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Daffodil International University
Dhaka, Bangladesh

Study on Operation and Maintenance of a Power Plant

(Based on summit power plant)

This thesis has been submitted to the Department of Electrical and Electronic Engineering in partial fulfillment of the requirement for the degree of Bachelor of Science in Electrical & Electronic Engineering.

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APPROVAL

This Thesis titled “Study on Operation and Maintenance of Power Plant” (**Based on summit power plant**) submitted by **Samiul Islam,** ID: 153-33-220 to the Department of Electrical and Electronic Engineering, Daffodil International University, has been found as satisfactory and accepted for the partial fulfillment of the requirement for the degree of Bachelor of Science in Electrical and Electronic Engineering and approved as to its valuable information and contents.

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DECLARATION

We hereby declare that, this thesis is based on **"Study on Operation and Maintenance of a Power Plant"** has been done by **Samiul Islam** and submitted to the department of Electrical and Electronic Engineering, Faculty of Engineering, Daffodil International University. This thesis is submitted to Daffodil International University for partial fulfillment of the requirement of the degree of B.Sc. in Electrical and Electronics Engineering. This thesis neither in whole nor in part has been previously submitted for any degree.

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DEDICATION

This Thesis paper is dedicated to our heart left gratitude to almighty to Allah and to Our parents.

ACKNOWLEDGEMENTS

At first, I expressed our hearties thanks and gratefulness to almighty Allah for his divine blessing because of making to complete this thesis successfully.

We express our sincere gratitude and indebtedness to the thesis supervisor Senior Lecturer Md. Ashraful Haque Department of Electrical and Electronic Engineering, Daffodil International University (DIU), Dhaka, Bangladesh for his cordial encouragement, guidance and valuable suggestions at all stages of this thesis work.

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ABSTRACT

This field work is on "**study on Operation and Maintenance of a Power plant"** (**Based Summit Power Plant**)".With needs of power, power Generation company has been increasingly used in private power generation of Bangladesh. In order to increase power and to reduce the initial investment and to minimize the maintenance costs in terms of money and human resource, control engineers recommend that all program control system should be used of power generation. In the starting period of our internship, I have walked around the power plant. With The help of experienced engineer, I have worked on control and Maintenance of power generation. For generating power and purpose of distributing, we have used generator, switchgear, circuit breaker, transformer etc. Most important things used to engine, alternator, substation, fuel for power generation. Some of this are cylinder head, cylinder linear, cylinder block, rocker arm, crank shaft cam shaft, spark plug, piston, piston ring, connecting rod, main bearing, turbocharger etc. Besides that we have learned the method of ignition system, fuel system, air starting system, air inlet and exhaust system, lubricating system, engine cooling system, starter system etc. Also besides that we have learned about current transformer (CT), potential transformer (PT), radiator, earth switch, isolator, surge counter, different types of relay, sensor etc.

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Chapter-1

Introduction to Engine:

1.1.1Introduction:

Summit Power Limited (SPL) is a subsidiary of Singapore-based holding company Summit Power International (SPI). It was incorporated in Bangladesh on March 30, 1997 and later on June 7, 2004 the company was converted into a Public Limited Company under the Companies Act (1994).

Presently, SPL owns and operates 15 power plants at different locations in Bangladesh having a total Installed capacity of 975.96 MW. SPL supplies electricity to Bangladesh Power Development Board (BPDB) and Bangladesh Rural Electrification Board (BREB) with whom we have long-term purchase agreements in place. The company has many certifications among which are ISO 9001:2008 – Quality Management System, ISO 14001:2004 – Environment Management System and OSHAS 18001:2007 – Occupational Health and Safety

1.1.2 Company Information:

Summit Power Limited, an independent power producer, generates and supplies electricity in Bangladesh. The company generates electricity from natural gas and furnace oil. It owns and operates 15 power plants with a total capacity of 975.96 megawatts. The company sells electricity to the Bangladesh Power Development Board and Bangladesh Rural Electrification Board. Summit Power Limited was incorporated in 1997 and is based in Dhaka, Bangladesh. Summit Power Limited is a subsidiary of Summit Corporation Limited.

1.1.3 Classification of Engine:

In the case of an adequately ventilated enclosure containing gas-fuelled engines it need not be classified solely by reason of the engine fuel. This is the case with a normal power plant installation.

In the case of a gas compressor driven by a gas engine, the engine is seen as an ignition source and the gas compressor is a source of possible gas leak. The possibility of a gas leak is considered to be much higher in a gas compressor, thus, a gas engine driven compressor is classified as hazardous area, normally zone 2 or class I division 2.

1.1.4Working principle of Engine:

Working principle depends on strokes needed to complete one working cycle.

- To convert the chemical energy of the fuel into useful mechanical energy all internal combustion engine must go through four events:
  Intake, Compressor, Power and Exhaust= one working cycle

- 4-stroke engine
  -Requires four stroke of the piston to complete one full working cycle.
  - Requires two rotation of the crankshaft to completed one cycle.

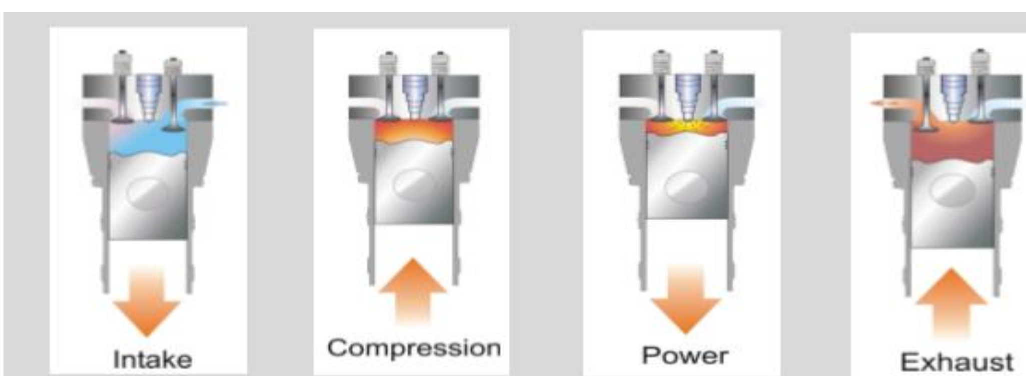


Fig: 4-strokes process

In a lean burn gas engine the mixture of air and fuel in the cylinder is comprimized lean, i.e. there is more air than needed for combustion. In order to stabilize the ignition and the combustion of the lean mixture, a richer fuel mixture starts the combustion through a prechamber. The ignition is initiated by a spark plug located in the prechamber, giving a high-energy ignition source for the main fuel charge in the cylinder. The prechamber is located in the center of the cylinder head.

- 2-stroke process

Power /exhaust

1. This strokes occurs immidiately after the ignition .
2. The piston is force down.
3. In a certain point, the exhaust valve opens and exhaustgas escape.
4. Once the top of the piston passes the inlet ports the compressed charge air enter the cylinder.

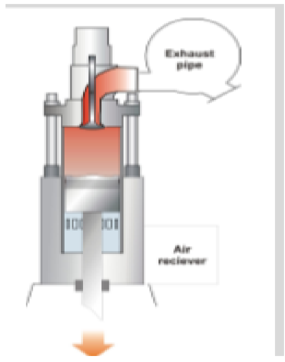


Fig: Power/ exhaust

Intake/Compression

1. The piston begins to move up and inlet ports close.
2. The exhaust valve close and the air will be compressed.
3. The compressed air is ignited by the spark plug and the cycle begins again.

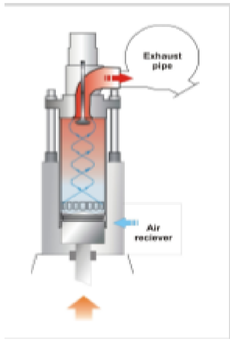


Fig: Intake/copression

<u>1.1.5 Engine speed:</u>

-Low speed engine: below 300 rpm

-Low speed engines are commonly used on ships and for generation of electricity.

- Medium speed engine: between 300–1200 rpm

- Medium speed engines are used for a wide range of purposes including ship propulsion, generation of electricity, traction, gas compression and pumping and pumping of liquids

- High speed engine: over 1200 rpm

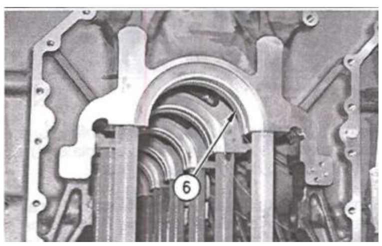
- High-speed engines are used in transportation and for small gen-sets.

Fig: Engine

1.1.6 Crankshaft- install:

Keep all parts clean from contaminants. Contaminants may cause rapid wear and shortened component life.

1. Clean the crankshaft.
2. Clean the crankshaft main bearings. Refers to the guidelines for reusable parts SEBF8009, main and connecting rod bearings for additional information.
3. Clean the cylinder block.
4. If the studs wear removed tighten the studs (1) for the main bearing cap to a torque of 100 20.



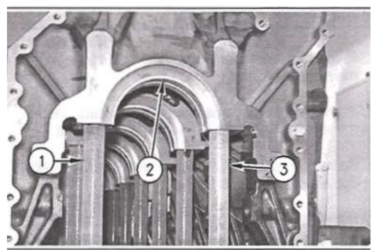
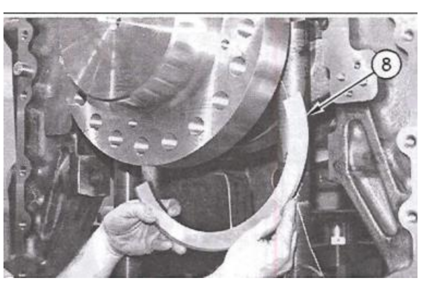


Fig: Crankshaft install

5. Put the 50mm (2 inch) plastic sleeves on the main bearing studs in order to prevent damage to the crankshaft during the removal procedure.
6. Put the upper halves (2) of the main bearings position into cylinder block. Ensure that the tap on the back on the bearing in engaged with slot in the cylinder block.
7. Put clean engine oil on the bearings.
8. Be sure to identify the front of the crankshaft and the rear of the crankshaft. The front center hub of the crankshaft is stamped with “FRT”.
9. The rear of the crankshaft is identified three holes in the flange.
10. Removed the plastic sleeves from the main bearing studs.



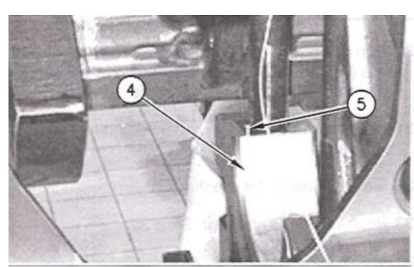
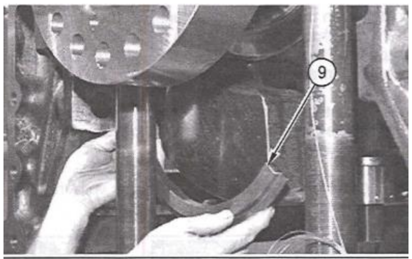


Fig: Crankshaft install

11. Put clean engine oil on the bearings.
12. Raise the main bearing cap (4) on the studs.
13. Ensure that the dowel (5) engages with hole in the cylinder block.
14. Install the washers (6) and the nuts (7) tighten the nuts by hand.
15. Lower the lifting device.
16. Put clean engine oil on the face of the rear thrust plate plate (8).
17. Install the brackets for the crankshaft timing pins.



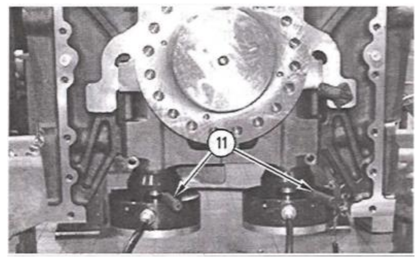


Fig: Crankshaft install

18. Put the reaction sleeves in position over the nuts.
19. Use the wrench (11) in order to tighten the nut securely.
20. Slowly release the pressure.
21. Move the oil pan into position under the cylinder block.
22. Install the prelube pump.
23. Install two bolts in the crankshaft flywheel flange.
24. Use bar in order to turn the crankshaft.
25. The crankshaft must ratite freely.

1.1.7 Exhaust Camshaft:

The exhaust camshaft assumes a control function for the decompression of the cylinder. At a low rotational speed of the engine, the exhaust camshaft briefly lifts the exhaust valve during each stroke, so that the compressed air can exit and the engine starts easier. At higher rotational speeds, i.e. when the engine is running, centrifugal force turns the decompression cam into an ineffective position and the compressed air cannot exit. The part is hot forged, machined, induction hardened, hard machined and then mounted ready for assembly with two other supplied components.

Fig: Exhaust Camshaf

1.1.8 Camshaft Install:

The role of the camshaft is to time the valve openings in order to allow air to enter and exhaust gasses to leave the combustion chamber. The correct relationship of the camshaft segments must be observed at the time of assembly. If the camshaft segments are not properly timed, serious engine damage will occur.

1. Before assembly, check the location of the dowel the height of each camshaft journal .
2. Put clean engine oil on the rear camshaft bearing.
3. Put the spacer (3) in position on the camshaft drive shaft assembly (1). Align the dowel in the drive shaft assembly will the dowel hole in the camshaft segments. Install drive shaft assembly (1).

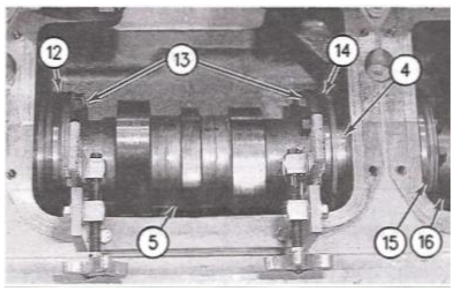


Fig: Camshaft install

4. Install the plate assembly and bolts that hold the plate in position.
5. Install the plate (2) on the drive assembly (1).
6. Put the spacer (9) in position on the camshaft journal (7)
7. Install the bolts (10) that hole the camshaft journal to the camshaft segments.
8. Put the spacer (7) and spacer (6) in position on the camshaft journals.
9. Install camshaft inspection cover on the side of the engine.
10. Install camshaft drive gear refer to the disassembly and assembly.

