water cooling system of WDM3A diesel locomotive

Introduction:

- Water cooling is a method of heat removal from components and industrial equipments. As opposed to air, water is used as the heat conductor.

HEAT SOURCES

1. Burning of fuel
2. Heat developed by compression of air
3. Frictional heat

HEAT DISTRIBUTION

1). **1/3** = converted into **useful work** (transferred into **mechanical energy**

2). **1/3** = lost as **exhaust gases**

3). **1/3** = lost for **cooling** / absorbed by metallic walls of the combustion chamber.

OVERHEATING

1). Breakdown of L.O. Film.

2). Loss in material strenght.

3). Excessive stresses due to unequal temperatures.

4). Faliure to maintain proper clearances between running parts.

COOLANTS

1). Water

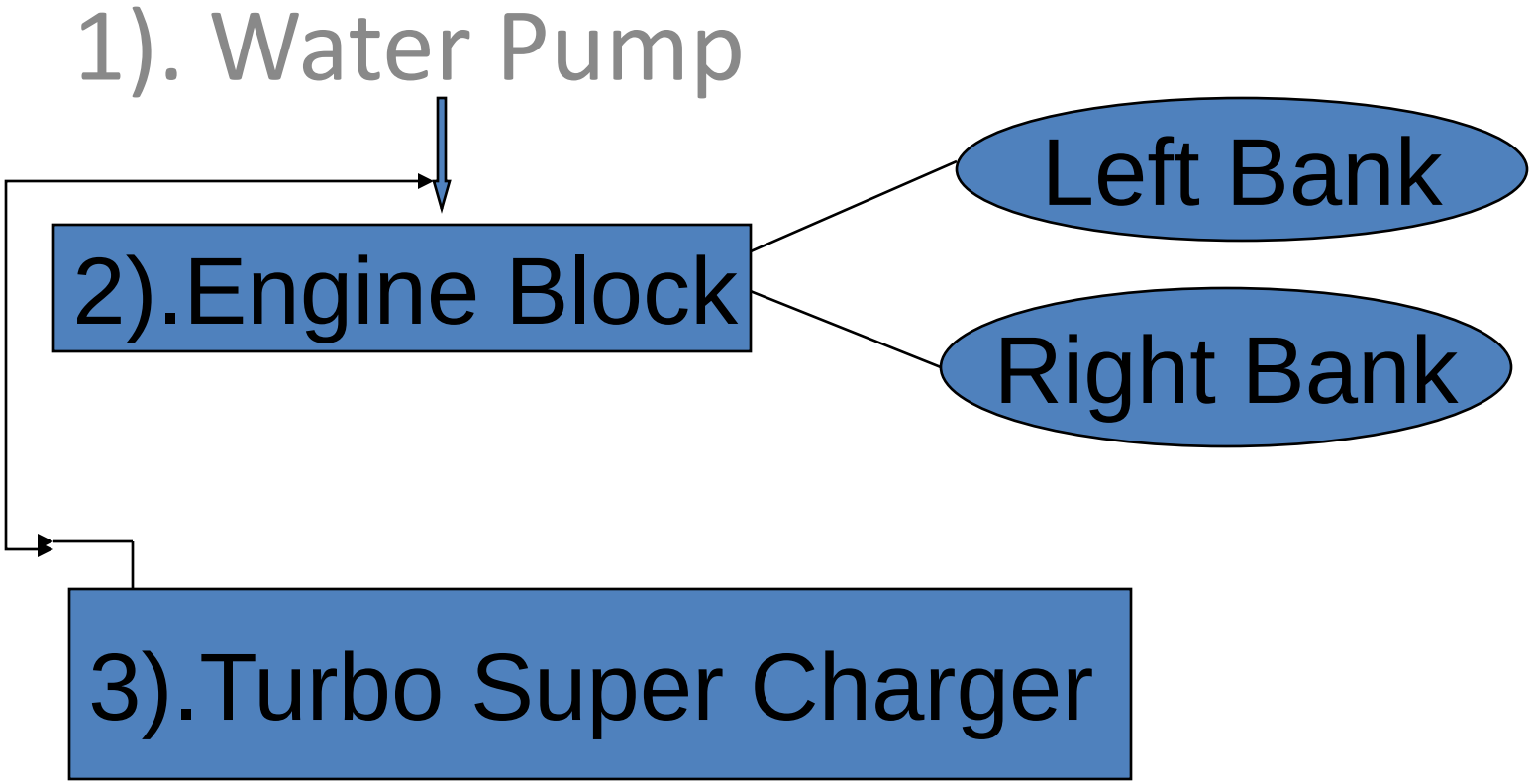
1.1). Raw water

1.2). Distilled water

1.3). De- mineralized water

2). Lub oil

MAIN COMPONENTS OF SYSTEM


1). Water Pump
2).Engine Block
Left Bank
Right Bank
3).Turbo Super Charger

Water pump tell tale Hole

POWER PACK

POWER PACK OF ALCO LOCO

4). Cylinder Liners

5). Water Jumpers

6). Cylinder Heads

7). Water Raisers

8). Water return header pipes

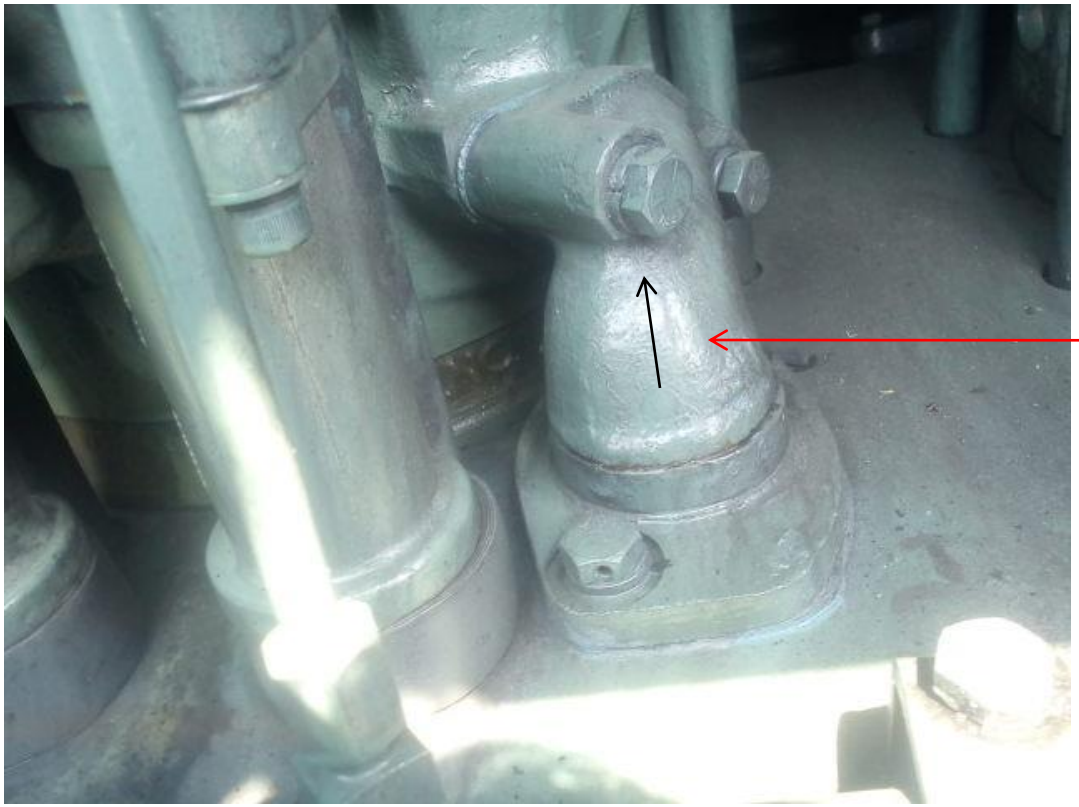
9). Bubble Collectors

10). TSC Vent Pipes

11). Water Temperature Manifold

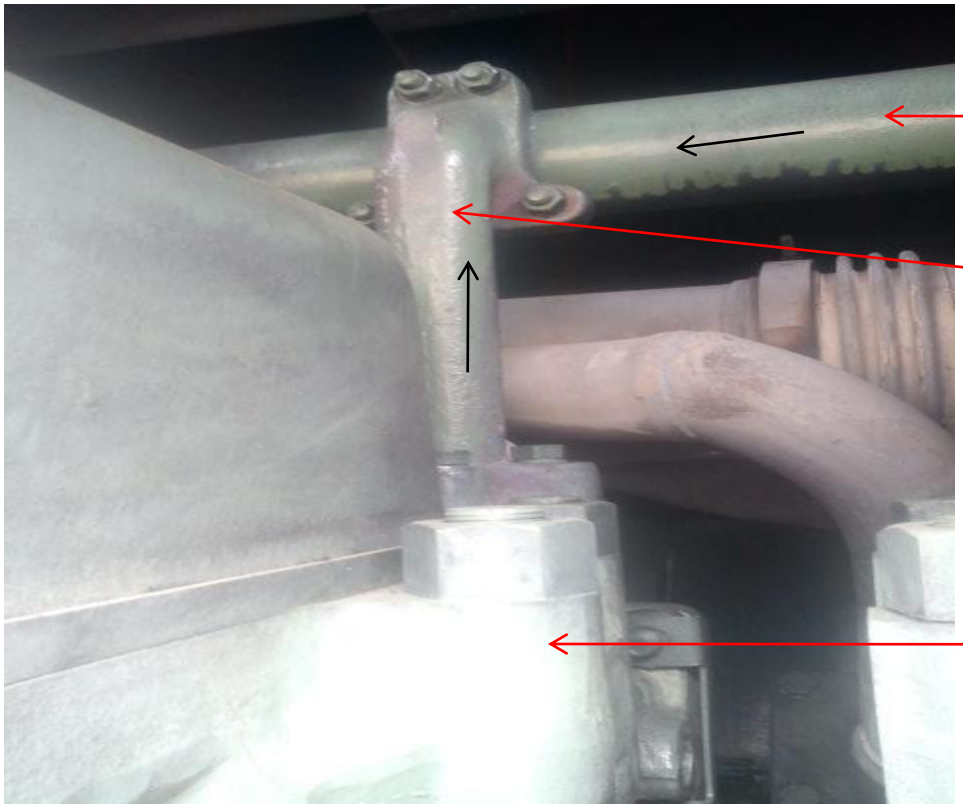
Water jumper hole in cylinder head

Hole on block for water jumper



Water jumper connected from Water jacket to cylinder head

In above picture water flowing direction is shown. The cooling water flows from water jacket To cylinder head for cooling of cylinder head.



