as air temperature changes, and bleed air into flue to protect against over temperature and large fans.

Applications for metallic recuperators are recovering heat from soaking and annealing ovens, melting furnaces, afterburners and gas incinerators.

Fuel savings depend on the extent of air preheat and the baseline furnace efficiency as calculated from the flue temperature and excess air. Fuel savings can range from 40% for preheating air to 1000'F 537.5 °C in melting.[10]

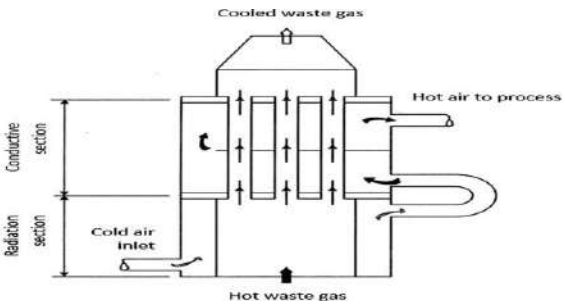


Figure 20 Combined radiation and convective type recuperator [8]

2.5.2 **Regenerators**

Regenerators transfer heat from the hot gas duct to the cold gas duct through storing the waste heat in a high heat capacity material. The system consists of a chamber which is used as a link between the hot air duct and the cold air duct that takes the heat energy from the hot side, stores and delivers it to the cold side. For instance, regenerative furnaces consist of two brick chambers through which hot and cold air exchange heat. As hot combustion gases pass through the brick chamber, heat from the hot flue gas is absorbed, stored and delivered to the cold airflow when it is passed through the chamber. The flow of the preheated gas is then injected into the flow going to the combustion chamber, decreasing the amount of energy needed to heat the system.

Two chambers are used so that, one is transferring heat to the flow entering the system, the other one is absorbing heat. The direction of inlet flow is changed frequently to allow a constant heat transfer rate to be obtained.

Regenerators are suitable for high temperature applications such as glass furnaces and coke ovens and they have been historically used with open-hearth steel furnaces. Regenerators are particularly suitable for applications with dirty exhausts, however, they can be very large in size and have very high capital costs, which is a disadvantage with this technology [8].

2.6 Heat pipe systems

A heat pipe is a tube with a capillary wick inside that has been evacuated, filled with a refrigerant and sealed. Heat at one end causes the refrigerant to vaporize and travel to the other end of the tube. The heat is removed, and the vapor condenses and returns to the other end of the tube to complete the cycle. Heat pipe heat exchangers are available on the market for transferring heat between clean or dirty exhaust air or flue gases and clean air streams.

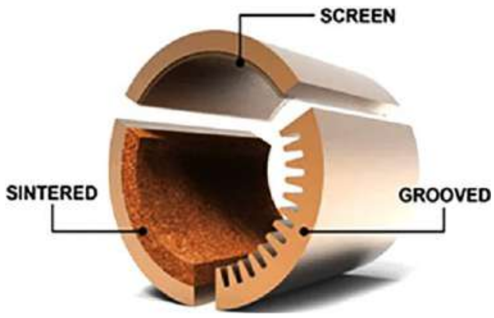


Figure 21 Common wick types of a heat pipe [8]

Heat pipes are compact and have high heat transfer effectiveness for gas/gas applications. Applications for currently available heat pipes using organic working fluids such as refrigerants are in the medium temperature range (400'F 204.4 °c - 600'F 315.5 °C) for flue gas recovery. They can be used in ovens, kilns, dryers and furnaces.[10]

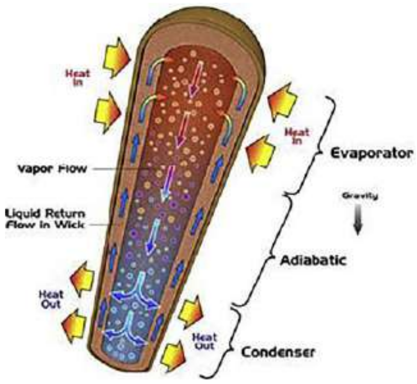


Figure 22 Schematic of a heat pipe [8]

2.7 Heat recovery steam generator (HRSG)

The heat recovery steam generator (HRSG) is a complex system used to recover the waste heat from the exhaust of a power generation plant.

It consists of several heat recovery sections such as an evaporator, super heater, economiser and steam drum, which are very large in size.

By looking at the configuration of a HRSG in Fig. 23, it can be pointed out that the superheater is placed in the path of the hottest gas upstream of the evaporator and the economiser is placed downstream of the evaporator in coolest gas.

Typically, HRSGs comprise a triple pressure system, this being high pressure, reheat or intermediate pressure and low pressure.

The system can also recover the waste heat from the exhaust of manufacturing processes to improve overall efficiencies by generating steam that can be used for process heating in the factory or for driving a steam turbine to generate electricity. It is reported that with the use of HRSG for steam production, a system efficiency of as high as 75–85% can be achieved.

The system contains an evaporator section and a steam drum for converting water to steam. The steam is then superheated as its temperature is increased beyond the saturation point. As can be seen from Fig. 23, the evaporator is located between the economiser and the superheater with the steam drum on top of it.

In the evaporator, the steam for the turbine is generated which is then delivered to the steam drum and the superheater. As shown in Fig. 24, in the steam drum the steam and water mixture is separated from the saturated steam as the feedwater is delivered to the evaporator.

The steam is separated in two steps through a combination of gravity and mechanical work before it gets delivered to the superheater.

This heats the steam beyond the saturation temperature, i.e. generating superheated steam. The economiser on the other hand, preheats the feed water to the evaporator, thus improving the efficiency of steam generation. The steam generated in the process is then sent to a thermodynamic cycle such to generate power and improve the efficiency of the plant. [11]

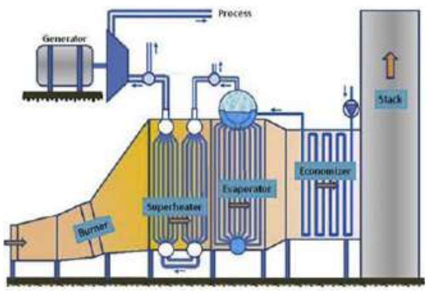


Figure 23 Heat Recovery Steam Generator (HRSG) [8]

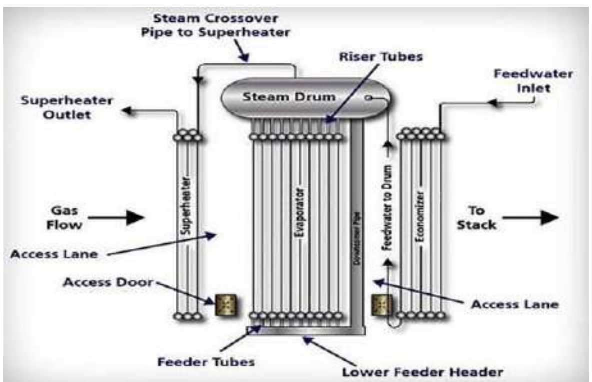


Figure 24 Typical heat recovery steam generator components [8]

3.1 **Introduction**

The diesel engine is an auto-ignition engine in which fuel and air are mixed inside the engine. The air required for combustion is highly compressed inside the combustion chamber.

This generates high temperatures which are sufficient for the diesel fuel to ignite spontaneously when it is injected into the cylinder.

Thus, the diesel engine uses heat to release the chemical energy contained in the diesel fuel and to convert it into mechanical force.

Carbon and hydrogen construct the origin of diesel fuel like most fossil fuels. For ideal thermodynamic equilibrium, the complete combustion of diesel fuel would only generate CO2 and H2O in combustion chambers of engine. [12].

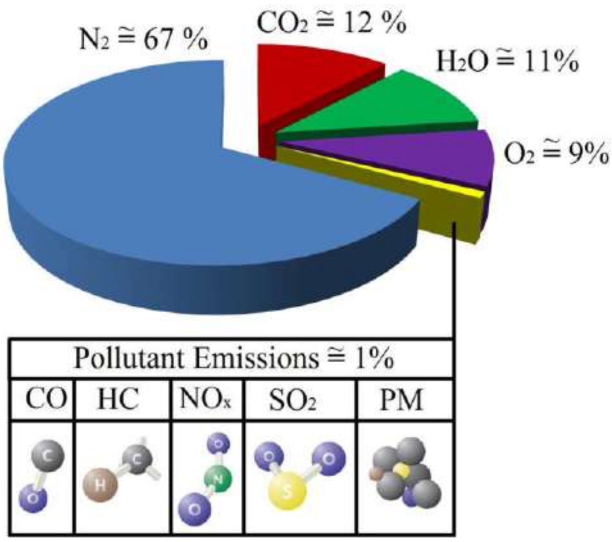


Figure 25 The compositions of diesel exhaust gas [13]

However, many factors (the air–fuel ratio, ignition timing, turbulence in the combustion chamber, combustion form, air–fuel concentration, combustion temperature, etc.) make it the results impossible, and a number of harmful products are generated as results of combustion.

The most significant harmful products are CO, HC, NO_x, and PM. Fig 25 shows the approximate composition of diesel exhaust gas. Pollutant emissions have a rate of less than 1 % in the diesel exhaust gas.

NO_x has the highest proportion of diesel pollutant emissions with a rate of more than 50 %. After NO_x emissions, PM has the second highest proportion in pollutant emissions.

Because diesel engines are lean combustion engines, and the concentration of CO and HC is minimal. Besides,

pollutant emissions include a modicum of SO2 depending the specifications and quality of fuel. It is produced by the sulfates contained in diesel fuel. For the present, there is not any after treatment system like a catalytic converter to eliminate SO2. Nowadays, most of oil distributors and customers prefer ultra low sulfur diesel (ULSD) for diesel engines to prevent harmful effect of SO.[13]

3.2 Diesel oxidation catalyst (DOC)

The main function of Diesel oxidation catalyst (DOC) is to oxidize HC and CO emissions. Besides, DOC play a role in decreasing the mass of diesel particulate emissions by oxidizing some of the hydrocarbons that are adsorbed onto the carbon particles.