1.1.9 Piston rings:

1. Two chrome compression ring.
2. One spring loaded oil scraper ring.

Fig: Piston rings

1.1.10 Connecting rod:

1. Connecting rod,Upper part
2. Shim
3. Big end, Upper half
4. Big end, Lower half
5. Big end

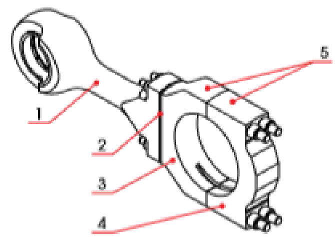


Fig: Connecting rod

The connecting rod is forged and machined of alloyed steel and splitted horizontally in three parts to allow removal of piston and connecting rod parts. All connecting rod bolts are hydraulically tightened.

1.1.11 Spark plug:

The spark plug can be tight due to carbon deposits in the threads. The threads in the prechamber should be cleaned before a new spark plug is mounted. Clean the spark plugs, but do not apply any grease on the threads. Oil and/or grease may cause a shortened lifetime of the spark plugs.

Mount the new spark plug and seal ring by hand until it contacts the sealing surface. Mount all spark plugs by hand before tightening any of them to stated torque. By this procedure, the temperature of the spark plugs gets time to get stabilized to the same temperature level as the cylinder heads.

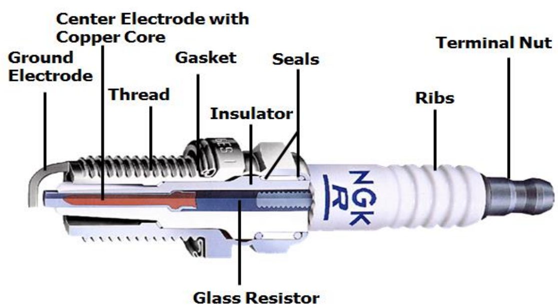


Fig: Spark plug

1.1.12 Valves:

Inlet valve

- Stellite sealing face.
- Diameter 112mm.
- Sealing angle 40º

Exhaust valve

- Stellite sealing face
- Diameter 107mm
- Sealing angle 40º

Valve rotators on all valves

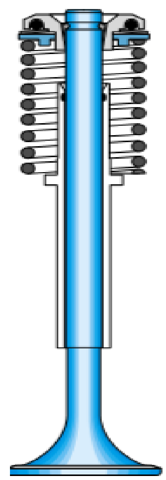


Fig: Valves

1.1.13 Cooling water jacket:

The cooling system of the engine uses chemically treated fresh water. The system is divided into JACKET Water system and A Separate Circuit cooling System. The jacket water system is enclosed with Cylinder Block, Cylinder Head and Turbocharger. The Separate Circuit cooling system consists of the After cooler and Oil cooler circuit (AC/OC). The cooling water is circulated in the system by directly driven centrifugal pumps mounted on the engine.

The water is cooled in radiators with electrically driven cooling fans. The temperature in the both circuits is controlled by three-way valves. The temperature control valves direct the water to the radiators or back to the engine, depending on the temperature of the water. The speed of the radiator fans is regulated according to the temperature of the water.

Fig: Cooling water jacket

A preheating unit is used to heat the jacket water before the engine is started. The both circuits use separate expansion vessel. There is a makeup line from the expansion vessel to the to coolant inlet. This line helps keeps the coolant in the circuit (AC/OC) at correct level.

1.2 External combustion Engine:

1.2.1 Main Bearing assembly:

The main bearing journals should be inspected for surface finish. Damaged journals, i.e. rough surface, scratches, marks of shocks etc., should be polished. If, after a longer running period, considerably uneven wear appears, see section 06.2, the crankshaft may be reground and used together with thicker bearing shells, see Spare Parts Catalogue.

Fig: Main Bearing

1.2.2 Cylinder Liner:

1. Bore cooled collar type with anti-polishing ring.
2. Lowered water jacked.
3. Improved cooling.
4. Simplified tem sensor assembly.
5. Liner clamped to engine block.
6. Weight of the liner is 238 kg.

Fig: Cylinder Liner

1.2.3 Engine Block:

- The engine block is cast in one piece.
- Jacket water distributing pipe and charge air receiver are integrated
- The main bearings are hanging
- Weight of 20V34SG engine block is 20.000kg

Fig: Cylinder block

1.2.4 Crank shaft:

The crankshaft alignment is always done on a thoroughly warm engine, immediately after the engine is stopped. The crankshaft alignment should be carried out rapidly but carefully. Only the crankcase cover for the cylinder being measured should be opened and it should be closed immediately after measuring. It is recommended to switch off any forced ventilation close to the engine.

Fig: Crank shaft

1.2.5 CamShaft:

•The camshaft is built out of one cylinder cam pieces with separate bearing pieces in between.
•There are three cams in one camshaft piece, one for the inlet and one for exhaust valves and one for the prechamber valve.
•The camshafts are driven by the crankshaft through a gear train.

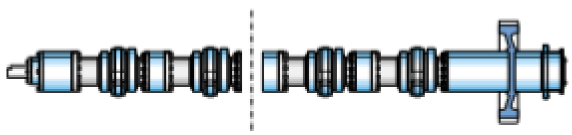


Fig: Cam Shaft

1.2.6 Camshaft plece:

- The camshaftpiecehastwo fixedcamsand onebolted-on cam
- Forgedsteel, induction hardenedcontactsurfaces
- Weightof onecamshaftpieceis 92kg.

Fig: Camshaft plece

1.2.7 Rocker arms:

1. Rigid rocker arm bracket.
2. 3-rocker arms.
   -Small rocker arm for pcc valve between inlet and exhaust arms.

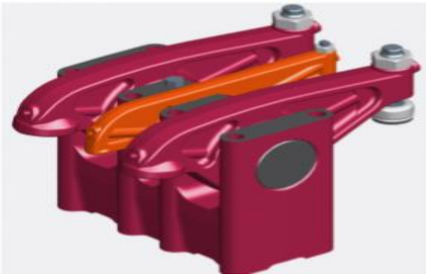


Fig: Rocker arms

1.2.8 Oil sump:

•A light weight welded design (for 20V34SG: 2.100kg).
•It is bolted to the engine block from below and sealed. by an O-ring.
•Suction pipes for main lube oil pump and for separator.
•Main distributing pipe for lube oil.

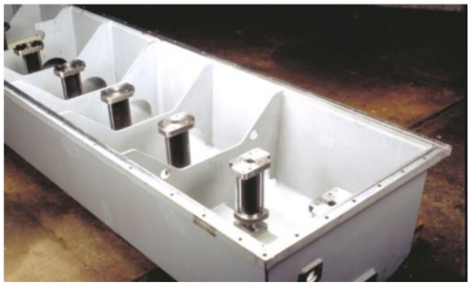


Fig: Oil sump

1.2.9 Cylinder Head :

1. Cylinder head is made out of nodular cast iron.
2. A directed water flow is used for intense cooling of exhaust.
3. Weight of a cpmpleted cylinder head 430kg.

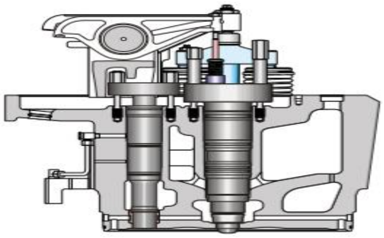


Fig: Cylinder head

1.2.10 Vibration Damper:

Vibration Dampers definition: A device designed to compensate for and reduce the effects of torsional vibration in the crankshaft of an engine. Four-stroke piston engines exhibit non-uniform rotation. The separate strokes combined with the firing order of the individual cylinders dictate that the crankshaft is continuously accelerated and decelerated.

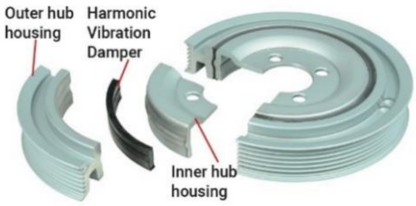


Fig: Vibration Damper

1.3 Oil wetted filter:

1.3.1 Operating principle:

1. The multi duty is viscous metallic air filter automatically driven with self- cleaning panel.
2. The dust is removed from the air passing 2 times through the panel impregnate with a special gel: the VICOSINE.
3. In the air section, the panels are overlapping one another like a tileroofine so as to form an endless dense curtain.
4. The curtain moves a few times per hour and accomplishes a complete revolution 24 hours.
5. The panels are separated and hang widely spaced for ease of cleaning as they pass through the viscosine bath at the fitter.
6. The dust removed from panels by the viscosine are filling by gravity and the sludge can be removed periodically from the filter.
7. Bottom with the sludge scraper.

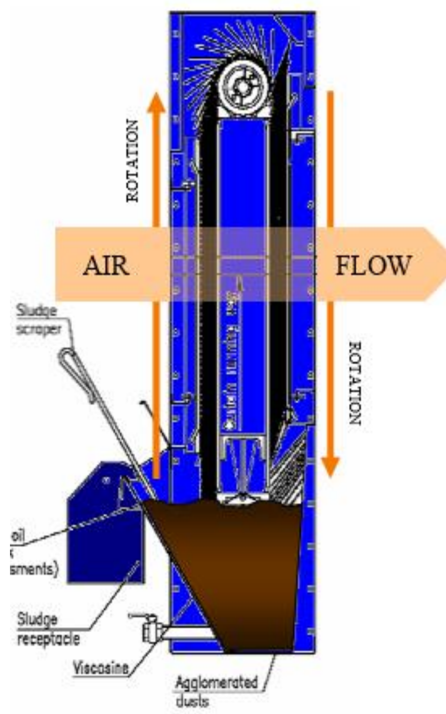


Fig: Oil wetted filter

1.3.2 Hydraulic jack:

1. Mounted between the main distribution pipe and main bearing caps.
2. Its use lower and lift the main bearings caps.
3. Lubrication oil is led to the main bearings and crankshaft trough this jack.

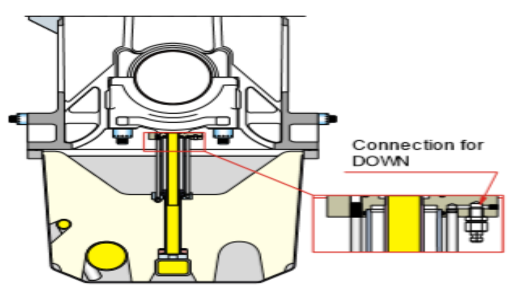


Fig: Hydraulic jack

Chapter-2

Module and Auxiliary module System:

2.1 Charge air cooler:

The charge air cooler built on the in line engine is alternatively of single or two stage type and for V-engine normally of two stage type.

The wartsila 4- stroke engine contains four major sources off heat load to be cooled away.

Jacket cooling= Cylinder jacket and cylinder heat cooling circuit.

HT CAC= High temperature (1st stage) charge air cooler.

LT CAC= Low temperature (2 nd stage) charge air cooler.

LOC= Lube oil cooler, can be engine mounted or external system.

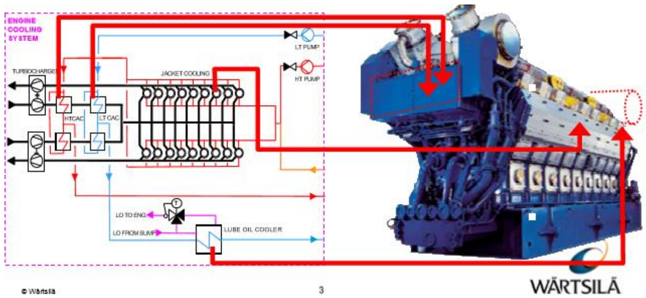


Fig: Charge air cooler

2.2 Thermostatic valves:

Thermomechanical

Two types of applications

i. In external system as complete valve assembly
ii. Regulating elements only, intrgrated into the engine castings.

- Self-powered, simple mechanical design.
- Can be used in both mixing and diverting **mode .**

Fig: Thermomechanical

- Fixed set point temperature, to change setpoint the regulating elements need replaced.

Electropneumatic

- Linear action diaphragm actuator commonly integrate positioner and I/p converter.
- Different valve internals for mixing and diverting modes.
- Actuator requires lots of space mounting operation options limited.
- Good control linearity virtualy no leakage.

Fig: Electropneumatic

2.3 Ignition System:

The ignition system is tailor made for this engine type, and is integrated with the engine control system. The control system (WECS) determines the timing of the spark and the timing can be set individually for the cylinders. The ignition coil is located on the top of the cylinder head cover, as close to the spark plug as possible.

1. Nut
2. Sleeve
3. O-ring
4. O-ring
5. Spark plug
6. Prechamber
7. Prechamber valve
9. Sealing ring
10. Pilot gas feed pipe
11. Sealing sleeve

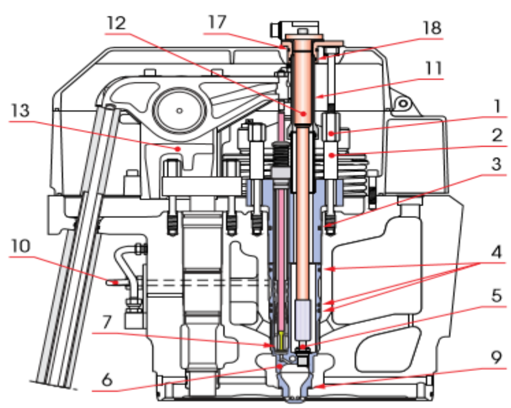


Fig: Ignition System

12. Ignition coil
13.Rocker arm backet
17. O-ring
18. O-ring

The high voltage link between the ignition coil and the spark plug is a stiff, super isolated extension (12), with no joints, see Fig 16-2. This is effectively minimizing the possible disturbances on the ignition system. The spark plug (5) is of a large and durable design, see Fig.

2.4 Fuel injection timing :

Mixing of air and natural gas may be a problem when using port injection [1]. Injection timing is selected to be centered around top dead center (TDC) gas-exchange at low to medium injection durations, and early enough to finish injection 30 degrees before inlet valve closing (IVC at 230 degrees after top dead center, ATDC) for long injection durations. This strategy ensures sufficient airflow past the inlet valve for mixing of air and natural gas. If the fuel is injected after IVC the next cycle will receive a stratified charge due to poor mixing.

