FUEL OIL SYSTEM

OBJECTIVE

- Understand the Fuel Oil System of WDM2 Locomotive.
- Learn the function of individual components of Fuel Oil System.
- Learn the concept of Fuel Feed System and Fuel Injection System.
- Check the efficiency of fuel feed system on full load condition
- Learn the purpose of fuel efficient kit application on diesel engine

STRUCTURE

1. Introduction
2. Fuel Feed System and it's associate components
3. Functioning of fuel feed system
4. Fuel Injection System (fuel injection pump & nozzle)
5. Orifice test of fuel feed system
6. Calibration of fuel injection pumps
7. Phasing of fuel injection pumps
8. Fuel injection nozzle test
9. Nozzle valve lift
10. Fuel efficient kit
11. Summary
12. Self Assessment

INTRODUCTION

All locomotive units have individual fuel oil system. The fuel oil system is designed to introduce fuel oil into the engine cylinders at the correct time, at correct pressure, at correct quantity and correctly atomised. The system injects into the cylinder correctly metered amount of fuel in highly atomised form. High pressure of fuel is required to lift the nozzle valve and for better penetration of fuel into the combustion chamber. High pressure also helps in proper atomisation so that the small droplets come in better contact with the fresh air in the combustion chamber, resulting in better combustion. Metering of fuel quantity is important because the locomotive engine is a variable speed and variable load engine with variable requirement of fuel. Time of fuel injection is also important for better combustion.

FUEL OIL SYSTEM

The fuel oil system consists of two integrated systems. These are-

- FUEL FEED SYSTEM.
- FUEL INJECTION SYSTEM.

FUEL FEED SYSTEM AND ITS ASSOCIATE COMPONENTS

The fuel feed system provides the back-up support to the fuel injection pumps by maintaining steady supply of fuel to them at the required pressure so that the fuel pump can meter and deliver the oil to the cylinder at correct pressure and time. The fuel feed system includes the following:-

- **Fuel oil tank**

A fuel oil tank of required capacity (normally 5000ltrs), is fabricated under the superstructure of the locomotive and located in between the two bogies. Baffle walls are used inside it to arrest surge of oil when the locomotive is moving. A strainer filter at the filling plug, an indirect vent, drain plug, and glow rod type level indicators are also provided.

- **Fuel primary filter**

A filter is provided on the suction side of the fuel transfer pump to allow only filtered oil into the pump. This enhances the working life of the fuel transfer pump. This filter is most often a renewable bleached cotton waste packed filter, commonly known as socks type filter element. These socks type filters are coarse filters and have a greater ability to absorb moisture, and are economical. However, in certain places, it has been replaced by paper type filter, which have longer service life.

- **Fuel transfer pump or booster pump**

The fuel feed system has a transfer pump to lift the fuel from the tank. The gear type pump is driven by a dc motor, which is run by storage batteries through a suitable circuit. The pump capacity is 14 ltrs per minute at 1725 rpm at pressure 4 to 4.8 kg/cm. sq.

- **Fuel relief valve**

The spring- loaded relief valve is meant for by passing excess oil back to the fuel tank, thus releasing excess load on the pump and on the motor, to ensure their safety. It is adjusted to a required pressure (normally 5 kg/cm^2), and it by- passes the excess fuel back to the oil tank. It also ensures the safety of the secondary filter and the pipe lines.

- **Fuel secondary filter**

The fuel secondary filter is located after the booster pump in the fuel feed system. The filter used is a paper type filter, cartridge of finer quality, renewable at regular intervals. This filter arrests the finer dirt particles left over by the primary filter and ensures longer life of the fuel injection equipments.

- **Fuel regulating valve**

The fuel-regulating valve is spring-loaded valve of similar design as the fuel relief valve. It is located after the secondary filter in the fuel feed system. This valve is adjusted to the required pressure (3 kg/cm^2), and always maintains the same pressure in the fuel feed system by releasing the excess oil to the fuel oil tank. There is no by-passing of oil if the pressure is less than the adjusted level.

Functioning of fuel feed system

The fuel booster pump or transfer pump is switched on and the pump starts sucking oil from the fuel oil tank, filtered through the primary filter. Because of variable consumption by the engine, the delivery pressure of the pump may rise increasing load on the pump and its drive motor. When the rate of consumption of the fuel by the engine is low, the relief valve ensures the safety of the components by releasing load, by- passing the excess pressure back to the tank. Then oil passes through the paper type secondary filter and proceeds to the right side fuel header. The fuel header is connected to eight numbers of fuel injection pumps on the right-bank of the engine, and a steady oil supply is maintained to the pumps at a pressure of 3 Kg./ sq. cm. Then the fuel oil passes on to the left side header and reaches eight fuel injection pumps on the left bank through jumper pipes. The regulating valve remaining after the left side fuel header, takes care of excess pressure over 3 Kg/cm Square by passing the extra oil back to the tank. A gauge connection is taken from here leading to the driver's cabin for indicating the fuel oil feed pressure. Thus the fuel feed system keeps fuel continuously available to the fuel injection pumps, which the pumps may use or refuse depending on the demand of the engine.

FUEL INJECTION SYSTEM

When diesel engine is started, all fuel injection pumps start functioning. According to firing order all F.I. pumps start discharging fuel oil at high pressure to there respective nozzles through high pressure line tube. Fuel injection nozzle injects fuel oil to combustion chamber at 4000 psi. The internal function of F.I. pump and nozzle are described below.

1.

