Specifications and Torque

Providing and maintaining an adequate supply of clean, high-quality fuel, lubricating oil, grease and coolant in an engine is one way of insuring long life and satisfactory performance.

Lubricant, Fuel and Coolant

Lubricating Oil

Lubricating oil is used in Cummins engines to lubricate moving parts, provide internal cooling and keep the engine clean by suspending contaminants until removed by the oil filters. Lubricating oil also acts as a combustion seal and protects internal parts from rust and corrosion.

The use of quality lubricating oil, combined with appropriate lubricating oil, drain and filter change intervals, is an important factor in extending engine life. Cummins Engine Company, Inc. does not recommend any specific brand of lubricating oil. The responsibility for meeting the specifications, quality and performance of lubricating oils must necessarily rest with the oil supplier.

Oil Performance Specifications

The majority of lubricating oils marketed in North America (and many oils marketed world-wide) are designed to meet oil performance specifications which have been established by the U.S. Department of Defense and the Automobile Manufacturers Association. A booklet entitled "Lubricating Oils for Heavy Duty Automotive and Industrial Engines" listing commercially available brand name lubricants and the performance classification for which they are designed is available from Engine Manufacturing Association, 111 East Wacker Drive, Chicago, Illinois 60601.

Following are brief descriptions of the specifications most commonly used for commercial lubricating oils.

Table 3-1: Oil Recommendations

Light Service Only (Stop-and-Go) All Diesel Models	Naturally Aspirated Diesel Models	Turbocharged Diesel Models	All Natural Gas Models All Service
API Class CC/SC [2/5] 1.85% Maximum Sulfated Ash Content [3]	API Class CC [1] 1.85% Maximum Sulfated Ash Content [3]	API Class CC/CD [2] 1.85% Maximum Sulfated Ash Content [3]	API Class CC 0.03 to 0.85 Sulfated Ash Content [4]

[1] API classification CC and CD quality oils as used in turbocharged engines and API classification CC/SC quality oils as used for stop-and-go service are satisfactory for use in naturally aspirated engines.

[2] API classification CC/SC and CC/CD indicate that the oil must be blended to the quality level required by both specifications. The range of oil quality permitted by the CC classification is so broad that some oils that meet the classification will not provide adequate protection (varnish and ring sticking) for engines operated in certain applications. For example, turbocharged engines require the additional protection provided by the CD classification. Engines operated in stop-and-go service require the additional protection provided by the SC classification.

[3] A sulfated ash limit has been placed on all lubricating oils for Cummins engines because past experience has shown that high ash oils may produce harmful deposits on valves that can progress to guttering and valve burning.

[4] Completely ashless oils or high ash content oils, are not recommended for use in gas engines; a range of ash content is specified.

[5] SD or SE may be substituted for SC.

API classification CC is the current American Petroleum Institute classification for lubricating oils for heavy duty gasoline and diesel service. Lubricating oils meeting this specification are designed to protect the engine from sludge deposits and rusting (aggravated by stop-and-go operation) and to provide protection from high temperature operation, ring sticking and piston deposits.

API classification CD is the current American Petroleum Institute classification for severe duty lubricating oil to be used in highly rated diesel engines operating with high loads. Lubricating oils which meet this specification have a high detergent content and will provide added protection against piston deposits and ring sticking during high temperature operation.

API classification SC, SD and SE were established for the Automobile Manufacturers Association. They require a sequence of tests for approval. The primary advantage of lubricating oils in these categroies is low temperature operation protection against sludge, rust, combustion chamber deposits and bearing corrosion. The test procedure for these specifications are published by the American Society for Testing and Materials as STP-315.

Break In Oils

Special "Break-In" lubricating oils are not recommended for new or rebuilt Cummins Engines. Use the same lubricating oil as will be used for the normal engine operation.

Viscosity Recommendations

1. Multigraded lubricating oils may be used in applications with wide variations in ambient temperatures if they meet the appropriate performance specifications and ash content limits shown in Table 3-1. Multigraded oils are generally produced by adding viscosity index improver additives to a low viscosity base stock to retard thinning effects at operating temperatures. Poor quality multigraded oils use a viscosity index improver additive which has a tendency to lose its effectiveness after a short period of use in a high speed engine. These oils should be avoided.

2. Oils which meet the low temperature SAE viscosity standard (0 deg. F [−18 deg. C] carry a suffix "W". Oils that meet the high temperature viscosity SAE standard 210 deg. F [99 deg. C] as well as the low temperature carry both viscosity ratings – example 20-20W. See Table 3-2.

Table 3-2: Operating Temperatures VS Viscosity

Ambient Temperatures	Viscosity
−10 deg. F [−23 deg. C] and below	See Table 3-3.
−10 to 30 deg. F [−23 to −1 deg. C]	10W
20 to 60 deg. F [−7 to 16 deg. C]	20-20W
40 deg. F [4 deg. C] and above	30

Arctic Operations

For operation in areas where the ambient temperature is consistently below −10 deg. F [−23 deg. C] and there is no provision for keeping engines warm during shutdowns, the lubricating oil should meet the requirements in Table 3-3.

Due to extreme operating conditions, oil change intervals should be carefully evaluated paying particular attention to viscosity changes and total base number decrease. Oil designed to meet MIL-L-10295-A, which is void, and SAE 5W mineral oils should not be used.

Table 3-3: Arctic Oil Recommendations

Parameter (Test Method)	Specifications
Performance Quality Level	API class CC/SC API class CC/CD
Viscosity	10,000 Centistokes Max. @ −30 deg. F 5.75 Centistokes Min. @ 210 deg. F
Pour Point (ASTM D-97)	At least 10 deg. F [6 deg. C] below lowest expected ambient temperature
Ash, sulfated (ASTM D-874)	1.85 wt. % Maximum

Grease

Cummins Engine Company, Inc., recommends use of grease meeting the specifications of MIL-G-3545, excluding those of sodium or soda soap thickeners. Contact lubricant supplier for grease meeting these specifications.

TEST	TEST PROCEDURE
High-Temperature Performance	
Dropping point, deg. F.	ASTM D 2265 350 min.
Bearing life, hours at 300 deg. F. 10,000 rpm	*FTM 331 600 min.
Low-Temperature Properties	
Torque, GCM	ASTM D 1478
Start at 0 deg. F.	15,000 max.
Run at 0 deg. F.	5,000 max.
Rust Protection and Water Resistance	
Rust test	ASTM D 1743 Pass
Water resistance, %	ASTM D 1264 20 max.
Stability	
Oil separation, % 30 Hours @ 212 deg. F.	*FTM 321 5 max.
Penetration	
Worked	ASTM D 217 250-300
Bomb Test, PSI Drop	ASTM D 942
100 Hours	10 max.
500 Hours	25 max.
Copper, Corrosion	*FTM 5309 Pass
Dirt Count, Particles/cc	*FTM 3005
25 Micron +	5,000 max.
75 Micron +	1,000 max.
125 Micron +	None
Rubber Swell	*FTM 3606 10 max.

* Federal Test Method Standard No. 791a.

Caution: Do not mix brands of grease as damage to bearings may result. Excessive lubrication is as harmful as inadequate lubrication. After lubricating fan hub, replace both pipe plugs. Use of fittings will allow lubricant to be thrown out, due to rotative speed.

Fuel Oil

Cummins Diesel Engines have been developed to take advantage of the high energy content and generally lower cost of No. 2 Diesel Fuels. Experience has shown that a Cummins Diesel Engine will also operate satisfactorily on No. 1 fuels or other fuels within the following specifications.

Recommended Fuel Oil Properties:

Viscosity (ASTM D-445)	Centistokes 1.4 to 5.8 @ 100 deg. F. (30 to 45 SUS)
Cetane Number (ASTM D-613)	40 minimum except in cold weather or in service with prolonged idle, a higher cetane number is desirable.
Sulfur Content (ASTM D-129 or 1552)	Not to exceed 1% by weight.
Water and Sediment (ASTM D-1796)	Not to exceed 0.1% by weight.
Carbon Residue (Ransbottom ASTM D-524 or D-189)	Not to exceed 0.25% by weight on 10% residue.
Flash Point (ASTM D-93)	At least 125 deg. for legal temperature if higher than 125 deg. F.
Gravity (ASTM D-287)	30 to 42 deg. A.P.I. at 60 deg. F. (0.815 to 0.875 sp. gr.)
Pour Point (ASTM D-97)	Below lowest temperature expected.
Active Sulfur-Copper Strip Corrosion (ASTM D-130)	Not to exceed No. 2 rating after 3 hours at 122 deg. F.
Ash (ASTM D-482)	Not to exceed 0.02% by weight.
Distillation (ASTM D-86)	The distillation curve should be smooth and continuous. At least 90% of the fuel should evaporate at less than 675 deg. F. All of the fuel should evaporate at less than 725 deg. F.

Coolant

Water should be clear and free of any corrosive chemicals such as chloride, sulfates and acids. It should be kept slightly alkaline with pH value in range of 8.0 to 9.5. Any water which is suitable for drinking can be treated as described in the following paragraphs for use in an engine.

Maintain the Fleetguard DCA Water Filter on the engine. The filter by-passes a small amount of coolant from the system via a filtering and treating element which must be replaced periodically.

1. In summer, with no antifreeze, fill system with water.

2. In winter, select an antifreeze and use with water as required by temperature.

Note: Some antifreeze also contain anti-leak additives such as inert inorganic fibers, polymer particles or ginger root, these antifreeze should not be used in conjunction with the water filter. The filter element will filter out the additives and/or become clogged and ineffective.

3. Install or replace DCA Water Filter as follows and as recommended in Section 2.

New Engines Going Into Service Equipped With DCA Water Filters

1. New engines shipped from the Factory are equipped with water filters containing a DCA precharge element. This element is compatible with plain water or all permanent-type antifreeze except Dowtherm 209. See Table 3-4 for Dowtherm 209 precharge instructions.

2. At the first "B" Check (oil change period) the DCA precharge element should be changed to DCA Service Element. See Table 3-4.

3. Replace the DCA Service Element at each succeeding "B" Check.

a. If make-up coolant must be added between element changes, use coolant from a pre-treated supply, see "Make-Up Coolant Specifications", Section 2.

b. Each time system is drained, precharge according to Table 3-4.

4. Service element may be changed at "C" Check if 3300858 (DCA-4L) direct chemical additive is added to the cooling system at each "B" Check between service element changes. One bottle of direct additive should be used for every 10 gallon of cooling system capacity. Add one bottle for every 15 gallon capacity if methoxy propanol antifreeze (Dowtherm 209) is used in the cooling system.

5. To insure adequate corrosion protection have the coolant checked at each third element change or more often. See "Check Engine Coolant", Section 2.

Engine Now In Service With Spin-On Type Chromate Corrosion Resistor Element

1. Remove chromate element.

2. Clean and flush cooling system.

3. Install service DCA element and precharge according to Table 3-4. Operate engine to next "B" Check; then treat as "New Engine Going Into Service" above. See Table 3-4.

Engines Now In Service With Package (Bag) Or Canister Type Chromate Corrosion Resistor Elements

1. Remove chromate package or canister, discard package element and plates or canister, retain spring for use with DCA service element.

2. Flush cooling system.

Table 3-4: Spin-On Type DCA Water Filter

Cooling System	Ethylene Clycol Base Antifreeze		Methoxy Propanol Base Antifreeze (Dowtherm 209)	
Capacity (U.S. Gallons)	**DCA-4L Precharge (P/N 3300858)**	**Service Element(s)**	**DCA-4L Precharge (P/N 3300858)**	**Service Element(s)**
0-8	1	WF-2010 (P/N 299080)	1	WF-2011 (P/N 3300721)
9-15	2	WF-2010	2	WF-2011
16-30	5	WF-2010	4	WF-2011
31-60	10	(2) WF-2010	8	(2) WF-2011
35-90 (V-1710)	12	(2) WF-2016 (P/N 299086)	8	(2) WF-2017 (P/N 3300724)
70-90 (KT-2300)	16	(4) WF-2010	16	(4) WF-2011

3. Precharge system with coolant and DCA-4L, Part No. 3300858, according to Table 3-5, using applicable service canister.

4. At next "B" Check install service canister, replacing regularly at each succeeding "B" Check thereafter, except under following conditions:

a. If make-up coolant must be added between canister changes use coolant from a pre-treated supply, see "Make-Up Coolant Specifications", Section 2.

b. Each time system is drained revert back to Step 3 instructions for one oil change period.

Table 3-5: Canister Type

DCA Precharge Canister	DCA Service Canister	Fleetguard P/N
None *	299071	WF-2001
None *	299074	WF-2004
None *	(2) 299091	(2) WF-2021

*** 3300858 (DCA-4L) Precharge To Be Used With Service Elements.**

Cooling System U.S. Gal.	Service Element 299074	Service Element 299071	Service Element 299091	Service Element (2) 299091
0-5	1			
5-9	2	1		
9-13	3	2	1	
13-17	0	3	2	
17-21	0	4	3	1
21-25	0	5	4	2
25-28	0	0	5	3
28-32	0	0	6	4
32-36	0	0	7	5
36-40	0	0	8	6
40-45	0	0	0	7
45-49	0	0	0	8
49-53	0	0	0	9
53-57	0	0	0	10
57-61	0	0	0	11
61-65	0	0	0	12
65-69	0	0	0	13
69-73	0	0	0	14
73-79	0	0	0	15
79-81	0	0	0	16

Note: Canister type elements are not available for use with methoxy propanol base antifreeze (Dowtherm 209); however, conversion kits are available to convert the pot type water filters to spin-on elements.

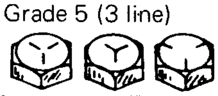
Capscrew Markings and Torque Values

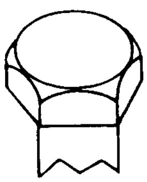
Current Usage	Much Used	Much Used	Used at Times	Used at Times
Minimum Tensile Strength PSI [MPa]	To 1/2–69,000 [476] To 3/4–64,000 [421] To 1–55,000 [379]	To 3/4–120,000 [827] To 1–115,000 [793]	To 5/8–140,000 [965] To 3/4–133,000 [917]	150,000 [1 034]
Quality of Material	Indeterminate	Minimum Commercial	Medium Commercial	Best Commercial
SAE Grade Number	1 or 2	5	6 or 7	8

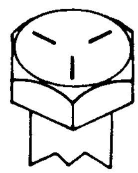
Capscrew Head Markings

Manufacturer's marks may vary

These are all SAE Grade 5 (3 line)







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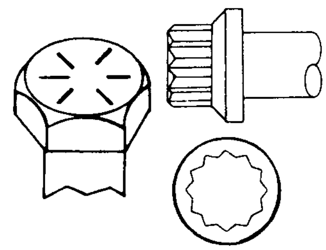


Capscrew Body Size (Inches) – (Thread)	Torque Ft-Lb [N• m]	Torque Ft-Lb [N• m]	Torque Ft-Lb [N• m]	Torque Ft-Lb [N• m]
1/4 – 20	5 [7]	8 [11]	10 [14]	12 [16]
– 28	6 [8]	10 [14]		14 [19]
5/16 – 18	11 [15]	17 [23]	19 [26]	24 [33]
– 24	13 [18]	19 [26]		27 [37]
3/8 – 16	18 [24]	31 [42]	34 [46]	44 [60]
– 24	20 [27]	35 [47]		49 [66]
7/16 – 14	28 [38]	49 [66]	55 [75]	70 [95]
– 20	30 [41]	55 [75]		78 [106]
1/2 – 13	39 [53]	75 [102]	85 [115]	105 [142]
– 20	41 [56]	85 [115]		120 [163]
9/16 – 12	51 [69]	110 [149]	120 [163]	155 [210]
– 18	55 [75]	120 [163]		170 [231]
5/8 – 11	83 [113]	150 [203]	167 [226]	210 [285]
– 18	95 [129]	170 [231]		240 [325]
3/4 – 10	105 [142]	270 [366]	280 [380]	375 [508]
– 16	115 [156]	295 [400]		420 [569]
7/8 – 9	160 [217]	395 [536]	440 [597]	605 [820]
– 14	175 [237]	435 [590]		675 [915]
1 – 8	235 [319]	590 [800]	660 [895]	910 [1234]
– 14	250 [339]	660 [895]		990 [1342]

Notes:

1. Always use the torque values listed above when specific torque values are not available.
2. Do not use above values in place of those specified in other sections of this manual; special attention should be observed when using SAE Grade 6, 7 and 8 capscrews.
3. The above is based on use of clean, dry threads.
4. Reduce torque by 10% when engine oil is used as a lubricant.
5. Reduce torque by 20% if new plated capscrews are used.
6. Capscrews threaded into aluminum may require reductions in torque of 30% or more of Grade 5 capscrews torque and must attain two capscrew diameters of thread engagement.

Trouble Shooting

Trouble shooting is an organized study of the problem and a planned method of procedure for investigation and correction of the difficulty. The chart on the following page includes some of the problems that an operator may encounter during the service life of a Cummins Diesel Engine.

Cummins Diesel Engines

The chart does not give all the answers for correction of problems listed, but it is meant to stimulate a train of thought and indicate a work procedure directed toward the source of trouble. To use the trouble shooting chart, find the complaint at top of chart; then follow down that column to a black dot. Refer to left of dot for the possible cause.

Think Before Acting

Study the problem thoroughly. Ask these questions:

1. What were the warning signs preceding the trouble?

2. What previous repair and maintenance work has been done?

3. Has similar trouble occurred before?

4. If the engine still runs, is it safe to continue running it to make further checks?

Do Easiest Things First

Most troubles are simple and easily corrected; examples are "low-power" complaints caused by loose throttle linkage or dirty fuel filters, "excessive lubricating oil consumption" caused by leaking gaskets or connections, etc.

Always check the easiest and obvious things first; following this simple rule will save time and trouble.