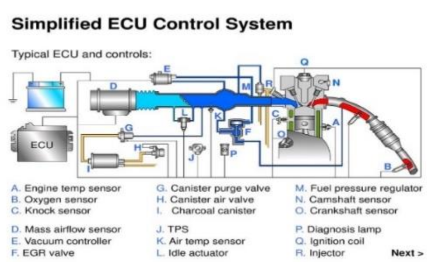


Fig: Fuel system

2.5 Air Starting System:

The engine is started with compressed air of max. 30 bar. Minimum air pressure required is 15 bar and the WECS engine control system gives an alarm for low starting air pressure at this level. The starting air pressure is measured by the transducer (2) and monitored on the engine control desktop.

1. Engine control unit (WECS)
2. Pressure transducer
3. Drain valve
4. Main starting valve
5. Starting valve
6. Flame arrester
7. Connection piece
8. Air block
9. Blocking valve
11. End plate
13. Plate
14. Spring
15. Control piston
16. Liner 17. Plug
19. Safety valve
18. Connection piece
20. Pressure regulating valve
21. Starting air distributor

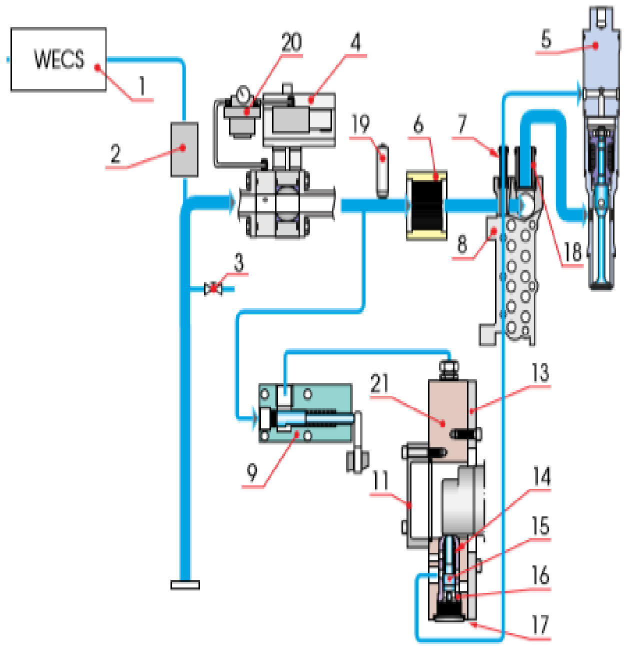


Fig: Air starting system

The starting air pipe is provided with a flame arrester (6) and a transducer (2) after the main starting valve (4). The main starting valve is activated by the WECS control system.

When the main starting valve opens, the starting air passes partly through the air block (8) to the starting valves (5) and partly to the starting air distributor (21). The distributor guides control air to starting valves (5) in those cylinders that are in working phase. V-engines have starting valves only on the A-bank

2.6 Cleaning the turbine and the compressor of the turbocharger:

1 Record the charge air pressure, cylinder exhaust gas temperatures, and turbocharger speed at nominal load.
2 If the generating set is operating in island mode, adjust the engine load. The exhaust gas temperature at the inlet to the turbocharger must not exceed 430 °C. When operating parallel with the grid, the load is automatically adjusted by the PLC.
3 Open the compressed air supply to the valve unit.
4 Open the water supply to the valve unit and adjust the water flow as required.
5 Start the cleaning from WOIS. The cleaning is carried out automatically once it has been started. Note!

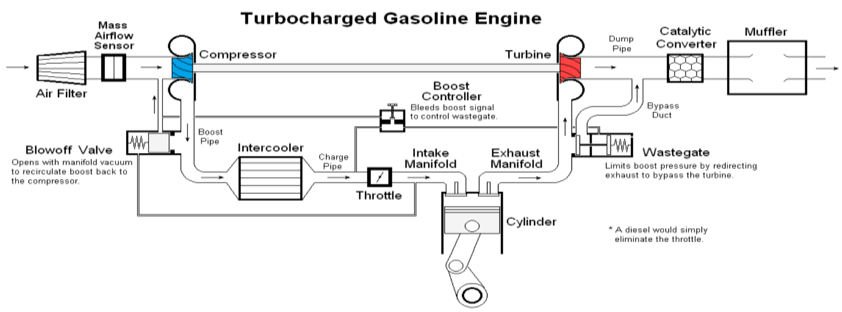


Fig: Clean the turbine and compressor of the turbocharger

6 If the cleaning is disturbed due to a failure or if the operator stops the sequence from WOIS, an alarm occurs. The cleaning can be restarted after 10 minutes.
7 After the engine has been running one hour at normal load, check the charge air pressure, cylinder exhaust gas temperatures, and turbocharger speed. The efficiency of the cleaning can be evaluated by comparing the readings with the values recorded before the cleaning. To ensure that all parts in the exhaust system are completely dry, do not stop the engine immediately after cleaning the turbocharger. The engine must be run for at least 20 minutes before stopping.

2.7 Use of non-approved Lubricating oils:

Before using a lubricating oil not listed in the tables above, the engine manufacturer must be contacted. Lubricating oils that are not approved have to be tested according to engine manufacturer's procedure.

Should unapproved lubricating oils be used during the engine warranty period, and there exist no agreement with the engine manufacturer about testing, the engine guarantee does not hold.

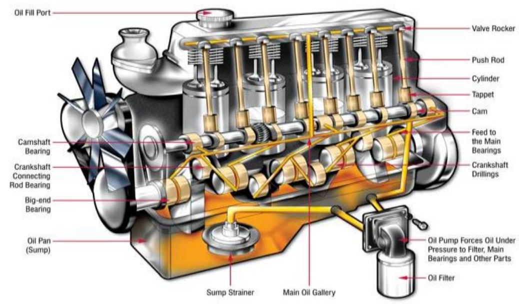


Fig: Lubrication oils

2.8 Approved Lubricating oil Engine Turning Device:

It is recommended to use EP-gear oils, viscosity 400-500 cSt at 40 °C = ISO VG 460 as lubricating oils for turning device.

LUBRICATING OILS FOR ENGINE TURNING DEVIC				
SUPPLIER	**BRAND NAME**	**VISCOSITY cSt at 40 °C**	**VISCOSITY cSt at 100 °C**	**VISCOSITY INDEX (VI)**
BP	**Energol GR-XP 46**	**425**	**27**	**88**
Castrol	**Alpha SP 460**	**460**	**30.5**	**95**
Chevron	**Meropa 460**	**460**	**31.6**	**100**
ENI s.p.A	**Blasia 320**	**300**	**23**	**95**
Exxonmobil	**Spartan EP 460** **Mobilgear 634**	**460** **437**	**30.8** **27.8**	**96** **96**
shell	**Omala Oil 460**	**460**	**30.8**	**97**
Total/Lubmarine	**Elf Epona Z 460**	**470**	**30.3**	**93**

2.9 Engine Cooling System:

4- stroke engine contains four major sources off heat load to be cooled away.

1. Jacket cooling = Cylinder jacket and cylinder head cooling circuit.
2. HT CAC= High temperature charge air cooler.
3. LT=Low temperature charge air cooler.
4. LOC= lube oil cooler can be engine mounted or external system.

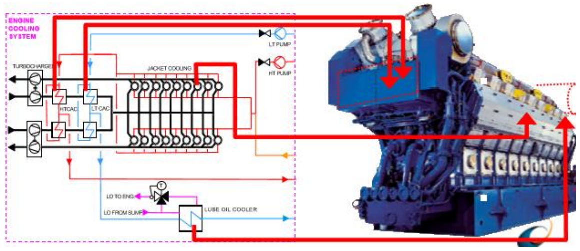


Fig: Engine cooling system

The cooling system is responsible for the flowing operating parameters of the engine:

- Jacket cooling water output temperature.
- Charge air temperature into the cylinders.
- Lube oil inlet temperature into the engine.

Above the listed temperature may be controlled directly or through intermediate e.g charge air temp is commonly controlled via the set point LT – water temperature.

The cooling system and engine deterring

- The charge air temperature is direct deterring parameters in the gas engine via knock controlfunction, where by deviations in this parameter have direct impact in a engine output.
- Deviations in a jacket cooling and LO temperature parameters will influence the longterm reliability and performance of the engine. Although no derating parameters are directly couple to this temperature. Large deviations will trigger a safety shattdown of the engine.

2.10 Preheating:

- Engine have to preheat before starting.
- The energy required for heating of the HT cooling water main and auxiliary engine can be taken from a running engine or a separate sources.
- A pump and heat module is use for this purpose.

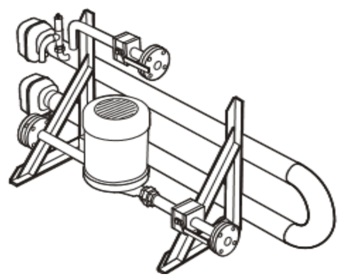


Fig: Preheating

2.11 Control air system:

1. A separate control air compressor is used because of the higher quality requirements compard to starting air.
2. Compressor is mounted on a skid including refrigeration dryer, filters and air bottle and control cabinet.
3. If pipe are very long an additional air bottle can be placed closer to the consumers.
4. The operation pressure is 7 bar.
5. The compressor is of screw type which has a no noise level and is suitable 24 day use.

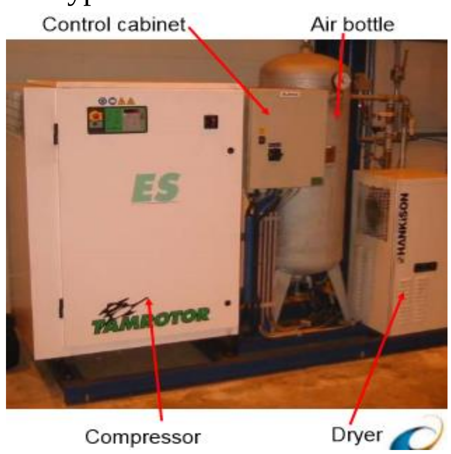


Fig: Control air system

2.12 Starting air compressor unit:

1. The starting air compressor are producing 30 bar air for the starting air system.
2. Piston type are compressor.
3. Should be able to fill the air bottles in approx. 1 h
4. Also 7 bar connection to supply back up instrument air in emergency cases.
5. Usually two electrical driven compressors mounted in one module, one working and one standby.
6. The module can also consist of one electrical and one diesel engine driven compressor in cases to be able to start it in black out situations.

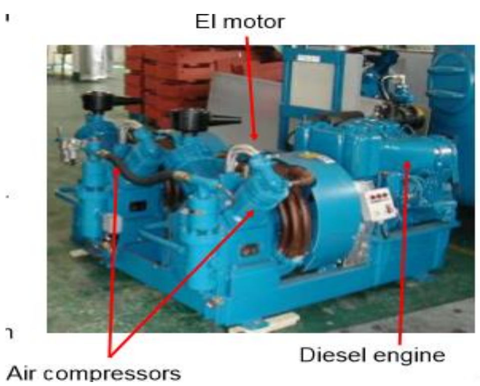


Fig: Starting air compressor unit

2.13 Engine events during start sequence:

Rpm	SG engine	DF engine
0	-Starter motors/start air valves are engaged - Waste gate closed	-Starter motors engaged -Main diesel fuel ramp to stop position
	Ventilation turns completed	-Ventilation turns completed
50	-Ignition started − Pre combustion chamber gas injection started − Main combustion chamber gas injection started	-Pilot fuel injection started
135	-Starting motors/start air valves disengaged -Waste gate taken into operation	
140		
175	-Engine to RUN-mode control -Main combustion chamber gas injection from start fuel limiter to PID control	-Main diesel fuel ramp released from stop position -Engine ready for gas operation - Cylinder boost (pilot fuel injection) on
350		
730	-Exhaust gas temperature balancing started - Cylinder boost on -Ignition map to use	-Cylinder boost (main gas injection) on - Exhaust gas temperature balancing started

Chapter-3

Plant Electrical System

3.1.1 Synchronous Generator Operating Principle:

The generator has two magnetic structures, one is the stator which is fixed in space, and the other is the rotor which is driven by a prime-mover. They are separated by an annular space called the air-gap.

Each structure carries windings that are linked by a mutual flux crossing the air-gap, and as a result a generated-emf is produced in the stator. Current in the rotor field-coils produce a rotating magnetic-field called field-flux

Each structure carries windings that are linked by a mutual flux crossing the air-gap, and as a result a generated-emf is produced in the stator. Current in the rotor field-coils produce a rotating magnetic-field called field-flux.

In general, for cylindrical-rotor machines the modification appears as shift in pattern, while for salient-pole machines there is pattern distortion.

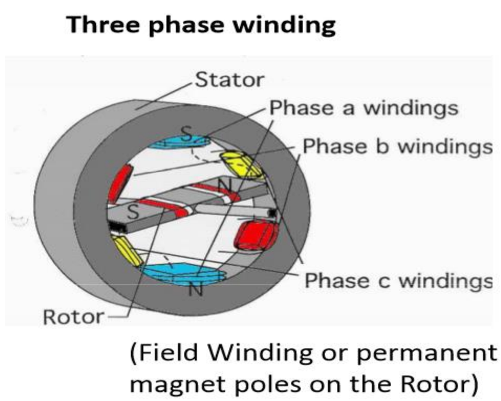


Fig: Synchronous Generator Operating Principle

3.1.2 Excitation control of Generator:

1. Speed drop is controlling the engine speed or generator frequency with respect to generator active power and voltage drop is controlling the generator terminal of with respect of generator reactive power.
2. The generator and the engine have to control simultaneously. For generator control we used AVR and for engine control we used Governor.

Fig: Excitation control of Generator

3. When in island mode operation and there is only one unit is running or several units running without load sharing, then the control mode Voltage Droop and Speed Droop are used to control the genset.
4. In Voltage Droop Compensation Control Mode, all units' AVRs are communicating with each other via RS485 MODBUS Protocol. And all AVRs are trying to maintain the excitation current with average excitation current so that all units' terminal voltage will be same and constant.
5. When in GRID MODE operation, all Units' AVRs are trying to control the reactive power generation of the generators with respect to the power factor settings of the genset. And all units' Governors are trying to control the engine speeds i.e. grid frequency with respect to the generators active power settings.