Water return header

Water riser pipe

Cylinder head

The incoming water goes out after cooling the cylinder head through water riser to water return header.

Bubble collector

Right side water return header

Water riser pipe

12). Radiators

13). After Cooler

14). Radiator Fan

15). Expansion Tanks

16). Expansion Tank Equilising Pipe

17). Water Filling Cap

18). Water Pressurisation Cap

19). Glow Rod Gauge

20). Water ‘L’ Pipe

21). Water Drain Cock

22). Suction Pipe

Right side
Bubble collector

Right side bubble collector and its connection from water return header is shown.

Bubble Collector


DE-
AERATOR
ASSEMBLY

Principles of operation

- Thermal de-aeration relies on the principle that the solubility of a gas in water decreases as the water temperature increases and approaches its boiling point. In the de-aerator, water is heated up to close to its boiling point with a minimum pressure drop and minimum vent. De-aeration is done by spraying feed water into a chamber to increase its surface area, and may involve flow over multiple layers of trays. This scrubbing (or stripping) steam is fed to the bottom of the de-aeration section of the de-aerator. When steam contacts the feed water, it heats it up to its boiling point and dissolved gases are released from the feed water and vented from the de-aerator through the vent. The treated water falls into a storage tank below the de-aerator.


Trays seen
from bottom

Water Cooling System of WDM3A Locomotive

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 liner, cylinder head etc. Unless the heat is taken away from them and dispersed elsewhere, the components are likely to fail under thermal stresses.

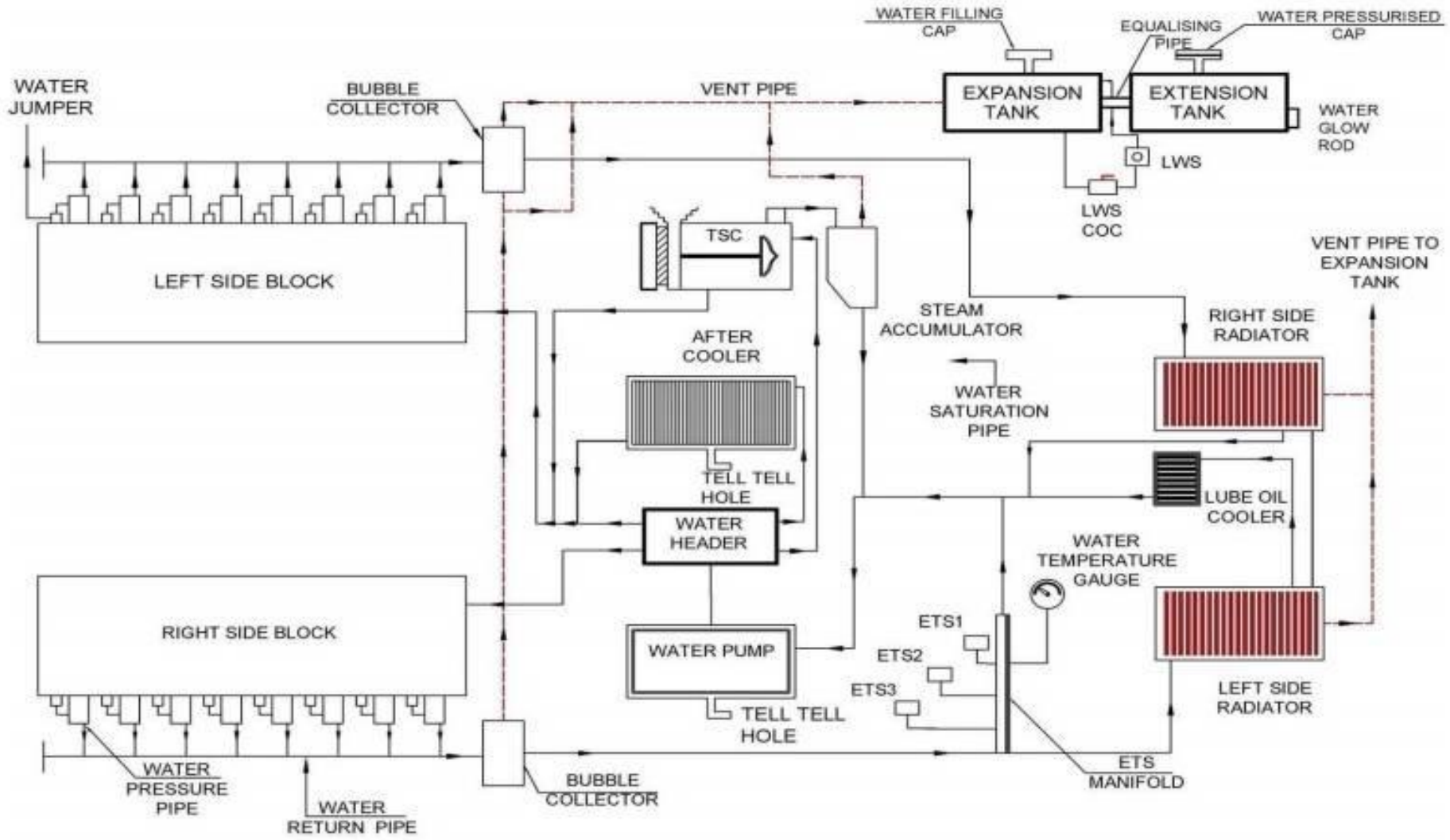
- The WDM3A class locomotives have a closed circuit pressurized water cooling system for the engine. The system is filled in by 1210 liters of de-mineralised water treated with corrosion inhibitor.
- The water circuit has two storage tanks in two segments known as expansion tanks on top of the locomotive.

Driven of Water Pump

centrifugal pump is main part.

A centrifugal pump driven by the engine crankshaft through a Extension gear. It sucks water from the system and delivers it through outlet under pressure.

WATER COOLING SYSTEM OF ALCO LOCO



Three-way pipe

This pipe connection is the delivery side of water pump. From this junction point one connection Goes to right side of block water gallery and second connection goes to left side water gallery. The third connection goes to turbo super charger.

This pipe is outlet of right side radiator and connected on the suction side of water pump.

(1)

- The First 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.

Right side block water jacket.

Left side block water jacket.

In above picture block water jackets are shown. Water pump outlet pipe are being Connected on both jacket flange through branch pipe.

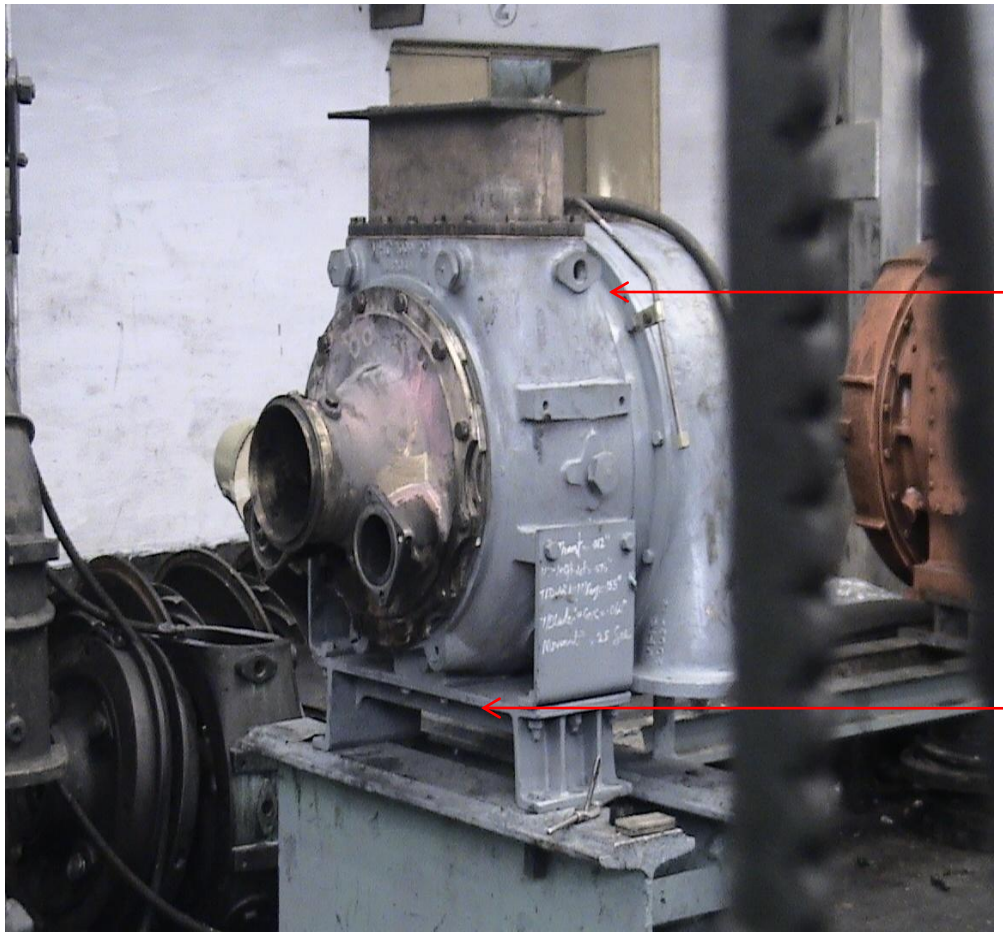
The Second connection from the three-way elbow leads to the right side of the cylinder block. After cooling the cylinder liners, heads etc. On the right bank the water reaches the left side radiator for cooling itself.