Double-Check Before Beginning Disassembly Operations

The source of most engine troubles can be traced not to one part alone but to the relationship of one part with another. For instance, excessive fuel consumption may not be due to an incorrectly adjusted fuel pump, but instead, to a clogged air cleaner or possibly a restricted exhaust passage, causing excessive back pressure. Too often, engines are completely disassembled in search of the cause of a certain complaint and all evidence is destroyed during disassembly operations. Check again to be sure an easy solution to the problem has not been overlooked.

Find And Correct Basic Cause Of Trouble

After a mechanical failure has been corrected, be sure to locate and correct the cause of the trouble so the same failure will not be repeated. A complaint of "sticking injector plungers" is corrected by replacing the faulty injectors, but something caused the plungers to stick. The cause may be improper injector adjustment, or more often, water in the fuel.

TROUBLE SHOOTING

CUMMINS ENGINES

CAUSES		Hard Starting or Failure to Start	Engine Misses	Excessive Smoking at Idling	Excessive Smoke Under Load	Low Power or Loss of Power	Cannot Reach Governed RPM	Low Air Output	Excessive Fuel Consumption	Poor Deceleration	Erratic Idle Speeds	Engine Dies	Surging at Governed RPM	Excessive Lube Oil Consumption	Crankcase Sludge	Dilution	Low Lubrication Oil Pressure	Fuel Leakage AFC Vent Capscrew	Coolant Temperature too Low	Coolant Temperature too High	Lube Oil too Hot	Piston, Liner and Ring Wear	Wear of Bearings and Journals	Worn Valves and Guides	Fuel Knocks	Mechanical Knocks	Gear Train Whine	Excessive Engine Vibration
AIR SYSTEM	Restricted Air Intake	●			●	●		●	●																			
	High Exhaust Back Pressure				●	●			●											●								
	Thin Air In Hot Weather or High Alt.				●	●		●																				
	Air Leaks Between Cleaner and Engine							●														●	●	●				
	Dirty Turbocharger Compressor				●	●		●	●																			
	Improper Use of Starter Aid/Air Temp.	●																							●			
FUEL SYSTEM	Out of Fuel or Fuel Shut-Off Closed	●										●																
	Poor Quality Fuel	●	●		●	●			●			●													●			
	Air Leaks in Suction Lines	●	●			●				●	●	●	●												●			
	Restricted Fuel Lines: Stuck Drain Valve	●	●	●	●	●	●		●	●																		
	External or Internal Fuel Leaks					●			●			●				●	●											
	Plugged Injector Spray Holes	●	●	●	●	●			●																			
	Broken Fuel Pump Drive Shaft	●										●																
	Scored Gear Pump or Worn Gears	●				●																						
	Loose Injector Inlet or Drain Connection	●														●												
	Wrong Injector Cups			●	●	●			●							●												
	Cracked Injector Body or Cup	●	●	●	●	●			●							●												
	Mutilated Injector Cup "O" Ring								●							●												
	Throttle Linkage or Adjustment					●	●			●	●	●	●															
	Incorrectly Assembled Idle Springs									●	●	●																
	Governor Weights Assembled Incorrectly										●	●																
	High-Speed Governor Set Too Low					●	●																					
	Water in Fuel	●	●				●					●																
	Aneroid Set Improperly				●	●																						
	Aneroid Check Valve Stuck Open	●																										
	AFC Set Improperly			●		●																						
	Damaged or Worn AFC Plunger Seal																	●										
LUBRICATING SYSTEM	External and Internal Oil Leaks													●		●												
	Dirty Oil Filter														●		●						●	●				
	Faulty Cylinder Oil Control			●	●									●		●						●						
	Clogged Oil Drillings																					●	●	●				
	Oil Suction Line Restriction																●					●	●	●				
	Faulty Oil Pressure Regulator																●											
	Crankcase Low or Out of Oil																●			●	●	●	●	●				
	Wrong Grade Oil for Weather Conditions													●			●											
	Oil Level Too High					●			●					●							●							
COOLING SYSTEM	Insufficient Coolant					●											●			●	●							
	Worn Water Pump					●											●			●	●							
	Faulty Thermostats					●									●		●		●	●	●							
	Damaged Water Hose																●			●	●							
	Loose Fan Belts																●			●	●							
	Radiator Shutters Stuck Open														●				●									
	Clogged Water Passages																●			●	●							
	Internal Water Leaks															●												
	Clogged Oil Cooler																●				●							
	Radiator Core Openings Dirty																●			●	●							
	Air in Cooling System																●			●	●							
	Exterior Water Leaks																●			●	●							
	Insufficient Coolant Capacity					●											●			●	●							
	Coolant Temperature Low														●	●									●			
OPERATION AND MAINTENANCE PRACTICES	Dirty Filters and Screens					●									●							●	●	●				
	Long Idle Periods	●	●	●	●	●									●	●												
	Engine Overloaded				●				●								●			●	●	●	●	●	●	●		
	Oil Needs Changing														●							●	●	●				
	Engine Exterior Caked with Dirt																●			●	●							
MECHANICAL ADJUSTMENTS OR REPAIR	Gasket Blow-by or Leakage			●	●	●										●												
	Faulty Vibration Damper																									●		●
	Unbalanced or Loose Flywheel																									●		●
	Valve Leakage	●	●			●																		●				
	Broken or Worn Piston Rings	●	●	●	●	●								●								●				●		
	Incorrect Bearing Clearances					●			●								●						●			●	●	
	Excessive Crankshaft End Clearance																						●			●	●	
	Main Bearing Bore Out of Alignment																						●			●		●
	Engine Due for Overhaul	●		●	●	●			●					●			●					●	●	●		●	●	●
	Damaged Main or Rod Bearings																●						●			●		
	Broken Tooth in Gear Train																									●	●	
	Excessive Gear Back Lash																									●	●	
	Misalignment Engine to Driven Unit								●														●				●	●
	Loose Mounting Bolts																									●		●
	Incorrect Valve and Injection Timing	●		●	●	●																		●	●			
	Worn or Scored Liners or Pistons			●	●	●								●								●				●		
	Injectors Need Adjustment		●	●	●	●			●																●			

Operating Principles

Dependable service can be expected from a Cummins Diesel Engine when the operating procedures are based upon a clear understanding of the engine working principles. Each part of the engine affects the operation of every other working part and of the engine as a whole. Cummins Diesel Engines treated in this manual are four-stroke-cycle, high-speed, full-diesel engines.

The Cummins Diesel Engine

Cummins Diesel Cycle

Cummins Diesel Engines differ from spark-ignited engines in a number of ways. Compression ratios are higher, the charge taken into combustion chamber during the intake stroke consists of air only — with no fuel mixture. Cummins injectors receive low-pressure fuel from the fuel pump and deliver it into individual combustion chambers at the proper time, in equal quantity and atomized condition for burning. Ignition of fuel is caused by heat of compressed air in the combustion chamber.

The four strokes and order in which they occur are: Intake Stroke, Compression Stroke, Power Stroke and Exhaust Stroke.

In order for the four strokes to function properly, valves and injectors must act in direct relation to each of the four strokes of the piston. The intake valves, exhaust valves and injectors are camshaft actuated, linked by tappets or cam followers, push rods, rocker levers and valve crosshead. The camshaft is gear driven by the crankshaft gear, thus rotation of the crankshaft directs the action of the camshaft which in turn controls the opening and closing sequence of the valves and the injection timing (fuel delivery).

Intake Stroke

During intake stroke, the piston travels downward; intake valves are open, and exhaust valves are closed. The downward travel of the piston allows air from the atmosphere to enter the cylinder. On turbocharged engines the intake manifold is pressurized as the turbocharger forces more air into the cylinder through the intake manifold. The intake charge consists of air only with no fuel mixture.

Compression Stroke

At the end of the intake stroke, intake valves close and piston starts upward on compression stroke. The exhaust valves remain closed.

At end of compression stroke, air in combustion chamber has been forced by the piston to occupy a smaller space (depending upon engine model about one-fourteenth to one-sixteenth as great in volume) than it occupied at beginning of stroke. Thus, compression ratio is the direct proportion in the amount of air in the combustion chamber before and after being compressed.

Compressing air into a small space causes temperature of air to rise to a point high enough for ignition of fuel.

During last part of compression stroke and early part of power stroke, a small metered charge of fuel is injected into combustion chamber.

Almost immediately after fuel charge is injected into combustion chamber, fuel is ignited by the existing hot compressed air.

Power Stroke

During the beginning of the power stroke, the piston is pushed downward by the burning and expanding gases; both intake and exhaust valves are closed. As more fuel is added and burns, gases get hotter and expand more to further force piston downward and thus adds driving force to crankshaft rotation.

Exhaust Stroke

During exhaust stroke, intake valves are closed, exhaust valves are open, and piston is on upstroke.

Upward travel of piston forces burned gases out of combustion chamber through open exhaust valve ports and into the exhaust manifold.

Proper engine operation depends upon two things — first, compression for ignition; and second, that fuel be measured and injected into cylinders in proper quantity at proper time.

Fuel System

The PT fuel system is used exclusively on Cummins Diesel. The identifying letters, "PT", are an abbreviation for "pressure-time".

The operation of the Cummins PT Fuel System is based on the principle that the volume of liquid flow is proportionate to the fluid pressure, the time allowed to flow and the passage size through which the liquid flows. To apply this simple principle to the Cummins PT Fuel System, it is necessary to provide:

1. A fuel pump to draw fuel from the supply tank and deliver it to individual injectors of each cylinder.

2. A means of controlling pressure of the fuel being delivered by the fuel pump to injectors so individual cylinders will receive the right amount of fuel for the power required of the engine.

3. Fuel passages of the proper size and type so fuel will be distributed to all injectors and cylinders with equal pressure under all speed and load conditions.

4. Injectors to receive low-pressure fuel from the fuel pump and deliver it into the individual combustion chambers at the right time, in equal quantities and proper condition to burn.

The PT fuel system consists of fuel suction line, fuel filters, fuel pump, aneroid, supply lines, fuel passages, fuel manifolds, injectors, drain passages and drain lines. See Fig's. 5-1 through 5-5 for fuel flow.

There are five types of fuel pumps currently used on Cummins Engines. The PT (type G), PT (type G) AFC, PT (type G) VS, PT (type G) VS-AFC and the PT (type R) MVS.

Fuel Pump

The fuel pump is coupled to the air compressor, vacuum pump or fuel pump drive which is driven from the engine gear train. Fuel pump main shaft in turn drives the gear pump, governor and tachometer shaft assemblies.

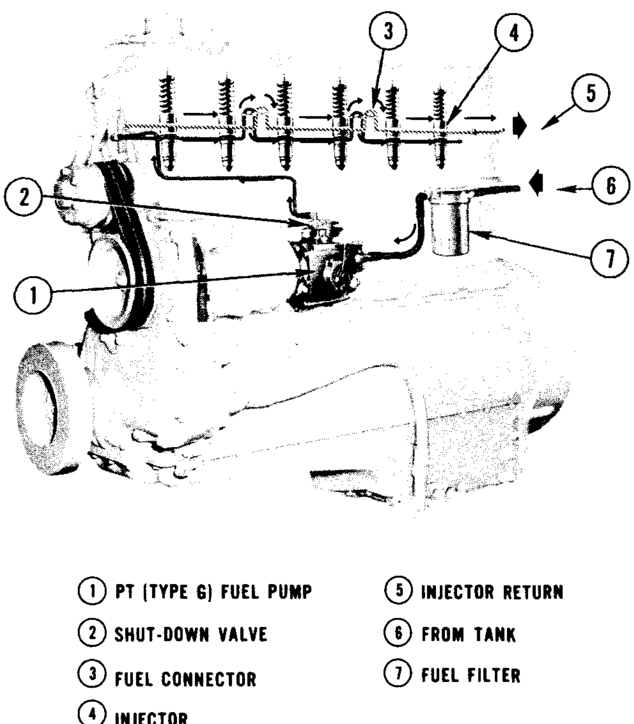


Fig. 5-1, (FWC-13) Fuel flow diagram – PT (type G) pump – Inline

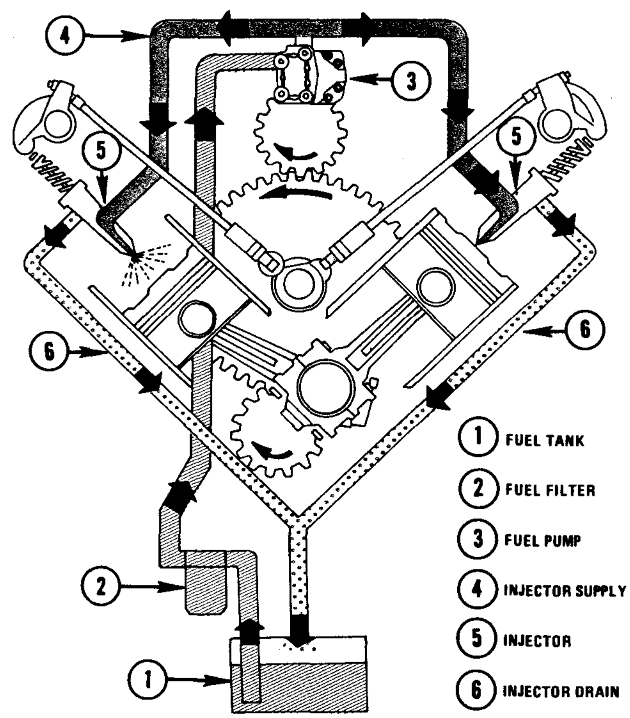


Fig. 5-2, (FWC-30) PT fuel system flow schematic – V engine

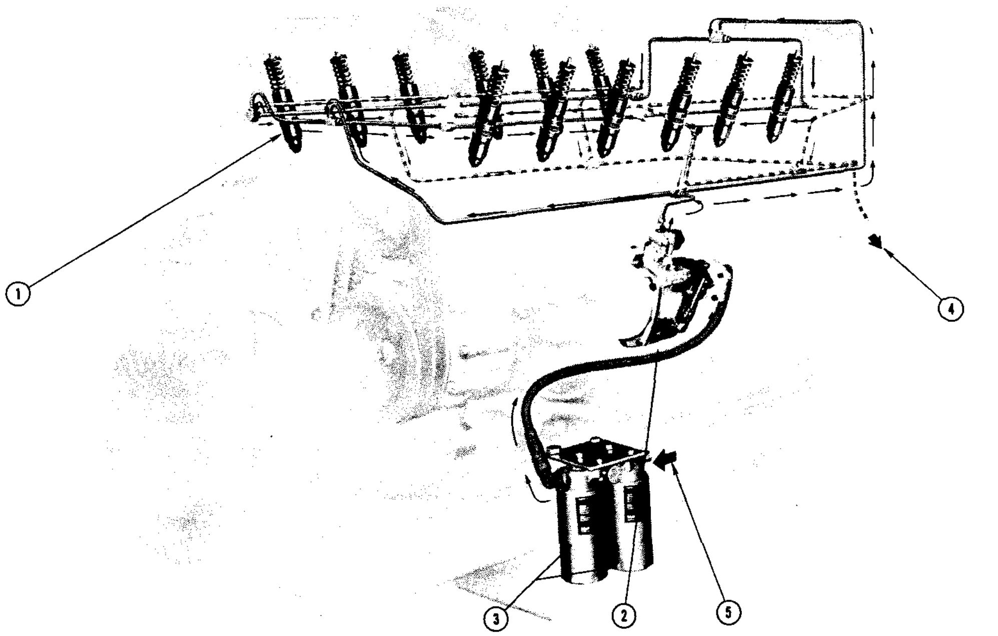


Fig. 5-3, (FWC-15A). Fuel flow schematic – V-1710 Engine Series

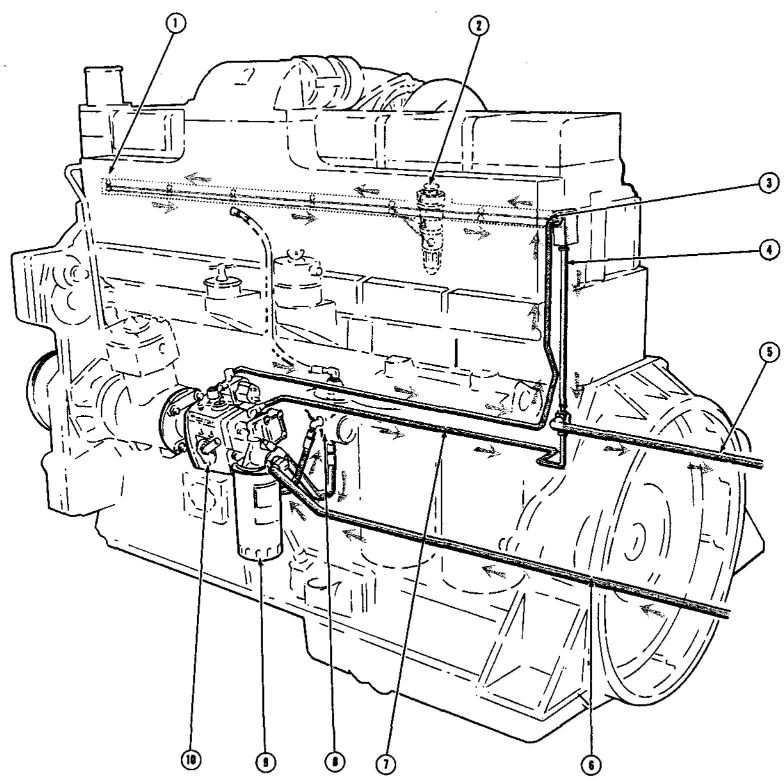


Fig. 5-4, (K11941). Fuel flow schematic – KT(A)-1150 Engine Series

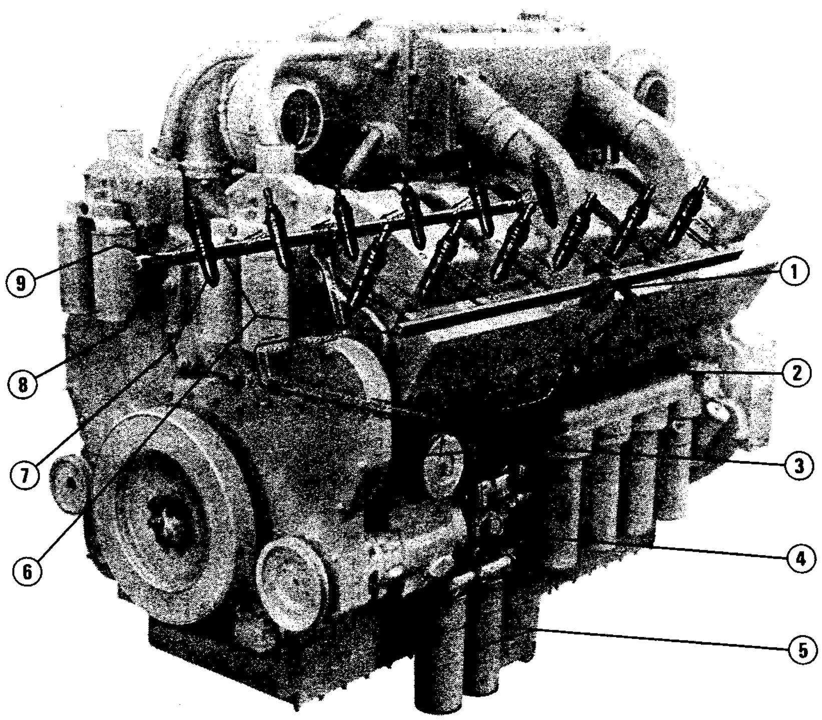


Fig. 5-5, (FWK-40). Fuel flow schematic — KT(A)-2300 Engine Series

PT (type G) Fuel Pump

The PT (type G) fuel pump assembly, Fig. 5-6, is made up of three main units; the gear pump, standard governor and throttle.