3.1.3 Round rotor:

- The round rotor is used for large high speed (3600rpm) machines.
- A forged iron core (not laminated, DC) is installed on the shaft.
- Slots are milled in the iron and insulted copper bars are placed in the slots.
- The slots are closed by wedges and re-enforced with steel rings.

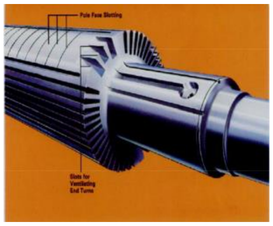


Fig: Round rotor

3.1.4 Exhaust gas system ventilation:

The exhaust system is equipped with a ventilation system. The system consists of a centrifugal fan, a flow switch and a butterfly valve equipped with a limit switch. This valve is opened and the fan is started either after every engine stop or before every engine start ventilating the exhaust system. However, in an emergency mode the fan is not operating.

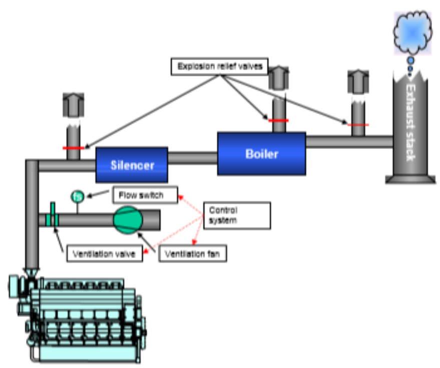


Fig: Exhaust gas system ventilation

The flow switch confirms that the fan is rotating. The capacity of the fan and the running time of it is chosen such that it is able to change the volume in the exhaust system at least three times during the ventilation run. Figure 10 shows exhaust gas ventilation system.

3.1.5 Current Transformer(CT):

A current transformer (CT) is a type of transformer that is used to measure alternating current (AC). It produces a current in its secondary which is proportional to the current in its primary. Current transformers, along with voltage or potential transformers, are instrument transformers. Instrument transformers scale the large values of voltage or current to small, standardized values that are easy to handle for measuring instruments and protective relays. The current transformer presents a negligible load to the primary circuit.

Fig Current Transformer(CT)

3.1.6 Potential Transformer (PT):

The potential transformer may be defined as an instrument transformer used for the transformation of voltage from a higher value to the lower value. This transformer step down the voltage to a safe limit value which can be easily measured by the ordinary low voltage instrument like a voltmeter, wattmeter and watt-hour meters, etc.

Fig: Potential Transformer(PT)

3.1.7 Vacuum circuit breakers:

In vacuum circuit breakers, the vacuum is used as the arc quenching medium. Vacuum offers the highest insulating strength. So it has far superior arc quenching properties than any other medium. The technology is suitable for mainly medium voltage application. For higher voltage vacuum technology has been developed but not commercially viable.

Fig: Vacuum circuit breakers

3.1.8 11-33 KV bus bar:

High voltage heat shrink bus bar insulation tubings provide flashover protection against accidental bridging of straight or angled, rectangular and round HV bus bars, 11kV-33kV. HV bus bar tubings are suitable for enclosed and exposed bus work and for high voltage connections in switchgear line ups and substations. HV high voltage bus bar heat shrink tubes also enable clearance reduction within high voltage electrical insulation applications, 11kV-33kV.

Fig: 11-33kv bus bar

3.2Transformer:

3.2.1 Auxiliary Transformer:

Oil filled transformers are typically used for equipment deliveries, EPC projects where the layout does not permit the use of a type transformer.

-The advantage will oil transformer are:

- The transformer can be placed outside.
- The transformer is slightly less expensive.

Fig: Transformer

3.2.2 Standard Oil type main technical features:

Standard: IEC76

Type : Hermetically seal

Rated power: 315-3500 KVA AN

Rated voltage: HV 6- 15

Frequency: 50/60 Hz

Ambient Temperature: 50/40/30 °C, temp rise Oil/Wind ings.

Altitude: 1000m

Connection Group: Dyn 11, Dyn 5

Windings: cu/cu

Enclosure: IP00, IP 54

3.2.3 Step up transformer:

- Low Voltage: 11…13.8 kV, Um 12…17.5 kV Insulation level LIWL 95 kV, Power frequency 38 kV 15 kV (70-170 MVA, 50Hz), Um 17.5kV Insulation level LIWL 95, power frequency 38 kV y
- Frequency: 50/60Hz
- Ambient temperature: 50/40/30 °C, temp rise Oil/Wind ings50/55 °C Altitude: 1000 m
- Connection group: YNd11, YNd1, YNd5, YNd7 •Windings: Cu/Cu Enclosure: IP 00
- Impedance voltage: 10% up to 40 MVA, over 40 MVA 11% and over 63 MVA 18%
- Total losses at MVA 0.5%
- Design short circuit: According to IEC 60076-5

Fig: Step up transformer

3.2.4 Conservator:

When transformer is loaded and when ambient temperature rises, the volume of oil inside transformer increases. A conservator tank of transformer provides adequate space to this expanded transformer oil. It also acts as a reservoir for transformer insulating oil.

When volume of transformer insulating oil increases due to load and ambient temperature, the vacant space above the oil level inside the conservator is partially occupied by the expanded oil. Consequently, corresponding quantity of air of that space is pushed away through breather. On other hand, when load of transformer decreases, the transformer is switched off and when the ambient temperature decreases, the oil inside the transformer contracts. This causes outside air to enter in the conservator tank of transformer through silica gel breather.

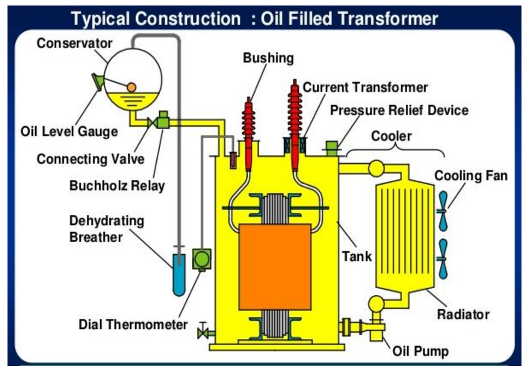


Fig: Conservator

3.2.5 Silica Gel Breather:

Silica gel is used as a visual indicator of moisture in the transformer oil. When moisture in air comes in contact with the silica gel it will change colour.It is used outside the transformer in a breather container which is connected to an opening above the oil of the transformer via pipes.

Fig: Silica Gel Breather

At the bottom of the breather there is an oil reservoir which acts as a one way valve. When there is pressure from the transformer oil side air will flow through the breather and bubble through the reservoir. No air can reverse through the breather as long as there is oil in the bottom reservoir.

3.2.6 Oil Level Indicator:

This device is used to indicate the position of transformer insulating oil level in conservator of transformer.

Fig: Oil Level Indicator

Check the oil level in the oil sump/oil tank. Estimate the appearance and consistency of the oil. A simple control of the water content: A drop of oil on a hot surface (about 150°C), e.g. a hot-plate. If the drop keeps "quiet", it does not contain water; if it "frizzles" it contains water. Compensate for oil consumption by adding max. 10 % fresh oil at a time.

3.2.7 Winding temperature indicator:

All large transformers have an oil or a winding temperature indicating device of some type, and most have temperature recorders as well. Indication may be for top-oil temperature or hotspot temperature. Additional temperature-sensing equipment may be installed to provide alarm and control signals needed to activate automatic cooling systems.

Fig: Winding Temperature Indicator

3.2.8 Isolator:

An isolator is a device used for isolating a circuit or equipment from a source of power. An isolator is a mechanical switching device that, in the open position, allows for isolation of the input and output of a device.

Fig: Isolator

3.2.9 Earth Switch:

Earthing switch is a kind of mechanical switching device for earthing parts of a circuit. It can be used as part of disconnector or stand-alone. It is capable of withstanding currents under abnormal conditions such as those of short circuit for a specified time, but not required to carry current under normal conditions of the circuit.

Fig: Earth Switch

3.2.10 Outdoor Vacuum Circuit Breaker(OVCB):

Siemens puts large effort into developing and m anufacturing its medium-voltage circuit-breakers to the highest possible standards, enabling them to withstand the toughest climates and function reliably in practically every kind of environment. The circuitbreaker research and development center in Berlin, Germany, and the Siemens Centers of Competence worldwide are part of a global R&D network, underscoring the emphasis Siemens places on the reliability of its products. Here, circuit-breaker operators and interrupters are designed, developed, and tested, while design (type) short- circuit tests are performed at independent power test laboratories.

Fig:Outdoor Vacuum Circuit Brear

Chapter- 4

Electrical view of power plant

4.1.1Single Line Diagram of power plant:

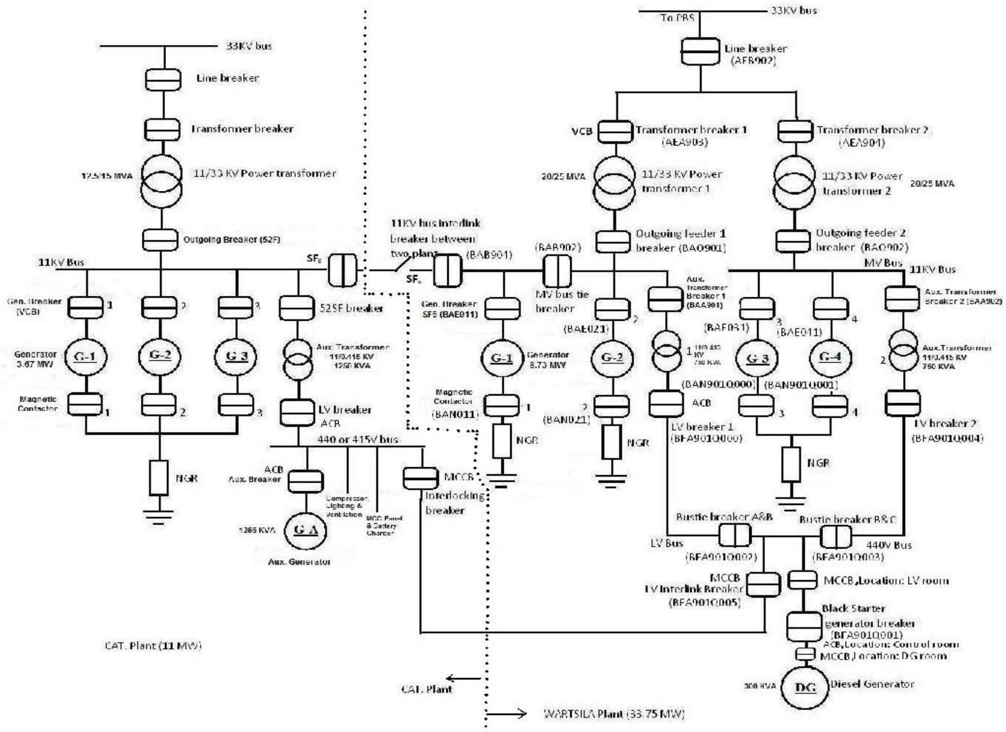


Fig. : Combined Single Line Diagram of CAT. & Wartsila Plant

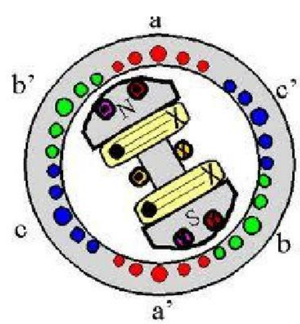
Fig: Single Line Diagram of Power plant

4.1.2 Synchronous Generators

In a synchronous generator a DC current is applied to the rotor winiding Producing a rotor magneticfield. The roto is then turned by external means producing a rotating magnetic field, which induces 3 phase voltage within the stator winding.

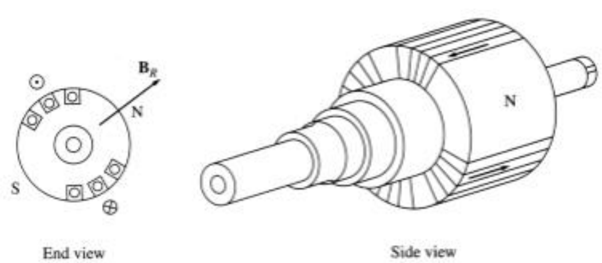
Fig: Synchronous Generator

- Field winding are the windings producing the main magnetic field.
- Armature are the windings where the main voltage is induced.



4.1.3 Construction of synchronous machines:

The rotor of a synchronous machine is a large electromagnet. The magnetic poles can be salient or non- salient construction.



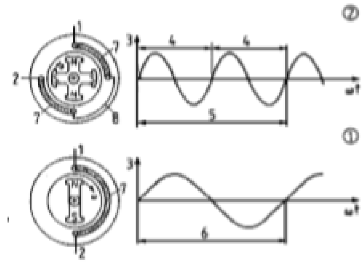
Non salient pole rotor Usually two and four pole rotors. Sailient pole rotor. Four and more poles

Rotor are made laminated to reduce eddy current losses.

4.1.4 Rotation speed of synchronous generator:

By the definition, synchronous generator produce electricity whose frequency is synchronized with the machanical rotational speed.

$$f_e = \frac{p}{120} n_m$$



Where fe is the electrical frequency, Hz;

nm is the rotor speed of the machine, rpm;

p is the number of poles.

• Steam turbines are most efficient when rotating at high speed; therefore, to generate 60 Hz, they are usually rotating at 3600 rpm (2-pole).

• Water turbines are most efficient when rotating at low speeds (200-300 rpm); therefore, they usually turn generators with many poles.

4.1.5 Before starting Engine:

Work around the generator set before the engine is start . Ensure that no one is on the generator set. Also ensure that no one is underneath the generator set, or close to the generator set. Ensure that the area is free of personnel.

Ensure that the generator set is equipped with a lithing system that is suitable for the conditions. Ensure that all lights work property.

See survice manual for repairs and for adjustment.