- Individual inlet connection with water jumper pipes and outlet by water riser pipes are provided to each cylinder head for entry and outlet of water from the cylinder head to the water outlet header. Cooling of cylinder liners, cylinder heads, valves and fuel injection nozzles are done in this process.

Valve Lever Mechanism

(3)

- To the turbo super charger through a flexible pipe to cool the intermediate casing, bearings on both sides of rotor and turbine casing.



Above is the picture of ALCO model TSC. Water enters in TSC from bottom of intermediate Casing and out from top of turbine casing. Through a pipe outlet is connected from water pump suction line.

RETURNING OF WATER

1). From TSC

2). From Left Bank

3). From Right Bank

(1) FROM TSC

After cooling the components in the turbo-supercharger, water returns to the inlet side of the pump through a Steam Accumulator. The Steam Accumulator with a vent line is a means to collect air bubbles formed due to evaporation and pass it on to the expansion tank so that they cannot cause air lock in the water circulatory system.

(2) FROM LEFT BANK

After cooling the cylinder liners, cylinder heads on the left bank of the engine then pass on to the water outlet header.

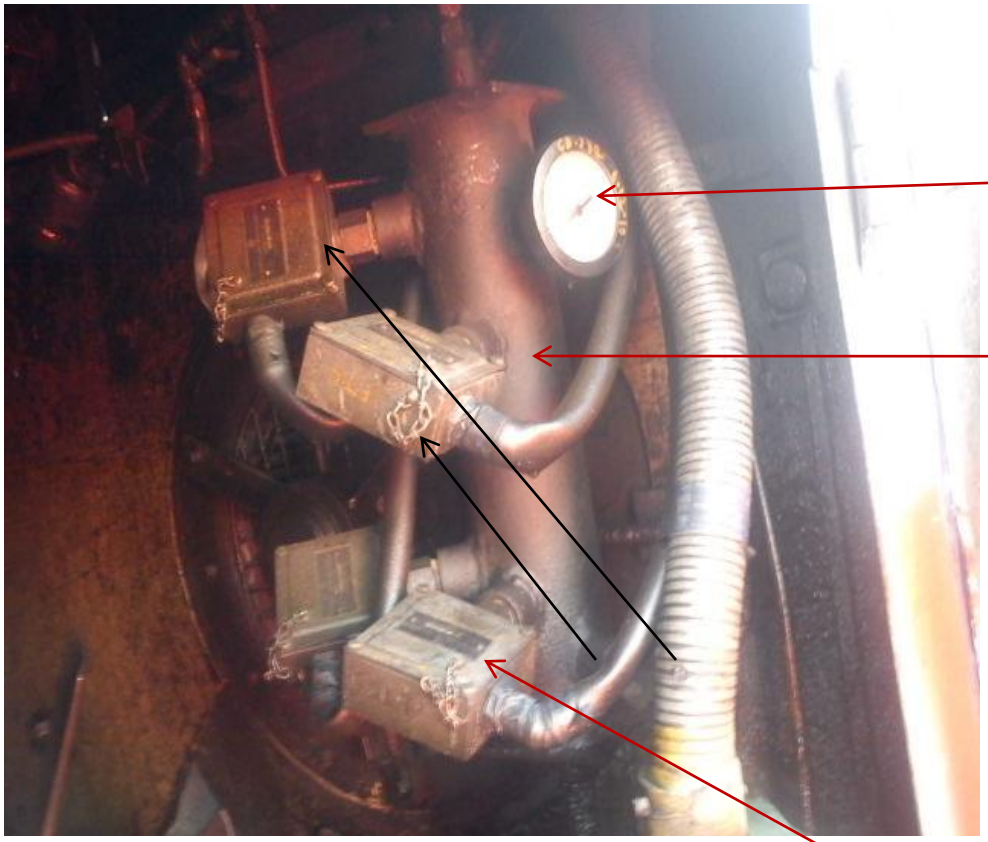
Water then proceed to the Right side radiator for circulation through it and release its heat to the atmosphere to cool down itself before recirculation through the engine once again.

(3) FROM RIGHT BANK

After cooling the cylinder liners, heads etc. on the right bank, reach the Left 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.

TEMPERATURE MANIFOLD

Three other temperature switches are also provided here out of which ETS-1 is for starting the movement of radiator fan at 68 deg. C slowly, through the eddy current clutch. The second switch ETS-2 picks up at a water temperature of 74 deg. C and accelerate the radiator fan speed to full.



Temperature gauge

Water header for engine Temperature switches

ETS-1,2,3.

ETS-3 SAFETY DEVICE

The ETS-3 is set to 90 deg. C as a protection against hot engine. The above action helps in bringing down the cooling water temperature quickly with the radiator fan moving at full speed.

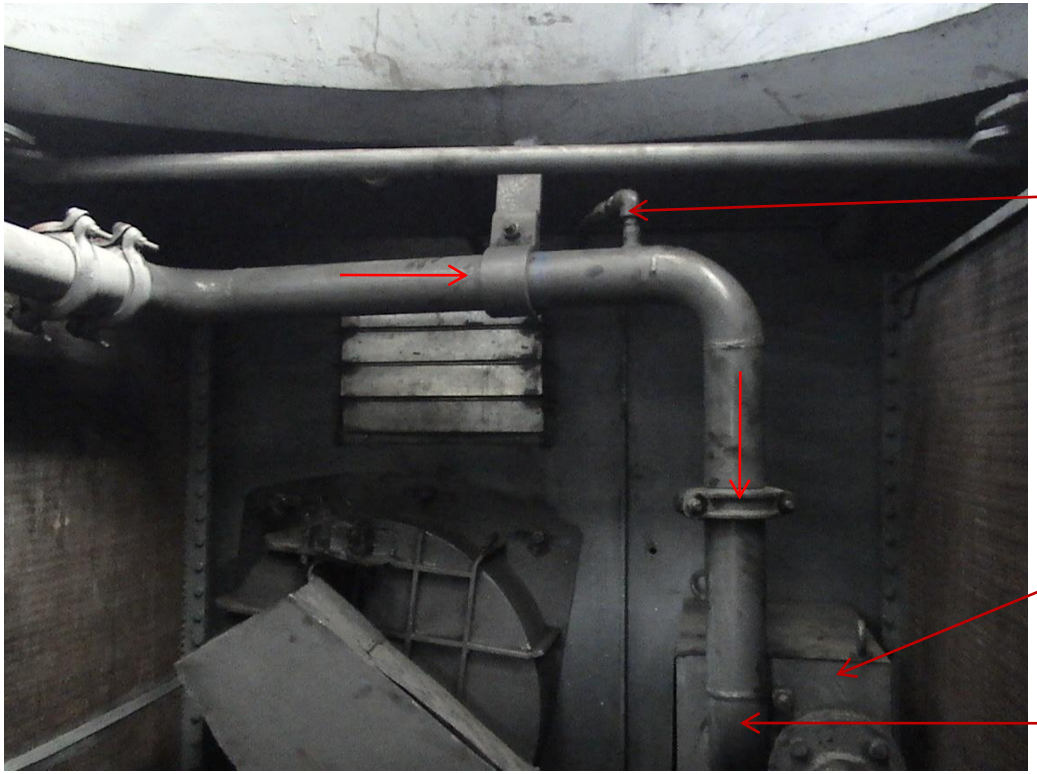
CONTROLLING OF WATER TEMP.

- Water temperature is controlled by controlling the movement of radiator fan.
- Cooled water from the left side radiator passes through the lube oil cooler where water circulation is through a bunch of element tubes and lube oil circulation around the tubes.

Left side radiator outlet pipe
Goes to lube oil cooler (as inlet).

Left side radiator two-core

RTTM Blower



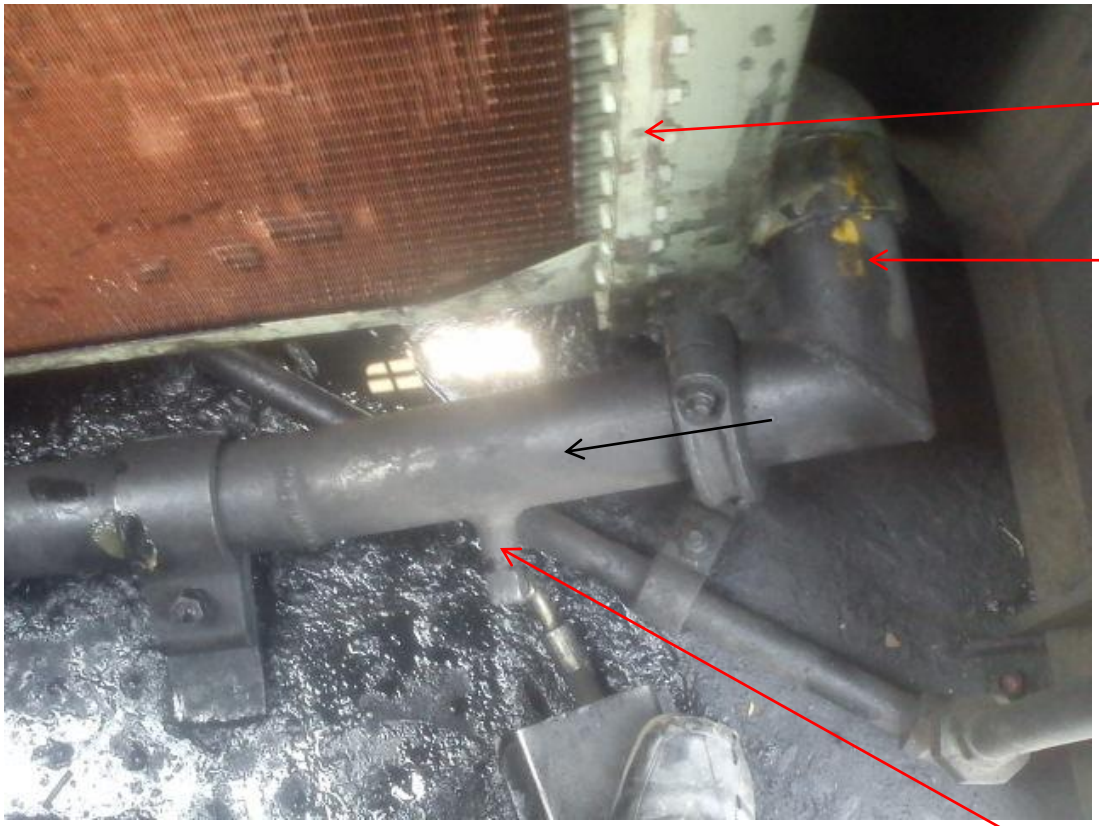
Vent pipe goes to water expansion Tank.