PT (type G) VS Fuel Pump

The PT (type G) VS fuel pump, Fig. 5-8, is made up of four main units; the gear pump, standard governor, throttle as in PT (type G) Fuel Pump and a VS (Variable Speed) governor.

Air/Fuel Control (AFC)

The Air/Fuel Control is an acceleration exhaust smoke control device built internally in the PTG fuel pump, Fig's. 5-7 and 5-9. It restricts fuel proportionally to intake manifold pressure during engine acceleration.

The Air/Fuel Control provides a more completely combustible fuel to air mixture by continuously monitoring turbocharger air pressure and proportionally responding to load or acceleration changes.

Fuel Flow (Air/Fuel Control)

1. The only external plumbing required is to connect the intake manifold air pressure hose to a No. 4 fitting located in the AFC cover plate.

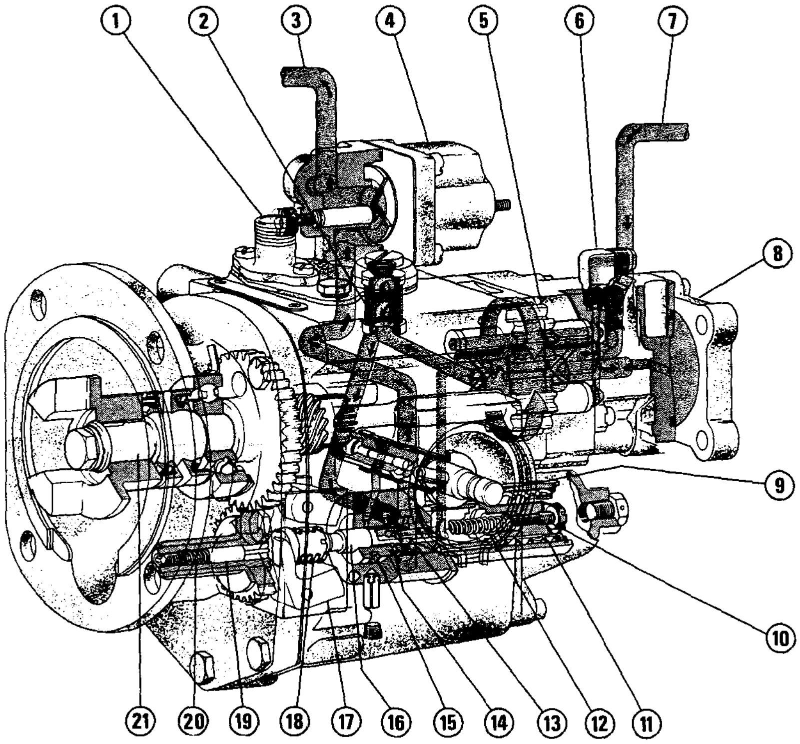
2. Fuel enters the AFC control after leaving the governor and passing through the throttle shaft.

3. When "no air" pressure is supplied from the turbocharger the AFC plunger closes off the primary fuel flow circuit. A secondary passage controlled by the position of the "no air" needle valve supplies fuel for this condition, such as, engine cranking or at initial engine acceleration. The "no air" needle valve is located directly above the throttle shaft under the throttle cover plate.

4. As intake manifold pressure increases (or decreases) the AFC throttling plunger reacts to deliver a proportional increase (or decrease) in fuel. This prevents the fuel to air mixture from getting overrich and causing excessive exhaust smoke.

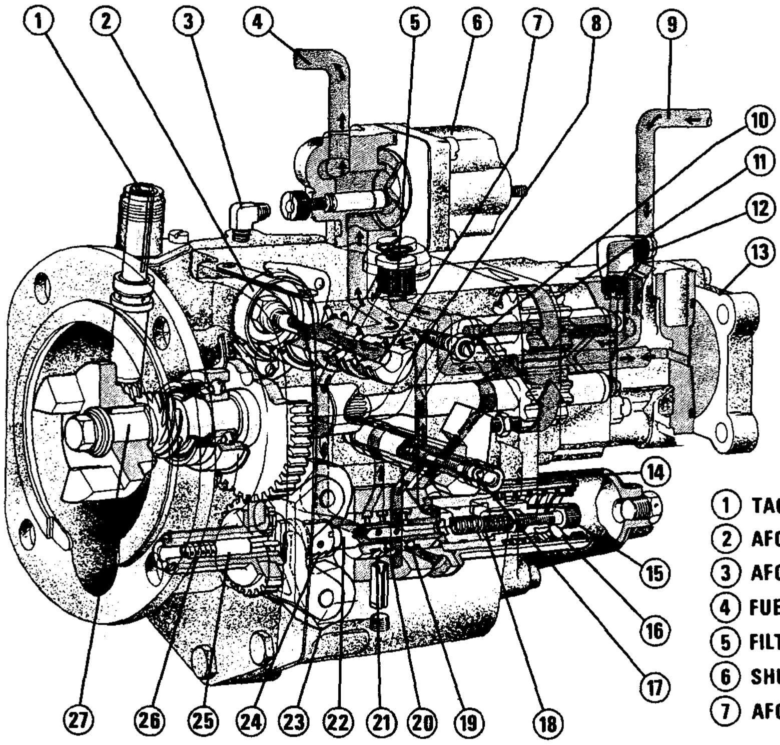
5. The AFC plunger is positioned by action of intake manifold air pressure acting against a piston and diaphragm, but restrained to a proportional travel by an opposing spring force.

6. Fuel flow through the AFC is unrestricted during full throttle lug down conditions.



1. TACHOMETER SHAFT
2. FILTER SCREEN
3. FUEL TO INJECTORS
4. SHUT-DOWN VALVE
5. GEAR PUMP
6. CHECK VALVE ELBOW
7. FUEL FROM TANK
8. PULSATION DAMPER
9. THROTTLE SHAFT
10. IDLE ADJUSTING SCREW
11. HIGH SPEED SPRING
12. IDLE SPRING
13. GEAR PUMP PRESSURE
14. FUEL MANIFOLD PRESSURE
15. IDLE PRESSURE
16. GOVERNOR PLUNGER
17. GOVERNOR WEIGHTS
18. TORQUE SPRING
19. GOVERNOR ASSIST PLUNGER
20. GOVERNOR ASSIST SPRING
21. MAIN SHAFT

Fig. 5-6, (FWC-31). PT(type G) fuel pump and fuel flows



1. TACHOMETER SHAFT
2. AFC PISTON
3. AFC AIR IN
4. FUEL TO INJECTORS
5. FILTER SCREEN
6. SHUT-DOWN VALVE
7. AFC CONTROL PLUNGER
8. AFC FUEL BARREL
9. FUEL FROM FILTER
10. AFC NEEDLE VALVE
11. GEAR PUMP
12. CHECK VALVE ELBOW
13. PULSATION DAMPER
14. THROTTLE SHAFT
15. IDLE ADJUSTING SCREW
16. HIGH SPEED SPRING
17. FUEL ADJUSTING SCREW
18. IDLE SPRING
19. GEAR PUMP PRESSURE
20. FUEL MANIFOLD PRESSURE
21. IDLE PRESSURE
22. GOVERNOR PLUNGER
23. GOVERNOR WEIGHTS
24. TORQUE SPRING
25. GOVERNOR ASSIST PLUNGER
26. GOVERNOR ASSIST SPRING
27. MAIN SHAFT

Fig. 5-7, (FWC-37). PT (type G) AFC fuel pump and fuel flow

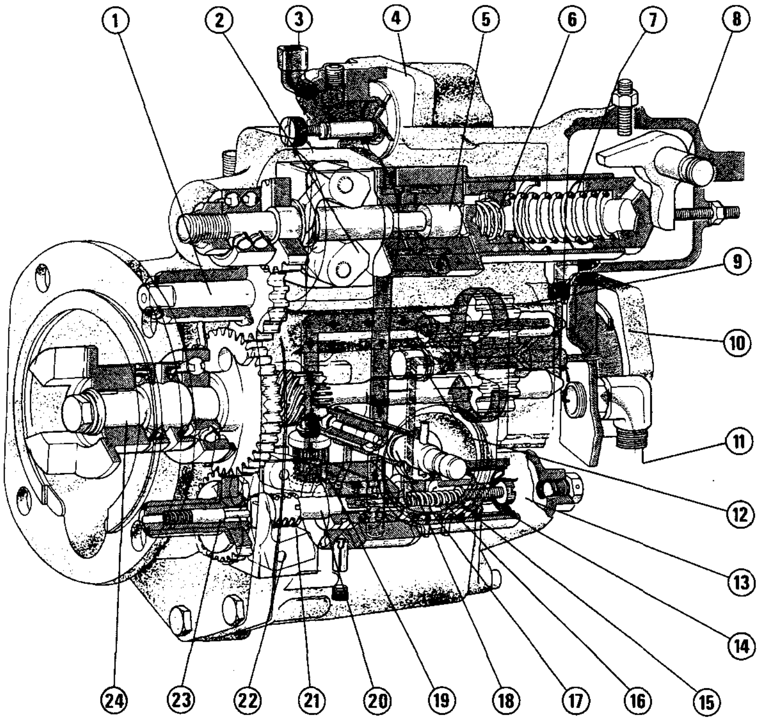


Fig. 5-8, (FWC-35). PT (type G) VS (Variable Speed) fuel pump and fuel flow

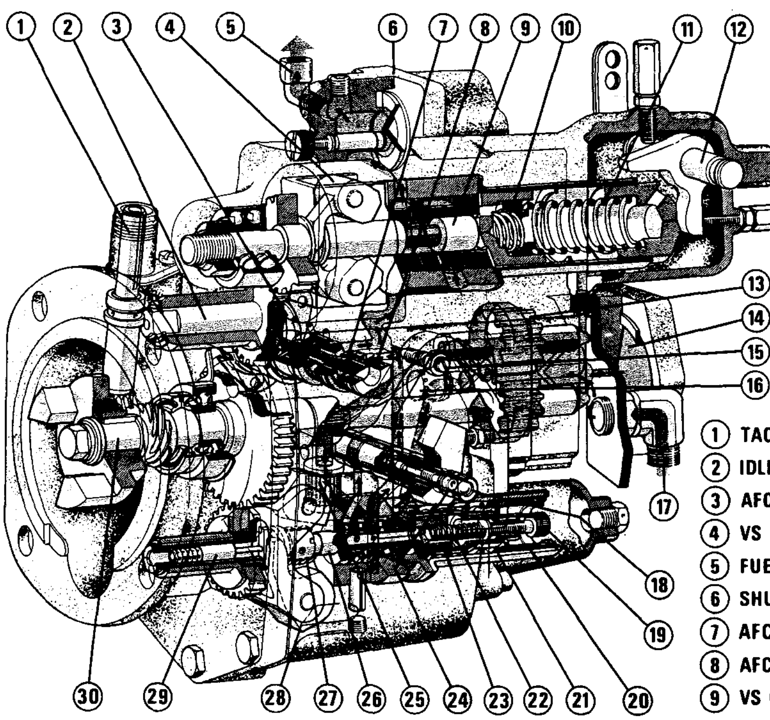
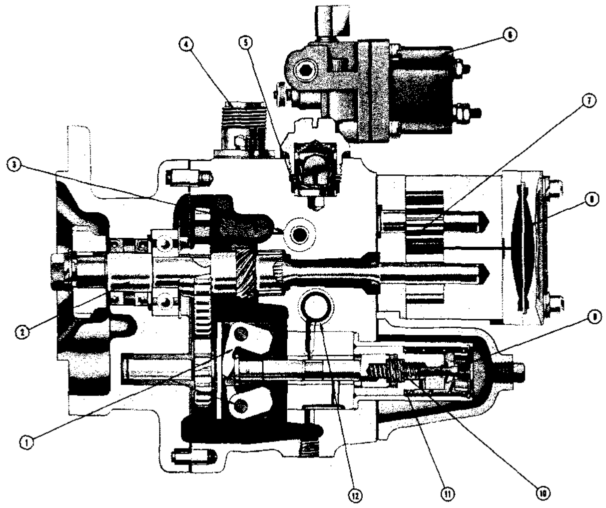
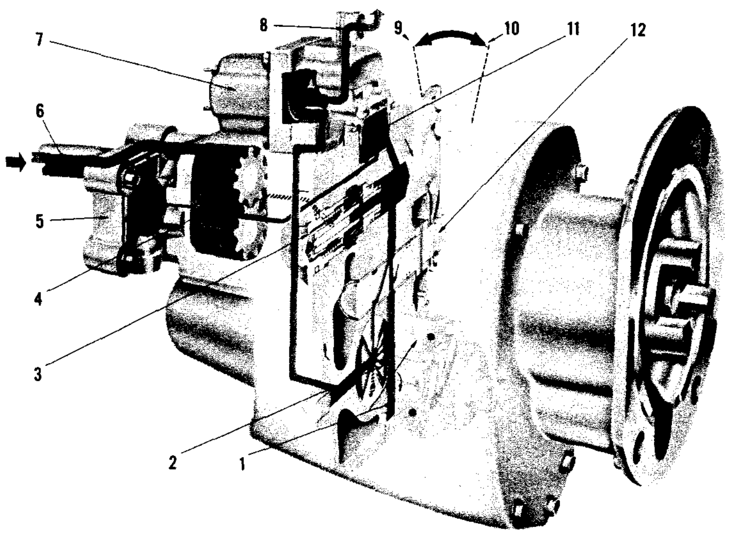


Fig. 5-9, (FWC-38). PT (type G) VS (Variable Speed) AFC fuel pump and fuel flow



1 GOVERNOR WEIGHTS
2 MAIN SHAFT
3 PRESSURE REGULATOR
4 TACHOMETER CONNECTION
5 FILTER SCREEN
6 SHUT-DOWN VALVE
7 GEAR PUMP
8 PULSATION DAMPER
9 IDLE SPEED SCREW
10 IDLE SPRINGS
11 MAXIMUM SPEED SPRING
12 THROTTLE SHAFT

Fig. 5-10, (FWC-4). PT (Type R) fuel pump and fuel flow



1 GOVERNOR WEIGHTS
2 GOVERNOR PLUNGER
3 PRESSURE REGULATOR
4 GEAR PUMP
5 PULSATION DAMPER
6 FROM TANK
7 SHUT-DOWN VALVE
8 TO INJECTORS
9 IDLE
10 FULL
11 FILTER SCREEN
12 THROTTLE SHAFT

PT (type R) Fuel Pump

The PT (type R) fuel pump, Fig. 5-10, can be identified easily by the presence of a fuel return line from the top of the fuel pump housing to the supply tank. The pump assembly is made up of four main units: The gear pump, pressure regulator, throttle, and the governor assembly.

Gear Pump And Pulsation Damper

The gear pump is driven by the pump main shaft and contains a single set of gears to pick up and deliver fuel throughout the fuel system. Inlet to the gear pump on small V-type engines may be through the fuel pump main housing. On other engines it's at the rear of the gear pump.

A pulsation damper mounted to the gear pump contains a steel diaphragm which absorbs pulsations and smooths fuel flow through the fuel system. From the gear pump, fuel flows through the filter screen and:

1. In the PT (type G) and PT (type G) VS fuel pumps to the governor assembly as shown in Fig's. 5-6, 5-7, 5-8 and 5-9.

2. In the PT (type R) fuel pump to the pressure regulator assembly as shown in Fig. 5-10.

Pressure Regulator

Used in the PT (type R) functions as a by-pass valve to regulate fuel pressure to the injectors. By-passed fuel flows back to the suction side of the gear pump. See Fig. 5-10.

There are three types of by-pass holes located in most plungers: (a) fuel adjustment holes to regulate fuel manifold pressure, (b) torque holes for engine torque characteristics, (c) dump holes to prevent excessive gear pump pressures.

Throttle

The throttle provides a means for the operator to manually control engine speed above idle as required by varying operating conditions of speed and load.