Currently, DOC containing Platinum rate(Pt) and Palladium rate (Pd) is most commonly used for oxidation and many studies conducted by researchers focused on these precious metal-based catalysts. [14]

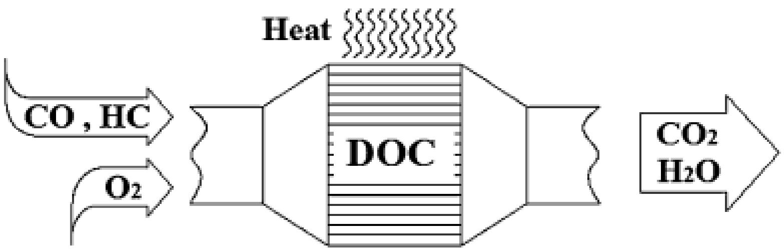


Figure 26 Diesel oxidation catalyst working process [13]

The chemical reaction in the DOC:

$$CO + \frac{1}{2} O_2 \rightarrow CO_2$$

$$C_3H_6 + 9/2\ O_2 \rightarrow 3\ CO_2 + 3H_2O$$

$$NO + \frac{1}{2} O_2 \rightarrow NO_2$$

The major properties in choice of DOCs are light-off temperature, conversion efficiency, temperature stability, and tolerance to poisoning and manufacturing costs. However, parameters as channel density (specified in cpsi (channels per square inch)), wall thickness of the individual channels, and the external dimensions of converter (cross sectional area and length) have a significant role on properties of DOCs. Channel density and wall thickness determine heat up response, exhaust-gas backpressure, and mechanical stability of the catalytic converter.[15]

3.3 Diesel particulate filter (DPF)

DPFs have been applied in the production of vehicles since 2000. They are used to remove PM emissions from the exhaust gas by physical filtration and usually made of either cordierite (2MgO–2Al2O3–5SiO2) or silicon carbide (SiC) honeycomb structure monolith with the channels blocked at alternate ends. The plugged channels at each the filter walls are designed to have an optimum porosity, enabling the exhaust gases to pass through their walls without much hindrance, whilst being sufficiently impervious to collect the particulate species. As the filter becomes increasingly saturated with soot .[13]

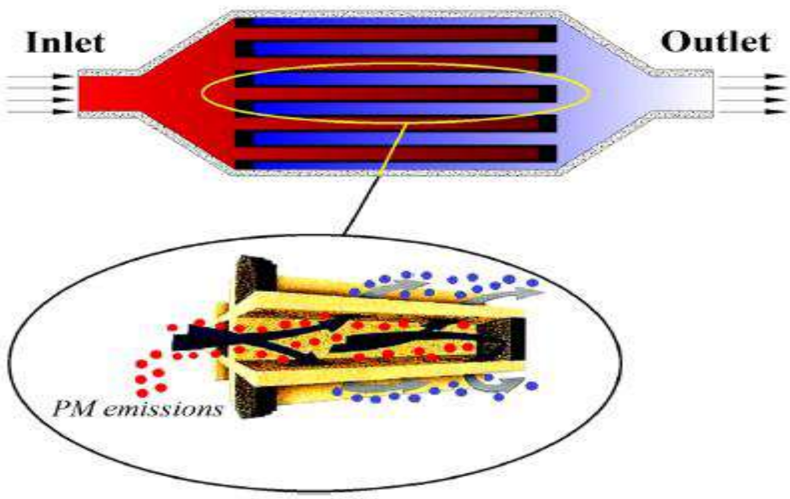


Figure 27 Diesel particulate filter (DPF) [13]

3.4 Exhaust Gas Recirculation (EGR)

Future emissions regulations like EURO 6 in Europe force Diesel engine manufacturers to find ever more complex ways to reduce exhaust gas pollutant emissions, in particular NOx and particulate matter (PM) emissions. Exhaust gas recirculation (EGR) into the engine intake is an established technology to reduce NOx emissions . The decrease of NOx emissions with EGR is the result of complex and sometimes opposite phenomena occurring during combustion.

At the same time, the decrease in combustion temperatures and oxygen concentration while increasing EGR rate reduces both soot production in the spray core and soot oxidation in the diffusion flame around the jet . Thus the final impact of EGR on PM emissions is complex and is the result of contradictory phenomena. In the conventional Diesel high-temperature combustion (HTC), the increase of EGR rate (at constant boost pressure) is accompanied by an increase of PM emissions.[16]

Table 1: Commercial application of EGR systems on diesel engines [17]

Emission Legislation	NOx Limit	Areas of EGR Application
Light-Duty Vehicles		
Euro 1/2 (1992/96)	NOx+HC = 0.97-0.7 g/km	Introduced in DI and larger IDI Euro 1 engines, EGR (non-cooled) became the main NOx reduction strategy in nearly all Euro 2 vehicles.
Euro 3/4 (2000/05)	NOx= 0.5-0.25 g/km	Cooled EGR introduced in larger size Euro 3 engines, and became the standard in Euro 4 and later diesel passenger cars and light trucks.
Heavy-Duty Engines		
US Tier 3 (2006)	NOx ≈ 2 g/bhp-hr	Cooled EGR introduced on heavy-duty truck and bus engines by most manufacturers (Cummins, Volvo/Mack, DDC, International). Miller-type intake valve timing was the alternative technology to EGR (Caterpillar).
US Tier 4i / EU Stage IIIB (2011)	NOx = 3.5 g/kWh	EGR introduced by some manufacturers of heavy-duty truck and bus engines (Scania, MAN); used in competition to urea-SCR technology.
IMO Tier III (2016)	NOx = 2.0 g/kWh	EGR introduced by some manufacturers of heavy-duty truck and bus engines (Hino, Isuzu); used in competition to urea-SCR technology.
US Tier 3 (2006)	NOx ≈ 1 g/bhp-hr	EGR used on heavy-duty truck and bus engines by all manufacturers.
US Tier 4i / EU Stage IIIB (2011)	NOx = 2 g/kWh	EGR continues to be used in some products by several OEMs (Scania and MAN), however, no OEM relies solely on EGR. Urea-SCR is still the competing technology.
IMO Tier III (2016)	NOx = 0.2 g/bhp-hr	EGR combined with NOx credits allows one heavy-duty diesel engine manufacturer (Navistar) to certify engines to a 0.5 g/bhp-hr NOx level. All other manufacturers rely on a combination of EGR and urea-SCR.
US Tier 3 (2006)	NOx = 0.4 g/kWh	Most manufacturers use a combination of EGR and urea-SCR. The competing technology is urea-SCR without EGR (Iveco and some Scania engines).
Nonroad Engines		
US Tier 3 (2006)	NOx = 4.0 g/kWh	Cooled EGR engines introduced by John Deere. A number of other manufacturers used internal EGR.
US Tier 4i / EU Stage IIIB (2011)	NOx ≈ 2 g/kWh	Cooled EGR introduced by a number of nonroad engine manufacturers; used in competition to urea-SCR technology.
IMO Tier III (2016)	NOx = 3.4 to 1.96 g/kWh	EGR will be used in some two-stroke low-speed marine diesel engine applications (MAN Diesel & Turbo). Ammonia-SCR is an important competing technology.

3.4.1 **Light-Duty Engines.**

The introduction of EGR technology to diesel passenger cars in the 1990s went almost unnoticed and was not considered a major breakthrough for several reasons. Because the required NOx reduction was quite modest, the system allowed little EGR back into the cylinder and there was no need for EGR cooling. Typical passenger car engines operate mostly at part load conditions where temperatures are relatively low. It was only the Euro 3/4 legislation that created higher demands on EGR systems and triggered the introduction of increasingly more sophisticated, electronically controlled cooled EGR systems on light-duty engines.

The EGR system is a high pressure loop, cooled EGR configuration. A portion of the exhaust is channeled through an EGR control valve and proceeds to the EGR cooler. From the cooler, EGR flows to a throttle valve assembly where it is mixed with filtered, high-pressure, fresh combustion air that has been cooled by an intercooler to recover some of its density. The mixture of air and EGR is then inducted into the engine through the intake manifold. While the engine is equipped with a variable geometry turbocharger (VTG) that can create a higher exhaust manifold than intake pressure to drive EGR, the intake throttle is used under some conditions when it is not possible to create a sufficient differential with the VTG. This system is very similar to EGR systems used in other Euro 3 as well as EPA Tier 1 and Tier 2 Bin 10 applications.

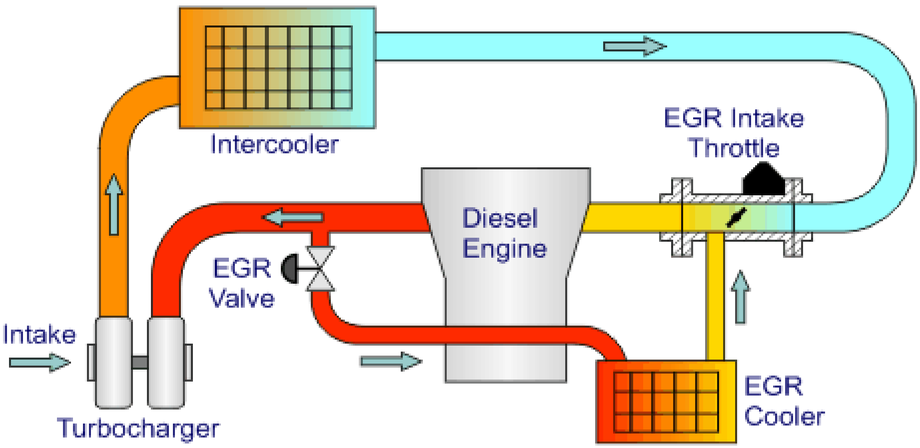


Figure 28 Schematic representation of a high-speed passenger car EGR/intake throttle system for Euro 3 application Audi 3.3 L V8 TDI engine [17]

3.4.2 **Heavy-Duty Engines.**

Heavy-duty applications of EGR date back to at least 1977 when the technology was used on some naturally aspirated engines—such as Caterpillar's 3208—to comply with California's 5 g/bhp-hr NOx+HC limit for heavy-duty diesel engines. However, through the 1980s and 1990s the use of EGR on heavy-duty engines remained limited—EGR was not required to meet regulatory emission standards and the application of the technology was driven primarily by incentives such as the US EPA voluntary "low emission vehicle" certification program.

The wide scale launch of cooled EGR on heavy-duty engines that attracted a lot of attention to the technology took place in late 2002 in the North American market.

High pressure loop cooled EGR was the most expedient in-cylinder NOx reduction technology that could achieve this emission level

EGR continued to be the primary NOx reduction technology and allowed a number of engine makers to reach about 1 g/bhp-hr NOx. For EPA 2010, the 0.2 g/bhp-hr NOx limit proved to be too low to be effectively reached with EGR alone and additional help from NOx after treatment was required. Navistar—the only manufacturer to temporarily use EGR without aftertreatment for EPA 2010—was able to do so only by certifying engines to 0.4-0.5 g/bhp-hr NOx and making up the difference with credits.