Plate type lube oil cooler

Water inlet pipe of lube oil cooler

A water pipe connection from left side radiator to lube oil cooler is shown. In plate type Lube oil cooler a alternative plate of lube oil and water are fitted. When water comes in contact of lube oil plate it takes heat from lube oil and thus lube oil becomes cool.

- Thus passing through the lube oil cooler and cooling lube oil it unites with the right side radiator outlet, to be back again to the suction of the pump for recirculation through the cooling circuit.



Right side radiator

Right side radiator outlet pipe

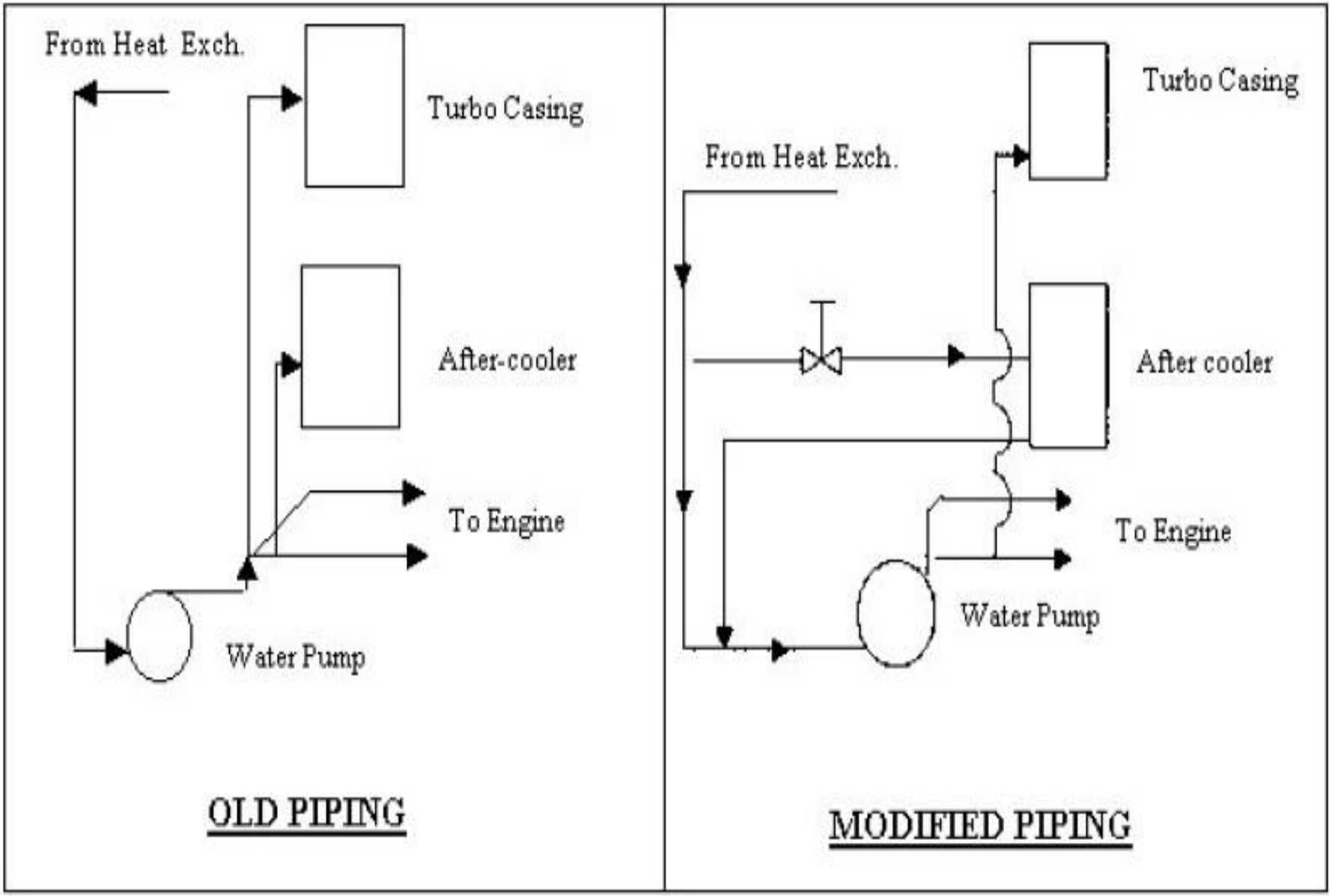
Water equalizing pipe from Right side to left side radiator

Equalizing pipe connected to left side radiator outlet pipe

Junction point of lube oil cooler outlet And right side radiator outlet water pipe Connected to water pump suction line

AFTER COOLER

- Water inlet pipe of after cooler is connected before suction pipe of pump. Returns pipe of after cooler is connected to the suction pipe of the pump.
- After Cooler is a HEAT EXCHANGER.


From Heat Exch.
Turbo Casing
After-cooler
To Engine
Water Pump
OLD PIPING
Turbo Casing
From Heat Exch.
After cooler
To Engine
Water Pump
MODIFIED PIPING

Conventional

Larger

- Boosted air by compressor of TSC is cooled in after cooler.
- There are water in tubes of after cooler and air surrounding it.
- Compressed air is cooled and regain its density, which is the ultimate goal of after cooler.

LWS- SAFETY DEVICE

- Apart from hot engine protection another safety is also provided by way of a LWS. In the event of cooling water level falling below 1” from the bottom of the expansion tank the LWS connected to it, shuts down the engine through the governor with warning bell and lamp indication to ensure safety to the engine.

LWS three-way cut out cock

Vent pipe

This is a picture of LWS three-way cut out cock. This cock is for test purpose of LWS. During testing when chamber completely made empty, and water drained out the cock Made close and water start to fill up in floating chamber. The time of filling should not be More than 7 to 10 seconds. The bell ringing and LED glowing will be stopped.

VENT- LINES

- Vent lines are provided from after cooler, lube oil cooler, turbo-supercharger vent box and bubble collectors etc. to maintain uninterrupted circulation of cooling water by eliminating the hazard of air locks in the system.

LABORATORY TEST

- Cooling water is subject to laboratory test at regular intervals for quality control. Contamination, chloride contents and hardness etc. are checked to reduce corrosion and scaling. The concentration of anti-corrosive mixture is also checked.

and the laboratory advises corrective action in case of contamination, required addition of anti-corrosive mixture or change of cooling water. Proper quality control of cooling water and use of proper quantity of anti-corrosive mixture prevents scaling and corrosion in the system and ensures longer life of components.

WHY TO USE CORROSION INHIBITORS?

- Large amount of heat is generated in the diesel engine of locomotives.
- Water is used as cooling medium for engine components.
- This water develops corrosive action at elevated temperatures.
- Corrosion is very harmful for engine components.
- **To protect engine components form this corrosive effect suitable CORROSION INHIBITOR is used.**

CHROMATE BASED INHIBITORS

- Since inception of ALCO locos in India Chromate based coolants were used for water treatment:
- Composition of chromate compound
  - Sodium chromate---60%
  - Sodium carbonate---30%
  - Potassium Dichromate—5
  - Calgon (Sodium hexamata phosphate)—5%
- Attained pH value in the range of 8.5 to 9.5
- **Discarded being unfriendly to the environment.**

BORON BASED INHIBITORS

- With increase in awareness towards ENVIORONMENTAL POLLUTION , chromate based coolants were discarded and boron base coolants were introduced in late 90s.
- **Type of base Brand name Manufacturer**
- **Borate Nitrate Indion-1344 M/S ION Exchange**
- **Borate Nitrate Nalco-2100 M/S Nalco Ltd.**
- Borate Nitrate treated water contains Boron @642 – ppm.
- Achieved pH in the range of 9.5 to 11.8.
- **Discarded very soon being unfriendly to the environment.**

CURRENTLY RECOMMENDED CHEMICALS

- Under-mentioned two coolants are widely in use :
  - Type of base Brand name Manufacturer
  - (i) Benzoate Nitrate X-GT M/S Vinni Chemicals. (Boron free)
  - (ii)Hp Radiator & Engine protector POWER COOL – RR M/S HPC (carboxylate based)
- Coolant water is to be changed completely when contaminated with lube oil or any suspended materials.

ECONOMICS INVOLVED.

Particulars	INDION 1344	NALCO 2100	X-GT	POWER KOOL-RR
Mfd By.	M/s ION Exchange Pvt. Ltd.	M/s Ravi Chemicals, KKK	M/s Vinni Chemicals	M/s. HPCL
Base	Boron	Boron	Boron Free	Boron Free
Reqt per loco /year	110 kg.	470 liters.	375 liters.	187 liters.
Unit Rate (Rs.)	192 (Current Rate)	137.50 (As per P.O dt 31.03.07)	88 (Current Rate)	162 (As per P.O dt 28.01.10)
Annual Usage Value	21,120	64,625	33,000	30,294

From above table it is clear that use of **INDION 1344 is very much economical** besides ease in topping and better pH value leading to better NON-CORROSIVE action.