FUEL INJECTION PUMP

It is a constant stroke plunger type pump with variable quantity of fuel delivery to suit the demands of the engine. The fuel cam controls the pumping stroke of the plunger. The length of the stroke of the plunger and the time of the stroke is dependent on the cam angle and cam profile, and the plunger spring controls the return stroke of the plunger. The plunger moves inside the barrel, which has very close tolerances with the plunger. When the plunger reaches to the BDC, spill ports in the barrel, which are connected to the fuel feed system, open up. Oil then fills up the empty space inside the barrel. At the correct time in the diesel cycle, the fuel cam pushes the plunger forward, and the moving plunger covers the spill ports. Thus, the oil trapped in the barrel is forced out through the delivery valve to be injected into the combustion chamber through the injection nozzle. The plunger has two identical helical grooves or helix cut at the top edge with the relief slot. At the bottom of the plunger, there is a lug to fit into the slot of the control sleeve. When the rotation of the engine moves the camshaft, the fuel cam moves the plunger to make the upward stroke. It may also rotate slightly, if necessary through the engine governor, control shaft, control rack, and control sleeve. This rotary movement of the plunger along with reciprocating stroke changes the position of the helical relief in respect to the spill port and oil, instead of being delivered through the pump outlet, escapes back to the low pressure feed system. The governor for engine speed control, on sensing the requirement of fuel, controls the rotary motion of the plunger, while it also has reciprocating pumping strokes. Thus, the alignment of helix relief with the spill ports will determine the effectiveness of the stroke. If the helix is constantly in alignment with the spill ports, it bypasses the entire amount of oil, and nothing is delivered by the pump. The engine stops because of no fuel injected, and this is known as 'NO-FUEL' position. When alignment of helix relief with spill port is delayed, it results in a partly effective stroke and engine runs at low speed and power output is not the maximum. When the helix is not in alignment with the spill port through out the stroke, this is known as 'FULL FUEL POSITION', because the entire stroke is effective.

Oil is then passed through the delivery valve, which is spring loaded. It opens at the oil pressure developed by the pump plunger. This helps in increasing the delivery pressure of oil. it functions as a non-return valve, retaining oil in the high pressure line. This also helps in snap termination of fuel injection, to arrest the tendency of dribbling during the fuel injection. The specially designed delivery valve opens up due to the pressure built up by the pumping stroke of plunger. When the oil pressure drops inside the barrel, the landing on the valve moves backward to increase the space available in the high-pressure line. Thus, the pressure inside the high-pressure line collapses, helping in snap termination of fuel injection. This reduces the chances of dribbling at the beginning or end of fuel injection through the fuel injection nozzles.

FUEL INJECTION NOZZLE

The fuel injection nozzle or the fuel injector is fitted in the cylinder head with its tip projected inside the combustion chamber. It remains connected to the respective fuel injection pump with a steel tube known as fuel high pressure line. The fuel injection nozzle is of multi-hole needle valve type operating against spring tension. The needle valve closes the oil holes by blocking the oil holes due to spring pressure. Proper angle on the valve and the valve seat, and perfect bearing ensures proper closing of the valve.

Due to the delivery stroke of the fuel injection pump, pressure of fuel oil in the fuel duct and the pressure chamber inside the nozzle increases. When the pressure of oil is higher than the valve spring pressure, valve moves away from its seat, which uncovers the small holes in the nozzle tip. High-pressure oil is then injected into the combustion chamber through these holes in a highly atomised form. Due to injection, hydraulic pressure drops, and the valve returns back to its seat terminating the fuel injection, termination of fuel injection may also be due to the bypassing of fuel injection through the helix in the fuel injection pump causing a sudden drop in pressure.

ORIFICE TEST

This test is a rough and ready method to ascertain the efficiency of the fuel feed system under full load condition. The procedure of testing is as under:

1. An orifice plate of 1/8 inch is fitted in the system before the regulating valve.
2. A container to be placed under the orifice to collect the oil that would leak through it during the test.
3. The fuel booster pump to be switched on for 60 seconds.

The rate of leakage should be about 9 lt. of fuel per minute through the orifice (with the engine in stopped condition). The system should be able to maintain 3 kg /cm.sq pressure with this rate of leakage, which simulates approx. the full load consumption by the engine. In the event of drop in pressure the rate of leakage would also be less indicating some defect in the system reducing its efficiency to meet the full requirement of fuel during peak load. The above test is easy, reliable and also saves time.

CALIBRATION OF FUEL INJECTION PUMPS

Each fuel injection pump is subject to test and calibration after repair or overhaul to ensure that they deliver the same and stipulated amount of fuel at a particular rack position. Every pump must deliver regulated and equal quantity of fuel at the same time so that the engine output is optimum and at the same time running is smooth with minimum vibration.

The calibration and testing of fuel pumps are done on a specially designed machine. The machine has a 5 HP reversible motor to drive a cam shaft through V belt. The blended test oil of recommended viscosity under controlled temperature is circulated through a pump at a specified pressure for feeding the pump under test. It is very much necessary to follow the laid down standard procedure of testing to obtain standard test results. The pump under test is fixed on top of the cam box and its rack set at a particular position to find out the quantum of fuel delivery at that position. The machine is then switched on and the cam starts making delivery strokes. **A revolution counter attached to it is set to trip at 300 RPM or 100 RPM as required**. With the cam making strokes, if the pump delivers any oil, it returns back to the reservoir in normal state. A manually operated solenoid switch is switched on and the oil is diverted to a measure glass till 300 strokes are completed after operation of the solenoid switch. Thus the oil discharged at 300 working strokes of the pump is measured which should normally be within the stipulated limit. The purpose of measuring the output in 300 strokes is to take an average to avoid errors. The pump is tested at idling and full fuel positions to make sure that they deliver the correct amount of fuel for maintaining the idling speed and so also deliver full HP at full load. A counter check of the result at idling is done on the reverse position of the motor which simulates slow running of the engine.

If the test results are not within the stipulated limits as indicated by the makers then adjustment of the fuel rack position may be required by moving the rack pointer, by addition or removal of shims behind it. The thickness of shims used should be punched on the pump body. The adjustment of rack is done at the full fuel position to ensure that the engine would deliver full horse power. Once the adjustment is done at full fuel position other adjustment should come automatically. In the event of inconsistency in results between full fuel and idling fuel, it may call for change of plunger and barrel assembly.

The calibration value of fuel injection pump of WDM2 engines as supplied by the makers is as follows at 300 working strokes:

9 mm (Idling) 34 cc +1/-5

30 mm (Full load) 351 cc +5/-10

The calibration values for YDM4 engines are as under.