In PT (type G) and PT (type G) VS fuel pumps, fuel flows through the governor to throttle shaft. At idle speed, fuel flows through idle port in governor barrel, past the throttle shaft. To operate above idle speed, fuel flows through the main governor barrel port to throttling hole in shaft.

In the PT (type R) fuel pump, fuel flows past pressure regulator to throttle shaft. Under idling conditions, fuel passes around the shaft to the idle port in governor barrel. For operation above idle speed, fuel passes through throttling hole in shaft and enters the governor barrel through main fuel port.

Governors

Idling and High-Speed Mechanical Governor: The mechanical governor, on both PT (type G) and PT (type R) fuel pumps, is actuated by a system of springs and weights, and has two functions. First, the governor maintains sufficient fuel for idling with the throttle control in idle position; second, it cuts off fuel to the injectors above maximum rated rpm. The idle springs in the governor spring pack, position the governor plunger so the idle fuel port is opened enough to permit passage of fuel to maintain engine idle speed.

During operation between idle and maximum speeds, fuel flows through the governor to the injectors. This fuel is controlled by the throttle and limited by the size of the idle spring plunger counterbore on PT (type G) fuel pumps and pressure regulator of PT (type R) fuel pumps. When the engine reaches governed speed, the governor weights move the governor plunger, and fuel passages to the injectors are shut off. At the same time another passage opens and dumps the fuel back into the main pump body. In this manner, engine speed is controlled and limited by the governor regardless of throttle position. Fuel leaving the governor flows through the shut-down valve, inlet supply lines and on into the injectors.

PT (type G) Variable-Speed Governors

The VS governor, Fig's. 5-8 and 5-9, in the upper portion of the fuel pump housing, operates in series with the standard governor to permit operation at any desired (near constant) speed setting within the range of the standard governor. Speed can be varied with the VS speed control lever, located at top of pump. This pump gives surge free governing throughout the engine speed range with a speed droop smaller than the standard governor and is suited to the varying speed requirements of power take-off etc., in which the same engine is used for propelling the unit and also driving a pump or other fixed-speed machine.

When operating the PT (type G) VS fuel pump at any desired constant speed, the VS governor lever should be placed in operating position and the throttle locked in full open position to allow a full flow of fuel through the standard governor.

PT (type R) Mechanical Variable-Speed Governor

On some applications this governor replaces the standard mechanical governor to meet the requirements of applications on which the engine must operate at a constant speed, but where extremely close regulation is not necessary.

Adjustment for different rpm can be made by means of a lever control or adjusting screw. At full-rated speed this governor has a speed droop between full-load and no-load of approximately eight percent. A cross section of this governor is shown in Fig. 5-11.

Hydraulic Governor

Hydraulic governors are used on stationary power applications where it is desirable to maintain a constant speed with varying loads.

The Woodward Hydraulic Governor uses lubricating oil, under pressure, as an energy medium. It is supplied from a sump on governor drive housing. For oil viscosity, see Page 3-2.

The governor acts through oil pressure to increase fuel delivery. An opposing spring in governor control linkage acts to decrease fuel delivery.

In order that its operation may be stable, speed droop is introduced into governing system. Speed droop means the characteristic of decreasing speed with increasing load. The desired magnitude of this speed droop varies with engine applications and may easily be adjusted to cover a range of 0 to 5 percent on the PSG to seven percent on SG.

Assume a certain amount of load is applied to the engine. The speed will drop, flyballs will be forced inward and will lower pilot valve plunger. This will admit oil pressure underneath servo piston, which will rise (as shown in Fig. 5-12). The movement of servo piston is transmitted to

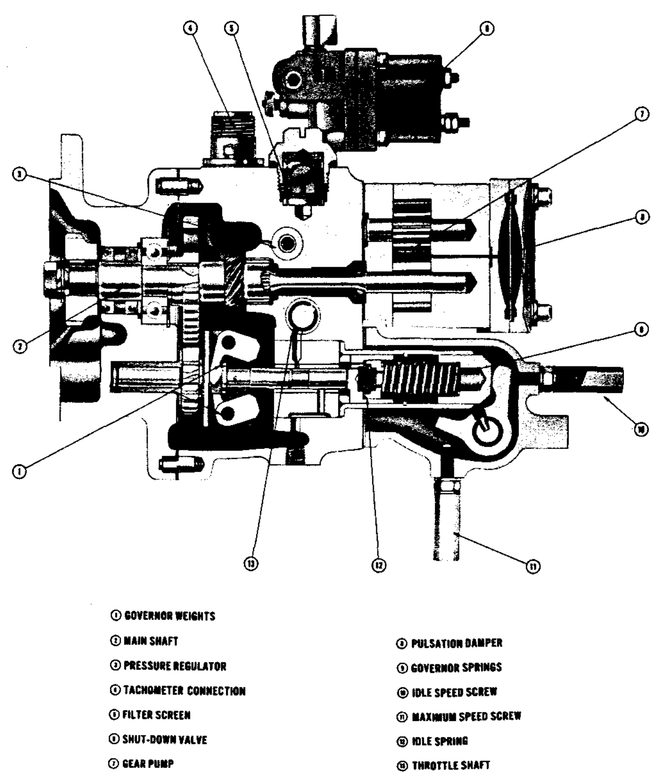
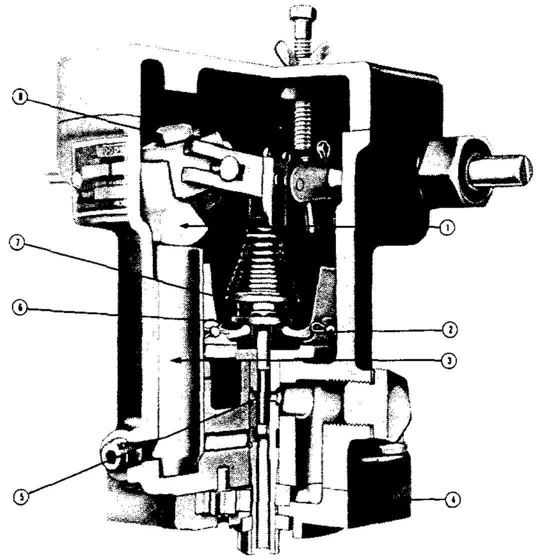


Fig. 5-11, (FWC-7). PT (type R) fuel pump with MVS governor



1 TERMINAL LEVER
2 BALLARM PIN
3 SERVO MOTOR PISTON
4 GOVERNOR BASE
5 PILOT VALVE PLUNGER
6 THRUST BEARING
7 SPRING SEAT
8 SPEED DROP ADJUSTING SCREW

Fig. 5-12, (FWC-1). Woodward SG hydraulic governor

terminal shaft by terminal lever. Rotation of terminal shaft causes fuel setting of engine to be increased.

Aneroid

The aneroid control, Fig. 5-13, provides a fuel by-pass system that responds to air manifold pressure and is used on turbocharged engines for close control of exhaust smoke.

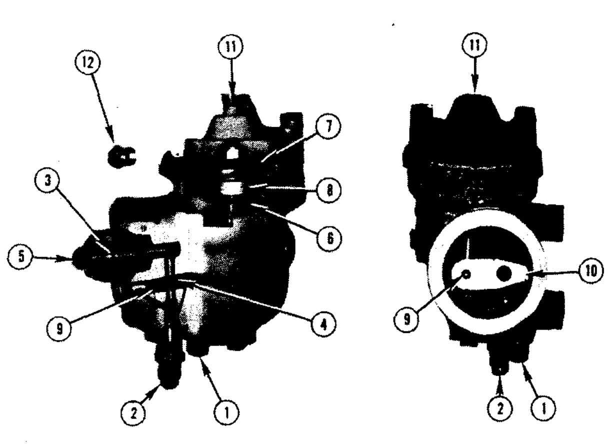


Fig. 5-13, (F-5244). Aneroid cutaway

The aneroid limits fuel pressure to the injectors when accelerating the engine from speeds below normal operating range, and while air intake manifold air pressure is not sufficient for complete combustion. Air intake manifold pressure rises with the turbocharger speed which is powered by exhaust gas energy and is therefore low at low engine speed and exhaust gas output.

During acceleration or rapid engine load changes, turbocharger speed (intake manifold pressure) change inherently lags behind the power or fuel demand exercised by opening of the throttle. This lag does not exist in the fuel system; therefore, an overrich or high fuel to air ratio, usually accompanied by smoke, occurs until the turbocharger "catches up".

The function of the aneroid is to create a lag in fuel system so response is equivalent to the turbocharger, thus controlling engine smoke level.

Caution: Aneroids must not be removed, disconnected or otherwise rendered ineffective, nor should settings be altered to exceed specifications as set at the factory, see "Maintenance Schedule".

Fuel Flow

1. Fuel from the fuel pump enters the aneroid and is directed to starting check valve area (5, Fig. 5-13).

2. The starting check valve (3) prevents aneroid from by-passing fuel at engine cranking speeds. For speeds above cranking, fuel pressure forces the check valve open, allowing fuel to flow to valve port (4) of shaft (9).

3. Shaft (9) and its bore form a fuel by-pass valve. This shaft and bore allows passage or restricts fuel flow.

4. The shaft and sleeve are by-passing fuel when arm (10) of lever is resting against adjusting screw (1). The amount of fuel by-passed is adjusted by this screw, which protrudes from bottom of aneroid.

5. The lever arm connected to piston (8) by actuating shaft (6), rotates shaft; closing valve port. The lever is rotated by action of air intake manifold pressure (11) against piston and diaphragm (7), moving actuating shaft downward against resisting spring force.

6. Anytime engine intake manifold air pressure is above preset "air actuation pressure", aneroid is "out of system".

7. The aneroid begins dumping when intake manifold pressure drops below preset value.

8. The aneroid does not by-pass fuel under full throttle lug down conditions until speed is low enough to reduce intake manifold air pressure to aneroid operating range (usually below engine stall-out speed).

9. Fuel allowed to pass through by-pass valve is returned (2)

to suction side (inlet fitting) of PT gear pump. The by-passed fuel reduces fuel pump out-put to engine and reduces fuel manifold pressure in proportion to the by-pass rate.

PT (type D) Injectors

The injector provides a means of introducing fuel into each combustion chamber. It combines the acts of metering, timing and injection. Principles of operation are the same for inline and V-engines but injectors size and internal design differs slightly. Fig's. 5-14, 5-15 and 5-16.

Fuel supply and drain flow are accomplished through internal drillings in the cylinder heads. Fig's. 5-1 through 5-5. A radial groove around each injector mates with the drilled passages in the cylinder head and admits fuel through an adjustable (adjustable by burnishing to size at test stand) orifice plug in the injector body. A fine mesh screen at each inlet provides final fuel filtration.

The fuel grooves around the injectors are separated by "O" rings which seal against the cylinder head injector bore. This forms a leak-proof passage between the injectors and the cylinder head injector bore surface.

Fuel flows from a connection atop the fuel pump shut-down valve through a supply line into the lower drilled passage in the cylinder head. A second drilling in the head is aligned with the upper injector radial groove to drain away excess fuel. A fuel drain allows return of the unused fuel to the fuel tank.

The injector contains a ball check valve. As the injector plunger moves downward to cover the feed opening, an impulse pressure wave seats the ball and at the same time traps a positive amount of fuel in the injector cup for injection. As the continuing downward plunger movement injects fuel into the combustion chamber, it also uncovers the drain opening and the ball rises from its seat. This allows free flow through the injector and out the drain for cooling purposes and purging gases from the cup.

Fuel Lines, Connections And Valves

Supply And Drain Lines

Fuel is supplied through lines to cylinder heads. A common drain line returns fuel not injected, to supply tank.

On engines using flanged injectors, fuel is supplied through a single tube to the fuel supply manifold. The drain manifold returns fuel not injected to the supply tank through a drain line.

The PT (type R) fuel pump has a drain line returning from the top of the pump to the supply tank. This line is not necessary with the PT (type G) pump.

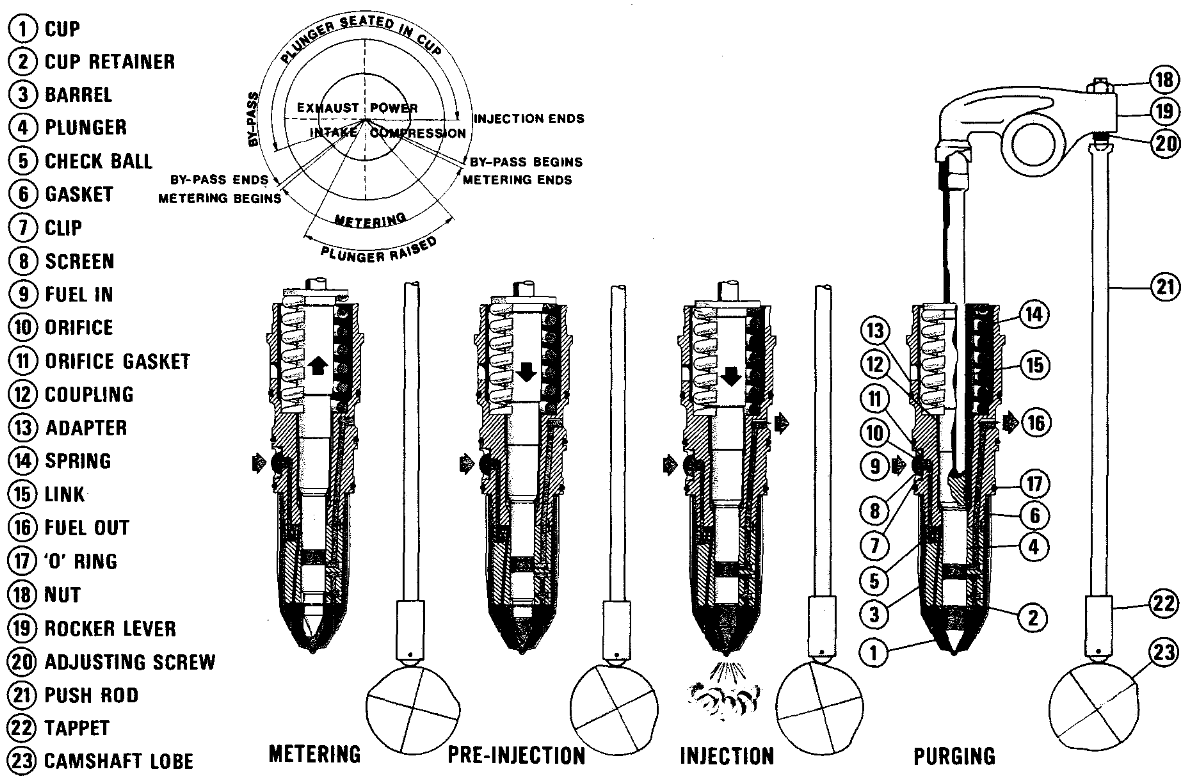


Fig. 5-14, (FWC-28). Fuel injection cycle PT (type D) injector 3/8 inch diameter plunger

1. CUP
2. CUP RETAINER
3. BARREL
4. PLUNGER
5. CHECK BALL
6. GASKET
7. CLIP
8. SCREEN
9. FUEL IN
10. ORIFICE
11. ORIFICE GASKET
12. COUPLING
13. ADAPTER
14. SPRING
15. LINK
16. FUEL OUT
17. 'O' RING
18. NUT
19. ROCKER LEVER
20. ADJUSTING SCREW
21. PUSH ROD
22. TAPPET
23. CAMSHAFT LOBE
24. TOP STOP
25. LOCKNUT
26. WASHER

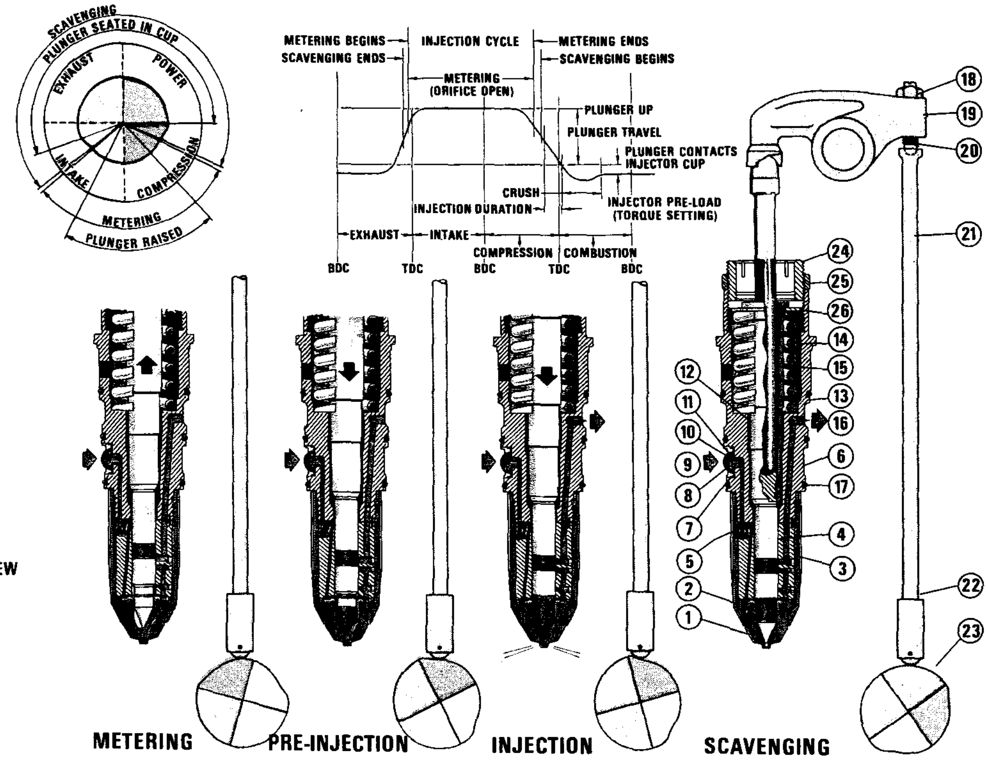


Fig. 5-15, (FWC-39). Fuel injection cycle PT (type D) top stop injector 3/8 inch diameter plunger