In Europe, a couple of heavy-duty on-road engine makers introduced EGR-only engines at the Euro IV stage, with the remainder relying solely on urea SCR. By Euro V, However, the use of EGR was often minimized and in some cases, restricted to certain low load conditions with no EGR used at higher load operating conditions such as highway cruise. Examples of the later approach are the Volvo D11 and D13 engines launched in 2013 that utilized uncooled EGR to control NOx and increase the exhaust temperature for the SCR catalyst at low engine loads. [17]

3.4.3 **Nonroad Engines.**

EGR technology was also adopted by nonroad engines. Some of the first nonroad application of cooled external EGR were the US Tier 3 John Deere PowerTech Plus engines. The first cooled EGR John Deere engine was the 6 cylinder 9 L model (6090) launched in 2006, followed by the 6.8 L and 13.5 L models. These engines used high pressure loop cooled EGR and a variable geometry turbocharger. It is interesting to note that the 6090 EGR engine used in the John Deere 8000 series tractor in 2006 had the lowest fuel consumption of all time (as determined by the University of Nebraska Tractor Test Laboratory), demonstrating that the fuel economy penalty associated with EGR can be overcome by skillful engine design. Other applications of cooled EGR for Tier 3 included Komatsu’s 11.0, 15.2 and 23.2 [17]

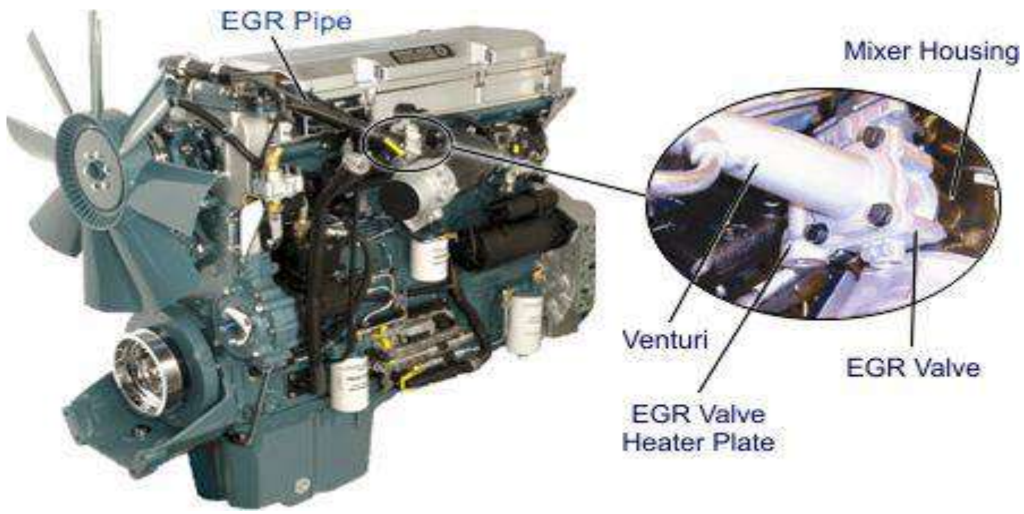


Figure 29 Detroit Diesel Corporation Series 60 equipped with cooled HPL EGR [17]

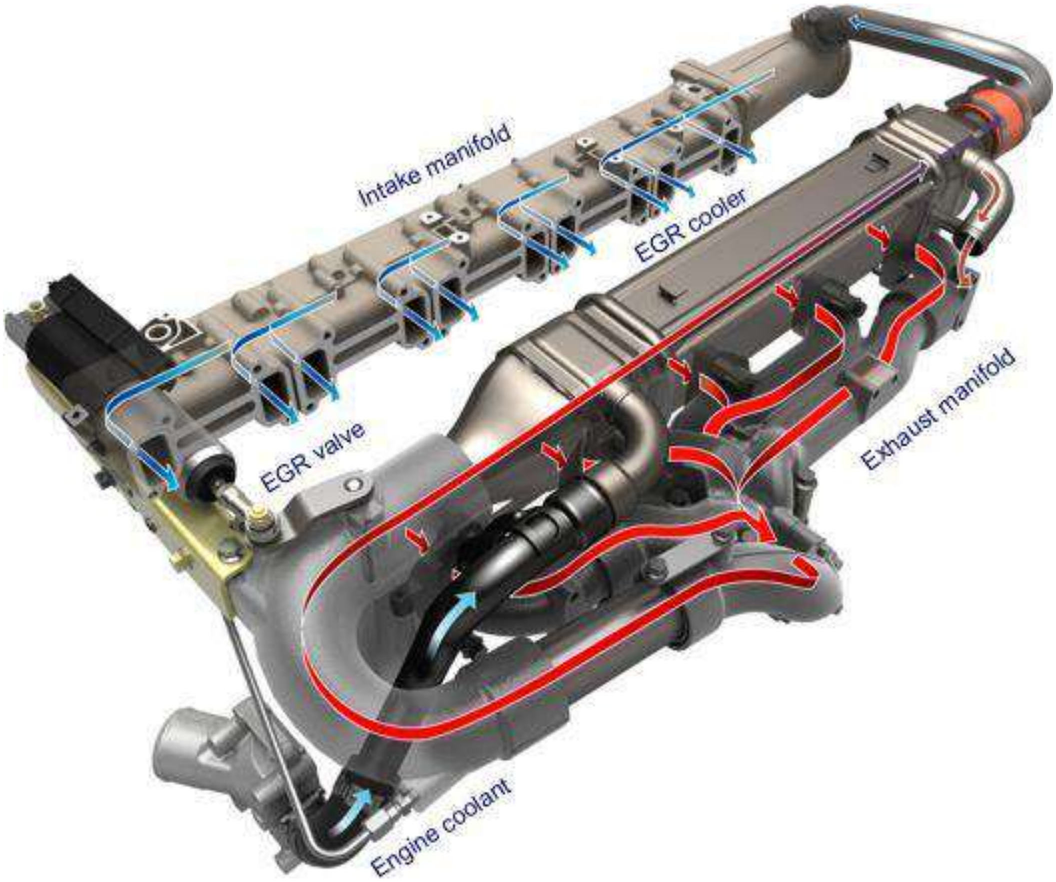


Figure 30 EGR system with one-stage cooling for Scania Euro IV engines [17]

3.5 **EGR Benefits**

The important benefit of EGR system is the redaction of NOx

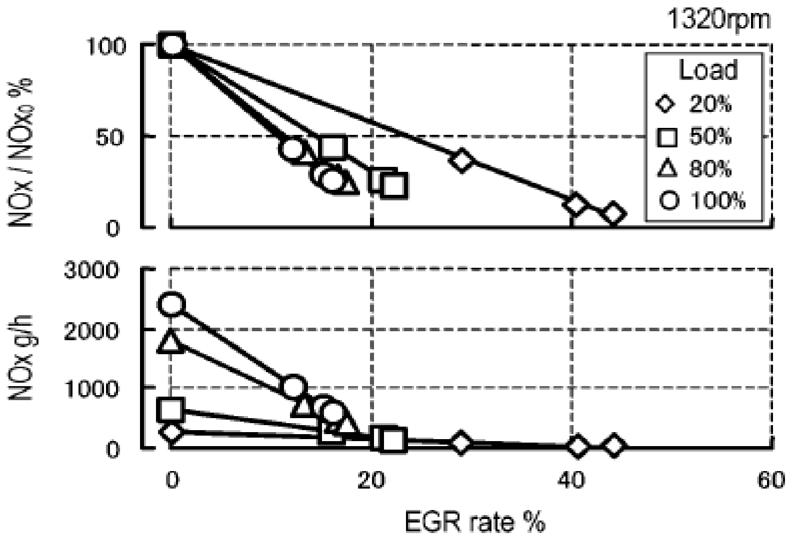


Figure 31 Relationship between EGR rate and NOx [17]

Fig. 31 shows the typical NOx reduction effect of EGR at the mid-speed range of the test engine. Under all load conditions, the amount of NOx decreases as the EGR rate increases. The graph also shows that the NOx reduction curves with the 0 % EGR point as the origin slope downward at different angles according to the load, the steeper the angle. In other words, the NOx reduction effect at the same EGR rate increases as the engine load becomes higher.

It is generally known that there are two reasons to reduce NOx by EGR.

The first of them is the reduction of combustion temperature. The addition of exhaust gases to the intake air increases the amount of combustion-accompanying gases (mainly CO_2), which in turn increases the heat capacity and lowers the combustion temperature.

The second effect is the reduction of oxygen concentration in the intake air, which restrains the generation of NOx. [17]

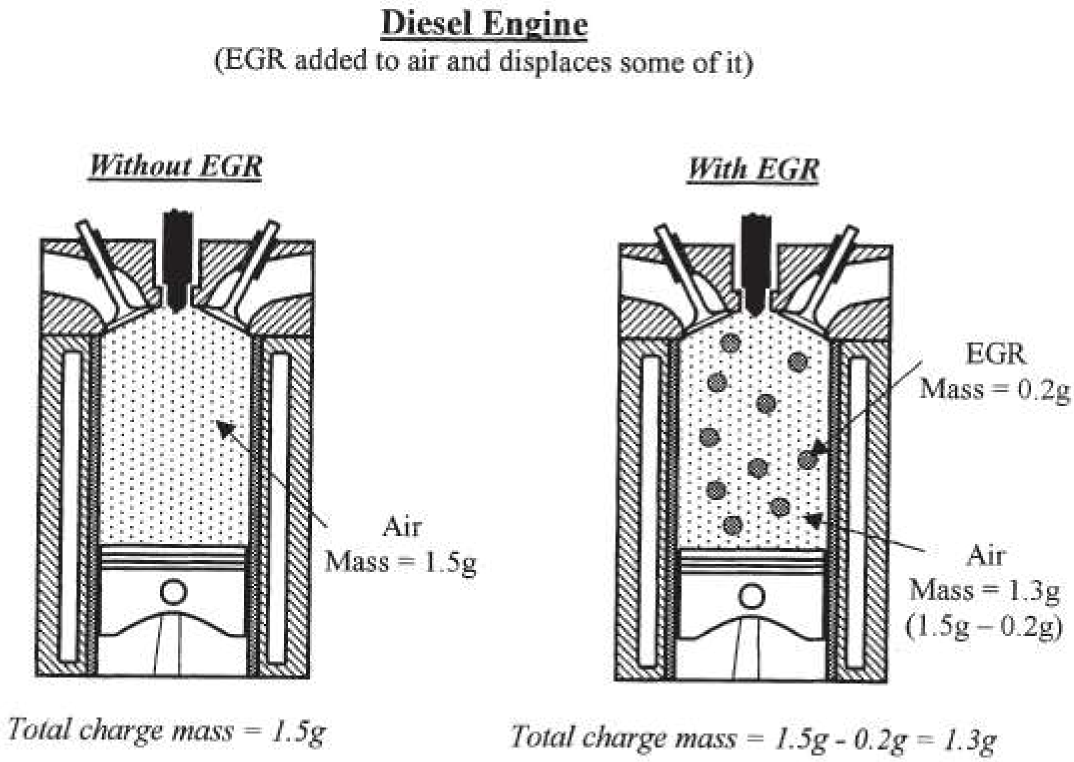


Figure 32 reduction of oxygen concentration in the intake air [29]

4.1 Introduction

Before HP pump skid design or selection can began, specification need to be established which express several requirements only requirements pertaining to the hydraulic of the pump are considered here, other considerations are the reliability, durability, noise and vibration, maintenance, installation and control these affect primarily the mechanical design of the pump materials selection accessory components instruments and frame design

4.2 Description

The HP hydraulic station consist from HP pump able to supply the required water capacity and water pressure powered by internal combustion engine, an exchanger recorded with the exhaust manifold to heat the water before ejected by the HP pump, all the equipments are fixed together and installed in a robust steel frame.