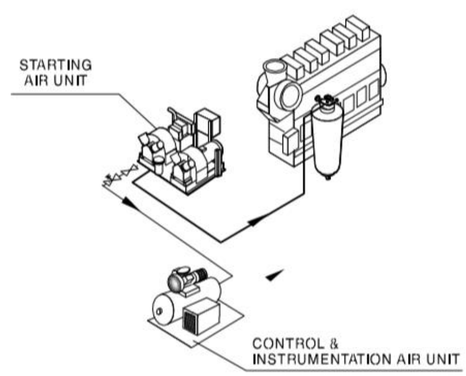


Fig: Before starting engine

4.1.6 Engine starting:

Before starting the engine, check that:

- the lubricating oil level is correct
- the fuel system is in running order (correct pressure)
- both cooling water system circuits, LT and HT water circuit, are in running order (correct pressures, circulating water preheated and pre-circulated sufficiently to heat the engine)
- the starting air pressure is 20 bar (normally, 15 bar is still sufficient to start the engine)
- the starting air system is drained of condensate
- the drain pipe of the air cooler casing is open, no leakage.

4.1.7 Engine stopping from control room:

Stop the engine, In order to avoid overheating accelarater wear of the engine components, refer to the engine operration and maintenance manual, ‘engine stopping’. Use the emergengy stop button Only in an emegency situation. Do use the emergency stop button for manual engine stopping. Ater an emergency stop do not start the engine until the problem that caused the emergency stop has the corrected.

Fig: Engine stopping

On the initial start up of a new engine or an engine that has been serviced make provision to stop the engine if an overspeed occurs. This may be accomplished by shutting off the fuel suply to the engine or shutting off the ignition system.

.

4.2.1 Exhaust gas system:

The exhaust gas system leads the exhaust gases out of the power house and reduces the noise. Exhaust gas from the exhaust manifold causes the turbocharger turbine wheel to turn. The turbine wheel is connected to the shaft that drives the compressor wheel. Depending upon on the speed and load requirements of the engine, exhaust gases are directed either through the exhaust outlet to the turbocharger or through the exhaust bypass valve. The exhaust gases enter the stack by way of a stack-integrated silencer. Exhaust gas silencer and stack The exhaust gas silencer reduces the environmental noise from the engine. The operation of the silencer is based on reactive and absorptive attenuation. The silencer is equipped with a condensate drain.

Fig : Exhaust gas system

4.2.2 Starting air compressor:

1. Make visual check of the machine, ensure that all guards secure and that nothing is obstructing the proper ventilation of, or free access to the machine.
2. Check the oil level in the bare compressor before each use by removing the oil filler plug. Add if necessary.
3. Make sure that the air inlet filter/silencer be kept clean at all times
4. Make sure that the main discharge valve is open.
5. Check the line and control voltage are available.
6. Push the reset button.
7. The fault indication will extinguish.
8. Switch the ON/OFF switch to the ON position.
9. The compressor will start and then load automa.

4.2.3 Measuring Fuel system pressure:

The pressure in the fuel system should be checked regularly. If the pressure drops check the Gas RMS differential filter pressure and clean if necessary to boost the feeder fuel pressure according to the engine load. If the Gas pressure from the TBS feeder is lower than the required level for the engine load inform it Titas gas representative to take necessary action

4.2.4 Exhaust system:

- The exhaust gas system leads the exhaust gases to turbocharger and after that out of the power house thus ensuring that emissions noise are kept on and acceptable level.
- The exhaust gas system consist of pipes flexible bellows compensate for thermal expunction, exhaust gas silencer.

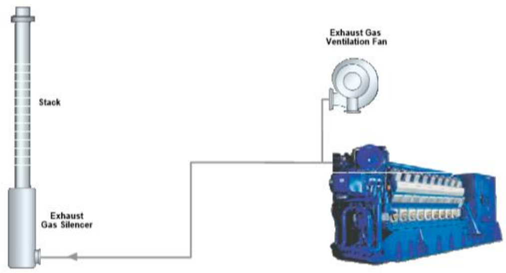


Fig: Exhaust gas system

- The exhaust gas system are equipped with ventilation unit and explosion vent located at strategic places.

4.2.5 Radiator capacity control:

The capacity control of radiators is by nature slow to respond

- Large time delays in the system due to long piping to from radiator.
- Large masses in the system.

The engine temperature control is always performed with 3 way control valves.

- Radiator capacity control use to keep control valve within the working range, keeping radiator outlet(s) slightly below desired engine inlet temperature.
- With above criteria fulfilled the secondary function is to minimize the system own consumption acc. To changing the engine load and ambient temperature.

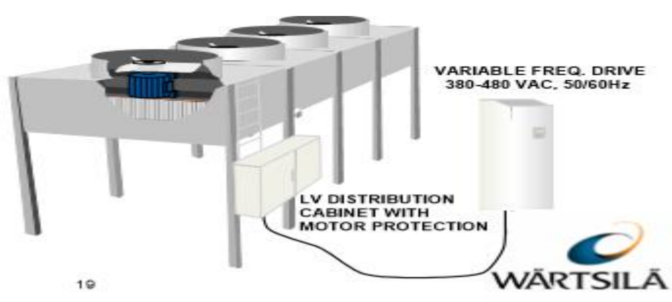


Fig: Radiator capacity control

4.2.6 Advantage of radiator cooling:

- Closed circuit.
- No water consumption
- Small environmental impact.
- No fog plumes or release of hot water to environment.
- Simple construction low maintenance.
- Straight forward engineering with engine wise radiators.

Fig: Advantage of radiator cooling

4.2.7 Cooling system:

The cooling water system removes heat generated by the engine. The cooling water also circulates through heat exchangers, where it is used for cooling the lubricating oil and the air & fuel mixture. The cooling water system preheats the engine before start, and keeps it heated during shutdown. Charge air and exhaust The charge air system provides the engine with clean combustion air, and the Exhaust gas system disposes of the exhaust gases from the engine. Output: SF-AUX-0

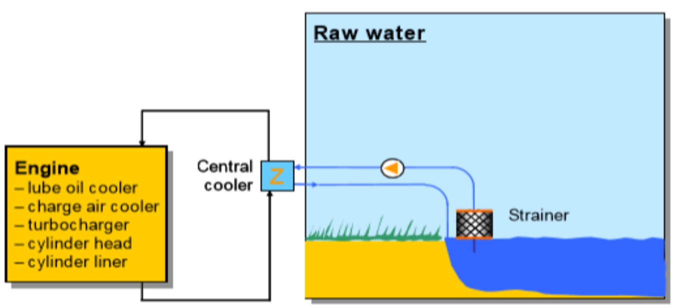


Fig: Cooling System

4.2.9The smart Substation:

Today, there is not a single component in a substation that has not been enhanced, enriched or augmented by some form of embedded digital technology, making them operate better at higher ratings with more reliability than ever before. However, the challenge now is integrating all of these elements into a totally digital substation and making it work in a demanding environment.

Long before there was a smart grid, the electric power industry had a stratagem of an all-knowing grid with technology-enabled substations networked into a communicating transmission and distribution grid.

Fig: The smart substation

4.2.10 Auxiliary Transformer energize procedure:

1. Check the transformer physically.
2. Check oil level, silica gel, winding and oil temperature, safety level setting.
3. Check the MV voltage.
4. Reset all MV breakers.
5. Close the transformer incoming breaker from MV bus.
6. Close the out going breaker to LV bus.

Fig: Auxiliary transformer

4.2.11 Auxiliary Transformer de- energize procedure:

1. Open the outgoing breaker to LV bus.
2. Open the transformer incoming breaker from MV bus.

4.2.12 Starting the DC system:

Output: SF AUX-01

1. Check the battery water level, specific gravity and voltage.
2. Check the LV voltage the available to power up the battery charger unit.

3. Close the battery charger respective breaker from LV panel.
4. Close the main breaker mounted inside the battery charger panel.
5. Reset the battery charger alarm.
6. Check input voltage, output voltage, output current and battery current.
7. Close the respective breaker DC loads from the DCDB panel.

4.2.13 Stopping the DC system:

1. Open all the respective breakers of DC loads one by one from the DBDC panel.
2. Open the main breaker mounted inside the battery charger panel.
3. Open the battery charger respective breaker from LV panel.

4.3 Operating and supervising the plant

4.3.1: Topping up the cooling water circuits:

The water level in the expansion vessel may due to evaporation of water or leaks in the system. If the minimum level reached in the vessel, water should be added to the cooling water circuit. Make sure that the maintenance water tank contains a sufficient amount of water and that the chemical content is correct.

Set the valves at the maintenance water pump in the correct positions to allow to be pumped to the cooling water circuit.

Open the shut-off valve in one of the filing lines from the maintenance water pump to the cooling water circuit. Start the water pump.

When normal level reached in the expansion vessel, stop the water pump.

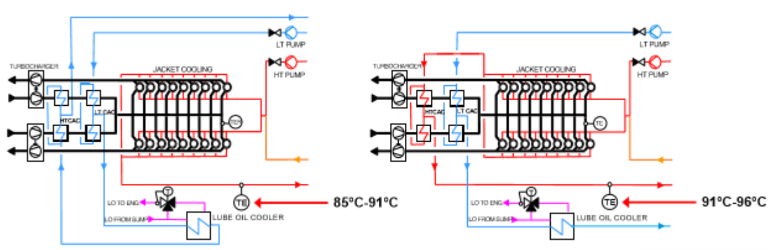


Fig: Cooling water circuit

4.3.2 Mixing chemicals to the cooling water:

The cooling water has to be analyzed regularly and chemical added to the water as necessary. Chemical can be added to the cooling water using the maintenance water tank and pump.

1. Fill the maintenance water tank with water.
2. Set the valves at the maintenance water pump in the correct positions. The water should be circulated within the maintenance water when the water tank is running.
3. Start the water pump.
4. Add the appropriate chemical to the water. Use the hose for chemical dosing.
5. Circulated the tank content until the chemicals are completely mixing with water.
6. Stop the pump.

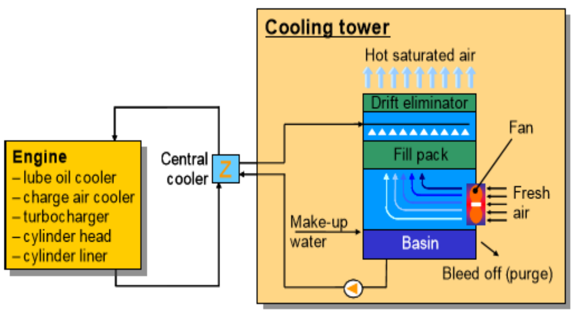


Fig: Mixing chemicals to the cooling water

4.3.3 Adjusting the fuel system valves:

The pressure of the fuel system should be checked regularly.

Note the pressure normally very according to engine load.

4.3.4 Lubricating oil sampling:

The lubricating oil samples should be taken from circulating oil with the engine in operation. Summary of the most important lubricating oil properties, preferred analysing methods, impacts on engine function, condemning limits and recommended levels for optimum performance.

Property	Impacts on engine function	Condemning limit	Recommended level for optimum performance
Base Number (BN) (*mg KOH / g*) ASTM D2896	Prevents corrosion.	Max. 50% depletion from fresh oil level.	Max. *50%* depletion from fresh oil level.
Viscosity (*cSt, at 100 °C*) ASTM D445	Provides hydrodynamic lubrication for bearings, etc. Reduces friction and thus fuel oil consumption.	Max. + 25% from fresh oil levels, at 100 °C. Max. + 50% from fresh oil levels, at 40 °C.	Max. + 15% from fresh oil levels, at 100 °C. Max. + 25% from fresh oil levels, at 40 °C.
Water (*vol-%*) or (*w-%*) ASTM D95 or D1744	Introduces corrosion. Deteriorates the hydrodynamic properties of the oil. Affects additive function.	Max 0.3 *vol-% / w-%*.	Max 0.3 *vol-% / w-%*.
Insolubles (*w-%*) ASTM D893b	Deteriorates the hydrodynamic properties of the oil. Affects additive function.	Max. 1.0 *w-%*, as n-pentane insolubles.	Max. 1.0 *w-%*, as n-pentane insolubles.
Total Acid Number (TAN) (*mg KOH / g*) ASTM D664	Corrosion. Oxidation and nitration (ageing) of lube oil compounds. Possible lacquer and deposit formations.	Max. 2.5 *mg KOH/g* increase from fresh oil levels.	Max. 2.5 *mg KOH/g* increase from fresh oil levels.
Oxidation (*Abs/cm*) IR	Possible lacquer and deposit formations. Viscosity increase.	Max. 25	Max. 25
Nitration (*Abs/cm*) IR	Possible lacquer and deposit formations. Viscosity increase.	Max. 20	Max. 20

4.4 Daily Engine Operation and power generation & related information:

Unit:1						
START	SYN	STOP	DESYN	AT(00 hours)		
		13.35		ENERGY METTER READING		ENERGY GENERATION TODAY
		14.02		TODAY	YESTERDAY	
15:22				414023	613858	165
		17:58				
20:40						
				SERVICE HOURS		
				TODAY	YESTERDAY	TODAY
				83176	83157	19

Unit:2						
START	**SYN**	**DESYN**	**STOP**	**AT(00 hours)**		
				ENERGY METTER(CFC) READING(MWH)		ENERGY GENERATION TODAY(MWH)
			14:02	TODAY	YESTERDAY	
14.58				569705	569543	142
			17:58			
19:14						
			19:38	**SERVICE HOURS**		
21:04				TODAY	YESTERDAY	TODAY
			2229	81595	81575	20
2249						

Unit:3						
START	**SYN**	**DESYN**	**STOP**	**AT(00 hours)**		
			12:51	ENERGY METTER(CFC) READING(MWH)		ENERGY GENERATION TODAY(MWH)
13:25				TODAY	YESTERDAY	
				566241	563073	168
			14:02			
15:15						
			17:58	**SERVICE HOURS**		
13:10				TODAY	YESTERDAY	TODAY
			14:38	80261	80244	20
20:37						

Unit:4						
START	**SYN**	**DESYN**	**STOP**	**AT(00 hours)**		
10:28			00:00	ENERGY METTER(CFC) READING(MWH)		ENERGY GENERATION TODAY(MWH)
				TODAY	YESTERDAY	
			11:02			
15:02						
			17:58			
19:05				**SERVICE HOURS**		
20:40			19:38	TODAY	YESTERDAY	TODAY
				80595	80584	11