1. CUP
2. CUP RETAINER
3. BARREL
4. PLUNGER
5. CHECK BALL
6. GASKET
7. CLIP
8. SCREEN
9. FUEL IN
10. ORIFICE
11. ORIFICE GASKET
12. COUPLING
13. ADAPTER
14. SPRING
15. LINK
16. FUEL OUT
17. 'O' RING
18. NUT
19. ROCKER LEVER
20. ADJUSTING SCREW
21. PUSH ROD
22. TAPPET
23. CAMSHAFT LOBE

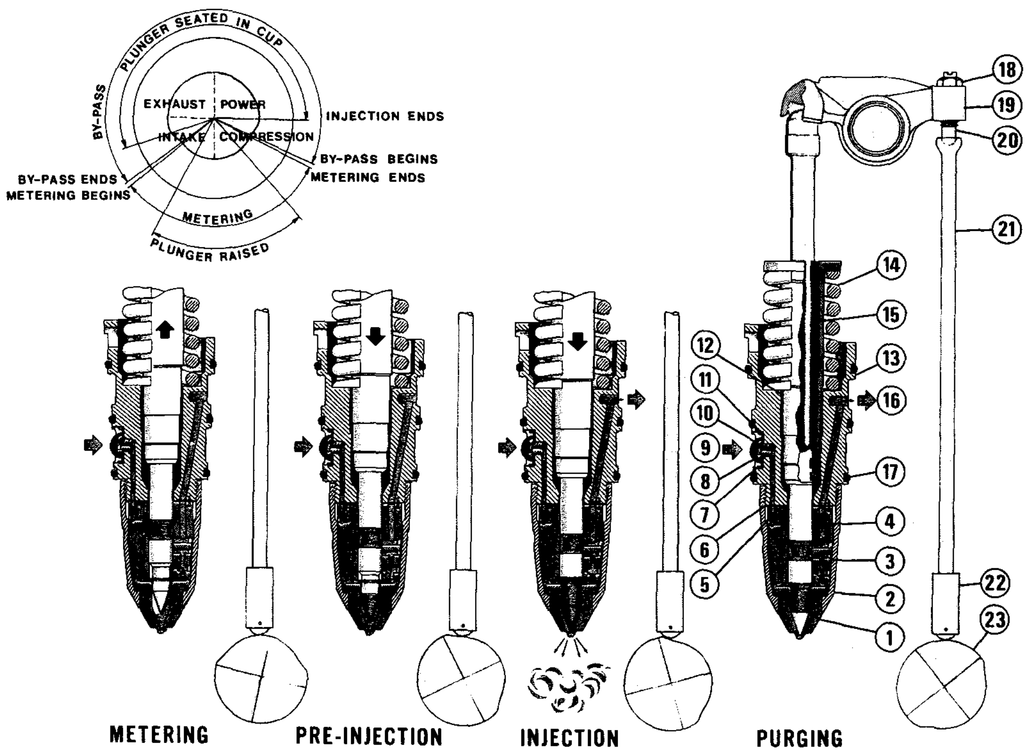


Fig. 5-16, (FWC-29). Fuel injection cylce PT (type D) injector 5/16 inch diameter plunger

Connections

Fuel connectors are used between the inline engine cylinder heads to bridge the gap between each supply and drain passage (3, Fig. 5-1).

Flanged injectors are connected to the supply and drain manifolds through connections. The inlet connection contains a fine mesch screen which acts as the final filter before fuel enters the combustion chamber.

Shut-Down Valve

Either a manual or an electric shut-down valve is used on Cummins fuel pumps.

With a manual valve, the control lever must be fully clockwise or open to permit fuel flow through the valve.

With the electric valve, the manual control knob must be fully counterclockwise to permit the solenoid to open the valve when the "switch key" is turned on. For emergency operation in case of electrical failure, turn manual knob clockwise to permit fuel to flow through the valve.

Lubricating System

Cummins engines are pressure lubricated, pressure is supplied by a gear-type lubricating oil pump located in oil pan or on side of the engine.

A pressure regulator is mounted in the lubricating oil pump to control lubricating oil pressure.

Filters and screens are provided in lubricating oil system to remove foreign material from circulation and prevent damage to bearings or mating surfaces. A by-pass valve is provided in full-flow oil filter head as insurance against interruption of oil flow by a dirty or clogged element.

Maximum cleansing and filtration is achieved through use of both by-pass and full-flow lubricating oil filters. Full-flow filters are standard on all engines; by-pass filters are used on all turbocharged models and optionally on all other engines.

Some engines are equipped with special oil pans and filters for some applications, and other with auxiliary oil coolers to maintain closer oil temperature regulation.

Air compressors and turbochargers are lubricated from engine oil system. Turbocharger is also cooled by same lubricating oil used for lubrication.

Fuel pumps and injectors are lubricated by fuel oil.

Inline Engines

NH And NT Series

Oil is drawn into the pump through an external oil line connected to the oil pan sump. A screen in the sump filters the oil. On NH and NT engines (Fig. 5-17) oil is drawn from the pan by the pump out through a full-flow filter and

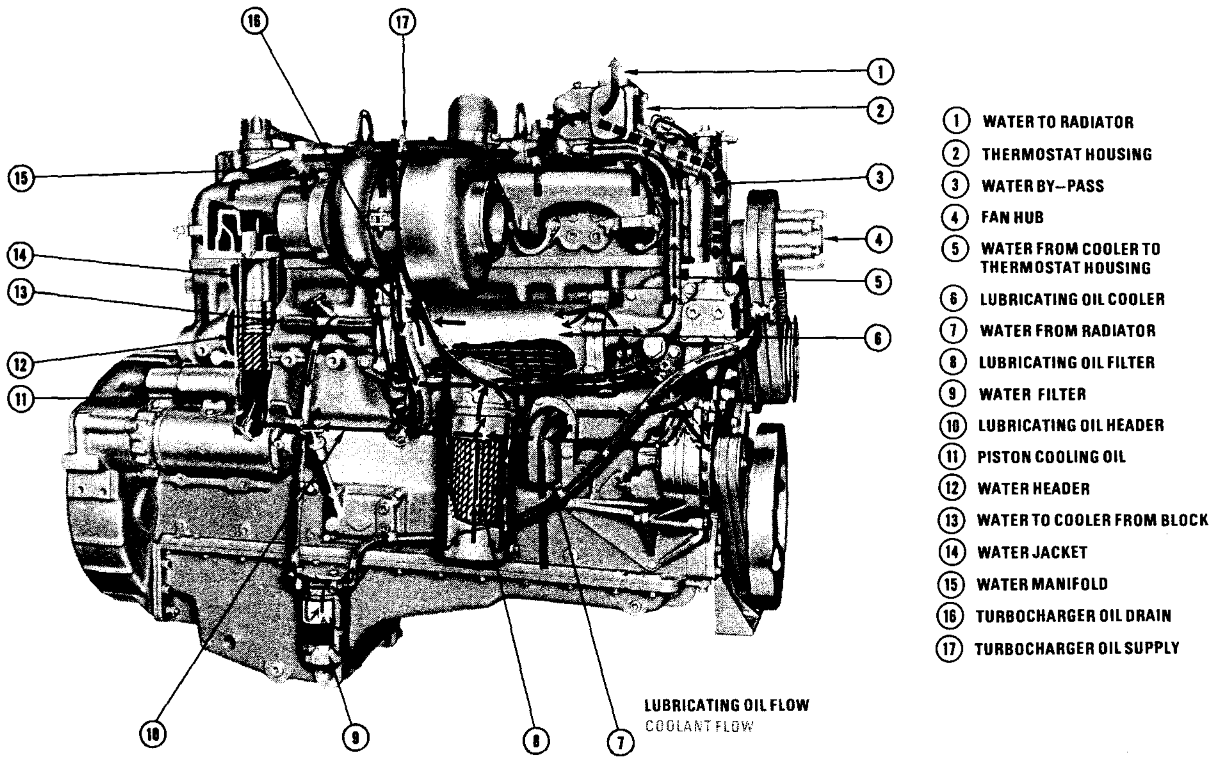


Fig. 5-17, (LWC-18). Lubricating oil and coolant flow Inline Engine circulates back into the block. The filter may be mounted directly to the rear of pump, vertically mounted on exhaust side of engine or remote mounted. External lines are used for remote mounting arrangements.

On remote and pump mounted filters oil flows from the pump to the oil cooler then flows to oil headers through internal drillings in the gear case. On NTA engines oil flow is from pan to pump, to filter, to oil cooler, to block.

An oil header drilled full length of block, fuel pump side, delivers oil to moving parts within the engine. Oil pipes carry oil from the camshaft to upper rocker housings and drillings through the block, crankshaft, connecting rods, and rocker levers complete the oil circulating passages.

On engines equipped with oil cooled pistons, an oil header drilled the length of the block, exhaust manifold side, supplies oil to six spray nozzles used for piston cooling.

A piston cooling oil pump, as a second section of engine lubricating oil pump or a larger capacity oil pump, pumps this oil to the oil header.

NTC Series (Full Flow Oil Cooling)

The NTC (FFC) engine is pressure lubricated by a gear-type lubricating oil pump located on the intake manifold side of the engine. Oil pressure to the main rifle is controlled by a regulator located in the cooler support on the exhaust side of the engine.

Lubricating oil is drawn from the pan, through a suction tube, by the lubricating oil pump, Fig's. 5-18 and 5-19, then transferred from the suction cavity by the pump gears into the pressure cavity.

Lubricating oil passes from the pump into the block, then across the front of the block by means of an internal oil passage and enters the cooler support. Oil is routed out of the cooler support and into the cooler housing, passing through the cooler housing. (The oil cooler is a counterflow tube-and-shell type heat exchanger, with oil passing from front to rear through the shell and coolant water passing from rear to front through the tubes.) Oil exits the cooler housing and passes into the cooler cover, then enters the "rifle drilling" at the bottom rear of the cooler housing and flows forward into the filter head.

Lubricating oil flowing into the filter shell from the filter head enters outside the filter element and passes through the element from outside to inside. Filtered lubricating oil then re-enters the filter head and flows through rifle drilling in the bottom of the cooler housing, then flows forward out of the cooler housing and into the cooler support where the flow divides.

Filtered and cooled lubricating oil from the cooler support is routed to the turbocharger through the supply hose. Turbocharger return oil is then routed by the drain hose back to the crankcase.

FFC OIL FLOW CIRCUIT

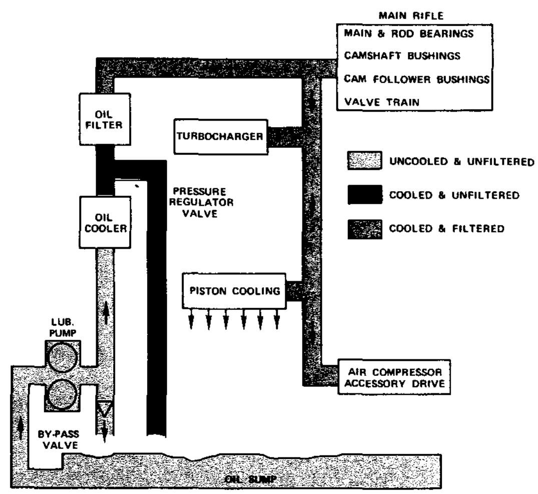


Fig. 5-18, (N10740). Full flow oil cooling (NTC Series)

Filtered and cooled lubricating oil re-enters the block from the cooler support and is transferred internally back across the front of the block through a drilled oil transfer passage to the head of the main rifle drilling. Accessory drive lubrication is supplied from the transfer passage leading to the head of the main rifle drilling. An intersection drilling routes lubricating oil from the transfer passage out the front of the block and into the gear cover on the exhaust side of the engine, then across the front of the engine through a tube in the gear cover. The flow path then splits, part being routed to the accessory drive bushing in the gear cover and the rest being routed to the air compressor.

Piston-cooling is supplied from the transfer passage leading to the head of the main rifle drilling. An intersecting drilling allows flow to the piston-cooling rifle from the oil transfer passage. The piston-cooling rifle extends from the front to the rear of the block on the exhaust side of the engine. Six piston-cooling nozzles inserted from the outside of the block direct a spray of lubricating oil from the piston-cooling rifle to the bottom of each piston.

Lubricating oil entering the main rifle is routed by means of drilled passages and pipes to the main bearings, rod bearings, piston pin bushings, camshaft bushings, cam followers shafts and levers, rocker box shafts and rocker levers, etc., then returns to the oil pan.

V Series Engines

V6 and V8 Series engines are pressure lubricated by a gear

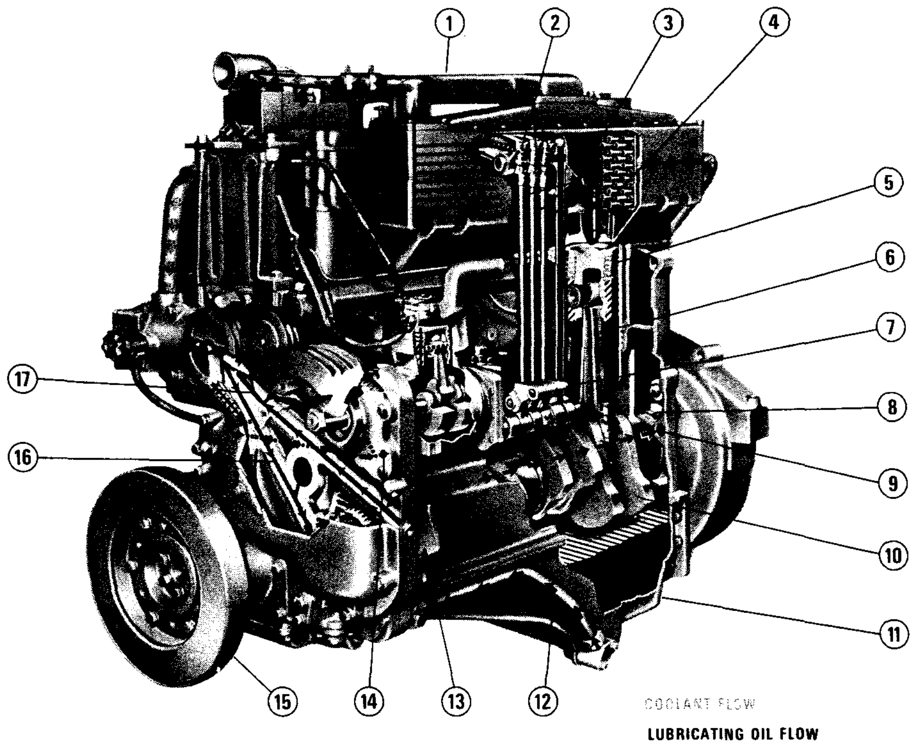


Fig. 5-19, (LWC-25). Lubricating oil and coolant flow — FFC (NTC Series)

type lubricating oil pump mounted on bottom of block, enclosed in oil pan, and gear driven from crankshaft gear.

Oil drawn from pan sump through a screen is delivered to engine working components through oil lines and oil headers which are drilled the length of block. Drillings in block, cylinder head, crankshaft and rocker lever shafts complete oil circulation passages. Fig's. 5-20 and 5-21.

Oil flows through a suction tube to the lubricating oil pump up a passage in rear of block to the cooler (if used) and filter.

V-903 Series Engines

1. Oil flows from cooler and filter to right bank of oil drilling at front of engine to front center of block. Oil flows through crossover at front of block to left bank and right bank main oil drillings (drilled length of block). Fig. 5-20.

2. Oil flows through left bank drilling toward rear of engine to left bank tappets, accessory drive, to numbers 2, 3, 4 and 5 cam bushings, main bearings and connecting rods.

3. At the same time oil flows to a right bank drilling toward rear of engine to oil right bank tappets.

4. Right bank rocker levers are oiled intermittently from rear cam bushing location. Left bank rocker levers are oiled intermittently from front cam bushing.

V-378, V-504 And V-555 Series Engines

1. Oil flows from filter to right bank oil drilling at rear of engine to accessory drive gear, rear cam bushing and rear main bearing which in turn supplies the two rear connecting rods. Fig. 5-21.

2. Right bank rocker levers are oiled intermittently from rear cam bushing location.

3. Oil flows through the right bank drilling toward front of engine to right bank injector tappets, to center cam bushings, main bearings and connecting rods.

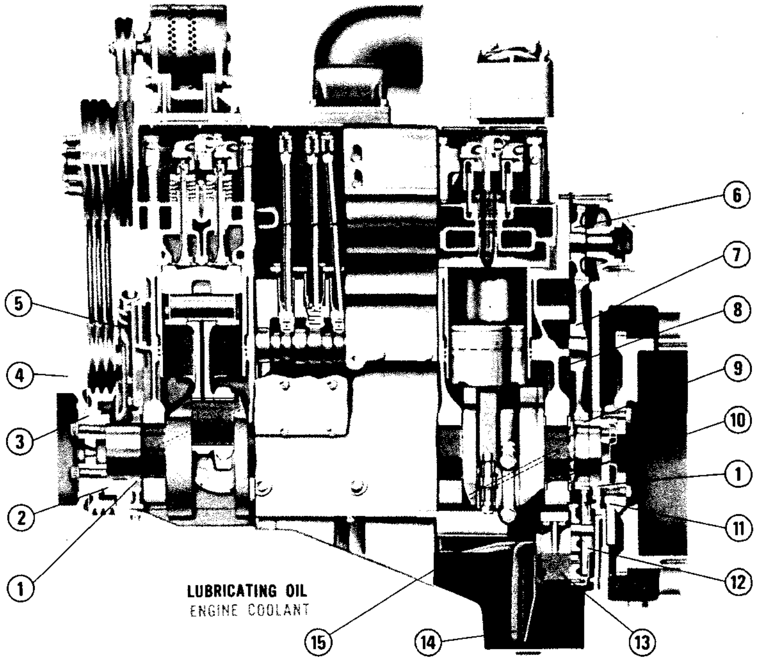
4. Oil flows through a crossover at front of block to left bank.