4.3 High pressure triplex pump

We select HPP ECH 44/320 regarding the availability and high efficiency

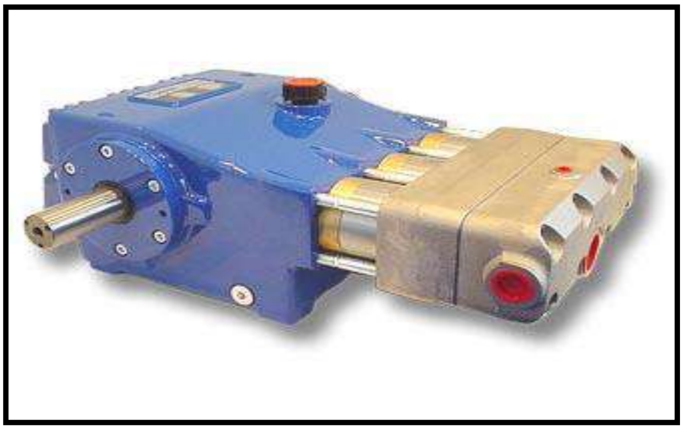


Figure 33 HPP 44/320 triplex pump [18]

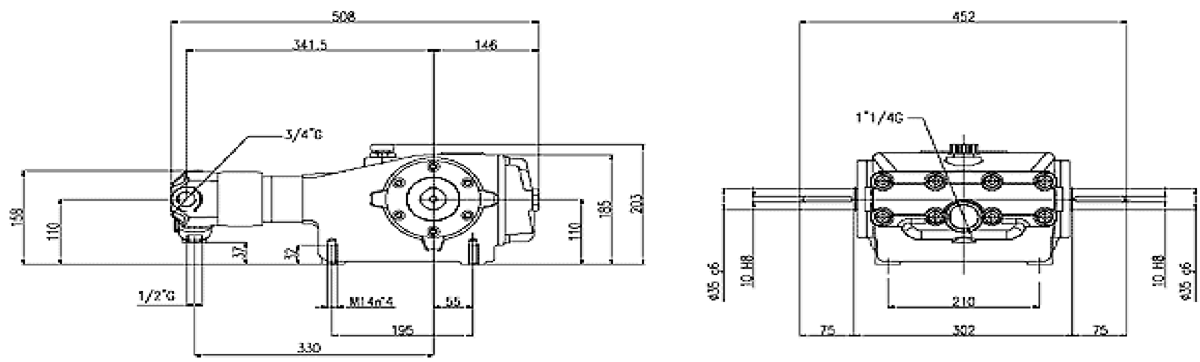


Figure 34 HPP 44/320 triplex pump drawing [18]

4.3.1 Pump specification:

The plunger pump is able to provide extra energy to water; it can be operated with an electric, hydraulic or internal-combustion motor.

The reciprocating-motion pistons compress the water inside the cylinders, thus boosting pressure.

The pump has 3 pistons to cope with requirements of capacity &outlet water flow regularity.

Pump body: anodized aluminum Head: stainless steel.

Eccentric shaft: high-resistance steel.

Shaft support bearings dimensioned for long duration.

Connecting rods: special alloys.

Guiding piston: stainless steel.

Pumping pistons: ceramic integrated.

Valves: stainless steel.

Seals: high dependability.

Max working pressure: 320 bar

Max flow rate : 44l/min

Max rpm without reducer: 1000 r/min

Max rpm with reducer: 1500 r/min

Total weight : 80 Kg
Max Water Charge : Max 3 BAR (43.5 psi). [18]

4.4 Engine

There are different engine-pump setups for the skid units. For every specific pump model is recommended to use an specific engine that provides the necessary power.

We select to install the 403D-11G Perkins engine regarding the high performance and long durability. [19]

Figure 35 403D-11G perkins engine [19]

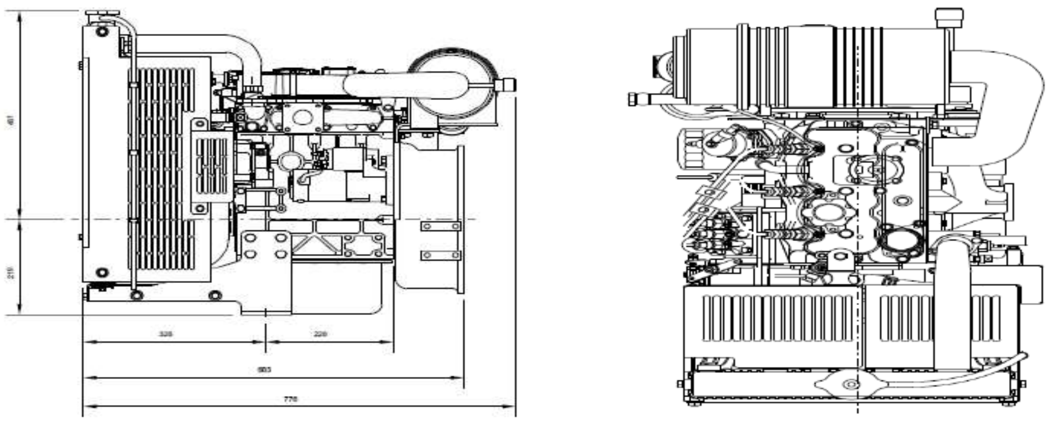


Figure 36 403D-11G perkins engine drawing [19]

4.4.1 Technical Data

4.4.1.1 Overall dimensions

Height .. .. ……... ... 700 mm

Length .. .. 776 mm

Width (including mounting brackets) ... 449 mm

4.4.1.2 **Basic technical data**

Number of cylinders:…………….... 3

Cylinder arrangement... ... ... Vertical in-line

Cycle ... ... four stroke

Induction system .. .. Naturally aspirated

Compression ratio 23:1

Bore.. ... ... 77 mm

Stroke... ... ... 81 mm

Cubic capacity.. ... ... .1·131 litres

Direction of rotation .. .. anti-clockwise viewed from flywheel

Estimated total weight (dry).. .... 129,2 kg

Engine speed………………………..1500 rpm

4.4.1.3 **Thermal specification**

Table 2: Energy and thermal specification of engine [19]

Designation	Unit	
Brake mean effective pressure	KPa	610
Mean piston speed	m/s	41
Coolant Flow	l/min	27.3
Combustion air flow	m^3/min	0.7
Exhaust gas flow	m^3/min	1.66
Exhaust gas temperature outlet (max)	°C	368
Overall thermal efficiency	%	32
Energy		
Energy In fuel (heat of combustion)	KW	25.9
Energy in power output (gross)	KW	8.6
Energy to cooling fan	KW	0.2
Energy in power output (net)	KW	8.4
Energy to cooling and lubricating oil	KW	8.3
Energy to exhaust	KW	7.3
Heat to radiator	KW	1.7

4.4.1.4 **Fuel consumption**

Table 3: Fuel consumption respect to engine load [19]

Engine load %	100%	75 %	50 %
Fuel consumption (liter/hr)	2.6	2.0	1.5

4.5 Exchanger

The design criteria of heat exchanger vary with the requirement or their functionality [26]. much research study and implementation of spiral and straight pipes heat transfer exchanger are today demanded for various applications.

Conventionally, the heat exchanger mechanism is attributed to many factors such as geometrical configurations, compact size, bigger thermal conduction space, number of loops, etc. Numerous researches have been conducted to investigate and determine what configuration and geometry of pipes could enhance the thermal coupling between them and the conducting volume

4.5.1 Geometry

Based on other studies which compare between spiral and straight pipes heat exchanger we can select the appropriate heat exchanger and determine suitable one for our study

4.5.1.1 Study 1: Effect of geometrical parameters on Temperature drop and heat transfer by Shiva Kumar, K Vasudey, Karanth

4.5.1.1.1 Temperature drop

Table 4: Dimensional & operating parameters of the helical coil tube heat exchanger

S.No	Dimensional parameters	Dimension
1	Average coil diameter	40 mm
2	Tube diameter	10 mm
3	Tube length	1000 mm
4	Working fluid	Water
5	Average hot water temperature	332K
6	Constant wall temperature	293K

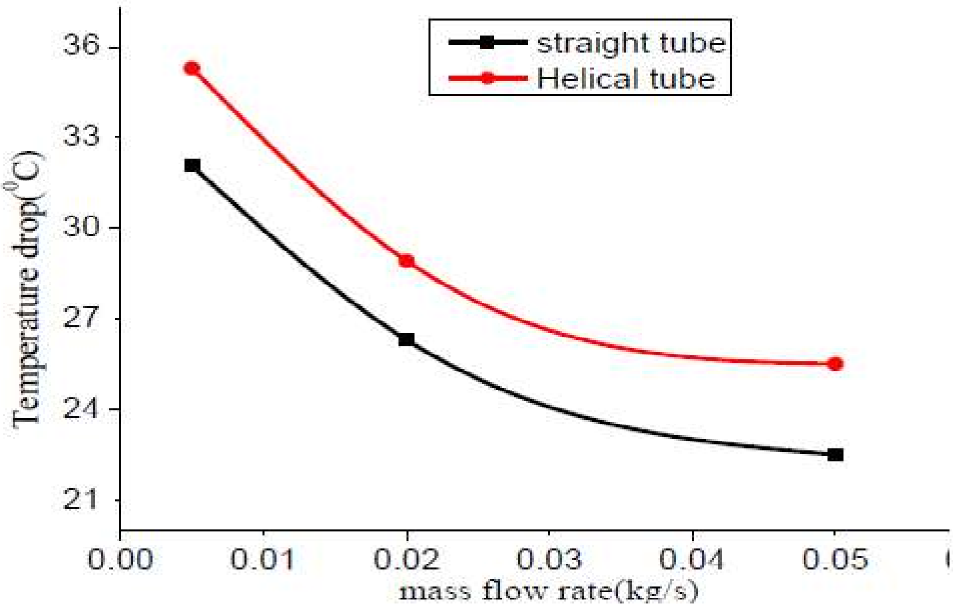


Figure 37 Variation of temperature drop with mass flow rate for straight and helical tube [20]