9 mm (idling) 45 cc +1/-5
28 mm (full load) 401 cc +4/-11

Errors are likely to develop on the calibration machine in course of time and it is necessary to check the machine at times with master pumps supplied by the makers. These pumps are perfectly calibrated and meant for use as reference to test the calibration machine itself. Two master pumps, one for full fuel and the other for idling fuel are there and they have to be very carefully preserved only for the said purpose.

PHASING OF FUEL INJECTION PUMPS

Every fuel injection pump after repair / overhauling and testing needs phasing while fitting on the engine. In course of working the drive mechanism of the FIP suffers from wear and causes loss of motion. This may also cause shorter length of plunger stroke and lesser fuel delivery. The pump lifter is adjusted individually for all the FIPs. An adjustment is provided in the valve lifter mechanism to adjust the markings between the guide cup and the sight window so that they coincide with each other after positioning the engine. This adjustment is known as
phasing of the pump to make up the wear loses.

FUEL INJECTION NOZZLE TEST

The criteria for good nozzle is good atomization, correct spray pattern and no leakage or dribbling. Before a nozzle is put to test the assembly must be rinsed in fuel oil, nozzle holes cleaned with wire brush and spray holes cleaned with steel wire of correct thickness.

The fuel injection nozzles are tested on a specially designed test stand, where the following tests are conducted.

SPRAY PATTERN

Spray of fuel should take place through all the holes uniformly and properly atomized. While the atomization can be seen through the glass jar, an impression taken on a sheet of blotting paper at a distance of 1 to 1 1/2 inch also gives a clear impression of the spray pattern.

SPRAY PRESSURE

The stipulated correct pressure at which the spray should take place 3900-4050 psi for new and 3700-3800 psi for reconditioned nozzles. If the pressure is down to 3600 psi the nozzle needs replacement. The spray pressure is indicated in the gauge provided in the test machine. Shims are being used to increase or decrease the tension of nozzle spring which increases or decreases the spray pressure

DRIBBLING

There should be no loose drops of fuel coming out of the nozzle before or after the injections. In fact the nozzle tip of a good nozzle should always remain dry. The process of checking dribbling during testing is by having injections manually done couple of times quickly and check the nozzle tip whether leaky.
Raising the pressure within 100 psi of set injection pressure and holding it for about 10 seconds may also give a clear idea of the

The reasons of nozzle dribbling are 1) Improper pressure setting 2) Dirt stuck up between the valve and the valve seat 3) Improper contact between the valve and valve seat 4) Valve sticking inside the valve body.

NOZZLE CHATTER

The chattering sound is a sort of cracking noise created due to free movement of the nozzle valve inside the valve body. If is not proper then chances are that the valve is not moving freely inside the nozzle.

NOZZLE LEAK OFF RATE

A very minute portion of the oil inside the nozzle passes clearance between the valve and the valve body for the purpose of lubrication. Excess clearance between them may cause excess leak off, thus reducing the amount of fuel actually injected.

The process of checking the leak off rate is by creating pressure in the nozzle up to 3500 psi and holds the pressure till it drops to 1000 psi. The drop of pressure is due to the leak off and higher the leak off rate the pressure drop is quicker. In the event of the leak off time recorded below stipulation the nozzle valve and the valve body have to be changed for excessive wear and clearance between them.

CHECKING OF NOZZLE VALVE LIFT

The valve and the valve seat are surface hardened components. Any attempt to work them beyond the hardened surface is restricted. The amount of wear on the valve face and the seat is measured with the help of a dial gauge and the process is known as checking of valve lift.

FUEL EFFICIENT KIT

Certain modifications carried out on WDM2 locomotive engine to improve specific fuel consumption by over 6%, reduction in existing exhaust gas temperature by over 100 deg.-C and reduction in lube oil consumption. These modifications are considered as fuel efficient kit. Modifications are given below:

1. Modified water connection to after cooler: - Water inlet of the after cooler is connected from outlet of the radiator, to provide water at minimum possible temperature into the after cooler. Previously it was connected from water pump discharge side.

2. 17 mm fuel injection pump: - 15 mm pumps are being replaced by 17 mm pumps, to have sharper fuel injection. For this, modified fuel pump support with wider fuel cam roller, shall be used on fuel-efficient engine. The maximum rack opening with 17 mm pump is restricted to 28+_ 0.25 mm instead of existing 29.5+-0.25 mm. Changes will have to be made in the lever/ linkage of the governor for this.

3. Modified camshaft with 140 degree over lap: - The camshaft has been modified to increase the over lap from 123 degree to 140 degree to improve the scavenging.

4. Large After Cooler: Large After Cooler with higher effectiveness has been introduced to provide cooled air to engine. For this Turbo mounting bracket and certain pipe line connections will need to be changed.

5. Steel capped pistons: In the fuel efficient engine, peak firing pressure likely to exceed 1800 psi and thus steel cap pistons are required to be used. Use of steel cap pistons will also result in lower lube oil consumption.

6. High efficiency Turbo Charger: Existing 720 turbo chargers being replaced by high efficiency ABB VTC 304/ NAPIER NA 295 turbo chargers having capacity to develop 2.2kg/cm2 air pressure/ booster pressure.

SUMMARY

Fuel Feed System is responsible for supply of clean oil with adequate quantity at required pressure to Fuel Injection System, to meet the requirement of fuel oil of the engine at rated output. In Fuel Feed System, Fuel tank acts as reservoir of HSD oil of the engine; Primary and Secondary filters maintain cleanliness of oil in the system. Fuel Booster Pump works for generating pressure and maintaining adequate supply of fuel in the system; Relief and Regulating Valves maintain constant pressure in the feed system.

Fuel Injection System comprises of mainly two components (a) Fuel Injection Pump (b) Fuel Injection Nozzle. Fuel Injection Pump is a plunger type Pump having constant stroke with variable delivery. The quantity of fuel delivered is decided by the position of the helix groove, that varies with the twisting of the plunger according to the fuel rack position. Hence it is responsible for supplying correct quantity of pressurized fuel upto the nozzle. Nozzle is responsible for delivering pressurized fuel in atomized form into the combustion chamber. The breaking pressure i.e. the final pressure at which fuel is released into the combustion chamber is decided by the setting of Nozzle Valve Spring pressure.

