INTRODUCTION HAND BOOK ON GENERAL MOTOR DIESEL LOCOMOTIVE

(For official use only)

IRCAMTECH/2006/M/D/GM loco/1.0

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Centre for Advanced Maintenance TECHnology

Excellence in Maintenance

MAHARAJPUR, GWALIOR – 474020
INTRODUCTION HAND BOOK
ON
GENERAL MOTOR DIESEL
LOCOMOTIVE
PREFACE

The GM Locomotives have been included in the Diesel Locomotive fleet of Indian railway. Production of GM locomotive has already started in DLW, Varanasi. The 4000 HP, computer controlled GM locomotive has a large number of special and improved features vis-a-vis the Alco design diesel locomotive presently running in Indian railway. All those in the field of diesel locomotive need to get acquainted with the GM locomotive. This book “Introduction hand book on GM locomotive” prepared by the CAMTECH has been prepared with the purpose of disseminating the introductory information to all those in diesel loco maintenance field.

The suggestions are invited from the readers to improve and make the book more useful. Any such suggestion shell be included in next publication.

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Director (Mech)
<table>
<thead>
<tr>
<th>S No.</th>
<th>Description</th>
<th>Page No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Preface</td>
<td>i</td>
</tr>
<tr>
<td>2.</td>
<td>Contents</td>
<td>ii</td>
</tr>
<tr>
<td>3.</td>
<td>Book details</td>
<td>iii</td>
</tr>
<tr>
<td>4.</td>
<td>Correction slips</td>
<td>iv</td>
</tr>
<tr>
<td>5.</td>
<td>Introduction of the GM Locomotive</td>
<td>1 to 2</td>
</tr>
<tr>
<td>6.</td>
<td>General information data</td>
<td>3 to 6</td>
</tr>
<tr>
<td>7.</td>
<td>Various parts and its location</td>
<td>7 to 21</td>
</tr>
<tr>
<td>8.</td>
<td>Fuel Oil System</td>
<td>22 to 25</td>
</tr>
<tr>
<td>9.</td>
<td>Cooling Water System</td>
<td>26 to 30</td>
</tr>
<tr>
<td>10.</td>
<td>Lube Oil System</td>
<td>31 to 37</td>
</tr>
<tr>
<td>11.</td>
<td>Air Intake System</td>
<td>38 to 41</td>
</tr>
<tr>
<td>12.</td>
<td>Compressed air system</td>
<td>42 to 43</td>
</tr>
<tr>
<td>13.</td>
<td>CCB Air Brake System</td>
<td>44 to 59</td>
</tr>
<tr>
<td>14.</td>
<td>Electrical System</td>
<td>50 to 52</td>
</tr>
<tr>
<td>15.</td>
<td>Computers control of locomotive</td>
<td>53 to 55</td>
</tr>
<tr>
<td>16.</td>
<td>Major equipments of GM locomotives</td>
<td>56 to 63</td>
</tr>
<tr>
<td>17.</td>
<td>Differences between WDG₄ &amp; WDP₄ Locomotives</td>
<td>64 to 65</td>
</tr>
</tbody>
</table>
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CORRECTION SLIPS

The correction slips to be issued in future for this handbook will be numbered as follows:

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CORRECTION SLIPS ISSUED

<table>
<thead>
<tr>
<th>Sr. No. of Correction Slip</th>
<th>Date of issue</th>
<th>Page no. and Item no. modified</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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</tbody>
</table>
INTRODUCTION OF THE GM LOCOMOTIVE

1. The WDG₄ & WDP₄ series of DLW make locomotives are GM (General Motor) locomotives.
2. The GM locomotive models are GT46 MAC for goods service and GT46 PAC for passengers service.
3. The GM locomotive is fitted with engine model no. 710G3B.
4. The GM locomotive is equipped with a microprocessor based computer control system - referred to as EM-2000 locomotive.
   The computer controlled system is equipped with a diagnostic display system (DDS) in the cab to provide an interface between the locomotive driver and the computer. The EM-2000 computer is programmed to monitor and control locomotive traction power, record and indicate faults, and allow diagnostic testing.
5. The GM locomotives are also fitted with equipments like Engine, Turbo super charger, Compressor, Alternator, Traction motors etc. like those in ALCO locomotive but their designs are different.
6. The GM locomotive are also provided with Fuel oil system, Lube oil system, Cooling water system, Charged air system, Compressed air system, Air brake system, Electrical system and various safety devices like those in ALCO locomotive but their designs are different.
7. The GM locomotive power pack is 16 cylinder, Two strokes, 'V‘ –arrangement, Internal combustion engine.

8. The GM locomotive is highly fuel efficient having 11% better fuel efficiency compared to the ALCO design locomotive.

9. The GM locomotive is a 4000 BHP locomotive.

10. The GM locomotive is having highly improved maintainability compared to ALCO locomotive.
GENERAL INFORMATION DATA

Locomotive

Model Designation : GT46MAC
Under Truck : CO-CO Type
Nominal Locomotive Power : 4000HP

Diesel Engine

Engine Model(s) : 710G3B
Number of Cylinders : 16
Engine Type : Two-Stroke, Turbo Charged
Cylinder Arrangement : 45° “V” Arrangement
Compression Ratio : 16:1
Displacement per Cylinder : 11635cm³ (710 Cu.In)
Cylinder Bore : 230.19 mm (9-1/16”)
Cylinder Stroke : 279.4 m (11”)
Rotation (Facing Generator End) : Counter- clock-wise)
Full Speed : 904 RPM
Normal Idle Speed : 269 RPM
Low Idle Speed : 200 RPM

Main Generator Assembly

Main Generator : TA17-CA6B
Traction Alternator (includes rectifier) : TA17
Companion Alternator : CA6B

Traction Alternator Rectified Output Ratings

Maximum Voltage : 2600 VDC
Max. Continuous Current : 1250 Ampere

**Companion Alternator Output**
- Maximum Voltage : 230 VAC
- Frequency at 904 RPM : 120 HZ
- Maximum Power : 250 kVA (P. Factor 0.8)

**Auxiliary Generator & Rectified Output Ratings**
- Model : 5A-8147
- Nominal Voltage : 74 volts DC (Rectified)
- Maximum Power : 18 kW

**Traction Motors**
- Model : Siemens 1TB-2622-0TA 02
- Quantity : 6 (3 in parallel per bogie)
- Type : 3 Phase AC Induction, Axle Hung with Tapered Roller Support Bearings Forced Air Ventilated
- Nominal Ratings : 500 kW, 2027 VAC, 3220 RPM

**Traction Inverters (Traction Control Converters TCC1, TCC2)**
- Model : 1GE420 050 9010.00 MB 74
- Rating : 1430 kW
- Quantity : 2, per bogie (truck)
- Type : Voltage Source Inverter With Gate Turn-Off Thyristors
Bogies

- Model: HTSC
- Gear Ratio: 90:17

Driving Wheels

- Quantity: 3 Wheel Sets per bogie
- Diameter: 1092 mm (43 inches)

Brake Rigging

- Type: Single Shoe (16”)
- Material: Composite
- Cylinder Brake: 4 per bogie (truck)

Air Compressor

- Air Compressor Model: WLNA9BB
- Type: Two Stage, 3 Cylinders
- Coolant: Engine Coolant
- Displacement at 900 RPM: 7.19M³/Min
- Lube Oil Capacity: 10 liters

Air Brake Control System

- KNORR CCB equipment

Locomotive Storage Batteries

- Model: Surrette16CH-25Unitized
- Arrangement: 2 Series-connected 16 Cell Lead-Acid Batteries
- Total Quantity of Cells: 32
- Total Potential of 2 Series Connected Batteries: 64 Volts
Specific Gravity of Electrolyte : 1.250
8 hour Capacity : 500 Amp. Hour

**Supplies/ Capacities**

- Lube Oil System Capacity : 950 Liters
- Cooling System capacity : 1045 Liters
- Sand Boxes (8) Capacity : 0.04M³ box (15ft³/ box)
- Fuel Capacity : 6000 Liters

**Nominal Dimensions**

- Height, over Cooling Hood : 4.16 M (13’ 7.75”)
- Height Over Horn : 4.22M (13’10”)
- Height over Cab : 3.94 M (12’11”)
- Width over handrails : 2.92 M (9’ 7.12”)
- Width over Under frame : 2.74 M (9’0”)
- Width over Cab : 2.74 M (9’0”)
- Width over Brake Cylinders : 3.07 M (10’1”)

**Locomotive Speeds/ Tractive Effort**

- Locomotive Minimum Speeds : 22.5 Km/ h
- Locomotive Max Speed: RPM) : 120 Km/ h
- Maximum Stall tractive Effort : 540 KN
- Max. Continuous Tractive Efforts : 400 KN
- Reduced Tractive Effort Limit : 294 KN
VARIOUS PARTS AND ITS LOCATION