4.5.1.1.1.1 Results discussion

Temperature drop for helical coiled tube is higher than the straight tube. This is due to the curvature effect of the helical coil. Fluid streams in the outer layer of the pipe moves faster than the fluid streams in the inner layer. This difference in the velocity will set in a secondary flow by which heat transfer will be increased. It can be seen that for the helical coil the average temperature drop was increased by 9.5% as compared to the straight coil when the mass flow rate varied from 0.005 kg/s to 0.05 kg/s.The difference in temperature drops between straight and helical coil increases with the mass flow rate as depicted by fig 8 showing the better performance the helical coils than the straight tube.[20]

4.5.1.1.2 The transfer heat

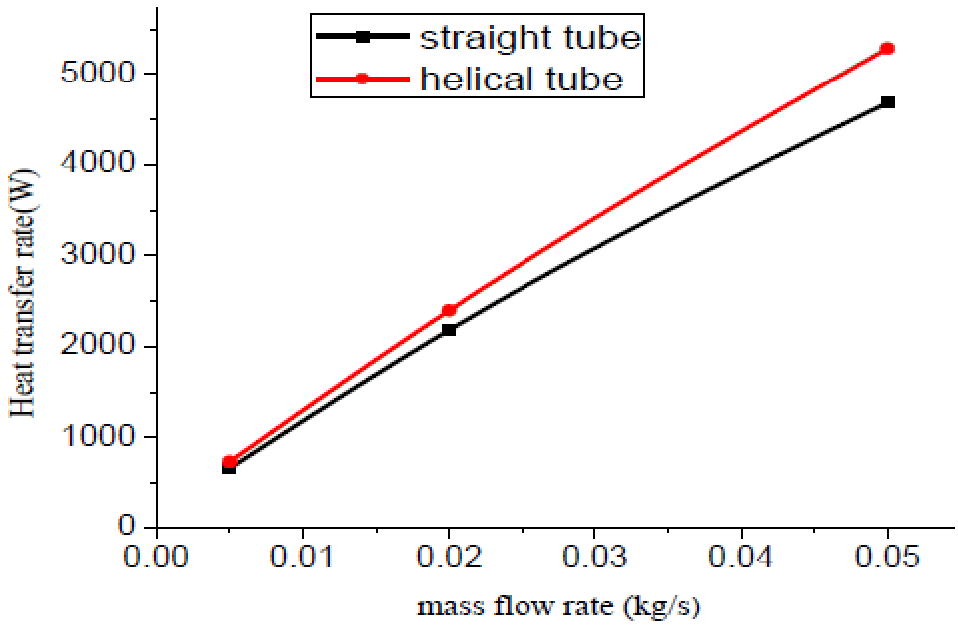


Figure 38 the variation of heat transfer rate through the water for straight and helical coil with mass flow rate [20]

4.5.1.1.2.1 Results discussion

Heat transfer rate increases with mass flow rate for both cases and It can be observed that for higher mass flow rate, heat transfer increase better helical coils then straight pipes.[20]

4.5.1.2 **Study 2: Influence of Number of loops on the heat transfer** by Esam Jassim

4.5.1.2.1 Experimental Set-up

For the purpose of the experiments, a 19 mm diameter copper-tubes coils each of 10.6 m length are used. Only 5% of the length is straight before and after the helical portion. The tubes are carefully furnished from inner surface to reduce the flow resistance. External pipes are connected to the coil with straight joints at the two ends. Insulation was applied to the external pipes to avoid any heat gain/loss from the surroundings other than the container. Thermal insulation material is covering the conducting volume (container) to minimize the heat losses to the surroundings. [21]

During the experiment, the fluid flowing inside the coil absorbs heat energy from the water of the container while passing through the spiral tube. The inlet/outlet temperatures of the spiral pipes are measured using the installed digital thermometers. Similarly, the inlet/outlet pressures were measured too using the installed pressure transducers. Important data were captured momently and recorded until steady state occurs.[21]

The constraints of the experiments are illustrated below.

Table 5: Thermal Properties and System Dimensions.[21]

Property	Unit	Value
Pipe diameter	mm	19
Coil Length	m	10.6
Container (*l* x *w* x h)	m	1.14x0.65x0.4
density	kg.m-3	8
Dynamic viscosity	kg.m$_{-1}$.s$_{-1}$	994
Thermal conductivity	W.m$_{-1}$.K$_{-1}$	0.653x10-3
Specific heat	J.kg$_{-1}$.K$_{-1}$	0.648
Prandtl Number		4190
		4.23

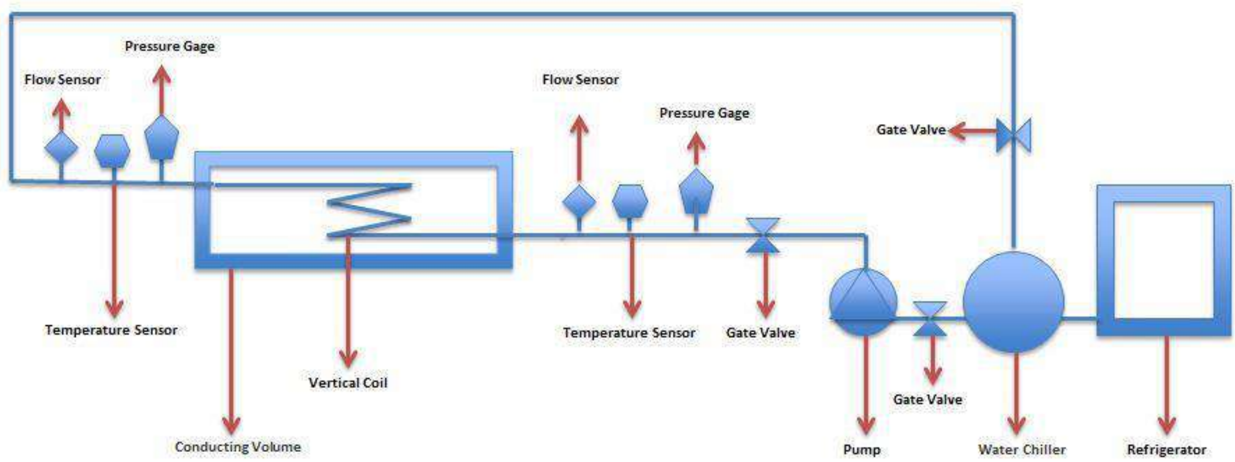


Figure 39 Experimental Apparatus.[21]

Experiments are carried out for different boundary conditions and coil parameters but we take only the part for number of loops.

The coil selected for studying the influence of its geometry has helix diameter of (D = 15 cm), Pitch of (H = 2 cm), and 10 loops. The coil was firmly mounted vertically and sunk completely inside the pool. Coil inlet/exit temperatures and pressures, container medium temperature, and flow rate have been recorded each minute.

Another coil of 5 loops with same length and pitch but different loop diameter (30 cm) is vertically investigated under similar conditions illustrated in table 5. [21]

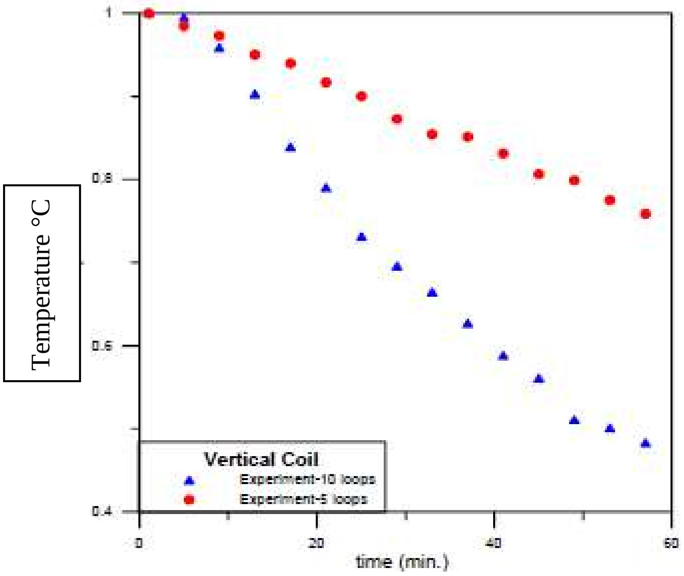


Figure 40 Influence of Number of loops [21]

4.5.1.2.2 Results discussion

The behavior of the coil due to the change in the number of loops are presented in Fig 40 . The comparison of the normalized temperature of the container medium is clearly shown that increasing the number of loops would increase the rate of heat transfer despite the identical length of the two coils. [21]

4.5.2 **Study 3: Influence of flow nature on overall heat transfer coefficient** by N. D. Shirgire, P. Vishwanath Kumar

The heat exchanger consists of a shell and helically coiled tube unit with two different coil diameters. Each coil is fabricated by bending a 9.50 mm diameter straight copper tube into a helical-coil tube of thirteen turns. Cold and hot water are used as working fluids in shell side and tube side, respectively. The experiment done at the cold and hot water mass flow rates ranging between 0.10 and 0.22 kg/s, and between 0.02 and 0.12 kg/s, respectively. The inlet temperatures of cold and hot water are between 15 and 25 °C, and between 35 and 45 °C, respectively. The effects of the inlet conditions of both working fluids flowing through the test section on the heat transfer characteristics discussed.[22]