ALL COOLANTS AT A GLANCE

SN	Particulars	INDION 1344	NALCO 2100	X-GT	POWER KOOL-RR
1	Physical Form	Powder	Liquid	Liquid	Liquid
2	Color	Pink	Red	Fluorescent Yellowish Green	Yellowish Green
3	Initial Top up Quantity	8.2 kgs.	36 lts.	120 lts.	36 lts.
4	Method of Topping	Manual	Mechanized System reqd	Mechanized System reqd.	Mechanized System reqd
5	Topping Flexibility	Any where in shed	Only on platforms.	Only on platforms.	Only on platforms.
6	pH	9.5 to 11.0	9.5 to 10.0	8.5 Maxm.	
7	Concentration of Treated Water in ppm	1250-1400 in terms of NaNO2	1850-2150 in terms of NaNO2	2000-2150 in terms of NaNO2	1000-1400 in terms of Carboxylate

PRESSURIZATION OF COOLING WATER SYSTEM

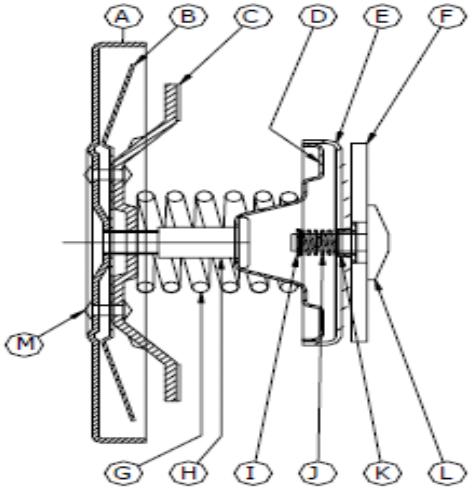
- Initially the cooling water system was not pressurized.
- Hot engine alarm was set at 84’c.
- There were frequent hot engine cases during summers.
- To reduce water loss due to vaporization idea of increasing the boiling point of water developed.
- By 0.5 kg/cm2 pressurization, boiling point has been increased by 11^0c.

Fig.-12 Alco conventional design pressure cap

Fig.-13 Alco conventional design pressure cap assembly

PRESSURE CAP ASSEMBLY

The pressure cap assembly shown in **Fig.2** below, comprises of 2 valves- one operates for releasing the excess pressure and the other operates to destroy the excess vacuum, spring loaded cap, perforated sheet, nitrile rubber gasket & springs. The assembly is secured by a riveted joint at the top. Most of the metallic parts are non ferrous /stainless steel except the M.S. spring loaded cap. A chain is welded with spring loaded cap and bottom plate, to avoid the cap getting misplaced.



A –SPRING LOADED CAP
B –CAP SUPPORTING PLATE
C –LOCKING PLATE
D –PERFORATED SHEET
E - VALVE
F - GASKET
G –COMPRESSION SPRING
H - PIN
I - CIRCLIP
J – COMPRESSION SPRING
K –VALVE BUSH
L -VACCUM VALVE
M –SNAP HEAD RIVET

Fig. 2 Pressure Cap Assembly

MAINTENANCE OF PRESSURE CAP ASSEMBLY

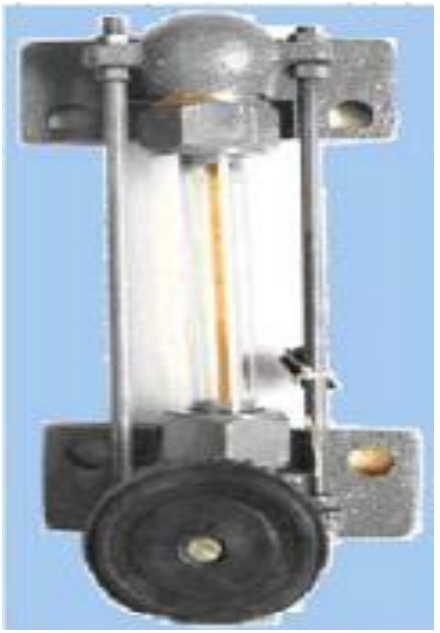
- The unit maintains pressure in the cooling water system as well as safeguards the working of system due to creation of Vacuum (due to condensation of water vapors) in the system.
  - The function of this pressure cap is to maintain the pressure in the cooling water system in the expansion tank between a value of 0.07 kg/cm^2 below atmosphere to 0.5 kg/cm^2 above atmosphere.
- The assembly should be checked visually in quarterly schedules and replaced in M24 schedules as per RDSO instructions.

WATER LEVEL GAUGE

- Provided on the rear expansion tank for checking the level of water in expansion tanks.
- Impurities and corrosion inhibitor present in the water the discolor the Perspex sheet cover and it becomes difficult to assess the water level in the tanks.
- The gauge should be checked & reconditioned during M12 schedule.

EMD TYPE GAUGES

- RDSO has advised to change all the conventional glow rod type water level gauges with glass tube type level gauges originally fitted on EMD locos.
- Advantages over glow rod type gauge
  - Better visibility,
  - Ease in change of glass tube
  - No need of draining whole water from tank,
  - Less time and man power involvement etc.



Advantages of water cooling system over air cooling system

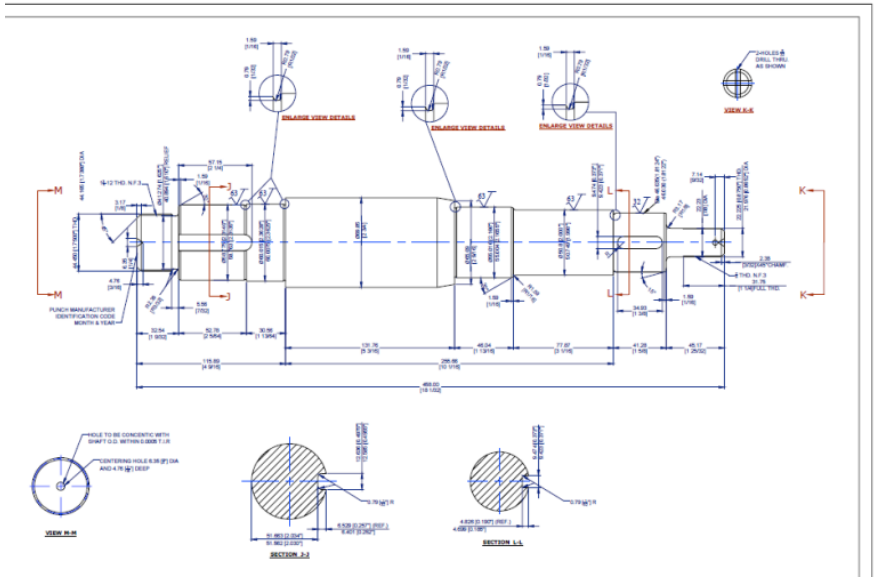
- The advantages of using water cooling over air cooling include water's higher specific heat capacity, density, and thermal conductivity.
- This allows water to transmit heat over greater distances with much less volumetric flow and reduced temperature difference .

MAINTENANCE OF WATER PUMP

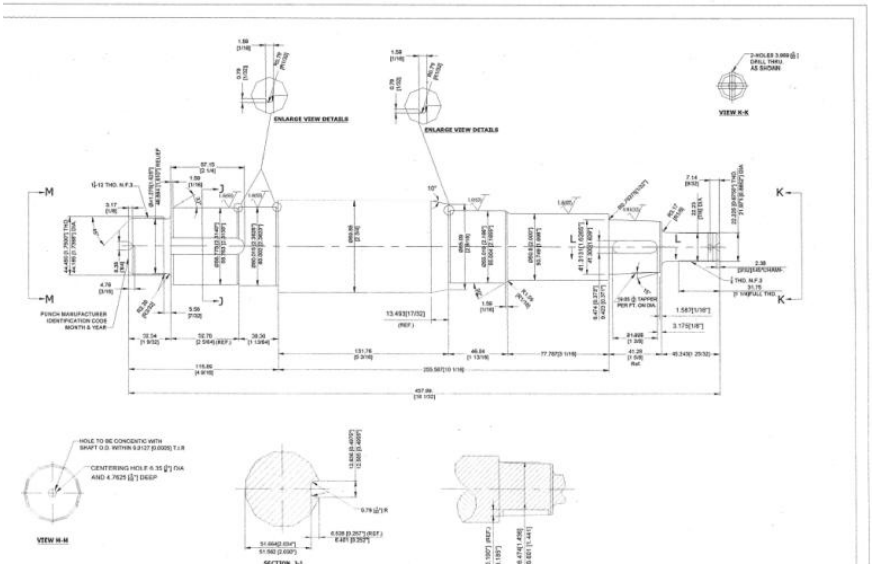
- Any failure of this pump will cause
  - Loss of water circulation
  - Rise in temperature of critical components
  - Increased failure.
- Recently RDSO has changed the drawing and material specification of water pump shaft to Stainless Steel retaining the taper sleeve arrangement to prevent cases of shaft failures. **(Modification Sheet No. MP-MOD-ES-01-13-11 April 2012)**