The GM locomotive can be broadly divided into the following compartments where various parts (As shown) are located:

(A) Nose Compartment
(B) Driver’s Cab
(C) Electrical control cabinet
(D) Traction Control Converters Compartments
(E) Main Generator Compartment
(F) Engine Compartment
(G) Engine Accessories
(H) Compressor Compartment
(I) Radiator Compartment
(J) Superstructure of locomotive

(A) **Nose Compartment**: consists of

- Air Brake Equipment Panel for CCB (Computer Controlled Brake)

(B) **Driver’s Cab**

- **Control Stands**: 2 Nos

  Each control stand consists of

  1. Locomotive Controller

     a) Reverser Handle

     b) Throttle /Dynamic Brake Handle
2. Cab Control Unit (CCU)
   a) Automatic Brake Handle with 5 positions,
      - Release (Spring loaded for over charging)
      - Run
      - Minimum Reduction
      - Full Service
      - Emergency
   b) Independent Brake Handle with 2 positions
      - Release
      - Application
        - Bail off (Quick Release) by spring loaded handle
   c) Air Brake Trail/ Lead Setup Switch (like MU2B0 with 3 positions.
      - Trail: Loco is trailing and also in leading Loco non- working Control Stand.
      - Lead in: Used with loco in lead or controlling unit.
      - Lead Out: Used during Brake pipe leakage testing/ banking loco working control stand.

When Lead/ Trail switch is set:
   - In Trail position
     - Both automatic and independent Brake functions will be isolated except Emergency of automatic brake functions.
• **In Lead Position:**
  Both automatic and independent Brake will have normal functions.

• **In Lead out Position:**
  Independent Brake will and also automatic brake controller will function during emergency position only.

**d) Control and Operating Switch**
- Engine Run Slide Button Switch
- GF Slide Button Switch
- Fuel Pump Control Slide Button Switch
- Dynamic Brake Control Circuit Breaker
- MU push button Switch

**e) Gauges provided on the Control stand**
- Duplex air pr. Gauges in kg/cm square
  - MR & MR Equalizing Pressure
  - BP & BC Pressures
- Air Flow Indicator
- Speedometer in KMPH
- Tractive Effort Meter in KN

**f) Flasher Lamp Switches**
- Cap end
- Hood end

**g) Wind Shield Wiper Control Knobs**

**h) Indicating Light Panel**
- Tractive Effort Limit Light
- Sand Light
- Wheel Slip Light
- Flasher Lamp Light
- PCS open Light
- Brake waning Light

i) Reset (Alertness Control) Push button Switch: It senses driver’s alertness.

j) Manual Sanding Switch: For sanding

k) Horn Push Button Switches: No. 2

l) Head Light Switches: Front & Rear

m) Clip Board: To keep caution, order, Fuel Balance Sheet BPC, ETC.

(C) Electrical Control Cabinet:
The cabinet can be divided into:

a) Driver Cab end panel

b) Back panel

a. **Driver Cab end panel**

There are four Operator Accessible Panels on the driver’s cab end panel

1. Circuit Breaker Panel
2. Engine Control Panel
3. Circuit Breaker and Panel
4. EM 2000 Display panel

1. Circuit Breaker Panel: Consist two type of breaker:

   Breakers in “black” labeled section of the panel must be “ON” during loco operation. Breakers in “White” labeled section are used as per the required

   a) Black Labeled Section Breakers:

   - Air Dryer Breaker:
     - MR air

   - AC Control Breaker:
     - Protects companion alternator output

   - Control Breaker:
     - Set up the fuel pump breaker

   - Local Control
     - Operator heavy duty switch gear, magnet valves, Contactors, blowers and miscellaneous relays operated by locomotive battery/ Auxiliary Generator.

   - Filter blower motor breaker

   - AC GTO No. 1 power supply breaker.

   - AC GTO No. 2 power supply breaker.

   - Auxiliary Generator field breaker.

   - Fuel pump breaker.

   - TCC1 Computer breaker

   - TCC2 Computer breaker.
• Turbo circuit breaker:
  • Provide power and protection to the turbo lube oil pump motor.
• Computer Control Breaker:
  • Protect the loco control Computer.
• TCC electrical blower motor circuit breaker.
• Micro Air Brake Control breaker:
  • This provides power from loco batteries to the CCB computer.

b) White labeled section Breakers:
• Light Breaker (miscellaneous breaker )
• Head light breaker
• Can fan breaker
• DC link control breaker
• Ground relay cutout Toggle switch

2. Engine Control panel: Consist control equipment used in loco operation.
• Isolation switch:
  • This is a two position rotary switch.
    1. Start/ Stop/ Isolate position.
    2. Run position.
• Dynamic brake Cut out Slide switch
• Exterior lights switch
• Maintenance room lights switch.
• EFCO emergency fuel Cutoff/ Stop switch.
• Battery charging ammeter.
• Alerter alarm
• Classification Lights switch:
  • Rotary switch having three position
1. Long Hood forward or short hood forward.
2. Off.
3. Cab end forward.

3. Circuit Breaker and Test Panel:
   - Circuit Breaker panel
     - Generator field Circuit breaker
     - TCC1 blower circuit breaker
     - TCC2 blower circuit breaker
   - Test Panel
     - Test panel jacks allow maintenance personnel to measure the voltages.

4. EM 2000 display panel:

   This is the display diagnostic system which is an interactive device provides an interface between the control computer and the loco operating crew.

   EM 2000 display panel consists of:
   1. Display Screen : Direct operator by displaying messages on the screen
   2. Keypad : Provide with sixteen push button keys

b. Back panel of the electrical control cabinet:
   This is provided in electrical cabinet and consist of following:
   - Main control panel (relays, Resistors etc.)
• Locomotive control Computer (EM2000)
• Computer power supply
• Digital Voltage Regulator Module (DVR)
• GTO (Gate Turn Off) panel
• Excitation panel
• 4 breaking contactors (B1, B2, B3 and B4)
• DC link transfer switch (DCL 123, 456)
• Silicon Charging rectifier (BC)
• Electrical cabinet Blower with filter in order to keep the components cool and dust free.

(D) **Traction Control Converter Compartment**

It consist of:

• TCC1
• TCC2
• Dynamic Breaking Grids
• Dynamic Grid Cooling fans (two nos.)
• TCC electronic blowers (two nos.) for TCC1 & TCC2.
• Blower for inertial filters (Dust Bins Blowers)

(E) **Main Generator Compartment**: Consists of following components:

• Inertial air inlet filters for engine left/ right air intake and for TM blower:
• Traction Motor blower
• Traction Generator with companion alternator.
• Turbo super charger with after cooler
• Auxiliary Generator.
• Engine starting motors (two in no)
• Fibre glass Baggie type engine air intake filters.

(F) Engine Compartment:
• Diesel engine with all accessories.
• Battery knife switch and fuse (provided at engine rear end right side i.e. loco’s left on generator end).
• Turbo lube oil pump (soak back pump) is provided at the engine left side. (Loco right side).
• Lube oil dip stick gauges are provided on both left and right banks of the engine.

(G) Engine Accessories Compartment:
• Wood ward governor.
• Lube oil pumps. (gear driven)
• Water pumps (2 Nos.) for left and right banks. (gear driven).

   i. Scavenging pump: Draws oil from lube oil sump through scavenging strainer and supplies to main lube oil pump through lube oil filter and cooler.

   ii. Main lube oil pump: For piston cooling and engine lubrication.
• Lube oil strainer housing consists of:
  • Two strainer elements
  • Michiana Filter drain cock and strainer housing oil drain cock.
• Michiana Filter drain cock and strainer housing oil drain cock.
• Michiana Filter housing consists of 5 filter elements (paper type).
• Lube oil cooler.
• Engine water tank with water level gauge and pressure vent cock (pressure release cap)
• Fuel primary filter
• Fuel pump (At engine right bank)
• Engine mounted fuel oil secondary filter (two nos.) spin-on type with sight glasses provided on engine Rt. free end side.
• Fuel prime/ engine start switch, provided at the left side of the engine equipment rack.
• Hans brake on Lt. side of engine accessories compartment (Will apply brake for the 5th wheel only).
• EPD (Engine Protection Device): Provided on engine. Lt. free end side. Following are the productions by EPD:
  • Low lube oil pressure protection.
• Low water level / pressure protection.
• Crank case low pressure Protection (CC Vacuum)
• Hot lube oil sensor / protector (Engine Lube Oil)

(H) **Compressor Compartment**: Consist of:
  • **Air Compressor**: WLN type A9BB
    Gardner & Denver make, two stage, 3 cylinders air compressor, Water cooled cooling system (by engine).
    • Computer controlled pneumatically operated compressor clutch.