5. Left bank rocker levers are oiled intermittently through front cam bushing.

6. Oil then flows to a left bank drilling toward rear of engine to oil left bank injector tappets.

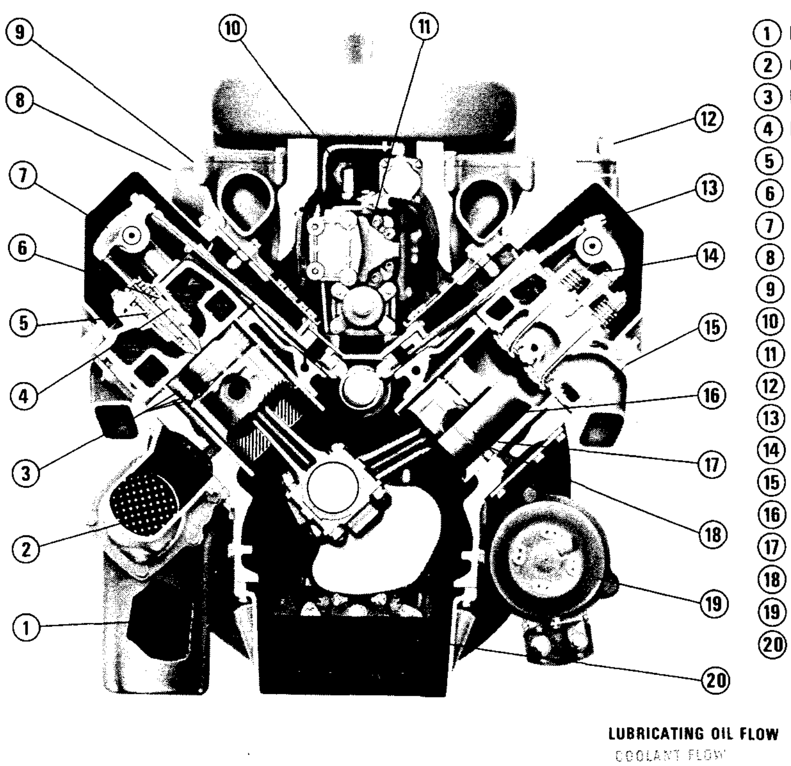
V-1710 Series Engines

Cummins V-1710 Series engines, Fig. 5-22, are pressure lubricated, pressure being supplied by a gear-type



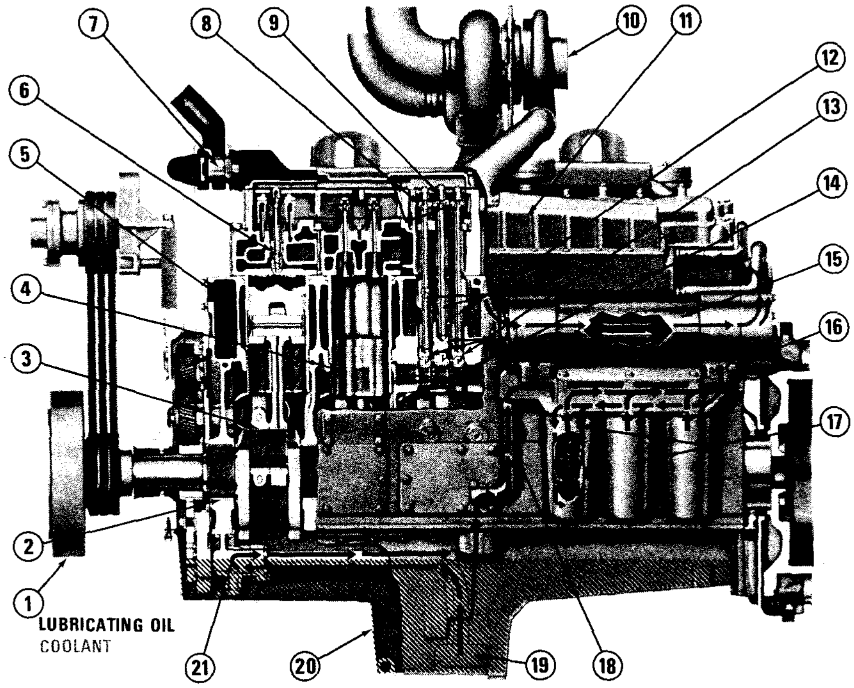
1. SEAL WEAR SLEEVE
2. CRANKSHAFT PULLEY ADAPTER
3. CRANKSHAFT PULLEY
4. VIBRATION DAMPER
5. WATER PUMP
6. ACCESSORY DRIVE GEAR
7. CAMSHAFT GEAR
8. CAMSHAFT THRUST RING
9. CRANKSHAFT GEAR
10. CRANKSHAFT THRUST RINGS
11. FLYWHEEL ADAPTER
12. LUBRICATING OIL PUMP DRIVE GEAR
13. LUBRICATING OIL PUMP
14. LUBRICATING OIL SUCTION TUBE
15. LUBRICATING OIL BY-PASS TUBE

Fig. 5-20, (LWC-16). Lubricating oil and coolant flow — V-903 Series Engines



1. FULL-FLOW LUBRICATING OIL FILTER
2. OIL COOLER
3. PISTON RINGS
4. FUEL IN
5. FUEL OUT
6. INJECTOR
7. INJECTOR ROCKER LEVER
8. LIFTING BRACKET
9. AIR INTAKE MANIFOLD
10. FUEL SUCTION INLET TO PUMP
11. FUEL PUMP
12. OIL FILLER CAP
13. VALVE ROCKER LEVER
14. VALVE CROSSHEAD
15. EXHAUST MANIFOLD
16. CYLINDER LINER
17. CREVICE SEAL
18. PACKING RING
19. CRANKING MOTOR
20. LUBRICATING OIL PUMP

Fig. 5-21, (LWC-4). Lubricating oil and coolant flow — Medium Duty Vee Series



1. VIBRATION DAMPER
2. MAIN BEARING
3. CONNECTING ROD BEARING
4. PISTON
5. COOLANT PASSAGE
6. INJECTOR
7. THERMOSTAT
8. VALVE ROCKER LEVER
9. INJECTOR ROCKER LEVER
10. T-18A TURBOCHARGER
11. INTER-COOLER/AIR INTAKE MANIFOLD
12. PUSH TUBES
13. TAPPETS
14. CAMSHAFT
15. OIL COOLER
16. OIL TO ENGINE
17. FULL FLOW OIL FILTERS
18. OIL TO COOLER
19. OIL SUCTION
20. LUBRICATING OIL PAN
21. LUBRICATING OIL PUMP

Fig. 5-22, (CWC-13). Lubricating oil and coolant flow — side view, V-1710 Series Engines

lubricating oil pump, located in the oil pan and gear driven from the crankshaft gear.

A by-pass valve is provided in full-flow oil filter(s) as insurance against interruption of oil flow by a dirty or clogged element.

1. Oil is drawn into pump through an oil line to oil pan sump. A screen in sump strains the oil.

2. Internal lubricating oil flows from pump to cooler to full-flow filters mounted on side of engine, then to oil headers in block.

3. Main oil header, drilled full length in center of block delivers oil to moving parts within engine.

4. Oil pipes — or a combination of pipes and passages — carry oil from camshaft to upper rocker housings; various drillings through block, crankshaft, connecting rods and rocker levers complete oil circulating system.

5. On engines equipped with oil-cooled pistons, oil is supplied from the front of the block to oil headers which are drilled the length of block on each side; headers supply oil to spray nozzles, which direct oil to piston skirts.

6. Lubricating oil pressure is controlled by a regulator located in the lubricating oil pump.

KT(A)-1150 Series Engines

The KT(A)-1150 engines are pressure lubricated by a gear-type lubricating oil pump located on the exhaust manifold side of the engine directly below the water pump inside the gear cover.

Lubricating oil is drawn from the pan, through a suction tube, by the lubricating oil pump, Fig. 5-23, then transferred from the suction cavity by the pump gears into the pressure cavity. A pressure regulator valve dumps excess oil directly into the pump intake rather than back into the oil pan.

From the lubricating oil pump, oil flows to lubricating oil cooler, through the cooler, then across the block. On air intake side of block it flows to filter head, Fig. 5-24. A by-pass valve is provided in the oil inlet cavity to assure against interruption of oil flow if filter elements become clogged. From the filter head oil enters the shells and passes through the elements then up, splitting into two passages. One flows to the main engine oil passage and the other to the piston-cooling passage. A second pressure control valve, located in the base of the filter head, limits the flow of lubricating oil to nozzles depending on pump supplied pressure.

Main bearings are lubricated through intersecting drillings, directly from the main oil passage. Oil flows from the main passage into camshaft bushings; from there, by constant

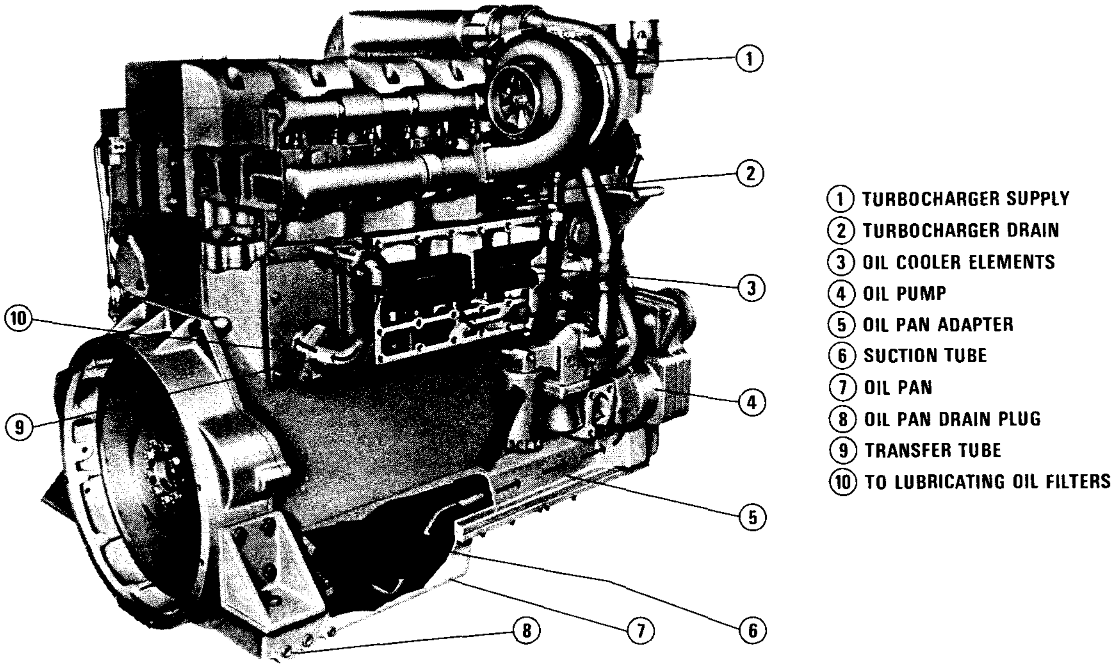


Fig. 5-23, (LWC-29). Lubricating oil flow, KT(A)-1150 Series Engines

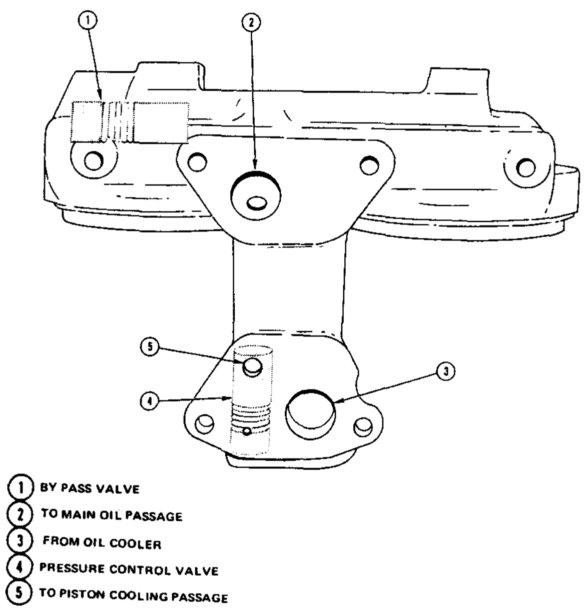


Fig. 5-24, (K11943). Filter mounting head oil flow

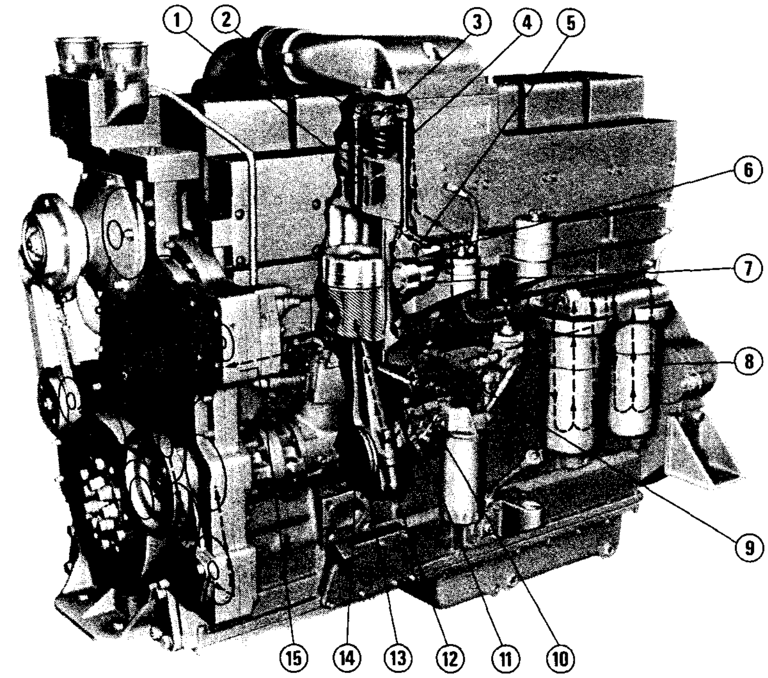
flow, it goes to cam follower shafts and up through the cylinder heads. The cam followers are lubricated from their shaft; the cam followers are individually drilled to supply lubricating oil to rollers and push tube seats. The rocker lever bushings are also shaft lubricated. Adjusting screws are lubricated through drillings in levers and bushings. See Fig. 5-25.

The connecting rod bearings get lubrication from cross drillings in the crankshaft; oil then flows through angle drillings in the connecting rods to lubricate piston pins and bushings. It is then routed from the main passage through drillings in the gear housing and cover to the camshaft and water pump idler gears, Fig. 5-26. It then moves across to the gear cover and is routed by drillings to the rest of the gears and bushings.

Filtered and cooled lubricating oil is routed to the turbocharger through an external drilling in the gear housing. Turbocharger drain oil is dumped directly into the crankcase. Fig. 5-23.

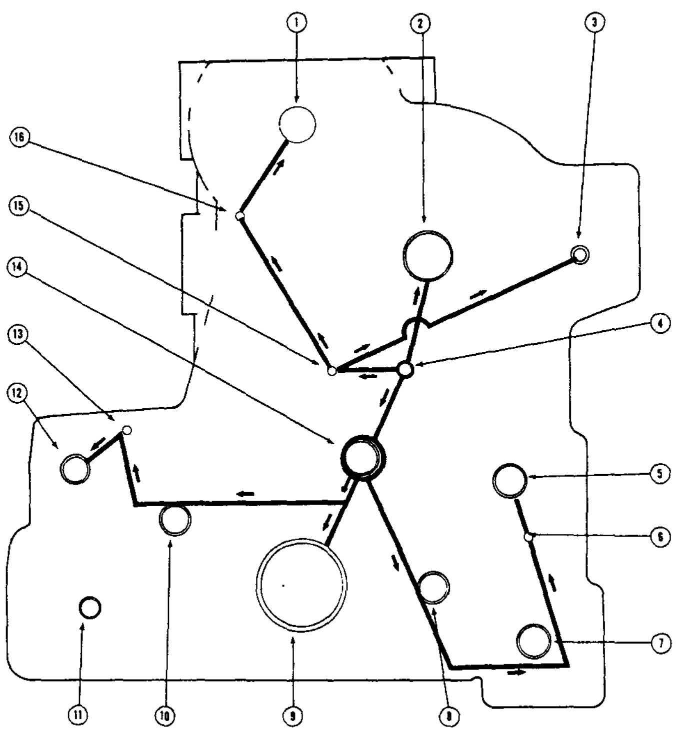
KT(A)-2300 Series Engines

The KT(A)-2300 engines are pressure lubricated by a gear-type lubricating oil pump located in the oil pan at the rear of the engine. The pump is mounted to block directly below crankshaft and is driven from rear crankshaft gear.