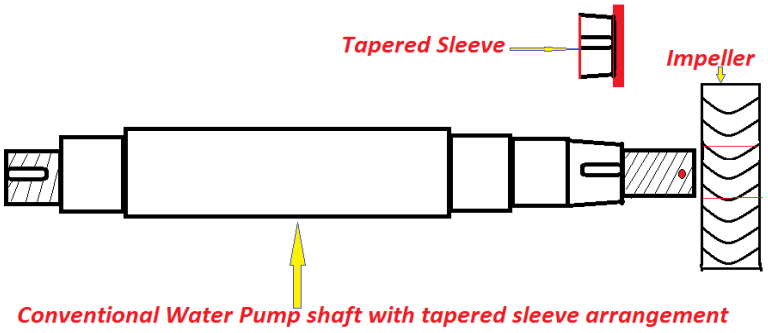
Comparison of Shaft designs

Stainless Steel shaft with taper sleeve

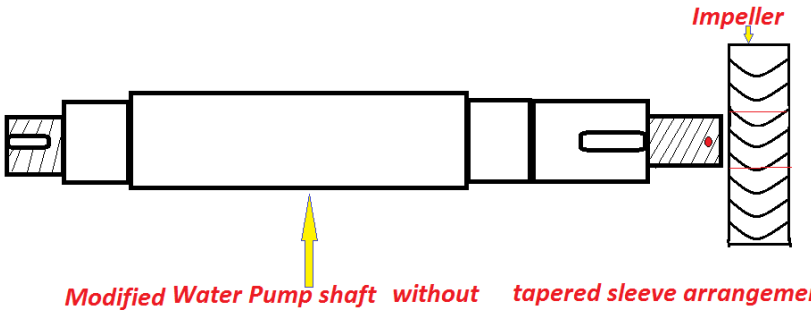


Stainless Steel shaft without taper sleeve





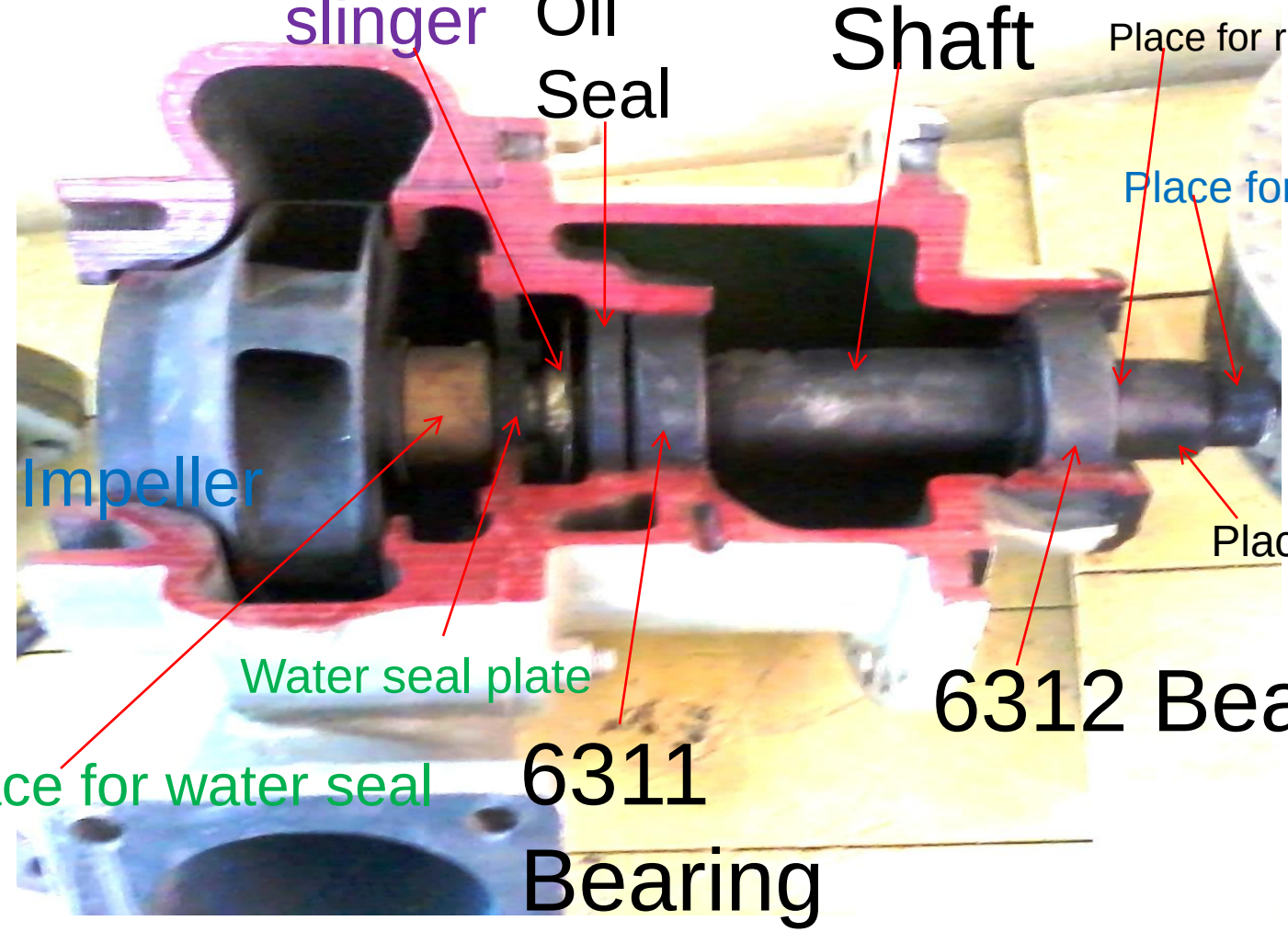
Conventional Water Pump shaft with tapered sleeve arrangement



Modified Water Pump shaft without tapered sleeve arrangement

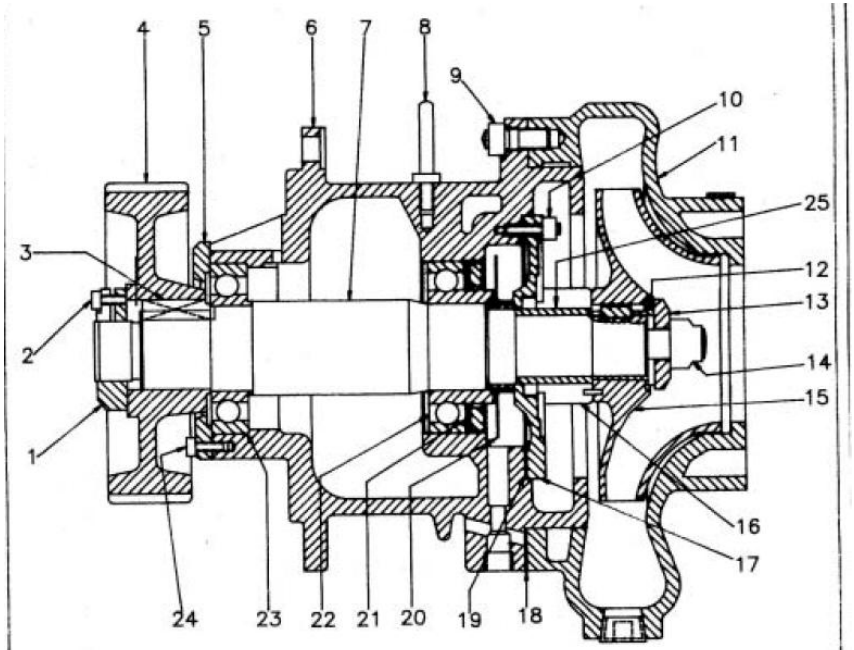

Locking Bolt
Gear Nut
Gear
Bearing Housing
Impeller Casing

Sectional view- Water Pump



DETAILS OF WATER PUMP

- Overhauling has to be done
  - M12 and Onward or
  - Out of course repairs.
- All the gaskets & seals replaced.
- Shaft and impeller
  - Checked for cracks/ defects.
- Gear teeth
  - Checked for any signs of wear / burrs etc.
- Condition of both bearings
  - Checked for excessive sound/ play.

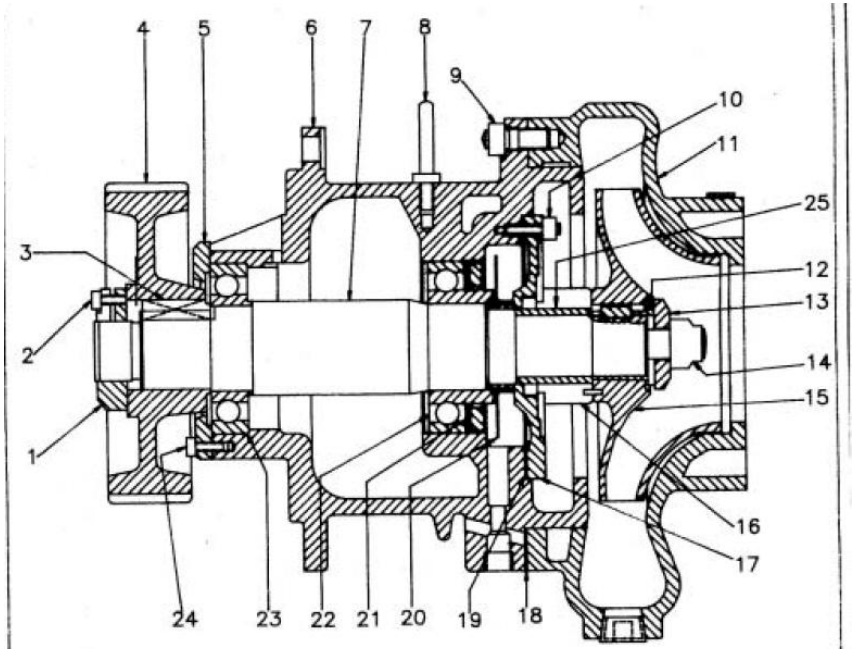


1.	Gear Nut
2.	Clamp Screw and Locking Wire
3.	Gear Key
4.	Gear
5.	Thrust Bearing Reatiner
6.	Bearing Housing
7.	Pump Shaft
8.	Lifting Eyebolt
9.	Nut
10.	Nut and Locking Wire
11.	Pump Casing
12.	Split Sleeve
13.	Washer

14.	Castellated Nut
15.	Impeller
16.	Water Seal Assembly
17.	Seal Plate
18.	Gasket
19.	Gasket
20.	Oil Slinger
21.	Oil Seal
22.	Radial Bearing
23.	Thrust Bearing
24.	Cap Screw and Locking Wire
25.	Shaft Sleeve

WATER PUMP DETAILS

- Maintain specified interference between impeller and shaft.
- Tighten impeller nut to specified torque value.
- Renew stainless steel split pin every time.
- Check assembled water pump on test bench before fitment on engine.
- Maintain proper backlash during its fitment on engine.