(I) **Radiator Compartment**:
  • Radiators (2 Nos.) located above the cooling fans.
  • Two radiator cooling fans (AC motor driven).
  • Main reservoir air cooling coils.

(J) **Super structure of Loco Consists**:
  • Fuel tank of 6000 Ltrs. capacity (provided between two trucks underneath the super structure).
  • Cranking circuit board is located underneath the superstructure on Rt. side of the loco.
- Battery box consists of two nos. of batteries located underneath the superstructure between front truck and fuel tank (Loco left side).
- 2 Main reservoir are provided underneath the superstructure on left side of loco.
- Air dryer is provided at the Rt. side of the loco below superstructure near fuel tank.
- Radiator is provided to sense the actual ground speed and is provided in between front truck & fuel tank (loco right side).
- D24 B feed valve (for FP pressure) provided at right side of loco underneath the superstructure behind the air dryer.
- MR safety valve provided on Lt. side of the loco between MR1 & MR2.
- Trucks BC cutout cocks are provided for each truck on Rt. side of the loco.
- MR & BC equilising cut out cocks are provided at both ends of loco.
- BP & FP angular cut out cocks are provided at both ends of the loco.
- 8 number sandboxes are provided on wheel pairs 1,3,4 & 6.
- Wheel flange lubricating spray nozzles are provided on both leading wheel sets.
1) Head light
2) Inertial Filter Air Inlet
3) Starting Fuse and Battery Knife Switch
4) Handrails
5) Cooling System Air Inlet
6) Radiator and Fan Access
7) Coupler “E/F” Type
8) Sanding Box (8)
9) Jacking Pads (4)
10). Wheels (6)
11). Fuel Tank
12). Compressed Air System Main Reservoirs
13). Battery Box
14). Trucks (3 axle 3 motor HTSC type) Qty. 2
15). Under frame
16). Dynamic Brake Grids
17). Dynamic Brake Fans (2)
1) Electrical Control Cabinet
2) Fuel Pump
3) Engine Starting Motors
4) Traction Control Cabinet
5) Traction Motor Cooling Air Blower
6) Main Generator/Companion Alternator Blower
7) Engine Exhaust Stack
8) Engine Exhaust Manifold
9) 16-710G3B Diesel Engine
10) Governor
11) Engine room Vent
12) Engine Water Tank
13) Lube Oil Cooler
14) Primary Fuel Filter
15) Air Compressor
16) Radiators
17) AC Radiator Cooling Fans (2)
18) Draft Gear
19) Air Compressor Air Filter
20) Lube Oil Filter Tank
21) Lube Oil Strainer
22) Lube Oil Sump
23) Main Generator/Companion Alternator
24) Electrical Control Cabinet Air Filter Box
25) Traction Motors (6)
1) Air Brake Rack
2) Engineers Control Console
3) Cab Door
4) Traction Control Cabinets
5) Inertial Air Filters
6) TCC Electronics Blower
7) Engine Air Filter
8) Radiators
9) Engine
10) AC Auxiliary Generator
11) Inertial Filter Dust Bin Blower and Motor
12) Electrical Control Cabinet
13) Cab Seat
FUEL OIL SYSTEM

The fuel oil system is designed to supply fuel to the engine in correct quantity and at the right time according to the engine requirements. The fuel oil system draws fuel from fuel tank, filter the fuel, pressurise the fuel, and inject the fuel into the engine in correct quantity in atomised condition.

- Fuel oil system consist of
  1. Fuel feed system
  2. Fuel injection system

**Fuel feed system:**

Fuel is drawn from the fuel oil tank through a suction strainer by the fuel pump. The strainer separates foreign particles from the fuel oil, and protects the fuel pump. The pump is designed to supply adequate quantity of fuel to the engine at various speeds and load conditions.
Fuel then goes to primary fuel filter. This primary filter is provided with a 30-PSI by pass valve with sight glass, which should be normally empty. Whenever the primary filter is Choked/clogged and the pressure difference reaches 30 PSI this by-pass value open allowing the fuel oil directly to the system, which can be noticed by the flow of by-pass fuel in the sight glass. Under such cases the primary filter element is changed.

The fuel then passes to 02 engine mounted secondary filters, which are of spin-on type. Secondary fuel filters are also provided with a by-pass value, which is set at 60 PSI. Whenever the filters are choked/clogged and the pressure difference across the secondary filters reaches 60 PSI, this by-pass valve opens and diverts the fuel oil back to fuel tank, avoiding damage to fuel injectors due to unfiltered fuel oil. A by-pass sight glass is also provided to indicate the condition of the fuel secondary filters and the sight glass should be normally empty.

From the secondary filters the fuel oil is supplied to all unit injectors through fuel supply manifolds located inside the top deck on both banks. The governor controls the quantity of fuel to be injected through the injectors to the engine.

At the end of the fuel supply manifolds, a regulating valve with a sight glass is provided which is set to 10 PSI. The regulating valve ensures constant fuel supply to all unit injector in all working conditions. If the system is working properly the sight glass should indicate clear and clean fuel oil flow all the
time. Air bubbles, interrupted fuel flow or no fuel flow in the return sight glass indicates problem in the fuel feed system.

**Fuel injection system:**

Fuel supplied by the fuel feed system is always available at all the unit fuel injectors. The fuel oil available at each injector are to be pressurized to very high pressure, timed and to be injected in the cylinder in atomized form. The timing of each unit injector is decided by the camshaft and the fuel is pressurized by the in-built fuel injection pump which is operated by individual cam lobe of the cam shaft.

The quantity of fuel to be injected will be regulated and controlled by engine mounted wood word governor according to the notch and load conditions. The governor operates fuel control shaft, linkage mechanism and fuel racks. The individual fuel injector nozzle does the atomization of the fuel to be injected in the cylinder.

**Alco locomotive Vs GM locomotive**

Although the purpose for which the fuel oil system is designed is same for Alco locomotive and GM locomotive, but the design of the fuel oil system differs in Alco and GM locomotive in respect of general arrangement, position of various components, make and design of components etc. The important comparisons between the two locomotives are given below-

1. The fuel tank capacity in GM loco is 6000 lts. and in Alco loco is 5000 lts.
2. Both have a strainer with wire mesh element.
3. Both the locomotives have a positive displacement gear type fuel feed pump.
4. Both the locomotives have a relief valve for fuel feed pump safety.
5. Both the locomotives have a regulating valve after the fuel manifold for the safety of the fuel system and to maintain adequate fuel supply to fuel injectors.

6. Both the locomotives have a paper type primary filter. In GM locomotive a sight glass is also provided on the primary filter housing.

7. Both the locomotives have a secondary filter but in GM locomotive a spin-on type 02 secondary filters with return sight glass and bypass sight glass are provided on the filter housing.

8. In Alco locomotive fuel injection pumps and injectors connected by high pressure tube are separate units but GM locomotive a unit type fuel injection pump with injector is provided, and there is no provision of HP tube.

9. Fuel oil pressure (Alco loco)  
   - 5.0 Kg/Cm$^2$ (Idle)  
   - 3.2 Kg/Cm$^2$ (8th Notch and Full load)

   Fuel oil pressure (GM loco)  
   There is no pressure gauge in system
COOLING WATER SYSTEM

Engine cooling water system is a closed loop pressurized water cooling system. The water cooling system cools – All the engine cylinder liners, cylinder heads, after cooler, lube oil cooler and compressor.

LINE DIAGRAM OF THE COOLING WATER SYSTEM

In the water cooling system, there are 02 nos. engine mounted water pumps (centrifugal type). The water pump receive water from the radiator through lube oil cooler. Water from the water pump is sent to the two (left and right Bank) water main header (also called water inlet manifold). From the water main header water enter to all the cylinder liner jackets through water jumper. After cooling the cylinder liners water enter in the cylinder head through 12 holes which are matched to cylinder liner with “O” rings and cools the combustion
chamber of the cylinder head. Outlet water from each cylinder head goes to the return header (also called water outlet manifold) which carry water to the radiator.

Each water main header is connected at the rear end from where a water pipe line carry water to cool the after cooler. Water from the aftercooler goes to water return header and through water return header to radiator.

A water pipe line from the water pump carry water to compressor to cool the compressor liners, cylinder head, valves and the compressed air inside the inter cooler. Air compressor cooling is done whenever engine is running.

The radiators are located in a hatch at the top of the long hood end of the locomotive. The hatch contains the radiator assemblies, which are grouped in two banks. Each radiator bank consists of two quad length radiator core assemblies, bolted end-to-end. Headers are mounted on the radiator core to form the inlet and outlet ends of the radiator assembly, a bypass line is provided between the inlet and outlet lines in order to reduce velocity in the radiator tubes.