SELF ASSESSMENT

1. What are the functions of Relief Valve and Regulating Valve in fuel feed system?

2. Draw a neat sketch of the Fuel Feed System of WDM2 type locomotive and label it

3. How quantity of fuel delivery varies in Fuel Injection Pump?

4. What are the functions of Fuel Injection Nozzle?

5. Describe the function of fuel injection nozzle.
6. How can you check the efficiency of the fuel feed system under full load condition?
7. What is fuel-efficient kit?

CHARGE AIR SYSTEM

OBJECTIVE

The objective of this unit is to make you understand about :-

- the need for supercharging
- various methods of supercharging
- Turbo Supercharging as applied in WDM2 type Locomotive
- various components of Turbo Supercharger and their duties.
- Lubricating, Cooling and Air Cushioning of Turbo Supercharger Components.
- Cooling of supercharged air

STRUCTURE

1. Introduction
2. Advantage of supercharging
3. Turbo Supercharger and its working principle
4. Main components of Turbo Supercharger
5. Lubricating, Cooling and Air Cushioning
6. After cooling of Charge Air
7. Summary
8. Self Assessment

INTRODUCTION

The diesel engine produces mechanical energy by converting heat energy derived from burning of fuel inside the cylinder. For efficient burning of fuel, availability of sufficient air in proper ratio is a prerequisite.

In a naturally aspirated engine, during the suction stroke, air is being sucked into the cylinder from the atmosphere. The volume of air thus drawn into the cylinder through restricted inlet valve passage, within a limited time would also be limited and at a pressure slightly less than the atmosphere. The availability of less quantity of air of low density inside the cylinder would limit the scope of burning of fuel. Hence mechanical power produced in the cylinder is also limited.

An improvement in the naturally aspirated engines is the super-charged or pressure charged engines. During the suction stroke, pressurised stroke of high density is being charged into the cylinder through the open suction valve. Air of higher density containing more oxygen will make it possible to inject more fuel into the \same size of cylinder and produce more power, by effectively burning it. The 2600 HP WDM_2 engine is mainly equipped with ALCO 720 A model turbo supercharger.

ADVANTAGES OF SUPER CHARGED ENGINES.

A super charged engine of given bore and stroke dimensions can produce 50 percent or more power than a naturally aspirated engine. The power to weight ratio in such a case is much more favourable.

Charging of air during the suction stroke causes better scavenging in the cylinders. This ensures carbon free cylinders and valves, and better health for the engine also.

Higher heat developed in a super charged engine due to the burning of more fuel, calls for better cooling of the components. The cool air charged into the cylinders has better cooling effect on the cylinders, piston, cylinder head, and valves, and save them from failure due to thermal stresses.

Better ignition due to higher temperature developed by higher compression in the cylinder.

Better fuel efficiency due to complete combustion of fuel by ensuring availability of matching quantity of air or oxygen.

METHOD OF SUPERCHARGING

Different methods of pressurising air for supercharging in engines are adopted.

Using a reciprocating type of air compressor. These are unsuitable for locomotive engines, because of their large size, and higher power demand. Moreover, The system does not maintain proper air to fuel ratio.

Specially designed roots blower or centrifugal blowers. These have the same drawbacks as the reciprocating compressors.

Most efficient and economical method of supercharging is by a centrifugal blower run by the exhaust gas driven turbine. In the system, energy left over in the exhaust gas, which would otherwise have been wasted, is used to drive the gas turbine in the turbo super charger. The turbine in turn drives the centrifugal blower, which sucks air from atmosphere and pressurises it. This does away with the need for an additional power required for driving the blower, thus saving energy. Moreover, this system can maintain more favourable air and fuel ratio at all speed and load conditions of the engine than any other system.

TURBO SUPERCHARGER AND ITS WORKING PRINCIPLE

The exhaust gas discharge from all the cylinders accumulate in the common exhaust manifold at the end of which, turbo- supercharger is fitted. The gas under pressure there after enters the turbo- supercharger through the torpedo shaped bell mouth connector and then passes through the fixed nozzle ring. Then it is directed on the turbine blades at increased pressure and at the most suitable angle to achieve rotary motion of the turbine at maximum efficiency. After rotating the turbine, the exhaust gas goes out to the atmosphere through the exhaust chimney. The turbine has a centrifugal blower mounted at the other end of the same shaft and the rotation of the turbine drives the blower at the same speed. The blower connected to the atmosphere through a set of oil bath filters, sucks air from atmosphere, and delivers at higher velocity. The air then passes through the diffuser inside the turbo- supercharger, where the velocity is diffused to increase the pressure of air before it is delivered from the turbo- supercharger.

Pressurising air increases its density, but due to compression heat develops. It causes expansion and reduces the density. This effects supply of high-density air to the engine. To take care of this, air is passed through a heat exchanger known as after cooler. The after cooler is a radiator, where cooling water of lower temperature is circulated through the tubes and around the tubes air passes. The heat in the air is thus transferred to the cooling water and air regains its lost density. From the after cooler air goes to a common inlet manifold connected to each cylinder head. In the suction stroke as soon as the inlet valve opens the booster air of higher pressure density rushes into the cylinder completing the process of super charging.

The engine initially starts as naturally aspirated engine. With the increased quantity of fuel injection increases the exhaust gas pressure on the turbine. Thus the self-adjusting system maintains a proper air and fuel ratio under all speed and load conditions of the engine on its own. The maximum rotational speed of the turbine is 18000 rpm for the 720A model Turbo supercharger and creates 1.8 kg/cm2 air pressure in air manifold of diesel engine, known as booster pressure. Low booster pressure causes black smoke due to incomplete combustion of fuel. High exhaust gas temperature due to after burning of fuel may result in considerable damage to the turbo supercharger and other component in the engine.