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Modifications

- Impeller Size- 9 to 10 Inch
- More thickness of carbon pack
- Elimination of Water seal Bush
- Elimination of Impeller Sleeve
- Larger After cooler with improved water piping

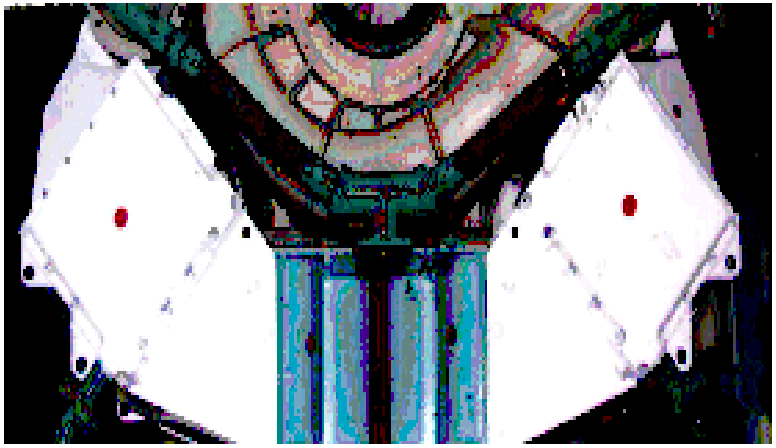
- water connection to After cooler has been given directly from RH Radiator for better cooling.

-cooling efficiency of After Cooler Increased

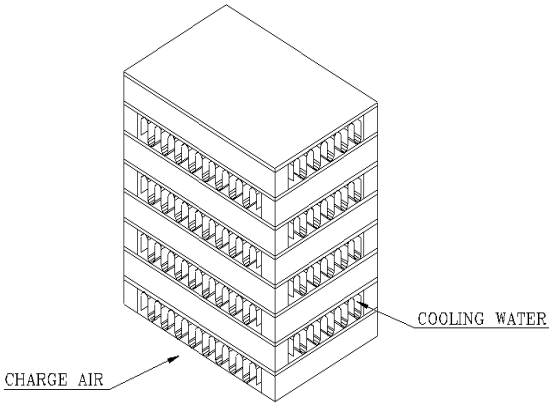
Conventional A/C

Larger After cooler

After coolers



Twin After cooler fitted with double volute GE TSC



Aluminium After cooler

Description	Conventional A/C 10 rows	Large A/C 12rows	Large A/C 16 rows	Twin A/C	Al, A/C
Effectiveness	50%	70%	80%	95%	90%
EGT	600°C	550°C	520°C	500°C	500°C

- Mechanically Bonded Radiators:-

1. Used to improve reliability and longer life of radiators.
2. They are made of seamless tubes and bonded mechanically with the headers.
3. The conventional radiators were made of rolled and soldered tubes and are soldered with the headers.
4. Heat dissipation capacity increased to 1,00,000 BTU/min from 71,000 BTU/min.

5.Higher tube thickness of MBR-0.4 mm thick HFW(High Frequency Welded) Tubes used in MBR instead of 0.25 mm thick soldered tube, which is more reliable and less prone to leakage as compared to soldered tube. HFW tubes also provides higher bursting pressure.

6.Higher fin thickness of MBR-0.095 mm thick fins are used in MBR instead of 0.06 mm thick fins. Higher fin thickness prevents deterioration and distortion of the fin even in the bad climate condition, Thus increase the life of radiator.

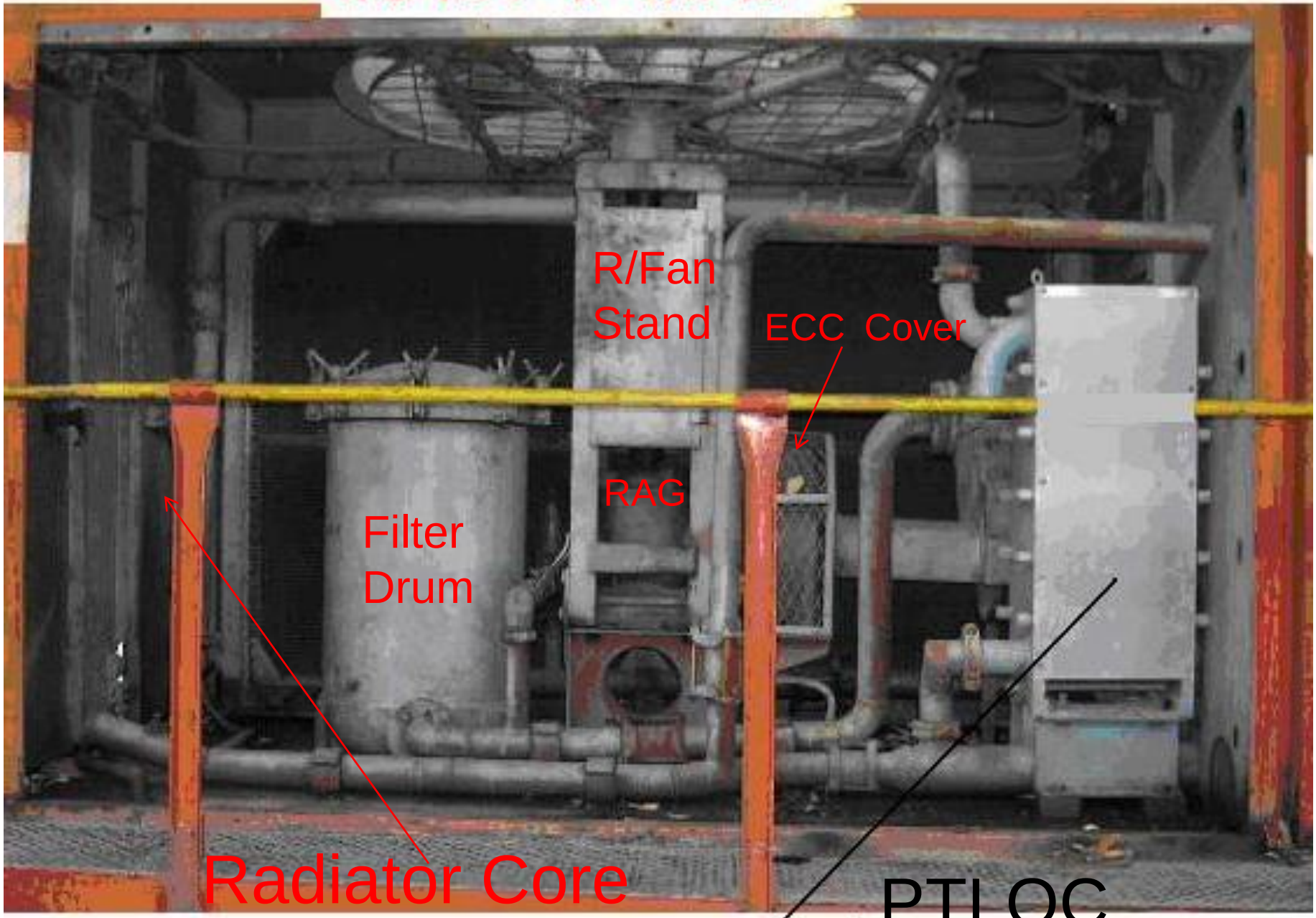
7. Higher header plate thickness – 19 mm thick header plate is used in MBR instead of 2.5 mm, which provide uniform flatness and gives proper bonding of the tube with header and help in reducing the leakage through joints.

8. Life of MBR- The overall life of MBR is almost three times as compared to the soldered radiator providing more reliable operating conditions.

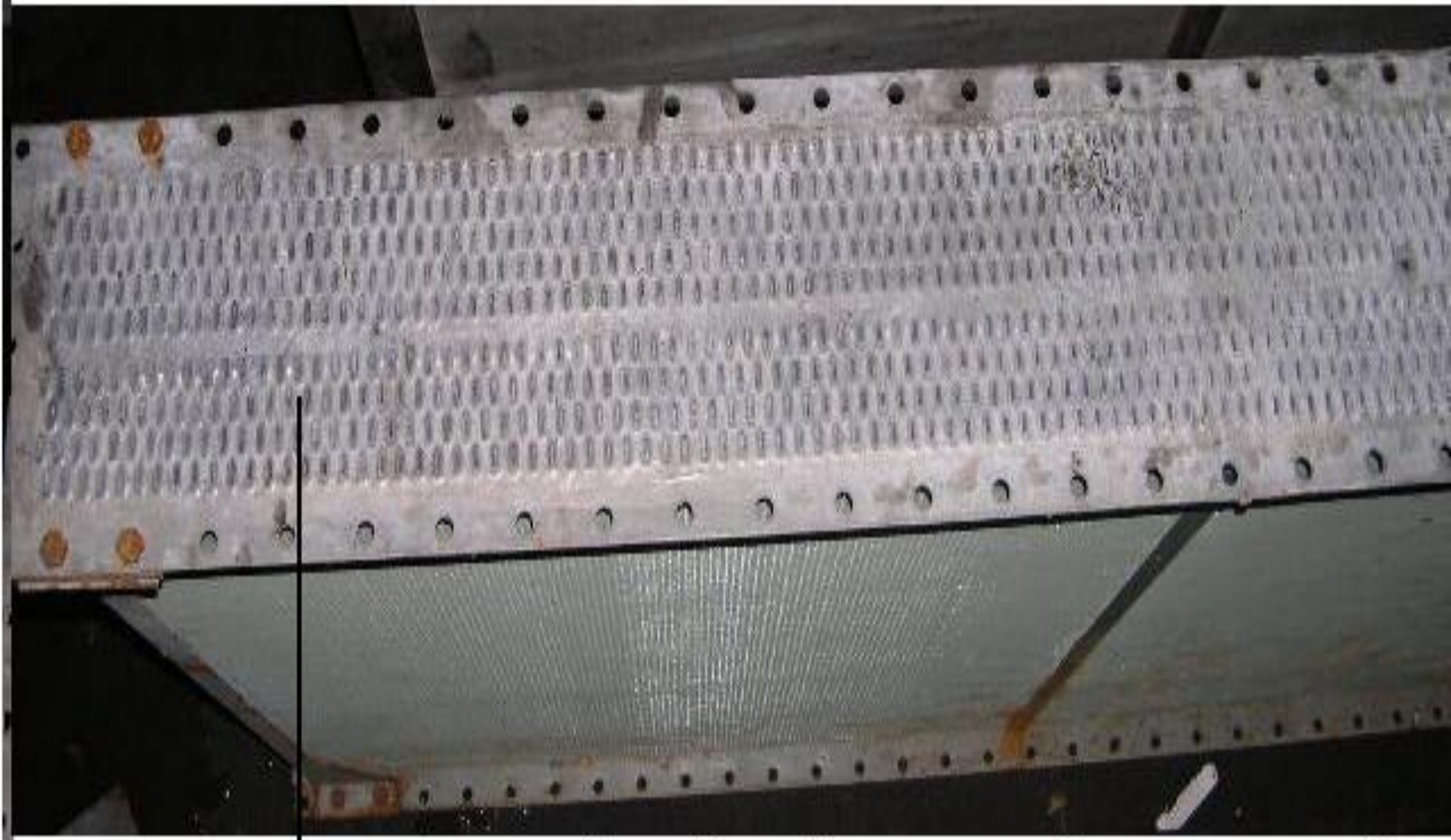
IN VIEW OF PROBLEMS FACED WITH 7 ROW MBR IN 3300 HP WDM3D LOCOS, 8 ROW MBR HAS BEEN DEVELOPED FOR HIGHER HEAT DISSIPATION CAPACITY.