Two 8-blade 52” cooling fans, which operate independently, are located under the radiators in the long hood carbody structure. They are numbered 1, and 2, with the No. 1 fan being closest to the driver cab.

The water pump inlet side is connected to an expansion tank for makeup water in the water system. The expansion tank is located in the equipment rack.
Temperature control by the cooling system

Mainly the two electronic temperature sensing probes (ETP1 & ETP 2), EM2000 computer and the radiator fans take part in controlling the water temperature.

Two electronic temperature-sensing probes (ETP1 & ETP 2) are located in the water pipe line between the lube oil cooler to the inlet of the water pump on the engine left side. Temperature probe readings are converted by ADA Module from analog to digital signals which are used by the EM2000 to control all cooling functions.

Each cooling fan is driven by a two-speed AC motor, which in turn is powered by the companion alternator. As the engine coolant temperature rises, the fans are energized in sequence by the control computer (slow speed). As additional cooling is required, the fans switch to full speed in progression as coolant temperature rises. As coolant temperature drops, the fans switch off one at a time.

The cooling fans are controlled by the computer which act on the contactors. The computer also controls the fan sequencing duty cycle and speed (low or high) to ensure even fan and contactor wear.

The engine water temperature can be observed by a gauge located on the inlet line to water pump. The gauge is colour coded to indicate cold (Blue), normal (green) and hot (red).

When the engine temperature become excessively high, the EM 2000 will display “HOT ENGINE”- and throttle 6 limit” message. The computer will initiate the reduction in engine speed and load upto 6th notch. This condition will remain in effect until the temperature return to safe limit.

If the engine water temperature is below 115 °F (46 °C), the engine speed will be raised to throttle 2 automatically by the computer. Once the engine water temperature reaches above 125 °F (52 °C), the engine speed will be reduced to IDLE.
The reason for engine speed up will be displayed to the driver on EM 2000 computer monitor as “Engine speed increase- low water temperature”.

**Cooling System Pressurisation:**

The cooling system is pressurized to raise the boiling point of cooling water. This in turn permits higher engine operating temperatures, with a minimum loss of coolant due to pressurization and also ensures a uniform water flow and minimizes the possibility of water pump cavitation during transient high temperature conditions.

A pressure cap, which is located on the water tank-filling pipe, opens at approximately 20 PSI. It prevents the damages of cooling system components by relieving excessive pressure from the system. The pressure cap is equipped with a handle which helps installing and removing of the cap. The most important function of the pressure cap handle is to release pressure developed in the water system before removing the pressure cap.

**GM locomotive Vs Alco locomotive**

Although the purpose for which the cooling water system is designed is same for Alco locomotive and GM locomotive, but the design of the cooling water system differs in Alco and GM locomotive in respect of general arrangement, position of various components, make and design of components etc. The important comparisons between the two locomotives are given below-

1. The water system capacity in GM loco is 1045 lts. and in Alco loco is 1210 lts.
2. Both the locomotives have a closed loop pressurized water cooling system.
3. Both have radiators but their locations and capacities are different. In GM loco the radiators are located in a hatch at
the top of the long hood end. In Alco loco the radiators are placed in vertical position in radiator compartment.

4. Both the locomotives have centrifugal type water pump.
5. In GM locomotive 2 water pumps are provided one for right bank and one for left bank. In Alco locomotive only one water pump is provided.
6. In GM locomotive Berate nitrate water is used for cooling water and in Alco locomotive chromate water is used for cooling water.
7. In GM loco radiator fans operate by electrical motors and in Alco radiator driven by mechanical power.
8. The expansion tank is located in the equipment rack in GM loco. In Alco loco the expansion tank is located in radiator room at the top of the long hood end.
9. Both have pressurization cap which open at approximately 20 PSI.
10. In GM loco, the water system cools the compressor also. But in Alco loco, the expresser / compressor is air cooled.
11. GM loco has got low water temperature control system. In Alco, no such system provide.
12. The water temp. control system has EM 2000 computer and electronic temp. sensing probes ETP1 & ETP2 in GM loco but in Alco control is done by ETS1, ETS2 and ETS3.
13. In GM loco the turbo charger cooling is done by lubricating oil but in Alco loco the turbo charger cooled by water system.
LUBE OIL SYSTEM

The complete engine lubricating oil system is a combination of 04 oil systems. These are:
(1) Scavenging oil system
(2) Main lubricating oil system
(3) Piston cooling oil system
(4) Soak Back or turbo lube system

Lube oil pumps

- Each system has its own lube oil pump.
- The main lube oil pump, piston cooling oil pump and scavenging oil pumps are driven from the accessory gear train at the front end of the engine.
- The soak back or turbo lube system is driven by an electric motor.
- The main lube oil pump and piston cooling oil pump is an individual pump but both contained in one housing and driven from a common drive shaft.

1. Scavenging Oil System

The scavenging oil pump is a positive displacement, helical gear type pump. This pump takes lube oil from 02 sources - from the engine oil sump and from the oil strainer.

The pump feed lube oil to lube oil filter tank (also called Michiana oil filter). Oil from the filter tank goes to lube oil cooler where it is cooled by the engine cooling system. Oil then passes to lube oil strainer where it is filtered once again.

The oil filter (Michiana oil filter) contain 5 paper type filter elements. A bypass valve provided across the filter tank and set at 40 PSI. If the filter is clogged and pressure difference reaches to 40 PSI oil is by passed to lube oil cooler. This ensures adequate lube oil supply to the engine avoiding damages to the moving parts.

The oil filter and the lube oil cooler are located in the equipment rake.
The lube oil strainer is having 02 fine mesh strainer elements.

2. Piston Cooling Oil System

There is a suction pipe (coming from the lube oil strainer) for the piston cooling oil system and the main lube oil system. The piston cooling oil system pump receives oil from a common suction pipe and delivers oil to the 2 piston cooling oil manifolds extending the full length of the engine, one on each bank. A piston cooling oil pipe at each cylinder directs a stream of oil to cool the underside of the piston crown. This stream of oil also lubricate the ring belt. Some of this oil enters oil grooves in the piston pin bearing for lubrication. Oil after cooling and lubrication drains back in to the oil sump.

3. Main Lubricating Oil System

The main lubricating oil system supplies oil under pressure to most of the moving parts of the engine. The main lube oil pump takes oil from the strainer housing through a common suction. Oil from the pump goes to the main oil manifold, which is located above the crankshaft, extends to the length of the engine. Maximum oil pressure in the system is control by a relief valve in the passage between the pump and the main oil manifold. The pressure relief valve is set to 125PSI, which relieves excess oil back to the sump.

Oil tubes in the centre of the each main bearing receives oil from the main manifold to the upper half of the crankshaft main bearings. Drilled passage in the crankshaft supplies oil to the connecting rod bearings, vibration damper and accessory drive gear at the front end of the crankshaft. Oil from the manifold enters gear train at the rear end of the engine at the idler gear stub shaft. Oil passes in the base of the stub shaft from where oil is distributed to various parts through passage. One passage conducts oil to the left bank camshaft drive gear stub shaft bracket through a jumper. Another passage conducts oil to the Right Bank camshaft
drive stub shaft bracket and the turbo charger oil filter supply line.

Oil enters the hollow bore camshaft from the camshaft stub shafts. Radial holes in the camshafts conducts oil to each camshaft bearing. An oil line from each camshaft bearing at each cylinder supplies oil to the rocker arm shaft, rocker arm cam follower assemblies, hydraulic lash adjusters and to rocker arm. Leaks of oil return to the sump.

**LINE DIAGRAM OF LUBE OIL SYSTEM**
The turbo charger oil filter supply line sands oil to the turbo lube oil filter which sands oil to the turbo oil manifold and then to turbo for cooling and lubrication. A branch line taken to the wood word governor low lube oil pressure shut down
device and also to the hot oil detector. The minimum oil pressure is approximately 8-12 PSI at idle and 25-29 PSI at full speed. In the event of insufficient oil pressure, a shutdown feature in the governor will automatically protect the engine by shutting down.

The turbo charger oil filter provides additional protection for the high-speed bearing and other lubricated areas of the turbo. The filter heads contains 2 check valves, one to prevent the lube oil from the soak back system from going into the turbo charger filter during soak back pump operation and the other to prevent lube oil from the turbo charger filter from entering the soak back system when the engine is running. Passages in the turbo charger conducts oil to the turbo bearings, idler gear, planet gear assembly and auxiliary drive bore.