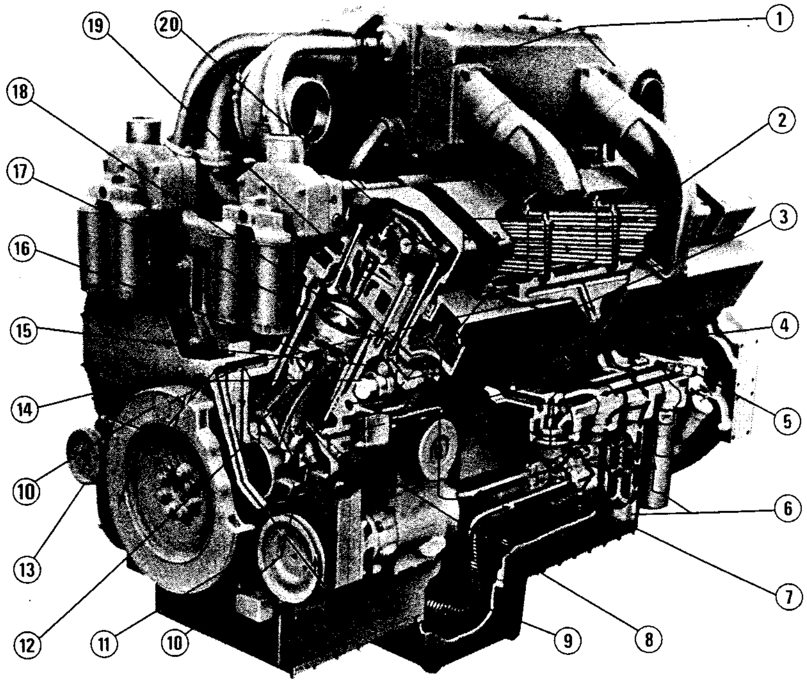
1. INJECTOR
2. ROCKER LEVER
3. ROCKER LEVER SHAFT
4. PUSH TUBE
5. CAM FOLLOWER
6. CAM FOLLOWER SHAFT
7. CAMSHAFT
8. LUBRICATING OIL FILTERS
9. MAIN OIL PASSAGE
10. PISTON COOLING OIL PASSAGE
11. PISTON COOLING NOZZLE
12. CONNECTING ROD
13. PISTON PIN
14. CRANKSHAFT
15. OIL FLOW TO GEAR TRAIN

Fig. 5-25, (LWC-28). Lubricating oil flow KT(A)-1150 Series Engines



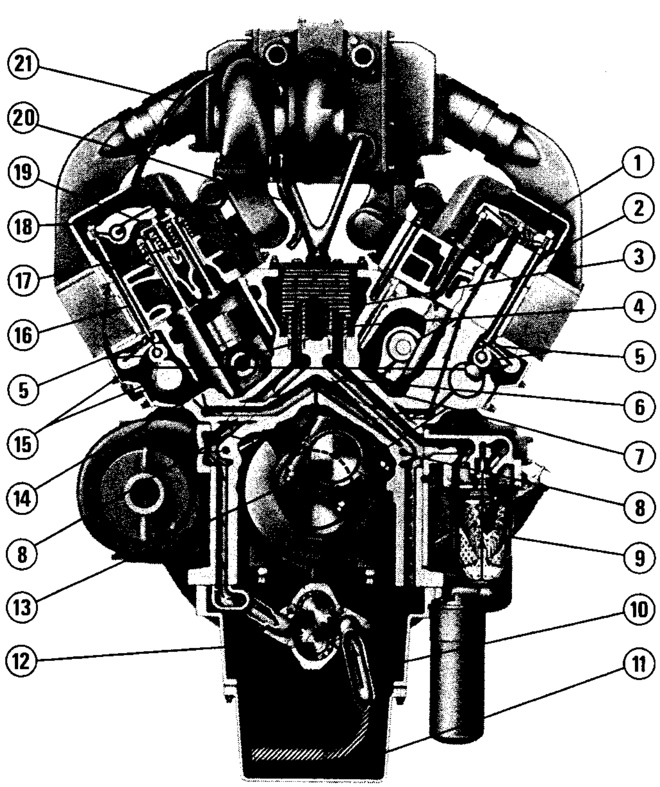
1. FAN DRIVE
2. CAMSHAFT
3. BARRING ARRANGEMENT
4. OIL PASSAGE – MAIN
5. ACCESSORY DRIVE
6. OIL PASSAGE – AIR COMPRESSOR
7. AUXILIARY DRIVE
8. IDLER GEAR
9. CRANKSHAFT
10. IDLER GEAR
11. LUBRICATING OIL PUMP
12. ALTERNATOR/WATER PUMP DRIVE
13. OIL PASSAGE – WATER PUMP
14. IDLER GEAR
15. OIL PASSAGE – TRANSFER
16. OIL PASSAGE – FAN HUB

Fig. 5-26, (K11945). Lubricating oil flow (gear train) KT(A)-1150 Series Engines



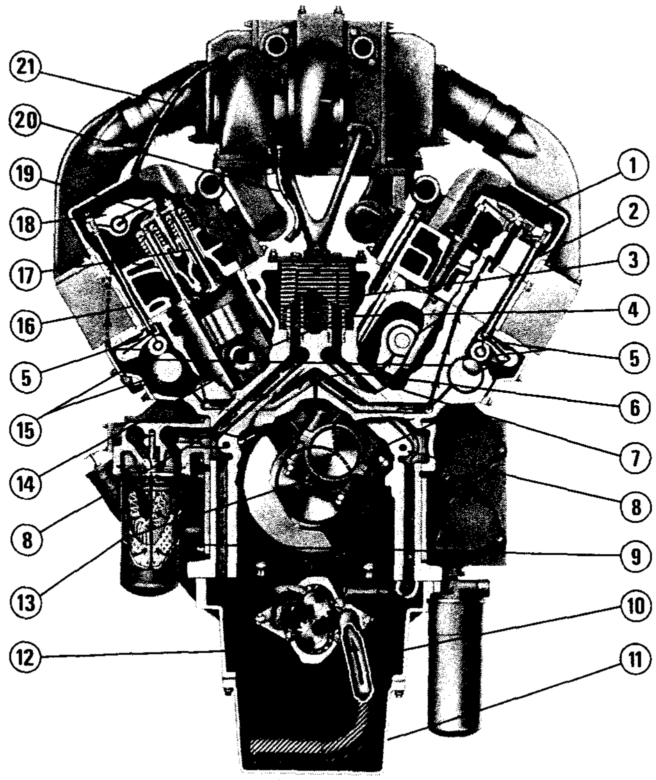
1. TURBOCHARGERS
2. OIL COOLER ELEMENTS
3. OIL SUPPLY TO COOLER
4. OIL TO ENGINE FROM FILTERS
5. PRESSURE REGULATOR
6. FULL FLOW OIL FILTERS
7. LUBRICATING OIL PUMP
8. PISTON COOLING NOZZLE
9. OIL SUCTION TUBE
10. OIL FLOW AT CAM BUSHINGS
11. ACCESSORY DRIVE
12. MAIN BEARING
13. WATER PUMP DRIVE
14. CAMSHAFT
15. CAM FOLLOWER
16. PISTON PIN
17. PISTON
18. PUSH TUBE
19. VALVE GUIDE
20. INJECTOR ROCKER LEVER

Fig. 5-27, (LWC-32). KV-12 Series 3/4 front view oil flow



1. INJECTOR ROCKER LEVER
2. INJECTOR PUSH TUBE
3. OIL COOLER ELEMENT
4. PISTON PIN
5. CAM FOLLOWER
6. MAIN OIL RIFLE
7. CONNECTING ROD
8. PISTON COOLING RIFLE
9. FULL FLOW OIL FILTER
10. OIL SUCTION TUBE
11. OIL PAN
12. OIL PUMP
13. CRANKSHAFT
14. CYLINDER LINER
15. CAMSHAFT
16. VALVE PUSHROD
17. VALVE GUIDE
18. VALVE ROCKER ARM
19. VALVE CROSS HEAD
20. TURBO DRAIN LINE
21. TURBO SUPPLY HOSE

Fig. 5-28, (LWC-35). KV-12 Series front view standard oil flow



1. INJECTOR ROCKER LEVER
2. INJECTOR PUSH TUBE
3. OIL COOLER ELEMENT
4. PISTON PIN
5. CAM FOLLOWER
6. MAIN OIL RIFLE
7. CONNECTING ROD
8. PISTON COOLING RIFLE
9. FULL FLOW OIL FILTER
10. OIL SUCTION TUBE
11. OIL PAN
12. OIL PUMP
13. CRANKSHAFT
14. CYLINDER LINER
15. CAMSHAFT
16. VALVE PUSHROD
17. VALVE GUIDE
18. VALVE ROCKER ARM
19. VALVE CROSS HEAD
20. TURBO DRAIN LINE
21. TURBO SUPPLY HOSE

Fig. 5-29, (LWC-34). KV-12 Series front view optional oil flow

Lubricating oil is drawn from the pan, through a suction tube, by the pump then transferred from suction cavity by pump gears into pressure cavity. A pressure regulator valve dumps excess oil back into the oil pan.

From lubricating oil pump, oil flows through block drillings to lubricating oil cooler located in block "V", through cooler, then to filters which may be mounted on either side of block. Fig's. 5-28 and 5-29. A by-pass valve is provided in filter head oil inlet cavity to assure against interruption of oil flow if filter elements become clogged.

From filter head, oil enters and passes through filter elements; it then flows to the main oil passage located in block "V". This passage feeds two (2) camshaft and two (2) piston cooling drillings in the block. Pressure control valves limit the flow of lubricating oil to piston cooling nozzles, depending on lubricating oil pump pressure.

Main bearings are lubricated through intersecting drillings, directly from the main oil passage. Oil flows from cam passages into camshaft bushings; from there by constant flow, it goes to cam follower shafts and up through cylinder heads. The cam followers are lubricated from their shaft; cam followers are individually drilled to supply lubricating oil to rollers and push tube seats. Rocker lever bushings are also shaft lubricated. Adjusting screws and valve guides are lubricated through drillings in rocker levers and bushings.

Connecting rod bearings are lubricated from cross drillings in the crankshaft; oil then flows through angle drillings in connecting rods to lubricate piston pins and bushings. Lubricating oil is routed from main oil passage through passages in gear housing and cover to lubricate front gear train gears, bushings and idler shafts. The rear gear train receives lubrication through an intersecting drilling from the right bank camshaft passage.

Filtered and cooled lubricating oil is routed from camshaft passages to each turbocharger through external lines from drillings in cylinder block. Turbocharger drain oil is dumped back into oil pan through drilling in cylinder block.

Cooling System

Water is circulated by a centrifugal water pump mounted either in or on the front of the engine belt driven from the accessory drive or crankshaft.

Water circulates around wet-type cylinder liners, through the cylinder heads and around injector sleeves. Fig. 5-17 through Fig. 5-22. Injector sleeves, in which injectors are mounted, are designed for fast dissipation of heat. The engine has a thermostat or thermostats to control engine operating temperature. Engine coolant is cooled by a radiator and fan or a heat exchanger.

The Fleetguard Water Filter is standard on Cummins Engines. The filter by-passes a small amount of coolant from the system via a filtering and treating element which must be replaced periodically. Refer to Coolant Specifications for water filter capacity and treatment of make-up water.

NTA Aftercooled Engine

Water flows from radiator into cavity of water pump, where water flow splits. One portion circulates to the cylinder block water header around wet type cylinder liners, through the cylinder head and around the injector sleeves, upwards to the water manifold, to the thermostat housing. At the rear of the block water header, water is directed to the aftercooler, Fig. 5-30. Water flows forward through the aftercooler to the water crossover to the thermostat housing. The second portion of water flows from the cavity of the water pump housing through the oil cooler and tubing to the rear of the water manifold forward to the thermostat housing, to control engine temperature.

KT(A)-1150 Series Engines

Water is circulated by a centrifugal water pump, Fig. 5-31, mounted on exhaust side of block. The pump is driven by an idler gear from the crankshaft.

Coolant flows from water pump volute into the oil cooler housing, through cooler housing (serving as a water distribution manifold) into block, maintaining an equal flow around all cylinder liners. From liner area coolant

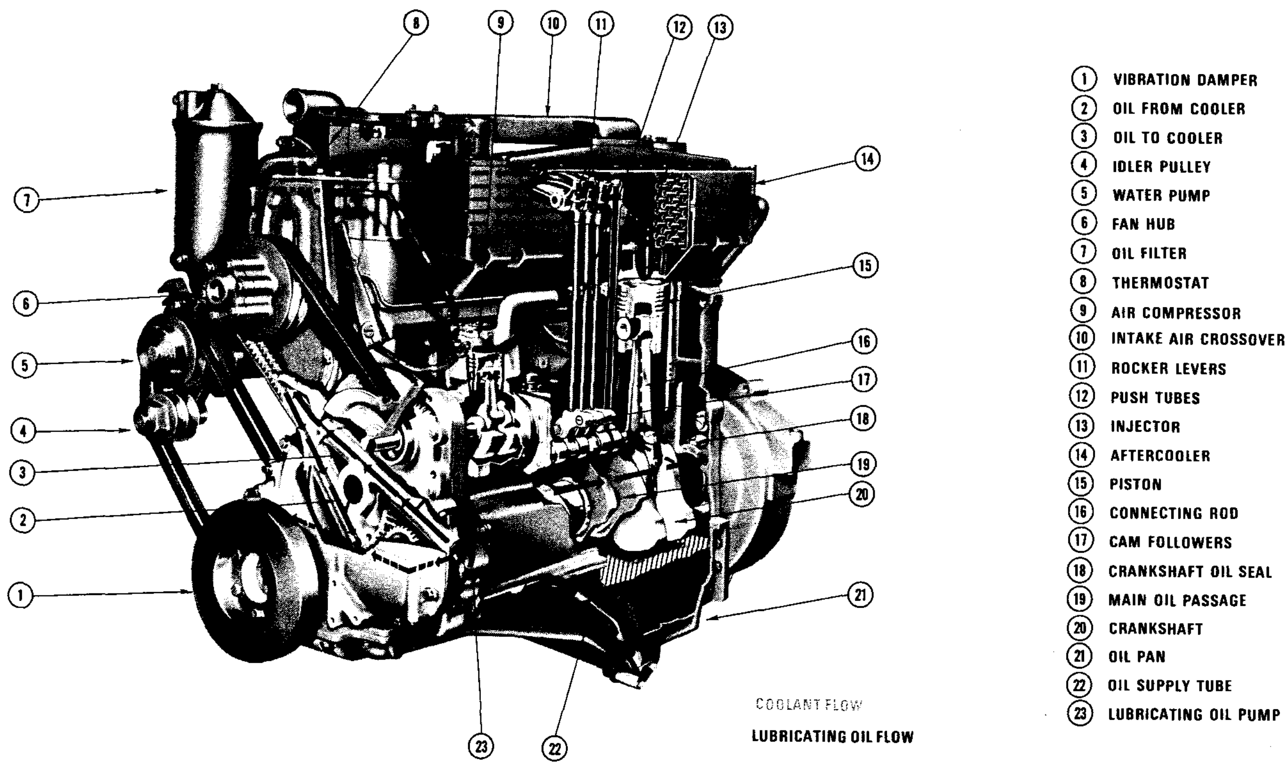
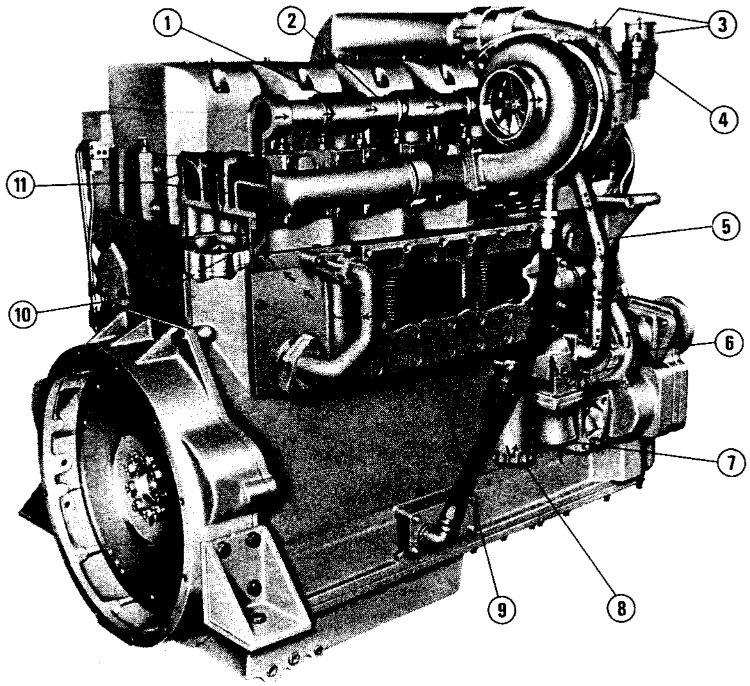
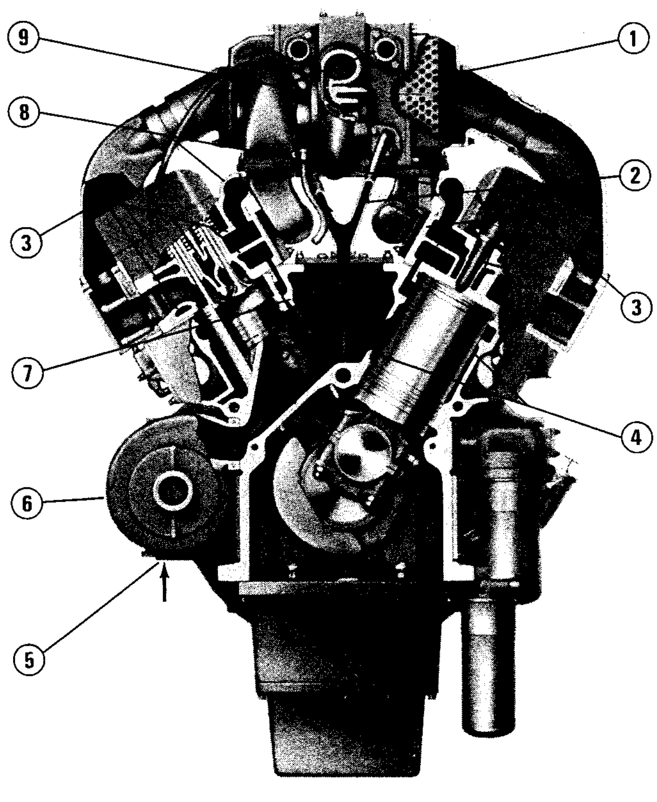


Fig. 5-30, (LWC-22). Coolant and lubricating oil flow – NTA Inline Engine Series



(1) WATER MANIFOLD
(2) TRANSFER TUBE
(3) WATER 'OUT'
(4) THERMOSTAT HOUSING
(5) BY-PASS TUBE
(6) WATER PUMP
(7) WATER 'IN'
(8) WATER FILTER
(9) LUBRICATING OIL COOLERS
(10) WATER 'THROUGH' BLOCK
(11) WATER 'THROUGH' HEADS

Fig. 5-31, (CWC-14). Coolant flow – KT(A)-1150 Series Engines



(1) AFTERCOOLER ELEMENTS
(2) AFTERCOOLER COOLANT SUPPLY
(3) COOLANT PASSAGES IN HEADS
(4) COOLANT AROUND LINERS
(5) COOLANT INLET
(6) WATER PUMP
(7) COOLANT IN BLOCK "V".
(8) COOLANT TRANSFER TUBE (HEAD TO HEAD)
(9) AFTERCOOLER OUT TO THERMOSTAT HOUSING

Fig. 5-32, (CWC-27). Coolant flow – KT(A)-2300 Series Engines flows into individual cylinder heads through holes drilled between valves and around injector "wells". From cylinder heads water flows to rocker housing (water outlet manifold) then to thermostat housing. At thermostat housing water is returned to water pump via a by-pass tube until engine coolant temperature activates dual thermostats. Coolant flow is then directed through a radiator or heat exchanger.