MAIN COMPONENTS OF TURBO-SUPERCHARGER

Turbo- supercharger consists of following main components.

- Gas inlet casing.
- Turbine casing.
- Intermediate casing
- Blower casing with diffuser
- Rotor assembly with turbine and rotor on the same shaft.

GAS INLET CASING

The inlet casing of the latest type of turbo are of CH 20 stainless steel which is highly heat resistant. The function of this casing is to take hot gases from the exhaust manifold and pass them through the nozzle ring, which is bolted to the casing face. This assembly is fitted on the turbine casing with cap screws.

TURBINE CASING

The turbine casing houses the turbine inside it, and is cored to have circulation of water through it for cooling purposes. It has an oval shaped gas outlet passage at the top. It is fitted in between the inlet casing and the intermediate casing. It is made of alloy cast iron or fabricated.

INTERMEDIATE CASING

This casing is also water-cooled and have cored passage for water circulation and is made of alloy cast iron or fabricated like the turbine casing. It is placed between turbine casing and the blower casing. It separated the exhaust and the airside and also supports the turbine rotor on the two tri-metal bearings, which are interference-fit in the intermediate casing.

BLOWER HOUSING ASSEMBLY

This houses the blower and is in two parts, namely the blower inlet, and the blower housing. Air enters through the blower inlet axially, and discharged radially from the blower through the vane diffuser. The vane diffuser is a precision alluminium casting and screwed on the blower casing.

ROTOR ASSEMBLY

The rotor assembly consists of rotor shaft, rotor blades, thrust collar, impeller, inducer, centre studs, nosepiece, locknut etc. assembled together. The rotor blades are fitted into fir tree slots, and locked by tab lock washers. This is a dynamically balanced component, as this has a very high rotational speed.

LUBRICATING, COOLING AND AIR CUSHIONING

LUBRICATING SYSTEM

One branch line from the lubricating system of the engine is connected to the turbo-supercharger. Oil from the lube oils system circulated through the turbo- supercharger for lubrication of its bearings. After the lubrication is over, the oil returns back to the lube oil system through a return pipe. Oil seals are provided on both the turbine and blower ends of the bearings to prevent oil leakage to the blower or the turbine housing.

COOLING SYSTEM

The cooling system is integral to the water cooling system of the engine. Circulation of water takes place through the intermediate casing and the turbine casing, which are in contact with hot exhaust gases. The cooling water after being circulated through the turbo- supercharger returns back again to the cooling system of the locomotive.

AIR CUSHIONING

There is an arrangement for air cushioning between the rotor disc and the intermediate casing face to reduce thrust load on the thrust face of the bearing which also solve the following purposes.

- it prevents hot gases from coming in contact with the lube oil.
- it prevents leakage of lube oil through oil seals.

- it cools the hot turbine disc.

Pressurised air from the blower casing is taken through a pipe inserted in the turbo-supercharger to the space between the rotor disc and the intermediate casing. It serves the purpose as described above.

TURBO RUN –DOWN TEST

Turbo run-down test is a very common type of test done to check the free running time of turbo rotor. It indicates whether there is any abnormal sound in the turbo, seizer/ partial seizer of bearing, physical damages to the turbine, or any other abnormality inside it. The engine is started and warmed up to normal working temperature and running at fourth notch speed. Engine is then shut down through the over speed trip machanism. When the rotation of the crank shaft stops, the free running time of the turbine is watched through the chimney and recorded by a stop watch. THE minimum time allowed for free running is90 seconds and maximum 180 seconds. Low or high turbo run down time are both considered to be harmful for the engine.

AFTER COOLER

It is a simple radiator, which cools the air to increase its density. Scales formation on the tubes, both internally and externally, or choking of the tubes can reduce heat transfer capacity. This can also reduce the flow of air through it. This reduces the efficiency of the diesel engine. This is evident from black exhaust smoke emissions and a fall in booster pressure.

NEW GENERATION TURBO SUPERCHARGER- the following new generation turbo superchargers with higher capacity and higher efficiency have been identified by RDSO for fuel efficient 2600 HP and upgraded (3100/ 3300 HP) diesel engine.

ABB VTC 304, NAPIER NA-295, GE 7S1716, HISPANO SUIZA HS 5800 NGT, ABB TPL61

SUMMARY

Supercharging is the method of pressurizing the induced air to increase the efficiency and performance of the engine. This can be achieved by any of the methods, like, engine crankshaft driven Centrifugal / Roots Blower, exhaust gas driven Turbo Supercharger etc. Exhaust gas driven Turbo Supercharger being more economical and scientific, it is applied in WDM2 Locomotive Engine. In this system, the streamlined exhaust manifold collects the exhaust gas of all cylinders and directs it to Turbine through a Fixed Nozzle Ring. The Rotor Shaft comprises of Turbine and

Compressor unit integral on it, which is supported by two Nos. Trimetal Bearings, housed in the intermediate casing. Thus exhaust gas driven turbine drives the compressor, being the integral part of the rotor shaft. The discharge of the compressor gets pressurized at diffuser and finally the hot compressed air after getting cooled at Aftercooler is stored in the Inlet Manifold of the engine, which in turn goes into the cylinder as per the working cycle.

SELF-ASSESSMENT

1. What are the advantages of supercharging?
2. What are the various methods of supercharging? Which method is considered to be more scientific and why?
3. What is the importance of air cushioning? How is it done?
4. Describe the wdm2 loco charge air system with neat sketch.

LUBE OIL SYSTEM

OBJECTIVE

To understand about: -

- the function of lubrication system in diesel engine
- the lube oil system of WDM2 locomotive engine
- the function of Relief & Regulating valve
- the purpose of by passing arrangement of lube oil
- the factors affect the low lube oil pressure & contamination in lube oil
- the factors affect high lube oil consumption

STRUCTURE

1. Introduction

2. Lube Oil system of WDM2 Locomotive

3. Problems in lube oil system

4. Lube oil quality observation by laboratory

5. Summary

6. Self assessment

INTRODUCTION

The lubricating system in a diesel engine is of vital importance. The lubricating oil provides a film of soft slippery oil in between two frictional surfaces to reduce friction and wear. It also serves the following purposes.