SI NO	ITEM	UNIT	UNIT 1	UNIT 2	UNIT 3	UNIT 4	TOTAL THIS DAY	TOTAL THIS MONTH	TOTAL THIS YEAR
1	GENERATOR CONTROL PANEL	MWH							
	a) GENERATION		**204**	**196**	**209**	**199**	**806**		
2	RUNNING HOUR		**83200**	**81619**	**80288**	**80618**			
3	OPERATNIG HOUR		**24**	**24**	**24**	**23**	**95**		
4	STANBY HRS		**0**	**0**	**0**	**0**	**0**		
5	OUTGE HRS								
	a) PLANNED		**0**	**0**	**0**	**0**	**0**		
	b) FORCED		**0**	**0**	**0**	**1**	**1**		
	c) EXTERNAL REASON		**0**	**0**	**0**	**0**	**0**		
6	LOAD FACTOR	%					**99.51**		
7	AVAILABILITY FACTOR	%					**97.92**		
8	PLANT FACTOR	%					**97.78**		
9	AUXILIARY COSUMPTION	MWH							
10	GAS CONSUMED (Based on direct metter reading))	M^3					**34354**		
		SM^3							
11	AVG. GAS PRESSURE	(Psi)					**72.00**		
12	AVERAGE GAS TEMPERATURE						**72.69**		
13	OIL CONSUMED	Ltr.							
	a) LUBE OIL	Ltr.	**60**	**18**	**55.09**	**36**	**169.09**		
	b) Hyd. Oil	Ltr.							
	c) Brg.oil	Ltr.							
	d) Non. Detergent oil	Ltr.							
	e) Grease	Ltr.							
14	SCA CONSUMED	Ltr.							
15	AVG.LUBE CONSUMPTION	Ltr.					**0.1787**		
16	LUBE OIL FILLED	Ltr							
17	LUBE OIL RECEIVED	Ltr							
18	HEAT RATE	Kj/kwh					**8637.393**		
19	ENERGY EXPORT	MWH							
	a) 33kv metter						**792.00**		
	b) At quantum metter						**801.72**		
20	ENEGY IMPORT								
	b) 33kv metter	MWH							

	c) At quantum metter	MWH							
21	ENERGY EXPORT								
	At 33KV metter	MWH					**163.80**		

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Revision No:00
Effective Date:20June-19

SI NO.	ITEM	UNIT	UNIT				TOTAL THIS DAY	TOTAL THIS MONTH	TOTAL THIS YEAR
			1	2	3	4			
1	GENERATOR CONTROL PANEL	MWH	167	0	170	168	505		
	d) GENERATION								
2	RUNNING HOUR		83376	81646	80475	**80790**			
3	OPERATNIG HOUR		**20**	**0**	**20**	**20**	**60**		
4	STANBY HRS		**4**	**0**	**4**	**4**	**12**		
5	OUTGE HRS								
	d) PLANNED		**0**	**24**	**0**	**0**	**24**		
	e) FORCED		**0**	**0**	**0**	**0**	**0**		
	f) EXTERNAL REASON		**0**	**0**	**0**	**0**	**0**		
6	LOAD FACTOR	%					**62.35**		
7	AVAILABILITY FACTOR	%					**75.00**		
8	PLANT FACTOR	%					**60.96**		
9	AUXILIARY COSUMPTION	MWH					**11.20**		
10	GAS CONSUMED (Based on direct metter reading))	M^3					**21976**		
		SM^3							
11	AVG. GAS PRESSURE	(Psi)					**72**		
12	AVERAGE GAS TEMPERATURE						**72**		
13	OIL CONSUMED	Ltr.							
	f) LUBE OIL	Ltr.	**18**	**0**	**24**	**30**	**72**		
	g) Hyd. Oil	Ltr.							
	h) Brg.oil	Ltr.							
	i) Non. Detergent oil	Ltr.							
	j) Grease	Ltr.							
14	SCA CONSUMED	Ltr.							
15	AVG.LUBE CONSUMPTION	Ltr.					**0.1584**		

16	LUBE OIL FILLED	Ltr							
17	LUBE OIL RECEIVED	Ltr							
18	HEAT RATE	Kj/kwh					**8753**		
19	ENERGY EXPORT	MWH							
	c) 33kv metter						**493.80**		
	d) At quantum metter						**497.05**		
20	ENEGY IMPORT								
	e) 33kv metter	MWH							
	f) At quantum metter	MWH							
21	ENERGY EXPORT								
	At 33KV metter	MWH					**100.80**		

SUMMIT POWER PLANT LIMITED
ASHULIA 33.75 MW POWER PLANT
Date:25 june 2019

PARAMETER		TIME HRS	3:00				6:00				9:00			
		UNIT	1	2	3	4	1	2	3	4	1	2	3	4
1	ENERGY METTER	MWH	323054	310272	295472	314485	323075	3100	295496	314503	323096	310308	295517	314520
2	GEN LOAD	MV	7.5	6.8	8.0	6.0	7.2	4.4	8.0	6.0	5.51	5.6		5.56
3	GEN POWER FACTOR		.98	.98	.98	.95	.98	.98	.98	.95	.79	.80		.80
4	GEN. FREQUENCY	HZ	50.47	50.0	50.0	49.3	50.3	50.4	50.3	50.4	50.78	50.5	50.78	50.9
5	GEN. MV BUSBAR VOLTAGE	KV	11.2	10.8	11.2	11.3	11.1	11.3	11.2	11.2	11.2	11.3	11.50	11.5
6.1	GEN PHAGE CURRENT L1	AMPS	320	410	404	415	320	310	333	410	377	375		395
6.2	GEN PHAGE CURRENT L2	AMPS	300	320	325	344	384	315	285	325	402	395		378
6.3	GEN PHSGE CURRENT L3	AMPS	312	313	324	344	326	345	287	302	321	341		355
7.1	GEN. WINDING TEMP (L1)		76	88	78	86	77	88	78	85	84	78		86
7.2	GEN. WINDING TEMP (L2)		78	77	86	85	78	85	84	83	83	79		78
7.3	GEN. WINDING TEAMP (L3)	°C	76	78	87	86	85	87	79	83	84	85		79
8.1	GEN. BRG TEMP…end		85	83	85	83	85	86	87	87	78	87		87

Chapter-5

Switchgear Protection Relay:

- MV Switchgear
- LV Switchgear
- Voltage and Frequency Relay
- Generator Protection Relay
- Knock margine control
- Alarms
- Sychronizing or Synchronism
- Directional Relay

5.1 Medium Voltage Switchgear(MV):

The task of the medium voltage switchgear is to gather and distribute the generated power to a receiving network.

Standard medium voltage switchgear main features:

Standard: IEC60298,60694

Type: Metal clad, (LSC2B-PM)

Enclosure: IP4x, internal IP 2x

Ambiant: Max 40 °C (35°C 24h) Min -5°C

Altitude: 1000 m

Bus bar material: Cu

Breaker type: SF6, Vacuum

Fig: MV Switchgear

5.2 Low Voltage Switchgear (LV):

Low voltage system the station service system distributes low-voltage power to the consumers in the power plant, such as pumps, fans and heaters. The power for the internal consumption of the power plant is supplied from the medium voltage system through station service transformers. The power to the auxiliary units in the

Fig: Low Voltage Switchgear(LV)

power plant is distributed by a cubicle-type switchboard. The LV system includes several bus bar sections for distribution of power to engine-specific and common consumers. The bus bars are connected by circuit breakers. The low voltage system also supplies power to the DC system of the power plant.

5.3 Voltage and Frequency Relay:

The Reyrolle 7SR158 Argus voltage and frequency relays are numerical, multifunctional devices, with functionality designed for connection to voltage transformers Relays have three voltage inputs, six binary inputs and eight binary outputs and are housed in a size E4 case. Programmable logic is provided to allow the optimal configuration of relay functionality.

Fig: Voltage and Frequency Relay

5.4 Generator Protection Relay:

To protect the generator, the generator breaker is tripped by the generator protection relay in case of a fault. The generator protection relay includes a number of protection functions, such as:

• Thermal overload in stator winding; I >

• Network short-circuit, I >>

• Stator inter-winding short-circuit, differential protection relay

• Stator earth-fault, earth-fault relay

• Over voltage, Over voltage, relay

• Unbalanced load or shorted turns in the same phase, I2/In

• Under excitation and loss of synchromism, under-reactance relay

• Under-voltage and intermittent loss of voltage, under-voltage relay

• Temperature supervision of temperature detectors, PT-100 monitoring

• Inlet cooling air temperature high

• Leakage water detection (if applicable)

• Lubrication of jack-up pumps not in operation (if applicable) Additional protection:

• Frequency disturbance

• Reverse power

• Diode fault

• Vibration level

The protection system also includes a differential current relay.

Fig: Generator Protection relay

5.5 Knock margin control:

The main control module compares each cylinder's knock margine values and adjust the duration and of the individual gas valves with an offset in order to keep the currect margin.

Knock margin control use in high loads.

System components:

1. 01 main gas admission valve.
2. 02 knock sensor.
3. 03 exhaust gas temperature sensor.
4. 04 Cylider liner gas temperature sensor.

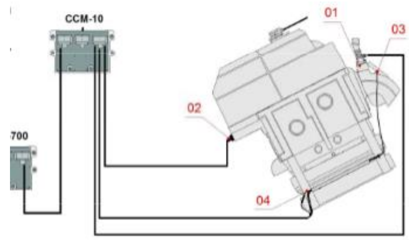


Fig: Knock margin control

5.6 Alarms:

- Main & PCC gas pressure deviation.
- High internal temperature in CCM unit(s)
- High load oscillation •HighTCspeed
- Crankcase pressure high
- De-rating caused by knocking
- HT-water temperature engine inlet high
- Light knocking
- Engine overload
- High HT water temperature, engine outlet
- Low control air pressure
- Low starting air pressure (+start block) LHT
- High cylinder liner temperature
- Highchargeairtemperature
- Low LT water pressure
- One phase sensor failed
- High charge air temperature
- High internal temperature in CCM unit(s)
- Turning gear engaged
- Chargeairtemperaturehigh
- High internal temperature in MCM unit Charge air temperature high
- Degassing failure
- Emergency stop activated High TC speed
- HT-water temperature engine inlet low
- Load deviation between reference and actual
- High lube oil temperature, engine inlet
- Low lube oil pressure
- Low instrument air pressure
- High exhaust gas temperature after turbo • .
- High main bearing temperature
- Low HT water pressure
- Low lube oil sump level
- Onespeedsensorfailed
- High fuel oil temperature
- One speed sensor failed
- Start attempt failed.

5Engine modes:

Emergency mode:

proceeded after any other mode. The engine is standstill or under deceleration, and brought to this mode by a WECS internal emergency stop (severe engine or WECS failure), or by an external emergency stop input.

Shutdown mode:

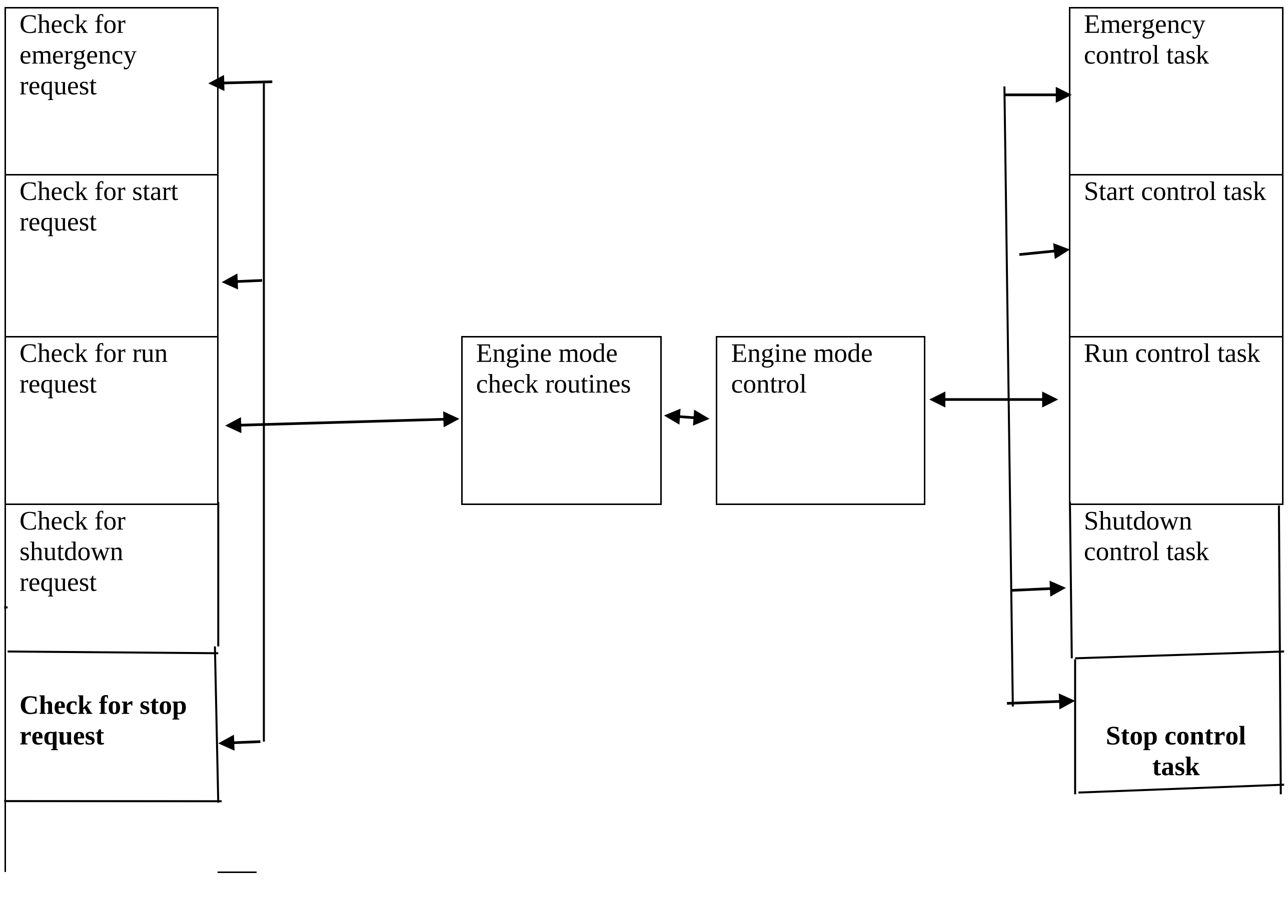
proceeded after stop mode, start mode or run mode.
The engine is standstill or under deceleration, and brought to this mode by an internal shutdown (engine or WECS failure), or by a shutdown input.