KT(A)-2300 Series Engines

Water is circulated by a centrifugal water pump mounted on right bank side of block. The pump is driven by an idler gear from the crankshaft.

Coolant flows from water pump volute into center of "V" of cylinder block, around lubricating oil cooler elements. The center of "V" serves as a water distribution manifold to supply a flow of coolant through aftercooler elements and around cylinder liners.

From liner area coolant flows into individual cylinder heads through passages between valves and around injector "wells". From cylinder heads coolant flows to rocker housing (water outlet manifold) then to thermostat housings. At thermostat housings coolant is returned to water pump via a by-pass tube until engine coolant temperature activates thermostats. Coolant flow is then directed through a radiator or heat exchanger. Coolant circulated through the aftercooler is also returned into the thermostat housings.

Air System

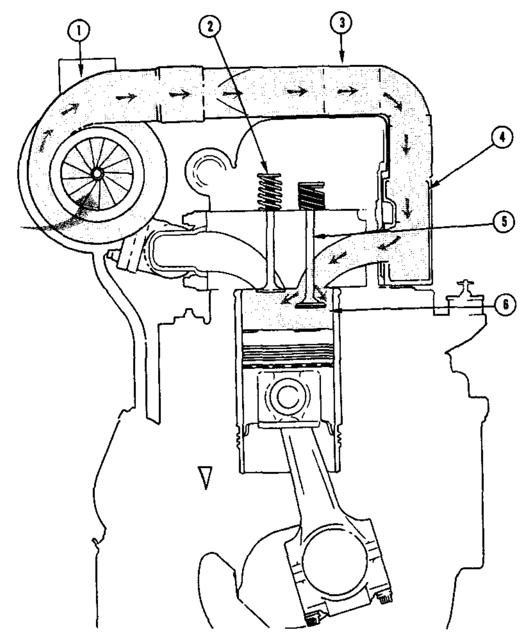
The diesel engine requires hundreds of gallons of air for every gallon of fuel that it burns. For the engine to operate efficiently, it must breathe freely, intake and exhaust systems must not be restricted.

The intake air should always be routed through an air cleaner. The cleaner may be mounted on engine or equipment and may be either oil bath, paper element or composite type depending upon engine application. Air is routed from air cleaner directly to intake air manifold, or turbocharger.

NTA And KT(A)-1150 Series Aftercooler

An aftercooler (or intercooler as it is sometimes called) is a device in the engine intake system designed to reduce intake air temperature and/or preheat intake air temperature.

The aftercooler consists of a housing, used as a portion of the engine intake air manifold, with an internal core. The core is made of tubes through which engine coolant circulates. Air is cooled or heated by passing over the core prior to going into the engine combustion chambers. Fig. 5-33. Therefore, improved combustion results from better control of intake air temperature cooling or warming as applied by the aftercooler.



(1) TURBOCHARGER (4) AIR INTAKE MANIFOLD
(2) EXHAUST VALVE (5) INTAKE VALVE
(3) CROSSOVER (6) COMBUSTION CHAMBER

Fig. 5-33, (K11947). Intake air flow KT(A)-1150 Series Engines

KT(A)-2300 Series Aftercooler

The aftercooler consists of a housing, mounted above the cylinder block, with two (2) internal cores. The cores through which engine coolant circulates, cools or heats the air passing over the core prior to going into the engine combustion chambers. Therefore, improved combustion results.

Turbocharger

The turbocharger forces additional air into combustion chambers so engine can burn more fuel and develop more horsepower than if it were naturally aspirated. In some cases the turbocharger is used for the engine to retain efficiency (balanced fuel to air ratio) at altitudes above sea level.

The turbocharger consists of a turbine wheel and a centrifugal blower, or compressor wheel, separately encased but mounted on and rotating with a common shaft.

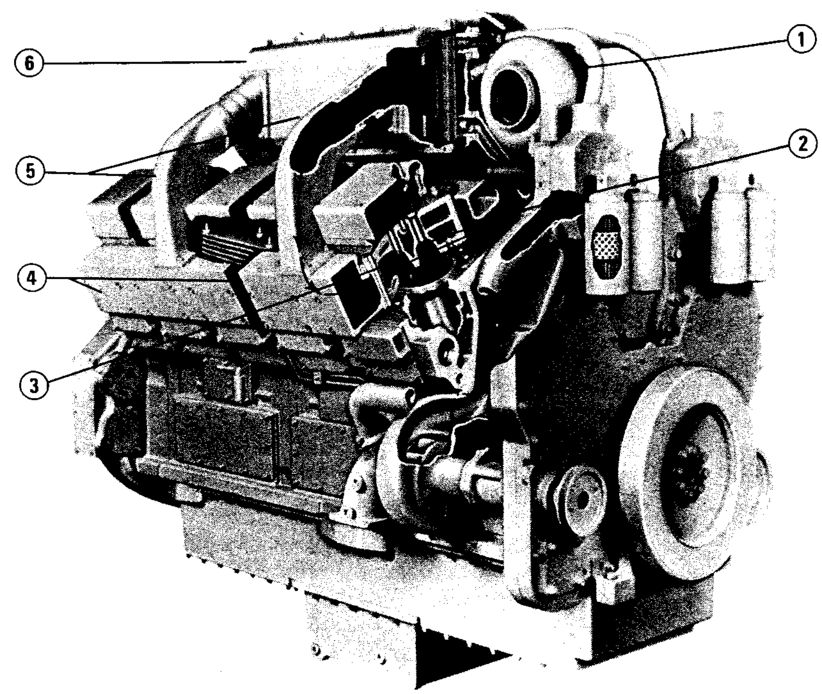
The power to drive the turbine wheel — which in turn drives the compressor — is obtained from energy of engine exhaust gases. Rotating speed of the turbine changes as the energy level of gas changes; therefore, the engine is supplied with enough air to burn fuel for its load requirements. Fig's. 5-35, 5-36, 5-37 and 5-38. The turbocharger is lubricated and cooled by engine lubricating oil.

Air Compressor

The Cummins air compressor may be either a single or two cylinder unit coupling or gear driven from the engine gear train accessory drive. Lubrication is received from the engine lubricating system, with oil carried by internal drillings, on 80 deg. tilt engines air compressor crankcase is drained by a scavenger pump mounted on gear case cover and is driven by lubricating oil pump drive gear. The cylinder head is cooled by engine coolant. Operating functions are as follows:

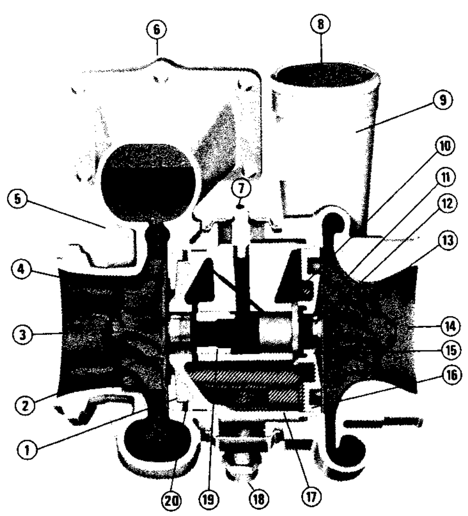
Air Intake

Air is drawn into the compressor through the engine intake



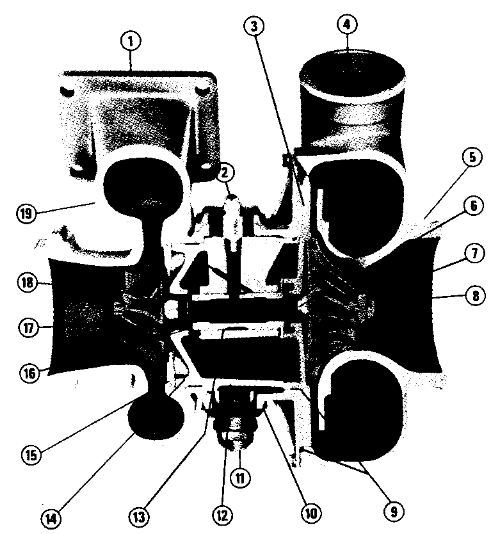
1. TURBOCHARGER
2. INTAKE VALVES
3. INTAKE PORT
4. INTAKE MANIFOLD
5. INTAKE CROSSOVER
6. AFTERCOOLER

Fig. 5-34, (AWC-19). Intake air flow KT(A)-2300 Series Engines



1. HEAT SHIELD
2. SEALING RING
3. EXHAUST OUT
4. TURBINE WHEEL AND SHAFT
5. TURBINE CASING
6. EXHAUST IN
7. OIL IN
8. AIR TO ENGINE
9. COMPRESSOR CASING
10. BEARING INSERT
11. OIL SEAL SLEEVE
12. SEALING RING
13. COMPRESSOR WHEEL
14. AIR IN
15. OIL SEAL PLATE
16. "O" RING SEAL
17. BEARING HOUSING
18. OIL OUT
19. FLOATING BEARING
20. INSULATION BATT

Fig. 5-35, (AWC-8). T-50 turbocharger (cross section)



1. EXHAUST IN
2. OIL IN
3. DIFFUSER PLATE
4. AIR TO ENGINE
5. COMPRESSOR CASING
6. OIL SEAL SLEEVE
7. COMPRESSOR WHEEL
8. AIR IN
9. "O" RING SEAL
10. "V" BAND CLAMP
11. OIL OUT
12. BEARING HOUSING
13. FLOATING BEARING
14. INSULATION BATT
15. HEAT SHIELD
16. SEALING RING
17. EXHAUST OUT
18. TURBINE WHEEL AND SHAFT
19. TURBINE CASING

Fig. 5-36, (AWC-9). VT-50 turbocharger (cross-section)

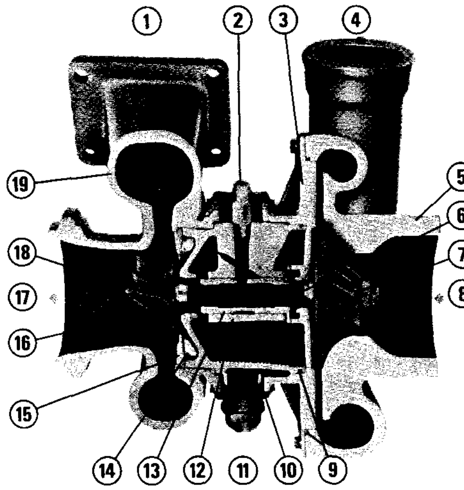


Fig. 5-37, (AWC-12). ST-50 turbocharger (cross-section)

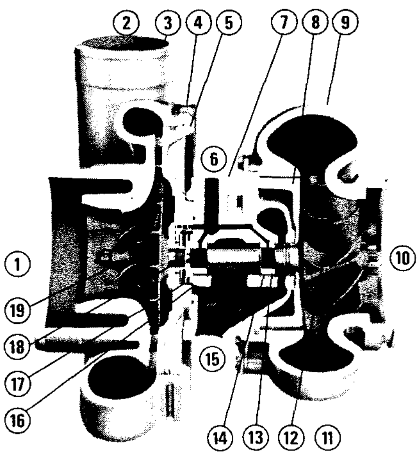


Fig. 5-38, (TA-1). T18-A turbocharger (cross-section)

air manifold or compressor mounted breather. As the piston moves down, a partial vacuum occurs above it.

The difference in cylinder pressure and atmospheric pressure forces the inlet valve down from its seat, allowing the air to flow through the intake port and into the cylinder. When the piston has reached the bottom of its stroke, spring pressure is sufficient to overcome lesser pressure differential and forces the valve against its seat. Fig's. 5-39 and 5-40.

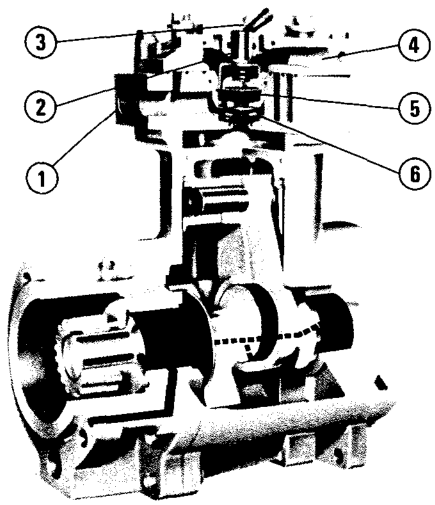


Fig. 5-39, (AWC-10). Cummins air compressor (single cylinder)

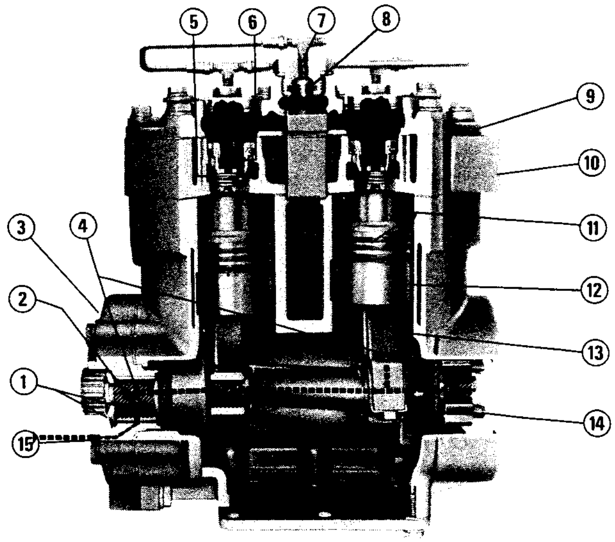
Compression

When the piston starts its upward stroke, the increased pressure of air in the cylinder and head forces the outlet valve away from its seat. The compressed air then flows through outlet ports and into the air tank as the piston continues its upward stroke. On piston downstroke, the exhaust valve closes and the intake valve opens except during unloading period.

Unloading

When pressure in the air tank is at a predetermined level, air pressure is applied to top of unloader cap by a compressor governor. This pressure forces the unloader cap down and holds the intake valve open during non-pumping cycle.

When pressure in air tank drops, the unloader cap returns to its upper position and intake and compression sequences begin once again.



(1) THRUST WASHERS
(2) CRANKSHAFT
(3) SUPPORT
(4) BUSHINGS
(5) EXHAUST VALVE
(6) INTAKE VALVE
(7) AIR GOVERNOR INLET
(8) UNLOADER VALVE ASSEMBLY
(9) CYLINDER HEAD COVER
(10) CYLINDER HEAD
(11) PISTON RINGS
(12) PISTON
(13) CONNECTING ROD
(14) FUEL PUMP DRIVE
(15) LUBRICATING OIL INLET

Fig. 5-40, (AWC-11). Cummins air compressor (two cylinder)

Vacuum Pump

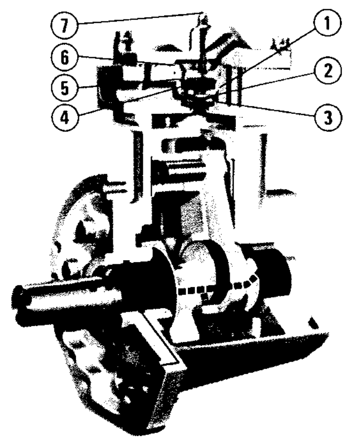
The Cummins Vacuum Pump, shown in Fig. 5-41, is an adaptation of Cummins Air Compressor; it is a single-cylinder unit driven from engine gear train accessory drive. Lubrication is received from engine lubricating system, with oil carried by internal drillings. The cylinder head is cooled by engine coolant. Operating functions are as follows:

Air Intake

As piston moves downward on intake stroke a vacuum occurs above piston. The difference in cylinder pressure and atmospheric pressure forces inlet valve from its seat allowing air to flow through intake port into cylinder from vacuum tank thus creating vacuum in vacuum tank. When piston has reached bottom of its stroke, spring pressure is sufficient to overcome lesser pressure differential and forces valve against its seat.

Compression

When piston starts upward stroke, increased pressure of air in cylinder and head forces outlet valve away from seat. Air then flows through outlet port and is discharged into vacuum pump crankcase or engine crankcase, as piston continues upward stroke. When piston reaches end of



(1) EXHAUST VALVE SEAT
(2) EXHAUST VALVE
(3) EXHAUST VALVE SPRING
(4) INTAKE VALVE SPRING
(5) INTAKE VALVE
(6) INTAKE VALVE SEAT
(7) VALVE SET SCREW

Fig. 5-41, (V11205). Cummins vacuum pump

stroke, air pressure in head drops to a point where spring forces exhaust valve against seat and closes outlet passage.

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