1. Cooling of bearing, pistons etc.

2. Protection of metal surfaces from corrosion, rust, surface damages and wear.

3. Keep the components clean and free from carbon, lacquer deposits and prevent damage due to deposits.

The importance of lube oil system is comparable to the blood circulation system in the human body. Safety of the engine, its components, and their life span will largely depend upon the correct quality of oil in correct quantity and pressure to various location of diesel engine.

LUBE OIL SYSTEM OF WDM2 LOCO

The diesel engine of WDM2 class locomotives has full flow filtration lube oil system with bypass protection. The system essentially consists of the following components.

1. Gear type lube oil pump driven by the engine crankshaft.
2. Spring loaded relief valve, adjusted to 7.5 kg/cm^2.
3. Lube oil filter tank accommodating eight nos. of filter elements.
4. Differential bypass valve set at 1.4 kg/cm^2 differential pressure across the filter tank.
5. Lube oil cooler, which has a bunch of element tubes through which cooling water circulates and circulation of lube oil takes place around the tubes.
6. Regulating valve, which is a spring loaded valve adjusted to 4kg/cm^2.
7. Lube oil strainer, which is a wire mesh type filter reusable after cleaning.
8. Oil pressure switch (OPS), which is meant to automatically shut down the engine in case of a drop in lube oil pressure below 1.3 kg/cm^2.
9. Oil pressure gauge, which indicates the main oil header pressure.
10. Oil sump having capacity 1260 lt. RR606 multigrade oil.

The lube oil pump on the free end of the engine is driven by the engine crankshaft through suitable gears and keeps it running along with the engine. When the engine is started the pump draws oil from the engine oil sump and delivers it. The delivery pressure of the pump has to be controlled as the pump is driven by an engine of variable speed and would often have higher delivery pressure or load on it than actually required. This would mean loss of more power from the engine for driving the pump. Higher pressure may also endanger the safety of the filters and the pipelines and its joints. The relief valve releases the delivery pressure above its setting and bypasses it back to the oil sump. Oil then flows to a filter tank containing eight nos. of paper type filter elements. The filter has a bypass valve across it set a differential pressure of 1.4 kg/cm2. Due to the choking of the filter elements, if the pressure differential between the inlet and the outlet of the tank is more than 1.4 kg/cm2, then the differential bypass valve opens up to bypass a part of oil without filtration, and thus reduces the pressure on the filters. Although allowing unfiltered oil into the engine is not advisable, but there is another filter at later stage through which oil has to pass before entering the engine. Moreover, higher pressure on the filters may cause damage to the filters, and cause greater damage to the engines. After the filtration, the oil passes to the coolers, gets cooled by transferring heat to water, and regains its lost viscosity. At the discharge side of the cooler, a regulating valve adjusted at 4 kg/cm2 is provided to regulate the pressure. Excess pressure is regulated by passing the oil back to the engine oil sump. The oil then finds its way to the main oil header after another stage of filtration in the strainer type filter from which it is distributed for lubrication to different places as required. Direct individual connections are taken from the main oil header to all the main bearings. Oil thus passes through the main bearings supporting the crankshaft on the engine block, passes through the crank pin to lubricate the connecting rod big end bearing and the crank pin journals. It reaches the small end through rifle drilled hole and after lubricating the gudgeon pin and bearings enters into the pistons. The Aluminum alloy pistons are provide with spiral oil passage inside them for internal circulation of lube oil. This is done with the purpose of cooling the pistons, which are highly thermally loaded components. After circulation through the pistons, the oil returns back to the oil sump, but in this process, a part of the oil hits the running connecting rod and splashes on the cylinder liners for their lubrication. The actual lube oil pressure is a function of lube oil pump, temperature of oil, engine speed and regulating valve setting. A line from the main oil header is connected to a gauge in the driver's cabin to indicate the pressure level. If lube oil pressure drops to less than 1.3 kg/cm2, engine will automatically shut down through a safety device (OPS) to protect it from damage due to insufficient lubrication. From the main oil header, two branch lines are taken to the right and left side secondary headers to lubricate the components on both banks of the V shape engine. Each branch line of the secondary header lubricates the camshaft bearings, fuel pump lifters, valve lever mechanisms, and spray oil to lubricate the gears for camshaft drive. A separate connection is taken to the turbo super charger from the right side header for lubrication of its bearings. After circulation to all the points of lubrication, the oil returns back to the sump for recirculation through the same circuit.

Problems in lube oil system

There are four factors, which effect the lube oil system pressure directly that is lube oil pump discharge capacity, diesel engine temperature, pressure setting value of Relief & Regulating valve and quality of lube oil. Some other factors like choking of filters / strainer, low oil level in c/case, contaminated lube oil, low idling speed and excessive wear/ clearance in bearings also effect the system pressure.

During running of diesel engine it is observed that lube oil contaminated with water and oil level in c/case is increasing, which indicates water leakage inside the c/case. The sources are leakage of cylinder liner bottom gasket & sleeve, cracked cylinder liner, cracked cylinder head etc. Sometimes it is observed that lube oil contaminated with fuel oil, which indicates nozzles dribbling or fuel leak off gallery cracked. It is also observed that some engines consume high rate of lube oil, which indicates clearance between valve and valve guide is more, engine piston rings worn out or turbo oil seal damaged.

Lube oil quality observation by laboratory

To maintain sound health of the engine, control on quality of oil is as much necessary as the pressure. Every maintenance depot/diesel shed is equipped with a laboratory, which keeps strict watch on the quality of lube oil of each individual loco.

Contamination in any form i .e. by fuel oil, cooling water, soot, dirt etc. in service is immediately reported for corrective action in maintenance. Change in other properties like viscosity, PH value, TBNE etc. are also watched at regular intervals. Lube oil changing in locos are normally done on condition basis.

Spectrographic analysis at regular schedule is also done to ascertain the extent of concentration of wear metal particles in the oil. This can indicate the wear pattern of the engine components or ensure longer service life.