4. Soak Back Oil System: -

To ensure lubrication of the turbo charger prior to the engine start and the removal of residual heat from the turbo after engine shutdown, a separate lube oil pressure source is provided. This pressure system is controlled automatically by the locomotive control system.

An electrically operated turbo soak back pump draws oil from the oil sump, feed the oil through a soak back filter and finally to the turbo. A 70-PSI soak back filter bypass valve is provided inside the soak back filter housing to bypass filter whenever it clogs to protect Turbo-charger.

This soak back pump automatically starts working before cranking the engine. When the engine start, the motor driven soak back pump is still running, main lube oil pressure from the engine driven pump becomes greater than the motor driven soak back pump pressure. As there is no outlet for the lower pressure oil, the relief valve is provided in the filter head set to 32 PSI will return the oil back to engine sump.
1- LUBE OIL FILTER
2- OIL COOLER
3- MAIN LUBE AND PISTON COOLING PUMP
4- ENGINE OIL PRESSURE GAUGE
5- TURBOCHARGER
6- TURBOCHARGER OIL FILTER
7- TURBOCHARGER LUBE OIL PUMP
8- OIL PAN SUMP
9- TURBOCHARGER AUXILIARY LUBE OIL FILTER
10- SCAVENGING OIL PUMP
11- OIL STRAINER
Considerable heat will remain in the metal parts of the turbine when the engine is shutdown and due to sudden cut off oil supply to the bearings, damage or more wear will take place in the bearings since the turbo rotor will be rotating even after the engine stops due to its momentum. To avoid the thermal stressing and unwanted wear in the bearings due to no oil supply, this soak back pump automatically start working after shutting down of the engine. Soak back pump will be working for 30 to 35 minute approximately even after engine shutdown. This ultimately increases the life of the turbo.

**Lube Oil Separator**

The oil separator is an elbow shaped cylindrical housing containing a wire mesh screen element. It is mounted on turbo charger housing. An elbow assembly connects the separator to the ejector tube assembly in the exhaust stack. The eductor tube in the exhaust stack creates suction in the engine crankcase and draws up oil vapor from the engine crankcase, while doing so. The oil drawn will be collected on the wire mesh element and drain back to the engine sump.

**Hot Oil Detector**

Normally there is a close relationship between engine coolant temperature and engine lube oil temperature. Hot oil detector senses the oil temperature and send informations to EM2000. If the temperature of the oil exceeds approximately 255 degree F (124 degree C) EM 2000 will shut down the engine through governor and the fault will be displayed on the EM2000 screen.
**GM locomotive Vs Alco locomotive**

Although the purpose for which the lube oil system is designed is same for Alco locomotive and GM locomotive, and the design of the lube oil system differs in Alco and GM locomotive in respect of all arrangement, position of various components, make and design of components etc. The important comparisons between the two locomotives are given below-

1. The lube oil system capacity in GM loco is 950 lts and Alco loco is 910 lts.
2. In GM locomotive 4 different lube oil pumps are provided for different areas of lubrication. In Alco locomotive only one lube oil pump is provided.
3. Both the locomotives have a pressurized lube oil system.
4. Both have lube oil filter, relief valve, regulating valve, bypass valve and strainer assembly but their locations are different.
5. Both the locomotives have a paper filter type filter assembly.
6. Both the locomotives have a strainer assembly for final filter.
7. Both the locomotives have a lube oil cooler assembly.
8. In GM locomotive a soak back system is provided for turbo charger cooling but in Alco loco turbocharger is water-cooled.
9. A separate system is used for piston cooling in GM loco but in Alco loco, there is no separate system of piston lubrication.
10. A separate system is used for turbo lubrication in GM loco but in Alco loco, there is no separate system of turbo cooling.
AIR INTAKE SYSTEM

Air intake system consists of the following components.

- Turbo charger,
- Inertial air intake filters,
- Baggie type fibre glass air intake filters,
- After cooler

Turbo Charger: -

The primary use of the turbo charger is to increase air supply to engine to produce more horsepower and provide better fuel efficiency by the utilization of exhaust gases.

The turbo charger has a single stage turbine with a connecting gear train. The connecting gear train work in the condition of engine starting/ light load operation and rapid acceleration.

When the engine work on full load (approximately in 6\textsuperscript{th} notch) the energy of the exhaust gases is sufficient to drive the turbo charger and the turbine rotor rotates without any mechanical help from the engine. At this point, an over riding clutch in the drive gear train disengages and the turbo charger drive is disconnected from the engine gear train.

The rotor shaft assembly of turbo is divide into 3 parts:

a) Sun-gear shaft: -When engine is starting or it works on slow speeds or lower notch operations, the sun-gear shaft receive drive from the engine through the planet gear system and a clutch.

b) Exhaust gas driven turbine: - The burnt exhaust gases are directed to passage through a fixed nozzle ring between exhaust manifold and turbine. The exhaust gases is directed by the fixed nozzle ring on to the turbine wheel blades and the heat energy is converted into mechanical rotary motion. The diffuser is another aerodynamic device located in the turbine section of the turbo. The diffuser is basically an arrangement of 3 to 4 vanes, which are
placed behind the turbine blades these provide a smooth transition path for the gas to flow, there by eliminating turbulence. Then exhaust gases are expelled out through exhaust duct. A built in aspirator tube provided in exhaust ducts contains an “eductor tube” which provide suction in the engine crank case and maintains vacuum in the engine crankcase.

c) **Impeller with diffuser:** - On the other end of the rotor assembly, an impeller (compressor) with a diffuser ring is provided. The impeller induces a partial vacuum in the air inlet casing. The impeller inducer draws air from the clean air room where the clean air available after passing through cyclonic air inlet filter and secondary through a baggy type fibre glass secondary filter. The air drawn by the blower is compressed in the blower causing and presses through a compressor diffuser directs the flow of compressed air to provide a smooth air delivery which is free from turbulence.

**Inertial Air Intake Filter**

The inertial air inlet filters are cyclonic types consisting of many filter tubes mounted in a single assembly. The reduction in pressure in the clean air compartment causes the outside air to rush through the filters to fill the depression. As the air passes through the filter tubes and stationary vanes in the intake throats imparts a spinning motion to the air. By spinning motion dirt particles are thrown to the outer wall of the tube by a centrifugal force. These particles are carried to he bleeds duct (dustbin), where
they are removed by dustbin blower and thrown out from the locomotive. The resulting clean air enters in the air compartment. In addition to clean the filters, the dust bin blower increases their efficiency by increasing the velocity of the air passing from the filter tubes.

**Baggie Type Air Intake Filters**

The diesel engine requires fine clean air for combustion of the fuel. The inertial air filters approach 90% efficiency on throttle 8\textsuperscript{th} but it is not adequate to the engine. A secondary engine air filters are provided to filter the reminder contaminants. These filters are oil coated and made by fiberglass material. This material is very efficient in filtration.

![Air Intake Filters](image)

**Aftercooler**

A four-passage aftercooler is provide on the engines. Which cools the compressed air before entering the air box by its efficient heat exchange capacity. Thus the density of the air also increases and high density fresh, clean and compressed air is available for combustion of the fuel.
**GM locomotive Vs Alco locomotive**

Although the purpose for which the Air intake system is designed is same for Alco locomotive and GM locomotive, and the design of Air intake system differs in Alco and GM locomotive in respect of all arrangement, position of various components, make and design of components etc. The important comparisons between the two locomotives are given below-

1. In GM locomotive the turbocharger is driven by gear train at lower notches and by exhaust gases at higher notches but in Alco loco the turbo charger is driven by only exhaust gases.
2. In both the locomotives the turbo air is cooled by water in the aftercooler.
3. GM loco engine receives very fine clean air through double filtration. In Alco loco engine air filtered by single filter assembly.
4. In GM locomotive the turbo charger fitted on generator end side but in Alco loco the turbo charger fitted on free end side.
5. In GM loco turbo air goes to both side air boxes for combustion and in Alco loco turbo air goes to a common air gallery for combustion.
COMPRESSED AIR SYSTEM

Compressed air in GM locomotive is used for the locomotive brake system as well as for auxiliary systems such as sanders, bell, horn, windshield wipers, rail lube systems, and radar head air cleaner.

The GM locomotive uses WLNA9BB model three cylinder air compressor which is a two stage (low-pressure and high-pressure) compressor. The compressor is water-cooled. The compressor is mechanically driven by a driveshaft from the front or accessory end of the locomotive engine. This driveshaft is equipped with flexible couplings to couple the compressor.