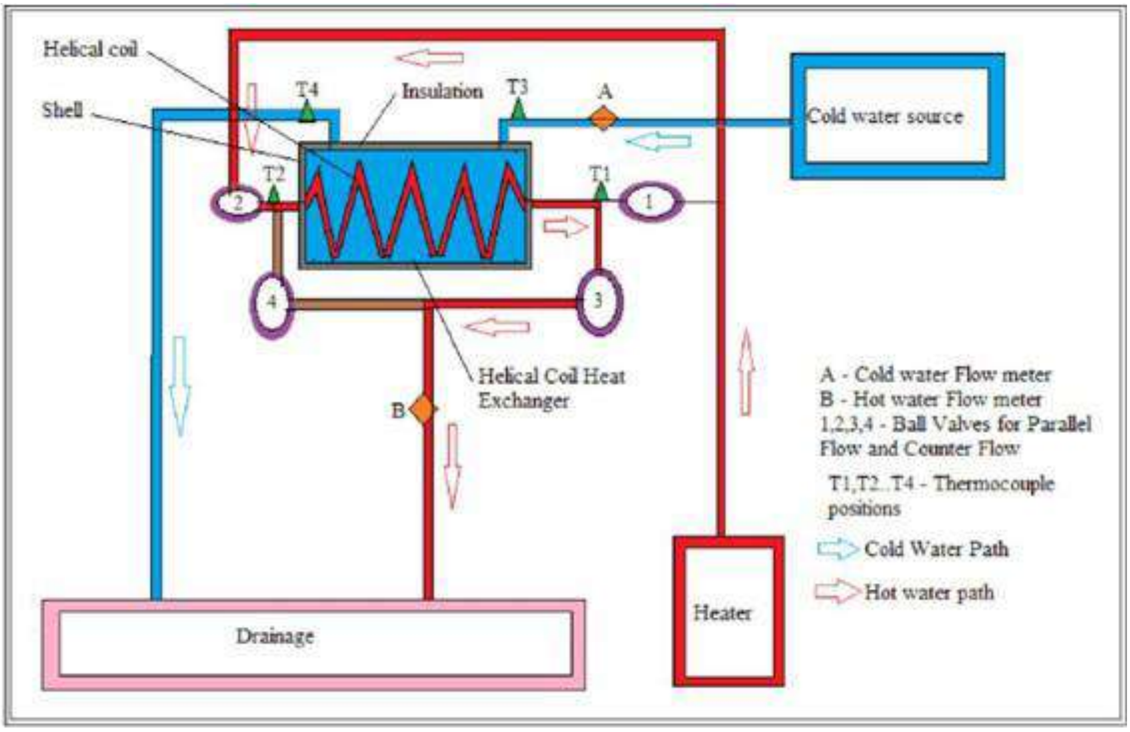


Figure 41 Schematic of Helical Coil tube Heat Exchanger [22]

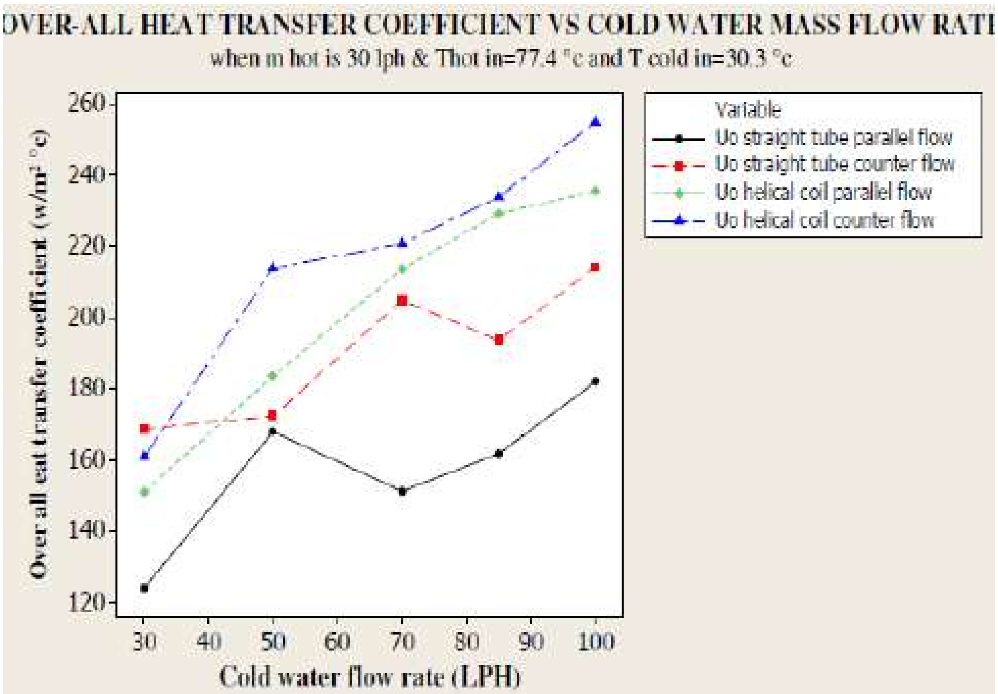


Figure 42 Comparison Of Overall Heat transfer Coefficient For Helical Coil And Straight Tube Heat Exchanger.[22]

4.5.2.1 **Results discussion**

Fig 42 shown that the helical coil counter flow is most effective then helical and straight tube parallel flow heat exchanger.[22]

4.5.2.2 **Conclusion**

Results show that the heat transfer characteristics of the helical tube heat exchanger are much better than that of straight tube heat exchanger. [23]

Use of a helical coil heat exchanger was seen to increase the heat transfer coefficient compared to a similarly dimensioned straight tube heat exchanger [24].

Increasing number of loops per unit length of spiral coil enhances the rate of heat transfer. [21]

Helical coil counter flow is most effective in all these conditions and straight tube parallel flow heat exchanger is least effective. [21]

So, as per the results and studies above we can fabricate our heat exchanger with the geometric characteristics below:

Form: helical coil tube

Flow orientation: counter flow

Number of loops: max possible as per suitable size available

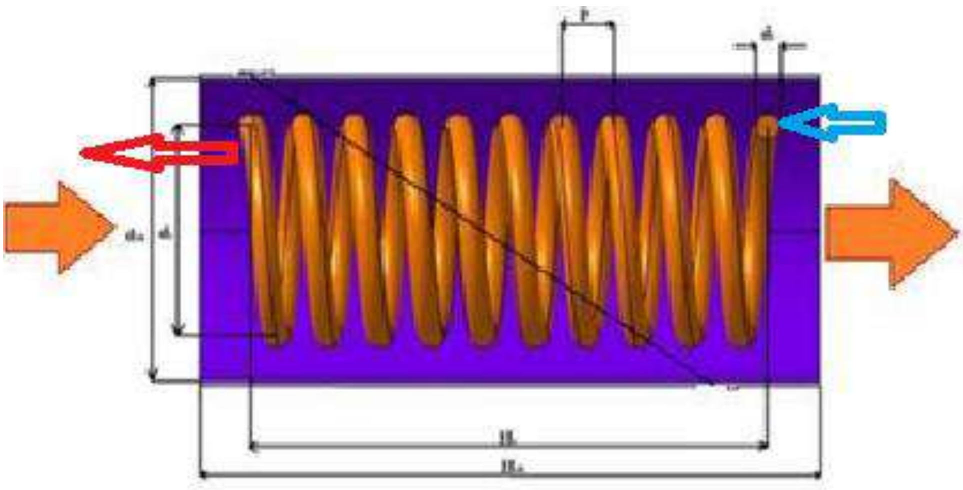


Figure 43 The drawing of proposed helical coil tube heat exchange

5.1 Introduction

This research implementation method starts from a preparation stage, apparatus engineering, testing, and finishing that require 05 months from January to end of may 2021 in Sarl LTPS workshop at IRARA 02, HASSI MESSAOUD base, Sarl LTPS founded in 2009 as a service company in pumping, injection and technical solution.

The preparation stage consists of literature study, survey, and apparatus designing. The unit engineering stage consists of Heat Exchanger apparatus making (Helical tube part), frame construction, pipe installation, engine and pump installation, additional apparatus procurement, and instrumentation. Next step is the testing stage which consists of research apparatus setup with instrumentation, apparatus testing and data collection. In the meantime, the last stage has been conducted.

5.2 Frame constriction

The frame was implemented by steel EPU 100 with dimension 2m of length x 1m of wide x 1 m of height

Figure 44 frame of installation

5.3 Storage Tank :

Figure 45 Storage tank

Tank with stainless steel as per frame measurement with dimension 2m of length x 1m of wide x 1 m of height (fig 45)

5.4 Exchanger

The main apparatus that are used in this research are Heat Exchanger of helical coil type and pipe installation.

Heat Exchanger of helical coil consists of copper pipe with 6.5 m of length shaped into an helical coil. The spiral tube was cylindrical steel container with 0.36 m of length and 0.15 m of diameter (fig 46)

5.4.1 Parameters of a helical coil heat pipe

Material of pipe: copper
cold fluid: water
Hot fluid: exhaust gases
Outer diameter of pipe: 22 mm
Pipe thickness : 1 mm
Pipe length: 650 mm
Helical coil length: 350 mm
Helix diameter Dc : 130 mm
Number of Loops: 13
Length of shell “container”: 360 mm
Shell diameter: 150 mm