SUMMARY

The Diesel Engine of WDM 2 Locomotive has full flow filtration lube oil system with bypass protection. RR-407 is the Lube oil used in the system. Engine crankshaft driven, gear type lube oil pump sucks oil from the engine sump and delivers it into the system. A relief valve, set at 110 psi, is fitted just after the pump to save the pump from excess loading. Pumped oil then passes through filter tank, containing 8 Nos. of filter elements, for filtration. A bypass valve, set at 20 psi differential pressure, is fitted across the filter tank to maintain the continuity of flow, in case the filter gets choked.. Lube oil cooler fitted in the system maintain operating temperature of lube oil, by dissipating excess heat through water, circulating around it. Regulating valve, set at 75 psi, maintains the pressure of the whole system. The oil then passes through a strainer and finally gets stored into main and secondary headers, from where it is distributed to various components of the engine for lubrication. Cooling of Piston is done by circulation of lube oil through it. For this, lube oil from main header reaches to main bearing through S-pipes. Again from main bearing, through internal drill passages of crankshaft and con.rod, oil reaches to piston. After circulating inside the piston, the oil flows down to sump through an opening provided in the piston. While flowing down the oil gets splashed by crankshaft for lubricating liners. Finally the oil drops down to sump after lubricating all the components of the engine.

SELF ASSESSMENT

1. What are the various factors that affect the low lube oil system pressure?
2. Draw a neat sketch of WDM2 engine Lube Oil system and label it.
3. What are the various factors that affect the high lube oil consumption?
4. What are the sources for fuel contamination in lube oil?
5. What are the sources for water contamination in lube oil?

COOLING SYSTEM

OBJECTIVE

To understand about

- the need for cooling system in a diesel engine
- the benefit of water cooling system
- harmful effects of natural water in cooling system
- the method of water treatment and the quality of treated water
- the water cooling system of WDM2 Locomotive

STRUCTURE

1. Introduction
2. Cooling water and its treatment
3. Cooling water system of wdm2 locomotive engine
4. Water pump
5. Modifications in cooling system
6. Summary
7. Self assessment

INTRODUCTION

After combustion of fuel in the engine, about 25-30 % of heat produced inside the cylinder is absorbed by the components surrounding the combustion chamber like piston, cylinder, cylinder head etc. Unless the heat is taken away from them and dispersed elsewhere, the components are likely to fail under thermal stresses. All internal combustion engines are provided with a cooling system designed to cool the excessively hot components, distribute the heat to the other surrounding components to maintain uniform temperature throughout the engine, and finally dissipate the excess heat to atmosphere to keep the engine temperature within suitable limits. Different cooling systems, like air cooling, water cooling are adopted, depending on the engine design, working conditions and service etc.. The advantage of having a water cooling system is that it maintains a uniform level of temperature throughout the engine and by controlling the water temperature, the engine temperature can be controlled effectively.

COOLING WATER AND ITS TREATMENT

Although natural water can meet the basic requirement, its use is prohibited for the cooling of the engine because it contains many dissolved solids and corrosive elements. Some of the dissolved solids may form scales on the heat exchanger surface and reduce the heat transfer coefficient. It also accelerates corrosion. Other minerals get collected in the form off sludge at an elevated temperature. This sludge may get deposited at the low-pressure zone and choke the passage of circulation. The insulation caused by the scale deposits results in unequal expansion and localized stress, which may eventually rupture the engine block, cylinder block, cylinder heads etc. to eliminate all of these, distilled or de-mineralized water is used in the cooling system of the diesel locomotive.

The water sample is tested for chromate concentration, hardness, pH value, and chloride content. In case Chromate concentration is found lower than the required quantity, mixture is added. Water is changed if hardness and chloride is higher than the recommended limit. Water is also changed if found contaminated with oil etc.

When water is changed due to contamination etc. the system is cleaned by adding Tri-Sodium Phosphate, and circulating water for 45min, this water is drained out, and fresh distilled water with chromate mixture is filled in the locomotive.

COOLING WATER SYSTEM

The WDM2 class locomotives have a closed circuit non-pressurised water cooling system for the engine. The system is filled in by 1210 ltrs. Of distilled water or demineralised water treated with nonchromate corrosion inhibitor (Borate nitrite treatment) to maintain a concentration of 4000 PPM. The pH value is '8.5-9.5'. The water circuit has two storage tanks in two segments known as expansion tanks on top of the locomotive. Apart from supplementing in case of shortage in the system, these interconnected tanks have some empty space left at the top to provide expansion to the water when it is hot. A centrifugal pump driven by the engine crankshaft through a gear sucks water from the system and delivers it through outlet under pressure. The outlet of the pump has three branch lines from a three-way elbow. The branching off leads water to the different places as follows-

1. To the turbo-supercharger through a flexible pipe to cool the intermediate casing, bearings on both sides of the rotor and the turbine casing. After cooling the components in the turbo-supercharger, water return to the inlet side of the pump through a bubble collector. The bubble collector with a vent line is a means to collect air bubbles formed due to evaporation and pass it onto the expansion tank, so that thy cannot cause air lock in the water circulatory system.

2. The second line leads to the left bank of the cylinder block and water enter the engine block and circulates around the cylinder liners, cylinder heads on the left bank of the engine, and then passes onto the water outlet header. Individual inlet connections with water jumper pipes and outlet water riser pipes are provided to each cylinder head for entry and outlet of water from cylinder head to the water outlet header. Cooling of cylinder liners, piston rings, cylinder heads, valves, and fuel injection nozzles are done in this process. Water then proceeds the left side radiator for circulation through it, and releases its heat into the atmosphere to cool itself down before recirculation through the engine once again.