WLNA9BB - AIR COMPRESSOR ASSEMBLY
The compressor is equipped with three cylinders, two low pressures and one (in the center) high pressure. Air is sucked through two dry pamic type air filters and compressed by the two low pressure cylinders. After that the low-pressure compressed air passed through an intercooler. The intercooler reduced the compressed air temperatures. A pressure relief valve is provided on the intercooler for intercooler safety. After this the compressed air moves on to the high-pressure cylinder where it is again compressed to main reservoir pressure. Between the compressor and main reservoir an aftercooler cooling coil is provided to reduced the air temperature.

The compressor has its’ own internal oil pump and pressure lubricating system with an oil filter. The oil level is checked during running by means of the dipstick mounted on the side of the compressor crankcase. When adding oil in the compressor it must be in stop position.

At idle speed and normal operating temperature, the oil pressure should be between 18-25 psi. A plugged opening is provided for installation of an oil pressure gauge.

**GM locomotive Vs Alco locomotive**

1. In GM locomotive the compressor and air is water-cooled but in Alco loco the compressor and air is cooled by air.
2. Both compressors have its own lubrication system.
3. Both compressors have an intercooler between low-pressure cylinder and high-pressure cylinder.
4. Both locos have an after cooler cooling coil between the compressor and reservoir.
5. Both locos have a loading –unloading arrangement.
COMPUTER CONTROLLED BRAKE SYSTEM (CCB)

The loco is equipped with a KNORR brake system. The KNORR system is computer controlled air brake system (CCB). The CCB equipment is a complete microprocessor based air brake control system. All logics are computer controlled.

The driver uses one of the two control stands (cab control unit (CCU) to control the CCB system. Emergency applications are also initiated pneumatically in parallel with computer initiated emergency applications. The main parts of the CCB system are as follow:

Brake Valve Controller (BVC)

Automatic Brake Valve: (This is for the full train with loco.)

Automatic Brake valve having 5 positions:
- Release/Over charging) (Spring Loaded) 5kg/cm²
- Running
  ER and BP Pr. =5.2 kg/cm²
- Minimum service
  ER/BP reduce to 4.7kg/cm², BCP=1.1kg/cm²
- Full Service
  ER reduces to 3.4kg/cm², BCP= 4.35kgs/cm²
- Emergency
  ER reduces to 0, BP, reduces to <1.0 kg/cm²
  BCP=4.35 kg/cm², BCEP=3.57kg/cm²

ER = Equalizing reservoir pressure
BP = Brake Pipe pressure
BCP = Brake cylinder pressure

Independent Brake Valve: (This is for the loco brake only)

It is direct Brakes having following positions
- Release positions
  BCP=0
- Application zone
Max Brake position: BCP 5.2kg/cm²  
BCEP=3.7Kg/cm²  

BCEP = Brake cylinder equalizing pressure

- Bail off
  When an automatic brake is applied, lifting the bail off ring which is provided in the brake valve handle in any position will release BC as a result of BP reduction. Independent brake handle bail off ring is spring-loaded and by lifting it the bail off function will actuate.

CONTROL STAND

Selector Switch or Air Brake Trial /Lead Set Up Switch:
The trail/Lead setup switch is located on the brake control next to independent brake handle. The switch has the following 3 positions:

- **Trail**
  Used with loco in trailing position and on non-working control of the working loco.
• **Lead-In**
  Used with loco in leading unit or controlling unit in MU consists. Air brake system responds to air brake handle movements when trail/Lead switch is in this position.

• **Lead-Out**
  Used during brake pipe leakage testing and on banking loco control stand.

**Air Brake Equipment Rack:**
Provided in the nose compartment consisting following:

- Voltage conditioning Unit (VCU)
- Computer Relay Unit (CRU) or Air Brake computer
- Analog Converters.
- Magnet Valves
- Pneumatic Valves
- Filters
- Transducers
- KE Distributor Valve (Back-up valve)
- Reservoirs

**Brake Pipe Control System**
According to the auto brake valve controller handle position, signals from the brake handle will go to the fiber optic receiver (FOR) then to the air brake computer. Computer will send signals to analog converter.

The analog converter operates magnet valves provided in it and from the magnet valves piloting air pressure will go to the other main magnet valve which is controlled by CCB computer. the output air pressure of the main magnet valve is called as equalizing Reservoir and is acting as pilot pressure for the BP relay valve. BP relay valve is a self lapping pressure maintaining pneumatic valve which maintains the BP pressure to the level of ER against train brake pipe leakage conditions.

There are transducers provided in the ER pipe and BP pipe to send feed back signals to the computer regarding the pressures available or maintained in the respective pipe lines.
Emergency Application:

An emergency application means to apply brakes at the maximum rate. When the brake valve handle is placed in the emergency position, ER reduces at the faster rate to zero pressure and also the brake valve mechanically opens a vent valve. In addition the brake controller is provided with a switch which opens sending an emergency signal to the computer. Then the computer energizes an emergency magnet valve (MVEM). The opening of MVEM vents the pilot port of the high capacity BP relay pneumatic valve (PVEM) exhausting BP pressure.

Automatic Brake Application on Loco:

The brake pipes transducer (BPT) provided in the BP pipe detects the reduction in BP and sends signal to computer. The computer calculates the required brake cylinder pressure and commands the BC analog converter to maintain the desired rate of pressure level in the brake cylinder. The brake cylinder analog converter operates a BC magnet valve. The output pressure of the BC magnet valve work as a pilot pressure for the BC relay valve. BC relay valve is a self lapping pressure maintaining pneumatic valve which will come to the lap position when matches with the BC pilot air pressure. The application is complete if the BC pressure is maintained at the level commanded by the computer until the brake valve handle is again moved.

Bail-Off Automatic Application:

When the automatic brake is applied lifting the bail-off ring provided in the independent brake valve handle in any position will release the brake cylinders of the loco.

On the LEAD UNIT, the CCB computer commands the BC analog converter to release the pilot air pressure which in turn drives the BC relay valve to release the BC pressure, if an emergency brake has been mad, the brake will reapply to maximum as soon as the bail off ring is released.
NOTE: If the bail-off continuous for longer than 50 seconds the BC pressure will be restored and a fault will be displayed on the EM 2000 display screen. The crew messages the center point of display and it will indicate fault condition that required immediate attention.

**Independent Brake Operation:**

According to the independent brake valve controller handle position, signals from the brake valve handle will go to the fibre optic receiver (FOR) and then to the computer. Computer will send signals to the BC analog converter. The analog converter operates the BC relay valve. BC relay valve is a self lapping pressure maintaining pneumatic valve which will come to the lap position when matches with the BC pilots air pressure.

Any leakage in the BC pipe will be noticed by the BC transducer (BCT) and the feedback signals will go to CCB computer. Then computer will in turn take corrective action to maintain BC pressure. The BC equalizing pipe (BCEP) is used to supply air to end from all the trailing units of the locomotive consist to control application and release of both automatic and independent brakes. The only exception to this operation is locomotive consist separation.

According to the service positions of the brake controller valve handles, CCB computer gets signals from the FOR. Then the computer sends the signals to BCEP analog converter to supply piloting air pressure to BCEP relay valve. When the BC pressure equalizes BCEP, the BCEP relay valve moves to LAP position.

Maximum BCEP = 3.7Kg/Cm²

**Introduction Of Blended Brake System**

The passenger service locomotive is equipped with a blended brake system. It simultaneously applies dynamic braking and air braking when the driver operates the automatic air brake handle in the service zone. The Knorr CCB air brake system controls the air brakes on the locomotive and carriages coupled in trains, and requests the
required amount of dynamic braking from EM 2000 computer for blended brake operation.
Power Distribution system in GT46MAC locomotives

The diesel engine is the source of locomotive power, when the engine is running it directly drives three electrical generators:

1. Main generator (traction alternator)
2. Companion alternator
3. Auxiliary generator

Main generator (traction alternator)

The main generator (traction alternator) rotates at engine speed generating AC power. Rectifiers are covered within the generator assembly. The rectifiers convert the AC power to DC, and the DC output is applied to DC link. Switch gear and contractors supply DC voltage to traction inverter circuits. The traction inverters convert the DC link voltage to 3-phase AC power for the traction motors. There are two separate computers TCC1 and TCC2 which control the traction motors by varying the voltage and frequency which is fed to traction motors to get the proper torque and speed i.e., the output from traction motors.

Companion alternator

The companion alternator is directly coupled to the traction alternator and is within the main generator assembly itself. Output is utilized for the following:

- To excite the main generator (traction alternator) field.
- To drive the two rectifier cooling fan motors.
- To drive the inertial blower motors.
- To drive the traction inverter blowers.
- Various transducers and control devices.

Auxiliary generator

The auxiliary generator is driven by engine gear train. The output of aux. Gen. is converted to 74V DC in a rectifier & output from the rectifier is utilized for the following:

- To excite the companion alternator fields.
• Control systems.
• Battery charging.
• F. P. Motor.
• Turbo charger soak-back pump.
• Lighting and Misc. equipment.