- **EACH CORE CONSISTS OF 8 ROWS OF TUBES WITH 100 TUBES/ROW.**

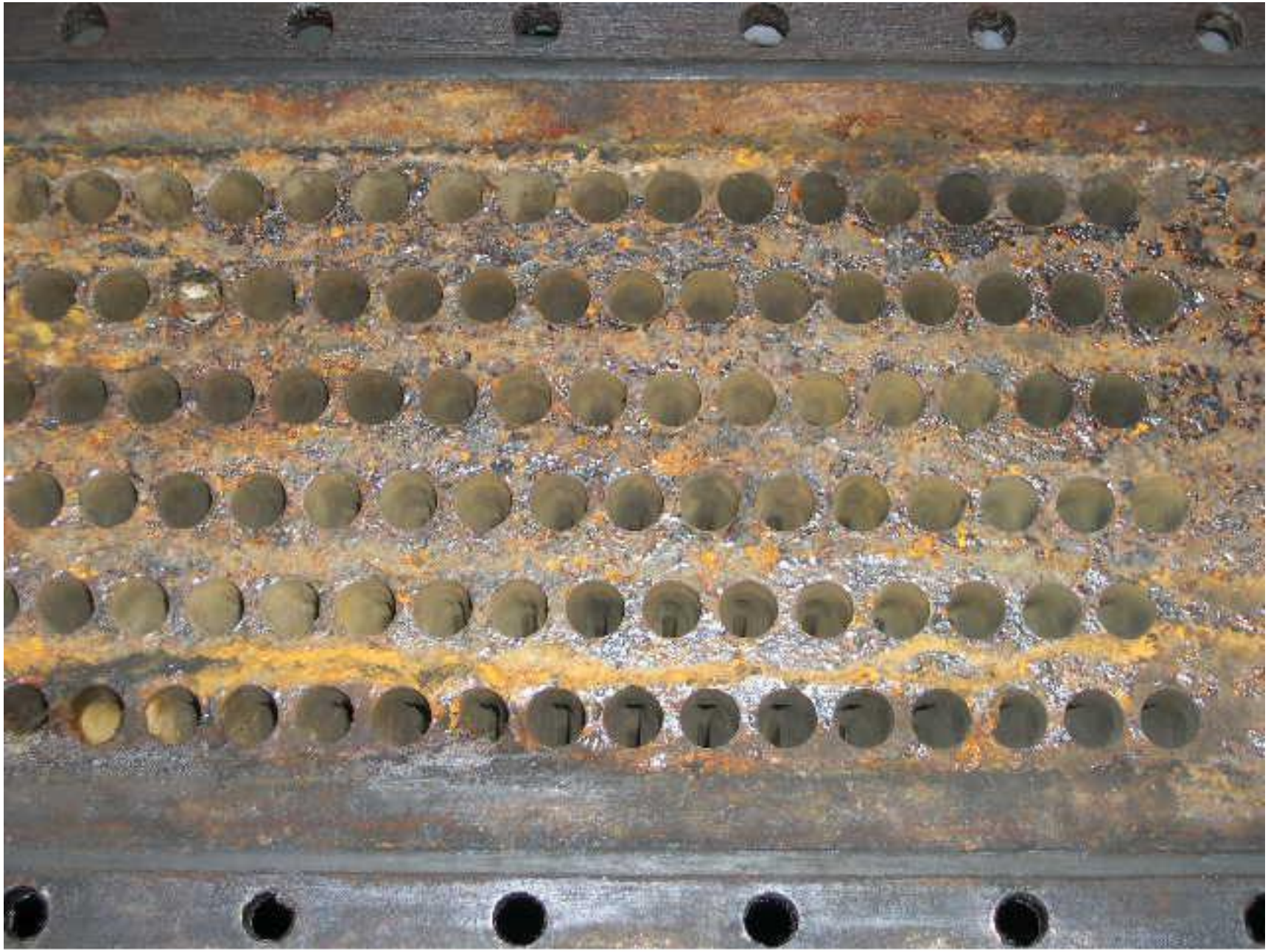
रेडियेटर कम्पार्टमेंट



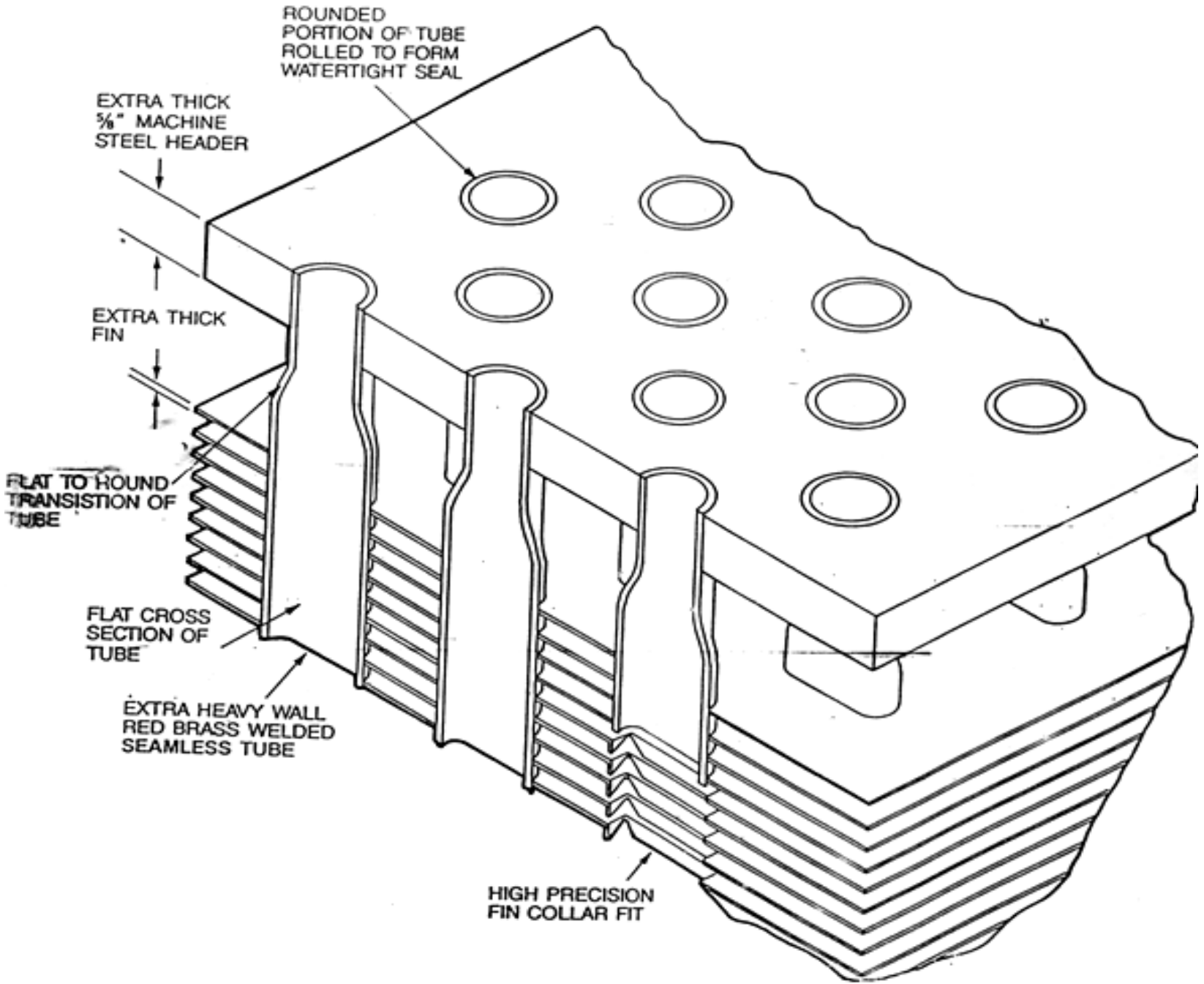
कन्वेंशनल रेडियेटर कोर



टयूब को फ्लेंज में साल्डर किया जाता है



मैकेनिकल बॉडड (ऊपर से राउंड होता है)


ROUNDED PORTION OF TUBE ROLLED TO FORM WATERTIGHT SEAL
EXTRA THICK 5/8" MACHINE STEEL HEADER
EXTRA THICK FIN
FLAT TO ROUND TRANSISTION OF TUBE
FLAT CROSS SECTION OF TUBE
EXTRA HEAVY WALL RED BRASS WELDED SEAMLESS TUBE
HIGH PRECISION FIN COLLAR FIT

MODIFIED WATER JUMPERS

- For obtaining better leak proof joint even in case of slight misalignment between the engine block and the cylinder head.




Pressurized cooling water system

- Due to pressurization up to 7 psi boiling point of water raises by11°C,this not only saves water due to boiling but also the heat dissipation rate across radiator improves due to higher temperature gradient.

- Revised ETS setting :-

Previously ,ETS 3 was set at 84°C as hot engine safety & alarm, now it is 90°C hot engine alarm will ring, giving indication to the driver about hot engine