5.4.2 Helical coil pipe exchanger fabrication steps

Figure 46 Helical Coil fabrication

Figure 47 container “shell” installation

Figure 48 helical coil exchanger installation

Figure 49 Exchanger isolation and final installation

5.5 The installation drawing

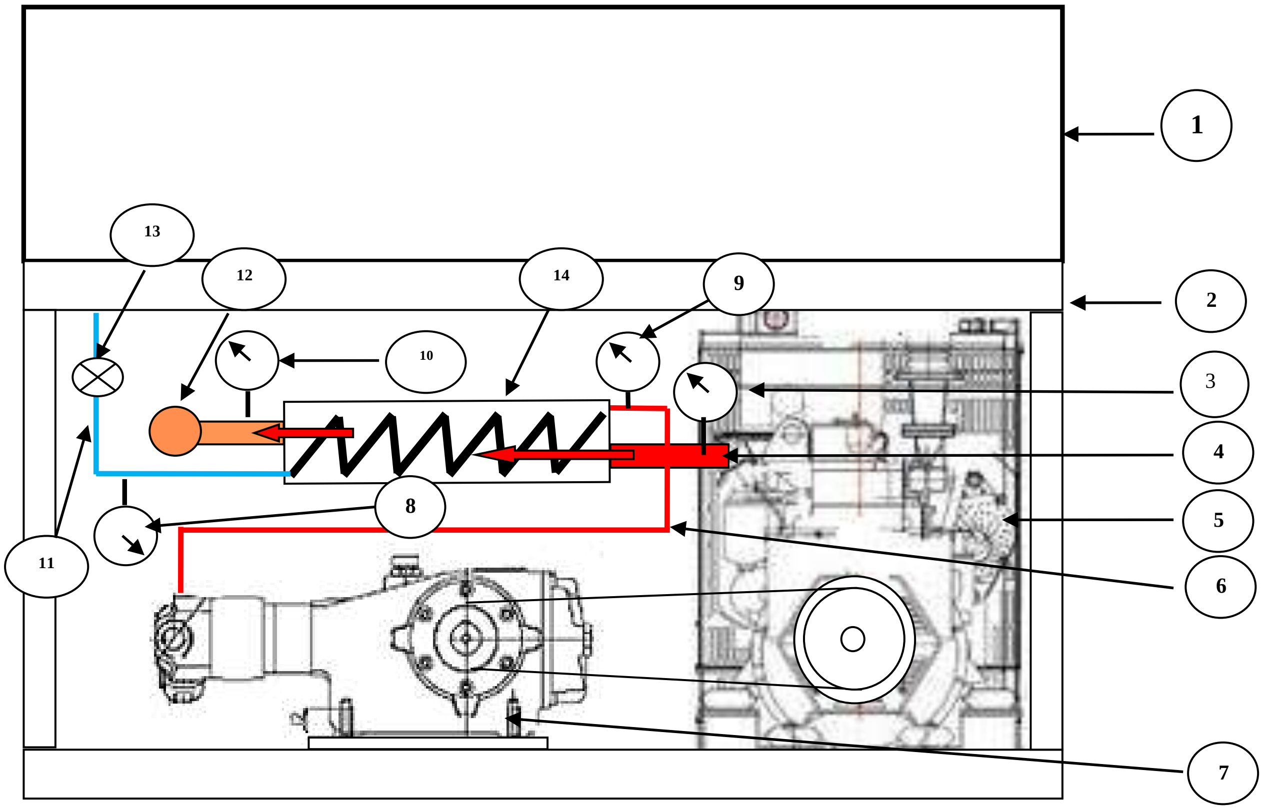


Figure 50 Installation drawing

N°	Designation
01	Storage tank
02	frame
03	Exhaust gas inlet temprature gage
04	Exhaust gas manifold
05	Engine
06	Hot water Outlet
07	HP pump
08	Inlet water temprature gage
09	Outlet water gage
10	Exhaust gas inlet temprature gage
11	Inlet water pipe
12	Outlet exhaust gas temprature gage
13	Inlet water valve
14	Helical coil tupe exchanger

5.5.1 Water flow working process:

After the engine (5) starting for 2 min we open the tank valve (13) the water with (tw1)of temperature pass from the water tank (1) to the exchanger (14) where the water recover the heat from the exhaust gases, we can record the inlet temperature (Te1) by gage (03) and outlet exhaust gas temperature by gage (10)

The water inter the HP pump (07) which powered by the engine (5) with (tw2) of temperature and out with high temperature and high pressure

Figure 51 The final skid installation

5.6 Experimental study of water heated by exhaust gases

5.6.1 Method

The present study was carried out to design and develop an HP hydraulic cleaner with hot water heated by helical coil tube heat exchanger with exhaust gases heat using the installation above.

First, starting the engine for 02 minutes to obtain the stability where of engine after that we open the water tank valve, the water pass from the tank to the helical coil exchanger where the exhaust gas energy was flowed through the heat exchanger aiming the emission heat transfer to the water, after that to the HP pump to eject with high pressure and high temperature

Te_1 and Te_2 were considered as EG temperatures inlet and outlet of heat exchanger. Meanwhile, tw_1 and tw_2 were considered as water temperatures before and after helical coil tube heat exchanger

We fix the flow rate in 7 l/min to obtain pressure between 250 - 300 Bar and we record the measurements of temperatures (Te1, Te2, tw1, tw2) after 02 minutes from engine starting for every 30 second, the results registered in the table 6 below:

Table 6: The temperatures (Te1, Te2, tw1, tw2) record table

Time (s)	Te1 °C	Te2 °C	tw1°C	tw2 °C
30	120	80	33	38
60	125	82	33	40
90	130	85	35	46
120	135	88	38	55
150	138	90	38	65
180	140	90	40	68
210	140	90	40	70
240	140	90	40	73
270	140	90	40	75
300	140	90	40	77
330	140	90	40	77
360	140	90	40	77

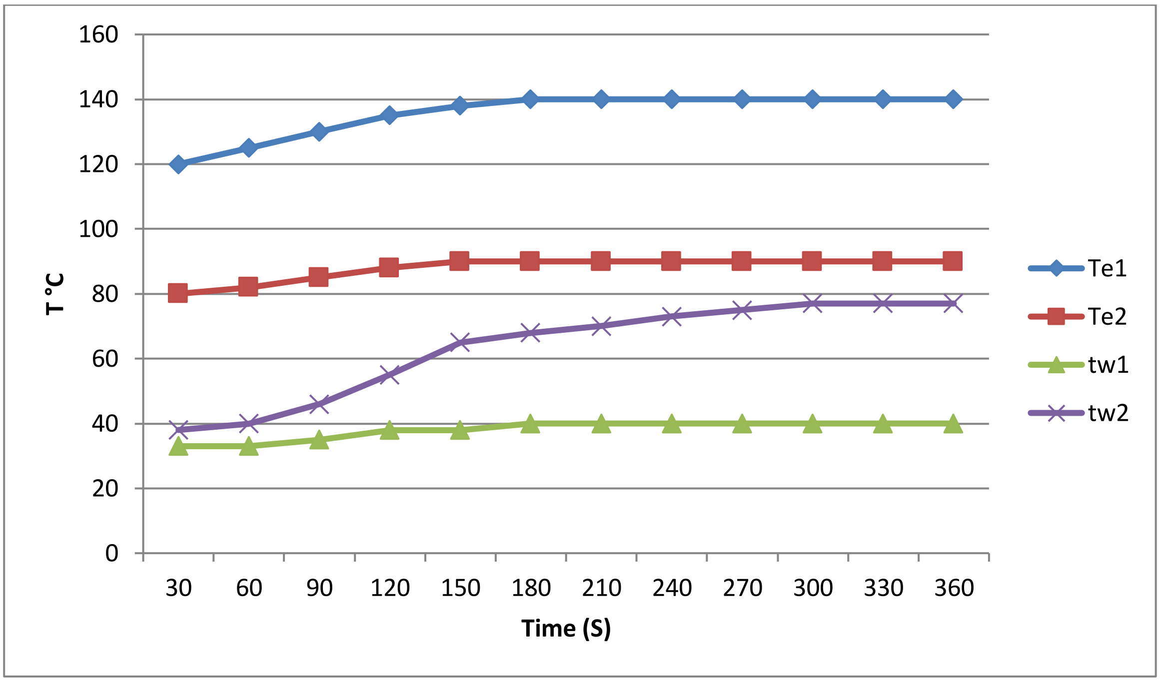


Figure 52 variation of outlet, inlet temperature for EG (Te1, Te2) and water (tw1, tw2)

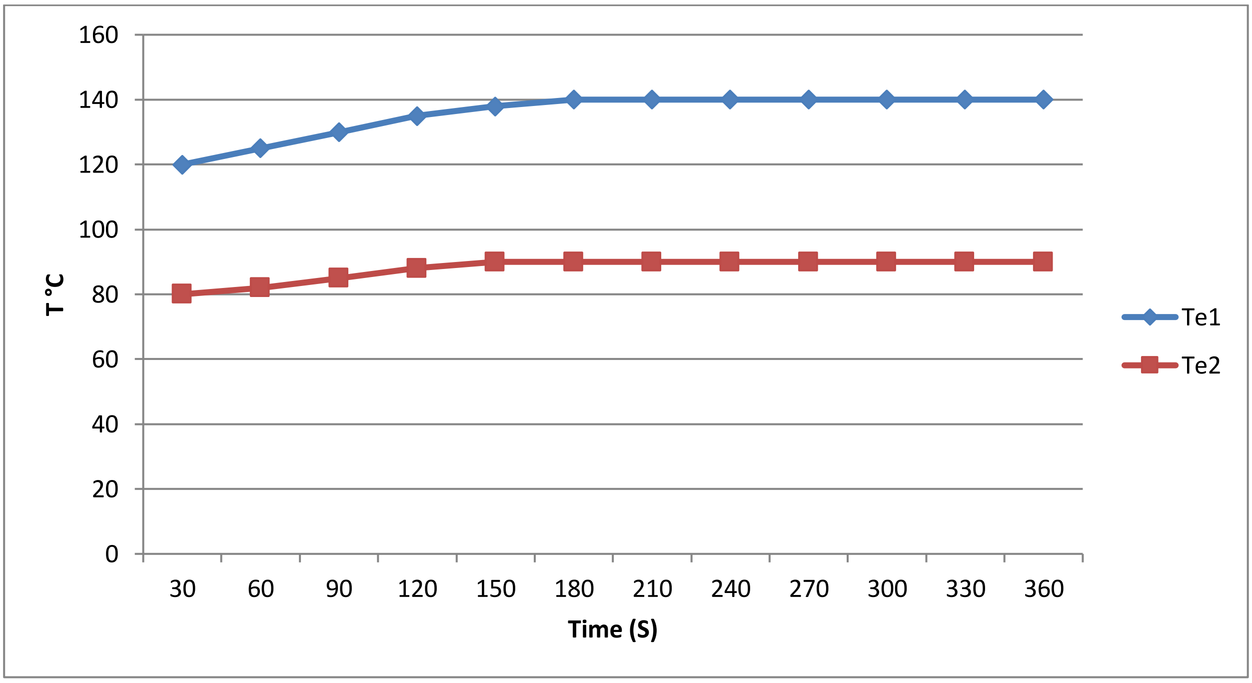


Figure 53 comparison between (Te1) and (Te2) timre s

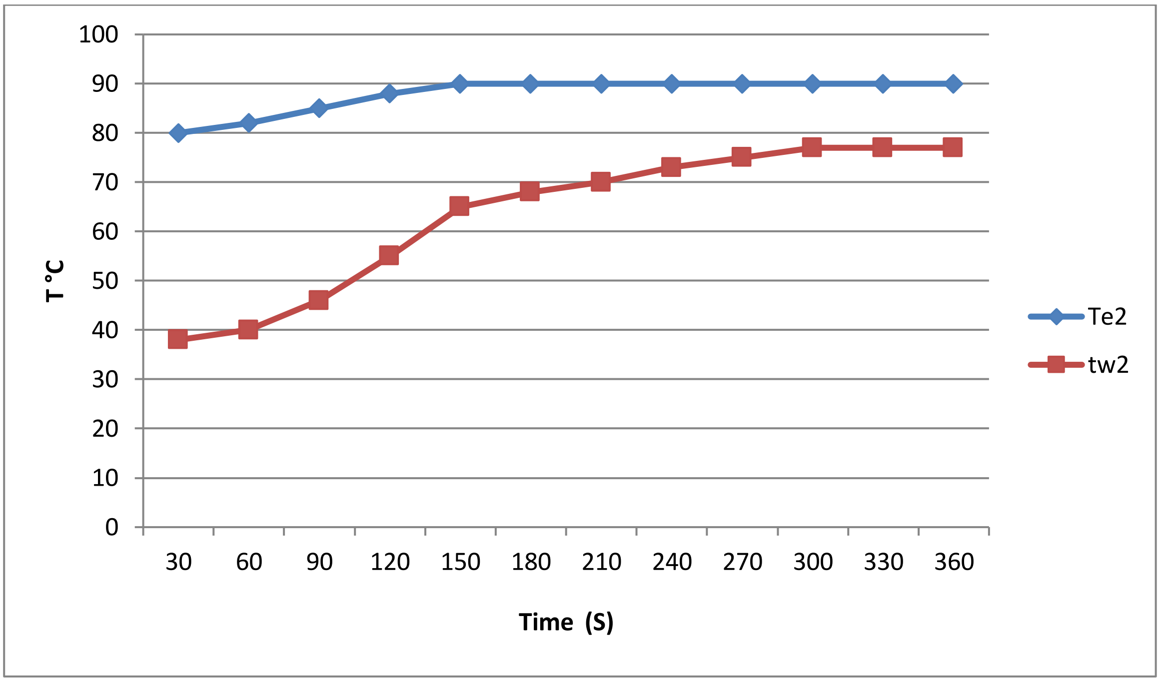


Figure 54 comparison between (Te1) and (tw2)