Run mode: proceeded after start mode.
The engine is running, i.e. the speed is above a pre-set speed limit and no stop, shutdown or emergency stop are active.

Start mode: proceeded after stop mode.
The engine is in start sequence (under acceleration). The start is initiated by a remote (or blackout) start control without any start blocking active.

Stop mode: proceeded after shutdown mode or emergency mode. The engine is standstill and stopped by a stop control device. The engine could also be in stop mode after an emergency stop or a shutdown. Any such sequence is finished and reset is performed. The engine is not necessary ready for start, a start blocking device can be active in this mode.

Engine Mode Control



5.7 Recommended operating data:

Apply to normal operation at nominal speed.

	Normal valus	Alarm (stop) limits
Load	100%	30-100%
	Temperatures, (°C)	
Lube oil before engin	60	80
Lube oil after engine	No measurement	
HT water after engine	91-100	100(105)
HT water before engin	5-8 lower	
LT water before charge air coole	28-38	
Charge air in air receiver	45	70
Exhaust gas after cylinder	See test records	550(580)
Exhaust gas before turbocharger		
Preheating of HT water	70	
	Pressure(bar)	
Lube oil before engine at a speed of 600 RPM (10.0 r/s)	4.5	3.0(2.0)
720 RPM (12.0 r/s) - 750 RPM (12.5 r/s)	4.5-5.5	3.0(2.0)
HT/LT water before HT/LT pump (=static)	0.7-1.5	
HT water before engine	2.5 + static press.(x)	1.0 + static press.
Gas before engine	4,5	
Compressed air	Max30	18
Charge air	See test records	
Instrument air	7	5
	Others pressures(bar)	
Opening pressure of safety valve on lube oil pump	6-8	
Electronic alarm for high pressure drop over lube oil filter	0.8-2.0	0.8 (first) 2.0 (second alarm

Chapter-6

Sensor of Engine:

6.1.1 Thermostatic valve :

When the temperature exceeds the nominal value, the contents of the elements (1) expands and forces the valve unit (2) towards the end flange, thus passing a part of the oil through the cooler. This movement is continous and maintains the right temperature of the mixed oil. As the cooler becomes dirtier, the temperature will rise a few degrees, which is quite normal, as the valve needs a certain temperature rise to increase the oil flow through the cooler.

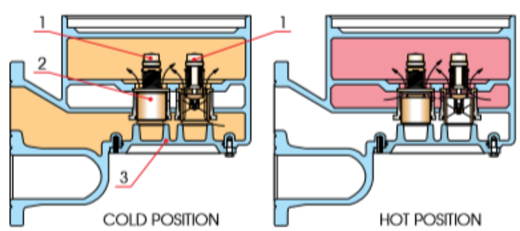


Fig: Thermostatic valve

1. Thermostat elements

2. Valve unit

3. End flang

6.1.2 Exhaust wastegate:

•Used on high loads to obtain correct air flow into the cylinder
•One throttle valve used for both exhaust banks
•Charge air pressure is used as input parameter
•Reference and monitored value used for function control
•Malfunction gives load reduction

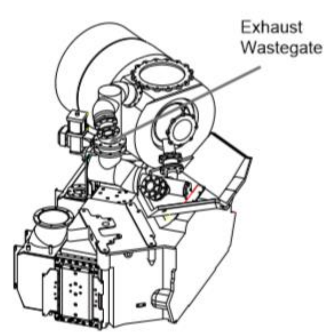


Fig: Exhaust wastegate

6.1.3 Wastegate valve:

•High temperature resistant butterfly valve

•Pneumatic actuator

•Pneumatic positioner

•I/P converter is creating the pressure signal

Fig:Wastegate valve

6.1.4 Charge air cooler:

•The charge air cooler is a as standard of 2-stage type, consisting of HT-and LT-water stage

•Fresh water is used for both circuits.

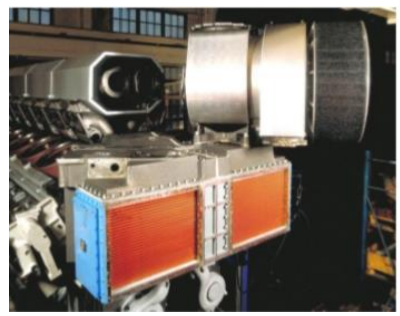


Fig Charge air cooler

6.1.5 Combustion chamber

The Quartette combustion chamber breaks down the swirl into turbulence and promotes rapid combustion. The Turbine combustion chamber is the standard combustion chamber for this engine type with low turbulence and slow combustion as a consequence. The Turbine combustion chamber is the standard combustion chamber for this engine type with low turbulence and slow combustion as a consequence. For both combustion chambers the spark plug is centrally located in the cylinder head. One drawback with a fast burning combustion chamber is that the exhaust gases are colder due to the increase in effective expansion ratio.

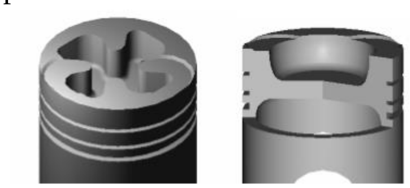


Fig: Turbine combustion chambers

The ignition timing resulting in maximum efficiency is called MBT ignition (maximum brake torque ignition). A common rule says that 50% of the fuel is burned at about 10 CAD ATDC, resulting in PMAXα ≈ 16 CAD ATDC [3], at MBT ignition. Earlier tests with this fast burning combustion chamber show that MBT ignition is when 50% of the fuel is burned at 8-10 CAD ATDC, resulting in PMAXα ≈ 12-14 CAD ATDC

6.1.6 Programmable logic controller(PLC):

Stop and shutdown procedures are equal regarding the engine functions. The difference between these two is in the initiation. Stop is initiated by the operator or PLC. Shutdown is initiated by engine control system (WECS) or by PLC and is caused by some parameter or measured value exceeding shutdown limit. In both cases the actual procedure is the same but varies between engine types.

When the stop request is activated, the PLC first unloads the engine and then shuts off the gas supply from gas regulating unit to the engine. The PLC then tells the WECS to shut down the engine.

Fig: Programmable logic controler

In case of engine initiated shutdown, the PLC shuts off the gas supply to engine immediately after WECS signal. Note that the engine is not unloaded in this case.

6.1.7Analog output modules:

- Same module for different signal types ±10V; 0 ... 10V; ±20mA ; 0 ... 20mA; 4 ... 20mA
- 4-channel cards for Wärtsiläprojects
- Red LEDs for group faults/errors Miblh 200m
- Maximum cable length 200m
- Mechanical coding element for the wiring connector to avoid connecting to wrong type of card

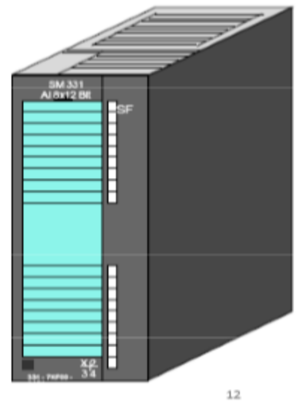


Fig: Analog Output modules

6.1.8 Digital input modules:

- Input types: 24 VDC, 120 VAC and 120/230 VAC
- Inputs are optically isolated
- Green LEDs to indicate signal statuses at the inputs
- Maximum cable length:
  –Unshielded 600m –Shielded 1000m
- Mechanical coding element for the wiring connector to avoid connecting to wrong type of card

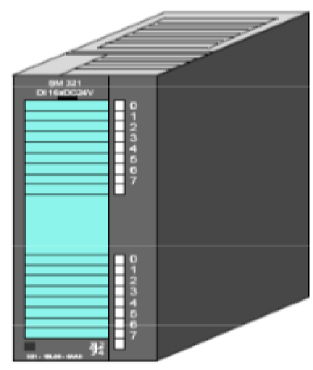


Fig: Digital input modules

6.2.1Fire fighting and gas detection system:

Each country has it's own fire protection legislation and codes of practise. Therefore, project design is to be reviewed with the local authorities and the system is chosen on a case by case basis. The power plant is subdivided into separate fire areas for the purpose of limiting the spread of fire, protecting personnel and limiting the resultant consequential damage to the plant. Fire areas are separated from each other with fire barriers, spatial separation or other approved means.

Media capable of burning in a gas power plant are:

• Gas

• Cables

• Lubrication oil

6.2.2Emergency mode of control system:

Emergency mode is initiated by a hardwired signal. Emergency mode for power plant is shown in Figure 2. Emergency can be initiated either by pressing emergency stop push buttons in:

• common panel, which means a plant emergency mode is initiated and all the engines are shut down or

• by engine wise panels, which means an emergency mode is initiated for that engine only o

by a fire or gas detector

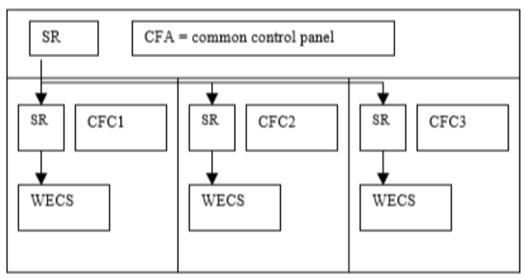


Figure: A schematic diagram for emergency mode of control system.

6.2.3 Gas trips (DF):

In addition to normal alarms and shutdowns, the DF engine can be tripped from gas operation to diesel operation in case of problem. Reasons to trip the engine are following:

- Charge air pressure sensor failure, which may cause incorrect A/F-ratio and misfiring.
- Heavy knocking, may indicate too much gas being admitted to cylinder.
- Pilot fuel pressure sensor failure may cause misfiring due to incorrect pilot fuel pressure.
- Low/high pilot fuel pressure may cause misfiring.
- Gas pressure build up time elapsed. Gas pressure has not risen to correct value within time limit.
- Gas pressure deviation. May lead to misfiring due to incorrect A/F-ratio.
- Exhaust gas temperature deviation. May indicate improper A/F-ratio.
- Max idle time. As with SG engine

6.Engine speed measuring:

The engine speed is measured, based on the signal from two speed sensors. Both speed sensors are connected directly to the main control module (MCM-700) and CCM-10 modules, in which the speed calculation is carried out. The information in MCM-700 is used as feedback for the internal speed controller, but also for overspeed protection, and additionally in some engine speed dependent control maps. In case both speed signals interrupt in the main control module, it will use the speed indication sent out over CAN from the cylinder control modules.

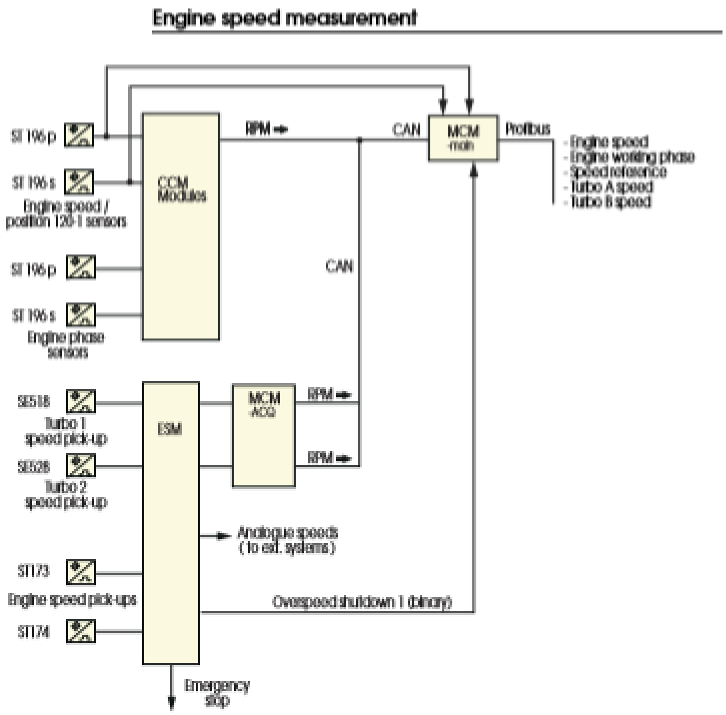


Fig: Engine speed measuring

The sensing gap for these engine speed sensors has to be 2,5 mm +/-0,2mm. The speed signal pulse train from the two speed sensors will have the shape as in picture below. This signal is connected to all cylinder control modules, as well as to the main control module.

The main control module however, has no use of the TDC information, only the speed level.

As the engines controlled by WECS 8000 are 4-stroke engines, the crankshaft and thereby flywheel will make two revolutions for one complete engine cycle. To detect which TDC marker signal (missing pulse) belongs to the working phase of cylinder A(1), also engine phase detection is needed. Two phase sensors are provided of redundancy reasons.

6.Phase sensors on camshaft end:

All four sensors are individually monitored in the cylinder control modules, and an alarm will be initiated if any of these sensors would fail. Each cylinder control module sends the calculated speed over CAN to the main control module, and if the prime speed signal fails in the main control module, it will initiate an alarm, and use the information over CAN as back-up signal for the speed controller and other calculations.

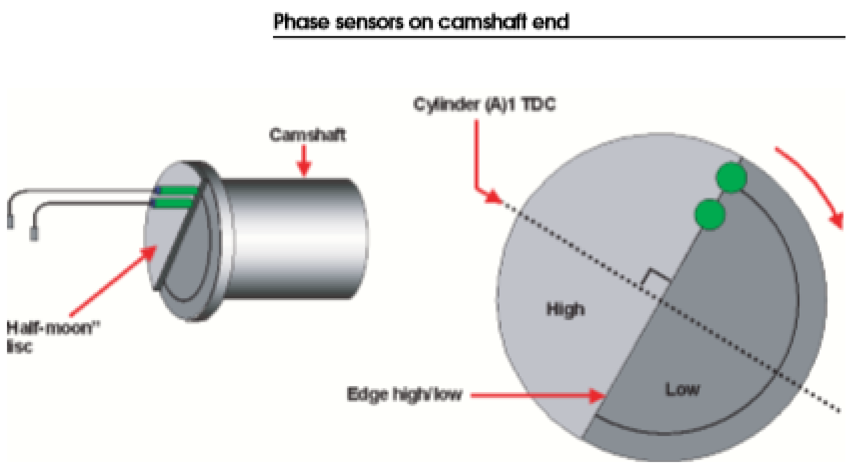


Fig: Phase sensors on camshaft end

In case of an engine overspeed, the main control module will instantly initiate an emergency stop. Also an independent second overspeed protection is provided on the engines, as part of the ESM module's functionality. Two separate back-up engine speed sensors are located on the flywheel end of the A-bank camshaft and these are connected to this independent safety module, which is located in the WECS cabinet. The ESM initiates independently of WECS an emergency stop of the engine, in case engine overspeed is detected.