**DC link voltage**

During motoring the DC output from the main generator is called the DC link voltage & is supplied to traction inverters. DC link voltage varies with throttle position from 600 V DC to 2600 V DC at 8th notch.

There is one traction inverter for each set of three parallel traction motors. The two traction inverters TCC1 and TCC2 invert the DC link voltage in to variable voltage and variable frequency 3 phase AC voltage. Both inverters are in turn controlled by EM2000 computer.

**Dynamic braking**

During dynamic braking the energy of the moving train is transmitted into rotating energy in the Traction motors. AC supply generated by all TMs will be fed back to traction inverters TCC1 and TCC2 and is converted to DC. The converted DC supply is now fed to dynamic braking grids which dissipate the electrical power in the form of the heat. This loss of energy causes train to slow down. EM2000 maintains the braking efforts required by the driver.

**EM2000 computer**

Both inverters are directly controlled by EM 2000 locomotive control computer, which displays control system information on the screen. Most control and protective functions are programmed into the EM2000 computer that monitors critical functions in the locomotive power system provides a display message if a fault occurs. For serious faults the EM 2000 also sounds the alarm bell and & takes corrective action.
Power Distribution system in GT46 MAC locomotives
COMPUTERS CONTROL OF LOCOMOTIVE

The GM locomotives are equipped with four interrelated computers to provide electronic control of the various functions involved in locomotive operation. These individual computers are:

1. The locomotive control computer, designated as EM2000.
   i. The primary control system device is the EM 2000 locomotive control computer (LCC).
   ii. The locomotive operating controls provide inputs to the control computer, which then directs electrical power equipment and the diesel engine to operate within the constraints of the power and brake requirements.
   iii. The EM 2000 exerts over all control over the other computers. Thus the other three computers are somewhat dependent on the EM 2000.

2. The Knorr CCB computer - This controls the air brake system based on control inputs from the electrical brake valve and feedback from the active brake elements.

3. The Siemens SIBAS 16 computers- (02 Nos)
   i. The EM 2000 manages the entire traction system through 02 Siemens SIBAS 16 computers and the traction control converters (TCC1, TCC2).
   ii. SIBAS 16 monitors feedback signals and protective functions for each Traction Control converters(TCC1, TCC2).
   iii. The EM 2000 locomotive computer controls the main locomotive functions based on inputs from the two traction control computers SIBAS 16.
   iv. Each SIBAS 16 uses an Intel 8086 microprocessor with an Ultra-Violet Erasable /Programmable Read Only Memory (UVEPROM).
The EM2000 locomotive computer

1. The EM2000 locomotive computer controls-
   - Generation of traction.
   - Brake reference signals.
   - Display/Diagnostic System (computer display).
   - Locomotive Cooling System - cooling fans, radiator shutters.
   - Diesel Engine - governor speed settings, turbo. lube pump, fuel pump.
   - Engine Starting Circuit.
   - Dynamic Brake System -braking contactors/braking effort.
   - Excitation - monitors companion alternator (CA6B) output and controls main generator excitation.
   - Vigilance and wheel flange lubrication systems.

2. All communication with EM 2000 is through the key board on the display panel.

3. The microprocessor display panel is made of 6 line 40 columns vacuum fluorescent display with a 16-button feedback key pad.

4. The display panel combined with loco control computer is referred as to display diagnostic system.
Thus the display diagnostic system is an interactive device that provides an interface between EM 2000-control computer and the driver.

5. The computer provides massage for driver on the screen indicating loco control, maintenance and trouble shooting function.

6. The computer is shaving four function keys F1, F2, F3 & F4 which indicates to cutout traction motor or truck, reset a fault or request more information about other stored data.

7. The display screen displays crew messages under normal operating conditions as well as problems occur on loco such as:
   ♦ Engine speed up for low water temperature.
   ♦ Loco is not set up for the requested mode of operation.
   ♦ Power is limited.
   ♦ Some piece of equipment or system has failed and protective function is active.

8. Data can be downloaded.
MAJOR EQUIPMENTS OF GM LOCOMOTIVES

The GM locomotive equipped with the following special features equipments in constitutional aspect-

Main Alternator

The main alternator TA17 is a 3-phase, 10 pole, 90 slots machine equipped with two independent and interwoven sets of stator winding. The main alternator construction is such that it is basically two alternators in one - two sets of stator windings, permanently connected in series, work with a rotating field common to both the windings in order to provide higher alternator output voltage, which is a basic requirement of a low current high voltage alternator used on AC-AC locomotives.

The diesel engine drives the main alternator. The main alternator converts the mechanical power of diesel engine into electrical power. The internal rectifier bank of the main alternator converts alternating current into direct current there by providing a DC power output. The DC power output from the main alternator is called the DC link voltage and is applied to the traction inverters. DC link voltage varies with the engine speed from 600 V DC at idle to 2600 V DC at full speed. The inverter changes DC into variable AC power.
Alternator and Traction Motor Blower

The Main Alternator Blower and Traction Motor Blower share a common housing mounted on the front side of the auxiliary generator. Although both the blowers are mounted on the auxiliary generator shaft an internal partition separates the two blower portions. Air is drawn from the central air compartment into the alternator blower close to the auxiliary generator and pass through a duct to the main alternator air box. Air from alternator blower first cools the main alternator rectifier banks then passes internally through the alternator and companion alternator to the engine room. This creates a slight positive pressure to keep the dirt from entering the engine room.

Companion Alternator

Companion alternator is a three phase AC steady state alternator of 250 kVA rating, which is physically connected but electrically independent of the main alternator. The companion alternator rotor field is excited directly by auxiliary supply of the locomotive. It receives the excitation current from the auxiliary alternator through a pair of slip rings, which are located adjacent to the slip rings of the main alternator.

The companion alternator develops power whenever the diesel engine is running. The output voltage is directly proportional to the speed of rotation but varies to some extent with change in alternator temperature and load. It is used for excitation of the main alternator as well as for supply to Inertial (dustbin) blower, TCC1 and TCC2 blower motor, TCC electronic blower, 55-220 V AC for radiator fans and various control circuits. An AC auxiliary
alternator of 18 kW rating is used for meeting the auxiliary and control system load.

**Inertial Blower (Dustbin Blower)**

Outside air is cleaned by Inertial (dustbin) Blower, before it enters central air cabinet. In the Inertial Blower there are two inertial filter panels, one mounted on either side of the locomotive. Outside air is drawn rapidly through the tubes which contains specially designed vanes that induce a spinning motion to the contaminated incoming air. Dirt and dust particles, because they are heavier than air are thrown to the outer wall of the tube and carried to the bleed duct where it is removed by the scavenging action of the Inertial blower and expelled through the roof of the locomotive. The resulting clean air continues on through the smaller diameter portion of the tube where the air is again caused to swirl by internal vanes. The particles are carried to the bleed duct and the resulting clean air enters the central air compartment.

**AC Traction Motors**

AC-AC transmission has the advantage of high adhesion and high tractive effort, maintenance free Siemens ITB - 2622 - 0TA02 Three phase AC traction motors, high reliability and availability and higher energy efficiency. A specialty of this motor is that there is no separate stator frame resulting
in reduction of weight. In braking mode, the three-phase motors act as generators and power is fed back to the DC link via the two inverters.

Traction Motor Blower
The Traction Motor Blower is mounted on the auxiliary generator, supplies air for traction motor cooling, generator pit aspirator operation, main electrical cabinet pressurisation and traction computer cooling. Air is drawn through a movable inlet guide vane through the blower, and delivered into a duct to the traction motors. A portion of this air is diverted through a set of filters for delivery to the computer module portion of traction inverter cabinets for module cooling. Another set of filters cleans the air used to pressurise the main electrical cabinet.

TCC1 and TCC2 Inverters
The locomotive has two inverters TCC1 and TCC2. The output converter, a pulse width modulated (PWM) inverter, is responsible for providing the variable frequency and the variable terminal voltage for the three-phase motor. The main alternator feeds electrical power to the DC link via two series connected diode rectifiers. Two identical PWM inverters TCC1 and TCC2 with GTO and their capacitors are connected electrically to the DC link via isolating switches. There is one traction inverter for each parallel set of three traction motors, which are responsible for supplying power to them. A protective circuit based on GTO is connected to the DC link to protect the inverters against any over-voltages. The TCC blower defuses heat produced by losses generated in TCC.