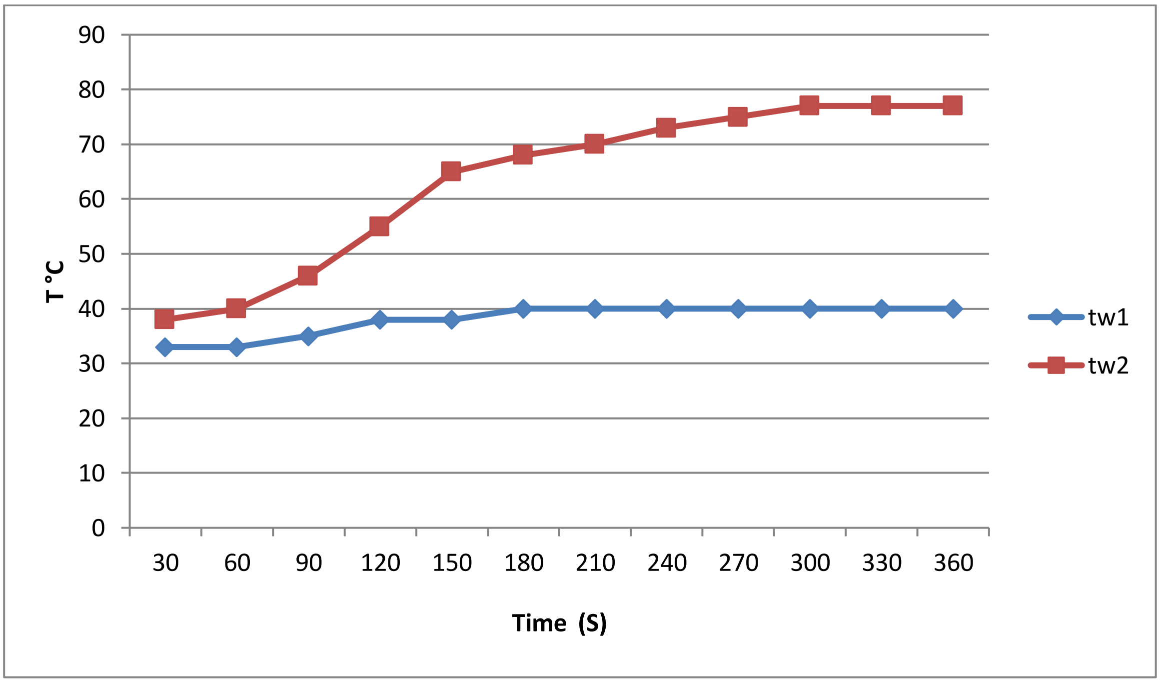


Figure 55 comparison between (Te1) and (tw2)

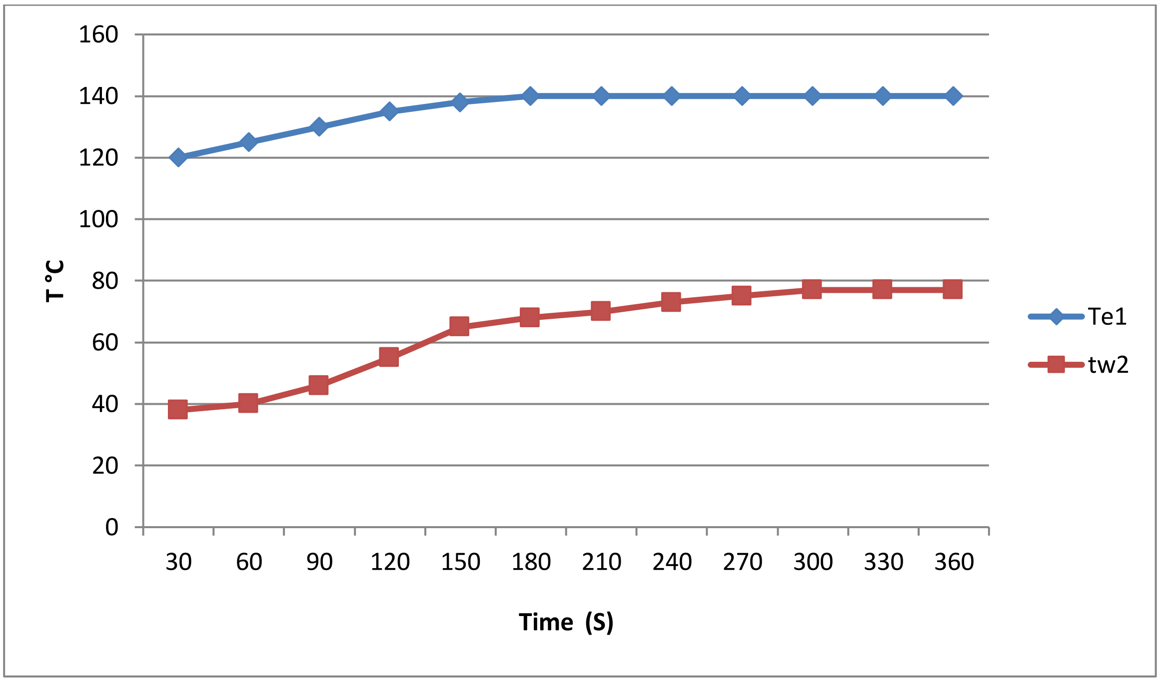


Figure 56 comparison between (tw2) and (Te1)

5.6.2 Results discussion

In a diesel engine normally the temperature of exhaust gas will attain steady state within a period of 5 min at a given load. However it is observed in the present work, that we start the engine 02 minutes before the experience and after 03 minutes from beginning the experience we get the maximum value 140 °C; due to the thermal heat released from the engine the exhaust gas temperature increases.[25]

From Fig 52 it could be seen that All temperature records (Te1,Te2,tw1,tw2) increase with respect to time.

Fig 53 we observe that the defiance between Te1 and Te2 increase from 40°C at 30 S to 50°c at 180 S due the heat recovered in helical coil exchanger.

Fig 54 the deference between (Te2 – tw2) decreases from 42°C at 30S to 13°c at 300 S which impact on the exchanger efficiency.

Fig 55 the inlet tw1 increase with little value regarding the conduction effect on the inlet tube

Fig 56 we observe that when the inlet Te1 increase the tw2 increase due to the transfer of heat in the helical coil exchanger.

Conclusion:

The exhaust gas energy of diesel engine bring big benefits, it would solve the matters related to energy saving, pollution reduction, economic improvement. The results of this study are:

Get high Outlet water temperature from the exchanger, up to 77 °C and it's very acceptable for cleaning operation.

- Reduce the temperature of exhaust gases out from the IC engine30%.
- Implement a safe installation by avoiding all electrical components.
- Recover the lost energy and transfer it to useful energy.
- Reduce the size of HP hydraulic cleaning skid with hot water by adding an exchanger only which impact on the total cost also.

The results of this study will take to design, fabricate and implement a heat exchanger to recover the exhaust gas heat of diesel engines, and convert to useful energy.

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Abstract

In oil & gas industry the cleaning procedure with hot water it's very important in regular technical survey and major maintenance activities, Hot water pressure washer system have the great advantage of being able to degrease effectively and quickly, they can perfectly clean mechanical components covered with oil, engines and surfaces dirty with oil or grease in a short time.

There are so many kind of HP washers with hot water but the water is heated by an electric system which impact on safety said regarding the electric sparks, the study propose to design HP hydraulic system by using the heat recovery from the exhaust gases to heat the water until can eliminate all health & safety hazards.

A large part of the power generated by an internal combustion engine is wasted heat and not realized as work output, but dumped through exhaust gases and cooling system were approximately 25–35% to the atmosphere as waste heat.

The project is to design and develop HP washer with hot water by:

- Select the appropriate engine and HP pump suitable to clean the oils and residues of oil and gas industry.
- Construct a helical coil tube exchanger after the exhaust manifold in order to recover the exhaust gases heat and transfer it to the water before inter to the HP pump.

في ميدان صناعة البترول و الغاز تعد عملية الغسيل بالماء الساخن ذات أهمية كبيرة في المراقبة التقنية الدورية و عمليات الصيانة الكبرى لدى فان نظام الغسيل بالماء الساخن له القدرة و الكفاءة العالية لإزالة الزيوت و الشحوم على المكينات، المحركات و الأسطح في وقت قصير، هناك الكثير من أنواع نظم الغسيل بالماء الساخن لكن معظمها يسخن الماء بنظام كهربائي مما يؤثر على جانب السلامة لوجود شرارات كهربائية .

الدراسة تقترح وضع نضام هيدروليكي يتم استخدام حرارة عادم المحرك الذي يقوم بتدوير المضخة عالية الضغط في تسخين ماء التنظيف وبدلك يتم العمل في أمان و تجنب كامل الأخطار .

نجد أن قسم كبير من الطاقة المنتجة من المحرك تكون ضائعة عبر غازات العادم أو ماء التبريد بحوالي 25- 35 % تقريبا

المشروع يقوم بوضع و تطوير نظام غسيل بالماء الساخن ودلك بـ :

- اختيار المحرك و مضخة الضغط العالي المناسبين لإزالة رواسب الزيوت و الشحوم العالقة في مجال صناعة البترول و الغاز
- صناعة مبادل حراري لولبي يركب بعد مجمع غازات العادم لاجل تسخين الماء قبل ولوجه الى مضخة الضغط العالي.