6Alarm and safety system

Before the PLC activates a start request, the engine must be ready for start. The status for all start blockings (and alarms) and engine ready to start signals, is sent to the PLC via Profibus.

The list below shows all the conditions that must be fulfilled to get the engine ready for start.

- Engine must be in stop mode.
- The emergency stop button on the cabinet must be in normal position.
- Limit switch indicating turning gear engaged must not be activated
- Start air pressure must be higher than a preset limit.

- The prelubrication pressure must be higher than a preset level.
- The MCM digital input “engine stop” must be deactivated.
- HT-water temperature must be higher than a preset start blocking limit.
- The power supply to the CCM must be switched on.

6Emergency stop:

The emergency stop is generated in the MCM, caused of an emergency stop request. The status of these are all sent via Profibus to the PLC.

The emergency stop requests are:

- **Emergency stop push button on engine, or externally pressed (connected to input "External shutdown 4")**
- **Engine overload.**
- **Both speed sensors failed.**
- **Overspeed from speed sensors (MCM-700) .**
- **Overspeed from ESM (Engine Safety Module).**
- **Degassing failure in shutdown mode. Activated if the gas pressure is still present after the shutdown control task has disabled the inlet gas pressure control.**
- **CCM power supply low/high.**
- **Safety wire loop released.**

6Gas injection:

The gas supplied to the engine passes two regulating units, one for MCC gas and one for PCC gas supply. The gas regulating units consist of a filter, pressure regulating valves, safety (shut-off) valves and ventilation valves, see Fig 23-16.

The solenoid valves (safety and vent valves) on the gas regulating unit are controlled by the PLC. The pressure regulating valves are controlled by the MCM.

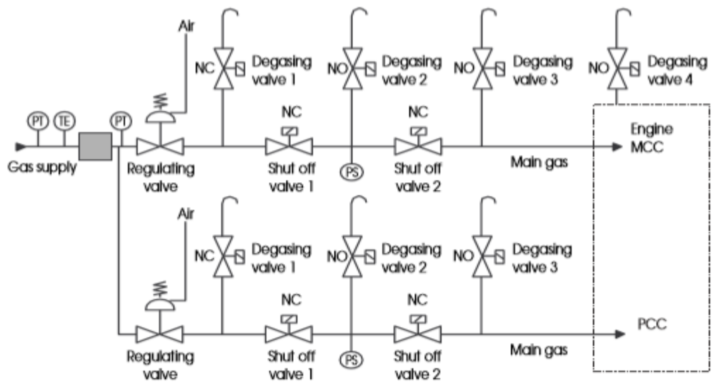


Fig: Gas injection

The gas supply pressure reference from the MCM is set to depend on the engine load. The actual pressure is measured and set according to a reference pressure map, see Fig 23-17. If the deviation is too high an alarm will be initiated and sent to the PLC via Profibus. If the deviation increases more, the safety valves on the gas regulating unit will cut the gas supply to the engine immediately. Both references and actual pressures are sent to the PLC via Profibus for the main gas system.

6Ignition timing control:

For ignition timing control, two hardwired signals are used, spark firing timing and spark reference. These signals are connected between the CCM A1/B1 and the WCD-10 ignition modules. As the ignition control module has no internal engine position measurement, these signals will over the complete engine cycle accurately define when each firing must occur. The firing order for a specific engine is handled by relevant wiring set-up between the cylinder control module‘s drive outputs and the coil-on-plugs for each cylinder.

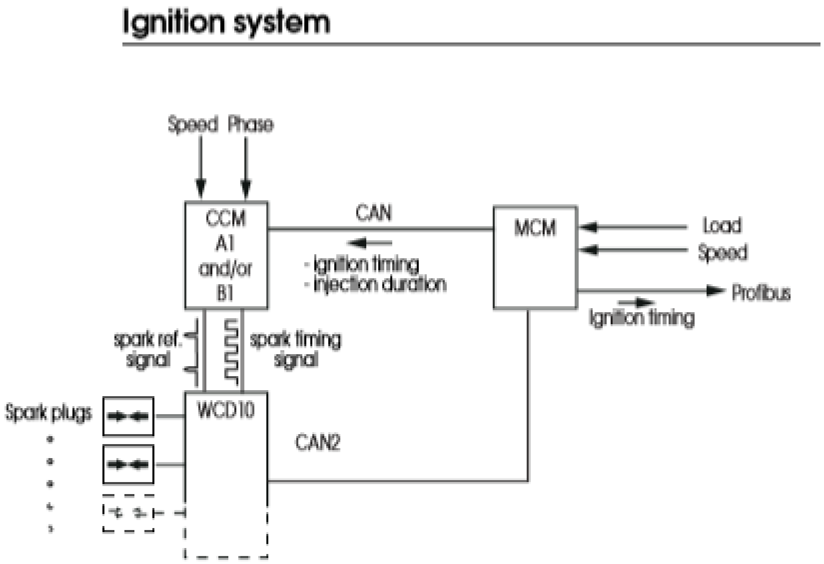


Fig: Ignition system

The ignition system is of capacitor discharge (CD) type. Internally the WCD-10 boosts the 24VDC up around 400VDC. The high voltage is used to charge the so called discharge capacitor. When the WCD-10 get a spark firing timing order it will discharge the energy stored in the capacitor to the primary circuit on the ignition coil COP (Coil On Plug = integrated ignition coil and high voltage extender). This will induce a linear fast rising voltage on the secondary circuit. Depending on load and spark plug condition the voltage is normally 8 to 15kV.

6.2.4 Maintenance Schedule:

04.1	Every second day, irrespective of the engine being in operation or not.	
Automatic prelubrication	Check operation	03.2 18.9

04.2	Once a week irrespective of the engine being in operation or not

03.2	Test start (if the engine on stand-by).	03.2

04.3	**Interval: 50 operating hours**	15.5
Air coolers	**Check draining of air coolers** 15.5 Check that the draining pipes are open, check if any leakage	03.4.1
Automation	**Check operating values** Check and record all operating values.	03.4.1
Cooling water system	**Check water level in cooling system** Check the water level in the expansion tank(s) and/or the static pressure in the engine cooling circuits.	19.1.3
Connecting rod	**Check tightening of the connecting rod screws** Check the tightening of the connecting rod screws after the first 50 operating hours on a new engine and, after overhaul, those screws that have been opened. Note! Pump to stated pressure. Tighten if possible. Do not loosen!	07.3
Crankshaft V-engines	**Check tightening of the counterweight fastening nuts** Check tightening of the counterweight fastening nuts after 50 running hours. Re-tighten the nuts.	03.4.1
Gas and lub. oil filters	**Check pressure drop indicators** Replace filter cartridges if high pressure drop is indicated	03.4.1 18.2
Lubricating oil sump	**Check oil level in sump** Check oil level by means of dip stick, compensate for consumption	18.2 02.2
Main bearings	**Check tightening of main bearing screws** Check the tightening of main bearing screws after the first 50 operating hours on a new engine and, after overhaul, those screws that have been opened. Note! Pump to stated pressure. Tighten if possible. Do not loosen!	10.3.3 07.3
Multiduct	**Check the tightening of the multiduct screws** Check the tightening of the screws after the first 50 operating hours on a new engine and those screws after an overhaul that have been removed.	07.1
Running-in filter	**Remove the running in filter** Remove the running-in filters after the first 50 operating hours and mount the hydraulic jack in upper level.	10
Turbocharger	**Water cleaning of compressor** Clean the compressor by injecting water.	15.3.3
Valve mechanism	**Check the valve clearances** Check the valve clearances after 50 hours' running in new and overhauled engines.	12.2 06.1

04.4	**Interval: 500 operating hours**	
Cooling water	**Check water quality** Check content of additives	19.2 02.3
Lubricating oil	**Take oil sample** In a new installation or after change to use of a new lubricating oil brand, take samples for analyzing.	02.2.3

04.5	**Interval: 1000 operating hours**	
Air filter (on-built)	**Clean turbocharger air filter** Remove the filter(s) and clean according to instructions of the manufacturer (more often, if necessary).	15.2

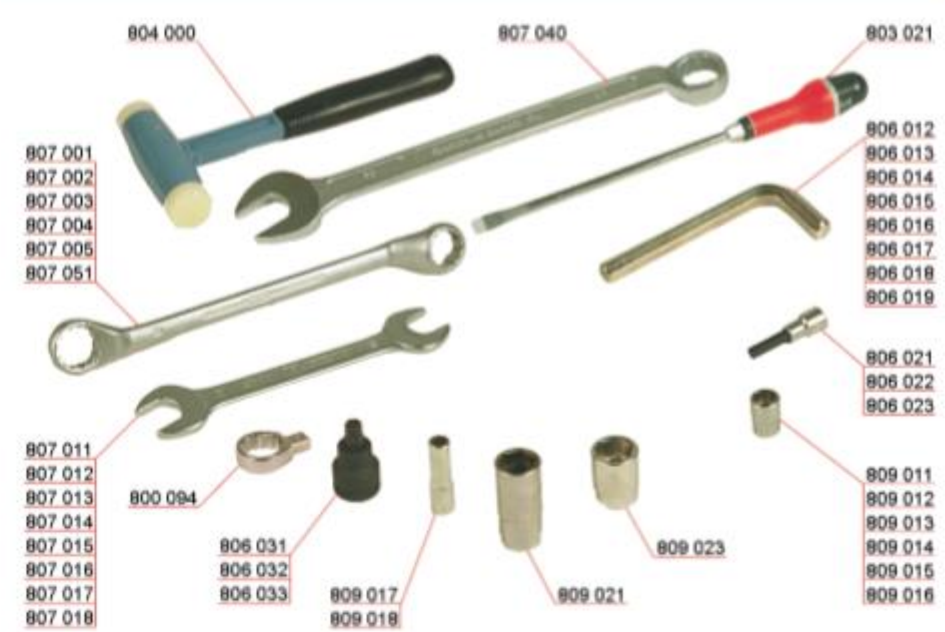
El. lubricating oil pump	Regrease prelubricating pump Regrease the pump under running condition.	18.9
Gas filter Engine mounted	**Replace gas filter cartridges** Replace the engine mounted filter cartridge after the first 1000 operating hours on a new installation. Clean the filter housing outside an inside. Following intervals for both filters 4000 hours	17. 17.2
Ignition system	**Replace spark plugs** Replace the spark plugs if the engine is started/stopped daily or more often.	16.4.3
Ignition system	**Clean and check the condition of the ignition coil** Clean and check the condition of the extension if the engine is started/stopped daily or more often. Replace O-rings.	16.4.2

6.3Maintenance Tools:

6.3.1Tightening Tools:

Code	Description	Drawing No.
800093	Torque wrench	75-400 Nm
806000	Hexagon bar kW 27	4V80G0018
820000	Torque wrench 20-100 Nm 4V92K0207 820003	4V92K0207
820003	Ratchet handle 20x630 with 3/4" square drive	4V80K0014
820004	Ratchet handle 12.5x300 with 1/2" square driv	
820005	Speed brace B12.5x50	
820006	Extension bar B12.5x250 with 1/2" square driv	
820007	Adapter socket wrench A20x12.5, 3/4"x1/2	
820009	Torque wrench 150-800 Nm	4V92K0207

6.3.2 Hand Tools:



Code	Description	Drawing No.
800094	Box wrench head 24 mm	4V92K0208
803021	Screwdriver 2x12M	4V84L0019
804000	Non recoiling hammer D40	4V80L0005
806012	Key for hexagon socket screw 4	
806013	Key for hexagon socket screw5	
806014	Key for hexagon socket screw	
806015	Key for hexagon socket screw	
806016	Key for hexagon socket screw 10	
806017	Key for hexagon socket screw 12	
806018	Key for hexagon socket screw 14	
806019	Key for hexagon socket screw 17	
806021	Bit, hexagon socket screw 6 with 1/2" square drive	4V80L0001
806022	Bit, hexagon socket screw 8 with 1/2" square drive	4V80L0001
806023	Bit, hexagon socket screw 10 with 1/2" square drive	4V80L0001
806031	Bit, hexagon socket screw 14 with 3/4" square drive	4V80L0001
806032	Bit, hexagon socket screw 17 with 3/4" square drive	4V80L0001
806033	Bit, hexagon socket screw 19 with 3/4" square drive	4V80L0001

6.3.3 Measuring and testing equipment:

Code	Description	Drawing No.
800117	Cylinder pressure indicator, Kistler 2515A electronic mode	
800118	Laser temp.meter Thermo-Hunter PT3LF	
800119	Multi loop calibrator Jofra MLC	
800120	Charger for Jofra MLC	
847010	Pressure sensor tester	3V84H0038
848030	Tachometer	
848031	Temperature transducer control equipmen	
848033	Cylinder pressure indicator, electronic model	
848034	Voltmeter	
848035	Voltmeter, universial	
848036	Oscilloscope	

6.3.4 Miscellaneous Tools:

Code	Description	Drawing No
800062	Mounting & removing tool for camshaft bearing bush	3V83H0167
800063	Hydraulic extractor (1)	3V83E0061
800064	Checking tool for cylinder/valves tightness	
800065	Deflection indicator	4V84K0058
800066	Locking plate for injection pump tappet	4V83E0121
800067	Securing pin for valve tappet	4V83E0124
800068	Lifting eye bolt M12	
800069	Lifting eye bolt M16	
800074	Wrench for centrifugal filter	4V80G0049
800122	Extractor plate for holder of thermostatic element	4V83H0490
800124	Mounting tool for connection piece (2)	1V84G0580
800132	Pneumatic test equipment for injection pump	1V16T0167
800151	Mounting tool for connection piece	2V84G0583
837058	Nut for extractor (water injection system)	4V83H0536
846059	AMP hand crimping tool	4V84G0475
846197	Mounting tool for pump cover, when TC in the free end	1V84G0613

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