TCC Blower
An electronic blower in each TCC cabinet driven by its own 3-phase AC motor draws the air from central air compartment in across the modules and expels it across the R2 snubber resistor. This air is used for cooling and pressurising in some parts of the inverter cabinet. This air keeps dirt from contaminating areas containing DC link.
capacitors, gate units and traction computers. The TCC blower motor is a dual speed 3-phase AC induction motor. It operates as a series-Y wound machine for lower speed (only low speed configuration is used on WDG4 locomotives). Power for the motors is taken from the companion alternator through the main contacts of TCC1SS and TCC2SS. EM2000 exercises control of the blower contactors at the request of the TCC via RS-485 serial link.

**Radiator Cooling Fan Motors**

Radiator Cooling Fan Motors are of the inverted squirrel cage induction type and are integral part of the cooling fan assembly. Each cooling fan (total two per locomotive) is driven by a two-speed AC motor, which in turn is powered by the companion alternator. Cooling fans are powered through contactors, which are controlled by the EM2000 program. Each fan motor circuit consists of one slow-speed and two fast-speed contactors that are located in the AC cabinet.

**Computer EM 2000**

The WDG4 locomotive is equipped with a microprocessor based computer control system. It provides fault detection of components and systems, it contains 'self tests' to aid in trouble shooting locomotive faults. It has basic features like, significant reduction in number of control modules, better fault detection of components, memory archive and data snap shot. The microprocessor EM2000 is the locomotive control computer. EM 2000 utilises "Flash PROM" memory. It is a 32 bit computer based on Motorola 68020 microprocessor running at 16 MHz with a math co-processor communication through RS-232 serial cable / port. EM 2000 controls the main locomotive functions based on inputs from two traction computers. This system is equipped with a diagnostic display system in the cab to provide an interface between the maintenance personnel and the computer. The computer is programmed to monitor and control locomotive traction power, record and indicate faults that have been incorporated into EM 2000 system.
Computer Control Brake

The locomotive is equipped with KNORR/NYAB CCB (computer controlled braking) 1.5 system. This system is an electro-pneumatic microprocessor based system with 30A CDW type desktop controls. The overall purpose of using a computer (microprocessor) to control the air brake system is to eliminate as many of the electrical and mechanical devices as possible, thereby reducing periodic maintenance, simplifying trouble shooting, fault diagnostics etc. It allows greater reliability and flexibility for future system upgrade.

Dynamic Brake

Each unit of the Dynamic Brake Grid Blower Assembly consists of fan assembly powered by a 36 HP series wound DC motor. During dynamic braking, a portion of the current (rectified DC) from the traction motors is shunted around one of the resistor grids and used to power the grid blower motor. Air driven by the grid blower drives grid heat to atmosphere.

Traction Control Computers

There are two SIBAS 16 traction control computers. Each computer is dedicated to one inverter. SIBAS 16 is a 16-bit computer based on an INTEL 8086 microprocessor running at 5.6 MHz. The TCC receives data via RS-485 serial link from the locomotive computer EM2000. The bi-directional bus carries data such as how much power for traction the TCC must develop as well as other information to control activation of devices like blowers and heaters. In addition to the RS-485 data, information constantly gets fed back into the TCC, to monitor various things such as status of relays and temperature of various components, voltages and currents. Based on this feedback data and information received via RS-485 serial link, the programs stored in the TCC work to drive the TCC as well as to protect it in the event of faulty operating conditions.
Radar

The locomotive is equipped with a K- BAND RADAR module. The mounting location of radar under the cab of the locomotive near the end plate. This particular type of RADAR system mounts at an angle of 37.5° with respect to the rail. It is particularly susceptible to signal error as a result of inaccurate mounting.

Under Truck

The WDG4 locomotive is equipped with a high adhesion HTSC (High Tensile Steel Cast) truck or bogie. The bogie assembly supports the weight of the locomotive and provides the means for transmission of power to the rails. The HTSC bogie is designed as a powered 'bolsterless unit'. Although the bogie or truck frame itself is rigid, the design allows the end axles to move or "yaw" within the frame. This movement will allow the wheels to position themselves tangent to the rails on curves for reduced wheel and rail wear. Axles 1 and 3 can move or kink a little bit to negotiate a curve from 0-8 degree deflection, increases the tractive effort and improves the rolling resistance.

Traction loads are transmitted from the truck or bogie to the locomotive under frame through the carbody pivot pin assembly. Each bogie is equipped with three unidirectional AC traction motors for better adhesion characteristics. The motors are geared to the driving axles, which in turn apply rotational force to the rails through the wheels. The driving force is transmitted to the bogie through tractive rod attached to the journal-bearing adapter in the frame. From the truck / bogie frame the driving force is transmitted to the locomotive carbody through the carbody pivot pin.
### Differences Between WDG₄ and WDP₄ GM Locomotives

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Description</th>
<th>WDG₄</th>
<th>WDP₄</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Model</td>
<td>GT46MAC</td>
<td>GT46PAC</td>
</tr>
<tr>
<td>2.</td>
<td>Service</td>
<td>Goods</td>
<td>Passenger</td>
</tr>
<tr>
<td>3.</td>
<td>Speed</td>
<td>100KMPH</td>
<td>160KMPH</td>
</tr>
<tr>
<td>4.</td>
<td>Speedometer</td>
<td>0-120KMPH</td>
<td>0-180KMPH</td>
</tr>
<tr>
<td>5.</td>
<td>Weight</td>
<td>129Tonne</td>
<td>115.8Tonnes</td>
</tr>
<tr>
<td>6.</td>
<td>No. of Axis</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>7.</td>
<td>No. of Traction Motor</td>
<td>6( Each Bogie 3 Drivers)</td>
<td>4( Each Bogie 2 Drivers)</td>
</tr>
<tr>
<td>8.</td>
<td>Under TCC1</td>
<td>1,2,&amp; 3 Axle TM</td>
<td>1, &amp; 2 Axle TM</td>
</tr>
<tr>
<td>9.</td>
<td>Under TCC2</td>
<td>4,5 &amp; 6 Axle TM</td>
<td>5 &amp; 6 Axle TM</td>
</tr>
<tr>
<td>10.</td>
<td>TM Pinion and Bull Gear Ratio</td>
<td>17:90</td>
<td>17:77</td>
</tr>
<tr>
<td>11.</td>
<td>Batteries</td>
<td>LEAD ACID</td>
<td>NICKEL CADMIUM</td>
</tr>
<tr>
<td>12.</td>
<td>No. of Batteries</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>13.</td>
<td>No. of Cells</td>
<td>32</td>
<td>50</td>
</tr>
<tr>
<td>14.</td>
<td>Cell Voltage</td>
<td>2.1</td>
<td>1.5</td>
</tr>
<tr>
<td>15.</td>
<td>Total Voltage</td>
<td>68</td>
<td>75</td>
</tr>
<tr>
<td>16.</td>
<td>Engine Starting Switch</td>
<td>Located in Engine starting room</td>
<td>Located in Engine control panel</td>
</tr>
<tr>
<td>17.</td>
<td>For quick engine firing</td>
<td>Governor Lay Shaft Manually operation</td>
<td>Governor booster pump starts automatically</td>
</tr>
<tr>
<td>18.</td>
<td>Radar System</td>
<td>Located between front bogie &amp;Fuel tank</td>
<td>Located between fuel tank &amp;rear bogie</td>
</tr>
<tr>
<td>19.</td>
<td>Cab Light Switch</td>
<td>Near Cab Light</td>
<td>In control stand side switch panel</td>
</tr>
<tr>
<td></td>
<td>Lube oil Filter Drum</td>
<td>Only Bye-pass Valve</td>
<td>Bye-pass valve with gauge (Like fuel oil Primary filter)</td>
</tr>
<tr>
<td>---</td>
<td>---------------------</td>
<td>---------------------</td>
<td>---------------------------------------------------------</td>
</tr>
<tr>
<td>20</td>
<td>Blended Brake</td>
<td>Not provided</td>
<td>Provided</td>
</tr>
<tr>
<td>21</td>
<td>Location of Blended Brake</td>
<td>Not provided</td>
<td>On engine control panel</td>
</tr>
<tr>
<td>22</td>
<td>Low water Level Switch</td>
<td>Not provided</td>
<td>Provided in the engine Cooling Water system</td>
</tr>
<tr>
<td>23</td>
<td>Temperature Gauge</td>
<td>Not provided</td>
<td>Located on the inlet line to the Water pump</td>
</tr>
<tr>
<td>24</td>
<td>Colour Code (Temperature gauge)</td>
<td>Not provided</td>
<td>Blue (cold), Green (Normal) &amp; Red (Hot)</td>
</tr>
</tbody>
</table>

************
OUR OBJECTIVE

To upgrade maintenance technologies and methodologies and achieve improvement in productivity and performance of all Railway assets and man power which inter-alia would cover reliability, availability, utilisation and efficiency.

If you have any suggestions and any specific comments, please write to us.

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