3. The third connection from the three-way elbow leads to the right side of the cylinder block. After cooling the cylinder liners, heads etc. on the Right Bank the water reaches the right side radiator for cooling itself. Before it enters the radiator, a connection is taken to the water temperature manifold where a thermometer is fitted to indicate the water temperature. Four other temperature switches are also provided here, out of which T1 is for starting the movement of radiator fan at 60^{O} C slowly through the eddy current clutch. The second switch T2 picks up at a water temperature of 64^{O} C and accelerates the radiator fan to full speed. The third switch is the ETS3 (Engine Temperature Switch),set at 90 degree calcius protection against hot engine, which gives bell alarm and red lamp indication. The fourth switch is ETS4 (set at 95 degree calcius) which brings the engine back to the idling speed and power cutoff also takes place to reduce load on the engine. In this situation the GF switch is cut off and engine is notched up to full notch. It helps in bringing down the cooling water temperature quickly with the radiator fan moving at full speed. Water temperature is controlled by controlling the movement of the radiator fan. Cooling water from the left side radiator passes through the lube oil cooler, where water circulates inside a bunch of element tubes and lube oil circulates around the tubes. Thus passing through the lube oil cooler and cooling the lube oil, it unites with the suction pipe for recirculation through the cooling circuit. Cooling water from right side radiator passes through after cooler, where water circulates inside a bunch of element tubes and cooling the charge air, it unites with the suction pipe for recirculation.

Apart from hot engine protection, another safety is also provided by way of low water switch (LWS). In the event of cooling water level falling below one inch from the bottom of the tank, the LWS shuts down the engine through the governor with warning bell and alarm indication to ensure the safety of the engine. Vent lines are provided from the after cooler, lube oil cooler, radiators. Turbo-supercharger vent box and bubble collectors etc. are provided to maintain uninterrupted circulation of cooling water by eliminating the hazards of air locks in the system.

Cooling water is subjected to laboratory tests at regular intervals for quality controls. Contamination, chloride contents, and hardness etc.. are checked to reduce corrosion and scaling. The concentration of anti-corrosive mixture is also checked and laboratory advises corrective action in case of contamination. Proper quality control of cooling water and use of proper quantity of nonchromate corrosion inhivitor prevents scaling and corrosion in the system, and ensures longer life of the components. Normally 8.2kg is added for new water in WDM2 locomotive.

WATER PUMP

MODIFICATIONS PERTAINING TO COOLING WATER SYSTEM OF WDM2 LOOMOTIVE

Louvred fin radiator: - The radiator core has been redesigned by providing louvred fins thereby increasing the cooling capacity by 14% due to improved air flow pattern through the radiator.

High efficiency turbochargers:- High efficiency turbochargers has been provided on the fuel efficient version of wdm2 locos. This has resulted in lowering of the exhaust gas temperature by around 15% with modified after cooler.

Large after cooler & water connection:- Large after cooler & water connection has been provided on the fuel efficient locos. This has reduced the heat input to the cooling system.

Revision of ETS setting :- The setting of ETS3 is raised to 90 deg.C from 85 deg.C in order to avoid frequent hot engine alarms. Subsequently, with the introduction of pressurised cooling water system, one more ETS is added with the idea of providing only hot engine alarm through ETS3 at 90 deg. C and bringing the engine to idle by ETS4 at 95 deg. C. This change not only reduces the occurrences of hot engine alarm but also increases the heat transfer potential of the radiator at high temperature.

Revised setting of OPS:- The setting of low lube oil pressure switch on WDM2 locos used to be 1.8 kg/ cm2 with a view to obviate the problem of engine shutting down due to operation of OPS while suddenly easing throttle from higher notches to idle, particularly during summer season, the OPS setting has been revised to 1.3 kg/ cm2.

Pressurisation of cooling water system:- The cooling water circuit has been pressurised upto 7 psi thereby increasing the boiling point by 11 deg. C. This has not only increased the margin before the cooling water gets converted to steam but has also increased the temperature differential acrossed the radiators at peak engine temperature, thereby increasing the rate of cooling in radiators. This has been achieved by providing a pressure cap assembly on the water tank.

Flexible water inlet elbow:- Rubber hose type flexible water inlet elbow has been developed in place of the rigid one piece metallic water inlet elbow for obtaining better leakproofness even in face of mislignments between the engine block and the cylinder head.

Digital water temperature indicator cum switch:- This has been developed to replace the existing water temperature gauge as well as the four engine temperature switches whose performance was quite unreliable. This aims at ensuring operation of radiator fan and alarm at proper temperature.

Electronic water level indicator cum switch:- This has been developed to replaced the existing water level gauge as well as the low water switch. This indicator shall give precise and reliable information regarding the water level to the driver in the cab itself.

Improved type pipe joints:- This has been improved to replace the existing pipe joints viz. dressers victaulics by superior rubber hoses along with double wire stainless steel clamps and by stainless steel bellows.

SUMMARY

In the process of combustion, about 25% to 30% of the total heat developed is absorbed by the components of the engine forming the combustion chamber. Hence an effective cooling system is essential to dissipate the accumulated heat. Amongst the various methods of cooling the water cooling system is the most effective method of cooling, as it maintains the uniformity of temperature through out the engine. In WDM2 type engine water cooling system is being used with 1200 ltrs system capacity. Dimeneralised water treated with chromium compound is used as coolant water. In this system a centrifugal pump, driven by engine crankshaft is being used to deliver water into the system with pressure. The outlet of the pump is being divided into main three heads- one for cooling turbo charger and after-cooler and the other two for cooling the engine components situated at left and right bank of the engine. Finally the water gets collected at headers and sent to radiator for cooling. An induced draft radiator fan is used to blow air through the radiators for cooling. The radiator fan takes drive from the engine crankshaft through ECC (EDDY CURRENT CLUTCH). A temperature switch controls the clutching effect of ECC and hence radiator fan rpm. Safety devices are provided both for hot engine and low water conditions of the engine.

SELF ASSESSMENT

1. What type of water is used in cooling water system of locomotive? How water treatment is done?

2. What are the harmful effects of using natural water in cooling system?

3. Draw a neat sketch of the cooling water system and label it.
4. How does Radiator Fan get drive? How its rpm is controlled?
5. What is the purpose of providing vent box and bubble collector in cooling water circuit?
6. What are the modifications carried out in cooling water system?